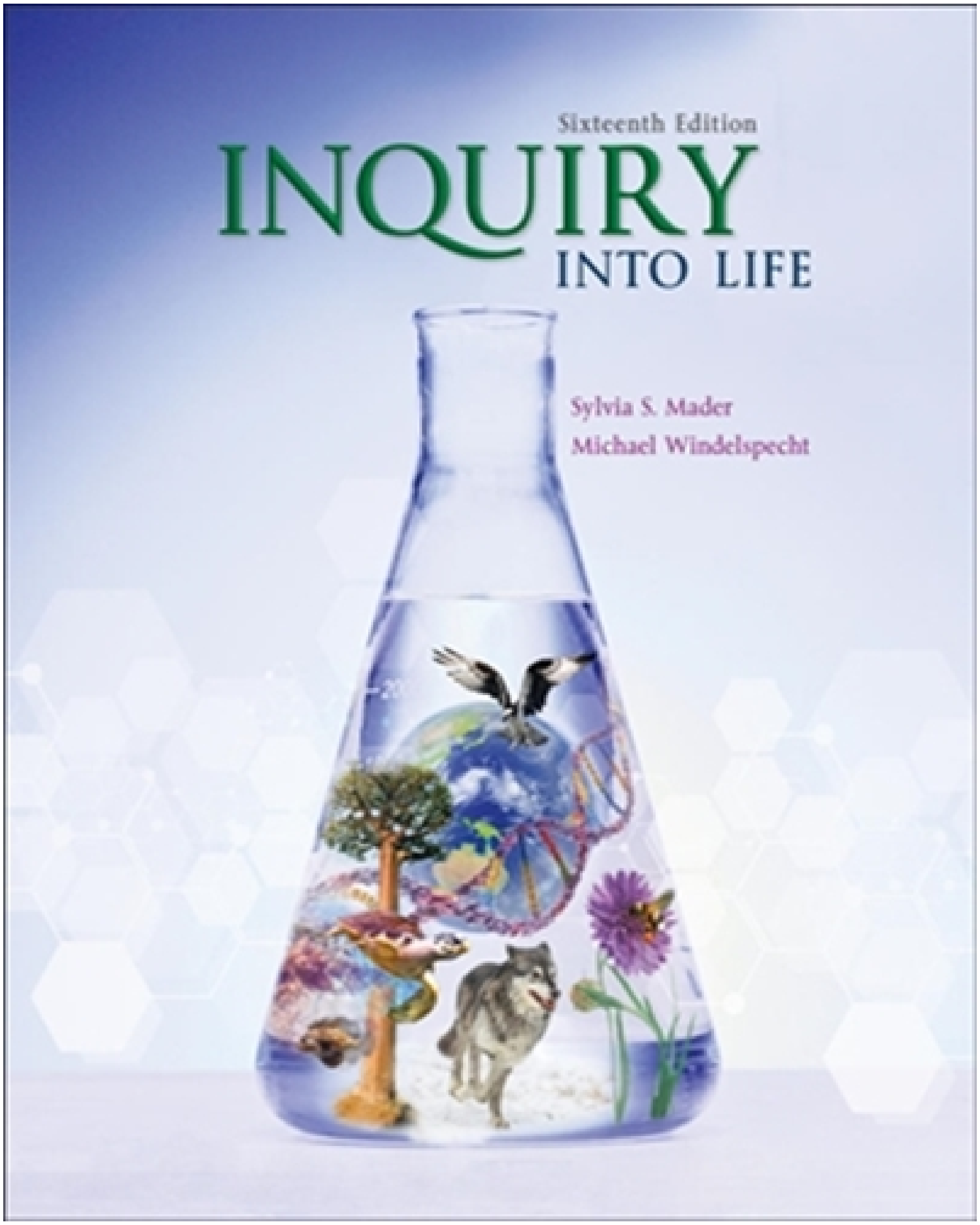
Solutions for Inquiry into Life 16th Edition by Mader



Solutions

UNIT 1: CELL BIOLOGY
CHAPTER 2: THE MOLECULES OF CELLS

LEARNING OUTCOMES

2.1 Introduction to Chemistry

1. Describe how protons, neutrons, and electrons relate to atomic structure.
2. Understand how to interpret the periodic table of elements.
3. Describe how variations in an atomic nucleus account for its physical properties.
4. Identify the beneficial and harmful uses of radiation.

2.2 Molecules and Compounds

1. Describe how elements are combined into molecules and compounds.
2. List the different types of bonds that occur between elements.
3. Compare the relative strengths of ionic, covalent, and hydrogen bonds.

2.3 Chemistry of Water

1. Evaluate which properties of water are important for biological life.
2. Identify common acidic and basic substances.
3. Describe how buffers are important to living organisms.

2.4 Organic Molecules

1. Compare inorganic molecules to organic molecules.
2. Identify the role of a functional group.
3. Recognize how monomers are joined to form polymers.

2.5 Carbohydrates

1. Identify the structural components of a carbohydrate.
2. List several examples of important monosaccharides and polysaccharides.

2.6 Lipids

1. Compare the structures of fats, phospholipids, and steroids.
2. Identify the functions lipids play in our bodies.

2.7 Proteins

1. Describe the functions of proteins in cells.
2. Explain how a polypeptide is constructed from amino acids.
3. Compare the four levels of protein structure.

2.8 Nucleic Acids

1. Compare the structure and function of DNA and RNA.
2. Explain the role of ATP in the cell.

LECTURE OUTLINE

2.1 Introduction to Chemistry

Matter refers to anything that takes up space and has mass. All matter, both nonliving and living, is composed of certain basic substances called **elements**.

Atomic Structure

Elements consist of tiny particles called **atoms**, which are the smallest part of an element that displays the properties of that element. Atoms are made up of positively charged **protons**, uncharged **neutrons**, and negatively charged **electrons**. All atoms of an element have the same number of protons. This number is called the **atomic number**. The **mass number** is the sum of an atom's protons and neutrons.

The Periodic Table

The periodic table was constructed as a way to group the elements according to certain similar chemical and physical characteristics.

Radioactive Isotopes

Isotopes are atoms of the same element that differ in their number of neutrons; therefore, isotopes have the same number of protons, but their mass numbers are different.

Low Levels of Radiation

The chemical behavior of a radioactive isotope is essentially the same as that of the stable isotopes of an element, so you can use small amounts of radioactive isotopes as tracers to detect molecular changes.

High Levels of Radiation

Radioactive substances in the environment can harm cells, damage DNA, and cause cancer. Radiation is also used to sterilize items, treat cancer, and provide images (X-rays) of things we otherwise couldn't see directly.

Electrons

In an electrically neutral atom, the positive charges of the protons in the nucleus are balanced by the negative charges of electrons moving outside the nucleus in orbitals. The number of electrons in the outer orbital determines whether an atom reacts with other atoms. A common model of the atom, devised by Niels Bohr, shows electrons in concentric rings around the nucleus.

2.2 Molecules and Compounds

A **molecule** is formed when two or more atoms bond together. When the atoms of two or more different elements bond together, the product is called a **compound**.

Ionic Bonding

Ions form when electrons are transferred from one atom to another. Ionic compounds are held together by an attraction between negatively and positively charged **ions** called an **ionic bond**. An example is NaCl.

Covalent Bonding

A **covalent bond** results when two atoms share electrons in such a way that each atom has a complete outer orbital.

The Shape of Molecules

Molecules have a three-dimensional shape that often determines their biological function. The shapes of molecules are necessary to the structural and functional role they play in living things.

Nonpolar and Polar Covalent Bonds

When the sharing of electrons between two atoms is fairly equal, the covalent bond is said to be nonpolar. The unequal sharing of electrons in a covalent bond results in a slightly negative charge and a slightly positive charge, and the covalent bond is polar.

Hydrogen Bonding

Polarity within a water molecule causes the hydrogen atoms in one molecule to be attracted to the oxygen atoms in other water molecules, forming a **hydrogen bond**.

2.3 Chemistry of Water

The unique properties of water make it essential to the existence of life.

Properties of Water

High Heat Capacity

The many hydrogen bonds that link water molecules help water absorb heat without a great change in temperature. Water has a high heat capacity because the main hydrogen bonds that link water molecules together help water absorb heat without a great change in temperature.

High Heat of Vaporization

Water has a high heat of vaporization because hydrogen bonds must be broken before water boils and changes to a vaporized state.

Solvent

Water is a solvent, and due to its polarity, it facilitates chemical reactions inside and outside living organisms.

Cohesive and Adhesive

Water molecules are cohesive and adhesive. Water flows freely, but its molecules do not separate, and it is able to adhere to polar surfaces. The strong hydrogen bonds between water molecules result in high surface tension.

Frozen Water Less Dense Than Liquid Water

Ice is less dense than liquid water because the water molecules form a regular crystal lattice with more open space, and, therefore, ice floats.

Acids and Bases

When water ionizes, it releases an equal number of hydrogen ions and hydroxide ions.

Acid Solutions (High H^+ Concentrations)

Acids are substances that release hydrogen ions (H^+) when they dissociate in water.

Basic Solutions (Low H^+ Concentration)

Bases are substances that either take up hydrogen ions (H^+) or release hydroxide ions (OH^-).

pH Scale

The **pH scale** is used to indicate the acidity or basicity (alkalinity) of solutions. The pH scale ranges from 0 to 14.

Buffers and pH

A **buffer** is a substance that keeps pH within normal limits. In animals, the pH of body fluids is maintained within a narrow range or else health suffers.

2.4 Organic Molecules

Organic molecules always contain carbon (C) and hydrogen (H). To achieve eight electrons in its outer shell, a carbon atom shares electrons covalently with as many as four other atoms, including other carbon atoms.

Functional Groups

A **functional group** is a specific combination of bonded atoms that always react in the same way.

From Monomers to Polymers

A **monomer** is a simple organic molecule that exists individually or can link with other monomers to form a **polymer**. **Dehydration** and **hydrolysis reactions** join monomers and degrade polymers, respectively.

2.5 Carbohydrates

Carbohydrates function as quick fuel and short-term energy storage in all organisms and play a structural role in woody plants, bacteria, and insects. Carbohydrate molecules are characterized by the presence of the atomic grouping H–C–OH.

Monosaccharides—Simple Sugars

Monosaccharides consist of a single sugar molecule and are called simple sugars. They have a carbon backbone of three to six carbons. **Glucose** is a six-carbon monosaccharide found in our blood.

Disaccharides

A **disaccharide** contains two monosaccharides that have joined during a dehydration reaction.

Polysaccharides—Complex Carbohydrates

Long polymers such as starch, glycogen, and cellulose are **polysaccharides** that contain many glucose subunits.

Energy Storage Polysaccharides

Plants store large amounts of glucose as **starch**; animals store it as **glycogen**.

Structural Polysaccharides

The polysaccharide **cellulose** is found in plant cell walls and makes them strong. **Chitin**, another structural polysaccharide, is found in the exoskeleton of crabs and related animals.

2.6 Lipids

Lipids function as energy storage molecules. Their structures vary, but all are hydrophobic molecules that are insoluble in water. Phospholipids form a membrane that separates the cell from its environment, and the steroids are a large class of lipids that includes, among others, the sex hormones.

Triglycerides: Fats and Oils

Fats are usually of animal origin and solid at room temperature while **oils** are of plant origin and liquid. In the body, fat is used for long-term energy storage, to insulate against heat loss, and to form a protective cushion around major organs. Fats and oils form when one glycerol molecule reacts with three fatty acid molecules. A fat molecule is sometimes called a **triglyceride**.

Saturated, Unsaturated, and Trans-Fatty Acids

A **fatty acid** is a hydrocarbon chain that ends with the acidic group –COOH.

Saturated fatty acids have no double covalent bonds between carbon atoms.

Unsaturated fatty acids have double bonds between carbon atoms.

Trans fats are often produced by hydrogenation or the chemical addition of hydrogen to vegetable oils.

Phospholipids

Phospholipids contain a phosphate group and have a hydrophobic end and a hydrophilic end. They are the primary components of cellular membranes.

Steroids

Steroids have a backbone of four fused carbon rings. Cholesterol is an important steroid because it is a component of a cell's plasma membrane and the precursor to other steroids.

2.7 Proteins

Proteins are polymers composed of amino acid monomers. An amino acid has a central carbon atom bonded to a hydrogen atom, an amino group ($–NH_2$), an acidic group (–COOH), and an *R* group. **Amino acids** differ by their *R* groups. Proteins perform many functions. Some are **enzymes** that speed chemical reactions.

Peptides

A **polypeptide** is a chain of amino acids that are joined to one another by a **peptide bond**.

Levels of Protein Organization

Proteins have a *primary* (linear sequence of amino acids), *secondary* (alpha helices or beta pleated sheet), and *tertiary structure* (globular shape). Some proteins exhibit a *quaternary structure* (more than one polypeptide chain). The final shape of a protein is very important to its function.

2.8 Nucleic Acids

The two types of nucleic acids are **DNA** (**deoxyribonucleic acid**) and **RNA** (**ribonucleic acid**). DNA stores genetic information in the cell and in the organism.

Structure of DNA and RNA

Both DNA and RNA are polymers of nucleotides. Every **nucleotide** is composed of a phosphate, a pentose sugar, and a nitrogen-containing base. The nucleotides form a linear molecule. DNA is a **double helix**, while RNA is single stranded.

ATP (Adenosine Triphosphate)

ATP (**adenosine triphosphate**) is the energy carrier in cells, storing the energy in glucose and providing that energy to reactions in the cell.

LECTURE ENRICHMENT IDEAS

1. The various organic molecules and types of bonds are easily visualized with models and remembered better than when presented on flat pictures in the textbook, videos, or computer screen.
2. Students should research the topic of acid rain on the Internet before coming to class. They should also collect and bring in water samples from their dorm faucets, drinking fountains, rainwater, snow, or a nearby pond or stream. Have pH paper or a pH meter available in class to determine the pH of these samples. Discuss the known or potential effects of acid rain in your particular geographic location, which

might include effects on forests (including interruption of the symbiotic association between trees and their mycorrhizae), depletion of fisheries in lakes, or deterioration of car finishes and statues.

3. Bring in various types of colas and coffee. Have pH paper or a pH meter available in class to determine the pH of these beverages. How acidic are these? Discuss why you can drink such acidic beverages and not damage your stomach.
4. Have students read the Science in Your Life—Health "Japan's Nuclear Crisis" before coming to class. Discuss the answers to the discussion questions at the end of the reading.
5. Have students read the Science in Your Life—Health "A Balanced Diet" before coming to class. Discuss the answers to the discussion questions at the end of the reading.
6. Of the four organic molecules discussed in this section (carbohydrates, lipids, proteins, and nucleic acids), why are nucleic acids the best suited to store and transmit information? What properties of DNA allow these particular functions?

ESSAY QUESTIONS WITH ANSWERS

1. Name five characteristics of water and relate them to the structure of water.

Answer: Because electrons orbit around oxygen more than hydrogen, a slight positive charge is present on the hydrogen atoms and a slight negative charge on the oxygen atom, creating a polarity. Hydrogen bonds form between the water molecules, which leads to various characteristics of water: boils at 100°C and freezes at 0°C; absorbs large amounts of heat before it becomes warm and evaporates, which helps to maintain constant body temperature; excellent transport medium; ice floats in liquid water (less dense); and dissolves various chemical substances.

2. All proteins have three basic structural levels. Describe those. Why does hemoglobin have a quaternary structure?

Answer: The primary structure of a protein consists of the linear sequence of amino acids joined by peptide bonds. The secondary structure comes about when the polypeptide chain takes a particular orientation in space (alpha helix or beta pleated sheet). The tertiary structure represents the final three-dimensional shape of the protein. When more than one polypeptide chain is present, a quaternary structure is formed, which is found in hemoglobin.

3. Explain how soaps, when added to oils, will cause the oil to mix with water.

Answer: Soaps have a polar and a nonpolar end. The nonpolar ends of the soap project into the nonpolar fat droplet while the polar ends of the soap project outward into the water, which is polar.

LABORATORY 1 Scientific Method

MATERIALS AND PREPARATIONS

Instructions are grouped by procedure. Some materials may be used in more than one procedure.

Special Requirements

Living material. Live pillbugs, *Armadillidium vulgare*, for all sections of the lab.

Earthworm alternative. Refer to the section titled "Earthworm Alternative" at the end of this laboratory if you wish to use earthworms instead of pillbugs.

Fresh material. Substances for instructor to feed pillbugs and substances for students to test pillbug behavior are listed in Section 1.4.

1.2 Observing a Pillbug

_____ pillbugs, *Armadillidium vulgare*, live (Carolina 14-3082)
_____ pen, white (or correction fluid, white) or taped tags
_____ magnifying lenses or stereomicroscopes
_____ small glass or plastic dishes, such as disposable Petri dishes
_____ graduated cylinders or small beakers for observing pillbug movement
_____ rulers, metric, 30 cm plastic
_____ stopwatch

Live pillbugs. Obtain 50 pillbugs for a class of 20 to 35 or more students. Order pillbugs so that they arrive as close as possible to the date they will be needed. Use one container of fresh pillbugs for each lab.

Care and feeding of pillbugs: Follow care and feeding instructions provided with the pillbug order. Withdraw food 1–2 days prior to the experiment.

Use white correction fluid, different colors of nail polish, or tape tabs to number the pillbugs for identification.

Collecting pillbugs. Pillbugs like moisture, and avoid sunlight. They can be found next to brick buildings along the grass line or next to sidewalks, or under logs and planks of wood. They are attracted to wet grass covered with a cardboard box or plastic tarp. Encourage students to collect their own pillbugs and give them lab participation points. Collect pillbugs in the spring, summer, and fall as they are hard to find in the winter.

Maintaining pillbugs in the lab. After collecting, pillbugs can be easily maintained in a terrarium to keep a fresh supply all year long. They feed primarily on decaying organic matter;

they like moisture and avoid sunlight. They like carrots and cucumbers. Change the food daily to prevent mold growth.

1.4 Performing the Experiment and Coming to a Conclusion

_____ pillbugs, *Armadillidium vulgare*, live (Carolina 14-3082)
_____ small beakers, 35-mm film cans, watch glasses, or small Petri dishes for distributing test substances
_____ Petri dishes, preferably 150 mm (or else 100 mm) for testing the pillbugs
_____ small plastic bottle for spritzing
_____ distilled water
_____ cotton balls

Suggested test substances:

_____ flour
_____ cornstarch or brand flakes
_____ coffee creamer
_____ baking soda
_____ fine sand (control)
_____ milk
_____ orange juice or apple juice
_____ ketchup
_____ applesauce
_____ carbonated beverage
_____ water (control)

Do not use salt, vinegar, or honey, as these substances are harmful to pillbugs.
Plain water is used as a control for liquids. Fine sand is used as a control for powders.

Experimental design. These methods are recommended: For a dry substance, make a circle of the test substance in a Petri dish and put the pillbug in the center of the circle. For a liquid, put a cotton ball soaked with the test substance in the pillbug's path. Rinse pillbugs between testing procedures by spritzing with distilled water and then placing them on a paper towel to dry.

Cleanup. Cleanup is easier and the experiment goes well if there is a limited number of test substances and each student chooses only two dry and two liquid test substances. Substances can be distributed to several stations in small beakers, 35-mm film cans, watch glasses, or small Petri dishes. Testing pillbugs in 150 mm Petri dishes works well.

PRE-LAB QUESTIONS

1. **What is the purpose of this lab?** *This lab offers an opportunity to practice the scientific method and learn about pillbug behavior.*
2. **What is the purpose of the scientific method?** *The scientific method is used to learn about the natural world.*
3. **Considering you will be testing how pillbugs move toward or away from particular foods or repellents, how are the observations from this section important?** *These observations of normal behavior will serve as a comparison.*

4. **Why is it important to have sand and water as controls in this experiment?** *Controls are used for comparisons to treatment groups.*
5. **Briefly list the steps of this experimental procedure.** *Place a substance in the petri dish, observe the pillbug's reaction, rinse pillbug, repeat with new substance.*
6. **If a pillbug shows the same attraction toward a control and food, can you conclude the pillbug is attracted to the food?** *No, if the behavior is the same it cannot be concluded the pillbug is attracted.*

EXERCISE QUESTIONS

1.1 Observing a Pillbug

Observation: Pillbug's External Anatomy

1. **Drawing.** ***Drawings should include labels for the head, thorax, abdomen, antennae, eyes, legs, and uropods.***

Observation: Pillbug's Motion

1. **Observe how the pillbug moves for a few moments. Describe in detail what you observed.** *Descriptions will vary.*
2. **Measure the speed of three pillbugs.** *Example results shown in table below.*

Table 1.1 Pillbug Speed*

Pillbug	Millimeters (mm) Traveled	Time (sec)	Speed (mm/sec)
1	*71*	*30*	*2.36*
2	*122*	*60*	*2.20*
3	*64*	*30*	*2.12*

Average speed: *2.23 mm/sec*

**Answers will vary. The answers provided here are examples.*

1.2 Formulating Hypotheses

1-3. *See Table 1.2 showing three possible student hypotheses regarding flour. Students use "0" for no response, "—" for moves away from the substance, and "+" for moves toward the substance and eats it.*

Table 1.2 Hypotheses about Pillbug's Response to Potential Foods

Substance	Hypothesis About Pillbug's Response to Potential Foods	Reason for Hypothesis
Flour	*0*	*Flour is a bland substance.*
Flour	—	*Flour is a dry substance.*
Flour	+	*Flour is a food substance.*

1.3 Performing the Experiment and Coming to a Conclusion

Experimental Procedure: Pillbug's Response to Potential Foods

1-3. *See Table 1.3 showing three possible student results.*

Table 1.3 Pillbug's Response to Potential Foods

Substance	Pillbug's Response	Hypothesis supported?
Flour	+	*Depends on hypotheses*
Cornstarch	+	
Coffee creamer	+	
Baking soda	—	
Fine sand	*0**	
Milk	+	
Orange juice	—	
Ketchup	—	
Applesauce	+	
Carbonated beverage	+	
Water	*0**	

**Pillbugs may move toward these substances but not eat them.*

Conclusion

5. **Do your results support your hypotheses?** *Answer depends on results.*
6. **Class Results.**
   Table 1.4 Pillbug's Response to Potential Foods: Class Results
   Answers will vary depending on class data.

7. **Scientists prefer to come to conclusions on the basis of many trials. Why is this the best methodology?** *Since results of individual trials may vary, using multiple trials provides more valid results.*
8. **Comparing the results from the controls to other substances, did the pillbugs behave differently? How do the results of the control affect your conclusions about the tested substances?** *If the pillbugs behaved the same way toward controls and other substances, then pillbugs are not attracted or repelled by the substance.*

LABORATORY REVIEW 1

1. **What kind of animal is a pillbug?** *Crustacean*
2. **What kind of skeleton does a pillbug have?** *Exoskeleton*

3. **What structures do pillbugs use for gas exchange and what condition must these structure be in to function properly?** *Gills; moist*
4. **What do scientists do first when they begin to study a specific topic?** *Make observations*
5. **What is a tentative decision about the outcome of an experiment?** *Hypothesis*
6. **What do we call the sample that lacks the factor being tested and goes through all the experimental steps?** *A control*
7. **What do scientists call the information they collect while doing experiments or making observations?** *Data*
8. **Which is made by a scientist following experiments and observations, a theory or a conclusion?** *Conclusion*

9. **What do scientists develop after many years of experimentation and a lot of similar individual conclusions?** *Scientific theory*
10. **If your hypothesis was your pillbug would be attracted to applesauce and your pillbug moved toward the applesauce, what would you say about your hypothesis?** *It was correct.*
11. **If a pillbug travels 3mm in 30 seconds, what is its rate of speed?** *0.1 mm/sec*
12. **If a pillbug moves toward a substance, is it attracted to or repelled by that substance?** *Attracted to*

For questions 13 and 14, indicate whether the statements are hypotheses, conclusions or scientific theories.

13. **All living things are made of cells.** *Scientific theory*
14. **The data show that trans-fat intake raises cholesterol and contributes to heart disease.** *Conclusion*

Thought Questions

15. **Why is a theory more comprehensive than a conclusion?** *A conclusion is based on data obtained from one experiment. A theory is based on many conclusions made by multiple researchers in the same field.*
16. **Why is it important to have a control substance for an experiment?** *The results associated with the control determine if the procedure is flawed or the hypothesis is false.*
17. **Why is it important to test a pillbug's response using one substance at a time?** *Only then can you be certain of the pillbug's reaction to that particular substance.*

Earthworm Alternative

Earthworms can be used instead of pillbugs for all of the exercises in this laboratory.

Place earthworms in large rectangular plastic storage containers and let them roam around for approximately 15 min. These containers can also be used to keep earthworms between experiments. Plexiglass is also needed to place test substances on while holding earthworms above to see behavior towards substances.

Earthworms want to move rapidly to escape. They are inclined to move away from light, move under things, and seem to want to move downward. They are expected to move away from a heat source. They also move toward each other and pile up on each other. They can move up and down on glass at a 45° angle.

With regard to what students already know about earthworm activity, they might predict certain behaviors. Earthworms live (or hide) in the soil, so they would move down and through soil. Soil prevents desiccation and keeps them cool and moist. By moving under things, they could stay cooler, stay moist, and stay hidden in the dark. Perhaps light bothers them also.

Earthworms can move backward and forward from both ends. When they are investigating a substance, they make a long, skinny point out of the end they are investigating with, and if they are repelled by a substance, they pull back and the end becomes thick and round.

When testing with liquids, if the earthworm even gets close to the substance, the substance will be pulled along the earthworm's body without the earthworm doing anything. Capillary action or cohesion tension? To prevent this, hold the earthworm above the substance, in case the substance (especially lemon juice) might harm the earthworm. Just let the worm move its pointed end into or near the substance. You can tell when it is repelled as it will pull away. Rinse the earthworm right away if it touches a substance (especially lemon juice).

WHEN FINISHED WITH EARTHWORMS, mix damp potting soil with some oatmeal, potato peels, lettuce, or other organic matter from the test—not too much, just enough to give the earthworms something to eat. Add earthworms. Cover container with newspaper. Keep soil damp. When completely finished, release earthworms into garden or greenhouse soil.

LABORATORY
2
Measuring With Metric

MATERIALS AND PREPARATIONS

Instructions are grouped by exercise. Some materials may be used in more than one exercise.

2.1 Length

_____ meter stick, metric and English
_____ long bones from disarticulated human skeleton
_____ cardboard (10 cm × 30 cm), two pieces
_____ rulers, plastic millimeter

2.2 Weight

_____ sturdy balance scale
_____ wooden block, small enough to hold in hand
_____ object, such as a piece of granite, or a trilobite fossil, small enough to fit through the opening of a small graduated cylinder
_____ triple beam balance
_____ objects to weigh: penny, paper clip, quarter

2.3 Volume

_____ wooden block and object from above
_____ graduated cylinders, 50 ml or 100 ml
_____ test tubes (large enough to hold 20 ml of water)
_____ dropper bottles containing water
_____ index card, blank white (20 cm × 30 cm)
_____ beaker, 50 ml
_____ graduated pipette (for demonstration)

2.4 Temperature

_____ thermometer, Celsius
_____ cold water, hot water, ice water

PRE-LAB QUESTIONS

1. **Why is a standard system of measurement useful across the sciences?** *A standard system allows scientists to communicate more easily.*
2. **Which types of measurements will you perform in this lab?** *Length, weight, volume, and temperature will be practiced.*
3. **What is the base unit for length?** *Meter (m)*
4. **Which metric units of measurement are on a typical ruler?** *Centimeter (cm) and millimeter (mm)*

5. **What is the base unit for weight?** *Gram (g)*
6. **Which unit is typically used for larger weights such as human body weight?** *Kilogram (kg)*
7. **What is the base unit for volume?** *Liter (l)*
8. **What is another way 1 ml can be expressed?** *1 cubic centimeter (cm^3)*
9. **Convert 98.6°F to Celsius.** *37°C*

EXERCISE QUESTIONS

2.1 Length

Experimental Procedure: Length

1. **How many centimeters are represented?** *Usually 15* **One centimeter equals how many millimeters?** *10*
   According to Table 2.1, 1 µm = *0.001* **mm, and 1 nm =** *0.000001* **mm.**
   Therefore, 1 mm = *1,000* **µm =** *1,000,000* **nm.**
2. **Measure the diameter of the circle shown to the nearest millimeter. This circle is** *38* **mm =** *38,000* **µm =** *38,000,000* **nm.**
3. **How many centimeters are in a meter?** *100* **How many millimeters are in a meter?** *1,000* **The prefix *milli* means** *thousandth.*
4. **For example, if the bone measures from the 22 cm mark to the 50 cm mark, the length of the bone is** *28* **cm. If the bone measures from the 22 cm marks to midway between the 50 cm and 51 cm marks, its length is** *285* **mm, or** *28.5* **cm.**
5. **Record the length of two bones.** *Recorded lengths will vary.*

2.2 Weight

2g = *2,000* **mg; 0.2 g =** *200* **mg; and 2 mg =** *0.002* **g**

Experimental Procedure: Weight

2. **Measure the weight of the block to the tenth of a gram.** *Answers will vary.*
3. **Measure the weight of an item small enough to fit inside the opening of a 50 ml graduated cylinder.** *Answers will vary.*

2.3 Volume

Experimental Procedure: Volume

1. **What is the actual volume of water.** *Answers will vary around 40ml.*
2. **About how many drops equal 1 ml of water.** *Answers will vary around 10-20 drops.*
3. **Hypothesize how you can measure the volume of the object with the water in the graduated cylinder.** *Drop the object into the cylinder holding 20 ml water and read the new, elevated volume. The difference between the two readings is the volume of the object alone.*
   Why is it easier to use this method to measure volume of the object compared to using length measurements to calculate the volume? *Irregular objects are difficult to measure using length.*

2.4 Temperature

Experimental Procedure: Temperature

1.
   a. Water freezes at either *32*°**F =** *0*°**C.**
   b. Water boils at either *212*°**F =** *100*°**C.**

2. Human body temperature of 98°F is what temperature on the Celsius scale? *37°C*

3. Record any two of the following temperatures in your lab environment. *Answers will vary.*

LABORATORY REVIEW 2

1. **What system of measurement is used in science?** *Metric*
2. **Which types of measurements were examined in this lab?** *Length, volume, weight, temperature*
3. **What is the base unit for length?** *Meter (m)*
4. **19 mm equals how many cm?** *1.9 cm*
5. **880 mm equals how many m?** *0.88 m*
6. **What instruments are used to observe objects smaller than a millimeter?** *Microscopes*
7. **What is the base unit for mass?** *Gram*
8. **What instrument is used to measure mass?** *Balance, scale*
9. **2700 mg equals how many grams.** *2.7 g*
10. **One ml is equal to how many cubic centimeters?** *1 ml = 1 cm*^{3}.
11. **3.4 l equals how many ml?** *3,400 ml*
12. **To properly measure 20 ml of water, what must be at the 20 ml mark of the graduated cylinder?** *The meniscus*
13. **Which temperature scale is used in science?** *Celsius*
14. **22˚C equals how many degrees F?** *71.6˚C*

Thought Questions

15. **Describe the advantages of using the metric system you discovered during this lab.** *Answers may vary. Converting between units was simple, decimals were easy to understand, and temperature scale made more sense with 0˚C as freezing and 100˚C as boiling.*
16. **Explain how you would measure the volume of a solid object such as a rock.** *I would partially fill a graduated cylinder or similar container with water and record the initial volume. Then, I would place the object in the container and record the new volume of water. Subtracting the initial volume from the final volume would give the volume of the object in ml which is also equivalent to cubic centimeters.*
17. **Why is it advantageous to use a standard measurement system in all sciences?** *Scientists from different countries are better able to share their information if they all use a standard system.*

LABORATORY 3 Microscopy

MATERIALS AND PREPARATIONS

Instructions are grouped by procedure. Some materials may be used in more than one procedure.

Special Requirements

Living material. *Euglena*

Fresh material. Onion, pond water (Order if not available locally.)

Notes

Microscope supplies. Set aside an area in the laboratory for storage of clean microscope slides, coverslips, and lens paper. Post a notice in this area, outlining the established procedures for handling dirty slides. Possible procedures include:

1. Wash, rinse, and dry all slides, and return them to their boxes; discard plastic coverslips.
2. Wash and rinse all slides, and place them in the drying rack.
3. Place dirty slides in the detergent solution provided; discard plastic coverslips. Some laboratories prefer that the laboratory assistant wash all slides in an ultrasonic cleaner, rinse the slides in distilled water, and allow the slides to drain dry.
4. Discard plastic coverslips. Glass coverslips should be placed in detergent solution in a beaker.

3.2 Stereomicroscope (Dissecting Microscope)

______ microscope, stereomicroscope with illuminator
______ lens paper
______ an assortment of objects for viewing (e.g., coins, plastomount)

3.3 Use of the Compound Light Microscope

______ microscopes, compound light
______ lens paper
______ slide, prepared: letter *e*; or newspaper, scissors, slides, and coverslips
______ rulers, clear plastic millimeter
______ slide, prepared: colored threads; or, to prepare your own, you will need slides and coverslips, three or four colors of sewing thread (or hairs), scissors, and a dropping bottle of water

3.4 Microscopic Observations

_______ microscope slides (glass or plastic)
_______ coverslips
_______ lens paper booklets
_______ microscopes, compound light
_______ toothpicks, prepackaged flat
_______ ethyl alcohol (ethanol), 70%; or alcohol prep swabs (if toothpicks are not prepackaged)
_______ optional prepared slide: human stratified squamous epithelium, cheek
_______ methylene blue solution, or iodine-potassium-iodide (IKI) solution (premade)
_______ biohazard waste container for toothpicks (Carolina 831660, 831665)
_______ container of 10% bleach solution for slides and coverslips (to be washed directly or autoclaved and washed at lab technician's discretion)
_______ dropping bottles, or bottles with droppers
_______ onion, fresh
_______ scalpel
_______ cutting board
_______ Protoslo® (Carolina 88 5141) or methyl cellulose solution
_______ pond water, fresh or ordered or live *Euglena* culture
_______ pictorial guides such as:

Needham, J. G., and P.R. Needham, 1988, *A Guide to the Study of Freshwater Biology: With Special Reference to Aquatic Insects and Other Invertebrate Animals,* 5th ed. Charles C. Thomas Publishers, ISBN: 0070461276

Patterson, D. J., and Hedley, S. 1996. *Free-Living Freshwater Protozoa: A Color Guide.* John Wiley & Sons, ISBN: 0470235675

Prescott, G. W. 1978. *How to Know the Freshwater Algae.* McGraw-Hill Higher Education, ISBN: 0697047547

Rainis, K. G., and Russell, B. J. 1996. *Guide to Microlife.* Franklin Watts, Inc., ISBN: 053112667

Smith, Douglas Grant 2001. *Pennak's Freshwater Invertebrates of the United States.* John Wiley & Sons, ISBN: 9780471258374. (Carolina 45 3901)

Methylene blue solution. Make up a 1.5% stock solution, using 1.5 g methylene blue stain (dye powder) in 100 ml of 95% ethyl alcohol (ethanol). Dilute one-part stock solution with nine parts water for laboratory use, or use iodine (IKI) solution. Methylene blue staining solution can also be purchased premade. Disperse in dropping bottles.

Iodine (IKI) solution. Iodine-potassium-iodide (IKI) solution can be purchased premade, or the ingredients can be purchased separately as potassium iodide (KI) and iodine (I). These dry ingredients have a long shelf life and can be mixed as needed, according to the following recipe:

To make a liter of stock solution, add 20 g of potassium iodide (KI) to 1 liter of distilled water, and stir to dissolve. Then add 4 g of iodine crystals, and stir on a stir plate; dissolution will take a few hours or more. Keep the stock reagent in dark, stoppered bottles. For student use, place in dropping bottles. Label as "iodine (IKI) solution."

Iodine solution stored in clear bottles loses potency over time. If the solution lightens significantly, replace it. Small dropper bottles can be stored for about a month, and they are used in other exercises. A screw-capped, brown bottle of stock iodine can be stored for about six months. Dispose of it if the solution turns light in color.

Dropping bottles. Various styles of dropping bottles are available—for example, dropper vials, glass screw-cap (Carolina 71 6438, 71 6434) with attached droppers; Barnes dropping bottles (Carolina 71 6525); and plastic dropping bottles (Carolina 71 6550). See also Carolina's Laboratory Equipment and Supplies section in Carolina catalogue.

Human epithelium cheek slide. To eliminate the possibility of contact with pathogens, this exercise can be done as a demonstration using a flexscope or videoscope for students to view from their seats. Otherwise, because of the hazards connected with human tissue samples and body fluids, you should take special precautions if students are preparing their own epithelium slides. Use a biohazardous waste container for toothpick disposal, and wash slides and coverslips in a 10% bleach solution. Microscopes should also be wiped with a disinfecting solution.

Protoslo® (or methyl cellulose solution). You can also use glycerol (Carolina 865530) and water as a substitute for Protoslo®. *Note:* Thickened Protoslo® can be reconstituted with distilled water.

Pond water. A good culture of pond water can be maintained to provide algae and protozoans during any season. Collect pond water during an active growing season from any local pond or stream. Include some algae and a *small* amount of organic debris and living aquatic (aquarium) plants, such as *Elodea.* Place the collected pond water and other items in a transparent container with a large surface area. Both container and lid should be transparent.

Examples of suitable containers are:
A large culture dish (Carolina 74 1006) covered with a second large culture dish
A plastic aquarium and aquarium cover (1.5 gal. plastic, Carolina 67 0388), (cover, Carolina 67 0389)
A small glass aquarium with a lid (5.5 gal., cover)

If kept in diffuse window light or under artificial illumination, the culture will grow and provide material for future labs, even in the middle of winter. If live cultures of pond water organisms or *Euglena* are purchased for a particular laboratory, they can be added to the maintained culture once they are no longer in use.

PRE-LAB QUESTIONS

1. **What is the purpose of this lab and what specific tool will you be using?** *This lab will explore the characteristics and use of microscopes.*
2. **List several differences between a light and electron microscope.** *Electron microscopes have higher resolution and use beams of electrons rather than light to magnify an object.*

3. **Looking at Figure 3.1, what specimens or structures might you see today?** *Insects, eggs, plant and animal cells, bacteria, chloroplasts*
4. **Label Figure 3.3 with the help of your textbook. (Labeled image below in Exercise Questions.)**
5. **List several unique objects or specimens you could view with a stereomicroscope.** *Insects, fossils, rocks, any small three-dimensional object*
6. **Label Figure 3.4 with the help of your textbook.**
7. **Compound light microscopes are parfocal and parcentric. In terms of using the multiple objective lenses, why are these features beneficial?** *The parfocal and parcentric features allow the field of view to stay centered and focused while changing objectives.*
8. **Review the Observation exercises below for Onion Epidermal Cells, Human Epithelial Cells, and Pond Water. Which specific cell structures do you predict will be most visible?** *Nuclei, cell walls, cell membrane, cytoplasm, cilia, flagella*

EXERCISE QUESTIONS

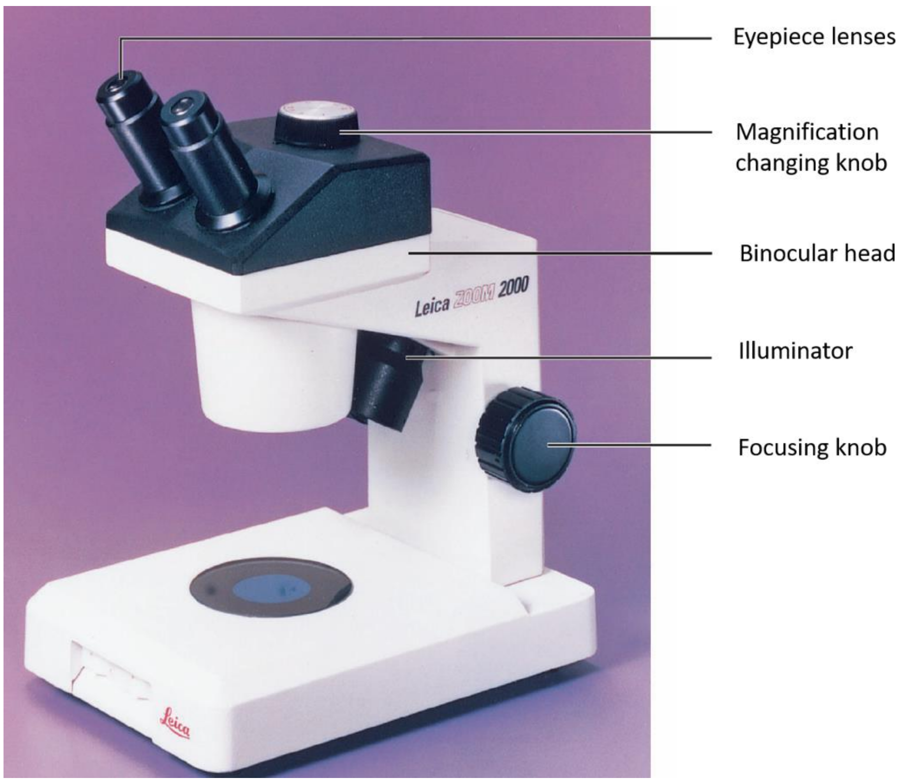
3.1 Stereomicroscope (Dissecting Microscope)

Identifying the Parts

2. **What is the magnification of your eyepieces?** *10× or 20×*

Locate each of these parts on your stereomicroscope, and label them on Figure 3.3.

Figure 3.3: *eyepiece lenses, magnification changing knob, binocular head, illuminator, focusing knob*



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Focusing the Stereomicroscope

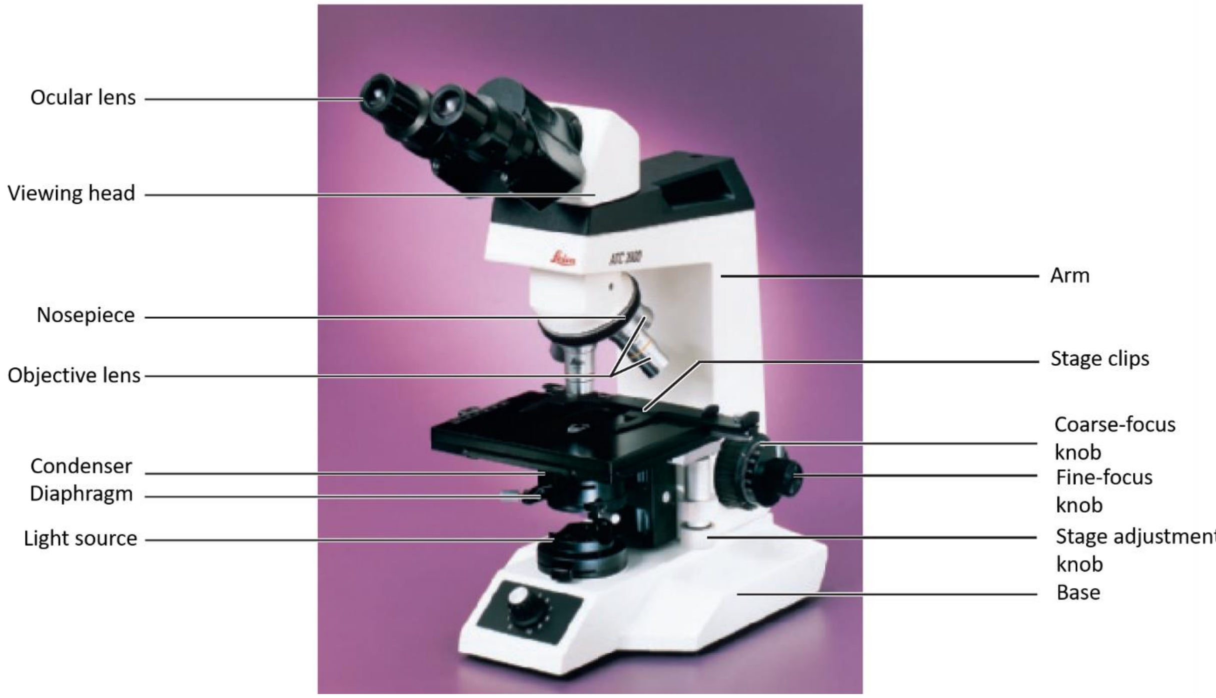
4. **Does your microscope have an independent focusing eyepiece?** *yes (most likely)* **Is the image inverted?** *no*
5. **What kind of mechanism is on your microscope?** *Answers will vary.*

3.2 Use of the Compound Light Microscope

Identifying the Parts

Identify the following parts on your microscope, and label them in Figure 3.4 with the help of the text material.

Figure 3.4 (left side, top to bottom): *ocular lens or lenses, viewing head, nosepiece, objective lens or lenses, condenser, diaphragm/diaphragm control lever; light source* **(right side, top to bottom):** *arm, stage clips, coarse-adjustment knob, fine-adjustment knob, light source, stage, base*



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1. **What is the magnifying power of the ocular lenses on your microscope?** *usually 10×.*
5.
   a. **What is the magnifying power of the scanning objective lens on your microscope?** *usually 4×*
   b. **What is the magnifying power of the low-power objective lens on your microscope?** *usually 10×*
   c. **What is the magnifying power of the high-power objective lens on your microscope?** *usually 40×*
   d. **Does your microscope have an oil immersion objective?** *depends on microscope*
6. **Does your microscope have a mechanical stage?** *depends on microscope*

Inversion

Observation: Inversion

1. **Draw the letter *e* as it appears on the slide (with the unaided eye, not looking through the eyepiece).** *The letter should be in the normal position.*
2. **Draw the letter *e* as it appears when you look through the eyepiece.** *The letter should be upside down and reversed.*
3. **What differences do you notice?** *The letter is inverted—that is, it appears to be upside down and reversed compared to its appearance when viewed by the unaided eye.*
4. **Move the slide to the right. Which way does the image appear to move?** *When moved to the right, the image appears to move to the left.*
5. **Move the slide toward you. Which way does the image appear to move?** *When moved toward you, the image appears to move away from you.*

Focusing the Compound Light Microscope—Higher Powers

5. **On a drawing of the letter *e*, draw a circle around the portion of the letter that you are now seeing with high-power magnification.** *Answers will vary.*

Total Magnification

Observation: Total Magnification

Table 3.1 Total Magnification*

Objective	Ocular Lens	Objective Lens	Total Magnification
Scanning power (if present)	*10×*	*4×*	*40×*
Low power	*10×*	*10×*	*100×*
High power	*10×*	*40×*	*400×*
Oil immersion (if present)	*10×*	*100×*	*1,000×*

**Answers may vary with equipment.*

Field of View

Observation: Field of View

Low-Power (10×) Diameter of Field

2. **Estimate the number of millimeters, to tenths, that you see along the field:** *Approximately 1.6* **mm. Convert the observed number of millimeters to micrometers:** *Approximately 1,600* **μm.**

High-Power (40×) Diameter of Field

1. **To compute the high-power diameter of field (HPD), substitute these data into the formula given:** *(Students record the data for LPD, LPM, and HPM for their specific microscope—answers may vary with equipment.)*
   a. **LPD = low-power diameter of field (in micrometers) =** *1,600* μm
   b. **LPM = low-power total magnification (from Table 2.3) =** *100×*
   c. **HPM = high-power total magnification (from Table 2.3) =** *400×*