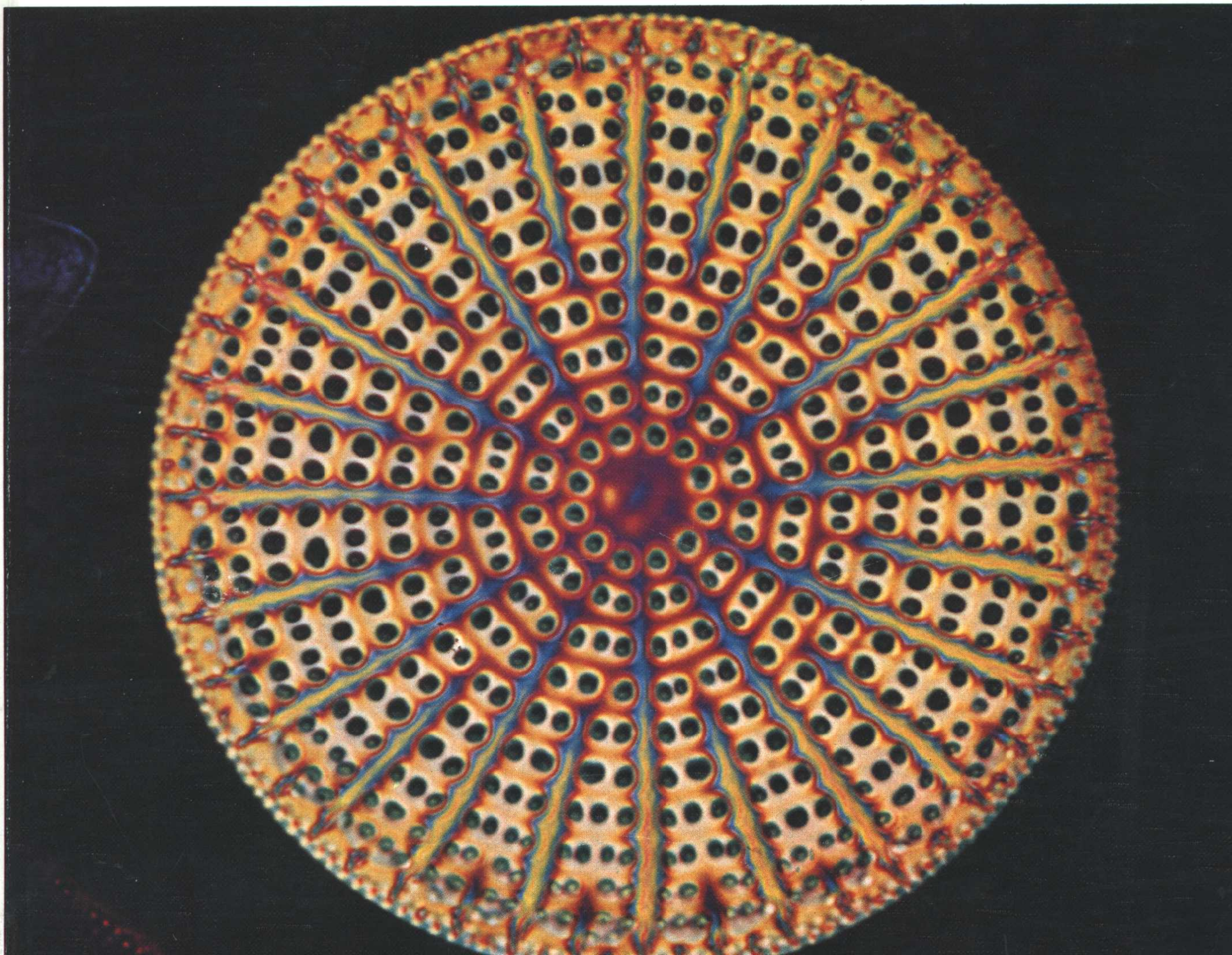
BROCK and BROCK

# Basic Microbiology

WITH APPLICATIONS

Second Edition



# Basic Microbiology

## WITH APPLICATIONS

**For Emily and Brian**

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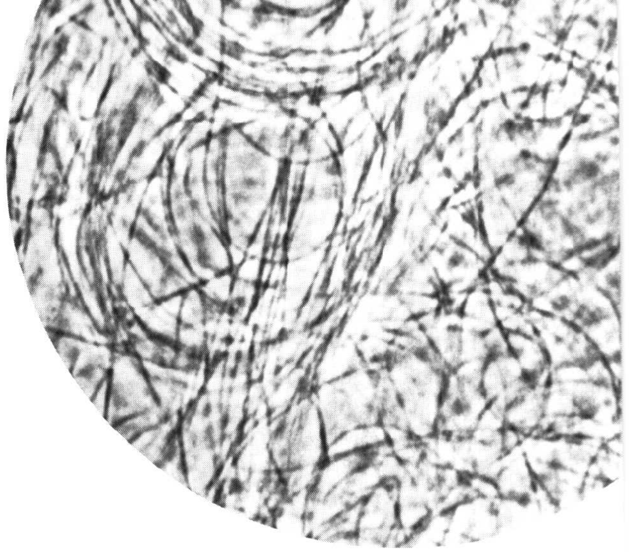
# PREFACE



*Basic Microbiology with applications,* second edition, is intended to serve as an introduction to microbiology for students interested in science, as well as for liberal arts students who are not going to major in biology or microbiology. The book is oriented in a very practical way and deals primarily with those aspects of microbiology that directly affect human affairs. Such fields as nursing, environmental protection, agriculture, food technology, and public health are given special attention.

We have been pleased that students and instructors alike found the first edition of this book to be readable as well as informative. A primary objective in writing the second edition was to bring the same level of accessibility to the discussion of several new, user-suggested topics, including chemistry, molecular biology, and genetics. Some exposure to chemistry is inevitable in the field of microbiology, and so we have added a chapter on chemistry sufficient for comprehending this text. Previous college chemistry is neither assumed nor required.

Chapter 5, "Chemical and Physical Background," also serves to prepare students for the discussions of microbial metabolism and biosynthesis and microbial genetics in Chapters 6 and 7. This important new triad of chapters comprises Part 2, "Molecular Biology." We have attempted to present a readily understandable introduction to this aspect of microbiology for students at this level.

The history of microbiology is introduced in Chapter 1 not only because it is a fascinating topic but also as a means to present to readers ideas and themes that are amplified throughout the book. Thus, although this chapter is rather long, it need not be read as a unit; relevant sections may be read to accompany various topics in later chapters.

Material on host-parasite relationships, immunology, and epidemiology has been considerably expanded. Emphasis is given in this edition to infectious disease and disease-causing organisms. We have chosen to organize this material around the organisms themselves rather than around organ systems affected or portals of entry. We elect this approach because it seems to us more logical from a practical microbiological point of view. In diagnostic microbiology, the main emphasis is on identification of the causal agent. The pathologist may be concerned with organ systems and the epidemiologist with portals of entry but the microbiologist is concerned with microorganisms.

Suggested readings lists are descriptive and direct readers to noteworthy publications, both basic and specialized, that further explore the subject of each chapter. The glossary, classification appendix, and index are useful for readers during the course of study and even, we hope, beyond.

Another important concern in the choice of material and manner of presentation has been to keep the size of the book within reasonable bounds. We have had clearly in mind in this regard the fact that this text will be used for courses of varying lengths and emphases, and we have tried to select material with the broadest interest and appeal. We have included a great many photographs, in particular, of real-world situations.

This book has a distinctly ecological flavor. Our own research interests lie in this direction, so that it has been easy for us to weave environmental thinking into the fabric of the text; but we have been further encouraged to do so by the obvious need for a textbook with more ecological emphasis. We hope that this book will stimulate students to turn to careers in the increasingly crucial fields of environmental studies and public health.

Thomas D. Brock
Katherine M. Brock

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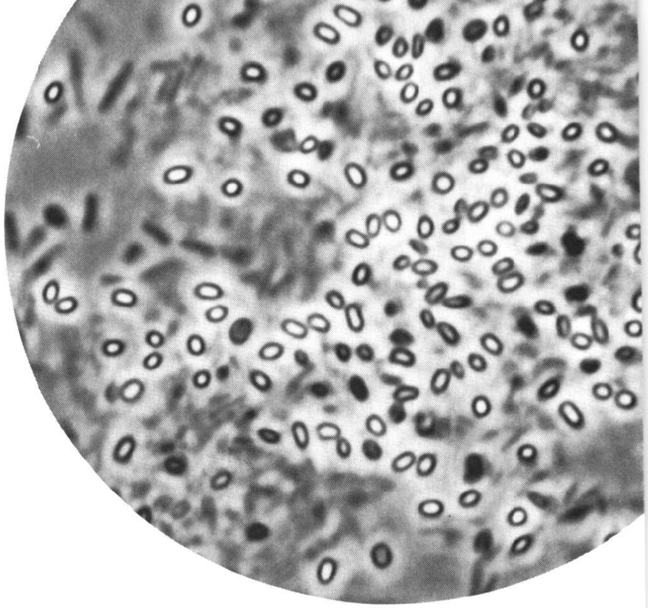
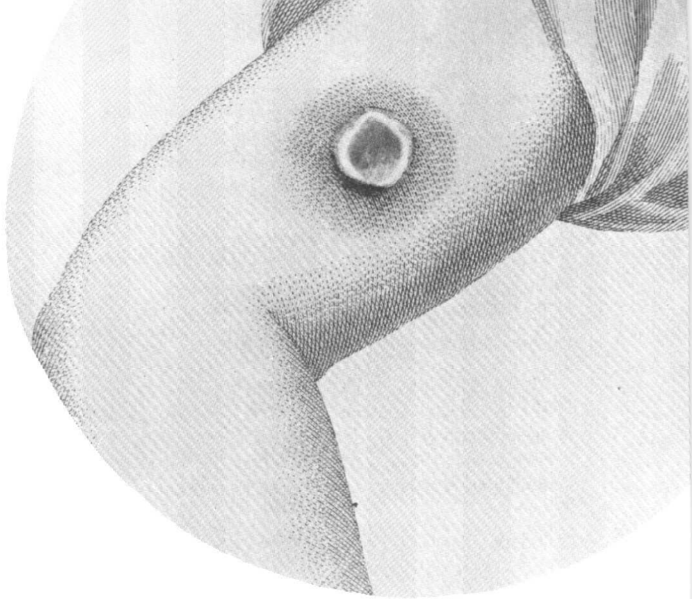


# Introduction: the roots of microbiology

# Chapter 1



In health and in disease, the activities of microorganisms greatly affect human life. Whether in country or city, tropics, midlatitudes, or the arctic, human beings are continually influenced by microbes. The science that deals with the study of microorganisms is called *microbiology* and is a branch of biology parallel to *botany*, the study of plants, and *zoology*, the study of animals. However, the procedures and practices by which microorganisms are studied are quite different from those used to study plants and animals, and it is for this reason that microbiology has developed as a science independent of botany and zoology. The goal of the microbiologist is to understand the beneficial and harmful activities of microorganisms and through this understanding to devise ways that benefits may be increased and damages curtailed. Microbiologists have been successful in achieving this goal, and microbiology has played a major role in the advancement of human health and welfare.

Microbiology may be the most applied of the biological sciences. At the same time, it is one of the most basic of the biological sciences, because microorganisms have provided the most suitable experimental materials for studies on the nature of life itself, studies now classified under the heading of *molecular biology*. Molecular biology has developed into an independent science, but microbiology as an applied science has remained intact and is no less important now than it was before the rise of molecular biology. One apprecia-

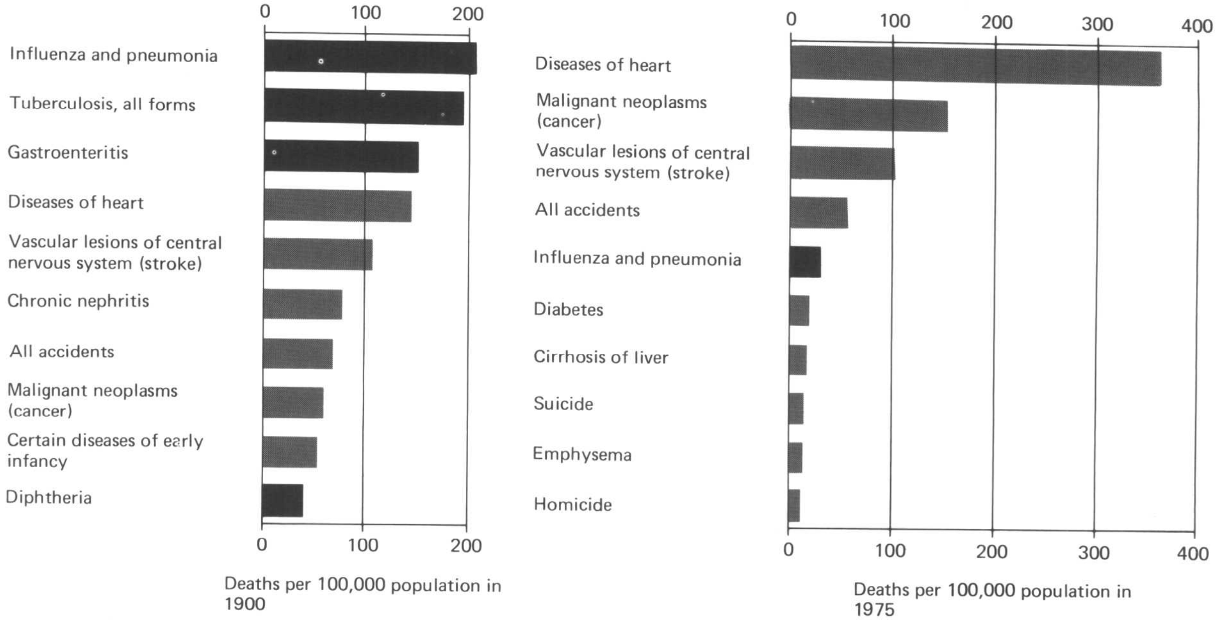


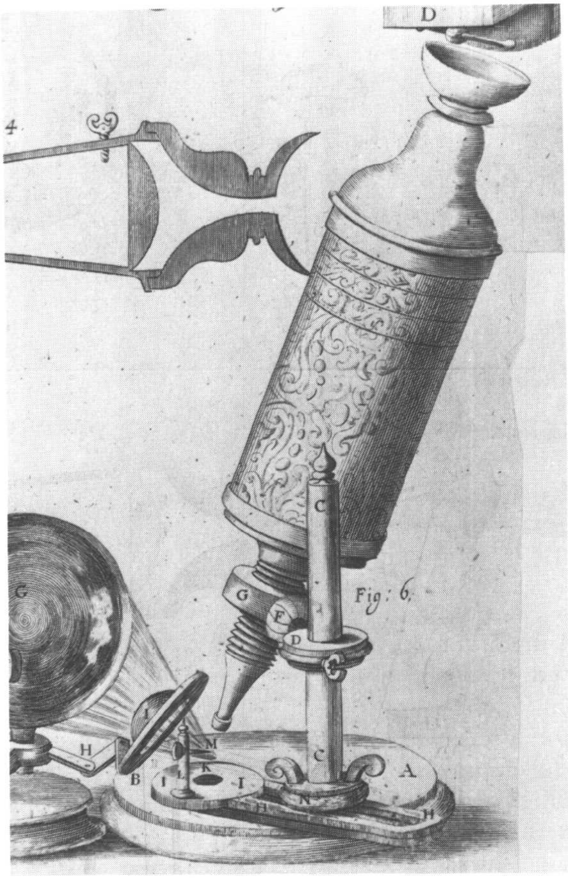

**FIGURE 1.1**
Death rates for the 10 leading causes of death: 1900 and 1975. Infectious diseases were the leading causes of death in 1900, whereas today they are much less important. From *U.S. Public Health Service Publ. No. 600* (revised 1967) and *Statistical Abstract of the United States*, 1975.

tion of the importance of microbiology for human health is shown by the statistics in Figure 1.1, which compares death rates in the United States in 1900 and 1975. In 1900, the major causes of death were all infectious diseases; currently, infectious diseases are of only minor importance. Control of infectious disease has come as a result of our vast scientific understanding of disease processes. Microbiology had its beginnings in these studies of disease.

In this chapter, we introduce the subject of microbiology through the presentation of a series of brief historical essays. Most of these sections concern studies that were done, primarily in the nineteenth century, to understand and control infectious disease. However, the striving to control infectious disease was not the only impetus for the development of microbiology. We also find that some interesting and important advances were made through studies on food and agricultural problems. And one of the most significant advances, the discovery of microorganisms themselves, occurred as a result of basic research done without any preconceived practical goal, but merely because of an interest in using microscopes to see the very small.

## 1.1 The discovery of microorganisms

Although the existence of creatures too small to be seen with the eye had long been suspected, their discovery was linked to the invention of the microscope. Robert Hooke, using elegantly ornate microscopes (Figure 1.2*a*), described the fruiting structures of molds in 1664 (Figure 1.2*b*), but the first person to see microorganisms in any detail was the Dutch amateur microscope builder Antoni van Leeuwenhoek, who used simple microscopes of his own construction (Figure 1.3). Leeuwenhoek's microscopes were extremely crude by today's standards, but by careful manipulation and focusing he was able to see organisms as small as bacteria. He reported his observations in a series of letters to the Royal Society of London, which published them in English translation. Drawings of some of Leeuwenhoek's "wee animalcules" are shown in Figure 1.4. His observations were confirmed by other workers, but progress in understanding the nature of these tiny organisms came slowly. Only in the nineteenth century did improved microscopes become available and widely distributed. At all stages of its history, the science of microbiology has taken the greatest steps forward when better microscopes have been developed, for these enable scientists to penetrate ever deeper into the mysteries of the cell.

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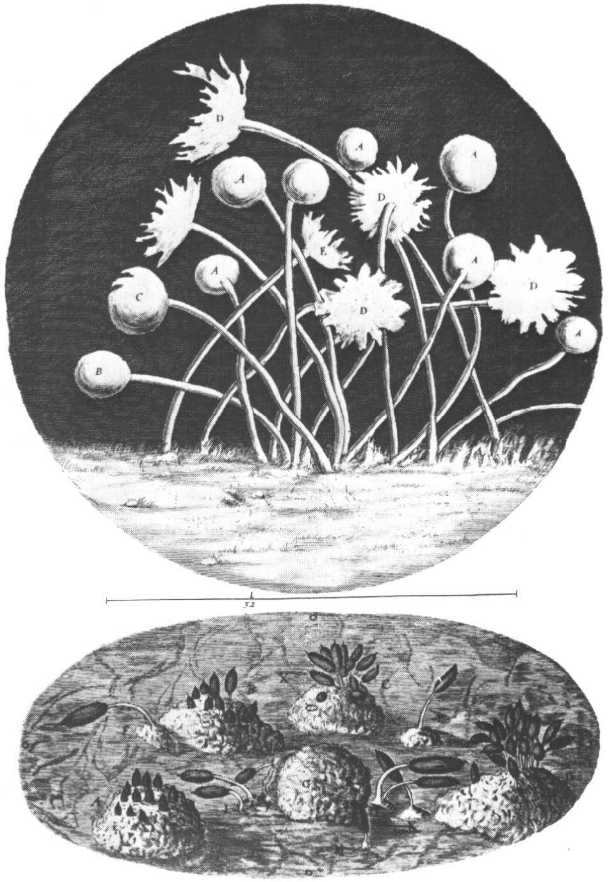

b

**FIGURE 1.2**
The early microscopic observation of a microorganism by Robert Hooke. *a* Robert Hooke's microscope, as illustrated in his great book, *Micrographia*, published in 1665. This is a compound microscope having two lenses, one near the eye and the other near the object. *b* Hooke's drawing of a blue mold growing on the surface of leather; the round structures contain spores of the mold.

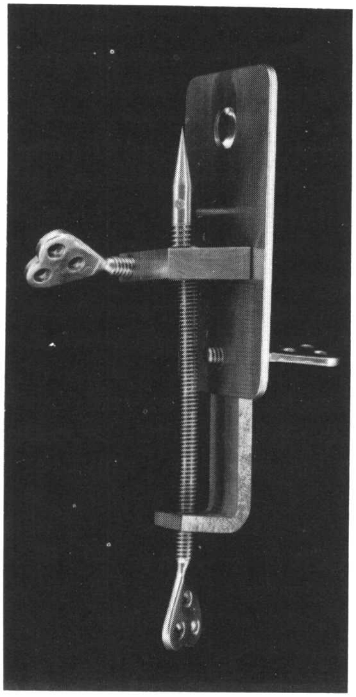

**FIGURE 1.3**
A replica of the microscope Leeuwenhoek used. The object to be viewed was placed on the pointed tip at the end of the screw and was moved back and forth by turning the screw. This is a simple microscope, composed of only a single lens. Although a simple microscope theoretically provides less resolution than a compound microscope such as Hooke's (Figure 1.2*a*), actually Leeuwenhoek was a superb lensmaker, and his microscopes resolved better than Hooke's.

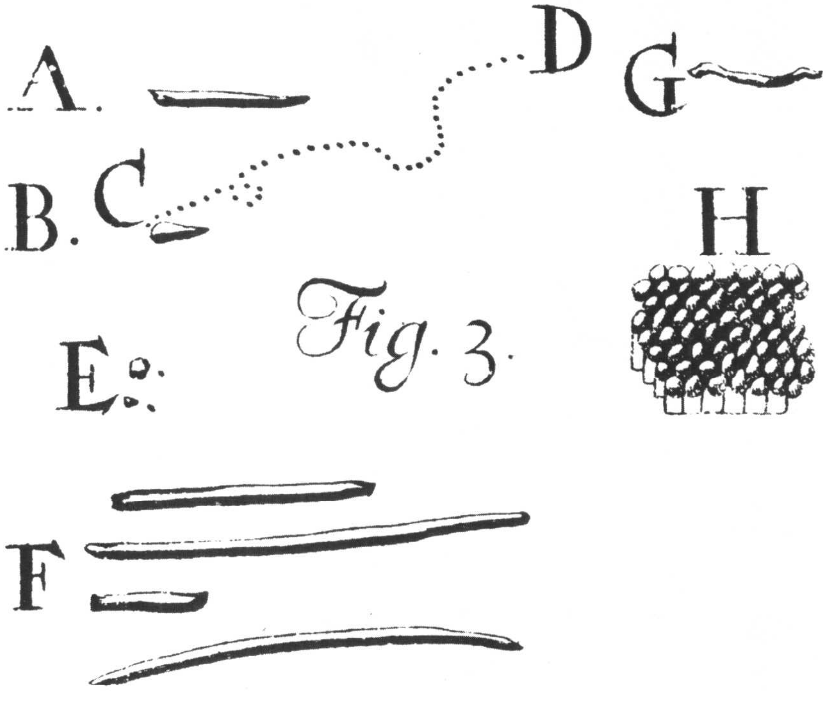


**FIGURE 1.4**
Leeuwenhoek's drawings of bacteria, published in 1684. Even from these crude drawings we can recognize several kinds of common bacteria. Those lettered A, C, F, and G are rod-shaped; E, spherical or coccus-shaped; H, coccus-shaped bacteria in packets. From A. van Leeuwenhoek, *Phil. Trans. Roy. Soc.*, London, **14**, 568, 1684.

Microbiology did not develop as a science until the latter part of the nineteenth century. This long delay occurred because, in addition to microscopy, certain other basic techniques for the study of microorganisms needed to be devised. In the nineteenth century, investigation of two perplexing questions led to the development of these techniques and laid the foundation of microbiological science: (1) Does spontaneous generation occur? (2) What is the nature of contagious disease? These two questions were studied simultaneously, and sometimes the same people worked on both. By the end of the century, both questions were answered, and microbiology was firmly established as a distinct and growing field of science.

## 1.2 Spontaneous generation

The basic idea of spontaneous generation can easily be understood. If food is allowed to stand for some time, it putrefies, and when the putrefied material is examined microscopically, it is found to be teeming with bacteria. Where do these bacteria come from, since they are not seen in fresh food? Some people said they developed from seeds or germs that had entered the food from the air, whereas others said that they arose spontaneously.

Spontaneous generation would mean that life could arise from something nonliving, and many people could not imagine something so complex as a living cell arising spontaneously from dead materials. The most powerful opponent of spontaneous generation was the French chemist Louis Pasteur, whose work on this problem was the most exacting and convincing. Pasteur first showed that there were structures present in air that closely resembled the microorganisms seen in putrefying materials. He did this by passing air through guncotton filters, the fibers of which stop solid particles. After the guncotton was dissolved in a mixture of alcohol and ether, the particles that it trapped fell to the bottom of the liquid and were examined on a microscope slide. Pasteur found that in ordinary air there exists constantly a variety of solid structures ranging in size from 0.01 millimeter (mm) to more than 1.0 mm. Many of these structures resembled the spores of common molds, the cysts of protozoa, and various other microbial cells. As many as 20 to 30 of them were found in 15 liters of ordinary air, and they could not be distinguished from the organisms found in much larger numbers in putrefying materials. Pasteur concluded, therefore, that the organisms found in putrefying materials originated from the organized bodies present in the air, which are constantly being deposited on all objects. If this conclusion was correct, it meant that food treated to destroy all the living organisms contaminating it would not putrefy. In fact, Nicholas Appert had already devised a method for food preservation based on heat treatment (see Section 1.5) but did not understand the principle upon which his method worked.

Pasteur used heat to eliminate contaminants, since many workers had shown that if a nutrient infusion was sealed in a glass flask and heated to boiling, it never putrefied. The proponents of spontaneous generation had criticized such experiments by declaring that fresh air was necessary for spontaneous generation and that the air inside the sealed flask was affected in some way by heating so that it would no longer support spontaneous generation. Pasteur skirted this objection simply and brilliantly by constructing a swan-necked