THE BIOLOGICAL APPROACH TO BACTERIOLOGY[1]

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There probably is no scientific society, unless it be the chemical society, in which the membership represents a greater diversity of interest than does the membership of our society. Some of our members are interested in discoveries which may aid medical or sanitary science, which may alleviate suffering, help in the conquest of disease. Some are interested in the advance of agriculture, animal husbandry, the dairy industry, the fermentation industries or various other industries in which bacteria play a rôle. Much good bacteriological work has been done in the service of these special interests. In the popular mind practical discovery in applied bacteriology justifies the existence of bacteriology and certainly attracts to it considerable financial support. Of those who tread these avenues of approach to bacteriology it may be said that they are interested in what bacteria do rather than in what they are and more especially in some of the things that they may do. All of us are more or less guilty of having special interests whether we serve them or not. However, we have also a common interest which makes this society more than a federation of bacteriological workers and this meeting more than a composite of its various sections. It is for this reason that many of us are attracted to these meetings. We come here not merely to hear papers on medical, dairy or agricultural bacteriology, but rather to broaden our view of the whole field of bacteriology and to cultivate the acquaintance of our colleagues. Our common interest is bacteria, what they are as well as what they do. Some of us may be heretical enough to

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admit that we are less interested in sick patients, sick food, sick beer or big holes in swiss cheese than in the bacteria which cause these results.

Diversity of interest does not necessarily imply diversity of motive. It is not inappropriate that I should share one of the prejudices of a fellow Baltimorean who has shown an appreciative interest in microbiology and the custodianship of some of whose yeasts I inherited from my predecessor at Johns Hopkins University, the former president of this society. Mr. H. L. Mencken writing of The Scientist says:

> The value the world sets upon motives is often grossly unjust and inaccurate. Consider, for example, two of them: mere insatiable curiosity and the desire to do good. The latter is put high above the former, and yet it is the former that moves some of the greatest men the human race has yet produced: the scientific investigators. What animates a great pathologist? Is it the desire to cure disease, to save life? Surely not, save perhaps as an afterthought. He is too intelligent, deep down in his soul, to see anything praiseworthy in such a desire. He knows by life-long observation that his discoveries will do quite as much harm as good, that a thousand scoundrels will profit to every honest man, that the folks who most deserve to be saved will probably be the last to be saved. No man of self-respect could devote himself to pathology on such terms. What actually moves him is his unquenchable curiosity—his boundless, almost pathological thirst to penetrate the unknown, to uncover the secret, to find out what has not been found out before. His prototype is not the liberator releasing slaves, the good Samaritan lifting up the fallen, but the dog sniffing tremendously at an infinite series of rat-holes. And yet he is one of the greatest and noblest of men. And yet he stands in the very front rank of the race.

It is in defense of those who enjoy "sniffing at rat-holes" that I speak this evening. Many who approach bacteriology from the medical or industrial avenue become inoculated with the virus of pure curiosity. Others, thrilled by the first view of the world of microscopic life, entering bacteriology from curiosity, but irresistibly drawn into industrial or medical bacteriology, may,

nevertheless, retain that curiosity and may share the feeling of Pasteur who is reported to have said:

> If I have a regret, it is that I did not follow the route, less rude it seems to me, and which would have led, I am convinced to wonderful discoveries. A sudden turn threw me into the study of fermentation, fermentation set me at diseases, but I am still inconsolable to think that I have never had the time to go back to my old subject.

None will deny that bacteriology is a branch of biology. None would expect biological interest to be dominated by horticulture or animal husbandry. The arts of applied biology find their fertile fundamental concepts in the discoveries of pure biology. Similarly, applied bacteriology is dependent upon fundamental discoveries in pure bacteriology, whether made by botanists, industrialists or medical men. For such discoveries the biological approach is necessary. Bacteria themselves must be studied. What were some of the fundamental discoveries in bacteriology which made applied bacteriology possible? The discovery of the existence of bacteria; their form; their nature; methods and media for cultivating them; the method of excluding them by use of the cotton plug; methods of destroying them (sterilization); the existence and function of spores; methods of staining; the growth of colonies on solid media and the isolation of pure cultures; research on the so-called question of spontaneous generation (biogenesis or abiogenesis); the question of heterogenesis, xenogenesis or the existence of stable groups of bacteria; systematic bacteriology. These were fundamental biological studies in bacteriology. Without them, little or no subsequent progress could have been made. The first discovery that a microörganism might bring about such chemical changes as fermentation and putrefaction was a biological discovery of prime importance. Almost equally fundamental was the discovery that different kinds of bacteria produce different fermentations, the recognition of specificity. Less fundamental was the seeking out of the various organisms that bring about the different fermentations. Likewise, the first discovery that a microörganism was the etiological agent of an infectious disease, whether of man or of worm,

was a biological discovery of far greater importance than the subsequent discovery of such specific pathogens as the tuberculosis bacillus, the typhoid bacillus or the diphtheria bacillus. I think that Pasteur's almost accidental discovery of the possibility of immunizing chickens against fowl cholera was a greater biological discovery than his subsequent immunizations against anthrax and rabies. However, his genius was revealed in the application to the latter discoveries of the correct observations and deductions from the fowl cholera experiments. These instances serve, in some degree, to illustrate the difference between the merit of the thing discovered and the merit of the act of discovery. A discovery of prime importance is sometimes made with little effort. A great deal of genius may be displayed and hard effort expended with relatively unimportant results. Scientific discoveries are the result of genius and luck in varying proportions. In the discoverer, we justly admire genius and perseverance. As to the merit of the thing discovered, it makes not a particle of difference whether the discovery was the result of personal effort or luck. The merit of a discovery in pure science depends upon its usefulness, either as a method or as an idea, as exerted on subsequent research. Judged by this standard, possibly Leeuwenhoek's observations and the demonstration of the usefulness of the cotton plug by Schroeder and Dusch were greater discoveries than that of the tuberculosis bacillus by Koch. History may be viewed either from the biographical viewpoint or by tracing the development of ideas, social movements, etc. To me, in the history of science, the dependence of one discovery upon another, the growth of science irrespective of the human instruments of discovery, is the more interesting view.

Tonight, I wish to call attention to the return of the purely biological interest in bacteria. Apparently bacteriology was born of three interests; the philosophical, the industrial and the medical. Perhaps these interests might better be called the biological, the industrial and the medical, biology lying well within the scope of natural philosophy. These avenues of approach are easily traced in the history of bacteriology. It is difficult to say whether interest in the origin and nature of minute living things, the cause

and nature of putrefaction and fermentation or the cause and nature of contagious disease was first in time. Since the beginning of recorded history there have been many theories regarding these phenomena. The birth of bacteriology was delayed by the lack of a proper instrument, the microscope. There are three recognizable periods in the history of bacteriology. The first period was that of fundamental biological and technical discovery beginning with the first descriptions of bacteria by Leeuwenhoek in 1675 and extending to about 1885, the greater part of modern bacteriological technique having been developed during the last thirty years of this period. Since then there have been many improvements in technique but relatively few fundamental discoveries in technique,—among which, however, might be mentioned the ultra-microscope, the determination of reaction in terms of hydrogen-ion concentration, the use of ultra-violet light and methods of isolating single cells.

The second period may be described as that of the microbe hunters, beginning about 1849 with the discovery of the anthrax bacillus by Pollender and extending to about 1900. Undoubtedly, to those engaged in the search for specific organisms and to the world at large this was the most exciting period in the history of bacteriology. The technical and biological discoveries of the previous period bore fruit very rapidly. Certain industries and medical science were revolutionized. A noted bacteriologist of this period has said that it was difficult to wait for the morning newspaper to learn what pathogenic germ had been discovered. Within two decades, from 1880 until 1899, scarcely a year passed without the announcement of the discovery of the etiological agents of several long dreaded diseases against which mankind had been almost helpless. In 1892 John Tyndall said

> We have been scourged by invisible thongs, attacked from impenetrable ambuscades, and it is only today that the light of science is being let in upon the murderous dominion of our foes.

The light revealed not only the microbes of disease but also their mode of transmission, means of avoiding infection and, in some instances, means of overcoming infections. There were revealed

not only the hidden enemies of man but also his microscopic friends that henceforth could be made to serve more efficiently in the preparation of food, drink, clothing and chemical products as well as in the fertilization of the soil. The industrial revolution brought about by bacteriology can be compared to that wrought by the use of electricity. Much of the bacteriological work of this period was inspired by medical and industrial interest. Biological interest in bacteria was rather incidental. Although advance in systematic bacteriology continued, the dominant school of medical bacteriologists was rather impatient with such attempts and it is still difficult to interest them in the biology of non-pathogenic bacteria. Even Pasteur cared little about the morphology of bacteria and less about what they might be called or their relation to each other but was intensely interested in their activities in so far as they affected human welfare. A period of too exclusive devotion to practical results is self-limiting in any branch of science. Bacteriology began to slow up a pace. It came of age. There were still etiological agents of disease and industrial applications to be discovered but they did not readily yield up their secrets to application of the old knowledge and technique.

The period of modern bacteriology began slowly to dawn. Many of us who began to work at this time felt the difficulties that were encountered. We looked back with envy upon the spectacular period that had been written so recently into our textbooks. The older methods were no longer sufficient. It became necessary to dig deeper into chemistry and biology. The foundations of bacteriology needed broadening. Bacteriology ceased to be merely a tool of industry and pathology and began to reappear as a separate branch of biology, the subject matter of which was not disease or fermentation but bacteria. This society and its journal represent this trend. We hear less about recently discovered etiological agents and more about biological and cultural phenomena such as bacteriophage, microbic dissociation, growth phases, the physiology of bacteria, the possibility of the existence of life cycles and of filterable forms of bacteria. These are all recent fundamental biological discoveries and prob-

lems. Incidentally these phenomena may have practical significance, such as relations to virulence and immunity, but the fundamentally important considerations are the existence and nature of the phenomena. Bacteriology is not alone in showing a tendency to adopt a more purely biological viewpoint. Immunology has become quite as much concerned with the relation of bacteria to each other, the chemical constitution of the antigenic constituents of the cell, and the physico-chemical mechanism of serological reactions as with immunity or recovery from disease. Pathology and clinical investigation are biological sciences as; in fact, is all medical science as distinguished from medical practice. There are indications of a growing tendency to approach medical science from the biological rather than the therapeutic avenue. I have been much impressed by the following passage from the recent presidential address of Dr. F. G. Blake before the American Society for Clinical Investigation.

> I believe it should be kept in mind that the purpose of this study of disease should be primarily to find out about disease, largely for the fun of doing it, to discover the circumstances or conditions under which disease develops, the nature and mechanism of the disturbances of function and structure which take place during the course of disease, and the circumstances or conditions under which recovery or death occur. Secondarily, this may lead, and fortunately sometimes will, to the discovery of methods of prevention, amelioration or cure, but these practical and humane purposes should, I believe, be kept in the background, if clinical investigation is not to be too soon diverted and frequently misled in following its main purpose, the elucidation of the phenomena of disease.

More startling, perhaps, is the following which Dr. Blake quotes from Slesinger on "The Drift of the Social Sciences."

> Social science shares with medical science the necessity of having to free itself of the desire to do good and of measuring its success by the amount of good accomplished. The medical sciences are only recently beginning to abandon the therapeutic aim in research. It is not to be wondered at, therefore, that the younger social scientists find themselves still slightly hampered by an attitude growing not out of this subject matter, but out of the personnel attracted to the field during a

stage in the development of research when welfare was more important than truth.

I might add that I do not think that these quotations imply that there is not a science of therapeutics but the aim of this science should be to find out what may influence the course of disease favorably or unfavorably; why certain reactions follow certain treatment. The desire to do good may quite properly motivate the practice of medicine or the application of science in general but there is a danger in allowing any other motive to enter into scientific research than that of finding out, of discovering truth. A humane desire or an industrial need may indicate where research is needed but during the progress of research such desires are best forgotten. If such desires motivate the research, the researcher becomes a prospector rather than an explorer, an inventor rather than a scientist. In students it is most important to cultivate healthy skepticism and a critical faculty. They are impatient with details, anxious for practical results, eager to read only the latest publications. Just as it is unsafe to build a super-structure of theory upon too few facts, there is a double danger in the too eager application of new discovery to practical ends. There may be danger to man himself, as illustrated by the tragedy of the therapeutic use of tuberculin too soon after its discovery and possibly by too great confidence in the avirulence of rough dissociates of pathogenic bacteria used for immunization. There is also the danger that fundamental research may be arrested by attention being diverted to its practical application. It would be unfortunate if interest in bacteriophage should be abandoned because it has not been found to be a panacea for disease. Science can wait and cares little for the individual or for this generation of individuals in preference to the next.

The drift of the social sciences, medical science and bacteriology to biology reminds me of the drift of all science towards greater exactness as pointed out by Professor Bowman in a series of lectures on philosophy delivered some years ago at Princeton University. Professor Bowman, as I remember it, stated that as the several sciences become more mature, social science drifts

towards and tends to find explanations to interpret its phenomena in terms of biology; biology, in like manner, drifts towards chemistry; chemistry towards physics; and physics towards mathematics.

When one arrives at mathematics there seems but one other thing to do—to philosophize. We are justified in asking—If the desire to promote human welfare, to do good, is to be excluded from scientific research, what is its justification? The trite answer is "truth for truth's sake" just as art may be justified for art's sake. As a proximate answer this may serve very well but actually it is no answer at all. A man may do research for the fun of doing it but he can not expect to be supported for the fun of doing it. After all, truth and art are human concerns and have no justification and probably no existence outside of the mind. Pontius Pilate's question, "What is truth?", was not answered. Herbert Spencer stated that

> what we call truth, guiding us to successful action and the consequent maintenance of life, is simply the accurate correspondence of subjective to objective relations; while error, leading to failure and therefore towards death, is the absence of such accurate correspondence.

This definition of truth seems to me to contain the whole of the pragmatic philosophy. The motive of those who sniff at rat-holes is curiosity and the fun of doing it. Their reward is curiosity satisfied. Their social justification is that experience has shown that this motive most effectually excludes prejudice and most successfully contributes to a body of truth which enables man to make that "continuous adjustment of internal relations to external relations" which is Spencer's definition of life.

In trying to emphasize the importance of the biological approach to bacteriology I have not meant to speak disparagingly of research undertaken for solving practical problems. We need not be ashamed of being prospectors or inventors at times. Even Mr. Spencer invented "A New Invalid-bed" and "A New Fishing-rod Joint." In speaking of the biologist I refer not to individuals but to any of us in what may be called our biological moments, those moments when we are actuated by purely scien-

tific motives. At such times the medical man and the industrial bacteriologist are biologists. It is because bacteriology is a biological science of which the chief concern should be bacteria and because the biologist is relatively free from those praiseworthy but prejudicial motives which may influence those who are interested primarily in applied science that I view with gratification what seems to me to be the renaissance of the biological approach to bacteriology.