Six months ago, when we landed on this island, absolutely nothing was known concerning the propagation and spread of yellow fever—it was all an unfathomable mystery—but to-day the curtain has been drawn.

And later on New Year's Eve, he wrote:

Only ten minutes of the old century remain. Here have I been sitting, reading that most wonderful book, "La Roche on Yellow Fever," written in 1853. Forty-seven years later it has been permitted to me and my assistants to lift the impenetrable veil that has surrounded the causation of this most wonderful, dreadful pest of humanity and to put it on a rational and scientific basis. I thank God that this has been accomplished during the latter days of the old century. May its cure be brought out in the early days of the new.

Yet we need not wait for any of the great discoveries of the future to make the public health campaign of the present day bear fruit. We want sanitary statesmen as much as investigators. We need organizers and propagandists for the cause of health, capable of building wisely the great scheme of health protection of the future and of enlisting in its support the enthusiastic cooperation of the peoples of the earth To the administrator, as much as to the investigator comes the consciousness of a reward for his labors, fuller and more immediate than that which can be earned in many walks of life, for he can know that in a given city in a given year so many hundreds or thousands of men and women and children are alive and well who would have been in their graves except for him. What old Sir John Simon said of industrial diseases is true of every kind of preventable malady which afflicts mankind.

The canker of . . . disease gnaws at the very root of our national strength. The sufferers are not few or insignificant. They are the bread winners for at least a third part of our population. . . . That they have causes of disease indolently left to blight them amid their toil . . . is surely an intolerable wrong. And to be able to redress that wrong is perhaps among the greatest opportunities for good which human institutions can afford.

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THE ORGANIZATION OF RESEARCH[1]

THIS is an age of organization. Almost within the lifetime of some of us the industries, with the exception of agriculture, have passed in large degree from the individualistic to the corporate form. Combinations not merely of national but of international scope exercise a large measure of control over manufacturing and commercial activities, while associations of the greatest variety—commercial, charitable, reformatory, labor—have multiplied until their name is "legion." Almost every conceivable calling, from the midwife's to the undertaker's, is organized.

Since science is a product of human activity its methods must necessarily be influenced by the spirit of the time. In particular, the successes of groups of scientific men in making important contributions to the solution of the technical problems raised by the entry of the United States into the world war has led to an emphasis upon the advantages of organization and cooperation in research which was very much in evidence at the last meeting of this association. This was particularly evident, perhaps among the biologists where it was, in the words of another, "the dominant note," but the same note has been sounded by various prominent writers both before and since that meeting. It seems desirable, therefore, in view of this apparently strong trend of both public and scientific opinion, to inquire somewhat carefully into the extent to which it is justified and as to the probability that a more complete organization of research will enable it to render more efficient public service. In attempting to do so I shall, of course, have reference particularly to agricultural research—implicitly if not explicitly.

In the early history of science, research was necessarily upon an almost purely individualistic basis. Men of genius here and there were laying the foundations of the present amazing superstructure not only without

[1] Address of the vice-president and chairman of Section M—Agriculture, American Association for the Advancement of Science, St. Louis, December, 1919.

public support but subject sometimes to scorn and even persecution but more often to an indifference not reaching the level of contempt. By slow degrees, however, it began to dawn upon the public that the investigations of these dreamers really had some significance for the practical conduct of life. Very gradually at first, but with an accelerated velocity as time went on, the scientist came to be recognized as a useful member of society although even yet he seems too often regarded in the light of a sort of "medicine man" who can be called upon to work magical incantations in times of need or peril or as a magician who, by some sort of legerdemain, can accomplish the seemingly impossible.

Along with this growing recognition of the economic and commercial value of its results, scientific research began in time to be regarded more and more as a public function and to be more or less adequately supported, either by private endowment or notably by governmental action. The latter has been especially the case with agricultural research. I need not rehearse to this audience the familiar story, beginning with the foundation of the first public experiment station at Moeckern in 1852, the growth of the European experiment stations, the founding of the early American stations by state action, the enactment of the Hatch and Adams Acts, the increasing appropriations by the states and the enormous growth of the United States Department of Agriculture. For agricultural research it has been a period of expansion and organization upon an unprecedented scale and it is scarcely to be wondered at that the real nature of the end aimed at was sometimes lost sight of in the consideration of the means by which it was to be reached nor that the proper freedom of research should have been in some degree menaced, on the one hand by bureaucratic administration and on the other by the pressure for immediately useful results.

It is unnecessary to remind you that this tendency gave rise to a wholesome reaction. For several years it appeared necessary to stress the fundamental significance of the initiative and independence of the individual investigator but by the time the United States entered the war it may be said that this view had received fairly general recognition and there was perhaps a tendency to excessive individualism and a certain lack of coordination and cooperation in agricultural research.

With our entry into the war began a new era in scientific activity as well as in world politics. Urgent war needs led to a concentration of scientific effort upon special problems of the most varied character and to a degree of cooperation and coordination until then unknown. The results were almost spectacular and as a natural consequence there has come a revival of interest in cooperative work and the demand for better organization of research which has already been referred to. Probably the most conspicuous as well as the most familiar example of this is found in the statement made by The Hon. Elihu Root before the Advisory Committee on Industrial Research of the National Research Council.[2] He says:

> Scientific men are only recently realizing that the principles which apply to success on a large scale in transportation and manufacture and general staff work apply to them; that the difference between a mob and an army does not depend upon occupation or purpose but upon human nature; that the effective power of a great number of scientific men may be increased by organization just as the effective power of a great number of laborers may be increased by military discipline.
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> . . . . . .
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> All other (than very great) minds need to be guided away from the useless and towards the useful. That can be done only by the application of scientific method to science itself through the purely scientific process of organizing effort.
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> It remains to be seen whether peoples thoroughly imbued with the ideas and accustomed to the traditions of separate private initiative are capable of organizing scientific research for practical ends as effectively as an autocratic government giving direction to a docile and submissive people.

Similarly Whetzel[3] writes:

[2] Science, November 29, 1919.

[3] Science, July 18, 1919.

The fact remains that while the rest of mankind has gone far along the way which we (the scientific men) have discovered and pointed out we still remain largely isolated and intrenched in the feudal towers of our individualism. Here behind moat and wall we shape and fashion those intellectual darts with which at our annual tourneys we hope to pierce the haughty pride of some brother baron. Yet common sense, the common good, the very progress of our profession demands that we abandon this ancient outworn attitude.

And Coulter[4] says:

Our isolated, more or less competitive investigations have resulted in a certain amount of progress; but it has been very slow compared with what cooperation would have secured.

Nor do the advocates of organization lack apparently convincing examples of success in scientific cooperation. Not to speak of the striking wartime achievements in the applications of chemistry, physics and engineering, one may name such typical illustrations in the field of agriculture as those cited by Shear,[5] namely, the cooperative work of several bureaus of the Department of Agriculture upon the chestnut blight problem and upon the spoilage of fruits and vegetables in transit and especially the work of the War Board of the American Society of Phytopathologists, while in a related field the work of the Interallied Scientific Food Commission, although cut short by the German collapse, may also be cited. Shear speaks of this trend cooperation as a "tide in the affairs of men."

But not withstanding all these emphatic dicta, may it not be well to call a moment's halt to consider whither this tide is carrying us and whether it really "leads on to fortune." May there not be a certain danger of overlooking the significance of the individual? We must beware of being stampeded by the brilliant successes of the war time into an undue exaltation of the virtues of cooperation and organization. Both are doubtless very valuable but many of their ardent advocates seem to overlook the fact that the recent highly successful essays in cooperation which they emphasize were chiefly directed to the solution of immediate technical problems by the application of knowledge acquired largely by individual research. The striking results of war-time cooperation were very largely of the nature of inventions rather than of discoveries. The achievements in sound-ranging, in ballistics, in submarine detection, in aviation, in gas warfare, in the control of plant diseases and the like were possible only as the fruition of long and patient researches into the fundamental laws of physics, chemistry, and biology conducted quietly by individuals or by little groups without public notice or applause. It is just as true to-day as it ever was that the permanent and significant advances of science depend in the last analysis on the initiative and originality of individuals. Nothing can alter this fundamental fact.

But on the other hand the fullest recognition of the paramount importance of the individual investigator should not blind us to the great significance of the experiences of the last few years. Let us first consider what they teach us as to the sort of problems best suited for cooperative effort. What is the field of cooperation as contrasted with individualism?

As just noted, the problems of war-time cooperation were largely the problems of practise and it is these practical problems which seem to offer the greatest opportunity for cooperation. Such problems, however, constitute one extreme of an intergrading series whose other extreme is the problems of so-called "pure" science. Using Coulter's[6] terminology and speaking of the former as superficial and of the latter as fundamental problems, it may be said that in general as we pass from the superficial toward the fundamental, cooperation becomes a less and less promising method for research. Usually the best thing that can be done for the man of scientific vision, who is capable of the most fundamental kind of research, is to supply him with the necessary equipment and facilities and then let him alone. Committees and cooperators are in danger of being hindrances rather than helps. Comparatively few of us

[4] SCIENCE, April 18, 1919.

[5] *Scientific Monthly*, October, 1919, p. 342.

[6] SCIENCE, April 18, 1919, p. 365.

can be ranked in that class, however. The majority of investigators must be content to be journeymen rather than master builders on the edifice of science and the rate of progress of the structure depends very largely on the persistent, conscientious work of the ordinary investigator. The advance of science as a whole is, after all, a rather prosaic affair, including a vast amount of drudgery and requiring patient "plugging" rather than genius.

Furthermore, the problems of more immediate importance to mankind are often the less fundamental ones or those near the middle of the series. It is for the more superficial or practical problems and for the ordinary investigator that organized cooperation seems most promising. It is investigators of this type, possessing varying degrees of initiative and inspiration, who can profit most largely by mutual association, particularly in connection with the more superficial problems, while it is in this type of investigation that the initiative and inspiration of the individual is at once most significant and most in danger of being suppressed. They, more than the genius, need the inspiration and stimulus to initiative which comes from close contact with their fellow workers.

Another class of problems in which cooperation seems especially called for are those requiring the application of diverse branches of science. Such was notably true of many war problems and is perhaps particularly the case with the larger agricultural problems of a more or less practical nature—especially regional problems such as the development of farming in the semi-arid regions, the study of plant diseases or, in a different field, such questions as sewage disposal.

In brief the teaching of our war experiences, as I see it, is that our rate of future scientific progress will depend, not exclusively upon cooperation on the one hand nor upon individualism on the other but upon a wise combination and adjustment of the two in varying proportion according to the nature of the problem attacked and the abilities of the investigators concerned.

Granting the truth of this view, a second fundamental question is, "How can cooperative effort, where desirable, be most efficiently organized?"

Substantially three things are to be effected. First, that effort shall be directed to really significant and fundamental problems. The issues of civilization are too vast for us to lapse into dilettanteism. Second, that the methods employed shall be sound, so that effort may not be frittered away in empirical experiments leading nowhere. Third, to secure that stimulus to zeal and persistence which comes from association in a common cause.

How can these objects be realized? How can we gain the advantages of association and cooperation without sacrificing that initiative of the individual upon which, in the last analysis, the efficiency of even practical research depends. I think we should all agree that this can not be effected by any such bureaucratic or even military organization as would seem to be contemplated by the words of some writers—notably by Mr. Root in the passages which I have quoted. Let me repeat a single phrase:

> That the effective power of a great number of scientific men may be increased by organization just as the effective power of a great number of laborers may be increased by military discipline.

Such expressions as these, like a certain notorious report on academic efficiency, if taken at their face value, betray an almost ludicrous misconception of the conditions of productive scientific activity and are particularly surprising in a man of Mr. Root's breadth of view, who in the same statement has shown so clear an appreciation of the value of abstract research. Organization of this sort may serve for a works laboratory doing routine control work or perhaps for the law offices of a great firm but we can not stimulate scientific investigation by strangling personal initiative. The question is how investigation can be coordinated without destroying the individuality of the investigator. This can not be done by laying down hard and fast plans involving any sort of factory system of division of labor.

And yet, as I have tried to make clear, reasonable cooperation and coordination in research offer possibilities for greatly increasing the rate of scientific progress. Individualism and cooperation must not be antagonists but yokefellows in the chariot of science. What then shall be the binding force which shall fuse these two ideas? Precisely the same that held together the various groups of scientific men during the war, viz.; the tie of a common interest and a common purpose. I have compared the great body of investigators to journeymen but this does not mean that they are merely "hands." They are self-directed workers and therefore any organization of them must be democratic. They are all partners in the enterprise and sharers in its profits. The men who worked together almost night and day to devise efficient gas masks or means of submarine detection or methods of sound ranging were not workmen under the orders of a superior, but free associations of scientists with training in common or related fields of research and under the inspiration of a common patriotism. Precisely this is what is needed to achieve the victories of peace. Effective cooperation can not be imposed from above by administrative authority but can only come by free democratic action of investigators themselves. In saying this I am not charging administrators with either indifference or incompetency. The difficulty lies in the nature of things. There must be the will to cooperate.

We may, I think, distinguish two distinct forms of cooperative organization which we may call for convenience institutional organization and subject-matter organization.

In the agricultural field, at least, much emphasis has been laid in the past upon institutional cooperation as between different experiment stations, between the stations and the U. S. Department of Agriculture, and to some extent at least between some of the bureaus of the latter department. Much anxiety has been expressed over the real or supposed duplication of work by the state stations and Section 3 of the Hatch Act seems to contemplate more or less coordination of experiments. It is within the memory of some present, too, that the first conception of the Office of Experiment Stations was that of a central directing agency. While this idea was early abandoned, numerous voluntary efforts toward the coordination of projects have been attempted through committees of the Association of Colleges and Experiment Stations, one recent suggestion, that of a sort of Agricultural Research Council, constituting more or less of a reversion to the early conception of the Office of Experiment Stations.

On the whole, however, it may be doubted whether the results reached in this way have been commensurate with the conscientious and praiseworthy efforts put forth by the experiment stations and the Department of Agriculture. These institutions and to a large degree the individual bureaus largely go their own way, with the exception in the case of the stations of the restrictions involved in the approval of projects by the Office of Experiment Stations, and this condition seems likely to continue.

Meantime the various forms of war work have afforded striking illustrations of the success of the second type of cooperative effort, *viz.*, cooperation by subject-matter. The significant lesson of war-time organization is the efficiency with which scientific men in the same field have got together, largely independent of institutional or administrative subdivisions. I believe that this same principle can be applied to the more fundamental research problems—that scientific men may to advantage organize in this way, forming group or regional conferences which might be especially profitable for those living in somewhat isolated localities and not in such ready contact with their fellows as is the case with those situated on the Atlantic seaboard. Such free conferences, formulating the common judgment of workers in identical or related fields can scarcely fail to furnish both guidance and inspiration for the progress of research. In brief, I believe we can very effectively promote research by consultation and conference of those interested in particular subjects or groups of subjects. We should thus have a loose organization at right

angles, so to speak, to the administrative organization, which would bring the collective judgment of experts to bear upon the choice of scientific problems and upon the adoption of adequate methods for their solution and which would not be in any sense antagonistic to the official organization.

Much progress has already been made in this direction. For example The American Society of Animal Production has formulated a valuable set of standard methods for the conduct of feeding experiments, while the very effective work of the War Board of the American Society of Phytopathologists is familiar to us all and still another illustration is the Association of Southern Agricultural Workers. But the most significant and comprehensive achievement in the organization of American research is one which has been prominently before the scientific public and with which we are all familiar, viz; the National Research Council. From the point of view advocated in this paper its organization is peculiarly significant because it was effected by the voluntary initiative of the investigators themselves and because, therefore, it is thoroughly democratic in form and has been careful both in its initiation and development to conserve the individuality of the research men. The past successes of this wise combination of organization and individualism demonstrate its essential soundness and constitute the best guarantee of its future achievements.

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SCIENTIFIC EVENTS

CONFERENCE OF BRITISH RESEARCH ASSOCIATIONS

A conference of research associations—the second of a series—organized by the British Department of Scientific and Industrial Research, was held according to *Nature* on December 12 in the lecture-theater of the Institution of Civil Engineers. The Right Hon. A. J. Balfour, Lord President of the Council, appropriately presided, the Department of Scientific and Industrial Research being a committee of the Privy Council. Mr. Balfour, who was warmly greeted on his first public appearance in his capacity of head of the department, delivered a short introductory address on the national need for scientific research, especially in its application to industry. Three points emphasized by Mr. Balfour were that, though man does not live by bread alone, the amelioration of the material lot of mankind can come only through progress in scientific knowledge; that we must not imitate, but follow the example of the Germans in realizing a helpful and close alliance between science and industry; and that in the prosecution of this aim the paramount interests of pure science must not be overlooked. Papers were afterwards read by Major H. J. W. Bliss, director of the British Research Association for the Woollen and Worsted Industries, on "Research Associations and Consulting Work and the Collection and Indexing of Information," and by Dr. W. Lawrence Balls on "The Equipment of Research Laboratories." There was a general discussion on the subject-matter of the two papers, from which it was clear that, although there is a large common measure of agreement among the different associations, there is also enough variety of circumstance and character to make it desirable for each association to work out its own salvation in many problems of organization and method. It is the intention of the Department of Scientific and Industrial Research to continue periodically these conferences of research associations. As the department, in fostering the associations, is engaged in a novel adventure in government enterprise, the research associations have to set sail on uncharted seas, without maps or precedent experience to guide them, and these periodical conferences must be of great help to them in mapping out their courses and taking their soundings.

THE MEDICAL STRIKE IN SPAIN

The *Journal* of the American Medical Association states that the town of Jerez de la Frontera, which has a world reputation on account of its famous wines, has just witnessed the first general strike of physicians. This