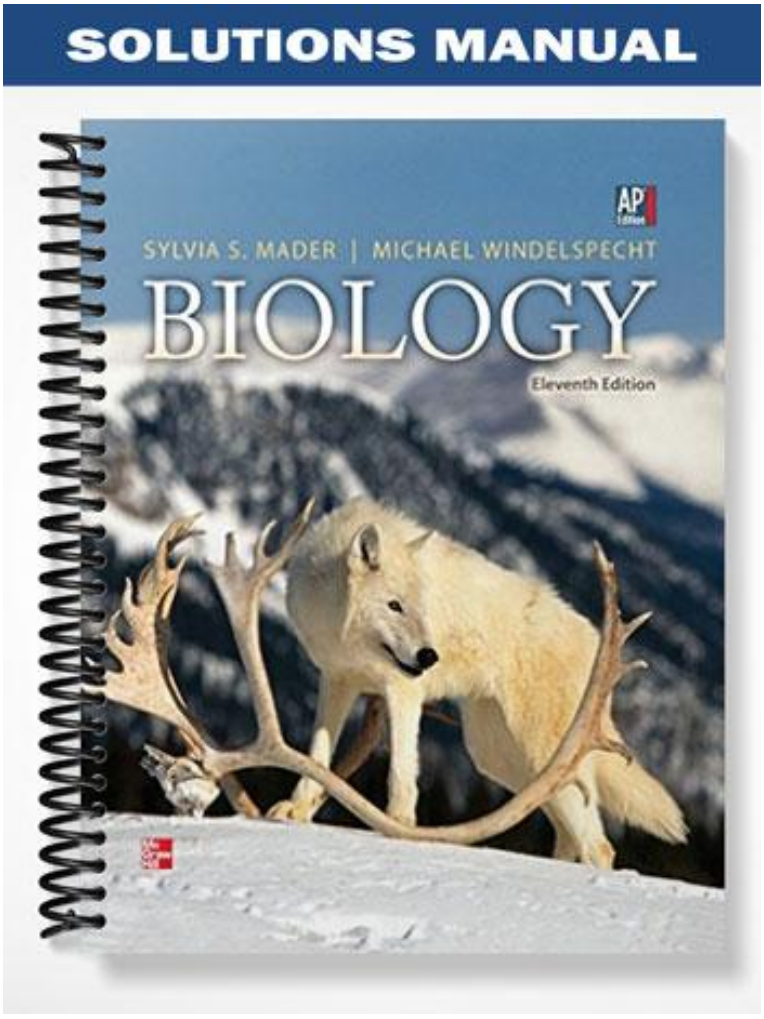
SOLUTIONS MANUAL



Instructor's Manual
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For
Biology 11e by Sylvia Mader

The Instructor's Manual

The *Instructor's Manual* is designed to help you coordinate the various ancillaries and aids that accompany *Biology.* The manual is aligned with the text. There is a chapter in the manual for each chapter in the text. Each chapter includes the following:

Learning Outcomes

The major goals of each section of the chapter are provided in the textbook and in this manual. All learning outcomes may be assessed using McGraw-Hill Connect® Biology activities.

The Chapter Outline

The concepts as presented in the text are outlined under each major heading in each chapter. The outline provides a basis for an organized lecture or discussion class, and the outline format is kept direct and concise to help students who have not developed good outlining skills to learn them. While it is critical that students meaningfully internalize distinct biology concepts, biology majors must also organize this huge body of information as they pursue advanced work and specialize. Note-taking in an organized manner is an important aspect of understanding the intellectual content of biology. An instructor who presents material in a clear and logically organized manner helps to set the student's understanding of the chapter concepts. The importance of organizing biology concepts by outline cannot be overstated.

Lecture Enrichment Ideas

Every chapter in this *Instructor's Manual* includes from 3–20 enrichment ideas. These provide ideas for discussions, techniques to relate the concepts to students meaningfully within their realm of experiences, suggested questioning strategies, and additional applications of the chapter concepts.

Critical Thinking Questions

Sample critical thinking questions are supplied for use in testing or to stimulate class discussion.

1 INTRODUCTION

CHAPTER 1 A VIEW OF LIFE

The text opens with a description of the characteristics of life, followed by a discussion of the human species' integration into the highly-diverse biosphere. Taxonomic classification, the system by which all organisms are categorized, is discussed. The steps of the scientific method are outlined. Two specific types of scientific experiments—the controlled study and the field study—are described in detail.

Learning Outcomes

1.1 How to Define Life

1. Distinguish between the levels of biological organization.
2. Identify the basic characteristics of life.

1.2 Evolution, the Unifying Concept in Biology

1. Distinguish between the three domains of life.
2. Explain the relationship between the process of natural selection and evolutionary change.

1.3 How the Biosphere is Organized

1. Distinguish among populations, communities, ecosystems, and the biosphere.
2. Recognize the importance of maintaining biodiversity.

1.4 The Process of Science

1. Identify the components of the scientific method.
2. Distinguish between a theory and a hypothesis.
3. Analyze a scientific experiment and identify the hypothesis, experiment, control groups, and conclusions.

Chapter Outline

1.1 How to Define Life

A. Living Things Are Organized

1. Organization of living systems begins with **atoms**, which make up basic building blocks called **elements.**
2. The **cell** is the basic structural and functional unit of all living things.
    a. **Unicellular** organisms are single celled organisms that either live independently, or as colonies.
    b. **Multicellular** organisms are made up of many cells that work together.
3. Different cells combine to make up **tissues** (e.g., nerve tissue).
4. Tissues combine to make up an **organ** (e.g., the brain).
5. Specific organs work together as an organ **system** (e.g., the brain, spinal cord, etc.).
6. Multicellular organisms (each an "individual" within a particular species) contain **organ systems** (e.g.,
7. A species in a particular area (e.g., gray squirrels in a forest) constitutes a **population.**
8. Interacting populations in a particular area comprise a **community.**

9. A community plus its physical environment is an **ecosystem.**
10. The **biosphere** is comprised of regions of the Earth's crust, waters, and atmosphere inhabited by organisms.
11. Each level of organization is more complex than the level preceding it.
12. Each level of organization has **emergent properties** due to interactions between the parts making up the whole; all emergent properties follow the laws of physics and chemistry.

B. Living Things Acquire Materials and Energy
1. Maintaining organization and conducting life-sustaining processes require an outside source of **energy**, defined as the capacity to do "work."
2. **Metabolism** is all the chemical reactions that occur in a cell.
3. The ultimate source of energy for nearly all life on Earth is the sun; plants and certain other organisms convert solar energy into chemical energy by the process of **photosynthesis.**

C. Living Things Maintain Homeostasis
1. All organisms must maintain a state of biological balance, or homeostasis.
2. Temperature, moisture level, pH, etc. must be maintained within the tolerance range of the organism.
3. In order to maintain homeostasis, body systems monitory internal conditions and make adjustments when needed.
4. Organisms have intricate feedback and control mechanisms to maintain homeostatic balance.

D. Living Things Respond
1. Living things interact with the environment and with other living things.
2. Response often results in movement of the organism (e.g., a plant bending toward the sun to capture solar energy, a turtle withdrawing into its shell for safety, etc.).
3. Responses help ensure survival of the organism and allow the organism to carry out its biological activities.
4. The collective responses of an organism constitute the behavior of the organism.

E. Living Things Reproduce and Develop
1. Reproduction is the ability of every organism to give rise to another organism like itself.
2. Bacteria, protozoans, and other unicellular organisms can reproduce asexually by splitting in two (binary fission).
3. Multicellular organisms often reproduce sexually, uniting sperm and egg, each from a different individual, resulting in an immature individual that develops into the adult.
4. The instructions for an organism's organization and development are encoded in genes.
5. Genes are comprised of long molecules of DNA (deoxyribonucleic acid); DNA is the genetic code in all living things.
6. Genes are passed on from generation to generations. Methods to ensure genetic variability include random combination of sperm and egg and mutations.

F. Living Things Have Adaptations
1. **Adaptations** are modifications that make organisms better able to function in an environment
2. **Evolution** includes changes in organisms to better adapt to their environment over long periods of time.

1.2 Evolution, the Unifying Concept of Biology

A. Organizing Diversity
1. **Taxonomy** is the discipline of identifying and grouping organisms according to certain rules.
2. **Systematics** is the study of the evolutionary relationships between organisms.
3. Taxonomic classification changes as more is learned about living things, including the evolutionary

relationships between species.

4. From smaller (least inclusive) categories to larger (more inclusive), the sequence of classification categories is: species, genus, family, order, class, phylum, kingdom, and domain.
5. The species within one genus share many specific characteristics and are the most closely related, while species in the same kingdom share only general characteristics with one another.
6. Biochemical evidence suggests that there are three domains: **Bacteria, Archaea,** and **Eukarya.**
7. The domains Bacteria and Archaea contain unicellular prokaryotes; organisms in the domain Eukarya are eukaryotes that have a membrane-bound nucleus.
8. The prokaryotes are structurally simple but are metabolically complex.
9. Archaea can live in water devoid of oxygen, and are able to survive harsh environmental conditions (temperatures, salinity, pH).
10. Bacteria are adapted to live almost anywhere (water, soil, atmosphere, in/on the human body, etc.).
11. The domains Archaea and Bacteria are not yet categorized into kingdoms.
12. Eukarya contains four kingdoms: **Protista, Fungi, Plantae**, and **Animalia.**
13. **Protists** (kingdom Protista) range from unicellular forms to multicellular forms.
14. **Plants** (kingdom Plantae) are multicellular photosynthetic organisms.
15. **Fungi** (kingdom Fungi) are the molds and mushrooms.
16. **Animals** (kingdom Animalia) are multicellular organisms that ingest and process their food.
17. **Bionomial nomenclature** refers to a two-part scientific name: the genus (first word, capitalized) and the specific epithet of a species (second word, not capitalized).
18. Binomial names are based on Latin and are used universally by biologists.

B. Evolution is Common Decent with Modification

1. **Natural selection** is the process by which species become modified over time.
2. In natural selection, members of a species may inherit a genetic change that makes them better suited to a particular environment.
3. These members would be more likely to produce higher numbers of surviving offspring.

1.3 How the Biosphere is organized

1. The **biosphere** is the zone of air, land, and water where organisms exist.
2. A **population** consists of all members of one species in a particular area.
3. A **community** consists of all of the local interacting populations.
4. An **ecosystem** includes all aspects of a living community and the physical environment (soil, atmosphere, etc.).
5. Interactions between various food chains make up a **food web.**
6. Ecosystems are characterized by chemical cycling and energy flow.
7. Ecosystems stay in existence because of a constant input of solar energy and the ability of photosynthetic organisms to absorb it.

A. The Human Population

1. The human population modifies existing ecosystems which can upset their natural nutrient cycles, causing harm to human populations and disrupting the ecosystem's natural energy flow.

B. Biodiversity

1. Two biologically diverse ecosystems, rain forests and coral reefs, are severely threatened by the human population.
2. Destruction of healthy ecosystems has unintended effects including: loss of food, medicine, raw materials, and extinction of organisms.
3. **Biodiversity** is the total number of species, their variable genes, and their ecosystems.

4. **Extinction** is the death of a species or larger group; perhaps 400 species become extinct every day.
5. The continued existence of the human species is dependent on the preservation of ecosystems and the biosphere.

1.4 The Process of Science

A. Scientific Method
   1. **Biology** is the scientific study of life, and it consists of many disciplines.
   2. The scientific process differs from other ways of learning in that science follows the **scientific method**, which is characterized by **observation,** development of a **hypothesis, experimentation** and **data collection,** and forming a **conclusion.**

B. Observation
   1. Scientists believe nature is orderly and measurable, and that natural laws (e.g., gravity) do not change with time.
   2. Natural events, called **phenomena,** can therefore be understood from observations.
   3. Scientists also use the knowledge and experiences of other scientists to expand their understanding of phenomena.
   4. Chance alone can sometimes help a scientist get an idea (e.g., Alexander Fleming's discovery of penicillin).

C. Hypothesis
   1. **Inductive reasoning** allows a person to combine isolated facts into a cohesive whole.
   2. A scientist uses inductive reasoning to develop a possible explanation (a **hypothesis**) for a natural event; the scientist presents the hypothesis as an actual statement.
   3. Scientists only consider hypotheses that can be tested (i.e., moral and religious beliefs may not be testable by the scientific method).

D. Experiments, Observations, and Data
   1. Testing a hypothesis involves either conducting an experiment or making further observations.
   2. **Deductive reasoning** involves "if, then" logic to make a **prediction** that the hypothesis can be supported by experimentation.
   3. An **experimental design** is proposed to test the hypothesis in a meaningful way.
   4. An experiment should include a **control group** which goes through all the steps of an experiment but lacks (or is not exposed to) the factor being tested.
   5. Scientists may use a **model** (a representation of an actual object) in their experiments.
   6. Results obtained from use of a model will remain a hypothesis in need of testing if it is impossible to test the actual phenomenon.
   7. **Data** are the results of an experiment, and are observable and objective rather than subjective.
   8. Data are often displayed in a graph or table.
   9. Results usually include a **standard deviation**, which is a statistical analysis that is a measure of how much the data in the experiment varies.
   10. Many studies rely on statistical data which, among other things, determines the probability of error in the experiment.

E. Conclusion
   1. Whether the data support or reject the hypothesis is the basis for the **conclusion.**
   2. The conclusion of one experiment can lead to the hypothesis for another experiment.
   3. Scientists report their findings in scientific journals so that their methodology and data are available to other scientists.
   4. The experiments and observations must be repeatable or the research is suspect.

F. Scientific Theory

1. The ultimate goal is to understand the natural world in **scientific theories,** which are concepts that join supported, related hypotheses, and are supported by a broad range of observations, experiments, and data.
2. Some basic theories of biology are:
    a. Cell: all organisms are made of cells.
    b. Homeostasis: the internal environment of an organism stays relatively constant.
    c. Gene: organisms contain coded information that dictates their form, function, and behavior.
    d. Ecosystem: organisms are members of populations which interact with each other and the physical environment.
    e. Evolution: all living things have a common ancestor.
3. A **principle** or a **law** is a theory that is generally accepted by most scientists.

G. Using the Scientific Method
1. A controlled study ensures that the outcome is due to the **experimental (independent) variable,** the factor being tested.
2. The result is called the **responding (dependent) variable** because it is due to the dependent variable.
3. The Experiment
    a. Observation: Nitrogen fertilizer in the short run exchanges yield and increases food supplies.
    b. Hypothesis: pigeon pea/winter wheat rotation will increase winter wheat production as well as or better than the use of nitrogen fertilizer.
    c. Prediction: wheat biomass following the growth of pigeon peas in the soil will surpass wheat biomass following nitrogen fertilizer treatment.
    d. Control group: winter wheat that receives no fertilizer.
    e. Test groups: winter wheat treated with different levels of fertilizer; winter wheat grown in soil into which pigeon pea plants had been tilled.
    f. Environmental conditions and watering were identical in control and test groups.
    g. Results: all test groups produced more biomass than control group, but high level of nitrogen fertilizer produced more biomass than pigeon pea test group. Thus, hypothesis is **not supported.**
4. Continuing the Experiment
    a. To test the hypothesis that pigeon pea residues will build up over time and will increase winter wheat production compared to nitrogen fertilizer, the study is continued for another year.
    b. The fertilizer-only treatment no longer exceeded biomass production with the use of pigeon peas; biomass in the pigeon pea-treated test group was highest.
    c. Conclusion: at the end of two years, the yield of winter wheat is better in the pigeon pea-treated test group. Hypothesis **supported.**
    d. Continuation of the study for another year showed that the soil was continuously improved by the pigeon peas compared to the nitrogen fertilizer test groups.
    e. Results were reported in a scientific journal.

H. A Field Study
1. Hypothesis: aggression of the male mountain bluebird varies during the reproductive cycle.
2. Prediction: aggression will change after the nest is built, after the first egg is laid, and after hatching.
3. To test the hypothesis, a male bluebird model was placed near the nest while the male was gone and observations were made upon his return.
4. Control: a model of a male robin placed near certain nests.
5. Results: resident male bluebirds did not bother the control model but were aggressive toward the male bluebird model depending on the stage in the reproductive cycle.
6. Conclusion: hypothesis is **supported.**

7. Study was reported in scientific journal with evolutionary interpretation.

I. The Benefits and Limitations of Statistical Studies (*Nature of Science* reading)
   1. Benefits of Statistical Studies
      a. Benefits of statistical studies include: Basis for supporting null or alternative hypotheses, gaining information and insights into problems scientists are trying to solve.
   2. Limitations of Statistical Studies
      a. One of the main limitations to statistical studies is that data collected supports correlations, not causations.
      b. There are always additional details that could be identified and quantified. There is no scientific study that has collected the perfect quantity and quality of data.

Lecture Enrichment Ideas

Experience Base: [*As teachers, we make assumptions about the common experiences shared with our students and thus the meaningfulness of the vocabulary we use. Questions that solicit student feedback establish if those experiences are adequate and the concepts are being understood. Students who relate their experiences and understanding in turn help classmates learn the concepts*.] Lecturers new to a college or university may wish to confer with veteran teachers about the state's high school biology and other science requirements, and the proportion of students likely to come from farm or urban backgrounds. Most high school biology textbooks address basic properties of life and the five kingdom system. Only the 1998 texts onward mention domains. Most entering college undergraduates do not have genuine experience with open-ended and purposeful science research.

1. Ask the students to think about how they may use the scientific method in every day life.

2. Give the students a list of items, both life organisms and objects. Ask the students which items are living and why? Have them go through the characteristics of living things to determine their answers.

3. Discuss some current events that relate to how human populations are disrupting ecosystems. Perhaps have students look in newspapers to find relevant articles, or discuss some major events: Chernobyl, the BP oil spill in the Gulf of Mexico, or even clearing land for housing or commercial developments.

4. Provide pictures of organisms and have students group them based on taxonomic classification.

5. People from all backgrounds and educational levels make distinctions between living and non-living things. Even if they have not read the material in the text, students can be led through a common sense discussion of "what is life?" List the common traits of living things: growth, reproduction, response to the environment, metabolism, etc. Ask whether any one of these aspects alone distinguishes a living organism from a nonliving substance. Is it necessary, for example, that every individual within a species be able to reproduce? Select specific species from various kingdoms and describe some of the responses and some of the adaptations those species have. Discuss how those responses and adaptations allow those species to survive in their environment.

6. Scientists are continuing attempts to confirm whether there is or ever has been life on Mars. What phenomena should they look for? What is required for us to know for sure that there is or was life on Mars?

7. Read job descriptions for biologists (e.g., biochemist, anatomist, population ecologist, etc.) available from current journals and newspapers and ask students what level of biological organization the scientist studies.

8. List organisms with which students should be familiar; ask them to place the organisms into the correct kingdom based on their known characteristics. List unfamiliar organisms and their characteristics; ask students

to determine the kingdom to which they belong.

9. Discuss the evolutionary relatedness of mammals. Ask students to consider Australian marsupials that fit into the various niches filled by other mammals in other parts of the world. Note how marsupials are more closely related to one another but have diversified to fill many niches.

10. Discuss the theory that proposes that all life is a result of the development from unicellular ancestors with the same basic chemical structures and metabolism.

11. Discuss how organisms diversify due to the effects of mutation and selection by the environment.

12. Caution students not to confuse use of the terms "name," "identify," and "classify." "Classify" only involves grouping. Only a specialist who describes and publishes a new species "names" the species. In most cases, we are merely "identifying" organisms that are already known to science, originally "named" by taxonomists and "classified" by systematists.

13. Ask students to design an experiment, following the scientific method, in which they test a weight loss drug. Ensure that the experiments have the proper controls, are conducted logically and realistically, that the data (made up by the instructor for the sake of this experiment) are interpreted correctly, and that a proper conclusion is drawn.

14. Ask students for examples of scientific method in their everyday lives, such as preparing dinner, determining how to dress for the day's weather or activities, finding their way around a strange area, or dealing with a malfunctioning car.

15. Have students search a week's newspapers for examples of using the scientific method in the news—such as testing consumer goods or reports on medical research—and discuss them in class. Bring in a tabloid newspaper making fabulous claims and discuss why it does not fulfill scientific standards.

16. Discuss the difference between scientific observations of the natural world and superstitions such as those associated with Friday the thirteenth and black cats. Scientific examination of examples involving water dousing, spontaneous human combustion, crop circles, and other modern misbeliefs are given in the *Skeptic* and *Skeptical Inquirer* magazines.

17. Discuss why it is possible to prove a hypothesis or theory false but not to prove it absolutely true. (This Karl Popper concept of "falsifiability" has limited usage in science and is not applicable in all areas of biology. However, deep discussion of this concept is best left to upper level philosophy of science courses where the students will have had some actual direct experiences with genuine research.)

18. Ask students if they believe the world is spherical. Have them cite evidence to support their belief. However, unless they have flown in the Concorde, they have no direct observational evidence to prove that the Earth is in fact spherical. Emphasize the point that even though they have no direct, personal evidence that fits the spherical Earth model, science frequently relies on *reasoning* and *models* as well as observational data.

Critical Thinking

Question 1. Assume that you found an object that you think might be "alive." What would be several things you would need to observe about this object to determine if it was, in fact, alive?

Answer: You could subject the object to environmental stimuli (heat, pH changes, physical pressure, etc.) to see if it responded to any of those stimuli. The object should have a number of physical characteristics (adaptations) that allow it to survive in a particular environment. The object would have a metabolism. At the biochemical level, the object would have DNA and certain molecules in common with all known life on Earth. The object may or may not be able to reproduce: it could be a sterile individual of a species or it could be a sexually-reproducing organism, in which case a "mate" would be needed!

Question 2. Arguments about teaching evolution in the public school classroom continually attract public attention as elected school boards (in certain states) meet to approve new science teaching curricula. Issues raised in the public sector (not from scientists) include arguments about evolution being "just a theory," giving religious creationism "equal time," and replacing the definition of science as study of natural phenomena with science as a logical construct. Why do scientists reject these arguments?

Answer: Although school boards must vote on policy, scientists do not "vote" on science. The nature of "theory" in this context means considerably more than the street vernacular "it's just a theory." Science does not provide "equal time" to non-science explanations that do not lend themselves to observation, experimentation, and the development of new research. And, although many academic fields are based on "logic" (most notably mathematics), science is defined and uniquely tethered to concepts that are in agreement with the workings of the natural world. "Supernatural" explanations simply do not allow a researcher to formulate tests and expand understanding of the "natural world."

Question 3. Ecology experiments can be separated into two general categories. Some ecologists prefer to bring an organism into the laboratory and isolate it in a chamber where they can keep the setup simple and where they determine all the environmental conditions. Other ecologists prefer to study organisms in the wild and attempt to determine why they occur in certain natural habitats. Using terms for scientific methodology, explain the benefits of both systems.

Answer: The natural environment is so complex that only simple lab settings can eliminate complex factors and show how an organism responds to just one variable. A controlled chamber allows the scientist to set up a control group that lacks just the experimental variable. On the other hand, a natural environment is closer to what the organism actually encounters. There may be many factors in a natural environment that are major and important influences on an organism but which a researcher has not considered in a controlled lab setting experiment. While two "equal" field sites can be used, one as a treatment and one as a control, the ecologist cannot be certain that another uncontrolled factor in nature is not involved or that chance variation is not a contributing factor. Ecologists often integrate the results of both types of research to formulate their conclusions.

PART I THE CELL

Because the cell is the basic unit of life, cell structure, function, and metabolism are major concepts necessary to understand life. Cellular metabolism is simplified and cellular processes are described in preparation for an understanding of genetic control, the origin of the cell, and adaptation to the environment.

2. Basic Chemistry
3. The Chemistry of Organic Molecules
4. Cell Structure and Function
5. Membrane Structure and Function
6. Metabolism: Energy and Enzymes
7. Photosynthesis
8. Cellular Respiration

CHAPTER 2 BASIC CHEMISTRY

Living organisms and non-living substances are composed of matter. The basic unit of matter is the atom. This chapter presents a study of atomic structure, which allows us to see how atoms interact by ionic or covalent bonds to form molecules. All living things are composed of 70-90% water; as such, a thorough knowledge of the chemical and physical properties of water, as well as those properties of acids and bases, is critical to understanding the chemistry of life. The chemical and physical properties of water are presented in detail, as is the concept of acids and bases.

Learning Outcomes

2.1 Chemical Elements

1. Describe how protons, neutrons, and electrons relate to atomic structure.
2. Use the periodic table to evaluate relationships between atomic number and mass number.
3. Describe how variations in an atomic nucleus account for its physical properties.
4. Determine how electrons are configured around a nucleus.

2.2 Molecules and Compounds

1. Describe how elements are combined into compounds and molecules.
2. List 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. Describe how water associates with other molecules in solution.
2. Evaluate which property of water is important for biological life.
3. Analyze how water's solid, liquid, and vapor state allow life to exist on Earth.

2.4 Acids and Bases

1. Identify common acidic and basic substances.
2. Determine pH from a known H^+ or OH^- concentration.
3. Analyze how buffers prevent large pH changes in solutions.

Chapter Outline

2.1 Chemical Elements

1. **Matter** is defined as anything that takes up space and has mass.
2. Matter exists in three states: solid, liquid, and gas.

A. Elements

1. All matter (both living and non-living) is composed of 92 naturally-occurring elements.
2. Elements, by definition, cannot be broken down to simpler substances with different chemical or physical properties.
3. Six elements (carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur—acronym CHNOPS) make up 95% of the body weight of organisms.

B. Atoms

1. Elements consist of tiny particles called atoms.
2. An **atom** is the smallest unit of an element that displays the properties of the element.
3. One or two letters (e.g., H, Na) create the **atomic symbol** of the element.
4. Atoms contain specific numbers of protons, neutrons, and electrons.

5. Protons are positively charged particles; neutrons have no charge; electrons are negatively charged particles.
6. Protons and neutrons are in the nucleus of an atom; electrons move in orbitals around the nucleus in an **electron shell**.

C. Atomic Mass and Atomic Number

1. The **atomic number** equals the number of protons and electrons of an element.
2. Each element has a different atomic number.
3. The **mass number** is the sum of protons and neutrons in the nucleus.
4. Protons and neutrons have one atomic mass unit (amu) of weight; electrons have zero.

D. The Periodic Table

1. The periodic table shows how various characteristics of atoms of elements recur.
2. The **atomic mass** is the average of the AMU for all the isotopes of that atom.
3. Groups are the vertical columns in the table and periods are the horizontal rows. Atomic mass increases as you move down a group or across a period.

E. Isotopes

1. **Isotopes** are atoms of the same element that differ in the number of neutrons (and therefore have different atomic masses). For example, carbon-12 has 6 protons and 6 neutrons; carbon-14 has 6 protons and 8 neutrons.
2. A carbon atom with 8 rather than 6 neutrons is unstable; it releases energy and subatomic particles and is thus a radioactive isotope.
3. Because the chemical behavior of a radioactive isotope is the same as a stable isotope of a particular element, low levels of the radioactive isotope (e.g., radioactive iodine or glucose) allow researchers to trace the location and activity of the element in living tissues; these isotopes are called tracers.
4. High levels of radiation can destroy cells and cause cancer; careful use of radiation can sterilize products and kill cancer cells.

F. Electrons and Energy

1. In an electrically neutral atom, the positively charged protons are balanced by the negatively charged electrons (remember that neutrons are electrically neutral).
2. Since electrons are found outside the nucleus and occupy orbitals around the nucleus, many scientists have tried to create models to show the exact location of the electrons.
3. The Bohr model (named after physicist Niels Bohr) is a helpful way to visualize electron location in an element.
4. According to the Bohr model, electrons occupy orbitals within various energy levels (or electron shells) near or distant from the nucleus of the atom. The farther the orbital from the nucleus, the higher the energy level.
5. When atoms absorb energy during photosynthesis, electrons are boosted to higher energy levels. When the electrons return to their original energy level, the released energy is converted into chemical energy. This chemical energy supports all life on Earth.
6. The innermost shell of an atom is complete with 2 electrons; all other shells are complete with 8 electrons. This is called the octet rule.
7. The outermost electron shell is called the valence shell, and determines the atom's chemical properties; atoms will give up, accept, or share electrons in order to have 8 electrons in its valence shell.

2.2 Molecules and Compounds

1. When atoms of two or more elements bond together, they form a **molecule** and is the smallest part of a compound that has the properties of the compound.
2. A compound is a molecule that contains at least two different elements (ex. H_2O).

3. A **formula** tells you the number of each kind of atom in a molecule (ex., Glucose, $C_6H_{12}O_6$).
4. Electrons possess energy, and bonds that exist between atoms in molecules therefore contain energy.

A. Ionic Bonding

1. An **ionic bond** forms when electrons are transferred from one atom to another atom.
2. By losing or gaining electrons, atoms fill outer shells, and are more stable (the octet rule).
3. Example: sodium loses an electron and therefore has a positive charge; chlorine gains an electron to give it a negative charge. Such charged particles are called ions.
4. Attraction of oppositely charged ions holds the two atoms together in an ionic bond.
5. A salt (e.g., NaCl) is an example of an ionically-bonded compound.

B. Covalent Bonding

1. **Covalent bonds** result when two atoms share electrons so each atom has an octet of electrons in the outer shell (or, in the case of hydrogen, 2 electrons).
2. Hydrogen can give up an electron to become a hydrogen ion (H^+) or share an electron with another atom to complete its shell with 2 electrons.
3. The structural formula of a compound indicates a shared pair of electrons by a line between the two atoms; e.g., single covalent bond (H–H), double covalent bond (O=O), and triple covalent bond (N ≡ N). Each line between the atoms represents a pair of electrons.
4. There are two types of covalent bonds: nonpolar covalent bonds and polar covalent bonds.
5. In **nonpolar covalent bonds**, sharing of electrons is equal, i.e., the electrons are not attracted to either atom to a greater degree.
6. With **polar covalent bonds**, the sharing of electrons is unequal.
    a. In a water molecule (H2O), sharing of electrons by oxygen and hydrogen is not equal; m with more protons attracts the electrons closer to it, and thus dominates the H2O association.
    b. Attraction of an atom for electrons in a covalent bond is called the electronegativity of the atom; an oxygen atom is more electronegative than a hydrogen atom.
    c. Oxygen in a water molecule, more attracted to the electron pair, assumes a partial negative charge.
    d. The polarity of molecules affects how they interact with other molecules.

2.3 Chemistry of Water

1. The shape of water and of all organic molecules is necessary to the structural and functional roles they play in living things.
2. A hydrogen bond is the attraction of a slightly positive hydrogen to a slightly negative atom in the vicinity.

A. Hydrogen Bonding

1. A hydrogen bond is a weak attractive force between the slightly positive charge of the hydrogen atom of one molecule and slightly negative charge of another atom (e.g., oxygen, nitrogen) in another or the same molecule.
2. Many hydrogen bonds together are relatively strong.
3. Hydrogen bonds between and within complex biological molecules (e.g., DNA, proteins) help maintain their proper structure and function.

B. Properties of Water

2. Water has a high heat capacity
    a. The temperature of liquid water rises and falls more slowly than that of most other liquids.
    b. A calorie is the amount of heat energy required to raise the temperature of one gram of water 1º C.
    c. Because the hydrogen bonds between water molecules hold more heat, water temperature falls more slowly than other liquids; this protects organisms from rapid temperature changes and helps them maintain homeostatic temperature.

3. Water has a high heat of evaporation
    a. When water boils, it evaporates, or vaporizes into the environment.
    b. Hydrogen bonds between water molecules require a relatively large amount of heat to break.
    c. This property moderates Earth's surface temperature and permits living systems to exist.
    d. When animals sweat, evaporation of the sweat removes body heat, thus cooling the animal.
4. Water is a solvent
    a. Water dissolves a great number of substances (e.g., salts, large polar molecules).
    b. A solution contains dissolved substances called solutes.
    c. Ionized or polar molecules attracted to water are hydrophilic ("water loving").
    d. Nonionized and nonpolar molecules that cannot attract water are hydrophobic ("water fearing").
5. Water molecules are cohesive and adhesive
    a. Cohesion allows water to flow freely without molecules separating.
    b. Adhesion is the ability to adhere to polar surfaces; water molecules have positive and negative poles.
    c. Water rises up a tree from roots to leaves through small tubes.
    d. Adhesion of water to walls of vessels prevents water column from breaking apart.
    e. Cohesion allows evaporation from leaves to pull water column from roots.
    f. Water has a high **surface tension** and is relatively difficult to break through at its surface.
    g. This property permits a rock to be skipped across a pond surface, and supports insects walking on surface.
6. Frozen water (ice) is less dense than liquid water
    a. Unlike most substances, frozen water (ice) is less dense than liquid water.
    b. Below 4º C, hydrogen bonding becomes more rigid but more open, causing expansion.
    c. Because ice is less dense, it floats; therefore, bodies of water freeze from the top down.
    d. If ice was heavier than water, ice would sink and bodies of water would freeze solid.
    e. This property allows ice to act as an insulator on bodies of water, thereby protecting aquatic organisms during the winter.

2.4. Acids and Bases

1. When water ionizes or dissociates, it releases a small (1×10^{-7} moles/liter) but equal number of hydrogen (H^+) ions and hydroxide (OH^-) ions; $H - O - H \rightarrow H^+ + OH^-$.
2. **Acid** molecules dissociate in water, releasing hydrogen (H^+) ions: $HCl \rightarrow H^+ + Cl^-$.
3. **Bases** are molecules that take up hydrogen ions or release hydroxide ions. $NaOH \rightarrow Na^+ + OH^-$.
4. The **pH scale** indicates acidity and basicity (alkalinity) of a solution.
    a. pH is the measurement of free hydrogen ions, expressed as a negative logarithm of the H^+ concentration ($\log [H^+]$).
    b. pH values range from 0 (1×10^0 moles/liter; most acidic) to 14 (1×10^{-14} moles/liter; most basic).
    c. One mole of water has 1×10^{-7} moles/liter of hydrogen ions; therefore, has neutral pH of 7.
    d. An acid is a substance with pH less than 7; a base is a substance with pH greater than 7.
    e. Because it is a logarithmic scale, each lower unit has 10 times the amount of hydrogen ions as next higher pH unit; moving up pH scale, each unit has 10 times the basicity of previous unit.
5. Buffers keep pH steady and within normal limits in living organisms.
    a. Buffers stabilize pH of a solution by taking up excess hydrogen (H^+) or hydroxide (OH^-) ions.
    b. Carbonic acid helps keep blood pH within normal limits.

A. The Interconnectedness of Water, Plants, and People (*Biological Systems* reading)

1. Acid deposition is rain or snow with pH < 5.0, and dry acidic particles that settle on the Earth from the atmosphere.

2. The burning of fossil fuels increases the amount of acid deposition that falls from the atmosphere to the Earth.
3. Impact of Lakes
    a. Aluminum is leached from the soil converts mercury deposits to methyl mercury, which is toxic and accumulates in fish.
4. Impact on Forests
    a. Acid rain damages plant leaves so they cannot conduct photosynthesis.
    b. Acid rain stresses plants and they are then more susceptible to disease and pests.
    c. When toxins are leached into the soil, the toxins can kill vital soil fungi that help roots absorb nutrients.
5. Impact on Humans and Structures
    a. Inhaling dry acidic particles can increase the chance of respiratory illnesses such as asthma.
    b. Limestone and marble structures break down from acid rain.
    c. Paint on houses and cars can also degrade from acid rain.

Lecture Enrichment Ideas

Experience Base: In many states, fewer than half of high school graduates have taken a chemistry course although students majoring in biology are more likely to have such background. An instructor cannot assume that students have previously been exposed to many chemical concepts in a meaningful way.

1. Either bring in a variety of household liquids, or ask students to bring in household liquids and test the pH using either pH paper or a pH meter. The students are often surprised that some items are acidic or basic.

2. If your institution has molecular modeling kits, these are a good resource to use for the chemistry component of the text. Students can create molecules and have a better understanding of ionic and covalent bonds.

3. Students can examine the periodic table and locate the elements that are common in living organisms. Have them determine how many electrons are in the outer shell by examining the atomic numbers.

4. Describe how carbon14 breaks down into nitrogen14 and what the differences in protons and neutrons would be between these elements. Discuss why some isotopes are radioactive and others are not.

5. “Radioactive isotopes” are often confused with “radiation,” the energy or particle given off by the radioactive isotopes. Keep explanations clear and use words carefully to distinguish the two. Isotopes with very low levels of radiation can be concentrated in one tissue, such as iodine in the thyroid, and the radiation can be used to damage local cells. Discuss the medical use of this.

6. Discuss the formation of ions and how electrons are lost or gained in such formation. Make sure students understand that an ion can be a combination of atoms, and that even large molecules (e.g., H_3PO_4) may become ionized at different locations within the molecule.

7. Consider the protons and electrons of an atom as similar to the ends of a bar magnet, with positive and negative charges attracting each other, and electrons at greater distances from the nucleus having more energy because they are not as closely attracted to the positive charges of the protons.

8. Adhesion, cohesion, and surface tension are difficult concepts for some students. The ability of a water strider to support itself on the water's surface can be described based on water molecules pushing in all directions; lack of water above the surface provides an upward surface tension "support." Water droplets rolling across the hood of a newly waxed car illustrate cohesion, and supporting a water droplet between your fingers viewing with an overhead projector can illustrate both adhesion (to fingers) and cohesion (of water).

Critical Thinking

Question 1. Water drawn through trees by transpiration evaporates into the air above forests and generates updrafts of lighter weight moist air! Glider pilots know that they can gain lift from these currents by flying above forests. Consider that a molecule of water displaces a molecule of nitrogen or oxygen gas. Why then is air lighter when we add moisture to it?

Answer: The atomic mass of one oxygen and two small hydrogen atoms is less than the mass of two nitrogen or two oxygen atoms. Therefore, when an H_2O displaces an O_2 or N_2, a volume of air is lighter because the mass of atoms is lighter.

Question 2. Detergent soaps reduce the surface tension of water, therefore making water "wetter" and better able to penetrate dirt on dishes, etc. A water strider is an insect that "skates" across the surface of fresh water streams and ponds to locate food. Disregarding any chemical reactions that might be toxic to the insect, what would happen to the water strider if detergent was added to the surface of that stream or pond?

Answer: Because the water strider relies on the surface tension of the water to stay on the surface, the wetting effect of the detergent would keep the insect's feet from staying on top of the water's surface.

Question 3. The discovery of liquid water under the frozen surface of a distant moon in our solar system has caused scientists to speculate on the possibility of life on that moon. Researchers hold no hope of any life form existing on any planet or moon in the absence of water. Why?

Answer: The metabolic pathways in a cell are the chemical reactions for life and all are dependent upon water as a solvent. Water also moderates the environment, serves as a transport medium, supplies H^+ or OH^- ions, and has hydraulic properties for capillary action.

Question 4. Why does water freeze at a temperature lower than 0^oC when salt is added to it?

Answer: The salt disrupts the water's ability to form rigid hydrogen bonds as the temperature lowers. The water thus remains liquid at a temperature where, without the salt, the water would form the solid state ice.