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## THE ART AND SCIENCE OF MEDICINE[1]

THIS twentieth anniversary meeting of the American Society for Clinical Investigation marks the active inauguration of a policy which has for its purpose the perpetuation of the youthfulness of the organization. The members who to-day retire to the emeritus list are those who formed the society and on whose shoulders for many years fell the burden of directing its course. During this score of years in this country has occurred practically the entire growth of medical clinics as we understand them to-day. The physical organization and intellectual direction of most of these clinics has fallen to the lot of our early members. As a result of this pioneer work the younger members of this society have at their disposal facilities for following careers as clinical investigators scarcely equalled anywhere in the world.

But points of view are probably more important than mere places for work. It is sometimes well to stop and survey our territory, our methods and our attitude. An anniversary event, such as we are to-day celebrating, offers an opportunity for such a survey.

Not unfamiliar to you are the terms "science of medicine" and "art of medicine." Usually they are expressed in a manner which implies the existence of two mutually exclusive fields or manners of endeavor. It is true that custom gives meaning to words or phrases; but this is no excuse for allowing these phrases to fix unalterably our attitude towards the subjects which they symbolize.

In the expression "art and science of medicine" at least three separate ideas are included: medicine, art and science; hence it becomes desirable to attempt to define these terms. Medicine is that department of biology which considers disease in all its aspects. This assumes that disease is a departure from normal living, *i.e.*, from physiological processes. Correctly speaking, it would exclude from study the manifestations of aging, for these in a strict sense must be considered as physiological, *i.e.*, normal to life. But such definitions must be generally inclusive rather than specifically exclusive. In a field as broad as medicine we can define the aims, but the boundaries and ramifications must not be limited.

[1] Presidential address before the American Society for Clinical Investigation, Washington, D. C., April 30, 1928. From the hospital of the Rockefeller Institute for Medical Research, New York City.

In the development of language the ideas represented by the words art and science have been closely related. Art implies arrangement, a creation of special conditions or relationships from available material; it is not concerned with the origin of the material, but merely uses that which seems best suited for a definite purpose. Science, on the other hand, consists in knowledge of the phenomena of nature; its function is to determine the materials and relationships in any given condition. This, of necessity, implies the discovery of new ones, if all possible features and combinations are not already known. The relationship of the two ideas has been paraphrased thus: "Art consists in doing, science consists in knowing." In other words, when one tries to do something in order to know he must use the technique and methods of art. When, on the other hand, he tries to know something in order to do, he must either take the knowledge science has furnished, or go to nature and apply the methods of science to furnish him with new knowledge. Thus he assumes the alternate rôle of scientist or artist, according to the immediate aim of his requirements. As the sum of our knowledge is still relatively small, and as there is an ever-increasing addition of new discoveries, obviously there occurs an ever-constant change in the relationship of the known and knowable. Hence the scope of both art and science is continually altering; art has a never-ending task in arranging new combinations of materials which are constantly increased by science.

In his effort to help himself when sick or injured primitive man doubtless made and correlated observations which constituted a crude science of medicine; but the admixture of religious superstition constantly confused the picture. Only with the Greeks did the various relationships of medicine become well formulated. The main characteristics of Hippocratic medicine included: (1) Its social aspects, the relationship of physicians to one another and to the patients as exemplified in the Hippocratic oath; (2) its scientific aspects, the necessity for observation of the phenomena of disease, and the recognition of laws governing disease. This doubtless resulted from the comparison of the results of observation; (3) its aspects as an art. The possibility of arranging conditions to alter effects was recognized in a system of therapeutics.

While the study of human anatomy flourished, its chief effect seemed to emerge in the plastic arts rather than as an aid to the physician. Because the study of disturbed function could not be readily correlated with that of abnormal form in a system of pathology, the school of Empiricism developed in Alexandria in the same environment that fostered the most distinguished anatomists. As empiricism has always such an important place in medicine it may be useful to note the method developed in that school. It rested upon the tripod of (1) observation, (2) history (record of observation) and (3) judgment by analogy. One can not but recognize the importance of empiricism in the development of knowledge in all branches of science. Particularly in utilizing the results of comparative physiology and pathology is it necessary to apply argument by analogy. The chief weakness of the system for centuries, however, rested in the limitations imposed by the formation of judgment *exclusively* by analogy.

Furthermore, not the least of the dangers of empiricism is the presence of scholasticism, which is undue worship of authority and the acceptance of judgment of others unsubstantiated by experiment. This was for centuries the great handicap, which even to-day is imposed by a too rigorous schedule of formal instruction in our schools. True, Galen tried to combine the study of function and form in physiology and anatomy. But his misinterpretations of the functions of many anatomical structures were perpetuated by the Scholastics until comparatively recent times.

But with the Renaissance a new attitude developed. In the person of Francis Bacon the feeling against the old scholastic doctrines which blindly followed authority became so strong that an entirely new method of learning was evolved. To remove the influence of preformed judgments he advised the attaining of knowledge by observation of as many facts or phenomena as possible, and then in any given case the elimination of the unessential by means of tables. But elimination involves the art of judgment; and time has shown that scientific judgment is best controlled by experiment. Indeed, during the period when Bacon was developing his inductive method, many scientists were applying the experimental method and establishing facts that have stood the test of time. Probably of greatest import to us as physicians was the discovery of the circulation of the blood by Bacon's contemporary, Harvey. This year is the three hundredth anniversary of the publication of that great milestone in medicine, "De Motu Cardis et Sanguinis." With the discovery of the circulation of the blood occurred the birth of modern medicine. We can with profit reread this work not only as the recitation of keen observation, but as an example of the method to be used in approaching medical problems. One feature deserves special emphasis: not until he had labored years on this subject, demonstrated before his colleagues, and invited and answered their criticism, did he publish his conclusions; and then in a single

short monograph of seventy-two pages did he present his completed work, which ever since has stood as a model of thought, observation and deduction.

However profitable it might be, it is impractical to recite now the many discoveries in medicine of Harvey's contemporaries and successors. It is, however, important to note that the mere study of form did not satisfy most of these investigators. They were curious to learn how a structure had assumed its peculiar form; in other words, they tried to correlate form and function. Such a correlation served as a control, for if a reasonable explanation in terms of function could not be adduced for the form of a structure this was an added stimulus for inquiry further into the nature of both its form and function. Hence arose an appreciation of the value of doubt. Harvey's first chapter is a recitation of doubts; Bacon codified what must be doubted; Descartes emphasized the rôle of doubt in the words, "When we doubt, we think." These masters were interested not alone in knowledge, but in how it was to be gained and in the relationship of knowledge to life. Indeed, Descartes postulates the three means to knowledge as imagination, the senses (observation) and memory (recorded knowledge). How this corresponds with our modern conception of the scientific method will shortly appear.

Let us turn, now, to medicine, the science that most intimately concerns man, for it deals directly with his body in a state of disease. It rests immediately upon the other sciences of physiology and anatomy, which concern themselves with normal function and form, but includes both pathology, which concerns itself with abnormal function and form, and therapeutics, which in a broad sense deals with the means and methods by which pathological states may be altered or prevented. All these in turn must rest upon physics and chemistry and some upon bacteriology, but they are not physics, chemistry or bacteriology; for each science, because of the peculiarity of the phenomena with which it deals, has its own particular province. Each may borrow methods from other sciences, but must in turn develop its own hypotheses and theories.

In regarding the successes of physics and of chemistry we are liable to become discouraged because the complexity of the phenomena of disease makes our way harder, and to feel that unless we can apply the methods of the physicist and chemist in the same manner as they do ours must of necessity be a crudely empirical procedure.

Proponents of the doctrine of Emergence have, however, clearly demonstrated that the manifold forms in which matter exists make necessary the application of methods which must be adapted to the peculiarities of the immediate problem. Just as in the nebulae the astronomer or astrophysicist now recognizes the existence of states of oxygen and nitrogen which he can not reproduce in his laboratory, so in a diseased body we often have phenomena which may not be reproducible in any other place. The study of disease, therefore, even by the altering of its course by influences brought to bear from the outside, is not in any way less dignified than the study of a gas by similar manoeuvers.

Acceptance of medicine as a science, then, compels adoption of the experimental method as a means of solution of the problems presented, either in the abstract study of disease, or in the concrete study of a disease in a patient, for this method is the one that has proven the most useful in the solution of the problems in all branches of science. Even though elementary, it may be profitable to outline our conception of this method. As a result of observation of some phenomenon a question is asked. This leads to the formation of a hypothesis which is a reasonable explanation of the phenomenon. An experiment is planned and performed to test the validity of the hypothesis. If the experimental observations confirm the hypothesis it then becomes a theory; and with a correct theory we are able to prognosticate that with a given set of conditions a definite set of results will ensue. The experimental method rests, therefore, upon the tripod of observation, reasoning and experiment. You will recall that the tripod of the ancient empiricism was observation, history or record of observations and judgment by analogy. The difference between the two methods is that in the experimental method judgment is based upon experiment planned from hypothesis; subsequent action is guided by the theory so devised; whereas in the empirical method judgment is based upon analogy and is unsupported by experiment.

But in the different steps of the scientific method the technique of art must be invoked. The art of observation must be highly developed to discover the question requiring solution. The formation of a hypothesis is an art of the highest type; the hall-mark of the great scientist is his ability to formulate brilliant and useful hypotheses. A hypothesis must be reasonable, must be applicable to the question at hand and must be amenable to experimental testing. It is important to remember always that an experiment has for its object the *testing*, not the substantiation, of the hypothesis. The planning of an experiment and the manipulation of the apparatus is again an art. What we determine by this method is the relationship of one set of facts or events to another; in other words, we learn the relationships of phenomena.

As previously noted, a great difficulty in experimental medicine, and all medicine is experimental, rests on the complexity of the animal body. For ex-

perimental purposes it is necessary as far as possible to analyze the various phenomena into simple relationships, but to approximate the truth about the whole it is necessary to synthesize our analytical data into a picture which will best explain the conditions. Such a synthesis is a great art, for only the ability to picture accurately and to differentiate primary from secondary phenomena and to distinguish causal from concomitant relationships in complicated vital reactions gives us the power to alter their course.

A moment ago it was stated that all medicine was experimental. By this it was meant to imply that it is necessary for the physician, whether in the laboratory or at the bedside, to approach his problem from the experimental viewpoint. Only by postulating that we know all about a disease or all about a sick man dare we conclude that we have the necessary knowledge which will enable us to control all the symptoms, that is, the phenomena of disease. No one would be so rash as to claim such knowledge. Why, then, should he be so bold as to approach either a sick man or the problem of disease in any attitude but that of the scientist?

Just as in the formation of a hypothesis we make observations and often apply previously established theories, so in the making of a diagnosis we observe, state a question, form a hypothesis and see if the conditions observable confirm our hypothesis. If not, we go back and form a new one and make new observations, until finally our working hypothesis or diagnosis gives us sufficient assurance to permit us to try the experiment of treatment. Every treatment is a therapeutic trial. In some conditions we have sufficiently well-established theories to permit a fair prognostication of the results to be expected from certain therapeutic measures. I say fair prognostication, for often we experience disappointment because we have not sufficiently complete knowledge of the complicating factors to foresee their influence.

It seems to me that to remove therapeutics from the province of medicine would eventually remove medicine from the list of sciences and leave in its place only pathology. By this it is not meant to imply that therapeutics should be the immediate end of all study, but that often manipulations of conditions whereby the phenomena of disease are altered may be one of the important modes of studying those phenomena, just as changing the phase of a compound from the solid to the gaseous state or *vice versa* by appropriate measures may furnish important information concerning that compound. The danger lies in allowing the alteration in form or phase to become the immediate and only aim of our manipulation, thus causing us to forget the nature and relationship of the changes we have brought about.

A criticism frequently brought against modern medical education is that there is not enough systematic teaching of the art of medicine or of therapeutics. Strictly speaking, it is doubtful whether the art of medicine ever has been taught or can be taught any more than can any other art. Instruction can be given in technique and in method, models can be furnished, but the skill which we recognize as art, because of the manner in which it is exercised as well as in the final result, must be acquired by actual practice. Possibly the fault concerning therapeutics is that it is taught from the viewpoint of the ancient school of empiricism rather than from that of the modern aspect of the scientific method. If each treatment were regarded as an experiment different pedagogic results might follow. While much time is devoted in our hospitals to objective observation and recording, it is rare to see notes on the history charts which state why a certain drug was given, what effect was expected and whether or not it was obtained. In other words, it is not customary to record the hypothesis which determined the therapeutic experiment, an observation of the effect and a criticism of the results. It is probable that if the scientific method were applied more rigidly to therapeutics, the latter would assume a more dignified position both as an art and as a science.

The existence of any type of art presupposes the existence of artists. No artist can be very eminent without knowing the fundamentals of his art. The fundamentals of medicine rest in the science of medicine. We have already noted how the scientific method is essentially an artistic method; there is required successively the art of observation, of ideation in the formation of the hypothesis, of experimentation in testing the hypothesis and of synthesis in correlating the observed phenomena. In the process certain rules can be formulated, but they are merely those of logic which provide the technique of correct thinking. But no rules can be formulated to determine just how an artist shall use his materials. In putting these together in the proper manner he expresses his art and himself.

Because of man's complex mind and many potentialities the physician is brought into contact with a multitude of human activities. In so far as any of them has a direct bearing on his immediate problems he must consider it, but it is always necessary to disregard some and to emphasize others.

The vastness of nature has forced upon man the necessity of adopting the experimental method in questioning nature. This is the method of analyzing, of ascertaining details—often unrelated. But it is the harmony of nature that we wish to understand. Harmony postulates relationships, not individual tones, not mere sensation. Many modern artists seem

only to aim at producing certain sensations, without regard to harmony or beauty. Many scientists have considered it their task simply to analyze certain phenomena, functions or sensations, without any regard to the relationships of these phenomena to others. Other eminent scientists, however, are questioning the value of isolated observations made without regard to relationships. It is necessary to keep constantly in mind that analysis and synthesis should not be mutually exclusive, but rather mutually cooperative.

The worship of organization in this country has many dangers. To do big things, to encourage economic mass production, we form big machines, which work more or less automatically. A man at certain places in the machine performs certain motions which it can not be made to perform. But in doing this he becomes the slave of the machine; his actions depend upon those of the machine and hence become merely mechanical. In organizing hospitals, group clinics and educational institutions, there is a comparable danger. Each individual has a set task and a rate of motion imposed upon him by demands of the rest of the organization; this consumes so much of his energy that there is little left to apply to independent thought. Machines and organizations should do man's work and not his thinking; they should release his energy so that he may think. When they consume his energy and inhibit his thinking they are a menace rather than an aid to progress. Because applied science has made possible these wonderful and fearful machines with their consequent demands, many persons are asking to-day whether science, which has made them possible, has not failed in its object to better man's condition. They recognize that materially he may be more comfortable, and physically more healthy, but ask whether mentally he is superior to his predecessors and whether he has retained his freedom. We as scientists must face these questions and honestly try to determine wherein lies the fault. Have we in our zeal for analysis been trying to make science do too much? Have we allowed it to exclude certain elements present in the world and in man and as yet beyond its domain? Have we forgotten that its chief function is to answer the immediate *how* rather than the ultimate *why*? Is it not necessary to try to be artists in syntheses as well as scientists in analyses?

A strong feeling has also developed that science is not a part of general culture, but that art and the humanities represent the cultural side of man. In this attitude it is often forgotten that science in the past has played an important rôle in providing material for the artist. Knowledge of man's body, of his environment or of the universe is no less a part of real culture than is knowledge of man's past efforts. But is this exclusive attitude the fault of the humanities or of science? I venture to suggest that it is because the representatives in each field refuse to allow their own discipline to articulate or to come into contact with the other. In other words, there must be more working together with what all hold in common, and each must allow an influence to be exerted by what the other possesses as peculiarly his own. We must try to be artists in our syntheses and attempt to develop harmony from our mutual efforts. A few lines and pigments properly applied may produce a more effective picture than thousands of lines and much paint; on one page a poet may express a truer relationship than a scientist does in a monograph. The great requisites are the proper selection of material and imaginative synthesis to express what the artist sees. All human activities must mutually influence one another by expressing truth as we best can know it. This idea has doubtless been made articulate many times, but probably never better than by Plato, who defines science as the discovery of things as they really are, and further states, "Now when all of these studies reach the point of intercommunication and connection with one another and come to be considered in their mutual affinities, then I think and not till then will the pursuit of them have a value."

And so in the field of effort called clinical investigation we should constantly keep in mind the relationships of its various elements. The science of medicine should furnish us with knowledge and a technique for acquiring more knowledge. Although the art of medicine may indicate the manner in which that knowledge may be applied it should also assist in the technique for acquiring new knowledge. Because science can give us only a partial description of our universe, art must be ever at hand to supply the deficiency. Not all the art of medicine is at the bedside, nor all the science of medicine in the laboratory. In our respective activities the skill with which we mingle the two will determine our success.

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## QUANTITATIVE VS. QUALITATIVE STUDIES IN GEOLOGY[1]

IT has been quite habitual among geologists to record relative or qualitative accomplishment in geologic processes. We say "this topography is older than that," "resistant rocks weather more slowly than soft ones," "this volcano has erupted more than that," but we are not able to say how old in years or geologic periods either piece of topography is, how

[1] Presented to the Geology Section of the Ohio Academy of Science, Cincinnati, April 6, 1928.