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RESEARCH IN THE SERVICE OF THE STATE[1]

EVERYTHING has a beginning—even commencement. This annual festival of American colleges which we celebrate to-day traces back centuries ago to the medieval universities, where in form it was quite different from the present-day commencement.

The antecedent of this occasion was known in medieval times as "inception," and marked the admission of the graduate to the career of teaching. Hence the custom was for those who received the bachelor's degree to be invested with the insignia of the new rank —often the cap and ring—be placed in the master's chair and "incept" or begin to teach. Our word *commencement* was borrowed from Cambridge University, where the earlier form had been modified, and the first commencement exercises in this country were held at Harvard in 1642. In course of time the day came to be not only of academic importance but one of great festivity, evidently leading to excesses at times, for we read that in 1722 sumptuary laws were passed in this state prohibiting "commencers" from providing refreshments or liquors in their chambers, with what success we need not inquire at this remote date.

The medieval formalities of "inception" later developed into the expounding of theses or the defense of dissertations by the graduates and still later into the delivery of orations. Latterly it has come to be a listening-in occasion for the graduating class and their friends alike, with an address by an outsider, an innovation which in my student days would have been a welcome relief. But the world continues to move, and still another change may be in store. Already we have courses of instruction given by radio which do away with the need of assembly; may not the radio commencement, therefore, be waiting just around the corner?

However, for the class of '25, this is your day and for all of you it marks an inception, if not into teaching into a new stage in the working out of a career. It is the close of a preparatory period which helps the student to find himself, to understand his relations to the world and inspires purpose within him. Higher education is still limited to the few, amounting to less than one per cent. of the entire population in this country, or only about two per cent. of those of adult age. Every twenty of you

[1] Commencement address delivered at the Massachusetts Agricultural College, June 15, 1925.

who graduate thus represent a group of one thousand adults, taken the country over, 980 of whom do not have the privilege of a college education and only 140 of whom finish high school. Hence the obligation this privilege implies.

The advantage of the college course to the individual and to society depends on his understanding of the purpose of education, the use he is prepared to make of it and the attitude it helps him to acquire toward life and growth. For college teaches men how to live and how to grow, as well as how to make a living. Education deals with what is known not merely for the information it gives, but as a means of looking forward and preparation to meet conditions the future will bring, realizing that the future will be very different from the present. In this sense, education prepares for future building, giving a receptive mind toward what is new. Away from the environment of study, absorbed in making his start in life, the graduate must fight against allowing himself to fall into a rut, against losing the challenge of his mind which makes him a live, effective individual, instead of a link in the chain to be used by others.

We recognize it as a law of nature that the tree, the plant, all living things, must continue to grow in order to live. Likewise the man must continue to grow and develop if he is to be a living factor; to advance with the forward movement of the world and our knowledge of it. And the same holds true for society and for the state. They must have within themselves the elements of progress which enable them to keep abreast of the times. This brings me to the central theme of my subject—research as a means of growth and power.

It is an old saying that what man doesn't know he doesn't worry about, but however blissful ignorance may be it usually turns out to be very expensive. Man has learned by hard experience that lack of knowledge has been the greatest source of his ills and worries and mistakes, and that the acquisition of knowledge is the surest way out. Most of what we know that is reliable, the epoch-making inventions that fire our admiration, a very large share of the material and intellectual progress of the world, rest back on the results of research—the determination of sound facts and their correct interpretation.

Research is the process by which we learn new things about the world and the forces around us, how to bring ourselves into harmony with them and how to use them. It discloses, as Carlyle said, "the inner harmony of things; what Nature meant."

Knowledge is a human product revealed to man through his efforts. It is built up for the most part by minute additions made by many workers. The French scientist, Berthelot, expressed this idea when he declared that "if each of us adds something to the common domain in the field of science or art or morality, it is because a long series of generations have lived, worked, thought and suffered before us." This is another way of saying that our civilization, our knowledge, such mastery as we have attained have been built up step by step; that progress is essentially an evolutionary process.

We are told that in the beginning man was given dominion over the world, but it is only by very gradual stages that he has fitted himself to exercise that dominion. The power came slowly at first, and for many centuries was delayed. It is estimated that mankind has been on the earth five hundred thousand years, a period so long we can hardly comprehend it; and yet it is maintained that fully half the knowledge we have of nature and of control over it has come within the past hundred years. What has been achieved, even, affords only a glimpse of what may be accomplished through science and its teachings; and many equally revolutionary changes may be expected before this graduating class holds its twenty-fifth reunion.

A discovery rarely emerges full-fledged and complete in its potentiality and application. It is unfolded by degrees, often with but slight conception at first of its full significance. Sir Oliver Lodge recalls that Faraday's first magneto-electric machine, the forerunner of the dynamo, produced such insignificant results that a member of the Royal Institution, after a demonstration of it, asked what on earth was the use of it. A dignitary of the church, however, had a larger conception of its possibilities as a new tool in the hands of incendiaries, which led him to deplore the discovery. An apparently insignificant beginning may embody immense potentialities.

"We live forward, but we understand backwards," as a Danish thinker said. Knowledge comes before understanding or the application of it. We must know the forces and the conditions under which they operate before we can take advantage of them. What is discovered to-day can be used to-morrow. What we do not understand to-day we shall understand to-morrow, and it will help us to see and act more rationally.

Research is a study of relationships. One of the most important of these is that of man to the earth. His great struggle is not only to adapt himself to his environment, but to devise means by which he can make his environment subservient to him. This is what is being done to-day through the physical and biological sciences; and there are few more

striking applications of it than in the field of agriculture. That industry, which touches the lives and well-being of all the people at so many vital points, was late in receiving the benefits of science. This fact tended to make it backward and inefficient to a degree that led thinking people in Europe a century and a quarter ago to feel real concern for the future food supply of the growing population.

It was a gloomy view, but in keeping with the times and the prospect as then seen. For many hundred years man had been unable to increase greatly the yields of the principal crops. In fact, there had been practically no improvement in the agriculture of western Europe from the fall of the Roman Empire up to the close of the eighteenth century, when the Malthusian doctrine was announced. There had been little suggestion of the increase in productivity to be effected in food plants through breeding and selection, the stimulation of the soil by fertilizers and better handling, the more adequate return from farm animals and the increase of man's resourcefulness in a thousand ways.

The situation gives a striking background against which to project the remarkable changes which soon began to portend the new day of an efficient and enlightened agriculture. For the nineteenth century not only witnessed the greatest revolution in farm practice the world had known, but it ushered in the beginning of systematic research in agriculture, notably in agricultural chemistry, which gave new conceptions of the life of the plant and its relations to the earth. This was soon followed by the establishment of the experiment station, that powerful agency for applied science which has few counterparts, and which steadily has spread to every civilized country. The manifold results of the investigation thus stimulated have been felt by practically every branch and phase of agricultural production, not only, but have changed the attitude toward that industry. Its benefits have not been confined to the farming people, but have been shared in by other industries and by the people as a whole.

Understanding goes before improvement. As a first step toward a correct understanding of the plant and its environment, research dissolved the age-long mystery of how plants feed and how crops grow. The world waited long for such information, for it was scarcely a century ago that it became known. Gradually the plant was disclosed as a group of living factories, more wonderful than those made by man, drawing a part of their raw materials from the soil and much the larger part from the air, and from them elaborating a great multitude of different products.

This was an important starting point for determining what is essential and how improvement can be wrought. We no longer look upon the soil as a purely inert material but as one teeming with microscopic life which is influenced by tillage and in turn influences the process by which the plant gets raw materials from this source. We realize that the plant has to feed itself first, and then store up a reserve or surplus in tissues, seeds and other products, which man intercepts as return for cultivation. The greater the efficiency of the plant or crop as a factory for elaborating food or fiber or other desired materials, the more valuable it is for cultivation; and the provision of suitable soil and cultural conditions enables the plant to yield its largest return. It is this increase in efficiency of the crop, its quality or special adaptation and its favorable response to treatment that is the aim in plant breeding, culture, fertilizer and other experiments all along the way from seeding to harvest.

The proof that certain classes of plants, through partnership with nodules on their roots filled with bacteria, take up and use the nitrogen of the air in supplying the needs of growth was a great stride, an accomplishment in technique which has made every farmer more intelligent about the rôle of legumes.

Experimentation has given far more productive staple crops of higher quality, has introduced new crops for special purposes and greatly extended the area of successful farming in unfavored regions. Corn-growing, for example, has been pushed steadily northward more than three hundred miles beyond what was formerly believed to be possible. Fruit-growing is a profitable industry in many localities where formerly only the hardiest sorts could be grown. A new industry has been provided in the production of sugar from beets, and possibilities in that line developed which would make us independent of outside supply if necessity should require.

Science has given more appetizing and attractive food products prized by all—the perfect specimen of fruit, superior vegetables throughout the year, a greater variety and healthful preserved products. In fine, it has made more secure and satisfying the answer to the universal prayer to "give us this day our daily bread," by its constructive work in every branch of food production, including the improvement of cereals, their milling and baking.

Research does for the farm exactly what it does for the industrial plant—studies the operation at each step to see how it may be improved or made more economical, and measures the output of these natural factories to determine their efficiency. And it does more; it safeguards the output in another way.

For production is a continual contest; eternal

vigilance is its price, and that vigilance must be guided. The more intensive production becomes, the more severe the contest with diseases and pests, with the forces of evil against the powers of light. The farmer unaided is powerless to cope with these things until he has been shown. The specialist is required not only to diagnose a new trouble but to work out the mysteries of its life history and its relationships, the means by which it is propagated and spread, and determine its susceptibility to treatment. Left to itself the trouble means waste and destruction, possibly the ultimate discontinuance of that crop; studied by the expert, its successful control may mean only a slight change in cultural practice.

The working out of a mysterious destructive disease of potatoes whose cause could not be seen but only its effects, the means by which its death virus is spread from plant to plant by lice sucking the juices of the leaf they feed upon, and finally the demonstration that these invaders live over, not on the potato but on the rose bush, supplies an example of the deliberate, purposeful forging of a chain of evidence that is typical of constructive research, for it combined with imagination, perception and intelligent study the indomitable will to know.

Plant quarantine now checks the introduction of pests to prey upon our field crops, gardens, orchards and forests, albeit after hundreds of such pests unwittingly have been allowed to enter which reduce crop yields by more than a billion dollars a year. The setting up of such safeguards resulted from the teachings of research and supplies a type of prevention more mighty than cure—and far less costly.

After the food has been produced research stands guard over the quality of it until it reaches the consumer. This relates not only to freedom from adulteration but to wholesomeness of manufacture and healthfulness of the product. The provision of a supply of clean, wholesome milk the year around, free from the dangers of disease, is a benefit which reaches every family, and it is a notable result of agricultural investigation. Indeed the whole industry of dairying and dairy farming, the selection of more productive stock, the development of the silo and more rational feeding, and the manufacture of dairy products of all kinds has been revolutionized by agricultural research, to the great advantage not only of the farmer but likewise of those who enjoy a more uniform and higher quality of products. The same type of activity has disclosed the dangers and the channels of transmission through food of diseases like tuberculosis, with the result that neglect of known precautions has become a crime against society. It thus has an important relation to public health.

It may not be realized that the study of human food and nutrition in this country originated in the experiment stations, or that the work done there and in the national department of agriculture has been one of the chief means of bringing home the importance of proper nutrition and the basis for it. The subject of vitamines, for example, their sources and the malnutrition diseases, like rickets, scurvy and other troubles which result from their deficiency in the diet, has long been one in which the stations have taken a leading part. The bearing of these studies on the normal development of children in towns and cities is even more applicable than in the country.

The discovery that a disease of cattle in the southern states is transmitted by a tick and can be controlled by the elimination of that carrier may not have meant much to the people at large at the time, but it gave a wholly new conception of the spread of such dread diseases as yellow fever, malaria, typhus and others by insect carriers. Is it too much to claim this by-product of agricultural research as one of the most significant additions to medical science, making possible among other things such triumphs of sanitation as enabled the construction of the Panama Canal?

To realize the full importance of research in agriculture it is necessary to understand the part this industry plays in our business, our commerce and our well-being. Statistics are stupid things until interpreted to show what they mean. The fact that nearly twenty billion dollars worth of agricultural products a year are essential to the operation of leading manufacturing industries in this country may signify little beyond a figure incomprehensible to most of us. But when we learn that this amount comprises from one half to two thirds of the total value of raw materials entering into all manufactures, we see how indispensable agriculture is to these great industries.

Not only does manufacturing demand enormous quantities of agricultural products, but these must have special qualities to meet the need—a desirable hardness of wheat for milling; flavor, aroma and burning qualities in tobacco; size, attractiveness, uniformity and various other requirements of the trades. Agriculture is now remarkably responsive to these trade requirements, thanks to research. Is a long-fiber cotton needed—it is developed and adapted to growth in suitable locations; does change in the process of manufacture call for a shorter staple—strains are produced which combine with this quality a yield which enables the farmers to grow it; does the packing industry call for products of special

quality—experiments are made in the production of that quality on a commercial scale. The farmer as an individual producer would be wholly unable to supply such standardized products without the aid of investigation.

These things make clear the reciprocal interests of farming and manufacturing and the direct benefit of research to both lines. The great manufacturing state of Massachusetts, in addition to drawing its food very largely from sections quite remote, is dependent on agriculture outside its borders for most of its raw materials. Measured in value, considerably more than half the total output of its factories is manufactured from products of the soil. Its industries could not survive a single year without these supplies drawn from the south, the west and foreign lands, and the maintenance of both volume and quality is absolutely vital. Thus the benefits of agricultural research are not bounded by state lines; they are no less real to this commonwealth than in the regions where its raw materials are grown.

Research is itself a process of learning, but not all centers of teaching are likewise centers for enlarging the field of knowledge. A conspicuous feature of the group of institutions to which this one belongs is that they are fulfiling the double mission of centers of teaching and agencies for learning. It is this that has made them truly democratic—not merely for the few who come to their halls, but for all who will take advantage of the practical results of their research spread broadcast.

The people of this country have built up the most comprehensive and effective system for agricultural research to be found anywhere, represented by the federal department of agriculture and the state experiment stations. The station system started in Connecticut fifty years ago, with an appropriation of less than $3,000, and it is interesting to note that plans are under way for a national observance of this important anniversary at New Haven a few months hence.

In the development which has taken place in the half century, the New England states have had a leading place, noticeably so in the earlier stages. The names of Atwater, Johnson and Jenkins in Connecticut and of Jordan in Maine will stand out as pioneers who supplied ideals on which the American stations rest; while our own Goessmann, Fernald and Brooks will be remembered with great honor for their notable contributions which led the way in channels that were new.

From these small beginnings the experiment stations have grown to a national system, with an aggregate maintenance fund of $10,000,000 a year, equivalent to the income from an endowment of $200,000,000 —this for a twenty-five billion dollar industry from which half the entire business of the country, half the tonnage value of the railroads and a large share of the commerce arise. To-day these stations, with the federal department of agriculture, constitute one of the most powerful agencies for the benefit of human welfare in any line.

If some great aggregation of wealth should announce the provision of an endowment of $200,000,000 for research, it would call for the largest type the newspapers had and would be heralded as a great benefaction. Such an endowment would be a remarkable tribute to the appreciation of this type of service—and it is, the more so because it expresses the judgment of the people in forty-eight states. The latest congressional measure, to go into effect next month, came as a response for relief of the agricultural industry. It is a great endorsement, for it represents the mature judgment that agricultural prosperity can not be assured through special legislation, but that safe advancement must rely on sound knowledge of scientific and economic principles to be worked out through research.

Out over the country, stretching from this eastern boundary to the Pacific and beyond, is a small army of zealous, faithful workers spending their lives in research for agriculture—for the benefit of the consumers as well as the producers in that field. They represent an infinitesimal proportion of those to whom their labors mean very much. Many of them have come from this institution. They are a product in which to take genuine pride. They have helped to make agriculture what it is, and they look forward to increasing usefulness. For they are builders of vision, the men who can!

We glory in the man who can;
We glory in his might and mastery.
We glory that within the sullen clod
His eyes have read the secrets of our God;
That his own hands have grappled with the key
For fellowmen to set those secrets free.
We glory of his deeds to tell;
And it is well.

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RESEARCHES ON INSULIN[1]

I. IS INSULIN AN UNSTABLE SULPHUR COMPOUND?

IN the early autumn of 1924 we were invited by Professor A. A. Noyes, director of the Gates Chem-

[1] From the Gates Chemical Laboratory, California Institute of Technology, Pasadena, California. Carried out under a grant from the Carnegie Foundation.