Agronomy, with Section G, will visit the greenhouses and laboratory of the University of Chicago. In the evening Section O and the American Society of Agronomy will attend the dinner for botanists and ecologists. On Wednesday and Thursday mornings Section O and the American Society of Agronomy will meet with Section G, the American Phytopathological Society and the American Society of Plant Physiologists for programs on progress in plant pathology during the century (see announcement of Section G). On Wednesday afternoon Section O and the American Society of Agronomy will meet in joint session with Section F and the American Society of Naturalists in a symposium on Heredity (see announcement of American Society of Naturalists). On Wednesday evening Section O will hold a dinner at which Sir Daniel Hall, of England, will speak on "Polyploidy and the Special Question in the Genus Tulipa," and Professor Jean Dufrénoy, of Brice, France, on "Death—The Change of Living Substance within the Cell." On Wednesday morning, June 28, Section O and the American Society of Agronomy will hold a joint session with Section K and the Econometric Society of America on "Elasticity of Demand for Agricultural Products," which will be discussed by Sir Daniel Hall, of England. It is hoped that Professor G. F. Warren, of Cornell University, Mr. Mordecai Ezekiel and Mr. E. J. Working, of the U. S. Department of Agriculture, will also speak.

Q—Education

Q-1. Section Q of the Association. June 29-30.
Vice-president, Walter F. Dearborn; *Secretary*, William S. Gray.

Q-2. National Society for the Study of Education. June 29-30.
President, M. E. Haggerty; *Secretary*, Guy M. Whipple.

Section Q will hold a joint meeting with the National Society for the Study of Education, the Department of Supervisors and Directors of Instruction and the American Educational Research Association. On Thursday afternoon Section Q and affiliated societies will hold a session on "Recent Advances in the Study of Components of Mental Ability." Professor Frank N. Freeman will preside. Dr. Charles Spearman, of the University of London, will report on recent experiments in factor analysis. Dr. Karl Holzinger, of the University of Chicago, will discuss the general theory of factor analysis and Professor Louis L. Thurstone will lead the discussion. A program for Friday morning is being organized around "The Function, Value and Future of Educational Research." Professor Walter S. Monroe, of the University of Illinois, will preside. This will be discussed with reference to research activities (a) in public school systems, by Dr. W. W. Theisen, assistant superintendent of schools, Milwaukee, Wisconsin; (b) in colleges and universities, by Dr. V. A. C. Henmon, of the University of Wisconsin; (c) in departments of education, by Professor Edgar Blake, of Ohio State University. "Dependability and Value of Survey Types of Investigation" will be discussed by Dr. Harl Douglass, of the University of Minnesota. On Friday afternoon there will be a session on "Essentials of an Education," Professor Ernest Horn, presiding. The discussion will be introduced by papers on "Maturation and Its Relation to Instruction." Dr. Charles H. Judd, of the University of Chicago, will speak on "The Application of Maturation to School Organization and Teaching," and Professor C. R. Griffith, of the University of Illinois, will speak on "The Psychology of Maturation." The remainder of the program will consider the essentials of an education in contemporary life at (a) the elementary school level, by Miss Bess Goodykoontz, of the U. S. Office of Education; (b) the secondary school level, by Dr. A. K. Loomis, of the University of Chicago, and (c) the college level, by Vice-president Clarence S. Yoakum, of the University of Michigan. A program is being organized for Friday evening on "Education for a Democracy." Dr. Walter F. Dearborn will preside. Miss Jane Addams, of Hull House, and President Robert M. Hutchins, of the University of Chicago, will speak.

THE VALUE OF SCIENTIFIC RESEARCH TO AGRICULTURE[1]

By Secretary HENRY A. WALLACE

U. S. DEPARTMENT OF AGRICULTURE

IN this series of radio broadcasts it is the custom, as I understand it, for each Cabinet officer to do a little boasting about his own department. I am more than willing to do my share of that on behalf of the Department of Agriculture; but in my remarks to-night I hope not only to discuss the past of this department, but also to consider its future.

Necessarily, that involves the new farm bill. By

[1] Address over a national radio network of the N.B.C. on May 1.

to-night I had hoped to be able to talk in some detail about it, but since the bill has not yet become law, detailed discussion will have to wait. In lieu of that, let me discuss the view that the new bill is the logical next step in the work of the Department of Agriculture in particular, and of all government in general.

In order properly to appraise the work of this far-flung department of the Federal Government, suppose we cut through a tedious underbrush of official and legal language, and set forth, in plain words, what the Department of Agriculture was established to do.

If you have thought about mankind's struggle through the ages to build an orderly society, you will agree that there have been two primary problems: first, to produce enough food and fiber to feed and clothe us all; second, to divide what we produce as equitably as possible.

We have always had to be concerned with production. Whatever else man can do without, he can not live without food. And that was no simple problem back in the days when men lived in tribes in the forests, and when the food supply depended upon a man's skill with crude weapons. When the first faint stirrings of commerce and industry drew men to live in larger groups in cities, the problem of a food supply became even more acute. Those who lived in the ancient cities could not grow their own food and fiber. Those who remained on the farm had the new job of growing enough not only for themselves, but for other families in nearby cities. Thus the dependence of the city dweller upon the farmer is overwhelmingly real. It is the key-log in this structure we call modern civilization.

And there were times when the structure was in danger of collapse, or indeed did collapse, because the key-log weakened and gave way. By reason of abnormal seasons, drought or flood, famines came and wrecked whole segments of human society. It was customary to blame those catastrophes on nature. Man, weak creature, was powerless if nature chose to starve him or drown him or otherwise maltreat him.

Somewhere back in the ages, a few individuals, more daring, more imaginative than the rest, began to wonder whether that was true. They reasoned that though nature could not be ignored, it could be modified. Man began doing that when he learned how to make fire by rubbing sticks together. We have been modifying the behavior of nature ever since, to prevent famine, flood and other disasters, until, as Julian Huxley puts it, man has done more in five thousand years to alter the biological aspect of the planet than nature has done in five million years. By putting nature in harness, so far as possible, we have solved mankind's first great problem—the problem of producing enough food to go round. We have solved it too well, as a matter of fact, but I shall speak of that later.

When it is possible for the farmers of a nation to increase production 50 per cent., while crop acreage is increasing only 25 per cent., we know that science has been at work. That is exactly what has happened in the United States during the past 30 years. In large part it is a result of the scientific work of the United States Department of Agriculture and the cooperating state institutions.

It was for the purpose of putting science to work in agriculture that this Federal Department of Agriculture was established by act of Congress 71 years ago. Washington, Jefferson and Franklin saw the need for it even back in their day. The department was created primarily for scientific research, its main job always has been a research job, and I hope research will always remain a principal duty.

Of course it is not enough to discover facts: a public institution has also the obligation to see that the facts are made available to all who can profit by them.

When a plant breeder in the department develops a variety of wheat that is highly resistant to rust, the job of the department has not ended with that discovery. The new variety has to be tried out in various regions, in the field. Next, the results of those trials have to be made known to wheat growers. That involves publications, both technical and popular, and articles for the press, and radio broadcasting. Then the seed of the new variety has to be made available to farmers. The county extension agent may step into the picture at this point, and suggest that the interested wheat grower sow some of the new seed in a test plot, alongside some of the seed he and his neighbors have been using in the past. And when the old and the new varieties of wheat are up and are harvested, let the neighbors for miles around come in to compare them, and decide whether or not the new variety is better than the old and worth investing in.

That is a thumbnail sketch of the way science is applied to agriculture in this country, and it portrays a system that is the envy of many another nation. Sir Horace Plunkett, Ireland's great authority on agriculture, in 1928 was moved to describe the Department of Agriculture as "the most widely useful department in the world." I am inclined to agree, and I only hope that its future will be as brilliantly successful as its past.

Whether he knows it or not, every farmer in the United States is farming differently to-day—and better—because of the scientific discoveries resulting from state and federal appropriations. The average hour of man labor and the average acre of land is undoubtedly 20 to 30 per cent. more productive to-day because of this scientific work. From the fundamental point of view—that of supplying the food and fiber needed by our modern civilization—the millions of dollars spent by state and federal agencies during the past generation have been abundantly worth while.

I appreciate that it is often difficult for the layman to see any earthly use in many of the things that scientists do and talk about doing. Of what value is it to you and to me, for instance, for a man to spend his time trying to discover the workings of nature? How can a man—we are inclined to say—do anything useful unless he works directly with the things that we all can touch and see, that we know have practical utility?

Well, when confronted by questions like that, I think of men like Faraday and Mendel and some of the scientists in the employ of the Federal Government. About a hundred years ago in England Michael Faraday was what we might call an experimental philosopher. He never concerned himself with the invention of machines. His sole aim was to learn something about the workings of nature. He discovered the principle of electromagnetic induction, and if you remember your high-school science, you will recall that without that discovery, we would to-day have no means of putting electrical energy to work for us. Without Faraday, the amazing inventions of Edison and Marconi would not have been possible, and your radio and your electric lights would not exist.

And Mendel, that cloistered Moravian monk who whiled away the hours studying plants and experimenting with the cross-breeding of varieties of garden peas—of what earthly use was all that? He did it because it interested him. But was it of any use to the rest of us? I can assure you that it was, for the principles he discovered have been employed by the plant breeders of to-day in developing more productive varieties of every plant that feeds and clothes you. Scientists like Mendel and Faraday were working in what we call pure science. They were trying to discover nature's fundamental secrets, but without thought of any practical application of their discoveries. Had some overzealous administrator tried to restrict their curiosity to some specific object, or the immediate solution of some highly practical problem, we would have been deprived, in all probability, of their great discoveries.

It falls upon another group of scientists to apply these basic principles to the pressing problems of the world and turn them to practical account. Thus most of the scientific research in government departments is applied science. The surprising thing, however, is that even in the field of applied science far-reaching discoveries are made, often as a by-product of the immediate task.

One of the most famous examples was the discovery by scientists in the Department of Agriculture some forty years ago, that a microorganism found in the blood of cattle is the cause of splenetic fever, and that the disease is transmitted by the cattle tick.

During the years 1888 to 1893, four men spent most of their time trying to make that discovery. Splenetic fever had become a costly disease of cattle throughout the South. Home-made remedies, treatment by skilled veterinarians, alike proved futile. The disease was costing the live-stock industry, and ultimately the consumer of meat, many millions of dollars.

The four Department of Agricuture scientists, in the employ of the government because they wanted to pursue scientific research without interruption, and at salaries sadly out of line with their worth to the nation—these men kept doggedly on the job despite all sorts of obstacles and disappointments. The joy of achievement was their chief reward. And their achievement proved to be of lasting benefit not only to the live-stock industry, but to all mankind, for their research was the first demonstration that a microbial disease can be transmitted exclusively by an insect host or carrier.

From that came the knowledge, at the hands of other scientists, that yellow fever, malaria, sleeping sickness and other maladies are similarly transmitted. From that flowed the successful control of yellow fever, for instance, which in turn made possible the building of the Panama Canal. So it can truthfully be said that the success of four Department of Agriculture scientists in discovering the cause of a cattle disease was a first step in the construction of the Panama Canal.

These scientists—by name Theobald Smith, Curtice, Kilgore and Salmon—of course had no idea of the far-reaching consequences of their discovery. They were intent on finding the cause of a cattle disease, not in discovering a fundamental principle in medicine. But that happens often in scientific research.

And at other times, a scientist may fail to solve one problem, only to solve another unexpectedly. Not long ago some chemists in the Department of Agriculture were examining molds—fungous growths, that is —to find one that would produce tartaric acid. Patiently they tested one after another, until they had exhausted the possibilities of 149 different molds. Finally the 150th rewarded their long search with success—but not the success they were expecting. Instead of producing tartaric acid, the 150th mold unexpectedly produced gluconic acid. This is now used in making calcium gluconate, the only calcium salt that can be injected between the muscles, without causing abscesses, in treating certain human diseases. This salt used to cost $150 a pound. As a result of this research, it may now be had for 50 cents a pound.

Much of the scientific work of the department, however, calls for more than the ordinary equipment of a scientist. I am thinking of the plant explorers, the men who cut their way through treacherous jungles, or press on across the forbidding deserts of Mongolia in search of plants that we need here at home. Whenever you eat bread made from durum wheat, or enjoy a choice steak or pork chops from cattle or hogs fed on alfalfa and soybeans, or sample a package of dates or a crate of navel oranges from California or the new Satsuma oranges from Florida —whenever you enjoy any of these things, you are reaping the benefit of the work done by a handful of explorers employed by the Department of Agriculture.

If you live in the Gulf Coast region, you probably are familiar with the rise of a new industry down there, the growing of tung oil trees. About 25 years ago tung oil revolutionized the manufacture of varnish, but the oil had to be imported from China. Back in 1905 David Fairchild, plant explorer of the Department of Agriculture, brought the first seeds of the tung trees to the United States from the Yangtze Valley of China. Our plant industry men discovered, after a good deal of experimentation, that the trees do well in the Gulf Coast region, and the new industry is to-day firmly established there.

Not every trip of a plant explorer, of course, is so productive. Every trip has its dangers and its adventures, but frequently the results are slight. Yet the introduction of a navel orange or a useful variety of soybeans or a hardy wheat atones for many unsuccessful trips.

In one way or another, I have said, every farmer in the United States is farming differently to-day because of the scientific discoveries resulting from state and federal appropriations. To be specific and as up-to-date as possible, suppose we run down the list of research achievements reported by one bureau of the Department of Agriculture for the past year. Before me is a summarized report for the Bureau of Plant Industry, and among their accomplishments I find these items:

Established the superiority of five new hybrid lines of corn in Iowa tests; released, for the use of growers, two new lines of hybrid sweet corn that will be resistant to bacterial wilt; released, for the use of growers, a new wilt-resistant variety of tomato, known as the Pritchard; introduced a new blackberry variety, the Brainerd, especially adapted for the West and South, and also introduced three improved varieties of strawberry; developed new root-stocks for Satsuma oranges, and found new disease-resistant stocks for California grape vineyards; introduced a new sugar beet, U. S. No. 1, that is resistant to the costly curly-top disease, and that also greatly outyields older varieties; tested some promising new sugar-cane seedlings, crosses of American and New Guinea varieties; reported distinct progress in breeding alfalfa that will be immune to bacterial wilt; developed a new variety of Egyptian cotton in Arizona.

As another part of its job, this bureau investigates the storing, handling and processing of foods. For the year under report the bureau scientists discovered, among other things, that putting apples in cold storage immediately after picking almost completely prevents soft scald; that adding sulfur dioxide to the sawdust packing of grapes retards the development of mold; and that treating fruits with carbon dioxide before shipment is as effective as pre-cooling in preventing spoilage.

That is a partial report of the research accomplishments of one bureau. It gives point to the statement that research can stabilize crop production and eliminate or reduce those hazards—of disease, of climate, even of soil—which make agricultural production uncertain. For it remains true that though drouth or disease or insect pests may raise the price of a crop by reducing the supply, such higher prices are cold comfort to the particular farmer whose cotton has been destroyed by the boll weevil or whose wheat has been hit by rust. I have, I think, a proper scientific respect for insects and diseases, but I question whether we ought to leave it up to them to determine the size of our crops and the level of our incomes. Nor can I forget that every year, according to Dr. L. O. Howard, the damage wrought by insects nullifies the labor of a million men.

If time and your patience permitted, it would be possible to cite instances to show how research has affected all our major farm crops and classes of live stock, how the patience, the skill and the informed imagination of scientists employed by the Department of Agriculture have altered the agricultural map of this country and modified the farm practises of every farmer in the land. Many farmers are not aware of this, for the results of research reach the individual farm by an intricate, devious path, but they get there just the same.

If you will agree with me on that, I suspect you are at the same moment questioning whether this research has proved to be an unmixed blessing. For science and invention, you will say, have not only made it possible for us to produce enough to go around: they have made it possible for us to pile up towering surpluses, which in turn seem capable of bringing our whole economic system crashing down around our ears.

We can not deny that, when scientists in the Department of Agriculture develop a variety of wheat that produces five bushels more per acre than the variety commonly grown, one result may be, and often is, too much wheat. When our modern knowledge of nutrition enables one bushel of corn to go as far as two bushels did in the pioneer days in feeding live stock, one result may be too much pork and lard.

Of late years the Department of Agriculture and the colleges have been aware of the problem. They have tried to meet it by helping the individual farmer adjust his own production to changing market needs. They have hoped that advice and complete information on supply and demand would suffice.

Where they have been remiss, in my judgment, is in declining to face the fact that the individual farmer can not adjust his production intelligently, unless he knows, with some degree of certainty, that his neighbors will do likewise. And it is to face that fact realistically that the new farm bill has been drafted. The essence of it is collective action, by all the producers, to accommodate their production to the market that actually exists.

Our expenditures for science, our efforts at increasing productive efficiency have in no sense been unwise. Certainly no thoughtful person could approve the abandonment of scientific research, or the relegation of our machines to the ash-heap. To do that would be like abandoning the use of automobiles because we have automobile accidents. As a rule, the fault is not with the automobile, but with the driver.

It is not the fault of science that we have unused piles of wheat on Nebraska farms and tragic breadlines in New York City at one and the same moment. Rather it is because we have refused to apply science to the development of social machinery, machinery that will regulate our economic system to the end that what we produce can be equitably divided.

I am not one to ask for less efficiency. I want more, and I know that we can get far more. But I want the efficiency to be controlled in such a way that it does more good than harm. I want to see the farmers of the South grow 300 pounds of cotton per acre instead of 150 pounds, and the farmers of the North 50 bushels of corn per acre instead of 35 bushels. I want to see the average milk cow yield 400 pounds of butter fat per year instead of 200. And I see no reason why our hogs eventually should not produce 100 pounds of pork on the average from 6 bushels of corn, instead of from 9 bushels.

These things can all be done. The research now going on will make it possible, and will pave the way for countless new agricultural achievements as well.

Only the other day I learned that research now in progress indicates that crops grown in some regions of the nation have a higher nutritional value than do apparently similar crops grown in other areas. If further study bears this out, the consequences will certainly be far-reaching. We may have a new agricultural map a decade from now.

The research job, far from being done, is only well begun. We shall need new varieties of cereals and grasses to resist diseases better than those we now have. We shall have to keep cutting costs of production by increasing yields per acre. Methods of cultivation, like methods of feeding and managing live stock, must be subject to continuing investigation if we are to keep abreast of the continually changing economic world about us.

When our chemists, not long ago, discovered an economical method by which bagasse, a sugar cane waste, could be made into high-quality cellulose, suitable for rayon, we patted ourselves on the back for an achievement of considerable importance. But over in the Bureau of Chemistry and Soils is a small bottle of a brownish cellulose substance called lignin, which was derived from the corn plant after many years of experimentation. The chemist will tell you that lignin is one of the principal parts of woody plant tissues; that it can therefore be obtained in abundance; and that it may yield a startling new collection of products. Already he has discovered in lignin such compounds as phenol and creosol. Lignin may yet rank, in its rich potentialities, in its influence on disposing of farm wastes, with our major chemical discoveries.

No, the job of scientific research in agriculture is not over, nor will it ever be. But to-day we have a new job, a new field for experimenting—that of social control. Research to increase productive efficiency, to widen markets, must continue. Eliminate the less important research activities, in deference to the need for economy; get rid of the dead wood in our scientific organizations—but keep the men of science at the tasks which will always need doing. And add to the old job the one that has been begun so well, this new job of developing the machinery of social control.

Can we, do you suppose, become as efficient in our social experimenting as we have already proven ourselves in scientific experimenting? If this can be done, we can go ahead into one triumph after another in the scientific world. If it is not done, I fear for the future of our civilization.

The farm bill is an effort in the direction of such social inventiveness. In some ways, it is perhaps as crude as the first automobile. But I believe it is profoundly right in purpose, for it attempts a reconciliation between science and social justice; and I believe it can be made to work, if the rank and file of the people of the United States—the men who grow our food, the men who handle and distribute it, the men and women who consume it—the new machine will work if all these people are genuinely hungry to distribute the fruits of science in a just way.

For that is our great modern problem. Having conquered the fear of famine, with the aid of science, having been brought into an age of abundance, we now have to learn how to live with abundance. Some-times I think it requires stronger characters, greater hearts and keener minds, to endure abundance than it takes to endure penury. Certainly it requires a new degree of tolerance among competing economic groups and a willingness to subordinate the will of the few to the welfare of the many.

Personally, I think the last twelve years have imprinted this lesson deeply on all of us. I think we are ready, now, to reach out towards a new order. I believe we are ready to attempt to plan our economic life in return for stability and security. If this is true, then we have reached a great moment in the history of mankind. We have determined to become the masters rather than the victims of destiny. We are daring to bring the economic interests of men under conscious human control.

We may make mistakes along the way; we may have difficulty in mastering all the intricacies of an economic system that is full of puzzling contradictions; but if we operate our new social machinery with the spirit of social justice in all our hearts, I believe that it will work.

THE SIGNIFICANCE OF RECENT MEASUREMENTS OF COSMIC RAYS[1]

By Professor ARTHUR H. COMPTON

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THREE major methods of observing cosmic rays have been developed. By means of an ionization chamber filled with a gas such as argon under high pressure the cosmic rays can be measured in terms of the conductivity or ionization they produce in the gas. Thus it is found that at high altitudes in a balloon or on a mountain a much greater ionization is observed than at sea-level, while inside a deep tunnel, if the gas is shielded from gamma-rays, ionization is almost completely absent. The cloud expansion chamber, invented by C. T. R. Wilson, makes visible the paths of the ionizing particles associated with the cosmic rays, as they break into ions some of the air molecules through which they pass. Some of these particles seem to be the cosmic rays themselves, whereas others are secondary particles produced by the cosmic rays. Highly sensitive ion chambers, connected through amplifying tubes to electrical recorders, serve to count the cosmic rays as they pass through the chambers. These are known as "counting tubes." By arranging these tubes in pairs, so connected that they will record only when both are excited simultaneously, it is possible to study the direction from which the cosmic rays are coming.

With the help of such devices it has been found that a kind of ray exists which comes from high above the earth and is strongly but not completely absorbed as it passes through the earth's atmosphere. Believing that these rays have originated in the remote parts of space, they have been called cosmic rays. The heat that they bring to the earth is less than that of starlight. But they are the most penetrating rays with which we are acquainted.

[1] Based on an address delivered at the dedication of the Eastman Research Laboratories of Physics and Chemistry, at the Massachusetts Institute of Technology, May 1, 1933.

Two types of theories have been suggested to account for the origin of these rays. The first type assumes the cosmic rays to be photons, or electromagnetic waves, like light or x-rays or the gamma-rays from radium, but of much shorter wave-length. If the rays are of this type, their observed penetrating power corresponds to the energy of rays that might be emitted by subatomic processes, such as the formation of hydrogen out of helium or the annihilation of hydrogen atoms. Dr. Robert A. Millikan has strongly defended the view that cosmic rays are emitted at the formation of heavy atomic nuclei from groups of lighter nuclei, and has made this a stage in the life cycle of matter in a continuous universe. Sir James Jeans has proposed the annihilation of hydrogen atoms as a source of the most penetrating cosmic rays, and sees this as one way in which the universe is running down.

The second class of theories supposes that cosmic rays are not photons, but electrically charged particles entering the earth's atmosphere from outer space. Dauvillier imagines that these particles are shot out from the sun by intense local electric fields. Swann suggests that they come from the changing magnetic field of sunspots on the hotter stars. But by far the most romantic and by no means the least plausible theory is that of Abbe Georges H. Lemaitre. He attributes them to a primeval explosion of the universe some thousands of millions of years ago, since which time the universe has been expanding, and certain atoms and pieces of atoms that have been flying about in space ever since constitute the cosmic rays which we now observe.

In order that a choice may be made among these theories, it is important that the nature of the cosmic rays be learned. Five methods of approaching this problem may be mentioned: