PHYSICS FOR THE PRE-MEDIC STUDENT.

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The time has passed when an argument for the position of physics in the pre-medic curriculum deserves a place on any program. That question has long since been settled. But the kind of physics to be taught may still be discussed with profit.

Since my first class of pre-medic students, I have been more and more of the opinion that the subject should be presented to them in a far different way than to a class of engineers. This notion was strengthened when I took a review course at the University in a class composed of pre-medics, and noted their reactions to the subject and to the method of presentation. The subject did not interest them for they saw no possible means of connecting it with their future work. The method of presentation antagonized them, for it was so different from the method of approach used in the sciences they had already studied that they could not easily orient themselves.

But when I broached to my fellow teachers the idea that pre-medics should be taught in a class by themselves and given a modified course, it was immediately assumed that "modified" meant "weakened" and the idea vigorously opposed. I am glad to think that opposition is much less pronounced now.

That medical students dislike the dose we are supposed to hand them is quite understandable if we consider the vehicle in which the drug is administered. The traditional course in physics grew up in connection with the study of engineering problems, and in the continual effort to make it interesting, illustrations, problems and applications were drawn from engineering work. What wonder that men looking forward to a study of the most intricate piece of mechanism known should fail to get enthusiastic over equations and diagrams and laws whose only application, as far as they were shown, was to inanimate assemblages of leather, wood and metal? Long after the principle of transfer of training had been discredited by psychologists, we continued to base our training upon it, and to assume that the man who had learned to use levers in the laboratory could, years afterward, calculate the strain on the gastrocnemial muscle. I could cite absurd solutions of this very problem in standard college physiologies to show the error of this assumption.

Let us admit at once that the teacher of physics should teach physics. He should not teach an emasculated subject, nor selected topics only. He should not attempt to teach physiology. But he should be familiar enough with a good modern textbook of physiology to get from it abundant illustrative material for the subject he is teaching. It goes without saying that without interest on the part of the student nothing will be taught. And the one thing that the medical student is interested in above all others is the functioning of the animal body. Why not vivify the study of physics, then, by calling his attention to the debt he will be under, as he goes on with his medical course, to the work of the physicists? To mention only a few items: the microscope, the cystoscope, the opthalmoscope, the electrocardiagraph, the X-ray tube as a diagnostic and a therapeutic agent, the use of radium, the knowledge of the mechanics of the circulation of the blood, the interpretation of the sounds detected by auscultation and percussion, etc. etc. Nor is the account all on one side. The contributions to the science of physics made by practicing physicians may well be a matter of pride to those of that profession. The work of Dr. Mayer, who first stated the law of the Conservation of Energy as of general application, and of Young, who dared to give evidence for the wave theory of light in the teeth of the authority of such a master mind as Newton's, are only two of several cases that might be mentioned.

Do not be bound, then, by traditional methods of presentation. If pre-medical students listen to your discussion of the stresses and strains in a roof truss, it is because of their politeness or because they can't get away. But show them a diagram of the compression system of trabeculae in the head of the thigh bone, and point out their arrangement to take up the stresses with a maximum of rigidity and a minimum of material, and see their eyes light up. Instead of questions about lifting barrels of sugar, get your problems from the muscles and bones. The engineer must be able to calculate the horse-power and efficiency of the engine that can lift a long ton of coal from the 900 foot level in one minute, but the same principles are used in getting the power and efficiency of a 200 pound man climbing a flight of stairs. Then let your students figure out how much glycogen must be converted to lactic acid by this effort, and you will have 100% of efforts, if not of accuracy. But is the latter so very important, if you really get the interest aroused, and the principles impressed so that they will be remembered?

When we come to the study of heat, how rich the supply of illustrative material! Do they know that the Fahrenheit scale is a development from that on one of the primitive thermometers, which divide the difference of temperature between the (supposed) temperature of the human body and that of freezing water into ninety-six steps and that it was only later that the temperature of boiling water was found to be constant at 212 of these steps above that of a mixture of snow and ammonium chloride, supposed to be the coldest thing possible, which, in turn, was thirty-two of these steps below the freezing point of water? Are you teaching Charles' Law? How much greater is the volume of expired than of inspired air on a winter day? Calorimetric problems involving the different kinds of food materials are innumerable. Diathermy is coming to be of immense importance in therapeutics. When the students realize that heat may be applied as heat itself,—as radiant energy, to be converted into heat at greater or less depths below the surface dependent on the wave length of the "light" used,—or as high frequency electric currents which become heat at the points of greatest resistance, namely: at the surfaces of the cells, they will have a knowledge of the convertibility of energy meaning much more than that which they would ever get by problems on the combustion of fuel in a power plant. Again, Atwater has proved that a man at rest must be supplied with 2700 large Calories daily, while a man at hard labor needs 4500 Calories. If we may assume that the difference is all converted into work, how many joules of work are done, and what is the efficiency of the man as a machine. McKendrick, in another series of experiments, measured the heat produced in twenty-four hours as 3724 Calories and estimated the work done by the heart, by respiration, and by muscles as 3.11×10^{11} joules. By how many per cent did his estimate differ from the second one given by Atwater? Once more. The combustion value of protein is 5.754 Calories per gram. But one-third of a gram of urea, combustion value 2.5 Calories per gram, is excreted for each gram of protein ingested. What then is the efficiency of protein as an energy producer, assuming, which is not quite the case, that all the nitrogen is excreted as urea?

What about the Second Law of Thermodynamics? Well, when they have learned that the maximum efficiency of the ideal heat engine is given by the ratio dT/T, where T is the absolute temperature of the heated stuff, and dT is the drop in temperature, ask them to calculate the necessary initial temperature if, as is the case with the muscles, 25% of the energy supplied is converted into work, and the final temperature is 37° C. It will be evident that the potential energy of the food is converted into work through some other intermediary than heat. The fact that CO_2 is not produced *during* contraction but afterward, and that most of the heat is produced after contraction, verifies this supposition. Furthermore, the possible work that a muscle can do is proportional, not to its volume, as we should expect if its activity were due to a chemical change, but to its surface. To this I refer later.

In the case of the study of sound, is there any good reason why a model of the larynx rather than the violin should not be used to teach the principles of vibrating strings? A violin or sonometer simpler, you say? Possibly, but remember, no matter how simple an illustration may be it is valueless if uninteresting. And Helmholz's work with resonators in the analysis of the vowel sounds is certainly as valuable and instructive as the physics of the wind instruments. The ear is an organ deserving study, and full of possibilities for teaching the science of sound.

The study of light should be so fascinating to the medical student that the subject teaches itself. Illumination? Make it a study of the foot-candles required in different occupations in order to avoid eye-strain. Diffused reflection? Again, a matter of eye-health. Concave mirrors? Study the opthalmoscope. Refraction? Lenses? The eye, its defects and their correction will give you every reason for going into the subject as deeply as you desire. The crystalline lens offers a splendid chance for a discussion of spherical aberration, since its peculiar structure reduces this to a minimum. Show your students why. Give more attention to the microscope your students are using than to the telescope they may never see. Look at a catalogue of microscopes. Do your students understand the terms well enough to judge which of two instruments there described is better value for the price? If you want a knowledge of diffraction to stay with them after they have left your class, show them how diffraction limits the magnifying power of the microscope to not much more than that reached at present.

Don't forget that polarized light is useful for many other things than the examination of sugars. Show them a picture of how a contracted muscle fiber looks in polarized light and in ordinary light. The laboratory should own a good polariscope. Two of my old students came back from their examinations in medical college to tell me how a remembrance of what they had learned about polarization had saved them on two important questions.

Absorption spectra can be taught as easily by reference to those of the blood and other body fluids as by the Fraunhofer lines. A solution of chlorophyll shows a good absorption band. Explain that the particular wave lengths absorbed are particularly effective in the decomposition of CO_2 and the synthesis of starch, and you have again impressed the convertibility of energy upon their minds.

When we come to the subject of electricity, there is a multitude of applications that will be meaningful to the pre-medical student where the illustrations ordinarily used will soon be forgotten. When teaching the different means of producing a potential difference, why not mention that the cut end of a nerve or muscle is negative as compared with the uninjured portion. And if the student is told that the propagation of a nerve impulse is accompanied by a wave of negative electrons, traveling at the rate of 120 meters per second or less, probably produced, as Dr. Gerhard of the University of Chicago thinks, by an explosive oxidation as in a fuse, his interest is immediately stimulated. He is not likely afterwards, to be satisfied with the careless statement that the nerve impulse is electrical in its nature, and lazily identify it with an electrical current.

Dr. Hugo Frick says that the film which surrounds the blood corpuscle is 4×10^{-11} centimeters thick, and has an electrical capacity of 0.8 microfarads per square centimeter, varying in health and disease. It has been proved that the capacity and conductivity of a tumour varies with its malignancy. Will a medical student be willing to study electrical resistance and capacity after hearing this? If he will not, it will be perfectly advisable to flunk him for he will never get through a medical course. The illustrative material from the physiological processes and from the methods of the physiological laboratories is so abundant that books have been written on Medical Electricity.

The ordinary laboratory is provided with a variety of galvanometers, the working of which the student is supposed to understand. But how many students have ever seen a string galvanometer, or a capillary electrometer, which are so important in physiological investigations, or will be able to understand them when he meets them in his advanced work. Time spent in studying instruments useful only to the engineer to the exclusion of instruments used in his own work would not seem to be the best use of the limited time for the subject.

Beyond all these topics mentioned, however, there remains something more to be said. There is one section of physics usually neglected or at best very briefly treated, that is of so much importance that in order to give it some attention, I believe we might seriously consider the omission of some things usually included in an engineering course. I refer to the physics of colloids, and to the subject of surface energy, including osmotic pressure, all of these being rather closely connected in physiological processes. These are difficult subjects, and new subjects, so that it is not easy to find material in such shape that without preparation it can safely be fed to sophomore students. But the body is a mass of colloids, and as soon as he opens his physiology he begins to read about them. The whole process of food assimilation seems to consist in changing from colloids of one kind to another, or from particles of one size to another, thus changing the surface energy. Probably chemical energy is rendered available as muscular energy with surface energy as an intermediary form. Again, the elements of the digested food get about from one organ of the body to another by osmosis, and not by any simple osmosis at that. It is sometimes an osmosis of molecules, sometimes of positive ions, sometimes of negative ions. The electrical charge on the separating membrane is often a factor of importance. It would seem as if the medical student should have a general knowledge of these topics before he is thrown into a situation where a familiarity with them is assumed. With this exception, however, I can see no reason why the pre-medic should not, in the main, study the same physics as his brother in the engineering course. But he should be in a class by himself, and his course should be enriched by illustrations drawn from his own field; not, as I have said, to teach him physiology, any more than the problems his brother wrestles with are to teach *him* bridge-building, or mining, or electrical engineering, but really to teach him physics, in such a way that he may see its value, get a love for it, and remember a modicum of its principles for use in his future work.