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AGRICULTURAL RESEARCH IN RELATION TO THE COMMUNITY[1]

IT is a common reproach that agriculturists have not made the same use of science as have those engaged in the other great industries—that farming is still a rule of thumb process carried out by methods which have their origin in the dark backward and abyss of time. In some respects this is indeed true. One has only to read Cato or Columella to realize that the Italian peasant of to-day is working and living in very much the same way as his Roman forebears, and even the more highly organized farming of Great Britain or Denmark or Holland is carrying on many of the essential operations of cultivation on lines that were laid down by the first great civilizers—the Romans. It is easy in fact to trace modern agriculture to a Roman ancestry; in Britain, for example, by the transplantation from the fifteenth century onwards of the traditions and practices that persisted through the dark ages in the Low Countries.

None the less progress has taken place and scientific development is going on. Under medieval systems of agriculture the yield from England's land was of the order of six to eight bushels of wheat to the acre. The enclosure of common lands, the introduction of a recuperative clover crop into the rotation and of forage crops like turnips for the winter feeding of cattle and the making of farmyard manure, the return to Roman methods, in fact, raised the level of production to about twenty bushels of wheat per acre. This was about the average when agricultural science dawned nearly a hundred years ago—say about 1840, when Liebig exposed his theory of plant nutrition and Lawes began his experiments at Rothamsted. Growing scientific knowledge and the introduction of fertilizers raised the level of English production by 50 per cent. during the next generation, so that by 1870 the average yield of wheat per acre in England had become thirty-two bushels. At that level it has more or less remained down to the present day because a new factor then came into play, the importation of cheap wheat through the opening up of the middle west, of Argentina and of Australia. The economic factors of gold scarcity and rising costs of labor cooperated to limit the profit attached to high farming: the English farmer had to cheapen his production and lower his standard so that he only obtains the same yield to-day, though the acreage under wheat has shrunk on to the better land. Latterly we have seen

[1] An address delivered before the Graduate School of the U. S. Department of Agriculture, January 26, 1925.

the yield creeping up a little through the introduction of heavier cropping wheats—the products of scientific research.

In other directions there has been progress. The introduction of the self-binder alone has meant great economies in man power. From machinery in one way or another I estimate that English farming with an equal or greater output employs some 25 per cent. less labor than it did fifty years ago. Cattle feeding is more economic. Breeding for early maturity, better adjustment of rations either for meat or milk production, have all tended to a cheaper output. There is still an immense margin for improvement. From scientific experiments one may calculate with some degree of confidence how much meat and milk a given quantity of fodder of one kind or another ought to yield. Yet when in the dark days of the war we took stock of our resources in cattle food, because tonnage could no longer be spared for aught but human food, soldiers or munitions, it was estimated that in the five years before the war the farmers of the United Kingdom at large only realized one third of the meat and milk that was theoretically possible from the fodder that had been then available.

Disease amongst animals is another field in which research has not been idle; enormous savings have been effected in the average efficiency of our flocks and herds. Yet last year Great Britain had to pay a bill of approximately $20,000,000 to stamp out foot and mouth disease, and this was compensation only for slaughtered animals and took no account of the losses the farmers endured by the break-up of their businesses.

Great are the achievements and still greater the possibilities of agricultural research, but we must recognize that there are limitations to the effect of science upon agriculture which do not hold for the other industries. In the first place, in agriculture we are dealing with a living organism and the amount of control that we have obtained over plant or animal, over that stubborn essence we call life, is far less than we can exercise over inanimate nature, over iron or cement, over even the ether or the atom. When we attack vital problems we find that we can not speed up processes or enlarge the unit in the way we can deal with the dynamo or spinning frame. It still takes the wheat plant six or nine months to develop, and cows bring forth their calves neither more quickly nor more numerously for us than they did for Abraham. We see no way of growing three or four crops a year under temperate climatic conditions. The organisms we are dealing with will go through their cycle and you can not hurry them. When you start hustling you find you let in secondary troubles of all sorts.

These limitations lie in the nature of things, and though on looking back we can count up the immense advances that agriculture owes to the application of knowledge we must not hope for sudden developments or revolutionary changes such as have been seen in flying or wireless telegraphy. In fact for the time being I am bound to say that agriculture is actually suffering from the rapid developments and scientific achievements that have distinguished other industries. I say this advisedly and most solemnly. Agriculture is the fundamental industry, because we must all be fed, and yet you can not point to any part of the world where agricultural wealth is being turned out and find the producers in a flourishing condition.

The rewards in agriculture, whether to the capitalist entrepreneur or to the laboring man, are not commensurate with those obtainable in industry or commerce, and so men are being drawn away to the towns and capital is being diverted from the farms. The movement is one common to all civilized countries, its sources are social as well as economic. The lure of the town has been secular, but modern facilities of communication and transport have given it a range of action hitherto unknown; yet it can not go on forever, for the world must be fed. One must interpret the steady rise of food prices which has marked this century, a rise now being resumed after the excessive fluctuations caused by the war, as evidence that we are approaching a limitation to the development of the towns because there is not food enough to go round.

The old economists would see a simple solution to this impasse; prices of food have only to rise sufficiently and men will be attracted back to the land in order to secure the profits it promises—the balance will be restored. But, looking back historically, has this ever happened? I can find no example of an urban population migrating into the country. If the countryside does replenish itself in men it is by breeding and by finding space in the country for the country bred. The great increase in the food supplies of the world the last half century has witnessed has been due to the new countries becoming accessible, whereby opportunities were given to the rural population to put their sons on new land. But that process is nearly at an end, there are no longer the great vacant areas waiting for men.

Are we not to look for progress in another direction; can we not so intensify the farming of our existing land by taking advantage of science, machinery and organization that agriculture production will become an industry capable of competing against other industries for men and capital? It was by a process of this sort, by enclosing the common lands and building up small capitalist businesses, that Britain succeeded a century and a half ago in meeting the needs of a population which was then beginning to expand as the industrial age approached. Our businesses have remained small, too small to be efficient to-day

perhaps, and I can point to few examples of large scale industrial farming in successful operation.

In fact, though I pin my faith to big business on the land as necessary to the future production of food in order to meet the growth of cities, I am bound to say that the current seems sweeping in the other direction. Agricultural businesses, such as we have, find it difficult to pay the wages that will retain men on the land, with all its disadvantages of quietness and lack of amusement. Social and economic motives in our country are working towards the break-up of farming businesses into single man or rather family farms, and similar forces have been even more powerfully at work in Continental countries in dividing up the land. The desire of men for independence, the determination to call no man master, the innate feeling among country folk that a man has a right to a bit of land of his own as he has a right to a vote or to a soul of his own, makes in many countries the single-man holding a burning political question. And the man is ready to pay—to pay in labor, in days that endure from dawn to dark, in days that include the hours of his wife and children, in toil as against the regular pace of a factory, for the privilege of being a landowner.

But I doubt whether the process is fundamentally economic. Farming may become immediately more intensive when a great estate is cut up into small holdings, but the community so created becomes an unprogressive one, little fitted to take advantage of modern science, modern machinery, modern organization. It is fundamentally uneconomic because it is employing more men than are necessary to produce the food on which the community can be supported. I conceive it to be possible for 15 per cent. of the working population to be able to produce the necessary food for the rest of the nation, and the larger the margin that remains after this prime task has been performed of men who can be making boots and clothes, houses and motor cars, the greater the divisible wealth of the community.

But the only hope I can see at present for large-scale production, for organized industry on the land, lies in the advances that science can make. It is research alone that will enable the big agricultural business to compete with the excessive labor of the one-man farm, to pay wages and give conditions of life to its workmen equal to those prevailing in the urban industries. It becomes then a matter of the first import to the growth of civilization itself, not merely to agriculture, that agricultural research should be encouraged.

We may consider research from two points of view. In the first place, it is an intellectual affair carried out by the individual in response to the insatiable curiosity of the mind about its surroundings and its own existence. As such, it proceeds from an artistic impulse, it is not under control and it is not amenable to considerations of utility. Just as some men must write poems or paint or make music, as other men find themselves compelled to speculate, to become philosophers or metaphysicians, so similarly the class of men we are considering must investigate nature.

The passion to do this is part of the man's make-up and can not be created by any act of will on his part. I may remind you of the story of the old school-fellow who met Dr. Johnson at the height of his fame. "Doctor," he said, "I have often tried to become a philosopher myself, but cheerfulness will keep breaking in." And as a man can not deny himself a desire to investigate, so he is not drawn to investigation by any ulterior motive.

I may take an illustration in the science of astronomy. Historically the study of the stars would appear to have had its beginnings in the search for useful knowledge. In the early civilization of Egypt it was necessary to find out a means of determining exactly the length of the year and the recurrence of the seasons. Later on the delusive promises of astrology led to further observation, and as we know, the first organized observatories were built for the service of the sailor for the drawing up of what we call a nautical almanac. But these prime necessities were easily satisfied and the real science of astronomy can not for the last hundred years have served any useful purpose to any man. Nonetheless, the development of the science and the foundation of observatories has proceeded at a greater pace than ever before, purely in response to the universal feeling of curiosity. Oddly enough, this kind of knowledge has proved itself singularly attractive to the American millionaire, who has latterly been the great founder of observatories. Indeed the uselessness of astronomy is to many people one of its great attractions. A great astronomer once said to me, "One advantage I enjoy is that my science can not make money for anybody —at least no merchant traffics in my heart." We may parallel this feeling with the remark of some noble lord who was being congratulated on his elevation to the Garter, "The best of the Garter is that it implies no damned nonsense about merit."

Research again possesses this quality in common with what are usually called the arts—its characteristic mental process is intuition. When we were students we used to be told that the two processes of thought by which science proceeded were deduction and induction. It was pointed out that the barrenness of the medieval schoolmen was due to the fact that they worked by deduction alone from imperfect premises. Bacon became the father of modern science by recalling it to induction and to the painful collection of facts. Bacon's apothegm was recalled,

"Hypothesis non fingo," and it was suggested that the method of science was to collect an assemblage of facts and put them into some kind of sorting machine, whereupon a theory will emerge. However, a little examination of the actual history of discovery soon shows that it does not proceed in such a fashion. The function of facts is to provide tests for your hypotheses, but you can not begin to collect the facts unless you have a preliminary hypothesis.

Let me take an example in the science of meteorology. For generations people made observations of the weather, set down the records of temperature, rainfall, barometric height and so forth. Nothing whatever came of these facts until in the study one or two workers evolved from their own consciousness the theory of the cyclone. Induction in fact failed. Bacon's other great catchword, "Experimentum crucis," showed that he really had a better appreciation of the true processes of science, and the really beneficial influence he exerted upon the early science of the seventeenth century was that he directed men's attention to experiment and to the mechanic arts as the sources of knowledge. To come back to our text, neither induction nor deduction complete the story of the mental processes by which investigation proceeds. We now realize a third category in the shape of intuition, the power of seizing the truth by a sudden flash of illumination. Indeed the great discoverer may be a man in whom what is commonly called the scientific habit of mind is imperfectly developed. He may not be severely logical, methodical in his arrangement of facts, meticulous in accepting deductions.

As a recent example we may instance the late Sir William Crookes, whose marvelous discoveries certainly did not proceed by a process of minute but steady accretions from known foundations. By a sudden jump of mind he invented the radiometer, regarding which his explanations were mistaken, but his intuition led him from this point on to the whole gamut of high vacuum discovery which has resulted in such developments as the Röntgen rays, the elucidation of the structure of the atom, wireless telephony, etc. Sir William Ramsay provides another instance. In the eighteenth century Cavendish had noted that after removing all the oxygen and nitrogen from air a small residuum was left uncombined. In true scientific spirit he put this down to the inevitable errors of the experiment. But working on the same track and worrying over the discrepancy between the atomic weights of nitrogen obtained from different sources, Ramsay's intuition led him on to the discovery of argon and the range of new light elements.

So far I have only been considering research from its intellectual side as a response to man's curiosity, but the nineteenth century proved it had also a practical side inasmuch as it led to an enormously increased control over the forces of nature. I need not sing the praises of what has been effected by steam, by electricity, by modern medicine; willynilly the results are being incorporated into our daily life. Research leads to efficiency, and efficiency is a means of making money. The modern state must cultivate research if it is to become efficient and survive in the world's competition; hence all are agreed now on the endowment of research, and since in farming there are no great business corporations agricultural research must for many years to come be maintained by the state.

If, then, research is to become of such importance to the state, it behooves us to ensure conditions for the research worker under which discoveries are likely to be produced. To do this properly we must understand the psychology of the investigator. If it is true that research, like art, grows by a process of intuition, we can no more organize it into existence than we can organize the output of poetry. Nor are we likely to obtain it by a system of prizes, of rewards, commensurate to those obtained in the great professions, in industry or commerce. What we can do is to contrive sheltered places in our community in which research workers can live. We can not guarantee results, but we may wait in faith because, as we have said, the impulse to make discoveries is fundamental in man's mind. Now the sheltered places in which the research worker can live are the universities.

One last word, the state must have research in order to obtain efficiency, but does mankind really care about efficiency? At bottom man does not, he wants to "loaf and possess his soul." Efficiency is a beautiful word, but efficiency to what end? If pursued for its own sake it may become a curse. Many people have vivid recollections of the sufferings they endured under a really efficient parent in an efficient household. I, myself, am officially engaged in promoting efficiency, in bringing up the efficient farmer and in insuring the efficient use of the land. But I can not help having a great deal of sympathy with the old-fashioned farmer, who is content with what the land brings him, who is making his living but not worrying overmuch about making money. He is often inefficient, but again he is often a very worthy human being.

To take another illustration, I have a vivid recollection years ago of a little piece of swampy meadow, half encircled by a brook, which after other wanderings found its way into the Thames. There was a patch of reeds and willows, an old salley garden, where the reed warbler swung her nest and flitted through the tangled herbage. The wet meadow itself was starred over in August with Grass of Parnassus. In it was indeed one of the most southern holds of that flower of the cool northern hillsides. Well, the efficient man came along, saw his opportunity,

grubbed up the willows and laid out the meadow in watercress beds. He is a benefactor of his kind and has caused millions of blades of an edible kind to grow where there was none before; but I have a sore spot in my heart for the vanished warblers and the lost Grass of Parnassus. I fear, however, that the pursuit of efficiency is one of those contradictory elements in man's make-up that won't let him rest, that is always urging him against his will towards further attainment. What a dreary prospect if it only results in adding an ever greater and greater population to a world always working harder and harder! Is there any way out of this impasse? I can only again suggest the kindly force of that other element in the texture of men's minds, the passion for artistic expression. The winds of beauty come and go, but as they rustle through the tree of life, among the dropping leaves that are ourselves, men will cease from their toil to listen and pause while they tell of them in their own speech.

A. D. HALL

SOME SUGGESTIONS ON CLASSIFICATION

IN a note to SCIENCE,[1] the writer called attention to the very antiquated system of classification still in vogue among many botanists, and ventured to suggest that it might be worth while to adopt a system more in harmony with our present knowledge of the relationships of the larger division of the plant kingdom.

That a definitive classification is not possible at present the writer fully realizes; and the present communication is offered rather as a suggestion for further consideration of the subject than as a definite scheme to be adopted *in toto*.

Surveying the whole plant kingdom, we find below the mosses an immense heterogeneous assemblage of plants, which even now it has pleased most of our text-book writers to treat as a single primary division, or sub-kingdom, Thallophyta.

This, it seems to the writer, is no more justified than it would be for zoologists to consider all invertebrates as belonging to a single sub-kingdom. It might be permissible to retain the term Thallophyte as contrasted with the Embryophytes (Archegoniates and Spermatophytes), but only as the zoologist may find it convenient to discuss invertebrates in contrast with vertebrates, without any thought that the two are in any scientific sense coordinate.

Just as the invertebrates are universally recognized as comprising a number of quite distinct sub-kingdoms, so the "Thallophytes" include several groups, each of which should be treated as a primary division or sub-kingdom, coordinate with the whole group of Embryophytes.

When it comes to delimiting these sub-kingdoms, however, there may well be a difference of opinion as to how many of them should be recognized.

At the bottom of the scale are the extremely simple and presumably ancient forms like Bacteria, Cyanophyceae, Flagellata and Slime-moulds or Myxomycetes. The two latter have obvious relationships with the lower Protozoa, and we might perhaps adopt Haeckel's term Protista to include them; or, perhaps, we might unite these lowest plant-forms into a single sub-kingdom Protophyta.[2]

Above these simplest organisms are two great assemblages of plants, Algae and Fungi, as to whose origin and inter-relationships we have still much to learn.

The division of the higher plants or Embryophytes into Archegoniates and Spermatophytes is a more or less artificial one, and as they are all undoubtedly more or less intimately related, we shall probably best reduce them to a single sub-kingdom, Embryophyta.

The classification adopted by most of our text-book writers is essentially that of Eichler,[3] published in 1883, and even then decidedly antiquated.

The writer[4] in 1890 ventured to discard the term Thallophyte, and recognized the Algae and Fungi as primary divisions or sub-kingdoms. The term Protophyte was adopted from Sachs's Text-book, to include the Schizophyta, Myxomycetes and Volvocineae.

Engler in "Die Natürlichen Pflanzenfamilien"[5] divides the plant kingdom into Thallophytes and Embryophytes, the latter including the Archegoniates and seed-plants. The Thallophytes were divided into Myxothallophyta (= Myxomycetes) and Euthallophyta including Schizophyta, Algae (Euphyceae) and Fungi (Eumycetes).

In 1907 the late Professor C. E. Bessey published his "Synopsis of Plant Phyla,"[6] in which he discards the term Thallophyte and recognizes fifteen "phyla," or primary divisions. In this classification he does not include either the Myxomycetes or Flagellata. He divides the Green Algae into three phyla, exclusive of the Characeae, which he unites with the Red Algae, "Carpophyceae." The Phycomycetes are as-

[1] SCIENCE: Vol. LX, No. 1542, 64–65, July, 1924.

[2] See Sachs, Text-book, English translation, 1882, p. 244.

[3] Eichler, A. W., Syllabus, 3rd Edition.

[4] Campbell, D. H., "Elements of Structural and Systematic Botany."

[5] 1897.

[6] University Studies, Vol. VII, No. 4, University of Nebraska, Oct., 1907.