ADDING *LIFE* TO

PHYSICAL PRINCIPLES have always played a basic role in the processes of living. In particular they have provided the framework of physical medicine, and also of medical practice in general. In spite of this, physics only recently has become recognized as the basic science for courses in biology and medicine, and has won its place as a cultural subject as well. The failure of physics to gain general appreciation earlier in these fields was not due to any limitations of physics. On the contrary, it was a result of a number of factors and circumstances of which the following were among the more important. The earlier outstanding and obvious successes achieved by physics in the rapidly expanding mechanical world diverted the attention of physicists from the less apparent part being played by their science in biology and in medicine. There could be no doubt as to the importance of the applications of physics in engineering or as to the place of physics in the curriculum of a school of engineering. It was obviously a useful subject for any person to study as a part of his preparation to live in what came to be called the mechanical age. It followed quite naturally that the authors of textbooks in physics should draw their illustrative material largely from the engineering fields, since it was a required subject in all types of courses in engineering. For students in such courses the illustrations were interesting and quite appropriate, but they did leave the students in other fields with the feeling that physics, if not beyond them, was certainly not for them.

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As might be expected, physics texts for high school students were written for the most part along the same lines, since the authors were generally men who had made names for themselves in college or university circles. But texts of the engineering slant were even less suitable at the lower levels. It is, therefore, easy to see why physics was not a popular subject among high school students where its difficulties were far more widely stressed than its values were appreciated. All this helps one to understand the antipathy towards physics so many of the students had even when entering the universities.

For physics a new day has dawned, thanks to the great diversification in the work of physicists. The recent outstanding accomplishments attained by them in electronics, nuclear studies, and in giving biology and medicine new instruments and discoveries, has brought about universal recognition and enhanced appreciation of the important part played by physics. Indeed, physicists have attained prominence on the international political scene, and leadership in physics is considered a distinct national advantage. Certainly physics is no longer looked upon as merely a science basic to the training of engineers and of importance in only engineering projects.

Perhaps the most significant expansions of the subject have been in the biological and medical fields. The tools of the biologist are largely instruments developed by physicists and are based on physical principles. The optics and the form of the microscope fit it quite as well to the needs of the biologist, the physician, the chemist, or the geologist, as it meets the requirements of the physicist. The development of the electron microscope greatly extended the frontiers of the biologist and has made it possible not only to view for the first time viruses and other particles of practically molecular dimensions, but through the new knowledge gained thereby to make direct and successful attacks on many medical problems which previously baffled all attempts at solution. For example, the study of "brain waves", so important in the diagnosis of many nerve or mental disorders, has only comparatively recently become really practicable. Their existence was detected eighty years ago and the development of the string galvanometer early in the present century made possible a

PHYSICS

A new day has dawned for physics, says the author of this article, thanks to increased application of physical principles in other scientific and technical fields.

By ***E. L. Harrington***

limited study of their form. But it was not until about twenty years ago that special electronic instruments, known as electroencephalographs, made it possible to obtain tracings of sufficient detail to be of great use medically. These two examples should make clear the meaning of these statements by Glasser in his introduction to *Medical Physics:* ". . . although recent developments in modern medicine have led to a steadily increasing recognition of physics as one of the essential substructures of modern medicine, the fact is that progress in biology and medicine has always been significantly related to advances in physics." The second statement is even stronger: ". . . physics has supplied instruments and methods of measurement that have led to many discoveries in physiology and medicine, and the methods of physical research have revolutionized many of the older approaches to the biologic sciences." The modern investigator in one of these sciences may be quite as conversant with the use of an electronic amplifier as the physicist.

Even apart from the more specialized applications of physics in medical practice or in biological research, the student in the laboratories of these sciences meets again physical equipment with which he should have become familiar in a physics laboratory. Motors, levers, manometers, lamps, lenses, meters, induction coils, and the like make the physiology laboratory resemble one in physics, and they certainly operate on the same principles whatever the name of the laboratory.

In spite of this close resemblance of the laboratories, the lectures in physics given to classes a few decades ago did little to prepare the student for his biological or medical sciences, or even for the understanding of vital processes within his own body. A few illustrations should make this point clear. Practically all texts in general physics deal with the combination of forces and their moments, and very appropriately include diagrams of levers, derricks, bridges, and so on. Few of these are likely to become important to the student unless he becomes an engineer, and certainly the magnitudes of the forces suggested in the problems mean little to him. Most texts included a diagram of the levers of the arm. This was a good start since the weights lifted could be kept in line with experience, and since the concept incidentally recognized the suitability of biological applications of physical principles. But applications to the foot were less likely to appear, and the budding medico was never led to suspect that the force in an ankle joint when a person tiptoes on one foot easily may amount to six or eight hundred pounds. Such a fact should help him to understand why the area of contact in this, as well as in other joints subject to large forces, must be large. The pains characteristic of arthritis in the shoulder are easier for both the patient and the physician to understand and to deal with if they realize that lifting the arm to a horizontal position may involve a thrust in the joint of the order of a hundred pounds, much more if the hand supports a weight. Consider the total moment exerted by the muscles of the back about a point in the back—say the fifth lumbar vertebra. It must be equal to the sum of the moments exerted about the same axis by the weights of the trunk of the body, the head, the arms, and of any masses they may support. Calculations, involving reasonable and typical values, show that this vertebra often may be called upon to withstand forces of the order of eight hundred pounds. Applying the same principles, one may demonstrate the great importance of proper posture and of avoiding excessive overweight in the matter of body forces and therefore of health. Such applications are quite as useful in the illustrating of physical principles as those borrowed from engineering and they are far more interesting, even to the engineer.

Another group of familiar and equally interesting applications has to do with pressure beneath the surface of a liquid. A student might succeed in finding the pressure in a tank of brine at a point five feet below its surface, given the specific gravity of the brine, but he could just as easily find the pressure of a five-foot column of blood if given its specific gravity. The latter would help to fix exactly the same principles, but would be of more enduring interest. Archimedes' principle is always included in a course in general physics. The student learns to connect this principle with a ship floating in an ocean, or with the loss in apparent weight of a stone suspended in some liquid. His interest would be deepened if it were pointed out to him that his blood corpuscles profit by the same sort of buoyant effect, and that his brain is mainly supported by the buoyant effect of the cerobrospinal fluid in which it is immersed. It is important to know that the fetus is completely supported and protected against shocks by the amniotic fluid. In this it therefore has great freedom of movement as well as insurance against the shocks which it certainly would experience in the absence of such support. One who understands Archimedes' principle will readily appreciate the advantage to the arthritic patient, mentioned in the previous paragraph, of having his arm immersed while exercising it, an advantage characteristic of hydrotherapy generally. Archimedes' principle, thus vitalized, is ever so much more interesting than it could be to the student who can associate it with only a distant ship.

In hydrodynamics one may be concerned with viscosity, specific gravity, velocity, tube diameters, vertical depths, and the like, and the ordinary waterworks of a city may provide suitable material for the purpose of illustrating the principles involved. But the student will be more interested in learning that the circulatory system of the body provides an additional illustration of almost every principle concerned in the water system. An understanding of the importance of these principles with respect to the work required of the heart might go far in preparing the future physician to deal intelligently with this increasingly important problem, and the general student for helpful cooperation with his doctor, later. The principles are important and of educational value whatever the applications made, for they are identical.

In a similar manner one might go on through the various divisions of physics and find an abundance of illustrative material which might be added to or in part substituted for some of the material traditionally included in a course in general physics. A course, thus enriched, is just as truly a course in general physics as is the more conventional one. Fortunately there is a promising trend towards including more material of the sort mentioned above. Strange as it may seem, the majority of both physicists and medical men, thirty or forty years ago, were opposed to the use of medical and biological applications in physics classes. The former felt that "physics is physics" and the latter wished to reserve for themselves the medical applications. Actually the former were poorly informed as to biological illustrations of physical principles, and the latter lacked confidence in their grasp of these principles as such. In strong contrast, physicists in more recent times have shown a rapidly increasing interest in the broader applications of their science and in their meetings are manifesting a lively interest in the present trend towards a more extensive use of medical material.

A certain general text published little more than twenty years ago by a top-rank physicist in a leading American university, called attention to only four biological applications. At the present time the same university provides a course rich in such material. Two of the recently published texts contain not only many times as many such applications but also problems related to them. For some years the writer has been developing a course which progressively included more and more of such material. While at first only premedical students were in mind, experience showed that the student in Arts and Science found the course just as useful as a general course and far more interesting than the traditional type. In his lectures the writer tended to restrict the use of such material to those topics for which he happened to be familiar with suitable applications, just as most lecturers do. But when he undertook the preparation of a general text (*General College Physics*, now in press, D. Van Nostrand Co., Inc.) which would consistently keep the newer point of view before the student, he was gratified, if not surprised, to find that there was hardly a chapter for which some suitable biological applications could not be found and included along with many of the more conventional type.

Actually the problem of securing the material discussed above is becoming much easier. The richest single source is the two-volume compendium on *Medical Physics*, edited by Dr. O. Glasser (Year Book Publishers, Inc.) but written by several hundred contributors selected on the basis of their special interests. There are books on physical therapy, electrotherapy, and radiology, and the like, as well as texts on anatomy and on physiology written by authors who were aware of the physical aspects and implications of their material. Recently books and periodicals dealing with the new radioactive-tracer work have appeared. With such material at hand and a suitable text, there is little to hinder the professor of physics from introducing, to any extent he cares to, applications related to living bodies. By so modifying his course, he can make physics more vitally interesting to both the general student and to the premedical or predental student. The change can be made without materially modifying the laboratory work, since the same principles are presented. Abundant evidence is now at hand that medical students who have had a course of the type described, do carry over into their medical sciences and the clinical work and also into later practice a competence in using physical principles that is gratifying to both the physicists and the students.

Before closing this discussion, attention should be called to the rapid increase in the number of universities establishing departments of biophysics. While the nature of the work covered has not yet acquired any uniformity among universities it must be obvious that a proper appreciation of physics and its applications to problems in biology and medicine is as essential to a student undertaking work in biophysics as is organic chemistry to one going into biochemistry. Those undertaking medical research similarly have need of a suitable foundational course in physics.

Looking to the future it is gratifying to observe that physicists in the newer fields of nuclear physics are rapidly gaining an awareness of the biological and medical implications of the developments in their branch of physics.