culties were removed and all the phenomena expressed in one simple equation.

One interesting experiment of Henry's in this connection was to show that although there were differences in the shock produced in the secondary coil when the current was made or broken in the primary, there was no difference at all in the fling of the galvanometer needle. This observation led him to a very careful study of the phenomena associated with making and breaking a circuit.

The discrepancies between the observations of Henry and of Faraday, depending upon the fact that the former was observing as a rule electromotive force, while the latter was measuring the quantity of current, reminds one very much of the discrepancies which existed in the early history of mechanics, discrepancies which were only cleared up by the mathematical work of D'Alembert. Mechanics had its origin, as is known to you all, in the work of Galileo, Newton and Huyghens, and in the century that followed their first publications a controversy arose as to the proper measure of those agencies in nature which produce the changes in velocity of a body. One school of writers insisted that the proper measure of the effect of such agencies was to be found in the difference in the squares of the velocities of the body at the beginning and the end of the action. Another school insisted vehemently that the effect should be measured by the difference in the velocity. If this dispute were stated in modern language it would be somewhat as follows: Is the effect to be measured by the change in the kinetic energy or by the change in the momentum? It was D'Alembert who first showed that neither one of them was the proper measure, because the change in the kinetic energy is equal to the product of the force by the distance through which the body moves under the action of the force, while the change in the momentum is equal to the product of the force by the time during which the body is under the action of the force. Or, it may be said, if one wishes to, that both schools were right and that they were looking at the two sides of the shield as in the ancient fable. Something of the same kind may be said in regard to the work of Henry and Faraday. Their research work was absolutely trustworthy, but their interpretation of this could not be completely satisfactory until the work of Ohm was appreciated and until the mathematicians had completed their study.

I can add but little to what is well known concerning Henry's qualities as an investigator and administrator. As one reads the various papers contributed to the memorial volume devoted to his life, one is struck by the universal admiration for his broad philosophy, his accuracy of observation, his brilliant intuitions and his devotion to the cause of science in its widest interpretation. He was unselfish to a marked degree. He was not interested the faintest in personal advancement or in advancing claims for discoveries or inventions. His sole purposes in life were to interpret nature and to diffuse knowledge among men. Beyond any doubt he is the outstanding figure in the history of the scientific life of America.

THE RELATIONSHIPS OF THE NATURAL SCIENCES AND THE SOCIAL SCIENCES IN AGRICULTURAL EDUCATION IN THE UNITED STATES[1]

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IN this country the program of agricultural education, as it relates to both teaching and research, centers in the natural and social sciences. It is perhaps safer and wiser to describe the functions of these sciences in this program in rather broad and general terms, as no two persons would likely fully agree on any exhaustive statement about either of them.

Natural science, in its application to agricultural and pastural products intended for consumption, has to do with improving and increasing production by reducing the amount of time or effort necessary to produce a unit of product and by making more resources for production available. It is addressed to the soil for such purposes as increasing balancing and maintaining its plant food elements, controlling its moisture content and improving its condition with respect to tillage. It is applied to plant life as it relates to agriculture and deals with the breeding and selection of plants and their adaptation to given conditions and needs. It has to do with their culture and with means of protecting them from the ravages of disease and insect pests. Along practically the same lines it deals with animal life in agriculture. And it also has to do with the interrelationships of soil and plants and animals.

Social science deals with human wants and primarily those which are satisfied only by associated or

[1] Address of the retiring vice-president and chairman of Section O—Agriculture, American Association for the Advancement of Science, New Orleans, December 29, 1931.

group action. Hence we often think of it as a science that deals with society as a whole. In agriculture we restrict its application, in large part, to that portion of society known as the rural population. The social science subjects most emphasized in agricultural education are economies and sociology, but it should be borne in mind that such subjects as history, government and politics belong in this field. It is well, too, not to overlook the fact that a considerable amount of the subject-matter in agricultural economies is directed to individual rather than to group wants. Reference is here made to teaching and research aimed at such matters as adjustments on the individual farm for the purpose of increasing individual efficiency and advantage. While there is a sharp division between individual and group wants at some points, they merge at others; therefore we can not confine the application of social science solely to group wants, but when the objective is an individual rather than a group want, the results sought are very similar to, if not identical to, the results desired when natural science is the agency used.

Social science is concerned with problems of distribution of wealth and income. It has to deal with questions of credit finance and taxation. Price is an organizer of economic activity and a factor in distribution and it becomes a function for a subject like agricultural economies to consider price factors and movements as they relate to agricultural products.

It is a function of a subject like rural sociology, through a technique all its own, to give attention to the improvement of human factors in agriculture to the end that there shall be a sound development of rural social policy. Attention must be given to these human factors if the improvement of agriculture itself is not to be defeated. "The capacity of the rank and file of farmers to receive instruction can be stimulated and greatly increased through processes of socialization of families, groups and communities so as to effect a nicer adjustment of individuals to a larger and more complex organization of life."[2] Dean C. B. Hutchison, of the College of Agriculture, University of California, recently gave in broad and general terms the following as the function of social science research as it applies to agriculture.[3] "It relates to the balancing of production and consumption, the ways and means of making adjustments and changes, and the distribution of the benefits from scientific progress among the members of society."

Agricultural institutions for teaching and research are more at home with subjects in natural science than with those in social science, the reason being that the national system of agricultural education was developed by placing emphasis primarily on the natural sciences. There was a logical basis for this method of development. The need for harnessing and overcoming the forces of nature was much more obvious to the farmer and even to the educator than were needs along social lines. The farmer was often squarely confronted by the limitations of cold, drouth, disease, pests, low producing powers of plants and animals, etc. As to these needs he had no trouble in expressing himself, whereas he was more or less inarticulate regarding his social needs because he could not clearly comprehend them. Moreover, a number of the present rural social problems did not develop in acute form until the system of agricultural teaching and research had become well established.

When the agricultural colleges were provided for by the federal government through the Morrill Act of 1862, a large percentage of American farmers were operating on a self-sufficient basis in considerable degree and continued so to do until well up toward the close of the past century. During most of this period rural standards of living were, in large part, determined by the capacity to be self-sufficient. The farmer's attitude was extremely individualistic. The family then enjoying a high standard of living was the large family that produced crops successfully, converted a portion of them efficiently into family needs, sold enough to pay for comparatively light overhead costs, saved a little money for investment in more land and managed to satisfy social and educational wants within the home and the closely circumscribed community.

We had of course developed the production of staple crops far in excess of the consumption needs of the agricultural population before the close of the past century. We had passed through periods of discouragingly low prices, but even so production remained the paramount idea in agriculture. With our own population growing so rapidly, we looked forward to great increases in population at home and abroad. We were impressed by the theory of Malthus concerning population, and hence felt that the only check to increases in population would result from restrictions in food, clothing and shelter. We visioned the hungry maws of England, Germany and other European countries clamoring for more food and as we turned the century the public mind entertained a fear of being unable to produce enough to feed the oncoming millions. There were those amongst the intelligentsia in agricultural education who saw the time only shortly ahead here in expansive America when we would have to limit our consumption of meat materially in order to have enough

[2] From monograph, "Rural Sociological Research in the United States," 1927.

[3] From paper read before the section of experiment stations, annual meeting of Association of Land Grant Colleges and Universities, Chicago, Illinois, November, 1931.

food from our available acres to feed our own people.

In sum, our whole agricultural philosophy was faced toward production and we were so occupied with the problems surrounding production that we pretty largely allowed social and economic problems to take care of themselves. Some of us may have thought that if we could adequately discover ways and means of overcoming controllable handicaps to production, we would solve our rural social and economic problems. For the natural science worker in agriculture almost invariably had social and economic values in mind as he has applied himself to his tasks. It was not a matter of entirely overlooking these values, but rather a matter of opinion as to how they might be realized.

While extensive consideration of social and economic problems is a comparatively recent development in agricultural education it would be hardly true to say that the problems themselves are of recent development. But much has transpired since the beginning of the present century to bring them to the fore with greatly added emphasis, and doubtless some new problems have developed. They now stand out so prominently that it would be quite impossible to deny them large consideration in any intelligent program of education.

Many things have happened to bring the economic and social problems of agriculture to the fore, but of them all two seem to be more significant than any of the others. One is the stupendous augmentation of machine economy which has occurred during the past two decades; the other is the spread of birth control. The first has greatly increased the producing power of the individual farmer and has extended crop areas by utilizing types of land which probably could not have been cropped economically without power machinery operating on an extensive scale. Then, too, the acceleration of the machine economy throughout all groups of society has had a most noticeable effect on the habits of the people, and by encouraging a more sedentary type of living has reduced the per capita consumption of food and has had an effect on the types of food preferred.

Although the machine age has been on the way for many years, what has been referred to as the new machine age ushered in at about the time the world war opened was not foreseen in its gigantic proportions and far-reaching consequences. Apparently none of us could foresee the extent to which human hands and backs would be replaced by labor-saving machinery. None of us could foresee that within a decade 30,000,000 acres of agricultural land would have to be devoted to some new use because of the decimation of the horse population. Nor could we foresee that while this would be happening the total amount of land under cultivation would be materially increased, all of which would be brought about by the greater adaptation of mechanic power and machines to farm practices.

It was no easier to foresee the movement toward birth control than the sudden upsurge of the machine economy. Either as a national or world-wide movement it was entirely outside of our thinking. In the November, 1931, *Forum*, Louis I. Dublin says: "In years preceding 1880, the birth rate in most countries was 35 to 40 per each 1,000 population. This figure is not very far from the upper limit of human reproductive capacity in a normally organized population. To-day with a very few important exceptions, as in Russia and Italy, the rates vary from 15 to 20 per thousand." Dublin goes on to say that evidence points to the conscious control of propagation through contraceptive methods as the new element which has altered the situation with respect to birth rate. He further says, "The outlook for the future is a wider application of these methods and toward their dissemination to all peoples. Whether we like it or not we look forward to much lower birth rates in all parts of the world." It therefore seems necessary to reverse the way we thought about population during the boom days of agricultural education in the first decade of the century. Again, Dublin says: "We of the United States are evidently not destined to become the great reservoir of humanity where liberty and prosperity are to reside side by side. Instead, we shall, from now on, accustom ourselves to hear questions like these. How long will America continue to increase in numbers; what will its maximum population be; how rapidly will the population decline once it begins to fall; what effect will this decline have on age distribution and therefore upon business and employment conditions; how will it affect America's position of leadership abroad? In short, now that one frontier has completely disappeared a new era of the history of the nation has set in."

We are all aware, of course, of the fundamental cause underlying birth control, namely, that with our changing modes of life there are other things more desirable than the expensive luxury of a large family. Even on the farm children are no longer an economic asset, but rather an economic liability of considerable magnitude. In consideration of the way in which we are headed there is small probability of their becoming an economic asset. Therefore, Dublin is probably correct in his views about declining birth rates.

What has happened and is happening with respect to machine economy and birth control clearly shows that we can no longer count on increase of population to take care of increases in agricultural production which may be brought about by the agencies within the field of natural science. The massive

forces of the machine economy alone are too powerful for any possible rate of population increase to cope with our power to expand production, to say nothing of the fact that the rate is declining. It is clear that, from now on, the matter of balance between the production and the consumption of agricultural products will be of vital importance. In many respects it will be a delicate balance and any onrushing movement to increase production, as has been the case in the greater application of machine power, will cause serious maladjustments. From now on rural people must keep their eyes upon both the production and the disposal of their products. Already some of them have called attention to their conviction that our agricultural institutions are emphasizing production to the neglect of distribution. They have gone so far as to assert that we might very well take a holiday on matters pertaining to production in order that we may catch up with our information on distribution. In this they are wrong because much of the work in natural science is not directed toward larger production and they are unaware of the complaint that would be made were we to follow their suggestion. But their criticism carries significance, nevertheless, for it indicates their realization of how impossible it is for us to continue with an unbridled policy of production. Consequently, the long-established natural science forces in agricultural education should seek and welcome the development of social science as it may be applied to agriculture.

If we are to secure the full benefits of natural science teaching and research, under present conditions in agriculture, we must have a sound and adequate development of social science. It is the science upon which we must rely for finding the ways and means of making adjustments, of balancing production to the needs and desires of the people. Unless these things are done, natural science teaching and research will be greatly weakened as potent influences in rural life. If they are done, if production is expanded only as fast as there is need for it, then the gains or benefits from natural science can be turned into better living rather than in surplus production.

We should not conclude that study and research in social science alone will not improve conditions. Any such contention is futile. The sources of wealth are to be found in goods and services. The farmer's source of wealth lies in goods which he produces, hence he must maintain an active interest in production. In its productive phases agriculture is a biological industry and hence as subject to change and variation as the biological forces themselves. The natural science worker in agriculture need have no fear of ever being out of a job, for his services will always be in demand. He will continue to be called upon to make discoveries and to work out their applications. It will remain for social science to lead in determining where, how and how rapidly they shall be applied. So for best results, in fact for safe results, it becomes apparent that a knowledge of natural science must dovetail with a knowledge of social science. In turn each becomes the handmaiden of the other.

We would agree, I think, that the more intelligent American farmers have come to appreciate the value of natural science research as it applies to their individual businesses. In order that social science may pull itself up to the level of the accomplishments of natural science, it must engage in rather large-scale social and economic experiments which involve individuals who are acquainted with what is being attempted and who are willing to subject themselves to experimentation. Reference is made to some of the large experiments in cooperative marketing and to new ventures in land policy such as the state of New York is undertaking by acquiring abandoned farm land adjudged to be unfit for agriculture. One object in the acquisition of these lands is to prevent the waste of human effort and capital on land wholly unsuited to farming. Another is to effect savings in expenditures for schools, roads and local government. The time has come when we can scarcely avoid experiments of this sort, although it is doubtful if we should attempt to be as ambitious as Italy or Russia along these lines. The confidence that has been built up in research through natural science will help to pave the way for confidence in researches of this sort. This does not indicate a relationship between the sciences but rather a service one has rendered the other.

Attention has been called to the fact that natural science workers in agriculture have almost invariably had social and economic values in mind. There is, of course, a social reason for encouraging greater production. But aside from this, the worker in horticulture who deals with fruit and vegetable growing or the growing of ornamental plants may have little notion of boosting the total production in agriculture, but rather the hope that he may make some contribution to the satisfaction of living. The agricultural engineer, who clears the way for farm electrification, may talk all the while about how electricity on the farm can make for the efficiency of production, while deep down in his heart he may be hoping to make farm life more cheerful, happy and satisfying. We must bear in mind, too, that unless we run to seed on the subject, there is a social satisfaction in attaining efficiency in production. Many a man has spent his life in producing superior purebred live stock, fully realizing that he might have made a little more money by producing for the open market.

Many a man has lost a little money by adding increments of labor to his enterprise purely for the sake of doing the job well. Many a man has been carried on through hours of discouragement in agriculture by his knowledge of his ability to perform creditably in the processes of production. So, after all, there are no hard-and-fast lines between the two fields of science. To attempt to draw such lines would hamper both natural and social science effort.

It has frequently been difficult for natural science workers to see an important place for social science in the scheme of agricultural teaching and research.[4] In other words, they have not had a genuine respect for it as a science. Since social science is of later development than natural science in agricultural education, particularly, there was a lag in the refinement of its technique. Then, too, the complex interrelationships of social and economic phenomena are hard to understand and measure. Only in recent years have we come to feel that scientific research can be applied to these phenomena. Descriptive studies have been under way for a long time, and "qualitative analyses of cause and effect relationships based on assumptions, mainly because data were not available, have been made for more than one hundred years." Through their determination to discover principles and to secure reliable measurements of relationships the workers in social science are winning the respect of the natural scientists. Nothing else could do quite so much toward bringing about the kind of cooperation needed between the workers of the two fields.

Healthy cooperation between natural and social science can be fostered by placing adequate emphasis on the social sciences in the agricultural curriculum. Students should not be graduated without some basic knowledge of social and economic principles any more than they should be graduated without basic knowledge of the fundamental principles of natural science and particularly the biological sciences. This can be accomplished without lessening the emphasis given to natural science—in fact it is being done to a limited extent by giving less time to courses that are nothing more than "glorified practicums." Such courses are not without value, but their prominence must wane in any sound program of agricultural education. It has long since been demonstrated that the acquirement of a number of practical skills in college does not produce a finished farmer, much less a capable leader in agricultural thought.

Nor have we met the situation when we train technical farmers and technical research workers who perhaps receive no more than one or two elementary courses in economics which so often give the impression that society is governed by immutable laws and, therefore, nothing can be done about it. More training in social science than this is needed and it should be the kind of training which demonstrates that the laws governing society are no more rigid than the laws governing the forces of nature, and that an understanding of these laws can contribute to social progress quite as much as an understanding of natural laws can contribute to technical progress.

The natural science worker has implicit faith in his task. In this he is fully justified, for he has to his credit a great record of achievement. He has worked untiringly and in most cases in the spirit of altruism, or at least not in the spirit of selfishness. The world has acclaimed him and has increasingly accepted his leadership. We increasingly speak of the gains the scientific temper has brought us. But in spite of all the advantages we can mention, we must admit that, for some reason, the world is sick, that agriculture is depressed, that we have overreached ourselves in production, that by gaining control of the forces of production, we have apparently lost economic control and brought social distress to ourselves. Some would sarcastically and wrongly say that through technical efficiency we have bankrupted ourselves and broken our social morale. Evidently we are confused, muddled, lost even in our thinking. The way out is not to call a retreat in technical efficiency. The way out is to realize that the results of the discoveries of natural science must be intelligently handled by society, that it is not natural science which is causing grief, but rather the unintelligent application of its discoveries by society.

With the automatic device for handling increase in agricultural production going into the discard, namely, increase in population, it becomes clear that our production can run wild, and probably will, unless a science is developed within our rural society for the purpose of turning efficient production into channels of better and happier living for every one.

On the one hand, our agriculture needs a science to make us intelligent and efficient in our processes of production; on the other hand, it needs a science to make us intelligent and efficient in distributing our production and adjusting it to the logical demand for it. If the amount of production greatly exceeds the demand for it, interest in intelligent and efficient production and the science underlying it is sure to sag. If production should be unintelligent and inefficient, no system of distributing and adjusting production to demand could bring prosperity and better living to rural people. In these very simple terms, the essential relationship between the natural and social sciences in agriculture may be expressed.

[4] The discussion in this and the two succeeding paragraphs closely parallels discussion to be found in the paper of Dean C. B. Hutchison read before the section of experiment stations, annual meeting of Association of Land Grant Colleges and Universities, Chicago, Illinois, November, 1931.