2

CHEMISTRY OF LIFE

Chapter Outline

2.1 ATOMS AND ELEMENTS
- Elements are pure substances
- Atoms are composed of smaller particles
- Isotopes are varying forms of atoms

2.2 PET SCANNING—USING RADIOISOTOPES IN MEDICINE

2.3 CHEMICAL BONDS: HOW ATOMS INTERACT
- Atoms interact through their electrons
- Chemical bonds join atoms into molecules
- Molecules may contain atoms of a single element or of different elements

2.4 IMPORTANT BONDS IN BIOLOGICAL MOLECULES
- An ionic bond joins atoms that have opposite electrical charges
- In a covalent bond, atoms share electrons
- A hydrogen bond links polar molecules

2.5 WATER: NECESSARY FOR LIFE
- Hydrogen bonds make water liquid
- Water can absorb and hold heat
- Water is a solvent

2.6 ANTIOXIDANTS HELP PROTECT CELLS

2.7 ACIDS, BASES, AND BUFFERS: BODY FLUIDS IN FLUX
- The pH scale indicates the concentration of hydrogen ions in fluids
- Acids give up H^+ and bases accept H^+
- A salt releases other kinds of ions
- Buffers protect against shifts in pH

2.8 MOLECULES OF LIFE
- Biological molecules contain carbon
- Carbon's key feature is versatile bonding
- Functional groups affect the chemical behavior of organic compounds
- Cells have chemical tools to assemble, break apart and rearrange biological molecules

2.9 CARBOHYDRATES: PLENTIFUL AND VARIED
- Simple sugars are the simplest carbohydrates
- Oligosaccharides are short chains of sugar units
- Polysaccharides are sugar chains that store energy

Objectives

2.1 Describe the relationship between atoms and elements.
2.1.1 Explain why elements are pure substances.
2.1.2 Describe the composition of atoms.
2.1.3 Describe isotopes and radioactive decay.
2.2 Explain the use of radioisotopes in medicine.
2.3 Explain how chemical bonds are formed.
2.3.1 Describe how atoms interact through their electrons.
2.3.2 Explain how chemical bonds join atoms to form molecules.
2.3.3 Distinguish between compounds and mixtures.
2.4 Describe the three types of chemical bonds that occur in biological molecules.
2.4.1 Describe the formation of ionic bonds and covalent bonds.
2.4.2 Explain how polar molecules are linked through a hydrogen bond.
2.5 Describe the chemical properties of water that help support life.
2.5.1 Explain how hydrogen bonds make water liquid.
2.5.2 Describe how water can absorb and hold heat.
2.5.3 Explain why water is a good solvent.
2.6 Explain how antioxidants help protect cells.
2.7 Explain the role of acids, bases, salts, and buffers in the body.

2.7.1 Describe the significance of the pH scale.
2.7.2 Describe how acids and bases affect the body.
2.7.3 Describe salts.
2.7.4 Explain how buffers protect against shifts in the pH of body fluids.
2.8 Describe the properties of biological molecules.
2.8.1 Identify the four main kinds of biological molecules.
2.8.2 Describe carbon's versatile bonding behavior.
2.8.3 Explain the significance of functional groups to organic compounds.
2.8.4 Identify five ways in which cells alter organic compounds.
2.9 Describe the properties of the three types of carbohydrates.
2.9.1 Describe the properties of monosaccharides, oligosaccharides, and polysaccharides.
2.10 Describe the composition and functions of three types of lipids.
2.10.1 Explain why fats are considered to be energy-storing lipids.
2.10.2 Describe the structure of phospholipids and their significance to cell membranes.
2.10.3 Describe the structure of sterols and their importance to the body.
2.11 Describe the seven biological roles of proteins.
2.11.1 Describe the structure of amino acids.
2.11.2 Describe the primary structure of proteins.
2.12 Explain the relationship between a protein's shape and its function.
2.12.1 Describe how the tertiary structures of proteins are formed.
2.12.2 Identify four proteins with a quaternary structure.
2.12.3 Describe how lipoproteins and glycoproteins are formed.
2.12.4 Explain the effects of denaturing a protein.
2.13 Describe the composition and functions of nucleotides and nucleic acids.
2.13.1 Identify three functions of nucleotides.
2.13.2 Distinguish between DNA and RNA.
2.14 Describe the effects of the use of chemicals in food production.

Key Terms

element
atom
isotope
radioisotope
tracer
chemical bond
molecule
compound
mixture
ion
ionic bond
covalent bond
hydrogen bond
biological molecule
hydrophilic
hydrophobic
solvent
solute
free radical
antioxidant
hydrogen ions, H^+
hydroxide ions, OH^-
pH scale
acid
base
salts
buffers
organic compound
inorganic compound
functional group
enzymes
condensation reaction
polymer

monomers
hydrolysis reaction
carbohydrates
monosaccharides
oligosaccharides
polysaccharides
lipid
fat
fatty acid
triglycerides
phospholipid
sterol
protein
amino acid
peptide bond
polypeptide chain
primary structure
lipoproteins
glycoproteins
nucleotide
ATP
coenzymes
nucleic acid
DNA (deoxyribonucleic acid)
RNA (ribonucleic acid)

Lecture Outline

A. Certain substances can serve as vital nutrients, present health hazards, or both.

2.1 Atoms and Elements

A. Elements are pure substances.
   1. Elements, mostly carbon, oxygen, hydrogen and nitrogen, make up all living things.
   2. Elements are made of atoms.

B. Atoms are composed of smaller particles.
   1. An atom is the smallest unit of matter that is unique to a particular element.
   2. Atoms are composed of three particles:
      a. Protons (p^+) are part of the atomic nucleus and have a positive charge. Their quantity is called the atomic number (unique for each element).
      b. Electrons (e^-) have a negative charge. Their quantity is equal to that of the protons. They move around the nucleus.
      c. Neutrons are also a part of the nucleus; they are neutral. Protons plus neutrons = atomic mass number.

C. Isotopes are varying forms of atoms.
   1. Atoms with the same number of protons (e.g., carbon has six) but a different number of neutrons (carbon can have six, seven, or eight) are called *isotopes* (^{12}C, ^{13}C, ^{14}C).
   2. Some radioactive isotopes are unstable and tend to decay into more stable atoms.
      a. They can be used to date rocks and fossils.

2.2 PET Scanning—Using Radioisotopes in Medicine

A. Tracers are substances containing radioisotopes that can be injected into patients to study tissues or tissue function.

B. Radiation therapy uses the radiation from isotopes to destroy or impair the activity of cells that do not work properly, such as cancer cells.

2.3 Chemical Bonds: How Atoms Interact

A. Atoms interact through their electrons.
   1. In chemical reactions, an atom can share electrons with another atom, accept extra electrons, or donate electrons.
   2. Electrons are attracted to protons, but are repelled by other electrons.
   3. Orbitals can be thought of as occupying shells around the nucleus, representing different energy levels.

B. Chemical bonds join atoms into molecules.
   1. A chemical bond is a union between the electron structures of atoms.
   2. Having a filled outer shell is the most stable state for atoms.
      a. The shell closest to the nucleus has one orbital holding a maximum of two electrons.
      b. The next shell can have four orbitals with two electrons each for a total of eight electrons.
      c. Atoms with "unfilled" orbitals in their outermost shell tend to be reactive with other atoms—they want to "fill" their outer shell with the maximal eight electrons allowed.

C. Molecules may contain atoms of a single element or of different elements.
   1. Molecules may contain more than one atom of the same element, N_2 for example.
   2. Compounds consist of two or more elements in strict proportions.
   3. A mixture is an intermingling of molecules in varying proportions.

2.4 Important Bonds in Biological Molecules

A. An ionic bond joins atoms that have opposite electrical charges.
   1. When an atom loses or gains one or more electrons, it becomes positively or negatively charged—an ion.
   2. In an ionic bond, positive and negative ions are linked by mutual attraction of opposite charges, for example, NaCl.

B. In a covalent bond, atoms share electrons.
   1. A covalent bond holds together two atoms that share one or more pairs of electrons.
   2. In a nonpolar covalent bond, atoms share electrons equally; H_2 is an example.
   3. In a polar covalent bond, because atoms share the electron unequally, there is a slight difference in charge (electronegativity) between the two atoms participating in the bond; water is an example.

C. A hydrogen bond links polar molecules.
   1. In a hydrogen bond, a slightly negative atom of a polar molecule interacts weakly with a hydrogen atom already taking part in a polar covalent bond.
   2. These bonds impart structure to liquid water and stabilize nucleic acids and other large molecules.

2.5 Water: Necessary for Life

A. Hydrogen bonds make water liquid.

1. Water is a polar molecule because of a slightly negative charge at the oxygen end and a slightly positive charge at the hydrogen end.
2. Water molecules can form hydrogen bonds with each other.
3. Polar substances are hydrophilic (water loving); nonpolar ones are hydrophobic (water dreading) and are repelled by water.

B. Water can absorb and hold heat.
1. Water tends to stabilize temperature because it has a high heat capacity—the ability to absorb considerable heat before its temperature changes.
2. This is an important property in evaporative and freezing processes.

C. Water is a solvent.
1. The solvent properties of water are greatest with respect to polar molecules because "spheres of hydration" are formed around the solute (dissolved) molecules.
2. For example, the Na^+ of salt attracts the negative end of water molecules, while the Cl^- attracts the positive end.

2.6 Antioxidants Help Protect Cells
1. Oxidation is the process whereby an atom or molecule loses one or more electrons.
2. Oxidation can produce free radicals that may "steal" electrons from other molecules.
3. In large numbers, free radicals can damage other molecules in a cell, such as DNA.

2.7 Acids, Bases, and Buffers: Body Fluids in Flux

A. The pH scale indicates the concentration of hydrogen ions in fluid.
1. pH is a measure of the H^+ concentration in a solution; the greater the H^+ the lower the value on the pH scale.
2. The scale extends from 0 (acidic) to 7 (neutral) to 14 (basic).

B. Acids give up H^+ and bases accept H^+.
1. A substance that releases hydrogen ions (H^+) in solution is an acid—for example, HCl.
2. Substances that release ions such as (OH^-) that can combine with hydrogen ions are called bases (example: baking soda).
3. High concentrations of strong acids or bases can disrupt living systems both internal and external to the body.

C. A salt releases other kinds of ions.
1. A salt is an ionic compound formed when an acid reacts with a base; for example: $HCl + NaOH \rightarrow NaCl + H_2O$.
2. Many salts dissolve into ions that have key functions in the body; for example, Na, K, and Ca in nerves and muscles.

D. Buffers protect against shifts in pH.
1. Buffer molecules combine with, or release, H^+ to prevent drastic changes in pH.
2. Bicarbonate is one of the body's major buffers.

2.8 Molecules of Life

A. Biological molecules contain carbon.
   1. Only living cells synthesize the molecules characteristic of life—carbohydrates, lipids, proteins, and nucleic acids.
   2. These molecules are organic compounds, meaning they consist of atoms of carbon and one or more other elements, held together by covalent bonds.

B. Carbon's key feature is versatile bonding.
   1. Living organisms are mostly oxygen, hydrogen, and carbon.
   2. Much of the hydrogen and oxygen are linked as water.
   3. Carbon can form four covalent bonds with other atoms to form organic molecules of several configurations.
   4. By definition, a hydrocarbon has only hydrogen atoms attached to a carbon backbone.

C. Functional groups affect the chemical behavior of organic compounds.
   1. Functional groups—atoms or groups of atoms covalently bonded to a carbon backbone—convey distinct properties, such as solubility, to the complete molecule.

D. Cells have chemical tools to assemble, break apart, and rearrange biological molecules.
   1. Enzymes speed up specific metabolic reactions.
   2. In condensation reactions, one molecule is stripped of its H^+; another is stripped of its OH^-.
      a. The two molecule fragments join to form a new compound; the H^+ and OH^- form water (dehydration synthesis).
      b. Cells use series of condensation reactions to build polymers out of smaller monomers.
   3. In hydrolysis reactions, the reverse happens: one molecule is split by the addition of H^+ and OH^- (from water) to yield the individual components.

2.9 Carbohydrates: Plentiful and Varied

A. Simple sugars are the simplest carbohydrates.
   1. A monosaccharide—one sugar unit—is the simplest carbohydrate.
   2. Sugars are soluble in water and may be sweet-tasting.
   3. Ribose and deoxyribose (five-carbon backbones) are building blocks for nucleic acids.
   4. Glucose (six-carbon backbone) is a primary energy source and precursor of many organic molecules.

B. Oligosaccharides are short chains of sugar units.
   1. An oligosaccharide is a short chain resulting from the covalent bonding of two or three monosaccharides.
   2. Lactose (milk sugar) is glucose plus galactose; sucrose (table sugar) is glucose plus fructose.

3. Oligosaccharides are used to modify protein structure and have a role in the body's defense against disease.

C. Polysaccharides are sugar chains that store energy.
1. A polysaccharide consists of many sugar units (same or different) covalently linked.
2. Starch (energy storage in plants) and cellulose (structure of plant cell walls) are made of glucose units but in different bonding arrangements.
3. Glycogen is a storage form of glucose found in animal tissues.

2.10 Lipids: Fats and Their Chemical Relatives

A. Fats are energy-storing lipids.
1. Fats are lipids that have one, two, or three fatty acids attached to glycerol.
2. A fatty acid is a long, unbranched hydrocarbon with a carboxyl group (—COOH) at one end.
   a. Saturated fatty acids have only single C—C bonds in their tails, are solids at room temperature, and are derived from animal sources.
   b. Unsaturated fatty acids have one or more double bonds between the carbons that form "kinks" in the tails; they tend to come from plants and are liquid at room temperature.
3. Triglycerides have three fatty acids attached to one glycerol.
   a. They are the body's most abundant lipids.
   b. On a per-weight basis, these molecules yield twice as much energy as carbohydrates.
4. Trans fatty acids are partially saturated (hydrogenated) lipids implicated in some types of heart disease.

B. Phospholipids are basic building blocks of cell membranes.
1. A phospholipid has a glycerol backbone, two fatty acids, a phosphate group, and a small hydrophilic group.
2. They are important components of cell membranes.

C. Cholesterol and steroid hormones are built from sterols.
1. Steroids have a backbone of four carbon rings, but no fatty acids.
2. Cholesterol is an essential component of cell membranes in animals and can be modified to form sex hormones.

2.11 Proteins: Biological Molecules with Many Roles

Because they are the most diverse of the large biological molecules, proteins function as enzymes, in cell movements, as storage and transport agents, as hormones, in body defense, and as structural material throughout the body.

A. Proteins are built from amino acids.
1. Amino acids are small organic molecules with an amino group, an acid group, a hydrogen atom, and one of 20 varying "R" groups.
2. They form large polymers called proteins.

B. The sequence of amino acids is a protein's primary structure.

1. Primary structure is defined as the chain (polypeptide) of amino acids.
2. The amino acids are linked together in a definite sequence by peptide bonds between an amino group of one and an acid group of another.
3. The final shape and function of any given protein is determined by its primary structure.

2.12 A Protein's Shape and Function

A. Proteins fold into complex shapes that determine their function.
   1. Secondary structure is the helical coil or sheet-like array that will result from hydrogen bonding of side groups on the amino acid chains.
   2. Tertiary structure is caused by interactions among R groups, resulting in a complex three-dimensional shape.
B. A protein may have more than one polypeptide chain.
   1. Hemoglobin, the oxygen-carrying protein in the blood, is an example of a protein with quaternary structure—the complexing of two or more polypeptide chains to form globular or fibrous proteins.
   2. Hemoglobin has four polypeptide chains (globins), each coiled and folded with a heme group at the center.
C. Glycoproteins have sugars attached, and lipoproteins have lipids attached.
   1. Certain proteins combine with triglycerides, cholesterol, and phospholipids to form lipoproteins for transport in the body.
   2. Glycoproteins form when oligosaccharides are added to proteins.
D. Disrupting a protein's shape prevents it from functioning normally.
   1. High temperatures or chemicals can cause the three-dimensional shape to be disrupted.
   2. Normal functioning is lost upon denaturation, which is often irreversible.

2.13 Nucleotides and Nucleic Acids

A. Nucleotides are energy carriers and have other roles.
   1. Each nucleotide has a five-carbon sugar (ribose or deoxyribose), a nitrogen-containing base, and a phosphate group.
   2. ATP molecules link cellular reactions that transfer energy.
   3. Other nucleotides include the coenzymes, which accept and transfer hydrogen atoms and electrons during cellular reactions, and chemical messengers.
B. Nucleic acids include DNA and the RNAs.
   1. In nucleic acids, nucleotides are bonded together to form large single- or double-stranded molecules.
   2. DNA (deoxyribonucleic acid) is double-stranded; genetic messages are encoded in its base sequences.
   3. RNA (ribonucleic acid) is single-stranded; it functions in the assembly of proteins.

2.14 Food Production and a Chemical Arms Race

A. Natural plant defenses have been augmented by the development of synthetic toxins designed to kill pests and increase crop yields.

Suggestions for Presenting the Material

- One approach that might help your students in organizing this material is to write it in outline form on the board or on an overhead transparency. This may work especially well for this chapter because a large portion of the material consists of definitions.
- The use of ball-and-stick models (see the "Classroom and Laboratory Enrichment" section below) is very helpful. If the lecture room is large, you may have to "tour" the room with the models for better viewing.
- If students become discouraged, assure them that several of these topics will be reinforced in future chapters and all are relevant throughout the semester.
- The text gives careful attention to useful examples of isotopes, bonding, buffers, and water.
- Using Figure 2.12 (pH scale) as a visual reference will help in explaining acids, bases, and the pH scale. Note particularly the pH values of common household products. Emphasize that acids and bases are not necessarily terms that describe *corrosive* substances!
- The properties of water are important to life on Earth. Describe the polarity of water molecules; then proceed to describe the influence that water molecules have on cells and cellular environments.
- It is valuable to point out that carbon, hydrogen, and oxygen are the principal atoms in the "molecules of life." Sulfur, phosphorous, and nitrogen also participate in proteins and nucleotides.
- Students may recognize the macromolecules of life as major food groups. Capitalize on this to generate student interest and understanding.
- Make extensive use of the overhead transparencies and PowerPoint slides available for this chapter. Soon students will be able to recognize these molecules on sight.
- Carbohydrates are easy to describe because they are built by readily identifiable monomers. Lipids are a more diverse group and will need to be defined according to *solubility* rather than *common structural features*.
- Proteins are complex because of: (a) their number of amino acid subunits, and (b) the levels of structure, that is, primary to quaternary. Use a string of beads and a Slinky® to help here (see the Enrichment section below).
- Preview the future lecture(s) on protein synthesis by stating: "Amino acids are in a precisely defined sequence from one end of a protein to the other." How does the cell select, from the 20 amino acid choices, the proper one at the proper time?
- The nucleotide and nucleic acid section is only a preview of more extensive information found in Chapter 22. Mention that this material will be reviewed in more detail later in the semester.

- Some instructors may want to also include two more of the molecules of life, namely *vitamins* and *minerals*. If so, these are discussed in Chapter 7.
- Stress the importance of Table 2.5 (Summary of the Main Organic Molecules in Living Things) as a useful summary of biological molecules.
- Many of the concepts in this chapter can be visualized with common objects, toys, or a virtual trip through the kitchen - be creative! Students often have a better time remembering everyday examples than science concepts, and if they can remember the examples, the concepts will get through.

Classroom and Laboratory Enrichment

- Students often approach even basic chemistry with considerable trepidation, especially if they lack sufficient high school background in this area or if they have been out of school for several years. Emphasize the biological significance of chemistry; stress that an elemental knowledge of chemistry is essential to understanding the structure and function of living things. Give students frequent opportunities to use new terms. Use overheads or diagrams, pause often, and interject questions to gauge their level of understanding.
- Use as many models and diagrams as possible. If emphasizing electron orbitals, use foam-and-stick models of the orbitals to make this concept seem clearer.
- Students frequently have trouble visualizing atoms and molecules as real entities. To help them get a clearer mental picture of some of the basic atoms and molecules, use ball-and-stick models that are very large and easy to see from the back of the room. These models will help students to understand the size relationships among molecules. Overhead transparencies or slides of ball-and-stick diagrams will also help. Such models and diagrams will be especially useful when covering the larger carbon compounds.
- Present sketches of a polar covalent molecule and a nonpolar covalent molecule. Ask students to identify which molecule is polar and which is nonpolar, and to explain their choices.
- Ball-and-stick models are also useful for demonstrating the hydrogen bonding that occurs between water molecules in the latticework structure of ice.
- Fill a large jar with water, then add salad oil. Shake the bottle, then allow it to sit on the front desk. Ask students to explain what has happened. Add a few drops of methylene blue (a polar dye) and Sudan III fat stain (a nonpolar dye) to the jar and shake. Students will note that the water layer is blue and the oil layer is red; ask them why this is so.
- Draw a pH scale on the board (or use an overhead transparency or PowerPoint slide of Figure 2.12), and discuss pH values of familiar substances.
- If the class is small, demonstrate the use of a pH meter. For larger groups, pH paper can be used to give each student a chance to quickly determine the pH of some sample solutions.
- If the class is being held in a room with a periodic table of the elements hanging on the wall, point out the major elements, or use an overhead transparency to show the same items.

- Prepare a glass of iced tea (instant mix) with added sugar and lemon. Which ingredients are compounds? What are the components of the mixture?
- Bring a package of "buffered" and "regular" aspirin to class. Ask students to discover the difference(s) in the ingredients listed on the labels.
- Using the names of the active ingredients on an antacid package, explain how they act as buffers to stomach acid.
- Use models, diagrams, transparencies, or slides to demonstrate the functional groups emphasized. Stress the importance of knowing several characteristic functional groups by identifying those functional groups present in diagrams or models of real molecules.
- To illustrate amino acid structure, draw a generalized amino acid stem (as shown in Figure 2.24 but with an empty spot at the R-group location) on an overhead transparency. Create different amino acids by changing the R groups, each sketched on a small piece of transparency material.
- Show a ball-and-stick diagram or three-dimensional model of any protein. An enzyme would be a good example; ball-and-stick diagrams of enzymes are readily available. Students will likely be amazed at the large size of proteins when compared to carbohydrates and lipids.
- Protein primary structure can be demonstrated by a string of beads or a Christmas tree garland. Individual beads can be colored with felt-tip markers for greater clarity and distinction. Secondary structure (alpha helices and beta sheets) is adequately illustrated by use of a Slinky® or bead strings. Tertiary structure can be demonstrated by carefully folding a portion of the expanded Slinky®.
- Students have been exposed to many words related to those in this chapter, whether in print or broadcast media. Use this opportunity to explain complex carbohydrates, polyunsaturates, cholesterol, fiber, high-fructose syrup, dextrose, and anabolic steroids.
- Select a variety of food products from your pantry and bring them to class. Ask students to check the ingredients list for forms of sugar. Can you find it in some very unlikely places, such as table salt?
- Help students to understand nucleotide structure with models or diagrams. If students can get a good grasp of nucleotides now, they will have a better understanding of ATP and nucleic acids when these topics are covered in later chapters.
- Expose students to videos or video news clips of stories relating to "healthy" and "non-healthy" foods or diets. Help them see how a basic knowledge of chemistry can help them live healthier lives.

Classroom Discussion Ideas

- Do you read food labels to see how much fat, particularly *trans* fat, is contained in the food? Why or why not?

- Producers can state "zero grams of *trans* fat" if a serving has less than half a gram. Do you think this is a wise idea? Consider how many food "servings" you consume per day, and calculate your *trans* fat consumption if each had 0.5 grams of *trans* fat.
- Are there options other than *trans* fats that could be used in food preparation? If so, why do producers avoid using them?
- Distinguish between: a compound and a mixture, an atom and a molecule. What is the difference between the composition of a molecule of a substance and an atom of that substance?
- What chemicals are in the human body? Ask students to name as many as they can; help them complete their list.
- What is the difference between polar and nonpolar covalent bonds?
- Why do soft drinks have such a low pH? What ingredient is responsible for this low pH?
- What is acid precipitation? What chemical reaction is responsible for the mildly acidic pH of normal rainwater? What chemicals are responsible for acid precipitation?
- How do we know so much about the structure of atoms?
- Water is the "universal solvent" for Earth. Do you know of any other compound that would serve as well, or better?
- Compare the calorie contents of carbohydrates, lipids, and proteins.
- Why do alcohols dissolve in water?
- What is the difference between methyl alcohol and ethyl alcohol? How is each of these alcohols processed by the human body?
- What is a complex carbohydrate?
- Why do animal cells not contain cellulose? Can you think of at least one reason why cellulose in an animal cell could be considered a drawback?
- Why are saturated fatty acids solid at room temperature while unsaturated fatty acids are liquid?
- What is the difference between a globular protein and a fibrous protein?
- Why is sugar (in various forms) so prevalent as an additive in our packaged food products?
- Which yields more energy: a pound of carbohydrate or a pound of fat?
- Cellulose and starch both consist of chains of glucose units. One is a useful source of energy to humans; the other is not. Identify which is which and why they differ.
- Where is glycogen stored in the human body? What regulates interconversions of glucose and glycogen?
- Television advertising implies that the ideal diet would include zero cholesterol. Is this feasible? Would it even be desirable?

Term Paper Topics, Library Activities, and Special Projects

- How are hydrophobic substances such as fats broken down in the human digestive tract? What chemicals are released by the body to assist with fat breakdown?
- Why are the cells lining the stomach able to withstand pH ranges between one and three?
- How does the body measure blood pH? What are the homeostatic mechanisms that help the human body to regulate blood pH?
- Discuss strategies currently being considered by the United States and other nations to remedy acid precipitation. What suggestions would you make to help solve this problem?
- Describe some of the roles played by ions in the human body.
- Many elements have radioactive isotopes that are useful as tracers in biological systems. Show how $^{14}CO_2$ can be used to follow the fate of carbon as it is incorporated into carbohydrate.
- The structure of atoms can be deduced using nuclear magnetic resonance (NMR) and mass spectrometer machines. Report on the principles underlying the performance of each of these instruments.
- Using a pH meter, test the degree of acidity/alkalinity of common household products. If the substance is not a liquid, mix it with water according to package directions before testing. What happens when a buffer is added?
- Most of the content of human blood is water. However, synthetic blood has been made and tested. What is the base in this fluid? Is it a feasible substitute? Report on its advantages and disadvantages.
- How are termites able to digest wood products?
- What is aspartame? How is it processed by the body? Describe studies that have been done regarding its safety as a food additive.
- What is dietary fiber? Describe its possible role as an anti-carcinogen.
- Learn more about the recently synthesized artificial fats that can be used to replace fats in foods.
- Why do women have a higher percentage of body fat than men do? Can you think of any adaptive value for this characteristic?
- Discuss the role of cholesterol in diet. Why is it a necessary molecule?
- Describe how scientists discovered the structure of hemoglobin.
- Search the body-building magazines currently available for diet supplement advertising that might be misleading or outright false. Report on the distortions you find.
- After searching for background information on the extent and variety of steroid use by athletes, interview persons who can give a “local and inside” perspective. Can you document any damage to heavy users?

Selected Videos, Animations, and Websites

VIDEOS

Northland Community and Technical College - Water
Video of the chemistry of water.
http://programs.northlandcollege.edu/biology/biology1111/animations/hydrogenbonds.html

Northland Community and Technical College - Solubility
Video of how substances dissolve in water.
http://www.northland.cc.mn.us/biology/biology1111/animations/dissolve.html

Wisconsin Technical College System: WISC Online – Carbohydrates
An animated overview of carbohydrates.
http://www.wisc-online.com/Objects/ViewObject.aspx?ID=AP13104

Wisconsin Technical College System: WISC Online – The Lipids
An animated overview of lipids.
http://www.wisc-online.com/Objects/ViewObject.aspx?ID=AP13204

Wisconsin Technical College System: WISC Online – Peptide Bonds
An animated video of peptide bond formation with an overview of amino acids.
http://www.wisc-online.com/Objects/ViewObject.aspx?ID=BIC007

Wisconsin Technical College System: WISC Online – Proteins
An animated overview of proteins.
http://www.wisc-online.com/Objects/ViewObject.aspx?ID=AP13304

ANIMATIONS

Water – John Kyrk
Animation of the chemistry of water and pH.
http://www.johnkyrk.com/H2O.html

WEBSITES

American Museum of Natural History Water H2O = Life Exhibit
An exhibit on the properties and importance of water

http://www.amnh.org/exhibitions/water/

Modern Physics – University of Virginia
An overview of the history of atomic theory.
http://galileo.phys.virginia.edu/classes/252/atoms.html

USGS Water Basics
Information on many aspects of water
http://ga.water.usgs.gov/edu/mwater.html

Centers for Disease Control: Nutrition – Carbohydrates
An overview of carbohydrates and how they are incorporated into a healthy diet.
http://www.cdc.gov/nutrition/everyone/basics/carbs.html

Centers for Disease Control: Nutrition – Proteins
An overview of proteins and how they are incorporated into a healthy diet.
http://www.cdc.gov/nutrition/everyone/basics/protein.html

Centers for Disease Control: Nutrition – Dietary Fat
An overview of dietary fats and how they are incorporated into a healthy diet.
http://www.cdc.gov/nutrition/everyone/basics/fat/index.html

Centers for Disease Control: Nutrition – Water
An overview of water and why it is important to maintain health.
http://www.cdc.gov/nutrition/everyone/basics/water.html

Possible Responses to *Review* Questions

1. An element is a fundamental form of matter (such as oxygen) that can't be broken down; an atom is the smallest unit that retains all of the properties of the element (atoms in turn are composed of protons, neutrons, and electrons). Atoms bond to form molecules (atoms are all of one element). For contrast, a compound is a mixture of elements.

2. Ionic bonds are formed by the association of ions of opposite charge; the ions can give up electrons easily, and so the bonds can readily come apart (forming separate ions). Covalent bonds, on the other hand, are much more stable and stronger bonds. Here atoms are shared rather than given up.

3. Hydrogen bonds are the weakest of the bonds, forming between hydrogen ions and other molecules or parts of the same molecule. The bonds represent weak associations between weakly polar atoms. The fact that they are weak, however, is what makes them important to biological reactions.

4. Three vital properties of water are that water is liquid at room temperature, it absorbs and holds heat, and it is an important biological solvent.

5. Carbohydrates are composed of sugar units, usually in a 1:2:1 ratio of carbon, hydrogen, and oxygen. Lipids form from long chain hydrocarbons (fatty acids) and often a skeletal structure such as glycerol (fatty acids + glycerol = triglyceride). Proteins are assembled from amino acids, of which there are 20 different kinds. Nucleic acids are made from nucleotides, each of which is composed of a sugar, a phosphate group, and a nitrogenous base.

6. Answers: a) amino acid; b) carbohydrate; c) polypeptide; and d) fatty acid.

7. Proteins can be described by four levels of organization. Primary structure represents the basic sequence of amino acids that makes up the protein. Secondary structure encompasses local regions of folding, such as in coils or sheets, and tertiary structure takes these local regions and folds them further to produce a globular protein, often the final functional form. If a protein is formed from more than one polypeptide strand, then it has quaternary structure. The R groups on the amino acids form various bonds with other R groups in the peptide and so dictate final structure. Denaturation involves the unfolding of a protein, often without the ability to refold it correctly.

8. Monosaccharides are single sugar units; put two together and you have a disaccharide; more than two together is a polysaccharide. Peptide bonds are the bonds that form between amino acids, linking the carboxyl group of one amino acid with the amino group of another. Peptide bonds are needed to link amino acids together to form the actual polypeptide. Glycerol is a small molecule to which tails of hydrocarbons (fatty acids) can be attached to form larger lipids. Nucleotides are the individual units of a nucleic acid strand.

Possible Responses to *Explore On Your Own* Questions

Learning objective:
2.7 Explain the role of acids, bases, salts, and buffers in the body.
2.7.1 Describe the significance of the pH scale.
2.7.2 Describe how acids and bases affect the body.

- Anthocyanins are pH indicators and are pink in acidic solutions, purple in neutral solutions, green-yellow in alkaline and colorless in very alkaline solution. Adding ammonia to the cranberry juice neutralizes the normal acidity of the juice because ammonia is a base. The solution should go from pink to purple depending on how much ammonia is added. Adding vinegar to the mixture returns the pH to an acidic level and returns the color to pink.

Possible Responses to *Critical Thinking* Questions

1. No, the coffee at pH 5 is **not** twice as acidic as the milk of magnesia at pH 10 because the scale is logarithmic. This means that the coffee is actually 100,000 times more acidic.

2. The uncharged nitrogen atom would have two electrons in the first shell and five electrons in the second shell.

3. Ah yes, the ol' "natural" substance ploy. The best way to answer this is with a bit of bad English: "Chemicals is chemicals." Vitamin C is a chemical. It does not matter if it is extracted from rose hips or synthesized in a lab. Your body will not be able to detect any difference. Of course, the purveyor of the "natural" vitamin C will be able to detect a difference—in his cash register!

4. On the Internet you should be able to find examples of damage to vegetation, aquatic animal life, building facades, statuary, metal objects—virtually anything that is exposed to the weather for prolonged periods of time. Even the most durable substances, such as marble, may eventually show damage.

5. The release of the H^+ will lower the pH deep into the acidic range.