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THE RELATIONS OF AGRICULTURE TO OTHER SCIENCES

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THE subject assigned me is Agriculture in Relation to Science. For this subject, almost cosmical in its vastness, I offer no apology, but ask your indulgence while I attempt to point out a few of the achievements of the new agriculture and to show their relation to the advancement of civilization. While the progress has consisted partly in opening up such lands as are not highly cultivated to people who can cultivate them, its chief progress has been in the improvement of man's methods of cultivating the soil and of using plants and animals to support his ever-increasing numbers. Since population is increasing rapidly and more food is required each year to support the life of the people born into the world, unless the production of food becomes greater in proportion to the unit man and the unit acre, starvation awaits the race. In 1899 Sir William Crookes argued seriously, before a meeting of the British Association, that the world's wheat-supply is already threatened by the failing fertility of the available soil. As the low average of less than thirteen bushels per acre means starvation for the rapidly increasing population of wheat-eaters, when he found the limit of available wheat-lands nearly reached, he saw no hope for the race except by increasing the fertility of the soil.

Man has, however, shown a wonderful ability to utilize the different

food-materials and to produce increased supplies from a limited area when he has been compelled to do so. The Harlemer polders support nearly two and a half persons to the acre, and in portions of China and Japan five or six persons often get their living from this extent of soil. These lands, however, are exceptionally fertile. But even on an average acre of land, where the ordinary farmer would make only five dollars' worth of produce, gardeners can easily make five hundred dollars' worth. For these and many other reasons we cannot be very much alarmed about mere food for the race.

It is a narrow view of agriculture, however, which regards this great art only as a means of providing men with the simplest means of existence. We are interested in the progress of agriculture not only as the means of supplying the food necessary for the increasing peoples of the earth, but as the art which chiefly supports man's advancement along all lines, intellectual, moral, and spiritual, as well as physical. "Man shall not live by bread alone." It is a condition of civilization that man is not satisfied with a mere subsistence, but that his wants increase with his development. The modern man is not satisfied with the simplest food or the plainest raiment, or the barest shelter. He wants attractive and delightful food, because such food promotes health, happiness, and the development of his finer nature. Hence there have been developed the various special branches of agriculture and horticulture and the many arts of milling, manufacture, preparing, and preserving the products of the soil so as to make food-substances tempting and delicious, as well as convenient for use. The American people, for example, owe much of their success as purveyors to the clever methods of preparing food-materials of all kinds, and to their skill and taste in presenting them to the public. It is not enough that quantity alone should be considered, for, in these days, quality plays an increasingly important part in food-production. Hence the arts of producing choice meats, "hygienic milk," cereals of greater food-value, etc., which arts may properly be termed the "higher agriculture;" hence also the arts of pomology, viticulture, etc., with the resultant practical arts of wine-making, canning, and preserving, which may be properly considered as a "higher horticulture." These arts, with the important domestic art of cooking, have all been developed in response to man's demand for more refined and delicious food, a demand which is certain to grow more exacting with the progress of civilization. The same law of progress characterizes our demand for raiment and for shelter. With the development of the esthetic sense and the growth of truer ideas of hygiene and comfort, the demand for more beautiful clothing and more sanitary houses will grow steadily.

But this is not all that can be said about the higher results of the new agriculture. Progress in agriculture contributes largely to the

intellectual, moral, and spiritual development of a people, as well as to their physical evolution. Perhaps the most encouraging characteristic of the times is the improvement in farm-life in respect to the means of culture. Formerly the isolation and loneliness of country life was the chief cause of that exodus from country to city which until recently continued to depopulate our rural communities. It is a sad fact that the majority of the inmates of our insane asylums in these states are women, a large per cent of them farmers' wives, sent to the hospitals as a result of melancholy induced by the narrowness and monotony of their lives. But now all these conditions are improving. The consolidated school and free transportation of pupils is fast converting the little "red schoolhouse" into a centre of vital community life. The rural free delivery of mails takes not only the letters of friends, but the daily papers and illustrated magazines, into all the farm-homes; the telephone makes visiting easy for lonesome women; and the traveling library stimulates many to improve their minds, who would otherwise live in stupid ignorance. Many of the features which formerly made farm-life so distasteful and narrowing, even maddening at times, are thus being removed; and many of the advantages, which heretofore could be had only in the city, are being put within the reach of those who spend their lives on the farm.

Every one concedes in a general way that the prosperity of one class diffuses itself throughout the whole community; but good harvests are far more valuable and important to the people than prosperity anywhere else. Agriculture not only provides food and raw material for those engaged in manufacture and commerce, but good harvests increase the purchasing power of the largest and most intelligent body of our citizenship, scattered throughout the whole land. The relation of the farmer to the merchant, the miner, and the manufacturer, is indeed a reciprocal one. Each consumes what the other produces. In the circle of trade, whatever produces a demand at any one point accelerates the amount and velocity of exchange in all directions. Good crops, by supplying the manufacturer, merchant, and miner with food or raw materials, are, the world over, the chief factor in profitable exchange.

But abundant harvests signify even more than this. Every series of exchanges must have a beginning, and the first step in starting the movement of products must be taken by those who supply the elementary and vital wants of the race. The miner will dig no ore, the manufacturer make no machinery, the merchant store no goods, until he knows or thinks he knows that somebody wants these things; but the farmer, being very sure that everybody wants food at all times, is sure to plant and to reap, whether there is an expressed demand for his produce or not. The nature of the demand, it is true, will decide for him which seed he should sow and whether on one or two acres;

but sow he will, as surely as the spring comes; and when he sows, he is almost certain to reap. As nature does more work for the farmer than for any other producer, he finds it easier to turn out an almost regular supply of his products. The sun himself is the commander-in-chief of the agricultural army. The changing seasons order the farmer's plowing, sowing, and reaping, and fundamentally every series of human exchanges starts with the farmer.

Good crops are always and everywhere makers of good times. While this is true for all peoples and all lands, it is particularly true of America, which from natural causes is the greatest agricultural country in the world. In this country agricultural prosperity touches, and for a long time to come will continue to touch, the lives and interests of a larger proportion of the people than in any other land. It causes immediately an advance in the standards of living and a broadening in the scope of the demands of the largest number of intelligent, progressive people; and it produces a home market of such tremendous proportions as to furnish independently of foreign nations a sufficient motive for the development of gigantic manufactures and enormous trade. Further the American farmer is a man of so much intelligence and such large wants that his standards of living increase very rapidly with the improvement of his financial condition. He is liberal to his family, ambitious for his children, and he desires above everything else to raise their standard of living and to increase their advantages in all ways beyond those which he himself enjoyed in his youth.

Another cause of the great economic influence of the American farmer is found in the fact that as a rule he owns his own land. In addition to the profit upon his labors he receives the rent on his land. This not only puts a larger sum at his disposal, but it also creates a motive for additional expenditure for improvements and equipments upon that land. The American farmer, moreover, seldom hoards his money, but promptly expends his surplus for improvements, or else puts it in the bank, where others can use it. He is, all things considered, the wisest and safest investor among us, and his prosperity is therefore the greatest blessing that can possibly come to the nation. Our conclusion is thus that the progress of agriculture is the greatest practical concern of civilized man, and especially of the American.

We have found that the problem of agriculture is to produce more and better supplies for the support of human life under conditions that will enable the farmer and his family, and with them the people of the whole country, to live the happiest and most complete life possible, a life which, as the decades and centuries pass, shall be constantly expanding, strengthening, and growing deeper and richer. The question, then, is "How shall agriculture do this?" What prospect is there that this art shall be able to supply these ever-increasing

demands, not merely for food to keep the body alive, but for all the resources needed to support a life growing ever more true and beautiful? What encouragement, then, can we find in recent progress, for believing that this world-old art will improve with the years and the demands of the race?

The improvement of agriculture depends, of course, upon the soil, including location as to latitude, longitude, climate, etc., upon the plants and animals used; but most of all, after these things are provided, upon the farmer and his methods. The most we can do here is to give a few illustrations of the advances made in recent years in improving the soil and increasing its fertility, in developing plants, and in training the farmer himself and improving his methods. We hope in this way to give some idea of what we may expect to accomplish in the future for the advancement of agriculture.

Agriculture, the oldest of the arts, was the very latest to apply the discoveries of science. This is due to two causes. In the first place, agriculture is the most difficult of the arts, and involves, one way and another, directly and indirectly, the application of all the sciences. Secondly, its workers have in the past been less trained in scientific methods than those in other callings. Until recently agriculture has been almost wholly an empirical art and only in very recent times has the farmer received any special training for his profession. Always intensely conservative he has learned new methods very slowly. Many breaches have, however, been made in the wall of empiricism which has surrounded him for centuries and the farmer who formerly derided book-farming has now opened his mind to the lessons of science.

Since the farmer commenced to use the teachings of science, the progress of agriculture has been extremely rapid; and as we may expect that agriculture will make gigantic strides in the next decade, the new agriculture, which is based on science rather than empiricism and which is just now being introduced, is destined to advance all the other industries and give the race a new forward impulse.

This we must believe from the progress already made. Consider, for example, the progress made since the time of Liebig in the study of soils. Liebig based all his proposals for the conservation of fertility and the improvement of the soil upon chemical composition, and his teachings did much to improve our agricultural methods. According to his theory the soil was composed of dead, inert matter, and the question was how to provide the so-called mineral food of plants in sufficient quantity and available form. For fifty years all methods of soil improvement and culture were based upon this idea. The soil was supposed to be devoid of all vitality until the crop appeared, and the chief business of the farmer was to destroy every other form of life. The question of nitrogen-supply had come to be looked upon

as lying at the very foundation of agriculture and demanding the most careful consideration because the conditions of life in the civilized quarters of the globe were thought to cause a constant loss of nitrogen. Every collection of animals, brute and human, was destroying the combined nitrogen-supply; every town and city was dissipating enormous quantities of it through its sewers and into the atmosphere. Tons of this valuable element were being burned in explosives, and nitrates enough to grow bread for a whole city were being destroyed in single battles. At one time there were many who, like Sir William Crookes, predicted a nitrogen famine in the soil which in time would lead to a bread famine throughout the world.

One does not have to read far in the agricultural literature of to-day before finding that all these ideas have been entirely changed. The soil is now known to be filled so completely with living things as to entitle it to be considered a vital mass itself, and even those elements in it not endowed with life now have the highest significance as the necessary environment of the living organisms which they help to nourish. We know that there are countless organisms in the soil, rendering many different kinds of service in preparing it to be the home of the plants, and, what is more important, in preparing the food for the plants themselves. Some of these organisms dissolve the mineral matter of the soils, others exert their activity on the organic nitrogen in the humus of the soil; others develop parasitically or symbiotically with growing plants, like the legumes, herding in colonies upon their roots and securing by their vitality, in a way we do not fully understand, the oxidation of the free nitrogen of the atmosphere. Still others have the ability, independently, apparently without the aid of plant vitality, either to secure the oxidation of atmospheric nitrogen or to produce ammonia. Investigations along these lines, which have now led to the systematic distribution of nitrogen-fixing bacteria for inoculating the soil, have, for a time at least, dispelled all dreams of early famines, and have given the world an assurance of a sufficiency of bread for at least an indefinite period. The refined scientific investigations of Nobbe in Germany have now been made practically effective in fixing nitrogen in the soil. Soil or seed can now be inoculated with the nitrogen-fixing bacteria just as dough is inoculated with yeast.

Mention might also be made in this connection of the proposals to combine the nitrogen and oxygen of the atmosphere by the electric spark, as is now being actually attempted at Niagara. Definite reports of results are not yet obtainable, but if this can be done on a large scale, we shall be able to utilize the great water-powers to make this valuable food for plants from the inexhaustible stores of the atmosphere.

Great progress has also been made in this country in the study of the physics of the soil, with the result that vast new areas, like the alkali soils, are being reclaimed; and crops have been found for many other soils which were supposed to be useless. The proper comprehension of the relation of the soil to moisture has expelled many of the empirical methods of culture, and has given us a new conception of the meaning of tillage. The same may be said of the relation of the soil to heat.

The main object in all farming being the production of larger yields and better quality of crops, scientific men have given a large share of their energy in recent years to investigations having these objects directly in view. This work has included the testing of field-crops, fruits, and vegetables, for the purpose of finding those best suited to given regions and conditions; the improvement of methods of culture, the production of improved varieties by selection and breeding, and the better utilization of the product. Burbank's marvelous work in new flowers and fruits, trees and plants of all kinds, has at last received the popular recognition it has long deserved. The possibilities in this direction now appear almost limitless.

The staple crops of the country, such as wheat and maize, or Indian corn, have been the subjects of much investigation, covering every phase of their improvement by selection, breeding, tillage, fertilization, harvesting, curing, preparation, and utilization. The results have been of vast practical value. Those in the cases of wheat and corn will illustrate the progress made.

Not only has it been shown that the quality of wheat for special purposes can be materially changed at will to suit necessary conditions or special wants, but the productivity of races or types of the grain can be fixed by systematic seed-selection. For plants can be bred just like animals. Burbank's wonderful work is so well known now that we need not describe it. At the Minnesota Experiment Station new varieties of wheat have been produced by breeding and selection, which, we are told, will increase the yield in the hard-wheat region of the Northwest by from three to five bushels per acre. Reduced to a practical basis, this means an increase in the wealth of the three states, Minnesota, and North and South Dakota, of from $20,000,000 to $40,000,000 annually. The yield and quality of wheats in that region has already shown a marked improvement as a result of the distribution of seed of two or three improved varieties. As varieties suitable for other sections will undoubtedly be originated in due time, the results that will accrue when these methods have been extended to all the wheat-producing areas of the United States can hardly be imagined. The wheat crop of this country for the year 1902 was 675,000,000 bushels, valued at $425,000,000. The average yield of wheat is only a little over thirteen bushels per acre, con-

siderably smaller than that of England where it is twenty-six, and that of Germany where it is thirty-one. If, by the introduction of these improved varieties and of better methods of tillage, the average yield of this country can be increased no more than two bushels per acre, the total increase for the entire country will be 100,000,000 bushels per year, worth about $100,000,000. This would seem to be entirely practicable. If the excellent prospect of increasing the nitrogen-supply in the soil for cereals does not allay all anxiety regarding starvation, the results in breeding new varieties of wheat and other food-plants should certainly put that fear to sleep for a long time to come.

No less interesting and instructive is the recent work in corn-breeding conducted at the Illinois and Kansas stations. Although corn, which is this year yielding probably two and three-fourths billions of bushels, worth approximately one and a half billions of dollars, heads the list of cereals in value, until the valuable work of these experiment stations was announced there had been no material improvement in the production of this crop in twenty years. The Illinois station has shown that if the methods of selection practiced by it, which are quite feasible and within the reach of every farmer, were followed throughout that single state, the increase in production in one year would amount approximately to $20,000,000.

Methods have also been found for changing the composition of the grain itself to meet special requirements: such as an increased yield of oil or of protein. Since the manufacture of oil from corn has become an industry, the amount of this constituent is a matter of considerable consequence. By selection the oil-content has been doubled in some varieties.

The most important question, however, connected with the improvement of corn is that which relates to its value as a well-balanced food. Its relative deficiency in protein has probably been the chief reason this grain has not been more extensively used as a human food in continental countries. It has, therefore, long been a question how to increase the protein in a grain of corn at the expense of the starch and fats. As the nitrogen, like the other constituents in the grain, varies in the different varieties, the way is thus opened for the control of the variations in this important element. The Illinois and Kansas stations have been engaged for some time upon this problem. By the selection of varieties containing a high percentage of protein, it has been found possible to develop strains containing an increased amount of this desirable substance. The protein-content of some varieties of corn, now apparently well fixed, has been increased fully 2.5 per cent, that is, from about 10 to about 12.50 per cent, which makes corn equal to the average wheat in this respect. In special cases it has been increased to even as much as 17 per cent. Should

wheat then fail us, Indian corn will be ready to take its place with an equal amount of protein.

The development of the rice industry in Louisiana and Texas furnishes a good example of the building-up of a new industry by the introduction of a new type of seed and of improved methods of cultivation and harvesting. Rice was one of the earliest introductions into this country and was grown for nearly two hundred years in South Carolina and the adjacent states with little improvement of method. It was thought that these states were the only ones that possessed the requisite irrigable lands. It has recently been discovered, however, that the prairie lands of southern Louisiana and Texas will produce large crops of rice, if provided with the requisite water, which is now obtained from bayous or artesian wells. The water is drained off in time to permit the ground to dry and the crop is then harvested with machinery similar to that used with wheat. As a result of these improved methods, the total rice-production of this country has increased in five years from about 100,000,000 pounds to about 400,000,000 pounds. The two states mentioned produce over 90 per cent of this. As the American people import some 40,000,000 pounds of rice annually, there is still room for the development of this industry. It is estimated that there are available in these two states alone 3,000,000 acres of land suitable for rice-growing. This is perhaps the best single illustration of the introduction of new races of seed and the use of improved methods of cultivation in their production.

I wish next to suggest another place where scientific investigations of a similar character are greatly needed. Cotton-culture needs precisely the same sort of attention from scientific men and expert agriculturists as has been given to wheat, corn, and rice. Considering the immense importance of this crop, it is remarkable that it has not received more systematic study.

A group of states in the southern portion of America, constituting less than one fourth of the total area of the United States, grows from 60 to 70 per cent of the cotton consumed in the world. The total value of the annual crop is exceeded, among the cultivated crops of the United States, only by Indian corn and occasionally by wheat, both of which are grown in almost every state. Since it is fair to assume that all the fibers have been pretty well tested as to their capabilities and uses, we may conclude that cotton, now the preferred fiber, is destined to grow steadily in favor with civilized man, and will continue to be used by him in increasing amounts. We are constantly finding new uses for it, and may safely predict that the demand for cotton will increase rather than diminish. It has been estimated that to meet the world's demand, when its standard of consumption has been raised to that of the civilized nations, will

require an annual crop of at least 45,000,000 bales. It is therefore eminently desirable that the Southern States of America should meet this demand. Will they do it?

Present tendencies in the cotton world, at least, seem to answer "No." During the last four years the consumption of cotton seems to be rapidly overtaking the production, with the consequence that many of the mills in the United States, in England, and on the Continent have been running on short time. There are two principal causes which have contributed to this shortage. The most important has been the large increase, amounting now to at least 500,000 bales per annum, in the world's consumption. Of this increase, the greater part was in the Southern States themselves, where the consumption of cotton was doubled within the last ten years. These states are now taking nearly twenty per cent of the cotton produced by them. The second cause of the shortage is the failure of the American cotton-planter to respond to the increased demand, and perhaps a slight falling-off in the yield per acre. In fact there are some reasons to believe that the yield per acre has been slowly but steadily declining for a number of years.

Although in many sections from 500 to 800 pounds of cotton may be obtained by good cultivation, the average yield of cotton in the United States is only about 190 pounds of lint per acre. There is evidently great room for improvement in the methods of cultivation and fertilization, and especially for improvement of the plant itself. Any one who has traveled through the South will acknowledge that the methods of cotton-culture are the poorest and most backward used with any staple crop in our country.

Cotton is limited by climatic conditions to that portion of America south of latitude 37. The essential features of the climate in this section are a long, warm season and a peculiar distribution of the rainfall. Statistics show that the fluctuations in the yield per acre in a given section are less in the case of cotton than in that of almost any other product of the soil. The production of cotton may be due to the greater uniformity of all the climatic conditions obtaining in the cotton-belt, but the chief determining condition as between different sections of our country is the amount of light and heat distributed over the required number of days. For cotton is a sun plant. As a rule a certain amount of sunshine produces, upon a given territory, a certain amount of cotton. The distribution of rainfall is also important, but sunlight is the chief factor The plant requires an abundant supply of moisture during the growing stage, but can stand a good deal of drought after the middle of summer is passed. Now the section of the country providing these conditions measures only about 500,000 square miles, less than one third of the total settled area of the United States. Some 50 per cent of this area is contained in farms,

and about 21 per cent is improved; but only about five per cent of the total area, or one tenth of the area in farms and one fourth of the area of the improved lands, is annually cultivated in cotton. If the whole area in farms in this section were cultivated in cotton, it would produce at least 80,000,000 bales. So far, therefore, as soil and climatic conditions are concerned, the Southern States can produce seven or eight times as much cotton as they now do.

But soil and climate are not the only conditions. It requires men and mules to make a cotton crop. It is generally recognized that the labor used in the production of cotton is something over fifty per cent of the total expense of growing the crop. This exceeds the cost of labor in growing corn and wheat, and also in many manufacturing industries. But statistics of population show that there is labor enough available in the South to handle an increase in the cotton crop such as the cotton-belt is capable of producing under favorable conditions. The Negro is well adapted for working in the cotton-fields, and his children are the only successful cotton-pickers known. The great need is that this labor be better trained and organized. Although the supply of mules and horses is inadequate at present for the production of a crop of this size, they might be raised within a few years.

We come thus to the question why the South does not actually produce more cotton to supply the world's increasing demand. It is commonly stated that the low prices which prevailed for a number of years led the planters to diversify their farming and to devote more of their means and energy to the production of general farm-supplies. This is true; but when this has been successfully accomplished, the planters should be in an even better position to produce the crop demanded. Where then is the trouble? Experts seem to agree that the chief difficulties are the impoverishment of the cotton-soils through continued cropping under the renting system, and the running-out of the seed. Observation in the cotton-belt leads us to believe that fully two thirds of the planters use seed taken entirely at random from the public gins, about which they know nothing whatever.

It is safe to estimate that the cotton crop could be doubled on the same acreage by the use of good seed and careful methods of tillage and fertilization. Questions of tillage and fertilization must be left to the farmers chiefly, but the experiment stations should take up the question of improving the seed.

Certain definite things should be kept in mind in the process of cotton-seed development. Among these are an increased yield of fiber and of seed, an increased length of fiber with uniformity, the strength of the fiber, the season of maturity, adaptation to soil and climate, and resistance to diseases. It is probable that cotton having

these different qualities will have to be bred to suit the soil and climatic conditions of each section. Here then is a great task, one, however, which offers magnificent rewards. It is firmly believed that the scientist and the cotton-planter will together be fully equal to its solution.

We have sought by these few illustrations to show what science has already contributed to the advancement of agriculture and how it may be expected to do still more for it in the future. No one now doubts that the progress of agriculture in the future depends chiefly upon the discoveries in science and their application to the practical problems of the farmer.

The discoveries of science, however, and the demonstrations of the United States Department of Agriculture through its experiment stations, will be of little value to the American farmer unless he is well enough educated to understand them and skilled enough to apply them. More secondary agricultural schools and schools for the training of horticulturists, dairymen, and other specialists are needed in all our states. The higher agricultural institutions and departments of agriculture in our universities are answering an admirable purpose in training experts and investigators; but so far we have very few secondary agricultural schools. It is believed that the next development will be along this line. Certainly the greatest need of American agriculture is farmers trained to habits of observation and skilled in the application of science to their business. What the new agriculture will do for the advancement of the race when even a majority of farmers have learned its methods confounds the imagination. This greatest of productive industries will lay a new foundation, deep and broad, upon which man will build a new life, growing ever nobler and truer "unto the perfect day."