ECONOMIC AND INDUSTRIAL ASPECTS OF SECONDARY SCHOOL BIOLOGY.

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I am to speak on the "Economic and Industrial Aspects of Secondary School Biology," but the biology of the secondary school, as I have seen it, has no industrial or economic aspects, and with this statement and its demonstration I might plead that my duty to your program was technically fulfilled. There would be little value, however, in such a treatment of our topic, and little satisfaction in such a conclusion, and I must suppose that the question we have to discuss is virtually this: Do we wish to give an economic aspect and bearing to our secondary school biology; and if so, how may this be done?

I think it will help us to conclusions on this subject if we make some partial survey of the field of economic biology, in order to see what there is in it of value which is possibly available for the high school, and in order to distinguish the biological methods which a study and application of economic biology exercise and require. We must also distinguish the different views and plans of high school work in biology now current among us, and must try to ascertain with which of them economic and industrial biology will best affiliate; and we must come to conclusions as to any modification of plan and method in biological teaching which this affiliation would require. Finally, we should endeavor to estimate the gains and the losses, and the balance between them, which the introduction of the economics of plant and animal life would bring to the high school course.

It will be a great convenience to me, and will make, I think, no essential difference in the outcome, if I am permitted to confine myself to that part of biology with which I am most familiar, speaking of economic and industrial zoology only.

The first impression, I think, which one will receive who scans carefully the subject matter of economic zoology will be that of the bewildering amount, the variety, and the unexpected importance of its material; and the second impression will be that of the heterogeneous and disconnected character of this material, such as to defy organization on any lines of natural unity. It forms a huge pile of bricks, many of them broken; of gravel and plaster and cut stone; of boards and beams and pillars—the

plunder and wreckage of a great building, quite unfit to be built into anything complete in itself, and either to be taken as a mass of separate facts which can at best be assorted merely into more or less orderly series, or else to be supplemented by other building materials, not at all economic, if any self-consistent structure is to be put together.

Indeed, if we are to do anything with the economic feature in high school biology it must be limited, locally and practically, and made to include only those matters of fact and those modes of action which may be supposed immediately applicable to the economic and industrial welfare of the individual American citizen or of the American people at large.

Furthermore, if the subject is to be really economic, it must be so presented and so taught as to be economically and industrially useful to the very persons studying it. It must impart knowledge and it must give training which will enable the successful student of it to recognize and interpret the facts of his own experience, and it must end in effective economic action.

Let us work out our topic, then, on the idea that economic zoology for the American high school is that part of zoological knowledge and economic practice which shows the American citizen what he may do to avail himself and others of the benefits and to protect himself and others against the losses and injuries which American animals may bring to him or to other members of his social or political group. This not only greatly diminishes the number of the objects of our study, but it cuts out at a stroke all those parts of the zoology of the economic animals themselves which have no bearing on effective action directed to the economic end. On the other hand, it emphasizes the importance of the fullest knowledge of those parts which *are* so helpful, however insignificant they may be in the scientific sense; and it gives an indispensable value to that kind of personal training of eye and hand and mind which is necessary to an intelligent acquaintance with the features of one's own environment and to a rational program of procedure which may be adapted to any emergency. Furthermore, many of the facts of economic zoology are of national importance, and call for state and national action in the common interest, and this common interest is often antagonized by certain private interests which will fight persistently for their own and against the public welfare. The protection of the fur-

seal, the preservation of game, the renewal and multiplication of food fishes, and the protection of useful birds, are examples of these interests. We must appeal, consequently, to the public spirit of our high-school boy, must define for him the public interest in this subject, and must prepare him to discharge his duties as a citizen in this regard; and this is economic zoology of the best and most useful kind.

Chosen with these ideas in view, the body of available zoological matter will be limited to a relatively small list of injurious and beneficial animals selected mainly from insects, fishes, mammals and birds, including, of course, the domesticated animals, and to this we must add such general biological and economic topics as are of real value for our purposes. I think we may say that the ground will be fairly well covered if the high-school graduate has a familiar acquaintance with certain applicable facts about, say, a hundred species of insects, twenty kinds of birds, a dozen mammals, a score or so of fishes, and a brief but carefully selected list of other native animals; if he knows in a practical way what may be done for the maintenance and development of the beneficial members of this group, and for the restraint and destruction of the injurious species; and if he understands and appreciates the public agencies at work and the public operations in progress in the field of zoological economics.

Examining now the assemblage of animals which I have mentioned as available for economic high-school work, we shall readily see that they divide into two principal groups, widely different from each other regarded as materials for study and instruction. In the first group are animals maintained under artificial conditions—the domesticated mammals and birds, fishes bred in confinement, silkworms, bees, and the like—and in the other group are all animals which are economic because of their relations to us and to our interests while living their free lives in their natural environment. To maintain a domesticated animal, a dog, for instance, in health and happiness, we need to know what is good for him in the way of food, medicine, exercise, shelter, hygienic conditions and companionship; and if we are dog-fanciers, desirous of preserving or improving a breed or strain of dogs, for either pleasure or gain, we shall need a practical knowledge of variation, reproduction and inheritance. To catch the wild wolf, on the other hand, we must understand his actions.

powers, habits, haunts, likes and dislikes, and the probable effect of season, weather and day and night on his movements and his enterprises. That is, we need to know, for economic purposes, the *ecology* of the wild animals, and the *physiology* and *thremmatology* of those reared in domestication. This distinction shows us at once that any comprehensive course in economic zoology must be both physiological and ecological.

We shall also readily see that an acquaintance with the *distinguishing characters* of economic animals is absolutely necessary to the economic end. This means, of course, trained observation and a faithful memory. The skilled stock-breeder not only knows the breeds of animals at a glance, and the special uses and values of each, but he has a standard for each breed, an ideal of perfection, and can judge for each individual animal where and how closely it approximates to that ideal, and where and how much it departs from its type; and the young economic entomologist must also know at sight his hundred or so of economic insects, distinguishing them not only from each other, but from all other insects as well. Descriptive zoology is thus an unavoidable necessity for the economic student.

On the other hand, we also readily see that there is little place in our scheme of economic zoology for pure morphology or phylogeny or embryology, and not much for geographical distribution or for theoretical zoology in general. If our high-school course is to become largely economic, these subjects must be left mainly to the college period, must be left out, that is to say, for all except a very few. We must eliminate all the needless and unprofitable part of our present courses, the parts which are of little use in themselves, and which lead to nothing useful or important—the dissection of crawfishes, the physiology of earthworms, the indiscriminate collection of insects—and we must teach those things which are economically useful or which immediately underlie economic utilities.

We must know the laws of variation and heredity which control progressive stock breeding; and such laws of life as explain the food-value of warmth, the milk-value and the fat-value of “the simple life;” the meaning and the composition of the balanced ration; such laws and facts of economics as will enable us to understand the relative cost and values of animal and vegetable food for man in the various stages of his economic and industrial

progress; such as will enable us to see how the largest product may be got from the land with the smallest final loss of its fertility.

We do not need to know, concerning insects, the structure of their tissues, or the facts of their embryology, or their morphological relations to other animals, but we do need to know those facts concerning their structures, their adaptations, their habits, their life histories, and their relations to nature at large, which make them harmful or helpful to man, and especially those which make them subject to our control.

As to the methods of instruction in economic zoology, these will depend, as in most other subjects, almost wholly on the capacities and ideals of the teacher. The subject may be taught didactically, as an exercise in memory merely; or it may be so taught as to tax the powers of observation and comparison to an unusual degree, and to require descriptive and graphic representation, analysis, generalization, inference and experiment, ending in the practical application of results. That is, it may be made a mere information study, justified to the average mind by the practical value of the information given, or it may be made the means of a very considerable training in the processes and methods of science. Using the first method, the teacher will describe and demonstrate and narrate and reason and instruct and give explicit directions for each practical measure—and this is the way in which economic zoology seems most commonly to be taught at present, where it is taught at all. The second method is essentially the problem method. The pupil having access to the necessary facts, will be asked—and assisted if need be—to devise and test measures appropriate to the desired economic end, or to explain and account for the utility, or perhaps the usefulness, of some proposed or accepted procedure.

If it be thought that this problem method, as compared with the method of direct instruction, sacrifices the economic to the scientific end, and makes useful knowledge subordinate to mere mental gymnasium practice, then I should say that no amount of *economic information* is of much use to an unobservant, inaccurate, and irrational man; that *there is nothing in education so thoroughly and permanently economic as the training which will make one observant, accurate, and rational with respect to the facts of his own experience.*

Another topic, the discussion of which we must not omit, is

that of the subdivision and organization of our subject matter. What is the unit of instruction in economic zoology? By unit of instruction I mean that smallest division of the subject which is complete in itself and which may be combined with other like units to constitute the elements, at least, of the subject as a whole. In classification, for example, the unit is the biological species; in morphology it is the structure of an individual; in ecology it is the series of interactions between one individual and some one feature of its environment. In economic biology this unit of instruction is the whole body of knowledge necessary to the utilization or control of one economic species. There is no economic value in an ability merely to recognize all the economic species of my neighborhood or in a knowledge of the mere life histories of them all, but there is a very appreciable economic value in a knowledge of *any one* of these species sufficient to put its services at my disposal, or to enable me to protect my person or property against its injuries. The subject matter must be presented, consequently, not in scraps of one kind of information about one thing and another kind of information about another thing, or of one kind of information about several things, but in masses of all necessary information about one thing at a time. Or if conditions compel a scrappy presentation of the subject, we must be sure that the scraps all finally fit together—and are actually so fitted—to make an orderly collection of completed units.

By this means we shall not only make sure that our instruction is all economic in reality and not in superficial appearance merely, but we shall begin to get, at the beginning, the advantages derivable from all the varieties of mental operation and of practical experience which are contained in the whole subject. To acquire a complete economic knowledge of the army-worm or of the horse involves all the varieties of mental and physical action that it does to get the same kind of knowledge of a hundred injurious insects or of all the animals which have ever been domesticated.

And whenever it is possible to choose, with some latitude, among such units of instruction, these should be so chosen that they will lie well together to build some more important structure. In this way we may reach the larger relations and generalizations, both economic and biological, without which our teaching may

lead to an acquaintance with facts, but can give no knowledge of science.

The several schemes of biological instruction now competing with each other in the secondary school may be roughly divided into the morphological and the ecological, with physiology intervening between these two and contributing variously to both. Both and all are legitimate and desirable parts of a really comprehensive scheme of high-school biology, but pressure of other interests, usually referred to as lack of time, makes the scheme as a whole impracticable, as a rule, in the secondary school, and we are thus driven to a choice between fractions of a natural unit. If we compare the contents of economic biology as just outlined with those of the various existing high-school courses, we shall see that our subject works more easily into the ecological outline than into the morphological; to teach it would necessitate a mere modification of an ecological course, but the virtual displacement of a morphological one. If I am teaching the ecology of insects I can, without great difficulty, develop my subject at certain points in a way to engraft upon it naturally an economic treatment of certain selected species, and this with no great disturbance of the symmetry of my course, and no injury whatever to its organic unity. If, however, I try to fasten an economic topic to a morphological study, I find that the relation of the two is one of juxtaposition merely, provoking the friction of independent bodies rather than the common movement of one.

In any attempted amalgamation of economic and industrial with scientific biology, I should hope that the economic end would not be allowed to overshadow the educational ends which the teacher of biology now has in view; and indeed it does not seem to me that this is at all necessary. A fact is none the less a fact, science is none the less scientific, because they may have an economic application. No value of any kind is subtracted from a new discovery or from a new method of research if it is some time found that they may be made serviceable to human welfare. The scientific method is none the less useful as an educational agency, but really more so, if it is used in working out an economic problem.

I believe that a biological course may be made, out of materials largely but not wholly economic, which may be taught as directly and effectually to the educational end as is any biological

course at the present time, and which will have an educational value greatly surpassing that of the usual high-school course. Indeed, the very object of intelligent economic teaching is such that the method of that teaching must be more scientific, and the outcome of it must be more educational, than are the object and the method of the ordinary laboratory course of the present time—the type course now so firmly fixed in the high-school curriculum. In an economic course well taught, the student is brought into the most frequent contact possible with the living animal and plant; he is expected to study it primarily and chiefly as a living thing, and his attention is focused strongly on its relations to nature, and hence to the welfare of man. He is taught that his work is virtually wasted if he does not become so acquainted with the objects of his study that he shall always surely know them whenever he sees them, that he shall know when and where and how they are likely to be found, and what they will be doing then and there, and that he shall be able to adapt his knowledge of practical measures for their control to the states and conditions existing at the time and place. Such a student has also learned that he must depend wholly on his own observations, illuminated by the contents of his own memory; that he simply *must* reason clearly and correctly on the facts before him, thoroughly testing his reasonings where they are in the least in doubt, for if he fails in any of these things, the unfortunate consequences of his failure will be inevitably visited upon him.

But teaching is not merely or mainly a matter of instruction. It is still more a matter of influence—the influence of the subject and the influence of the teacher on the life, the character, and the mental attitude of the pupil taught. There remains, therefore, the most important question of all. How will this limitation of the biological course in some directions, and this expansion and elaboration of it in others, affect its influence on the student, and affect the teacher's influence in the teaching of it? There are dangers here which, if we can not find means to evade them, may possibly overbalance any good to be expected from the changes we have proposed.

What will be the influence of the economic aspect which we think of giving to biology, on its sympathetic, its aesthetic, and its unitary aspects? Shall we lose the power and the opportunity to exhibit to our students the kinship of all living things, the

essential unity of life upon the earth, the inclusion of the whole living world under universal law? Can we so combine the utilitarian with the aesthetic view that the charm of nature shall not be dissipated, as is so much of the charm of life? I am inclined to think that we can by being aware and by taking pains.

The primitive human traits which lead to the study of nature are curiosity, imagination, and the love of power. Curiosity, cultivated and indulged, makes in time the scientific investigator; imagination awakened by the observation of nature, makes the poet-naturalist; and the desire for power over the objects and forces of the living world makes the economic biologist. These several faculties are not mutually exclusive, do not, indeed, conflict at all in active operation, but each may aid the others, a stimulus to one arousing all to action. Whether the original motive is scientific, aesthetic, or utilitarian, need make little difference if the natural tendencies of the student are allowed their way.

The teacher may, I think, expect that his pupils' interest will pass over quite easily and naturally from the economic to the scientific aspects of biology, from the scientific to the aesthetic, provided only that the natural movements of the mind are encouraged and provided for. Indeed, in my classes more students go on from my economic into my scientific courses than from the scientific into the economic.

I have left to the last the obvious suggestion that secondary-school biology would be greatly strengthened in the public estimation by the addition of certain economic and industrial features, and I think that the underlying feeling that much of our present high-school and college work is virtually useless to the average student is perfectly well grounded. The life of the ordinary man is divided mainly between his business, his recreations, and his functions as a member of his family and of his social group; between his employments, his enjoyments, and his duties, and any element in education which has no important bearing on any one of these, which increases neither his earning power, his capacity for enjoyment, nor his social utility and effectiveness, is likely soon to disappear from the curriculum. Test our ordinary high-school course in botany or zoology by this rule, test even our college courses by it, and we shall see good reason for a dwindling interest in these subjects; we shall see the best of reasons for a

vigorous effort to strengthen our courses on the practical side, especially since by intelligently doing this we shall also strengthen them on the scientific side.

Permit me, finally, to close this mere introduction to the discussion of our subject by a brief summary of the principal suggestions thus far made.

1. To give an economic aspect to secondary-school biology, the biological course must be largely modified by the introduction of economic materials and by the use and teaching of the scientific method.

2. Biological materials to be economic must be applicable, must be actually applied, to the promotion of the economic welfare of the individual and of the people at large.

3. To apply economic materials to his own welfare the individual must see and understand the economic factors of his own environment, must know the means to the economic end, and must reason correctly and act efficiently in the application of these means to the end desired.

4. To apply biological knowledge to the general welfare the individual must know what biological materials are of general economic value, and what general and individual action is necessary to their economic use and application. He must know and do his social and political duty in this regard.

5. Zoological materials of a sufficient economic value to entitle them to consideration in the secondary school are mainly to be found in the biology of the domesticated animals and that of injurious and beneficial insects, birds, and fishes, with a small selected list of other animals.

6. The kinds of zoological knowledge economically applicable are, first, an acquaintance with economic families, genera, species, varieties, breeds, and strains, sufficient for their certain recognition, and, second, a knowledge of the periods, activities, habits, products, and ecological relationships of the economic animals which make them economic, and especially of those facts which indicate and determine practical measures for their economic utilization and control. Besides a recognition acquaintance with the economic forms, this necessary knowledge is mainly ecological and physiological, ecology predominating in the zoology of the injurious groups, and physiology (including thremmatology) in that of the domesticated animals.

7. The kind of scientific training necessary to make such zoological knowledge practically economic, practically applicable to the individual welfare, is training in observation, recollection, analysis, inference and experiment. An economic course must be strongly scientific, for the method of science is economically more important than any scientific facts.

8. The high-school course which shall meet these requirements must be different from any now commonly taught. It must be a composite of a biological and an ecological course, with morphology mostly omitted, and with instruction, training and practice in the method of science carried to the limit of time and opportunity. It ought to make a strong, good and popular course—one whose practical utility, directly as this is aimed at, will not surpass its value as an element in scientific education.

9. If I were to undertake to apply these suggestions in a secondary school, I would modify the existing course, of whatever kind it might be, by the gradual introduction of economic elements, feeling my way experimentally, and proceeding only so fast and so far as the results should justify. I would do this, however, with careful reference to what I have called the unit of instruction, making sure that these economic elements were incorporated into the course in complete and unbroken units, to the end that the full benefit of the innovation might begin to appear from the very first, and I would do my best that no really material element of a liberal preparation for the life of an educated man should be sacrificed to the economic advantages aimed at, but would seek to apply faithfully that fundamental principle of all rational progress, "to prove all things," whether old or new, "and to hold fast that which is good."

DISCUSSION.

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The question before us is whether we wish to study plants and animals with reference to their value for the purposes of man. We need to get away from the old idea that everything centers about man. We must decide our question from the standpoint of the high-school teacher and his opportunities. There is relatively little time given to the study of biology in secondary