An Institute of Microbiology—Its Aims and Purposes

Selman A. Waksman

Rutgers University, New Brunswick, New Jersey

MICROBIOLOGY comprises the field of knowledge of various microscopic forms of life including the bacteria, fungi, yeasts, actinomycetes, protozoa, and algae. This science embraces a study of the occurrence of microorganisms in nature, their nutrition, their structure and life cycle, their role in numerous natural processes, and their relation to man, to domesticated and wild animals and plants, and to one another.

Although various microbes have been utilized by man since time immemorial and although some of the diseases caused by microbes have been combated since prehistoric man, the science of microbiology is of very recent origin. One of the youngest of sciences, it was hardly recognized as such a hundred years ago. Particularly striking progress has been made in late years, however, in our knowledge of the fundamental aspects of the physiology and nutrition of microorganisms and in the practical applications of this knowledge. In a relatively brief time, an important field of science has come into being—a science with applications in virtually every field of human endeavor. Microorganisms are recognized now as playing very important roles in natural processes; they are the most important causative agents of human, animal, and plant disease; they are the cause of fermentation and therefore play an important part in certain industrial processes and in the preparation of many foodstuffs and beverages; they are largely responsible for food spoilage, deterioration, and destruction of all types of materials, ranging from textiles to steel pipes; and finally they are recognized as the all-important agents in a great number of soil processes. More recently, with the development of our knowledge of the production of antibiotics and their use for combating a wide variety of diseases, microorganisms have come to occupy another highly important role in human economy.

Unfortunately, microbiology was heretofore treated as an inferior among the older sciences. It was usually considered a handmaiden of various applied sciences and, as such, was accorded a second place. It was always subservient to such fields as medicine, where it was closely tied up with pathology; public health, where it was associated with sewage disposal and sanitary conditions in general; and agriculture, where it was concerned largely with soil processes, composts, and the preparation of silage and foodstuffs.

Microbiology, it may be said, has not yet come into its own. This may be due partly to the fact that the two greatest early bacteriologists were interested not in microbiology as a fundamental science, but rather in its applications. Louis Pasteur was a chemist and Robert Koch was a clinician. They were more concerned with brewery and fermentation problems on the one hand, and with infectious diseases on the other, than with the organisms causing these. It is true that Ferdinand Cohn, a botanist, fully appreciated the significance of bacteria as biological systems, but neither he nor the botanists following him recognized the great importance of this observation; they allowed the medical people and the fermentation industries to take over microbiology and, primarily, its application. Microbes were thus considered as agents responsible for certain diseases or for certain important natural processes; they were to be either discouraged or encouraged, whichever the case might be, but they were to receive only scant recognition as independent biological systems.

It is further important to note that the general tendency has been, until recently, to limit the subject of microbiology largely to the study and utilization of bacteria. It was, for example, only four or five years ago that a group of botanists came to the conclusion that microbiology is a field of knowledge in itself. They then proceeded to recognize it by organizing a new society of microbiology—apparently in order to correct the blunder made by the botanical world some seventy-five years ago, in failing to recognize the great potential importance of the bacteria and other microscopic forms of life studied by Ferdinand Cohn.

On the other hand, many bacteriologists have also erred in this direction, some going so far as to consider the disease-producing bacteria as the only microscopic forms of life worth studying. The very large number of saprophytic microorganisms which comprise bacteria, fungi, and actinomycetes, were usually either dismissed from consideration entirely or referred to casually as organisms that belong to the domain of soil bacteriology, and have, therefore, limited importance. One illustration will suffice. William Bullock, an outstanding British bacteriologist,

who has contributed to the science of microbiology one of the most comprehensive histories of the subject, not only omitted consideration of the fungi and the actinomycetes, but even among the bacteria he gave little or no attention to the autotrophic and to the nitrogen-fixing organisms—two groups of bacteria that occupy a unique place in microbiology because of their specific physiological properties, their significance in bacterial taxonomy, and their great economic importance.

Because of such neglect, even on the part of experts in the field, many microbiologists felt rather skeptical about proper recognition of their branch of science. In addressing the Third International Congress of Microbiology on the eve of World War II, Prof. Kluyver, one of the leading microbiologists in the world today, spoke bitterly of the lack of recognition of microbiology as a field of science. He even anticipated attacks upon his lecture, and said that some critic might write: "The lecture gave additional evidence of the correctness of my earlier statement that it is questionable whether bacteriology is entitled to the rank of science. And if some benevolent judge might be willing to answer this question in the affirmative sense, then it should be remarked that the lecture showed once more that bacteriology is a science which has no laws and almost no bacteriologists."

Kluyver was not the only microbiologist who voiced bitter disappointment in the prevailing attitude toward this science. By way of another illustration, I cite a statement made privately to me by another prominent microbiologist, Charles Thom, formerly of the United States Department of Agriculture, to the effect that a colleague of his once remarked that soil microbiology had been *the most futile field of labor*—judged by what it produced—that he had any knowledge about.

It is not my purpose either to defend the science of microbiology or to magnify its great theoretical and practical importance. I only emphasize the fact that during the last few years microbiology has had focused upon it the attention of both the scientist and the practical man. I should like to give consideration here to the importance of only two groups of microorganisms—namely, the fungi and the actinomycetes, both of which previously were largely neglected, except in certain limited fields of application.

At no time in past history have these two groups of microorganisms played so great a part in the affairs of man as during World War II. Few laymen, even among those who participated in the war, appreciated the great importance of the fungi—as agents of destruction of essential materials, as causative agents of human diseases, and as producers of drugs, such as penicillin, that could be utilized successfully for combating many of the diseases caused by bacteria. Because of these important activities, the fungi tended to overshadow even the bacteria and other microbes, notably the protozoa and the viruses, in spite of the fact that these continued their important role in human economy, especially in the causation of disease and epidemics.

It is true that fungi have long been recognized as having great potentialities for destroying a great variety of materials. This was appreciated particularly by the plant pathologist, who was continuously faced with the fact that fungi are more concerned in the diseases of cultivated and wild plants and cause greater damage than all other organisms combined, with the possible exception of insects. The soil microbiologist, too has long known that fungi are responsible for the major destruction of the plant and animal residues in composts and in soil, and thus not only contribute to the removal of wastes, but also lead to the liberation in available form of the chemical elements essential for plant growth. And fungi are no strangers to the housewife, who in her attempt to preserve jams, jellies, bread, and other foodstuffs, is continuously faced with the problem of combating spoilage by a great variety of molds. The lover of mushrooms also appreciates the fungi, but as a friend rather than as an enemy. The great potentialities of fungi have also been recognized in certain other fields of human endeavor. It is sufficient to mention the manufacturer of foods, such as cheeses; of beverages, such as beer and distilled liquors; and of industrial products, such as citric acid, gluconic acid, fumaric acid, ethyl alcohol, and glycerol.

As already mentioned, it was only during the last war that full recognition was given to the great importance of fungi. With the concentration of large quantities of service materials in tropical and subtropical areas under the prevailing conditions of high humidity and high temperature, the damage potential of the fungi became apparent. Fungi attacked optical and electrical equipment, clothing, tents, and other materials used by service personnel, and even infected the human body. Although the physiology of the fungi and methods of their control had received much consideration, especially by plant pathologists and soil microbiologists, discoveries in these fields did not lend themselves readily for application to the problem at hand. Thus a rapid survey had to be made of the nature of the fungi causing the damage, the added role of bacteria, insects, mites, and other lower forms of life, the nature of the damage brought about, the nature of the fungistatic and fungicidal agents required to protect different kinds of service materials, the methods for measuring the protection thus rendered, and a host of other problems. It was only

natural that all these problems, dealt with under pressure of wartime conditions, were studied largely from the point of view of immediate necessity and not from that of a fundamental science. Here was a biological problem that should have been investigated in great detail, so that information would have been ready for immediate use. It required the coordinated efforts of many investigators, and resulted in great accomplishments, none greater than the emphasis laid upon the importance of fungi in natural processes.

Antibiotics were another wartime development. Just on the eve of World War II, I said in a public address: "We are finally approaching a new field of domestication of microorganisms for combating the microbial enemies of man and of his domesticated plants and animals. Surely microbiology is entering a new phase of development. This new phase has now been called the subject of antibiotics."

Just what are antibiotics? This question was placed before me less than eight years ago, in 1941. The following definition is based upon my earlier designation of the term: "An antibiotic or an antibiotic substance is a substance produced by microorganisms, which has the capacity of inhibiting the growth and even of destroying other microorganisms." The action of an antibiotic against bacteria and other microorganisms, as distinct from common antiseptics and disinfectants, is selective in nature, since only some bacteria are affected by a given agent, and others not at all, or only to a limited extent. Antibiotics vary greatly in their toxicity to animals and in their activity *in vivo*. Because of these characteristics, only a very few of the antibiotics so far isolated have received recognition as chemotherapeutic agents.

I need hardly dwell upon the great progress made in the field of antibiotics during the last seven or eight years. Although the chemist feels somewhat slighted because the clinician is claiming most of the credit for developing this field, and although the pharmacologist and physiologist have made their important contributions, you will agree with me that it is the microbiologist who is entitled to the credit for having opened up this field of science and for continuing to make substantial contributions to its development.

What has been said of the importance of fungi applies to a greater extent, though in a somewhat different way, to the actinomycetes. Here is a large and heterogeneous group of microorganisms which had aroused little interest on the part of the microbiologists or any other group of investigators. An important plant disease or two, a rare and peculiar human or animal infection encountered at very infrequent intervals, abundant occurrence in the soil—this much was known about the actinomycetes—but nobody cared to waste much time in determining what these delicate, mycelium-producing, odoriferous, microscopic forms of life do either in the soil or in a manure pile. It is the field of antibiotics that has focused attention upon the possibility of utilizing certain hidden physiological properties of these organisms. When one realizes that twenty percent or more of all actinomycetes that are freshly isolated from natural substrates have been found capable of inhibiting the growth of bacteria or other microorganisms, one comes to appreciate their great potentialities in this respect.

Thus our recently developed knowledge of vitamins and their role in human nutrition, of the utilization of penicillin, streptomycin, aureomycin, chloromycetin, and other antibiotics in the control of disease, of the potential part that bacteria may play as agents of biological warfare, of the destruction of service materials under tropical conditions, of industrial fermentations, and of many other microbiological processes has focused renewed attention upon the vast number of applications of microorganisms and their great importance to our economy, public health, and medicine. It is, therefore, essential to recognize these developments and to plan a comprehensive study of the fundamental aspects of the nature and activities of various groups of microorganisms, their role in natural processes, and their use in agriculture, industry, public health, and other aspects of human economy.

With this in view, an Institute of Microbiology is being established by Rutgers University. In this institute particular attention will be devoted to the fundamental aspects of the study of microorganisms, their physiology, their biochemical activities, and their relations to higher forms of life, notably to man and to his domesticated animals and plants. In other words, microbiology will be treated as a fundamental science. Certain of the practical or applied phases resulting from these studies will be carefully examined by other divisions of the institute.

In planning the program of the Microbiological Institute, the broad field of microbiology is conceived as covering six of the major groups of microorganisms, namely bacteria, actinomycetes, filamentous fungi or molds, yeasts, protozoa, and viruses. Minor consideration may also be given to other groups, such as the higher or mushroom fungi, the algae, certain worms, and other microscopic forms of life.

The functions of the institute will comprise both research and teaching, largely on graduate student and postdoctorate levels. The staff of the institute will offer courses in the various fields of microbiology to graduate students at Rutgers University and will conduct seminars for graduate and postdoctorate stu-

dents. These courses will also include supervision of various research problems, in both the fundamental and the applied phases of the subject. The institute will serve as a gathering place for seminars and conferences on microbiological subjects. It will also serve as a depository of cultures of microorganisms of theoretical or practical importance.

Although it is not intended to overorganize or departmentalize the Institute of Microbiology, it is tentatively proposed that it should include six major divisions or fields of research:

I. *General Microbiology.* This division will be concerned with the study of the structure and functions of microorganisms. Particular attention will be paid to morphology, cytology, genetic characteristics, taxonomic relationships, and ecology.

II. *Microbial Physiology.* This division will be concerned with the study of the physiology of different groups of microorganisms, their nutrition, intermediary metabolism, and other biochemical properties. Its program will include studies of the physiology of certain representative types of organisms found among the pathogenic and saprophytic bacteria, fungi, actinomycetes, viruses, and others.

III. *Antibiotics of Microorganisms.* This division will be concerned with the study of the formation of antibiotics by microorganisms, their isolation and purification, their chemical composition, their mode of action upon bacteria and other microorganisms, and their utilization for disease control. Particular attention will be paid to the isolation of antibiotics active against *Mycobacterium tuberculosis,* against viruses, and possibly against tumor cells also.

IV. *Vitamins and Enzymes.* This division will be concerned primarily with the study of the role of vitamins and enzymes in the nutrition of microorganisms, their production under different conditions of growth, and their utilization.

V. *Ecology of Microorganisms.* This division will be concerned with the occurrence, activities, importance, and control of microorganisms in soils, composts and water basins, in various agricultural products, and in foodstuffs.

VI. *Applied Microbiology.* This division will deal primarily with the application of microorganisms. Problems given consideration here will be largely of a practical nature. It is sufficient to mention such fields as the microbiology of foodstuffs, microbiology of soils and manures, microbial fermentations, causation of spoilage and methods of control, antiseptics and disinfectants, and finally—and not least important—the relations and interrelations of microorganisms in human, animal, and plant diseases.

Although the highly important fields of medicine, veterinary science, and various concomitant branches, such as immunology and disease control, will be avoided in principle, certain aspects will be considered in connection with some of the work proposed for the institute whenever the problems under consideration necessitate the study of disease-producing organisms, their physiology, and methods of control. This may involve collaboration with pharmacologists and medical investigators in industrial laboratories and in medical institutes.

Surely microbiology may be said to have come of age. Surely the establishment of an institute which is to be devoted to the task of training advanced students in the field of microbiology and to planning a program of research in the fundamentals of microbiology needs no apology. It is a great field, rich in scientific potential and in practical applications. The future for this field is bright indeed.

Based on an address delivered May 3, before representatives of the press and radio, on the organization of the Institute of Microbiology at Rutgers University, the State University of New Jersey.