substitute for ice, and superior to ice in many respects because of less weight and volume, durability, and no free moisture. Two units are placed in the carton separated from the mosquitoes by a pasteboard partition. Any remaining space is packed with insulating material. This carton is sealed and centered in additional insulating material within a much larger carton (a standard 24-bottle beer case is a satisfactory size and is well made). We use mineral wool insulating blankets, of the type commonly used in building construction, sometimes supplemented by wadded newspaper. The outer carton, when sealed and wrapped in heavy brown paper, is ready for shipment.

In laboratory tests and in actual practice we have observed that in summer or at room temperature the effectiveness of the refrigerant, under the conditions described above, decreases gradually up to 50 hr and by 72 hr is lost. At this point a sudden rise in mosquito mortality may be expected, and usually occurs, so that the survival rate at 3 days is 80 percent or less. At 4 and 5 days mortality was excessive, in some cases 100 percent; invariably it was over 50 percent. Increasing the number of Refreezant units to 3 and to 4, and providing supplementary humidity, either by dampening mosquito bags or by adding moistened absorbent cotton, did not significantly alter the effective holding time or the survival rate.

Twenty-two shipments of live mosquitoes have been made, principally by air express. Twenty of these were to the Rocky Mountain Laboratory from Washington, eastern Montana, western Nebraska, and Arizona, and 2 were colony mosquitoes from Hamilton, Montana to Maryland. The number of mosquitoes per shipment varied from 30 to nearly 700 and averaged about 300. Nineteen shipments were considered successful. Mortality for the most part was negligible and in none did it exceed 15 percent. In the remaining 3 shipments, for reasons that we cannot satisfactorily explain, the mortality rate exceeded 50 percent. In all shipments the elapsed time from packing to unpacking was less than 60 hr and in most cases less than 36 hr.

In spite of the limitation imposed by the time factor of 3 days or less, we have found this shipping technic to be very useful, and feel that we are not premature in recommending it to others.

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# *Communications*

## Group Research

IN an article on "Free Research versus Design Research" [*Science* **118**, 91 (1953)], Curt P. Richter examined the present policy governing allocation of grants-in-aid to research workers and, *inter alia,* used the occasion to deplore the present trend toward team or group research, which was represented by him as out of harmony with scientific tradition and as a somewhat naive tactic introduced by those who themselves understand little of the ways of scientists. Since group research involves an arrangement by which at least two persons undertake to solve a problem in concert, it is obvious that there will be almost as many arrangements as there are persons and that, before a fair evaluation of group research is possible, some effort has to be made to recognize the different ways in which such research has been and is carried out.

By and large, the theoretical scientist in all fields is a "rugged individualist" and has always been so. Collaboration between two theorists in the same field would be like collaboration between two champion chess players. They would hardly complement each other and, very likely, would just get in each other's hair. The very opposite tradition has always prevailed in the experimental sciences. Some of the greatest experimentalists of all times—Pasteur, Lavoisier, Rutherford, J. J. Thomson, T. H. Morgan, Emil Fischer, O. Meyerhof—thoroughly enjoyed working intimately with a band of colleagues and, in many cases, owed much of their success as experimentalists to the qualities that some of their colleagues possessed.

Why has group research found favor among the experimentalists? It is, I believe, the consequence of the fact that the major problems of the experimental sciences are usually far beyond the capacity of any one individual, however gifted, to solve unaided even after a lifetime of work. Consider a relatively straightforward problem, such as the mode of action of insulin. Despite heroic efforts by many workers in laboratories all over the world, this problem had still eluded solution. A vast number of hypotheses have been advanced, but a prodigious effort is involved in testing each one. Some hypotheses cannot even be tested with present methods and must await further technical advances. Major problems of experimental science are like giant jigsaw puzzles, which cannot be solved until hundreds of individual pieces are placed together in the proper patterns, and the placing together of any two pieces is a problem of no mean proportions. Clearly, when the over-all problem has so many facets, the chances of solution are roughly proportional to the number of facets investigated. The single investigator just cannot cope with the volume of experimentation, of trial-and-error search needed to find the necessary clues. Thus, it is not a question of whether group research is necessary in experimental science, but rather of what kind of group research works best.

Group research has come to mean to some a grotesque arrangement whereby some dictator in his office directs the energies of an army of research stooges in the laboratory by push-button control. If this is what group research is taken to be, then nobody in his right mind can make out a case for such a monstrosity. If, however, group research is looked upon as an effort by a group of individuals to solve collectively a problem which no one of the individuals could expect to solve singlehandedly, then group research falls in line with a long tradition in experimental science.

Group research is not only a scientific venture but also an experiment in human relationships. In the ideal group, such as existed in the laboratories of some great experimentalists, petty jealousies were minimized and the creative skills of all members were used to the fullest. The proper leader of a research group should be interested primarily in solving a problem. Anyone who can contribute to this end must be encouraged. A group dedicated to the solution of a problem, governed by the conviction that seniority, title, and rank are irrelevant issues in the evaluation of ideas and suggestions, and convinced that the fortune of the individual is tied up with the fortune of the group as a whole is, I believe, one of the most powerful instruments yet devised for conducting experimental research.

The standards of modern science impose an almost herculean burden on the lone investigator. For example, the successful prosecution of any of a large number of biochemical problems requires considerable competence in the techniques of protein fractionation, organic syntheses, manometry, spectrophotometry, and chromatography and in the fields of analytic, organic, physical, and biological chemistry. There have been and probably will be a few giants who will be equal to such all-but-impossible assignments. However, the great mass of investigators can be effective only by dint of specialization. Thus, group work provides one of the few devices by which the efforts of specialists can be integrated and unified and by which skills, useless when uncomplemented, can be fully utilized.

There is a vague uneasy feeling among some scientists that group research means the end of the individual. All research in the end is individual research, and group research conducted properly refers to individuals working together with other individuals. Any tactic that does violence to the rights, privileges, and sensibilities of the individual should be as abhorrent to the group as to the individual. Group research has often foundered on the rocks because the leader has failed in his duties to the individual members of the group by being arbitrary and inflexible or by suppressing differences of opinion. Where group research has prospered, the rights of the individual have rarely been neglected.

In tackling a major experimental problem, there is no telling from which direction a solution may come. The individual, perforce, is limited to a single choice; and, while he may show superior discrimination in the exercise of this choice, he is at a great disadvantage *vis-a-vis* a group where multiple choices may be made and followed up simultaneously. One can be more daring and enterprising in a group where multiple failures for several individuals can be compensated by at least one successful venture by another in the group. If the individual has to carry alone the weight of failure which can be more equitable distributed within a group, he is not likely to undertake a problem that holds forth prospects of more than a fair share of unrewarded exploratory work and experimental dead ends.

There is ample room in our scientific life for both individual and group research. The nature of the problems, of the individuals, and of the physical setup should be the determining factors in deciding which arrangement should be followed, and not a cut-and-dried formula that science can prosper only by leaving the individual to his own devices.

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## Contribution to the Chemistry of Thorium and Morin

THE U.S. Geological Survey has been studying the reaction of thorium with organic compounds in a search for a highly sensitive and, if possible, selective reagent for the quantitative determination of trace amounts of thorium. One phase of this investigation consisted of a spectrophotometric and fluorimetric study of the complex formed in the reaction between thorium and morin. Morin is 2′,3,4′,5,7-pentahydroxyflavone ($C_{15}H_{10}O_7$).

In weakly acid solutions, the stable complex Th(morin)$_2$ with a dissociation constant of approximately $2 \times 10^{-10}$ is formed. The sensitivity of the reaction is such that 0.1 to 0.2 μg of $ThO_2$ in 50 ml of solution can be determined either colorimetrically or fluorimetrically. The color system follows Beer's law; and, under proper conditions, the fluorescence shows a linear relationship with the concentration of thorium over a wide range. Morin is about 2½ times as sensitive to thorium as thoron, 1-(O-arsonophenyllazo),-2-naphthol-3,6,-disulfonic acid ($C_{16}H_{13}O_{10}N_2S_2As$), which is the most sensitive reagent generally available. So far, morin has been used only with pure solutions of thorium, but the reaction could be used as the starting point in the development of methods for the quantitative determination of trace amounts of thorium in rocks and other materials.

In the course of this work, the fundamental relationship between the fluorescence and light absorption was studied, and a mathematical equation was derived to express this relationship. Uncombined morin in the solution affects the fluorescence produced in two opposing ways. The amount of complex formed from a given amount of thorium is a direct function of the amount of free morin, whereas the amount of fluorescence obtainable from a given amount of complex is an inverse function of the amount of free morin. The inverse function results from quenching by the morin, and an equation has been derived that relates the amount of fluorescence obtained to the amount of free morin. The relationship is hyperbolic and similar to that shown by other fluorescent systems reported in the literature.