MICROBIOLOGY

AN INTRODUCTION

ERNEST A. GRAY

M.Sc., M.R.C.V.S.

Chief Bacteriologist, Bayer's Biological Institute, Exning.

MICROBIOLOGY

An Introduction

ERNEST GRAY
M.Sc., (Cantab.) M.R.C.V.S.
Chief Bacteriologist to Bayers Biological Institute, Exning, Suffolk.

1954
LONDON
CROSBY LOCKWOOD & SON, LTD.
26 OLD BROMPTON ROAD, S.W.7

THIS BOOK is designed as a simple introduction to Microbiology. It is not intended to compete with the many excellent works which cover in detail the various fields of the subject. The plan of the book follows that adopted by the author during some years teaching of Microbiology to classes of laboratory assistants, and others more generally interested in the subject. Many students it was found were excellent technicians, but only a few really understood why they did what they had been taught to do. They lacked, as might be expected, any biological knowledge however simple to provide a background and link up the various fields. There was a general impression, too, that Microbiology is a modern subject that came in with the Atom bomb while the older science of Bacteriology was established about the time Professor Fleming was a medical student. All that was written before his time was so much waste paper. In the present work it is hoped that by indicating how organisms are so intimately associated in nature —in other words, by stressing their ecology—and at the same time pointing to the invaluable work of pioneers many of whom are unjustly forgotten—that is by stressing the historical background of a science which, so far from being modern, has been studied under another name for three centuries—a more sober and a more realistic approach is made to Microbiology as a whole or to the many fascinating and important puzzles it presents.

by the same author:

DISEASES OF POULTRY

PRINCIPLES OF PLANT INFECTION

A TEXT-BOOK OF GENERAL PLANT PATHOLOGY FOR BIOLOGISTS, AGRICULTURISTS, FORESTERS AND PLANT BREEDERS

ERNST GÄUMANN

PROFESSOR OF SPECIAL BOTANY IN THE FEDERAL INSTITUTE OF TECHNOLOGY, ZÜRICH

Authorized English Edition by

WILLIAM B. BRIERLEY

Professor of Agricultural Botany in the University of Reading

'It is fortunate that from time to time in the march of science a scholar of deep insight and widely ranging mind brings together in one volume the whole scope of a particular field of enquiry and synthesizes it in such a way that divergent viewpoints and masses of data fall into place to create a unified and harmonious pictures Professor Gäumann's work shows a far-reaching comprehension, a masterly handling of data and an elegance of treatment which derive only from a scholarly mind.—Annals of Applied Biology.'

560 *pages.* 311 *illustrations. Cloth bound* 63*s.*

* * * *

CROSBY LOCKWOOD & SON, LTD.

Preface

This little book is designed as a simple introduction to Microbiology. It is not intended to compete with the many excellent works which cover in detail the various fields of the subject. The plan of the book follows that adopted by the author during some years teaching of Microbiology to classes of laboratory assistants, and others more generally interested in the subject. Many students it was found were excellent technicians, but only a few really understood why they did what they had been taught to do. They lacked, as might be expected, any biological knowledge however simple to provide a background and link up the various fields. There was a general impression, too, that Microbiology is a modern subject that came in with the Atom bomb while the older science of Bacteriology was established about the time Professor Fleming was a medical student. All that was written before his time was so much waste paper. In the present work it is hoped that by indicating how organisms are so intimately associated in nature—in other words, by stressing their ecology—and at the same time pointing to the invaluable work of pioneers many of whom are unjustly forgotten—that is by stressing the historical background of a science which, so far from being modern, has been studied under another name for three centuries—a more sober and a more realistic approach is made to Microbiology as a whole or to the many fascinating and important puzzles it presents.

In writing this book, generous assistance has been extended from so many individuals, but space does not permit mention of more than a few. The book begins with the late Dr. Walter E. Collinge, formerly Lecturer in Zoology at Birmingham and St. Andrews, for twenty-five years ago he directed into orderly channels the writer's enthusiasm for the mysterious organisms revealed in ponds by the microscope presented him by his parents. Professor H. Nicol of the West of Scotland Agricultural College, University of Glasgow, has minutely checked proofs and provided salutary criticism. Dr. Barnes and other members of the staff of the Low Temperature Research Station, and Mr. E. A. George, Curator of the Culture Collection of Algae at the Botany School, University of Cambridge, found time to read the bacteria and alga sections, while Mr. L. Y. Whittingham of the National Agricultural Advisory Service, Eastern Province, took great pains to ensure the author's accuracy in all matters relating to milk. To them, and to all others at home and abroad who have encouraged his researches into soil and water microbiology, the author is glad to acknowledge his indebtedness. At the same time, in fairness to them he must make it clear that while they offered information and advice, he alone is responsible for the approach of the book, its format, and any conclusions drawn. He therefore must bear all criticisms of his attempt to provide an Introduction intended as a foundation for subsequent specialised study in any of the fields covered by Microbiology.

Cambridge, 1954. ERNEST A. GRAY.

TO MY PARENTS

"Nature is not governed
except by obeying her"

FRANCIS BACON.

Contents

List of Illustrations

ACKNOWLEDGMENTS

Figs. 11, 12a, 12b. Reproduced from Turtox Key Cards by permission of General Biological Supply House, Chicago, 37, Ill.

Fig. 14. (A group of diatoms) is reproduced by courtesy of N. Ingram Hendey, Central Metallurgical Laboratory, Hants.

Fig. 24. From Freshwater Biology and Water Supply in Britain, W. H. Pearsall, A. C. Gardiner and F. Greenshields. Scientific Publication No. 11 Freshwater Biological Association of the British Empire, by courtesy of the authors and the Director of the Association.

CHAPTER I

THE BIOLOGY OF MICRO-ORGANISMS

BIOLOGY THE STUDY OF LIFE

Biology is the study of life, and microbiology (Greek Micros, small; Bios, life) the study of life as displayed by organisms so small that a microscope is necessary to make out their structure. The term microbiology is frequently applied to the study of bacteria only (the former science of *Bacteriology*). This is reasonable in one sense because bacteria are also called microbes—i.e. small forms of life—and moreover are a very large and important group. However, to be exact microbiology should cover not only study of bacteria, but also of viruses, higher bacteria, fungi, algae, and protozoa; all organisms so small as to require special methods of examination. With the exception of viruses, which have little structure, and protozoa, which are animals, they are coloured or colourless plants.

If the fungi and viruses are omitted, and the microscopic rotifers included, these micro-organisms comprise the group known as the *Infusoria* because it was once believed they generated spontaneously in infusions of hay, pepper, and other vegetable substances. For centuries the wonder of microscopists, patiently delineated in the plates for example of G. Ehrenberg's famous 'Die Infusionthierchen' (1828) and Saville Kent's classic 'Manual of the Infusoria' (1888) their study as a group became neglected when interest focused on the particular importance of bacteria to man. This interest has inevitably widened. Professor Kluyver recently observed in a paper read to the Royal Society that the microbe has been regarded in the past as a wonder, a curiosity, the enemy of man, and is now recognised as an integral part of nature. Today microbiology assembles this miscellaneous group of Infusoria together again as a collection of small organisms common in watery vegetable infusions and possessing features shared by all.

LIFE IS THE SAME IN ALL ORGANISMS

Biology reveals that the properties and processes of life are essentially the same in all living things, whether they are

plants or animals, and whatever their size. Indeed, they are may be more clear in small primitive organisms since in higher plants and animals they become progressively more complicated. In microbiology it is found that the various groups of organisms listed above, numerous as they are, still have certain basic characters in common and which are shared with higher forms of life. A microbiologist, therefore, is a biologist whose particular interests lie in the activities of small organisms. He may specialise in a particular group, indeed he is usually forced to do so; but he is first of all a biologist whose grasp of the basic principles of Life enables him to turn with ease from study of any one group of micro-organisms to another. He recognises that since Life exhibits the same features and makes the same demands in every organism, it can be modified only within limits by the habits of the group under examination.

THE CHARACTERISTICS OF LIFE: MOVEMENT AND GROWTH

Two obvious characteristics of life are movement and growth. Movement occurs in inanimate nature. But the movement of living organisms is adaptive. An organism responds to a stimulus according to the nature of the stimulus and the particular character of the organism; it is not wholly under the influence of physical and chemical factors. Algae may be repelled or attracted by the same chemical solution; protozoa may move in the direction of gravity or away from it. All living things are subject in a greater or lesser degree to the laws governing inanimate nature. But in the struggle for survival, cramping restrictions of physical force or chemical reaction have been overcome by an almost infinite number of adaptations.

Growth, too, occurs in inanimate nature. A crystal grows by addition (accretion) of fresh material on the outside of the original. A living organism however grows by placing new material between the particles of the old, by interception or intussusception, not by accretion as in a crystal. A crystal grows as a wall is built, by laying new bricks upon the old; a living organism by wedging new bricks between those already laid down.

IRRITABILITY AND REPRODUCTION

If the individual organism is to survive, it must be irritable.

It must be able to react to changes in light intensity, chemical reaction, and so on.

If the race is to survive, it must be able to reproduce. After a certain maximum growth, all organisms tend to reproduce. Like always produces like. Spontaneous generation, the creation of new life out of lifeless substances, does not, so far as is known, occur in the world today. Viruses are rather a puzzle, but for practical purposes, as Pasteur proved, crude spontaneous generation is a myth. Presumably it must have occurred at least once in the history of the world, when conditions were totally different from those prevailing today.

FEEDING AND BREATHING

Two other features of Life are feeding and breathing. The two processes are complementary and designed to procure energy. Organisms obtain energy (e.g. for movement) and materials for structural repair and maintenance by converting the potential stored energy of foods into active kinetic energy by *oxidation*. The latter process consists either of the addition of oxygen or the abstraction of hydrogen. As a result of oxidation, the food is consumed or burnt. The products of combustion are incorporated (if suitable) into the structure of the organism, or excreted. Oxidation has been described as the process by which an organism splits what it needs from useless products which are discarded.

AUTOTROPHS AND HETEROTROPHS

Food may be very simple in character. Some micro-organisms (*Autotrophs*) derive energy from the oxidation of simple sulphur, or the oxidation of ferrous iron to ferric salts. Other organisms are unable to obtain energy from inorganic compounds, and rely upon the progressive oxidation of complex organic compounds sometimes referred to as pre-formed foods. This group, which includes many bacteria and the fungi, are known as *Heterotrophs*.

OXIDATION BY REDUCTION OR COMBINATION WITH OXYGEN; AEROBES AND ANAEROBES

Organisms which require a free supply of oxygen for oxidation are called *Aerobes*. Some organisms can only exist in the presence of reduced amounts of oxygen, or in its total

absence; free oxygen is poisonous to certain bacteria. These organisms oxidise their foods by reduction (i.e. removal of oxygen or addition of hydrogen) and are called *Anaerobes*. The presence of a carbohydrate (sugar) appears to be necessary for oxidation by reduction. Many of the micro-organisms studied by the microbiologist are potential or *facultative* anaerobes. If necessary, they can turn from oxidation by combination with free oxygen to oxidation by reduction. Bacteria and protozoa living in habitats with a reduced oxygen tension (e.g. sewage, or mud) have very low demands for free oxygen and may be wholly anaerobic. *Amoeba*, a primitive member of the protozoa, may be found in ponds with a relatively high percentage of dissolved oxygen in the water. In 1920, however, Pantin found that in the complete absence of oxygen (as tested by bleaching of methylene blue) amoebae continued to move for five to seven hours, although in the presence of only small amounts of free oxygen movement continued three times as long.

THE VALUE OF PIGMENTS

Certain organisms utilise such simple substances as carbon dioxide, water, or solutions of mineral salts for foods, and to enable them to do so, trap the radiant energy of the sun by means of *photosynthetic pigments*. A variety of photosynthetic pigments are known, varying in colour from purple to certain shades of red; blue, brown and yellow. Purple and red photosynthetic pigments are produced by some bacteria and marine algae. The most efficient pigment of all is the green compound *Chlorophyll*. Its absorption of solar radiation is so high that green algae, herbs and trees are enabled to turn carbon dioxide and water into sugar in their tissues by its aid with comparative ease.

METABOLISM

The sum total of all the chemical processes that make up the day-to-day life of an organism, is called *Metabolism*. It includes two opposite and contrasting processes, *Anabolism* or building up, and *Katabolism*, breaking down. The balance of Life is poised between these two extremes. If the former process is in excess of the latter, growth results. But in old organisms Katabolism overtakes Anabolism and growth ceases.