have established that myoglobin and a few other pigments in vitro have the same property.

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Changing Environment of Zoological Research

The era of abundance in funds and transportation opens new vistas for research and exploration.

Herbert Friedmann

When an ecologist studies the relations between the species of animals and plants in a given type of environment, he tries to measure, as far as he can, the various external factors, but at the same time he is aware of the fact that the degree or the speed of reaction to these factors varies individually within more or less specific limits for each species. Obviously, the more responsive individuals will be either helped or harmed, by any external change, to a greater degree than the less responsive ones, but, by and large, the ecologist comes to assume a mean response for each species and then proceeds to treat all the individuals of that species as essentially alike. Similarly, in this attempt to survey the present environment in which we work, I assume an average zoologist, if there be such a person, and pay attention to the environment in which he goes through the motions and activities inherent in being a zoologist.

The old, traditional concept of the scholar or the research worker is that of a relatively solitary individual, plodding along with his studies and only too glad to be left alone to pursue them. For many years, for centuries even, in the early history of science, the scholar was considered to be possibly quite interesting, but neither a direct contributor to the welfare of mankind, nor actually harmful. It was only when it began to be realized generally that no knowledge was without potential value that society began to pay an increasing amount of attention to the individuals engaged in extending the limits of knowledge. There is no need to trace the details of this historical change of attitude from the time of the Renaissance, when scholars were still the protégés of powerful and enlightened princes and dukes and even of lesser, local VIP's, so we may jump to the situation as it was in our own experience a generation or two ago, limiting the picture to the zoological portion of the scientific panorama, and comparing that situation with the present one.

The situation as it was then was far more favorable for the prosecution of zoological work than it had been at any previous time. There were literally hundreds of laboratories in our colleges and universities, not all equally well equipped or of equal coverage, but still capable of training future zoologists and of providing, within very variable limits, the opportunity for research. Most of our major research museums were in existence, although their collections were far less complete than they are now, and library facilities, which have since increased greatly in scope and in completeness, were generally adequate. There were some, but not many, organizations from which research grants might be obtained, although most of these organizations had established fairly definite perimeters to their interests.

Within this setting the hypothetical average zoologist went about his work, and the results, seen in the perspective of 30 years, were good. There was little need to do anything other than enlarge the facilities and provide opportunities for an increasing number of people in the zoological field. To judge by present conditions there was a more leisurely atmosphere then than now.

Urgency and Research

At the present time we are faced with a tension in the political atmosphere that has unfortunately invaded the scientific environment to a dangerous degree. We are expected to do research, but with an urgency that has no place in research; we must do things without delay, lest the Russians anticipate us; we are told that our survival depends on our intensity and application in scientific work. While this unfortunate trend may or may not have some validity in matters of missiles and other defense developments, it has no place in many areas of science, including zoology. The preachers of urgency forget that research is one of the most ennobling forms of human endeavor and

The author is head curator of the department of zoology, Smithsonian Institution, Washington, D.C. This article is adapted from his vice presidential address, delivered before Section F (Zoological Sciences), during the Chicago meeting of the AAAS, 26–31 Dec. 1959.

that the unfolding and expanding of the trained and critically disciplined imagination entailed in this activity make up one of the most valuable results and one of the finest features of our culture. To mar this with needless haste and with a deplorable spirit of competition in place of intellectual cooperation is to degrade one of the best aspects of the civilization for whose survival we are asked to concentrate our efforts.

This unnecessary impatience and overvaluation of immediacy has affected adversely one element in the research environment—namely, time. Time is very important—time to think things out, time to muse and to ponder over the various ramifications and implications that emerge from, or that come into contact with, the specific problem under investigation, either directly or tangentially. How often has it happened in the experience of many of us that some of our best thoughts, some of our most pertinent or most searching questions, have come only when we were writing up the results of an investigation and were attempting to see what conclusions seemed to be warranted. Ideally, the investigator should then feel free to go back and take whatever time he may need for further work, for collateral reading, for extensive rewriting of his manuscript—he should even feel free, if need be, to put his manuscript away for months so that he may read it again with a fresh eye before submitting it for publication.

The mental processes involved in thinking out a sizable problem, in arranging masses of new data in a meaningful sequence, and in interpreting them in relation to broader concepts are, as I am sure most of us have found, not merely a series of logical steps. We often experience something almost like a flash of intuition that suddenly illuminates the material and the ideas and even seems to organize and to arrange parts of the contents for us. Of course, this is not really merely intuition, but is the result of what might be termed "mental digestion." It takes time to digest and to assimilate all the discrete facts and thoughts, and until this assimilation takes place we cannot hurry through with a publishable report in order to meet an externally arranged deadline. Time remains, and always will remain, an essential element of the environment in which research is done. Yet this, too, can be overemphasized, and when deadlines prevent this from happening, they serve a purpose. But these deadlines must not be allowed to cut short investigations that, as they develop, are found to require more time than was originally estimated. I think that, by and large, many of the agencies or organizations that grant funds for research are aware of this, but there still is a tendency to evaluate projects in terms of their duration, one particular project as a two-year study, another as a three-year one.

Funds for Research

It is one of the most paradoxical aspects of the current climate of science that, whereas formerly the scholar had ample time to do his work but often had difficulty in getting adequate support for it, today he feels under some pressure to hurry and even to expand his program to make use of the funds now available in unprecedented amounts. The great growth of available financial resources is partly due to the increase in the number of foundations making grants, but in the past few years it has been even more the result of the greatly expanded support of science by the federal government. The indications are that this support will continue and will probably increase in scope rather than decrease. It is a far cry from the historical state in which society was slow to recognize that all knowledge is useful, or at least potentially so, to the present state in which it seems to be society's more or less official policy that all knowledge is vital and cannot be acquired too soon. This judgment, originally formulated in connection with such aspects of physics and chemistry as were of possible military application, has spread to cover all the sciences. As a result, the zoologists, like many other groups of scientists, are being carried along on the coat-tails of the nuclear physicists and chemists. While we may get a feeling of exhilaration and a sense of importance from this unaccustomed speed of travel, I think we owe it to ourselves to take stock and to do some planning for the trip.

First, we may look at the possibly undesirable side of the picture. Many may look askance at the idea of federal funds being poured into the support of research, not merely in federal agencies, but particularly, on either a grant or a contract basis, in our universities and other private or semiprivate organizations. There is still a residual feeling that it is not the proper function of government to do purely cultural things; that if our colleges and universities and museums and laboratories cannot afford to do them, we as a nation cannot afford them either and should not undertake them. However, the facts are that as a nation we can afford them and the government has already entered the field on an unprecedented scale, and it seems better to live with our conditions and make the best possible use of them than to retire into ourselves and ignore the current environment. Fortunately, as shown in C. V. Kidd's recent book *American Universities and Federal Research,* the policies governing the administration of federal contracts or grants are so arranged as to constitute no threat to the freedom of the institutions whose staff members are involved.

There is another element of doubt in that there is a danger that in a large program of federally supported research an undue share may be given to projects of foreseeable utility—in other words, to applied rather than to pure research. To us as scientists the great danger in applied research seems to be that in applied research it is the project that is supported, whereas in pure research it is the individual. We all are aware of the primary importance of the creative mind of the scientist who uses his skills, his insight, and his imagination in probing for unknown data, and we can hardly acquiesce in any plan that would make the person subservient to the project. At this point I hasten to state that many, if not most, of the granting agencies, governmental and private, are aware of this and make serious efforts to prevent it from happening. One of the great granting organizations, the Guggenheim Foundation, years ago, at its very inception, decided that its grants would be made solely to individuals and not to the institutions in which the individuals were doing their work. The support of the creative worker was the foundation's goal, and this goal has been kept in mind ever since. The postdoctoral research fellowships of the National Research Council, which were established in 1923, had an aim that was similar, although it was set forth in language that suggested that by giving the chosen candidates one or two or even three years for research early in their careers, the urge to continue with research might become so well entrenched that it would survive the vicissitudes of subsequent heavy teaching schedules or other duties imposed by the positions in which the candidates would eventually find themselves.

Now, however, with the rise of other foundations, with the involvement of the federal government, and with the correspondingly great increase in the total amount of funds available for research, there is the danger of a growing tendency to emphasize the project, not the individual, as the selling point. No one, no matter how well established or how highly regarded he might be in his own special field, would think of writing to one of the agencies or foundations for support unless he had a definite project. Inasmuch as most such organizations refer all applications to a panel of experts for appraisal, it follows that the evaluation of the project may easily be the deciding factor. It is true that a recognized individual favored by the panel might get a grant for a minor project for which an unknown newcomer might be turned down. On the other hand, it is also true that the project, and especially the argument advanced in its support, would, in most cases, reveal something of the applicant's fitness.

Geographical Expansion

Not only is the environment of zoological research more bountifully supplied with financial resources than ever before, but it is also of larger geographic scope than ever before. The great advances in aviation and in aviation facilities that began with World War II and that have increased at a constantly accelerating rate ever since have made distance and time of little account, and so many remote or inaccessible places have been opened up and provided with airfields that practically all parts of the world can now be readily reached. Two examples may suffice to make this clear. Last October I was in Ann Arbor for a couple of days and had occasion to talk with some of the staff at the Museum of Zoology of the University of Michigan about their hopes and ideas concerning the possible establishment of a field station for tropical zoology. In their thinking they had more or less narrowed their geographical choice to southern Mexico, partly because of the relative ease and low cost of travel to that area. Yet, I was told that one of their advisers, a man by no means inexperienced or lacking in knowledge of matters involved in field zoology, suggested that they give serious consideration to a location in the interior highlands of New Guinea, a place that, until the close of World War II, was about as difficult, dangerous, and costly (in terms both of time and money) to reach as any spot on earth. Yet now, with airfields established there, with fairly frequent service from Australia, and with the native tribes pacified, the rich and wonderful fauna of that great island is available for study. It is possible to take in equipment of a bulky sort that would have posed real difficulties when the long overland voyage had to be made on foot, and it is possible for a zoologist interested in studying particular creatures intensively, not just in collecting specimens, to go there and work.

Not long ago I happened to be involved as an adviser on plans for future zoological work in Antarctica in the continuing projects that stemmed from the IGY program of 1958. In the course of the discussions I was asked whether I would care to go to Antarctica for two or three months. When I replied that it would hardly be economical for anyone to spend only two or three months in a place when the travel there and back would take much longer than that, I was told that Navy flights from Washington to Antarctica take three days, and that such flights could be arranged without long delays. I was told, moreover, that facilities are in existence at several spots in that bleak continent where a visiting zoologist can be put up and where he can do his work without the great bother of establishing and maintaining a camp.

Opportunities in Marine Zoology

The recent first international congress of oceanography may be expected to result in a great increase of facilities, as well as of projects and support, for studying the still little known but enormously diverse animal life of the oceans. Zoologists in university departments that include training in invertebrate zoology in their program might keep in mind the fact that there will be an increased call for specialists on marine invertebrates in the near future. Marine zoology generally has lagged behind terrestrial zoology because it is a more costly and a less accessible field for investigation. There is reason to believe that this lag may be lessened, possibly more rapidly than would have been the case without the impetus afforded by the congress. Whereas formerly advances in our knowledge of the ecology and systematics and life histories of marine organisms occurred in spurts as the findings of individual oceanographic vessels or expeditions were reported, today the oceanographers have, or plan to have, fleets of ships especially designed for oceanographic research. Recently the National Academy of Sciences announced the appointment of a coordinator of United States and international activities in connection with the forthcoming multination exploration of the Indian Ocean. This work is being undertaken jointly by Australia, Denmark, France, Germany, Great Britain, India, Indonesia, Japan, the Union of South Africa, the U.S.S.R., and the United States. The peak activity is expected to occur in 1962 and 1963, when 15 or more ships will be in the Indian Ocean simultaneously. The Magnuson bill, due to come up for hearing before a congressional committee, is another sign of the tremendous new interest in the oceans. While it is true that the programs involved in all of these projects are largely centered around the physics and chemistry of the seas, marine zoology is certain to be advanced very greatly as well.

Unification in Zoological Study

The fauna of the world, then, may now be studied in the field to a greater extent than ever before, and the zoologists will have only themselves to blame if they do not take advantage of the situation. There is an old saying to the effect that for every problem in biology there is some ideal species in which the problem may be more directly approached than in others or in which the complicating factors are reduced. This is particularly true in the fields of animal behavior and animal ecology, but the saying is also applicable to any of those branches of zoological work where the animal is studied as an entity.

This leads us to the next change in what I have termed the environment of zoological research. Much of the work of the experimental laboratories has been done, and is still being done, on a mere handful of species of animals, largely the pets and parasites of man and the commoner marine organisms in a relatively small number of favored localities, such as Woods Hole, Friday Harbor, and the Bay of Naples, to mention but a few. This is partly due to the availability of these species and partly to the fact that it is easier to compare new data with old when both involve the same organisms than when they do not. We all know

that variation is the one invariable rule in living creatures, and that animal life exists in a truly enormous diversity of forms and habits. Yet, in many areas of zoology we have built up a science of animal studies on the basis of a small—a really surprisingly small and, statistically, almost dangerously small—sampling of the animal kingdom. Here the talents and knowledge of the specialists within the broad field of zoology, if properly used and directed, may become factors of great importance. The taxonomists and the naturalists, to use a term that is rapidly recovering its original prestige after a period of obsolescence, are almost the only zoologists sufficiently well acquainted with the total fauna of the world to be able to suggest which other species might be as good as, or even better than, those now being used for particular studies, or to choose with some judgment promising species with which to test whether or not some concepts based on other forms may need modification before they are generally accepted. Also, the taxonomists, with their broad, if possibly superficial, knowledge of the world's fauna, may be in a position to see problems against this wide evolutionary background to a degree not always possible for the experimentalist in his laboratory. On the other hand, the descriptive zoologist frequently has to concern himself with facts for the elucidation of which he needs the advice and help of the physiologist, the geneticist, and the behaviorist. Each group of zoological specialists has much to give to each of the others, and it is encouraging to note that in many fields there is a growing realization that we need to know more about a given species of animal as a whole—about its life history and its ecological requirements as well as its structure—regardless of whether this knowledge is closely or only distantly related to the special investigation of, let us say, some aspect of its morphology or some puzzling behavior or some detail of its physiological processes. Even more significant is the increasing tendency among the various groups of zoologists, geneticists, physiologists, anatomists, ecologists, ethologists, and taxonomists to look upon all of zoology as a single subject and to conclude that fragmentation of zoology into isolated compartments may be detrimental to the isolates and that results so obtained may be less of a contribution to the field as a whole than might otherwise have been the case.

Those of us who work in the larger research museums are perhaps more aware of this than others, because we are constantly faced with the problem of incorporating the pertinent data and ideas emanating from any types of biological work into, and thereby improving the objective accuracy of, our concepts of phylogeny and our systems of classification of animals. Many zoologists not personally concerned with systematics assume that museums are merely depositories, nearly as dead as the specimens they contain. This is far from true, as has been shown by the emanation from museum studies of data and of ideas that have brought to light analogies in such diverse fields as paleontology and genetics. One might as well say that a great library is only a cemetery for the thoughts of dead authors. It all depends on how the materials are used.

Change and the Zoologist

In a state of nature animals live their lives in fairly close adjustment to their environment. When a change occurs, either they take advantage of it and improve their status, or they continue as before, unaffected by it, or they are unable to withstand the change and therefore perish. It seems to me that zoologists today are in a more favored position. First of all, the change is in their favor and is not forced upon them; they can take it or not, but there is the opportunity, as never before, to extend and to expand zoological investigations. If I have discussed ecological and systematic aspects of zoology more than other aspects, it should not be assumed that these aspects are more favored by the changes in the environment of research. All fields are equally affected. Consider, for example, the role of electron microscopy in zoological science. An electron microscope is a costly piece of apparatus, and accordingly, its use has been limited to the larger zoological laboratories. With the increased support of scientific activity it seems reasonable to think that more and more institutions will be able to add this or any other new and promising instrument to their equipment for the prosecution of research, as actual needs are demonstrated. Similarly, the new field of molecular biology cannot help but be advanced rapidly by the great activity in molecular physics and chemistry, and by the application of the data, methods, and instrumentation thereby developed.

The zoologist today finds himself in an environment of abundance and is naturally tempted to turn the abundance to good account. It would be a great pity if these opportunities were not utilized as fully as possible, but it would be an even greater pity if individual researchers were to be made over into mere seekers after the expedient. We owe it to ourselves to use our enlarged environment effectively without losing our individual approaches and our individual reflections and contemplations in working with the teams we are given the chance to create. Teams may amass new data, but ideas and interpretations still are the product of individual minds.

I shall close these remarks with a purely personal statement of what I think may develop in the field of zoology. Zoology may develop a broader base for its concepts; it may make fuller use of the world's fauna wherever there is reason to question whether the presently used species are really representative of all conditions, or wherever the concepts are based on a single or an inadequate number of species. Zoologists may be able to follow their researches wherever the problems may lead them rather than cut off their studies when they get to the end of their own special techniques and knowledge. It should be possible for a specialist in any zoological discipline to formulate a broad attack on his problem and, if need be, to enlist, on a temporary basis at least, the services of specialists in tangential fields. A good, well-thought-out project, either of philosophical or of more immediate importance, will find support. Older lines of work, still unfinished, should be continued and completed, even if they do not seem to provide the immediate interest and temporary glamor of new ones, because we shall always need this basic information. One problem that still remains to be tackled adequately is that of getting the results of research published within a reasonable time. Printing costs keep rising, and journals are swamped with backlogs of manuscripts, yet the urge to do more and more research is constantly with us.

The zoologists, together with other groups of scientists, are in a position to take advantage of, and to benefit from, the recent impetus for the support of science provided in the first place by the nuclear and atomic physicists. If the world is not first destroyed through today's incredible expansion in the field of nuclear studies, we who come in the wake of the nuclear physicists will have a wonderful opportunity to learn much more about it than ever before.