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SCIENCE AND CULTURE[1]

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"ON the truth of nature," declared Sir Francis Bacon over 300 years ago, "we shall build a system for the general amelioration of mankind." Bacon was voicing the first significant dissent from the old authoritarianism which had come down from Aristotle. "Let us look at the facts and then draw our conclusions," said Bacon, and while he was writing on the inductive method Harvey was putting it into practise in his demonstration of the circulation of the blood, "on the truth of nature." Descartes, having set analytical geometry on its conquering way 50 years later, exclaimed: "When we know the force and action of fire, water, air, the stars, the heavens and all other objects as we now know the various trades, we shall make ourselves masters and possessors of life. . . . This will not be solely for the pleasure of enjoying with ease . . . the good things of the world [he continues], but principally for the preservation and improvement of human health which is both the foundation of all other goods and the means of strengthening the human spirit." By a slight paraphrasis we may find in Descartes' words an outline of the great services of science during these 300 years: (1) Contributing to the ease and comfort and convenience of life; (2) the improvement of human health; and (3) strengthening the human spirit. Does any one doubt the first of these great services? Let him look back only a generation to kerosene lamps, wood stoves, horse and buggy transportation. Or the second? Let

[1] A dedicatory address delivered on the occasion of opening the new science building at Ursinus College, Collegeville, Pa., June 5, 1933.

him recall the typhoid fever epidemics of only 30 years ago—the last one in Philadelphia occurred while I was there as a student in 1900; the enormous mortality from tuberculosis only twenty years ago; the ravages of rickets in children of the tenements only ten years ago—all these and many other diseases either wholly brought under control, to remain so (if we remain civilized), or rapidly yielding to the science of prevention and treatment. True, there is much for medical science yet to do. Cancer, influenza and pneumonia remain unconquered, but there is definite hope in the case of pneumonia at least, and scores of scientific men are concentrating on cancer. Nobody doubts that the means of prevention or cure some day will be found.

May I point out here the intimate and wholly surprising relation between the economic depression and health and allude briefly to a personal experience? Late in November, 1932, I was summoned to Washington by the Surgeon-General of the U. S. Public Health Service and requested to represent him at a conference called by the Health Organization of the League of Nations in Berlin early in December. Dr. Kenneth Blackfan of Harvard also was invited. We met the representatives of Germany, France, Austria, Italy, England, Holland, Denmark and Belgium at the League office in Berlin on December 5, 6 and 7. The situation which the Permanent Health Committee of the League had discovered at its meeting in Geneva in September was this. The death rates and sickness rates of all the countries most affected by the economic crisis had steadily decreased since its precipitation in 1929. In Paris, Amsterdam, Warsaw, Cologne, Budapest, Milan and Prague—seven great cities of Europe which had been most carefully studied—there was, without exception, lower morbidity and lower mortality since 1929 than for the five-year average just before that date. With less money to buy food, less for clothing, overcrowding because of the necessity to save on rent, people were not dying so fast or getting sick so much as when they were prosperous. Here appeared a great mystery. But surely if people were not actually reporting themselves ill, they must at least be suffering from poor nutrition. Indeed, there were already many reports to this effect, and soon illness might break out with greater intensity.

The conference which we attended was given the task to lay out a program of study by which the nutritional status of necessitous people of the different countries could be rapidly determined and compared. A survey containing many of the features of our report[2] recently has been made in nine of our American cities. The situation with respect to tuberculosis was of special interest. This disease more than any other has declined more rapidly, as judged by the number of open cases reported, since 1929 than before. The principal reason seems to be this: *Compelled to rest because he has had no work,* the exposed person has resisted the disease better than if he were employed.[3] What does the physician do with us, if he finds tuberculosis already established in the lung? He puts us to bed and compels us to rest for several months. Nobody had ever thought of putting whole populations to bed as a means of prevention of tuberculosis; but that in effect is just what the depression has done.[4] Could anybody offer a stronger argument for the "amelioration of mankind," for mitigation of the storm and stress of life for multitudes of workers?

But my main theme has to do with the third great service of science, *to strengthen the human spirit.* Here lies the realm of true culture. Suppose we accept the definition of culture which was first given, I believe, by Matthew Arnold: Culture is the criticism of life, that is, criticizing life so as to choose what is worth while and eliminate that which is not. Without regard to material welfare what can these young men and young women of Ursinus gain from science that will strengthen this kind of a life? Three sources of strength at least. The first is confidence that the solution of life's problems lies in the use of reason, not passion, however lofty, nor propaganda, however clever. What better method of gaining confidence in the human mind than constant contact with the great masters of science who have achieved greatly with their minds. There is nothing so good as example in the application of common sense, and science, said Huxley, is only trained and organized common sense.

Observe Harvey laboriously studying the valves of all the veins of the body. All, without exception, open toward the heart. What could it mean but that the blood flows through the veins toward the heart? He grasped the blood vessels between his fingers on one side of a beating heart; the heart failed to fill. He grasped them on the other side; the heart failed to empty. What could it mean save that the first set of vessels furnishes blood to the heart; the second set receives it from the heart? Finally he placed a light bandage about the arm, the hand became warm and suffused with blood; he drew the bandage tight and the hand became cold and pale. What could it mean save that the superficial veins compressed by the light bandage carry blood up the arm from the hand, and the deep-lying artery, compressed only by the tight

2 *Quarterly Bulletin of the Health Organization of the League of Nations,* Vol. II, p. 116.

3 "The Economic Depression and Public Health," memorandum prepared by the Health Section, *Quarterly Bulletin of the Health Organization, League of Nations,* I, No. 3, p. 436; *ibid.,* I, No. 4, p. 507, 1932.

4 Obviously this does not express the whole truth regarding tuberculosis.

bandage, carries blood down the arm to the hand. Putting all these observations together, what could be the common-sense meaning save that the blood circulates round and round, ceaselessly flowing. Now perfectly clear to us, these matters once were completely obscured in uncertainty, because nobody until Harvey had the audacity to question the ancient doctrines of Aristotle and Galen, to trust his own senses and draw his own perfectly obvious common-sense conclusions. Can you imagine how that triumph strengthened the human spirit, gave it courage to seek the truth of nature at first hand?

For an entirely different picture of human audacity and triumph of mind observe Newton weighing the moon. The story as told by Voltaire, you remember, is that seeing an apple fall from a tree, Newton was led to wonder if the same force which pulls the apple to the earth may not extend its influence as well into great distances, and apply, for example, to the moon, or possibly to the still more distant heavenly bodies.[5] Obviously, said Newton, some force pulls the moon constantly toward the earth; otherwise it would fly off at a tangent, as a piece of mud flies off a carriage wheel, and it would never return. But it does return every 28 days.

The thought which came to his mind was this: Let me make a diagram illustrating the orbital course of the moon for a given period of time—say one minute. I shall then find that the moon departs from a straight line by a measurable distance; that is to say, it is pulled toward the earth by an amount which represents the difference between its observed position and the position it would have had, if its course were tangential. That difference, that fall every minute should agree with the law of inverse squares as do objects near the earth. The problem is a perfectly simple one which any freshman who knows his trigonometry can do. Newton undertook this calculation of the moon's fall, as he called it, first in 1666 and found, using the values then available for the moon's distance and the earth's radius, that the moon should fall toward the earth 13 feet every minute. On the supposition that the force of gravity decreases inversely as the square of the distance which Newton had found to be true for falling bodies at the surface of the earth, the fall should have been a little over 15 feet. I have known a good many freshmen who would let it go at that. The agreement was not good enough for a Newton and the problem never wholly escaped from his mind. Sixteen years later, upon learning that a French astronomer, Picard, had made more accurate measurements of the earth's dimensions (finding, for example, that 1° of the earth's meridian was actually 69.1 miles instead of 60 miles, which was the value Newton had used to get the radius), he at once took up again the problem of the falling moon. As he proceeded with his calculations he became more and more certain that this time the calculated displacement would agree with his law of inverse squares. The story goes, you remember, he was so completely overwhelmed with emotion that he was forced to ask a friend to complete the calculation. Can one imagine that emotion? For the first time the human mind had demonstrated to itself the obedience of a heavenly body to the same law that governs the falling of an apple from a tree. Newton saw that this same law probably compelled all heavenly bodies to their orbits as, indeed, was subsequently proved. What an uplift to the human spirit! LaGrange, who frequently asserted that Newton was the greatest genius that ever lived, used to add, "and the most fortunate, for nobody ever again could be the first to set the world in order."[6] The reflective mind captures the truth. Newton's mind by previous training and reflection was prepared for the incident of the falling apple. He himself tells us he was led to formulate the law of gravitation by "intending" his mind steadily to the problem for long hours at a time.

The story of Harvey's and Newton's discoveries illustrates early but outstanding successes of what we call to-day the research mind. Starting with an observation which may have been accidental or the result of mere curiosity, the research mind, unlike the ordinary mind, is compelled by some inner feeling of dissatisfaction to repeat and then to reflect upon the observation until an explanation is suggested. This may lead to experiment as in Harvey's case or to mathematical search for proof as in Newton's. Once conviction of a new truth is reached, clearness and forcefulness of presentation and courage in its defense bring the reward of recognition.

Seen from our present position, what made Harvey's and Newton's discoveries in their respective fields stand out like beacons on the dark coast of ignorance was the completeness of their proofs. When either of them had finished with a subject there was no longer any room for reasonable doubt.

We move forward 200 years. We are now at the beginning of the modern period of experimentation in biological science. Observations without number have been recorded, and Darwin has used many of them to prove that new species arise from old. If we wish to know *how* such a thing as the origin of new species could occur we must resort to experimentation. Incidentally, the new science of genetics is now ready to prove to you, not only that new species do occur, but how. If Bryan had lived only a few years more his challenge to the biologist to show him a single new species could have been answered with a number of

[5] Henry Smith Williams, "A History of Science," New York, 1904, II, 237.

[6] *Ibid.*, II, p. 250.

them, produced in the laboratory or the experimental field outdoors.

Observe the experimentalist at work. Let me give you two illustrations from France—Claude Bernard, the greatest physiologist of his time and founder of experimental medicine, and Louis Pasteur, the great chemist, biologist and founder, with Koch, of the science of bacteriology. Bernard was a man of marvelous skill in operative procedures. But he was much more, and we are not interested so much in his hands as in his mind. Let us see how his mind worked. As he himself has told us, "To the observer brooding over the phenomena which he has witnessed, there comes the thought that if a certain state of things were supposed to exist or a certain sequence of events were supposed to take place, the occurrence of the phenomena as witnessed would necessarily follow," and forthwith the scientific mind sets about to seek for evidence that the supposed state of things does exist or the supposed sequence of events does take place. "Observation starts an hypothesis and experimentation tests whether the hypothesis be true."

Bernard himself one day observed that the blood of a dog coming from the liver contained more sugar than the blood entering that organ, although the dog had been fed no carbohydrate. How could this be? The liver must produce sugar out of something else. What could that substance be? Possibly meat—the hypothesis. He feeds a dog on nothing but meat. Now no sugar at all is in the alimentary tract, no sugar passing from it to the liver—the experiment; and here's the answer, much sugar still coming out of the liver. The hypothesis is now a fact. The liver does produce sugar from protein, and at once we have learned why the diabetic person suffers emaciation, and a whole new field of chemical transformations in the body is opened up for further investigation. That field we now call intermediary metabolism and it answers such questions as these; how does the protein of the ox which you eat as beefsteak get transformed into substance of your own muscle? One crucial fact thoroughly proved and a thousand additional facts become available; they fall into line. Thus does knowledge grow and become organized into science.

In 1879 Pasteur was engaged in the study of chicken cholera. Returning from a vacation he found that some of his cultures of the cholera organism had become sterile. He could not produce the disease from them. About to throw away these old cultures, it occurred to him that it might be well to see whether a fresh young culture would produce the disease in chickens which resisted the old culture. To his amazement they resisted, while other chickens not treated with the old culture succumbed. With one blow not only chicken cholera was controlled, but the great principle of vaccination was explained.[7] DuClaux, the distinguished pupil of Pasteur, has written a book about him entitled "The History of a Mind." "What secret instinct, what spirit of divination," asks DuClaux, "impelled Pasteur to knock at this door which was waiting to be opened?" The answer is, the subconscious mind influenced by the incessant ponderings which had been going on in the conscious realm, coupled with the power of imagination. As Pasteur himself expresses the thought:

> The illusions of the experimenter form a great part of his power. These are the preconceived ideas which serve to guide him. Many of them must vanish in the long path which he must travel, but one fine day he discovers and proves that some of them are adequate to the truth. Then he finds himself master of facts and of new principles, the applications of which, sooner or later, bestow their benefits.[8]

It should be our aim in our teaching to preserve the atmosphere of the great minds of science, and we should not omit to study their lives constantly. Not having time in the curriculum for this, it has been our custom for many years to gather the staff and graduate students at our house once a month for readings and discussion in the history of science and particularly in the lives and works of the great men of science. Confidence in these great minds, which have known how to draw inference from demonstrated fact, how to apply common sense, how to knock at doors ready to be opened, is an essential part of the culture of modern education. For this is a confidence each of us should have in his own mind.

The second source of strength to the human spirit which science ought to furnish is the simple, unaffected pleasure of finding things out for oneself. Put the question to any one of the great scientists of the past, Why did you labor so long and so painfully at this problem of yours? Hear Harvey's answer: "It is sweet not merely to toil, but to grow weary, when the pains of discovering are amply compensated by the pleasure of discovery." When Pasteur separated from his mixture of tartaric acid crystals those which had right-handed hemihedral facets from those which had the left-handed and found that the former rotated polarized light to the right and the latter rotated it to the left, just as he had predicted, he received such a shock of pleasure that he left the laboratory immediately, incapable of applying his eye again to the polariscope. He was simply overwhelmed with joy. It was a game—an intellectual contest with nature—he had put the question in such a way that she was compelled to answer and to answer in the way he had guessed. It was the joy of conquest.

[7] E. DuClaux, "Pasteur: The History of a Mind," p. 281; translated by Erwin F. Smith, Philadelphia, 1920.
[8] E. DuClaux, *ibid.*, p. 280.

Listen to Kepler when he had completed the evidence which established his third law of planetary motion:

> What I prophesied two-and-twenty years ago . . . at length I have brought to light and recognized its truth beyond my most sanguine expectations. It is not 18 months since I got the first glimpse of light, 3 months since the dawn, very few days since the unveiled sun burst upon me. Nothing holds me; I will indulge my sacred fury.

Again the joy of conquest by one's own strength. This is still the attitude of the scientist. Dr. A. V. Hill, probably the greatest living biophysicist, expressed it well a few years ago by saying that men work at these problems mainly "because it is amusing."[9] We have encouraged our young men and women to rejoice in physical conquest. Have we taught them to rejoice equally in mental conquest? Why not?

I have spoken of scientific research as a game. Our laboratories, even the elementary laboratories, must be pervaded with the atmosphere of research. We must encourage the student to see for himself and reason from the observation to the explanation—for the pure joy of arriving at the answer for himself—just as on the playground, we encourage him to carry the ball, to sprint, pole vault, himself. Here is Huxley's description of the great game:

> The life, the fortune and the happiness of every one of us depends on our knowing something of the rules of a game infinitely more complicated than chess. It is a game which has been played for untold ages, each man and woman of us being one of the two players in a game of his or her own. The chess-board is the world, the pieces are the phenomena of the universe, the rules of the game are what we call the laws of nature. The player on the other side is hidden from us. We know that his play is always fair, just and patient. But we also know, to our cost, that he never overlooks a mistake or makes the smallest allowance for ignorance. To the man who plays well, the highest stakes are paid, with that sort of overflowing generosity with which the strong delight in strength. And one who plays ill is checkmated —without haste, but without remorse. My metaphor will remind you of the famous picture in which a great painter has depicted Satan playing at chess with man for his soul. Substitute for the mocking fiend in that picture a calm, strong angel who is playing for love, . . . and would rather lose than win, and I should accept it as an image of human life. Well, what I mean by education is learning the rules of this mighty game. In other words, education is the instruction of the intellect in the laws of nature, under which name I include not merely things and their forces but men and their ways.

[9] A. V. Hill, "Muscular Movement in Man," p. 1, New York, 1927.

And a little farther on it is added that "a liberal education should teach us to love all beauty, whether of nature or of art."[10] Professor Archibald Henderson recently has expressed this thought something as follows: "If art be defined as man's joy in the pursuit of beauty, science is the expression of man's joy in the pursuit of truth."[11]

The third source of strength to the human spirit which may be derived from science is the love of *truth—not* as something of one's own to be defended and advocated, but as something universal, belonging to all. Just as the player on a football team very properly takes pride in his own contribution, his higher motive is to win for his college—something bigger than himself. So the scientist, with a just pride in his own work and pardonable pleasure in winning the game—the true scientist thinks mainly of establishing truth for what good it may bring to his fellow man. Could Harvey claim that the circulation of the blood was his own property? Could Newton secure a patent on the law of gravitation?

We are learning slowly that it doesn't matter whose truth it is that prevails so much as it matters that we find truth which all fair minds can accept. The depression from which we are beginning to emerge has taught us that it is not important whether Democratic theories of government or Republican shall prevail—we are concerned rather to find a plan which will work. What if it does require some experimenting to find a method which shall bring a fair share of prosperity to the farmer—nobody well trained in science is afraid of an experiment as such—that's his everyday life. All science to-day is experimental. Why should not the science of government be experimental? The aim of the experiment in chemistry, in physics, in biology is to bring out the truth. Training in any or all of these sciences should fit us the better to apply any method no difference what its name, so long as it brings the truth. "Truth," said Coleridge, "is the highest good man can keep."

To be cultured one must be critical of life. To be justly critical one must have confidence in one's own reason, must find pleasure in working out one's own way of life and must prize the truth above anything else.

Life at Ursinus has taken on new value with the completion of the temple of science which you are about to dedicate. I congratulate President Omwake especially on this achievement, and all Ursinus students who are to have the opportunity of becoming devotees within the temple. I am not of that number

[10] T. H. Huxley, "Science and Education," p. 82, New York, 1898.

[11] W. A. Nielson, "Roads to Knowledge," Chapter on "Mathematics," p. 207.

who fear that a beautiful building will distract a man from his work. Beautiful architecture has a highly cultural effect; for daily contact with it brings a capacity to criticize the inferior styles and to appreciate the superior. Heaven knows we need such criticism in America! At the same time we must not lose sight of the fact that fine buildings and fine equipment do not make a college. There must be money to pay for brains. Superior men must be obtained and retained at all costs, even if it means that others must lose their jobs; for the service of the true scientist to these young men and women is the all important thing. They will miss an element in their culture which they can never obtain in any other way if they are not brought in contact with keen, productive minds. Science makes no claim to monopoly in the zeal for truth; but it does offer to-day the surest means of eliminating superstition and make-believe which still linger in the college atmosphere, of keeping one's feet on the ground, of gaining confidence in the processes of reason, and thereby strengthening the human spirit.

NOMENCLATURE OF THE HYDROGEN ISOTOPES AND THEIR COMPOUNDS

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THE separation in quantity of the hydrogen isotope of mass 2 has presented some interesting and very important nomenclature problems. The Nomenclature, Spelling and Pronunciation Committee of the American Chemical Society has been studying these. It has had the help of representatives of the American Physical Society. The committee has reached definite conclusions with reference to most features of the problem, but owing to certain circumstances thinks it best to make only an informal report in the form of this statement by its chairman at the present time. A similar study is being made in England. It is the hope of the committee that by submitting this informal preliminary report it will gain the advantage of suggestions from interested readers, with reference in particular to the more controversial points, as the question of symbols, and that it may be helpful in guiding usage during this early period of activity in which confusion in nomenclature is springing up. A formal report with definite recommendations can better be made a little later and it is promised.

It has been considered important to keep in mind certain general view-points in connection with this work. These take into consideration such matters as (*a*) the existence of many isotopes, (*b*) the fact that the isotopes of hydrogen are still forms of hydrogen and not new elements, (*c*) the effect of names and symbols on ease of thinking, (*d*) the teacher's viewpoint, (*e*) established nomenclature, (*f*) convenience and (*g*) indexing (this includes the use of indexes). An effort has been made to see the picture as completely as possible and with the broadest view.

Even so it has been considered justifiable to regard hydrogen as presenting a special case. Convenience seems almost to require special names and symbols for the hydrogen isotopes or at least for the isotope of mass 2. Hydrogen is a common element and its compounds are numerous (the whole field of organic chemistry is involved). The differences between isotopes of the other elements will no doubt be slight in comparison. Because of their large mass numbers other isotopes can be referred to by use of the element names followed by the mass numbers more conveniently than can hydrogen.

The committee is of the opinion that under most circumstances, as in compounds as a rule, just the name hydrogen and its symbol H will serve in place of a special name and symbol for the isotope of mass 1. As one committee member put it, "The fact that classical hydrogen has now been shown to have been slightly impure should not lead us to call it anything but hydrogen." It seems likely that there will be circumstances under which it will be helpful and in the interest of scientific exactness to have a special name and symbol for the hydrogen isotope of mass 1, but it is not proposed that the whole of our existing nomenclature for hydrogen and its many compounds shall be revised.

When the committee's work was started the isotope of mass 3 had only been predicted so that the committee did not include it in its program of work. It will no doubt be considered later.

For convenience the isotopes of mass 1 and mass 2 will be referred to as H^1 and H^2, respectively, in the remainder of this article.

Several names have been proposed for the isotopes. None of these has seemed preferable to the names protium and deuterium for H^1 and H^2, respectively, proposed by the discoverers of the isotopes, Harold

[1] Chairman of the Nomenclature, Spelling and Pronunciation Committee of the American Chemical Society.