Nihil Obstat.

MICHAEL MAHER, S.J.,
Censor deputatus.

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WHAT IS LIFE? A STUDY OF VITALISM AND NEO-VITALISM.

By BERTRAM C. A. WINDLE, M.A., M.D., Sc.D., LL.D., F.R.S.,
F.S.A.

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A STUDY OF

VITALISM AND NEO-VITALISM

BY

BERTRAM C. A. WINDLE

M.A., M.D., SC.D., LL.D., F.R.S., F.S.A.
PRESIDENT OF QUEEN'S COLLEGE, CORK

*Pulchra quæ videntur, pulchriora quæ existimantur, longe
pulcherrima quæ ignorantur*

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To
MY GUIDE, PHILOSOPHER AND FRIEND
THE RIGHT REV.
MGR. HENRY PARKINSON, D.D., PH.D.
RECTOR OF ST. MARIE'S COLLEGE, OSCOTT
IN MEMORY OF
MANY SYMPOSIA IN SUTTON PARK AND ELSEWHERE

SIC REDDIT AD DOMINUM QUOD FUIT ANTE SUUM

PREFACE

IN March 1906 I delivered a lecture, entitled "The Secret of the Cell," as one of the Westminster Series for that year, in the Hall of Westminster Cathedral. The arranger of those lectures, who is also the Editor of this Series, asked me to expand that necessarily much compressed discourse of mine into a book, and the result is now in the reader's hands. As the book is avowedly an expansion of that lecture I have not hesitated to use the same arguments, the same examples and even in some cases the same phraseology. But I have tried to explain more fully matters which I was obliged to pass over far too briefly in the lecture, and I have also added a very large amount of new matter and examples.

I hope that I have confessed my indebtedness to the many writers whose works I have consulted whilst drawing up this summary of the Vitalistic position. There is one, however, whose name must

—or I must confess myself the most ungrateful of men—receive special mention, and that is my friend Fr. M. Maher, S.J., D.Litt. (Lond.), to whom I owe more than I can express for his kindness in reading my manuscript and supplying me with many most useful suggestions. The figures have been redrawn by my wife for this book.

BERTRAM C. A. WINDLE.

QUEEN'S COLLEGE, CORK.

In Festo Omn. Anim. 1907.

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WHAT IS LIFE

CHAPTER I

CHANGES IN SCIENTIFIC OPINION—ALCHEMISTS AND CHEMISTS—VITALISTS, MECHANISTS AND NEOVIT- ALISTS

SCIENTIFIC opinion regarding any particular point is apt to waver from view to view as new facts swim into one's ken ; it swings from one side to another like a pendulum and is sometimes found, after a long interval of time, to have returned to a position which it might have been supposed had been abandoned for ever. That such must necessarily be the case will not require much demonstration when one remembers the vast number of undiscovered facts which lie all around us and the potent and corroding effect which the discoveries of to-morrow may consequently have upon the most cherished theories of to-day.

In the pre-scientific period, as some would call Alchemy it, at any rate at a period when science was in an even more crude and chaotic condition than it is to-day, the chemists, or, as they were then called,

the alchemists, believed that there was a *materia prima*, a simple essence out of which all existing substances were built. And this being the case they held that there was no real reason why any one substance might not be turned into any other, no reason, for example, why lead should not be transmuted into gold. Stripped of all its gorgeous imagery, deprived of its Red Dragon and the other fanciful terms which it brought into its nomenclature, this was the underlying theory which dominated all the work of the alchemists. And as time went on and new discoveries were made, men laughed at the follies of the alchemists and wondered that any persons could have been so foolish as to imagine that there was really only one kind of basal principle of which the things that are were various and differing manifestations.

Chemical
elements

So we were taught that there were seventy odd chemical elements and that each of these was a simple and undecomposable substance incapable of being split up or of being transmuted into anything else but itself. And so the underlying theory became and for long remained one which proclaimed an essential and absolute difference between the so-called chemical elements.

Radium

Time rolled on, and but a few years ago M. and Mme. Curie discovered radium, and the extraordinary facts of radio-activity began to be

gradually brought to light. Following upon these discoveries has arisen a new theory of matter wholly different from that which has for so many years held the field. This theory teaches that the atoms of which all chemical elements are made up consist of electrons or corpuscles and that these corpuscles are moving units of negative electricity with the ether associated therewith, ensphered by an envelope of positive electricity. Moreover it teaches that the differences between the atoms of any two substances is a difference of arrangement of the electrons or of the ether with which they are associated. Now a single glance will show that this is really in essence the theory of the alchemists, for the negative electricity plus ether is virtually the old *materia prima*, and if all things in their ultimate analysis are constructed from it, it is clear that there is no inherent impossibility in the proposition which asserts that means may yet be found whereby the fundamental arrangements of one molecule—say of lead—may be so altered that it becomes transmuted into another totally different molecule—say that of gold. Indeed it would appear, from the fact that radium is believed to be constantly transmuting itself into helium, that such changes are actually taking place, though in obedience to laws of which we are in total ignorance.

It is of course true that the views thus briefly

outlined are by no means universally accepted and that at any moment further facts may come into notice which may utterly upset both this and the earlier hypothesis. But the example will suffice to show how uncertain even the oldest and most respectable scientific theories may really be, and will also serve as an excellent parallel to the changes of opinion which have taken place in connection with the question with which this present book is concerned, that is the nature of life and of living things.

Those biologists—if we may so speak of them—who flourished at the same time that the alchemists were endeavouring to discover the philosopher's stone, had no doubt at all as to the existence of some further factor in living things than those which were to be met with in inorganic objects. Fr. Maher¹ tells us that “the principle of life in the lower animals was held by the schoolmen to be an example of a simple principle which is nevertheless not spiritual, since it is altogether dependent upon the organism, or, as they said, *completely immersed* in the body. St. Thomas accordingly speaks of the *corporeal souls* of brutes.” In fact the scholastic philosophy assigned what it called “souls,” sensitive and vegetative souls, to vegetables as well as to the lower animals, and by that

Scholastics
and vitalism

¹ *Psychology*, 5th ed., p. 469.

term "soul" signified that principle of life which, as vitalists hold, is the factor—the elusive but none the less certainly existent factor—which distinguishes living from not-living matter, which places the meanest drop of living protoplasm, the microscopic *Amoeba*, in a position separated by a gulf of immeasurable width from the most complicated product or substance of the inorganic world. Such in essence was the view at the period in question, and it is a theory which, unlike that of the alchemists, has never ceased to have its adherents.

But, with the great outburst of scientific investigation and scientific knowledge which took place in the nineteenth century the vitalistic theory came to have its strenuous opponents. There were those who maintained that it was a mere piece of mysticism and even at the present day, as we shall shortly see, there are many who would as soon confess their belief in the existence of a vital factor in living things as they would admit the existence of an Almighty Creator of all things. Both these ancient views would to them seem to savour of superstition and to belong to a dark age of science. Perhaps in the beginning of the scientific outburst such a point of view was comprehensible if not legitimate. There were—as there still are—an extraordinary number of scientific facts lying around waiting to be picked up. The very number, variety

and importance of these was intoxicating and it is not hard to understand how men came to think, for a time, that there was nothing in the earth or in the heavens over the earth which was past their finding out. And so Professor Huxley¹ proclaimed that "the whole world, living and not-living, is the result of the mutual interaction, according to definite laws, of the forces possessed by the molecules of which the primitive nebulosity of the universe was composed".

And again² he stated "that the living body is a mechanism . . . is now the expressed or implied fundamental proposition of the whole of scientific physiology". There is a curious difference between the phrasing of the first and second editions of this article which very clearly shows how definite the late professor's views were on this point, and how rigidly he excluded any such thing as a vital force from his philosophy. In the first edition he wrote "our volition counts for something as a condition of the course of events". But, in a later edition, fearing evidently lest he might have seemed to have bowed down in the House of Rimmon, he altered this so that it reads "or, to speak more accurately, the physical state of which our volition is the expression". And here he shows himself to

¹ Belfast Address, 1874.

² *Collected Essays*, i., 163.

have been a whole-hearted adherent of the most rigidly mechanical school. The first quotation is consistent with a vitalistic view of life, for no one will deny that in certain respects the human and other bodies are mechanisms and that the processes which take place in them are to be explained in terms of chemistry and physics. But the vitalist would add to this the statement that all the processes which take place in the body are not explicable in these terms, and moreover that none of them find their full explanation in any such way. Huxley's second statement shows that his view was not such as has just been indicated, but agreed with that put forward, in 1889, by the late distinguished physiologist, Professor Burdon Sanderson, that "for the future, the word 'vital,' as distinctive of physiological processes, might be abandoned altogether," a statement, the inaccuracy of which will very shortly be made manifest. A similarly rigid view is held to-day by a number of scientific men and as an example of one of the most recent utterances of this kind may be cited the statements of M. Le Dantec¹ that "between life and death the difference is of the same order as that which exists between a phenol and a sulphate, or between an electrified body and a neutral body.

¹ *The Nature and Origin of Life*, Hodder and Stoughton, 1907.

In other words, all phenomena which we study objectively in living beings can be analysed by the methods of physics and chemistry" (p. 5). And again (p. 250), speaking of the possibility of the artificial fabrication of a living cell, he says: "When the effective synthesis is obtained, it will have no surprises in it—and it will be utterly useless. With the new knowledge acquired by science, the enlightened mind no longer needs to see the fabrication of protoplasm in order to be convinced of the absence of all essential difference and all absolute discontinuity between living and not-living matter."

We can now see clearly the meaning of this explanation of life. It teaches that all the phenomena exhibited by living bodies, including the poetry of Shakespeare and Wordsworth, the profound reasonings of Aristotle or Sir Isaac Newton, the generous instincts of a Fry or a Howard, these and all minor manifestations of life are explicable and may, therefore, some day be explained in terms of chemical equations and physical experiments. It seems a hard saying and one thing is clear, namely, that if it is true, there is an end to biology as a science, an end also to psychology, an end to all branches of science dealing with living things, since all these must resolve themselves into branches of the two only sciences of chemistry and physics.

But there are others who refuse to accept this ^{Neo-}vitalism explanation of life and to set forward the arguments in favour of their point of view is the object of this little book. And first it may be pointed out that some of those processes in the human body which forty or fifty years ago seemed most clearly to be mechanical in their nature, some of those processes to which Burdon Sanderson alluded in the quotation above, some of these processes have, in later years, been shown to be wholly inexplicable in terms of a mechanical explanation. One or two examples of what is meant will make matters clear to the unscientific reader.

The food which we take into our stomachs is there and elsewhere in the alimentary canal acted upon by various juices and converted into a digested semi-fluid substance capable of absorption and utilisation by the body. This substance passes through the cells which line a portion of the alimentary tract, and it was formerly supposed that this passage through the cells was of the nature of a filtration, or at least of an osmotic process such as may take place through a dead animal membrane.

But more recent experiments have shown that the occurrences which take place cannot be explained in any such mechanical way, but that there is another factor or there are other factors at work

which do not come into operation in connection with the process of chemical osmosis. Again the process of secretion by glands, such as those which produce the saliva, is now known not to be one in which the secreting cells "act in a passive inert manner as filtering mechanisms, or as membranes possessing constant permeabilities for different dissolved substances in the plasma, or as media in which different substances possess different solubilities". This "is proven by many experimental observations. Thus that the rate of secretion is not merely passively dependent upon blood pressure and blood supply (although under normal conditions it is subject to variations corresponding to changes in these physical factors) is shown by the observation of Ludwig that the secretion pressure in the sub-maxillary salivary gland, when the outflow is resisted by fluid in a manometer, may rise much above the arterial pressure; and also by the observation that after administration of a drug, such as atropin, the blood supply may be increased as much as before administration of the drug on stimulation of the secretory nerve, without, however, calling forth any flow of secretion."¹ These and other instances, such as that of oxidation, which might also be cited, show that further knowledge

¹B. Moore in *Recent Advances in Physiology and Bio-Chemistry*, ed. L. Hill, Arnold, 1906.

has disposed of the simpler mechanical explanation, which at first seemed to be sufficient, in favour of another and far more complicated solution of the difficulty.

These and other difficulties, which it will be the business of this book to bring forward, have led many men of science to abandon the mechanical explanation of nature as inadequate, and have caused them to endeavour to substitute for it a further theory of living matter. Thus Dr. Haldane¹ says: "In a living organism there is a specific influence at work, which so controls all the movements of the body and of the material entering or leaving it, that the structure peculiar to the organism is developed and maintained". And again: "To any physiologist who candidly reviews the progress of the last fifty years it must be perfectly evident that, so far from having advanced towards a physico-chemical explanation of life, we are in appearance very much farther from one than we were fifty years ago". As an American witness, Professor Wilson, perhaps the most eminent exponent living of the problems of cell-life, may be cited, and he tells us² that "the study of the cell has on the whole seemed to widen rather than to narrow the enormous gap

¹ *Nineteenth Century*, 1898, ii., p. 400.

² *The Cell in Development and Inheritance*, Macmillan & Co., 2nd ed., 1900, p. 434.

c/ that separates even the lowest forms of life from the inorganic world".

Well might Von Bunge, the celebrated German organic chemist, declare, as he did in 1886, at almost the very date when Huxley and others were ringing the knell of all but mechanical explanations, that "the mechanical theories of the present are urging us surely onwards to the vitalistic theory of the future".

It is somewhat curious that vitalistic views have made much more head-way in America and in Germany than they have done in England, and this has been explained by the undoubted fact that the biologists of the two former countries have devoted their attention much more largely to ontogenetic questions, that is, to matters relating to the life-histories of living things, whilst English attention, thanks no doubt to the stimulus given by Darwin, has been more directed to phylogenetic inquiries, that is, to the consideration of relationships between different living things.

It is also a curious point that physicists and chemists are far more chary of agreeing to the chemico-physical explanation of life than are biologists, and this fact is no doubt explained by the greater knowledge of the limitations and possibilities of their subjects which is possessed by chemists and by physicists as compared with the

acquaintance with those subjects which falls to the share of most workers in biology.

To return, however, to the point with which we were dealing, it must be admitted that the upholders of a vitalistic view do not always describe themselves as vitalists. But neither do the supporters of the electron view of matter call themselves alchemists. It is the fashion now to be neo-something or an-
 other, and so, besides neo-Darwinians and neo-
 Lamarckians, we have "neo-vitalists," who describe the entity which it would be superstitious to call a "vital principle" under some other name. Williams calls it a "genetic energy"; Cope a "growth- or bathmic-force". Henslow speaks of it as a "property of self-adaptation," and Eimer as one of "direction". Professor B. Moore,¹ who is one of the most recent persons—we are dealing here only with competent persons and not with incompetent expositors—to deal with this matter, calls it "biotic energy" and does so, as he says, to "avoid confusion with ancient fallacies".

Neo-
vitalistic
terminology

His remarks are so important and so illuminating that they will bear fuller quotation. "It is unfortunate," he says, "that the rebound from the bondage of the old view of a mysterious *vital force* or *vital energy*, possessing no connection or correlation with the forms of energy exhibited by non-

¹ *Op. cit.*, p. 4.

living transformers of energy, should have led to the equally mischievous view of the present day, that no form of energy whatever is present in living cells save such as are seen in the case of non-living matter." Then he suggests his own term of "biotic energy," to "represent that form of energy peculiar to living matter, and exhibited in those energy phenomena which are confined to living matter, and are indeed its intrinsic property, by which it is differentiated and known to be alive. It must be pointed out that this point of view is equally distinct from the ancient one of vital force, which postulated something entirely distinct from the forms of energy of the non-living world, and on the other from the modern view that there exists in living matter no form of energy which is not *identical* with the forms of energy exhibited in non-living structures." In this passage Professor Moore appears to depart from his usual lucid clearness. Two things must be either identical or distinct, and the question as to whether they are distinct or "entirely distinct" is one of degree and of minor importance. Now, on the writer's own showing, his "biotic energy" is not identical with the forms of energy exhibited by non-living matter. It must therefore be distinct from such forms. When this point is taken into consideration there does not seem to be any real difference, save one

of terminology, between Professor Moore and other neo-vitalists and the schoolmen who taught, in their own language, which few men of science think it worth their while to try to understand, that the vital principle (or, if you will, for we will not quarrel over terminology, the "biotic energy") is a simple principle which is entirely dependent upon the organism, or, as again they put it, is completely immersed in the body. That it should have been called a corporeal soul is again a matter of terminology. Let it be noted that this view is a wholly different one from that which looked upon the soul or vital principle as a kind of little super-man existent in some part of the body, as Descartes supposed it existed in the pineal gland. So far as the present writer is capable of understanding the views of Professor Moore and others who hold like opinions with him, there is no real difference, no difference at all but one of terminology between him and older writers—or at least some of the older writers on the vitalistic question.

At least this may be said, that all alike proclaim that in living bodies there is something else present in addition to what is found existing in non-living bodies, and that "something over" is—whatever we call it—the vital principle as defined by the schoolmen from whom quotation has been made.

CHAPTER II

THE CELL—ITS PARTS—PROTOPLASM AND ITS CHAR- ACTERS—NUCLEUS—CHROMOSOMES—RELATIONS OF NUCLEUS AND CELL PROTOPLASM

IN 1651 William Harvey, the great English naturalist and physician, in his work *De Generatione Animalium*, laid down the axiom *Omne vivum ex ovo*. This generalisation has since been shown to have lacked complete accuracy, since certain living things propagate themselves by fission. But if we alter it to read *Omne vivum ex vivo* we arrive at a statement which is now generally accepted by the scientific world, though it has been strenuously opposed and is still contested by a few as will be more fully described in the chapter dealing with abiogenesis. Second only in importance to this generalisation is that which Virchow proclaimed in 1858, *Omnis cellula ex cellula*. From that time the study of the cell has absorbed the attention of scores of workers and especially of late years has developed an enormous literature entirely its own. Nor is this wonderful when one remembers the remarkable results which have followed upon this

discovery. Originally enunciated by Schwann and Schleiden in 1838-9, it was, as has been said, first formally laid down as a principle by Virchow in the work which revolutionised pathology and is the foundation of all modern knowledge in that subject. It was through this discovery that the common plan of organisation of plants and animals first became evident. It was through it also that we have arrived at an understanding of the processes of fertilisation and of development. It is clear, therefore, as Wilson¹ says "that the key to all ultimate biological problems must, in the last analysis, be sought in the cell". Von Bunge points out that it is no simple exercise which we set ourselves when we proceed to endeavour to unravel its mysteries. "When," he says, "with the help of scalpel and microscope, we have dissected the organism to its last shred, when we are concerned only with the single cell—then the greatest riddle still lies before us. The single cell, the formless structureless microscopically small drop of protoplasm—it shows all the essential functions of life: nourishment, growth, reproduction, motion, sensation—yes, even functions which at least compensate for the 'sensorium,' the conscious life of the higher animals."

The cell is indeed a very small object of study.

¹ *Op. cit.*, p. 1.

The tiny mass of protoplasm, though we now know that it is by no means structureless, would seem to the casual observer to be an object whose possibilities must soon be exhausted. Yet the more microscopes are improved, the more methods of staining and of observation are perfected, the more the cell is studied, the greater are the mysteries which it is found to contain. Again we may quote from Wilson, the highest authority on this subject, who expresses the opinion that "the recent advance of discovery has not tended to simplify our conceptions of cell-life, but has rather led to an emphasised sense of the diversity and complexity of its problems".

Schwann, when he first enunciated the cell-theory, thought that he had disposed of the question of vitalism once for all and in a sense contrary to that theory of life. But Schwann was mistaken and the theory on which he based his conclusion has since been shown to be incorrect. What Schwann did was to shift the question to a smaller region, but in doing so he by no means made it an easier question to be solved.

Since then the cell is the basis of all biological inquiries it will be well for us to commence our quest by briefly considering its characters and structure.

The cell (see fig. i), speaking in the most general

terms, is a small spherical mass of protoplasm containing a nucleus or specialised central portion.

Protoplasm, a term first used by Purkinje in *Protoplasm* 1840 is a viscid albuminoid substance like the un-boiled white of an egg. It was well described by

Diagram of a cell Its basis consists of a meshwork containing numerous minute granules (microsomes) and traversing a transparent ground-substance. From Wilson.

FIG. I.

Huxley as "the physical basis of life," and there can be no doubt that it is "the immediate substratum of all vital activity". To attempt to enter into any complete description of this most important substance would be impossible, even if it were advisable in a work of this character, but

the following points, at least, must be made clear. In the first place whilst we can watch the movements of and in living protoplasm under the microscope, we cannot stain that protoplasm or still more examine it chemically without killing it and thus, it is highly probable, fundamentally altering its characters. So that when one reads about the chemistry of protoplasm, or about certain things in the cell which are studied by the aid of chemical re-agents, it is always important to remember that it is dead protoplasm and a dead cell which we are reading about, and that in that fact lies the possibility of a fundamental fallacy. With this reservation then we may say that protoplasm is composed of relatively few chemical elements. It contains carbon, which we know of, under one of its forms, as charcoal. It contains hydrogen and oxygen, two gases which enter into combination to form water, and it contains nitrogen, another gas which with oxygen makes up most of the air which we breathe. These four substances are its most important constituents, but in addition to this there are minute quantities of other elements, notably phosphorus. It is not to the number of elements contained then that protoplasm owes its complexity. But there can be no doubt that the molecule of protoplasm, if indeed it is in any way correct to say that protoplasm has a chemical molecule, must

Has protoplasm a molecule?

be one of enormous complexity. Again, however, it must be insisted that we know not what may be the actual state of affairs in living protoplasm, nor do we even know that the composition of the protoplasm in one part of a cell may not differ from that in another part, whilst that cell is alive. "Protoplasm," says Wallace,¹ "is so complex chemically as to defy exact analysis, being an elaborate structure of atoms built up into a molecule in which each atom must occupy its true place, like every carved stone in a Gothic Cathedral." Pflüger, too, a very distinguished German physiologist, tells us that living proteid or protoplasm is a huge molecule, undergoing constant, never-ending formation and decomposition, and gives us an illuminating view of its characters when he says that it probably behaves towards the usual chemical molecules as the sun behaves to small meteors.

Much attention has been devoted to the solution of the question of the structure of protoplasm, but so far, if must be admitted, without any definite results.

The cell is generally included by a wall, and if Parts of cell the unscientific person wishes to obtain a rough idea of what it is like he may imagine a child's toy air-balloon filled with unboiled white of egg. In the centre of this white of egg let him suppose that

¹ *Man's Place in the Universe*, p. 199.

there is floating a small glass sphere as big as—say—a Tangerine orange, and that inside this sphere are some tangled skeins of red tape floating in a further mass of unboiled white of egg. He will then have constructed a mental model of a generalised cell. The air-balloon will represent the cell wall and the white of egg within the cell-protoplasm or cytoplasm. The contained sphere will represent the nucleus and the skeins of red-tape the chromatin skeins which it contains. The nucleus is generally—though not at all times—included in a nuclear membrane which is to it what the cell-wall is to the cell. Within this membrane is a reticulum or net-work, a ground substance or nuclear sap and often one or more nucleoli.

Nucleus

Of all these portions the most essential is the reticulum which consists of two parts, a general protoplasmic basis, or linin, which closely resembles cytoplasm, and a second constituent known, from its faculty of staining deeply with certain re-agents, as chromatin. There are some who maintain that the interstitial protoplasm is the most important part of the nucleus, but the great weight of scientific opinion at present inclines to the view that the chromatin fragments are the essential part not only of the nucleus but of the whole cell. It seems as if it were the only part of the nucleus which is specifically sorted out so as to be handed

Chromatin

on from cell to cell, and it also seems that it has the power of producing all the other elements of the cell. It consists of a number of small bodies which are called chromosomes and in the division of cells—of which fuller details will shortly be given—these chromosomes are evenly divided between the mother and the daughter cells.

The nucleus is then the most important part of the cell and the chromosomes are the essential part of the nucleus. Slightly to anticipate matters which will be made more clear in another chapter, it may here be said that in addition to the two axioms laid down at the commencement of this chapter we are now in a position to accept a third, laid down by Flemming in 1882, *Omnis nucleus e nucleo* and even a fourth, postulated by Boveri in 1903, *Omne chromosoma e chromosomate*, for we know that as living thing comes from living thing and cell from cell and not otherwise so nucleus is derived from nucleus and chromosome from chromosome and also not otherwise.

But though the nucleus is the essential part of the cell and its chromosomes are the most essential factor of the whole structure it does not follow nor is it the case that the nucleus or its chromosomes are self-sufficing. This has been proved by direct experiment. It is possible for the skilled manipulator to deprive a unicellular organism of its nucleus.

Relations of
nucleus and
cell

What happens? The cell—thus emptied of its most important part—does not immediately die. For a time it will go on exhibiting what we shall shortly learn is one of the most important and characteristic activities of life, namely irritability. But it has lost, and that permanently, all its former powers of assimilation, of growth and of repair. It is not dead but it is dying and nothing can hinder or delay its final death. Hence, as Roux and others claim, and it would appear justly claim, the nucleus is the controlling agency in the cell.

But, on the other hand, if the cell cannot get on without the nucleus, neither can the nucleus get on without the cell, for it too perishes if it be cut off completely from it. It seems as if the cytoplasm, or cell-protoplasm in some way acts as a stimulant to the nuclear protoplasm and hence, though the nucleus is, or appears to be, the main factor in division, it is possible that the cytoplasm may “indirectly regulate the process of cleavage”.¹

Cytoplasm then is necessary to nucleus and nucleus to cytoplasm. If a unicellular organism be so divided up that certain of the fragments into which it is separated contain portions of the nucleus and certain do not, those fragments which contain

¹ Morgan, *The Development of the Frog's Egg*, p. 128.

bits of the nucleus will continue to live and what is more will gradually reconstruct themselves so that each of them will become a new organism. But not so the bits which have not been fortunate enough to secure a fragment of nuclear substance. As above stated these portions linger for a time with some of the signs of life but ultimately die.

Hence we may conclude with Balbiani¹ that "the cellular life neither resides exclusively in the protoplasm [*i.e.*, cytoplasm or cell-protoplasm as opposed to nucleoplasm] nor within the nucleus, but results from the reciprocal relations which are established between these two elements. Isolated one from the other, neither of them is capable of life by itself."

The various structures which have thus briefly been passed under review are the main constituents, not only of the unicellular organism, but also of all living cells, whether they be gland, nerve, muscle or bone cells. Each of these specialised cells, however, has its own peculiar powers and duties and its own characteristic features. In addition to the structures mentioned, a cell may contain fatty substances, vacuoles or cavities containing fluid and even crystals.

Having now studied the appearance of the cell as it presents itself to us under the microscope it

¹ *Annales de Micrographie*, 1893.

will next be necessary to consider the characteristic activities of which it is the seat, and to inquire in how far these resemble the behaviour of inorganic substances and in what ways they differ from them.

CHAPTER III

CHARACTERISTICS OF LIVING MATTER—AMOEBA— MOTION—IRRITABILITY—ASSIMILATION AND META- BOLIC PROCESSES—RESPIRATION—REPRODUCTION— DEATH

MANY pages could be devoted to a list of the various definitions of life which have been given by different writers, yet none of which has met with full and complete acceptance. But though the final definition is still to seek there are certain characteristics of living matter recognisable by all, which must now form the subject of our inquiries.

Suppose we take the case of the unicellular *Amoeba* organism known as amoeba,¹ a creature somewhere about $\frac{1}{160}$ inch in diameter and nearly conforming to our notion of the generalised cell, since it consists of an outer coat or ectoplasm, an inner granular protoplasm, a nucleus and a contractile vacuole.

If we watch this lowly creature we may first of *Motion* all notice that it moves (see fig. ii.). It does this by pushing out a fragment or projection of its own

¹ For a fuller account see Hartog, "Protozoa," in *Cambridge Natural History*.

body and then drawing the remainder up to the promontory which has been put forth. Thus it is able to move itself from place to place. But beyond this we may observe the granules which generally exist in the protoplasm to be also in movement.

Amoeba, showing clear ectoplasm, granular endoplasm, dark nucleus, and lighter contractile vacuole (From Verworn)

Amoeba devouring a plant cell; four successive stages of ingestion. (From Verworn)

FIG. II.

We can see that these "stream constantly forwards along the central axis of each process as it forms, and backwards within the clear layer all round, like a fountain playing in a bell-jar."¹

So that the movements take place within the creature and it is also able to transport itself from

¹ Hartog.

place to place. Further, if we set up a current in the water in which the amoeba is floating we shall find that it always moves against that current. This is a function of most unicellular forms and of more highly organised creatures as well, for water-fleas and other small crustacea will swim away from the fluid which is rushing into the pipette designed to capture them. It is clear that this disposition to swim against the stream must be of considerable advantage to the amoeba in keeping it in its place in spite of the natural and ordinary currents in the water in which it may be living, or those other adventitious currents which may be set up from time to time by the passage of other creatures or by other means.

This power of being able to move itself is one of the most prominent and striking differences between the living creature and the non-living substance, and it was seized upon by St. Thomas Aquinas for his definition of a living thing. Thus he defines it: "*Illa proprie sunt viventia quae seipsa secundum aliquam speciem motus movent*";¹ and again, "*Ens vivum est substantia cui convenit secundum suam naturam movere seipsam*".² But it must not be supposed that in making this definition, which is a natural one and the most accurate

¹ *Summa Theol.*, 1^a, 9, 1, art. 1 c.

² *Ibid.*, 1^a, 9, 18, art. 2 c.

yet arrived at, St. Thomas was treating only of the movement of transportation. His intention, as Mercier¹ makes quite clear, was to take movement as the synonym of action, or more rigorously of any kind of action which involves a change. "Entre la simple aptitude au mouvement ou la pure puissance, d'une part, et le fait actuel qui suppose l'aptitude satisfaite ou la puissance réalisée, d'autre part, il y a la mise en œuvre de la puissance, son exercice, la réalisation du fait, c'est là le mouvement proprement dit. C'est l'acte de quelque chose qui n'est pas complet, dit saint Thomas 'actus imperfecti,' ou, comme s'exprimait Aristote,² 'c'est l'acte d'un être en puissance, en tant qu'il est encore en puissance.' Pour que l'esprit conçoive le mouvement, il faut qu'il ait simultanément en vue une double relation du mobile, l'une avec une puissance déjà réalisée, l'autre avec un acte encore réalisable le mouvement est tout à la fois la réalisation d'une certaine potentialité, et l'acheminement vers un acte ultérieur plus complet, c'est donc bien l'acte d'une puissance encore en puissance."

Irritability

In the second place if we watch the amoeba we shall find that it is capable of responding to certain stimuli, such as a touch, to which it replies by contracting itself and by drawing in any projections

¹ *La Definition Philosophique de la Vie*, Louvain, 1898, p. 60.

² *Physic.*, v., 1.

which it may have thrust out from its body. This property of "irritability" is one of the most remarkable which is possessed by living matter. It was defined by Claude Bernard as being the property possessed by the protoplasm of every anatomical element of being stimulated to activity and of reacting in one particular way to the external stimuli to which it might be submitted. What happens in this case of irritability is that some of the internal energy of the amoeba is transformed from the potential to the kinetic state and that in "response to an action of itself inadequate to produce it; and has been compared not inaptly to the discharge of a cannon, where foot-tons of energy are liberated in consequence of the pull of a few inch-grains on the trigger, or to an indefinitely small push which makes electric contact: the energy set free is that which is stored up in the charge".¹

Thirdly, the amoeba may be observed to feed **Assimilation** and this it does by putting forth processes of its body wherewith it surrounds any particle of food which may be in the water around. Having accomplished this it then dissolves the particle or such portions thereof as are available for its purpose, utilises the dissolved material for the re-building of its tissues and the replenishment of the energy which it has expended in its various actions and

¹ Hartog.

Metabolism

casts out the useless refuse from its body. In some manner or another all living bodies and all living cells must be fed, must change their food into the materials suitable for their own use and must get rid of waste and superfluous portions. In this brief statement is included the whole vast science of physiological chemistry, even to glance at which would be impossible in this book. Speaking in the most general manner it may be said that these metabolic changes, as they are called, are of two kinds. On the one hand less complex and more stable substances are built up into other substances of diametrically opposite character, they being more complicated in their nature and less stable. During this "anabolic" process energy is absorbed.

And on the other hand there is the reverse process called "catabolic," in which these unstable, complex substances are broken up into simpler and more stable matters, a process accompanied by the giving out of energy. Further one must remember that the chemical processes which take place in a cell may be looked at, from quite another point of view, as dual. There are the processes which are carried on for the renewal of the cell itself and for the maintenance of the various energies of which it is the seat, and this is true whether the cell is isolated—a unicellular organism—or whether it is one of many as a portion of a multicellular organ-

ism. But, secondly, in many cases other substances, which we may speak of as bye-products, are constructed in the course of the operations carried on in the cell-laboratory. These bye-products do not appear to be of primarily or indeed of any importance to the cell, and may be actually injurious to it if retained, yet they are or may be highly beneficial or even necessary to other parts of the body, or in other cases they may be of high value to other living creatures, wholly unconnected with the organism which has produced them.

As an example of the first kind of substance ^{Bye-products} one may instance the bile which is secreted by the liver cells or the pancreatic juice or a number of the other internal secretions, such as those of the thyroid body or adrenals, all of these being of prime importance to the well-being or even existence of the body, but none of them being of first importance to the cells concerned themselves so far as we know.

The second group of excretions includes the various vegetable oils, and substances such as musk in the animal kingdom. As to these it is difficult, if not impossible, to say that they are of no service to the plant or animal which produces them, and it is only their great value to us which makes us look at them more from our point of view than from that of the organism which produced them. But, at any rate,

it is quite clear that the various excreta are got rid of because they are of no further use to the animal excreting them, yet they may be of great service for purposes of fertilisation.

Finally, as regards this question of nutrition and digestion, the result of this taking in of food, and of the changes which take place in it, is an increase in size always, however, within certain limits peculiar to each species, very wide limits in some cases but still definite limits, so that one can always say of any given species that it will not exceed a certain size or fall below a given limit.

Respiration Respiration is a process closely associated with those which we have been considering. We cannot see it taking place in the amoeba but we must suppose that the interchange of gases which constitutes this process takes place all over the surface of the creature.

Reproduction But if we cannot see the respiration taking place there is one further very remarkable phenomenon which we can study and that is the process of reproduction. In the amoeba this consists of a division, first of the nucleus and secondly of the whole cell into two portions, so that where there was previously but one amoeba, now there are two. It is obvious that in such a case it is impossible to speak of mother and daughter, since both cells might lay claim to either title, each representing

one half of the original cell. Some such process of multiplication takes place in all living things, but this important matter is one which will require fuller treatment in a succeeding chapter.

Last scene of all which ends this strange event-**Death**ful history, the amoeba may die. Weismann teaches that the unicellular organism is potentially immortal, and indeed there seems to be no reason why an amoeba should not go on living for an indefinite period, unless we regard the time when a given amoeba divides into two new forms as being really a period or moment of dissolution and recreation. But, at any rate, it is quite clear that we can kill an amoeba by a strong current of electricity, by exposing it to a temperature higher than it can bear, or by mixing certain chemicals with the water in which it lives. Under any one of these circumstances the amoeba dies, that is the living substance of which it consisted becomes not-living and the oxygen and other chemical substances which had up to this moment been its slaves now become its masters and destroy it. "This change is associated with alterations in the mechanical and optical properties of the protoplasm, which loses its viscosity and becomes opaque, having undergone a process of *de*-solution ; for the water it contained is now held only mechanically in the interstices of a network, or in cavities of a

honeycomb, while the solid forming the residuum has a refractive index of a little over 1.6. Therefore, it only regains its full transparency when the water is replaced by a liquid of high refractive index, such as an essential oil or phenol. A similar change may be effected by pouring white of egg into boiling water or absolute alcohol, and is attended with the same optical results.”¹

Such, then, are the chief characteristics revealed by our study of the amoeba. It moves, it responds to stimuli, it breathes and it feeds, it carries on complicated chemical processes in its interior. It increases and multiplies and it may die.

These observations are not only true of the single-celled organism but of the multicellular and they are equally applicable to the animal and to the plant.

Perhaps, however, it may be right to call the attention of those unaccustomed to consider biological problems to the difference—apart from all question of multitude or number of cells—which exists between the unicellular and the multicellular organism. In the former case all the functions which the animal performs are carried out by the single cell. To put matters plainly this one cell is brains, lungs, heart, stomach, intestines and reproductive mechanism. In the multicellular

¹ Hartog.

organism there is a division of labour, so that whilst there are many more cells, each of them is capable of doing less work or a lesser variety of work than the single cell of amoeba. We may compare the conditions exhibited by the two to the older and the newer conditions of mechanical labour. In olden days the artisan made the whole of—say—a watch, nowadays, he makes a pin or a screw and nothing else and knows and perhaps cares nothing about what the pin or screw is for or how it affects the operations of other hands.

Moreover in the multicellular organism each cell has its own life as well as sharing in that of the whole body. It may have its birth and its death, of both of which the body as a whole is entirely ignorant.

But whether it is an isolated cell or a member of a cell-congeries, as a part of a multicellular organism, it will exhibit the characteristics dealt with in this chapter, though, of course, in varying degree in accordance with its site and its functions.

CHAPTER IV

CHEMICAL CHARACTERS OF CELL—CRYSTALLISATION— BYE-PRODUCTS OF CELL—MOVEMENT—IRRITA- BILITY OR TACTISM

THE comparison between living bodies and a machine will form the subject of another chapter, but having proceeded as far as we have in the study of the cell it may be wise to pause for a short time and consider in how far the facts narrated in the previous chapters tally with the conditions obtaining in inanimate nature and how far the two categories are at variance with one another.

Chemistry
of living
matter

In the first place it may safely be said that the chemical constitution of living matter, as far as we know it, does not in any way help us to understand its possibilities. As we have seen, we gain an idea of enormous complexity of composition, but that complexity does not begin to be an explanation of the wonderful powers of living matter. There are other highly complicated organic compounds but they do not display any beginning of vital powers nor anything which is on the road thereto, so far as they have as yet been investigated. It is true that

cyanogen was declared by Pflüger to be half-alive, but the phrase was rhetorically used, for what is really meant is not by any means what might be taken to be meant by the phrase in question. To explain the matter fully would lead one too far into the paths of chemistry, but this at least may be said that no chemist would assert that cyanogen or any of its compounds was in any way even on the road to being what may be properly understood to be a living organism even of the most lowly character.

Hertwig¹ says that the work of the investigator of the peculiar problems of life begins where that of the chemist comes to an end. "Over the growth of the chemical molecules is placed the growth of the cell, and over this again the growth of plants and animals with their unions of millions and millions of different cells. Chemical knowledge as it exists at present has nothing to do with that new world of organised substances in which the manifestations of life are first made obvious."

The living cell, as we have seen, is composed of comparatively few elements. It derives its food from all sort of things and from this food it builds and rebuilds its own substance, bending the materials which it assimilates to its own uses and purposes. This process of assimilation is no doubt

¹ *Allgemeine Biologie*, 2 te. ed., 1906, s. 19.

in some measure chemical, that is to say chemical changes and operations take place during its progress. But when one says so much one is not saying that the changes are purely chemical, for such, in fact, is not the case. In the course of an ordinary chemical combination two—or it may be more—substances unite to form a third, as common salt, for example, is formed from sodium and hydrochloric acid. But the cell takes up not-living matter and assimilates it and converts it into living protoplasm. Moreover this process of growth is interstitial in its character and not superficial, in other words it is not a growth in size due to the deposition of new layers on top of the old ones, as in the case of a rolling snowball. The deposition of new material occurs throughout the entire substance of the cell, so that its increase in size is due to a general expansion of the entire organism.

Crystals and
living things

And herein lies a prime difference between the living organism and a crystal, forms between which some have urged that a close resemblance exists, or at least have argued that between crystallisation and assimilation there were sufficiently close resemblances to permit it to be argued that there was no fundamental difference between the two processes. The difference just mentioned is fundamental in character and sufficient in itself to distinguish the two processes. But beyond this

it may be pointed out that when a crystal is formed by the evaporation of the solution of some salt, say the sulphate of copper which is formed into the huge blue crystalline masses often exposed in chemists' windows, what happens is that particles of an identical chemical character come together and take up—for reasons, it must frankly be admitted, of which we are entirely ignorant—the characteristic form or any of the characteristic forms of the crystals of the substance which was in solution. So that a crystal is a mass of homogeneous particles, collected together and built up into a regular edifice. Suppose we add new material to this, with a view to increasing the size of the edifice. All that happens is that new material of a precisely similar character is added layer by layer to the surface of the old, and this new material must be identical in character with that to which it is added. But in the cell, not only is the addition not layer by layer but interstitial and intimate, but also the substances which are taken in are moulded to the purposes of the cell and are broken up and converted into the very substance of the cell itself or into bye-products of one kind or another. Of this production of bye-products more must be said in a further paragraph, but before passing to the general question, it may be well, as we engaged upon the topic of crystal-

lisation, to point out that some living organisms do construct crystals within themselves so that if the parallel between crystallisation and assimilation were a fair one we should be confronted with the somewhat bizarre fact that one kind of crystallisation was making use of another for its own purposes.

Living
Crystals

The facts, however, which have been brought forward by Professor Minchin¹ show not only how different the two processes are but also how the living cell is able to modify the process of natural crystallisation for its own purposes. He says : "An ordinary crystal owes its peculiar characteristics entirely to the action of the laws of inorganic matter, laws which admit of being accurately formulated and accurately calculated. Crystalline bodies are, however, known to occur which have been deposited within living bodies, and which owe their origin to vital activities. In such cases, the crystals, while identical in their chemical composition and molecular structure with crystals of inorganic origin, may exhibit, at the same time, certain peculiarities which are due entirely to the circumstances of their origin. . . . The relation of the spicules to the structure of the sponge shows that they have a definite function to perform and an important part to play in the economy of the

¹ "Living Crystals," *Proc. Roy. Inst.*, vol. xv.

organism which produced them. . . . We may, therefore, sum up in regard to the living crystals as follows—their composition is that of calcite crystals, but their external form is that which the sponge requires, and not that which they would naturally assume. They furnish us, in fact, with a beautiful instance of what is called adaptation; that is to say, the fact that any living organism tends to have just that form, structure and organisation in all its parts which it requires in order to maintain its existence in its peculiar mode of life, whatever it may be.”

Finally, as regards the question of crystallisation, the crystal of any rock can be dissolved and will re-crystallise under suitable conditions, and these two processes can be repeated *ad infinitum*. But the living cell once destroyed cannot be reformed, another fundamental difference between the two.

The question of bye-products is one which has been already touched upon more than once; and what a remarkable series of bye-products there are when one contemplates the vegetable world alone! There are the numerous alkaloids and essential oils which are so much used in medicine and in the arts, the essences with which perfumes are made, waxes, turpentine and a whole host of other compounds all constructed by the cell in its

Bye-products of cell

N.B.

own laboratory and out of the comparatively few elements, for the greater part four or five only, with which it works.

Yet all the time that the cell is doing this, all the time that it is breaking up and rebuilding its own substance, whilst it is concocting in its internal manufactory the bye-products of which we are speaking, all this time the cell remains unaltered or unaltered save in immaterial characteristics. It is the same cell, though all its constituents may have been changed. Just so our bodies remain our bodies, though the constituents of which they are composed are constantly altering. One is reminded of the knife which was the same knife though it had had a new handle and new blade or of the more poetical simile of Wordsworth :—

For, backward, Duddon ! as I cast my eyes,
I see what was, and is, and will abide ;
Still glides the Stream and shall for ever glide ;
The Form remains, the Function never dies.

NB { Chemistry then does not raise the veil which hides the secret of life, and physics is equally incompetent to do so, indeed Lord Kelvin¹ says that “the only contribution of dynamics to theoretical biology is absolute negation of automatic commencement or automatic maintenance of life.”

Movement

Movement, which we have seen to be one of

¹ *Properties of Matter*, p. 415.

the characteristics of living things, is not, except in the form of the so-called Brownian movement,¹ exhibited by not-living matter. A stone on the moor will not shift its position, nor will any internal movements take place within it, unless the wind or the rain or the action of some other force cause it passively to be moved. Atoms of non-living material thrown into water will sink or swim according to their specific gravity, and if they are capable of floating they will be borne down stream or hither or thither as the currents in the water may determine. But the living animal, even of the lowliest character, swims, if he chooses, and it generally does choose, against the stream, whether it does this like the amoeba by the putting forth of temporary processes, or like the ciliata by the waving of tiny permanent projections, or like the fish by the aid of its fins. NB

This tendency to move against the stream is called rheotaxy. But thus to name the capability or further to tell us that one of the characteristics of living matter is to react in this way to running water is not to explain the occurrence. Many Rheotaxy

¹ These movements, first described by Robert Brown, the botanist, are of a vibrating character, but there is no movement here of transportation as there is in living things, and the movements vary according to the condition of surface tension of the fluid in which the fragments—say of gamboge—are suspended; this tension may be modified by solution of soap for example. NB

people are satisfied if they have named a phenomenon and others are quite happy if they have restated the terms of the occurrence in fresh phraseology, but it must be quite obvious that neither of these processes helps one very far along the road which leads to an explanation of the process itself.

Let us, however, suppose for a moment, that the so-called rheotaxy is really a reflex action set up by the running water. At any rate it falls into line with a number of so-called other taxies, such as photo-taxy or the turning of certain plants towards the light and so on.

These we must look upon as examples of the power of irritability which the living protoplasm is possessed of, a possession which Hertwig describes as its most remarkable peculiarity. Moreover¹ he says that irritability exhibits its specific phenomena through the special structure of the irritable substance or, in other words, that irritability is a fundamental property of living protoplasm, but that it exhibits itself, according to its own specific structure, under the influence of the external world in specific energies and irritabilities.

NB
Does irritability exist?

The extreme school of mechanists deny that there is any such thing, strictly speaking, as irritability and with their views as formulated by one of

¹ *Op. cit.*, s. 136.

the most recent and most able writers on the subject, M. Le Dantec,¹ it will now be necessary to deal.

Spontaneity of movement, he tells us, is not an essential character of life. "If we observe with no other help than what nature affords all that goes on round about us, it will seem evident that the mouse moves in conditions where a stone of the same dimension and situated in the same place would remain motionless. In other words, where the stone's immobility shows that there is no cause of movement (wind, water-current, etc.), a mouse displaces itself *spontaneously*."

If we reasoned more closely, we should say: "Where the stone's immobility shows there is no displacing cause *for the stone*, the mouse's movement, on the contrary, should make us think—either the mouse is endowed with spontaneous mobility, or at the point where it is placed there is some cause of movement *for the mouse*."

This no doubt is perfectly true, but the real heart of the matter is the nexus between the cause of movement and the movement itself. It is clear that the nexus might be physical, since some one might pick up the mouse and throw it away. It is conceivable that it might be chemical, since we could imagine a condition of affairs in which contact, say,

¹ *Op. cit.*, p. 157. Italics in quotations from this author are as in original.

with a certain gas, should set up a quasi-effervescence in the mouse which would cause movement. Or again it may be vital, that is that the mouse moves because it chooses to move and is actuated to that choice by the sight of danger, by the smell of food, by the call of another mouse or what not.

We may, of course, exclude the first form of movement, for in it the mouse is as passive as the stone and is moved in no other way than a stone when it is cast from the hand.

As regards the other or chemical explanation, one must commence by making it clear that the comparison of the gas and the effervescence used above was employed as a very rough simile, purposely rough in order to make clear the kind of series of incidents which might be postulated, but hopelessly crude when applied to a body the main phenomena in which are based on the behaviour of the colloid substances of which it is built up. Of these substances and their behaviour we at present know very little, and most people would say that to dogmatise and generalise on that little is, in the face of the many reconstructions which new facts are almost sure to entail, to say the least of it a very unwise proceeding. However that is just what has been done, and the writer in question, after dealing with the subject of tactisms, of which

mention has just been made, states it as his opinion that "the *irritability* peculiar to this cell species can be thus reduced to a sum of perfectly well-defined *tactisms*" (the cell in question is the Tactisms antherozoid of a fern). He proceeds: "After this *nothing* remains of the pretended spontaneity of movement in living bodies. An observer conversant with the results of all these experiments in tactisms *knows* that the movements he observes in living bodies through the microscope are due to the colloid and chemical reactions of the mobile beings and the medium." This will seem to most readers of Le Dantec's book a sufficiently wide deduction to have been drawn from the comparatively few facts brought forward. But let that pass. The quotations just given make it abundantly clear that in the author's opinion, and he may be taken as the spokesman of a certain school of opinion, there is no such thing as spontaneous or voluntary movement, but all movement is in the nature of a chemical or physical or chemico-physical reaction, and that, although we may be wholly ignorant of how this takes place, we may be quite sure, from what we know of the behaviour of fern-antherozoids and the like, that it does take place. With this summary of the views under consideration we may now return to the writer's first example. What made the stone move? It moved because some

one kicked it, *i.e.*, its motion was passive. What made the mouse move? Let us suppose that it was because it saw a cat. Then its movement was active. Not so, says M. Le Dantec, as we must suppose from the opinions which he expresses, the presence of the cat exercises a tactic influence upon the mouse which obliges it to move, but its movement is not an active one but as passive as that of the stone. As far as the present writer can see the above is a fair statement of the views now under consideration.

If this is the case, however, there is one thing quite clear, namely that the tactic influence must work always and unerringly and altogether apart from any influence which the mouse may be supposed to be able to exhibit, granting for a moment that it could, if the passive sport of tactisms, exercise any influence over itself or anything else. This at least is clear, for the rigid unbending rules of chemistry and physics would make it impossible for any departure to arise from the regular series of events involved in a chemical or physical process. We may grant that a mouse does usually or even invariably fly from a cat when it sees one. The reaction regularly occurs. But we cannot be at all sure that if a cat was introduced for the first time into an island inhabited by mice that they would fly from it. So far as the present writer

is aware the experiment has never been tried. But a very similar experiment has been tried and its results seem quite fatal to the conclusions which have been set out above. Let us substitute a sea-bird for the mouse and a man for the cat. It will be granted by all that the re-actions which might be supposed to take place between the mouse and the cat might equally well take place between the bird and the man.

And as a matter of common observation we know that a sea-gull will not allow one to walk up to it, but will fly or exhibit the phenomenon of motion at the approach of a man. But this has not been true always or of all places. We know quite well from the writings of early explorers that when they set foot on islands where men had never previously trodden, they found the sea birds quite tame, and instead of exhibiting a movement of repulsion it was one of attraction which took place, for the creatures waddled up to see what new thing had drifted on to their shores. All this was changed when the poor birds came to know what men were and how dangerous it was to remain long in their vicinity.

Now one may fairly ask, what becomes of the theory of tactisms in this case? Here we have a sudden change of behaviour on the part of the birds towards the men, an alteration of a kind

wholly unknown to chemistry and physics, one which can only be explained on the ground that the birds were possessed of a sense not belonging to non-living matter. The only other explanation is that the contact with man caused such an alteration in the colloids of the sea-birds' bodies that a different re-action took place after some time of acquaintance to that which was first exhibited and such an explanation only needs to be formulated for its absurdity to be seen.

We may fairly claim then that though many phenomena exhibited by living things may be explained as tactisms, and as re-actions to certain chemical or physical forces, it is not possible to explain all the phenomena of life or of irritability in these terms.

CHAPTER V

REPRODUCTION—KARYOKINESIS—A VITAL PROCESS— CELL-DIVISION—IS IT MECHANICAL?—EXPERIMENTAL EMBRYOLOGY

WE have already seen that one of the leading characteristics of living things is their power to reproduce themselves, to increase and multiply. In the case of the amoeba this process is of the simplest nature, for from the single individual are formed two new members of the race, neither being strictly speaking mother nor daughter.

In the great majority of cases and in all the higher animals and plants reproduction takes place as the consequence of the fusion of elements derived respectively from the male and the female which combine to form a single cell from which are derived, by successive divisions, all the cells, however many and however differentiated from one another of which the adult body is built up.

In certain cases no remarkable phenomena attend this process of the division of a cell into two

parts, but in the majority of instances, and invariably in the case of the cell from which a new individual is to be built up, a singular series of events takes place of which some mention must now be made.

In a previous chapter the structure of the nucleus and cell in what is often called, though the term is a misleading one, the "resting stage" has been described and it will not be necessary to recapitulate the facts there laid down.

Prior to the division of the cell the linin of the nucleus, or most of it, becomes broken up into a series of threads on which the particles or granules of chromatin arrange themselves along the threads like so many beads on a string (see fig. iii.). Then each bead splits into halves and as the linin thread at the same time flattens out, the appearance comes

DESCRIPTION FOR FIG. III. ON PAGE 55.

A. Resting cell with reticular nucleus and true nucleolus; at *c* the attraction-sphere containing two centrosomes. B. The chromatin formed into a continuous tape, nucleolus present, amphiaster (*a*) formed around centrosomes. C. Spindle-shaped karyokinetic figure formed, consisting of two centrosomes with radial arrangement of protoplasm around each, equatorial plate (*e.p.*) of chromosomes in centre. D. The equatorial plate (*e.p.*) has split longitudinally (*n*) the cast-off nucleolus. E. The two sets of chromosomes are diverging and the interzonal fibres (*i.f.*) lie between them, the central spindle. The centrosomes are already doubled in anticipation of the next division. F. The cell-body has divided and the two groups of chromosomes are in process of reconstructing themselves into nuclei. G. Completion of the process of division. Two cells, with fully constituted nuclei and centrosomes take the place of the single cell shown in A.—From WILSON.

FIG. III.—DIAGRAM SHOWING THE PHASES OF KARYOKINESIS DESCRIBED IN THE TEXT.
(For description see page 54.)

to be that of a piece of tape along both edges of which small beads have been sewn. Then the piece of tape is split longitudinally, so that we now have two narrow bands of linin each with its single row of chromatin granules. When these processes have taken place—in many though not in all cases—the nuclear wall disappears and two little bodies, called centrosomes, come to lie one at either side of the cell. The chromosomes, for so the linin bands with chromatin beads are called, arrange themselves between the centrosomes in such a manner as to form a spindle-shaped figure with its broadest part in the centre of the cell and its apices at either side and converging on the centrosomes. Meantime the cytoplasm, or cell-protoplasm has also been rearranging itself in the neighbourhood of the centrosomes, forming around them a series of rays, so that there are at each side of the cell two figures resembling conventional representations of the sun, between which is the spindle-shaped basket of chromosomes.

The chromatin is now no longer arranged along the edges of the linin bands as it was at first, but becomes gathered together about the equator of the spindle, that is at its widest portion which is situated at the centre of the cell.

All these events may be considered as having been preparatory to the great business of division

which is now to take place. The chromatin masses, at the centre of the spindle, now become divided into two parts, each by a line of fission which is at right angles to the long axis of the spindle. Two groups of chromosomes are thus formed which we may roughly speak of as a right and a left group. Each of these now retreats farther and farther from the centre and from its sister group and approaches nearer and nearer to the periphery and to the centrosome.

It does not, however, actually reach this structure but stops short on arriving near it, so that we now find on either side of the cell a group of chromosomes situated to the inner side of the centrosome, which chromosomes as they take up this position become shorter and thicker and crowd up close to one another. A wall forms around each group of chromosomes, a new nucleus or pair of nuclei being thus constituted, and finally a wall of separation divides the two parts of the cell from one another and the process of division is complete, for where one cell alone existed there now are two. Such a process of division, accompanied by this kind of country-dance on the part of the chromosomes, is called a process of karyokinesis or of mitosis and one can hardly dwell at all deeply on the significance of it without coming to the conclusion that a part at least of its intention is that

Distribution
of chromo-
somes

there shall be a similar distribution of the chromosomes throughout all the cells of the body. The original cell from which the whole body is to be formed was possessed of a certain number of chromosomes, let us say eight. At the first division there occurs a halving of each of these, so that in each of the pair of cells which is derived from the original cell there will again be eight chromosomes and each of these will have a sister-chromosome in the other cell.

Further, as subsequent divisions take place and the number of cells becomes enormously increased, the same process is continued, so that there are always the same number of chromosomes in every cell—of a given species—and these are derived by direct descent from the chromosomes of the original cell. These remarkable facts, which are the outcome of the intense study of the cell which has been such a prominent feature of the biological work of the past quarter of a century, are of the profoundest significance and have formed the foundations of more than one imposing edifice of theory as to their meaning. Into these points it is not possible here to enter, but what one has to consider is the nature of the process which has just been described.

Vital or
mechanical

Is it chemico-physical in its character or is it a purely vital phenomenon? A good deal of atten-

tion has been directed to this inquiry, and particularly by Professor Hartog,¹ who points out that the spindle and the external radiations described above make up a "strain-figure," like that of the "lines of force" in relation to the poles of a magnet. "Such," he continues, "we can demonstrate in a plane by spreading or shaking iron filings on a piece of paper above the poles of a magnet, or in space by suspending finely divided iron in a thick liquid, such as mucilage or glycerine and bringing the vessel with the mixture into a strong magnetic field; the latter mode has the advantage of enabling us to watch the changes in the distribution of the lines under changing conditions or continued strain." From this we gather that there are at the very least strong features of resemblance between the remarkable dance of the chromosomes and operations which can be produced by means of purely physical conditions, but does this mean that the two are really identical or even similar processes? Similar, but not identical, is Professor Hartog's reply to this question. "Though," he says, "the forces at work in the dividing cell are similar in their effects to such physical forces as magnetism, static electricity, and even capillarity, and models utilising such physical forces have been devised to

¹ *Op. cit.*, p. 26, for references, etc., see his paper, *Proc. Roy. Soc.*, 1905, B. lxxvi., p. 548.

represent the strain figures of the cell, the cell forces are distinct from any known physical force." In other words the indications point to the fact that the remarkable happenings which have been described as taking place in the cell prior to and during division are vital manifestations, since they cannot be explained by any of the known forces of physical science.

Division of
ovum

We are now in a position to pass from this part of the question and to consider another of no less interest. The first division of the fertilised ovum had as a result the production of a two-celled creature. Each of these cells again divides, so that if division were always regular in its progression, which it is not, we should have the two-celled stage followed by one of four cells and that by others of eight, sixteen, thirty-two, sixty-four and so on. Such a progress of division does take place in some cases, but in others differences, as to which nothing can here be said, are exhibited. But whatever may be the sequence of division the result is the formation of a creature which from one cell has developed into a multicellular organisation. It is obvious that this multicellular organism might consist of identical cells or of cells differentiated from one another in groups so as to form different organs. Such is the condition which is met with in all the higher animals where, as, for example, in

man, differentiation is carried to a very great distance. Yet even in man the cells of the brain, of the liver, of bone, muscle and skin, so different from one another, so utterly unconvertible into one another, are all the descendants of a single cell and have been derived from it by processes similar to those described in the earlier part of the present chapter. Perhaps one may pause for a moment here to consider the bearing of these facts upon the question with which this book is concerned. The living body is often compared to a machine and is said by some to be nothing but a machine and explicable, did we know all the facts, on the same laws and principles as those whereby a machine is explained. Those who hold such views have, at least so it seems to the present writer, to encounter enormous, even insuperable, difficulties, when they arrive at this subject of development; for let us grant that the cell—the single cell—is a machine for the purposes of argument. Let us even suppose that such a machine should be capable of producing, of its own mere motion, other machines like unto itself. That is a sufficiently large assumption, since no machine has ever yet been made or thought of which does anything even faintly foreshadowing what is here imagined. Nor has any chemical compound the power of reduplicating itself, by means of its own inherent forces.

Living body
and machine

Suppose even that these things were believable they are nothing to what happens in the formation of the body of an animal. For here the original cell—or machine as some would have it—does far more than reproduce itself, it makes scores and hundreds of new and quite different machines. We might perhaps imagine a lathe which could beget other lathes, but here is a lathe which produces sewing-machines, organs, quick-firing guns, dredges, railway-engines and a whole host of other complicated assemblies of machinery. It is difficult if it is not impossible to believe anything of the kind. Some one has aptly remarked that if we were to fill the hull of the *Great Western* with machinery as fine as that which is met with in an ordinary watch it would in some measure represent the complicated arrangements and activities of the single cell, but what must be its powers if it is capable of developing in the manner and in the directions in which we know that it can and does develop. In order to parallel what it does by chemical processes one would have to imagine a crystal, say, of the so-called microcosmic salt since that has a tolerably complicated formula for an inorganic substance, placed in some sea water. We have then to suppose that this crystal collects to itself the necessary materials and surrounds itself with a number of crystals of other salts,

collects them into the same body, co-ordinates them and causes them all to work together for the common good, and finally splits off from itself small fragments not in any way resembling itself, from which, however, by a process of growth and development, further crystals like unto the congeries which we have been imagining are developed. Perhaps it will be said that the comparisons just made are crude and coarse and cannot fairly be taken as representing the delicate processes of nature. This may be freely admitted, but such comparisons bring out the difficulties which there are in accepting the mechanical theory of nature and, one may also say, exhibit the profound differences which exist between the inorganic and the organic worlds.

This argument is greatly strengthened when one takes into consideration the facts which have been elicited by the experimental study of developing ova during recent years. If there is one thing which is quite clear about chemical and physical processes it is that they are rigid and unvarying. So far as we know a certain result is attained by one series of steps and by that series alone, and any interference with that series leads to a collapse of the whole affair and a failure to achieve the end which would otherwise have been reached.

This is not the case in the process of develop-

Experiments
in embry-
ology

ment, for the egg possesses a power by which it is absolutely able to modify the course of nature and to arrive at its destination by a road never previously utilised by any egg. Some will reply that this is because the egg is adapted to reach a certain end and, therefore, does reach it. We shall have to consider more carefully the question of adaptations in a succeeding chapter but here it may at once be said that to explain or attempt to explain the occurrences which are about to be described by that method is really tantamount to explaining them by saying that what is intended to happen must happen, which does not help us very far upon our road.

And even those who hold to the most mechanical idea of adaptations, if such a word has any real meaning in the mechanical philosophy, which may be doubted, even these will be forced to admit that adaptations in nature would naturally be provided for purposes likely to occur in the ordinary course of nature. Now steps in the experimental embryologist, and with all the resources which science provides him with he sets himself to work to modify and distort the course of nature. What is the result? Within limits and wonderfully wide limits, the egg gets the better of him, for it arrives at the haven for which it set out without being deterred by the difficulties put in its way.

A number of experiments of this kind have been made and will be found in books dealing with questions of this kind. One or two of them may here be described in as simple language as possible, so that the reader unversed in biological literature may be able to understand something of the weight of evidence which lies behind the argument now under consideration.

First of all then we may consider certain experiments in the modification of the development of the eggs of frogs and sea-urchins, for both be- Frogs and sea-urchins have alike under these circumstances. The course of segmentation in these cases is as well known as the route from London to Brighton and the first result of segmentation is the production of a sphere of cells from which the later organism takes its form. Now the process of this development has been modified by placing the egg between plates of glass so that it must develop under pressure. As a result of this pressure it became impossible for the rapidly increasing number of cells to arrange themselves in a sphere as they would naturally have done, and they were forced to develop in a plane between the two sheets of glass. If the process were to be carried on too long the result would be the death of the developing creature from sheer want of room, so it must be released after the experiment has gone a certain distance. What

then happens? The egg goes on its way segmenting as if nothing had happened, there is no re-arrangement of the nuclei, a most significant fact, and finally a perfectly normal larva of frog or sea-urchin is the result. That is a frog or a sea-urchin has been developed by means of a series of events which one may safely say had never occurred before, a tolerably clear proof that there is within the egg a power which is able to steer it even through seas before unsailed by any egg.

N.B. }
Nereis

A further development of this is to be studied in experiments made by Wilson on the eggs of nereis, an annelid. It is a little difficult to describe this experiment without becoming highly technical, so that those who are familiar with the real facts of the case must deal leniently with the writer if he endeavours to make the circumstances clear by simplifying things to the utmost extent. In the normal development of nereis, then, it is known that certain cells will develop into certain parts of the later organism and others into different and distinct parts.

Now if the egg be allowed to develop under pressure as in the experiments above detailed, the lines of division are vertical in all cases, so that the segmented egg finally forms a plate, a flat plate, of eight cells. Now if these cells, thus formed into a plate, are released from the pressure under which

they have been developing they at once again divide in an approximately horizontal plane, so that sixteen cells now make up the congeries. The subsequent course of the development of these shows that some of the cells with, of course, their included nuclei, which would under normal circumstances have been worked up into one part of the body, are, under the altered conditions, actually converted into another. The significance of this experiment will be obvious to any one who considers it, but that significance will be increased when it is remembered that the results negative certain views which were held as to the specific character of the nuclei. It was held by some that the nucleus of each cell was of a specific character and could produce a cell of one type and of one type only. Even if this were the case it would not have helped us very far along the road towards an explanation of the powers of the cell, for we should still be ignorant of how the nucleus succeeded in so modifying the cell as to make it lead to the development of a liver or of some other part of the body. But this experiment, and many others of a similar kind might be cited, seems to show that the nuclei of the various cells during development, at any rate, have no specific character, but are capable, to put the matter colloquially, of

turning their hands to any job in the gradually rising edifice of the body.

A third and final experiment may be quoted, of quite a different character. It was also carried out by Wilson and is corroborated by other and similar experiments on other forms.

Amphioxus

There is a little creature which lives in certain seas and is known as the lancelet. To scientific men, and now indeed to numbers of readers who would not claim to be scientific, this creature is better known as the amphioxus. In the course of its development the single cell of which it was originally formed divides into two-, four-, eight-, sixteen-celled stages.

Now let us suppose that at the eight-celled stage the group is put into a test-tube with water and violently shaken. The result is that the eight cells are shaken apart and become completely separated from one another. Then a very remarkable thing happens. Most people would imagine that the immature creature must have been killed by such rough treatment, but such is not the case. Each of the eight cells, undaunted by what it has been through, sets itself to work, begins to divide on its own account and finally builds up a complete amphioxus. Let us consider what this means. A single cell, from the eight-celled groups, would under normal circumstances have constructed, one

may roughly say, one-eighth of the future amphioxus. It might have been worked up into its tail, into one of its internal organs, into a variety of portions of the body. But under the altered circumstances it is able to construct and does construct an entire and complete new amphioxus. It was the consideration of phenomena of this kind which led Driesch, one of the greatest of workers in this line, to declare that the egg seemed to act like an intelligent being.¹ And the same thing is admitted by Wilson in the preface to his great work² where he says: " 'One is sometimes tempted to conclude' was recently remarked by a well-known embryologist, 'that every egg is a law unto itself!' The jest, perhaps, embodies," he continues, "more of the truth than the author would seriously have maintained, expressing, as it does, a growing appreciation of the intricacy of cell phenomena, the difficulty of formulating their general aspects in simple terms, the inadequacy of some of the working hypotheses that have been our guides."

The facts of development and the observations which are due to the labours of the experimental embryologists present us with a picture wholly different from that afforded by a contemplation of the processes of inanimate bodies and it is the con-

¹ Morgan, *op. cit.*, p. 136.

² *Op. cit.*, p. xii.

templation of this wide and unbridgable difference which seems to be leading those or many of those whose work is chiefly of an embryological character to the conclusion that some kind of force other than that recognised by chemists and physicists must have its existence in the living cell, a force which is able to direct it to its appointed term of development and even, as we have seen, to lead it there in spite of difficulties which it could never have been supposed a few years ago by any scientific man would have been placed in its way.

CHAPTER VI

BIOGENESIS AND ABIOGENESIS—HISTORY OF THE CONTROVERSY—DR. BASTIAN'S VIEWS—WHERE DID LIVING MATTER COME FROM—THE CATHOLIC POSITION

THOSE who have followed the facts laid down in the last chapters will now be able to ascertain the foundation on which are constructed the four axioms mentioned in chapter II. :—*Omne vivum ex vivo, omnis cellula ex cellula, omnis nucleus e nucleo, omne chromosoma e chromosomate*. Something however still remains to be said respecting the first axiom, for after centuries of discussion the question of biogenesis or abiogenesis still seems unsettled to some.

Looking at things as we see them it is not wonderful that men should have believed, from the time of Aristotle onwards down to the seventeenth century, that living things could come directly from non-living things, that reptiles and worms were bred from the mud of rivers and that decaying flesh produced maggots. Harvey first proclaimed the contrary doctrine, and Redi, an Italian physician, showed in 1698 that the maggots found in putrid meat had not arisen from the meat but from the

eggs of flies deposited thereon, and moreover demonstrated the fact that if the meat was kept covered with gauze no maggots appeared in it. And as a result of this and of other observations the idea of spontaneous generation was put aside for a time, indeed until the microscope began to reveal the surprising number and variety of small living objects which had previously been hidden from men's eyes. The discussion continued at intervals during the eighteenth century and it is curious to note that two of the most active antagonists were both Catholic priests, Needham (1713-1781) who supported the theory of spontaneous generation, and Spallanzani (1729-1799) who opposed it. It was Spallanzani who first performed the experiment of boiling infusions for a sufficient time in hermetically sealed vessels, after which treatment, as he showed, no life was developed in them.

Spallanzani

After this demonstration the theory of spontaneous generation was once more consigned to oblivion, or at least to comparative oblivion, for it always possessed, as it does to this day, certain adherents.

Pouchet

Amongst these the most important was the elder Pouchet who in 1858 declared that he had seen the spontaneous production of infusoria in a sterilised fluid which had been exposed only to air also

deprived of all germs. The discussion on this subject became so active that the French Academy of Sciences in 1860 offered a prize for the solution of the matter. It was then that Pasteur came upon the scene and made the classical experiments which will always be associated with his name. First of all he showed, as Spallanzani had done before him, that infusions in which life would have appeared if they had not been sterilised, or if after sterilisation they had been left exposed to the air, would if boiled sufficiently long in closed vessels remain permanently without any signs of life. Then it was argued that this was because the fluid was deprived of fresh air. To this Pasteur retorted by the further experiment of filtering the air which was admitted to the sterilised fluid through a wad of cotton-wool. He even showed that if the flask in which the sterilised fluid was placed had a long neck bent into a zig-zag shape the contents remained untainted by life. The explanation of all these things is very simple, now that we know it. The air all around us is full of minute organisms, such as bacteria, which are capable of growing and multiplying with enormous rapidity in various infusions, such, for example, as beef-tea, and by their growth of causing the putrefaction of the fluid in question. Hence in all such fluids which have been exposed to the air there are these small

organisms and it is only a question of time as to when the fluid will "go bad" as we commonly put it. Let, however, such a fluid be boiled for long enough and all the organisms which it contains will have been killed and the fluid rendered temporarily sterile. Now if it is again exposed to the air it will again accumulate bacteria and again commence to decompose. Let us suppose, however, that when the process of boiling has gone on for long enough and the fluid is quite sterile, the neck of the flask in which it has been boiling is hermetically sealed up. No further bacteria can obtain admission and the contents will remain "good" as long as the seal of the neck remains perfect. It is on this experiment that the "canning" trade has been built up and every glass jar of soup or of calves'-foot jelly which we look at in a shop window is a standing proof of the truth of the facts which Pasteur proclaimed. As to the other two experiments, in the one case the bacteria are filtered out of the air mechanically by the wad of cotton-wool. The other is also a case of mechanical separation, for the tubular neck of the vessel being narrow and the bends in it frequent the bacteria become deposited on the sides of the tube before reaching the fluid contained within the flask. As a result of these experiments the view that all living matter is derived from living matter is now

NB }

almost universally held, though, of course, what Pasteur really proved was, not that living matter never arises from non-living matter, but that by observing certain laws and taking the necessary precautions certain substances which would otherwise become invaded by living things which would seize upon them for their food, would be kept intact from them. But as it was the appearance, apparently spontaneously, of life in such substances which had formed the foundation of the theory of spontaneous generation it has often, though inaccurately, been assumed that Pasteur proved that spontaneous generation does not take place.

Nevertheless the weight of scientific opinion at any rate at the present day is entirely against the possibility or at least the probability of spontaneous generation taking place. A few opinions may now be quoted.

Tyndall¹ says: "If you ask me whether there **Biogenesis** exists the least evidence to prove that any form of life can be developed out of matter without demonstrable antecedent life, my reply is . . . men of science frankly admit their inability to point to any satisfactory experimental proof that life can be developed save from demonstrable antecedent life." And that he remained of this opinion is shown by a statement four years later:² "I affirm that no

¹ "Belfast Address," 1874.

² *Nineteenth Century*, 1878.

shred of trustworthy experimental testimony exists to prove that life in our day has ever appeared independently of antecedent life."

Huxley, though he thought that spontaneous generation was "a necessary corollary from Darwin's views if legitimately carried out,"¹ yet admitted that in the controversy between biogenesisists and abiogenesisists the former were "victorious all along the line".² Virchow, the author of the *Cellular Pathology*, one of the greatest men of science of the last century, said in 1887:³ "Never has a living being, or even a living element—let us say, a living cell—been found, of which it could be predicated that it was the first of its species. Nor have any fossil remains ever been found of which it could ever be likely that it belonged to a being the first of its kind, or produced by spontaneous generation."

Two recent authorities will serve to close this catena of quotations. Hertwig in his recent magistral work⁴ says: "In the existing condition of Science there is little hope that any worker will be able to produce the simplest manifestation of life in any artificial way from non-living matter. He

¹ Letter to Charles Kingsley, *Life and Letters*, i., 352.

² *Critiques and Addresses*, Presidential Address to British Association.

³ In a address delivered at Wiesbaden.

⁴ *Allegem. Biologie*, 2te Aufl., s. 263.

has certainly no more chance of success in his endeavours than Wagner, in Goethe's 'Faust,' had of brewing a Homunculus in his retort."

Professor B. Moore, whose knowledge of biochemistry renders him a peculiarly valuable witness on this point, shall conclude the list. He says:¹ "The mode of production of living matter is characteristic, and cannot be brought about by the action solely of inorganic forms of energy. Living matter is produced only by the action of other living matter upon the materials and forms of energy of the non-living world. In the process the matter involved is built up into substances of great chemical complexity, and it has been supposed that this is the essential portion of the process of production of a living structure; but it must be noted that even this very production of complexity of structure from simple inorganic bodies at the expense of the energy of the solar rays take place and can only take place in a living structure itself. The very building up of the machine or transformer in which the manifestations of biotic energy are subsequently to take place is then a cogent argument that here we are dealing with a type of energy which is not met with elsewhere. For nowhere else in Nature does a similar process appear to that of the production of living structure, and by no

¹ *Op. cit.*, p. 7.

combination or application of the forms of energy apart from life can it be repeated or simulated."

It has seemed advisable to give this somewhat lengthy list of quotations in order to show that, though the possibility of spontaneous generation occurring cannot be excluded, there is at least an overwhelming belief that it does not take place.

Burke

Two recent attempts to dispute this conclusion must not be passed over without mention. The first is that of the so-called radiobes produced by Mr. Burke¹ by the action of radium upon beef bouillon. We need not delay over these appearances since they have been shown to be chemical in their character and to have nothing whatever to do with life or its beginnings.

Bastian

Dr. Charlton Bastian was one of Pasteur's antagonists during the time when the question of biogenesis or abiogenesis was really a burning one, and he has lately returned to the charge in a book² in which he maintains that Pasteur gained the victory by the aid of "illogical methods," a remark which is not very complimentary to the rest of the scientific world which has been quite imposed upon by these same methods. In this book he once more declares that he has been able to produce living from non-living materials.

¹ *The Origin of Life*, 1906.

² *The Evolution of Life*, 1907.

On this it may be remarked that if this were true the whole edifice which the modern science of bacteriology has built up comes to the ground and that it is a little remarkable that no one of the thousand workers at that subject have ever come in contact with any of the discoveries which Dr. Bastian has made.

Perhaps the reason for this may be found in a passage in which Dr. Bastian¹ says that : "Bacteriologists, as a result of repeated processes of heating at brief intervals and often at high temperatures for the special purpose of bringing about complete sterilisation, not only kill all pre-existing micro-organisms, but, as I maintain, destroy also any potential germinality of the media themselves. These media, after having been treated as above indicated, will nourish and favour the multiplication of living bacteria with which they are inoculated, but they will never engender them. They behave, in fact, exactly like a boiled ammonium tartrate solution—this also does not engender, but will freely nourish bacteria. As a result of habitually dealing with media thus treated (though they know that, with the exception of the spores of bacilli, all the microbes in their media may be destroyed by being boiled once only, for five minutes or less), bacteriologists have come to the conclusion that bacteria

¹P. 312.

never arise *de novo*." The repeated boilings and the high temperatures employed by bacteriologists are made use of for the very purpose of sterilising the media, and that the operation is a successful one seems to be proved by the facts admitted by Dr. Bastian, namely that (i.) no new life appears without inoculation and (ii.) that after inoculation the fluid can support the introduced life. It has not been injured as a pabulum though all pre-existing life has been destroyed in it. Dr. Bastian claims that besides the power of maintaining life there is also a power of engendering it which is destroyed by those measures which bacteriologists think necessary for the production of complete sterilisation. All that one can say is that if the power of engendering is not due to the presence of bacteria unkilld on account of insufficient sterilisation it is a power which has not been recognised by any other worker.

Where did
living matter
come from?

Suppose we grant that living matter has always come from living matter, which is indeed the scientific creed of the day, where did the first living matter come from? This world was once so hot that no living thing could exist upon it. It cooled down and a time arrived when life could exist. Where did it come from? It has been suggested that living matter might have been brought to this world from some other by means of a meteorite, but this view, even if likely, which is not the case,

does not help us one bit towards the origin of life, since the living thing which travelled on the meteorite must have come from somewhere and the life to which it belonged must have had its commencement somewhere, somewhen.

Faced with this difficulty many men of science unwilling to admit the possibility of a Creator have claimed that though spontaneous generation does not take place or cannot be proved to take place nowadays, yet it must have taken place at some former period, when conditions on the earth were far different from what they now are ; “ at a remote period in the past, when the temperature of the surface of the earth was much higher than at present, and other physical conditions were unlike those we know, inorganic matter, through successive complications, gave origin to organic matter,” as Herbert Spencer put it.¹

Huxley² thought that if it were given to him Huxley “ to look beyond the abyss of geologically recorded time ” he might “ expect to be a witness of the evolution of living protoplasm from not-living matter ”.

On these statements it may be remarked :—

1. It is quite certain that no person has ever seen living matter produced from not-living matter now or at any previous time.

¹ *Nineteenth Century*, May, 1886.

² *Critiques and Addresses*, p. 239.

2. It is equally certain that we have no facts on which to base the theory that it was spontaneously produced at some former period.

3. Nor have we the slightest suggestion from those who put forward the theory as to how the transformation may have taken place or under what conditions, nor are we told why it is impossible to reproduce those conditions in the chemist's laboratory. We are treated to a good many nebulous phrases, like Spencer's truly delightful and luminous explanation of "successive complications" but of solid bed-rock fact we get nothing whatsoever.

4. Finally, that as science deals and can only deal with ascertained facts, theories of this kind must be taken for what they are, namely "pious opinions," and estimated at the value which they therefore possess.

Weismann

Weismann, the distinguished biologist, declares,¹ "that spontaneous generation, in spite of all vain efforts to demonstrate it, remains for me a logical necessity".

Why a logical necessity? Because the only alternative is a return to that no doubt effete view that life was introduced into this world by the action of a Creator, for that is the only alternative. That must be admitted. If there is no such thing as spontaneous generation then one must admit

¹ *Essays*, Poulton's Trans., p. 34.

the existence of a Creator. But try all one may one cannot prove that spontaneous generation takes place. In fact all the proof is the other way. Then, of course, spontaneous generation must have taken place at some time or another, since otherwise there would be no life on the earth at this moment. So runs the argument, and so it must run if we are to deny the existence of a Creator. On the other hand there are many who will concur with Reinke :¹ "If we agree that living matter has at some time come from inorganic substances then, in my opinion, the Creation hypothesis is the only one which meets the necessities of Logic and of Causality and therewith answers to the needs of a prudent seeker after nature".

There are two further points which must be touched upon before this matter is concluded.

In the first place one must be quite clear of this fact that though the genesis of living from not-living matter has never yet been demonstrated it is not, therefore, impossible that it may some day fall to the lot of some fortunate investigator to announce such a discovery and to have his discovery recognised by a scientific jury. And if this were to be the case we may be quite sure that there would be hosts of persons prepared once more to announce the annihilation of all religion by the last great scientific discovery.

May living
come from
not-living
matter?

¹ *Einleitung in die Theoretische Biologie*, s. 559.

Such persons would be forgetful if not ignorant of the fact that the theory of spontaneous generation was held by many, perhaps by all the Fathers of the Church, and that St. Thomas Aquinas himself when rebuking Avicenna for teaching spontaneous generation did so because Avicenna held the thesis that it was by the power of matter alone that life arose, whereas, as St. Thomas says, if matter does produce life it is because the Creator has given it the power to do so.¹

In fact such a transition from non-living to living matter at some period is far the most likely thing to have occurred. What we claim is that, if it occurred, it did so at the will of the Creator and by virtue of the powers which He gave to it, nor do we deny that it is possible that that power is still inherent in non-living matter and may even be continually manifested, though we are unable to recognise the fact. "If," says Fr. Sharpe,² "against all probability, life could be shown to be spontaneously generated from matter, this would merely mean that the sentient or vegetative soul [which one may also speak of as the vital principle or under any other term which connotes the existence of an extra-physical agency in living matter] is a resultant from certain chemical combinations,

¹ *Summa Theol.* 1. p. q. 71, art. 1, ad 1 um.

² *The Principles of Christianity*, 1906, p. 56.

and not, as has been supposed, the direct work of the Creator. But there is no more inherent impossibility in holding that animal life is brought into being by a certain combination of chemical substances than in the converse belief, which is incontestable, that it is brought to an end by the dissolution, natural or artificial, of that combination. If we can destroy an animal's soul, as we certainly can, there is no *a priori* reason why we should not be able to make one."

Whilst, however, we allow all this, we must admit, with all who have studied the subject, that no approach has been made to any synthesis at all approaching that which would constitute living matter, and that those syntheses of organic compounds which have been arrived at do not afford any help in the direction in question as some have thought that they do. This is the second and final point to which allusion was to be made, and it may be clinched by quotations from two very distinguished chemists.

Sir Henry Roscoe¹ says: "It is true that there are those who profess to foresee that the day will arise when the chemist, by a succession of constructive efforts may pass beyond albumen, and gather the elements of lifeless matter into a living structure. Whatever may be said of this from other stand-

¹ Presidential Address, Brit. Ass., 1887.

points, the chemist can only say that at present no such problem lies within his province. Protoplasm, with which the simplest manifestations of life are associated, is not a compound, but a structure built up of compounds. The chemist may successfully synthesise any of its component compounds, but he has no more reason to look forward to the synthetic production of the structure than to imagine that the synthesis of gallic acid leads to the artificial production of gallnuts."

And a more recent utterance of the same kind has been made by Professor B. Moore¹ when speaking of "the products formed interstitially within the cell. Most of these," he says, "are so complex that they have not yet been synthesised by the organic chemist; but even of those that have been synthesised, it may be remarked that all proof is wanting that the syntheses have been carried out in identically the same fashion and by the employment of the same forms of energy in the case of the cell as in the chemist's laboratory. The conditions in the cell are widely different, and at the temperature of the cell and with such chemical materials as are at hand in the cell no such organic syntheses have been artificially carried out by the forms of energy extraneous to living tissue."

¹ *Op. cit.*, p. 10.

CHAPTER VII

ADAPTATIONS—PURPOSIVE ACTIONS IN LIVING THINGS

IN a previous chapter some mention has been made of that useful word adaptations, so frequently employed with the idea that it affords a complete explanation, in itself, of the phenomena with which it is connected. “Adaptations”

It is astonishing how many persons can be satisfied by a mere phrase and hundreds go happy away when told that Nature does so and so or provides for such and such a condition of affairs without appearing to be in any way concerned as to who or what Nature is or how it performs the wondrous works with which it is credited.

It is the same with that blessed word “inherent” which is also constantly used as if it were an explanation instead of a mere naming of a fact. “Inherence” That certain characteristics are inherent, say in a bull, is no doubt perfectly true, but to tell us that a bull is quarrelsome at times because that quality is inherent in bulls is certainly no explanation of how bulls came to have the quality in question.

If it be retorted that the upholders of a vital

principle or force in Nature are also guilty of a mere verbal explanation, such a retort on superficial examination would appear to have some force. But there is really no resemblance between the two conditions, as will be shown in the concluding chapter of this book.

To return to the question of adaptations ; when your hardened opponent of all esoteric explanations is sore gravelled to account for a fact "adaptation" is the steed on which he usually declares to win. Thus Weismann, endeavouring to account for behaviour on the part of a tubularia, which, to say the least of it, hardly seems to harmonise with the theories of that distinguished biologist,¹ says : "This also appears to us to be adaptive, and does not surprise us, since we have long been accustomed to recognise that what is adapted to an end will realise this if it be possible at all," and again, in a passage in which we have Nature brought in in the manner above alluded to : "It was, so to speak, not worth Nature's while to make such adaptations". It must be quite obvious to any person who thinks that such an explanation is really no explanation at all. A mowing-machine is no doubt adapted for keeping a lawn smooth and a pump for raising water from a well, but both of these are so adapted because they have

Adaptation
of machines

¹ *The Evolution Theory*, ii., 9.

been made for that purpose and no other. The term adaptation is only utilisable in connection with a telic explanation of living things, and it is just that telic explanation which is so unpalatable to the mechanist school. Yet it is difficult to see how such an explanation can be avoided by any one who really studies the behaviour of living things.

Our own behaviour and the behaviour of the animals and birds around us would seem to point clearly enough to purposive actions, and this is a fact which is tacitly at least admitted even by those who believe most strongly in mechanist views.

If any machine habitually repeats the same action and repeats that action in a precisely similar manner on every occasion, no one could have much difficulty in coming to the conclusion that it was for the purpose of performing that action that it was constructed. Moreover, if it performs no action but the one, it may reasonably be assumed that that action is automatically performed and no question as to the sentient nature of the machine will arise. On the other hand, whilst we can conceive—though with some difficulty—the idea of a machine which was capable of executing a wide and various range of movements, it is hard to think of a machine which could execute a wide range of movements and always and on every occasion in a

new way. Such a machine is quite inconceivable. Yet even the most strenuous supporters of the mechanical school are constrained to admit that the living thing constantly varies its method of meeting the various conditions with which it is confronted. "A living being," says M. Le Dantec,¹ "is not like an industrial machine manufactured with the design of accomplishing a certain kind of work and able to do no other. A locomotive can exercise only the locomotive's function. On the contrary, a dog, a duck, a serpent, are able to manifest in a thousand different ways *according to circumstances* their specific activity as dog or duck or serpent. Now, circumstances so vary around any given animal and the animal itself changes so quickly that we may say without exaggeration *an animal never does twice the same thing in the whole course of its existence.*"

The argument in the book from which this quotation has been taken is that the actions of living things are the result of tactisms and that these are due to changes in the chemical composition or reactions of the colloids of which the body is made up. Of what nature, one may fairly ask, are those chemical compounds which never react twice in the same way?

Even amongst the smallest and simplest forms

¹ *Op. cit.*, p. 67.

of animal life it is possible to come across actions ^{Purposive actions} which are undoubtedly purposive. One or two examples of these may now be cited.

Cienkowski¹ has described a little naked unicellular organism, very much like the amoeba which formed the subject of our study in an earlier chapter. Like the amoeba it lives in water and like it too it moves by a kind of crawling motion due to the protrusion of processes from its own body up to which the remainder of the body is drawn. Living in the water it is, of course, surrounded by a great variety of water-plants small and large, any of which, one might have supposed, would have sufficed for its food. Such, however, is not the case. Of all the algae or water-vegetables by which it is surrounded, it invariably seeks out one and one only, namely spirogyra and makes its meal off that.

Obviously it finds that the spirogyra suits it best or, as we should put it, it prefers spirogyra to any other kind of food, just as we too have our preferences in the same matter.

The same observer in relating the habits of another unicellular organism, called colpodella ^{Colpodella} pugnax, tells us that it lives solely on an alga

¹ The instances now about to be narrated have been detailed by Pauly in his book, *Darwinismus und Lamarckismus*, München, 1905, s. 147.

called *chlamydomonas*, whose chlorophyll, or green colouring substance, it sucks. Cienkowski says that the behaviour of this lowly organism in hunting after and obtaining its favourite nourishment is so remarkable that one is led to believe that one sees the operations of conscious life in it.

It is possible that some might argue that the attraction between these minute organisms and their food was entirely of a chemical character, but if so the argument must clearly be extended to all classes of living things and their food, and that would lead us on to conclusions, when we consider our own habits in respect to food, which few would be found to accept.

Foramini-
fera

Amongst the foraminifera, however, we can find instances which cannot be accounted for in this way.

These also are unicellular and microscopic and have the habit of encasing themselves in tiny shells, perforated by one or more holes—whence their name—through which are protruded the pseudopodia or protoplasmic processes by which they take hold of their prey or move about.

Tiny as they are, their bodies make up vast rocks, for most of the chalk consists of their remains and much of the oolite which forms a great band across England in the district of the Cotswolds is also constructed from the remains of these little creatures.

Enlarged models of the shells of the foraminifera may be seen in most zoological and geological museums and very beautiful objects they are. It is in the selection of the appropriate kind of substance for the construction of their shells, or "tests" as they are called, that we find our first example of the purposive actions of these little things.

Carpenter¹ says on this point: "The tests which they construct, when highly magnified, bear comparison with the most skilful masonry of man. From the same sandy bottom one species picks up the coarsest quartz grains, unites them together with a ferruginous cement, and thus constructs a flask-shaped test, having a short neck and a single large orifice; another picks up the finer grains and puts them together with the same cement into perfectly spherical tests of the most extraordinary finish, perforated with numerous small pores disposed at pretty regular intervals. Another species selects the minutest sand-grains and the terminal portions of sponge-spicules, and works them up together—apparently with no cement at all, but by the mere laying of the spicules—into perfect white spheres like homœopathic globules, each showing a single-fissured orifice. And another which makes a straight, many-chambered test, the

¹ Art. "Foraminifera," *Encyclopædia Britannica*.

conical mouth of each chamber projecting into the cavity of the next, while forming the walls of its chambers of ordinary sand grains rather loosely held together, shapes the conical mouths of the chambers by firmly cementing together the quartz grains which border it."

Well may the writer just quoted add the remark: "There is nothing more wonderful in nature than the building up of these elaborate and symmetrical structures by mere jelly-specks, presenting no traces whatever of that definite organisation which we are accustomed to regard as necessary to the manifestations of conscious life."

In this variety of construction and in this choice of materials it is hard not to see purpose. However, a further example of the purposive actions of these minute forms may be given before we leave the matter. There is a foraminifer named *arcella* which makes for itself a round concavo-convex test. On the concave side there is a single central round opening through which it is able to protrude its pseudopodia.

Arcella

One may colloquially speak of this surface as its front and the convex aspect as its back. Now sometimes it will occur that *arcella* will tumble over on to its convex back and in that position one would suppose that it would be as powerless and even more helpless than the beetle which one sees

feebly moving its legs and wondering apparently how it is ever going to get upon them again.

Arcella has its own method of achieving this task. It sets to work and by means of some mechanism of which we know nothing, it produces gas-bubbles in its interior.

These are arranged in one of two ways. In some cases they form at one side of the body only. The result is that that side is floated upwards and the little creature comes to stand on its edge. From that position it is easy, by the aid of its pseudopodia, for it to resume its normal position with the pseudopodia downwards.

In other cases the gas-bubbles, instead of being confined to one part of the body, are generally disseminated throughout it. The consequence of this is that the entire organism becomes sufficiently light to float to the top of the water in which it is immersed. There it is able to assume the position which it desires.

Such a purposive action as this is wholly different from the actions of chemical substances or of those which we study in the physical laboratory.

Forces of this latter kind look backward, not forward, for their explanation. They are the result of what has been and the end of the series of occurrences is an equilibrium.

Let us take an example. Suppose we add oil

of vitriol—sulphuric acid—to a piece of carbonate of lime. There will be profuse effervescence, due to the breaking up of the union between the carbonic acid and the lime and the giving-off of the former in the shape of gas. After a time this will cease and all the carbonic acid gas having been got rid of, sulphate of lime or gypsum will remain in the receptacle in which the mixture was made. Now all these things are explained by the bringing together of the sulphuric acid and the carbonate of lime, the former having a greater affinity for the lime-base than the latter drives it off and the operation is at an end. The train of circumstances looks backward for its explanation.

In the case of arcella this is not so. It, too, no doubt, produces gas, but not for the mere purpose of producing it, nor for the purpose of uniting two chemical substances with one another. It forms gas because that is its means of overcoming a problem in locomotion which has presented itself. Hence the formation of the gas looks forward for its explanation, in other words it is one which has a telic explanation and looks towards an end and that end a link in a chain of events, for the arcella makes the gas, no doubt, in the first instance, in order that it may turn right side up, but chiefly in order that it may resume the even tenor of its ways which have been temporarily interfered with

by the accident which laid it on its back. We may, if we like, say that it is adapted to get right side up again by this process, but if we do, we must not suppose that we have then explained all that requires explanation, and if we do use that phrase we may remember that no one ever talks about carbonate of lime being "adapted" to make gypsum and consider why the terminology which we consider suitable in the one case should be inappropriate in the other.

CHAPTER VIII

REPAIRS AND REGENERATION—EXPERIMENTS ON HYDRA AND OTHER FORMS

Repairs

ONE of the most remarkable powers of living matter is that which it possesses of making its own repairs, of mending itself where it has been damaged, and, in certain cases, of reconstructing large portions of the body which have been destroyed or separated from it.

In some form or another this power belongs to all living matter and when we watch a wound heal in ourselves or in any animal we see a minor example of the process of regeneration. The experimental study of this subject has been one of the most fruitful paths of scientific research during the past quarter of a century, and the more important results which have been obtained have been embodied in a very interesting work by Professor T. H. Morgan.¹

The power in question is one which is met with in plants and in animals and amongst the latter finds examples even of its major manifestations both amongst vertebrates and invertebrates.

¹ *Regeneration*, Macmillan Company, 1901.

Over the phenomena as exhibited in the vegetable kingdom we need not delay, for most people will be familiar with the manner in which begonias may be propagated by means of very small portions of the parent plant, from which entire specimens are reconstructed, and everybody, however ignorant of horticulture, must have seen cuttings being "struck," that is to say fragments of a plant, say a carnation, set in the ground and gradually constructing for themselves roots so as to become complete plants.

It will be more interesting to devote the space which can be allotted to this part of the subject to a consideration of some instances from the animal kingdom and we may commence with the classical instance of the hydra. It is interesting to note that the first experiments on this creature were made by a Catholic ecclesiastic, and that the first experiments in regeneration amongst vertebrates were made by another, so that here, as indeed in many other scientific subjects we find the figure of a cleric first treading a new path of scientific investigation.

The hydra is a small fresh-water creature, of a **Hydra** bright green colour and somewhat resembling a sea anemone, though very much smaller and of a more elongated build. It was on this creature that the Abbé Trembley carried out his classical experi-

ments in 1740, showing first of all that if the polyp was cut into two pieces each of those two pieces became a new and complete polyp.

It was known, of course, at this time that plants could be multiplied by a cutting process and Trembley seems at first to have been undecided as to whether he ought not to consider the hydra a plant, because it also could be multiplied in this way. However, his observations on its methods of feeding and its power of movement brought him to the conclusion that it was in truth an animal and that his discovery revealed a new and hitherto unknown power of animal life. "I felt," he says with commendable modesty, "strongly that nature is too vast, and too little known, for us to decide without temerity that this or that property is not found in one or another class of organised bodies." Trembley continued his experiments, which have constantly been repeated and verified in the years which have passed since his death. He found that a hydra could be divided into a number of pieces, and that each bit would, under favourable circumstances, develop into a new and complete creature. He also found that if the head-end was bisected, the result was the formation of a two-headed hydra. Moreover, he found that he could again and again bisect these heads until he had an eight-headed hydra with a single stalk or lower portion. It is

clear that this lowly, or comparatively lowly, form of animal life has powers of regenerating itself which are not inferior to those presented by plants.

The second experimenter of whom mention was made above was Spallanzani, whose name has already come before us in connection with the question of spontaneous generation. Spallanzani ^{Earth-} experimented on earth-worms and showed that they ^{worms} possessed powers like those of the hydra, though not so extensive, for whilst the earth-worm, if divided transversely, will produce a new head or a new tail, if divided longitudinally it dies.

But Spallanzani's most important experiments were those made upon the salamander, for this is ^{Salamander} a vertebrate animal, very much higher in the scale of nature than those with which we have been concerned up to now. He found that if the tail was cut off a new one would grow which would contain vertebræ—new vertebræ, of course—just like those which had formed the skeleton of the original appendage. Further he showed that if a leg, or even all four legs were cut off, it or they would grow again and that this process might be repeated time after time.

In one experiment which he carried out, he six times removed all four legs and the tail from one salamander during the three summer months. The unwearied animal reconstructed itself on each occa-

sion and even on the last occasion the process of reconstruction took place with the same rapidity as it had done on the first. Spallanzani calculated that during these three months the animal under experiment had made for itself no less than 647 new bones, not to speak of all the muscles, nerves and arteries which formed with the bones in question the various parts which were restored.

Spallanzani also found that the salamander could regenerate its upper and its lower jaws if these were snipped off. It is obvious, therefore, that an animal of quite high position in the scale of nature may possess very remarkable powers of repair. It will be noticed that there is one very important difference between the phenomena exhibited by the vertebrate and by the invertebrate and that is that the former cannot be so divided as to constitute from it two complete forms. There is then a limitation of the powers possessed by the more lowly form. On the other hand its reconstructive abilities are much greater than those which are possessed by any mammal. The mammal can heal up a wound if that wound is not of so serious a character as to cause death, but it cannot re-grow even a joint of a lost limb, much less reproduce the entire member as the salamander or newt can.

A further remarkable experiment has been

made upon the eyes of the larvæ of the triton or ^{The newt's} waternewt by Wollff.¹ This observer removed ^{eye} the crystalline lens from the eyes of triton larvæ, performing upon them, in fact, the operation known as "couching" in cases of cataract. He found that the animal was capable of regenerating its lens and did regenerate it in a few weeks. Sometimes it happened that a fragment of the old lens had been left behind and in these cases it was from this that the new one grew, a state of affairs which one can well understand. But in other cases a most remarkable state of affairs came under notice, for the new lens was reconstructed from the epithelium of the border of the iris, that is to say the coloured curtain, which in our eyes is blue or grey or brown. To the ordinary reader this will not seem more remarkable than any of the phenomena which have been already narrated and perhaps less remarkable than some of them, but to the embryologist it is a truly wonderful thing.

The lens and the iris are originally formed from wholly different layers of the developing embryo, so that when a new lens is formed from the iris it is being made not only in a way but from a material in which and from which no lens ever was made before so far as we know or indeed can imagine. Hence this experiment shows the re-

¹ *Arch. f. Entwickl.-Mech. d. Organismen*, bd. i., 1895.

storative powers of the triton organisation in a most remarkable manner.

The examples of this kind amongst invertebrates are legion and one or two may be mentioned here.

Tubularia

Observers of the common objects of the sea-shore can scarcely have failed to have seen specimens of the creature called tubularia. It has a stem, the base of which is embedded in the sand and a head-end surrounded by a ring of tentacles and provided with a sort of proboscis. Almost anything can be done with this creature in the way of regeneration. If the head be snipped off the base will grow a new head and the head a new base, just as a worm chopped in two will do. If instead of cutting it the animal be pulled up by the roots and replanted head downwards the head-end develops roots and the root-end becomes a head with tentacles and proboscis.

Finally, if we snip off the head and tail of the polyp and hang it up in the water by a thread, it will grow a head from either end.

Planaria

Another creature planaria, a parasitic worm, can be cut up into a number of pieces all of which will develop into complete individuals. Moreover like the hydra it can be partially bisected and will then grow into a kind of two-headed Nightingale amongst planarians, with a single body and two

heads. More wonderful still if oblique cuts be made into the sides of the body new heads or tails will grow from them according to the direction in which the incisions have been made (fig. iv.).

Regeneration of Planarians. A. an animal divided into three parts by two oblique cuts. B. the fragments (a.b.c) in process of regeneration C. an animal with various oblique incisions in the margin of the body, which have induced the new formation of heads (k), of tails (s), and pharynx (ph). A and B after Morgan; C after Walter Voigt.

FIG. IV.

Now in all these cases, wonderful as they are, it will be noticed that the new formation has grown directly from the organised substance of the old. This is remarkable enough in all conscience. To translate it into the language of machines one has to imagine a locomotive engine, which has been in

NB

a bad break-down, setting to work to grow for itself a new wheel or to construct a new connecting-rod. Or we may picture a lathe which has had a wound inflicted in its side setting to and producing a new chuck from the incision.

This would be wonderful enough and is hard enough to imagine, but still more difficult of mental imagery would be the state of affairs in which the wounded locomotive should resolve itself into its constituent steel and brass, and having done so should then, by the force of its own intrinsic powers, reconstruct a full, complete and working railway-engine. Yet this is what is done by another form and the whole chain of occurrences is so remarkable and so forcible an example of the powers of living matter, as well as of their differences from those of non-living objects, that it may be given here at length.

Clavellina

The observation in question was made by Driesch¹ who is the author of a neo-vitalistic theory of extreme complexity. It deals with *Clavellina lepadiformis*, a tolerably highly organised creature belonging to the class of ascidians placed by zoologists very near the lower vertebrates in the scale of animal life. It is about an inch in length and its body is divided into three portions; the uppermost of which forms an extraordinarily

¹ *Arch. f. Entwickl.-Mech. d. Organismen*, xiv., 1902.

large, basket-like gill, provided with an entrance and an exit for the water.

To this succeeds a small connecting body portion which contains part of the intestines and finally there is the so-called intestine-sac with stomach, intestine, heart, reproductive organs, etc. If we divide the body of a clavellina at the level of the connecting portion, so that the gill-basket and the intestinal-sac are separated from one another, either or both of these two portions can in three or four days complete itself into an entire organism, since by means of true regeneration proceeding from the incision, the gill-basket makes itself an intestinal-sac and the intestinal-sac a gill-basket.

With this process we have already become familiar, for it is the kind of thing which we have studied in the hydra and in the earth-worm, but the process of reconstruction sometimes takes place in quite a different manner, and this is especially the case in smaller individuals. In these cases reconstruction begins not by a process of renewal but by one of regression.

The organisation of the gill-basket, its ciliated clefts, its openings, etc., all gradually dwindle away. At the end of five or six days no more organisation is to be seen in these parts, which appear like white spheres, in fact the describer states that when he

first saw this condition he came to the conclusion that the clavellina was either dead or on the way to death. It was not so, however, for though the creature remains or may remain in this condition for two or three weeks, at last the day comes when it begins to clear and to stretch and then after the end of two or three days it is found that amorphous mass has once more become a complete ascidian with gill-basket and intestinal sac. It has become a perfectly new organism which has no continuity with the parts of the earlier organisation though it has with its material. Its gill-basket is not a derivative of the old one; it is very much smaller and has fewer and smaller openings. What has happened is that the old organised gill-basket has returned to an indifferent substance and then, from this indifferent substance on embryological lines, a new smaller individual has been constituted. But this is not the whole story, for it is not merely the isolated gill-basket which can restore itself by means of this roundabout process, but after having isolated the basket, it can be itself divided either into an upper and lower portion or into an anterior and a posterior bit and each of these portions will then go through the same process, that is each of them will first of all return to the indifferent condition and then from that re-constitute itself into a new small ascidian.

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Here then is a series of events which, if they could be imagined to take place in connection with a machine, could only be described in the way attempted above by supposing that the machine had resolved itself into its constituent metals and from these metals rebuilt itself into a new machine.

Assuredly these phenomena seem to point to the existence of some special energy or force intimately present throughout the entire living organism, unifying its various parts, dominating their activities, directing the evolution of the being as a whole towards a definite prefixed end, which, according to the old view was just the function of the "Vital Principle".¹

It is extremely difficult to imagine any theory which will account for the phenomena of regeneration on purely chemico-physical lines, since they, like the phenomena which we studied in connection with the developing ovum, so clearly point to the existence of a directive force in living matter which has no parallel in non-living substances.

Nothing proves this more clearly than the kind of explanation which is attempted to be given by those who deny the existence of the power in question. Amongst these the most prominent recent writers is Professor Weismann. He narrates

Attempted explanations—What they amount to

¹ Life viewed as a *principle* was *forma vel causa formalis*; viewed as activity or *operatio* it was *causa finalis* of the Being.

the behaviour of the tubularian which has been described in this chapter and then by way of accounting for it says, in words which have been quoted in the previous chapter: "This also appears to us to be adaptive, and does not surprise us, since we have long been accustomed to recognise that what is adapted to an end will realise this if it be possible at all". As a former chapter endeavoured to show, this so-called explanation is no explanation at all. It does not explain how the adaptation arose or how having arisen it carries itself out. It is simply tantamount to saying "the thing had to happen and so it happened" and put in that simple language no person would be hoodwinked into supposing that they had received an explanation when in reality they had only been listening to a re-statement of the question.

CHAPTER IX

LIVING THINGS AND MACHINES—THEIR DIFFERENCES —SPENCER AND WEISMANN—A “VERBAL EXPLANATION”

WE have now studied most of the fundamental activities of living bodies and have seen that they include many features which are not discoverable in non-living substances. That there may be a superficial similarity between some of the circumstances of the two kinds of matter may possibly be conceded, but when carefully examined it seems that the fundamental differences are far greater than the surface resemblances.

“The structure of a machine,” says Strasburger¹ a very distinguished German botanist, “might be called its organisation; and the fact that, when provided with a store of energy, it can be started by the opening of a valve to perform work conformable to its structure—this property might be called its sensibility. But the living substance is entirely distinguished from the dead machine by the ability to provide itself with the energy needful

Living thing
and machine

¹ *Das Protoplasma und die Reizbarkeit*, 1891, s. 24.

for its work ; to set itself in motion and keep itself going ; to repair itself, within certain limits, the defect that may arise ; and above all, by the fact that it constructs itself. In short, an organism—in contradistinction to the dead machine—is a living machine, one that does not depend upon external impulses for its movements, one that regulates its own course, and continues going as long as the environment will allow—only through the hostility of this or through irreparable misfortune is it brought to a halt.”

The power to repair itself—here is a thing not met with or begun to be suggested in any machine. Professor Hartog¹ very acutely points this out in connection with the so-called automatic machines. He says, “In its original use ‘automatism’ designates the continuous sequence and combination of actions, without external interference, performed by complex machines designed and made for specific ends by intelligent beings : thus we speak correctly of ‘automatic ball bearings’ that tighten themselves when they become loose ; but even these cannot take up fresh steel and re-deposit it, either to replace the worn parts or to strengthen a tube that is bending under a stress.”

The difference between the living organism and a machine has been very carefully considered by

¹ *Op. cit.*, p. 12.

Oscar Hertwig¹ and as there is no living biologist Hertwig whose reputation stands higher than his it will be useful to quote him *in extenso*, rather than to give a catena of quotations from other persons. He commences by saying that it is the more necessary that this matter should be set in the proper light because there is a growing tendency at the present time to try and explain the living organism in the terms of a machine and to believe that organic operations can be accounted for in this matter. He himself maintains that very important differences exist between a living organism and a machine.

A machine can only operate in one or at most in a few directions and that in an unchangeable manner in accordance with its original construction. Its individual parts cannot, by their own power, rearrange themselves, or enter into new combinations in correspondence with the new conditions with which they may find themselves confronted. Therefore the machine cannot react to outer influences in a purposeful and many-sided manner. The organism, on the contrary, has an innate power of construction. The single cell, the first step in the direction of an organism, is irritable towards warmth and light as well as towards all kinds of mechanical and chemical influences and

¹ *Op. cit.*, s. 141.

thus is responsive to the most manifold expressions of life. In the machine power is developed in a restricted direction, in the organism there is an extraordinarily free, many-sided play of powers.

A comparison will make the difference between the two more obvious. Look at the difference between a musical box or a gramophone and the human larynx combined with the lungs and the nerves and muscles which set it in operation. Both of these can give vent to numerous tunes and those of all kinds. But the difference between them is enormous. The instrument can only play the tune or tunes which it is constructed to play or the records which are inserted into it. On the other hand, without any visible change the human larynx can pass from one melody to another and alter its tune and time by the action of the muscles under the influence of the will of the individual who is singing. Moreover, at will the singer can alter the pitch, the time and the tone of his song, introduce all sorts of trills and runs and modifications which the instrument can never do, for that must always perform its task in exactly the same manner.

Then we come to a second difference. When, as the result of a stimulus, changes have taken place in the organism, say that a muscle has become altered in structure and tired by long use, it

has the power, after a time of rest, to return to its former condition, so that on the stimulus being repeated it will be found that the muscle can respond to it as it did on the previous occasion. The machine, on the contrary has no power of repairing injuries or wear and tear which may take place in it as the result of its ordinary use; it cannot lubricate itself or clean itself or make itself ready for new action.

And thirdly, no machine can beget a new machine nor has any one succeeded in constructing anything which, by division, will shape itself into two instruments where but one existed before. It is only and properly so in a living organism that we talk of irritability, of stimuli, of reflex actions, and it is a hopeless task to attempt to explain an organism on mechanical principles.

In a machine the movements of the rollers, wheels, levers and other parts can be explained on purely mechanical principles, but in the organism the operations of a chemical character, extraordinarily varied as they are, cannot be explained in this way.

Whilst in the machine the movements of the various parts are firmly united to one another by their construction, so that they cannot alter independently of one another, the living organism can alter its structure and at the same time set aside

bye-products without in any way interfering with its own existence or work. In the free play of powers to be met within the living organism lies a profound difference between it and the limited capabilities of the machine. Such, in paraphrase, are the views of the distinguished German biologist and the differences on which he insists, one would have thought, would have been such as would have appealed to most observers. Such, however, is not the case, as we may easily see by referring to the books of those who uphold the mechanical theory and how difficult it is to justify that theory may perhaps be best seen by studying the explanations of their views which have been given by some of the most distinguished amongst them.

Mechanical
explanations

Let us examine two instances, one from the writings of a living, the other from those of a recently deceased writer, and we will take the former first, in due order of time. Herbert Spencer¹ declines to admit the existence of a *nisus formativus* or vital force or principle, and is confronted with the necessity of accounting for the phenomena which he sees before him. How does he do it? He tells us that "the polarities of the molecules determine the *direction* in which the *power* (of environing forces) is turned".¹ This ex-

Spencer

¹ See *Principles of Biology*, vol. i., App. D., p. 705.

planation to the careless no doubt sounds to the full as satisfactory as did the blessed word Mesopotamia, but when we come to examine the meaning of the phrase we find that the explanation is not really an explanation at all.

In the first place we may well ask, what are these "polarities"? They seem to be nothing more or less than our old friends the "adaptations," which in other words mean the powers of the cell. So that the sentence really means, the powers of the cell determine what it shall do under certain circumstances, which is just what we knew all along. This explanation is an excellent example of what Professor Ward¹ alludes to when he points out that the system of explaining everything which is "going" because it is "going" is admirable "once you have got inside the system," but has no claim to be looked upon as a full explanation. No doubt the cell does conform itself to circumstances by virtue of the powers which it possesses, but to call these powers "polarities" and then to suppose that you have explained how they came to exist and how they carry on their operations is to be guilty of the merest word-explanation.

From the dead we will turn to the living philosopher and examine the explanation offered by

¹ *Naturalism and Agnosticism*, ii., 271.

Weismann

another vigorous opponent of vitalistic views, the very distinguished writer, Professor Weismann. We have already seen how he attempts to deal with the phenomena of regeneration so unaccountable on the mechanical hypothesis. And we have seen that his method of accounting for them amounts to nothing more than a mere restatement of the problem. Professor Weismann is far too eminent a biologist not to see that all vital phenomena require some explanation, and as he refuses to be persuaded by the vitalistic or neo-vitalistic school, he must perforce offer some other explanation. What is it? Let us try to make it plain.¹ In the first place he says that "the botanist Reinke," whose views have already been alluded to in these pages, "has recently called attention once again to the fact that machines cannot be directly made up of primary chemico-physical forces or energies, but that, as Lotze said, forces of a superior order are indispensable, which so dispose the fundamental chemico-physical forces that they must act in the way aimed at by the purpose of the machine". Thus in making a watch, gold, steel, jewels, etc., must not only be brought together, but brought into a definite relation with one another. Here it is human intelligence which effects the conjunction. "But organisms also are machines which perform

¹ *Op. cit.*, i., 402.

a particular and purposeful kind of work, and they are only capable of doing so because the energies which perform the work are forced into definite paths by superior forces; these superior forces are thus the steersmen of the energies." So far we may be all in agreement. That there are superior forces or that there is a superior force is precisely what all vitalists and neo-vitalists contend, and those who believe in a Creator also believe that it was His Will which conferred those powers on living nature. Reinke, from whom quotation has just been made, thinks that these superior forces have been put into the organism by a "cosmic intelligence" which is a polite periphrase, one must suppose, for the Creator.

Weismann will have none of that. Why not? "Because, in the first place, these superior 'forces' are not 'forces' at all." What, then, one asks, are they? The reply is ready. "They are constellations of energy, co-ordinations of matter, and the energies immanent therein, under complex and precisely defined conditions, and it is a matter of indifference whether chance or human intelligence has brought them together."

Here again is a fine high-sounding explanation which on analysis turns out to mean just—nothing. In the very centre of it is embedded a word which begs the whole question and that word is "immanent".

In this country we generally find that inherent is the term used, but as one means that something is sticking in something else and the other that something is remaining in something else it matters but little which of them we use. Neither of them explains anything, for neither of them tells us the least little bit how the something came to stick or to remain in the other something or what it is which sticks or remains there, and this is precisely what we want to know and what the explanation professed to be about to tell us.

Let us, however, pursue our inquiry into this explanation a little farther. Let us ask whether the phrase "constellations of energy" is only a rhetorical effort or whether it has any real significance in the world of facts. Does its author in any way define it or explain what it means? Yes, we find that these "constellations" are defined as being "the biophors, the determinants, and the 'groups of determinants' which we may think of as disposed in a manifold overlapping series".

We may think, of course, of any subject which it is not forbidden us to think about, and to think about biophors and the like is certainly not a mortal sin. But have they any real existence? Are we on any solid ground if we look to them as the constituent parts of the constellations of energy in which we are so much interested?

What after all are these biophors and determinants? Most biologists, it is not unfair to say, utterly refuse to believe in their existence and even their describer is obliged to admit that they cannot be seen by the microscope or recognised by any kind of objective test.

They are not objects known to science, for science only deals with observable facts. They are the products of a luxuriant and highly-developed scientific imagination and have been postulated by Professor Weismann for the purpose of explaining the phenomena of nature, and, *inter alia*, of disproving the existence of a vital force in the living organism. In point of fact Professor Weismann builds up an elaborate edifice of imagination, based on no sufficient substratum of fact, and then says, "This is how things may happen [and of course it is possible that they may] and as a matter of fact I have no doubt that this is how things do happen and that being so there is no need for your vitalistic theories". To which it may be replied, first, that there is no kind of evidence for the things by which Professor Weismann explains the phenomena of life, and, secondly, that if they were all as clear and patent as the rails and sleepers on a railway line they would no more explain the operations of nature than those parts of the railway system

explain to us how the locomotive comes to be able to haul its load along them.

This explanation then is another example of a verbal explanation which explains nothing.

But, it may be argued, the explanation of a vital force—we will retain that name as the most ancient, though it matters little what we call it—this explanation too is a verbal one, since you cannot see that force or detect it by the aid of any instrument. This we may admit without for a moment consenting to look upon the theory as a mere verbal one, for if we cannot see the force itself, we can see its manifestations, we can compare them with all the other manifestations with which we are familiar, and, by a process of elimination, we can come to the conclusion that here we are dealing with something of a nature different from that of any non-living force and unknown in non-living nature. We have excellent parallels and precedents for entertaining this belief. No one doubts the reality of gravitation, since all can perceive its operations, yet no one has ever seen this force nor has any person yet propounded an explanation of its nature which has met with anything like general approval in the scientific world.

Is it a
"verbal ex-
planation" ?

Gravitation

The ether

Or again take the question of the ether, the existence of which no scientific man doubts. Yet

Professor Duncan¹ says that "any discussion of ether leads out upon the high road to incredulity. A thing," he proceeds, "must be defined by its properties and the properties of the ether are for the most part negative ; so negative, indeed, are they, that when one says boldly that we cannot see ether, hear it, taste it, smell it, exhaust it, weigh it, or measure it, one feels timid that sane-minded people will meet these negative qualities of our ether by a decided negation of belief in its existence. But the fact of the matter is that if this thing 'ether' is not visible to the eye of sense it is visible to the eye of the mind which is much less liable to err." And he proceeds to show the grounds on which the ether is believed in, purely on account of its manifestations and not because it has been made obvious in itself to any of our senses aided or unaided.

If then the vitalistic explanation is verbal only so also is the theory of gravitation and so the existence of the ether.

It shall be left to a distinguished physiologist to have the last word on this subject in the present chapter. Dr. Haldane² says: "It is frequently urged that vitalism amounts to nothing more than the mere assertion that a physico-chemical explana-

¹ *The New Knowledge*, 1907, p. 3.

² *Loc. supra cit.*

tion of vital phenomena has not been found ; and that even though this assertion be correct, the only possible way to advance in physiology is by the further application of the principles of physics and chemistry, since there are and can be no other kinds of explanation but the causal ones which these sciences afford. This argument in its widest form is undoubtedly based on the metaphysical assumption that the universe, interpreted as it is in the physical sciences as a universe of matter and energy, corresponds to absolute reality, and is for this reason incapable of any further interpretation. The work of modern philosophy since Berkeley and Hume has shown that the assumption in question is without foundation."

CHAPTER X

THE LAW OF THE CONSERVATION OF ENERGY — “LAWS ” OF NATURE— ENERGIES OF LIFE — MATTER AND FORM

IN this chapter it will be necessary briefly to touch upon a difficulty in connection with the vitalistic view of living nature which has often been raised and forms the subject of quite a considerable literature.

This is the difficulty presented or supposed to be presented by the Law of the Conservation of Energy. Law of
Conservation
of Energy

Physical energy, that is to say the capacity for doing work, may be of two kinds. It may be kinetic or in actual evidence as it is in a flying bullet or a moving railway-train, or it may be potential or not evident to the careless eye as it is in a suspended weight. Now many experiments have been made respecting these different kinds of energy and respecting the different varieties of energy of which we shall have to speak shortly, and as a result of these experiments the following facts emerge or appear to emerge.

First of all it seems perfectly clear that when

one form of energy is changed into another, nothing is lost nor is anything gained. Consequently the following so-called "laws" have been formulated by men of science :—

1. That the sum of the kinetic and potential energies of any isolated system of bodies remains constant ; and—

2. That the sum-total of the energy in the universe remains the same.

Before considering the bearing of these laws on the question under consideration it will be well to be quite clear in our minds as to what is meant by a law of nature and what its precise value is.

The word "Law" has two distinct meanings, not unfrequently confounded. Sometimes the term stands for a decree or command, expressed by a sentence in the imperative mood. The Ten Commandments and Acts of Parliament are "laws" in this sense. At other times the term denotes some observed uniform mode of action or behaviour in phenomena which is signified by a general proposition in the indicative mood. The laws of chemistry and astronomy are examples. Now it cannot be too clearly kept in mind that the "laws of Nature" are of this latter kind.

Laws of
Nature

The term simply expresses our appreciation or conception of an orderly or supposed orderly sequence of events in the natural world. Viewed

strictly from this standpoint of science, as Huxley was careful to point out, there are no such things as laws in the ordinary sense of precepts or decrees, in the processes of Nature. What we do know is that there are certain observed sequences of events and that these do actually present to us a picture of a uniform nature. But this is a different thing from assuming, as many without any evidence are prone to do, that these sequences are the result of some inexorable compulsion or some intrinsic and absolute necessity emerging out of the nature of the universe, and that in no other way could things take place than that in which as a matter of fact we are accustomed to find that they do take place.

At the same time "for those who accept the theistic position," as Fr. Sharpe very clearly puts it,¹ the *rationale* of the whole matter is this. The observed course of Nature is due to the action of divine power, which having certain ends in view attains them in the most suitable way. So long, therefore, as the ends in view remain the same, the means adopted for their attainment will not vary; and a slight or infinitesimal variation in the ends will bring about a precisely corresponding variation in the means. But the ends to be secured by the course of Nature are always the same; or if they vary, do so by an infinitesimal gradation. The sensible world

¹ *Op. cit.*, p. 133.

consequently presents, so far as the general experience of mankind goes, the appearance of strict regulation.

Furthermore it is to be remembered that our conception of these uniformities or laws of Nature are based on our present experience, and that the extension of that experience may require us to introduce modifications into our expression of the facts as they appear to us, or, in other words, may lead to a change in the formulation of the law. In fine there is nothing sacrosanct about the laws of Nature, which forbids criticism or denies the possibility of error in our comprehension of them.

Vital
Energy

With these prefatory remarks we may attack the problem before us and at once admit that much difficulty has been felt in accounting for the power which, we have endeavoured to show, exists in living matter, the power which directs and, still more, initiates chemico-physical processes in the living organism. Is it subject to the laws above detailed? Where does it come from, and whither does it go? Many attempts have been made to clear up this difficulty though some maintain that it is no difficulty at all. Professor B. Moore, for example, as we have seen, believes in what he calls a "biotic energy," and this energy is, he thinks,¹

¹ *Op. cit.*, p. 4.

“just as closely, and no more related to the various forms of energy existing apart from life, as these are to one another, and that in the presence of the proper and adapted energy transformer, *viz.* the living cell, it is capable of being formed from or converted into various of these other forms of energy, the law of conservation of energy being obeyed in the process just as it would be if an exchange were taking place between any two or more of the latter forms”. It would hardly seem that Professor Moore had escaped from all the difficulties of the situation by this method of leaping over the fence, for we still require an account of the action of “the proper and adapted energy transformer, *viz.* the living cell” this being exactly the difficulty that is encountered in all the solutions of the difficulty which have been heretofore proposed.

It has, for example, been urged that the power which frees the energy is so small that it may be regarded as inappreciable when incorporated in the total result. In fact it has been compared with the tiny spark which is capable of exploding a mine of blasting-powder and releasing an enormous amount of energy by the expenditure of an amount which is so small as to be almost negligible in the whole account of the transaction. To some extent, no doubt, this is all quite true. “As far as we can

judge," says Balfour Stewart,¹ "life is always associated with machinery of a certain kind, in virtue of which an extremely delicate directive touch is magnified ultimately into a very considerable transmutation of energy." But a solution which proposes to omit any factor, no matter how small it may be, from the general account cannot be regarded as a satisfactory explanation. The disengaging power is either something or it is nothing. If it is nothing it is clear that it can do nothing. If it is something it must not be left out of consideration, but must be brought into account with the other items of the transaction.

If this and some other attempts to solve the difficulty do not seem to help us very far, must we then conclude that the Law of the Conservation of Energy excludes the possibility of the existence of a power controlling the operations of the cell? Certainly not. To do this would be to assume, as we have no right to do, that we know all about the Laws of Nature and the particular Law in question as well as to assume that the facts of living matter are opposed to the law as at present formulated, which is by no means certain.

"The very advance of physics," says Ward,² "is proving the most effectual cure for this ignorant

¹ *On the Conservation of Energy*, p. 163.

² *Op. cit.*, i., 180.

faith in matter and motion as the inmost substances rather than the most abstract symbols of the sum of existence."

Are we then to argue, as some have done, that the Law in question, whilst applicable to all inanimate Nature is abrogated in the world of Life?

Here it is prudent to revert to the considerations urged at the commencement of the chapter as to the real nature and significance of the term "Law of Nature," and to remember that this really means a generalisation from the facts before us up to date. "The term 'energy' itself," says Sir Oliver Lodge,¹ "as used in a definite sense by the physicist, rather involves a modern idea, and is itself a generalisation. Things as distinct from each other as light, heat, sound, rotation, vibration, elastic strain, gravitative separation, electric currents, and chemical affinity, have all to be generalised under the same heading (of the Conservation of Energy) in order to make the law true. Until 'heat' was included in the list of energies, the statement could not be made; and a short time ago it was sometimes discussed whether 'life' should or should not be included in the category of energy. I should give the answer decidedly No, but some might be inclined to say Yes; and this is sufficient as an example to show that the categories of energy are

¹ *Life and Matter*, p. 21.

not necessarily exhausted ; that new forms may be discovered ; and that if new forms exist, until they are discovered, the Law of Conservation of Energy, as now stated, may in some cases be strictly untrue, though partially and usefully true ; just as it would be untrue, though partially and usefully true, in the theory of machines, if heat were unknown or ignored."

We may feel perfectly clear from what we know best ourselves from our intimate and everyday experience, namely, conscious human life, and from the processes which take place in living matter, that life or the vital principle does modify the forces, energies, and movements of matter. Is it not perfectly obvious that the war-fever, religious revivals, electoral excitements are all ideas, yet all exercise potent influences over the energies and movements of matter, in the shape of human beings, not to speak of all the material activities which they control?

If the arguments in favour of the existence of an energy in living matter which is not to be found amongst the known energies of chemistry or physics are conclusive, as they appear to be to the present writer, and, as he has tried to show, to many men of science whose claims to be heard on this point are far greater than any which he can put forward, then it is quite clear either that the Law of Con-

servation of Energy is incorrectly formulated and will require modification when the state of our knowledge is more advanced, or that the form of energy in question stands to the Law in some relation which has not yet been made quite clear.

Before leaving the matter there are certain other points which should not be left out of consideration.

We recognise, of course, that there is a certain amount of energy displayed in all material activity. But this is not all. There is also a directive power, and this power plays the part of an orienter, so to speak, of the energy, though it does not increase or diminish its sum. We have, therefore, to recognise a qualitative element in all such operations. In fact, mechanism itself remains absolutely inexplicable if we try to reduce everything to the play of mechanical forces.

Hence we are driven, at all costs, to recognise a duality, the very duality so much objected to by the monistic school.

It is quite clear that an agent may modify the direction of a force or a moving particle without altering the quantity of its energy or adding to the work done. That is to say, it is possible to bring forward an example of a purely qualitative influence.

For a power acting at right angles to the

motion of a body can alter the direction of that body without increasing or diminishing the intensity of the motion.

The earth revolves around the sun in its elliptic course because the force of gravity holds it in that course. Suppose the sun were suddenly to disappear. Its attraction at an end, the earth would rush away at a tangent. The energy which it displays would not be altered in any way, but the direction would be wholly changed.

Of course it may be asked whether one can in any way show that the Will or the Vital Power does act at right angles to the forces of any material energy of the organism. That, however, is an objection or an inquiry which we may rightly consider to be unfair.

r All that one can be asked to do is to show that there is a method by which an agent *can* modify the action of physical energies without altering their quantity.

L So far, however, we have only spoken of the modification of a force "in being"; how about the initiation of the force or the initiation of the change of energetic direction? The pressure of the button which completes an electric circuit may produce prodigious effects, altogether out of proportion to the power exerted in the preliminary pressure; but pressure there must be.

In this connection we must remember Kant's dictum¹ that "if we seek the cause of any change of matter whatever, in life, we shall have to seek it at once in another substance, distinct from matter, although bound up with it."

"It is in meeting this difficulty," says Fr. Maher,² "that the Scholastic conception of the relation of Soul and Body in the theory of Matter and Form is most helpful. In that theory the vital principle is the 'form' or determining principle of the living being. Coalescing with the material or passive factor, it constitutes the living being. It gives it its specific nature, it unifies the material elements into one individual. It makes them, it constitutes them, it holds them a living being of a certain kind. Biology teaches us that the living organism is a mass of chemical compounds, many in very complex and unstable equilibrium. They are, many of them, tending of themselves to dissolution into simpler and more stable substances, and when life ceases the process of disintegration sets in with great rapidity. The function, then, of this active informing principle is of a unifying, conserving, restraining character, holding back and sustaining the potential energies of the organism

¹ *Metaphysische Anfangsgründe der Naturwissenschaft*, ed. Hartenstein, vol. iv., s. 440.

² *Life and the Conservation of Energy in the Lower Animals*.

in their unstable conditions. In this view of the relation of the vital principle to the material elements of the organism, it is obvious that the transformation of the potential energy of the organism may be effected without any form of positive pressure, however small.

“It will suffice simply to ‘let go,’ to cease to hold back and the energies thereby liberated will tend of themselves to issue from their unstable conditions.

“Conceive a sack of potatoes or a bladder of gas or water. Suppose that sack or bladder endowed with the power of giving way in particular places. The contents will at once issue forth into outer space by the force of gravitation or of their own mutual repulsions.

“Somewhat in a similar way the ‘Soul,’ ‘Vital Principle,’ or ‘Form’ is holding and preserving the material elements of the organism, not in a particular space, but in certain states and conditions of unstable equilibrium.”

In conclusion, as regards this matter, it may candidly be admitted that the last word on the problem of the Conservation of Energy in its relation to Life has not yet been said. But, at the same time, it is also clear that the supposed rigidity of the Law in question is in itself no reason why we should be called upon to deny a fact which

seems to be otherwise clearly demonstrable, and, it is also clear, that whether we are yet on the right track or not, it is at least possible to make some suggestions as to the direction in which the final solution of the difficulty may some day be arrived at.

CHAPTER XI

THE "SOMETHING OVER"—NEO-VITALISTS AND THEIR DEFINITIONS—CONCLUSION

PROFESSOR WARD¹ very forcibly describes the characteristics of living matter when he speaks of its "tendency to disturb existing equilibria, to reverse the dissipative processes which prevail throughout the inanimate world, to store and build up where they are ever scattering and pulling down, the tendency to conserve individual existence against antagonistic forces, to grow and to progress, not inertly taking the easier way but seemingly striving for the best, retaining every vantage secured, and working for new ones".

In the preceding chapters an attempt has been made to show that these and the other remarkable characters of living matter cannot be adequately explained in terms of chemistry and physics, and that the view here upheld is that of a large, an important, and, it may be added, an increasing number of those who have made a life-study of different branches of biology.

¹ *Op. cit. supra*, i., 285.

But if the facts in question cannot thus be explained we are then driven to the conclusion that there is a "something over" in living matter "Something over" which does not exist in non-living.

Some call this a "vital force," others, apparently thinking that that term savours of mediævalism and superstition, prefer to invent some new name.

It does not seem of any very great consequence what we call this force, and a careful study of the different definitions thereof leads one to the conclusion that the thing concerning which all the neo-vitalists are dealing in their works is the same, though the names which are applied to it may be quite different.

Moreover, if there is any meaning to be got out of words, the thing which the neo-vitalists mean is Neo-vitalism
and vitalism precisely the same thing as the vitalists—or, at least, those of the scholastic wing—also meant and mean. There was—perhaps may be still—a school of vitalists who looked upon the vital principle or the human soul as a little demi-god living in the body, as Descartes supposed in the pineal body, but not of it, though directing its actions and presiding over all its functions. Vitalists of this kind would also conceive of the animal soul or vital principle, or whatever term they might use for it, as being a thing apart from the body of the animal—or the vegetable as the case may be. But that

is not the view of scholastic philosophy. That its attitude has been misunderstood is probably due to the fact that those who have criticised it have often refrained from what they no doubt considered the unnecessary labour of trying to understand its terminology, which is its own and is not to be at once grasped by the casual outsider. Those who are aware of this fact will smile at Professor Huxley's statement that he plucked the heart out of the works of Suarez during a summer afternoon's study in the library of a Scotch University. If I say to the man whom I may casually meet in any smoking-room, " $\text{H}_3\text{C}_6\text{H}_5\text{O}_7 + 3\text{NaHCO}_3 = \text{Na}_3\text{C}_6\text{H}_5\text{O}_7 + 3\text{H}_2\text{O} + 3\text{CO}_2$," he will probably tell me that he has forgotten all the algebra which he learnt as a boy and that my remark is unintelligible to him. Whereas, if I say, "If you add lemon juice to baking-soda the mixture will fizz," his reply will probably be that my information is accurate if antiquated. Yet the two statements are precisely the same or connote exactly the same occurrences only that one is in the language of the chemist, the other that of the kitchen.

In the same way if we define the animal soul as a simple, incomplete substance or substantial principle immersed in matter, that definition is drawn up with the purpose of making clear the fact that in matter and life we have not two complete

beings accidentally conjoined, but two constituent factors or principles making up or coalescing into one complete being of a definite nature. Hence the scholastic would define the vital principle as an intrinsic principle of the living cell constituting it living and differentiating it from non-living matter.

It is hard to see how this definition and this way of looking at living matter differs from Professor Moore's definition of what he calls biotic energy, namely "that form of energy peculiar to living matter, and exhibited in those energy phenomena which are confined to living matter and are indeed its intrinsic property, by which it is differentiated and known to be alive".

The present writer confesses that to him at least the two definitions appear to be absolutely identical in essence and he thinks that the same might be said of Claude Bernard's statement:¹ Claude Bernard
"Arrivés au terme de nos études, nous voyons qu'elles nous imposent une conclusion très générale, fruit de l'expérience, c'est, à savoir, qu'entre les deux écoles qui font des phénomènes vitaux quelque chose absolument distincte des phénomènes physico-chimiques ou quelque chose de tout à fait identique à eux, il y a place pour une troisième doctrine, celle du vitalisme physique, qui tient compte de ce

¹ *Vide* Hertwig, *op. cit.*, s. 131.

qu'il y a de spécial dans les manifestations de la vie et de ce qu'il y a de conforme à l'action des forces générales: l'élément ultime du phénomène est physique; l'arrangement est vital". This view which distinguishes itself from the physico-chemical theories and, whilst allotting only those processes which are the outcome of general physical forces to the material element, assigns to "l'arrangement" or organising property (or "energy" or "force") the special vital phenomena, seems to approximate very closely to the old scholastic conception of the "forma substantialis" or the vital energy of the living body.

Let us con-
template
ourselves

But enough of definitions. If we clear our minds of such things and contemplate ourselves, is it really possible to conceive that what we know best amongst the activities of life, our own conscious states, our thoughts, our feelings and our volitions are nothing but physical "energies" or "forces" and are explicable in the same terms as the making of soda water is explicable? Is it not clear that the two classes of phenomena are wholly different from one another and that the activities of life are agencies of quite a different character? As Father Maher puts it¹ "they are phenomena unextended and indivisible, quite beyond the ken of physical science; and they are never convertible

¹ *Life and the Conservation of Energy.*

into any of the forms of 'energy' with which physical science deals. As Tyndal admitted, 'the chasm between them is intellectually impassable'."

"Correlated with mind," says Professor Ward,¹ "the complex characteristics of all forms of life are intelligible; but to interpret them literally in terms of physical interaction, and apart from mind, is surely impossible."

In conclusion the writer might perhaps be allowed to say that his sole object was to bring forward such biological evidence as had come under his notice in favour of a vitalistic or a neo-vitalistic—for as has been shown, the two are identical—explanation of living matter. It has been no part of his intention to deal with the question of the human soul and its relation to the activities of the human body, since that is a matter for theologians rather than for biologists to deal with. Nor has he desired to wander in the paths of the philosophers and debate the nature of the vital force nor to discuss, with Scotus, the question as to the relations of the operations of the cells or collections of cells into organs with the body of which they form a part. Whether all the "energiæ" are parts of a whole, or whether, as Scotus taught long ago, there are inferior or subservient kinds of "forms" or "energiæ" within the organism dom-

¹ *Op. cit.*, i., 285.

inated by and participating in the supreme "energia" which unifies and animates the whole organism, is not of any great consequence to the main thesis with which this book has endeavoured to deal, however interesting and fascinating a subject of discussion it may be in itself.

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