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CONTENTS

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ISOLATION OR COOPERATION IN RESEARCH[1]

THE phrase cooperation and coordination has become a familiar slogan in a number of fields of human activity. It is the slogan of an organization of scientific men with which I am connected. But not all scientific men accept it as a desirable slogan. Some scientific men think cooperation and coordination in science not only not desirable things to promote, but positively undesirable things to attempt to bring about. Part of this difference of opinion exists because there is no unanimity of understanding of what is meant by cooperation and coordination. But part of it exists because there is an honest disagreement as to the relative value of scientific men working as isolated individuals or as groups of individuals with a more or less well-defined program of work to be achieved.

Cooperation and coordination imply a certain degree of organization, and this word also brings its uncomfortable reactions. While scientific men will agree that organization is a good thing in business and industry, in factory production and in marketing, in carrying on war and managing a fleet, some of them do not at all like the word organization used in connection with science. They say that organization is out of place in science. They say that science, like music and art, ought not to be, and can not successfully be, organized. They ask if Copernicus, Galileo, Faraday, Darwin and Einstein could have been "organized." I am sure the answer is that they could not. Which is not at all to say, however, that much scientific work can not be advantageously organized, nor many scientific workers much aided by cooperating and coordinating measures. Even the Darwins can be helped by organized measures to remove material obstacles from their path; measures to relieve them of all distracting and wasteful exertions so that all their time and energy can be concentrated on their great adventures.

There are about six thousand professional working biologists in this country. But how many are Darwins? There are about seven hundred fellows and members of this society, but how many Hagens, Harrises, Walshs and Fitchs are there among us? That is to ask, how many of us scientific men are

[1] Annual public address before the Entomological Society of America, December 30, 1925, Kansas City, Missouri.

geniuses; almost all geniuses are absolute individualists, not cooperators and certainly not subject to coordinating organization. There are some extreme individualists, too, who are not geniuses. Their temperament and abilities are such that they can not work in team. These, too, are not to be organized.

But most of us are not geniuses. We are not likely to make an epochal discovery nor to produce an epoch-making idea. We are able, however, to do a lot of sound, useful, scientific work both in fundamental science and in its applications. We are just capable, industrious, well-trained workers with more or less pronounced gregarious instincts, socially minded, able and willing to play and work together. Our gregarious instincts reveal themselves in the establishing and occasional meeting of such societies as this one that is meeting to-night.

But these societies do not get formed simply because of our liking to come together socially. There is always in connection with them a conviction that by this association we may be and really are enabled to promote and achieve some undertaking of common interest and worth to all of us. We most of us believe at least in *this* form of cooperation in science.

For example, there has been organized comparatively recently a Union of American Biological Societies, resulting in a federation of about fifteen societies variously primarily interested in zoology, botany, physiology, ecology, and so on. The union is a federation, not an amalgamation, of the societies, and each one retains its individual integrity.

Now the especial reason-of-being of this federating action was that a certain important need common to all biologists had grown more and more obvious and there seemed to offer an opportunity, needing only firm seizing and strong backing, to get this need met. The strong backing required was a united pressure from all biologists of the country, which could best be exercised by setting up a federation of all the important biological societies. As a result of the endeavors of the union, strongly supported by the National Research Council, a subvention of $350,000, to be expended over a period of ten years, has been obtained from the Rockefeller Foundation, which makes possible the establishment and maintenance of a much-needed comprehensive journal of biological abstracts. The editors of this journal, already at work, expect to be able to produce and publish abstracts of every important biological article published in every important periodical in the world which publishes biological papers.

The union having accomplished this by cooperative endeavor—not only by virtue of cooperation among its member societies but by virtue of cooperation with another major scientific organization—is now in the way of making further efforts to help meet another prime need of the working biologists of the country, namely, the need for increased opportunities for the satisfactory publication of original papers. This will require still larger financial support than that necessary for the preparation and publication of biological abstracts, but the great philanthropic foundations are inclined to count the need more than the amount of money involved. They are inclined to be generous to those who can show a real need, and especially are they inclined to be generous to more or less well-organized groups of men ready to attempt to achieve a common goal by united effort.

But the formation or existence of scientific societies do not bring up the real moot point suggested by the phrase "cooperation in science." The setting up of societies made up of cooperating individuals and of unions made up of cooperating societies excites no special debate. Their utility and desirability are rather taken for granted. Experience has demonstrated to all of us their advantage. What *does* invite discussion is the bringing together of a group of scientific men to undertake investigation in conformity with a coordinated plan. This involves the statement of a major problem needing solution, its analysis into specific parts and an organized distribution, by mutual agreement, of these parts to individual workers, or small groups of workers, whose work, when accomplished, shall all be brought together and made known for the general benefit that this contribution to scientific knowledge may effect. This kind of cooperation and coordination, or in one word, organization, in science, is what excites a certain criticism—fortunately ever growing less in sharpness and amount.

This criticism proceeds, I think, not from any conviction, growing out of the observation of the scientific work accomplished in this cooperative manner, either of faulty work or harm to the workers, but from a rather widely accepted assumption that most of the great advances in scientific knowledge and theory have come from men working alone. It is true that most of the epoch-making events in the history of scientific advance are associated with the names of single individuals. But I have certain observations to make in connection with this matter.

First, I wish to suggest that a careful examination of the history of these epochal events will reveal that in most cases the coming about of these events has not been due alone to the individuals whose names are so familiar in connection with them, but to a rather sudden crystallization around them of a solution to which many men and minds have made their separate contributions. Of course, this crystallization has often come about at the particular time and place at which it did because of the

superior understanding, by the final contributor, of the significance of the many facts gradually made known from many sources. And because of this superior capacity for seeing significance and for generalizing, the so-called discoverer should have the special credit so widely conceded to him. It is undoubtedly true that many an important advance in science has had to wait for its realization for the coming of the special individual whose personal contributions have been so invaluable. But how much work of how many other men, lesser men, we may call them, have gone to making possible the culminatnig discovery? And how much could this special individual have been helped, and the discovery often been speeded up, if he had had the planned cooperative assistance of other workers, to save him time and energy?

And this brings me to my second observation regarding the dependence of the epoch-making event on the individual. The individual in this case is usually a genius. His is a super-brain driven to continuous work and cogitation by an innate force that needs little extraneous encouragement or aid. And his brain works constructively; it sees significance; it puts facts together; it generalizes. But the genius is a rare bird. If we look back over the history of science we are able to count a respectable total number of scientific geniuses. But this history covers many hundred years. How many scientific geniuses can you list of any single century? How many exist at any one time? How many exist today? I have already asked that question earlier in this discussion and suggested the answer. You will all agree with that answer.

But does the advance of entomological science depend solely on entomological geniuses? Are we who are deeply interested in this advance and ready to do our little part to help it along, to sit idle while we wait for the rare bird to wing his way over the horizon? Let us not be too modest. The seven hundred of us enrolled in this society mean something for entomology. Let us mean as much as we can. We can all do something, and we can do more if we help each other, if we plan together and work together along lines and by methods which recommend themselves by united counsel.

Herbert Hoover, in a recent important address before a body of master engineers in which he made a stirring plea for the advancement of fundamental scientific research in this country said: "The time is gone by when we can depend very much upon consequential discovery or invention being made by the genius in the garret. A host of men, great equipment, long patient scientific experiment to build up the structure of knowledge, not stone by stone, but grain by grain, are to-day the fundamental source of invention and discovery." But Mr. Hoover does not want the genius to be overlooked. He wants him to be helped with equipment, assistants and time to the fullest extent needed or desired by him. There is needed a certain organization of our scientific resources even to do this. But Mr. Hoover urges us not to depend on the genius alone. Let the lesser men, lesser as compared with the geniuses, but men intelligent, well-trained, industrious, devoted and eager—and that means most of us—do their best. Let them help each other by willing cooperation; let them put their heads together and plan and coordinate and organize their attacks on major problems, so that time and energy will be saved by avoidance of repetition, overlapping, undirected effort; in a word, by avoidance of physical and intellectual waste. Let us work individually at special parts of a major problem—but collectively in our attack on the whole problem.

Here is a little example chosen from among the various projects taken up by the Research Council. At the suggestion of some men especially interested in the problem of the biological relations of insects to flowers there was appointed, by the council's division of biology, a special committee under the chairmanship of Dr. Frank E. Lutz, of the American Museum of Natural History, to plan and carry through some coordinated work on insect visits to flowers with particular attention to the distinction between "ultra-violet flowers" and others.

As you all know, of course, much work has been done on the relation of flower colors and patterns to insect visits, but little of this work has taken into account the possible large importance of a possible recognition by insects of colors, if one may so call them, lying outside the solar spectrum visible to us.

The work as planned required the cooperation of entomologists, botanists and physicists. To support the work, that is, provide workers and the small funds needed, the council, the American Museum of Natural History, Cornell University and the University of Colorado, joined hands, and an admirable piece of work, or group of related pieces of work, was accomplished, as those of you who have seen the various published papers, giving the results of the undertaking, will bear witness.

I have chosen to refer to this comparatively small cooperative project rather than to one of the larger and more expensive ones which the council has set up because it touches a problem of special interest to entomologists. But it is an example of many others. There are, too, of course, numerous coordinated cooperative projects of research instituted by other agencies than the council. The Carnegie Institution's elaborate and important present seismological investigation is such a project. Various gov-

ernment scientific bureaus undertake such cooperative projects. I only refrain from referring specifically to others because I do not wish to take too much of your time, and because other examples must be already familiar to most of you.

Let us not be afraid of organization. It means no real surrender of individual freedom or achievement. It only means that we direct our efforts more intelligently, to more important undertakings, with more material aid and more mutual encouragement. Organization lies in the very spirit of America. See what great things it has accomplished in American industry. Can American science not profit also from it? No one wants to organize the geniuses; no one proposes to; no one can. But I am no genius and most of you are no geniuses. Yet you and I counselling together, planning together, working together, can do something steadily to advance scientific knowledge. And that some geniuses at least do not scorn association with other workers nor hesitate to recognize the advantage that coordinated work may bring to science, is proved by the fact that in some of the most pronounced attempts in this country to set up coordinating enterprises a number of the men to whom American science owes most and of whom we are all most proud, and whom we recognize as geniuses if we recognize any at all, are taking an enthusiastic part.

Dr. Henry Pritchett has said:

> The world still conceives of scientific investigators in much the same light as the old-time prospectors for the precious metals—each individual sinking his shaft here or there as chance or inclination may carry him. Of the great number so engaged a very few will strike veins of true gold, a larger number will obtain ore that will at least repay the labor and cost involved in their adventure, but the great majority will sink holes in barren and fruitless soil.
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> The prosecution of research to-day [he continues] is upon an entirely different basis. Not only do those in the same science coordinate their work, if they are to attain the highest results, but all branches of science are regarded not as separate and unrelated agencies, but as parts of a common effort. A research started in a purely physical field may find its solution in a chemical reaction or a physiological process. The research men of a nation are not isolated individuals but an organized and cooperating army.

And Elihu Root, not a scientist but a very wise man, looking in at us from outside has said:

> Science, like charity, should begin at home, but has done so very imperfectly. Science has been arranging, classifying, methodizing, simplifying everything except itself. It has made possible the tremendous modern development of the power of organization which has so multiplied the effective power of human effort as to make the differences from the past seem to be of kind rather than of degree. But it has organized itself very imperfectly.

The scientific body to whose upbuilding I am at present giving all my attention and effort wants to promote in every way possible to it the sound development and increase of scientific research in this country. It wants to avoid interfering in any way with what is already going forward in this direction; least of all things it wants to dictate to any scientific man or men the things he should do. There is fortunately no possibility of the National Research Council, or any other body, ever being able to dictate to scientific men; scientific men will suffer no dictation. But it wants to help, in making things easier for scientific workers from geniuses down; it wants to influence colleges and universities to recognize ever more clearly their research responsibilities; it wants to make clear to the great industries how inescapably their success depends on scientific advance and hence that they should in every way encourage such advance; it wants to bring the support of the great philanthropic foundations, with their large financial resources, to scientific men and undertakings. And it believes in cooperation and coordination of effort. It is not afraid of that bugaboo phrase "organization in science," which is still anathema to a few scientific men.

It believes that science should not be broken up into water-tight compartments, nor men of science separated from each other by artificial barriers. It believes that entomologists should mix with and learn from general zoologists and botanists and physicists and chemists—and that these should learn from entomologists. It likes to support projects of investigation which involve the working together, in concerted ways, of biologists and geologists and chemists, of mathematicians, physicists and astronomers. It believes in bringing scientific men together for counsel. It believes there is strength and speed in union, and weakness and lag in isolation. The genius individualist it applauds and would like to help if help is possible and desired. To the rest of us who are not geniuses it wants to bring its slogan of cooperation and coordination as indicating modern methods of effective work.

VERNON KELLOGG
NATIONAL RESEARCH COUNCIL

THE SCOPE OF BIBLIOGRAPHIES

APART from the activity of a genius, three things are chiefly necessary for realizing profitable scientific work: First, clear, precise formulation of the problems; second, sharp observations in field, laboratory