the paragraph devoted to the subject "Peritonitis" that "the patient must be kept under the influence of opiates for two days at least," we are a little apt to overlook many of the other merits of the volume.

A surprisingly large number of scientific workers are unable even to join a glass tube or make a T-piece that will not crack spontaneously, and it is to them that the *Handbook of Laboratory Glass-blowing*,¹¹ by Mr. BERNARD BOLAS, is addressed. A complete outline of the methods used in making commercial apparatus is not attempted, but by following its many valuable directions and hints the student should achieve increasing success in his efforts to manipulate glass in the laboratory.

¹¹ *A Handbook of Laboratory Glass-blowing*. By B. D. Bolas. With numerous diagrams in the text by N. Bolas. London: G. Routledge and Sons, Ltd. 1921. (Cr. 8vo, pp. 112; 17 figures. 3s. 6d. net.)

APPLIANCES AND PREPARATIONS.

An Anaesthetist's Screen.

DR. C. A. STIDSTON (Wolverhampton) writes: The following is the description of an anaesthetist's screen which I have recently devised. It consists of an upright tube 11 in. high, which can be screwed firmly on to any table; out of this telescopes a second tube 10 in. in length, on to which another tube 13 in. in length screws at right angles, and from the latter telescopes a fourth tube 21 in.

in length. By adjusting these tubes and their controlling screws in a vertical and horizontal direction a towel rail from 11 in. to 20 in. in height and 14 in. to 36 in. in length can be fixed at any angle across the patient's body.

While primarily intended for use in operations on the neck and chest under general anaesthesia, the screen can be used also for operations on all parts of the body below the head under local anaesthesia. The component parts are light in weight and pack easily into a small compass. The screen has been made by Messrs. Down Bros., St. Thomas's Street, Borough, S.E.

PHYSICAL SCIENCE AND THE LIVING ORGANISM.*

BY

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THIS lecture is meant to deal more with the general spirit than with the precise details of scientific methods applied to the problems of the living creature. Thirty or forty years ago a speaker on this subject might have tried to convince his audience of the advantages of a materialistic philosophy of life. If he had not done that, he would probably have "sided with the angels," and attempted to persuade them that the orthodox Christian faith was a sufficient account of the mysteries of life. It is only ten years ago that I attended a crowded lecture at Jena, in which William Ostwald the chemist, incited by Ernst Haeckel the biologist, reduced the whole world, conscious and unconscious, to manifestations and transformation of energy. Mine is a much humbler rôle. I shall not try to convince you that you and I are merely complicated systems of electrons, whirling away for a little while and in a moderately stable manner, on the road leading from the nothing whence we came to the nothing whither we go. I shall not attempt to mystify you, as Haeckel did our fathers, with the blessed

word "protoplasm." Neither shall I ask you to believe that the consciousness which we call *You* and *I* is merely an elaborate and convenient mechanism designed by natural selection to render our journey on that road a little longer and more comfortable, and our end less sudden. Nor shall I try to persuade you that intellect, goodness, beauty, and all the things that men strive after, are nothing but general relations of a physical universe, evolved somehow to secure the survival of the human species. Indeed, I want to persuade you of nothing more romantic than the advantages of exact scientific methods of studying the behaviour of the living creature.

The living creature is a very strange thing. Here it is in a physical, material, mechanical, chemical universe showing the most extreme dependence on physical conditions. It dies if it be frozen, or boiled, or deprived of food; it does not like strong acids, or ultra-violet light, or α rays, or trivalent positive ions; its properties depend to a most extraordinary degree on those of water; it conducts electricity; it obeys the laws of motion, of the conservation of energy, of the conservation of mass; and yet at the same time it shows, in its simplest forms, a complexity, an apparent purposefulness, an individuality, defying any physical hypothesis. One could treat a chemical theory of consciousness, or a physical theory of heredity, or a mechanical theory of intelligence, only one degree more seriously than the instruments recently designed by Mr. Edison for facilitating telephonic communication with the next world. And yet, deprive the brain of oxygen for a few seconds and consciousness is gone; remove the thyroid gland and a beautiful and intelligent child becomes a hideous imbecile; subject the egg-cell of some species to an appropriate salt solution and an individual will develop without a father. The absence of certain chemical bodies prepared inside the body by the thyroid gland, the lack of oxygen to carry on certain necessary combustions in the brain cells—both simple chemical changes—have obliterated the essential characters of the highest form of life. Wherever we look we find life in only one form, composed of compounds of hydrogen, oxygen, nitrogen, and carbon, living between certain narrow limits of temperature, giving out exactly as much energy as it takes in, dependent on the supply of foodstuffs from outside, exhibiting certain electrical properties, poisoned and destroyed by the most absurdly small doses of certain chemical substances. It is clear that the living creature does depend largely on purely physical factors. Largely, but how far?

Consider the case of heredity. The union of two cells starts off a developing organism, as small as a flea, or as large as a whale, in most respects very like its parents, but in some very unlike—a separate individual. We are so used to this recurrent miracle that most of us regard it as a commonplace; you would not regard me as speaking seriously if I said that I am daily amazed by the fact that the offspring of man is man, when it might have been an ox, an onion, or a tree. Consider all the complexity of a man—his elaborate physical body; his intricate, sentimental, adventurous mind; his extreme stupidity in examinations; the subtle inheritance of voice and manner, of colouring and movement, of aptitude of body and mind; all alike from one generation to another, yet with ever-varying individuality; all inherited through a little cell which bears to a tadpole the same relation as a second to a lifetime. Add to this the faculty of handing on the same characters to countless successive generations. Adopt the purely physical theory of life, and all future history is wrapped up in a little cell so small that you cannot see it at all without a microscope. It would seem inconceivable that any man should attempt to build a physical or chemical theory of inheritance.

Or, again, take the case of consciousness, our awareness of things, our conviction of free-will and self-determination, despite all the arguments of philosophers. Is it conceivable that the most ingenious designer of instruments could make a penny-in-the-slot machine possessing, even for a moment, this type of consciousness? And yet, apply a simple physical change—turn on the gas in his bedroom, give him a few milligrams of a salt with a positive trivalent ion, deprive him of oxygen, raise his temperature a few degrees, and all the elaboration, all the sentiment, all the stupidity in examinations, all the power of carrying on the inheritance, are gone. Where—if anywhere—does physics end, and where—if anywhere—do we come up

* A public lecture delivered at the University of Manchester.

against the fundamental biological and spiritual realities of life? I cannot answer that question, and all I shall try to do is to show that attempts to answer it are not profitless; indeed, that progress in the knowledge of the living creature comes largely, and will come mainly, from attempts to solve it by the methods and tools, mental and material, of the exact sciences. And remember that progress in our knowledge of the living creature means progress in medicine, in industry, in agriculture, in sociology, in all departments of life. Our ignorance of the living creature is very great, and we can overcome our ignorance, not by theoretical discussions, not by dogmatical assertions, not by ingenious hypotheses founded upon insufficient knowledge. Progress, in my opinion, will come mainly from tracing out in the living creature the consequences of the broader generalizations found to hold in the non-living world of the exact sciences, by the aid of the finer tools which they employ.

Physiology has three main functions—two very practical, one very philosophical. As the handmaid of medicine, and as the science of the behaviour of the normal living man, physiology has a great and practical part to play in national and social life. At the same time, however, physiology has its great intellectual part to play in attempting to describe the mechanisms underlying the manifestations of life; it is only this latter which we are discussing here. It may be asked what is meant by a mechanism, and how one would propose to study it. Before attempting to illustrate what I mean by a mechanism, let me give you a picture of a man as a community of a myriad living cells, each to some degree independent, each bound to the rest by ties of necessity, convenience, pride, comfort and inheritance. You—your personality as a whole—are the People, the Demos, the aggregate expression of the individual lives of all the little cells which make you up. You—your personality as a whole—express yourself more or less imperfectly by your representatives—the cells of your brain, meeting in parliament inside your skull. You—your personality as a whole—have a national pride and consciousness, expressed to some degree by your representatives. You decide, as a nation decides—goodness knows why!—to assault your neighbour. What happens? Your representatives, your government, the highly differentiated nerve cells of your cerebral cortex, interpreting your aggregate imperfectly expressed dislike of your neighbour, proceed to send a message to the various government departments—what we call the self-protective reflex centres (note that it is always self-protective)—ordering them to carry on. From that moment the War Office, the collection of reflex centres of the nervous system charged with “self-protection,” proceeds to take charge of all the movements and activities of the community. Various lower and more automatic centres are called into play—corresponding to the various branches of the General Staff; and, finally, we come down to the individual fighting unit—the private soldier, the muscle cell with its simple functions, depending upon orders received along the nerves for its co-ordinated activity.

Now suppose that a nation is involved in such an affray, and that a visitor from another world has arrived with the intention of studying the organization and habits of the human race—a visitor who has never seen a man before and has not the least idea what he is like. He would not be wise, I think, to walk straight into Parliament, or into the War Office, or, indeed, into the Senate of this University, in order to study the organization in its full complexity; he would be much wiser, I think, to seek out an individual citizen, or an individual soldier, and to make a preliminary study of the simple common man. Having gained a conception of the behaviour of the simple common man, his need of sleep, of beer and tobacco, of oxygen, of companionship, his prejudices and his enthusiasms, he would be better fortified to proceed to study the organization of the State as a whole; for, after all, the properties of the State depend upon those of its fundamental unit—man. Similarly the properties of man depend upon the properties of the little cells of which he is built up, and his behaviour is the aggregate expression of their behaviour. Now, what properties have these cells? The outward manifestations of their properties are exclusively physical—they move, they divide, they take in food and water, they absorb energy and they give out heat; presumably there is some

cause for all these manifestations, so we attribute a mechanism to a cell. The mechanism of a cell is the cause, the means, of the physical manifestations of the cell's activity. In talking of a mechanism inside a living cell, in talking of the mechanism of life, one is not affirming that life is nothing but mechanism; one is assuming—what is obvious—that many of the manifestations of life are physical, and that these physical manifestations must have a physical cause.

Let us consider shortly the properties of the living cell, the unit of which the community of the living man is made. The living cell is very small—a million million or so to a cubic inch—and it is necessary to employ a microscope to study its structure. It is so small that most physical methods cannot be applied to the single cell—we have to employ a large number of similar cells at a time. It is surrounded by a membrane possessing certain physical properties. It contains a nucleus concerned in some mysterious way with the continued existence of the cell and its power of subdivision. It requires food and oxygen; it gives out energy and CO_2 ; it needs salts and water; and it shows many highly specific chemical properties. Some cells—the cells of the green plant—can absorb the radiant energy of sunlight and store it as the chemical energy of oxygen and starch; without this property of taking up energy from the sunlight the world would be a dead world, with no possibility of life and thought. The cell obeys—so far as we know—all the physical and chemical laws governing our universe. And yet it shows a kind of independence, a degree of complexity, an apparent purposefulness, which makes it difficult to fit into any simple physical system. We know, of course, that science is still very young; the theory of relativity and modern views of electro-magnetic phenomena tend to show that all our simpler conceptions of time and space, the laws of motion, of the conservation of energy and mass, are only good first approximations to some more fundamental reality. To assert that present-day physics can supply an account of the behaviour of the living cell is simply to state what is obviously not true; but will physical science ever be able to supply such an account? In the last resort I believe it will not. This, I admit, is only a belief and not based upon definite scientific evidence. In the last resort, however, I believe it will be found that the living cell, or some arrangement of atoms containing the same kind of purposive, selective properties, has existed as long as matter, that it cannot originate from matter alone, but always had another cell before it, and that in some kind of way, and to some degree, the spiritual nature of the universe is reflected in the behaviour, the life and structure of the living cell.

One function—the chief function—of science is the discovery and formulation of exact laws. Do not imagine that the so-called exact sciences have a monopoly of exactly obeyed laws. Biology, the science of the living creature, has several laws to which no exception has been found. Every living cell comes from a living cell: the offspring resembles the parent: all living creatures appear to have originated from some common stock in the very distant past: every organ has a counterpart in other types and species: certain characteristics are inherited according to exact mathematical rules discovered by Mendel and amplified by Bateson. These generalizations have the same dignity as the conservation of energy or the laws of motion. One side of the work of the biologist is to trace out and establish these generalizations of biology by the methods of biology, by the observation of the behaviour of living cells, their ways, their inheritance, their abnormalities. The task of the physicist and chemist, on the other hand, is to elucidate the general principles underlying the phenomena of the non-living world. The function of the physiologist lies between these two, to judge between the physical and the biological laws, to see how far the methods and generalizations of physical science can describe the phenomena of life, and how far it is necessary to invoke other laws—biological or psychological in nature but established like the former by careful and exact observation—to describe them.

I have purposely discussed so far the philosophical, the strictly scientific, side of the subject. The first duty of a university is to encourage the pursuit of knowledge, and knowledge can never be pursued profitably except by those who are primarily interested in knowledge for its own

sake. The "get-rich-quick" attitude will never work in science. Do not let me be misunderstood; I should be the last to discourage the useful applications of science or those whose interest lies primarily in such applications; I hold strongly to the belief that a knowledge of the theories and applications of science is a necessary part of any liberal education, and I feel that such applications—if wisely and cautiously made—are an essential element in the progress of mankind. What I do wish to emphasize, however, is the fact that science will become sterile if we eliminate those—comparatively few—whose interest is primarily in the acquisition rather than in the application of knowledge. Those who need the encouragement and stimulus of a great university most are those who are in the firing line of the army which is promoting knowledge; without the units of the firing line the army cannot progress, necessary indeed as are those who follow behind to clear up, to consolidate, and to utilize the ground acquired. With this provision, however, let us consider a few cases in history where a study of the physical and chemical properties of the living creature have borne fruit in practical experience.

Pasteur investigating the optical properties of certain solutions was led to a study of the chemical properties of organisms, and thereby created modern bacteriology, modern knowledge of disease, modern hygiene, modern aseptic surgery: not to mention the fact that he saved the beer and silkworm industries of France. The world has never, I suppose, had a greater benefactor than Pasteur—on the material side the results of his work are to be reckoned in millions of lives and in millions of millions of pounds, and in the world of thought his discoveries are of no less value because, through them, disease has, to a large extent, ceased to be an unknown mysterious malignant spirit and become a matter which (though still unfortunately affecting the human race) is more or less understood, more or less a matter-of-fact plain thing. All this discovery and progress has resulted from Pasteur's interest in the optical properties of solutions.

Let us take another case. Here in Manchester, when a certain chemical body was urgently required in large quantities during the great war for the manufacture of propellant, bacteria were invoked to do what men found some difficulty in doing. In the future I think there is little doubt that manufacturing chemistry will come more and more in touch with biochemistry, and that more and more the chemist will employ strains of bacteria to deal with the molecule in an individual way impossible to his ordinary mass methods, and so to carry on processes which would otherwise be difficult or expensive. For example, a large part of the combined nitrogen, which is an essential constituent of food and an essential factor in chemical industry, is fixed for us by micro-organisms living on the roots of plants. Man has tamed the cow and the horse, the dog and the cat, till they have become an essential part of his social organization; in the future he will have to breed and tame the micro-organism and teach him also to minister to human needs.

Or take another case. When a muscle contracts, when a heart beats, when a nerve sends a message to or from the brain, certain electric currents are produced. The origin of these currents remains as yet a mystery, but the attempt to explain them has been one of the chief occupations of physiologists for fifty years. When you wish to do something you send a message to some muscle or group of muscles telling them to contract; this message goes 100 yards a second, 200 miles an hour—not as fast as a telegram, not, indeed, as fast as sound, but still many times faster than an express train. I called it a message, but what is it? Something goes along the nerve, some event, leaving nothing behind it, but causing the muscle to contract at the other end. The one thing we know about it is that this something, this event, this message is accompanied by an electric change: the elucidation of the mystery of this message will carry us far in describing the mechanism of life. But I am discussing practical applications. In order to study these electric currents, the Dutch physiologist Einthoven was led to design his string galvanometer, an extremely sensitive and rapid instrument for measuring and recording electric changes. This instrument has proved of recent years one of the most fertile agents in elucidating the problems provided by disease of the human heart. Most of us die in some way and in

some sense of heart failure in the end, so that anything which improves our knowledge of diseases of the heart may well be considered a useful application of physical, in this case of electrical, science to the living creature.

A study of the chemistry and physics of respiration, undertaken largely in an attempt to solve the purely scientific question of whether oxygen diffuses of itself into the blood through the lung substance, or whether the lung substance seizes on oxygen, so to speak, and pushes it through, has led largely to the therapeutic use of oxygen in disease, to a knowledge of mountain sickness and of the effects of flying at high altitudes, to means of avoiding the disease known as caisson disease induced by working at high atmospheric pressure—as, for instance, when digging a tunnel under a river—and to a study of the ventilation of mines and factories and submarines. A study of the chemistry of foods and of the things that happen to foods after they have been taken into the body, has led us to a knowledge of the vitamins—the so-called accessory food factors without which the animal becomes defective in vitality, mentality and development, without which a population may become the prey of rickets, scurvy or beri-beri.

What further applications lie in front of us? The synthesis of a plentiful supply of foods adequate in all respects to maintain life for a continually increasing population; the more efficient utilization of the sun's energy; a knowledge of the mechanism of the cell—just as necessary to the wise physician as a knowledge of the mechanism of a watch to the wise mender of watches—the nature and production of specific immunity from disease: after all, is it really in the nature of things that all our children should have measles and mumps and whooping-cough? the production of chemical bodies with specific properties—like those of salvarsan—of destroying micro-organisms without destroying the body which they have invaded; the effects of radio-activity, of fresh air and sunlight: there is no limit to the practical applications of the study. Advance is coming quickly: with the aid of physical and chemical methods it is coming more quickly, but still not quickly enough. We want more workers, more apparatus, more laboratories and a wider scientific education of the people.

As I prepare to end this lecture, in which I hope I may perhaps have been privileged to communicate to others a little of my own pleasure in these things, I will revert once more to the interest of such investigations, as distinguished from their application. Mankind, one type of living creature, has been endowed with the power of thought and with an insatiable love of adventure. This love of adventure expresses itself in many cases in an insatiable curiosity as to how things work. It is a natural desire, and, I maintain, it is a good desire; it is a desire common to children of 3 and to old gentlemen of 80. How do things work? The living creature undoubtedly does work, in many and strange ways, but the problem of how it works is about the most difficult of all the problems man has ever set himself to solve. To answer it requires the highest experimental skill, the most delicate equipment, and a mind subtle enough to counter all the nasty tricks which the living creature will try to play on one. The problem is a very difficult one—how does the living creature work? But the difficulty only adds zest to the pursuit.

At the last German congress for internal medicine it was decided to establish an institute for testing the therapeutical value of new drugs.

MESSRS. WILLIAM HODGE AND Co. will shortly publish in their series of Notable British Trials a volume dealing with the case of Burke and Hare, edited by Mr. William Roughhead.

The first meeting of the International Congress of Urology will be held in Paris from July 5th to 7th, under the presidency of Professor Legueu, with Professor Verhooze (Brussels), and Professor Brongesma (Amsterdam), as vice-presidents. The subjects for discussion are: (1) Nephritis, with uraemic syndromes; reporters, Hogge (Liège), Horder (London), Forbes (New York), Teissier (Lyons). (2) Remote results of wounds of the urethra; reporters, Kidd (London), Gardini (Bologna), Pasteau (Paris). (3) Pyelography; reporters, Lasio (Milan), Papin (Paris), Waters and Guy (Baltimore).