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CONTENTS

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THE INTER-RELATION OF THE MEDICAL SCIENCES[1]

SECTION N of the American Association for the Advancement of Science has for its field the medical sciences. I do not know that in this organization the question what are the medical sciences has ever been raised or discussed. I take it, however, that it is generally assumed that the medical sciences include at least human anatomy and human physiology. At any rate, the workers in these fields find no home in this association except in this section. It is also taken for granted that among the medical sciences are included all the myriad branches of medicine, many of which have sprung into being during recent decades. Recently it has almost seemed that whenever two or three have gathered together to deal with a special medical problem, the suffix o-l-o-g-y has been added to the name of the subject treated, and a new science has been born.

To the practical American there seems to be little value in attempting a rigid classification of the sciences, such as has been attempted by Bacon, Spencer, Karl Pearson and others. Yet any serious consideration of the various sciences and of their interrelations may make us realize how much we take for granted and how illogical in many respects is the present situation.

From its derivation, the term medicine has to do strictly with healing, and the term designates either the agent employed in healing or the branch of knowledge which has to do with the prevention, cure or alleviation of human disease. It is obvious, however, that in spite of this definition medicine has come to mean something much more inclusive than therapeutics. If it does not this section is dealing with the application of science, not science itself, even though various sciences are contributing to it. It is true that the application of knowledge to practical ends neither lessens the importance of that knowledge nor lowers the dignity of him who so uses it. This association, however, is chiefly interested in the pursuit of knowledge, not its application. And in the striving after knowledge, experience has shown that any limitations, such as usefulness, placed upon the results of the searcher seriously handicap him in his

[1] Address of the vice-president and chairman of Section N—Medical Sciences, American Association for the Advancement of Science, Nashville, December, 1927.

effectiveness. The true scientist can not be restricted to the production of results that are immediately useful or even of results that may be useful in the future. Notwithstanding this, we suspect that every scientist, even the most pure, cherishes a secret hope that his results will receive an early application, and the question may even be raised whether every searcher after truth is not stimulated in his endeavors by the consciousness that his contributions are bound in the end to contribute to the well being of mankind. But if scientists have a dogma, it is that the advancement of knowledge can best be accomplished by pursuing it quite independently of any immediate results, and if this association has a slogan, it should be, "Unrestricted Investigation."

For many centuries medicine has suffered from the restrictions implied in the term. At present these may be more imaginary than real, but, at least in the past, these restrictions have exerted an inhibiting influence even on the development of therapeutics itself, and have exerted a still greater inhibition on the growth of knowledge, concerning the real nature of disease in man, and also on knowledge regarding the structure and functions of man in health. These restrictions are partly inherent in the nature of the subject, but to a greater degree they have arisen as a result of the historical development of the organization through which this branch of knowledge has been cultivated.

Man's first interest in disease undoubtedly arose from a desire for relief. When he became conscious of an unusual physical state, usually evidenced by discomfort or "dis-ease," he ascribed it to some supernatural agency, and appealed to the gods for relief. Later he found by chance that through the employment of certain physical agents, pain might be relieved, especially when the abnormal state was the result of some obvious external agency. The priests who were the intermediaries with the gods in relieving the mysterious ailments, also became the healers who applied the less mysterious remedies. Thus originated the healers or physicians, and from the earliest times to the present, physicians have been the custodians of knowledge concerning disease. But physicians have been employed by the sick to heal them, and the physicians therefore could not be entirely disinterested seekers after truth. Under these circumstances, it would not have been remarkable if any seeking for knowledge which physicians undertook, should always have been directed to a search for cure. The Hippocratic Oath expresses lofty moral principles and registers a vow to transmit the knowledge of the art to certain disciples, but it contains not a word about attempting to learn more about disease.

To facilitate the transmission of the curative art to others, schools of medicine were organized, and these later became incorporated in the universities. Knowledge of disease consisted in deductions made from principles, but these principles were based upon the crudest analogies. Even such a state of affairs, however, is eminently satisfying to certain types of the philosophical mind, I will not say to all. It is interesting, if not amusing, to read in the most recent history of medicine, in the introduction written by a philosopher-physician—"And so do we arrive at the paradox—true, as are all genuine paradoxes—that, when in the sixteenth century medicine was, as we should say, less "scientific" than to-day, medicine was indeed, as now it is not, a science in very truth." But for good or ill, and it is difficult for us to be convinced of the evil results, the desire did arise to obtain knowledge about disease which was not deduced from principles, but which was derived from actual first-hand observation. Since little could be known about abnormalities in structure and function until more was known about the normal state, it was only natural that physicians should have been led into the study of anatomy and physiology. It can not be maintained that this knowledge was pursued solely for the sake of curing disease, but the pursuit of this knowledge originated in, and was practically confined to, the medical schools, and the search was almost exclusively conducted by physicians. Vesalius was a physician and even he forsook his study of anatomy for the more lucrative post of physician to Charles V. That Vesalius was a physician and that Harvey was a physician do not detract from their contributions to science. Rather it emphasizes the pride that all members of the medical profession should have in the fact that these men broke away from pursuing an immediately useful object, and attempted to discover Nature's secrets. But in so doing Vesalius and Harvey forsook their field, they entered a new province, they no longer were studying disease, they were no longer studying abnormalities in structure and function; they were studying the normal, the usual. Certain men like Leonardo da Vinci possibly undertook the study of anatomy chiefly to satisfy an insatiable curiosity. But even Leonardo was undoubtedly led to peer beneath the surface, at least partly, through a desire to be better able to depict the human form. Theoretically the study of human anatomy might just as well have been incorporated in the schools of art, but it was not to be, and, from the sixteenth century until to-day, the cultivation of the science of anatomy has occurred almost exclusively in the medical schools. It is only within our own day that those teaching and studying this subject and widening its boundaries, have not at the same time been engaged in applying

remedies, healing the sick. True it is that in the halcyon days of the fifteenth and sixteenth and seventeenth centuries the searcher after truth could ramble over the whole field of nature, and pluck flowers wherever he went. The investigator did not have far to go to encounter the unknown, it lay all about him. And very many of the searchers of these centuries were physicians. Paracelsus and his followers, Van Helmont and Stahl, knocking at the door of chemistry, were physicians; Galileo and Gilbert, Copernicus, and numerous others were trained in the art of medicine and many of them practiced it. But whereas physics, at an early day, and chemistry, somewhat later, were divorced from the medical school and were given independent positions in the universities, human anatomy and human physiology retained their incorporation in the medical school, and to this day they have never gained their independence. They are still called medical sciences and have had to bear the burden imposed upon them, by implication at least, of pursuing knowledge for a definite utilitarian purpose. Whatever the situation may be to-day, in the past this burden has too often been more than merely that imposed by implication, it has been a real impediment, sufficient actually to hamper the growth of these sciences. To-day anatomy and physiology are thriving best where they are most free from the restrictions enforced upon them through their inclusion in the medical school. These restrictions are not all associated with the relation of medicine to cure, however. Certain restrictions in the medical school have arisen from the attempt to provide a too rigid and all inclusive curriculum which expresses the antithesis of the university spirit. In England histology or microscopical anatomy is still taught in the department of physiology, to the detriment of anatomy. On the other hand, it must be admitted that in certain medical schools, in this country at least, the attitude is becoming much more liberal. Anatomy is becoming less and less restricted to pure description. We even have professors of physiological anatomy!

What has been said about anatomy and physiology refers to human anatomy and to human physiology. The study of structure and function in what we call the lower animals took a different course. It is to Aristotle that science owes the beginning of zoology, comparative anatomy and embryology. Although Aristotle's father was a physician, and although Aristotle is sometimes spoken of as an Asclepiad, and his enemies accused him of practicing medicine, he took little interest in medicine, and he is said to have produced but one medical work and that one is now lost. As Allbutt says, "Hippocratic physicians accumulated a remarkable series of facts . . . but their work was not, as that of Aristotle, for disinterested science but for practical ends." Ever since Aristotle the study of anatomy, physiology and embryology of animals other than man has not been relegated solely to the medical schools nor been exclusively engaged in by physicians, and this in spite of the fact that these subjects have a very direct relationship to human anatomy and physiology and medicine. Whether this separation from medicine has influenced the growth of these sciences, I do not feel competent to judge, but one may at least say that the followers of these sciences have made distinctly greater contributions to biological theories, and have had more influence in establishing biological principles than have the followers of human anatomy and human physiology.

When physicians became conscious of a desire to extend knowledge, their natural and legitimate field was disease itself. It is true that ever since Hippocrates, physicians had been attempting to describe and classify disease, so far as this could be done by mere observation of symptoms. But, of course, this was but the first step in arriving at any real understanding of disease. It was a long time after the beginning of anatomy before physicians began to make any serious investigation of the abnormalities in structure resulting from disease, at least before morbid anatomy consisted of more than fragmentary observations. It was two hundred years from Vesalius to Morgagni. One may say that only then did physicians begin to be scientists in the modern sense. The high aspirations of pathological anatomy is indicated by the title of Morgagni's monumental work, *De Sedibus et Causis Morborum,* though the title indicates a much greater confidence in the results to be obtained from the mere description of lesions than was justified. At first pathological anatomy was studied and taught by the anatomists, but later, to its great advantage, it became more closely integrated with clinical medicine, that is with the study of the manifestations of disease in the patient during life. As Billroth says, "The new material became vitalized only when the clinical physicians took hold of it and either themselves undertook the dissections or had them performed under their direction." But pathological anatomy, I will not say its followers, became proud, and pathological anatomy became pathology, the science of disease; its votaries became pathologists, and, in this country at least, pathologists they have remained to this day. That this assumption of exclusiveness was justified, no one will claim, for even the most ardent followers of this branch of knowledge must admit that alterations in structure alone can give but a very imperfect conception of disease. If the pathologists, in assuming their new

title, were animated by a desire to escape from the restrictions imposed upon medicine by the necessity of obtaining useful results, of promoting cures, no one can blame them. But the separation of pathological anatomy from the study of disease as a whole was neither good for pathological anatomy nor for medicine. Pathological anatomy or pathology, or whatever we call it, is not one of the medical sciences, or a contributory science to medicine. It is a part of medicine itself, unless medicine is to be restricted to the cure of disease. The science of medicine is no more applied pathology than pathological anatomy itself is applied anatomy and histology. The study of pathological anatomy is, or should be, only one of the methods for investigating disease, and the closer it can be interwoven with the other methods the more likely are its results to be of value. The field of pathological anatomy is the study of the effects of disease. To really learn about disease, that is to understand the alterations in function and structure which are exhibited by the abnormal individual, the individual himself must be studied, during life as well as after death, and this study must be combined with an attempt to explain the abnormal phenomena in the light of present knowledge and by the aid of all suitable methods. This is the science of medicine, if such there is, and if there is not such a science there ought to be.

The first and essential step in the pursuit of knowledge concerning disease consists in describing and classifying the phenomena to be studied, and that must be done by observing sick individuals. Disease is not something that exists apart from the patient. Knowledge was long retarded by considering that diseases were entities. Upon the seekers after this kind of knowledge the burdens of utilitarianism bear of necessity more heavily than they do on the followers of anatomy and physiology, or indeed on the votaries of any other science. They can not be entirely escaped. We may study earthquakes, or tides, or the natural attraction of bodies for one another as these phenomena present themselves. Certain phenomena we may reproduce at will. But in the study of disease in man we can not investigate the phenomena with hands off. We must always interfere by attempting to prevent harmful results. Moreover we are powerless to reproduce the phenomena artificially. The science of medicine is not analogous to theology but to demonology, and the restraints of morality, of religion, of conscience will not permit one to study these demons without attempting to cast them out and to destroy them. But one can do both things if he is not controlled entirely by his emotions, or worse by the temptations of self interest, and these are great indeed, but if he is also inspired by curiosity and controlled by reason. The true student of medicine must realize that before disease can be cured it must be understood. And to understand it, it must be studied at the bedside, in the laboratory and at the autopsy table. Clinical medicine, or whatever the study of the more superficial aspects of disease may be called, experimental medicine, pathological anatomy, pathological physiology, are but different aspects of the same thing, the study of disease, the science of medicine. Practical results in the way of cure are bound to follow the development of this science, but these must be the natural outcome, not the objects to be always held in view. Even therapeutics may be pursued in the spirit of a pure science, as witness the growth of pharmacology, which has flourished best and has been most productive when it has attempted to learn, not how to cure patients, but has investigated the action of drugs in producing alterations in function. It thus becomes a matter of emphasis as to whether medicine will be merely an applied science or not.

It must not be assumed, however, that the pursuit of practical ends precludes the advancement of knowledge. The reaction against the Baconian philosophy is not entirely justified. When we are tempted to disparage, let us remember that Bacon's spirit was responsible for the formation of the Royal Society. It would be a rash man who would belittle Pasteur as a scientist, yet most of his work consisted in pursuing very practical ends, and at least one of his two or three fundamental contributions was the direct outcome of an attempt to obtain a utilitarian result. That scientists will obtain useful results goes without saying. That they should not be under any obligations to obtain immediately useful results, and that their work should not be judged by any criterion of utility, experience seems to have shown.

The methods and accumulated results of all sciences must be used in pursuing the science of medicine. That some of these sciences are more closely related to medicine, in their methods and fields of endeavor, than are others is obvious. Biology, comparative anatomy, embryology, bacteriology, protozoology, certain branches of botany, anthropology, human anatomy, human physiology, psychology, and even certain aspects of the social sciences, have many close affiliations with medicine. The methods of the more general and fundamental sciences, mathematics, physics and chemistry become applicable in any science as that science develops, and the degree of development of any branch of science may be tested by the extent to which the fundamental concepts of physics and chemistry may be usefully employed in its pursuit. That biology is ready for such an approach, the development of general physiology bears witness.

That problems of disease may profitably be investigated by the employment of accurate quantitative methods, and be studied in relation to the laws of physics and chemistry, is evidence that the science of medicine already exists and that it has even grown out of its swaddling clothes. But none of these contributing sciences are medical sciences. None of them should be trammeled by serving medicine alone. The only medical science is the science of medicine itself, that is, the science whose field is the study of disease.

Thus far I have not referred to the large number of subjects which, in so far as they receive any scientific treatment at all, are parts of the science of medicine. These are subjects, such as neurology, psychiatry, dermatology, otology, cardiology, angiology, gastro-enterology and so on, *ad infinitum*. On the other hand, there is another group of subjects which are held to be closely related to medicine, but which belong, so far as they belong in any science at all, in some one of the other fundamental sciences. I refer to subjects like histology, cytology, immunology, endocrinology, climatology, radiology and so forth and so on. The multiplicity of these terms illustrates the extent of what we may call growth at the periphery of a science.

It must be admitted that the science of medicine has not reached a high state of development, even such as physiology has attained. And furthermore, we must admit that many of the most important contributions to this science have been made by workers in related fields. Nevertheless, I believe that its greatest advancement will come only when it shall be pursued by men whose primary interest is in disease. Important contributions have been made by clinicians, but only comparatively recently have any considerable number of physicians become conscious of their obligations to contribute to this science, and only still more recently have physicians been given any relief from the burdens of practice which will give them opportunities for studying disease by scientific methods. It is true that many of the contributors to other branches of science also teach, but the practice of medicine is a much more time- and energy-consuming occupation than is teaching.

From the philosophical standpoint, from which the object of all science is but to obtain an interpretation of nature as a whole, it is possible that medicine may be relatively unimportant. It may be, however, that the most important generalizations will proceed not from the study of the normal but from the investigation of the unusual. The object of all science is to reach underlying principles or laws. As Priestly said, "Science is an effort to compress as much knowledge as possible in the smallest compass." And Karl Pearson said, "Nobody believes now that science explains anything; we all look upon it as a short-hand description, as an economy of thought." A great mass of knowledge about the details of disease has been accumulated, and this knowledge is about as accurate as it is in the other domains of biology. This kind of knowledge in recent years has been extending at an enormous rate. Journals devoted to medicine in its various aspects number many hundreds. The science of medicine is developing centrifugally, not centripetally. One important reason for this is that it is so greatly exposed to utilitarian demands. In his efforts to be aware of all the facts the physician has no time for contemplation of their meaning. In his fear of overlooking that which may be of value in prolonging the life of the individual, he fails to discover that which may be of importance for the race. We even lack accurate definitions of disease, injury, recovery, death. Possibly such definitions can never be made. Scientists are not so sanguine as they once were of reducing knowledge of the universe to formulae. But the science of medicine, as all other sciences, demands that efforts be made in this direction. In spite of all that has been said, however, the heterogeneity that exists in the knowledge about disease is no greater than that in some other branches of knowledge, the scientific status of which is never questioned.

Medicine occupies a peculiar position among the sciences. By workers in other fields of science, medicine has been looked upon askance, even disregarded. In most of the classifications of science it is not even mentioned. It is even claimed that there is no such thing as a science of medicine. On the one hand, as medicine, it has been scorned and neglected, and on the other, as the medical sciences, it has been honored and respected, and held to embrace within its borders such important divisions of science as anatomy and physiology, and the name has been used to designate an important section in this association.

Every organization must have a function. There seem in the past to have been some doubts as to what the function of Section N really is. May not one of its functions at least, be the support and promotion of the science of medicine, even though Section N continues to be called the Section of Medical Sciences. On behalf of human anatomy and human physiology, however, although I have no authority to speak for them, I should be glad to see this section called the Section of Human Anatomy, Physiology and Medicine, or the Section of Medicine and Related Sciences.

The support and defense of the science of medicine is needed, the battle is not to be easily won, the result is not certain. Apart from the opposition of those who see in medicine only an art pursued for practical ends, and aside from the inertia, arising from tradi-

tional viewpoints, as exhibited in the treatment of medicine in the universities, there is the question that is bound to be raised as to whether the scientific method is, after all, the most effective one for the advancement of knowledge in this particular realm. Great advances have undoubtedly been made in this field through a purely empirical approach. The Nobel prize has just been awarded for a discovery in this field which was not made through what is considered the scientific method. This association believes, however, that the best approach to knowledge is through the gateway of science.

The science of medicine requires workers imbued with the scientific spirit. Opportunities must be available for men who want to learn about disease. These men must be stimulated, and their work given appreciative recognition by workers in better established fields. The bestowal of this recognition and stimulation offers one way in which science may be advanced by this fellowship of scientists.

In what has been said I have merely tried to give expression to what has already been in the minds of most of us. The programs of recent years, and the program of to-day, indicate that the motivating force in this society is the promotion of scientific medicine. Through the efforts of this organization may medicine ever become more scientific, to the great blessing of mankind.

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THE ROCKEFELLER INSTITUTE
FOR MEDICAL RESEARCH

TOO LITTLE MATHEMATICS—AND TOO MUCH[1]

IN speaking on a subject like mine of to-night it is necessary to proceed by classification, for what might be too little mathematics for some groups of students could well be too much for others.

First let us consider those who contemplate becoming professional mathematicians. These form a negligible group—negligible in numbers compared with all those who should take some collegiate mathematics, negligible for purposes of instruction because each will go more or less his own precocious way. It is improper for any department selfishly to lay its plan of teaching for the rare Galois or Gauss or Abel, or even for the commoner Richardson or Archibald or Wilson. The future professional who is worth his salt will get along somehow without much of our assistance and possibly even in spite of it. He will follow the courses he wants and make up his deficiencies by private study. The professional knows how to learn, and in mathematics he knows it young. There will be small chance that he have too little mathematics; you may think he can hardly have too much. Herein I should differ with you and maintain that his real danger is "too much." I do not, of course, refer to what he will have learned or may have forgotten by the time he comes to a ripe old age or even by the time he reaches middle life; I am speaking of the future professional mathematician as a student, first collegiate and then graduate. He should not be stuffed with courses until his brain has become a glorified paté de fois gras. That would deaden his originality, doubly diminish his ingenuity, and thus triply hinder his development as a true professional.

Our American university departments sin greatly in the great array of prerequisite specialized courses which they offer and expect their students to take. The aim of any advanced course should be to line out a straight path from relatively elementary work to the research line. When I was in Paris I took a course at the Sorbonne on the dynamical theory of light with Boussinesq. He did not hesitate to take his time to explain that $\cos(\pi - x)$ equals $-\cos x$ or to prove some ordinary proposition in solid analytical geometry or to integrate some common differential equation, and yet in 60 lectures he reached material to be found only in his own recent papers. When I asked him why he took the time to prove so many elementary theorems he said that it did the students good to see such propositions demonstrated and that he had a superabundance of time anyhow. Such a course in any one of many fields could be given in our American colleges to seniors who had had three consecutive years of mathematics, if only our teachers had the finesse to give it. A book must be somewhat encyclopedic; a course should be selective, eclectic, for the purpose of helping the student quickly to an original problem upon which he may go to work. You have here at Brown one of the best collegiate departments of mathematics in the United States; you have an able staff; you need not hesitate to offer the doctorate. What you may miss is encyclopedicity, you will for that very reason the more easily make up in the freshness and promptness with which you start on original investigation.

Let us turn from the future professional to the ordinary college man. He may well have too little mathematics, too little for his own future comfort. The college student of inorganic chemistry of 30 years ago who failed to take a good course in calculus has paid heavily for this omission. It has much increased his difficulties in physical chemistry, in the work of van't Hoff and of Nernst, of Lewis

[1] Read before the Mathematical Club of Brown University.