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MSS. intended for publication and books, etc., intended for review should be sent to Professor J. McKeen Cattell, Garrison-on-Hudson, N. Y.

THE AMERICAN SOCIETY OF NATURALISTS

SYMPOSIUM ON THE SCOPE OF BIOLOGICAL TEACHING IN RELATION TO NEW FIELDS OF DISCOVERY

FROM THE STANDPOINT OF A ZOOLOGIST

THE speaker must admit that upon taking time to reflect on the various ramifications of the subject announced his first reaction was one of wonder at himself for ever having agreed to enter into such a discussion; for obviously any statement must be the expression of a personal opinion influenced largely by the advocate's own training and the conditions which obtain in his local institution.

Upon roll-call one finds oneself confronted by such lusty newcomers as: ecology, animal behavior, comparative and general physiology, biochemistry, cytology, genetics, biometry, which, however, is really a method of work and not a special field of investigation; experimental zoology, a sort of general mélange which also includes some of the more special fields enumerated; experimental embryology, a subject inextricably interwoven with experimental cytology and which in recent times has sported a new offshoot—tissue-culture in vitro—already almost an ology in itself; not to omit such important applied subjects as parasitology, protozoology and the application of biological principles to human problems.

How much are we justified in letting these replace our traditional general zoology, invertebrate zoology, comparative anatomy of the vertebrates, histology and embryology? One realizes vividly the just merits of the new claimants, but when he faces the problem of deciding as to which

of the older subjects they shall supplant, he can not but hesitate. Which of these true and tried teething-rings of our zoological infancy shall be discarded? Can we spare any of them? I must confess that after considerable pondering I have concluded that for the training of the professional zoologist or the teacher of zoology I do not see how we can. I can find ways for shortening them to make room for new subjects and ways for injecting new meanings into them from our late fields of discovery, but it seems to me that when all is said and done, comparative morphology, including embryology, together with some histology, is a well-nigh indispensable ballast for our ship of biological progress. None of the newer experimental lines can yet take the place of these for training the zoological apprentice. I have yet to find the subjects in which I can pin my students down to exact observations, unequivocal inference and far-reaching generalizations in the concentrated form I can secure in a course of study based on morphology, but saturated throughout with demands for interpretation of the structures under consideration in terms of function and environment.

It seems to me, moreover, that nearly all of these newer lines actually or tacitly presuppose a considerable amount of systematic or morphological training. Much of our experimental zoology has bearings on the problems of evolution; hence what can such work mean to a student who has not reached an understanding of organic evolution from a careful comparative study of animals of different degrees of complexity? Or of what avail are many of the efforts of our statistical friends, the biometricians, without a keen appreciation on our part of the questions at issue, based fundamentally on an understanding of the real significance of variations? Or in the realm of animal behavior, one of the insistent new claimants for attention, the facts have meaning mainly as interpreted from the comparative or the evolutionary point of view, which presupposes knowledge of the relative complexities of the fundamental types of nervous systems. Of what significance, for example, is Professor Jennings's trained starfish, except as understood in terms of our knowledge of the starfish nervous system and the animal's relative position in the animal kingdom?

Or, taking the field of experimental embryology, how far should we get in true scientific appreciation of the recent work on tissue culture in vitro had we not considerable preliminary familiarity, not only with the structural nature of tissues but with general embryology as well? And when it comes to the quest for organ-forming substances, cytoplasmic prelocalizations or whatever we may be disposed to call precleavage differentiation, certainly the neophyte can travel the road towards understanding but a short distance without considerable preliminary knowledge of organogeny and even of cytology. Or again, in the field of genetics, while some of the practical values may be understood and utilized by those having meager knowledge of other biological facts, the full appreciation of the new discoveries can be grasped only by the well-rounded student, conversant with modern points of view in the fields of variation and evolution, embryology, cytology and general zoology.

Coming to cytology, no one, I think, will gainsay the statement that it is highly desirable for students to have had preliminary courses in comparative zoology, histology and embryology, to say nothing of a grasp of the problems of heredity and variation.

At the very outset of our planning, of course, we are met with the question, which of our students are we planning for? The five or ten per cent. who may become pro-

fessional zoologists, the somewhat larger proportion who are going into medicine, or the vastly greater proportion who are going to take only one, or, at most, two or three courses as part of their general education? Personally, after experimenting with various plans for different classes of students, I have reached the rather settled conviction that no matter what the later work of the students is to be, they may all profitably be subjected to the same first-year course; namely, a course which will give them a good perspective of the whole field of zoology, old and new, and which emphasizes general principles rather than morphological detail, though by no means ignoring the essentials of morphology, or in other words, a course arranged for principles and not primarily for types.

I think there is particular danger of the specialist letting his specialty obsess him to the disadvantage of his general introductory course. Even though facts are formally true in themselves, the student may be given an entirely erroneous view of the whole, if the facts emphasized are the less important components. To an entomologist all zoology may lie in the realm of the insect, or perhaps of even some particular group of insects; or, if a specialist in fungi, all botany centers, perhaps, in the toadstool and its anemic brethren; or if a cytologist, the student may hardly be led to realize that there may be something in the world of life worth studying that does not lie under a cover-slip. I thoroughly sympathize with the heartfelt cry that heads the title-page of a recent elementary text-book in botany, "More about hay, less about karyokinesis!"

The general course I have in mind, though omitting much of the technical detail that a professional zoologist must acquire, nevertheless should give the prospective specialist such an orientation in the whole field of his science as is almost indispensable for balance and which in all probability he will not get in any of his later courses. At the same time it must give the general student an intelligent insight into the real live problems of zoology and should tempt him to venture further into some of the special phases of the work which appeal to him. The laboratory work of this introductory course should, in my estimation, be a study of various animals in all their life relations, with a constant demand on the student for interpretation, not merely corroboration of anatomical and morphological descriptions. The forms should be selected to illustrate general principles of physiology, environmental relations, evolution and genetics as well as phylogenetic position. They should also introduce the student to the fields of embryology and histology. In our own university we have found a series consisting of the frog, ameba, paramecium, euglena, volvox, hydra, gonionemus, crayfish and bee to answer our purposes very well as an introduction to general principles in a one-semester course, although we prefer to have our students take a second semester of zoology supplementing the general work by additional forms taken partly from the same but mainly from other phyla of the animal kingdom.

The frog is admirably adapted to the elucidation of general principles of morphology, physiology and ecology, and also furnishes excellent material for an introduction to embryology and histology. In our own laboratory we devote a total of some fifty-six hours of work to the frog. We find it a decided advantage to begin with a form sufficiently large that every student can get to work on it during the first ten minutes of the first laboratory period. Having begun with a larger form, all will not come to the microscopical work

and require assistance at the same time. The transition from the histology of the frog to the amœba is a simple one, and in the succeeding series of forms we get not only more or less of a gradational morphological sequence which will give the student some idea of evolutionary progress, but a good series for the introduction of the ideas of animal behavior, differences between plants and animals and other fundamental problems. For instance, in volvox we see the beginnings of the body as distinct from the germ, and it affords a splendid opportunity for introducing ideas relative to germinal continuity, evolution of sex and the like. *Hydra* and *Gonionemus,* besides opening the way for the conception of metagenesis, illustrate the simpler principles of differentiation. The frog, crayfish and bee, when contrasted in their structural adjustments to environmental conditions, give an excellent selection for showing diverse means of meeting the same fundamental problems of existence. Lastly, the bee is excellent for guiding the student into the problems of genetics. I find that the single query in the laboratory outline as to how, inasmuch as the workers are sterile, their various characteristics are passed on to the next generation, is more serviceable in opening up to the student the real underlying problems of heredity than a considerable amount of mere lecture declamation on the subject would be.

From the first year on there will be a divergence among the students, depending upon their future intentions. Many will never get beyond the first course. On the part of general students, however, I find a strong and increasing demand for at least one or two additional courses which will afford them greater opportunity to get the bearings of biological principles on human problems. I think it can be justly urged, therefore, that this applied phase of the work is worthy of a modest course somewhere in the departmental curriculum after the first year. If "the true study of mankind is man," certainly the most promising approach to this study is through biology. Our social and educational problems have suffered too long already at the hands of the biologically untrained. I suspect that to the great majority of our students who will never become trained zoologists there is nothing of greater value we can give them than a clear-cut biological orientation towards the problems of human life. Train such students week by week and month by month in scientific discrimination and in the handling of biological evidence secured by their own efforts at observation, and we shall contribute to society fewer victims for the demagogue, the sensationalist and the charlatan.

Of all people, the prospective teacher and the social worker need the vivid knowledge of facts concerning living things that can be gained only by direct contact with the objects themselves, yet how few of either of this class ever get more than the colorless remnants of biological truth that may be gained at second hand through the paths of pedagogy and sociology! Many professors of pedagogy and sociology are coming to realize the importance of preliminary biological training for their protégés, and, although themselves biologically untrained, are endeavoring to make good the deficiency. While one sympathizes heartily with the feeling of necessity which prompts their endeavor, he can not but marvel at some of the biological rag-time effects not infrequently served up in these fields as biological truths.

How many teachers have an adequate understanding of the functional adjustments necessary to normal activities in either simple or complex animals? Yet, lacking this, how can they be expected to

prescribe for the imperfect mental or physical adjustments of their charges, to establish habits of thought or behavior, to correct defective habits by developing compensatory ones, or to lay down guiding principles for the most efficient furtherance of normal functions?

Or, to turn to the matter of natural endowment, how many of them realize that what a child becomes is determined in great measure by its inborn capacities and that education consists largely in applying the stimuli necessary to set going these potentialities and of affording opportunity for their expression? That of the good propensities some will require merely the start, others will need to be fostered and coaxed into permanence through the stereotyping effects of proper habits; that of the dangerous or bad, some must be kept dormant by preventing certain kinds of stimulation, others repressed by the cultivation of inhibitive tendencies, and yet others smothered or excluded by substituting in their place desirable traits? And yet if they are ignorant of all this are they not pretty much in the position of one who would attempt to operate a complicated engine without any understanding of its mechanism?

In this whole matter of human heredity, or eugenics, clearly the biologist is the one to lead the way, and yet we find this field being exploited by all sorts of impossible fanatics and incompetents. In spite of the badinage of the press and the confusion resulting from its use of the term eugenics in many senses, nearly all of them equally wrong, the science itself has come to stay, and the public, sensing the vital truth at bottom of it, is going to demand more and more enlightenment. Surely if anywhere we need here to guard against the ambitious enthusiast who promises the impossible, who, for instance, at one sword thrust would stay the demon of degeneracy and restore a sort of pristine purity to the human race. And yet how is the public to be guided aright unless biologists, the ones most competent to advise, step forward and keep them in touch with the more solid advances which are being made through the sure though unspectacular methods of research?

In our own institution I find a strong demand on the part of general students for at least an additional lecture course in genetics with emphasis on the eugenic phase. Some take the elementary embryology as a sort of laboratory course to accompany the work and it seems to me that this is a combination to be commended. I see no reason, moreover, why such students should not be encouraged to take, as many do with advantage, courses in ecology, animal behavior, elementary entomology or parasitology, according to their taste, even though they do not take the regular courses in invertebrate zoology or comparative anatomy which personally I feel are well-nigh indispensable to those who expect to teach zoology or become investigators.

But how, it may be urged, are we to find a place for the new subjects if we are still to retain our traditional courses? Will these not occupy quite all of the time that can be devoted to zoology?

One way to gain considerable time is to shorten some of these older subjects. This can be done without sacrifice of thoroughness on the part of the student, it seems to me, by dissecting fewer forms in detail and using the remaining forms largely for the study of the more significant features in which they are different. Why, for instance, have the student dissect out in minute detail the arterial system of the dog-fish, perch, necturus, turtle, pigeon and cat when a careful dissection of this system in the dog-fish, necturus and the cat, together

with a comparatively brief study of the corresponding systems in demonstration specimens of the other forms, will give him the necessary experience, knowledge and perspective to serve the full educative value of the work?

But does this advocacy of retaining the old standbys carry with it the corollary that they are to be taught in the same old way, from the same old malodorous specimens, and from the same old standpoint? By no means. There is such a thing as letting nearly all of the newer fields enter into the traditional courses to vitalize and illumine them while at the same time retaining their valuable disciplinary and informational features. We need not replace or dilute, but rather compress more of value into these courses by insisting on ecological and physiological along with the morphological and evolutionary interpretations. A frog, for example, is interesting enough as a piece of architecture, but it becomes many times more interesting when we advance to its interpretation as a machine constructed for the performance of a wide range of life activities. When the student examines our selected types of animal machines in the laboratory he should be made to realize that he is not only to interpret their respective structures as so many intergradients in an evolutionary series, but that he is also to explain the mechanism in each case in terms of function and adjustment to environment. What a given structure accomplishes and how it does it, what its efficiency is as compared with other types, is of fully as great importance as how, from the evolutionary point of view, this or that organ has advanced or regressed over the corresponding one in some other animal. Omit either kind of interpretation and the student has been deprived of valuable insight that he might have had with very little additional effort. It may seem banal even to call attention to this obvious fact, but visit the average laboratory or look into the laboratory manuals in common use and one can not but feel that this evident fact has been almost entirely ignored.

I think there is a nearly universal feeling to-day that we have been too closely wedded to structure and have wrongly divorced it from function and environmental adjustment; our convictions, however, find but tardy expression in our manuals and laboratory directions. Part of this situation is undoubtedly due to the inertia of routine. It is much easier to realize that another system is better than actively to break with traditional texts and guides and rearrange our work in harmony with our new ideals.

Supposing that I had a free hand to arrange a curriculum for a zoological department according to my own feeling of what would turn out a well-balanced student to undertake graduate work or to become a teacher in secondary work, I should plan about as follows: a two-semester course in elementary zoology of five credit hours per semester; a one-semester course each in invertebrate zoology, comparative organology of vertebrates, embryology and histology, omitting, if anything, the histology. Into all of these I would inject as much of the living animal and of experimental processes and interpretations as was at all practicable; that is, I would have these fundamental courses morphological but shot through and through with interpretations of functions and adjustments.

Finally I should want to see offered such additional courses in animal behavior, ecology, cytology, experimental embryology, general physiology, genetics and other special subjects, as the abilities and tastes of my departmental colleagues and myself would warrant.

As for graduate students it seems to me that since they are presumably mature individuals with thorough preliminary training in the main zoological subjects, one of the important things to do is to wean them away from mere course taking, a habit with which they are usually obsessed, and head them into problems and seminaries. If their preparation is inadequate let them take courses open to advanced undergraduates but strictly graduate courses can, I believe, be advantageously restricted to a few lectures per week in various special fields.

Being mature, the graduate student may well be expected to get much of his information by reading for himself. By way of suggestion I would give him a memorandum to the effect that it goes without saying that in addition to his more technical pursuits, every candidate for the doctorate will be expected to know modern evolution problems; the generally accepted views on phylogenetic relationships and the validity of the criteria on which these are based; and the elements of animal behavior, genetics and developmental mechanics. A suitable list of special references for study in these fields would be appended.

Furthermore, for the purpose of broadening his interests and cultivating a sense of proportion, each candidate might advantageously be given a list of fifty or more books that he is expected to have read before he completes his work. This list would include mainly the general classics of the subject in various departments, such as voyages, travels and explorations; history; biography; a few special memoirs; general principles; a few works of the better literary naturalists; and some of the more general works in special fields.

In conclusion I should say, then, that I see no need of abandoning our general zoology, comparative anatomy, invertebrate zoology, embryology and histology courses in favor of the newer biological sciences, though we can perhaps advantageously shorten them to make room for courses in the new subjects and we can pervade them all more or less with the method and thought of the newer work. If in these fundamental courses we will but put life back into our laboratory specimens, life into our method of offering them as subjects for thought, and life into our students by forcing them into the interpretative attitude of mind, then I think we shall have gone far toward introducing our charges to much that is significant in the newer fields without sacrificing the well-recognized values of the older discipline.

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FROM THE STANDPOINT OF A BOTANIST

THOSE of us who are possessed of a conservative temperament may be inclined to look askance at the newer fields of investigation, or to doubt their value for educational purposes. If so, we need merely to consider that not many years ago science of any kind was not regarded as a suitable subject for school or college. Moreover, the sciences themselves have undergone a marked evolution. The earliest biological studies were descriptive and enumerative; then came the study of internal structure, followed in its turn by the study of function, environment and inheritance. To an outsider it looks as though the subject of entomology were still largely in the taxonomic stage of development, which is not to be wondered at when one recalls that over half the species of animals are insects.

Instruction in biology has likewise exhibited an evolution; it no longer consists wholly or even largely of systematic work. Botanists still do a certain amount of "manual labor," but fortunately we have passed out of the period when first-year