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THE ORGANIZATION OF BIOLOGY AND AGRICULTURE

By Dr. ROBERT F. GRIGGS

CHAIRMAN, DIVISION OF BIOLOGY AND AGRICULTURE, THE NATIONAL RESEARCH COUNCIL

Over and over again as I endeavor to facilitate the contributions of biology and agriculture toward winning the war, I encounter the unorganized and incoherent condition of our group of sciences. I have come to believe that this lack of organization, and the lack of unified objectives that goes with it, is of itself partly responsible for the comparatively ineffective application of biology and agriculture to the needs of a total war.

To assist in clarifying our functions and our responsibilities, I have constructed an organization chart (Fig. 1). In its conception the chart is entirely abstract. Its contact with the present situation comes through the numbered references in the appropriate boxes to the national technical societies in whose hands to a large extent lies the professional guidance of those arts and sciences by which man produces his food and the organic raw materials which he uses in his civilization.

To point out that the products of the soil constitute the most fundamental and the only really essential factors in man's existence is to state a truism to which there is no occasion to call your attention. The chart is presented, rather, to emphasize the complexity of the problem of organization which is faced by biology, using that term in its widest sense including its applications.

The outstanding feature of biology and agriculture, and it must immediately occur upon any consideration of these fields, is the number and diversity of the organizations included in the group. Whereas chemists of all sorts support one strong chemical society, biologists have set up a number of weak societies. The problem of organizing biology and agriculture is altogether too similar to that of consummating the consolidation of the several weak Protestant churches frequently found in a rural community.

In its bulletin on "Industrial Research," p. 250, the National Resources Planning Board gives an organization chart for physics in America. It is neatly set forth in seven boxes, which include the national societies and culminates in the American Institute of Phys-

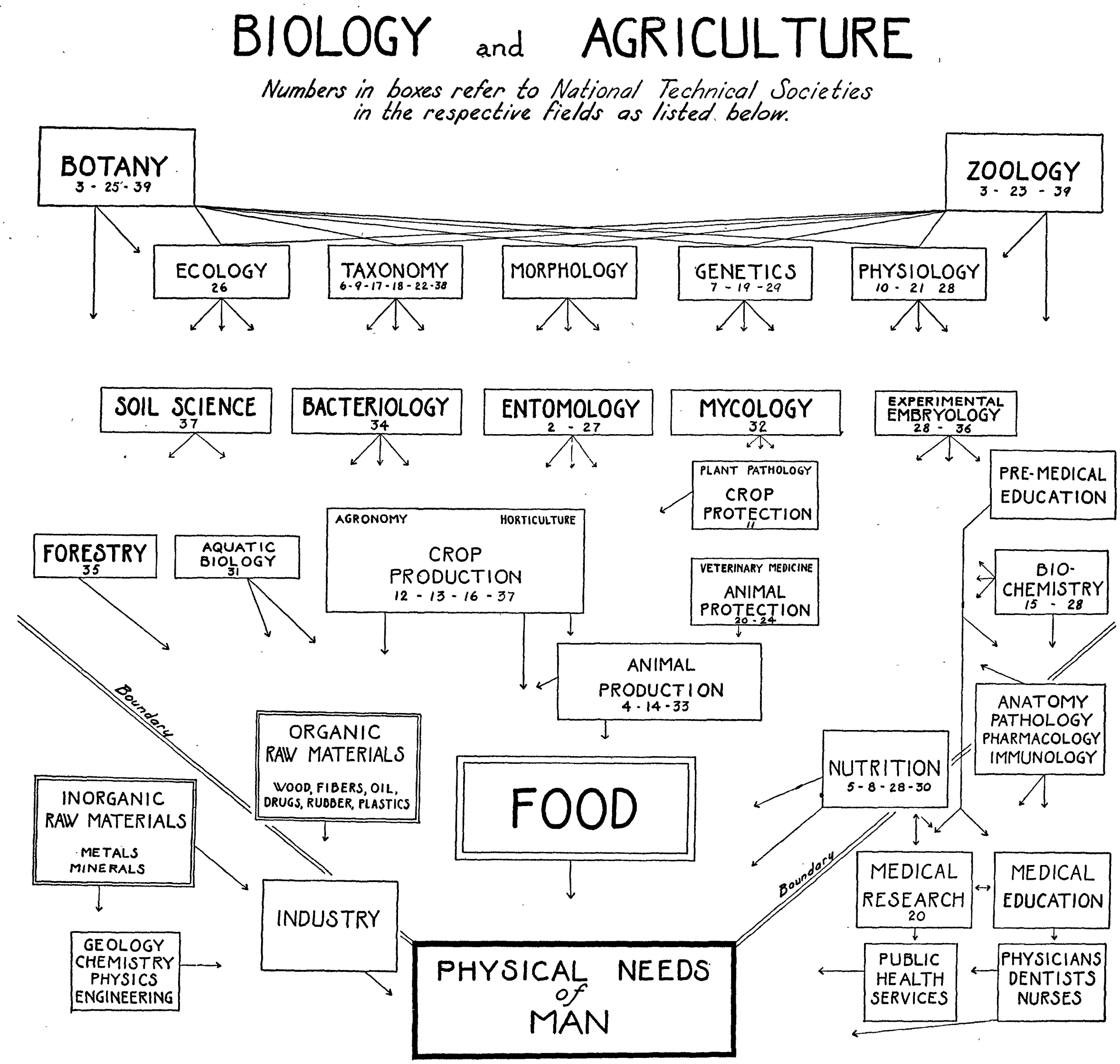

FIG. 1. Organization Chart.

National Technical Societies: 1. American Association of Anatomists. 2. American Association of Economic Entomologists. 3. American Biological Society. 4. American Dairy Science Association. 5. American Dietetic Association. 6. American Fern Society, Inc. 7. American Genetic Association. 8. American Institute of Nutrition. 9. American Ornithologists' Union. 10. American Physiological Society. 11. American Phytopathological Society. 12. American Society of Agricultural Sciences. 13. American Society of Agronomy. 14. American Society of Animal Production. 15. American Society of Biological Chemists, Inc. 16. American Society for Horticultural Science. 17. American Society of Ichthyologists and Herpetologists. 18. American Society of Mammalogists. 19. American Society of Naturalists. 20. American Society of Parasitologists. 21. American Society of Plant Physiologists. 22. American Society of Plant Taxonomists. 23. American Society of Zoologists. 24. American Veterinary Medical Association. 25. Botanical Society of America, Inc. 26. Ecological Society of America. 27. Entomological Society of America. 28. Federation of American Societies for Experimental Biology. 29. Genetics Society of America. 30. Institute of Food Technologists. 31. Limnological Society of America. 32. Mycological Society of America. 33. Poultry Science Association. 34. Society of American Bacteriologists. 35. Society of American Foresters. 36. Society for Experimental Biology and Medicine. 37. Soil Science Society of America. 38. Sullivant Moss Society. 39. Union of American Biological Societies.

ics. Probably physics is oversimplified by this chart. But could anybody reduce biology and agriculture and their societies to similar simplicity? The representation of our field in the 31 boxes used in the chart has, in fact, required considerable compression and generalization and the omission of many important relations.

A proper organization chart which shows by straight line connections dependence and responsibility is impossible for our group. One could so connect entomology and crop protection, for instance, but medicine and animal protection also are similarly dependent on entomology, and if the application of each of our sciences were thus shown our chart would become an unintelligible mass of crisscross lines. Several of our sciences have such varied responsibilities that the connections of each would make a spiderweb reaching into almost every box on the chart. On the other hand, most of the applied fields draw from a wide variety of underlying sciences. Forestry, for instance, depends on all but one of the sciences placed higher on the chart. In view of this complexity it was impracticable to show connecting lines but, instead, some of the interrelations were indicated by arrows. For example, an arrow from forestry toward raw materials suggests the chief function of forestry, but there was no opportunity even for suggesting other important functions of forestry such as controlling erosion, harboring wild life and providing recreation areas.

The fact is that any adequate representation of our group would require for almost every member a separate organization chart, only less complex than that presented for the whole. But separate charts would necessarily leave off the interconnections between the different fields and our problem lies exactly there, for these interconnections are fully as important as the special responsibilities of each science.

The writers of the bulletin on "Industrial Research" made some rather sharp criticisms of our field, pointing out that biology has not won anything like the acceptance in industry that has come to the physical sciences. They recommended that we establish an "American Institute of Biology" comparable to the Institute of Physics. If this were construed to mean that biology has not rendered as great practical services as have the physical sciences, it would be quite incorrect. The great public institutions, state and federal, devoted to scientific agriculture through the applications of biology have no counterpart in the physical sciences. The "colleges of agriculture and mechanic arts" contemplated by the Morrill Act have, in fact, gone much further in agriculture than in engineering. One reason why industrial concerns have few biologists on their staffs is that, whereas they know they must pay for consultants in engineering, they expect to get expert advice in agriculture for nothing from government employees.

Whether a system of private-paid or of public-free consultants is better public policy is a large question into which there is no occasion to enter here. But regardless of the merits of this question, there can be no doubt but that the man who collects fees of a hundred dollars a day holds himself in higher esteem and is more highly regarded by his neighbors than the man who renders the same service gratis. Biologists would strengthen both their own self-esteem and the standing of their professions if they curtailed the consultation services they render without compensation. In the case of men attached to public institutions, it would increase the prestige of both man and institution if fees were charged for their consultations. The fees might well go into the institutional treasury if the institution gave proper recognition to the value of its men by way of salary adjustments. The biologists who are called into consultation find upon rubbing shoulders with engineers employed in the same way that, both in ability and in the value of the services they can render, they measure up to the engineers.

Two other important differences between physics and biology are manifest. First, despite the complexity of modern physics and the disappearance of the old frontiers which used to separate it from chemistry, the physicists have developed a strong guild consciousness which brings to them a sense of solidarity not possessed by biology.

The chief influence which pushes us apart is the necessity for diversified specialization. It is clear that there can be little common understanding of details among our different fields, *e.g.*, forestry and veterinary medicine; and it is equally clear that there is no possibility of important progress in any scientific field except by concentration on comparatively limited objectives. Is, then, our case hopeless? I think not. The same degree of specialization is necessary in physics or in chemistry, where its disruptive tendency is greater by reason of the vastly larger number of entities with which chemistry must deal. But physics and chemistry both retain an esprit de corps and a guild consciousness which hold them together. The source of this unity lies, I believe, in common points of view.

Is there, latent, enough of a common point of view among all the groups associated under biology to bind them together with a degree of unity far beyond that now realized? I would not presume to answer this question in its entirety, but I think any biologist, figuratively looking out of the box in which he is placed in the chart, will recognize at least that he has much more in common with the people in neighboring boxes than is given expression to in our organization.

Second, the organization of physics does not include the applications of the science in engineering. In view of the manifest advantages to both physics and to engineering of their separate organizations which permit each to make its own distinctive contribution, it might be concluded that biology and agriculture should forthwith be similarly separated. Such separation looks right logically and will probably be desirable—ultimately. But in my opinion separation of agriculture from biology at the present time would be unwise. Biology is contributing so much to the development of agriculture and agriculture is stimulating the advance of biology so greatly that both would lose by separation at this juncture. Indeed I believe it can be demonstrated that a closer integration would increase the progress of both for some time to come. If this be correct, we should use every means to bring the two closer together.

The need for integration between biology and agriculture is increased by the war, for war at once puts greater emphasis on the practical and makes greater demands for innovations and these must be based on the principles of pure science.

Belief that a strong organization of the biological sciences would be advantageous is in no way novel or original to the writer. Some years since, the Union of American Biological Societies was organized and more recently the American Biological Society was launched. Both have been primarily concerned with promoting *Biological Abstracts,* a highly desirable project in itself but no adequate objective for such far-reaching organizations. Their initiation was indeed something like putting the cart before the horse. A strong federation of biologists would certainly feel the need of an abstracting journal and would support one. But such a journal can not create a federation.

I believe that all branches of biology (in the broadest sense) realize to some extent the advantages that would accrue from a strong federation of biological interests and, I think, all elements if properly treated will go along with steps to develop the bonds supplied by our many common interests. But such a living organization could not be produced by fiat. The present paper is submitted as an analysis of our actual situation. It does not include a program of action. It is my feeling that any changes in the relationships of our constituent groups will have to grow slowly and that to a large extent they will have to be initiated by the groups themselves.

Is it worth the great effort which will be required to federate the biological sciences? What may be expected from the life sciences in the years to come? During the past century the physical sciences have transformed our environment by producing all sorts of mechanical conveniences which have freed mankind from the long hours of toil before required to produce the bare necessities of existence. Among the life sciences this last century has been a time of preparation. We have learned how to protect man from many of the diseases which heretofore carried him off before his time. We have learned much of heredity and of the principles which underlie the production of improved domestic animals and crop plants. We are learning through the application of the new science of nutrition that man properly nourished maintains a vigor in life never before thought possible.

Such things have been slowly emerging through the period that is closing. The years ahead will see applications of biology to the betterment of human conditions such as we can now hardly imagine. This development will require all the detailed specialized technical tools that we possess—but more, it will require broad insight and applications of biological principles to world problems by men of affairs. Will the professional biologists play their rightful roles in this future, or will they barter their heritage for a mess of specialities?

Specialists often fail to recognize the bearing of advances in cognate fields on their work. If there were some way of bringing home to them their own need of relating their work to fields other than their own, the problem of the organization of biology and agriculture would be well on the way to solution, for there would be a spontaneous desire to bring together information and ideas from fields at present sharply separated. One trouble is that it is so much easier to follow developments in one narrow line than to keep abreast of advances along a wide front, and men will follow the line of least resistance. But lines of specialization are soon worked out and the men who survive have to shift into other lines. To adjust himself successfully to changing conditions, a man needs the broad outlook which can be most readily maintained by diversified contact with several fields.

Several correspondents have given the opinion that biologists are suffering from an inferiority complex and that this is one of the causes of our difficulties. It was partly with this idea that I suggested above the advisability of more paid consultative work by biologists and agriculturalists. Certainly it is advantageous for men in academic circles to have contacts with men of affairs. College and university men are too used to being taken care of by their institutions. We need to learn better to take care of ourselves, and in so far as we do so we will command a larger place in the scheme of things.

There are two main and fairly distinct, though considerably intertwined, avenues by which biologists serve society. These are in addition to the less direct general educational services that come from the cultural values of instruction in biology, which our fields share with other sciences, arts and letters.

The first and oldest of these two services is as preparation and background for the medical sciences. In the old days before the development of scientific medicine all of biology contributed thus to medicine. In the beginning the physician had largely to gather his own drug plants and so the early botanists were physicians who had specialized into a knowledge of plants. This was true of most of the old herbalists, of Linnaeus and of Asa Gray.

But the rise of pharmacology, which proved that comparatively few of the old herbs possess important therapeutic value, and the achievements of synthetic chemistry which produce more and more drugs in the laboratory took away the practical value of the old herb doctor's botanical lore. Thus botany came to play a minor part in medicine.

By this development botany was deprived for the time being of its chief professional outlet. At the same time the rise of comparative anatomy, embryology, physiology, and especially of experimental zoology, accompanied by the researches in medicine itself which led to the establishment of scientific medicine, greatly increased the importance of zoology to medicine and gave a greatly enlarged outlet to students of zoology. The improvements brought about in the treatment of disease likewise vastly expanded the opportunities for service in medicine and increased correspondingly the number of physicians. The training of recruits to the army of physicians, which now numbers above 150,000 in this country alone, is in itself a very large undertaking—large enough to absorb the energies of a considerable body of men.

Thus it has happened that, without looking beyond medicine with its preparatory and cognate subjects, the zoologists have found abundant profitable and useful scope. This is not to charge that zoologists have limited their activities in any narrow way to medical interests. The reverse is quite generally the case. Very often the zoologist whose students go largely into medicine undertakes researches as far removed from medical application as possible. But the fact that medicine is the destination of the majority of students who take zoology has given that science a bent which produces the largest element of disunity in our organization as may be seen by observing how the zoological and medical aspects of biology stand apart from the agricultural in our chart.

While zoology[1] has benefited very greatly by thus having an outlet for service through medicine, it has also suffered the loss through that outlet of many of its best men. Every teacher of zoology knows that many of the students best fitted to become zoologists go into medicine. If the pull of the medical sciences were not quite so strong, zoology itself might be stronger. If opportunities for placement of zoologists in premedical fields had been less, zoology might have entered more completely into the whole of its domain. As it is, it has left large segments of the animal sciences to be developed by other hands.

Both zoology and agriculture have lost by this separation. There are, for instance, among the zoologists many able geneticists. Their achievements in discovering and formulating the laws of inheritance have been outstanding. Among them is the only American biologist who has been awarded a Nobel prize. Few of these men, however, are in touch with the Society for Animal Production. Out of roughly a thousand members of the American Society of Zoologists only eleven are also members of the Society for Animal Production. Perhaps it is a direct consequence of the separation of these interests that during the four decades in which the Mendelian Theory has been available, animal breeding has brought forth no achievements comparable in economic returns with hybrid corn or even with the large number of polyploid flowers and fruits recently produced by plant breeders.

By all the logic of the natural relations of subject matter zoology should be as much interested in parasitology, entomology, veterinary medicine, animal production, animal breeding and animal ecology as in medicine. But as a matter of fact, zoologists have been so much occupied with premedical interests that the agricultural animal sciences have been largely left to Experiment Station workers, and there has been little community of interest between the two groups.

It is not intended to suggest that the same individual could attain proficiency in more than one branch of science. The significant thing is that the organizations of the two groups of animal sciences have drifted apart. Perhaps the most striking illustration of this divergence is that between zoology and entomology. Entomology grew up in the service of agriculture even more than zoology and medicine have grown together. While the American Association of Economic Entomologists was founded in 1889, it was not thought necessary until 1906 to foster the development of the science itself, as distinguished from its applications, by establishing the Entomological Society of America. Although insects are as much a

[1] Perhaps I am using zoology in too narrow a sense here. For present purposes I am drawing my definition of the science itself from the objectives and attitudes of the American Society of Zoologists, which I recognize is not an entirely fair procedure. Yet, that ought to be the proper way to find out the nature of zoology.

part of the domain of zoology as are marine invertebrates, the members of the American Society of Zoologists have concerned themselves very much more with the latter than with the former. Students of marine invertebrates are sufficiently at home in that society that they have not set up a specialized society of their own comparable with the entomological societies.

But while students of other groups of invertebrates are generally members of the American Society of Zoologists, the entomologists generally are not so affiliated. Less than one per cent. of the Association of Economic Entomologists and only six per cent of the members of the Entomological Society of America are members or associates of the American Society of Zoologists.

In the early days of their development both botany and zoology prided themselves on being "pure" sciences and disdained applications to industry and agriculture. Finding adequate outlets in the development of the medical sciences, zoology has maintained this position, though with little of the "holier than thou" attitude with which both botanists and zoologists regarded applied scientists forty years ago. To this day, however, comparatively few members of the American Society of Zoologists are professionally engaged in applied science. So far as medicine is concerned, the separation of the pure sciences underlying the applied medical arts has been enforced by strong professional esprit de corps among physicians as well as among zoologists.

Botany, however, was compelled to take a different course. Deprived of its original usefulness by the decline of the herb doctor, botany found itself without adequate outlet for the energy of its devotees or their students. It was forced to make itself useful to agriculture. With the passing of time that connection has broadened and strengthened to the mutual advantage of both participants.

It is instructive to remember that in the beginning botanists were as much traditionally opposed to economic work as any other scientists. One of the ablest of mycologists, for example, who was forced in his youth to accept a position in an Experiment Station and there made an outstanding contribution toward the control of potato scab, always as long as he lived professed to be ashamed of this work and devoted the balance of his life to the study of fungi with no possible economic importance. But this man stood alone for many years before his death and a large majority of his students took up economic work. Again the extent to which the integration of botany and plant pathology has gone may be judged by the fact that of the total membership of the Phytopathological Society, approximately 20 per cent. maintain membership in the Botanical Society of America.

The most significant advances among the plant sciences during the last decade have occurred in plant physiology. Here more than anywhere else the interdependence of pure and applied science has been manifest. As long as plant physiology remained a pure science confined to old line university departments of botany, it never amounted to much. Indeed beans and corn were about all the materials used and the work did not get beyond the demonstration of a few simple principles—just enough to show that the subject had potentialities.

But when agriculture began to ask questions about the scientific basis of plant production and coupled these questions with appropriations for their answer, plant physiology began to advance. This at once brought into high relief our lack of understanding of the fundamentals of that field. As a result the science itself has evolved, up to now, rather more than its applications. But within the last few years these advances in fundamentals have permitted applications of rapidly increasing importance, starting a development which bids fair to become one of the most important in all biology.

Because of its importance to medicine, bacteriology is closer to zoology than is any other of the plant sciences. There are, indeed, about as many teaching positions requiring a combination of bacteriology with zoology as with botany. But bacteriology in its own right is no more a medical subject than is chemistry. Like chemistry, its applications reach into almost every field of biology and agriculture. It was impossible, therefore, adequately to represent its relations on our organization chart. Unlike chemistry, however, bacteriology has permitted the importance of its applications to dwarf the growth of the science itself. A parallel situation would be presented if chemical engineering had attempted to advance without physical chemistry. It seems likely that if the bacteriologists could set aside some of their best men to develop the pure science of bacteriology for its own sake, the fundamental principles so brought to light would lead to greater applications even than those which have been made already.

Physiology is in many schools merely *human* physiology. There is very slight contact between the physiological departments of medical schools and *plant* physiology. Yet in its fundamentals physiology has as broad an applicability as any of the biological sciences. Many have emphasized the importance of *general* physiology and most agree that it ought to be widely taught, especially for the broadening of men preparing for medicine, but it has never flourished. The reason lies probably in the bias of the premedical students who flood our biology departments. They are continually pressing for courses more and more nearly similar to the medical work to which they look forward. Most medical schools as well as most departments of biology deplore this tendency and would be glad to compel premedical students to broaden the biological base on which to build their medical work. But they have not been strong enough to force the students into the preparation which would be best for them, and in this situation general physiology has languished.

Biochemistry, perhaps even more than physiology, is properly a field of general biology. But many departments of biochemistry instead of representing the fundamental science are mere adjuncts of medical schools. At the other extreme "Agricultural Chemistry" developed independently, starting from very narrow applications of chemistry to fertilizer analysis and such practical matters. Happily the progress of the science has brought about considerable rapprochement between the agricultural and the medical biochemists, but there is still far too wide a gap between them. Like physiology, biochemistry is in its nature more properly a pure science which (like physics) should be strongest in universities, rather than an applied science (like engineering) strongest in technical schools. In suggesting this I am not pleading especially for the pure sciences, for I believe it can not be gainsaid that strong departments concerned with these sciences for their own sake would extend and increase the usefulness of their applications.

The scarcity of departments of pure physiology and of pure biochemistry is sufficient evidence that the biological sciences in the universities are not strong enough to stretch out and occupy all of the fields of biology which should be cultivated. They need help here from the applied branches. Agriculture and medicine should unite in demanding that the universities establish departments of physiology, of biochemistry, and of bacteriology to prepare students for the technical schools with no more emphasis on applications than is given by university departments of physics preparing students for the engineering schools. If this were done, all biology would be greatly strengthened. The corresponding departments in the technical schools would find their own hands strengthened and would grow into an increased usefulness which would be hard to envisage at the present time.

All biological sciences spring from the same root. They are like a tree with many branches. Some of the branches, however, have grown so vigorously and reached such distances from the trunk that they have forgotten their origins and consider themselves independent trees. This analogy is due to C. V. Taylor of Stanford, a zoologist, who is distressed by the degree of separation that has developed among the different members of our group. Taylor points out that all living things are made of a protoplasm which, despite the widely diverse types into which it develops, remains on the whole surprisingly uniform in fundamental character throughout. The laws of its evolution and of its inheritance are the same everywhere. To a very large degree even its cellular structures are constant.

In so far as the analogy of the growing tree is applicable, it will be recognized that it is just those branches which grow most vigorously that get farthest away from the main trunk. Also, in the tree there is dead wood and there are rotten branches which may not be detected until stress and storm search them out. Likewise, on a tree leaves which almost touch may draw their sustenance from different branches which may have grown independently for a long time so that the only way to get from one to the other is to go clear back to the root. In the tree the original connection to trunk and to roots is essential. If it is severed at any point, every part beyond the cut dies.

The question really before the assemblage of sciences now grouped under biology and agriculture is whether we are comparable to a tree with a single trunk or whether we are more like a bush with many trunks from the same root. If we are like a bush, the health of any one branch is of little concern to the others. Indeed, when a branch is cut out of a bush the others grow all the better, profiting from the removal of competition. But if we are like a tree, then it behooves us to look after the health of the trunk that supports us all.

Is biology like a bush or is it like a tree? The question can be answered with assurance only with the passage of time. It is permissible, however, to make one observation: Bushes rarely attain any great height and they are mostly shortlived. The really tall and permanent growths are all trees.

OBITUARY

JOHN JOSEPH RONAN

ENEMY torpedo action on October 14, 1942, tragically ended the career of a young Canadian scientist, John Joseph Ronan, field officer of the Geological Survey of Newfoundland. On leave from St. Francis Xavier University, Antigonish, Nova Scotia, to whose staff he had just been appointed, Mr. Ronan was proceeding to Newfoundland to resume field work on war minerals when he was numbered with 137 who lost their lives in the sinking of the Newfoundland Railway Steamship *Caribou* in Cabot Strait.

John Joseph Ronan was born at Antigonish, Nova