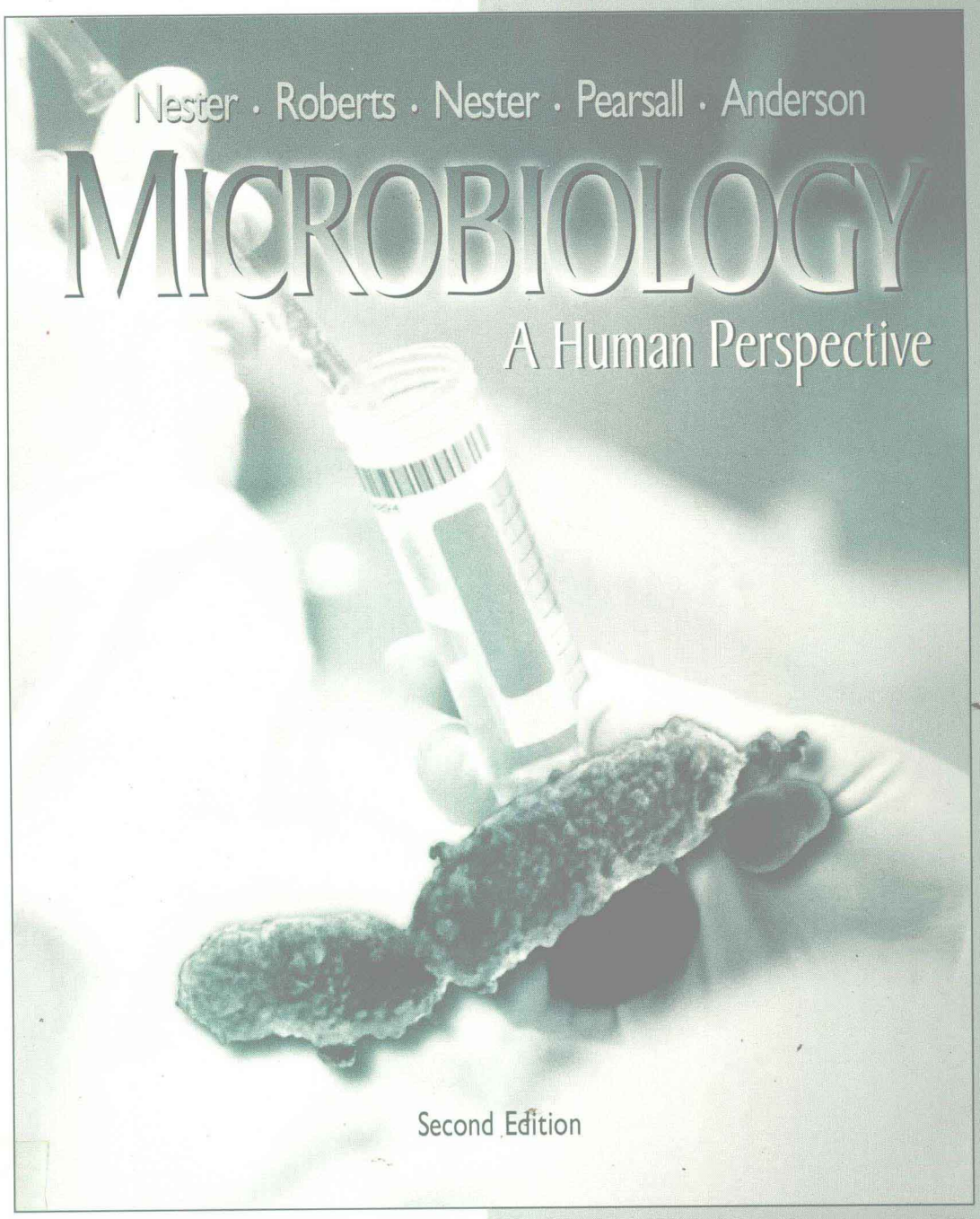
Student Study Guide

to accompany



Prepared by
William D. O'Dell

Student Study Guide

to accompany

Microbiology
A Human Perspective

Second Edition

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Student Study Guide to accompany
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Preface

You are about to embark on a new adventure, the study of microbiology. Some of you may be anxious about starting because you are not sure what lies ahead. Some may be anxious because they do know what is ahead. What lies ahead are new ideas and a fascinating world of microorganisms. You will discover or rediscover the impact that things too small to be seen without a microscope can have on your daily lives. Hopefully, you will marvel at the fact that something that may not even be alive, and is only a millionth of an inch big, can cause a grown man or woman to cough and sneeze for a week! Hopefully, you will grow excited at the complexity and beauty of your own immune system. Maybe you won't care and you will just want to finish the course. Either way you are starting a new adventure and this can be your guide.

This study guide is not intended to replace your textbook, but instead to supplement the textbook and to help direct you through the concepts and terminology of microbiology. The Student Study Guide follows the organization of your textbook. Following a short overview of the chapter contents, each chapter begins with a section titled, **KEY CONCEPTS**. This section states in numbered sentences the major concepts from the chapter in a direct, applied and usually nontechnical fashion. As you begin to study a chapter, and usually before the material is presented in class, you should read these concepts because they introduce you to the chapter.

The next section is the **SUMMARY**. This is an outline of the topics in the chapter and should help you in your reading and understanding of how ideas and concepts fit together and are related. Before you begin to read the chapter, it would be a good idea to browse through the summary to help organize your own thoughts. The summary is also helpful in taking reading notes as you proceed with your reading assignments. Use it to fill in details from your reading and from your class. It is usually very helpful if you have read the key concepts and summary before going to a lecture class. In addition, you will probably find it helpful to page through the textbook and identify the terms in bold lettering before you go to lecture. When you hear the terms in class they will not sound so foreign if you have already seen them once or twice.

The new terminology associated with microbiology is often one of the most difficult aspects of learning this or any new subject. To help you with this, the section **VOCABULARY: TERMS AND DEFINITIONS** provides you with definitions that are directly or closely paraphrased from your textbook. These terms appear in bold lettering in the text. Practice with these terms should help you master their meanings. When you have finished your reading, you can test your knowledge in the **SELF-TEST OF READING MATERIAL**. This section offers you the opportunity through multiple choice or matching questions to see if you have comprehended the reading material. The questions typically reflect the major concepts and sections of the chapter. Answers are provided so you may check immediately to see how you did.

The final section, **REVIEW QUESTIONS**, includes written questions that ask you simply to recall some text material or to think about something and synthesize a new answer. You can derive the most benefit from this section if you write out the answers because you will use the terms and arrange ideas into a specific answer. Hopefully, you will even find some of the questions fun and interesting.

Regardless of your reasons or approach to studying microbiology, enjoy yourself.

Contents

PREFACE v

PART 1 LIFE AND DEATH OF MICROORGANISMS

Chapter 1 Microbiology in the Biological World 1
Chapter 2 Biochemistry of the Molecules of Life 7
Chapter 3 Functional Anatomy of Prokaryotes and Eukaryotes 13
Chapter 4 Dynamics of Bacterial Growth 21
Chapter 5 Metabolism: The Generation of Energy and Synthesis of Small Molecules 29
Chapter 6 Informational Molecules: Function, Synthesis and Regulation of Activity 35
Chapter 7 Bacterial Genetics 41
Chapter 8 Microbiology and Biotechnology 47
Chapter 9 Control of Microbial Growth 53

PART 2 MICROBIAL WORLD

Chapter 10 Classification and Identification of Bacteria 59
Chapter 11 Prokaryotic Microorganisms: Eubacteria and Archaea 63
Chapter 12 Eukaryotic Microorganisms: Algae, Fungi, Protozoa 69
Chapter 13 The Nature and Study of Viruses 75
Chapter 14 Viruses of Animals and Plants 81

PART 3 MICROORGANISMS AND HUMANS

Chapter 15 Nonspecific Immunity 87
Chapter 16 Specific Immunity 93
Chapter 17 Functions and Applications of Immune Responses 99
Chapter 18 Immunologic Disorders 105
Chapter 19 Interactions Between Microorganisms and Humans 111
Chapter 20 Epidemiology and Public Health 117
Chapter 21 Antimicrobial and Antiviral Medicines 123
Chapter 22 Skin Infections 129
Chapter 23 Upper Respiratory System Infections 135
Chapter 24 Lower Respiratory System Infections 139
Chapter 25 Upper Alimentary System Infections 145
Chapter 26 Lower Alimentary System Infections 149
Chapter 27 Genitourinary Infections 155
Chapter 28 Nervous System Infections 161
Chapter 29 Wound Infections 167
Chapter 30 Blood and Lymphatic Infections 171
Chapter 31 HIV Disease and Complications of Immunodeficiency 175

PART 4 APPLIED MICROBIOLOGY

Chapter 32 Environmental Microbiology 183
Chapter 33 Water and Waste Treatment 189
Chapter 34 Microbiology of Food and Beverages 195

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1 MICROBIOLOGY IN THE BIOLOGICAL WORLD

This chapter provides an introduction to microbiology with a discussion of significant milestones that have been important in the development of microbiology. It also defines new directions for microbiologists of the future. The concepts of cell theory and cell types are introduced. The chapter concludes with a description of the various members of the microbial world and how we name them.

KEY CONCEPTS

1. Microorganisms have determined the course of history because of the diseases they cause.
2. New infectious diseases appear as lifestyles change, people travel to exotic places, and techniques for growing and identifying organisms and viruses improve.
3. Cells are the basic units of life, and all cells must carry out the same critical functions in order to survive.
4. Two major types of cells exist: the prokaryotes, which do not contain a "true" nucleus or other membrane-bound internal structures, and the eukaryotes, which do contain a true nucleus.
5. The microbial world consists of prokaryotes and eukaryotes, as well as nonliving agents, the viruses, viroids and prions.
6. All prokaryotes can be divided into two very distinct groups, the Eubacteria and the Archaea, based on their chemical composition.

SUMMARY

I. Introduction
   A. Microorganisms are, in large part, responsible for determining the course of human history.
   B. The use of modern sanitation facilities, vaccinations, as well as antibiotics has dramatically reduced the incidence of infectious disease.

II. Microorganisms Discovered
   A. Anton van Leeuwenhoek discovered microorganisms over 300 years ago by viewing water samples through lenses that magnified three hundred fold.
   B. The theory of spontaneous generation was revived with the discovery of the microbial world.
      1. Differing results from different investigators led to the controversy of whether living organisms could arise from dead organic matter. This controversy was not resolved until the 1860s.
      2. Pasteur demonstrated that the air is filled with microorganisms and showed that swan-necked flasks containing sterile infusions could remain sterile indefinitely.
      3. Tyndall and, independently, Cohn discovered that heat-resistant forms of bacteria, or endospores, were present in certain infusions.

III. Medical Microbiology - Past Triumphs
   A. Between 1875 and 1918, most disease-causing bacteria were identified.

IV. Medical Microbiology - Future Challenges
   A. "New" diseases are appearing. These include Legionnaires' disease, toxic shock syndrome, Lyme disease, AIDS, and hantavirus disease.
   B. Many diseases that were on the wane are now increasing in frequency. These include mumps, whooping cough, diphtheria, and most recently, tuberculosis.
   C. Organisms are becoming increasingly resistant to antibiotics.

V. Beneficial Applications of Microbiology - Past and Present
   A. Human life could not exist without the activity of microorganisms.
   B. Microorganisms have been used for centuries for food production.

VI. Biotechnology - New Applications for Microorganisms
   A. Microorganisms are now being developed to produce vaccines, clean up the environment, and to carry out many other processes designed to make life more comfortable.

VII. Cell Theory
   A. Schleiden and Schwann in the mid-1800s proposed the cell theory - that cells are the basic units of life.

VIII. Similarity in Composition and Function of All Cells
   A. All cells growing independently of other cells, such as bacteria, have one basic function - to reproduce. To do this, they must generate energy and synthesize the components of living matter.
   B. All cells are composed of the same macromolecules, such as nucleic acids (DNA and RNA) and proteins, which, in turn, are composed of the same subunits.

IX. Basic Cell Types
   A. There are two cell types: prokaryotic and eukaryotic. Prokaryotic cells are simple, without membrane-bound internal structures. Eukaryotic cells are larger, more complex, and have several internal membrane-bound structures. All bacteria are prokaryotic; algae, fungi, and protozoa are eukaryotic.
   B. A cell type has been found that appears to be intermediate between prokaryotes and eukaryotes. It has a true nucleus but no mitochondria.
   C. Bacteria can be divided into two domains, the Eubacteria and the Archaea.
      1. Both groups are similar microscopically, but differ in the chemical composition of several structures.
      2. The two groups are not closely related to each other or to the eukaryotes.
   D. Eubacteria include bacteria most familiar to microbiologists.
      1. This group is very diverse.
      2. The "typical" bacteria, which include both Eubacteria and Archaea, are the most common and although they are also heterogeneous, they do share some obvious properties.
   E. Archaea often grow under extreme conditions of temperature and salinity.

X. Members of the Microbial World
   A. The members include all unicellular organisms, which includes all prokaryotes.
   B. Algae, fungi, and protozoa are the eukaryotic members of the microbial world.
   C. Viruses, viroids, and prions are nonliving members of the microbial world.

XI. Nomenclature of Organisms
   A. All organisms are named according to the binomial system of genus and species.
   B. Names and descriptions of most bacteria are published in *Bergey's Manual of Systematic Bacteriology*.

VOCABULARY: TERMS AND DEFINITIONS

The following list contains new terms introduced in this chapter. Use these terms to fill-in the blanks of the sentences that follow and you will have a definition or description of each term.

microorganisms	**cell theory**	**fungi**
viruses	**prokaryotic**	**protozoa**
darkfield illumination	**algae**	**prions**
endospores	**eukaryotic**	
bioremediation	**binomial**	

1. _____ is a technique of microscopy in which faint objects appear brightly lit against a dark background.

2. Eukaryotic members of the microbial world include the _____ , the _____ , and the _____ .

3. Organisms that can be seen only with the aid of a microscope are called _____ .

4. _____ is a process by which living microorganisms are used to help clean up the environment.

5. _____ are heat-resistant, nondividing forms of bacteria.

6. _____ appear to be proteins without nucleic acid, either DNA or RNA.

7. _____ consist of a piece of genetic material surrounded by a protective protein coat.

8. The system developed by Linnaeus for naming organisms is known as the _____ system of nomenclature.

9. The _____ states that all organisms are composed of cells and that cells are the fundamental units of life.

10. Cells that do not have a membrane surrounding their genetic material are known as _____ cells.

11. Cells that have a membrane surrounding their genetic material are known as _____ cells.

SELF-TEST OF READING MATERIAL

1. Leeuwenhoek's discoveries were significant because
   a. he was the first person to use a microscope.
   b. he carefully recorded and reported his results.
   c. of his finely ground lenses.
   d. he was a renowned scientist of his day.
   e. he limited his observations.

2. Infectious diseases have essentially been eliminated by antibiotics and vaccination and are no longer a public health problem.
   a. True
   b. False

3. Diseases, once thought to be controlled, which are reappearing in developed countries include
   1. measles
   2. whooping cough
   3. AIDS
   4. tuberculosis
   5. mumps

   a. 1,2,3,4
   b. 2,3,4,5
   c. 3
   d. 1,2,4,5
   e. 1,3,4,5

4. The number of disease-producing microorganisms is _____ of the total number of microorganisms.
   a. a very large proportion
   b. about half
   c. a very small proportion

5. The discovery of the microbial world by Leeuwenhoek created a controversy that lasted almost 300 years. This controversy centered on
   a. the causes of disease.
   b. spontaneous generation.
   c. flies and maggots.
   d. the church and the scientist.
   e. the origin of life.

6. Pasteur's experiments demonstrated that microorganisms in the _____were indistinguishable from those that grew in contaminated flasks.
   a. corks
   b. broth
   c. air
   d. water
   e. soil

7. Tyndall and, independently, Cohn discovered a heat-resistant form of bacteria. This bacterial form became known as a(n)
   a. exospore.
   b. vegetative cell.
   c. prokaryotic cell.
   d. cell wall.
   e. endospore.

8. The cell theory states that
   a. cells come from other cells.
   b. cells are the fundamental units of life.
   c. all organisms are composed of cells.
   d. Only b. and c. are correct
   e. a., b., and c. are correct.

9. The original distinction between the two types of cells, prokaryotic and eukaryotic, was made on the basis of the
   a. structure of the cell wall.
   b. absence or presence of mitochondria.
   c. absence or presence of a nuclear membrane.
   d. absence or presence of ribosomes.
   e. structure of the cell membrane.

10. Bacteria, with the exception of Archaea, are prokaryotic cells.
    a. True
    b. False

11. While the Eubacteria, the "typical" bacteria, are a heterogeneous group, they do share some features in common. Which of the following features are shared by the Eubacteria?
    1. single-cell prokaryotes
    2. rigid cell walls
    3. single-cell eukaryotes
    4. multiply by binary fission; one cell divides into two
    5. rigid cell walls with cellulose
    a. 1,2,4
    b. 2,3,4
    c. 3,4,5
    d. 1,2
    e. 3,5

12. Which of the following would probably not be included in themicrobial kingdom?
    a. all single-cell organisms
    b. multicellular organisms with a cellular level of organization
    c. organisms with tissues and organs
    d. all single-cell eukaryotes
    e. all prokaryotes

13. We cannot describe viruses as prokaryotes or eukaryotes because viruses
    a. are not living.
    b. are agents and not organisms.
    c. were discovered after prokaryotes and eukaryotes.
    d. are not cellular.
    e. do not contain any genetic information.

14. Viruses are too small to contain all of the machinery and molecules necessary for life.
    a. True
    b. False

15. Which of the following is a correct way to represent the scientific name for a specific bacterium?
    a. Bacillus cereus
    b. Bacillus Cereus
    c. bacillus cereus
    d. Bacillus cereus
    e. bacillus Cereus

REVIEW QUESTIONS

1. What is the argument for including multicellular organisms such as algae and mushrooms in the microbial kingdom?

2. What problems contributed to the confusion of the early investigations into spontaneous generation?

3. Describe a few ways in which biotechnology might improve our lives now and in the future.

ANSWERS:

Vocabulary - Terms and Definitions

1. darkfield illumination 2. algae, fungi, protozoa 3. microorganisms 4. bioremediation 5. endospores 6. prions 7. viruses 8. binomial 9. cell theory 10. prokaryotic 11. eukaryotic

Self-Test of Reading Material

1. b 2. b 3. d 4. c 5. b 6. c 7. e 8. e 9. c 10. b 11. a 12. c 13. d 14. a 15. a

NOTES

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2 BIOCHEMISTRY OF THE MOLECULES OF LIFE

To understand how microorganisms live and die, produce disease, and do all of the other amazing things they do, requires some working knowledge of chemistry. This chapter presents the fundamental concepts of the chemistry of living organisms. It starts with the atom, the simplest level of organization, and moves to higher levels, to finish with the macromolecules. The structure and function of proteins, polysaccharides, nucleic acids and lipids are described.

KEY CONCEPTS

1. Four elements, carbon, oxygen, hydrogen, and nitrogen make up over 98% of all living matter. Two other elements, phosphorus and sulfur, are also very important.
2. The bonds that hold atoms together result from electrons interacting with each other. Bonds vary in strength which gives molecules characteristic properties.
3. Weak bonds are important in biological systems, since they often determine the most important properties of the molecules and are responsible for their proper functioning.
4. All life is based on the bonding properties of water which comprises over 90% of the cell's weight.
5. Macromolecules consist of many repeating subunits, each subunit consisting of a small, simple molecule. The subunits are synthesized, then bonded to form the macromolecule.

SUMMARY

I. Elements and Atoms
   A. An element is a pure substance that consists of a single type of atom. Atoms are the basic units of all matter. They consist of three major components: electrons, protons, and neutrons.

II. Formation of Molecules: Chemical Bonds
   A. Chemical bonds are of two types: strong and weak. The stronger the bond, the more energy is required to break it.
   B. Strong bonds are usually covalent bonds formed when atoms share electrons to fill their outer shell and thereby achieve maximum stability.
      1. Covalent bonds vary in their distribution of shared electrons, which results in the molecule having a positive and negative charge at different sites.
   C. Ionic bonds are formed by the loss and gain of electrons between atoms. In aqueous solutions, they are weak.
   D. Hydrogen bonds are weak but biologically very important. They hold the two strands of DNA together and are important in determining the shape of proteins.
      1. They result from the attraction of positively charged H atoms to negatively charged N or O atoms.

III. Important Molecules of Life
   A. Small molecules in the cell are both organic and inorganic.
      1. The inorganic molecules include many that are required for enzyme function.
      2. Organic molecules are mainly compounds that are being metabolized or molecules that are the subunits of macromolecules.
   B. All very large molecules in the cell (macromolecules) consist of repeating subunits called monomers.
      1. There are three important macromolecules.
         (1). Proteins are chains of amino acids that form a polypeptide.
         (2). Polysaccharides are chains of monosaccharides that form branching structures.
         (3). The nucleic acids are DNA and RNA, which are chains of nucleotides.
   C. Proteins are polymers of amino acids.
      1. Amino acids consist of a molecule with a carboxyl group and an amino group bonded to the same carbon atom. The carbon atom is bonded, in turn, to a side chain. Twenty different amino acids, each differing in their side chains, are present in proteins.

2. Peptide bond synthesis: A covalent bond is formed between the amino group of one amino acid and the carboxyl group of the adjacent amino acid with the removal of HOH (dehydration synthesis).
3. Levels of protein structure: Three features characterize a protein.
   (1). Its primary structure
   (2). Its shape, whether globular or long fibers
   (3). Whether or not the protein consists of one or several polypeptide chains. A variety of weak bonds are involved in maintaining the three dimensional shape of proteins.
4. Substitute proteins contain covalently bonded molecules other than amino acids. These include glycoproteins (sugars) and lipoproteins (lipids).

D. Polysaccharides are polymers of monosaccharide (carbohydrate) subunits. Carbohydrates (sugars) contain a large number of alcohol groups (-OH) in which the C atom is also bonded to an H atom to form H-C-OH.
   1. Monosaccharides are the subunits of polysaccharides. The most common are hexoses (6C) and pentoses (5C).
   2. Disaccharides are two monosaccharides joined together with a loss of water (dehydration synthesis).
   3. Different polysaccharides vary in size, their degree of branching, the bonding of monosaccharides to one another and the monosaccharides involved.

E. Nucleic acids, which include deoxyribonucleic acid (DNA) and ribonucleic acid (RNA), are polymers of nucleotide subunits and are unbranched.
   1. DNA. The nucleotides are composed of three units: a nitrogen base, [purine (adenine or guanine) or pyrimidine (thymine or cytosine)], covalently bonded to deoxyribose, which, in turn, is bonded to a phosphate molecule. A phosphate bonded to the sugar molecule joins the nucleotides together. DNA occurs in the cell as a double-stranded helix in which the two strands are held together by hydrogen bonding between adenine and thymine and between guanine and cytosine.
   2. Ribonucleic acid (RNA). Nucleotides are the same as in DNA except that ribose replaces deoxyribose, and uracil replaces thymine. RNA is shorter in length and does not occur as a double helix. Three different types of RNA exist in the cell.

F. Lipids are biologically important but are too small and heterogeneous to be considered macromolecules.
   1. All lipids have one property in common, they are insoluble in water, but soluble in organic solvents. This difference in solubility is due to their nonpolar, hydrophobic nature.
   2. They are not composed of similar subunits but rather a variety of substances that differ in chemical structure.
   3. Simple lipids, which contain only C, H, and O, include fats and steroids. Fats are composed of glycerol covalently bonded to fatty acids. Steroids have a four-membered ring structure.
   4. Compound lipids contain fatty acids and glycerol and, in addition, often elements other than C, H, and O. They include phospholipids, lipoproteins, and lipopolysaccharides. They all play important roles in the cell envelope of bacteria.
   5. Phospholipids consist of two parts, each with different properties. One end is polar and therefore is soluble in water. The other end, containing only C and H, is nonpolar and therefore insoluble in water, but soluble in organic solvents.

VOCABULARY: TERMS AND DEFINITIONS

The following list contains new terms introduced in this chapter. Use these terms to fill-in the blanks of the sentences that follow and you will have a definition or description of each term.

neutrons	**macromolecules**	**fats**
electrons	**polymers**	**oils**
covalent bonds	**dehydration synthesis**	**phospholipids**
ionic bonds	**disaccharide**	
hydrogen bonds	**nucleotides**	

1. _____ result from the attraction of positively charged H atoms to negatively charged N or O atoms.

2. A strong bond made by sharing electrons between atoms is a _____ .

3. _____ are lipids that are liquids at room temperature.

4. Polymers are made from their monomer units by the process of _____ .

5. _____ are negatively charged particles that participate in the bonding of atoms.

6. Membrane molecules that have both hydrophobic and hydrophilic parts are known as _____ .

7. Sucrose is an example of a _____ .

8. Atomic particles found in the nucleus of an atom that do not have an electrical charge are called _____ .

9. _____ are the monomers or building blocks of nucleic acids.

10. Proteins, polysaccharides, and nucleic acids are examples of very large molecules called _____ .

11. The combination of fatty acids and glycerol which are solids at room temperature are known as _____ .

12. _____ involve the complete transfer of electrons from one atom to another.

13. Large molecules formed by joining together the same small molecules or monomers, are called _____ .

14. Protein molecules are held in their three-dimensional shape by _____ .

SELF-TEST OF READING MATERIAL

1. The sodium ion, Na^+, has a single positive charge because it has
   a. more neutrons in its nucleus than electrons in orbit.
   b. more electrons in its nucleus than protons in orbit.
   c. six electrons.
   d. more protons in its nucleus than electrons in orbit.
   e. more electrons in its nucleus than neutrons in orbit.

2. Atoms are electrically neutral. Which of the following has an electrical charge?
   1. protons
   2. electrons
   3. ions
   4. neutrons
   5. atoms

   a. 1,3,5
   b. 3,4,5
   c. 1,2,3
   d. 3
   e. 1,2,3,4,5

3. The number of protons in the nucleus of an atom is its
   a. atomic number.
   b. number of electron orbitals.
   c. atomic weight.
   d. molecular weight.
   e. valence.

4. Weak bonds that are responsible for holding the strands of DNA together are
   a. ionic bonds
   b. hydrogen bonds
   c. disulfide bonds
   d. nitrogen bonds
   e. water bonds

5. Biological molecules made by covalently bonding amino acids are called
   a. proteins.
   b. lipids.
   c. nucleic acids.
   d. disaccharides.
   e. polysaccharides.

6. All macromolecules share the common feature of being synthesized by joining subunits or monomers together. This joining process is known as
   a. hydrolysis.
   b. dehydration synthesis.
   c. hydrogen bonding
   d. hydration synthesis.
   e. dehydrolysis.

7. The number and sequence of amino acids determines the
   a. primary structure of a polysaccharide.
   b. secondary structure of a protein.
   c. the secondary structure of a polysaccharide.
   d. the primary structure of a protein.
   e. tertiary structure of a protein.

8. Amino acids contain which of the following functional groups?
   1. an NH_2 group
   2. an "R" group
   3. glycerol
   4. a COOH group
   5. fatty acid

   a. 1,2,4
   b. 3,5,
   c. 1,2,3
   d. 1,5
   e. 3,4,

9. Peptide bonds are found in _____ while ester linkages are the bonds in _____ .
   a. lipids/proteins
   b. polysaccharides/nucleic acids
   c. proteins/lipids
   d. nucleic acids/polysaccharides
   e. proteins/polysaccharides

10. Lactose and sucrose are examples of
    a. DNA
    b. monosaccharides
    c. proteins
    d. polysaccharides
    e. disaccharides

11. The carbon to hydrogen to oxygen ratio of carbohydrates is
    a. very large.
    b. 1:2:1.
    c. 1:2:2.
    d. 2:1:4.
    e. impossible to determine

12. DNA differs from RNA in that DNA has
    1. two strands
    2. deoxyribose
    3. one strand
    4. ribose
    5. thymine
    6. uracil

    a. 1,2,4
    b. 3,4,6
    c. 2 only
    d. 1,2,5
    e. 1,2,6

13. Lipids that contain unsaturated fatty acids are usually solids at room temperature.
    a. True
    b. False

14. The backbone of the RNA molecule is composed of alternating units of
    a. ribose and phosphate.
    b. purine and pyrimidine.
    c. deoxyribose and phosphate.
    d. deoxyribose and ribose.
    e. uracil and ribose.

15. In the structure, C=O, how many pairs of electrons does carbon and oxygen share?
    a. one
    b. two
    c. three
    d. four
    e. five

16. Phospholipids
    a. have a polar and a nonpolar end.
    b. are found in cell membranes.
    c. function as cellular enzymes.
    d. are found only in prokaryotic cells.
    e. Two of the above are correct.

17. What type of bond is formed between the oxygen and the hydrogen atoms in a water molecule?
    a. nonpolar covalent bond
    b. ionic bond
    c. polar covalent bond
    d. savings bond
    e. hydrogen bond

Use the choices on the right to identify the molecules described on the left.

_____ 18. They are made of multiple (CH_2O) units.

_____ 19. They contain COOH and NH_2 groups.

_____ 20. They contain C, H, and O.

_____ 21. They have alternating sugar and phosphate groups.

_____ 22. They contain glycerol.

a. nucleic acids
b. proteins
c. lipids
d. carbohydrates
e. All of the above
f. None of the above

REVIEW QUESTIONS

1. What properties do macromolecules share?

2. Water is essential for life. What properties of water make it so critical for life? How are these properties related to the structure of water?

3. List the macromolecules in order of their importance to cells? Why is this so difficult?

NOTES

ANSWERS:

Vocabulary: Terms and Definitions

1. hydrogen bond 2. covalent bond 3. oils 4. dehydration synthesis 5. electrons 6. phospholipids 7. disaccharide 8. neutrons 9. nucleotides 10. macromolecules 11. fats 12. ionic bonds 13. polymers 14. hydrogen bonds

Self-Test of Reading Material

1. d 2. c 3. a 4. b 5. a 6. b 7. d 8. a 9. c 10. e 11. b 12. d 13. b 14. a 15. b 16. e 17. c 18. d 19. b 20. e 21. a 22. c

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