PHYSIOLOGY AS A SCIENCE STUDY IN THE HIGH SCHOOL.*

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Physiology was the first of the life sciences to have a place in the curricula of the schools, but in its introduction, and for many years thereafter, it bore little resemblance to a science as we now understand the term. It was a textbook subject, hated by the unhappy teacher to whom it was assigned and avoided by the pupils whenever possible.

At a later day it consisted chiefly of certain dicta concerning the effects of alcohol on the different systems of the human body. It was seldom or never illustrated, for illustration to the lay mind savored of the handling of "inwards," a thing to be religiously avoided.

It is small wonder then that this most important of the sciences has fallen into disrepute among educators themselves, and receives but a scanty and grudging recognition in the assignment of subjects.

In the face of all this I do not feel inclined to modify the statement I have made above, that it is the most important science in the curriculum. To it every other science, properly arranged, should lead; to it, also, the pupil should bring not only the facts of botany, zoölogy, chemistry and physics, but the feeling that here he is to learn how to make the most of himself—the best use of this wonderful machine which holds us each, and through which, and by means of which, we make the world better by our having lived.

The optimum and logical preparation for physiology would be that botany, zoölogy, chemistry and physics should precede it. This might be accomplished by placing it in the last half of the twelfth year. Parenthetically, let me say that we expect to offer such a course after this year, and that physiology is also taught

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in connection with zoölogy during a year's course in the latter subject. It is a part of the zoölogy, not a subject taken up at the end of work on vertebrates, but introduced by the study of foods, when we reached a point in invertebrate work where that could profitably be handled; by a farther study of glands and digestion, when glands and their functions became of interest in the zoölogy and by a study of motor organs (amoeboid cells, ciliated cells and muscles), when in worms and molluses, muscular activity was noticeable.

Study of circulatory systems is made when any animal large enough to have a distinct system for the circulation of blood, is taken up in the laboratory. Respiration and excretion follow naturally.

The study of the nervous system will be taken up in connection with work on vertebrates, beginning with functions of nerves and ganglia when the class finishes the work on arthropoda. The skeleton in this course will be the last thing to be considered, instead of, as usual, the first thing, and in connection with it will be some work on muscles. This work will be illustrated by the use of the "joint apparatus" devised by Dr. Fitz, of Harvard.

This outline is not primarily of physiology, but only of that treatment of the subject which it seems to me ought to be included in any course in zoölogy, unless the zoölogy has been preceded by physiology, or is to be followed by it.

Where physiology is to be studied by itself, the first thing to be considered in outlining the work is where it is to come in the high-school course. I have indicated what I consider its proper place. Others will undoubtedly think differently, but, at any rate, all will agree that if it is not preceded by some chemistry and physics, it must be illustrated by simple experiments in order to make it comprehensible by the student.

The teacher of physiology may talk of oxidation and digestion, of proteids in the food, calcium phosphate in the bones, of carbon dioxide and nitrogen in the air, but unless he and his pupils understand the elements of chemistry, unless they see and handle the things they talk about, they might as well talk of Greek verbs. With the microscope he may show them cells, but he can-

not go further—unless he is a chemist—and show them that the whole complex animal body has been built up of three invisible gases and carbon.

In this I find the starting point for my work; in the laboratory, without any textbook and only a sheet of directions as to processes, and questions as to results, the learner finds out for himself something about the substances which enter into the composition of his own body.

This introductory work is followed by a set of very simple experiments on acids and alkalies, and the whole by a sharp quiz which shall "fix" the results. Then the study of food can be introduced with experiments to show the reactions of various tests for starches, sugars, proteids, fats and minerals. A few foods may be tested to show how many and what food principles they contain, these studies to be followed by a series of experiments on digestion in which test tubes, containing foods and digestive fluids, are suspended in a water bath with a chemical thermometer and kept at a temperature of 99° F.

I like to precede the study of the alimentary canal by a dissection of some mammal, in which peristaltic action, the divisions of the canal, locations and connections of glands are pointed out. Students are sometimes required to make a hasty sketch of the dissection and compare with location of the same parts in the manikin. While the work on foods is going on in the laboratory in the class-room we discuss work and energy, uses of foods, etc., and oxidation and combustion are illustrated.

The alimentary canal and digestion are then studied in detail. The former illustrated by slides to show structure of stomach, intestines, glands, etc., and the latter by experiments on fat-digestion (emulsions and soaps) and absorption. A bit of sausage skin tied over the flaring end of a test tube whose closed end is chipped off will give good results as to absorption of digested and undigested proteids. In food study, as in many other parts of my laboratory work, I am indebted to Peabody's "Laboratory Manual" for suggestions.

We follow digestion with circulation. When it is possible we have in the laboratory three jars of blood, the whipped, coagulated, and fibrin from the first, with a microscopic study of frog's

and human blood. This gives us an impetus; aided by study of circulation in the frog's foot—or, better still, in the tadpole's tail or the caudal fin of a small fish, the interest grows until it is positive excitement when we study the beating heart of a frog or turtle, and dissect the calf's heart from the market.

Let me say in passing that careful counting and timing with a watch will show the comparative length of work and rest periods for the heart.

Difference in arterial and venous currents, pulse, arterial spurting and slowing of blood flow in capillaries are all illustrated in a simple piece of apparatus consisting of glass Y-tubes and rubber tubing, the construction of which is explained in Macy's Physiology.

At the end of this work, along with quiz and laboratory notes, I require each pupil to put on the board or paper his notion of the structure of the heart in a diagram that shall show chambers, valves, blood vessels, etc.

Respiration and excretion are next in order. So essential does the study of lung capacity seem to me that I have devised an apparatus for its measurement, a figure of which was published in SCHOOL SCIENCE, Vol. I., No. 7, p. 372. Accompanying it is an outline of the questions each pupil answers in regard to it. When the work is handed in, a personal talk with each pupil emphasizing the points made is very helpful. Students take pride in a good lung record and often take pains to improve it, taking occasional measurements through the year.

Dissection of kidney and slides of sections through the skin sufficiently illustrate the functions of excretion.

The students do not open their textbooks to study the nervous system until they have made a series of simple experiments on frogs to get an idea of the use of nerves and ganglia. In this work, especially, should care be taken that the learner distinguishes in the experiments the results he observes from the inferences drawn from these results.

If we should study the growth of civilization we should find it had been brought about by the mental operations of independent observation, experiment, classification, deduction and generalization. These lie at the bottom of all scientific study, all scientific

knowledge. The most profitable science teaching is that which teaches a pupil proper observation and experiment.

When physiology is challenged at the threshold of the high school—what do you bring that we should admit you here?—it must be able to answer and to prove with its kindred sciences that it brings the power of independent thought which is the greatest object to be desired among the masses of the people in present or future time.

Speaking of the moral factor in education at the N. E. A. last summer, President Faunce, of Brown University, said "Over every true school might well be inscribed the sentence which we find in Genesis: 'Let us make man.' Over the entrance to its scientific laboratories may be written: 'Let us help man to make the most of himself.' He who teaches at all follows in the wake of the Creator. He who teaches biology knows that the handful of dust which composes man worked its toil—some way from lowest protozoan to highest mammal, from mammal to man, and through an epitome of race history he must develop afresh the powers of each student.

"With earth's first clay they did the last man knead,
And then of the last harvest sowed the seed,
And the first morning of Creation wrote
What the last dawn of destiny shall read."

Physiology, hygiene and sanitation should, in the mind of the teacher, be the interpretation of the simple physiology of our course of study; for a knowledge of physiology is required in life, far beyond the ground covered by a course of lectures or an elementary textbook.

It is desirable that there be a widespread understanding of the nature of contagious diseases in order that the action of medical boards and boards of health may have a meaning in the minds of the public at large. The creation of such an understanding seems to me an important duty of the public schools.

Some of the most important questions we have to face in our country today arise from ignorance or reckless disregard of the fundamental facts of human existence. The unsanitary condition of the slums, the restriction of disease, the essential facts of contagion and disinfection, the conception of bacteria, infec-

tion and prophylactic measures, the children with neglected eyes and teeth and bodies, social evils and wrongs, from customs contrary to physiological facts—all these must be remedied by the training of young men and women in our laboratories, who shall save society. We can prevent it from becoming the prey of the evil only by producing the wise and good, who shall overcome the evil.

That righteousness tendeth to life, and the wages of sin is death, is not only morality, but physiology. Correct action is dependent upon correct thinking. The more familiar a man is with the laws of nature, the more he will obey them and work in harmony with them, to the benefit of himself and his fellows.

Let me quote once more from President Faunce: "The study of science itself has done much to promote exactness of observation and honesty of report. It has set before us as the model student of the nineteenth century, Charles Darwin, of whom it has been said that in all his voluminous writings not an instance can be found of a fact misstated or consciously perverted. It has given our students patience in study and taught them the greatness of creation."

And as to physiology Huxley said long ago: "There is a very convenient and handy animal which everybody has at hand, and that is himself. * * * Hence the general truths of anatomy and physiology can be taught to young people in a very real fashion by dealing with the broad facts of human structure. ~ * * So that, in my judgment, the best form of biology for teaching to very young people is elementary human physiology."