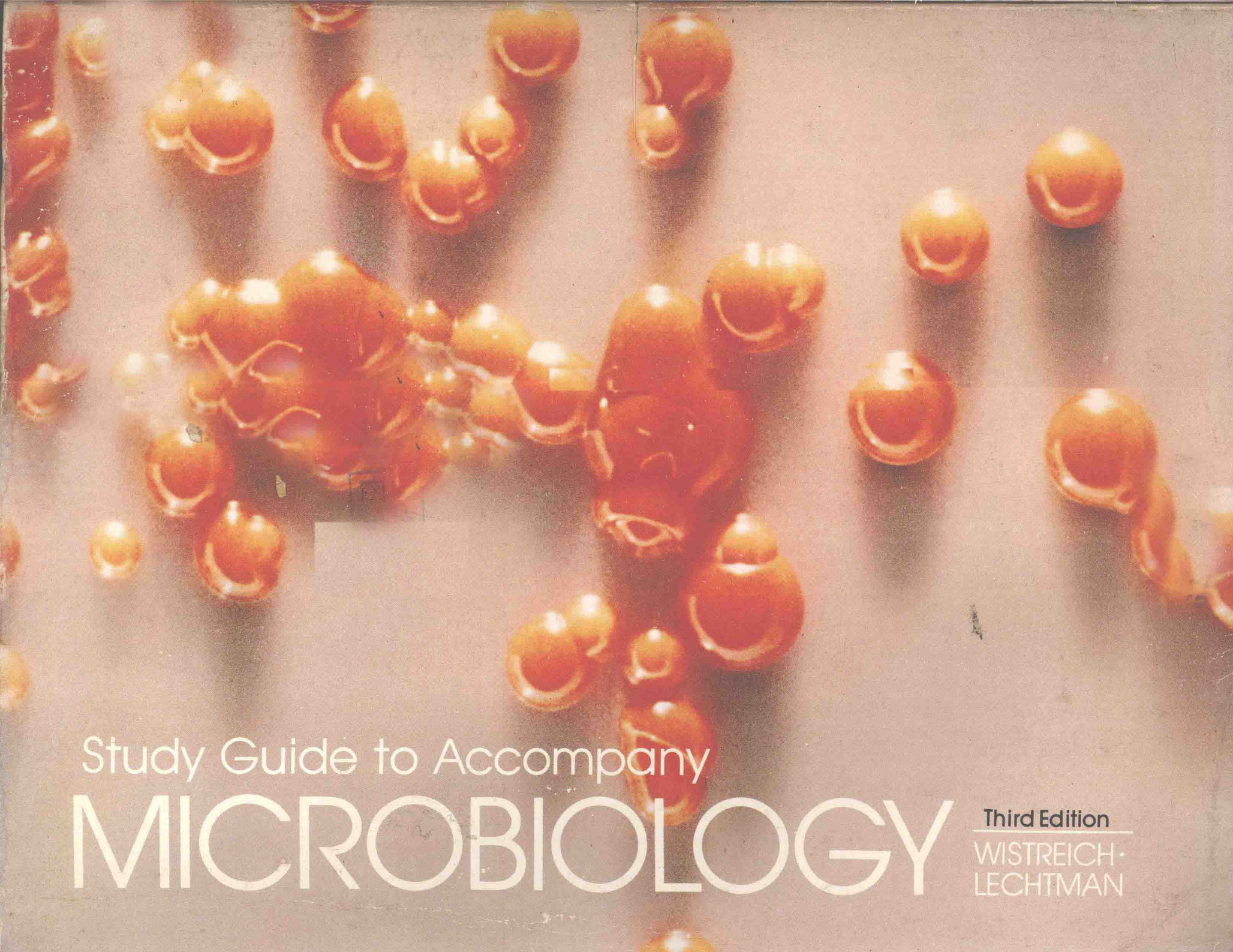

Study Guide to Accompany

MICROBIOLOGY

Third Edition

WISTREICH · LECHTMAN

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MICROBIOLOGY

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How to Use the Study Guide

This study guide has been prepared to help you to *identify, learn,* and *remember* basic concepts, principles, and terminology of microbiology. Think of it as an extension of your textbook. Diligent use of the guide will provide considerable benefits to you. Undoubtedly, you will develop your own method of using the study guide; however, here are some suggestions that may help you to get the most from your efforts and time in studying.

1. First, read the appropriate chapter in the text, using the stated objectives as indications of what you should know to achieve mastery of the subject matter. Underlining, or highlighting with a suitable colored pen, all important information can be helpful to emphasize basic facts, concepts, and terms.

2. Next, read the *Introduction* and *Preparation* sections of the corresponding study guide chapter. This will help you to visualize the overall organization and content of the chapter.

3. Now go to the *Pre-Test* section of the guide and test your knowledge. Write the answers for each question in the spaces provided. Compare your responses with the answers given at the end of the section. Add up the number of correct answers. The purpose of the *Pre-Test* is to enable you to evaluate your understanding of the subject matter and to reinforce your mastery of concepts, principles, and terminology. If your score of correct answers is 75 percent or better, proceed to the *Chapter Self-Test* and *Enrichment* sections. If your score is below 75 percent, proceed to the *Concepts and Terminology* section.

4. It could be helpful at this point to scan the *Preparation* section before continuing. If, however, you are short of time, read and study the *Concepts and Terminology* component. If certain terms or concepts prove difficult for you, underline them. Review underlined material after you have completed the section.

5. Now you are ready to find out how well you have mastered the subject matter presented. If you have gone through the various sections of the study guide, you should not find the *Chapter Self-Test* to be difficult. Answers to all questions appear at the end of the section.

6. The last section for most chapters—*Enrichment*—will emphasize or extend the discussions of some material presented in the chapter. The suggested readings, discussions, and challenge exercises presented here not only offer a diversion from the usual pattern of study, but should provide an opportunity to extend or apply the knowledge you have gained.

Contents

PART 1 Introduction to Microbiology

CHAPTER 1 The Scope of Microbiology

I. INTRODUCTION

Microorganisms are essentially the same biologically as other forms of life. Many are single-celled, while others are loose combinations or long filaments of independent cells. These forms of life perform the same fundamental activities within their individual cells as do higher organisms within their many-celled structures. This chapter provides general descriptions of the various types of microorganisms and branches of microbiology. The significance and uses of microorganisms are outlined to give you an overview of the text. A description of the scientific method, an approach used by scientists to explain biological phenomena, also is provided.

II. PREPARATION

The following terms are important for you to know. Refer to the glossary and the chapter if you are uncertain of any of them.

1. asexual reproduction
2. deoxyribonucleic acid (DNA)
3. host
4. intracellular
5. metabolism
6. microscopic
7. ribonucleic acid
8. parasite
9. sexual reproduction
10. submicroscopic

III. PRE-TEST

Correct answers to all questions can be found at the end of this section. Write your responses in the appropriate column space provided on the right.

Completion Questions

Provide the correct term or phrase for the following. Spelling counts.

1. Organisms capable of reproducing, metabolizing, and performing other activities in the absence of free oxygen are called __(1)__. 1. _____
2. __(2)__ are completely dependent on the cells of higher forms of life. 2. _____
3. The process by which a single cell divides and forms two new cells is known as __(3)__. 3. _____
4. The sum total of chemical reactions associated with the production of cellular energy is known as __(4)__. 4. _____
5. __(5)__ is the adjustment to environmental stimuli. 5. _____
6. A mutation is a __(6)__ genetic change. 6. _____
7. __(7)__ is the study of algae. 7. _____

8. ___(8)___ involves the study of molds and yeasts. 8. _____
9. Diagnostic procedures, disease preventive methods, and the study of a host's defense mechanisms are all aspects of ___(9)___. 9. _____
10. ___(10)___ are important to the production of several kinds of food and commercially available antibiotics. 10. _____
11. African sleeping sickness and malaria are examples of two diseases caused by ___(11)___. 11. _____
12. ___(12)___ are obligate intracellular parasites. 12. _____
13. ___(13)___ is noted for the recognition of a nonbacterial infective agent. 13. _____
14. ___(14)___ are disease-causing microorganisms. 14. _____
15. Proving the validity of a hypothesis is done by ___(15)___. 15. _____
16. A hypothesis that has been supported by various types of observations and experiments is called a ___(16)___. 16. _____
17. A ___(17)___ is a theory that has universal acceptance. 17. _____
18. The ___(18)___ is a common-sense approach to finding explanations for basic phenomena and showing their importance. 18. _____

Matching

Select the answer from the right-hand side that corresponds to the term or phrase on the left-hand side of the question sheet. An answer may be used more than once.

19. Interactions between microbes and their environments. 19. _____
20. Cellular properties of microorganisms 20. _____
21. Naming and cataloging microorganisms 21. _____
22. Metabolic activities of microbes 22. _____
23. The manufacture of fermented milk products 23. _____
24. The prevention of food spoilage and improvements in the flavor and quality of foods 24. _____
25. Investigations of the harmful effects of microbial pathogens 25. _____

a. microbial cytology
b. biophysics
c. microbial taxonomy
d. microbial genetics
e. none of these

Answers

1. anaerobes; 2. viruses; 3. asexual reproduction; 4. metabolism; 5. adaptability; 6. permanent; 7. phycology or algology; 8. mycology; 9. immunology; 10. fungi; 11. protozoa; 12. viruses; 13. Iwanowski; 14. pathogens; 15. experimentation; 16. theory; 17. law; 18. scientific method; 19. e; 20. a; 21. c; 22. e; 23. e; 24. e; 25. e.

IV. CONCEPTS AND TERMINOLOGY

The Microbial World

Microscopic forms of life are present in large numbers in nearly every environment, including soil, water, food, air, and surfaces of animals and plants. The majority of such microbes are not harmful to humans or to other forms of life. For the most part, microorganisms exhibit characteristic features common to biological systems. Several of these features together with brief explanations are listed in Table 1–1.

TABLE 1–1 Characteristics of Microorganisms

Characteristic	*Description*
Reproduction	The ability to duplicate or multiply. Many microorganisms are capable of reproducing both asexually (single cell division) and sexually (forming a genetically new individual from the union of nuclear material from two different cells).
Metabolism	The sum total of chemical reactions through which the energy needed for cellular activities is produced. Two categories of metabolism are recognized: *anabolism* (includes reactions involved with the formation of cell parts needed for growth, reproduction, and repair) and *catabolism* (includes reactions of digestion).
Growth	Most microorganisms increase in size as building materials are produced inside the cell—a process of growth from within.
Irritability	The ability to respond to environmental stimuli, such as acidity, intense light, temperature, and poisonous substances
Adaptability	Ability to adjust to environmental stimuli. Several microorganisms can survive unfavorable environments by altering certain of their activities.
Mutation	A permanent change in the genetic information of the microorganism; can be brought about either naturally or experimentally and is passed on to future generations
Organization	Needed to perform the various activities essential to existence and survival. It is appropriate to refer to microbes as small, organized units, or *microorganisms.*

Microbiology and Its Subdivisions

Microbiology includes the study of algae, bacteria, fungi (molds and yeasts), protozoa, and viruses. Table 1–2 lists and describes the major branches and specialty areas.

TABLE 1–2 Microbiology and Its Subdivisions

Subdivision	*Description*
Major Branch	
Bacteriology	The study of bacteria and their activities, which include causation of disease, decomposition of decaying or dead organic matter, and the production of various chemicals, foods, and other useful substances.
Immunology	A study of an individual's defense mechanisms against disease and materials foreign to the body. Involves determining the contributions of different body parts to this defense; also deals with diagnosis and development of new methods of disease detection and prevention.
Mycology	The study of fungi, which include molds, mushrooms, and yeasts. Activities include production of various types of food and antibiotics, and causation of disease.
Phycology (Algology)	The study of algae, which range in size from microscopic unicellular forms to lengths of 150 feet or more. Studies the activities of algae in organic matter decomposition and food production as well as harmful activities.
Protozoology	The study of protozoa, which are found in sewage, bodies of water, and damp soil, and can cause diseases such as malaria and African sleeping sickness
Virology	The study of viruses, submicroscopic intracellular parasites that need living cells for their survival and activities
Specialty Areas	
Microbial Cytology	The study of microscopic and submicroscopic details of microorganisms
Microbial Ecology	The study of relationships between microorganisms and their environments, e.g., how microbes respond to unfavorable situations
Microbial Genetics	The study of the activities and functions of the nuclear elements of microorganisms. Genetic engineering and investigations of how to regulate changes in growth and development of nuclear material brought on by mutation-causing agents are included in this specialty.
Microbial Physiology	The study of microbial functioning, which includes metabolism, nutritional needs, and effects of environmental factors on essential microbial activities.

TABLE 1–2 Microbiology and Its Subdivisions (Continued)

Subdivision	*Description*
Specialty Areas (Continued)	
Molecular Biology	The principal aim of molecular biology is to determine the relationship between the chemical structure and genetic makeup of microbial and higher forms. While this specialty is not limited to microbiology, microorganisms have served as important tools in uncovering basic knowledge of all life forms—e.g., how genetic information flows from deoxyribonucleic acid to ribonucleic acid during the formation of proteins.
Microbial Taxonomy	The naming and classification of microbes; involves determining similarities and differences among organisms, which serve as bases for classification and the demonstration of relationships.
Biochemistry	This specialty is concerned with the chemical basis of living matter and associated reactions. Determining the chemical composition of cells and how chemicals are formed and interact are just a few of the areas of investigation.
Biophysics	The study of the principles of physics as they apply to all living matter. Explores the basis of movement—how chemicals are combined and held together.

Applied Microbiology

The principles, basic information, and techniques of the different branches and specialties of microbiology can be applied to many areas. Examples are listed in Table 1–3.

TABLE 1–3 Examples of Applied Microbiology

Applied Area	*Description*
Food and Dairy Microbiology	The microbial conversion of raw materials into desirable end products. This process, known as fermentation, is responsible for the characteristic aroma, flavor, and general quality of foods such as yogurt, pickles, sauerkraut, and some cheeses.
Medical Microbiology	Includes studies dealing with the properties of microbial disease agents; developing methods for diagnosis and prevention of diseases; and incorporating both chemical and physical methods for the management and control of infectious diseases.
Veterinary Microbiology	Concerns studies of disease agents affecting pets and livestock, and the prevention, detection, and control of such agents. Worms and related parasites also are considered.

Microbiology and the Scientific Method

The scientific method is a common-sense approach to finding explanations for observed scientific phenomena and showing their relationships to other occurrences. The method employs four steps: 1) making careful observations of a particular event; 2) forming a hypothesis, which involves arranging these observations into a generalization to explain the observed phenomenon; 3) testing the validity of the hypothesis through *experimentation*; and 4) formulating a *theory*, which is a hypothesis supported by various observations and experiments. A theory that has universal acceptance is a *law*. Experiments must be designed to test the pertinent point of the hypothesis, to contain appropriate and adequate controls for purposes of comparison, and to avoid the subjectivity of the investigator.

The Vast Literature of Microbiology

An enormous body of experimental data in microbiology has accumulated in a relatively few years. Scientific publications serve to communicate such findings and to provide pertinent discussions and interpretations. Knowledge of important developments is a powerful and necessary tool for scientific investigations.

Some Challenges for Microbiology

Despite the years of intense study of microorganisms and their activities, numerous questions remain unanswered. Many decisions affecting the future of world populations and environments—e.g., food and energy production and control of diseases and pollution—may depend on microbial activities.

V. CHAPTER SELF-TEST

Continue with this section only after you have read Chapter 1 of the text and completed Section IV. A score of 80 percent or better is good. If your score is less than 65 percent, reread the chapter.

Correct answers to all questions can be found at the end of this section. Write your responses in the appropriate column space provided on the right.

Matching

Select the answer from the right-hand side that corresponds to the term or phrase on the left-hand side of the question sheet. An answer may be used more than once.

Topic: Subdivisions of microbiology

1. An organisms's resistance to disease	a. mycology	1. _____
2. Development of new methods of disease prevention and detection	b. virology	2. _____
3. The study of submicroscopic obligate intracellular parasites	c. microbial ecology d. immunology	3. _____
4. The study of microscopic details of microbial cells	e. food microbiology f. genetic engineering	4. _____
5. Naming and classifying microorganisms	g. none of these	5. _____
6. Blood typing		6. _____
7. The study of the principles of physics as they apply to all living matter		7. _____
8. Improvements of food quality		8. _____
9. Preventing heavy economic livestock losses		9. _____
10. The study of hookworms and tapeworms		10. _____

Multiple Choice

Select the best possible answer.

11. The ability of an organism to respond to environmental stimuli is known as: 11. _____
(a) catabolism (b) anabolism (c) metabolism (d) adaptability (e) none of these

12. Permanent genetic changes are called: 12. _____
(a) environmental factors (b) growths (c) metabolic reactions (d) mutations (e) all of these

Completion Questions

Write your responses in the appropriate column space provided on the right. Provide the correct term or phrase for the following. Spelling counts.

13. Organisms capable of growing in the absence of free oxygen are called (13). 13. _____
14. (14) are totally dependent for their survival on the cells of higher forms of life. 14. _____
15. The fusion of nuclear material from two different cells resulting in a genetically new individual is known as (15) reproduction. 15. _____
16. The majority of organisms that require free oxygen for their essential activities are known as (16). 16. _____
17. The study of yeasts belongs in the subdivision of (17). 17. _____
18. *Staphylococcus aureus* would be an example of a microorganism studied in the subdivision of (18). 18. _____
19. (19) are major sources of antibiotics. 19. _____
20. One example of a protozoan disease affecting humans is (20). 20. _____
21. Viruses that invade bacteria are called (21). 21. _____
22. The first viruses to be detected were found in infected (22). 22. _____
23. The control and possible elimination of certain human genetic defects through the transfer of genetic material from one type of organism to another is one aspect of the area known as (23). 23. _____
24. In the scientific method, proving a hypothesis to be correct is the basis of a (24). 24. _____
25. In order for an experiment to effectively support a hypothesis, it must be (25a) and it must contain adequate (25b). 25a. _____ 25b. _____
26. (26) serve as important means for the transmission of knowledge among areas of the scientific community. 26. _____

Answers

1. d; 2. d; 3. b; 4. g; 5. g; 6. d; 7. g; 8. e; 9. g; 10. g; 11. e; 12. d; 13. anaerobes; 14. viruses; 15. sexual; 16. aerobes; 17. mycology; 18. bacteriology; 19. molds (fungi); 20. malaria; 21. bacteriophages; 22. tobacco plants; 23. genetic engineering; 24. theory; 25a. pertinent; 25b. controls; 26. scientific publications (journals).

VI. ENRICHMENT

Responsibilities and Risks

Science can, directly and indirectly, produce useful knowledge and guides to improve the environment and the well-being of humans. It also appears that the greater the power to intervene in nature, the greater the possibility of doing harm as well as good. Through the years, the scientific community has been prepared to take responsibility for the benefits it bestows. But to what extent should it be prepared to take equal responsibility for the harm it can and does produce? This question often has not been faced squarely, either by scientists or by the general public. Scientists have long had a bargain with society by which they have produced ideas, and other types of time saving devices, without limitations. In recent years, a number of concerns have been raised about the safety of investigations and procedures used in a variety of areas, including military research, nuclear energy, and recombinant DNA research. This latter area has engendered considerable controversy, not only among segments of the lay public, but also among scientists themselves. It involves a technique whereby different DNA pieces are joined together using enzymes. The resulting genetic material is then inserted into a bacterium where it can be reproduced indefinitely. This form of DNA technology permits the addition or replacement of a few genes in living cells, and is the first prototype of genetic engineering. Successful applications of genetic engineering have resulted in the production by bacteria of human protein hormones such as insulin, somatostatin, growth hormone, and, more recently, the antiviral agent called interferon.

With the development of more sophisticated techniques, the ultimate potential of genetic engineering to modify and redesign animal and plant life to meet human needs and desires seems virtually without limit. However, the technology is not without potential hazard, especially since genetic material from a variety of sources can be combined in a common bacterium. Should there be any limitations on scientific inquiries in this as well as other areas? Changes in the nature of science or technology or in the external society could reshape the pattern of our lives and the world in which we live. Some interesting viewpoints concerning these and related topics are presented in the following articles:

Graham, L. R. 1978. Concerns about science and attempts to regulate inquiry. *Daedalus* 107:1–21.
Sinsheimer, R. L. 1978. The presumptions of science. *Daedalus* 107:23–25.
Baltimore, D. 1978. Limiting science: a biologist's perspective. *Daedalus* 107:37–45.

CHAPTER 2 Early History of Microbiology

I. INTRODUCTION

The science of microbiology had to await the invention and development of instruments such as the microscope and methods for cultivation. Following the discovery of microbes, studies indicated that microorganisms figure in the production and spoilage of various foods and alcoholic beverages. Further discoveries and experiments suggested that microorganisms are also responsible for various diseases. Findings such as these suggested that certain processes affecting human welfare have a biological explanation.

After reading this chapter, you will have some insight into the problems faced by early scientists in establishing the nature and functions of microorganisms and their relationship to fermentation, putrefaction, and infectious diseases.

II. PREPARATION

Chapters 1 and 2 should be read before continuing. The following terms are important for you to know. Refer to the glossary and the appropriate chapters if you are uncertain of any of them.

1. aerobe
2. anaerobe
3. antibiotic
4. antiseptic
5. catalyst
6. enzyme
7. fermentation
8. filtration
9. host
10. infusion
11. medium
12. motile
13. pathogen
14. putrefaction
15. resolving power
16. simple microscope
17. spontaneous generation
18. sterile
19. spore

III. PRE-TEST

Correct answers to all questions can be found at the end of this section. Write your responses in the appropriate column space provided on the right.

Completion Questions

Provide the correct term or phrase for the following. Spelling counts.

1. __(1)__ provided the first descriptions of microorganisms. — 1. _____
2. Among the microbes first observed were __(2a)__, __(2b)__, __(2c)__, and __(2d)__. — 2a. _____ 2b. _____ 2c. _____ 2d. _____
3. The __(3)__ microscope was the type used in these early observations. — 3. _____
4. __(4)__ was one of the first scientists to recognize the true biological functions of microbes. — 4. _____
5. The souring of milk is an example of __(5)__. — 5. _____

6. The (6) view of the basis of fermentation holds that yeasts were by-products of fermentation. 6. _____

7. The German physiologist (7) clearly demonstrated the role of yeasts in alcoholic fermentation. 7. _____

8. (8) can be used to destroy microbes that cause wine spoilage without altering the quality of the wine. 8. _____

9. The heating of milk and certain other foods at (9a) °C for (9b) minutes is sufficient to destroy, or to reduce in number, food-spoilage or pathogenic microbes. 9a. _____ 9b. _____

10. The theory of (10) holds that life could and did appear spontaneously from nonliving or decomposing matter. 10. _____

11. By a series of experiments, (11) showed that maggots and flies did not emerge spontaneously from putrefied meat. 11. _____

12. The filtration of air or the exposure of air to chemicals such as sulfuric acid and sodium hydroxide will render it (12). 12. _____

13. (13a) and (13b) introduced the use of cotton plugs for bacteriological culture flasks and tubes. 13a. _____ 13b. _____

14. Pasteur's various experiments to disprove spontaneous generation showed that life in organic infusion could not occur without the existence of (14). 14. _____

15. The heat-resistant bacterial structures found by Tyndall are known as (15). 15. _____

16. Intermittent sterilization is also known as (16). 16. _____

17. The (17) incorporates steam under pressure for sterilization. 17. _____

18. The process by which wound infections are prevented through the use of sterilized instruments and the application of carbolic acid to wounds is known as (18). 18. _____

19. (19) were the first microorganisms shown to be pathogenic. 19. _____

20. (20) can be used to show the direct role of a specific bacterium as the cause of a specific disease. 20. _____

21. The procedure to show the causal role of viruses in diseases was established by (21). 21. _____

22. Preparations containing various nutrient combinations for the cultivation of microbes are known as (22). 22. _____

23. The accumulations of bacteria on solid nutrient surfaces are called (23). 23. _____

24. (24) is the solidifying agent commonly used for laboratory media. 24. _____

25. (25) employs the use of chemicals for the treatment of diseases without damaging the infected individual. 25. _____

26. (26) is noted for the isolation of penicillin. 26. _____

Answers

1. Anton van Leeuwenhoek; 2a. algae; 2b. bacteria; 2c. protozoa; 2d. yeasts; 3. simple; 4. Louis Pasteur; 5. fermentation; 6. nonvital; 7. T. Schwann; 8. pasteurization; 9a. 63; 9b. 30; 10. spontaneous generation; 11. F. Redi; 12. sterile; 13a. F. Shröder; 13b. T. von Dusch; 14. microbes; 15. spores; 16. tyndallization; 17. autoclave; 18. antiseptic surgery; 19. fungi; 20. Koch's postulates; 21. T. M. Rivers; 22. media; 23. colonies; 24. agar; 25. chemotherapy; 26. A. Fleming.

IV. CONCEPTS AND TERMINOLOGY

Early Development of Microbiology

From 1673 to 1723, Anton van Leeuwenhoek designed and constructed one-lens (simple) microscopes to observe a variety of biological specimens, including single-celled microorganisms such as algae, bacteria, protozoa, and yeasts. Even though compound microscopes were in use at this time, Leeuwenhoek found that the lens of his instruments provided greater detail of *resolving power.* The study of microorganisms ceased after Leeuwenhoek's death, and was not resumed until the mid-1800s when Louis Pasteur demonstrated the biological functions of microorganisms.

The Germ Theory of Fermentation

Fermentation is recognized today as a natural process in which alcohols and organic acids such as ethanol and acetic and lactic acids result from the enzymatic action of microbes on substances containing sugar. Despite the discoveries of Leeuwenhoek, the biological basis of fermentation was not established until late into the nineteenth century. Two viewpoints were offered to explain the process—the nonvital (nonbiological) theory and the vital (biological) theory. According to the nonvital theory of fermentation, yeasts are by-products of fermentation. The vital theory of fermentation, which eventually proved to be true, held that yeasts such as *Saccharomyces cerevisiae* were responsible for the reaction.

Louis Pasteur made several contributions to fermentation research. He proved experimentally the microbial nature of fermentation and the specificity of fermentation reactions; he developed the heating process, called pasteurization, that kills most disease- and spoilage-causing organisms; and he discovered *anaerobes,* microorganisms that can live only in the absence of free oxygen.

The Spontaneous Generation, or Abiogenesis, Controversy

In the 4th century B.C., Aristotle proposed that lower forms of animal life arose spontaneously from nonliving or decomposing organic matter. This view became known as the doctrine of spontaneous generation. Disproving spontaneous generation at both the macroscopic and microscopic levels involved numerous individuals. Several of these scientists and their contributions are listed in Table 2–1.

Antiseptic Surgery

Joseph Lister devised procedures to prevent microorganisms from entering wounds. His approach, which became known as antiseptic surgery, includes sterilization of instruments and the application of chemicals to wounds. The concept of antiseptic surgery provided indirect support for the germ theory of disease.

The Germ Theory of Disease

The concept of infectious diseases preceded the proof of the existence of pathogens by several centuries. Fungi and protozoans were among the first microorganisms associated with disease. Robert Koch, from experiments with