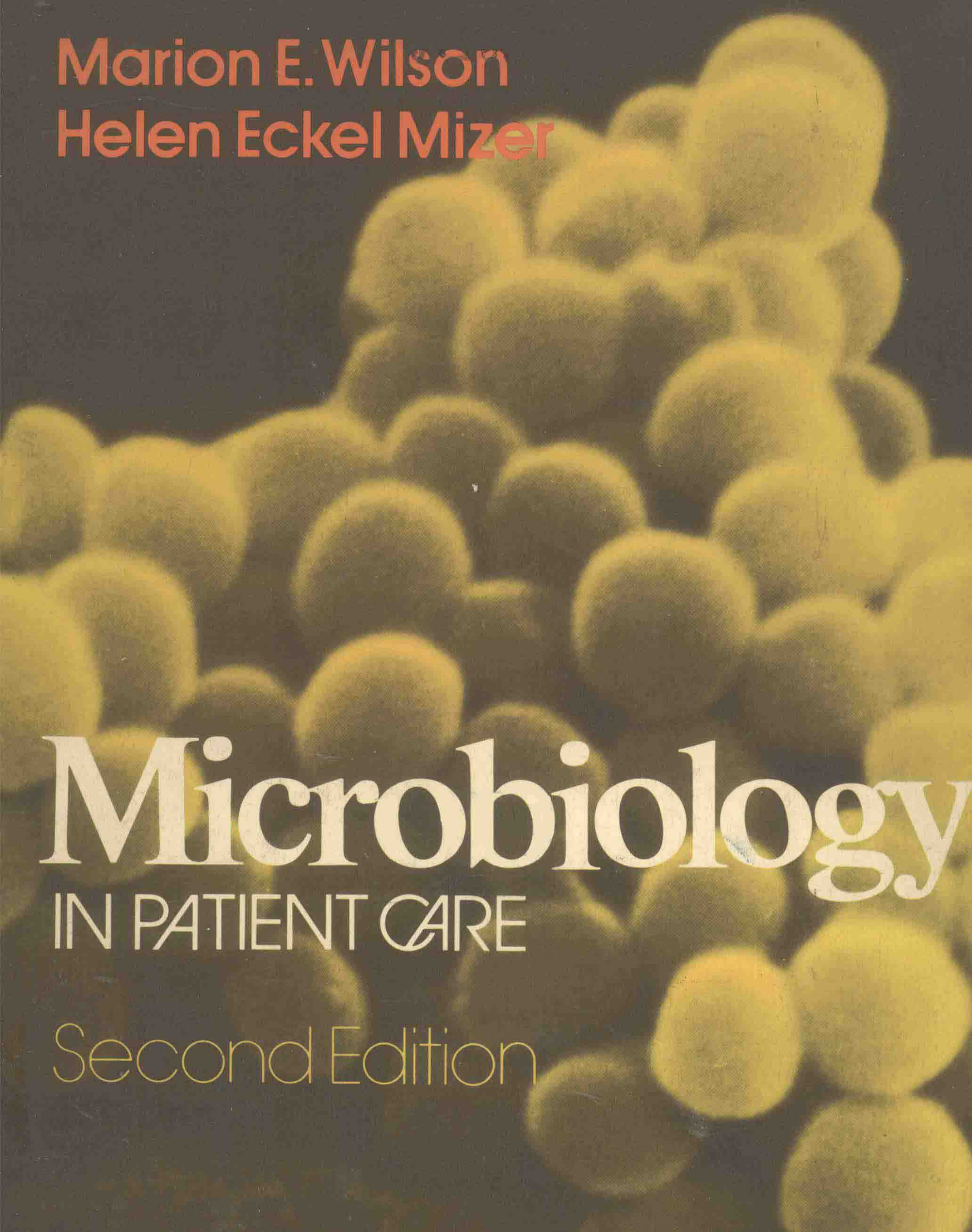

Marion E. Wilson
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Microbiology
IN PATIENT CARE

Second Edition

Microbiology
in Patient Care *second edition*

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IN MEMORY OF

Margaret Heise-Stevens

colleague, teacher, and enduring friend.
Her knowledge, skill, joy, valiance, and love
are stamped indelibly in many places,
including the pages of this book.

Preface

Continuous expansion of knowledge in the area of basic microbiology has been accompanied, in the past few years, by changing concepts of the application of microbiologic principles to patient care and health maintenance. Accordingly, this textbook, originally published as *Microbiology in Nursing Practice* (1969), has undergone some major revisions.

The second edition, now titled *Microbiology in Patient Care*, is oriented for use by the many students currently interested in careers in the health field. The special interests of the nursing student as well as the professional and technical nurse receive primary emphasis again, but the text is also directed to the overlapping concerns of others who will be learning specialized techniques in patient care. Operating room or cardiopulmonary technicians, inhalation therapists, dietitians, dental hygienists, optometric technicians, hospital sanitarians, and others in similar paramedical specialties will find this text pertinent to their own applications of microbiologic principles. It is designed not only to provide the student with fundamental knowledge of medical microbiology but also to continue to serve the graduate with reference information concerning nursing (or other) management and control of infectious diseases.

The order of presentation of material is essentially the same as in the first edition. Part One is intended for classroom use, its three sections covering the basic principles of medical microbiology: Section I, the nature and behavior of microorganisms; Section II, the interrelationships of microbes and the human host, in health and disease; Section III, principles of prevention and control of infectious diseases.

Part Two describes important human infectious diseases. This part is designed to be of value, to both student and graduate, as a source of rapidly obtainable, specific information concerning the nature, epidemiology, and management of particular diseases. The four sections of Part Two group diseases according to the most probable (or usual) routes of entry of the microbial agent, and to the nature of the infecting microorganism (bacterial, viral, rickettsial, fungal, and parasitic diseases are discussed in separate chapters of each section). It is hoped that this arrangement will be useful in locating information and, more important, will help the student to learn to associate the infectious agent of a given disease with its portal of entry and communicability. Once the portal is understood, techniques for prevention of further transmission of infection can be better appreciated and practiced.

Changes in the second edition include, in Part One, complete revision of Chapters 2, 3, and 4, and the updating of all others. The new material reviews current concepts of the classification of bacteria as protists, the evolutionary relationships of microorganisms, and their position in the biosphere. The classifying summary of pathogenic microorganisms that appeared in Chapter 12 of the first edition is now placed in Chapter 4, following discussion of methods for their identification. The newest edition of *Bergey's Manual of Determinative Bacteriology* (8th ed., Williams & Wilkins Co., Baltimore, 1974) has been followed in all classifications.

Every chapter in Part Two has been revised and updated. Diseases having several possible entry portals are described only under the one of most frequent importance and are otherwise cross-referenced for emphasis. New concepts of the etiology and epidemiology of equivocal diseases such as toxoplasmosis and infectious mononucleosis are presented. Melioidosis, an infection that drew fresh attention because of its serious incidence among soldiers wounded in Vietnam, is briefly described. Current concepts of effective immunization with improved vaccines are outlined, wherever applicable, under discussions of the epidemiology of specific diseases. Each chapter is ended with a summarizing table outlining salient features of disease entities described therein: agent, entry route(s), incubation and communicable periods, laboratory diagnosis, prevention, treatment, and management.

There are new electron micrographs, line drawings, and photographs throughout the book. The scanning electron micrograph technique, recently developed, is described and illustrated.

Questions at the end of each chapter are designed to assess the student's ability to apply classroom knowledge of microbiologic principles to patient-care situations.

Recommendations for additional reading are listed at the end of each chapter. They are made on the basis of pertinence, application, and availability of reading material. Highlighted among them are the very inexpensive *Scientific American Offprints* (published by W. H. Freeman & Co., 660 Market St., San Francisco, Calif. 94104).

Finally, several appendixes have been attached. These include summaries that may be useful as a rapid source of information concerning microbial flora of clinical specimens, skin tests and serologic procedures of diagnostic value, tissue localizations and transmission routes of animal parasites, aseptic nursing precautions, updated recommendations for sterilization and disinfection, and the bacteriologic control of sterilizing equipment.

The authors again acknowledge their debts to the many colleagues, friends, and relatives who have lent support to the preparation of this book. It owes its strengths to them, its imperfections to us.

Our particular thanks go to those who took the time to read parts or all of the manuscript and to make constructive suggestions. These include Ms. Paula Chipman, Instructor, Biology Department, Western Connecticut State College; Dr. Paul S. May, Deputy Director and Chief Research Scientist, Public Health Laboratory Services, New York City Department of Health; Dr. Irene Weitzman, Senior Research Scientist, Public Health Laboratory Services, New York City Department of Health; and Mr. Martin Weisburd, Research Scientist, Public Health Laboratory Services, New York City Department of Health, and Lecturer, New York City Community College (City University of New York).

The generous cooperation of Dr. N. E. Gibbons, editor of the eighth edition of *Bergey's Manual of Determinative Bacteriology* (Williams & Wilkins Co., Baltimore, Md., 1974) was especially helpful. During the preparation of a major revision of *Bergey's Manual* he found the time to respond to our inquiries concerning current microbial classifications. In turn, we gratefully acknowledge his contributions to our revised text.

The colleagues who generously provided photographs and other illustrations have our special appreciation. Their names appear throughout the text in the figure captions that acknowledge their contributions. The fine new line drawings are the work of Mr. Otto Schmidt of the Westchester Community College, Valhalla, New York, whose artistry also was seen in the first edition.

We could not have completed the work without the unfailing help of those who were closest to it, and most patient and encouraging with respect to its goals. In this context, our special thanks go to Dr. Yvonne C. Faur, Dr. Paul S. May, and Dr. Bernard Davidow, all of the Public Health Laboratory Services, New York City Department of Health; Mrs. Paul H. Rogers, R.N., Ms. Katherine Eierdanz, Mr. Edwin H. Mizer, and last—but not least—Paul and Elaine Mizer.

From the beginning it has been our pleasure to acknowledge the courteous cooperation of the Macmillan Publishing Co., Inc., in presenting this book. Once again the expert guidance of Ms. Joan C. Zulch, medical editor, who steered it through all preparative phases, and of Ms. Pat Larson, production editor, who skillfully converts manuscripts into printed works, have made its publication possible.

M. E. W.
H. E. M.

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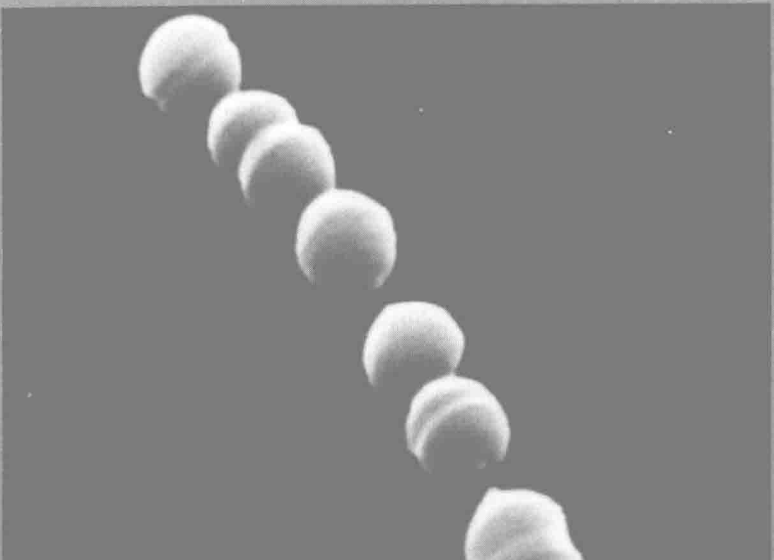
Part One Basic Principles of Microbiology



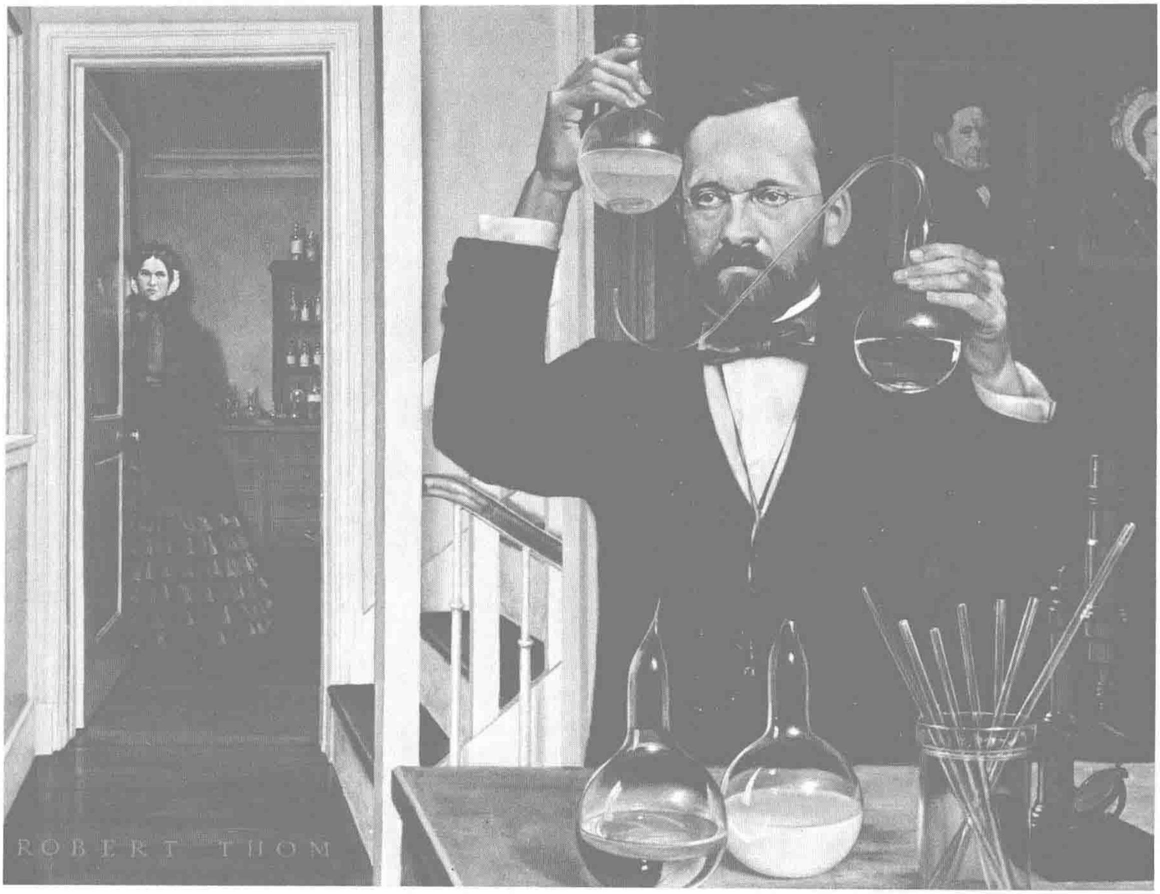
Section I
Character of Microorganisms

1 Introduction: Microbiology, Past and Present

2 The Microbial World Defined

3 Microbial Life

4 Tools and Techniques: Identification of Pathogenic Organisms



1 Introduction: Microbiology, Past and Present

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Just a little more than one hundred years ago mankind awoke to its first real hope that relief might be at hand for some of its most devastating diseases. The world was flooded with the light of the discovery that living but invisible organisms were at the root of such diseases as smallpox, diphtheria, and plague — afflictions that had decimated human populations from time to time throughout recorded history. Suddenly a new understanding of the mechanisms of many such diseases was at hand, and in that light the science of microbiology was born, expanded explosively, and became a root itself of modern medical practice and health care.

This new science derived its name from its focus on the study of living organisms too small to be seen except through the enlarging lenses of a microscope (*micro* = small; *bios* = living; *-ology* = study). The organisms newly discovered, being so minute, were called *microbes*, or *microorganisms*. Actually, they had been known to exist for almost two centuries prior to the recognition of their importance in disease in the late nineteenth century. Since that time it has become ever more apparent that the invisible microbial world is enormous and affects our lives enormously.

Microorganisms share all segments of the world we live in, being involved together with plants, animals, and human beings in the great biologic cycles of force and counterforce that characterize the ongoing physical life of our planet. Myriads of microbial species are constantly active in our natural environment. Many also live in continuous association with us on our body surfaces, or on animals and plants. These relationships lead to biologic interplays and interdependencies essential to our welfare, but they may also militate against us if we lose our physiologic balance.

Medical Microbiology

Among the vast numbers of species of microorganisms with which our lives are bound, there are a relative few whose properties and interactions with the human body may lead to development of disease. These are of concern in the field of *medical* microbiology where great progress has been made in defining the nature and properties of harmful microorganisms and the disease processes they induce. Such studies have led to the understanding that *infection* usually represents a balanced relationship between microbes and other living things, whereas *infectious* (or *microbial*) *disease* results from a more damaging interplay between microorganisms with injurious properties and the infected body's responses to them. It has also become clear that the properties of a particular microbe that are responsible for harmful effects in one individual or species do not necessarily induce injury in another, confirming the recognition of microbial disease as a series of interactions between two living organisms, each exerting opposing forces on the other, with resultant injury to the infected (or "host") organism. This concept provides an important basis for the application of microbiologic principles in medicine, nursing, and all patient care.

The management and control of infectious diseases today require the concerted efforts of people trained in several disciplines: physicians, nurses, pathologists, clinical microbiologists, chemists, and epidemiologists. Successful *treatment* of a microbial disease depends on its prompt, accurate *diagnosis*. This is the physician's area of skill and responsibility, supported by evidence provided by laboratory specialists. The *control* and *prevention* of these diseases are also essential, however, because they are so frequently communicable from one person to another and can involve whole populations in epidemics. Here the epidemiologist applies his special knowledge of microorganisms, of the manner in which they are transferred from man to man (or among animals, and from animals to man), of their capacity for survival in the natural environment, and of their reaction to changing environmental conditions.

The professional nurse, as a member of this team of specialists, has a highly important role to play in each aspect of the management of infectious disease — in diagnosis, treatment, and control of active infection, and in its prevention. In a very real sense, the nurse's professional education and training combine basic elements of each specialty involved, and she applies them continuously in her practice. She must be conversant with diagnostic signs of infectious disease and with methods of treatment, particularly with regard to the patient's response to antibiotic drugs. She must be able to participate in making the diagnosis, through accurate reporting of the patient's symptoms seen from her particularly close point of view, and by assuring well-timed, careful collection of specimens ordered for laboratory studies to identify the cause of infection. Using her knowledge of the nature of microbial agents of infectious disease, the nurse must apply appropriate precautionary measures in her bedside care of every patient so that communicable diseases cannot be spread from one to another, and problems of new infection are not superimposed upon patients who are ill with other conditions.

Control of active infectious disease requires a working knowledge of the usefulness and applications of physical and chemical agents that suppress or kill microorganisms, as well as familiarity with sources of potentially dangerous microbes, routes by which they spread, and their portals of entry into the human body. *Prevention* of infectious disease hinges on adequate control of these sources and transmission routes. It also frequently depends on specific measures designed to improve individual resistance to infectious microorganisms. Specific resistance is spoken of as *immunity* and plays a vital role in prevention.

While the nurse's responsibilities extend across all areas of infectious disease management, above all she must be a good epidemiologist, competent in her knowledge of the nature of infectious diseases and of available means for controlling or preventing them. In every field of nursing and patient care, whether it be practiced in hospitals, in the public health agency, in medical offices, or in industry, a knowledge of basic principles of microbiology is essential. The necessity for such a background of preparation in the nursing curriculum is further highlighted today by the dramatic ease, speed, and frequency of human travel that bring distant diseases closer to home, open up new pathways for communicability of infections, and create new problems in their control.

The Background of Microbiology

In beginning the study of microbiology it should be rewarding to glance first around the broad field of which it is a part and to see in general how it has evolved. As all living organisms are linked together by the interrelated mechanisms of their biologic processes, so those who would study any one group of living things find the field of their scientific interest interlocked with many others.

Biologists and Tools

The field of biology embraces all sciences that inquire into the nature of life — that is, into the structure, character, and behavior of living forms. These inquiries have been going on insistently since the beginning of recorded history. For centuries, botanists, zoologists, chemists, and physiologists have sought to define life in its many forms, at every observable level. Where the search has been hindered for lack of a method for accurate observation, efforts often have been concentrated on devising better tools or more refined techniques. In general, these efforts have constantly enlarged both our visual and our intellectual range, so that increasingly minute structural features have been visualized, or more subtle details of function have become better understood (Figs. 1–1 to 1–8). So it was that the world of microscopic life, long imagined but hitherto invisible, finally became apparent, late in the seventeenth century, when a curious eye looked through an enlarging lens at a suspension of material that contained living microbes, swimming and moving about.

The possessor of this eye, who applied it to a microscope of his own making and used them both so well that he became the founder of a new science of far-reaching influence, was Antony van Leeuwenhoek. He was a Dutch businessman with a hobbyist's interest in lens grinding and optics. His skill with lenses was extraordinary, and his interest in the world that they revealed to him was unending. In a long series of letters to the Royal Society of London, written over a period of 50 years, he described his observations of "incredibly small" living creatures abounding in drops of lake water, in scrapings of tartar from his teeth, in fecal suspensions, in pepper infusion, and in other fluids. His lenses gave him magnifications up to about three hundred diameters with which he could see "animalcules," as he called them. In a letter to the Royal Society dated 1683, and another in 1692, he included drawings that clearly depict forms identifiable as bacteria.

Leeuwenhoek's microscope was not the first to be invented. That achievement had come earlier in his century and spurred his interest in lenses, no doubt, but he preferred to make his own. He had received relatively little schooling and was not a scientist; so he may have been unaware that the existence of microorganisms had been postulated but unconfirmed by medical men concerned with the causation of diseases spread by "contagion." His contribution was all the more remarkable in view of his personal simplicity. The objective nature of his reports left no doubt as to the validity of his observations.

Controversies and Delays

Microbiology thus made a tentative beginning but was not to become a science in the disciplined sense for nearly two hundred years. Although Leeuwenhoek's animalcules were believable and could be confirmed, they were not taken seriously for a time. One of the reasons for this was that the simple observation of microbial life was difficult to interpret without some means of cultivating microorganisms and studying their properties. Certainly their relationship to some of the diseases of man, animals, or plants was not immediately recognizable and received little attention.

Over the ages there had been no dearth either of strong popular beliefs and superstitions or of highly astute, educated theories concerning the cause of contagious diseases, but these ideas had to be subjected to scientific testing before real progress could be made. It had been recognized from ancient times that diseases can spread from person to person, and many forms of control were devised accordingly, meeting with more or less success according to their basis in pure superstition or clear observation. Efforts to explain the nature of such diseases, and the dreadful epidemic form they so often took, led to some very discerning theories in a number of instances. Fracastorius in the sixteenth century, and Kircher in the seventeenth, both wrote with perceptive conviction and foresight of living but invisible agents as the possible cause of contagions. At the time, however, neither these nor conflicting ideas could be proved.

Through the centuries the question of the origin of life itself was interwoven with this problem. From the time of the early Greek philosophers the theory that life could be generated from nonliving matter had enjoyed strong support. By 1700 scientific experiments had dispelled belief in the spontaneous generation of animals of visible proportions, but when microorganisms were discovered, many people continued to apply the theory to this form of life. Thus, until the middle of the nineteenth century, Leeuwenhoek's little animalcules remained in the center of a controversy concerning their origin and were often the subjects of poorly designed experiments that led to claims of further proof of spontaneous generation. For example, flasks of vegetable broth that clouded with the growth of microbes after several days of exposure to air were thought to provide such proof. Nothing was known of the presence of bacteria in the air, or of their adherence to dust particles settling from air into open flasks containing nutrient material. Furthermore, nothing was known of the ability of some bacteria to form heat-resistant spores, so that experiments in which bacterial growth could be demonstrated even in flasks of heated broth were similarly open to misinterpretation.

In spite of the work of several investigators whose well-controlled experiments led to results that refuted the theory of spontaneous generation, the controversy continued until 1860 when Louis Pasteur, a French biochemist and physicist, conducted a series of classic experiments that demonstrated that no growth can occur in flasks of broth properly protected from contamination by airborne microorganisms. In one type of experiment, he introduced beef bouillon into a long-necked flask, then drew the neck of the flask out into a long, sinuous "swan-neck" shape. When he boiled the liquid in the flask, vaporization forced the air out of the opening at the end of the long neck. Upon cooling of the liquid, air was pulled back into the flask but had to pass over condensed moisture in the neck that washed it free of dust and other particles, so that the bouillon remained clear and free of growth. Control flasks were also heated, but immediately afterward the long necks were broken off, and as a result air pulled into the fluid during cooling was not first washed but delivered dust particles with their burden of viable microorganisms directly into the nutrient fluid, which soon became cloudy with microbial growth (see the illustration on p. 3). In another series of experiments, Pasteur used an idea of earlier workers and introduced a cotton plug into the necks of his flasks. The cotton acted as a filter, effectively straining out dust particles and keeping the nutrient in the flask free of microorganisms derived from the air. (Cotton plugs are still commonly used in test tubes or flasks, but screw caps and slip-on metal or plastic closures serve the same purpose of preventing air contamination and are easier to prepare and apply.)

When Pasteur presented the results of these experiments, the conclusion that life at every level must be self-reproducing, rather than spontaneous, began to take precedence and the way was cleared for the development and application of scientific methods to study the nature of microscopic organisms and the mechanisms of their self-duplication.

Bacteriology's Golden Age

Pasteur's greatest contributions evolved from his demonstrations of the relationship of certain microorganisms to the spoilage of wines and of others to a disease of silkworms. These were matters of great economic importance to France at the time. The experimental proof that they were of microbial origin led Pasteur to a similar approach in his study of anthrax in sheep and of certain human infections. The successful identification of particular microorganisms as the agents of individual diseases of plants, animals, and human beings then led him to reexamine and reformulate the old "germ theory of disease," which attributed the cause of infection to microbial agents. He brought sound scientific evidence to bear on this point for the first time, and this soon came to the attention of the great English surgeon Joseph Lister, who applied the theory in his surgical practice.

Lister speculated that if Pasteur was right about the ubiquitous presence of microorganisms in the

Microscopes

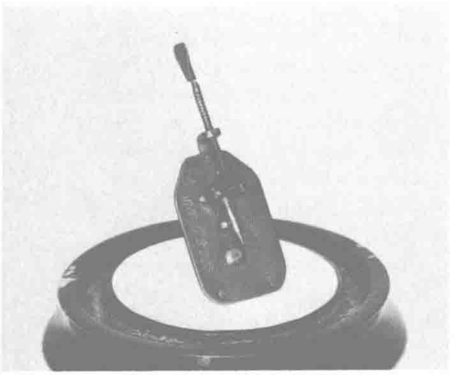

Fig. 1–1. Antony van Leeuwenhoek's microscope. A replica of one of the first microscopes made by Leeuwenhoek about 1673. A single little lens is in the peephole in the flat plate. The object to be viewed is placed on the spike and adjusted with screws. The microscope is held close to the eye for viewing. It provides magnifications of about 200× to 300×. (Courtesy of Armed Forces Institute of Pathology, Washington, D.C.)

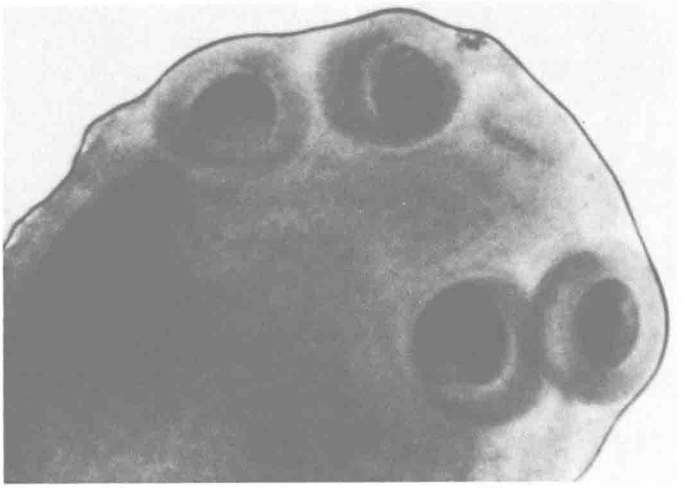

Fig. 1–2. This is the head (scolex) of the beef tapeworm (*Taenia saginata*). It has the dimensions of a very short, tiny pin when viewed without magnification. If examined through one of Leeuwenhoek's lenses it would look like this (lens magnification 200×).

Fig. 1–3. The Holmes microscope. A compound microscope devised by Oliver Wendell Holmes in 1873. A magnification of approximately 400× could be obtained. (Courtesy of Armed Forces Institute of Pathology, Washington, D.C.)

Fig. 1–4. *Endamoeba histolytica*, a microorganism (an ameba) that causes amebic dysentery (lens magnification 400×). Organisms of this size could readily be seen through the Holmes microscope (Fig. 1–3).