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Why Biophysics?

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The title chosen for this article, "Why biophysics?," suggests an inquiry into what role a particular branch of science, one which only recently acquired a name and personality, can play in medical progress and practice. Looking through the titles of this series (*Lectures on the Scientific Basis of Medicine*) in the last 5 years one finds that, whereas a large proportion are obviously derived from physiology or biochemistry, very few could reasonably be called biophysics—even if one includes a lecture by the president of the Royal College of Physicians on "Mind and matter"! This is natural and proper, for physics hitherto has not had the same intimate connection with medicine that physiology and chemistry have had: its applications have rather been to engineering, while its ideas have been derived not at all from biology but from mathematics, astronomy, and philosophy. It is true that physical ideas and physical instruments and methods are fundamental to nearly all fields of science; but it is only in recent times that separate branches of physics have been recognized in which the primary object was not physics itself but some other subject—for example, astrophysics aiming at the problems of astronomy, geophysics at those of the earth, physical chemistry at those of chemistry, and now biophysics at those of biology. Chemistry also has proliferated—into geochemistry, biochemistry, and a host of practical applications, the object of which is not the solving of purely chemical problems but the use of chemical ideas and methods for understanding, or doing, something else.

Biophysics is a newcomer; so was biochemistry 40 to 50 years ago. This does not mean that chemistry was not applied to biology and medicine long before, in fact chemistry and medicine grew up together; but it does mean that biochemistry began clearly to emerge as a separate and independent discipline, with its own ideas and methods, early in this century. It is unnecessary to insist that biochemistry is not just chemistry; to take the biological idea out of it would be like depriving a man, not of his clothes, but of his skin—he might be an interesting object of study, but he would cease to be a man. In the same way biophysics is not just physics, but a sturdy and promising child of physics and biology which has set out on the same road of independence as biochemistry did 40 or 50 years ago.

The idea of function, of organization, of design, is an essential part of biology as it is of engineering; in physics and chemistry, apart from their applications which are really engineering, it is meaningless. Whatever his philosophical or theological views, it is sensible and expedient for a physiologist, using that term in the wider sense, when investigating an organ, a structure, a response or an adaptation, to ask what its functional significance is, its relation to other parts of the machinery, its purpose in connection with behavior, survival, or inheritance. If his conscience, or his politics, forbids that much teleology, he had better take up something else; for in biology he will miss most of what is interesting. The biochemist is not merely a chemist working at the chemistry of material that was once alive or was produced by living activity; he is primarily concerned with processes that go on within the living organism and their dynamic connections with function or behavior. The comparative study of animals from the functional standpoint turns up innumerable examples of what any engineer, faced with them, would assume to be highly competent design—and botanists surely would insist that the same is true of plants. After all, evolution has been at work for a very long time, and we cannot neglect its consequences.

What Is Biophysics?

The term *biophysics* is coming today into common use, but as yet no clear definition of it has emerged. The emphasis must clearly be on the *bio*, on function and structure viewed through physical spectacles and investigated by physical ideas and methods. The word *definition* implies setting limits, and it is convenient to start defining biophysics by reciting many things which it is not. One thing it clearly is not is a second-rate branch of physics, a haven of refuge for indifferent physicists. It does not consist of teaching physics to medical students. It is just as unsuited—and some may think this a hard saying—to people who know no biology as to those who know no physics. It does not consist of constructing, or maintaining, physical equipment for use by anatomists, biochemists, physiologists, or clinicians. The employment of physical instruments in a biological laboratory does not make one a biophysicist—otherwise any user of a microscope, a balance, an x-ray equipment, a Geiger counter, or a pH meter, would drop automatically into that class. The crystallography of material of biological origin is not in itself biophysics, any more than organic chemistry is biochemistry. Using amplifying values or radioisotopes, or working on muscles and nerves, does not confer any biophysical status. It all depends on the motive, on the idea, on the method and manner of approach.

Science does not operate only in separate compartments of knowledge, and many of the best discoveries emerge from

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the borderland between several of them. One reason, however, for adopting a new name or inventing a new organization may be to find room for people whose special knowledge or talents cannot fit into the accepted scheme. The growth and recognition of biochemistry made it possible for people trained first in the discipline of chemistry to work in the biological field, on equal terms with those coming from medicine or biology. Few of these would have found a home and opportunity in laboratories of physiology, anatomy, pharmacology, or pathology, where most appointments were by tradition, and still are, reserved for medical graduates. Few of them could have established themselves in laboratories of zoology or botany, the scale and scope of which were usually too small. In the end it was better so, for biochemistry has emerged as an adult subject, asking nobody's leave to work at any of the problems of biology by chemical methods and with chemical ideas. Today, 40 to 50 years later, the same course is being followed by biophysics.

For some time now, and particularly since the recent war, an important number of young physicists have got hold of the notion that some of the most fruitful outlets for physical ideas and methods are likely to be found in biology. Perhaps this is partly due to a reaction against the aggressive dominance of nuclear physics and a reluctance to become a cog in that particular machine; partly, I am sure, it has been that biophysics offered scope to adventurous and adaptable minds. Another reason, probably, was the resource and initiative with which many young biologists mixed up with physicists, in telecommunications and in operational research, and the like, during the war.

In biology one has to live by one's wits, competing as in a game with living material which is always to some degree unpredictable; one does not have to go humbly to a theoretical biologist to plan the strategy of one's research. This tends to produce a quick response to the unexpected—which is useful in war and very often in research. Contact with such people may have given some young physicists an impression that biology, after all, can be quite a respectable subject, with many exciting problems waiting to be tackled by new and adventurous methods. It has even come about that eminent professional physicists are ready today to admit the interest and difficulty of biological problems and the intellectual and experimental skill required for tackling them. That was not always so, and again the analogy with biochemistry is apt.

At one time the professional chemist was likely to regard biochemistry as a nasty messy subject, not worthy of his distinguished attention. Today many of the leaders of chemistry are working in fields that verge on biochemistry—indeed to such an extent that some of them would like to appropriate the subject as their own, and biochemists have had obstinately to maintain their identity against the acquisitive dominance of chemistry. Out of the frying pan into the fire might have been the fate of biochemistry when it got away from physiology.

For many years physicists and mathematicians have been among my closest friends, and one of my functions has been to keep them humble by reminding them now and then that other subjects than theirs are intellectually quite as respectable, experimentally much more difficult, and generally far more amusing. The simplified problems of physics require only a small part of one's thinking apparatus, used no doubt very intensively; those of biology demand a much greater share of one's resources. Today my friends are more respectful; naturally they do not like their best pupils leaving them to go off into biophysics, but at least they do not regard such defection as an irretrievable disaster to science!

It would be a damaging mistake, however, to suppose that physics, in the narrower sense, is the only partner of biology in the new field of biophysics. Most vital processes take place in an aqueous medium, in which chemists are much more at home than physicists. There is no sharp boundary between chemistry and physics, nor should there be between biochemistry and biophysics. The natural division, in general, would be for biological problems involving physical chemistry to be drawn toward biophysics, as those involving organic chemistry would go to biochemistry. The physical chemists who turn over to biophysics may be expected to make at least as great a contribution as the physicists proper. With nuclear physics, as such, which tends at present to dominate physics, biology is little concerned. Biological processes are based on molecular change, and only to the extent that the chemistry of molecules is determined or affected by the physics of their atoms does the latter impinge directly on the interests of biologists. Indirectly, of course, by the tools it provides and the effects of its products, nuclear physics is of the greatest concern to biologists—as it is to everybody; but the fact remains that vital processes themselves, to an overwhelming extent, are more of a chemical, or a physicochemical, than of a purely physical character. Indeed, without physical chemistry as an essential component in its make-up, biophysics would have little reason for a separate existence.

Twenty-four years ago I addressed a gathering in Philadelphia, at the opening of a new laboratory of Medical Physics, of which my friend D. W. Bronk was head. Much good work, largely of a new scientific flavor, has come from that laboratory. Twenty years later I took part in the opening at Johns Hopkins University of another new laboratory of biophysics, also organized by Bronk. In the United States today there are many departments of biophysics, not always under that title, in which physical ideas and methods are being applied to biological problems. The great developments of nuclear physics in America, as in England to a somewhat smaller extent, have led to a large expansion of what can be called radiobiology: this is aimed partly at the protection of the human body from the effects of radiation, partly at improvement of medical treatment, but partly also at solving the fundamental scientific problem of how radiation of various kinds affects living cells, their functioning and inheritance. This, however, is only one aspect of biophysics; another important one is the study of the minute structure of living cells, which is being pursued in America, for example, at F. O. Schmitt's laboratory at Massachusetts Institute of Technology, and in London in Randall's laboratory at King's College. Three years ago the first regular university department of biophysics in England was started at University College. But let nobody suppose that biophysics is being pursued only in such regular departments of the subject; far from it—there are individuals and groups working at it in many laboratories and centers, in England and other countries, under many titles.

It is not at all necessary that there should be departments of biophysics in every university—any more than there should be of biochemistry; the important thing is that a few such departments should be established, to act as nuclei for teaching and research and to give the subject a place on the map, a personality and status which will draw young people of the right kind into its pursuit. The process has started well and can be left to develop largely of itself, with sympathetic help but without too much overhead planning. One need not advocate, for example, that there should be an international union, or international congresses, of biophysics; it can safely find its scope, at least for a long time yet, within those of physiology, biology and biochemistry.

With all these qualifications about what biophysics is not, may I try to define what it is: as the study of biological function, organization, and structure by physical and physicochemical ideas and methods. There is nothing very interesting or original about that; except perhaps the fact that ideas are put first, for physical methods and instruments of every kind may be used in any field of research. Biological phenomena, like many others, show aspects and relations susceptible of physical analysis and interpretation. It is by the choice of problems and by the intellectual processes with which they are formulated and attacked, more than by the particular techniques employed, that a subject can be most clearly defined. There are people to whom physical intuitions came naturally, who can state a problem in physical terms, who can recognize physical relations when they turn up, who can express results in physical terms. These intellectual qualities, more than any special facility with physical instruments and methods, are essential to the make-up of a biophysicist. Equally essential, however, are the corresponding qualities, intuitions, and experience of the biologist. A physicist who cannot develop the biological approach, who has no curiosity about vital processes and functions, who is not willing to spend time in learning the habits of living things, who regards biology simply as a branch of physics has no important future in biophysics.

In speaking of the intellectual side of the physical approach to biology you must not suppose that I underrate the technical side or imagine that theoretical physics has more than an occasional role at present to play in biology. So far, indeed, from underestimating fine physical techniques applied with the skill and understanding that come from experience in handling living material, one would insist rather that progress is waiting on their application, and that biological literature is beset by the results of imperfect experimentation. I am urging only that the primary condition is the right intellectual approach. Granted this condition, achievement can come only by highly skilled and often laborious experiments, laborious because of the essential lability of the material. In such experiments the instruments and methods must often be adapted to the object investigated, so that the principles of their design and working must be understood. When one is dealing with units of extremely small size like living cells, personal skill becomes of primary importance. It cannot usually be replaced by statistical methods, important as these are in their proper place. The chief concern in the development of biophysics is that those skills should be acquired by people who start with the right intellectual approach, physical and biological.

Let us think for a moment how the process of investigation goes. In the function or structure to be studied, some factor is chosen which not only is open to physical description or attack by physical method but also, if so treated, may lead to unambiguous results. It is all too easy—and frequent—to make beautiful experiments which cannot, in any case, tell us anything, or perhaps may tell us about something in which we are not interested. I recall experiments that purported to measure the elasticity of muscle but gave in fact, rather inadequately, the constant of gravitation; others that were intended to verify a particular theory of colloid behavior really proved nothing except the second law of thermodynamics. It is all too easy to employ fashionable physical devices for purposes better achieved by simpler traditional methods. For example, some years ago, an old-fashioned gas regulator with a tapered jet was found to beat all the best electronic devices of its day for maintaining a constant temperature in a water bath.

The use of the latest physical methods and devices does not make one a physicist, and the employment of such things in a biological laboratory is not necessarily biophysics. The man who has physical ideas, who can see physical problems, who recognizes the opportunity of physical investigation when it turns up, who understands and can use physical techniques can find unlimited opportunity in biology, if—and it is a fundamental *if*—he is willing to learn something also of the facts and philosophy of biology, to be apprenticed for a time in a biological workshop. Some of the most accomplished contributors to what is really biophysics, though it may be practiced in laboratories under other names, started in fact as biologists; and a complete department of biophysics really requires both kinds—with a reasonable admixture of engineers!

Relation of Biophysics to Biochemistry

In one important respect the roles of biophysics and biochemistry are complementary. The single unit in biology, the living cell, is very small; the quantities involved in its processes are beyond the range of ordinary chemical measurement. It is necessary therefore to use large numbers of cells, similar as far as possible, and to accept a statistical blurring of the result. For biophysical purposes, however, it is frequently possible to use single cells and to examine the individual process, with the limitation always that most physical methods are chemically nonspecific, so that interpretation in chemical terms is bound to be indirect. In biochemistry, even accepting the necessity of working with a large number of cells, there are two further limitations; its methods are usually insensitive and very slow, and many of them require the destruction of the tissue for their application. The astonishing thing is that biochemistry has, in fact, been able to achieve so much. In comparison, the methods of biophysics may be very sensitive and rapid and often leave the tissue unaltered so that observation can be continued; but they are not applicable to all problems and—one must insist—they are nearly always chemically unspecific.

Let us illustrate the contrast between biochemistry and biophysics by the example of muscle. Here the fundamental unit of response is the single muscle twitch, a very rapid affair involving only a minute chemical change. Physical methods are available of high sensitivity and speed which can give a quantitative picture, practically simultaneous with the events themselves, of electrical, optical, mechanical, and thermal changes accompanying a twitch. Direct chemical methods, however, can tell us nothing; in order to get measurable quantities it is necessary to subject the muscle to a sequence of stimuli spread over a longer interval. If it were possible to assume that a single chemical process was involved in muscular activity, that it went in one direction only and was not rapidly reversed, one might calculate that the chemical effect of 40 twitches was simply 40 times the effect of one twitch. In fact, however, the finer details of the complex sequence of chemical events are confused by repeating the stimulus many times; only the final or semifinal effects are accumulated. To take a simple example, the immediate physiological and biochemical consequences of running 20 meters at top speed would not be discovered at all by making a man run 2 kilometers as fast as possible and dividing the observed changes by 100.

This difficulty of examining chemically the ultimate physiological events is widespread, in nerves, in muscles of all kinds, in the central nervous system, in all tissues in fact in which activity occurs in small discrete packets, rather than continuously. This still leaves available for biochemical study a variety of tissues in which activity is apparently continuous; but such tissues usually get into a steady state, in which the total metabolic effect over an interval is all that is measured; and the unraveling of intermediate processes has always been one of the greatest problems and has led to the greatest scientific achievements of biochemistry. In muscle, with its high rate of chemical turnover and the rapid changes and reversals involved in its unit of activity, our chemical knowledge has largely been derived from studies of isolated enzyme systems and chemical constituents. But this knowledge cannot be extrapolated backward, without confirmatory evidence, to describe the actual chemical events of contraction. Such evidence can come only from methods of much higher speed and sensitivity than chemical technique is yet endowed with.

But—let us admit it humbly—to attempt to solve the problem by physical methods alone would be just as fantastic. Ultimately the machinery itself is chemical in nature, the fuel it uses for its recovery process is chemical, the "acid" and the "plates" of its "accumulators" are chemical, the free energy of chemical change provides the mechanical work, and various enzymes prescribe the course of the reactions. No physical methods conceivably available could give us the specific chemical information required to solve the problem properly. It is natural and healthy that biochemist and biophysicist should tease each other sometimes about the limitations of the other's methods: but each should be keenly aware of the limitations of his own and seek the cooperation which alone can solve their common problems. And perhaps it would be wise for them both to reflect, when they think they have solved them, that the biologist can still point out that although they may have found out how the machinery works—if indeed they have—this is very far from answering the question of how it grew and developed, how it maintains and adjusts itself, how its design is so singularly well-adapted to the needs and purposes of its owner.

Philosophy of Biophysics

On that occasion in Philadelphia in 1930 I spoke on the rather cryptic title "The physical reasonableness of life"; it allowed me to expound a faith that no limit will be found at which the application of physical methods and ideas—and, of course, this implies chemical ones, too—will be forced to stop in the investigation of living processes. I was at pains to emphasize that this certainly does not imply that biology will finally become simply physics and chemistry—at least as one knows those subjects now; indeed, the boot is rather on the other leg, physics and chemistry have in the end a great deal to learn from biology, in their philosophy and ideas as well as in their opportunities for research.

It is obvious indeed, at least to those biologists who know something about the properties of the nervous system, that physical theories and concepts can have no absolute validity apart from the brains that conceive and use them; if they *can* be conceived by the brain, it seems most unlikely that their pattern is not conditioned, and to some degree determined, by the properties and machinery of that organ. What we know of the working of brain and nervous system is largely the result of the application of physical, particularly of electrical, methods; perhaps, in the future, communication theory will make its contribution, and that is a mathematical branch of engineering. But if we assume that a consistent theory of the natural world is ultimately possible, we have to admit that just as scientific instruments and engineering appliances are designed to fit the human senses and faculties that employ them, so scientific theories have to be made to fit the human brain that uses them.

My physical friends are often rather indignant at any such idea; they have been brought up to believe that their postulates have some virtuous kind of absolute reality. The history of science scarcely bears out so naive an assumption; and when we know more about the mechanism of the brain I think we shall begin to see how it determines the pattern of any physical theory which it is humanly possible to conceive. This expectation accompanies an uncompromising conviction that the methods and ideas of the physical sciences are an unconditional necessity for biological progress; but it is part of an equally firm conviction that biology is not in the least danger of being swamped or subjected in the process. Physics and chemistry will dominate biology only by becoming biology. We can live in hope of the future unification of biological and physical science—but need not fear at all the dreadful prospect that life will be explained away in terms of present-day physics and chemistry.

It would be possible to make a number of platitudinous remarks about physics as a necessary ingredient in the training of a modern physician. So far as these were true they would mostly be obvious, and if they were not obvious they would probably be false. The important thing to remember is that even medical students are human. In India in 1944, in reply to pressing invitations from Indian friends which I should have loved to accept, I had often to insist that even a physiologist cannot be in more than two places at once. A similar limitation applies to medical students.

A few years ago I was temporarily involved with the problem of load carrying by the infantry soldier. In given circumstances, for a given individual there is an optimum load. With much less he will march and fight better—for a time—but soon he will have no food and water to march on, no weapons or tools to fight with. With much more load, he will march and fight worse, however well fed and armed. It is the same with the modern medical student: the poor boy, or girl, has a terrible load to bear anyhow and if you pile too much upon him (there is no danger of giving too little) you will make him unable to do the educational equivalent of fighting, namely, to think, criticize, and discuss. For this reason, much as we should like him to know more physics, chemistry, and mathematics, more biology, physiology, and anatomy, before we let him loose on his clinical course—much indeed as we should prefer him also to know more of literature, philosophy, and sociology and to have a wider culture and experience—we must think of him, like the poor infantryman, as having an optimum load which it is improvident to exceed. This load, as with the soldier, has to be the same for all, so it must be within reason for the weaker individuals, which means that the stronger ones could carry more. The extra physics, or the extra biology, or the extra culture and experience, must be regarded as an extra for those who can bear that particular burden easily enough. We must in fact provide opportunities outside the regular curriculum for the more talented students to follow their natural bents. It would be the greatest misfortune if biophysics or biochemistry were to draw no recruits from medicine.

It needs no argument to show that physics and chemistry—or even mathematics in the special form of statistics—impinge every day on medicine and public health. It is essential that every physician should have this much acquaintance with them that he knows, first, where to turn for help, whether to technician, specialist, manufacturer, or librarian, and, second, and even more important, not to be taken in by magic masquerading as science. In every field of medical science, and of medicine, we are witnessing the impact of chemistry and physics: on ways of looking at things, on research, on diagnosis and treatment. Indeed, the very nature of our modern society, based as it is on engineering applications of the physical sciences, is bringing a host of new problems, as well as of methods and equipment, to human biology and medicine. Indeed, these applications of the physical sciences are providing some of the major problems which the world has now to face, problems which human biology and medicine can neglect only at their peril. The question is—what are we going to do about it, in connection with medical education? The last thing one would want to do is to overemphasize—as the public is apt to do—the place and importance of the physical sciences. We have to realize that the calling of the good physician requires every faculty of critical intelligence and knowledge, of sympathetic understanding, of skill and patience, that a human being can possess. In planning his education we must aim at a practicable optimum, not an impossible ideal, and this means a sensible compromise between all the things he has to learn and do, taking good care that he has time and energy enough left over to grow as well as to be planned.

For some years, though a very long time ago, I was responsible for teaching physiology to medical students, and I frequently asked myself—and they asked me—what was the good of this or that? Most of them would have little direct use for many of these things in later life. Might not time saved in such irrelevant studies allow them to acquire a little more personal skill in handling patients —which could serve them and the patients better. Such queries might seem particularly pertinent in respect of the physical sciences in the premedical curriculum. There are many answers to such a question, most of which are well known. It is unnecessary to emphasize that physics and chemistry are an essential background today to the biological sciences, that these are fundamental to medicine, or that physical and chemical methods of diagnosis and treatment make up a large part of modern medicine. One has, rather, to answer the objection that within the very limited load a medical student can bear there can be so little given him of each of these preliminary sciences, and that what he learns he soon forgets. Since we cannot expect him to be an expert in physics and chemistry, may not a little knowledge be a dangerous thing?

The answer I think is this, it depends on a property of the human mind, a property we all know, unconsciously perhaps, very well. Let me illustrate what I mean by personal experience. I learned quite a lot of mathematics at school and in my first 2 years at Cambridge, but I have steadily been forgetting it ever since. One's mathematical knowledge seems to have a half-life of about 3 years! But it really has not mattered much. In countless jobs I have had to do, not only in physiology or biophysics, mathematical ideas and methods have been wanted. Somewhere deep in the brain the memory has continued of what mathematical ideas feel like, of what sort of problems can be tackled by mathematical means, of how to state a problem in mathematical terms, of where to look, either in books or to people, for a solution of it. My actual knowledge of mathematics for many years has been contemptible—yet I know how much the mathematical approach continues to influence the pattern of my work. Forgive me for referring to a personal experience; I do so because it is not really personal at all but depends upon a general property of the mind. If a boy or girl has been brought up with the discipline of a mathematical, physical, and chemical stiffening to his scientific training, he will find, whatever he does and however much he forgets, that a method of thinking and acting, of criticizing and assessing facts and theories, is available to him without which much of the world is meaningless: not only of the physical but of the biological world, not only the world of our engineering environment but that of medicine, of social relationships, and of human behavior.

This sounds like a tall order, but I think it is true. It implies that mathematics and the physical sciences can provide a framework for the other sciences that are to follow; and they should be learned early. This means that scientific biology should come later, as I think it should, for scientific biology, as distinct from simple natural history, is more intelligible on a background of physical and chemical knowledge. Do not suppose that placing biology second in time means putting it second in importance. A certain amount of biology is an essential ingredient in education—even of a physicist, a politician, a parson, or an engineer! But in the case of a professional biologist—as a physician should be counted—it can be learned best if the mind is prepared already by a reasonable preliminary dose of the physical sciences. It is hard to convince a medical student when he is 20 that a course in elementary mathematics is a useful preliminary to medicine; at that stage, indeed, it probably is not! It should have come 6 or 7 years earlier. To some extent, and to a different time scale, the same is true of physics and chemistry. In a modern building the steel is no more important than the other constituents—but it is essential to put it in first.

Why Biophysics?

I have wandered from the title of this article in talking about physical science in the education of the future physician, but if biophysics is to make its contribution to medicine it is necessary that most physicians should have some idea at least of what it is about, while some physicians should have a pretty good idea. The ideas and methods of physics and of physical chemistry are being applied today and will increasingly be applied, not only directly to physical medicine and radiology, but to neurology, to the study of circulation, of respiration and excretion, and of the adjustment of the body to abnormal conditions of life and work. At longer range, moreover, they will be aimed at the fundamental problems of minute structure and organization, of the physical basis of growth and inheritance, of the ordered and organized sequence of chemical reactions in vital processes, of the means by which energy is supplied and directed to vital ends. It is inevitable today that most of the discoveries in such fields will be made by people who have not passed through the gateway of medicine; but the greatest good comes from mixing people up, so that research and development (to use an industrial term) in promising fields can be guided to practical ends. This implies that those whose ends are practical (and the aims of medicine, like those of engineering, are practical, however great their intellectual content) should be on terms of familiar equality with those whose moving force is scientific curiosity. It is necessary that each should know what the other is talking and thinking about. The physicists and the chemists must be acquainted with biology, the biologists (including the medical people) must know some physics and chemistry.

The chief answer, then, to the query "Why biophysics?" is that the recognition of biophysics as a special subject of study will emphasize the fact, and I think it is a fact, that the future of biology and medicine will increasingly require the application of physical and physicochemical ideas and methods. To give biophysics a name and personality, to endow it with a few centers where it can be specially practiced, to realize that its recognition implies much more than just mixing up biologists and physicists (good as that is) will draw in recruits to a science that in 20 years or so may have the same importance to biology and medicine as biochemistry has come to have today. I am content myself to have been a physiologist, but that was luck because Walter Morley Fletcher was my tutor at Cambridge. Others of like tastes, but without such good fortune, may not find their way in at all unless the road is open and given a distinctive name.