1. Rensselaer Polytechnic, Troy, N. Y.
2. Union College, Schenectady, N. Y.
3. Cornell University, Ithaca, N. Y.
4. Kansas University, Lawrence, Kas.
5. Yale University, New Haven, Conn.
6. Nebraska University, Lincoln, Nebr.
7. Minnesota University, Minneapolis, Minn.
8. Ohio, State University of, Columbus, Ohio.
9. Pennsylvania, University of, Philadelphia, Pa.
10. Brown University, Providence, R. I.
11. Iowa, University of, Iowa City, Iowa.

In the Universities where the chapters have been established, the organization takes the place of Phi Beta Kappa among the science men, and the purpose of the organization is to recognize and associate the men of marked ability in scientific studies. The Society has been running long enough to show very clearly that there is an academic side to science, as well as to literature, and that the academic qualities promoted by scientific studies are as important as those fostered by the pure study of literature. It will be interesting to note in the course of the year to what extent the culture of the scientific qualifications of men gives them power of leadership among their fellows. It is certain that in business affairs we are already observing the important place which scientific ability takes in the really dominant men in America. If the conceptions of Sigma Xi are correct, we shall see a similar condition of leadership among the scientific scholars of the country when sufficient numbers of such scholars have been developed to overcome the precedence which we are accustomed to grant to literature as the standard of real scholarship. The chapters recently started in the University of Pennsylvania and in Brown University exhibit the enthusiasm which is already being kindled in this department of university life. The charter membership in both of these cases was composed, practically, of the whole staff of scientific professors of the university. As an honor society, it promises to take a leading part in all our universities in which science holds a prominent place.

The present officers of the Society are: *President*, H. S. Williams, Yale; *Vice-President*, S. W. Williston, Kansas; *Corresponding Secretary*, J. McMahon, Cornell; *Recording Secretary*, F. C. Caldwell, Ohio; *Treasurer*, E. W. Davis, Nebraska; *Chairman of Council*, E. L. Nichols, Cornell.

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*THE BIOLOGICAL SCIENCES AND THE PEOPLE.**

Like the American Association for the Advancement of Science (and other similar organizations), the Michigan Academy is an expression of the voluntary scientific activity of the people of the State, and depends for its continued usefulness on a rational interest and a helpful co-operation on the part of the people.

It has therefore occurred to me to inquire in what way the biological sciences, from whose adherents the Academy draws most of its membership, touch the people: what in the growth of these sciences makes toward and what away from a contributory interest on the part of the people. By contributory interest is meant that which aids in the upbuilding of the sciences by adding something of importance to their store of fact or theory. The question that is raised is then, not what benefit do the people receive from the biological sciences, for these are many in the practical and in the educational application of these sciences; the question is rather how may or how do the people benefit these sciences by aiding in their further growth.

I shall speak from the zoological standpoint, but what is true of zoology, is true, in this matter, in large measure, also of botany.

The question seems to be intimately associated with the recent history of zoology.

* Abstract of the address of the retiring president of the Michigan Academy of Sciences, delivered at the Lansing meeting, March 29, 1900.

The year 1859 found zoologists, the world over, working industriously and quietly at almost purely descriptive work. No more was expected of any zoologist than that he should discover and record the wonders of nature as revealed in the animal kingdom, and that he should duly express his astonishment at the infinite wisdom shown by the creator in arranging all these details. Of attempts to get at the meaning of the details there were very few. The popular notion of the zoologist's aim in life is expressed in a question that I remember to have heard asked in my student days, by a much respected professor of literature of his zoological colleague. "Well now what is that animal curious for?" In this year appeared Darwin's 'Origin of Species.' Its effect is thus graphically described by V. Graff in a recent lecture. "It came like a lightning flash in a period of quiet descriptive work, a period which had accustomed itself to consider the nature-philosophy ideas of the beginning of the century as absurd freaks of imagination, unproved and unprovable, a period which therefore clung anxiously to its foundation of facts. How the theory of natural selection put life into this dry describing, how it hurried the knife of the anatomist, and what a broad prospect it opened before the hitherto short sighted eye of the systematist! About the mummies of the species which, separated from one another by carefully formulated Latin diagnoses, filled the collections, there suddenly appeared the constricting noose of blood relationship. The petrified remains of extinct forms, hitherto shut out from the community of living beings, received flesh and blood and demanded to be included with the existing fauna and flora in a single great genealogical tree, representing the history of life on our earth."

Darwin's book brought essentially two contributions. In the first place it brought a mass of *evidence* in proof of the proposition that animals are related to one another by descent. The *idea* of a process of evolution is very old and Osborn has recently traced its history from the early Greeks to the time of Darwin. Darwin did not originate the idea, he established it by a mass of evidence and it has been ever since accepted.

In the second place Darwin contributed the theory of the origin of species by natural selection. This theory is so well known that it need not be restated here, but it may perhaps be pointed out that the theory does not attempt to account for the origin of the variations upon which it depends. It is a fact that these variations occur and Darwin's theory bases itself upon this fact. He spoke of such variations as fortuitous. Aside from certain correlations, variations seemed to Darwin to occur by chance, though he did not exclude the possibility of their being later found to be subject to law.

The idea that the multitude of animal forms had thus originated by a process of evolution, and that this process was governed by a simple law, affected the whole subsequent course of zoology.

Zoologists soon came to accept not only evolution as a process, but natural selection as at least the chief explanation of the process. The zoologists following Darwin made but little attempt to study the variations upon which the theory of natural selection based itself, or to determine the range of variations or their causes. Having decided that animals were related to one another, and having fixed the law governing the origin of the relationship, zoologists began to turn their attention to a study of the degree of relationship. A mania seems to have become prevalent for the construction of a genealogical tree of the entire animal kingdom. The ultimate aim of zoologists ten years ago, or even five years ago was animal genealogy, and such is still the aim of many working zoologists. Paleontology, comparative anatomy and embryology were

believed to furnish the means for unraveling animal genealogies.

All three of these lines of research have been pursued (from the phylogenetic standpoint) with great enthusiasm since 1859, and they are still being pursued; the results have, however, fallen far short of meeting anticipations. From the paleontological side it was evident from the first that many animals had left no recognizable fossil remains. In other cases the remains were so imperfect, so difficult of access and so few that nothing like a complete series could be hoped for. Paleontology has accomplished a great deal. Where it is available, it is without doubt the safest guide, perhaps the only safe guide in phylogenetic speculation. On the other hand it has not, and in the nature of its materials cannot lead to a realization of the zoologists' dream of a phylogenetic millenium.

Comparative anatomy has been to a considerable extent neglected during the past thirty years. Among the invertebrates, where the research could be carried on by the rapid methods of modern microscopic technique there has been more work, than among the larger vertebrates where it is necessary to use the tedious method of dissection. Among the anatomical research of the last quarter of a century there is a noticeable dearth of *monographic* work. In the earlier part of the century anatomists were not so much concerned with the discovery of relationships, they were content to work long on single animals, and there were thus produced anatomical monographs which have not since been surpassed in quality. With the advent of Darwinism came a feverish haste to detect relationships, and this resulted in a desire to compare large numbers of animals with one another. The time required to study the whole structure of a large series of animals was too great for the life time of one man. Much could, however, be accomplished by the comparison of a single organ through a large series of animals—and so the comparative anatomy of animals (monographic work) gave place to the comparative anatomy of organs.

A second characteristic of the comparative anatomy of this period has been its great reliance upon embryology. Its facts have been too often distorted to make them fit with the results of embryological work, and thus what should be the base of the pyramid has been made its apex.

Embryology was, however, the guiding star of the post-Darwinian workers. It seemed to offer by far the easiest and quickest solutions of their problems. It soon developed a technique of great intricacy and of great accuracy, and it came to offer easy conquests to the ambitious investigator. Its faintest hints at relationship were accepted as of the utmost importance and were given the deepest meaning. Scarcely any zoological work was complete without its embryological side. But it soon became evident that the development of an animal could not be construed as a simple repetition of its ancestral history. The ancestoral features were always more or less modified by features impressed upon the developing animal by its surroundings. The embryo was, so to speak, burdened by a double task. It not only repeated the history of its ancestor, but it had also to adapt itself to its own very different conditions. The development thus came to be considered as made up of two factors—those that were ancestral (phylogenetic) and those that were acquired by the embryo and peculiar to it (cænogenetic factors). The record was thus said to be falsified and to pick out the true from the false became the difficult task of the embryologist. This was a task requiring great judgment and one concerning which individual observers were likely to differ greatly. If an observer started out with a certain theory as to the ancestral

history of an animal, all those factors in its development which did not accord with the theory, were apt to seem to him to be falsifications of the record. Another observer with the same facts before him, but working on a different theory, would discover that many of these so-called falsifications were really ancestral features.

Another factor which has hampered embryology as a phylogenetic discipline has been the too frequent limitation of the investigation to a single organ. It is easier to investigate a single organ through a series of embryos than to investigate the entire structure of all the members of the series. We are able to judge correctly of the character of a man only when we know all the elements that make it up. And so with a series of embryos, we must know the whole structure, not merely a part of it. Monographic work is here quite as necessary as in comparative anatomy.

Many illustrations might be given of the grotesque results reached in animal genealogy, principally through too great reliance on embryology. That investigators with the same facts before them may reach diametrically opposite conclusions is shown in the attempt to trace the ancestry of the vertebrates. No less than a dozen invertebrate groups have been announced from time to time as having furnished the vertebrate ancestor. The cœlenterates, the annelids, the nemertines, the crustacea, the spiders, Balanoglossus and the tunicates have all been candidates for this honor, and perhaps all deserve it equally.

With such results the zoological pendulum may be said to have reached, for the present, the limit of its excursion in the direction of phylogeny. It is now beginning to swing in another direction. Within the last five years, zoologists have begun to see that phylogenetic speculations have been to a large extent fruitless of specific results. They cannot be undertaken to advantage until we have vastly widened our field of knowledge. Then too it is being realized that the construction of a phylogeny of animals is, after all, not a matter of the greatest consequence. So long as we know that animals are related to one another and so long as we are able to investigate the laws which have governed the establishment of that relationship, it does not so much matter just *what* the precise relationship may be.

Zoologists are then turning in other directions. There seem to me to be chiefly four.

1. There is among those engaged in purely descriptive anatomy or embryology a tendency, not yet very pronounced, but yet growing, to return to the monographic method of working. This is a return to the methods of the beginning of the century and betokens a purpose to let speculation rest for a while, until more materials have accumulated upon which to base it.

2. There is a marked tendency to study *variations*. The first book on this subject has appeared within a few years, and has stimulated the production of many papers. The purpose of the workers in this field is to determine the nature and range of variation so as to gain a familiarity with the nature of the materials upon which natural selection acts. It may thus be possible, as Bateson points out, for the investigator of the future to say not 'if such and such a variation should occur,' but 'since such and such a variation does occur.' Students of variation hope also to discover some of the laws which determine the production of variations. It is believed that they are not, as Darwin thought, fortuitous, matters of chance, but that they are subject to well defined laws.

All phylogenetic speculation is based upon the idea of homology, but the study of variations has set our ideas of homology toppling and until these ideas are reconstructed we cannot hope for any final determination of animal relationships.

3. Toward a study of the effect of environment in inducing and modifying developmental processes. Experimental morphology, experimental zoology, experimental embryology, are new subdivisions of our subject which express this tendency. It is possible to subject developing animals to the influence of various factors of the environment in order to determine their effect. Developing eggs may be subjected to different temperatures, or to chemical solutions of different sorts and strengths or to the influence of electricity. In this way we may find what influence each of these factors has on development. Adult animals may be subject to similar changes of environment. The results of such researches are usually expressible by mathematical symbols, such as geometric curves or algebraic equations.

Such work is only in the beginning but it may ultimately lead to such an analysis of the environment as to enable us to assign to each of its factors its proper value as an element in organic development.

Experimental work is also being directed toward a determination of the internal factors of development, those which are resident in the animal itself and are not impressed upon it by the environment. The effect of the removal of portions of the developing egg, enables us to determine the part taken by those portions in the normal development of the whole egg. Others of the internal factors of development may be studied by direct observation (without experiment) and by comparison.

4. Toward a study of the activities of animals. Animals exhibit many sorts of activities that may be classified. Those connected with the taking of food, with reproduction, with the rearing of young, with construction of dwellings, with community life and so on. We are beginning to suspect that many of these activities have features that are common to large numbers of animals and that their origin and development may be traced with as much certainty as the origin and development of the organs of the animals. Many of the activities of man himself may doubtless be traced to an origin in the lower animals and much light thereby thrown on what we are pleased to call *human nature*.

Monographic work in its descriptive branches, the study of variation experimental work, and the study and comparison of the activities of animals seem then to be the directions in which zoological research is now turning.

The phylogenetic phase has passed the height of its development for the present and must await the accumulation of new data before it can again become dominant. But since the study of phylogeny does not really solve any philosophical question (but only gives form to a question already assumed to be solved) it is likely that it will never again become ascendant. Time will bring the solution of many of its problems, but such solutions are likely in the future to possess only a secondary interest.

On the other hand the new lines of work look toward the solution of the most important questions concerning the *method* of origin of organic forms.

Coincident with the gradual acceptance of the evolution idea, and coincident with the great development of morphological and phylogenetic ideas in our universities, there seems to have been a decline in popular activity in natural history. This did not become manifest immediately after 1859, but began, perhaps, ten or fifteen years after that date and has been in progress since then, up very nearly to the present time.

The most striking evidence of this decline is afforded by the decay of natural history societies. In this state Detroit and Grand Rapids each formerly supported such societies. They were well patronized, had

rooms of their own, held stated meetings, and accumulated collections. The Detroit Society has long since decayed and its collections have passed into other hands. The people of Grand Rapids are so apathetic that there seems every reason to fear that they will permit the collections of the Kent County Society, to pass out of the city.

Many similar societies in other parts of the country have had like histories. A number of such are known to me.

This decline of popular interest has affected not so much the theories of natural history as its materials, not so much perhaps popular interest as popular participation. It has taken place by the side of an unprecedented activity in zoology in the universities and colleges and in the scientific work of the government.

May we not seek the explanation of it in two directions. First in the hostility or apathy of the church. So long as the study of natural history seemed merely to reveal the wonders of creation and to magnify the marvellous work of the creator, the church encouraged it. The evolution idea on the other hand was strongly combatted by the church. While it is, perhaps, not possible to trace the effect of this controversy on the popular interest in natural history, we may feel sure that a state of mind which looked upon every animal adaptation, as upon every visitation of disease, as an expression of divine wisdom, must have been more sympathetic toward the study of natural history, than one which saw in the animal only a vaguely comprehended end-result of an evolution process, itself subversive of accepted religious beliefs.

A further reason for the decline in popular interest may be sought in the lack of stimulus from above. The zoologists of the universities and colleges had become morphologists. A few of them kept up an interest in systematic zoology, but for the most part they were engaged in the laboratory study of the anatomy and development of preserved animals. Existing animals, the *end-results of an evolution process* were to be grouped in accordance with their genealogical history. The activities of animals, their habits, habitats, distribution, their relations to their environment, their ecology in short—all these were thought to be of little consequence. Students sent out from the laboratories of these teachers were much more familiar with sections and dissections than with living, or even entire animals. Once removed from the laboratory with its equipment of apparatus such students were quite helpless.

They experienced in most cases great difficulty in finding again in the field the animals that had served their laboratory studies. These students are the persons from among whom the membership in natural history societies is recruited. They are the persons who stimulate, in any community, an interest in natural history studies. These young recruits were then without interest in the study of living animals in their natural environment, while the people were, as they will likely always be, without interest in the laboratory study of anatomy and development. That which interests the people is not the dead end-product, but the living, active animal, the activities of animals, what they do and why they do it.

The people at large care but little about the structure even of man; they will know only what is necessary to care for the machine, and most of that they leave to the doctors. To know the origin of the various structures of man does not greatly interest them. How overwhelming on the other hand is their interest in man's *activities*. No other human interest transcends it.

But just as the structure of man has had a history: just as we may trace the development of his heart or brain through

various stages which exist in the lower animals, so have the activities of man also had a history. The germs of his doings are to be found, perhaps all of them, among the lower animals. The social instinct, the home-building instinct, the instinct to care for the young, and how many others do we find in the lower animals. That these activities of the lower animals have given rise to those of man there seems little room to doubt. Just as the structure of man must be viewed against a background formed of the structures of lower animals, in order that it may be understood, so must man's activities be viewed against the background formed of the activities of lower animals.

Zoologists are only slowly coming to realize this fact, and in the study of variation and its causes, in the study of the relation between the animal and its environment, in the study of ecology, or experimental zoology, we see evidence of this realization.

In this movement, indeed, the popular interest and the popular wisdom find their justification. In so far as zoology affords an explanation of the origin of human activities, it becomes important in the conduct of life, in so far it justifies itself in the eyes of the people. Zoology is now passing rapidly out of the ultra morphological and ultra systematic phase, into a phase where it will concern itself more with the activities of living animals and with the relation of these to the environment.

In these matters it will again appeal to the popular interest. Students from our colleges and universities when they have quitted the laboratory will no longer feel themselves strangers to nature. When they go among the people they will stimulate the study of a rational natural history.

From this cause and from the final lapse of the now nearly extinct opposition of the church we may expect a popular revival of interest in natural history subjects. Indeed, the introduction of nature study into our schools, the increasing number of popular books and magazine articles on natural history indicate that this revival is already at hand.

In the days before Darwin natural history societies contributed no inconsiderable part to the advancement of the sciences of zoology and botany. This they did through their collections and through the discovery by their members of new species, new localities and hitherto unknown habits of animals. May not the revival of popular interest which seems to be at hand again contribute to the advance of zoology? Observations on the daily life of animals, on their distribution and variations, on related subjects, may be made without the elaborate equipment of laboratory and library that is necessary for morphological work. Such observations are well possible to isolated members of a society like this one, and carefully made and well thought out, become real contributions to our science.

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THE STEAM-TURBINE.

An apparently important, and to the writer, at least, new, fact in the operation of the steam-turbine is revealed by experimental investigations in progress for some time past in the laboratories of Sibley College, with both saturated and superheated steam. Contrary to the usual theory of that apparatus, it is found that a very substantial gain may be had by the use of superheat, not only in efficiency but also in *capacity*.

The steam-turbine is not subject to that form of waste known as 'initial' or 'cylinder' condensation which adheres to every piston-engine as a consequence of the large fluctuations of temperature which accompany the variations within the cylinder be-