ON THE ORIGIN OF BIOLOGY AND ITS RELATION TO OTHER BRANCHES OF NATURAL SCIENCE.

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ORIGIN AND MEANING OF THE TERM "BIOLOGY."

THE word "biology," which is now so familiar as comprising the sum of the knowledge which has yet been acquired concerning living Nature, was unknown until after the beginning of the present century. The term was first employed by Treviranus, who proposed to himself as a life task the development of a new science, the aim of which should be to study the forms and phenomena of life, its origin and the conditions and laws of its existence, and embodied what was known on these subjects in a book of seven volumes, which he entitled *Biology, or the Philosophy of Living Nature*. He desired to found the new science on the fundamental distinction between living and non-living material. In discussing this distinction, he takes as his point of departure the constancy with which the activities which manifest themselves in the universe are balanced, emphasising the impossibility of excluding from that balance the vital activities of plants and animals. The difference between vital and physical processes he accordingly finds, not in the nature of the processes themselves, but in their co-ordination—that is, in their adaptedness to a given purpose, and to the peculiar and special relation in which the organism stands to the external world. He defined life as consisting in the reaction of the organism to external influences, and contrasts the uniformity of vital reactions with the variety of their exciting causes. This idea suggests the "idea of organism" as that to which all other biological ideas must relate. It also suggests, although perhaps it does not express it, that action is not an attribute of the organism but of its essence—that if, on the one hand, protoplasm is the basis of life, life is the basis of protoplasm; their relations to each other are reciprocal. We think of the visible structure only in connection with the invisible process.

The origin of life—the first transition from non-living to living—is a riddle which lies outside of our scope. No seriously-minded person, however, doubts that organised nature as it now presents itself to us has become what it is by a process of gradual perfecting or advancement, brought about by the elimination of those organisms which failed to obey the fundamental principle of adaptation which Treviranus indicated. Each step, therefore, in this evolution is a reaction to external influences, the motive of which is essentially the same as that by which, from moment to moment, the organism governs itself. And the whole process is a necessary outcome of the fact that those organisms are most prosperous which look best after their own welfare. As in that part of biology which deals with the internal relations of the organism, the interest of the individual is in like manner the sole motive by which every energy is guided. We may take what Treviranus called selfish adaptation—*Zweckmässigkeit für sich selber*—as a connecting link between the two branches of biological study. Out of this relation springs another, which, I need not say, was not recognised until after the Darwinian epoch—that, I mean, which subsists between the two evolutions, that of the race and that of the individual.

Biology naturally falls into three divisions, and these are even more sharply distinguished by their methods than by their subjects, namely: Physiology, of which the methods are entirely experimental; morphology, the science which deals with the forms and structure of plants and animals, and of which it may be said that the body is anatomy, the soul development; and, finally, œcology, which uses all the knowledge it can obtain from the other two, but chiefly rests

on the exploration of the endless varied phenomena of animal and plant life as they manifest themselves under natural conditions.

ORIGIN AND SCOPE OF MODERN PHYSIOLOGY.

Just as there was no true philosophy of living nature until Darwin, we may with almost equal truth say that physiology did not exist as a science before Johannes Müller. Müller taught in Berlin from 1833 to 1857. During that time a gradual change was in progress in the way in which biologists regarded the fundamental problem of life. Müller himself, in common with Treviranus and all the biological teachers of his time, was a vitalist, that is, he regarded what was then called the *vis vitalis*—the *Lebenskraft*—as something capable of being correlated with the physical forces. But during the period of Müller's greatest activity times were changing, and he was changing with them. During his long career as professor at Berlin he became more and more objective in his tendencies, and exercised an influence in the same direction on the men of the next generation, teaching them that it was better and more useful to observe than to philosophise: so that, although he himself is truly regarded as the last of the vitalists—for he was a vitalist to the last—his successors were adherents of what has been very inadequately designated the mechanistic view of the phenomena of life. The change thus brought about just before the middle of this century was a revolution.

From structure to function, from microscopical observation to physiological experiment, the transition was inevitable. Anatomy was able to answer some questions, but asked many more. Fifty years ago physiologists had microscopes but had no laboratories. English physiologists—Bowman, Paget, Sharpey—were at the same time anatomists, and in Berlin Johannes Müller, along with anatomy and physiology, taught comparative anatomy and pathology. But soon that specialisation which, however much we may regret its necessity, is an essential concomitant of progress, became more and more inevitable. The structural conditions on which the processes of life depend had become, if not known, at least accessible to investigation; but very little indeed had been ascertained of the nature of the processes themselves—so little, indeed, that if at this moment we could blot from the records of physiology the whole of the information which had been acquired, say in 1840, the loss would be difficult to trace—not that the previously known facts were of little value, but because every fact of moment has since been subjected to experimental verification. It is for this reason that, without any hesitation, we accord to Müller and to his successors Brücke, Du Bois-Reymond, and Helmholtz, who were his pupils, to Ludwig, in Germany, and to Claude Bernard in France, the title of founders of our science.

What were the conditions which brought about this great advance which coincided with the middle of the century? There is but little difficulty in answering the question. I have already said that the change was not one of doctrine but of method. There was, however, a leading idea in the minds of those who were chiefly concerned in bringing it about. That leading notion was that, however complicated may be the conditions under which vital energies manifest themselves, they can be split into processes which are identical in nature with those of the non-living world, and, as a corollary to this, that the analysing of a vital process into its physical and chemical constituents, so as to bring these constituents into measurable relation with physical or chemical standards, is the only mode of investigating them which can lead to satisfactory results.

The old meaning of the term "adaptation" as the equivalent of "design" had been abandoned, and no new meaning had yet been given to it, and consequently the word "mechanism" came to be employed as the equivalent of "process," as if the constant concomitance or sequence of two events was in itself a sufficient reason for assuming a mechanical relation between them. As in daily life so also in science the misuse of words leads to misconceptions.

In an eloquent Harveian oration, delivered last autumn by Dr. Bridges, it was indicated how, after Harvey's great discovery of the circulation, men were too apt to found upon it explanations of all phenomena whether of health or disease, to such an extent that the practice of medicine was even

prejudicially affected by it. In respect of its scientific importance, the epoch we are considering may well be compared with that of Harvey, and may have been followed by an undue preference of the new as compared with the old, but no more permanent unfavourable results have shown themselves. As regards the science of medicine, we need only remember that it was during the years between 1845 and 1860 that Virchow made those researches by which he brought the processes of disease into immediate relation with the normal processes of cell development and growth, and so, by making pathology a part of physiology, secured its subsequent progress and its influence on practical medicine. Similarly in physiology, the achievements of those years led on without any interruption or drawback to those of the following generation; while in general biology, the revolution in the mode of regarding the internal processes of the animal or plant organism which resulted from these achievements prepared the way for the acceptance of the still greater revolution which the Darwinian epoch brought about in the views entertained by naturalists of the relations of plants and animals to each other and to their surroundings.

THE SPECIFIC ENERGIES OF THE ORGANISM.

When in 1826 J. Müller was engaged in investigating the physiology of vision and hearing, he introduced into the discussion a term, "specific energy," the use of which by Helmholtz in his physiological writings has rendered it familiar to all students. Both writers mean by the word "energy" not the "capacity of doing work," but simply activity, using it in its old-fashioned meaning, that of the Greek word from which it is derived. With the qualification "specific" it serves, perhaps, better than any other expression to indicate the way in which adaptation manifests itself. As every living cell or tissue is called upon to act in the interest of the whole, the organism must be capable of influencing every part so as to regulate its action.

In general there is no difficulty in determining both the nature of the central influence exercised and the relation between it and the normal function. It may help to illustrate this relation to refer to the expressive word *Auslösung* by which it has for many years been designated by German writers. This word stands for the performance of function by the "letting off" of "specific energies." Carrying out the notion of "letting off" as expressing the link between action and reaction, we might compare the whole process to the mode of working of a repeating clock (or other similar mechanism), in which case the pressure of the finger on the button would represent the external influence or stimulus, the striking of the clock the normal reaction. And now may I ask you to consider in detail one or two illustrations of physiological reaction—the letting off of specific energy?

Probably everyone is acquainted with some of the familiar proofs that an object is seen for a much longer period than it is actually exposed to view; that the visual reaction lasts much longer than its cause. More precise observations teach us that this response is regulated according to laws which it has in common with all the higher functions of an organism. If, for example, the cells in the brain of the torpedo are "let off"—that is, awakened by an external stimulus—the electrical discharge, which, as in the case of vision, follows after a certain interval, lasts a certain time, first rapidly increasing to a maximum of intensity, then more slowly diminishing. In like manner, as regards the visual apparatus, we have, in the response to a sudden invasion of the eye by light, a rise and fall of a similar character. In the case of the electrical organ, and in many analogous instances, it is easy to investigate the time relations of the successive phenomena, so as to represent them graphically. Again, it is found that in many physiological reactions the period of rising "energy" (as Helmholtz called it) is followed by a period during which the responding structure is not only inactive, but its capacity for energising is so completely lost that the same exciting cause which a moment before "let off" the characteristic response is now without effect. As regards vision, it has long been believed that these general characteristics of physiological reaction have their counterpart in the visual process, the most striking evidence being that in the contemplation of a lightning flash—or, better, of an instantaneously

illuminated white disc²—the eye seems to receive a double stroke, indicating that, although the stimulus is single and instantaneous, the response is reduplicated. The most precise of the methods we until lately possessed for investigating the wax and wane of the visual reaction were not only difficult to carry out, but left a large margin of uncertainty. It was therefore particularly satisfactory when M. Charpentier, of Nancy, whose merits as an investigator are perhaps less known than they deserve to be, devised an experiment of extreme simplicity, which enables us, not only to observe, but to measure with great facility, both phases of the reaction. It is difficult to explain even the simplest apparatus without diagrams; you will, however, understand the experiment if you will imagine that you are contemplating a disc, like those ordinarily used for colour mixing; that it is divided by two radial lines which diverge from each other at an angle of 60°; that the sector which these lines enclose is white, the rest black; that the disc revolves slowly, about once in two seconds. You then see, close to the front edge of the advancing sector, a black bar, followed by a second at the same distance from itself, but much fainter. Now the scientific value of the experiment consists in this, that the angular distance of the bar from the black border is in proportion to the frequency of the revolutions—the faster the wider. If, for example, when the disc makes half a revolution in a second the distance is ten degrees, this obviously means that when light bursts into the eye the extinction happens one-eighteenth of a second after the excitation.

In all the instances, excepting the retina, in which the physiological response to stimulus has a definite time limitation, and in so far resembles an explosion—in other words, in all the higher forms of specific energy, it can be shown experimentally that the process is propagated from the part first directly acted on to other contiguous parts of similar endowment. M. Charpentier has now been able, by a method which, although simple, I must not attempt to describe, not only to prove its existence, but to measure its rate of progress over the visual field.

It has been lately assumed by some that vision, like every other specific energy, having been developed progressively, objects were seen by the most elementary forms of eye only in chiaroscuro, that afterwards some colours were distinguished, eventually all. As regards hearing it is so. The organ which, on structural grounds, we consider to represent that of hearing in animals low in the scale of organisation—as, for example, in the Ctenophora—has nothing to do with sound, but confers on its possessor the power of judging of the direction of its own movements in the water in which it swims, and of guiding these movements accordingly. In the lowest vertebrates—as, for example, in the dogfish—although the auditory apparatus is much more complicated in structure, and plainly corresponds with our own, we still find the particular part which is concerned in hearing scarcely traceable. All that is provided for is that sixth sense, which the higher animals also possess, and which enables them to judge of the direction of their own movements. But a stage higher in the vertebrate series we find the special mechanisms by which we ourselves appreciate sounds beginning to appear; not supplanting or taking the place of the imperfect organ, but added to it. As regards hearing, therefore, a new function is acquired without any transformation or fusion of the old into it. We ourselves possess the sixth sense, by which we keep our balance, and which serves as the guide to our bodily movements. It resides in the part of the internal ear which is called the labyrinth. At the same time we enjoy along with it the possession of the cochlea, that more complicated apparatus by which we are able to hear sounds and to discriminate their vibration rates.

As in all sensations of colour the sensation of brightness is mixed, it is obvious that one of the first points to be determined is whether the latter represents a "specific energy" or merely a certain combination of specific energies which are excited by colours. The question is not whether there is such a thing as white light, but whether we possess a separate faculty by which we judge of light and shade when a spectrum projected on a white surface is watched, while the intensity of the light is gradually diminished. As the colours fade away they become indistinguishable as such, the last seen being the primary red and green. Finally, they

also disappear, but a grey band of light still remains, of which the most luminous part is that which before was green. Whether or not the faculty by which we see grey in the dark is one which we possess in common with animals of imperfectly developed vision, there seems little doubt that there are individuals of our own species who, in the fullest sense of the expression, have no eye for colour, in whom all colour sense is absent, persons who inhabit a world of grey, seeing all things as they might have done had they and their ancestors always lived nocturnal lives. In the theory of colour vision, as it is commonly stated, reference is made to such a faculty as we are now discussing.

Professor Hering, who was among the first to subject the vision of the *totally* colour blind to accurate examination, is of opinion, on that and on other grounds, that the sensation of light and shade is a specific faculty. Very recently the same view has been advocated on a wide basis by a distinguished psychologist, Professor Ebbinghaus.³ The recent elaborate investigations of Captain Abney⁴ (with General Festing), representing graphically the results of his measurements of the subjective values of the different parts of the diminished spectrum, as well as those of the fully illuminated spectrum as seen by the totally colour blind, are in the closest accord with the observations of Hering, and have, moreover, been substantially confirmed in both points by the measurements of Dr. König in Helmholtz's laboratory at Berlin.⁵

At present the inference seems to be that such a specific energy as Hering's theory of vision postulates actually exists, and that it has for associates the colour-perceiving activities of the visual apparatus, provided that these are present; but that whenever the intensity of the illumination is below the chromatic threshold—that is, too feeble to awaken these activities—or when, as in the totally colour blind, they are wanting, it manifests itself independently.

EXPERIMENTAL PSYCHOLOGY.

It is by anatomical researches relating to the minute structure and to the development of the brain by observation of the facts of disease and, above all, by physiological experiment, that those changes in the ganglion cells of the brain and spinal cord which are the immediate antecedents of every kind of bodily action have been traced. Between the two—that is between sensation and the beginning of action—there is an intervening region which the physiologist has hitherto willingly resigned to psychology, feeling his incompetence to use the only instrument by which it can be explored—that of introspection.

I will make no attempt even to enumerate the special lines of inquiry which, during the last decade, have been conducted with such vigour in all parts of the world, all of them traceable to the influence of the Leipzig school; but will content myself with saying that the general purpose of these investigations has been to determine with the utmost attainable precision the nature of psychical relations. Some of these investigations begin with those simpler reactions which more or less resemble those of an automatic mechanism, proceeding to those in which the resulting action or movement is modified by the influence of auxiliary or antagonistic conditions or changed by the simultaneous or antecedent action on the reagent of other stimuli, in all of which cases the effect can be expressed quantitatively; others lead to results which do not so readily admit of measurement. In pursuing this course of inquiry the physiologist finds himself as he proceeds more and more the coadjutor of the psychologist, less and less his director; for whatever advantage the former may have in the mere *technique* of observation the things with which he has to do are revealed only to introspection, and can be studied only by methods which lie outside of his sphere. I might, in illustration of this, refer to many recent experimental researches—such, for example, as those by which it has been sought to obtain exact data as to the physiological concomitants of pleasure and of pain, or as to the influence of weariness and recuperation, as modifiers of psychological reactions. Another outwork of the mental citadel which has been invaded by the experimental method is that of memory. Even here it can be shown that in the comparison of transitory as compared with permanent memory—as, for example, in the getting off by heart of a wholly uninteresting series of words, with a subsequent

oblivion and reacquisition—the labour of acquiring and reacquiring may be measured, and consequently the relation between them; and that this ratio varies according to a simple numerical law.

PHOTOTAXIS AND CHEMIOTAXIS.

Considering that every organism must have sprung from a unicellular ancestor, some have thought that unless we are prepared to admit a deferred epigenesis of mind, we must look for psychical manifestations even among the lowest animals, and that as in the protozoön all the vital activities are blended together, mind should be present among them not merely potentially but actually, though in diminished degree.

In this connection it will be of interest to discuss the phenomena which relate to what may be termed the behaviour of unicellular organisms and of individual cells, in so far as these last are capable of reacting to external influences. The observations which afford us most information are those in which the stimuli employed can be easily measured, such as electrical currents, light, or chemical agents in solution.

A single instance, or at most two, must suffice to illustrate the influence of light in directing the movements of freely moving cells, or, as it is termed, phototaxis. The rod-like purple organism called by Engelmann "*bacterium photometricum*" is such a light lover that if you place a drop of water containing these organisms under the microscope, and focus the smallest possible beam of light on a particular spot in the field, the spot acts as a light trap and becomes so crowded with the little rodlets as to acquire a deep port-wine colour. If, instead of making his trap of white light, he projected on the field a microscopic spectrum, Engelmann found that the rodlets showed their preference for a spectral colour which is absorbed when transmitted through their bodies. By the aid of a light trap of the same kind, the very well-known spindle-shaped and flagellate cell of *Euglena* can be shown to have a similar power of discriminating colour, but its preference is different. This familiar organism advances with its flagellum forwards, the sharp end of the spindle having a red or orange eye point. Accordingly, the light it loves is again that which is most absorbed, namely, the blue of the spectrum (line F).

These examples may serve as an introduction to a similar one, in which the directing cause of movement is not physical but chemical. The spectral light trap is used in the way already described; the organisms to be observed are not coloured, but bacteria of that common sort which twenty years ago we used to call *bacterium termo*, and which is recognised as the ordinary determining cause of putrefaction. These organisms do not care for light, but are great oxygen lovers. Consequently, if you illuminate with your spectrum a filament of a confervoid alga, placed in water containing bacteria, the assimilation of carbon and consequent disengagement of oxygen is most active in the part of the filament which receives the red rays (B to C). To this part, therefore, where there is a dark band of absorption, the bacteria which want oxygen are attracted in crowds. The motive which brings them together is their desire for oxygen. Let us compare other instances in which the source of attraction is food.

The plasmodia of the myxomycetes, particularly one which has been recently investigated by Mr. Arthur Lister, may be taken as a typical instance of what may be called the chemical allurements of living protoplasm. In this organism, which in the active state is an expansion of labile living material, the delicacy of the reaction is comparable to that of the sense of smell in those animals in which the olfactory organs are adapted to an aquatic life. Just as, for example, the dogfish is attracted by food which it cannot see, so the plasmodium of *Badhamia* becomes aware, as if it smelled it, of the presence of its food—a particular kind of fungus. I have no diagram to explain this, but will ask you to imagine an expansion of living material, quite structureless, spreading itself along a wet surface; that this expansion of transparent material is bounded by an irregular coastline, and that somewhere near the coast there has been placed a fragment of the material on which the *Badhamia* feeds. The presence of this bit of stereum produces an excitement at the part of the plasmodium next to it. Towards this centre of activity

streams of living material converge. Soon the afflux leads to an outgrowth of the plasmodium, which in a few minutes advances towards the desired fragment, envelops, and incorporates it.

Very shortly after the publication of Engelmann's observations of the attraction of bacteria by oxygen, Pfeffer made the remarkable discovery that the movements of the antherozoids of ferns and of mosses are guided by impressions derived from chemical sources, by the allurement exercised upon them by certain chemical substances in solution—in one of the instances mentioned by sugar, in the other by an organic acid. The method consisted in introducing the substance to be tested, in any required strength, into a minute capillary tube closed at one end, and placing it under the microscope in water inhabited by antherozoids, which thereupon showed their predilection for the substance, or the contrary, by its effect on their movements. In accordance with the principle followed in experimental psychology, Pfeffer⁶ made it his object to determine, not the relative effects of different doses, but the smallest perceptible increase of dose which the organism was able to detect, with this result—that, just as in measurements of the relation between stimulus and reaction in ourselves we find that the sensational value of a stimulus depends, not on its absolute intensity, but on the ratio between that intensity and the previous excitation, so in this simplest of vital reagents the same so-called psycho-physical law manifests itself. It is not, however, with a view to this interesting relation that I have referred to Pfeffer's discovery, but because it serves as a centre around which other phenomena, observed alike in plants and animals, have been grouped. As a general designation of reactions of this kind, Pfeffer devised the term *chemotaxis*, or, as we in England prefer to call it, *chemiotaxis*. Pfeffer's contrivance for chemiotactic testing was borrowed from the pathologists, who have long used it for the purpose of determining the relation between a great variety of chemical compounds or products and the colourless corpuscles of the blood. I need, I am sure, make no apology for referring to a question which, although purely pathological, is of very great biological interest—the theory of the process by which, not only in man, but also, as Metschnikoff has strikingly shown, in animals far down in the scale of development, the organism protects itself against such harmful things as, whether particulate or not, are able to penetrate its framework. Since Cohnheim's great discovery in 1867 we have known that the central phenomenon of what is termed by pathologists inflammation is what would now be called a chemiotactic one; for it consists in the gathering together, like that of vultures to a carcass, of those migratory cells which have their home in the blood stream and in the lymphatic system, to any point where the living tissue of the body has been injured or damaged, as if the products of disintegration which are set free where such damage occurs were attractive to them.

The fact of chemiotaxis, therefore, as a constituent phenomenon of the process of inflammation was familiar in pathology long before it was understood. Cohnheim himself attributed it to changes in the channels along which the cells moved, and this explanation was generally accepted, though some writers, at all events, recognised its incompleteness. But no sooner was Pfeffer's discovery known than Leber,⁷ who for years had been working at the subject from the pathological side, at once saw that the two processes were of similar nature. A variety of researches of great interest demonstrated the importance of chemiotaxis in relation to the destruction of disease-producing microphytes. Much discussion has taken place, as many present are aware, as to the kind of wandering cells, or leucocytes, which in the first instance attack morbid microbes, and how they deal with them. The question is not by any means decided. It has, however, I venture to think, been conclusively shown that the process of destruction is a chemical one, that the destructive agent has its source in the chemiotactic cells, that is, cells which act under the orders of chemical stimuli. Two Cambridge observers, Kanthack and Hardy,⁸ have lately shown that, in the particular instance which they have investigated, the cells which are most directly concerned in the destruction of morbid bacilli, although chemiotactic, do not possess the

power of incorporating either bacilli or particles of any other kind. While, therefore, we must regard the relation between the process of devitalising and that of incorporating as not yet sufficiently determined, it is now no longer possible to regard the latter as essential to the former.

There seems, therefore, to be very little doubt that chemiotactic cells are among the agents by which the human or animal organism protects itself against infection. There are, however, many questions connected with this action which have not yet been answered. The first of these are chemical ones—that of the nature of the attractive substance and that of the process by which the living carriers of infection are destroyed. Another point to be determined is how far the process admits of adaptation to the particular infection which is present in each case, and to the state of liability or immunity of the infected individual. The subject is therefore of great complication. None of the points I have suggested can be settled by experiments in glass tubes such as I have described to you.

It is possible that many members of the Association are not aware of the unfavourable—I will not say discreditable—position that this country at present occupies in relation to the scientific study of this great subject—the causes and mode of prevention of infectious diseases. As regards administrative efficiency in matters relating to public health, England was at one time far ahead of all other countries, and still retains its superiority; but as regards scientific knowledge we are, in this subject as in others, content to borrow from our neighbours. Those who desire either to learn the methods of research or to carry out scientific inquiries have to go to Berlin, to Munich, to Breslau, or to the Pasteur Institute in Paris to obtain what England ought long ago to have provided; for to us, from the spread of our race all over the world, the prevention of acute infectious diseases is more important than to any other nation. At the beginning of this address I urged the claims of pure science. If I could, I should feel inclined to speak even more strongly of the application of science to the discovery of the causes of acute diseases. May I express the hope that the effort which is now being made to establish in England an institution for this purpose not inferior in efficiency to those of other countries, may have the sympathy of all present?

CONCLUSIONS.

"Organism" is a fact which encounters the biologist at every step. In referring it to any general principle, such as adaptation, we do not explain it. No explanation will be attainable until the conditions of its coming into existence can be subjected to experimental investigation, so as to correlate them with those of processes in the non living world. The patient endeavours which were made to obtain experimental proof of what was called *abiogenesis*, although they conducted materially to that better knowledge which we now possess of the conditions of life of bacteria, failed in the accomplishment of their purpose. The question still remains undetermined; it has, so to speak, been adjourned *sine die*. The only approach to it lies at present in the investigation of those rare instances in which, although the relations between a living organism and its environment ceases as a watch stops when it has not been wound, these relations can be re-established, the process of life reawakened, by the application of the required stimulus.

I was also desirous to illustrate the relation between physiology and its two neighbours on either side, natural philosophy (including chemistry) and psychology. As regards the latter, I need add nothing to what has already been said. As regards the former, it may be well to notice that although physiology can never become a mere branch of applied physics or chemistry, there are parts of physiology wherein the principles of these sciences may be applied directly. Thus, in the beginning of the century, Young applied his investigations as to the movements of liquids in a system of elastic tubes, directly to the phenomena of the circulation; and, a century before, Borelli successfully examined the mechanism of locomotion and the action of muscles, without reference to any excepting mechanical principles. Similarly, the foundation of our present knowledge of the process of nutrition was laid in the researches of Bidder and Schmidt in 1851, by determinations of the weight and composition of the body, the daily gain of weight by food or oxygen, the daily loss by the respiratory and other dis-

charges, all of which could be accomplished by chemical means. But in by far the greater number of physiological investigations, both methods (the physical or chemical and the physiological) must be brought to bear on the same question—to co-operate for the elucidation of the same problem. In the researches, for example, which during several years have occupied Professor Bohr, of Copenhagen, relating to the exchange of gases in respiration, he has shown that factors purely physical—namely, the partial pressures of oxygen and carbon dioxide in the blood which flows through the pulmonary capillaries—are, so to speak, interfered with in their action by the “specific energy” of the pulmonary tissue, in such a way as to render this fundamental process, which, since Lavoisier, has justly been regarded as one of the most important in physiology, much more complicated than we for a long time supposed it to be. In like manner Heidenhain has proved that the process of lymphatic absorption, which before we regarded as dependent on purely mechanical causes, that is, differences of pressure—is in great measure due to the specific energy of cells, and that in various processes of secretion the principal part is not, as we were inclined not many years ago to believe, attributable to liquid diffusion, but to the same agency. I wish that there had been time to have told you something of the discoveries which have been made in this particular field by Mr. Langley, who has made the subject of “specific energy” of secreting cells his own. It is in investigations of this kind, of which any number of examples could be given, in which vital reactions mix themselves up with physical and chemical ones so intimately that it is difficult to draw the line between them, that the physiologist derives most aid from whatever chemical and physical training he may be fortunate enough to possess.

There is, therefore, no doubt as to the advantages which physiology derives from the exact sciences. It could scarcely be averred that they would benefit in anything like the same degree from closer association with the science of life. Nevertheless, there are some points in respect of which that science may have usefully contributed to the advancement of physics or of chemistry. The discovery of Graham as to the characters of colloid substances, and as to the diffusion of bodies in solution through membranes, would never have been made had not Graham “ploughed,” so to speak, “with our heifer.” The relations of certain colouring matters to oxygen and carbon dioxide would have been unknown, had no experiments been made on the respiration of animals and the assimilative process in plants; and, similarly, the vast amount of knowledge which relates to the chemical action of ferments must be claimed as of physiological origin. So also there are methods, both physical and chemical, which were originally devised for physiological purposes. Thus the method by which meteorological phenomena are continuously recorded graphically originated from that used by Ludwig (1847) in his *Researches on the Circulation*; the mercurial pump, invented by Lothar Meyer, was perfected in the physiological laboratories of Bonn and Leipzig; the rendering the galvanometer needle aperiodic by damping was first realised by Du Bois-Reymond—in all of which cases invention was prompted by the requirements of physiological research.

REFERENCES.

¹ It is worthy of note that these five distinguished men were nearly contemporaries: Ludwig graduated in 1839, Bernard in 1843, the other three between those dates. Three survive—Helmholtz, Ludwig, Du Bois-Reymond. ² The phenomenon is best seen when, in a dark room, the light of a luminous spark is thrown on to a white screen with the aid of a suitable lens. ³ Ebbinghaus, “Theorie des Farbensehens,” *Zeitschr. f. Psychol.*, vol. v, 1893, p. 145. ⁴ Abney and Festing, “Colour Photometry,” Part III, *Phil. Trans.*, vol. clxxxiiiA, 1891, p. 531. ⁵ König, “Ueber den Helligkeitwerth der Spectralfarben bei verschiedener absoluter Intensität,” *Beiträge zur Psychologie*, etc., Festschrift zu H. von Helmholtz, 70 Geburtstage, 1891, p. 309. ⁶ Pfeffer, *Untersuch. a. d. botan. Institut z. Tübingen*, vol. I, Part III, 1884. ⁷ Leber, *Die Anhäufung der Leucocyten am Orte des Entzündungsreizes*, etc., *Die Entstehung der Entzündung*, etc., pp. 423-464, Leipzig, 1891. ⁸ Kanthack and Hardy, “On the Characters and Behaviour of the Wandering Cells of the Frog,” *Proceedings of the Royal Society*, vol. lli, p. 267.

DURING the second quarter of this year the birth-rate in Hamburg showed a remarkable decrease of about 10 per cent. It is believed that this may be attributed to the cholera epidemic in that city last autumn.

ABSTRACT OF AN ADDRESS ON THE INFLUENCE OF THE ERECT POSITION ON THE DEVELOPMENT OF THE HUMAN BODY, AND ESPECIALLY OF THE BRAIN.

Delivered before the Section of Anthropology of the British Association for the Advancement of Science at its Meeting on September 14th,

By ROBERT MUNRO, M.A., M.D., PRESIDENT,
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AFTER a few introductory remarks on the scope of anthropology, Dr. Munro proceeded to deal with the following propositions:—

1. The mechanical and physical advantages of the erect position.

2. The differentiation of the limbs into hands and feet.

3. The relation between the more perfect condition of these organs and the development of the brain.

The primary object of locomotion, he said, is to enable the organism to seek its food over a larger area than is attainable by a fixed position. In the higher vertebrates this is accomplished by means of the well-known mechanism of four movable limbs capable of supporting and transporting the animals. As these quadrupedal animals became more highly differentiated in virtue of the struggle for existence and the necessities of their surroundings, the limbs become modified in various ways so as to render them suitable for various kinds of locomotion, and for other purposes in the animal economy. The anterior limbs have been specially subject to these changes, but man alone has been able to divert them altogether from their primary function. This has resulted from his attaining the erect position, which has necessitated a complete division of labour in the functions of the limbs, the anterior pair having become restricted in their use to manipulative and prehensile purposes, while the posterior have retained their original function of locomotion. Coincident with this notable specialisation in function of the limbs a new field for advancement was opened to man, in which intelligence and mechanical skill became the leading factors in his further development. The maintenance of his body in the erect position has necessitated great changes in its structure, not only in the osseous system, but also in the soft parts. In the distal segments of the limbs the most remarkable changes took place. The changes which have occurred in the foot to make it the perfect mechanism for progression, that it is, as well as an efficient basis for supporting the weight of the body, were then enumerated. The modifications which the hand has undergone are quite as radical, but in an entirely different direction, namely, towards rendering it capable of performing the most delicate and intricate prehensile movements. The possession of such a perfect piece of mechanism at the extremity of a movable arm attached to the upper part of the trunk gives man a superiority in attack and defence over all other animals. Moreover, he possesses the power of performing a variety of movements, and of assuming attitudes and positions eminently adapted to the exercise of his manipulative skill, by which he is able to counteract the superior brute force of many of his antagonists. All his morphological peculiarities have been brought about without the destruction of any of the primary and typical homologies common to all the higher vertebrates.

It is, however, the intellectual and psychical manifestations of the brain—the organ of the mind—which gives to man's life functions their most remarkable character. We are forced to the conclusion that conscious sensation invariably takes place by means of nerve cells, whose functional activity requires to be nourished in precisely the same way as the muscular force required in walking. The brain is a dual organ, consisting of a double series of distinct ganglia, and connected to some extent by a complex system of nervous tissues not only with each other but with the central seat of consciousness and