UNITY AND BALANCE IN THE ZOOLOGY COURSE

In an earlier number of this journal,[1] apropos of an article by Professor Bradley M. Davis upon the botany course of the future, I briefly described the introductory course in zoology in operation for several years at the University of Michigan, and pointed out some of the advantages which a course centered around biological principles possessed over the usual course based on the dissection of types. Many inquiries concerning this course were received from all over this country, and several from the other side of the world, indicating a feeling of unrest and dissatisfaction with the present prevailing type course. Some of the writers of these letters clearly recognized the defects of the present method of teaching, and had striven to remedy them without completely reorganizing their courses. Others, while perceiving that something was wrong, had failed, it seems to me, to discern wherein lay the difficulties. In the hope that a clear understanding of the fundamental mistakes of the type course will assist in removing these difficulties, I have undertaken to present herewith what appear to me to be the requisites of the beginning course.

The nature of the first course in science should not be a matter of untrammeled opinion, it should be determined by certain principles. If those principles can be agreed upon, the details may perhaps be varied without harm. I submit two propositions which I regard as almost axiomatic, namely, that the course should be representative, and that it should possess unity. If these propositions are valid, the remainder of this article may have some value.

To apply the first of these rules, it is necessary to have in mind the content of the subject. On this question there may be differences of opinion, but most of these opinions can probably be arranged into two fairly well-defined groups. Zoology consists either (1) of a knowledge of Protozoa, Porifera, Coelenterata, Platyhelminthes, etc., or (2) of a body of principles that may be brought under such rubrics as morphology, physiology, ecology, taxonomy, geographical distribution, paleontology, and evolution. Between these views the teacher must make a choice, if he is to make his course representative, and the nature of the course will depend upon his decision. If the first of these views of the content of zoology should prevail, he who studies cell permeability in *Paramecium* is to be regarded as a protozoologist, not as a physiologist, or else he is not a zoologist at all; the student of heredity in *Drosophila* is a dipterist, not a geneticist; and one who traces the origin of the horse is a mammalogist, not a paleontologist or evolutionist. Very few of the scholars mentioned would be content with the proposed appellation.

If the second conception of the content of zoology be entertained, as has been done in the preparation of our first course, the incongruities just referred to disappear. Other difficulties are also removed, for the seven divisions of zoology named above are not mutually exclusive, but overlap, a circumstance which, far from being a misfortune, is of much value in connection with the second proposition to be developed later. Genetics might fairly be added as an eight division, but its main features are either morphological, or physiological, or evolutionary.

The beginning course must contain the elements of each of these branches of the subject, if it is to be a *general* course. Whether the course should be general or not may be debated, but if it is to be general it must include something from each field.

The classical course in zoology is morphological, a dissection of types of the chief animal groups. Very little even of physiology has been included in it, until in recent years in a very few institutions. Such a course was the proper course once upon a time, when zoology was an almost purely morphological subject. But as the subject grew, the type course became a misfit. It has been a misfit for a long time.

Good teachers have attempted to ameliorate this growing inaptness of their courses by

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putting the non-morphological phases of zoology into their lectures and recitations. But the laboratory work has inevitably put an over-emphasis on the morphological side, and may even have over-emphasized the physiological. The seven branches of the science need not, of course, be treated equally. Morphology deserves a greater share than any of the others, for each of the divisions is partly morphological. But a course on morphology alone (or nearly alone) can scarcely be representative. Unprotesting use of the type course means either that the teacher regards the content of zoology as Protozoa, Porifera, Cœlenterata, etc., or that he is satisfied to administer an unbalanced ration to his students.

Quite independent of the foregoing consideration of the content of zoology is the question of unity of the first course. Whether the type course or the topic course be employed, that course should be unified. It should proceed step by step, one thing leading up to and necessarily following others. Unity has not been ignored by those who employ the type method, but they have justified their course by the evolutionary series which the animal scale is supposed to present. When the animal series was thought to be single and continuous, that was a fair assumption. But this notion of the phylogenetic tree has been largely abandoned, it is recognized that the animal series is a disjointed one. At least if there are connections everywhere, they are so attenuated in places that even a superior student is unable to detect them. The step from an echinoderm to an annelid is not an easy one, nor the step from a mollusk to an arthropod.

The lack of unity consequent upon the employment of type dissections has long been recognized, and has led to the widespread notion, referred to above, that something is wrong with the beginning courses in biology. One can not converse long with teachers of biology who are interested in the pedagogy of their work, without encountering the question, what is to be done about the beginning course? Sometimes the unrest is vague, sometimes it is not recognized that lack of unity is the fundamental defect, but in few quarters is the present course regarded as satisfactory.

Various proposals have been made for remedying the defect. One plan offered by a botanist for the beginning course in botany is frankly to make the course practical, utilitarian. Since there may readily be a counterpart of this plan on the zoological side, it is worth considering. The author of this proposal does not recognize lack of unity as the thing to be overcome. He would, for example, study wheat: where it is grown, the proper kinds of soil, its uses, its markets, etc.; then potatoes, their soils, geography, industrial uses, diseases and so on. However desirable a course in agriculture may be, little can be said for the above plan with regard to its unity. One plant may, it is true, unify soils and markets after a fashion, but the gap between wheat and potatoes can hardly be bridged in the same arbitrary manner. The proposed course is simply a type course of another kind, the types being no more closely connected than are the taxonomic groups of organisms to which they belong.

One experienced teacher of zoology proposes that the history of the development of the biological sciences be employed. This teacher has detected the fundamental defect of the present course, and his plan is avowedly an attempt to secure unity. His plan could be successful if the historical development of the science were steadily from the simple to the related complex. If one could learn the history of the rise of a subject by the same steps as he learned the content of the subject, then history would be a unifying study. But were that done in zoology, one would study the development of the chick before he learned of the existence of cells: and he would know of the parthenogenesis of the honey bee before he knew the existence of germ cells. Whereas theoretically simple things should be discovered before complex ones, many circumstances, such as the lack of microscopes, has prevented that order from being followed.

Are we to forget that we now have microscopes, in order to let history unify our subject for us? History may explain a good many discrepancies, especially in earlier biology, but it does not unify anything. History unifies only subjects that are essentially historical in their nature, like political development, or philology. I do not mean that history is uninteresting or unimportant, for it is neither; but it unifies only the history, not the *content*, of biology. Only the facts of a science can unify the science itself.

Unity can be acquired only by arranging subjects, placing the simple first, and laying thereby a foundation for related subjects that are more complex. Each subject should lead to another, and rest upon those that precede. Such unity a course based on the dissection of types can have only in small degree. Otherwise one teacher could not begin with Protozoa, another with vertebrates, or another with Arthropoda which are followed by Protozoa, leaving the vertebrates to the last. Did types insure unity, we would not have that interesting chapter on "animals of uncertain affinities" squarely in the middle of the course. Nematodes do not lead naturally to the Bryozoa, nor do the annelids obviously follow the echinoderms. There is no manifest necessity for having the mollusks precede the arthropods. The teacher of the type course may claim unity for his course, on the ground that he goes from the simple to the complex. A grindstone, a bicycle, a typewriter and a calculating-machine may be arranged in order of complexity, but the unity permeating the series still not be very obvious.

Homology, on the contrary, does lead to taxonomy, taxonomy and ecology to distribution, distribution in space to distribution in time. Cell division leads to cell aggregation, and reproduction to embryology. The connections stated are not merely obvious, they are necessary.

The study of topics entails certain difficulties, one of them being the larger amount of diverse material required in the laboratory. Some may think that this use of many different animals is confusing, rather than unifying. Our experience indicates that such is not the case. Using many animals to demonstrate the truth of the cell doctrine is not more confusing than the study of profit and loss in arithmetic by problems involving vinegar, woolen goods, automobiles, and ostrich feathers. What would be thought of an arithmetic that employed problems relating to vinegar for addition, division, profit and loss, compound interest and cube root, before woolen goods were used to illustrate the same operations? Or what of a school system in which vinegar was studied chemically, biologically, and industrially before woolen goods were studied from the same points of view? Those would be type studies, type arithmetics, type school systems.

In only one other science, so far as I am aware, do teachers as consistently use the type method as we have done. Whether another method would do as well in that subject I am not qualified to say. Biology is, then, one of the few sciences which have allowed their wealth of material to obscure their subject matter.

How do the students react to the treatment I have described? Perhaps, although the course has been given seven times, we have not been using the new method long enough to speak authoritatively; but some things seem to be observable. I have seldom heard students ask that question formerly not infrequently heard, not only in our own laboratories but in those of other institutions, "How much of all this are we expected to remember?" Students now recognize for themselves that the things which they study are important, for they draw conclusions from them. They have perhaps been quicker than teachers to see the advantages of the new method. Verily, these things were hid from the wise and prudent, and were revealed unto babes.

If culture be measured by the number of ways one has of entertaining himself, certainly the knowledge of biological principles far outweighs from the cultural standpoint an acquaintance with the details of structure of selected forms. For a knowledge of animals, as members of taxonomic groups, is not lacking in those who pursue zoology in the way I have outlined; and about these animals there is always something besides structure that is worth knowing. In order that these worth-while things may be known adequately, they must be the subject matter of the laboratory exercises as well as the recitations.

Nothing in this article is intended to imply that advanced courses should be of the kind described for beginning students. It is recognized that to become a zoologist, or to prepare for certain professions, it is necessary to have a systematic knowledge, not only of taxonomic groups, but of several other fields of zoology as well. In the acquisition of such knowledge there must be courses in which facts seem to outweigh principles. But to attempt to gain such knowledge in the elementary courses, even for those who must later acquire it, is neither necessary nor desirable.

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A FORERUNNER OF EVOLUTION

BICENTENARY OF CHARLES DE BONNET, NATURALIST AND PHILOSOPHER

MARCH 13, 1920 marks the two hundredth anniversary of the birth of one of the most interesting of eighteenth century scientists, whose researches in entomology and botany were of solid and permanent importance in the history of these branches of learning, and whose philosophy, if superseded, was at least interesting and to some extent prophetic; yet who is comparatively seldom spoken of to-day.

Charles de Bonnet on that date was born in Geneva, the sometime home of one against whom he wielded most fiercely his philosophic pen—Jean Jacques Rousseau. Rather curiously, de Bonnet's birth and death dates anticipate by an exact century those of a pioneer of evolutionary science, John Tyndall. The earlier master died on May 20, 1793, after a life almost uneventful except for its mental activities.

One of the most striking facts about de Bonnet's career is the extreme precocity of his talent. His entire work in natural history is crowded into the first twenty-five years of his life; after which failing eyesight, induced by close work with the imperfect microscopes of the day, turned him perforce from laboratory research to theoretical speculation.

At sixteen he read Réamur's work on "Insectology." It proved the turning-point of his life. Born of a Huguenot exile family, all of whom were accustomed to hold high offices in the Swiss government, de Bonnet was studying law with the expectation of following in the footsteps of his kinfolk. His introduction to entomology ended his interest in law; although he persevered in his studies until he attained the degree of Doctor of Laws, he never practised, but devoted the rest of his life to the science which had become his passion.

Two years after he first read Réaumer and Pluche, he sent to the former a long list of "additions" to his works, based on further investigations. What was Réaumur's astonishment to discover that his valuable collaborator was a boy of eighteen! By the time he was twenty, de Bonnet had established the fact of at least usual, and probably invariable, parthenogenesis in aphides. Before he was of age, he had been appointed a corresponding member of the Academy of Sciences. Two years later he successfully demonstrated the reproduction of some forms of worms by simple fission; and in the same year he discovered the pores, or "stigmata," by which caterpillars and butterflies breathe, and made important studies in the structure of the tapeworm.

Turning to botany, and newly appointed a fellow of the Royal Society, the youthful scientist next experimented in plant physiology with special reference to the functions of leaves, and attempted to prove that all chlorophyllic plants are endowed with sensation and what he termed "discoverment." It was at this stage of his career that threatened blindness diverted his studies into an entirely different field.