

**SOME BY-PRODUCTS OF BIOLOGY TEACHING.**

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In the manufacture of illuminating gas by distillation from coal, there is left a sticky, tar-like mass that was for years a source of annoyance to the manufacturers of gas, and to the neighbors of the manufacturers. It was a waste product that was not only of no value, but a perfect nuisance, since it had to be removed from the gas stills and disposed of in some way. It was thrown into the streams, which killed the fish and aroused the angry protests of the farmers; it cost so much to handle the stuff that it was a heavy charge on the manufacture of gas, but it was impossible to make gas without producing considerable quantities of it. This nuisance remained unabated until an experimenting chemist hit upon a method of using the nasty stuff for making certain brilliant coloring matters, which are now used by the ton for dyeing ladies' dresses and chromosomes. I don't know whether the price of gas to the consumer has gone down on that account, but it would seem that if for some reason it should no longer be worth while to manufacture gas for lighting and heating purposes, it might still be worth while to make the gas and blow it off into the air, just for getting the coke, the ammonia and the coal-tar, the by-products of this process. I am not prepared to quote the exact figures, but at the present time the substances prepared from coal-tar exceed in actual value that of the gas for which the coal was primarily distilled, by some hundreds of percent.

Many modern industries are founded upon the by-products of other industries. We are so economical that not a scrap of material is wasted in the working up of cattle to make canned beef, glue, soap, glycerine, oleomargarine, sausage casing, fertilizer, shawl-straps, and I don't know what else; the total value of these by-products of the canning industry may or may not exceed the value of the net meat, but they are certainly worth saving. If they were not saved and utilized, it would mean smaller profits for those engaged in the business, or dearer meat for the rest of us, or both. If we should all stop eating meat, it might conceivably be still worth while to slaughter cattle for the other

products, the by-products. My point here is simply that in the industries the by-products, or the potential by-products, may not be profitably neglected.

In the business of teaching, much doubt has been cast upon the actual value of the product, from time to time. There are men and women by no means stupid who question not only the value of college and high-school education, but even that of the bulk of our elementary school education. There is great uncertainty in the minds of the public, and in the minds of many teachers, too, as to the real worth to the children of the results of the various efforts comprised under the name of teaching. We hear a great deal about the three R's, and fads and frills, about preparation for life and culture and training for efficiency. And the only reason that any one of us who takes the trouble to speak up may get a hearing is, that we are all at sea, teachers as well as the taught, and the parents of the taught. It may well be that the process has not been conducted economically, all things considered, that some of the possibilities have been neglected. We must look to the by-products.

When I speak of the by-products of teaching I do not mean the small graft in the way of sample copies of new books, or free tickets to an occasional lecture; nor do I mean the money you can make on the side because you have more leisure than the brick-layer; nor do I mean the glow of satisfaction that you feel when the minister speaks of consecrated lives, or the gratification yielded by an appreciative word from a former pupil. I have in mind solely the value of the product and of the by-product to the pupil, that is, to the taxpayer, the citizen, the laity. While personally I believe that the value of work should be considered as much for the satisfaction of the worker as for the yielding of various utilizable products, I also believe that at the present time we are not in a position to consider any more than the latter aspect of our work.

Now in the case of biology teaching there is as great dissatisfaction as in any other line. One principal complains that we do not give enough information, and in the reaction against informational teaching many of us have no doubt gone too far in the direction of eliminating information. The business man concedes that the information that we do give is curious enough, but he does not see what its value is; and we must admit that it seldom happens that a business man is helped in urging people to

buy goods by knowing that insects have three pairs of legs while spiders have four. The gentlemen and ladies complain that the information about frogs and horsechestnut twigs may be interesting, but does not give culture, and a particular lady tells me that while her Eddy is just crazy to be outdoors and study flowers and bugs, he is very awkward in company and is unable to converse on literary and other genteel topics. And again other parents complain that while their children got along very well in the grammar school, and with all their teachers, they cannot make anything out of high school biology. And so from every possible point of view the results of biology teaching are not satisfactory, with the possible exception of the practical applications that may be made of the results of physiology to personal hygiene.

Apart from information, the only important product that seems to be generally advertised is a certain training or development that is supposed to result from the exercise of the so-called mental faculties, like observation, memory, reason, and so on. But the psychologists, especially those that know the most biology, are telling us, have been telling us for many years, that the faculty-psychology is all wrong, and that you cannot strengthen the "faculties" by exercise the way you can the muscles; and our own observation may tell us that the pupils do not show greater ability in the use of these faculties because of their scientific training, except in connection with the materials and ideas they have actually dealt with in their studies. We are forced, therefore, I think, to find some other justification for a continuance of our teaching, and I would direct attention to the by-products.

But when I speak of the by-products of this process I do not wish to imply at all that our primary product is of no value, or of minor or secondary value, though it may well be; I emphasize the by-products because we are in no agreement as to the primary product. What seems essential to one seems secondary to others. Under the circumstances it is necessary to catalogue the total product and then determine each for himself which he will consider the staples and which the frills, or which the main objects of his teaching and which the secondary objects. It must happen in any such cataloguing that the coördinate terms will be of very unequal value.

The first and traditional result of the educative process is knowledge. In the teaching of Biology for information, there

are a few groups of ideas, with their related ideals, that are of preëminent value.

In the teaching of Physiology, whether plant or animal, a knowledge of the fundamental processes and conditions of life in general should be a major end. The knowledge of structure should be made subsidiary, and in the study of structure the emphasis should be on the degree of adaptation to function. If in the study of adaptation of organs the pupil can be made to feel that true worth is a function of efficiency, and that efficiency is a matter of adaptation to some purpose, there will have been established an ideal that is not Biology; it is essentially ethics. I am not confusing efficiency with an ideal of efficiency; efficiency is a legitimate end of education, but I do not think we shall attain to the highest efficiency of anything but machines without this ideal; and the only study that can teach it adequately to pupils of the early high school period is, I believe, biology. But this result, though only a by-product, may not be neglected.

In the teaching of Physiology there should be developed the idea of Division of Labor, and that of the Correlation of Functions. For example, I have found it worth while to get first-year pupils to analyze a factory in their minds, to discover what the essential elements in such an establishment are. After the analysis is sufficiently complete, I ask them to tell me which is the most important factor or part of the plant. On the first impulses, many different details are mentioned by different pupils, but each suggestion is naturally met with objections from the others. I give them time to talk it out, and without any help beyond that of keeping them confined to the problem, they finally come to an agreement on the ground that where each part is essential every part is equally indispensable, and therefore equally important. The results of this analysis are then applied directly to organs or organisms under discussion. Without ignoring differences in the relative magnitude or cost or intricacy of the several processes or factors, the pupils can get a very good idea of interdependence, of equality through difference; and this idea generalized is of great value in getting an organic concept of Society as against the prevailing architectural concept. This is not biology, but it is a by-product whose value is not to be overlooked.

In the teaching of ecology there should be developed the idea that in addition to the dependence of living things upon certain

factors of the environment, there is also constantly a struggle against certain factors of the environment. The pupils should understand clearly that the struggle is against inorganic factors and against organic factors; and here again the relations between merit and fitness should be emphasized. The study of the relations of plants and animals to their environments and to each other should be supplemented by the study of the relations of plants and animals to man. And in this connection the emphasis should be not on man the merchant, buying and selling, doing business, but on man the creature that loves to live, without regard to buying and selling. In the larger cities especially does it seem to me very important to fight the prevailing commercial evaluation of the things of nature. The economic importance of plants and animals is mentioned in many of our text-books and taught by many of our teachers. But too many of our teachers, in the text-book and out, too many of our pupils, and too many of our leading citizens see in "economic importance" simply another term for "commercial availability." What is the economic importance of the crustacea? a teacher will ask, and be satisfied if the pupil remembers that the lobster industry amounts to so many million dollars, whereas the shrimps are not so important because—they are eaten only by Frenchmen. It is true that the human importance of lobsters and that of shrimps are approximately in a ratio that may be expressed in terms of the commerce in these commodities; but it is not true in general that the economic importance of any factor of our environment is commensurable with its commercial value. For example, we teach a great deal about the importance of respiration in the life of an organism, but it does not occur to us to speak of the economic importance of the atmosphere. Yet that is just what we should do, and we should place all economic references upon precisely the same basis, namely, the relation to human life and welfare. It is obvious that some of the most important things in human life and welfare have not yet been commercialized, and that the commercial test is as far removed from the human test as any well can be. Whatever, then, the pupils may forget of strophioles or echinoderms or centrosomes; whatever they may remember of angiosperms or parenchyma or trochanters, of this I believe they can never know too much or too intimately—the intricate relations that exist between the life of man and the lives of other organisms; not in the way of the sentimentalist who will go

without a drink to spare the protozoa in the water, but in the way of the master who consciously chooses, as a gardener, what he shall retain and what reject. This is not biology, it is economics—the economics of human happiness.

But in this emphasis on the human side of our subject lies a danger which it is the duty of the biology teacher to anticipate and to overcome, for nowhere else will the high school pupil have a better chance to meet it. I refer to the prevalence of the anthropocentric superstition. Every child brings this with him to school; some have lost a little of it, and some have lost more, but probably no first year high school pupil comes entirely free of it. How many pupils leave the high school entirely emancipated from it? While I would constantly emphasize the human possibilities in all the material and ideas utilized in the course, I would just as constantly knock, knock, knock against the notion that these usable and these undesirable things exist because of man. In the teaching of plant and animal physiology there is always opportunity to contrast the *function* of an organ from the point of view of the organism, with the *use* of the organ or organism from the point of view of man. To learn that the progress and welfare, yes, the very existence of man in the midst of his various needs and of the various obstacles to his satisfying his needs, are *not* the results of a world having been made for him to suit him, but are the results of man's own knowing and doing; to learn that man's mastery of his environment comes only through perpetual striving in thought and in action, is to learn something of which we cannot afford to leave any person in ignorance. Whatever else the pupil does or does not learn in school, I believe that this one by-product is of sufficient value to justify the erection of the plant; and I don't know where the pupil can more easily get the results than in the biology course. But this is not biology, it is cosmology.

One other aspect of information that should never be ignored is the teaching of the idea of evolution, with the implanting of the related dynamic ideals. And by evolution one need not mean Darwinism, nor Lamarckism, nor any other special attempt to formulate the process. But if the pupil does not get from his high school biology the evolutionary idea and the dynamic ideal, he is most likely to go out of school without these things, for I don't know where else he can get them. Certainly not from his language work, with its complex rules and interminable excep-

tions; not from that series of more or less fortunate catastrophes that is taught him under the name of history; not from the adventures and romances that constitute the bulk of his literature; only *possibly* from his mathematics, except for the fact that the laws of mathematics are so abstract and so absolute, so relentless, and, therefore, so far removed from the apparent chance and irregularity of every-day affairs, that the pupil is more likely to conclude that law is something that exists only in the text-books and in heaven. The idea of order, the idea of causality, the idea of unity, the idea of constant change, and the ideal of progress, the revolt against the doctrine, "As it was in the beginning, is now, and ever shall be," in its ordinary static sense—these things are not biology, but a valuable asset to every person, and a possible by-product of biology teaching.

Biology has borrowed from social science three ideas that have influenced its development profoundly. The idea of Evolution, the idea of Division of Labor, and the idea of Struggle for Existence have been thus borrowed, with what results we all know. It is the duty of teachers of Biology to return to society these ideas, with compound interest of broadened application and fuller, more definite content.

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If we reject the faculty-psychology, as we must, we need not reject with it whatever benefits may accrue from the formation of useful habits. The method of the laboratory has been lauded for its remarkable effects upon the character of its devotees—or victims—and much has no doubt been credited to the laboratory that properly belongs elsewhere. But I think there can be no question as to the value of saying clearly and exactly what one means. If the laboratory is not the only place where this habit may be acquired, it is for the high school pupil the place where he can get the greatest amount of practice in this exercise, and under the most valuable control, the control, that is, of the objective limitations to the thoughts he is trying to express. Indeed, I sometimes think that too large a share of our teaching time is taken for doing the work that should be divided among all the departments of the school and which, it sometimes seems, is most systematically neglected by the English departments. The especial advantage of doing language work in connection with the objective material is generally recognized. At the same time we may be tempted to overestimate the importance of getting from

each pupil a complete and accurate statement of what he has seen or thought. While we may be sure, when the pupil makes such a satisfactory statement, that he has seen that of which he speaks, we may *not* be sure, when the pupil can neither describe nor draw nor model that which he is supposed to have seen, that he does *not* understand it. And this for the very simple reason that not only does expression follow impression, but it often follows at a very respectful distance. Every one of us knows that in the efforts to learn a foreign language, a stage is reached at which one is quite able to understand a rather long and complex sentence, without being able to formulate correctly a much simpler sentence in the foreign tongue. It may be the same with our pupil; he understands a great deal more than he is able to tell, and the difficulty of the teacher is to know when the pupil *understands* without waiting until the pupil can also *tell* what he understands. Yet if we have to wait for the telling, we have a by-product of great value. But this is not biology, it is expression, graphic or linguistic.

And the expression learned in the laboratory has the recognized advantage that it operates under conditions that permit of immediate and constant objective control as to accuracy and adequacy. I am not sure that science teaching does, as is often claimed, inculcate a love of truth. But I do feel sure that science teaching may impart a keen realization that there is a difference between truth and error which is quite independent of opinion or authority. It may perhaps stimulate in some cases a languid self-reliance. If the question the pupil is moved to ask by a suggestion from the material with which he works is promptly and satisfactorily answered by the teacher, there is great saving of time for the teacher, there is great increase of knowledge for the pupil, and everybody is happy—except a few cranks. For the more the pupil gets information by the mere asking from his teacher, the longer will it take him to learn that the only way the teacher found out was by looking at the material or by reading what some other looker had written; the longer will it take him to realize that he can find out more directly and more certainly without asking; the longer will it take him to throw off the superstitious awe for the authorities that have acquired their wisdom in some mysterious way supposedly beyond his reach. It is not necessary that the pupil be left with his specimen and his own resources “to observe,” but it is necessary that no opportunity



be lost to teach the pupil that most of the questions he asks he can answer for himself; to teach him that the opinions of men and women are worth just in proportion as they are founded on sound knowledge and on sound inference. To teach one that his own brain with its peripheral organs is an apparatus that can create knowledge as well as that of the writer of text-books, and to develop a habit of looking to this apparatus for first aid, instead of the habit of asking someone else—that is not teaching Biology, it is teaching self-reliance in thinking; and this by-product alone is worth the price of admission.

But it is not enough to think boldly and independently; it is necessary also that the thinking be logical and coherent. The study of grammar is under certain conditions nothing but the study of logic, but it is so formal and so attenuated and so much restricted by the special rules, that it is very uncertain, in regard to the pupils who attain high ratings in grammar, whether they are those who were better thinkers before they began the study, or those who acquired the art during the course of the study. On the other hand, the logic of the laboratory, like the expression of the laboratory, is constantly subject to the external, impersonal check. The method of the experiment leaves no room for opinion where certainty is possible. We hear it often objected that the method of science, meaning the method of thought in science, is all right for those who are to pursue the study of science further, but is of no use to the pupils who leave the high school at the end of one or two years. From this view I must dissent, and for the following reasons:

The pupil that becomes a scientist does so only on condition that he is prepared to meet his problems, prepared, that is, to think as a scientist. But the student that goes into the shop or the factory or the office without any more schooling than he gets by the end of the first or second year of high school, is still to become a citizen and a worker, and it is especially from the point of view of the citizen, who is called upon without any special preparation to declare periodically what shall or shall not be the policy of his city or state, and who shall or who shall not be entrusted with carrying out the will of the people, that the method of science can be of tremendous value. The habit of analyzing complex phenomena is of value to every man and to every woman that has to live in an environment complex enough to support human life. This habit is to be acquired only through the prac-

tice of analyzing complex phenomena, and will be regularly exercised only where there is a live realization that phenomena *are* to be analyzed. And nowhere in the school course is there presented an opportunity for such analysis, or for realizing its importance, like that furnished by biology teaching. Very few of the pupils that enter high school ever get a chance to study economics or any other branch of social science; yet every young person that lives long enough is expected to have opinions on the most complex problems, and that, too, when most people are not even aware that there is such a thing as analyzing a problem. They have heard of analyzing water from a suspected well or of analyzing adulterated food; but they don't know anything at all about analyzing the tariff question or the open shop question or the equal pay question. Of course I do not refer to the fact that they do not use the word "analyze" in this connection, but to the fact that they do not realize that there is such a process and that it must be applied to every question. Now I do not claim that the study of biology will make our pupils competent to pass sound judgments upon the public problems that confront the citizen, but I do claim that a habit of analyzing complex problems, the habit of looking for the factors or elements, is a decided advantage in meeting such problems, and this habit our course might establish more or less firmly, by our calling attention to the function of analysis in the activities of the physician or the engineer or the statesman, and to its function in the solution of the thousands of problems that arise in the practical conduct of each individual's affairs. This idea of analysis and the habit of analysis are of great value, but they are not specially biological.

In this connection our old friend, the faculty of observation, deserves a brief notice. It is quite certain that the practice in the observation of flowers and bugs does not establish the general habit of observing everything that comes within the range of our senses. But it is equally certain that a realization of the importance of certain classes of facts will make one both diligent and careful in the gathering of those facts. Now we can make the pupil realize that a knowledge of facts is essential to the solution of various problems, and that the facts are worthless unless they are the results of careful, accurate observation. Beyond that we can only make him familiar with types of structures in which he will discover details and variations more readily after practice; we can never teach a boy to take in at a glance his sis-

ter's new millinery dream by the application of the laboratory method to the inside of a crayfish.

All these methods of science, analysis, observation, inference and verification, will not become fixed habits of pupils unless a special effort is made to generalize their applications to the affairs of the trades and the professions and the interests of every-day life; and Biology furnishes the best basis for such generalizations, being on the one hand complex enough to be safe for analogies to practical affairs, and being on the other hand concrete enough to allow of objective and experimental study.

One might be tempted to ask whether I would teach anything in the biology course that is really biological, or whether I would leave anything for other departments of a school to do. To answer the latter question first, I would say that I believe that every subject in the school must contribute its share towards the inculcating of certain ideals, towards the establishment of certain habits of thought and action, and towards proficiency in the arts of expression or communication, in addition to the imparting of information proper to its department. That there are biological matters to be taught in the biology course goes without saying, but these other things to which I have referred are some of the by-products, actual or potential; and we cannot afford to ignore them.

To summarize, I should like to present this plan or ideal for utilizing the by-products of biology teaching:

Teach for thinking, as against merely remembering or believing.

Teach to think straight rather than loosely or crookedly.

Teach to think to some purpose, rather than diffusely, vaguely.

Teach to think to some human purpose, as against merely personal or commercial purpose; and finally—

Teach for an ideal of a dynamic human purpose, as against a static one.