MICROBIOLOGY

Second Edition

Sarles • Frazier • Wilson • Knight

MICROBIOLOGY

General and Applied

SECOND EDITION

By William Bowen Sarles

William Carroll Frazier

Joe Bransford Wilson

Stanley Glenn Knight

Department of Bacteriology
University of Wisconsin

HARPER & BROTHERS, New York

MICROBIOLOGY, GENERAL AND APPLIED,
SECOND EDITION

D-F

Library of Congress catalog card number: 56–6101

Preface to the First Edition

This book is for the use of students who are beginning a study of microbiology or bacteriology. It is realized that the majority of the students enrolled in their first course in this field of study will not become microbiologists or bacteriologists. For this reason an attempt is made to emphasize the application of microbiology to agriculture, to industry, and to the home. Some consideration is given to the disease-producing activities of microorganisms and to the general subject of immunity, but, unlike most books on general microbiology, this book deals mainly with the nondisease-producing microorganisms and the relation of their activities to the lives of plants, animals, and human beings.

For the benefit of those students who wish to obtain more information on any of the subjects considered in this book, a list of references is given at the end of each chapter to books, review articles, and papers which may be used as a starting point for a more thorough study of each subject.

This first printed edition has been prepared on the basis of knowledge gained through the use of five mimeographed editions, which were published in 1939, 1940, 1947, 1948, and 1949, respectively. Dr. Janet McCarter Woolley was a co-author of the first two editions; much of the material in PART VIII, Infectious Diseases of Animals and Plants, represents a revision of material prepared originally by Mrs. Woolley.

The help of Dr. G. A. Rohlich, Professor of Hydraulic and Sanitary Engineering, in the preparation of Chapters 22 and 23, is gratefully acknowledged. We also wish to acknowledge with thanks the aid of Professor A. J. Riker, Department of Plant Pathology, in the preparation of Chapter 33.

The authors also wish to thank their fellow members of the Department of Bacteriology for helpful criticisms and suggestions.

William B. Sarles
William C. Frazier
Joe B. Wilson
Stanley G. Knight

Madison, Wisconsin
November, 1950

Preface to the Second Edition

The second edition contains revisions which bring the subject matter up to date. In addition, revisions have been made to fulfill needs discovered in our own teaching experiences. We have also used suggestions from other teachers who have worked with the first edition in their courses. All or parts of Chapters 8, 28, 29, 30, and 31 have been rewritten. There has been extensive revision of Chapters 1, 2, 10, 13, 14, 17, 21, 25, and 26. New photographs have been used in Chapters 1, 2, 25, 28, and 29.

We acknowledge with thanks the criticisms and suggestions received from bacteriologists and students who have cooperated with us in our attempts to prepare a survey of general and applied microbiology.

W. B. S.
W. C. F.
J. B. W.
S. G. K.

Madison, Wisconsin
January, 1956

Contents

Part I

AN INTRODUCTION TO THE MICROORGANISMS

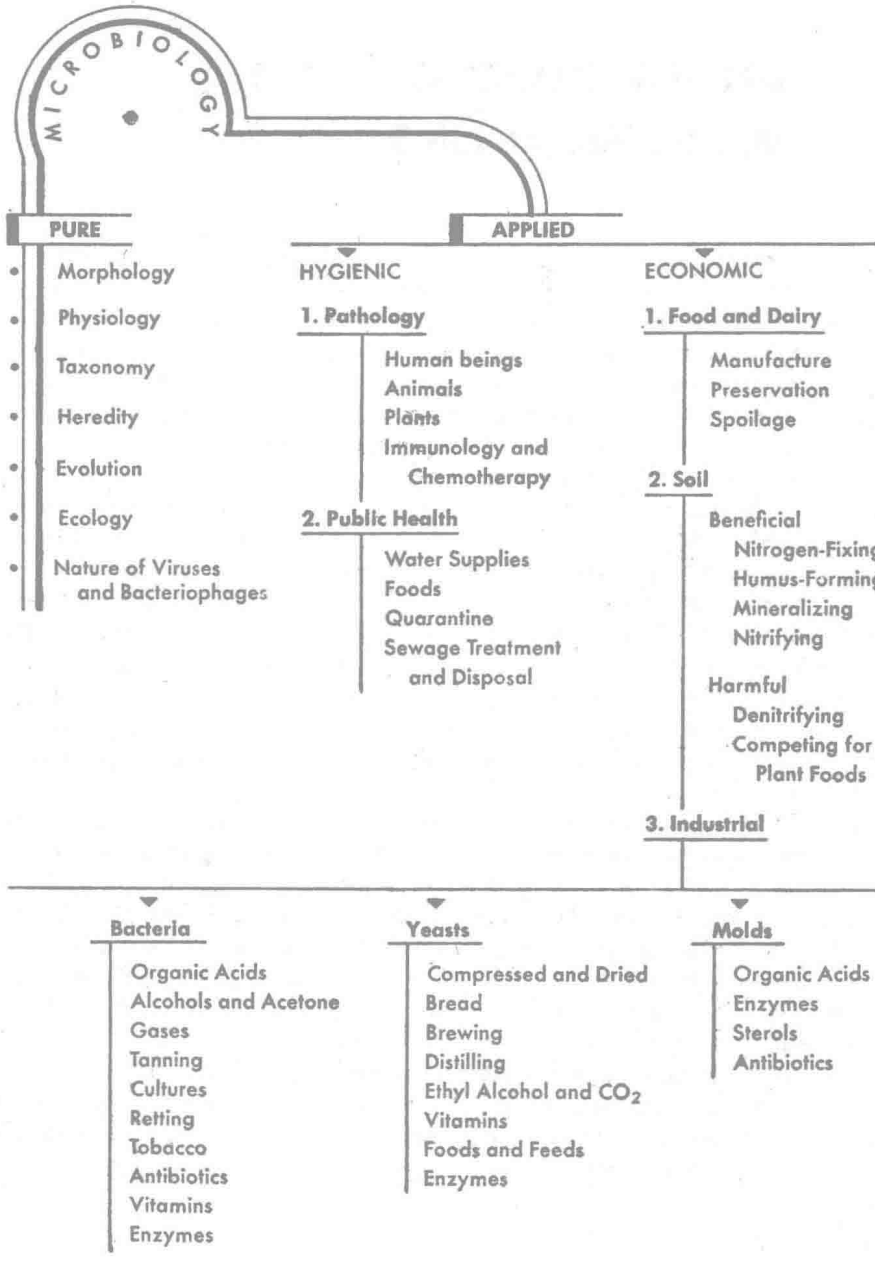
Microorganisms are living things so small that they can be seen only with the aid of a microscope. They are widely distributed in nature and are responsible for many physical and chemical changes of importance to the life of plants, of animals, and of human beings. Altogether too many students believe that all "microbes" or "germs" are harmful, and that they are an entirely undesirable group of living things. While it is true that some microorganisms produce disease, the great majority of them do not. In fact, the activities of these hosts of nondisease-producing microorganisms make possible the continued existence of plants and animals on the earth. In addition, many kinds of microorganisms are used in industries to manufacture products of great value to man. But the activities of nondisease-producing microorganisms are not always desirable. Foods may be spoiled as a result of their attack, fabrics and fibers may be rotted, and fermentation processes may be upset by undesirable organisms. From a practical point of view we are interested in the microorganisms because of the things that they do, the physical and chemical changes which they produce. Also, we are interested in ways and means to control undesirable organisms and to put the useful ones to work; but a study of the activities and the means for control of microorganisms must be based upon knowledge of their nature and life processes.

Microbiology or bacteriology is a branch of biological science which deals with the bacteria and related forms of life. Most of these related living organisms are not similar to the bacteria in form or structure, but they are included in a study of microbiology because often they are found living in association with the bacteria, and because their activities frequently are closely related to those of the bacteria.

It is not possible in a book of this size to describe in detail all of the different kinds of bacteria, rickettsiae, viruses, yeasts, molds, algae, and protozoa; nor is it considered necessary for a student interested in the practical applications of microbiology to memorize detailed classifications of these forms of life. A brief outline of the classification of these forms is given in Appendix A, and it is suggested that this outline be studied in order to gain some knowledge of the general taxonomic relationships of these organisms. It is the purpose of the first seven chapters of this

book to describe briefly the distinctive characteristics of the bacteria and of the related forms of life that have been mentioned.

The diagram which follows shows the main lines of work in modern microbiology.



1

True Bacteria

WHERE BACTERIA ARE FOUND, AND WHAT THEY ARE

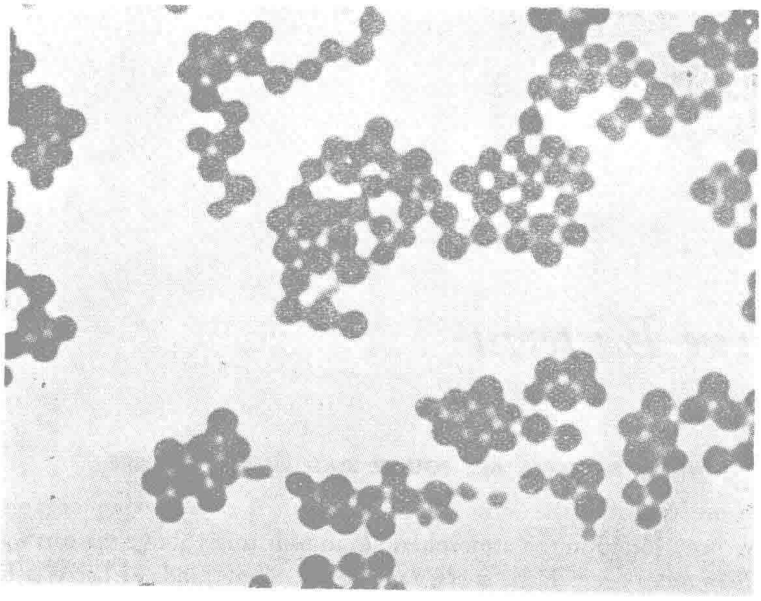
Bacteria are probably the most widely distributed of all living organisms. They have been found in the atmosphere up to four miles above the earth, and in mud three miles beneath the surface of the sea. Some kinds of bacteria have been isolated from the water of hot springs at a temperature of 75° C., others from antarctic ice. A fertile soil often contains as many as 100,000,000 bacteria per gram. With the facts in mind that an acre-foot of soil weighs approximately 2,000,000 pounds and that there are 453.6 grams in a pound, some idea can be obtained of the truly tremendous numbers of bacteria in the soil.

Actually, there are comparatively few places in nature where bacteria cannot be found. The blood of normal animals, tissues in the physiological interior of healthy animals and plants, deep layers of soil and rocks, and the pits of active volcanoes are about the only places in nature where bacteria are not commonly found.

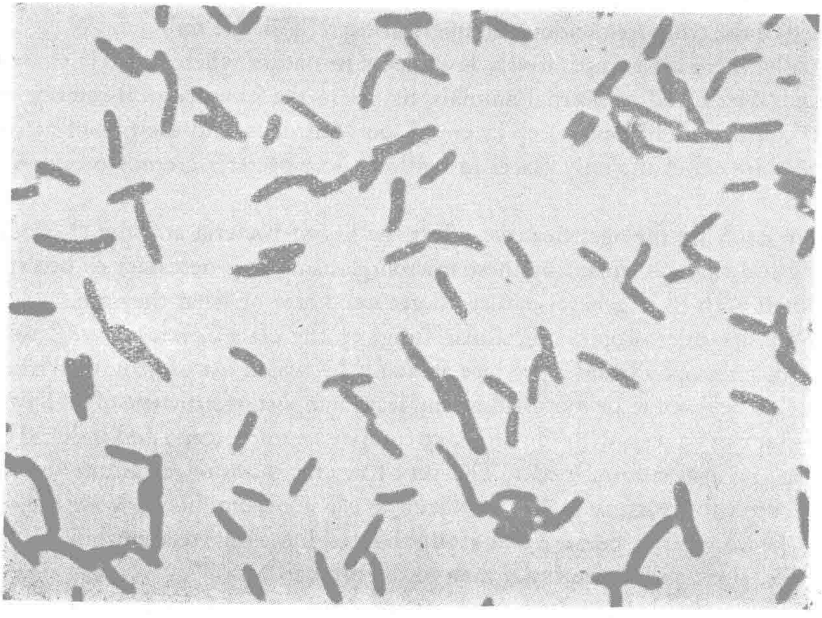
Before studying the agencies that affect the life of bacteria and the chemical and physical changes caused by these microorganisms, it is necessary to become acquainted with their general nature, to get some idea of what they are.

Bacteria are microscopic, unicellular fungi of the class *Schizomycetes;* they contain no chlorophyll, and reproduce asexually by fission. At present, the "true" bacteria are believed to be the smallest and least complex in structure of all living things that can be seen with the ordinary compound microscope and induced to grow on artificial culture media. The very fact that they are so minute in size and so simple in structure makes it difficult to classify them, but they are placed in the Plant Kingdom because as a group they exhibit closer relationships to the blue-green algae and to the fungi than to the protozoa.

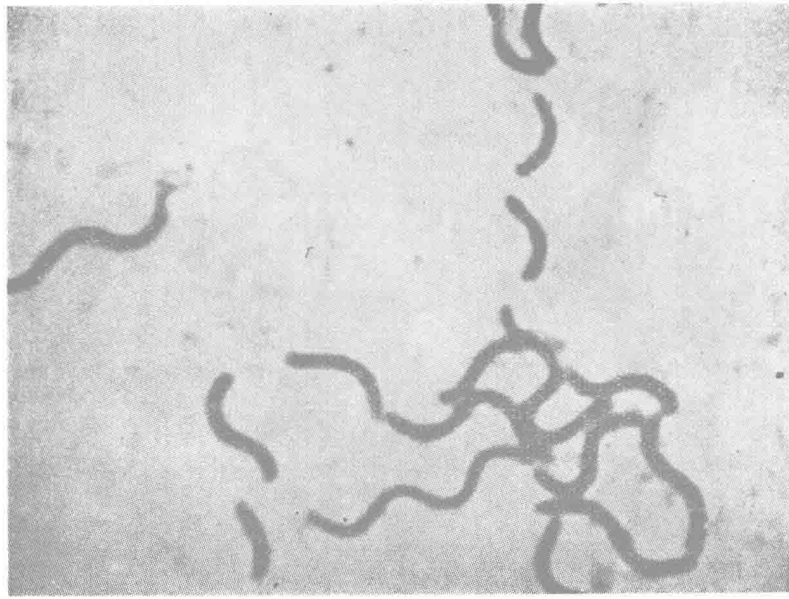
Bacteria are divided into two main groups, "true" bacteria and "higher" bac-



A



B

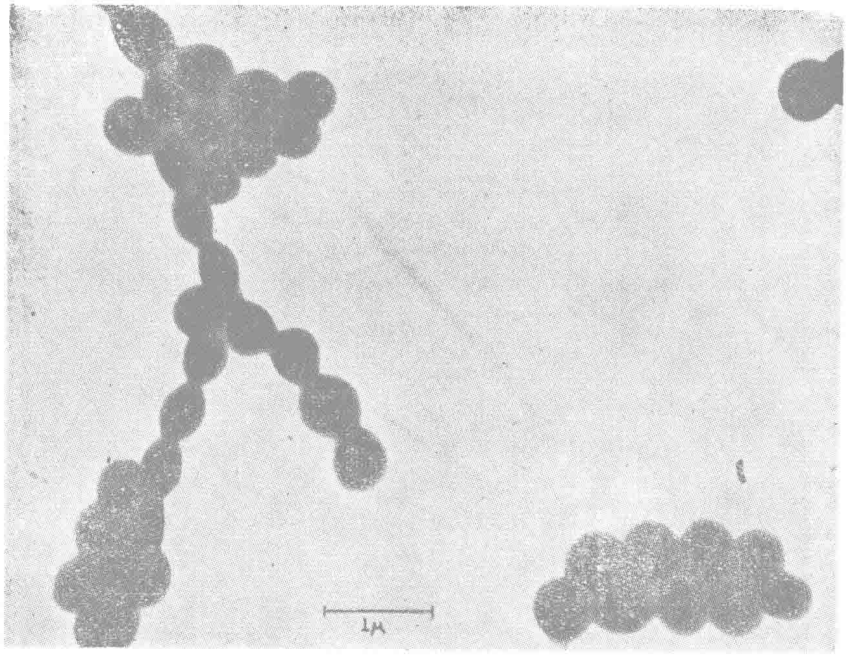


C

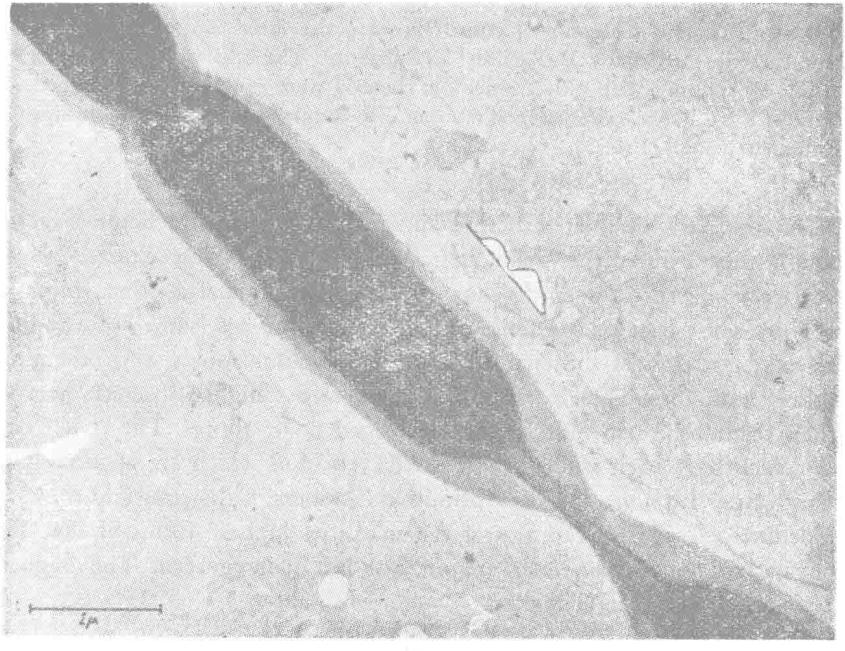
FIGURE 1. Light microscope pictures showing the three common shapes of true bacteria. A, Coccus. B, Bacillus. C, Spirillum. The cells were made more visible by staining with a dye. Since the bacteria were growing when stained, some of the cells are loosely joined to other cells to form short chains or clumps. Enlarged 2000X. (From J. Nowak.)

teria, on the basis of their structure and manner of growth. Some bacteria, although they exhibit the main characteristics of the class *Schizomycetes*, possess certain structures or develop in a manner similar to other forms of life. Thus, some bacteria resemble certain of the protozoa, some are alga-like, some exhibit a few of the characteristics of the slime molds, and others are definitely mold-like. These forms are referred to as "higher" bacteria because of their relationships to more highly developed living things. The "true" bacteria, which have been studied most extensively, and which are apparently of greatest importance, are the most primitive members of the class and show no well-defined relationships to any of the so-called "higher" forms of life. The "true" bacteria, or *Eubacteriales,* are our first and main concern.[1] The "higher" bacteria are described in Chapter 7.

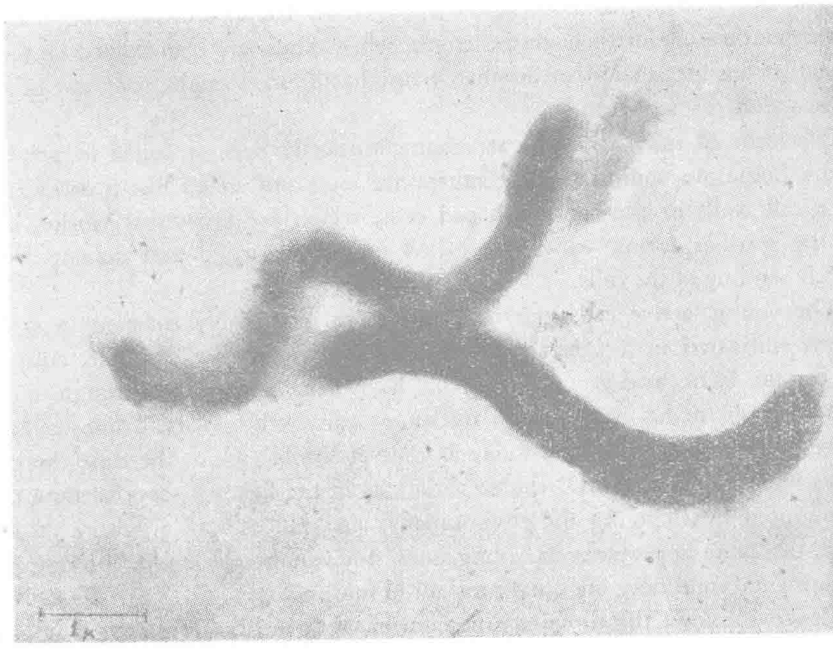
[1] An outline of the classification of bacteria will be found in Appendix B.



A



B



C

FIGURE 2. Electron microscope pictures showing the three common forms of true bacteria. A, Coccus. B, Bacillus. C, Spirillum. Note that some of the cocci and bacilli are in the process of dividing and thin strands of protoplasm connect incompletely divided cells. Enlarged about 18,750X, 21,000X, and 18,750X respectively. (A. Mudd and Anderson, S.A.B. No. 87; B. Johnson, S.A.B. No. 58; C. Polevitsky and Picard, S.A.B. No. 117.)

THE SHAPES OF TRUE BACTERIA

The cells of true bacteria exist in any one of three common forms: the spheroidal, or **coccus;** the cylindrical, or **bacillus;** and the spirillar, or **spirillum.**

The coccus form of bacterial cell is not truly spherical, but as a rule the cells are spheroidal. Under certain conditions, some of the cocci may become elongated so as to appear almost cylindrical, but when returned to their original environment they again become spheroidal. Bean-shaped and cone-shaped cocci are fairly common.

Bacilli are cylindrical, or rod-shaped, cells. In some bacillus forms the transverse is almost as long as the longitudinal axis, but in others the cell may be from three to ten times as long as its diameter. The ends of bacilli may be