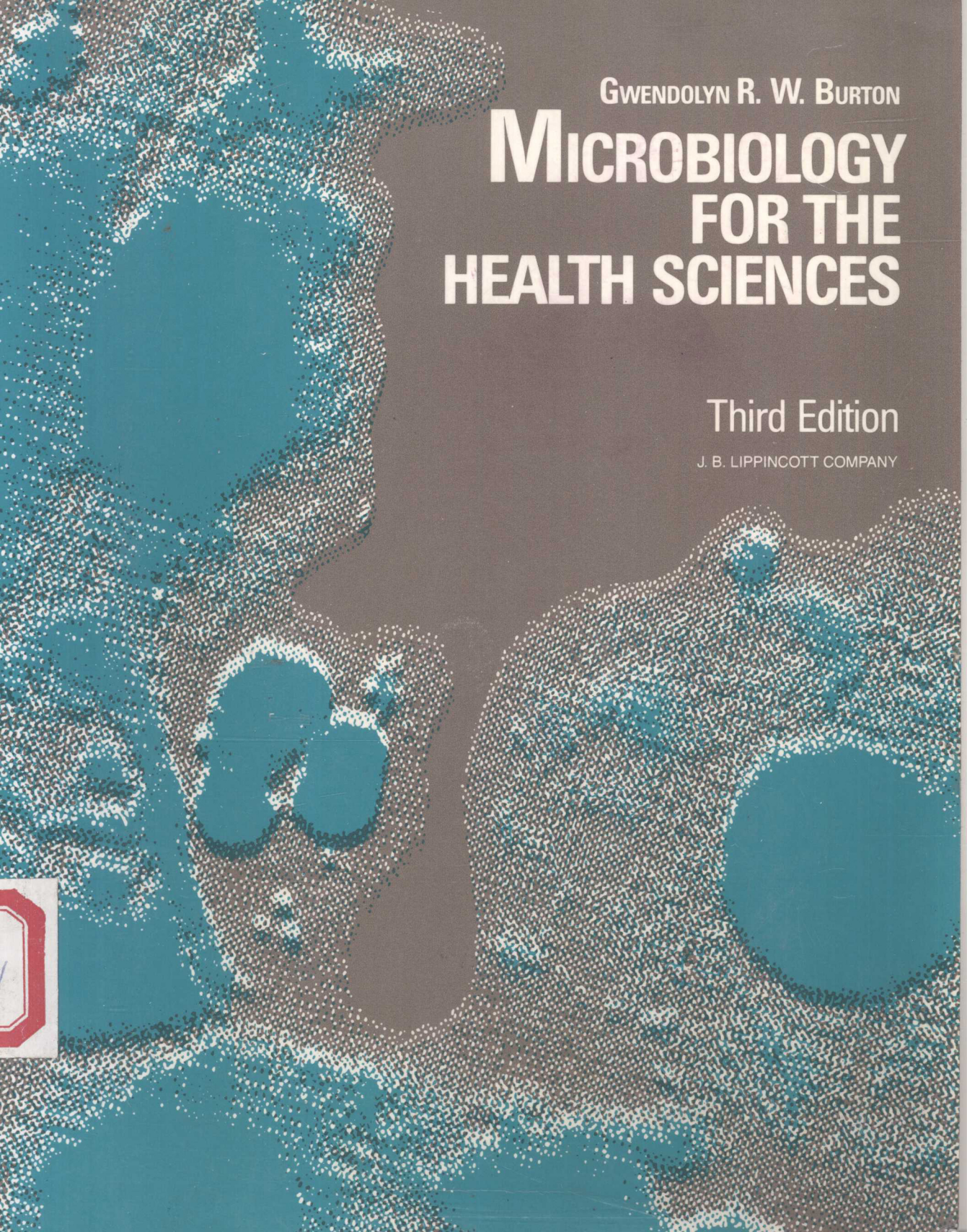

GWENDOLYN R. W. BURTON

MICROBIOLOGY FOR THE HEALTH SCIENCES

Third Edition

J. B. LIPPINCOTT COMPANY

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Microbiology

for the Health Sciences

Third edition

J. B. Lippincott Company Philadelphia
London, Mexico City, New York,
St. Louis, São Paulo, Sydney

Acquisition/Sponsoring Editor: Patti Cleary
Developmental Editor: Eleanor Faven
Manuscript Editor: Lorraine Smith
Indexer: Maria Coughlin
Designer: William Boehm
Design Coordinator: Anita Curry/Anne O'Donnell
Production Manager: Kathleen P. Dunn
Production Coordinator: George V. Gordon
Compositor: Circle Graphics
Printer/Binder: R. R. Donnelley & Sons Company
Cover Design: Kevin Curry
Cover Printer: Philips Offset Company, Inc.

Third Edition

6

Library of Congress Cataloging in Publication Data

Burton, Gwendolyn R. W. (Gwendolyn R. Wilson)
Microbiology for the health sciences.

Bibliography: p.
Includes index.
1. Microbiology. 2. Medical microbiology.
I. Title. [DNLM: 1. Allied Health Personnel.
2. Microbiology. QW 4 B974m]
QR41.2.B88 1987 616'.01 87-3527
ISBN 0-397-54672-6

Microbiology for the Health Sciences

For Cindy, Gary, Alan, Earl,
Robin, Penny, and Rae Lynn

Preface

Microbiology, the study of microbes, is a fascinating topic to those of us who feel its importance in our daily lives. Others find it necessary to learn the microbiological concepts and vocabulary in order to function well in their chosen vocations. For example, those who plan to work in any area of health care, such as prevention of disease or care and treatment of the diseased, must be aware of the principles of sterilization, disease causation, and disease prevention.

Microbiology for the Health Sciences will aid those who want to learn the basic microbiological concepts that apply to the health field. It is also intended for students who have little or no science background, and for mature students returning to school after several years' absence.

There is a need for a "simplified" microbiology text that presents the major concepts clearly and concisely for people entering the health occupations. This book is appropriate for use in a one-term allied health microbiology class or as one unit in a basic science class for health-oriented students.

Microbiology is an enormous and complex subject with many interrelated facets and hundreds of scientific terms. I have attempted a very fundamental approach to the subject matter by presenting at the beginning of each chapter the basic information necessary for understanding the more complex concepts with which the chapters conclude. Specialized vocabulary has been kept to a minimum. Key terms are in boldface type and are defined in the glossary at the beginning of each chapter for easy reference. A complete glossary can also be found in the back of the book. The glossaries also include aids to pronunciation. The objectives are clearly stated at the beginning of each chapter to

enable the student to survey the topics to be covered. Questions for review are included at the end of each chapter.

Although this book is intended primarily for non-science majors, it is not an "easy" text, because microbiology is not an "easy" topic. As the student will discover, the concise nature of this text has made each sentence significant. Thus, the reader will be intellectually challenged to learn each new concept as it is presented. It is my hope that the students will enjoy their study of microbiology and be motivated to further explore this fascinating field, especially as it relates to their occupations. A student workbook has been prepared for use as a supplementary learning device. It closely follows the sequence of material in the textbook and can be used hand-in-hand while reading the text or as a review for further studying.

I am deeply indebted to those colleagues, friends, family members, and students who served as sources of illustrations, advice, and encouragement, especially Dr. Robert L. Taylor, Dr. Paul Engelkirk, Ursi Chappelle, and my husband and children. I particularly wish to acknowledge Patti Cleary, sponsoring editor, and Eleanor Faven, developmental editor in the health sciences division, J. B. Lippincott Company, for their editorial assistance in the preparation of this manuscript.

Gwendolyn R. W. Burton

Contents

Chapter 1

Introduction to Microbiology

Objectives

After studying this chapter, you should be able to

1. Define microbiology
2. List some important functions of microbes in the environment
3. State the relevance of microbiology to the health professions
4. List some areas of study in microbiology
5. List some contributions of Leeuwenhoek, Pasteur, and Koch to microbiology
6. State the germ theory of fermentation
7. State the germ theory of disease
8. List Koch's postulates and give some circumstances in which they do not apply
9. Describe the difference between light microscopes and electron microscopes and the applications of both
10. List the metric units used in microscopic measurements and indicate their relative sizes

New Words to Pronounce and Understand

Algae (al'-gee). Plants with chlorophyll (capable of producing their own food)

Bacteria (back-tier'-ee-uh). Procaryotic, mostly unicellular organisms; most primitive organisms

Fungi (fun'-ji). Microorganisms that are incapable of producing their own food and that live on decaying organic material

Immunology (im-mew-noll'-oh-gee). The science that deals with immunity from disease and the production of immunity

Microorganism (my'-kro-or'-gan-izm). Microscopic organisms, usually single cells, sometimes called microbes

Opportunist (op-poor-tune'-ist). A microbe that causes disease in susceptible persons with lowered resistance
Pathogen (path'-o-jen). Disease-causing microorganism
Protozoa (pro-toe-zoe'-uh). Single-celled microscopic animals found in water and soil; a few are pathogens
Tyndallization (tin-dull-uh-zay'-shun). A process of boiling and cooling in which spores are allowed to germinate and then are killed by boiling again
Virology (vi-rol'-oh-gee). The study of viruses and the diseases they cause
Virus (vi'-rus). An infective agent smaller than a bacterium

What is microbiology? *Micro-* means very small, anything so small that it must be viewed with a microscope; *-bio* means "living organisms"; and *-ology* means "the study of." Therefore, microbiology is the study of very small living organisms. These microorganisms include the bacteria, algae, protozoa, fungi, and viruses (Fig. 1-1). They are often called *microbes*, single-celled organisms, and germs.

You may never see any microorganisms or understand the effect they have on your daily life. Occasionally, you may realize they are alive and active in and on your body when a cut or a burn becomes infected or when you have a sore throat. Have you ever been very sick after a picnic, and wondered which of the foods you ate contained harmful germs? Most of us are aware of *pathogens*, or disease-causing microorganisms, only when we are affected by them. Actually, only a small percentage of microbes are pathogenic or able to cause disease (Fig. 1-2). The others are beneficial, harmless, or cause disease only if they accidentally get into the "wrong" place at the "right" time, when the person's resistance is low and the growth conditions are right. Normally, these *opportunists* are harmless microorganisms, the so-called normal flora, living on the skin, in the mouth, and in the intestine.

Microorganisms can be found nearly everywhere as normal inhabitants of the earth, and with few exceptions they contribute to the welfare of humans. The normal flora that live on and within our bodies actually inhibit the growth of pathogens in those areas by occupying the space, using the food supply, and secreting materials (waste products, toxins, antibiotics) that may prevent or reduce the growth of pathogens. Many nonpathogens enable us to produce yogurt, cheeses, raised bread, beer, wine, and many other foods and drinks.

Many bacteria and fungi are *saprophytes*, which help to fertilize the soil by returning the inorganic nutrients to the soil; they break down dead organic materials (plants and animals) into nitrates, phosphates, carbon dioxide, water, and other chemicals necessary for plant growth (Fig. 1-3). These saprophytes also destroy paper, feces, and other biodegradable substances, although they cannot recycle most plastics and glass. The nitrogen-fixing bacteria, which live with the plants called legumes (peas, peanuts, alfalfa, clover), are able to return nitrogen from the air to the soil in the form of nitrates for use by other plants. This knowledge is important to the farmer

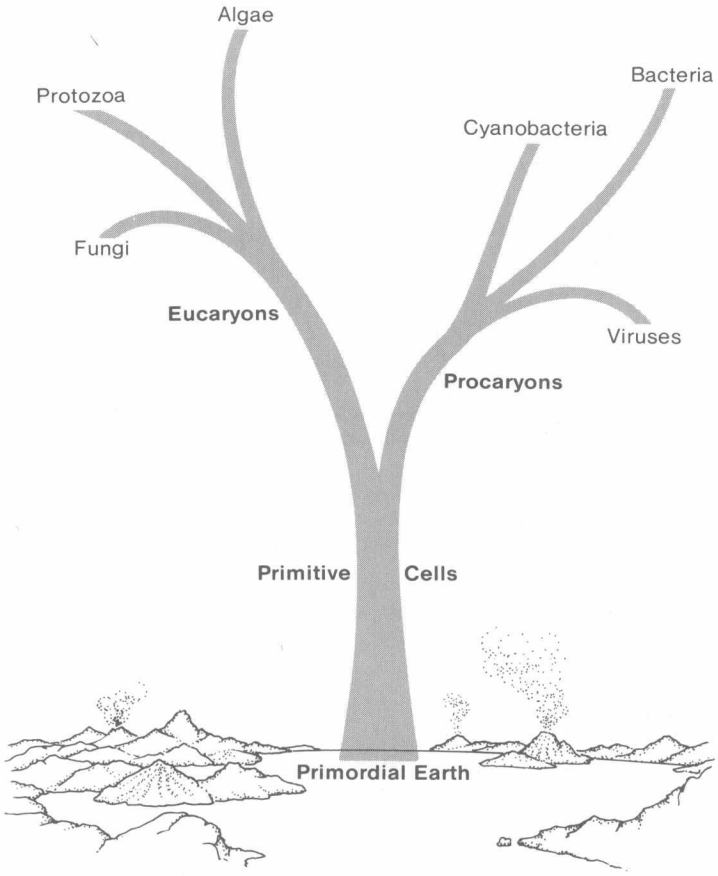

Fig. 1-1. Family tree of microorganisms.

who practices crop rotation to replenish his fields and to the gardener who keeps a compost pit as a source of natural fertilizer.

The purification of waste water is partially accomplished by bacteria in the holding tanks of sewage disposal plants, where feces, garbage, and other organic materials are collected and reduced to harmless waste. Some microorganisms such as the iron- and sulfur-using bacteria even break down metals and minerals. It is not difficult to observe the beneficial activities of the microbes because they are everywhere in our environment, in the land, water, and air.

Those who work in the health professions must be particularly aware of pathogens, their sources, and how they may be transmitted from one person to another. Physicians' assistants, dental assistants, nurses, laboratory technicians, respiratory therapists, orderlies, nurses' aides, and all others associated with patient care must take precautions to prevent the spread of pathogens. Harmful microorganisms may be transferred from health workers to patients; from patient to patient; from contaminated mechanical devices, instruments, and syringes to patients; from contaminated

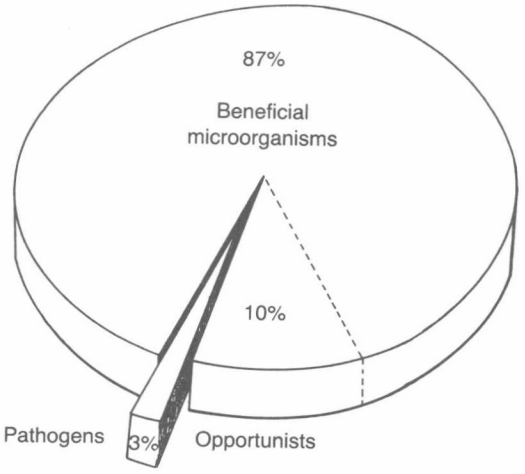

Fig. 1-2. Pathogens comprise about 3% of all the microorganisms. Another 10% are opportunistic microbes that may cause disease if they land in the appropriate place.

bedding, clothes, dishes, and food to patients; and from patients to health workers and other susceptible people.

The Scope of Microbiology

There are many fields of study within microbiology. One can specialize in any of many different types of microorganisms. For example, the bacteriologist concentrates on *bacteriology,* the study of structure, functions, and activities of bacteria. *Phycology* is the study of the various types of algae by scientists called phycologists. Those who specialize in the study of fungi, *mycology,* are the mycologists. Protozoologists explore the area of *protozoology,* the study of protozoa and their activities.

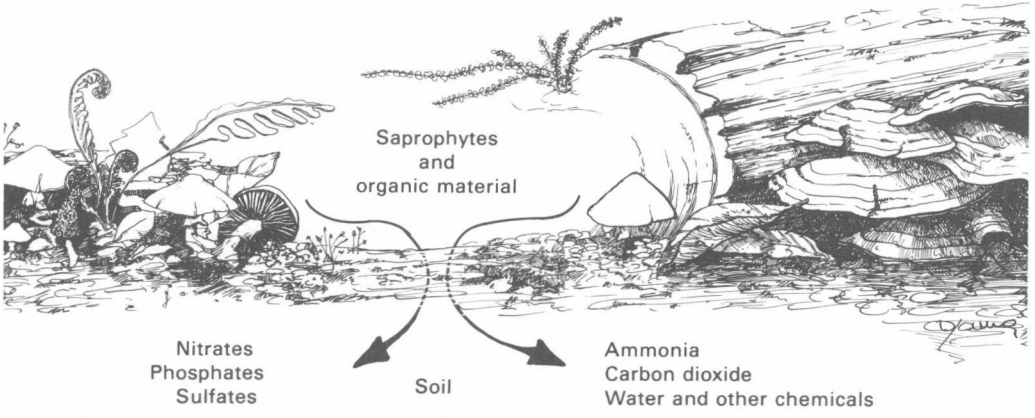

Fig. 1-3. Saprophytes break down dead, decaying organic material into inorganic nutrients in the soil.

Virology encompasses the study of viruses and their effects on living cells of all types. Virologists often become genetic engineers, manipulating the genetic material, DNA, from one cell to another.

Within the general field of microbiology there are many specialized areas in which the knowledge of all types of microorganisms and their applications is important. These areas include medical, veterinary, and agricultural microbiology, as well as applications in sewage disposal, industrial production, space research, and genetic engineering.

General Microbiology The study and classification of microorganisms and how they function is known as general microbiology. It encompasses all areas of microbiology.

Medical Microbiology The field of medical microbiology comprises the study of pathogens, the diseases caused by them, and the body's defenses against disease. It includes epidemiology, transmission of pathogens, prevention measures, aseptic techniques, treatment of infectious diseases, immunology, and the production of vaccines to protect against infectious diseases. The almost complete eradication of smallpox and diphtheria, the safety of modern surgery, and the treatment of AIDS victims are due to the many technological advances in this field.

Veterinary Microbiology The spread and control of diseases among animals is the concern of veterinary microbiologists. The production of food from livestock and other agriculturally important animals, the care of pets, and the transmission of diseases from animals to humans are areas of major importance in this field.

Agricultural Microbiology Included in the field of agricultural microbiology are studies of the beneficial and harmful roles of microbes in soil formation and fertility; in carbon, nitrogen, phosphorus, and sulfur cycles; in diseases of plants; in the digestive processes of cows and other ruminants; and in the production of crops and foods (Fig. 1-4). The *food microbiologist* is concerned with the production, processing, storage, cooking, and serving of food, as well as the prevention of food spoilage, food poisoning, and food toxicity. The *dairy microbiologist* oversees the grading, pasteurization, and processing of milk and cheeses to prevent contamination, spoilage, and transmission of diseases from environmental, animal, and human sources.

Sanitary Microbiology The field of *sanitary microbiology* includes the processing and disposal of garbage and sewage wastes, as well as the purification and processing of water supplies to ensure that no pathogens are carried to the consumer by the water. Sanitary microbiologists also inspect food processing installations and eating establishments to ensure the enforcement of proper food handling procedures.

Industrial Microbiology Many businesses and industries depend on the proper growth and maintenance of certain microbes to produce beer, wine, alcohol, and organic

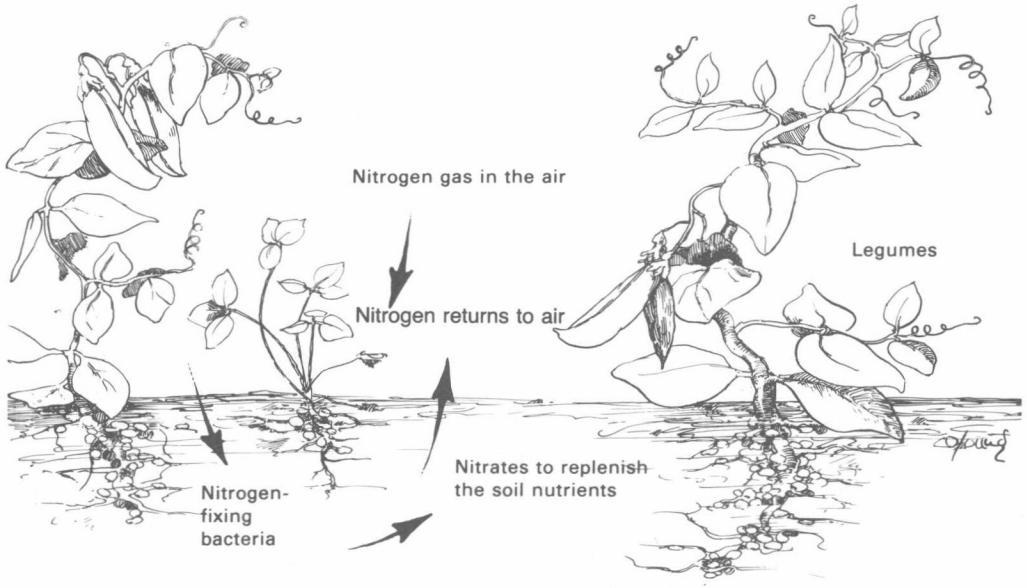

Fig. 1-4. Nitrogen fixation. The nitrogen-fixing bacteria that live on or near the roots of legumes convert free nitrogen from the air into nitrates to replenish the soil nutrients.

materials such as enzymes, vitamins, and antibiotics. *Industrial microbiologists* monitor and maintain the essential microorganisms for these commercial enterprises. *Applied microbiologists* conduct research aimed at producing new products and more effective antibiotics. The scope of microbiology, indeed, has broad, far-reaching effects on humans, on pathogens, and on their relationship to the environment.

Microbial Genetics Research in microbial genetics has contributed greatly to a clearer understanding of the science of genetics in general. Genetic manipulation is much easier and faster with viruses and bacteria than with the more complex eucaryotic cells; thus, everyday organisms such as the intestinal *Escherichia coli* are invaluable tools in this study.

Space Microbiology Sometimes called exobiology, space microbiology is a new area of microbiology begun when the first space vehicles were launched to probe outer space. It is concerned with the prevention of contamination of outer space with earth microbes and *vice versa*, and with the search for extraterrestrial life.

Environmental Microbiology The field of environmental microbiology has become important because of increased concern about the environment. This field encompasses the areas of soil, air, water, sewage, food, and dairy microbiology, as well as the cycling of the elements (see Fig. 1-4) by microbial, environmental, and geochemical processes.

Some Milestones of Microbiology

Since before the beginning of humanity, parasites have lived on, or in, other living organisms. We know human pathogens were present because damage caused by them has been observed in the bones of mummies and early humans, indicating that diseases, such as osteomyelitis and syphilis, were present.

In ancient Egypt and China, the people kept clean by washing with water in an effort to prevent disease. They also knew that some diseases were easily transmitted from one person to another, and they learned to isolate the sick to prevent the spread of these diseases, which we recognize today as being contagious. The Egyptians were aware of the effectiveness of biological warfare. They often used the blood and bodies of their diseased dead to contaminate the water supplies of their enemies and to spread diseases among them.

The Book of Leviticus in the Bible was probably the first recording of laws concerning public health. The Hebrew people were told to practice personal hygiene by washing and keeping clean. They were also instructed to bury their waste material away from their camp sites, to isolate those who were sick, and to burn soiled dressings. They were prohibited from eating animals that had died of natural causes. The procedure for killing an animal was clearly described, and the edible parts were so designated.

Most of the knowledge about public sanitation and transmission of disease was lost in Europe during the Middle Ages when there was a general stagnation of culture and learning for almost a thousand years. However, during the Renaissance, widespread epidemics of smallpox, syphilis, rabies, and other diseases caused the physicians and alchemists of the day to look for reasons for the contraction and transfer of diseases. Most people believed that diseases were caused by curses of the gods, and as a result, many bizarre treatments (bleeding, drilling holes in the head, attaching leeches) were used to drive the devils or evil spirits away and relieve the symptoms.

An Italian physician, Girolamo Fracastorius, having observed the syphilis epidemic of the 1500s, indicated in 1546 that the agents of communicable diseases were living germs that could be transmitted by direct contact with humans and animals and indirectly by objects. Proof of these vague theories was long delayed because the agents of disease could not be observed and experimental evidence was lacking.

Until the development of magnifying lenses and microscopes that could sufficiently magnify the microorganisms for them to be seen, the discovery of disease-causing agents was impossible. Actually, it is not known who built the first microscope, but compound microscopes, using two lenses to increase the magnification, were developed by Johannes Janssen (1590), Galileo Galilei (1609), and Robert Hooke (1660). When Antony van Leeuwenhoek first described bacteria in 1667, he used a small, simple microscope with one lens the size of a large pinhead and observed the material placed on the point of a pin. Leeuwenhoek is called the "Father of Microbiology" because he described the three shapes of bacteria as well as protozoa, sperm, and blood cells when he observed pepper water, tooth scrapings, gutter water, semen, blood, urine, feces, and other materials. His letters to the Royal Society of London