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RESEARCH, AN EDUCATIONAL ASSET[1]

IT is eminently fitting that the university should pause in the midst of its busy life to do honor to those students who have won distinction by their scholarly achievements. Educators of our day have complained that the "side shows" of our educational system are attracting more attention and receiving more generous support than the main purposes for which the system itself was established. Many a bitter complaint has been registered against the custom of lionizing the athletic hero and ignoring the student who has outstripped his fellows in the intellectual pursuits of the classroom. That such a tendency exists few will deny, but the evil, if such it be, can never be corrected by complaint nor by eulogizing the intellectual giants of the good old days when higher education was the privilege of the select few and the masses of the people were denied the educational advantages of which our modern democratic civilization is so proud. The purposes of Honor's Day and its associations are to recognize excellence in scholarship and to furnish in some tangible fashion a reward for leadership in the intellectual pursuits of college life.

There have been many definitions of the term education, but the ones that appeal most to me are those which take into account the development of the human mind as a preparation for better living. That person may be considered educated who has learned to adjust himself to his surroundings, who can live comfortably and successfully under unusual conditions, who can turn defeat into victory and use obstacles as stepping stones to success. We may consider any one undeveloped educationally who has not learned to accommodate himself to the conditions under which he must live and to meet the problems of life with a stout heart and firm determination to do his part in making the world a better place in which to live. It is to one of these factors in mental development that I desire to call your attention for a few minutes this morning.

Much has been written concerning the value of research and its place in a modern educational system. There seems to be little doubt concerning the value of investigations which have to do with the control of diseases, the utilization of by-products or the increase of food production. The successful completion of such a project prolongs life, decreases the cost of living or tends to increase human happiness and so

[1] Honor's Day address at the University of Illinois.

they have a practical aspect which presents a strong appeal. But any undertaking which can not point in advance to a practical application, which will not fill a long-felt want or which can not be immediately commercialized in figures of astonishing size is frequently looked upon as a useless expenditure of time and money. Any discovery of which it must be said "it is of scientific interest only" has little interest for the practical man who wants results and who insists that our educational system must be so constructed and operated that it will turn out practical men and women of the everyday world.

But the value of research is not always easily determined, since its bearing upon life is usually not evident at first. When Newton discovered the law of gravitation its value was not appreciated; when Dr. Morton first used the principle of anesthesia it must have been regarded as a useless curiosity; when Lavoisier discovered the element, oxygen, the practical men of his day probably asked "What of it?"; when Pasteur announced his germ theory of disease, no one realized its importance. Yet from each of these investigations there has sprung a modern science which is contributing in a large way to the comfort, safety and well-being of the human race. These have been discoveries of basic importance, yet in their infancy they seemed impractical, visionary and of scientific interest only.

Previous to 1860 the methods of identification of new substances required tedious and painstaking work upon the physical and chemical properties of the material under examination. The invention of the spectroscope by Robert Bunsen permitted the study of gases and incandescent solids by noting the wave length of the light which each absorbed or emitted. Soon this instrument was recognized as furnishing an efficient means of detecting the presence of new elements, and in its various modifications, spectrum analysis has been directly responsible for the discovery of nearly all the elements since the spectroscope first became available. It was first used in studying the atmosphere of the sun in a total eclipse which was visible in India in 1868. As a result of this study, the eminent British astronomer Lockyer reported a bright yellow line whose wave length did not agree with that produced by any known substance. Accordingly it was concluded that there must be a substance in the sun's atmosphere which did not exist upon the earth. The name helium—the sun element—was given to this substance and for twenty-seven years scientists speculated about its nature and its relationship to the earth. In 1895 Sir William Ramsay discovered that helium could be extracted from certain minerals and in 1903 Cady and McFarland reported that certain natural gas supplies in southern Kansas contained appreciable quantities of helium. Here was a succession of discoveries of great interest to scientists, but of so little practical application that they attracted little or no attention, and so they were all but forgotten. But when the Great War broke out and modern methods of military operation demanded the use of innumerable balloons for observation work, a new and serious problem arose. The gas hydrogen is inexpensive and efficient for the inflation of balloons, but it has one serious handicap—it is highly inflammable. A flash of lightning from a passing cloud, a flaming bullet from an enemy aeroplane or a spark from the dirigible's own motor and the balloon instantly becomes a roaring furnace with an appalling loss of life and property. An immediate and urgent demand arose for a light gas which would not burn and the only gas of that type known is helium. It was a courageous suggestion, for the largest quantity of helium which had been collected at that time was probably less than one hundred cubic feet and the cost was about $1,700 per cubic foot. At that rate the value of the helium required to lift the simple weight of an average man would be over three and one half million dollars. The application of modern scientific methods to the purification of helium has decreased its cost thirty thousand fold and permitted the United States government to prepare enough of the gas to fill four of the ordinary type of kite balloons before the signing of the armistice. While the development of this project did not come soon enough to aid in saving life during the war, it has contributed much to the safety of aviation in lighter-than-air craft, and the generous supply of helium in this country is to be regarded as one of the most important items of defense at our command.

While we are proud of these developments and watch with interest the growing importance of helium in aviation and in scientific pursuits, we should not forget that the discovery of the element, the finding of commercial quantities, the methods of extraction, purification and use are all due to the culmination of problems of research in pure science, which at first seemed wholly impractical and without useful application.

But it should not be necessary at this time and in this place to multiply examples of this kind to prove the point that research frequently has an importance greatly in excess of the expectations of its promoters. Even if we admit that nine out of every ten research problems fail to benefit the human race directly, it is clear that the tenth is sufficiently important to overbalance the cost of all ten.

But why should business be interested in research? It is doubtless unnecessary to argue in favor of any investigation on such problems as the methods of in-

creasing sales, improving manufacturing processes or utilization of waste materials. The value of such undertakings is evident to all. But in what way is the American business man interested in problems of pure science which may have no apparent bearing at all upon his business? The history of American business has shown that all too frequently the value of scientific research is ignored with disastrous results to a business which seemed to be as well established as Gibraltar itself. Let us look for illustrations to prove this statement.

Several years ago a firm was organized to put on the market a new variety of food products. The process was original, the product attractive and soon a thriving business was established. The process involved many chemical steps and the firm employed a chemist to develop the details of the work. When the business had become well established and the profits were coming in nicely, the manager summoned the chemist to his office and said: "We are now well established, our process is working satisfactorily and we are satisfied with our products. We appreciate the help you have given us but after the end of this month we shall not need your services any longer." Shortly after this interview, the chemist removed to another state and lost contact with his former associates. After several years he returned for a visit, expecting to see a greatly enlarged and thriving factory. Imagine his disappointment when he found the doors nailed up and the windows bearing mute testimony to the unerring accuracy of missiles from the hand of the small boy. As he looked upon the scene of desolation there appeared above the door an inscription, invisible to all save him, in these familiar words: "We are satisfied with our product."

In January, 1925, there was a thriving industry in this country producing wood alcohol or methanol and its by-products by the distillation of wood. The total investment in this industry was more than $100,000,000, while its annual production was about $35,000,000. The industry was one of our most flourishing enterprises, securely entrenched and supplying an essential basic material to several important industries. Two months later this prosperous industry was seemingly on the verge of complete wreck with almost a complete loss of the invested capital. What had happened to produce so sudden and so complete a change? Methanol was being manufactured in Europe from cheap raw material and the product was being imported by the United States at a price much below the cost of manufacture from wood. The American manufacturers, feeling secure in their position as producers of an essential basic material, had failed to remember that chemists are able to make rapid strides in the development of chemical manufactures. Failing to appreciate the importance of fundamental research, they had allowed the chemists of both France and Germany to develop a new process which means the entire remaking of their industry. It not only appeared certain that our wood distillation industry was doomed, but it also seemed likely that we would be compelled to manufacture our methanol under license from the German patentee. during the fifteen-year life of the patent. It is not to our credit to know that we are saved from such humiliation by a technicality of our own patent laws.

In one of our thriving mid-western cities there is a firm which may be called The People's Ice Company. Recently it enjoyed a practical monopoly in supplying ice to the homes, stores and factories in the entire community. Business was good and the future looked promising since growth was substantial and refrigeration is essential in the handling of food products. But in spite of optimism the sales began to drop off and the businesss was very evidently losing ground. Upon inquiry it was found that more and more the stores and homes were installing individual refrigerating plants which were operated by electric motor. It was evident that something must be done to save the business, for the days of the ice wagon seemed to be numbered. Investigation showed that the electric refrigerating process was based on well-known principles of physics and chemistry, so a group of scientific men was set at work to build an equipment which could compete with other devices of the sort. The experiment was successful and now The People's Ice Company is introducing its own appliances throughout the length and breadth of the land. By the time the ice wagon has disappeared from the city streets the business activities of the firm will be so completely adjusted to the new situation that the change will be welcome. In this case research has built a larger and broader business to meet the changing demands of a scientific age.

These illustrations are sufficient to indicate that research is a vital part of business if success is to continue in this rapidly advancing age of ours. Few industries are safe from the revolutionizing influences of scientific achievement unless they are constantly on the alert for the latest developments in their fields of endeavor. To discontinue research, to feel satisfied with the product, to fail to advance is to drop behind in the procession of modern scientific accomplishment. To attempt to stand still is to invite disaster in the rush of modern traffic.

Do these statements seem extravagant or over-enthusiastic? Is a scientist getting out of his field when he attempts to emphasize the importance of science in the business world? If so, then listen to a few sentences taken at randon from an article on "Science

and the Investor" published in a recent number of one of our leading metropolitan commercial journals:

> There is no business to-day whose welfare and interest are not bound up with chemistry. . . .
>
> There is no industry that is not in danger of waking up to-morrow and finding that the chemist has made a discovery that might revolutionize it. . . .
>
> No industry which does not command the resources of scientific laboratories can be regarded as secure. . . .
>
> No investor or banker can feel sure that his interest in any security is secure in the absence of the assurance given by the knowledge that science is on guard. . . .

These quotations sound like the enthusiastic endorsement of an over-zealous chemist, but it must be remembered that they were written by a man who is not primarily a scientist, but the financial editor of one of our greatest business journals. His best advice to prospective investors in any business undertaking might be epitomized thus: "Be sure the institution is keenly alive to the importance of scientific research before investing in its securities."

Similar testimony has recently been given by the vice-president of one of the largest banking institutions in New York City. He was quoted as saying in substance:

> When any New York banker is called upon to finance any corporation or business especially one based directly or indirectly upon scientific pursuits, the first investigation made is in regard to the attitude of the institution toward the advancement of scientific knowledge. If there is maintained a scientific laboratory with a generous regard for the advances in pure science, the security is, to that extent, considered good. But if no attempt is being made to keep up with, or a little in advance of the developments in science, then no considerable loan will be risked upon such a venture. Permanent business success is too intimately linked with scientific attainment to make any other attitude safe.

It is not to be presumed that these students of economic conditions had in mind any particular branch of science to the exclusion of others. For what is true in this respect concerning chemistry is true with equal force of physics, of engineering, of the social sciences, of business relations and many other lines of human endeavor which are touched by the advances of our modern civilization.

Perhaps all this seems far removed from the everyday problems of life. We might have little difficulty in reaching an agreement as to how research should be used to improve and stabilize big business, but how may it be applied to the everyday events and activities of our own existence? I believe the training received in investigational work and the mental attitude developed by it may be made a very potent factor in education, which should after all be a training for a useful and full-rounded life.

Research has been defined as a careful or critical inquiry or examination in seeking facts or principles; a systematic investigation of phenomena by the experimental method, to discover facts or to coordinate them into laws; a critical examination of conditions as we find them with the desire to improve whenever possible. In simple language research may be regarded as childish curiosity, grown to maturity and given a college education. The term "pure research" is sometimes used to refer to pursuit of knowledge for its own sake, to a search after truth for truth's sake, without a thought of the present or future value of the results. Consequently, there is an element of unselfishness in pure research, and the seeker after truth has no concern in the practical value of his discoveries. Many of civilization's most notable achievements have resulted from this unselfish spirit of research workers; this spirit has blessed the world thousands of times and it is still the actuating motive of a very large army of workers in various fields of human endeavor.

One of the most valuable assets to be obtained through the medium of education is the ability to think clearly and to analyze a complicated problem, putting the various factors into their proper relationship and value. Such a process is as truly research as the discovery of unknown lands in the polar seas, the perfecting of a new method of combating disease or the building of a new chemical compound. If we can subject the ordinary problems of our life to the careful scrutiny of critical examination; if then we can apply to these everyday matters the spirit of pure research with the unselfish desire to improve, to benefit and to serve, then we shall in some small measure justify the existence of the system of education of which we are a part. Study your job intently, whether it be the running of a great railway system or of a disc harrow; whether you are called upon to preside over a legislature or a country school; whether you wield a scepter or a broom. Bring to your task the spirit of research, of improvement, of service and of devotion; for by so doing work becomes a joy, a blessing, a benediction.

I congratulate the honor students of the University of Illinois for the excellent accomplishments of the past. It is no small achievement to be selected from so large a student body for the distinction of Honor's Day. You are to be congratulated upon your ability to keep in mind the prime purpose of a college education as well as for the excellence of your classroom records. I hope you feel a real pride in this accomplishment and I trust that you are inspired with the

determination to win new marks of distinction in whatever line of activity you may engage. I hope you have enjoyed the work in which you have been employed, that you have worked industriously in working hours, that you have played intently in hours of recreation, and that you have enjoyed the companionship of your associates in hours of relaxation. If this has been your record, you richly deserve the honor which is extended to you to-day. But however great our satisfaction for the good work of the past, I congratulate you more heartily for the opportunities which are opening before you. You are soon to become active factors in a world sick of war, worn by strife and perplexed by intricate political and economic problems. There is a great need for men and women who have been trained to think, to weigh, to decide and to act. Become an investigator of conditions as you find them and do your best to improve wherever you can. I congratulate you most heartily for the opportunity for hard work, intelligent accomplishment and useful service.

"So long as men shall be on earth
There will be tasks for them to do,
Some way for them to show their worth;
Each day shall bring its problems new.

And men shall dream of mightier deeds
Than ever have been done before:
There always shall be human needs
For men to work and struggle for."

B. S. HOPKINS

UNIVERSITY OF ILLINOIS

THE NEED FOR TRAINING TAXONOMIC BOTANISTS[1]

TAXONOMY is fundamental in its relation to other branches of botany in the sense that the correct identification of plants is the basis for all work which concerns the identity of species. Comparison of the results of investigations has value only in so far as there is certainty as to the plants compared. The cytologist compares the number of chromosomes in the allied species and their hybrids in a complex genus like Rubus or Rosa. The value of his conclusions depends on the accuracy with which his specimens have been identified. The pharmacist compares the oils derived from various species of oil grasses found in commerce. A taxonomist had to work over the group to which the oil grasses belong before the comparison was worthy of record. The proposition is so evident that further support would seem unnecessary.

I have shown in another place[2] that taxonomy was a dominant branch of botany during the early development of that science; that during the last half century taxonomy has lost that dominance; and that now, especially in this country, that branch of botany occupies a distinctly inferior position as compared to other branches. This unfortunate condition hampers the symmetrical development of botanical science as a whole. Taxonomy has its place as a primary coordinate branch of botany and its growth should be encouraged that it may keep pace with such other primary branches as physiology, morphology and genetics.

Within recent years the demand for exact information on the identity of species has become more insistent. This is noticeable in connection with the exploration and development of tropical regions. Those interested in the vegetable products coming from these regions wish to know the specific identity of the plants producing these. When chaulmoogra oil came into prominence in connection with leprosy it was found that the identity of the species producing it was uncertain. At once a taxonomic study of the group concerned was necessary. Information in such cases can be furnished only by the taxonomist. However, the number of taxonomists with sufficient training and experience is at present so limited that information can not be furnished as rapidly as wanted. In other words, the demand at present is far greater than the supply.

In another direction the demand exceeds the supply. It is now difficult to find trained young men or women to fill positions in taxonomy. At the present time there are positions awaiting properly qualified applicants, and there appear to be no such persons available.

The chief source of supply of people for positions requiring previous experience in taxonomy is the larger herbaria of the country of which there are few. The source of supply for these herbaria is the college graduates who have taken an interest in taxonomy and have specialized in that subject. In the main we must depend upon our colleges to equip students with sufficient training to fill positions requiring a fair knowledge of the principles of taxonomy. In my opinion the colleges are not doing this to the extent necessary. In fact I believe the colleges in the aggregate are not giving the attention to taxonomy indicated by its proportional importance as a primary coordinate branch of botany.

This condition appears to be due to two reasons, the lack of trained taxonomists in our colleges and the lack of interest in the subject itself. In the latter part

[1] Read at the meeting of the Botanical Society of America, systematic section, held at Nashville, December 28, 1927.

[2] "The Scope and Relations of Taxonomic Botany," SCIENCE, n.s., 43, pp. 331–342, 1916.