Solution Manual for Biology The Essentials 1st Edition by Hoefnagels

ISBN 9780078096921

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CHAPTER 2 – The Chemistry of Life

CHAPTER OUTLINE

2.1 Atoms Make Up All Matter
- A. Elements Are Fundamental Types of Matter
- B. Atoms Are Particles of Elements
- C. The Number of Neutrons May Vary

2.2 Chemical Bonds Link Atoms
- A. Electrons Determine Bonding
- B. In a Covalent Bond, Atoms Share Electrons
- C. In an Ionic Bond, One Atom Transfers Electrons to Another Atom
- D. Partial Charges on Polar Molecules Create Hydrogen Bonds
- E. Bonds Break and Form in Chemical Reactions

2.3 Water Is Essential to Life
- A. Water Is Cohesive
- B. Many Substances Dissolve in Water
- C. Water Regulates Temperature
- D. Water Expands as It Freezes
- E. Water Participates in Life's Chemical Reactions

2.4 Organisms Balance Acids and Bases

2.5 Organic Molecules Generate Life's Form and Function
- A. Carbohydrates Include Simple Sugars and Polysaccharides
- B. Lipids Are Hydrophobic and Energy-Rich C. Proteins Are Complex and Highly Versatile
- D. Nucleic Acids Store and Transmit Genetic Information

2.6 Investigating Life: E. T. and the Origin of Life

LEARNING OUTCOMES

02.00.01 Explain the chemical nature of biological molecules.
02.01.01 Identify the most important elements in living organisms.
02.01.02 Describe the structure of atoms.

02.02.01 Compare and contrast the different types of bonds.
02.02.02 Differentiate between atoms, molecules, and compounds.

02.03.01 Explain how the structure of water affects its chemical properties.
02.04.01 Explain how acids and bases affect pH.
02.05.01 Explain the relationship between monomers and polymers.
02.05.02 Compare and contrast the structures and functions of the four classes of biological molecules.
02.06.01 Explain how researchers used isotopes to test hypotheses about the extraterrestrial origin of organic molecules.

WHERE DOES IT ALL FIT IN?

Chapter 2 provides an overview of the basic principles of chemistry making up the first hierarchal level of living systems discussed in Chapter 1. The chemistry concepts and terminology can be intimidating to many students because of the diversity of concepts needed to build an understanding of biological molecules. Reinforce to students that the elemental chemistry being covered in this chapter is essential for understanding cell structure and organismic function, and principles of homeostasis being taught during the semester. The scope of information about organic matter covered in Chapter 2 sets down the foundation of understanding cell metabolism, cell replication, cell structure, genetics, and membrane transport. Regularly refer to Chapter 2 when discussing the topics that rely on information about elements, organic molecules, and the properties of water.

SYNOPSIS

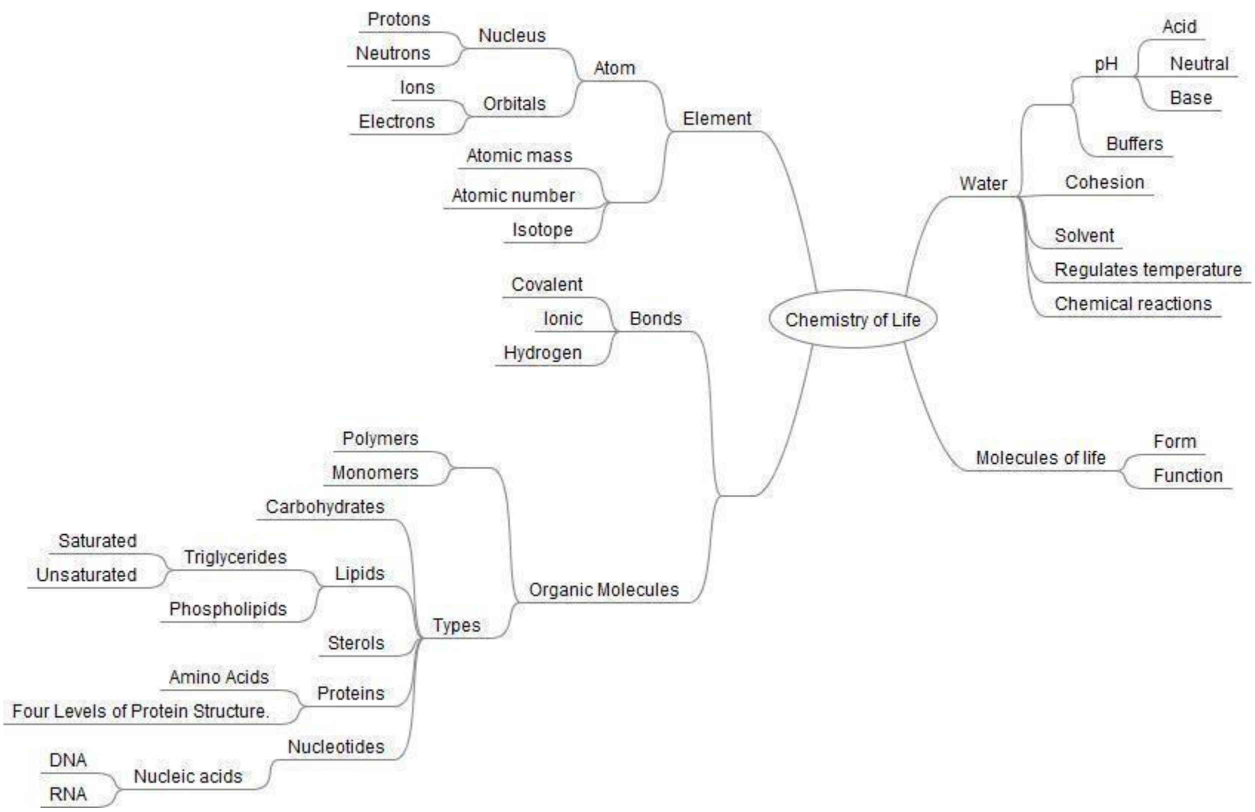
This chapter presents students with the basic chemistry background essential for understanding the underlying principles of biology. Living organisms can be viewed as chemical machinery composed of molecules that build their structure and that take part in chemical reactions that run a variety of metabolic reactions. The chapter demonstrates the roles of elements and molecules to the function and structure of organisms and their interaction with the environment. Basic concepts about atoms and elements are discussed in a way that is pertinent to biological systems. Emphasis is placed on the biological roles of ions and bonding. The important features of isotopes pertinent to living systems are also discussed.

The properties of water are also discussed in this chapter. The features of water that permit cell function and the overall survival of organisms on the Earth are highlighted. Examples of water's characteristics are illustrated using examples of how organisms adapted to the Earth's watery environment. It is stressed that water is the main unifying molecule that maintains the chemical and physical environmental conditions needed for cells and organisms to function. Coverage is also given to pH and its role in organisms and the environment. Buffers are introduced, as well as information about how organisms regulate their internal environments.

Organic molecules are later introduced in the chapter once the foundations of elements and bonds are established. The chapter introduces the fundamental properties of biological molecules and their existence as monomers and polymers. Each group of molecules is then introduced. The basic chemistry and biological roles of carbohydrates, lipids, proteins, and nucleic acids are discussed. Examples of common monomers and polymers are discussed. Enough background about each group of molecules is provided to promote class discussions about environmental health, medical treatments, and nutrition.

CONCEPT MAP

Concept mapping is a structured graphical presentation of the concepts covered in a particular topic. The following concept map represents the links between the information covered in this chapter. It is important to tell students to develop their own concept maps after covering the particular information covered in class.



COMMON STUDENT MISCONCEPTIONS

There is ample evidence in the educational literature that student misconceptions of information will inhibit the learning of concepts related to the misinformation. The following concepts covered in Chapter 2 are commonly the subject of student misconceptions. This information on "bioliteracy" was collected from faculty and the science education literature.

Mass and weight are the same and they are equal at all times.
The density of an object depends only on its volume.
Atoms can be seen with a standard microscope.
The terms atoms and elements are synonymous in meaning.
The atomic nucleus is large and in close proximity to the orbitals.
The electron shell is there to protect the nucleus.
Elements of solids are hard, whereas elements of gases are soft.
Atomic mass values are affected by electron number.
All bonds store and release energy.
Ionic compounds form neutral molecules such as Na^+Cl^- in water.
Electrons in covalent bonds belong to the particular atom they came from.
Electron pairs are equally shared in all covalent bonds.
The strength of acids and bases is the same thing as its concentration.
Substances containing H are acidic; substances containing OH are basic.
The pH scale represents a linear change in measurement.
Buffers make a solution neutral.
All acids and bases are harmful and poisonous.
Salts don't have a pH value.
pH is a measure of acidity.
The chemistry in biological systems does not follow all the same rules of chemistry.
Students are unsure about the hierarchical order of atoms, molecules, and cells.
Carbohydrates serve only as a source of fuel for the body.
All polysaccharides are starches.
All carbohydrate polymers are for food storage.
Proteins are not energy sources for the body.
There are only 20 types of amino acids in nature.
Amino acids and proteins are not related molecules.
Fats produce more energy than carbohydrates.
Fats only serve as a stored source of energy.
Students often confuse amino acids and nucleic acids.
All proteins have tertiary structure.
Proteins are a 100% representation of the DNA information.
Nucleic acids solely serve the purpose of genetic material.
Saturated fats are bad, while unsaturated fats are good.
Cholesterol is bad for the body.
Fats travel as clumps of insoluble material in the blood.
Organic molecules are only produced by organisms.

The following articles provide strategies for increasing bioliteracy in the college classroom:

Baldwin JD, Ebert-May D, Burns, D. 1999. The development of a college biology self-efficacy instrument for non-majors. Science Education 83(4): 397-408.

Ebert-May D. 2001. Research-based change: how one college professor approached the challenge of changing teaching. In: Implementing the Science Standards in Higher Education, eds. W. J. McIntosh and E. Siebert, pp. 36-39. Arlington, VA: National Science Teachers Association.

Khodor J, Halme DG, Walker GC. 2004. A Hierarchical Biology Concept Framework: A Tool for Course Design. Cell Biology Education, 3(2): 111-121.

Klymkowsky MW, Garvin-Doxas K, Zeilik M. 2003. Bioliteracy and teaching efficacy: what biologists can learn from physicists. Cell Biol Educ, 2(3):155-61.

INSTRUCTIONAL STRATEGY PRESENTATION ASSISTANCE

Molecular models are quite helpful when reinforcing the concept of molecular structure. Many aspects of chemistry such as the differences between isomers just don't work on a two-dimensional surface. Three-dimensional isomer models can be built and shown to the class. Large plastic or polystyrene molecular model kits usually used to teach organic chemistry are appropriate for large lecture sections. The importance of molecular shape in living organisms can be demonstrated using hands and different size gloves. The hands can represent a substrate and the gloves represent an enzyme that must bind with the substrate.

Researchers have been known to use common objects to represent the structure of molecules they were studying. Provide students with tangible examples of 3-D molecular structure by constructing molecules from polystyrene balls and straws. Pop-it beads are valuable for describing polymerization of nearly all of the molecules of life, especially amino acids forming polypeptide chains. A coiled telephone cord effectively resembles an alpha helix while a zigzag strip of crimped paper can demonstrate pleated sheets.

The characteristics of water become intuitive to students when related to everyday observations such as the tempering effects on weather, sweating, surface tension, and so forth. Use as many common examples as possible. Students can measure the relative pH of various household solutions using tea – the normal unadulterated drinking variety. Tea becomes more yellow in color when lemon juice is added because the juice is acidic, not because the tea is diluted by a yellow liquid. Red cabbage is also an acid-base indicator; red when acid, blue when basic.

Construct protein amino acid sequence demonstrations by using a chain of pop beads composed of 20 differently labeled beads to represent the 20 different amino acids commonly making up proteins (the beads can be labeled with an indelible marker). The beads can be put together to show the variation in primary structure. Pipe cleaners, or wire, can be used to help demonstrate secondary, tertiary, and quaternary structure.

It is encouraged to use some lecture or recitation time to discuss the "What's the Point?," "Why We Care," "Burning Questions" boxes, and the end-of-chapter reading titled "Investigating Life: E. T. and the Origin of Life." The information in these resources encourages students to use the chapter information in critical thinking situations.

When assigning the chapter as a reading, encourage the students to stop and complete the "Mastering Concepts" features as a way of assessing their knowledge of what they read.
In addition, the "Pull It Together" provides students with a visual summary of the important concepts in the chapter.

HIGHER LEVEL ASSESSMENT

Higher level assessment measures a student's ability to use terms and concepts learned from the lecture and the textbook. A complete understanding of biology content provides students with the tools to synthesize new hypotheses and knowledge using the facts they have learned. The following table provides examples of assessing a student's ability to apply, analyze, synthesize, and evaluate information from Chapter 2.

Application	Have students apply the concept of water cohesion to the properties of glue. Ask students to explain why the digestive system of animals must be adapted to break down covalent bonds yet there is no particular mechanism for breaking down ionic bonds. Ask students to explain why foods high in saturated fats stay fresher than foods high in unsaturated fats.
Analysis	Ask students to select and analyze three characteristics of water that would help an organism survive in the desert. Ask students to explain why keeping track of dietary amino acid intake is more important than just knowing what proteins are being taken in the diet. Ask students to explain what nutrient molecules would be deficient in food if crop plants were deprived of fertilizers containing nitrogen and phosphorus.
Synthesis	Ask students to come up with potential agricultural uses of an instrument that measures the types of elements found within an intact living organism. Ask students to design a hypothetical low calorie food using isomers of carbohydrates and alternative forms of lipids. Ask students to describe how an organism would have to adapt to extremely hot environmental conditions in which the tertiary structure of normal proteins is disrupted.
Evaluation	Ask students to discuss the probability of life on a planet that is not abundant in the elements that form covalent bonds. Ask students to evaluate the difference between nutrients obtained from nature versus those produced synthetically in a laboratory. Ask students to explain why the molecules in organisms found on another planet may not be of nutritional value to humans.

BIOETHICAL CONSIDERATION

Biological knowledge contributes to the betterment of human society in many ways. However, there are also various ethical concerns that are raised by the applications of this knowledge. An understanding of molecular structure has permitted scientists to create synthetic versions of naturally occurring biological molecules. These molecules are commonly used as medications and as nutritional supplements such as vitamins. An ethical consideration called "Vitamin E scare study used synthetic, not natural vitamin E" presents students with one concern about synthetic versus natural vitamins. Ask students to discuss the rationale for the writer's view and whether the view is consistent with the science of molecular structure. The issue can be found at: http://www.naturalnews.com/002352.html.

FUN FACTS

Trivial facts about biology are a fun way to spice up a lecture. They can be read in class or placed at appropriate points into a lecture using the board or a projected presentation. The trivia can be used as a jumping point for students to further investigate the fact.

The only letter not appearing on the periodic table of elements is the letter J.
Matter making up the Earth weighs approximately 7,000,000,000,000,000 tons.
Types of matter called atoms were believed to exist by the Greeks about 2,400 years ago.
At room temperature, the average air molecule travels at the speed of a rifle bullet.
Air becomes liquid at about -190^{o} C.
Cellophane food wrap is not made of plastic, rather it is made from cellulose that has been shredded and aged.
In a 100-year period, a water molecule spends 98 years in the ocean, 20 months as ice, about two weeks in fresh water bodies, and less than a week in the atmosphere.
An average adult human body contains around 250 g or ½ lb of salt.
The amount of carbon in the human body is enough to fill about 9,000 lead pencils.
It is estimated that a plastic container can resist decomposition when buried in a landfill for as long as 50,000 years.
A bee sting is acidic and a wasp sting is alkali.

IN-CLASS CONCEPTUAL DEMONSTRATION

Exposing the Carbon Skeleton of Organisms

Organic chemistry is often the least enjoyable subject covered in general biology courses. This demonstration reinforces the fact that all organic molecules have a carbon skeleton. It shows the prevalence of carbon in organic molecules versus inorganic molecules. Plus, it demonstrates the amount of bond energy stored in organic molecules. It uses sulfuric acid to break down the covalent bonds of organic molecules releasing the oxygen and hydrogen. What remains in the container is a carbon mass puffed with gases (carbon dioxide and sulfur oxides) released by the molecular degradation.

Special Precautions

> Caution must be used with this demonstration. It produces a rapid burst of heat and noxious fumes. It should be done using personal protection equipment (gloves, goggles, and a laboratory apron) and in a well-vented area near a source of running water. Be careful to conduct the demonstration in a manner that students cannot be harmed if the glass container cracks. The waste remaining from the demonstration should be disposed in an acid waste container.

This procedure can be shown to a large class using a videocam attached to an LCD projector.

Materials

Large glass thermometer
Three 400 ml Pyrex®, or equivalent glass,
beakers Three large glass test tubes
300 ml of room temperature water
Bottle of sucrose solution with dropper (20 g sucrose/100 ml water)
Bottle of amino acid solution with dropper (20 g amino acids/100 ml water)
Bottle of table salt solution with dropper (20 g table salt/100 ml water)
Bottle of concentrated sulfuric acid solution with dropper
Roll of aluminum foil
Personal protection equipment

Procedure and Inquiry

1. Explain to the class that you will be demonstrating the carbon composition of organic molecules compared to inorganic molecules.
2. Lay down a sheet of aluminum foil on the table where the demonstration will take place.
3. Place one beaker in the middle of the foil.
4. Add 100 ml of water to the beaker.
5. Place one test tube into the beaker.
6. Add 5 ml of sucrose solution to the test tube while explaining your action to the class.
7. Place the thermometer in the beaker so that the bulb is touching the base of the test tube.
8. Announce to the class the starting temperature of the solution.
9. Slowly add approximately 2 ml of the concentrated sulfur acid (do not mix or stir).
10. Direct the class to observe what happens (the solution will darken followed by the rapid eruption of a black column of "puffy material").
11. Announce to the class the final temperature of the solution.
12. Repeat steps 4 through 11 for the amino acid and salt solutions.
13. Ask the class to explain the elemental composition of the "puffy material" (they should be directed to answer carbon with hydrogen gas and carbon dioxide).
14. Ask them why the table salt solution did not show carbon "puffy stuff".
15. Ask the class to explain the temperature elevation (they should explain it was due to the energy released by the breakage of covalent bonds).
16. Ask the students what they should expect to find if a similar demonstration was performed on the following materials:
    A piece of chalk
    Lump of bacon fat
    A piece of paper

USEFUL INTERNET RESOURCES

1. The value of the periodic table is often understated in introductory biology lectures. Instructors can show the importance of the periodic table relating an element's placement on the table to its bonding property with other elements. An excellent website hosted by Iowa State University facilitates the relationship between certain elements found in organic molecules and their capacity to form covalent bonds. The website is located at http://www.chem.iastate.edu/group/Greenbowe/sections/projectfolder/flashfiles/reaction/bonding1.swf.
2. Animated three-dimensional models of biological chemicals add an exciting component to a lecture from Chapter 2. These images can be manipulated and altered to demonstrate different aspects of a wide array of molecules. The World of Molecules website http://www.worldofmolecules.com/3D/benzene_3d.htm maintains a sample database of interactive 3-D molecules that can be displayed in class. Another good website is from the University of Massachusetts at http://www.umass.edu/microbio/rasmol/. This website demonstrates how researchers use interactive 3-D computer models of molecules in biological research.
3. A lecture on pH can be enlivened by demonstrating the pH of various household and laboratory compounds. Birmingham Grid for Learning hosts an interactive website for demonstrating the pH properties of various compounds using virtual litmus paper or universal indicator. It even guides students through buffer reaction predictions. This entertaining interactive website is found at http://www.bgfl.org/bgfl/custom/resources_ftp/client_ftp/ks3/science/acids/
4. Visual demonstrations of laboratory activities are important for ensuring students are collecting the correct data for analysis. This website instructs students on the chemical analysis methods used to identify carbohydrates, lipids, and proteins in general biology laboratories. The website is found at http://nhscience.lonestar.edu/biol/macromol/controls.html.

QUICK LABORATORY IDEA

Two laboratory ideas are presented for this chapter.

Quick Laboratory Idea #1: Protein Contents of Foods

In this investigation students will hypothesize the presence of detectable levels of protein in different food substances.

Materials

1 cm cubes or small samples of grape, beef liver, canola oil, carrot, and potato Distilled water
1% albumin standard
Test tube rack
7 test tubes per group
Buiret solution

Procedure and Inquiry

1. Students should be asked to hypothesize the relative protein content of the foods provided in this activity: grape, beef liver, canola oil, carrot, and potato. This determination should be based on the tissue composition of the organisms from which the food was obtained.
2. Ask students to carry out the following instructions:
    a. Label one test tube “standard” and another test tube “water”. The remaining test tubes should be labeled with the names of the samples. Place the test tubes in the test tube rack.
    b. Place a small amount of each sample into the appropriately labeled test tube. Sample should be about the size of a fingernail.
    c. Add 5 ml of Biuret solution to each of the test tubes.
    d. Gently shake each tube for 2 minutes.
    e. Observe the tubes for a purple color change indicating the presence of protein.
    f. The “water” tube should stay blue and the 1% albumin labeled “standard” should be dark purple.
    g. Have students compare their findings to the hypotheses they made earlier.
    h. They should be encouraged to search the internet to confirm if their findings match the scientific and nutritional literature.
3. Buiret solution should be disposed as a hazardous waste.

Quick Laboratory Idea #2: The Chemistry of Food Preservation

This activity will have students investigate the rationale for using pH and salts in food preservation using the catalase test to look for cellular activity.

Materials

Potatoes
Instruments for cutting the potato samples
Petri plate halves or a surface for testing the potatoes for catalase Household hydrogen peroxide
Droppers
pH solutions (Popular chemical supply companies provide precalculated tablets that when added to water provide a buffered solution at a particular pH)

- pH 2
- pH 4
- pH 6
- pH 7
- pH 8
- pH 10
- pH 12

- 0% (distilled water)
- 0.5 %
- 1%
- 3 % (close to sea water)
- 5%
- 10%

Procedure and Inquiry

1. Explain to students that a chemical (enzyme) produced in healthy cells called catalase is an indicator of cell metabolism. Then explain that certain metabolic pathways associated with catalase cause the decay of certain foods such as vegetables.
2. Demonstrate the catalase test by adding hydrogen peroxide to a fresh section of potato (the test material). Bubbling (or the production of oxygen gas) is an indicator of catalase activity.
3. Ask the students to design a controlled experiment that investigates the ability of pH and certain salt concentrations to preserve food.
4. Students should also be asked what would be the most feasible pH or salt levels that preserve food while also maintaining edibility.
5. Provide students with the materials listed above.
6. The students should first add a drop of the test solutions and let it soak into a small slice of potato. They should then add the catalase to see if catalase activity was hindered or enhanced.
7. Have the students discuss how protein function may be affected by pH and salt concentration.

LEARNING THROUGH SERVICE

Service learning is a strategy of teaching, learning, and reflective assessment that merges the academic curriculum with meaningful community service. As a teaching methodology, it falls under the category of experiential education. It is a way students can carry out volunteer projects in the community for public agencies, nonprofit agencies, civic groups, charitable organizations, and governmental organizations. It encourages critical thinking and reinforces many of the concepts learned in a course.

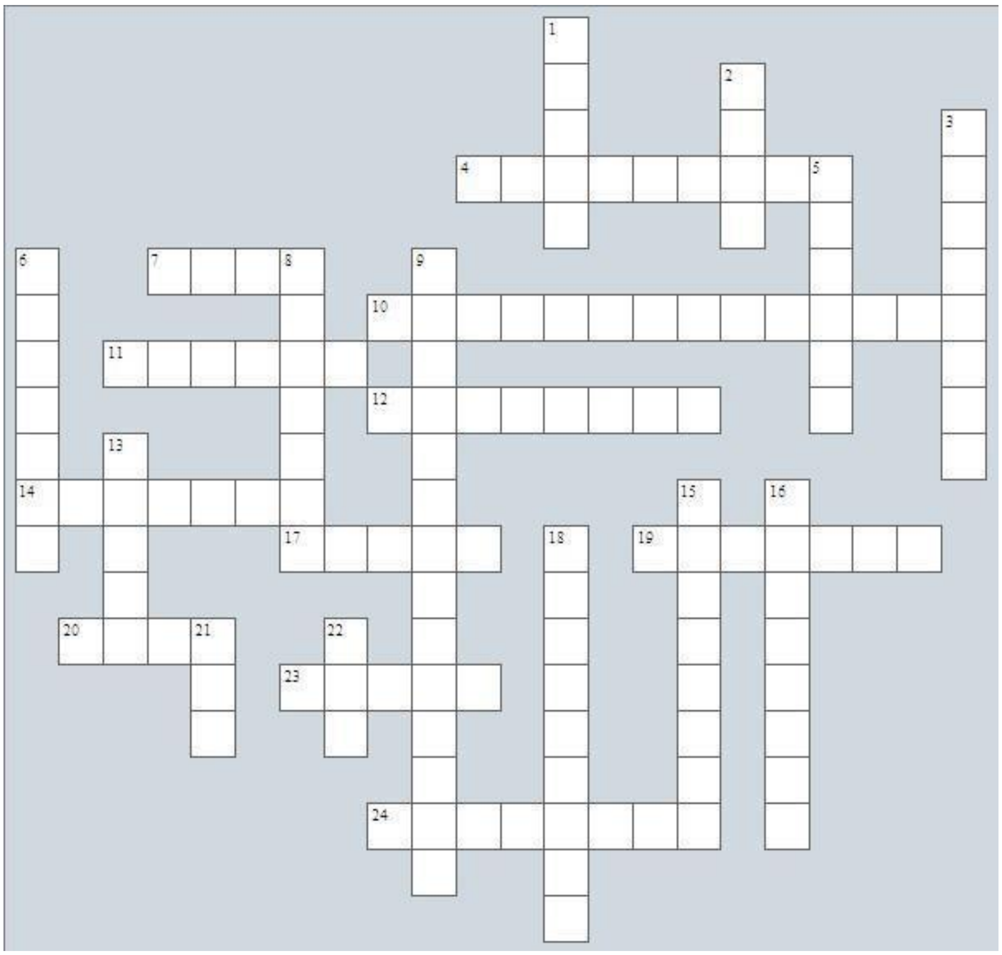
Students who have successfully mastered the content of Chapter 2 can apply their knowledge for service learning activities in the following ways:

1. Have students visit a local elementary school to give a presentation on nutrition by teaching about molecules that make up foods.
2. Have students talk to church or civic groups about understanding the chemistry of food labels.
3. Have students judge science fairs that focus on projects investigating the chemistry of biological molecules.
4. Have students tutor middle school or high school biology students studying the chemistry of life.

CROSSWORD PUZZLE

Use copies and a projected image of the crossword puzzle as an entertaining way to review the concepts in this chapter. Hand out the copies to the class and project an image of the crossword using an overhead or LCD projector. Then use student input to complete the crossword puzzle while quizzing them on other concepts and terms covered in the chapter.

Chemistry of Life



Across

4. Found in the orbitals
7. Has a pH value greater than 7
10. Starch is an example
11. Adjusts pH in an organism
12. Ability of water to form hydrogen bonds with itself
14. Composed of amino acids
17. Required in small amounts
19. Building blocks of polymers
20. Add hydrogen ions to a solution
23. Dissolves in water
24. Ability of water to form hydrogen bonds with other substances

Down

1. The solvent of life
2. The "stuff of life"
3. Found in triglycerides
5. Cholesterol is an example
6. An atom with a neutron number variation
8. A pure type of atom
9. Simplest type of carbohydrate
13. A bond formed between charged atoms
15. Composed of bonded elements
16. A bond that shares electron orbitals
18. The formation of polymers
21. A polymer of nucleic acids
22. An electrically charged atom

Answers

Across

4. ELECTRONS—Found in the orbitals
7. BASE—Has a pH value greater than 7
10. POLYSACCHARIDE—Starch is an example
11. BUFFER—Adjusts pH in an organism
12. COHESIVE—Ability of water to form hydrogen bonds with itself
14. PROTEIN—Composed of amino acids
17. TRACE—Required in small amounts
19. MONOMER—Building blocks of polymers
20. ACID—Add hydrogen ions to a solution
23. POLAR—Dissolves in water
24. ADHESIVE—Ability of water to form hydrogen bonds with other substances

Down

1. WATER—The solvent of life
2. ATOM—The "stuff of life"
3. GLYCEROL—Found in triglycerides
5. STEROL—Cholesterol is an example
6. ISOTOPE—An atom with a neutron number variation
8. ELEMENT—A pure type of atom
9. MONOSACCHARIDE—Simplest type of carbohydrate
13. IONIC—A bond formed between charged atoms
15. MOLECULE—Composed of bonded elements
16. COVALENT—A bond that shares electron orbitals
18. SYNTHESIS—The formation of polymers
21. DNA—A polymer of nucleic acids
22. ION—An electrically charged atom