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DYNAMIC BIOLOGY IN THE COLLEGE COURSE.

By C. F. HODGE, Clark University.

II.

Huxley cast the mould of our present course in biology about 1870. At that time his work was the stroke of a master genius and marked an epoch in modern biological instruction. In symmetry and perfection the course is a crystal of logic, and I do not see how any one who followed it, either under the great master himself or under his co-author, Martin, could ever fail in appreciation of its value or cease to regard this course with a certain degree of reverence. Still, as one who took the course with Martin, I feel that the time has come for a complete metamorphosis and moult. If I may be permitted to carry out the figure a little farther, it seems to me that the Huxley-Martin course represents a chrysalis stage in the development of the science—a time of ideal internal perfecting—and that it is to be succeeded by the adult stage in which the biologist must take his place as an active power in the community.

Transformations and moultings are difficult processes at best. The problem involved in the present instance is to save all that is best in the past and make the necessary adjustments to the demands of the present. That radical changes are imperative, is manifest on all sides. "Do you still use Huxley and Martin in the biological course at the Hopkins?" I recently asked the professor in charge. "No," he said, "we have not been able to work with that for a number of years. We use ——'s book, but it is not adapted to our course, and there is no book that is." Within a year the entire "biological" department in the high school of a progressive New England city was thrown out, ostensibly, on account of lack of room, but really, I think, because it had degenerated into technical, college botany and zoölogy. The recent action of the Regents of the State of New York, in discontinuing the old courses in botany and zoölogy in the secondary schools, putting *biology* in their place, is another case in point. In adapting the work to the required three years' basis at Clark, it was proposed to omit "freshman biology" altogether "as not of much account anyway." After discussing the matter, however, President Wright finally said: "Well, if we can have a new deal in freshman biology, there is not a subject I would rather have in the curriculum."

I propose to describe in some detail this "new deal" as it has taken form during the past three years. Before doing this, however, we shall need to follow the course of biological instruction from Huxley's time down to the present. Some may be inclined to think that there have been a number of "moult" already, but it seems to me that these are all to be classified under internal movements of resorption and inversion in preparation for the final change.

Huxley defined science as "trained and organized common sense." Before that, science was "classified and arranged knowledge." Before Huxley inaugurated the biological epoch, we had botany and zoölogy as two separate museums with the specimens classified, arranged and named. They were all dead and there was little common sense in either their classification, arrangement or naming. There were no organizing or vitalizing principles that united the two museums. Since the handling and study of dead animals and plants is a disagreeable task at best, most, if not all, of our courses in botany and zoölogy were done by the text-book method. Our heritage from this old regime is still in evidence in the fact that in some institutions the botanists and zoölogists are divided into not only distinct but jealous camps. "What a chance you have for these experiments," I remarked to a zoölogist friend in a large university, "with a greenhouse of your own." "You are greatly mistaken," he replied, "that greenhouse belongs to the botanical department. They have nothing in it, but a zoölogist does n't dare show his head inside." And then I made the mental note that there was very little in his magnificent aquaria and that probably no botanist need apply. In another instance a gall in a plant was sent to the botanist of a college, with a request for information. The botanist promptly sent it over to the zoölogical department as a case of insect work. The zoölogist reported "no insects present, probably a fungus;" and back it went to the botanist. I understand it finally dropped between the departments.

Biology is defined as the study of living things in their widest relations. It is inherently dynamic. It deals with the forces which act and interact upon organisms and which they themselves exert. I have emphasized the close relation which exists between dynamic biology and evolution in the preceding paper; and, while the science was christened by Lamarck and Trivarinus in 1802, as a reincarnation of the older evolutionary thought of the Greeks, and as an expression of the inadequate attempts toward a consistent philosophy of evolution of their time, it was really born in the evolutionary work of Huxley. For him the biological view was a logical neces-

sity. He could no longer be either a botanist or a zoölogist. As he says in the preface to his first edition:

"Very soon after I began to teach Natural History, or what we now call Biology, at the Royal School of Mines, some twenty years ago, I arrived at the conviction that the study of living bodies is really one discipline, which is divided into Botany and Zoölogy simply as a matter of convenience; and that the scientific zoölogist should no more be ignorant of the fundamental phenomena of vegetable life, than the scientific Botanist of those of animal existence."

The old botany and zoölogy could give us only at best an imperfect philosophy of plants and animals. What we need is a philosophy of life itself.

Huxley's series of types is a list to conjure by. I name them in the order in which they occur in his book: Yeast, *Protococcus*, *Amoeba*, bacteria,—then up the plant series with—Moulds, Stoneworts, Ferns, flowering plants—then back to the protozoa and up the animal side with—*Vorticella*, *Hydra*, Fresh-water Mussel, Crayfish, Frog. For the mature student, this logical sequence from the simple to the complex on the side of both animals and plants could leave little to be desired. Every one who followed this course in the laboratory came out by logical necessity an evolutionist and no teaching of the dogma was necessary. In fact this was tactfully held in abeyance, each member of the class being allowed to draw his own conclusions from the facts themselves. I well remember on completing this course in the Johns Hopkins our class had to wait upon Dr. Martin by special committee with the request that he give some additional lectures on the doctrine of evolution itself.

I should add, perhaps, that the course was filled out by a number of types, like *Spirogyra*, *Vaucheria* and *Polytrichum*, Earthworm, Perch, Turtle, Pigeon and Rat; and the work was concluded with the embryology of the chick. This gathered up all the loose ends and tied them fast. As given by Dr. Martin himself, I still look back upon it as the most ideal course I ever had, and in it we saw in microcosm a vision of the evolutionary process,—a form actually weaving its organization from a single cell, a protozoan, to a vertebrate, all in three days time.

I must also add that coming to this course as a mature post-graduate student my intense enjoyment of it has left me a confirmed stickler for the logical order. As a pure discipline in inductive reasoning nothing can supplant it. Still with immature students I realize that to begin with the Protozoa and Protophyta, the one-celled animals and plants, is really casting pearls before newly hatched chicks. They need gravel first and unless they have it, this most ideal and suggestive part of

the whole course is passed over before they are able to think what it means and they may be biologically crippled in consequence. How I avoid this in my present course will be cleared up a little later. Martin clung to the logical order to the end, but Huxley, after a few years' trial, changed it completely to what we may call a more natural or psychological order.

The reader should at this point refer to Huxley's preface to his "Revised Edition" (it should be read in full) in which he says:

"But besides these changes, the reader who compares the two editions will observe that the order in which the subjects are presented is completely changed. In the first edition the lowest forms of life were first dealt with; the series of plants followed in ascending order; and then the series of animals, from the Bell animalcule upwards to the Frog."

"No doubt there is much to be said for the principle of this arrangement, which leads the student from the study of simple to that of complex phenomena; but the experience of the Lecture room and the Laboratory taught me that philosophical as it might be in the theory, it had defects in practice."

"After two or three years' trial of this road from the simple to the complex, I became so thoroughly convinced that the way from the known to the unknown was easier for students, that I reversed my course, and began with such animals as a Rabbit or a Frog, about which everybody knows something, while their anatomy and physiology is illustrated by innumerable analogies with those of our own bodies."

Martin never admitted the cogency of this reasoning, but maintained that since we must descend to the cellular elements in order to an intelligent understanding of physiological process and anatomical organization, and since the bulk of the work dealt with minute and technical anatomical details, this order really plunged the student into not only one "unknown" but into a "most bewildering and complicated maze of unknowns." The first edition devotes 108 pages to the Frog, the Revised, 172, and other topics are likewise amplified, so that from a trim little book of 266 pages, the Revised Edition has grown to 498 pages. When Martin saw the Revised Edition, I heard him say in disgust: "It is a clear case of fatty degeneration."

I think Martin was right on both counts—as to the bewildering of anatomical details, which makes the new edition unusable, and as to the "fatty degeneration," which vitiates the whole and makes it undigestible. Some may be inclined to think that this is raking up dead issues; but to one who is grappling with the problem of biological education in the college and university and trying to co-ordinate with this elementary instruction and the present needs of the masses they are still very much alive. And I hope to show how, by adopting the dynamic view-point, we may be greatly aided in escaping

the difficulties of too great anatomical and unessential detail and still have a mentally and morally virile course.

Huxley was a biologist and physiologist by inclination but was forced to be an anatomist by the stress of his battle for evolution. Martin had already passed beyond the heat of this conflict and was a biologist and physiologist to the end. While Darwin did most of the work, it fell to Huxley's lot to fight his battles; and known as he is as the "bull-dog of evolution," since the struggle was fought out on the details of comparative anatomy, his position compelled him to be the foremost master of his data. Naturally the course of instruction which he formulated then was dominated by this fact. It fitted the time to perfection and was a veritable sowing of dragons' teeth to raise up champions for the cause.

Now the conflict is over, evolution has triumphed, and has become the common possession of thinking men. Is it not time to pause and ask ourselves whether a war measure adopted amid the clash of arms should be continued in force indefinitely? Is there no present conflict? Are there not modern issues that should largely dominate our choice of matter and method to-day? Is it less true now that "My people are destroyed for lack of knowledge?" Is the ancient monster of ignorance and prejudice and unfaith in life any less grim to-day? And when the people ask for bread, how long can the biologist put them off with: "Here is a most interesting fossil, will it not do as well?" And when they ask for a fish, how long shall we continue to offer them a type specimen of a snake instead?

The problem is extremely complicated, and in trying to weigh the values which shall determine the elements of our course, we can hardly hope to avoid mistakes and incur more or less serious misunderstandings. There are, of course, new issues and these have influenced modifications of our present courses in biology. Before speaking of these, however, we need to emphasize especially one point with reference to the Huxley-Martin phase of biological instruction. It was splendidly adapted to specialists. It is still a good course for beginners on the road toward medicine or toward professional biology. For those—and they ought to be the vast majority—who look to biology for help toward a liberal education and a sound philosophy of life, it is simply preposterous.

T. Jeffrey Parker's *Elementary Biology* appeared in 1891. The author is essentially a comparative anatomist and a morphological zoölogist, to the teaching of which subjects he has rendered illustrious services. He is thus well fitted to give us an ultra perfect type-specimen course of essentially form and structure studies. Still the physiological side is good and, apart from the lack of adequate suggestion for experiment, is

all that could be desired. Parker holds to Huxley's original logical order as of too "immense advantage" for the student to be lightly given up, but meets the difficulty by beginning in the laboratory with some preliminary study of a higher animal and plant, more purely physiological and biological. And he also makes the significant statement in his preface that this kind of work might be extended with advantage: "If there were no limitations as to time, and if it were possible to avoid altogether the valley of the shadow of the coming examination." This latter raises the interesting question whether leaders in rapidly growing sciences should main their students or educate or, failing in that, dynamite their examining boards.

Parker's course emphasizes another point that is most timely. There is already a very general feeling that mere laboratory work may be overdone. There are so many facts, and they are all so "interesting and important" that the most careful of us are in danger of loading the student so heavily with facts that he has no time or energy to think. With this danger in mind, I think that all teachers of biology, who are not too young to have grasped the "ideas" or are not petrified in the Gradgrind mould, will agree with Parker when he says: "That the main object of teaching biology as a part of a liberal education is to familiarize the student not so much with the facts as with the ideas of science."

Personally I feel that the greatest defect in Parker's book is its flawless perfection and completeness. I even hesitate to use it with my own students; because it runs along so smoothly, satisfyingly and restfully; because it typifies that "just-so," *ipse dixit* lecture style that soothes to sleep rather than stimulates to effort, that I fear the students will come out satisfied with what they know rather than eager investigators. In this I do not mean, of course, investigators in biology in the technical sense but, what is infinitely more important, investigators into the problems of their own lives.

Finally we now pass to a type of biological course which places the main emphasis upon the cell as the structural and physiological unit. Pre-eminent in this field is Sedgwick and Wilson's General Biology. No one can question for a moment the importance of the problems in this field to the highly specialized biologist and through him to the public at large. They represent vital and present issues about which the materials and methods of a course intended to produce specialists might group themselves naturally enough. The science of cellular structures and activities, cytology, forms in many respects the present growing tip of biology, and must furnish an increasingly large mass of foundation material for physiology

and hygiene; and, as applied to the reproductive cells, forms the natural basis for a science of heredity.

The feature of this course is the study of few types—Earthworm and Fern—so exhaustively and with such careful attention to fundamental processes and principles that the student will be equipped to study any desired form of animal or plant in a similar way. Theoretically this would seem well adapted to produce specialized investigators. On the side of practical working, however, we are brought to realize that technical equipment can never make an investigator. He must have a tremendous amount of motive power to keep his technique in working order.

From a well developed understanding of the subject as a whole, he must feel that his problem is worthy of his best efforts. Until we give him the "ideas" that can supply this motive power, the danger in forcing the student to the apex of specialization is that he feels that he has already reached the goal. We tire him out so that instead of being strengthened and inspired to go on, he lays down the work with a sigh of relief.

I am inclined to place most of the work in all courses of this character in the stratum of university instruction. For the college the bulk of the course should be on a much lower plane, much more directly and obviously related to the commoner problems of life, and requiring much less specialized technique.

In tracing the progress of biological instruction from Huxley's time down to the present we have seen that the tendency has been toward ever higher and higher specialization. The biologists have flown off on a tangent until they form a little group by themselves, working on their special problems, talking a language of their own and writing books for one another. In the main they have gone far beyond the hail of educated people in other professions. As the science of life itself it would seem that biology should touch the common life more intimately than any other body of knowledge. Is it not true that even now we need another Huxley to bring the science and the world together again?

In 1868, while Huxley was yet a biologist, he wrote an inspired passage—I often call it the finest in scientific literature—which I always read to the class as the text of our year's work. It is all so good, and I see it referred to so rarely, I give it in full.

"And by way of beginning, let us ask ourselves—What is education? Above all things, What is our ideal of a thoroughly liberal education?—of that education which, if we could begin life again, we would give ourselves—of that education which, if we could mould the fates to our own will, we would give our children? Well, I know not what may

be your conceptions upon this matter, but I will tell you mine, and I hope I shall find that our views are not very discrepant.

"Suppose it were perfectly certain that the life and fortune of every one of us would, one day or other, depend on his winning or losing a game at chess. Don't you think that we should all consider it to be a primary duty to learn at least the names and moves of the pieces; to have a notion of a gambit, and a keen eye for all the means of giving and getting out of check? Do you not think that we should look with a disapprobation amounting to scorn, upon the father who allowed his son, or the state which allowed its members, to grow up without knowing a pawn from a knight?

"Yet it is a very plain and elementary truth, that the life, the fortune, and the happiness of every one of us, and, more or less, of those who are connected with us, do depend upon our knowing something of the rules of a game infinitely more difficult and complicated than chess. It is a game which has been played for untold ages, every man and woman of us being one of the two players in a game of his or her own. The chess-board is the world, the pieces are the phenomena of the universe, the rules of the game are what we call the laws of Nature. The player on the other side is hidden from us. We know that his play is always fair, just and patient. But also we know, to our cost, that he never overlooks a mistake, or makes the smallest allowance for ignorance. To the man who plays well, the highest stakes are paid, with that sort of overflowing generosity with which the strong shows delight in strength. And one who plays ill is checkmated—without haste, but without remorse.

"My metaphor will remind some of you of the famous picture in which Retzsch has depicted Satan playing at chess with a man for his soul. Substitute for the mocking fiend in that picture a calm, strong angel who is playing for love, as we say, and would rather lose than win—and I should accept it as an image of human life.

"Well what I mean by education is learning the rules of this mighty game. In other words, education is the instruction of the intellect in the laws of Nature, under which name I include not merely things and their forces, but men and their ways; and the fashioning of the affections and of the will into an earnest and loving desire to move in harmony with those laws. For me, education means neither more nor less than this. Anything which professes to call itself education must be tried by this standard, and if it fails to stand the test, I will not call it education, whatever may be the force of authority, or of numbers, upon the other side." (A liberal Education and where to Find it. Science and Education Essays, pp. 81 ff. Appleton & Co., 1896.)

"To learn what is true in order to do what is right," is another way Huxley had of stating his position; and I have often asked myself what possible connection the learning of a great many of the anatomical details, even in his first edition, could have not only with "doing what is right" but with doing anything at all in case of the non-special student. As he says in his first preface: "The chief labor in drawing up these instructions has fallen on Dr. Martin." Much as I cherish his memory, I think we must remember that he was a young man when he worked out the details of his course. He was a specialist and had not studied principles or methods of education particularly, and he gave the course a distinct coloring of the period.

I have thus come to feel that this whole scheme of biological education has been accorded far more consideration than its due, and has long outlived its usefulness for all purposes of general culture, and I take my leave of it in the confident hope that we shall now be able to find a course better adapted to the needs of the time.

Within the last thirty years real university work has developed to a high degree of efficiency in this country and the preparation of specialists should be relegated to that. Aside from some preparation of a premedical character or for elementary teaching, the problem in the college is to develop courses in biological subjects that shall have the greatest culture value possible; and this, with reference to good citizenship and intelligent living rather than to future specialization.

In the Collegiate Department of Clark University this problem is being solved as follows: I shall describe in detail only the first-year biology, merely naming the other courses in order to show its setting.

FIRST YEAR.	SECOND YEAR.	THIRD YEAR.
Dynamic Biology.	Zoölogy, Invertebrate and Vertebrate.	Animal Physiology and Hygiene and Histology.
	Vertebrate Morphology and Embryology (as pre-medical).	(including a brief course in Bacteriology).
	Botany, Structural, Systematic and Ecological.	Plant Physiology, Histology and Plant Diseases.

The laboratory work is made somewhat different in most of the courses for general culture and pre-professional students.

Study Living Things as Forces in Nature. This, which may be taken as the motto of the first year's course, expresses the change of point of view from the anatomical to the dynamic. This change, of course, furnishes a different set of criteria, under which to select and arrange the subject matter. Still the anatomical type series has recognized scientific value and the fact that this is merely subordinated and not disregarded will be clear as we proceed with the details of the course. The question, then, becomes—What forces in nature have the greatest educational value and what types best serve to exemplify them? We must, of course, answer it strictly with reference to the attainments and needs of our students. Nothing is farther from my mind than to wish to see the course in dynamic biology become as rigid and fixed as the one I hope it may supersede. In fact, it seems to me that it has internal life and plasticity which shall keep it growing. It should differ in important details in different localities, but the greatest change must come from the changing needs of successive classes. Especially now that nature study is being developed in the public schools, as soon as the men come from the high school with

including a glimpse of embryology at the close, as the natural completion of the year's study. The immense superiority and advantage of vertebrate structure and organization over all other plans cannot be properly sensed unless this order is followed.

Dynamically, insects are of the utmost importance, and zoologically this is the age of insects. There are more than ten times as many insect species as of any other animals; and practically insects form the best possible introduction to the course. They furnish an abundance of forms with which to develop ideas of animal classification without even mentioning "cells" in the introductory lessons. Best of all, fully half the laboratory work through September and October may be done out of doors, a feature to which I attach great importance throughout the course. So far as practicable I would have the student find his specimens for himself and study them in their natural environment first and then bring them into the laboratory for further examination. In practice, however, this cannot be done without too great sacrifice of time and most of the types are not in the best condition for study at the season when the class must do the work; but many of their own specimens the students can collect for themselves, and many more, for the next year's class. All may thus be given incentive and experience in collecting in the field.

During the winter months—from November to April—the laboratory work is almost entirely indoors. Then again from April to June fishes, reptiles, amphibia and birds, together with trees and many points in the plant series purposely left to this time,—supply both matter and motive for out-door study.

After a preliminary lecture hour, in which, however, the class is *not* told what an insect is, the students are provided with collecting outfits and directed to gather in everything they know or think is an insect and nothing they think is not an insect. They are told to turn over logs and stones, tear to pieces old stumps, examine the bark of trees and hunt among the foliage and in the chinks and crevices of fences and buildings. The result of a three-hour laboratory period spent in this way should be the collection of from 100 to 1,000 specimens. We realize, however, how different this is from the usual methods when a number of the class come in without a single insect. "Could n't find any!" One man, a six footer, told me in all seriousness that he had hunted faithfully all the afternoon and did succeed in catching one mosquito, but—"it got away from me!" Generally, however, there will be a few in the class who will bring in enough to distribute to the rest and as a last resort requisition may be made upon the laboratory stock. In a lecture period, having named and described in gen-

eral terms the parts of an insect, we devote the next laboratory exercise to the attempt on the part of each student to classify his material. Along with this work a brief study of the external anatomy of the locust, requiring outline drawings, is made to familiarize the student with the data of classification. Then follows a standard scheme for the classification of insects and the student is furnished a mimeograph copy which he learns to use as an artificial key, and by the aid of which he selects from his own collected material one or more specimens illustrating each class and mounts them for future reference and study.

The next question is: What insect or insects do we wish to pay special attention to as dynamic types? In response to local conditions we selected the mosquitoes and the San Jose scale and have used them for the three years past, and shall probably continue to do so as long as they represent interesting dynamic problems. In addition to these, however, and in connection with students' collections and out-door laboratory work a number of other insects of importance both injurious and beneficial were discussed. On leaving the subject of insects, each member of the class is allowed to choose some insect, or group of insects, to work out during the remainder of the year the life history, foods, natural enemies and general dynamic relations. Toward the end of the year the student presents his results in the form of a lecture before the class; and, at the outset, he is informed that the manner in which this investigation is done will count heavily for or against his rank in the class. I know of no device which serves so well to develop initiative and reveal any facility for investigation which may exist in the class.

The object of all this work with insects is not so much information, or knowledge of anatomy or of systematic discrimination of minute details, or training of the powers of observation. These are only incidental and subordinate results of the chief purpose, which is to introduce the student to the dynamic problem of modern entomology; to actually let him try his hand at it, and learn how it feels to work in the field himself.

I shall not be able to enter even thus fully into details with many of the other topics. I consider one of the chief values to the student of this year in general biology to be the glimpse he gets of the different departments of the science. I look upon the course as a hallway through which to enter any desired department and if his view does not lead to specialization, we may surely make the course yield intelligent interests.

The insect work is on the whole rather easy, on the surface of things, and though the class has been analyzing mosquitoes by their claws, palpi and wing venation, and has studied the mouth parts of the San Jose scale with the compound micro-

scope, it has had no really tough propositions to test its metal. Something of this sort must come pretty early in the course, and it happens conveniently that the Crustacea follow the insects, and that we have a type which might have been made to order for the express purpose of demonstrating how much organization can be crowded into an almost microscopic animal. Cyclops strikes the students like lightning out of a cloudless sky, and they go down before it in heaps. They grovel and groan and give it up. But, finally, when asked whether they really intend to be beaten by such a little creature, most of them straighten their backs and do some creditable work. Of course they have laboratory specimens of lobster, crawfish and a number of the crabs for comparison, and they do a little work with *Daphne*, and have their attention called to a number of the parasitic marine copepods. A further reason for selecting this type is that dynamically the copepods are probably of greater biological importance as furnishing a food supply for marine and fresh water fishes than all the other groups combined.

With the earthworm as the type of annelid the first serious work is done with internal anatomy. This is studied out organ for organ and cell for cell, but from the point of view of discovering the mechanism by means of which vegetable mould is formed. Other forms are used in a subsidiary way, viz., the tape worm trichina and other nematodes, flukes, etc., which have dynamic problems associated with them.

The fresh water clam is studied largely from the anatomical standpoint, except that experiments and observations emphasize its foods and its water filtering power. *Hydra* is used in the usual way as a morphological type.

As many and as varied protozoan forms are studied as time will permit—*Acineta*, *Paramœcium*, *Stylonichia*, *Stentor*, *Vorticella*, *Actinospherium*, *Arcella*, *Amœba*, *Euglena*, *Volvox*; and special attention is directed to the water-polluting forms—*Dinobryin*, *Synura*, *Uroglena*, *Glenodinium* and *Peridinium*. Emphasis is also placed upon the Sporozoa in relation to malaria and other diseases and upon certain *Amœbas* which cause dysentery. Studied dynamically, with regard to variety of device and mechanism for movement, for securing food and in relation to reproductive power, no part of the course is of greater suggestive value to the student. No forms are so well adapted for showing the plasticity, the tireless activity and the infinite resourcefulness of living matter. All this supplies additional reasons for placing the protozoa in the very heart of our biological course.

Ascent through the plant series is now easy and may be rapidly made, the rather complete list of type forms being cor-

related and used in the laboratory in such wise as to assist rather than hinder the progress of the class. The types are studied in much the usual way, the dynamic features being subordination of structural details while emphasizing the active processes of growth and transformation of food materials. Everything is studied alive and at work, the attempt is made to show the class as many active processes—cell division, conjugation, starch formation, etc., as possible,—special stress being placed on the great reproductive energy of many of the lower forms. For all this the types and the order in which they are introduced speak for themselves. Among the algæ special attention is again called to the water-polluting forms—*Asterionella*, *Anabæna*, *Clathrocystis*, *Cœlosphœrium* and *Aphanizomenon*.

The fungi are taken up from much the same general point of view as the insects, prominence being given to the dynamic and economic problems involved. Members of the class are encouraged to work out research-wise the life history of such forms as *Monilia*, black knot, *Peronospera*, peach-leaf-curl and other rusts, mildews, smuts and blights. In this way the students are introduced into the important problems of plant diseases.

The fern is used as the type for the minute study of a plant much as the earthworm is on the animal side, and it is worked out cell for cell in root, rhizome and leaf. Thorough work here renders very facile the following studies of the structure of seeds, for which sprouting wheat and the peach serve as excellent types, historic, dynamic and suggestive to the core.

The bacteria are purposely pushed out of their logical position to the end of the laboratory series of plant studies on account of their manifold dynamic relations. A number of the standard culture media are made, demonstration-wise, in the laboratory and distributed in tubes and Petri dishes so that each student may make plantings from the air, water and dust, fly tracks, etc., and thus get a practical insight into bacteriological methods. By the courtesy of Dr. Moore samples of nitrogen fixing bacteria were obtained from Washington, and clover seed was inoculated and planted in pots in the laboratory. Comparative plots were also planted in a garden near by and several of the students did the same in their own gardens. Stained sections of root tubercles were next studied. Of course no culture experiments with pathogenic bacteria are attempted in such an elementary course, although sealed cultures are used for demonstration and prepared slides of a number of important forms are used in a similar way. For example, by the kindness of the physicians in charge a hundred sputum slides were obtained from the sanitarium at Rutland and each student

works over ten marked slides and passes in a written diagnosis as though he were a member of the hospital staff.

The text-book for part of this subject is the Board of Health Reports of the City of Worcester, and, after discussing the general topic of city sanitation and pointing out the diseases that are clearly known to be of bacterial origin, each member of the class is required to go over the entire report, without consultation with others, and hand in a written report giving his estimate of the number of preventable cases of death or disease for the year.

In this way the student is given a clear, practical notion of the rôle bacteria play in the economy of nature—as symbiotic, saprophytic and parasitic, and is thus introduced into the problems of modern bacteriology.

From this point on—which should be about the first of April—the course branches into a number of individual and small-group lines. The main branch, only part of the laboratory work of which is required of the whole class, passes up into vertebrate morphology and biology with a fish, frog, bird and mammal as the types. The pre-medical men, and those who are preparing to teach biology, study the types in much the usual way; but even here experience of the department has indicated that the structural may well be largely subordinated to the biological as giving the more fundamental and educational values for first-year work. The tendency is, thus, to crowd the purely morphological details more and more over into the two succeeding years, giving them a somewhat definitely specialized character.

The outline of this work is, briefly, Fishes, general plan of organization; common species with habitats, foods and spawning habits and seasons, numbers of eggs produced, methods of fishing to be employed in order to keep waters properly stocked.

The Batrachia are studied in much the same way except that the pre-professional section of the class spend more time with the anatomy, and the eggs are used for the outlines of vertebrate embryology—instead of the chick as used in Dr. Martin's course. More attention is also paid to the insectivorous habits of the group by way of feeding tests in the laboratory. The spawning habits and seasons, too, have been more carefully followed by the successive classes in the hope of publishing a complete account of this subject for all our common species of frogs, tree frogs, toads and salamanders. This is genuine investigation in which all the class take part during the spring months—and in some cases the study is continued voluntarily throughout the summer vacation—and the results will fill a serious gap in our natural history. These animals are practi-

cally all more or less important insect destroyers, and knowledge along these lines must come to underlie all practical work calculated to maintain the different species at their greatest efficiency.

The work with turtles and snakes is little more than incidental. A number of specimens are always collected during out-door laboratory periods and these may be utilized by some member of the class for feeding tests, and they also serve to demonstrate in a general way the various types of organization and some of the salient biological relations.

The study of birds is begun early in the fall with a brief statement that each member of the class will be required to know at least one hundred common species and be able by the end of the course to describe them as to color, markings, notes and songs, migration periods, habitats, nesting habits, and especially foods. By thus early sketching the plan of work for the year the student is enabled to organize all the knowledge he already has and utilize every opportunity for observation which may render his knowledge more complete. His attention is also called to a number of standard bird books including many of the U. S. Government Reports which give the foods and economic values of different species. These are kept for reference on a shelf in the laboratory. He is also required to supply himself with a field note book, and this is inspected from time to time, suggestions made, and then finally graded at the end of the year according to amount of work accomplished.

The species used as a dynamic and anatomical type is the English sparrow. The Bulletin of the United States Department of Agriculture on the English Sparrow in North America is referred to in detail on the foods and economic status of the species. The students are directed to note carefully observations under these heads, especially with regard to the relations between the English sparrow and native species, and finally the most effective methods of dealing with the intruders are considered.

Little work is attempted with mammals beyond noting general organization, and position in the animal series, leaving practically all the anatomy and special physiology to succeeding years. Toward the end, a little review work and some general suggestions are directed toward comparing the nervous systems of the various invertebrate and vertebrate types to introduce the student to the problems of modern neurology.

In order to accord plants their due share of attention a few suggestions toward systematic botany and the means of determining species are given and particular attention is directed to habits, habitats, seasons of flowering and ripening seed, geographical range and economic importance of native forest trees.

This part of the course is intended to give the students a glimpse into systematic botany and forestry.

I should add in conclusion one other feature of the entire course. The æsthetic is an important factor in the study of living nature; and while I should be inclined to give dynamic relations precedence in determining selection of types, between two types of equal dynamic importance I should choose the more beautiful. And, furthermore, we constantly discover æsthetic elements in the ugliest of types; and when by the aid of the dynamic standpoint we gain an insight into adjustments with environment and harmony in nature, we reach a deeper plane of æsthetic relations even more vital to our philosophies of life than that which lies on the surface. Very little can be said about all this and the less said the better, so long as the student is brought into personal relation to the fact that nature is beautiful to the core. Haeckel's "*Kunst Formen der Nature*" is the text for this phase of the course.

Nothing is farther from my thought than to claim for the above course anything approaching perfection. In fact, one of my chief motives for submitting it to the public in this form is to ask for criticism and suggestion by any who may be struggling with the same problem. I may add that from three years' experience the course seems to meet the requirements of the case rather better than I had dared to hope. It has apparently enabled a number of my students to discover their bent and decide upon their life work. Many more, who are specializing in directions other than biology, bear ample testimony that the work has not died within them but has become one among the number of permanent and cherished interests. When a young man a year or two after taking the course comes to me and says: "I am coming to realize more and more what our study of biology really means. Walking used to be rather dull business with me, but now it is more interesting than a novel. Every bird and tree and moss and fern and insect, frog, toad, fish or even snake has something new and interesting to tell me," may we not feel that we are, at least, approaching a solution to our problem?

I cannot close without again acknowledging my indebtedness to Huxley; and when he writes: (*Evolution and Ethics*, p. 50, 1893.) "Thus the most obvious attribute of the cosmos is its impermanence. It assumes the aspect not so much of a permanent entity as of a changeful process, in which naught endures save the flow of energy and the rational order which pervades it"—is he not clearly pointing toward dynamic biology? And again he says: "I cannot but think that there is room for all of us to work in helping to bridge over the great abyss of ignorance which lies at our feet."