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SCIENCE AND MEDICAL TEACHING[1]

PRESIDENT ELIOT, through the long years of his distinguished service, has begged for a larger cultivation of the sciences among our people and only recently he has demanded that such a wider tuition be introduced into our schools as a necessity of proper national reconstruction. The value of science to mankind is being everywhere more fully appreciated. It is of its prophets in the past that this paper is to deal.

In the preface to the fourth edition of Lavoisier's "Elements of Chemistry," as translated from the original French and printed in Philadelphia in 1799, one finds the following conception of the scientific method.

When we begin the study of any science, we are in a situation, respecting that science, similar to children; and the course by which we have to advance is precisely the same which Nature follows in the formation of their ideas. In a child, the idea is merely an effect produced by a sensation; and, in the same manner, in commencing the study of a physical science, we ought to form no idea but what is a necessary consequence, and immediate effect, of an experiment or observation. Besides, he who enters upon the career of science, is in a less advantageous situation than a child who is acquiring his first ideas. To the child, Nature gives various means of rectifying any mistakes he may commit respecting the salutary or hurtful qualities of the objects which surround him. On every occasion his judgments are corrected by experience; want and pain are the necessary consequences arising from false judgment; gratification and pleasure are produced by judging aright. Under such masters, we can not fail to become well informed; and we soon learn to reason justly, when want and pain are the necessary consequences of a contrary conduct.

In the study and practise of the sciences it is entirely different; the false judgments we may

[1] Address at the meeting for the award of honors to students of medicine of Harvard University, December 16, 1918.

form neither affect our existence nor our welfare; and we are not compelled by any physical necessity to correct them. Imagination, on the contrary, which is ever wandering beyond the bounds of truth, joined to self-love and that self-confidence we are so apt to indulge, prompt us to draw conclusions which are not immediately derived from facts; so that we become in some measure interested in deceiving ourselves. Hence it is by no means surprising, that, in the science of physics in general, men have so often formed suppositions, instead of drawing conclusions. These suppositions, handed down from one age to another, acquire additional weight from the authorities by which they are supported, till at last they are received, even by men of genius, as fundamental truths.

The only method of preventing such errors from taking place, and of correcting them when formed, is to restrain and simplify our reasoning as much as possible. This depends entirely on ourselves, and the neglect of it is the only source of our mistakes. We must trust to nothing but facts: These are presented to us by Nature, and can not deceive. We ought, in every instance, to submit our reasoning to the test of experiment, and never to search for truth, but by the natural road of experiment and observation.

Thoroughly convinced of these truths, I have imposed upon myself, as a law, never to advance but from what is known to what is unknown; never to form any conclusion which is not an immediate consequence necessarily flowing from observation and experiment.

Such, then, were the principles of this great master scientist of France as he wrote them a hundred and twenty-five years ago. And yet they seem vibrant with the teachings of our own day and generation. Perhaps it may be of interest to examine the growth of this modern mental attitude, especially in its relation to medicine.

The universities of Cambridge (founded in 1229) and Oxford (founded in 1249) were established at a time when authority was worshipped. It was not until after the revival of learning in Italy that the original versions of the ancient classics of Greece and Rome were brought to these English universities, there to be studied at first hand and the unknown culture of a bygone civilization revealed. In this way it was learned, for example, that Hippocrates (circa B.C. 430) had been misquoted by Galen, for the Father of Medicine in truth had remarked:

Whoever having undertaken to speak and write on medicine have first laid down for themselves some hypothesis to their argument such as hot or cold or moist or dry or whatever else they choose (thus reducing their subject within a narrow compass and supposing only one or two original causes of disease or of death among mankind) are clearly mistaken in much that they say.

This was a far more liberal doctrine than the interpretation of Galen († A.D. 200) who, in his medical definitions, says: "The elements of medicine, as some of the ancients thought, are hot and cold, moist and dry" and "Of what do our material bodies consist? Of the four elements, fire, air, earth and water."

So from this ancient fount of information Chaucer's doctor knew the causes of diseases:

He knew the cause of every malady
Were it of cold or hot or moist or dry
And where engendered and of what humour,
He was a very perfect practisour.

It is evident that the revival of learning in the fifteenth and sixteenth centuries, with its scholarly search through the buried classics, must have had a profound influence upon men's minds in its revelation of the forgotten past. That the elements of Empedocles, fire, air, earth and water, should have been the accepted basis of the chemical world for nearly two thousand years seems incredible to the modern mind. And yet, when one considers the past, one is forced to the conviction that the general adoption of revolutionary principles, as lately carried out in Russia, might once again reduce the world to the condition in which it existed during the Dark Ages. And one might conceive that a European or an American a hundred years hence might have to travel to Tokio in order to find a copy of the *Journal of Biological Chemistry.*

Galileo was born in 1564 and was the first great modern scientist who chose to trust his own observations rather than accept the teachings of authorities. In 1633 he was forced by the Inquisition to renounce his teachings. This was five years after the publication of Harvey's discovery of the circulation of the blood, which the intellectual world received with merciless criticism as being contrary to the doctrines of Galen. These were also the days of the Thirty Years War in Germany, a war of religious intolerance.

In 1651 Harvey published his "De Generatione," which was the finest piece of observation and analysis of his day. In 1656 he transferred property to his college which yielded an income of fifty-six pounds to be used as a salary for a librarian and to found an annual oration the object of which was "to search out and study the secrets of nature by way of experiment."

In 1660 the Royal Society of London was founded, the progenitor of which was the Royal Society Club, the oldest club in Europe. This latter was made up of men who clubbed together and ate their meals at a tavern, and the club still continues to dine weekly in London, drinking three toasts, "The King," "The Arts and Sciences" and "The Royal Society."

In Robert Boyle's "Hydrostatical Paradoxes," printed at Oxford in 1666, the preface begins:

> The Rise of the following Treatise being a Command imposed on me by the Royal Society.

Instead of being persecuted as Harvey had been, Boyle had the support of his friends of the Royal Society. On the last page of Boyle's volume he describes a biological experiment in which he had placed a tadpole under pressure equal to that of a column of water between two or three hundred feet high and concludes as follows:

> And yet all this weight being unable to oppress, or so much as manifestly to hurt, the tender Tadpole (which a very small weight would suffice to have crushed if it prest only upon one part of it and not on the other) we may thence learn the Truth of what we have been endeavoring to evince: That though water be allowed to press against water and all immersed Bodys; yet a Diver may well remain unoppressed at a great depth under water as long as the pressure of it is uniform against all the parts exposed thereunto.

We learn from this application of the Law of Pascal ("the ingenious Monsieur Pascal," Boyle calls him) how quickly the age of historical research liberated the mind so that an age of experimental observation set in.

Another hundred years roll around and bring to us the eccentric Cavendish, who discovered hydrogen and who was also a faithful attendant of the Royal Society; and Lavoisier, the master scientist of France; and our own Benjamin Franklin and Benjamin Thompson, the latter also known as Count Rumford.

Although the first half of the last century was a brilliant era in French science, it was not until about 1850 that Germany fully dissociated science from speculative philosophy and entered the field of scientific progress. Liebig, a pupil of Gay-Lussac, brought into Germany from Paris the knowledge of chemistry as it had been expounded by Lavoisier and Berthollet. It should be remembered that in the Middle Ages until 1618 Germany was a land of peaceful traders and there arose important cities, such as Augsburg and Nuremburg. In the latter city Hans Sachs had composed 6,000 pieces of poetry and Dürer had painted his wonderful masterpieces. It was a time of prosperity and cultivation, in evidence of which free public baths were being introduced into the cities in imitation of the Roman establishments. Then came the Thirty Years War, between 1618 and 1648, which is said to have reduced the population of Germany from 30,000,000 to 5,000,000 inhabitants. This war, carried on between Protestants and Catholics, brought abject poverty to the people, who reverted well nigh into barbarism. Germany was in this condition at the time of the founding of the Royal Society of London. Leibniz, who had visited Paris and London, was the founder and first president of the Academy of Sciences at Berlin which dates from the year 1700.

It is interesting to note that the town of Munich was put in orderly condition by Benjamin Thompson, who was born in the neighborhood of Concord, New Hampshire. Thompson, who was created Count Rumford, was a scientist of distinction and his work upon heat is acknowledged to be accurate and true. He exercised great influence in the kingdom of Bavaria and especially in the town of Munich. He found the soldiers indolent and he put them to work upon the land, thereby increasing the food supply. He studied the principles of stoves so that cooking might be done in the most economical manner. In 1790 he caused the soldiers to arrest within one week 2,600 beggars and vagabonds, who were also potential thieves, and put them to work, directing that it all be done in a kindly manner. This large number of indigents came from a total population of 60,000. Soup kitchens were provided and a soup made of bones and blood, the cheapest slaughter-house materials, was furnished for these workers. In this way he completely abolished poverty. The beautifully planned English Garden in Munich is another evidence of Count Rumford's capacity. This is a historical example of a distinguished scientific man in complete charge of a government. It finds a modern counterpart in the control of the Panama Canal Zone by General Gorgas.

The marvelous growth of German science since 1850 has been the admiration of the world. To the severely critical it may possibly seem to have passed through two stages; a first stage, that of the study of science for the love of finding out the truth, and a second stage, the study of science, because, as a German professor once wrote me, "pride in a scientific reputation as an incentive to ambition is not to be underestimated." One may also point out that no other nation more completely adopted the doctrines of Darwin, and that Koch continued the brilliant lead of Pasteur.

The other day, when speaking to my students of the work of Otto Neubauer upon the method of the deamination of amino-acids within the body, I called attention to the fact that this fine piece of work was not done in a chemical nor yet in a physiological institute but in the laboratory of the second medical clinic of Friedrich Müller in the town of Munich; that though we could celebrate with joy our victories over that vicious symposium of evil known as Prussian militarism, the leaders of which in cowardly manner have slunk out of harm's way, yet it would be unworthy of us if we could not continue to celebrate German triumphs of peaceful, scientific achievement.

About ten years ago I was in Berlin and heard bitter complaint that there was no money for new hospital buildings, no money for new laboratories, and all this because the Kaiser must have money for his new toys, battleships which were to be constructed. To-day, where are those battleships? Gone. Gone, also, the Kaiser. But the Charité Hospital in Berlin, with all that it has stood for in the history of medicine, still stands. Its past, at least, will endure and we have no right to wish anything for it but an equally brilliant future.

For the moment let us remember Longfellow's poem on Nuremburg:

> Vanished is the ancient splendor, and before my dreamy eye
> Wave these mingled shapes and figures, like a faded tapestry.
> Not thy Councils, not thy Kaisers, win for thee the world's regard;
> But thy painter, Albrecht Dürer, and Hans Sachs thy cobbler-bard.

There is only one thing that would be more stupid than our failure to recognize the importance of German scientific achievement and that would be that the Germans, having suffered disastrous and fitting punishment for the evil of their ways, should decide to exclude the thoughts and ideas, whether of morals, of art or of science, of those with whom they had lately been at war.

In the field of hospital nursing American institutions have long been preeminent. As a nation we have developed the quality of mercy to a high degree. This quality of mercy has been distinctly lacking in both the German character as well as in the administration of very many of their hospitals. But this quality of mercy is not the whole equipment of a modern physician, else the trained nurse or the Christian Science reader would be all-sufficient for assuaging the physical woes of mankind. Very much more than this is demanded of the physician, who has to interpret the derangements of the human body and attempt a reconstructive program. This knowledge can be obtained only from the biological sciences as applied to medicine.

It is interesting to follow the teachings of the brilliant school of French scientists which made Paris the rendezvous of the illustrious men of the continent. Lavoisier, in his "Elements of Chemistry," quotes the then recently deceased French philosopher, the Abbé de Condillac as follows:

> Instead of applying observation to the things we wished to know, we have chosen rather to imagine them. Advancing from one ill-founded supposition to another, we have at last bewildered ourselves amid a multitude of errors. These errors, becoming prejudices, are, of course, adopted as principles, and we thus bewilder ourselves more and more. The method, too, by which we conduct our reasonings is absurd. We abuse words which we do not understand, and call this the art of reasoning. When matters have been brought this length, when errors have been thus accumulated, there is but one remedy, by which order can be restored to the faculty of thinking; this is, to forget all that we have learned, to trace back our ideas to their source, to follow the train in which they rise, and, as Lord Bacon says, to frame the human understanding anew.

It is readily seen that such a standpoint as this, as well as that developed by Lavoisier and quoted at the beginning of this paper, would affect the ideas of thoughtful medical men. The French physiologist Magendie, who lived a generation later than Lavoisier and who was the founder of experimental physiology, wrote in 1836 in his "Elements of Physiology" the following words:

> In a few years physiology, which is already allied with the physical sciences, will not be able to advance one particle without their aid. Physiology will acquire the same rigor of method, the same precision of language and the same exactitude of results as characterize the physical sciences. Medicine, which is nothing more than the physiology of the sick man, will not delay to follow in the same direction and reach the same dignity. Then all those false interpretations which, as food for the weakest minds, have so long disfigured medicine, will disappear.

And this same idea was preached by Magendie's most distinguished pupil, Claude Bernard, when he said:

> The prudent and reasonable course is to explain all that part of disease which can be explained by physiology, and to leave that which we can not so explain to be explained by the future progress of biological science.

In considering science as a factor of human knowledge it is necessary to dissociate the mind from that provincialism which would hold that each country has its own special kind of science, a form of pleading which Rubner once endeavored to expound. American students, with their extreme loyalty to everything which may be good or bad about the educational institution to which accident may have attached them, are inclined to be narrow enough without accepting such a doctrine as this. The truth is the same whether it be in Boston or New York; in London, Paris or Berlin. Only the interpretation of the truth varies with the education of the mind of the individual. The inspiration and opportunity for seeking for the truth depends also on the human factors involved.

Before the war medical education in this country was rapidly advancing. In all the great centers men lived whose primary pleasure was the search for understanding regarding the complex processes of life in health and in disease. Such work brings joy to the worker or he would not do it. I recall a talk with my friend, Phoebus Levene. He had given a student the problem of finding the formula for chondroitin sulphuric acid and a year had passed without result. Levene said to his pupil:

> Work another year and then you will have it, and when all these men whose names are in the papers every day are dead, buried and forgotten, some one, long hence, when passing by will see this formula and will say of you "he painted that little picture."

To what extent this doctrine of future reward may affect the scientific seeker after knowledge can not be told, but there is no doubt that the chief origin of successful research lies in the love of it, and the joy of discovery of new things and their understanding. Of course, there are many factors which enter into the life of the adventurer into the unknown. One of the most powerful controls in scientific life is criticism. Pflüger has stated that criticism is the mainspring of every advance. Scientific criticism begins with the scientist himself, and then he extends it to others and in turn receives external aid in the revision of his own opinions. Sometimes this criticism is friendly; sometimes bitter. Questions of priority also arise. It seems that in the future the most courteous treatment would be to commence all polemical discussions under the caption "The errors of the author and his critics" and to remember that as far as priority is concerned a man's influence is equal to the sum of all the influences of his life and that questions of priority as between men are usually insignificant and unimportant. I overheard one of Voit's assistants say to him, "Your views, Professor, are bound to win" and Voit turned upon him in anger, saying, "It makes no difference *who* is right, so long as the truth is found."

The quality of mind is of interest in considering scientific types. Liebig was a dunce at school and his teacher ridiculed his ambition to become a chemist. Helmholtz studied the refraction of light with a prism under his desk during Latin recitations when he was a boy. Helmholtz, on the occasion of his seventieth birthday, stated that he had never had a great idea come to him when he was at his desk, nor when he was tired, nor after taking a glass of wine, but usually such had come to him when he was walking in the garden musing of other things. The scientist must have leisure to think over the problems which offer and he must have a certain discrimination in order to distinguish between the things which are worth doing and those which are not. To do this requires a certain delay in action in order that plans may be matured. The individual who can not be happy unless he is at work at full power all the time is much less likely to accomplish successful scientific work than he who will not commence a research until he has satisfied himself that it is worth doing. It is not to be denied that this essential qualification of scientific life is frequently regarded with scorn by the busy practitioner of medicine, who gives himself no time either for thought or study.

Though the capacity for discovering new things may not be given to all, yet all should have the training which comes from an environment, such as that existing in the Harvard Medical School, where the students are educated by men whose lives have been illumined by creative thought. Such men are patrons of the future, benefactors of mankind.

The war brought a temporary halt to promising activities. Many instances can be cited. In Bellevue Hospital Du Bois had just completed his calorimetric studies upon malarial fever. He was investigating the water output of the body during the night sweats in tuberculosis and, for the first time, the technic had been perfected so that this factor in the regulatory mechanism of the heat control could be studied. The declaration of war against Germany meant "down tools" for him, and he gave his services to his country. The important point now is to have the work completed with as little delay as possible.

But the war has also developed much that is of great value to the nation and medical science has been notably advanced in many lines. The work on "Trench Fever," edited by Major Richard P. Strong, of the Harvard Medical School, is one of the great medical triumphs of the war. It seems as though the value of science for the welfare of the nations of the world must have become more firmly defined in the minds of men than ever before. Let us hope that this is true.

Now is the time to take up the work where it was left at the outbreak of the war. It is our duty not only to continue but also to expand the work—to multiply facilities and to furnish a living wage. Scientific laboratories everywhere should be free from all commercial taint, which distracts and finally destroys. A laboratory should be a little community, happy in its daily life, and doing work worth while for the advancement of knowledge. The actual workers therein should be full-time men. Whether the titular chief should always be such is an undecided question and is largely dependent upon the personal equation.

Such laboratories as these are the glory of the Harvard Medical School. To the young men who are to be the leaders of the future belongs the present opportunity. The lands of Europe are wasted and impoverished by war. Only the wounded and the physically unfit were allowed to study medicine in England last winter. The men of England and the men of France have fought for four long years; ours for four months. The young physicians of America of the present generation have the obligation and may, perhaps, deserve the credit of establishing in the days to come, the dreams for medicine of Magendie and of Claude Bernard, thus insuring a notable scientific era in this great land of ours. Only thus can medicine progress; only through observation and experiment can the world grow in wealth of knowledge. We may thus endeavor, "as Lord Bacon says, to frame the human understanding anew."

GRAHAM LUSK

THE SMITHSONIAN "SOLAR CONSTANT" EXPEDITION TO CALAMA, CHILE

IN 1916 Secretary Walcott appropriated from the income of the Hodgkins Fund to equip and maintain for several years such a station in South America, but owing to the war it was temporarily located in the North Carolina mountains in 1917. The station proved very cloudy, and now it has proved possible though very expensive to go to Chile.

Dr. C. G. Abbott has reported to the National Academy of Sciences that after correspondence with the South African, Indian, Argentine and Chilean meteorological services he became convinced that near the nitrate desert of Chile is to be found the most cloudless region of the earth easily available. Dr. Walter Knoche, of Santiago, has most kindly furnished two years (1913 and 1914) of unpublished daily meteorological records for a number of Chilean stations. In his judgment the best station is Calama on the Loa River, Lat. S. 22° 28′, Long W. 68° 56′, altitude 2250 meters. For the two years the average number of wholly cloudless days is at 7 A.M., 228; 2 P.M., 206; 9 P.M., 299; and of wholly cloudy days, none. The precipitation is zero; wind seldom exceeds 3 on a scale of 12; temperature seldom falls below 0° or above 25° C.

The expedition, Director Alfred F. Moore, Assistant Leonard H. Abbot, reached Calama June 25, 1918, equipped with a full spectrobolometric, pyrheliometric and meteorological outfit of apparatus, as well as with books, tools, household supplies and everything foresight could furnish to make the work successful and life bearable. The Chilean government has facilitated the expedition in many ways, and the Chile Exploration Company has given the expedition quarters and observing station at an abandoned mine near Calama. Many others in Antofagasta, Chuquicamata and Calama have been of great assistance.

The apparatus is set up in an adobe building about 30 feet square, in which the observers have sleeping apartments. A 15-inch two-mirror coelostat reflects the solar beam to the slit of the spectro-bolometer. A Jena ultra-violet crown glass prism and speculum metal mirrors are used in the spectroscope The linear bolometer is in vacuum, and constructed in accord with complete theory for greatest efficiency. Its indications as measured by a highly sensitive galvanometer are recorded photographically on a moving plate which travels proportionally to the movement of the spectrum over the bolometer. Successive bolometric energy spectrum curves each occupying 8 minutes of time are taken from early morning till the sun is high and are thus recorded on the plate. Their intensity indications at 40 spectrum positions are reduced by aid of a special slide rule plotting machine.

A pair of silver disk pyrheliometers is read simultaneously with each spectro-bolographic determination. Measurements of humidity, temperature, and barometric pressure accom-