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AMERICAN LEARNING WHEN PEACE COMES. "THE NATURAL SCIENCES"[1]

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IN a consideration of the topic of American scientific learning in the post-war world, it must be understood that perhaps no other fields of human endeavor are as international in scope and attitude as are the natural sciences—astronomy, biology, botany, chemistry, geology, mathematics and physics. A great deal that can be said concerning these subjects goes far beyond the limits of national boundaries and is of importance to all human beings. However, it appears definitely worth while to consider specifically the problems of American scientific learning when peace comes so that the contributions to the natural sciences which must be made and, it may be predicted, will be made, by American scholars and workers, can be seen at least in outline and can serve as a goal to be attained. The problem of American scientific learning will be discussed on the basis of three factors: the world background as seen by scientific men, the basic qualities of the human intellect, curiosity and imagination, upon which depends all progress in the natural sciences, and the special tasks which American scientists must face in so far as these problems concern the position and growth of American scientific learning in the period following the present conflict.

In an endeavor to consider these questions one might well insist that the only problem of importance at the moment must be the winning of this global war, since failure in this task would make irrelevant any further discussion concerning the position of American scientific learning when peace comes once again. But such a negative attitude would certainly lead to no improvement in the lot of humankind and a more sensible, in fact, a desperately necessary view is to

[1] This is the second of a series of ten Baconian Lectures given under the auspices of the Baconian Club, State University of Iowa, Iowa City, Iowa, on October 8, 1943.

bring the problems confronting all peoples after the war into the light now, so that the future of mankind may be established on a more logical basis than has been done in the past. Will the human race have to go through an abyss of darkness, which is war, at periodic intervals; or is there hope that a new and more abundant civilization can appear on the surface of this earth? Scientifically trained men believe that the economic basis of human existence on this planet will be so profoundly affected by future scientific learning, discovery and invention and the subsequent repercussions in the economic sphere will be of such magnitude, that an age of plenty will be initiated where the present economic and political struggles between empires will tend to disappear. Perhaps no individual can offer at this moment a reasonable solution of current international difficulties as long as millions of people need food and clothing of which there is a scarcity. War and strife may be inevitable in a world in which 50 per cent. of the wealth is enjoyed by about 6 per cent. of the population. It is to be hoped that future generations will solve the problem of the distribution of wealth on a more equitable basis so that they may look back upon the present period with horror and unbelief, wondering how the social and economic injustices of to-day could ever have been perpetrated by so-called human beings. Mankind may well pray that future economic systems will not involve the existence of want in a world of plenty. May future generations learn to use the God-given abundance of this earth with wisdom and consideration for all, so that they need not curtail production while there is still want. Scientists may hope that their work and efforts will lead to a continued increase in the usable physical wealth of the world. They believe this enrichment will lead to a steady improvement in the relationships of nations, so that contending groups may gradually acquire knowledge of a proper basis for living together, just as individuals have found a way of cooperating in a society. Surely nations will learn to live and let live and some day evolve a system of association free from mistrust and suspicion and thus really attain more closely the ideal of the Golden Rule.

Hence the basic thought of this thesis is that a better world civilization will be possible because the economic foundation of human existence will be profoundly altered by future scientific discovery and invention. More of the world's goods will be produced at less cost to all through scientific research. Scientific thought and learning are the very foundation on which the progress just outlined must be built. Great strides have already been made, but an enormous amount of work must be done to create a world based on greater abundance.

For the further analysis of scientific learning it is necessary to discuss the second point of this theme; namely, the two qualities of the intellect, curiosity and imagination, which are fundamental so far as science is concerned. On this basis it is possible to understand past performance and whatever future progress may be expected in the realm of scientific study and research. The present-day sciences would never have been established had there not been individuals with abounding curiosity who were willing to overcome their inherent laziness and spend time and effort, without thought of reward, in order to learn about the physical universe surrounding them. However, an inquiring mind alone would never have produced the present edifice of scientific knowledge had it not been coupled with productive imagination. The latter is the most important quality of the human intellect in relation to the advancement of scientific learning.

It is an enticing exercise to let the imagination take its flight into the future and to attempt to visualize the world of to-morrow as conceived by the scientist of to-day. The basis of this projected thought picture, must, however, be the performance of the past, so that the description rendered may not take on the cloak of ridiculous fancy nor the shape of naive fallacy. Nevertheless, errors of too great conservatism must equally well be avoided. If the advances in the natural sciences for the last few decades are considered in retrospect, it is clearly seen that the possibilities of the future are great. It is to be hoped that the picture on the whole can be an optimistic one and the consensus of opinion of scientists warrants indeed a promising outlook in spite of the dreadful events which hold men chained at present to undertakings completely destructive and utterly senseless on any rational basis.

Because psychology is the science concerned with the systematic investigation of the mind and since imagination refers to a certain category of the functions of the human intellect, it is natural that the psychologist should render an analysis of the imaginative mental process. In the early history of psychology imagination was simply defined as the ability of having mental images or pictures. However, very soon a distinction was made between the mental activity of recalling images of earlier experiences, now called reproductive imagination or memory, and the formation of new mental pictures from a combination of already known ones. This latter performance can be called productive imagination, and it is this faculty which is of interest at the moment. The imaginative exercise may be defined as the process of conjuring new mental patterns from the background of experience. The verb, conjure, is used advisedly because of its usual reference to the practise of magic.

Productive scientific imagination is certainly mental magic in the realm of scientific possibility. The sequence of mental steps involved in creative scientific thinking leads to the formation of new and hence unexperienced pictures and ideas. These new constructs of the mind must in the case of the natural sciences remain within the framework of scientific law. Hence they can not be pure fantasy. However, an audacious spirit, not too hampered by conservatism, will lead the way to further achievement. Time and again discoveries and inventions have been announced which have reached beyond the wildest flights of the imagination of even the most daring dreamers of an earlier day. It must be said that imagination is the most far-reaching power in all the world. Creative imagination lies at the basis of every great achievement accomplished by man. The minds of all the great explorers were filled with imagination. These men were consumed by a burning desire to find out what was hidden beyond the geographic horizon. This country, this America, was at one time but a dream in the mind of a Viking discoverer. This university was but a picture on the mental canvas of its founders. Does any one doubt that these men of 1850, could they be here to-day, would be amazed beyond measure to see this edifice of learning? Can it be believed that ninety years ago, they could have imagined this great institution as it is to-day? One instinctively feels that their ability to visualize the future could not have been daring enough to portray what really exists here now. Need then the scientist be timid or afraid in his own contemplations of the future? Surely after looking about and seeing the accomplishments of the human race up to the present, he may throw caution to the winds and soar into the future with all the daring enthusiasm he can summon!

It is obvious that imaginative thought is important in all fields of human endeavor. Not only does the geographic horizon incite the mind to wonder what lies beyond and, being based on visual stimuli, conjure up pictures of places and peoples strange to one's actual knowledge, but also other stimuli may arouse the imagination. One type of sense experience either perceived or remembered can be the impetus to imaginative thought processes involving fruitful speculation in other directions. A picture or a painting may give rise to the stirring of the imagination as also may a play or a book. Worlds of thought and fancy may arise in the mind from a poem heard and remembered. One truly marvels at the complexity of the imaginative process!

Turning now to the third point of this thesis, namely, the special tasks of American scientists when peace comes, it is evident that they must direct their thoughts and energies to the problems of a war-weary world. Clearly America must play an important and guiding role in the rehabilitation of the stricken peoples of this earth. A note of warning seems necessary, for it must be realized that this nation is using up its physical wealth in fuel, metals, forests and soil unstintingly at a truly alarming rate. It is certainly questionable whether or not this continent can feed all the war-torn populations. Hence, from the point of view of the dwindling resources of this country, the possibility must be borne in mind that the United States may also become a "have not nation." Her scientists will then be confronted with new problems of inventing substitutes for materials of which there is no longer an abundance. No doubt their ingenuity and imagination will bring forth a multitude of new products which will in turn initiate unforeseen developments in every phase of human endeavor.

It is indeed a fascinating undertaking to revel in predictions concerning the state of things to come in the near future. In astronomy it may be expected that the two-hundred inch telescope at Mt. Palomar will be finished and put into operation, opening new vistas of the cosmos to closer scrutiny. The Schmidt telescope and camera will very likely be constructed and should rival the two-hundred-inch instrument in power and possibilities. Astrophysicists will make further progress in their field. The age-old question of the origin of the solar system may be solved by an acceptable theory. The newer ideas indicating that solar energy arises from a series of nuclear transformations will be further discussed and developed. On the practical side astronomy will further improve the method of marine and aerial navigation. Already a tenfold increase in precision of time measurement has been made since World War I, and further advances along these lines will lead to even better control of ships and planes.

The physicist will undoubtedly carry on his investigations of the decomposition of the nucleus of Uranium isotope 235, and the tremendous amounts of power released from this fission of an atomic nucleus may be harnessed. A new form of available energy would thereby be created surpassing present means of procuring work from coal, oil and waterfalls. Even now, the warring nations, including the United States, are said to expend vast sums of money in research along these lines, to be sure at the moment directed towards the destructive purposes of war. Should it be possible to carry out this age-old dream of taming the enormous energies hidden in the atom, a new era of technology would undoubtedly be initiated.

In connection with possible power developments one can not forget the suggestion of obtaining energy from the sun by direct means, instead of depending on accumulated stores such as petroleum and coal.

Simple solar heaters have been used for decades, but large-scale units are only in the blue print stage. So far coal and oil have furnished power for industrial use more economically. The post-war period will need power projects not dependent on dwindling resources. Energy equal to twenty-one billion tons of coal which the sun showers on the surface of the globe every hour offers fascinating possibilities. At the moment the difficulty is one of expense, since large and costly installations would be needed to convert solar energy directly into useful forms. But to-morrow's reality is woven from the dream fabric of to-day! Imagine that Icarus of Greek mythology could come to life and observe the modern aeroplane! Would he not admit that reality had reached beyond his wildest visions? May it be hoped that the human spirit still possesses similar daring and adventure!

After the war American physicists will be able to return to their atom-smashing machines and obtain further information regarding the atomic nucleus. The electron microscope will bring molecules of matter into the field of direct observation. Instead of magnifications of the order of 5,000, as obtained with the ordinary microscope using visible light, magnifications of the order of twenty to fifty thousand are even now possible by substituting electrons for radiation and by replacing lenses by electric and magnetic fields. Already very large molecules have been photographed and the progress that can be imagined by further improvement of the electron microscope is really breath-taking. Had any one, only twenty years ago, mentioned the possibility that molecules can be seen, he would have had his reason questioned, for the idea is utterly fantastic and preposterous to any one acquainted only with the ordinary microscope and unaware of the possibility of substituting electron stream for light beams. More detailed knowledge of matter in exceedingly small dimensions or on the level of molecular size will bring great technical improvements in manufacturing processes.

The biologists will continue their studies of the living cell, especially from the point of view of physical chemistry. No research group is required to have a larger background of learning than does the scientist who interests himself in the phenomenon of life. The complex structures of living organisms appear to be the culmination of all natural processes known to mankind. Life seems to be the highest form of creation, certainly when considered on the basis of complexity and intricate composition, as well as in breadth of function. Hence, it is not to be wondered at that scientists have not yet learned the secret of life. However, biologists will persist in their tasks and they will undoubtedly make the most far-reaching contributions to scientific learning not only in the post-war period but also in the more distant future, especially in the field of genetics, which will be of immense value to the human race in numberless directions. Of greatest immediate importance appears to be the study of molds and yeasts which may well revolutionize the world's food situation. Yeasts can be grown in a nutrient medium and they will there reproduce themselves very rapidly. Recent researches in this country show that molasses, ammonia gas, water, air and yeast may be mixed in large tanks where the yeast will grow to furnish an edible material rich in proteins and vitamins. It is entirely feasible that this biochemical method may become a serious competitor to our cattle raisers in the matter of furnishing protein foods for the nation. Flavors can be synthesized by the chemists making the yeast-cake more palatable. Furthermore, the biologist and geneticist are already developing various strains of yeasts yielding materials of different tastes. Enthusiasts visualize a new method of food production, more economical and less cumbersome and adaptable to the crowded regions of the globe. The program is now in its initial stages, and no doubt great developments may be expected in the very near future. Mankind has used yeasts as food for centuries in bread and ale, but these newer researches will give these lowly molds an entirely new role in human nutrition.

It should be noted, however, that, after all, the yeast cells must eat and the sugar or molasses must still be obtained from vegetation. As long as the chemist is unable to carry out photosynthesis in test-tubes, it will be necessary for the botanist and plant geneticist to continue their labors and produce for human consumption ever greater varieties of plants. The amazing performance of hybrid corn is too well known to be discussed in detail. Similar and equally startling developments are just beyond the horizon. From the plant kingdom is obtained cellulose, perhaps the most versatile material in technological use. Just as the past century has been called "the age of steel," so it has been predicted that the coming era will be called "the age of cellulose." If present demands on the iron ore deposits of this country continue for any length of time, there is no doubt that a serious metal shortage will have to be faced and many articles of commerce will be made from synthetic lumber or artificial wood derived from cellulose specially grown for this purpose under the guiding hand of the botanist and treated by the chemist for its varied uses. Moreover, cellulose when digested with water and acids changes into starch-like materials and sugar-like substances which have nutrient value and can serve as food. This wonderful substance in the form of lumber can house man; in the form of cotton and rayon, it can clothe him, and after chemical treatment, it can serve as his food!

The thought just expressed, that the present metal economy may be changed as the natural resources of this country dwindle, leads to the consideration of possible new supplies and how to find them. Geology in one of its aspects is responsible for the fundamental knowledge which is necessary for the discovery of new deposits of oils and minerals. While it is easy to picture the coming period as the age of flight, where every American family will own its model T helicopter, it remains to be seen where the gasoline is to come from to lift the whole nation into the air and move it at great speed through the clouds. The planes can be built from plywood if necessary, but where the fuel is to be obtained—that is another question! No doubt geologists using refined methods of detection as improved by geophysicists will be able to discover new oil fields, but the process can not go on indefinitely, and some day this nation will have to use its shale deposits and rely on the synthetic fuels obtained by chemists from the hydrogenation of coal. Luckily there exist within the borders of the United States enormous deposits of low-grade coal, which by chemical methods may be made to yield fuels needed to replace the natural petroleum. The dream of an air-age must be scrutinized carefully on the basis of the fuel economy if it is not to be mere fantasy. As in the case of petroleum, the advances made by the physicists in the use of short-wave radio equipment may also help the mineralogist in the discovery of new deposits. However, such ore developments may happen in other regions of the globe, as yet not as well explored as the land-mass of this continent. Large deposits of high-grade iron ore are known to exist in South America. The oceans may have to step into the picture and furnish light metals as is now the case with magnesium. The American geologist has a serious task to perform if this nation is to maintain its preeminent position as an industrial power. In its more theroetical aspects as a branch of scientific learning, geology in its many divisions will make its contributions to the advancement of human thought in the post-war period as it has done in the past.

Turning now to the chemistry of to-morrow, it can be said that a similar vista of new and startling developments can be expected in the realm of chemical learning. No doubt chemists will continue their studies of the structure of molecules, they will obtain more satisfactory knowledge of reaction mechanisms, and they will make further progress along the present line of theoretical chemical thought. The impact of this advance in fundamental chemical information on the applied field will be indicated in the improvement which is expected in chemical technology. The time interval between the discovery of new scientific knowledge and its application in industry is ever being shortened and, furthermore, industrial research laboratories themselves are turning their attention to basic theoretical investigations in their own respective fields. This great mass of scientific learning will make it possible for American chemists to furnish to the economy of the nation the prerequisite power resources and materials needed by industry. The problem of substitutes will be ever more important, and synthetic rubber and plastics will have an even more significant role to play in the post-war period than they do now. A greater variety of artificial fibers such as rayon and nylon will be produced; new types of glassware like pyrex will be available; more powerful fuels will drive the engines of to-morrow, and the light metals, aluminum and magnesium, will find enormously greater industrial uses. The most spectacular and important progress, however, is predicted in the fields of biochemistry and chemotherapy. Every one now knows of sulfa-drugs and of penicillin. The latter is obtained from a lowly mold and has remarkable therapeutic value. No doubt chemists will isolate, analyze and synthesize the active substance, and make it available to the public at reasonable cost. Another newcomer is clavacin, from a different mold, which may be even more remarkable in its ability to kill bacteria than is penicillin. Vitamin research will continue, and in the field of immunization it may be expected that antibodies will be prepared in glass flasks instead of obtaining them from animals in the present tedious way. Advances in scientific knowledge will be made along all lines of scientific endeavor. It must be realized that the various fields of human learning are so complex and interrelated that progress in one goes hand in hand with advancement in another.

Newer concepts in mathematics make it possible for the physicist to evolve a new theory of the atom, which induces the chemist in turn to change his ideas of chemical combination. No natural scientist, be he biologist, botanist, physicist or chemist, can hope to keep abreast in his field of learning without a thorough knowledge of related topics and especially of mathematics. The queen of the sciences rules the domain of scientific learning, but for homage paid, she gives great return. No category of human thought affords greater satisfaction than the ability to state logical propositions in terms of mathematical symbols, and to arrive at exact conclusions by mathematical operations. Mathematics is the universal scientific language, and any nation neglecting this subject will lose its place in post-war competition. By the same token it is necessary to find those individuals of the younger generations who have the God-given aptitude to become the scientists of to-morrow, so that they may carry on the torch of scientific learning. Were it possible to settle the problems of mankind on a rational basis rather than on the present emotional plane, the world of to-morrow would be a better place to live in.

The scientist has hope. Even though he now looks upon a distorted world of victor and vanquished, he knows that real progress will be made, for in his imagination he sees a future which will be an improvement over the past.

In chapter twenty-one of Revelations it is written of the future of a new Jerusalem:

And the building of the wall of it was of jasper, and the city was pure gold, like unto clear glass.

And the foundations of the wall of the city were garnished with all manner of precious stones. The first foundation was jasper; the second, sapphire; the third chalcedony; the fourth an emerald; the fifth sardonyx; the sixth sardius; the seventh chrysolyte; the eighth beryl; the ninth a topaz; the tenth a chrysoprasus; the eleventh a jacinth; the twelfth an amethyst.

And the twelve gates were twelve pearls; every several gate was of one pearl and the street of the city was of pure gold as it were transparent glass.

Should scientists accept these scriptures as a challenge? If not taken too literally, they have already done so.

An old Chinese philosopher has said of a gentleman: "To see clearly; to understand what he hears; to be warm in manner; dignified in bearing; faithful in speech; painstaking in his work; to ask when in doubt; in anger to think of difficulties; in sight of gain to think of right!"

All these qualities scientific men must possess and one more—imagination! With the ability of creative thought applied to their fields, scientists will transform the world!

OBITUARY

EDWARD BURR VAN VLECK
1863–1943

ON June 2, 1943, a leading figure was plucked from the ranks of American scholars, and especially from those of American mathematicians, through the death of Edward Burr Van Vleck.

Professor Van Vleck was born at Middletown, Conn., on June 7, 1863, the son of John Munroe and Ellen Maria (Burr) Van Vleck. His college training he received at Wesleyan University, Conn., from which he graduated in 1884. His graduate studies in mathematics and physics he pursued at the Johns Hopkins University from 1884–87, and, after an interim during which he served as an instructor at his Alma Mater, at the University of Göttingen, Germany, from which he received the doctorate in 1893.

Professor Van Vleck's period of activity as a teacher and mathematical investigator may be regarded as having properly begun with his acceptance of an instructorship at the University of Wisconsin in 1893. Simultaneously with this he took membership in the American Mathematical Society, and thereby actively affiliated himself with that group of young scholars whose enthusiasm and attainments were largely instrumental in establishing in America mathematical standards and research comparable with those of Europe. Of this group he was one of the first to make his home in the Middle West. Although Wesleyan University again called him in 1895 and held him in a professorship until 1905, he thereupon returned to Wisconsin to spend there the remainder of his life. His retirement from active teaching came in 1929.

The development of American mathematics during the first quarter of the present century was phenomenal, and in this Professor Van Vleck played a prominent part. He become a member of the council of the American Mathematical Society in 1902, and was a "Colloquium Lecturer" before this society in 1903. He served the society from 1905–10 as an editor of its *Transactions,* in 1908 as its vice-president and during the years 1913–14 as its president. The mathematical literature over a period of many years is dotted with papers of his on infinite series; on functions defined by ordinary differential equations; on continued fractions; on point sets; on functional equations; on the roots of polynomials, etc. As a teacher he stood at all times for the highest standards of scholarly integrity. A considerable number of America's more accomplished contemporary mathematicians have at one time or another come under his influence.

Professor Van Vleck was the recipient of many honors. Aside from the offices through which the American Mathematical Society honored him, he was distinguished by Clark University (1909) and Wesleyan University (1925) as a doctor of laws; by the University of Groningen (1914) as a doctor of mathematics and physics; and by the University of Chicago (1916) as a doctor of science. The French government named him officier de l'instruction publique (1920); he became a member of the National Academy (1911); and he held the chairmanship of Section A of the American Association for the Advancement of Science (1912).

In his person Professor Van Vleck was modest and