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CONSTRUCTIVE SCIENTIFIC RESEARCH BY COOPERATION¹

It has been occasionally suggested that one of the reasons for the slow advance of science lies in the fact that scientific research problems are still generally attacked by individuals or by small, local groups of workers influenced by a single individual, rather than by planned cooperation among a number of workers in different institutions. Individualistic research has been characterized, by the late Professor C. E. Bessey, as a kind of guerilla warfare upon the unknown. As in other lines of human activity, it seems highly desirable to outgrow this kind of attack, just as rapidly as the appeal of well-planned campaigns and the desire for a maximum of service to race advancement makes itself felt by scientific workers. Commercial research is now frequently carried on in this way, different individuals being actually paid for studying certain aspects of a broad problem and for bringing their minds to bear upon it in a cooperative way. The more fundamental aspects of scientific investigation and the clearing up of the broader, general principles of science have not usually been approached in this manner; the extremely individualistic methods of the Middle Ages seem still to be in vogue.

This state of affairs in science is sometimes thought to be due to the supposed fact that an investigator can not confine himself to what he starts out to study, but that he is constrained, by the nature of investigation itself, to follow his evanescent interests and caprices wherever they may lead. But the scientific researches undertaken and carried out by large commercial establishments and also, especially, those that were so remarkable furthered by preliminary planning and a division of work,

¹ Prepared by request of the chairman of the Division of Biology and Agriculture of the National Research Council.

under the governmental auspices of the nations recently at war, seem to furnish convincing argument against this view. When workers have been paid for solving a specific problem that fits itself into a general scheme of scientific progress—whether payment has been in money or in the approval of their contemporaries or in their own satisfaction in worthy service—it appears that they have been able to perform their separate parts of a broad plan and that they have often accomplished the almost impossible. One prime reason for the medieval methods followed by fundamental research seems to be that significant money rewards are not generally offered for this sort of work and that popular approval still goes to the guerilla rather than to the unit of an organization. The motive of worthy and constructive service to nation and race seems often to be thrust into the background, excepting in so far as the “bias of happy exercise”—with the satisfaction of doing just what one likes to do from day to day, unhampered by previously made plans—gives a person to feel that his own activities must be greatly worthy and outstandingly constructive. It seems, however, that all of us are strongly moved at times by the idea of communal service; for the most part we are glad to consider ourselves as doing our best to be worthy parts of a worthy whole, and therein lies the substratum out of which the morale of an army’s research division or of an industrial laboratory is organized.

The cooperative instinct is strong in most scientists, as in other people, but the practical lack of means whereby constructive cooperation might be planned and arranged makes it very difficult indeed for any single worker to break away from medieval individualism in research. To cooperate, it is necessary to find several others with whom to plan and work and with whom the detailed operations may be divided and shared; in short, to organize a cooperation or to find one already organized. If an individual feels the impulse for cooperative service so strongly as to lead him to act, he must first give up his actual investigations for a time, until the needed organization may

be created; he does not generally find it in existence. He may approach his colleagues in either of two ways, both of which are apt to lead to bitter disappointment, as things are to-day. First, he may seek workers who will join with him in attacking a fundamental problem already partly planned in his own mind. Without some money to expend on the work, or some position to offer, he may be met with the suspicion that his motives are ordinarily selfish, that he desires someone else to “pull his chestnuts from the fire.” Second, he may offer his services to those who have plans for constructive research problems in mind, but here also he may often be suspected of ulterior motives of low-grade selfishness, and his offers may be responded to by increased secretiveness, so that he may not receive the encouragement he sought. The whole idea of cooperation in such things is so novel that to propose it without money payment seems almost to argue an idealism that verges toward insanity. And yet the conception of cooperation among human beings forms the central strand about which has been braided the cable of most forms of human faith.

It appears that the democratic cooperation that is obviously needed requires an organization that shall not depend on the autocratic leadership of some individual enthusiast, who might soon get looked upon by his followers as a “super-man” or as possessing some sort of divine right (even though he himself might lay no claim to such attributes) and against whom opposition might grow ever stronger because of this very fact. A suitable motto for the organization needed might be that of the French republic, there being as much liberty and equality as is possible with true fraternity (which is cooperation). If such organizations as are here suggested are to be formed they should be cooperative from the very start and should center around several individuals. They should be democratic in nature. It must be clearly understood that the original group have merely tried to plan the work so as to bring about the greatest advancement, and that the original plan is but a temporary scaffold, to be modified from time to time and

finally replaced by other plans, as the work progresses and as new ideas are brought to light. This feature apparently requires repeated emphasis, to offset the mistaken thought that any free thinker is to be hampered in his scientific progress if he joins in with a group of others who already have in mind a broad, although always tentative, plan. On the other hand, it is especially essential that any organization for cooperation should exhibit a strong *esprit du corps*, and if a prospective co-operator feels that his entrance into the organization may result in too great modification of his own ideas of what he should do, if he does not respond to the general aims and motives of the group, he should consider carefully before he joins.

Given the needed organization, safeguarded against autocracy or bureaucracy, around which and in which cooperative research might develop—more as a coagulation due to the internal conditions of an emulsion than as a precipitate forced by a reagent from without—it really seems possible for beginnings to be made, even without considerable financial support. According to the writer's experience with his colleagues it is not true that scientific research workers do not generally wish to cooperate. A number of able workers can be found who will gladly join hands in the prosecution of almost any problem that may be mentioned. It is of course not to be expected that all workers will unite on any particular portion of the vast realm of science; if the project in question is concrete enough to be ready for actual attack there will, of necessity, be only relatively few who will take part. Furthermore, the more fundamental is the nature of the problem, the fewer will be the number of possible co-operators; many would join together to find ways of reducing the cost of living, while only a few could be found to work conjointly on the ultimate nature of life itself! Clearly, the function of the original organizations for cooperative scientific research must be to find the co-operators and to prepare a way by which these may cooperate. To accomplish this, the preliminary organization will of course require time and thought from several

persons, and some funds must be available for assistance and for travel. Scientists are not generally able to command even such small funds as will be needed; they will rightly feel that, if they devote time and serious thought to this matter of organization (thus temporarily setting aside their own investigations), the small amounts of money needed should come from elsewhere. It is not necessary, however, to pay for the time and thought of the co-operators themselves, these may be had for the asking; but mechanical and clerical assistance must be furnished to the preliminary organizations if they are to be successful. Without funds for this (and for travel, also, in many cases) such organizations ought not to be started, for without such funds they can do little more than distract the attention of their members from their own researches. An active guerilla warfare seems much better than mere social gatherings that would be unable to act upon a decision even if they should reach one, as to what is needed and what ought to be done. This consideration assumes special importance when it is remembered that the individualistic and non-cooperative method, poor as it confessedly is, is the only one that has been really tested in fundamental research, and that discussions within groups that are without adequate power to act are apt to detract from the volume of individual research, while they may add but little to true accomplishment.

To determine whether co-operators may be found for a given project it seems desirable to begin the organization in an experimental way. The preliminary organization will need widespread publicity among the proper public. Tentative plans for the problem in hand will need to be submitted to many minds, will need to be repeatedly modified or remade, until a sufficient group of workers are willing to enter into the proposed cooperation. Diversity of geographical location and of temperament and interest among scientists, make the preliminary testing of any cooperative project an operation that must necessarily consume much time; several years may generally elapse before a true decision can be reached as to

whether the project itself is really fitted for cooperation. It is clear that men who are busy with other matters will not generally be able to perform this sort of preliminary service unless adequate funds for assistance and travel are available.

In the preceding paragraphs the need and the apparent possibility for cooperation in productive fundamental research has been emphasized, but it is not to be forgotten that there are other lines of cooperative endeavor to which the attention of scientists might turn, lines along which larger numbers of co-operators might be willing to unite. Practical research, for example, which always holds forth hopes of financial return, is more generally attractive than fundamental research. Applied science readily finds financial support, either from individuals or from commercial organizations, while fundamental science is not so generally and practically appreciated. Another field of cooperation in which large numbers of scientists would surely cooperate is that in which lies the problem of suitable publication and dissemination of the results of research. This field also commands considerable support, partly on account of the fact that publications frequently pay their way in the commercial sense and partly because research institutions of various kinds (especially governmental ones) may hope to gain prestige through the publication and distribution, of good scientific contributions. Still another example may be mentioned, in the field of bibliography, with which the writer has dealt to some degree in other places.² A great cooperation of this kind, involving hundreds of workers, has recently been inaugurated in the new botanical abstract journal. Finally, there are possibilities for valuable cooperation in making the facilities for experimental research available to more workers than is now the case. Thus a number of workers might unite to find the needed buildings and apparatus for a research laboratory in which any scientist might work;

² See SCIENCE, 49: 199-207. 1919. The remark in the text refers also to some unpublished memoranda presented to the Division of Biology and Agriculture of the National Research Council.

this has been done in several instances. These and many other lines of cooperative endeavor that might be mentioned are all surely worthy of the best that we find in us, and it is not the intention of the writer to maintain that constructive, fundamental research is more important than any other line. This paper, however, is planned to deal especially with cooperation in fundamental scientific research itself, in the solving of the actual problems of science, and so other fields for cooperation are not here dwelt upon. The following paragraphs will set forth some of the apparently possible ways by which the organization of actual cooperative research might be attempted under the auspices of the National Research Council; there is no doubt that such activity lies within the prerogative of the council or of any of its divisions, should they see fit to undertake it.

POSSIBLE ORGANIZATIONS FOR COOPERATIVE PROJECTS

Since actual research deals with somewhat definite and concrete things, it is clear that a separate organization is required for each project and that a project must be relatively narrow in order to be suitable. A committee on the general subject of cooperation in research, without a specific problem, might be valuable in other ways—mainly educational—but it could not further research cooperation unless it narrowed its purview. General committees might be formed (some are already in existence) to canvass the various scientific fields and prepare, from time to time, lists of projects that seem promising for cooperation.

Before it can be decided whether or not a given project for research cooperation is to be undertaken, that project must of course be presented in a rather complete, though preliminary, way. Scientists might be encouraged to present plans for projects. These plans should show clearly what sort of work is contemplated, how it may be divided up among the co-operators, how the results may be handled so as to bring them into the permanent structure of fundamental science, what funds will be required for

assistance, travel, etc., and such other essential features as might enable an executive committee, or other similar board, to make a rational decision. After a set of preliminary plans had received the approval of a division of the council, the most promising course to follow might be to establish a special preliminary committee on the given project. This committee might be instructed to proceed to get the work started if funds are already available, or to attempt to procure these if they are not. It can not be too strongly emphasized that some funds are necessary, even for the activities of such a preliminary committee, for it is neither safe nor desirable to ask research workers to donate money, as well as time and energy, to this sort of endeavor. After the needed funds have become available the preliminary committee may proceed to consult or correspond with all probable cooperators, asking first their aid in completing and elaborating the details of the preliminary plan in such a way that it may be feasible. As this work goes on it should gradually become apparent how many cooperators may be hoped for, and when the preliminary committee judges that the project has reached a feasible stage the committee may enlarge itself so as to include all those of its correspondents who are willing to cooperate. This enlarged committee (which would be the organization mentioned above, as needed before a cooperative project may be actually started) may then reconsider the detailed plan and divide the work up among its members. A project may fail at any stage, even after the enlarged committee has been formed, but it seems probable that a good measure of success may be regarded as fairly assured when this stage shall have been reached. Haste is not desirable, to do good work much time must be allowed, but the preliminary committee would report the project as impossible at present, if it were found impracticable to obtain a reasonable number of cooperators, or the necessary funds for its work.

A cooperative organization started in some such way as this would almost surely be successful, but the contemplated measure of

its success must not be too large. It must be remembered that this sort of cooperation, if begun, would tread on new ground and would surely encounter unexpected difficulties. No considerable concrete results need be looked for at the end of a single year and the financial support available at the start ought to give promise of remaining available for several years at least. Nevertheless, the very idea of such cooperative endeavor in research fields is so extremely novel that much discussion and publicity in the proper circles would be needed before it might be realized, and each preliminary plan submitted, each preliminary committee appointed and each letter or publication or conference produced by such a committee, would help to build up the spirit of cooperation. It should be recognized that the fact of cooperation itself is vastly more important than cooperation on any special project; if one project should fail others should be attempted, the work must be regarded as experimental. It would make little difference just what particular problems were undertaken in this way, but it seems highly desirable that *some* problems might be so attacked. Once applied in a concrete case or two, the general idea would surely spread more rapidly than ever could be the case if it were held indefinitely in the phase of a *a priori* discussion. As in the prosecution of experimental research itself, it is only by actual trials that it can be found out what degree of success might attend such cooperative organizations as are here suggested.

SOME SPECIAL FEATURES OF COOPERATION IN EXPERIMENTAL RESEARCH

Several features of cooperative research have been impressed on the writer during a number of years' experience with this sort of attempt. First, there appear to be a large number of good experimenters who do not have well-selected problems in mind, who work on that which lies close to them rather than on that which seems to be most fundamental, most far-reaching or most imperatively needed for the growing structure of knowledge. These workers are generally the younger men, and they

almost always prove to be glad to join a cooperation that appeals to them as well planned. Of course they can not usually afford to finance such work and they are not always able to obtain financial support from their institutions, but they are generally very willing to work with great enthusiasm on a cooperative project if the actual expenses can be met. For example, about forty workers joined heartily in an experimental study of evaporation in the United States in 1907 and 1908, and all that was needed was that the requisite apparatus and materials should be furnished, together with postage for their reports. Similarly, about eight persons, none of them professional scientists, cooperated very successfully in an experimental study of the climatic conditions of Maryland in 1914. In this case all apparatus was furnished, and each station was visited fortnightly by the scientist who had the work in hand. For the most part, those who have been cooperating in the project on the Salt Requirements of Plants (Division of Biology and Agriculture, National Research Council) have provided their own apparatus, but it has been necessary to supply some equipment in a few cases and to furnish report blanks, seed, etc. Experience seems to indicate that many people are glad to cooperate if a project is well presented and if it has promise of being continued long enough to produce results. In the cooperations with which the writer has previously had to do, a definite time limit was set from the start and enthusiastic cooperation lasted through the period; indeed, in one case the work was continued by many cooperators for more than a year after the agreement came to an end, but it was possible to find the small amount of needed funds for this extension from sources other than the original one.

To maintain enthusiasm among a group of cooperators it would of course be necessary for the committee to see to it that an active correspondence should be kept up. Every one appreciates being written to about his work, being told of what others of the organization are accomplishing, being able to ask for suggestions and advice when difficulties arise,

etc. This means that a central office for each cooperative organization should be maintained, and that some competent person should act as secretary and custodian of records. Here is the main limit placed, by the nature of the work, upon the extent of cooperation in actual, concrete research. The number of cooperators would be limited by the amount of time and the amount of assistance that were available to the person acting as secretary. For obvious reasons formal letters would not be satisfactory, and each cooperator should be treated individually. In actual experimentation of an intricate kind it appears that a single individual, with adequate assistance, can care in this way for not more than perhaps a dozen cooperators. With a much larger group the work of the central office would have to be divided and the personal nature of the correspondence would be largely sacrificed. Of course a larger cooperative organization might be arranged in sections, each with its central office, but where all the work interlocks intimately with all the other work such subdivision would probably introduce difficulties requiring much special study. Furthermore, the experimental results obtained by the various cooperators would require very thorough study, tabulation and presentation in other ways, before they might take their place in the planned whole. This work can not generally be accomplished by the cooperators themselves, though each worker would always make his own interpretations as he proceeds. The central office would carry on the work of correlation and would keep the cooperators informed as to new developments coming from the work of others and from combinations of results from several sources. This feature of productive cooperation in research also sets a limit to the number of cooperators that may profitably work together on a concrete problem. Finally, it needs to be emphasized that the work as a whole would require adequate presentation in some suitable form of publication and that individual publications of the cooperators—although these might form a basis for this treatment of the whole problem—would not

suffice. What seems most needed are constructive and progressive contributions toward the solution of definite problems that are ready for experimental attack, and the central office of such an organization as is here considered would plan to undertake these. Preliminary presentations might be prepared and submitted to all cooperators. Out of the correspondence thus developed would eventually come a presentation that might measurably approach a truthful one, whereas single individuals could not hope to do more than make incomplete and more or less one-sided contributions in the desired direction, their papers being similar to most of those that now appear in the scientific publications.

From the last paragraph it will be appreciated that the writer's idea of cooperation in research involves the union of a number of minds in planning the attack on a problem, in working out the different parts, and in bringing the several component results together into a well-considered presentation that might really mark a tangible advance in scientific knowledge. Cooperations of this sort would bring it about that many of the experimental mistakes that cause so much discussion in scientific literature might be avoided at the start (through cooperative planning) and that most of the adverse criticism that leads to such wasteful polemics in many scientific fields might be already past before the main publication occurred, for each cooperator—and perhaps others also—would act as critic regarding the general presentation while it was still in manuscript form.

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SUGGESTIONS FOR ECOLOGIC INVESTIGATIONS IN VERTEBRATE ZOOLOGY¹

In a recent message transmitted to local administrators throughout the country praising them for their efforts during the war Food Administrator Hoover declared that the Amer-

ican people now "are summoned to a still larger task—to provision the Allies and the liberated nations of Europe, which face not their civilization together unless a steady stream of food supplies can be kept flowing to hunger alone, but the collapse of all that holds them to repair their gravest deficiencies, and in far greater volume than by utmost stress was sent last year."

As is well known to everyone, under the continuous and effective stimulus of the United States Department of Agriculture there has taken place a speeding-up process on the farms throughout the nation, a process which must apparently be continued and even augmented if we are to succeed in our wrestlings with the problem of world food shortage.

It is obvious that one very practical way in which to increase food production is to cut down the losses due to plant or animal pests. The department has addressed itself with extraordinary vigor to this problem and a comprehensive program in pest control is being administered by the different bureaus. That portion of the program concerned with reduction of losses due to rodents and other mammalian or bird pests devolves upon the Bureau of Biological Survey.

Current estimates place damage done to the carrying capacity of the open range and to cultivated crops generally by rodents in the western states at \$300,000,000 annually. Add to this the destruction of live stock by predatory mammals, estimated at some \$20,000,000 every year, and the damage done to goods in warehouses and stores throughout the United States by rats and mice, an additional \$200,000,000, and we have an impressive total. Particular interest attaches to these figures at this time in view of the comprehensive plans for the reclamation of arid and other lands in behalf of returned soldiers recommended by the Secretary of the Interior and given favorable mention by the President of the United States in his latest address to Congress. Potential or actual rodent pests exist on nearly every acre of the arid land which it is proposed to reclaim. In some sections effective

¹ Read before the Ecological Society of America, Johns Hopkins University, Baltimore, December 28, 1918.