BRIEF CONTENTS

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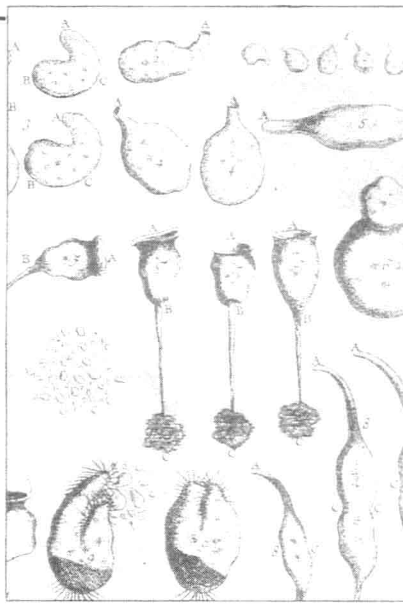
chapter 1

The Main Themes of Microbiology

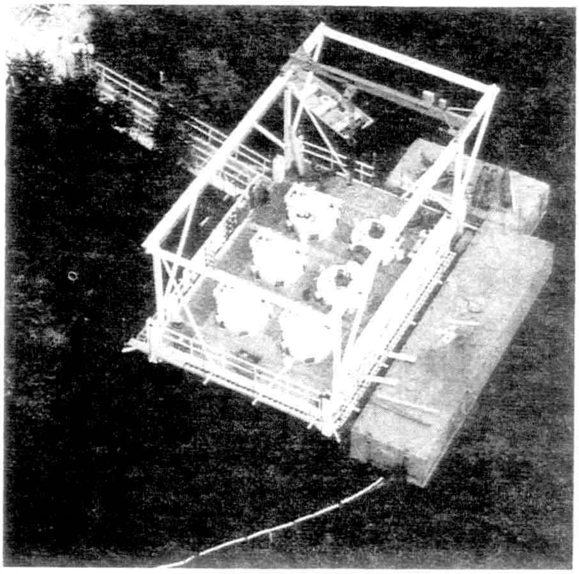


These are exciting times in the history of microbiology. We receive nearly daily reminders about the importance of microscopic creatures in our lives. Newspapers and magazines report on newly emerging diseases and keep us abreast of new methods of diagnosis and treatments. This negative view of microbes is balanced with constant reminders of the numerous beneficial roles that microbes play in our everyday lives and in the function of the earth itself. These paradoxical roles are a never-ending source of fascination.

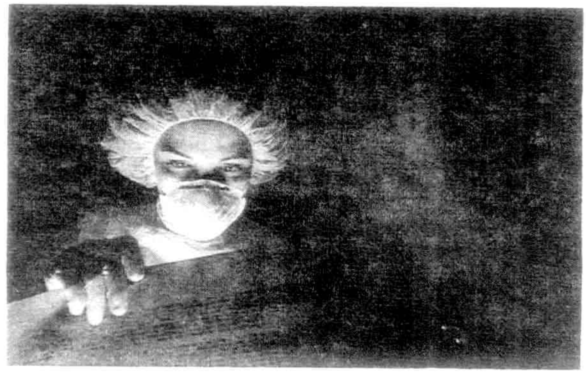
The world continues to experience an increase in new and emerging infectious agents such as the human immunodeficiency virus (HIV) and other retroviruses, and several older diseases such as tuberculosis regularly appear on the increase or continue to wreak their devastating effects (microfile 1.1). Microbiologists turn up intriguing connections between microorganisms and diseases whose causes have been unknown. Surprising correlations exist between type I diabetes and coxsackievirus infection, between schizophrenia and a virus called the borna agent, and between coronary artery disease and a common herpesvirus. These intriguing findings are the focus of serious ongoing research studies. In addition to their invasion of living organisms, microbes are also constantly invading and even thriving in new habitats created by commercial materials including computer chips, jet fuel, paints, concrete, metal, plastic, and paper.

On the plus side, microorganisms contribute to our lives in many ways. They are often called upon to solve various environmental, agricultural, and medical problems. Consider, for instance, the science of bioremediation, defined as the introduction of microbes to restore stability to disturbed or polluted environments (figure 1.1*a*). Increasingly, authorities are using microorganisms to clean up oil slicks or to remove pollutants from

One of the earliest glimpses into the microbial world emerged from the microscopes of the French naturalist Louis Jablot. He made these intricate drawings of protozoa growing in straw infusions in 1711. Despite the fanciful names he gave them, such as "little fish," "caterpillars," and "swans," the accuracy of his observations makes it possible for microbiologists to readily identify them even today.



(a)



(b)

Figure 1.1
Beneficial roles of microorganisms. *(a)* Polluted water and sediments can be bioremediated by placing submersible platforms in rivers and other waterways. Here, metal cylinders mix bacteria and mud with air to speed up the degradation of polychlorinated biphenyls (PCBs), highly toxic industrial chemicals. *(b)* A technician handles gel plates showing sequences of microbial DNA. She is surrounded by hundreds of these strips, just a tiny fraction of those required to completely unravel the genetics of just one bacterium.

lakes and water supplies. We rely on naturally occurring microbes to degrade the "biodegradable" materials poured into landfills as well as to clean up sewage, extract minerals, and generally "recycle" nutrients in all ecosystems on the earth.

The search for "friendly" microbes is a serious focus of genetic engineering, a field that manipulates genetic material to produce new types of biological materials, microbes, and even plants and animals. Some of the greatest hopes of humankind—a vaccine for AIDS (figure 1.1*b*), self-fertilizing plants, miracle drugs, cures for genetic diseases, elimination of pollution, and solutions to world hunger—seem within the grasp of this "new microbiology."

Clearly, microorganisms pervade our lives in both an everyday, mundane sense and in a far wider view. We wash our clothes with detergents containing microbe-produced enzymes, eat food that derives flavor from microbial action, and, in many cases, even eat microorganisms themselves. We are vaccinated with altered microbes to prevent diseases (that are caused by those very same microbes!); we treat various medical conditions with drugs produced by microbes; we dust our plants with insecticides of microbial origin; and we use microorganisms as tiny factories to churn out various industrial chemicals and plastics.

No one can emerge from a microbiology course without a changed view of the world and of themselves. There is no denying that humans are greatly affected by microbes that act as **pathogens,*** but we also depend upon microbes for many facets of life—one might say even for life itself.

*pathogens (patho'-oh-jenz) Gr. *pathos*, disease, and *gennan*, to produce. Disease-causing agents.

Chapter Checkpoints

There are many kinds of relationships between microorganisms and humans; most are beneficial, but some are harmful.

In the last 110 years, microbiologists have identified the causative agents for most of the infectious diseases. In addition, they have discovered distinct connections between microorganisms and diseases whose causes were previously unknown.

Microorganisms: We have to learn to live with them because we cannot live without them.

THE SCOPE OF MICROBIOLOGY

Microbiology is a specialized area of **biology*** that deals with living things ordinarily too small to be seen without magnification. Such **microscopic*** organisms are collectively referred to as **microorganisms,*** **microbes,*** or several other terms, depending upon the purpose. Some people call them germs or bugs in refer-

*biology Gr. *bios*, life, and *logos*, to study. The study of organisms.

*microscopic (my''-kroh-skaw'-pik) Gr. *mikros*, small, and *scopein*, to see.

*microorganism (my-kroh''-or'-gun-izm)

*microbe (my'-krohb) Gr. *mikros*, small, and *bios*, life.

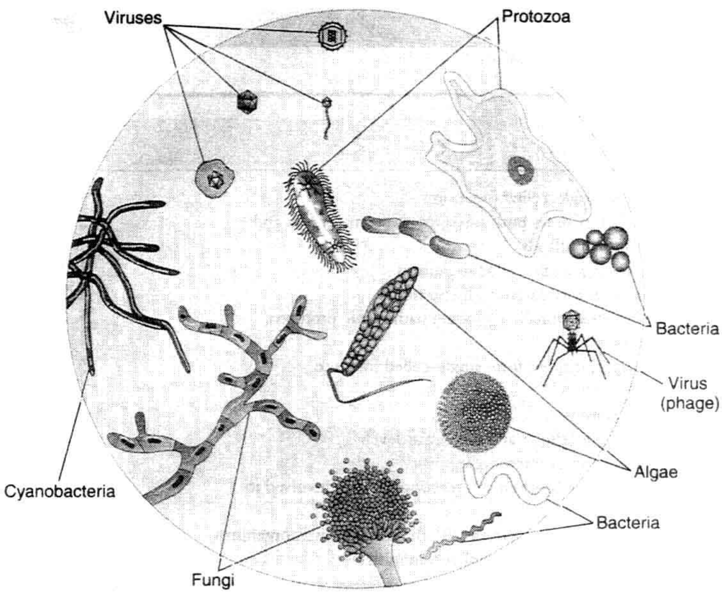


Figure 1.2
The Diversity of the Microbial World
(Not shown to scale)

ence to their role in infection and disease, but those terms have other biological meanings and perhaps place undue emphasis on the disagreeable reputation of microorganisms. Other terms that are encountered in our study are **bacteria, viruses, fungi, protozoa, algae,** and **helminths;** these microorganisms are the major biological groups that microbiologists study (figure 1.2). The very nature of microorganisms makes them ideal subjects for study. They often are more accessible than **macroscopic*** organisms because of their relative simplicity, rapid reproduction, and adaptability, which is the capacity of a living thing to change its structure or function in order to adjust to its environment.

Microbiology is one of the largest and most complex of the biological sciences because it deals with many diverse biological disciplines. In addition to studying the natural history of microbes, it also deals with every aspect of microbe-human and microbe-environmental interactions. These interactions include genetics, metabolism, infection, disease, drug therapy, immunology, genetic engineering, industry, agriculture, and ecology. The subordinate branches that come under the large and expanding umbrella of microbiology are presented in table 1.1.

Microbiology has numerous practical uses in industry and medicine. Some prominent areas that are heavily based on applications in microbiology are as follows:

Immunology studies the system of body defenses that protects against infection. It includes *serology,* a discipline that looks for the products of immune reactions in the blood and tissues and aids in diagnosis of infectious diseases by that means, and *allergy,* the study of hypersensitive responses to ordinary, harmless materials (see chapters 14, 15, 16, and 17).

*macroscopic (mak''-roh-skaw'-pik) Gr. *macros,* large, and *scopein,* to see. Visible with the naked eye.

Public health microbiology and **epidemiology** aim to monitor and control the spread of diseases in communities. The principal U.S. and global institutions involved in this concern are the United States Public Health Service (USPHS) with its main agency, the Centers for Disease Control and Prevention (CDC) located in Atlanta, Georgia, and the World Health Organization (WHO), the medical limb of the United Nations (see chapter 11). The CDC collects information on disease from around the United States and publishes it in a weekly newsletter called the *Morbidity and Mortality Weekly Report* (see data in end papers).

Food microbiology, dairy microbiology, and **aquatic microbiology** examine the ecological and practical roles of microbes in food and water (see chapter 22).

Agricultural microbiology is concerned with the relationships between microbes and crops, with an emphasis on improving yields and combating plant diseases.

Biotechnology includes any process in which humans use the metabolism of living things to arrive at a desired product, ranging from bread making to gene therapy (see chapters 10 and 26).

Industrial microbiology is concerned with the uses of microbes to produce or harvest large quantities of substances such as beer, vitamins, amino acids, drugs, and enzymes (see chapters 7 and 22).

Genetic engineering and **recombinant DNA technology** involve techniques that deliberately alter the genetic makeup of organisms to mass produce human hormones and other drugs, create totally novel substances, and develop organisms with unique methods of synthesis and adaptation. This is the most powerful and rapidly growing area in modern microbiology (see chapter 10).

TABLE 1.1

BRANCHES OF MICROBIOLOGY

Science	Area of Study	Chapter Reference
Bacteriology	The bacteria—the smallest, simplest single-celled organisms	4
Mycology	The fungi, a group of organisms that includes both microscopic forms (molds and yeasts) and larger forms (mushrooms, puffballs)	5, 22
Protozoology	The protozoa—animal-like and mostly single-celled organisms	5, 23
Virology	Viruses—minute, noncellular particles that parasitize living things	6, 24, 25
Parasitology	Parasitism and parasitic organisms—traditionally including pathogenic protozoa, helminth worms, and certain insects	5, 23
Phycology or algology	Simple aquatic organisms called algae, ranging from single-celled forms to large seaweeds	5
Microbial morphology	The detailed structure of microorganisms	4, 5, 6
Microbial physiology	Microbial function (metabolism) at the cellular and molecular levels	7, 8
Microbial taxonomy	Classification, naming, and identification of microorganisms	1, 4, 5
Microbial genetics, molecular biology	The function of genetic material and the biochemical reactions of cells involved in metabolism and growth	9, 10
Microbial ecology	Interrelationships between microbes and the environment; the roles of microorganisms in the nutrient cycles of soil, water, and other natural communities	7, 26

Each of the major disciplines in microbiology contains numerous subdivisions or specialties that in turn deal with a specific subject area or field. In fact, many areas of this science have become so specialized that it is not uncommon for a microbiologist to spend his or her whole life concentrating on a single group or type of microbe, biochemical process, or disease. On the other hand, rarely is one person a single type of microbiologist, and most can be classified in several ways. There are, for instance, bacterial physiologists who study industrial processes, molecular biologists who focus on the genetics of viruses, fungal taxonomists interested in agricultural pests, epidemiologists who are also nurses, and dentists who specialize in the microbiology of gum disease.

Studies in microbiology have led to greater understanding of many theoretical biological principles. For example, the study of microorganisms established universal concepts concerning the chemistry of life (see chapters 2 and 8), systems of inheritance (see chapter 9), and the global cycles of nutrients, minerals, and gases (see chapter 26). Microbiology is often *serendipitous*, meaning that basic research discoveries may later, quite by accident, lead to some new drug, therapy, food, or industrial process. For example, penicillin was discovered purely by a quirk of fate (see microfile 12.1).

INFECTIOUS DISEASES AND THE HUMAN CONDITION

Infectious diseases still devastate human populations worldwide despite wonderful strides made in understanding and treating them (see microfile 1.1). The World Health Organization (WHO), a medical agency of the United Nations, estimates that more than 17 million people die each year worldwide from preventable **infectious diseases** defined as the disruption to the body caused by the action of microbes or their products (figures 1.3 and 1.4). Many of these diseases occur in developing countries where medical care is unavailable or substandard. Adding to this toll are a growing list of emerging diseases discussed in microfile 1.1. To complicate matters even further, increased numbers of patients with severe compromised immune defenses due to AIDS and cancer are being kept alive for extended periods. These individuals are subject to infections from common environmental microorganisms that do not affect healthy people. Even with miracle medical technology, microbes still appear to have "the last word," to quote Louis Pasteur.

Chapter Checkpoints

- Microorganisms are defined as "living organisms too small to be seen with the naked eye" with three exceptions: viruses, which are not really alive, but are microscopic; helminth worms, which are not always microscopic; and certain insects, which, although visible, carry microscopic agents of disease.
- The scope of microbiology is incredibly diverse. It includes basic microbial research, research on infectious diseases, study of prevention and treatment of disease, environmental functions of microorganisms, and industrial use of microorganisms for commercial, agricultural, and medical purposes.

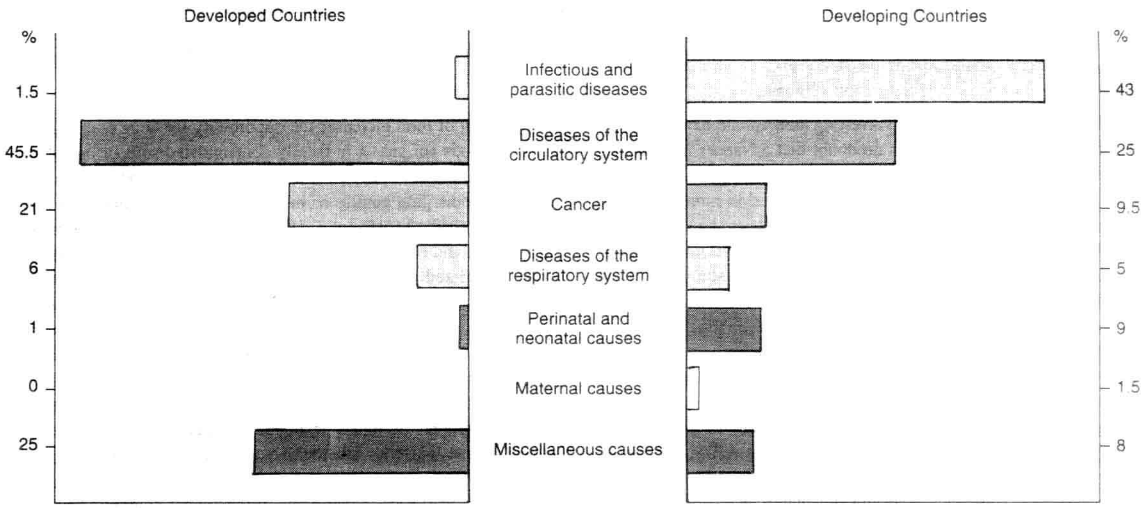


Figure 1.3
Graphs contrast the seven overall causes of death worldwide in developed, industrialized countries and in developing countries. Although mortality from infectious diseases has waned in countries such as the United States, it still has a major impact in countries with less development and access to medical care. Miscellaneous causes of death include accidents, suicides, war, and malnutrition.
Source: Data from World Health Organization 1996 reports.

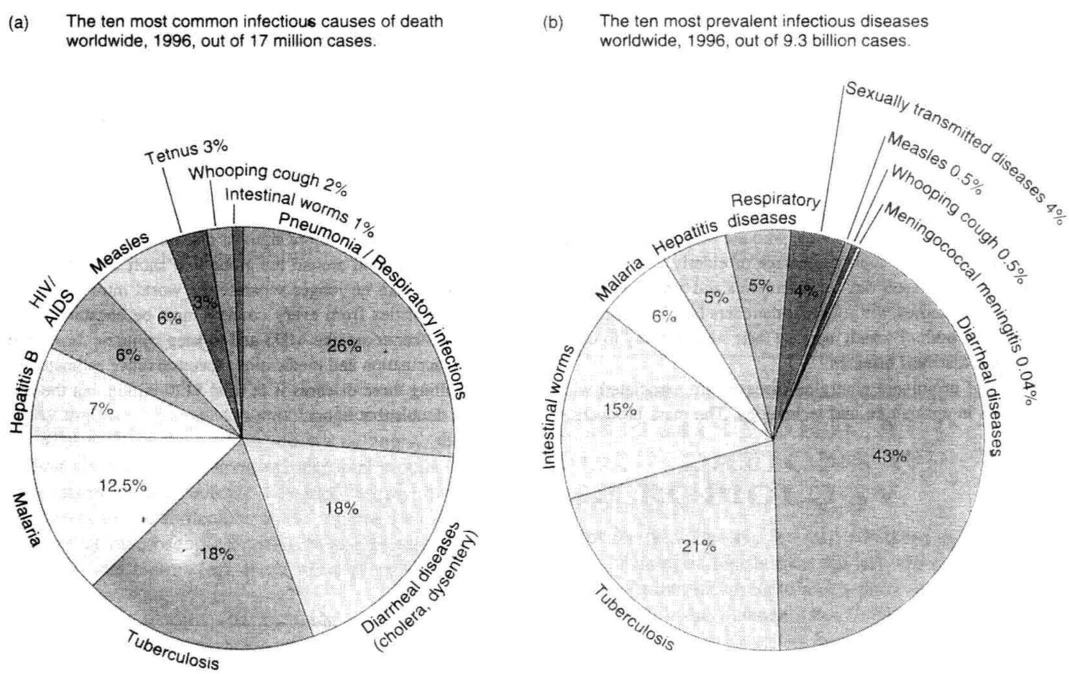


Figure 1.4
Infectious disease statistics rank the major causes of (*a*) mortality and (*b*) morbidity (rate of disease) on a global scale. A large number of diseases can be treated with drugs or prevented altogether with vaccination and improvements in health care and sanitation.
Source: World Health Organization, 1996; most recent data available.