ogy, if indeed it has any such relations. But I can not resist recalling the scorn with which, in my boyhood, I remember hearing the minister describe Tyndall's famous proposed "prayer-test." I am free to say that I can not at present see why such a proposal should have created such a storm. If people actually believe in the existence of God, and that in addition he does grant requests addressed to him by persons of suitable character, what could be more suitable for decision by the statistical method than such a simple question? Fortunately times have changed, and the nature of prayer is now supposed to be quite otherwise, and to have its beneficent effect by reaction on the emitter, quite irrespective of its treatment at the receiving station. Nothing is more striking than the varying attitudes of scientists toward the subject of theology and religion, from the simple faith of a Faraday, Maxwell or Kelvin to the quite different attitude of a Tyndal, Huxley, or Haeckel. I take this to be due to the difficulty of defining the meaning of the theological terms, and to hazard the opinion that if we could define them even as well as we can entropy we should be found not to disagree profoundly. If it be true that "the undevout astronomer is mad," it is true because we admit that the chief effect of the pursuit of science is to give us a profound admiration for the workings of nature, together with the conviction that its methods are beautiful, definite and simple, and are capable of being understood by the human mind. If this is to say that they thus show evidence of having been designed by a great intelligence, like the human, but enormously more powerful, very well, but it is at this point that we begin to differ as to the meaning of our terms. The chief thing that the scientist should have learned is the possibility of his being mistaken, and the danger of denying in cases where he has no evidence. We must therefore conclude that while the methods of physical science have a continually widening field of application, we must advise him who asks the profoundly interesting question, "If a man die, shall he live again," to seek to answer it by other methods, *if he can.*

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THE TEACHING OF PHYSIOLOGY TO MEDICAL STUDENTS[1]

IN no way is the relative importance of physiology in the medical curriculum better attested than it is by the designation of "the Institutes of Medicine," under which it still appears in the catalogues of some of the older universities. Originating as a division of anatomy, physiology gradually assumed such importance in the medical curriculum as to necessitate the creation of an independent department, although for long the close relationship of the two subjects was maintained on account of the fact that conclusions regarding function had in large part to be inferred from an accurate knowledge of structure. It is for this reason that the study of the microscopic structure of the tissues was, and in some schools still is, assigned to the physiologist, and it is indeed only within comparatively recent years that there has been anything like a general change in the nature of the practical work which the student must do in his course in physiology.

As it now stands, physiology is generally defined as being the study of the phenomena of living things. "It deals with the process of life." It has nothing to do with the structure or morphology of dead things, although obviously a sound knowledge of this must be acquired before any attempt

[1] Address of the vice-president and chairman of Section K, Physiology and Experimental Medicine, Atlanta, Ga., December, 1913.

can be made to explain the functioning of the parts. Physiology, in short, must concern itself with an application of the known laws of physical and chemical science to the process of living in both plants and animals. It must, for example, endeavor to show whether the facts known to the chemist can be made available to explain the synthesis of the various constituents of plants, and the liberation of energy which follows the ingestion of these foodstuffs in animals; it must ascertain whether the movements of a muscle, the secretion of a gland, the transmission of a nerve impulse, are adequately accounted for by the known laws of physics, or whether there exists in living things some force that entirely alters or entirely obscures the physical process.

As thus defined, the science of physiology is obviously too wide in scope, and its ramifications too diversified, to make possible its inclusion as a subject in the medical curriculum. It must be delimited. For this purpose, the object aimed at is of course a knowledge of the functioning of the human animal, although in gaining this we must constantly endeavor to show, by observations on the lower animals, how the same general laws of function apply throughout the animal world. We must, above all things, treat the subject from a broad scientific point of view, not narrowing it down to a mere study of the complicated mechanism of the higher mammalia, but making it a general study of the essential nature of the life processes. Just in so far as the knowledge of physiology is sound will the practise of the physician be likely to be proficient.

For the medical student, therefore, physiology must serve as the connecting link between his pre-medical scientific studies and the clinical work which is to follow. It must be considered as the center to which the basic sciences converge, and from which diverge the various subjects that are related to the study of disease.

A knowledge of physics, chemistry and morphological biology constitutes the bedrock upon which the foundation of medical knowledge, represented by physiology, must be built, and it is only after the foundation is completed that it becomes possible to add the superstructure which is represented by pharmacology, experimental pathology, hygiene and medicine. Physiology bears to medicine much the same relationship that anatomy bears to surgery, for the physiologist of to-day is the physician of to-morrow, just as the anatomist of to-day is the surgeon of to-morrow.

The objects which must be kept in view in framing the course in physiology for medical students may therefore be stated as being: (1) a knowledge of the application of the known laws of physics and chemistry in living things; (2) a knowledge of the behavior of those life processes which can not at present be explained on a physico-chemical basis. To impart such knowledge, we must, in the first place, offer the student ample opportunity for the direct observation of the behavior of living things, so that his knowledge of physiology may rest upon a basis of personal observation rather than upon one of authority. The student must, above all things, be trained to be an investigator of the behavior of living things, and he must be constantly reminded that the observations which he makes on the normal animal are later to serve him as a standard with which to compare the behavior of the disturbed functions in disease. But practical courses alone will not suffice. They must be supplemented by didactic instruction of such a nature as to show the student how the facts which he himself gathers from direct observation can be linked together with one another and with those of other investiga-

tors, so as to form a connected account of the working of living things.

As to the actual pedagogical methods by which we are to fulfill these requirements, it will be convenient to consider, first, the practical, and secondly, the didactic instruction. A thorough training in the methods of accurate observation, as applied to living things, must be the first step in the physiology course, for even granted that the student may have graduated in experimental physics, it will still be necessary for him to become familiar with methods by which to control and simplify the variable and complicated factor that the existence of a living tissue now introduces into his experiment. The experiment in physics is one in which everything is more or less controllable, a result once obtained being readily repeated; whereas in physiology a disturbing element is constantly present, for the physiological properties of the living object, whose movement or other function we are examining, may alter from time to time on account of vital processes over which we may not have any known means of control.

There are, I believe, no physiological experiments more suitable for this preliminary teaching than those on the nerve-muscle preparation of the frog. The actual physiological truths which the student may learn by doing these experiments are certainly not of much importance, at least from the medical standpoint, but the facility in accurate experimentation which he thereby acquires, as well as the ability to use his results for inductively drawing general conclusions, is essential to his further progress.

There is one other feature of these experiments that is of great value from the pedagogical standpoint, namely, the possibility of grading them with regard to complexity. In a few weeks the experiment may pass from the recording on a stationary drum of the degree of muscular contraction resulting from electric stimuli of varying strengths to the determination of the rate of transmission of an impulse along a nerve. When the student has acquired such technical facility that he can repeatedly obtain the same results in this experiment, he may be considered as competent to proceed with the more complicated experiments necessary to elucidate the fundamental truths of physiology.

The experiments on nerve-muscle being thus largely of a preliminary nature, the time occupied by them should not be unduly prolonged; sixteen sessions of two hours each are certainly adequate.

From such work to the study of the heart-beat in frogs and turtles is a natural step, the experimental technique being much the same, but greater care being demanded in the handling of the object under investigation. But another element now enters into the work, for the conclusions which may be drawn from the experiment come to be of great importance in themselves, and fundamental physiological truths concerning the nature of the heart-beat begin to unfold themselves to the observing student. He begins to feel that he is building up his fund of physiological knowledge at first hand, and he gradually comes to take a real interest in finding out, by consultation with his text-books, to what extent his observations and conclusions conform with those that are generally accepted. To encourage the spirit of independent investigation, and to add interest to the work, it is advisable, after a sufficient number of experiments has been performed, to devote a session or so of the class to a symposium in which the results obtained in the experimental work are collated and their significance discussed. For this purpose, each student should be required to prepare in

essay form a review of his findings, which he may be called upon to read before the class, and which is then discussed by the other students, with the object of bringing out the variations that occur, and of emphasizing the chief conclusions.

The time allowed for these experiments should be about one half of that occupied by the preliminary nerve-muscle work.

The student may now proceed to the experimental work on mammals, beginning with such problems as the control of blood pressure, the mass movement of blood, and other circulatory problems, and then proceeding with those pertaining to the respiratory, digestive, excretory and nervous systems. It is in the conduction of this course that the greatest pedagogic skill is demanded, for the experiments must be most carefully chosen so that their results may bring to light fundamental principles, and so that there may not be unnecessary repetition. The animals employed must be deeply anesthetized, and there must be sufficient competent oversight to make certain that at no stage do any of them show the least signs of consciousness. The animals must of course be killed at the termination of the experiment.

The question is sometimes asked as to whether it is necessary for the efficient training of medical students that they should participate in mammalian experiments. In my judgment, the question is as absurd as if it concerned the practical training of engineers. To drive our locomotives we do not employ men who have merely learned the theory of engine construction; we demand such as have gradually acquired a practical knowledge by actual experience.

It is obviously unnecessary that every student of the class should perform each experiment by himself; groups, composed of four or five students, should be formed, care being taken that the particular duties of the various members are so controlled by rotation that each has an opportunity during the course of actually taking part in every technical detail of the experiment. There should also be a sufficiency of trained instructors so that there is approximately one of these for every two groups. Conducted in this way, the experiments come to assume in part the nature of demonstrations, but they are of immensely greater value than the older lecture-table demonstration, because each student, by being an active participator in the work, comes to take a very much greater interest in the bearing of the experiment, besides acquiring greater operative and technical facility, which will be invaluable to him in his subsequent clinical work.

There are some persons who would doubt the necessity of even demonstrating any mammalian experiments to medical students. They maintain that it is unnecessary to repeat observations that have already been satisfactorily made and recorded. But if this were true for physiology, it must obviously also be true for physics and chemistry. According to those persons, there could be no value in *any* practical work in the pre-medical sciences, which would mean that the student on entering the wards would be no more familiar with the methods which are at his disposal for the accurate investigation of disease than would be a student of theology or law. When we bear in mind, however, that a patient with a disturbed blood circulation is strictly the same from the pathological standpoint as an anesthetized animal with corresponding conditions produced experimentally, we see how unreasonable such a contention comes to be. Is it better to have the student learn how to control a breakdown in the circulation on the patient or on the anesthetized animal? It is pos-

sible in a comparatively brief period of time to make the student of physiology acquainted with the fundamental conditions which disturb the circulation of the blood, for he creates the disturbance at will; it would take years to show him the same things on patients, because the lesions must be taken at random as the cases present themselves in the clinic.

It has been asserted that the mammalian experiments at least should be merely demonstrated to the students and that they themselves should not be called upon to participate in them. It has been pointed out, for example, that the fact that two loads are of equal weight is no more convincingly demonstrated by one's actually placing the loads on the scale pans of the balance than by seeing this done by another person. But the difference between this and a physiological experiment is very very great, and furnishes the very reason for which the latter should be performed by the student himself. For this difference depends on the fact that we are dealing with living processes that may materially alter the result of the experiment unless they are adequately controlled; to learn how to control them is one of the most important things that the student of medicine can learn. It would go beyond the scope of this article to present other arguments for or against the inclusion of practical work on mammals in the physiology course, but there is one pedagogical criticism that sometimes is made against the experiments that should be taken notice of. This refers to the possibility that the student may lose sight of the object for which the experiment is being performed on account of the attention which he must give in order to overcome the technical difficulties which it involves. This is undoubtedly likely to be the case unless great care is taken to have each experiment preceded by a conference, and, after several have been performed, to have the results reported and discussed in seminars. It is true that it may not be possible for the student immediately to correlate and place their full meaning on the experimental results which he obtains, and for this reason the teacher should as frequently as possible refer to these results in illustration of the principles which he is endeavoring to unfold in the didactic courses. Ultimately, however, the observations which he himself has made come to furnish the mainstay of the student's physiological knowledge, and he uses them as the basis for his further development.

Eight to ten sessions of four hours each are required for the mammalian experiments, after which several sessions are occupied in making accurate observations on the physiological functions of normal men, one student in each group serving in turn as the subject of investigation. In recent years the methods available for studies of this nature have very materially multiplied, indeed have done so to such an extent that several of the fundamental principles of physiology can now be as adequately demonstrated on man as by experiments on the lower animals. This permits of a certain amount of displacement of the experiments on anesthetized animals, an object which, for various reasons, should always be kept in view.

Coming now to the place of the didactic instruction, it may in general be stated that this should be so arranged as to supplement the practical. The lecture and recitation are certainly as indispensable as the practical class, for in them the principles of physiology—the institutes of medicine—must be expounded in logical sequence, and, as has already been stated, the bearing of the experiments which the students themselves have performed must

be clearly explained. It is in the lecture that an enthusiasm for the work may be instilled in the student's mind, and it is important that too much weight be not placed on detail, but that every opportunity be taken to show the application of physiological truths in the practise of medicine. For details the student should be referred to the text-books. It is often stated as an objection to systematic lectures that the students come to depend upon the notes which they succeed in taking during them in preparing for their examinations. To offset this possible tendency, there are two other features of didactic instruction which are of great importance. The one is the recitation or quiz, and the other, the symposium. One recitation should follow every two lectures, and it should be conducted, not by the lecturer himself, but by an assistant, who, although using a general outline of the lectures as his basis for questions, does not keep to that alone, but reviews the subject from his own point of view. It is important that a record be kept of the manner in which the questions are answered by each student, for otherwise it is difficult to hold every member of the class to thorough preparation. Review quizzes covering the larger subdivisions of the subject, such as circulation, respiration, etc., are also of great value.

The symposia constitute a most important feature of the course. Besides the symposia on practical work, which have already been discussed, there should be literary symposia, or journal-club meetings, in which each student in turn is required to read before the class a short paper compiled from the literature on some theme which has been allotted to him by ballot. The themes must be carefully chosen, so as to permit of presentation within the short time which is available for such work, and so that there is adequate representation in the English and American journals. Some students may be given themes requiring consultation of German or French journals, but in our experience the college training in modern languages is inadequate for their extended use in this way.

A general discussion, by the members of the class and by the instructor, should follow the presentation of each paper, the paper and discussion together occupying twenty minutes, thus permitting three papers to be presented in an hour. It is advantageous so to group the papers that the themes discussed during each symposium are closely related, for by doing so a much greater interest is likely to be aroused than if non-related subjects are presented. To prepare, even for the simplest of themes, a well-balanced and comprehensive review of the literature that shall occupy but ten minutes to present, is certainly by no means an easy task, not alone for beginners, but it is impressed upon the students that the practise which they get in attempting to do it will be invaluable to them when later, as practitioners of medicine, they desire to present papers at medical societies. Appropriate reprints of original articles can be lent from the department library to the students, but besides this they should have free access to such general reviews as the Index Medicus or the Surgeon General's Catalogue, the use and value of which they thus come to appreciate. In order to stimulate their best efforts, we have found it advantageous to offer to submit the best two or three papers for publication to the editor of the local medical journal. There should not be much difficulty in most large medical centers of finding some editor who would be glad to find room in his journal, at least during the summer months, for the publication of well-written, up-to-date reviews on

current physiological literature. A copy of each theme is placed in the department library, and its merit is taken into consideration in determining the final grade of the student.

Finally, at the very beginning of the physiological course there should be several lectures on general physiology, and at occasional periods during it there should be demonstrations by the instructors of more complicated experiments, which it would be impossible for the students themselves to perform.

Much has been written in recent times regarding the relationship of biochemistry to physiology, some believing that each subject should be assigned, like chemistry and physics, to separate departments, whereas others maintain that since physiology proper is the application of both chemistry and physics to the process of living, it should be taught by one who is more or less versed in both of these contributory sciences. In the present connection, our judgment is somewhat simplified by the fact that the question refers solely to the physiological training of medical students, to whom physiology must be taught because it is to serve as the foundation upon which is to be erected their subsequent knowledge of clinical medicine. It must be taught not in dissociated parts, but as an integrated assemblage of all the facts and observations from which its generalizations are induced. It does not matter very much whether the head of the department of physiology is primarily a chemist or a physicist. He should, however, be sufficiently familiar with both sciences to make it possible for him to teach the principles of physiology from both points of view, leaving detailed and practical instruction to associates who are specially trained in the purely experimental or in the purely chemical aspects of the subject. By such an arrangement, the professor of physiology in the medical school might be either an experimental or a chemical man, and his chief assistant would be especially qualified in whichever branch he himself was not so. Above all things, however, we believe that the two subjects should be taught together so that their interdependence may be constantly insisted upon.

Optional courses in special subjects, given by various members of the physiological staff, offer an important means for making the students cognizant of the nature of the research work which is going on in the physiological world. Although such courses are likely to be attended by the best students only, the class as a whole will come to realize that the department is alive and up-to-date, and that what they learn in the general course can represent but the very fundamentals of their science. The experience in teaching which the instructors gain by giving these optional courses is a further important reason for giving them. There is a growing opinion, and rightly so, we believe, that the experienced head man in the department should expend his energies in teaching the fundamentals of his science, and that he should delegate to his junior associates the conduction of advanced classes. This does not mean that he himself should not offer some advanced course in a subject in which he is specially interested and proficient, but it does mean that to leave to immature and undeveloped assistants the teaching of the fundamentals of the subject as a whole is pedagogically unsound, and is certain to produce a class of students that are unequally trained, and, besides, have a low estimate of the value of the course.

The object of a course in physiology being to train the student in the exercise of his faculties, rather than to jam his memory full of the accumulated truths that fill its

archives, it is important that he begin under the instruction of one who by experience is able to present the sequence of evidence which leads up to the establishment of even the most elementary truths of his science. If the scientific attitude be acquired at the beginning, the student's mind is prepared for the constant acquisition of new knowledge, which he comes to be able to assimilate with less effort, and with immensely greater profit to himself.

An unfortunate feature of every course is the necessity of examination. The necessity exists for two reasons: 1. To offer a disciplinary method by which each student is compelled to study the subject. 2. To ascertain whether he has mastered his subject sufficiently. It is not the purpose in the present paper to enter in any detail into this much-discussed pedagogical problem. It is certain, however, that in no other respect is the teaching of such a subject as physiology likely to be rendered inefficient and unpractical more than by too much examination. As we have stated before, a record of the general behavior of each student in the quizzes, in the practical courses, and in the symposia, should be kept, so as to serve as the main basis upon which his proficiency is determined, the finer grading being based on a comprehensive final examination, which should be partly oral and partly written in nature. In this final examination opportunity would be offered to sort out those students whose standing, as judged from the class records, is uncertain.

Occasional written "tests" are no doubt of some use in permitting the students to measure their standing, and in supplying them with a motive for reviewing their work. But it is a mistake to offer these tests too frequently, for it makes the student consider the obtaining of high grades as the main aim and object of his studies. By his success in getting high grades, the crammer, who merely memorizes what he hears or reads, comes to be considered as the really successful student, whereas the thinker who accepts nothing until he understands it is discouraged because he can not keep the pace.

And finally as to the future of the physiological student, how is his fund of knowledge to help him most in becoming an efficient diagnostician and therapeutist? The answer is by keeping him in constant touch with physiology during the time that he is acquiring his clinical knowledge. To accomplish this is, however, a most difficult problem, for it requires that the teacher of clinical medicine shall himself be well informed in the modern teachings of physiology, a qualification which unfortunately but few of our clinical experts possess, or which they make any effort to acquire. There has no doubt been a great change in the nature of the teaching of clinical medicine during recent years. The old-fashioned empirical dogmatism is gradually giving way to more logical and scientific methods, but even in our best-manned school clinics, there yet remain many who by their attitude towards such a science as physiology and towards the newer methods of refined diagnosis, which depend on the application in bedside work of physiological methods, make it very difficult to realize the above ideal. Naturally enough the unthinking student prefers to be taught cut-and-dry systems of diagnosis and treatment. In his textbooks of medicine, he finds tabulated groupings of symptoms by which he may distinguish one disease from another, and he expects that, having learned how to diagnose, all he has to do is to learn the prescribed treatment for the disease. By learning his medicine in such a manner—and of course it is in such a way that he

learns it when he attends so-called quiz classes in medicine—he is very likely to lose all of his scientific attitude towards the management of disease. He comes to think of diagnosis as being nothing more than an endeavor to find the text-book name for the disease under which the grouping of symptoms which he elicits happens to fall, and he loses sight of the fact that the symptoms are the outcome of disturbed function or functions, and that they may vary very much indeed in different individuals, according to the degree of physiological disturbance which the lesion creates. He becomes a student of symptoms rather than an investigator of the conditions which are their cause. After all, text-books of medicine are intended only as rough guides for the classification of disease, and it is fatal to efficiency in medical training if this fact is not constantly borne home on the student. He must be taught to study and treat each patient as an individual problem, and just as he has learned in the practical course in physiology that the same experimental condition may lead to different reactions in different animals, so must he expect to find among different patients the same want of uniformity in the symptoms which are produced by the same lesion. The student must be constantly reminded that the practise of medicine is in its merest infancy, and that its growth depends almost entirely on the degree to which it will be possible to apply the accurate methods of physiology and experimental medicine to its investigation. In the past, the development of knowledge of the disease of the circulating system, for example, has depended upon the use of the simple methods of auscultation and percussion; at the present it is bound up with the use of the electrocardiogram, the polysphygmogram and the skiagram, and in the future it will undoubtedly be largely dependent upon methods which will be born and cradled in the physiological laboratories. Every man trained in the right atmosphere becomes a potential contributor to the advancement of clinical knowledge.

In order to carry out these ideals in the teaching of medicine, it is necessary to provide courses such as experimental pharmacology and so-called experimental medicine, in which the more purely physiological experiment is modified so as to show how its results can be used in the investigation of disease. By giving pharmacology in the third year of the medical course, and experimental medicine in the fourth, the difficulty that the student will disregard the scientific aspect of medical practise is much lessened.

In this discussion it should be pointed out that the term physiology is employed in the broad sense under which it was defined at the outset, that is: it includes the physical, the purely biological and the chemical phenomena of life.

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ACCIDENTS IN COAL MINES

THE lack of comparable and accurate statistics of coal-mine accidents in the United States has led the Bureau of Mines to collect such data, and the results of these investigations have been compiled by Mr. F. W. Horton, in Bulletin No. 69, entitled "Coal Mine Accidents in the United States and Foreign Countries," which has just been issued. This report shows that during 1912, 2,360 men were killed in the coal mines in the United States as compared with 2,719 for 1911, and that the fatality rate was lowered from 3.73 in 1911, to 3.15 per 1,000 men employed in 1912. The report contains statistical information concerning the production, the number of men employed and the number of men killed in each state since 1896. From 1896 to 1907 the number of men