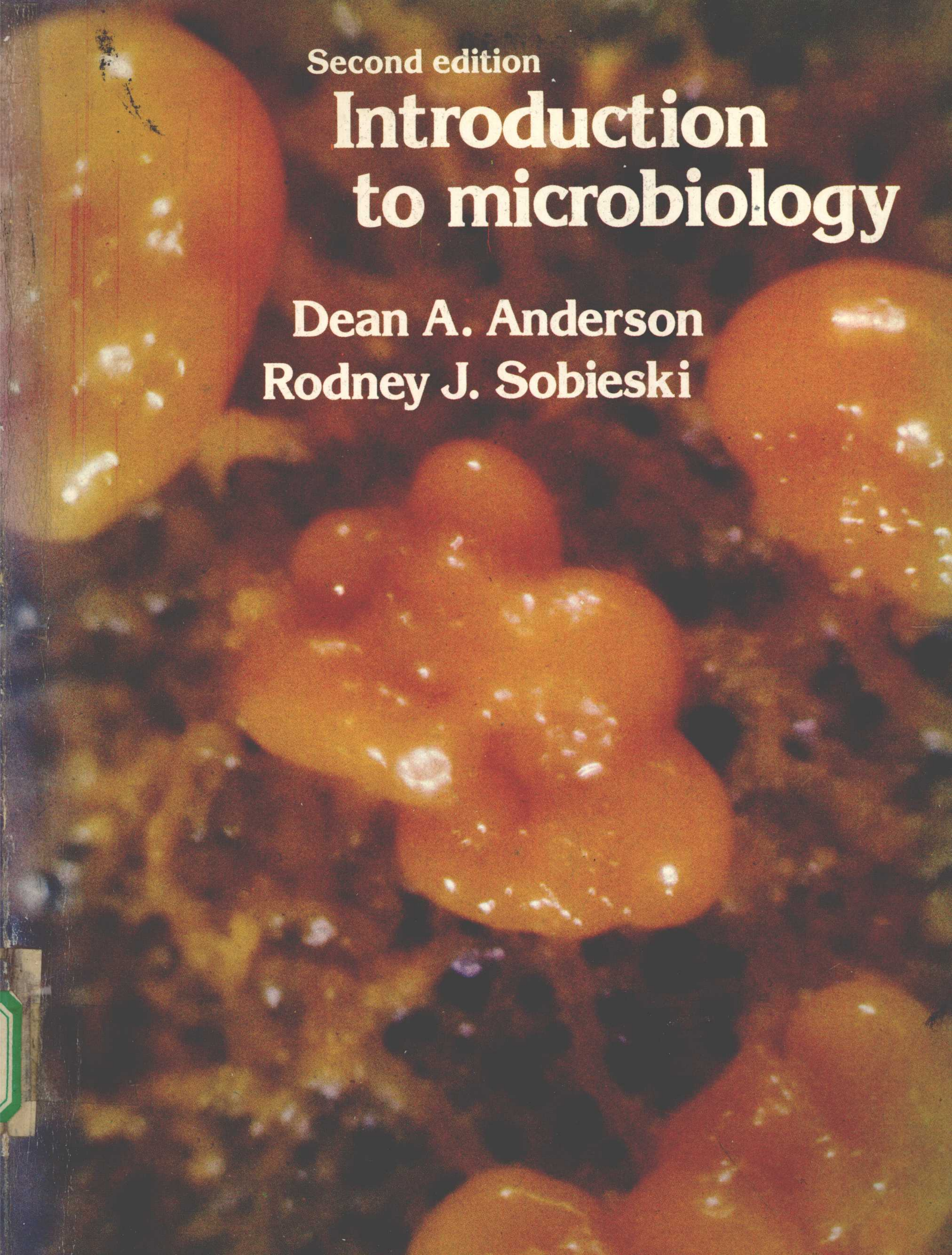
Second edition

Introduction to microbiology

Dean A. Anderson
Rodney J. Sobieski



Introduction to microbiology

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Cover photo of immature fruiting bodies of *Physarum*
courtesy of Richard P. Keeling

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Preface

This second edition retains many of the features of the original text. Its chapters are also grouped in three parts on fundamentals, applied aspects, and disease production. Revised and new chapters, like the original chapters, include the development of ideas and applications of the subject to day-to-day living. This approach serves to illustrate the roles played by microbes as the cause or solution of many of our problems and in revolutionizing many of our concepts of life processes.

Unlike many of the more advanced textbooks of general microbiology, *Introduction to Microbiology* is not based on the assumption that the student will have an extensive background in chemistry. However, the chemistry used is designed to give a simple illustration of the basic changes that are taking place.

Scientific names and scientific terms are employed without apology, but wherever possible the roots and meanings of each new scientific name or term are given the first time it appears. This, hopefully, provides a built-in glossary that will serve to clarify the reading matter.

This edition has been extensively revised. The part on fundamentals includes new chapters, "Historical Aspects of Microbiology," "The Bacteria," and "The Viruses," and extensively rewritten chapters, "Control of Microorganisms" and "Antibiotics and Chemotherapeutic Agents." The discussion of genetics in Chapter 13 includes new material on lysogeny, cloning vectors, genetic engineering, and recombinant DNA molecules.

The part dealing with disease-producing microorganisms now covers immunology in both Chapters 22 and 23 in addition to Appendix B, "Immunological Methods." Chapter 20, "Epidemiology," and Chapter 26, "Viruses and Disease," are new chapters, and along with the reorganization of several others complete the revision of this part of the text.

Many of the new and revised chapters contain examples that give the student a focus on various aspects of epidemiology. This will give the allied health student and the student in the general course an insight into the ability of microbiology to be considered from various points of view. By no means should this text be considered one devoted to epidemiology or any other particular field; the new chapters and some of the old ones are merely flavored with diverse tastes.

Much of the taxonomic information has been removed from the body of the text and is now contained in Appendix A, which updates taxonomic changes in the field that have occurred recently.

The chapter summaries at the end of each chapter provide a brief overview of each chapter and are new to this edition.

The metric conversions on the inside front cover are included to provide a handy aid to this style of measurement even though this revision gives metric values along with their English equivalents in the body of the text.

We are grateful to Dr. Y. Hokama for allowing us to use portions of his chapter from the first edition in this revision for Chapters 22 and 23 and Appendix B.

Acknowledgment is also given with great appreciation to the following people for their help, support, and encouragement: Victor B. Eichler, Daniel A. Johnson, John D. Lee, Mary Marie Moore, George Sweet, and Kenneth Wagner. D.A.A.'s colleagues at California State University at Los Angeles provided basic information on recombination studies with DNA. James M. Jay is due special thanks for being the stimulus for one of us, R.J.S., to begin a major in microbiology.

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Rodney J. Sobieski

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FOUNDATIONS OF THE SCIENCE

Microbiology, dealing as it does with the "world of invisible things," has existed as a recognizable segment of biology for scarcely a century. The science of zoology, on the other hand, gained a firm foundation when Aristotle (384-322 B.C.) published his *Historia Animalium.* This work, based on his own shrewd but not always accurate observation, was generously interlarded with folklore. Theophrastus (370-285 B.C.), with his encyclopedic *History of Plants,* performed a similar service for botany. However, microbiology, dealing with forms largely undiscernible to the eye, could have its inception only after the microscope had extended human vision into this invisible world.

Humankind was denied all but a most rudimentary knowledge of the invisible world of microbes because of the optical limitations of the eyes. The physical reason is that in the retina of the human eye, the spatial arrangement of rods and cones is such that the smallest objects that can be clearly discerned must be at least 0.1 to 0.2 mm (1/250 to 1/125 inch) in size. Most microorganisms are far smaller than this limiting dimension.

Although the crude microscopes of Leeuwenhoek (1632-1723) and others opened the door to the new world, microbiology as a science did not develop until more effective microscopes were available. This required nearly two centuries because not only were optically adequate microscopes lacking but many of the so-called scientists of the times, secure in their Aristotelian world of living things, evinced little interest in the newborn science. Even the idea of an invisible world of living things was only reluctantly accepted because it ran counter to many of the religious and philosophical beliefs of the times. The real awakening did not come until Louis Pasteur in the 1860's to 1880's zealously attacked the idea of spontaneous generation and advanced his, then highly controversial, germ theories of fermentation and disease. During this period, excited by his vision of the role of the microbes, he exulted to his doubting compatriots, "The infinitely small are infinitely great." At another time, with a touch of macabre humor, he shouted, "Gentlemen, the microbes will have the last word." It is tempting to assign to this period the birthpangs of the science of microbiology.

TERMINOLOGY USED AND NATURE OF THE INVISIBLE WORLD

The term "microorganisms" is derived from the Greek (*mikros* small + organisms [living things]). A synonym, microbe (*micro* + Gr. *bios* life) was suggested by Sedillot (1878) and has come into common usage, especially in popular writings.

Microorganisms fall into two groups, the relatively simple one-celled forms and the somewhat more complex multicellular forms. The individual cells of the unicellular forms are mostly far smaller than any objects visible to the unaided eye. Fig. 1-1 compares the sizes of a variety of microorganisms.

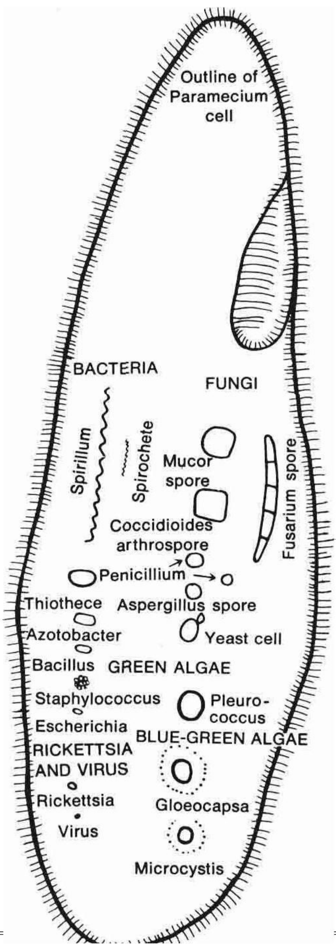

FIG. 1-1
Comparative sizes of variety of cells, spores, and so on, of fungi, unicellular algae, bacteria, rickettsiae, and viruses, arranged within outline of medium size paramecium (225 μ in length).

The term "invisible world" is something of a misnomer. Masses of growth of even the smallest bacteria are easily visible. What is invisible are the individual cells themselves. For example, with true bacteria, each cell is a complete and independent entity. Hence, bacteria are termed one-celled or unicellular forms. However, when bacteria proliferate in great numbers on a solid growth medium, they form a visible colony representing millions or billions of individual cells. Only when we smear this mass of growth on a microscope slide, stain it with a colored dye or stain, and examine it under a microscope with a magnification of a thousand times or so, can we readily discern the individual cells of the colony.

Great populations of bacteria are often encountered in our daily environment. For example, the slimy coating seen on spoiled fresh meat represents astronomical numbers of bacteria per square centimeter of slime. The magnitude of these numbers is indicated by the fact that a mass of bacterial cells the size of a drop of water would represent 5×10^{10} cells.

The best-known example of a mass of microbial cells is the commercial yeast cake. This represents billions of egg-shaped yeast cells, which are each an individual entity, several times larger than bacteria and approximately the same size as a red blood cell (Fig. 1-2).

Molds are simple multicellular fungi. The most familiar are the frequently seen masses of blue or green growth on apples, oranges, cheese, or bread. These are primarily members of the genus *Penicillium.* The mold itself is easily seen, but we do not see the intertwining threads of mycelia or the myriads of individual spores borne on the fruiting bodies of the mold plant. However, if we blow gently across the powdery blue mass on a moldy orange or apple, a faint cloud of spores arises.

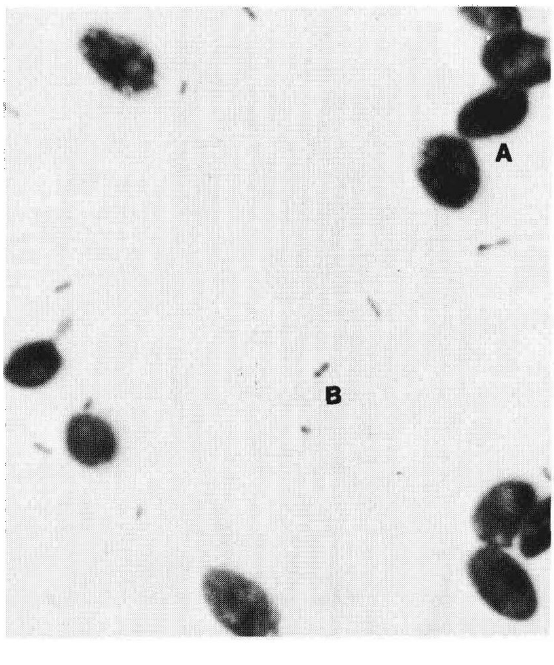

FIG. 1-2
Comparative sizes of **A,** *Saccharomyces cerevisiae* (common yeast) cells and **B,** *Escherichia coli* (common intestinal bacteria) (×2,000).

If a single *Penicillium* spore falls on a moist surface such as a break in the skin of an apple, it will germinate and send out threadlike filaments made up of tiny nucleated cells. These spread out in every direction. At first they form a white, faintly fuzzy mass. In a few days upright, fertile threads develop. On the tips of these are formed fingerlike structures and on each finger a beadlike string of spores is formed. A single invisible spore head might have dozens of individual spores, and the whole mold mass might have hundreds of such fruiting heads. These fruiting heads can be made out only with a good magnifying glass. To be seen clearly, the individual spores must be magnified 100 times or more.

ORIGIN OF MICROORGANISMS

Microorganisms, especially simple one-celled bacteria and the closely related blue-green algae, are definitely primitive forms occupying the lowest rungs of the evolutionary ladder. As yet we lack any clear indication of the initial source and manner by which these forms came into being. These minute forms, fragile as they are, have left practically no fossil story that would give even a remote hint as to their origin. The most striking evidence of the antiquity of bacteria on the earth has recently come to light when the distinctive filaments of *Flexibacter* have been found in sections of rock deposited around ancient hot springs. These ancient filamentous bacteria are almost identical to those still growing in the hot geysers of Yellowstone Park.

Several hypotheses relating to the origin of bacteria have been proposed. The first suggests that the initial life forms (probably bacteria) were borne to the young planet Earth on dust particles or meteorites from some older more advanced planet somewhere in our cosmic environs. Such an explanation only begs the question since it still fails to explain the initial source of these postulated interplanetary visitors. Also the fact that such an interplanetary traveller would have to be able to survive the rigors of extreme heat and cold and the deadly radiation hazard seriously weakens the validity of this theory. A second hypothesis is the autotroph (Gr. *autos* self + *trophē* nutrition) theory. This postulates that bacteria, which were able to secure their energy from sunlight and their carbon source from the carbon dioxide of the atmosphere, grew in the warm, mineral-laden waters of the earth and synthesized the first organic matter out of which to manufacture their own cells and to provide food for subsequent generations of other microbes. The chief difficulty in this concept is that the photosynthetic bacteria, as we now know them, are enzymatically relatively complex forms, which would have been unlikely to emerge suddenly. However, regardless of their origin, such forms must have played an important role in the primordial development of life on the earth.

More recently, the heterotroph (Gr. *heteros* other + *trophē*) hypothesis has been advanced. This postulates that forms that were unable to synthesize their own protoplasm from minerals and carbon dioxide developed from pre-