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THE TEACHING OF PHYSIOLOGY[1]

By Professor AUGUST KROGH

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I HAVE been engaged in physiological research and in teaching human physiology for about forty years during a period in which the most astounding progress has been made, and the subject from being of mainly academic interest has developed into being of deep significance for the welfare of mankind.

I wish to contend that the teaching of this branch of natural science has not kept pace with its increasing significance, that it should be taught to a larger number of people and in a more effective way than is usual at present.

I am not now concerned with the teaching of physiology to the small number of students who are going to engage in physiological research; they can pick up their factual knowledge during their apprenticeship, but I am thinking of all those people who need some knowledge of physiology to order their own lives and in their respective trades and professions, and my major contention is that this knowledge should be imparted mainly in a utilitarian way without any attempt to cover the whole subject as academically defined and delimited, but stressing definitely those parts of it which are most useful from the point of view of the pupils and therefore most likely to catch and hold their interest. I am convinced that at all stages the active cooperation of the pupils in the acquisition of this knowledge should be obtained.

Adopting this as my guiding principle, I would like to have the fundamentals of nutrition introduced as a subject in all lower schools—at least in the cities. While it is no doubt true that the instincts of children could guide them to a right selection of natural foods, this does not hold at all in the highly artificial environment in which most children are brought up; and they

[1] An address delivered before the American Academy of Arts and Sciences, Boston, on May 10, 1939.

should learn for their own sake and for that of future generations something about food values and the effects of stimulants in common use.

I would also, on principle, include in the curriculum for all adolescents the elements of sex physiology, but how far this is practicable must depend upon local conditions.

Going to deal now with the teaching of those classes in society which claim to be educated, I wish to record the fact that in Denmark human physiology was introduced in 1908 as a regular subject for all high-school pupils at the age of seventeen to eighteen years. We have nothing to compare with American colleges, and our high schools (called gymnasia) prepare directly for the universities. Allowing for considerable differences in methods and courses, the teaching of these youths corresponds to that in the two first years in college. The pupils, or those responsible for them, have to choose between three lines of education: one stressing classical languages; one, modern languages; and one, mathematics and natural sciences.

Both languages and science are taught, however, to the pupils along all the lines, and a knowledge of human physiology is considered a necessary and essential element of any liberal education.

Pupils, teachers and education authorities are in essential agreement that this subject has proved interesting in itself and of high educational value. I have no doubt that from the point of view of formal education, corresponding values could be obtained from other branches of biological science and that a presentation of the facts of general physiology is even logically preferable, but the natural interest of the pupils centers around their own organism, and here again I would strongly emphasize the utilitarian point of view. A knowledge of the bodily functions and some of their most common disturbances is, on the whole, useful knowledge, and a fairly large number of the pupils will find that this or that bit of it applies directly to their own case.

The physiology taught in our gymnasia is fairly comprehensive, although, of course, elementary. It utilizes the chemistry and physics which the students have at this stage been taught, and it covers the functions of digestion, circulation, respiration, excretion, etc. Nutrition is dealt with at some length, and the functions of endocrines and gonads are included. The nervous and muscular systems are treated in a somewhat summary fashion, but the sense organs, especially the eyes, in more detail. I may perhaps be allowed to refer for further information to an American edition of my own text-book published in 1934 and now therefore largely out of date.

The men and women who teach physiology on this level must themselves possess a sound and a wider knowledge of the subject, and it is essential that during their university training they should have grasped its character as a living and rapidly growing subject so as to be ready to assimilate and utilize the progress made during their subsequent teaching careers and not to be dogmatic on any point. In Denmark we think it important that they should be trained to perform and demonstrate to their pupils simple physiological experiments—mostly on human beings. I have been responsible for the university training of these teachers for thirty years, and although comparative physiology is my favorite field, I have not considered myself justified in introducing more than a few especially striking examples into the curriculum.

Familiarity with certain aspects of physiology is useful or even essential in certain professions. Dentists must know something about nutrition, and engineers ought to know something about the human organism as a motor; but for very large parts of our science, they have no direct application, and there is no reason why they should have more information on these parts than any educated citizen.

The profession in which human physiology is most useful and for which it is now in fact *the* basic science is the medical.

Forty years ago the recognized basis for clinical medicine was morbid anatomy, and the contributions of physiology to medicine as then taught and practised were not numerous, nor were they considered especially important.

The situation now is fundamentally different. Morbid anatomy is still important, of course, but disease is first and foremost a functional disturbance, and how far it can be controlled depends largely upon our understanding of normal and abnormal function. I am happy to state that the conception is gaining ground in this country that the teaching of physiology in medical schools has for its object to educate students to become doctors and not to become dabblers in the experimental and theoretical science of physiology, but tradition is strong, and, as I see it, there is still a great deal that will have to be weeded out from physiological curricula in medical schools and a great deal that will have to be put in. We have to start with the assumption that the students enter medical school because they are interested in medicine, and it is the duty of teachers to make it clear to them at every stage that what is taught has a bearing upon medicine and is going to help them to become good doctors. If this conception is kept in view, it should not be so very difficult to illustrate the teaching of physiology with clinical examples and to stress those phases which have a definite clinical bearing, as, for instance, the central and peripheral disturbances of circulation, the formation and absorption of edema, etc. It is a difficulty, of course, that in the preclinical stage in which physiology is mainly taught the pupils know very little about medicine, but I am convinced that this difficulty can be largely overcome. The practical courses should not, in my opinion, be arranged to introduce the pupils to the intricacies of physiological experimentation, but, beyond illustrating some basic principles, they should familiarize the students with methods actually useful in medicine. The growth of the science should be emphasized, and it should be taught how to find and use original literature.

I feel very definitely that the practice adopted by a few schools of giving those students who desire it an opportunity to reestablish a close connection between physiology and medicine is very beneficial. It can be done, as I have seen, by establishing courses for older students given jointly by clinical and physiological teachers, but other methods are no doubt available.

I have been much in favor of special chairs for the study and teaching of pathological physiology, and I still think that it may be, in certain circumstances, a useful development, but it would serve as an excuse to make the preclinical teaching too academic, and when a close cooperation can be established between those who teach physiology (normal *and* pathological) and those who teach clinical medicine and surgery, I think the best results can be achieved.

It may be said that the system which I advocate would discourage students from going into physiological research. My reply would be: So much the better. Students should be discouraged from choosing a career involving research, and we should welcome only those whose urge is strong enough to overcome discouragement and difficulties.

THE MODE OF ACTION OF SULPHANILAMID[1]

By Professor PHILIP A. SHAFFER

DISCOVERY of the dramatic therapeutic effect of sulphanilamid in various bacterial infections has stimulated wide-spread interest and renewed activity in the field of chemotherapy for infectious disease. From this renewed activity there should come the discovery of still better drugs for the control of infections. Progress in this new era of chemotherapy is likely to depend a good deal on an understanding of the ways in which the drugs exert their action; without that understanding the search for more useful therapeutic substances is apt to be largely a haphazard venture. It is therefore disappointing to find that in spite of the numerous investigations with sulphanilamid and related compounds there is yet no accepted explanation of their action. In Marshall's recent review of the pharmacology of sulphanilamid,[2] he states: " . . . no satisfactory explanation of the mechanism of action has been found." Yet certain facts have been known for some time which appear to point plainly enough in the direction of a logical explanation. The purpose of this communication is to draw attention to these facts and to cite briefly some new evidence, all of which when combined seem to provide an explanation of the mode of action of sulphanilamid and of related substances.

In June, 1937, R. L. Mayer pointed out[3] that the frequent appearance of methemoglobin in the blood of animals and patients treated with sulphanilamid suggests the formation in the body of an oxidation product of the drug which is responsible for the formation of methemoglobin. He further advanced the hypothesis that the bactericidal effect is due not to sulphanilamid but to the same oxidation product which oxidizes hemoglobin to methemoglobin. In support of this idea Mayer showed that p-hydroxyl amin benzene sulphonamid is highly bactericidal, as the corresponding amine is not. It is the opinion of the present writer that this hypothesis contains the important germ of truth, and if substantiated and developed may supply a rational chemical basis for this important branch of chemotherapy. Should this expectation prove to be correct it will represent the extension of a point of view that prompted Ehrlich in his early experiments with oxidation-reduction dyes and will incorporate also some of Pasteur's ideas on the relationship of fermentation to respiration.

The following facts would seem to be conclusive evidence that sulphanilamid and sulphapyridin are not themselves bactericidal and that their therapeutic (and toxic) effects are due to oxidation products of these substances formed by atmospheric oxygen under the catalytic influence of respiring tissues or organisms.

(1) Both drugs are wholly without effect on the growth of bacteria in the absence of oxygen. Both become more or less bacteriostatic or bactericidal under certain aerobic conditions, but promptly lose this property when the culture media become anaerobic in consequence of bacterial metabolism and the resulting consumption of dissolved oxygen.

The oxidation products of a number of more or less analogous substances, for example, benzoquinone and quinhydrone, are known to be highly bactericidal under anaerobic as well as aerobic conditions, whereas the reduced forms are bactericidal only under aerobic conditions, *i.e.*, when their oxidation is possible.

[1] From the Laboratory of Biological Chemistry, Washington University School of Medicine, Saint Louis.
[2] *Physiological Reviews*, 19: 254, April, 1939.
[3] *Bull. L'Academie de Med.*, 1937, 117: 727, 1937.