Holism and evolution

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HOLISM AND EVOLUTION

BY

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CHAPTER I

THE REFORM OF FUNDAMENTAL CONCEPTS

Summary.—In spite of the great advances which have been made in knowledge, some fundamental gaps still remain; matter, life and mind still remain utterly disparate phenomena. Yet the concepts of all three arise in experience, and in the human all three meet and apparently intermingle, so that the last word about them has not yet been said. Reformed concepts of all three are wanted. This will come from fuller scientific knowledge, and especially from a re-survey of the material from new points of view. The fresh outlook must accompany the collection of further detailed knowledge, and nowhere is the new outlook more urgently required than in the survey of these great divisions of knowledge.

Take Evolution as a case in point. The acceptance of Evolution as a fact, the origin of life-structures from the inorganic, must mean a complete revolution in our idea of matter. If matter holds the promise and potency of life and mind it is no longer the old matter of the physical materialists. We have accepted Evolution, but have failed to make the fundamental readjustment in our views which that acceptance involves. The old mechanical view-points persist, and Natural Selection itself has come to be looked upon as a mere mechanical factor. But this is wrong: Sexual Selection is admittedly a psychical factor, and even Natural Selection has merely the appearance of a mechanical process, because it is viewed as a statistical average, from which the real character of struggle among the living has been eliminated.

Nineteenth-century science went wrong mostly because of the hard and narrow concept of causation which dominated it. It was a fixed dogma that there could be no more in the effect than there was in the cause; hence creativeness and real progress became impossible. The narrow concept of causation again arose from a wider intellectual error of narrowing down all concepts into hard definite contours and wiping out their indefinite surrounding "fields." The concept of "fields" is absolutely necessary in order

to get back to the fluid plastic facts of nature. The elimination of their "fields" in which things and concepts alike meet and intermingle creatively made all understanding of real connections and inter-actions impossible. The double mistake of abstraction and generalisation has thus led to a departure in thought from the fluid procedure of nature. This narrowing of concepts and processes into hard and rigid outlines, and their rounding off into definite scientific contours temporarily simplified the problems of science and thought, but we have outlived the utility of this procedure, and for further advance we have now to return to the more difficult but more correct view of the natural plasticity and fluidity of natural things and processes. From this new view-point a re-survey will be made in the sequel of our ideas relating to matter, life and mind, and an attempt will be made to reach the fundamental unity and continuity which underlie and connect all three. We shall thus come to see all three as connected steps in the same great Process, the nature and functions of which will be investigated.

AMONG the great gaps in knowledge those which separate the phenomena of matter, life and mind still remain unbridged. Matter, life and mind remain utterly unlike each other. Apparently indeed their differences are ultimate, and nowhere does there appear a bridge for thought from one to the other. And their utter difference and disparateness produce the great breaks in knowledge, and separate knowledge into three different kingdoms or rather worlds. And yet they are all three in experience, and cannot therefore be so utterly unlike and alien to each other. What is more, they actually intermingle and co-exist in the human, which is compounded of matter, life and mind. If indeed there were no common basis to matter, life and mind, their union in the human individual would be the greatest mystery of all. What is in fact united in human experience and existence cannot be so infinitely far asunder in human thought, unless thought and fact are absolutely incongruous. Not only do they actually co-exist and mingle in the human, they appear to be genetically related and to give rise to each other in a definite series in the stages of Evolution; life appearing to arise in or from matter, and mind in or from life. The actual transitions have not been observed, but are assumed to have taken place under certain conditions in the course of cosmic Evolution. Hence arise the three series in the real world: physical, biological and psychical or mental. These connections between them, which are based not on thought but the facts of existence and experience, tend to show that they cannot be fundamentally alien and irreconcilable, and that some sort of bridge between them must be possible, unless we are to assume that our human experience is indeed a mere chaotic jumble of disconnected elements.

As I have said, the problem does not arise from the facts either of experience or of existence. The problem is one for our thought and our science. It is for our thought that the mystery exists, and it is for knowledge that the great gaps between the physical, the biological and the mental series arise. The solution must therefore ultimately depend on our more extended knowledge of these series and the discovery of interconnections between them. The great darknesses and gaps in experience are mostly due to ignorance. Our experience is clear and luminous only at certain points which are separated by wide regions of obscurity; hence the apparent mystery of the luminous points and of their isolation and unlikeness. Hence also the still greater mystery of their actual union in the threefold incarnation which constitutes human personality.

But it is just this union which ought to warn us that the apparent separateness of these three fundamental concepts is not well founded in fact, and that a wider knowledge and a deeper insight might be able to clear up the mystery, at least to some extent, and to produce for thought as for existence a sort of union or harmony of these apparently unrelated or independent elements in our real world. More knowledge is wanted. Our physical science ought to provide the solvent for our idea of hard impenetrable inert matter, and in the third chapter I shall inquire in how far there are already the materials for such a solvent. Again, our biological science should dispel the vagueness of the concept of life, and replace it by a more definite meaningful concept, which will yet not depend on purely material or physical elements. At present the concept of life is so indefinite and vague that, although the Kingdom of life is fully recognised, its government is placed under the rule of physical force or Mechanism. Life is practically banished from its own domain, and its throne is occupied by a usurper. Biology thus becomes a subject province of physical science—the Kingdom of Beauty, the free artistic plastic Kingdom of the universe, is inappropriately placed under the iron rule of force. Mind again, which is closest to us in experience, becomes farthest from us in exact thought. The concepts in which we envisage it are so vague and nebulous, compared with the hard and rigid contours of our concepts of matter, that the two appear poles asunder. Here too a reformed concept of mind might bring it much closer to a reformed concept of matter. And thus, out of the three at present utterly heterogeneous polar concepts of matter, life and mind it might be possible to develop concepts moulded more closely to fact and experience, freed of all adventitious and unnecessary elements of separateness and disparity, and forming (as in all true science they should rightly form) the co-operative elements and aspects in a wider, truer conception of Reality. It may be said that in making this demand for new concepts of matter, life and mind we are imposing an impossible task on thought. We are asking it to go beyond itself and deal with matters entirely beyond its own proper world. Matter, it may be urged, is essentially outside and beyond thought, something hard and impervious to thought, an object to thought which thought can only just barely reach up to in its utmost effort, and no more. Life is, of course, not alien to thought in the same sense as matter, but still it also falls outside the province of thought, it also has a reality of its own beyond thought, and it also is an object to thought. How then could thought embrace these provinces, how could it be a measure of these provinces beyond its ken; how could the part envisage the whole? Our standard of measurement is inadequate, our task therefore impossible.

The answer is that, while mind or thought may not have made matter, it has undoubtedly assisted in making the concept of matter; and this concept, based as it is on mere empirical experience, on inadequate knowledge and covered with a thick over-burden of unsifted tradition, may be mostly wrong, however deeply embedded in human thought it may be. A reform of the concept of matter is urgently required, and is indeed amply justified by the unprecedented recent advances in physical science, and especially in our knowledge of the constitution of matter. And a reform will, as I shall show in the third chapter, bring matter considerably nearer to the concept of life.

With regard again to the concept of life, what is most urgently required is that it should be rid of that haziness, indefiniteness, and vagueness which makes it practically worthless for all exact scientific purposes. Biological science has not in recent years made the same gigantic strides forward in the knowledge of fundamentals that physical science has taken, and yet for Biology too the sky has considerably cleared, and what two or three decades ago was still hotly disputed is to-day generally accepted. Besides, the greatest development in Biology during this century has taken place in the science of Genetics, and the trend there has been steadily away from the hard mechanical conceptions which dominated Biology more than a generation ago. The time here too may be ripe for a reconsideration of some of the fundamental concepts and standpoints. I may express the hope that the masters of this science will not concentrate all their attention on special researches, however promising the clues at present followed may be; but that they will find time for a reconsideration of the wider conceptions which, ever since the great time of Darwin, have been getting further out of gear. Unless Biology can succeed in clarifying her fundamental conceptions there is risk of great confusion in a science in which old general ideas have persisted in spite of great progress in detailed knowledge. If in the sequel I join in the discussion of the foundations of Biology, not as entitled of right to speak but more in the character of an outside spectator urging the importance of a new point of view, I hope my presumption in so doing may be forgiven me.

For welcome as any new and deeper knowledge would be on these high matters, the present situation calls even more urgently for fresh points of view. Matter, life and mind are, so to speak, the original alphabet of knowledge, the original nuclei of all experience, thought, and speculation. Their origin is purely empirical, their course has been shaped by tradition for thousands of years, and all sorts of discarded philosophies have gone towards the making of their popular meanings. In spite, therefore, of the great fundamental aspects of truth which they embody, the kernel of truth in them has become overlaid by deep incrustations of imperfect and erroneous knowledge. Modern science and philosophy have repeatedly ventured on reforms, but the popular use of these terms tends to obliterate all fine distinctions. I do not believe that an abiding scientific or philosophic advance in this respect will be possible until a more exact nomenclature has been adopted. Such a reform I am going to advocate and suggest in the sequel, but in the meantime I wish to emphasise how important it is, not merely to continue the acquisition of knowledge, but also to develop new view-points from which to envisage all our vast accumulated material of knowledge. The Copernican revolution was not a revolution in the acquisition of new knowledge, but in view-point and perspective in respect of existing knowledge. The most far-reaching revolutions in knowledge are often of this character. Evolution in the mind of Darwin was, like the Copernican revolution, a new view-point, from which vast masses of biological knowledge already existing fell into new alignments and became the illustrations of a great new Principle. And similarly Einstein's conception of General Relativity in the physical universe, whatever its final form may yet be, is a new view-point from which the whole universe and all its working mechanisms acquire a new perspective and meaning.

More knowledge is undoubtedly required, but its acquisition must go hand in hand with the exploration of new concepts and new points of view. It will not help merely to accumulate details of which, even in the special departments of the separate biological sciences, the masses are already becoming more than any individual mind can bear. New co-ordinations are required, new syntheses which will sum up and explain and illuminate the otherwise amorphous masses of material. While research is being prosecuted as never before, while in biological science great, and in the physical sciences unprecedented, progress is being recorded, the call becomes ever more urgent for a reconsideration of fundamental concepts and the discovery of new standpoints which might lead to the formulation of more general principles and wider generalisations. Nowhere are new view-points more urgently called for than in respect of the fundamental concepts of matter, life, and mind, of which the reform is overdue and the present state is rapidly becoming a real obstacle to further progress. And I may point out that the formulation of new view-points will depend not so much on masses of minute details, as on the consideration of the general principles in the light of recent advances, the collation and comparison of large masses of fact, and the survey of fairly large areas of knowledge. The road is to be discovered, not so much by minute local inspection as by wide roaming and exploration and surveying over large districts. Both methods are needed, and the question narrows itself down to one of comparative values. Just as in the cases of Newton and Einstein, the new clues are more likely to be indicated by certain crucial dominant facts than by small increments of research. It would therefore be a great mistake to let the completion of present detailed researches take precedence over the more general and urgent questions to which I am drawing attention.

Let me mention one matter of crucial significance to which I think sufficient importance has not yet been attached. To-day I think it is generally accepted that life has in the process of cosmic Evolution developed from or in the bosom of matter, and that mind itself has its inalienable physical basis. I do not think that among those who have given thought and attention to these matters there are to-day any who seriously question this position. Life is no dove that has flown to our shores from some world beyond this world; mind or soul is not an importation from some other universe. Life and mind are not mere visitants *to* this world, but not *of* this world. There is nothing alien in them to the substance of the universe; they are with us and they are of us. The popular view still looks upon the association of life and mind with matter as a sort of symbiosis, as the close living together of three different beings, as the dwelling of life and the soul in the body of matter, just as in the organic world one plant or animal organism will be found normally living with and in another. This popular traditional view comes from the hoary beginnings of human thought and speculation, but it is definitely abandoned by all those who have assimilated the modern view-point of Evolution. For them in some way not yet fully understood, but accepted as an undoubted fact, both life and mind have developed from matter or the physical basis of existence. The acceptance of this fact must have far-reaching consequences for our world-view.

But before I refer to that aspect of the matter let me point out how this acceptance affects the grave issues over which our fathers fought a continuous battle royal during the latter half of the nineteenth century. The materialists contended for this very point, namely, that life and mind were born of matter. From this they proceeded (quite illegitimately) to infer the primacy and self-sufficiency of matter in the order of the universe, and to reduce life and mind to a subsidiary and subordinate position as mere epiphenomena, as appearances on the surface of the one reality, matter. To use the Platonic figure, to them matter was the lyre, and the soul was the music of that lyre; the lyre was the substantive and abiding reality, and the music a mere passing product. And thus the priority and dominance of matter made of life and the soul merely transient and embarrassed phantoms on the stage of existence. This materialism was most hotly resented and contested by those who held to the spiritual values and realities. They denied not only the primacy of matter but also that life or mind sprang from it and were dependent on it in any real sense. In fact they denied the principle of Evolution as undermining all the spiritual and moral values of life. Both sides, materialists and spiritualists alike, were under the influence of the hard physical concepts of cause and effect which played such a great part in the science of the nineteenth century. There could be nothing more in the effect than there was already in the cause; and if matter caused the soul, there could be nothing more in the soul than there already was in matter. In other words, the soul was merely an apparent and no real substantial advance on matter. The abstract validity of this argument was never questioned and was thoroughly believed in by both sides. Hence those who affirmed the theory of Evolution logically tended to be materialists, and those who were spiritualists were logically forced to deny Evolution.

Without their knowing it the great battle raged, not over the facts of Evolution, but over a metaphysical theory of causation in which they both believed and were both wrong. Such is the irony of history. To-day we pick the poppies on the old bloody battlefield of Evolution, and can afford to be fair to both sides. The essential terms have changed their meaning for us. We believe in Evolution, but it is no more the mechanical Evolution of a generation or two ago, but a creative Evolution. We believe in the growth which is really such and becomes ever more and more in the process. We believe in Genesis which by its very nature is epigenesis. For us there is no such thing as static Evolution, a becoming which does not become but in its apparent permutations ever remains the same. The absolute equation of cause and effect, which was a dogma implicitly believed in by the men of that day, does not hold for us, as I shall later on explain. The temperature has changed, the view-point has shifted, and to-day thoughtful men and women are sincere and convinced Evolutionists, without troubling themselves over the dead and forgotten issue of materialism versus spiritualism. We accept the theory of descent, of life from matter, and of the mind from both. For educated men and women to-day Evolution is just as much part and parcel of their general outlook, of their intellectual atmosphere, so to say, as is the Copernican theory.

As I said before, this is a fact with very far-reaching implications. If we believe that life and mind come from matter, if they are evolved from matter, if matter holds the promise, the dread potencies of life and mind, it can for us no longer be the old matter of the materialists or the physicists. The acceptance of the view for which the materialists fought so hard means in effect a complete transformation of the simple situation which they envisaged. Matter discloses a great secret; in the act of giving birth to life or mind it shows itself in an entirely unsuspected character, and it can never be the old matter again. The matter which holds the secret of life and mind is no longer the old matter which was merely the vehicle of motion and energy. The landmarks of the old order are shifting, the straight contours of the old ideas are curving, the whole situation which we are contemplating in the relations of matter, life and mind is becoming fluid instead of remaining rigid. The point to grasp and hold on to firmly is that the full and complete acceptance of Evolution must produce a great change in the significance of the fundamental concepts for us. Life and mind now, instead of being extraneous elements in the physical universe, become identified with the physical order, and they are all recognised as very much of a piece. This being so, it obviously becomes impossible thereupon to proceed to erect an all-embracing physical order in which life and mind are once more declared aliens. This cat and mouse procedure is simply a case of logical confusion. This in-and-out game will not do. If Evolution is accepted, and life and mind are developments in and from the physical order, they are in that order, and it becomes impossible to continue to envisage the physical order as purely mechanical, as one in which they have no part or lot, in which they are no real factors, and from which they should be logically excluded. If

Evolution is right, if life and mind have arisen in and from matter, then the universe ceases to be a purely physical mechanism, and the system which results must provide a real place for the factors of life and mind. To my mind there is no escape from that argument, and its implications must have a very far-reaching effect on our ideas of the physical order, and on a biology in which mechanical views are still dominant.

The point I have been trying to make is that our ultimate concepts need reconsideration, and that above all new view-points are necessary from which to re-survey the vast masses of physical and biological knowledge which have already accumulated. I have said that certain large dominant facts may be sufficient to lead to a new orientation of our ideas. And I have taken the accepted fact of Evolution as a case in point. The older materialists and the present-day mechanical biologists have both fought hard for the acceptance of Evolution as a fact, without realising that such an acceptance must inevitably mean a transformation of their view-points, and that both the meaning of the concept of matter and the idea of the part played by mechanism in biology must be seriously affected by such acceptance. It is clear that the full significance of the great dominant idea of Evolution and its effect on the ordering of our ultimate world-view are not yet fully realised, and that we are in effect endeavouring simultaneously to go forward with two inconsistent sets of ideas, that is to say, with the idea of Evolution (not yet adequately realised) and the pre-Evolution physical ideas (not yet quite abandoned). This is, however, sheer confusion, and a clarification of our ideas and the realisation of new view-points have become necessary.

Let me now leave the general fact of Evolution as bearing on our world-view and call attention to another and somewhat similar case which arises in Darwin's theory of Descent. In that theory Natural Selection is usually but erroneously taken to be a purely mechanical factor. It is understood to operate as an external cause, eliminating the unfit in the struggle for existence, and leaving the fit in possession of the field to reproduce their kind and to continue the story of Evolution. Natural Selection, from whatever cause arising and in whatever way operating, is on this view taken to be merely a mechanical cause or factor, just as is a hailstorm which kills plants and animals with hailstones, or a drought which kills them from want of water. Whether the destruction arises from physical mechanical causes like storms or drought or lightning, or whether it arises from the action of living agencies such as enemies or disease or the like, makes no difference to the result, which is in either case the same. A broad generalised statistical view of the causes of elimination has been taken and Natural Selection as a whole has on this view assumed the appearance of a mere external mechanical factor. On this view of Natural Selection, therefore, Darwin's theory of Evolution has come powerfully to reinforce the generally prevalent mechanical position. The effect has been just the opposite to what one might have expected from a great biological advance. The kingdom of life, instead of fighting for its own rights and prerogatives, has tamely and blindly surrendered to the claims of physical force and actually joined hands with it and contributed to its supremacy. The acceptance of Darwinism, therefore, so far from stemming the tide of mechanical ideas, has actually furthered and assisted it, and raised it to full flood. Through a misconception of the nature of Natural Selection the mechanical ideas have invaded the domain of life, where opposition might have been expected, and through the conquest and occupation of that domain the mechanical position, which would otherwise have been confined to the material physical sphere, has been extended and powerfully consolidated. This result was due, as I say, to the generalised statistical concept of Natural Selection, irrespective of whether it was due to organic or inorganic causes.

There is, however, one form of Selection which cannot be thus indiscriminately dealt with. It arises not only from organic causes, but still more narrowly and quite indisputably from psychical or mental causes. Darwin called it Sexual Selection, and in spite of the opposition of A. R. Wallace and others not only attributed great importance to it, but as time went on and he saw his great vision more clearly, he gave it an ever-growing emphasis in his theory of Descent. Natural Selection operates on the unfit by destroying them or killing them off; Sexual Selection, on the contrary, has a more limited operation and applies only in respect of males, whose reproduction it handicaps, limits or prevents. In other words it is a struggle among males for the possession of females, and in this struggle males are assisted not only by their superior strength or fighting powers, but also by their superior power of song or beauty or scent or general attractiveness or excitiveness to females. It is clear that the real motive power of this form of selection is mostly biological and psychical. The female is excited and attracted by superior fighting force or superior artistic endowments among males competing for her favour. And when one considers the degree of perfection to which the male forms have attained largely under this stimulus of the female sex instinct, one is struck with amazement at the emotional sensitiveness thus implied on the part of female insects, birds, and beasts, and at the wonderful subtlety and fineness of the emotional discrimination which has resulted from it. The beauty of form and colour which characterises, for instance, the peacock's feathers are such that even our human eye can scarcely do justice to it. And yet on the principle of Sexual Selection that perfection of beauty is due to the amazing emotional sensitiveness and appreciation of the peahen, which through countless generations must have been attracted by the minute superiority of the one male over others in this respect. And the same applies in regard to the wonderful power of song among male birds and all the other secondary male characters. The psychical emotional powers implied on the part of the female on this theory are so wonderful as to be almost unintelligible; in many respects they are superhuman, and would appear to throw an astonishing light on the unconscious psychical developments of what we are pleased to call the lower creatures. If secondary sexual characters with all their perfection of form and colour did originate and develop under the stimulus of Sexual Selection, we shall have to revise our views radically as to the psychical sensitiveness and endowments of large classes of these lower animals. If, for instance, the human female showed the same sensitive judgment and discrimination as the female bird or insect shows a sensitive sex instinct, what supermen we sorry males in time would become! I am afraid, however, that the theory of Sexual Selection does not tell the whole story, and that there is more in the sexual situation than appears from that theory. I shall refer to the subject again in Chapter VIII. But for my present purpose it is only necessary to emphasise that this form of selection is not mechanical but psychical. If Sexual Selection plays the great part in organic Evolution which Darwin, Weismann and many other great biologists assign to it, we can only conclude that to that extent at any rate the motive force in Evolution is psychical and not mechanical.

I would go further and, in opposition to current views, I would contend that even Natural Selection, in so far as it is a struggle among animal and plant forms and not merely the pressure or agelong effect of the inorganic environment, is fundamentally psychical. The advance takes place generally because the more fit organism deliberately for its own purposes destroys the less fit organism. In its essence the organic struggle creates a psychical situation just as much as war among humans is a psychical situation. And it is only because we abstract from the situation its real character of animal struggle and view the total statistical effect of innumerable situations as itself a sort of personified operative force in the form of Natural Selection, that the appearance of a mechanical external factor is created, operating on Evolution from the outside and determining its course mechanically. Looked at as a whole, and at a distance in which all concrete cases are blurred in the general view, the struggle for existence among animals and plants seems to operate blindly and mechanically without any view to that improvement of species which results. But this general struggle is actually composed of infinite little concrete struggles in which the fit deliberately destroy the unfit. And the trend of the struggle is towards organic progress actually because of the character of the little concrete struggles. I do not mean to say that the striving, struggling individual in nature intends to improve its species. But it does fight for itself or its family or its tribe; and in so far as it is more "fit" than its beaten opponent it is in effect fighting the battle of organic progress. The psychical purposive character of the little concrete struggles imparts a psychological purposive character to the generalised factor of Natural Selection. In fact the current view of Natural Selection is a very striking illustration of the way in which a so-called mechanical force or cause is gratuitously constituted by abstraction and generalisation and statistical summation from elements which in their individual character and isolation are undoubtedly psychical and purposive. And this only shows how careful we must be to scrutinise concrete details and not to rest satisfied with large generalisations, if we would know what really happens in nature. Abstraction and generalisation, however useful and necessary for scientific purposes, do largely deprive real events of their true characters, which are vital to a correct understanding of reality.

To sum up, therefore: apart from the influence of the physical environment, the motive and directive forces of organic Descent in the form of Natural and Sexual Selection are psychical and not merely mechanical. And this result of the special Darwinian theory is therefore in complete accord with the more general considerations which we derived from the analysis of Evolution in general. Both in Evolution as a whole and in Darwin's more special theory of organic Descent, life and mind are no mere shadows or unreal accompaniments of some real mechanical process; they are there in their own right as true operative factors, and play a real and unmistakable part in determining both the advance and its specific direction. From the point of view of Evolution each of them must be looked upon as essentially a real *vera causa.* This does not affect what I have already said about the vagueness and unsatisfactoriness of their present concepts and the necessity of looking for more definite and adequate concepts. All I mean to say is that the things they stand for are real factors in nature and not mere words or appearances. In the sequel an effort will be made to give greater definiteness to these concepts, and to determine the nature and character of the activity of these factors. Here it must suffice to emphasise that the nature of Evolution has been obscured by mechanistic conceptions, and that erroneous views as to the character and operation of causation have contributed to this misunderstanding. And it may be useful, before concluding this introductory chapter, to add a few remarks on this subject, to which I have already briefly referred above.

The science of the nineteenth century was like its philosophy, its morals and its civilisation in general, distinguished by a certain hardness, primness and precise limitation and demarcation of ideas. Vagueness, indefinite and blurred outlines, anything savouring of mysticism, was abhorrent to that great age of limited exactitude. The rigid categories of physics were applied to the indefinite and hazy phenomena of life and mind. Concepts were in logic as well as in science narrowed down to their most luminous points, and the rest of their contents treated as non-existent. Situations were not envisaged as a whole of clear and vague obscure elements alike, but were analysed merely into their clear, outstanding, luminous points. A "cause," for instance, was not taken as a whole situation which at a certain stage insensibly passes into another situation, called the effect. No, the most outstanding feature in the first situation was isolated and abstracted and treated as the cause of the most outstanding and striking feature of the next situation, which was called the effect. Everything between this cause and this effect was blotted out, and the two sharp ideas or rather situations of cause and effect were made to confront each other in every case of causation like two opposing forces. This logical precision immediately had the effect of making it impossible to understand how the one passed into the other in actual causation. The efficient activity, which had of old been construed on the analogy of our muscular activity, was therefore resorted to in order to supply the explanation. As the muscular movement produces external action, so material cause was supposed to produce a material effect. Even then the mind found it difficult to realise the passage from the one to the other. Every causation seemed to imply some action at a distance, unless cause and effect were in absolute contact. But we know that there is no such thing as absolute contact even in the elements of the most closely packed situation. Hence causation of this rigid type really became unintelligible. Not even the old fiction of an ether which embraced all material things, and as a vehicle made transmission of influence from one to the other possible, seemed able to overcome the contradictions into which thought had landed itself through its hard and narrow concepts of cause and effect. And in fact there is no way out of the *impasse* but by retracing our steps and recognising that these concepts are partial and misleading abstractions. We have to return to the fluidity and plasticity of nature and experience in order to find the concepts of reality. When we do this we find that round every luminous point in experience there is a gradual shading off into haziness and obscurity. A " concept " is not merely its clear luminous centre, but embraces a surrounding sphere of meaning or influence of smaller or larger dimensions, in which the luminosity tails off and grows fainter until it disappears. Similarly a " thing " is not merely that which presents itself as such in clearest definite outline, but this central area is surrounded by a zone of intuitions and influences which shades off into the region of the indefinite. The hard abrupt contours of our ordinary conceptional system do not apply to reality and make reality inexplicable, not only in the case of causation, but in all cases of relations between things, qualities, and ideas. Conceive of a cause as a centre with a zone of activity or influence surrounding it and shading gradually off into indefiniteness. Next conceive of an effect as similarly surrounded. It is easy in that way to understand their interaction, and to see that cause and effect are interlocked, and embrace and influence each other through the interpenetration of their two fields. In fact the conception of Fields of force which has become customary in Electro-Magnetism is only a special case of phenomenon which is quite universal in the realms of thought and reality alike. Every " thing " has its field, like itself, only more attenuated; every concept has likewise its field. It is in these fields and these fields only that things really happen. It is the intermingling of fields which is creative or causal in nature as well as in life. The hard secluded concrete thing or concept is barren, and but for its field it could never come into real contact or into active or creative relations with any other thing or concept. Things, ideas, animals, plants, persons: all these, like physical forces, have their fields, and but for their fields they would be unintelligible, their activities would be impossible, and their relations barren and sterile. The abstract intelligence, in isolating things or ideas, and constituting them apart from their fields, and treating the latter as non-existent, has made the real world of matter and of life quite unintelligible and inexplicable. The world is thus in abstraction constituted of entities which are absolutely discontinuous, with nothing between them to bridge the impassable gulfs, little or great, which separate them from each other. The world becomes to us a mere collection of *disjecta membra,* drained of all union or mutual relations, dead, barren, inactive, unintelligible. And in order once more to bring relations into this scrap heap of disconnected entities, the mind has to conjure up spirits, influences, forces and what not from the vasty deep of its own imagination. And all this is due to the initial mistake of enclosing things or ideas or persons in hard contours which are purely artificial and are not in accordance with the natural shading-off continuities which are or should be well known to science and philosophy alike. One of the most salutary reforms in thought which could be effected would be for people to accustom themselves to the ideal of fields, and to look upon every concrete thing or person or even abstract idea as merely a centre, surrounded by zones or aurae or spheres of the same nature as the centre, only more attenuated and shading off into indefiniteness.

There is one more remark I wish to make in regard to the activity of the abstract intelligence in construing our actual experience. I have already shown how in a special case this abstract activity has converted the psychical factor of Natural Selection into the semblance of a mechanical force. The risk of error is, however, much greater than that particular instance may serve to indicate. One may say that the analytical character of thought has a far-reaching effect in obscuring the nature of reality, which has to be carefully guarded against. In order to understand and explore any concrete situation, we analyse it into its factors or elements, whose separate operation and effects are then studied, in isolation so to say. This procedure is not only quite legitimate, but the only one possible, if we wish to understand and investigate the complex groupings of nature. It is the analytical method which science has applied with such outstanding success; and but for this analysis of a complex phenomenon or situation into its separate elements and the study of these in isolation, it is fair to assume that very little progress would have been possible in the understanding of Nature with all her obscure processes. When the isolated elements or factors of the complex situation have been separately studied, they are recombined in order to reconstitute the original situation. Two sources of error here become possible. In the first place, in the original analysis something may have escaped, so that in the reconstruction we have no longer all the original elements present, but something less. I have already shown how "fields" escape in the idea of things and even in concepts. The same happens in regard to the elements into which a situation is analysed. And it is certain that in every case of analysis and reconstitution of a situation something escapes, which makes the artificial situation as reconstructed different from the original situation which was to be explored and explained. An element of more or less error has entered. This may be called the error of analysis.

In the second place, we are apt after the analysis and investigation of the isolated elements or factors to look upon them as the natural factors of the situation, and upon the situation itself as a sort of result brought about by them. The analytical elements thus become the real operative entities, while the situation or phenomenon to be explained becomes their product or resultant. As a matter of fact, just the opposite is the case. We started in nature with the complex situation or sensible phenomenon as the reality to be explained. The analytical elements or factors were merely the result of analysis, and might even be merely abstractions. But because they are simpler and admit of closer scrutiny and experiment, we have come to look upon them as real or constitutive, and upon the situation from which they were abstracted or analysed as artificial or constituted. Thus it has come about that in physical science, for instance, the elements of matter or force into which bodies have been analysed have tended to become the reals. Thus scientific entities like electrons and protons, and the physical energies or forces which they represent, are taken to be the real entities in nature, and sensible matter or bodies as something derivative and merely resulting from their activities. The abstract thus becomes the real, the concrete is relegated to a secondary position. This inversion of reality is very much the same procedure as was condemned in the case of the scholastic and other philosophers who attributed reality to universals instead of to concrete particulars. This may be called the error of abstraction or generalisation. Against both these forms of error we have to guard, if we wish faithfully to interpret Nature as we experience her.

Our object in studying and interpreting Nature is to be faithful to our experience of her. We do not want to recreate Nature in our own image, and as far as possible we wish to eliminate errors of observation or construction which are due to us as observers. We do not wish to spread Nature on a sort of Procrustes bed of our concepts and cut off here and there what appears surplus or unnecessary or even non-existent to our subjective standards. Our experience is largely fluid and plastic, with little that is rigid and with much that is indefinite about it. We should as far as possible withstand the temptation to pour this plastic experience into the moulds of our hard and narrow preconceived notions, and even at the risk of failing to explain all that we experience we should be modest and loyal in the handling of that experience. In that way a good deal of what we have hitherto felt certain may once more become uncertain; the solid and recognised landmarks may once more become blurred or shifting; the stable results of the nineteenth-century science may once more become unstable and uncertain. But the way will be open for the truer constructions of the future, and the foundations of our future science will be more deeply and securely laid.

In the following chapters a modest effort will be made to apply the above ideas and principles to a new interpretation of Nature, including, as it does, Matter, Life and Mind. Matter, Life and Mind, so far from being discontinuous and disparate, will appear as a more or less connected progressive series of the same great Process. And this Process will be shown to underlie and explain the characters of all three, and to give to Evolution, both inorganic and organic, a fundamental continuity which it does not seem to possess according to current scientific and philosophical ideas.

CHAPTER II

THE REFORMED CONCEPTS OF SPACE AND TIME

Summary.—It is not only in organic Evolution that the old fixed concepts and counters of thought are breaking down. Recent advances in physical science have extended the revolution to the domain of the inorganic; the fixity of the atom has followed that of species into the limbo of the obsolete. In many directions new concepts, more in harmony with the fluid creative process of nature, are called for.

We begin with the new concepts of Space and Time, which in the system of Relativity are taking the place of the old Newtonian concepts still commonly accepted. The new ideas of Space and Time arose from researches in the higher mathematics and physics, and were primarily concerned with the relative character of all actual motion in the universe, and the mathematical and physical consequences of this relativity. Thus according to the mathematical physicists to a moving observer a moving body appears to contract or to be shorter than it would be to a stationary observer, and the faster either of them moves the greater the contraction becomes. Time varies similarly, but in the opposite direction; while the space of the moving body appears to contract, its time appears to expand, so that it takes a longer time to pass a point than it would do if viewed by a stationary observer. This joint and inseparable variation of Space and Time was not only most important in itself, but led directly to the revolutionary conception that neither of them existed independently, but that together they form the Space–Time medium of the real physical world. From this point of view bodies and things as merely spatial are not real but abstractions, while events, which involve both Space and Time, Action in Space–Time, are real and form the units of reality. The deposition of the old Space and Time and their replacement by Space–Time have been tested in the most searching way both in the immense world of astronomy and in the most minute world of the atom, and in both cases the new concepts have been found to work satisfactorily.

The variation of Space and Time has led to the further conclusion that in a world of relative motion such as ours all standards of measurement and all clocks of Time are themselves variable and

give no constant results. Applying the conclusion to gravitation and the rotational movements of the universe, we find that the Space–Time medium of the universe is curved and warped and not of the homogeneous character which was attributed to Space and Time according to the old ideas. In all gravitational fields events happen in curves and follow the fundamental curves of the Space–Time universe. The result is that the entire universe acquires a definite structural character, and is not a diffuse homogeneity as was formerly supposed. According to the new Space–Time concept, structure, definite organised structure, becomes the essential characteristic of the physical universe, and this structural character accounts for many hitherto inexplicable phenomena.

In the preceding chapter I have tried to explain how the acceptance of the theory of Evolution must inevitably and profoundly affect our views as regards the nature of matter. In this chapter I proceed to inquire what bearing recent far-reaching physical researches and speculations have on this position. Our problem is to break away from the hard and narrow conceptions of the Victorian age, to see Nature once more in her fluid and creative plasticity, and to formulate our conceptions afresh from this deeper point of view. A great change has come over our views of Nature, a change great enough in the end to amount to one of the fundamental revolutions in human thought. But we are still in the process of that change, and it is therefore difficult for us to realise its full significance. Three dates stand out in bold relief as inaugurating that change: 1859, when Darwin's *Origin of Species* was published; 1896, when Becquerel discovered Radioactivity; and 1915, when Einstein published his *General Theory of Relativity*. Round these three great events other discoveries of profound interest have taken and are still taking place; and in the result our entire viewpoints and standpoints as regards Nature and reality are undergoing a fundamental change which must in the end affect every province of human thought and conduct. The fixity of organic species is gone; the fixity of inorganic elements is going. The position is once more becoming fluid, the old rigid order is visibly dissolving, the fixed landmarks and beacon-points by which former generations steered their course in science are becoming submerged. And the task awaits the future out of this fluid situation and these instabilities once more to build a stable world of ideas, which will be in closer harmony with the reality around us and within us. One of the aspects of Darwin's Theory has already briefly engaged our attention in the last chapter, and other aspects of it will be considered in Chapter VIII. In the present chapter reference must be made to Einstein's *General Theory of Relativity* and the bearing it has on our ideas of space and time as the framework in which events are located, and the medium in which Evolution takes place. The resulting view of the universe as structural, and of the element of structure as fundamental to the universe and all its forms, is important for the subject and the argument of this work.

People become frightened when they are invited to consider Einstein's theory. Its refined abstractions, its abstruse mathematical form, its complete novelty and reversal of ordinary common-sense view-points make it a terror to the uninitiated. And yet I believe the Einstein view-point can be quite simply and intelligibly put. Indeed it must be so put if it is ever to become part and parcel of ordinary educated thought. We must distinguish between the simple and clear view-point itself, and the recondite mathematical processes by which it was reached, and the technical mathematical form in which it is expressed, and from which for all ordinary purposes it can be separated. The understanding and appreciation of the Relativity view-point are not dependent on a knowledge of the process by which Einstein reached that view-point. The result is quite distinct from the process. It is like groping our way through a long, dark, rough tunnel, and at the end emerging into the clear daylight beyond: it is not necessary for the appreciation of the new view that one should plunge back into the dark tunnel. Besides, I must frankly state my own opinion that the Einstein theory, as distinguished from the broad view-point attained, has not yet found its final expression. All great truths are in their essence simple; and the absence of simplicity of statement only shows that the ultimate form has not yet been reached. The day may yet come when the ten recondite Einstein equations of gravitation may appear as but the scaffolding of the simpler structure yet to arise, the naturalness and inevitableness of which will be as evident to every educated person as the heliocentric conception of Copernicus has become.

The Einstein theory arose originally from mathematics, and a brief reference to this mathematical origin will be useful. Galileo and Newton were the fathers of the modern classical mechanics; they (and especially Newton) formulated the laws of moving bodies in an exact mathematical science. Now the germ of the new Relativity mechanics is the almost obvious fact that the motion of a body is never absolute, but is always relative to some other body or point. If this body or point of reference is stationary, Newton's laws of motion apply completely, and the geometry of Euclid also applies, so that the movements of bodies can be represented by geometrical figures. Such bodies are said to move in Euclidean space, which is the same and homogeneous all through and in all directions. Now since Newton's time a great deal of attention has been given to the case where the body of reference or the observer is not stationary but is also in motion. This case is important, because it is actually that of all bodies in our universe, in which all observers or points of reference are themselves in motion. A point on the earth, for instance, rotates with a certain velocity round the centre of the earth, while the earth again rotates with another velocity round the sun. The sun itself is not stationary but moving with reference to some star, which is itself in motion with reference to some other moving centre of reference. It is this case of the moving observer or point of reference with which Einstein's theory deals, and it is therefore clear that this theory faces the problem of motion as it actually exists in the universe. The impression of rest or stationariness to us as observers in the universe is a mere illusion, and the great service of Einstein was to explore this illusion and to show in exact mathematical form to what extent it affects our vision and judgment of movement in the world. Let us therefore take the case of moving observers. Now when a moving object (say a train in motion) is viewed by an observer in motion (say an observer in a motor-car moving on a road parallel to the train), certain curious results have been worked out by the mathematicians, of which the following are two important samples:

(A) The train appears a little shorter than it would to a stationary observer.

(B) The time taken by the train to pass a point appears a little longer (or the train appears to move somewhat more slowly) than it would to a stationary observer.

In other words, to a moving observer the length or the space occupied by a moving body is smaller in the direction of its motion than it would appear to a stationary observer; and similarly the time taken by the observed body to pass a point will be longer. And the faster the observer or observed body moves, the more the space and time of the observed body will vary for him, compared to what they would do if he were at rest. These two variations of space and time are joint variations, happening simultaneously but in an opposite direction, the one becoming less in proportion as the other becomes more to the moving observer. Space contracts and time expands in inverse proportions according to the rate of motion of a moving body of reference or a moving observer. One may generalise this result and say that so long as several observers move at different rates but uniformly and in straight lines with regard to each other, the velocity or speed of the moving body which they are observing appears the same to all of them, as the proportional co-variations of their respective spaces and times cancel each other out, so to say. This is a popular way of stating the main principle of Einstein's *Special Theory of Relativity*, first published in 1905, in rigorous mathematical form. It explained the fact, which had been repeatedly confirmed by the most accurate experiments, that the velocity of light is always the same, whatever the velocity of its source, and however great may be the difference in velocities of the moving observers who are trying to measure it. An observer moving away from a flash of light at a rate which is half that of light will see the flash at the same time as a stationary observer, and not later as one might suppose. The reason is that the time and space measures of the moving observer have changed jointly so as to neutralise the results which his motion might have on his observation.

The two salient facts to bear in mind as a result of the above are: that to moving observers clocks and standards of measurement in motion are no longer absolute but vary according to the rates of motion of these observers or of the clocks or standards, and that there is this curious joint and opposite variation of the space and time measures of moving observers or bodies. In fact separately Space and Time must be mere abstractions, as in all actual movements they are always found in inseparable conjoint action.

From this co-variation of Space and Time it is but a step to Minkowski's great idea, first formulated in 1908, that in natural events Space and Time are not independent factors, and that in the mathematical representation of events the correct way is to introduce time as a fourth dimension, not of space, but of the Space–Time continuum in which events really take place. Time is, of course, in many ways unlike space and is not another dimension of it, but this inseparable co-variation in all events which happen in nature makes it both feasible and proper that we should substitute the real Space–Time continuum of events for the old abstract three-dimensional space of bodies or points in space. In passing it may here be pointed out that the old notion of the separate reality of space and of time involved both the errors of analysis and of abstraction to which attention was drawn in the last chapter, and Minkowski's brilliant idea has simply brought us back to the natural fact as it occurs in experience, where nothing ever happens in space alone or in time alone, but always in both together, and where objects are not observed by themselves, but always as elements or items in the stream of perceived events. Nay more, it can be easily shown that the very ideas of Space and Time interpenetrate each other and are dependent on each other. Succession or the time-series, and co-existence or the space-series, are necessary to each other and would not be even intelligible apart from each other. For the succession (time) would perish at each step and would not even form a series, unless it had enduringness or co-existence (space). And similarly the co-existence (space) would stop at its first step and would not be spread out or extended unless it had also succession (time).

To Einstein this concept of a Space–Time continuum proved most welcome and fruitful, and he proceeded to apply it to the explanation of all movements in the universe, not only to uniform and rectilinear motions which take place in uniform Euclidean space, but also to rotating and accelerated motions which take place in a gravitational field of a non-Euclidean character.

His first step was to illustrate, by purely theoretical considerations, the fact that a body under the influence of a constant force, and therefore moving with a constantly increasing acceleration, would to an observer situated on it behave in exactly the same way as a body acted on by gravitation. Thus suppose a man enclosed in a cage so that he cannot observe any other body and cannot notice his own motion. And suppose this cage suspended in distant space where there is no gravitation. And suppose further that this cage is drawn upward with a constant force, so that it moves faster and faster with a constantly increasing acceleration. In truth the case is therefore one of acceleration. But by the enclosed observer this motion and acceleration of the cage and himself will not be noticed. He would only feel like being pulled down by his own weight. If he loses any object from his hand, it will fall to the bottom of the cage like a stone dropped on the earth. What is more, the rate at which the object drops is the same, *whatever its figure or size or amount of material*. The fact italicised is distinctive of gravitation. In other words, the man in the cage will think that he and the cage and the object therein are all acted upon by gravitation. What is really due to acceleration appears to be a case purely and simply of gravitation. Thus we see acceleration and gravitation are really the same phenomena and only different in appearance to observers. Acceleration and gravitation are, in fact, equivalent expressions. Einstein's closed cage may yet become as historic as Newton's falling apple.

Now take rotation, which is simply a special case of acceleration. And let us imagine an observer situated on a rotating or revolving plane circular disc and proceeding to measure the area of the disc and the rate at which it is revolving. He has two identical clocks, one of which he puts near the centre of the disc and the other near the circumference in order to take some time measurements. When he proceeds to take the time of the clock near the centre he finds that it moves more slowly than when he proceeds to read the clock placed near the circumference. We have already seen why this is so. The motion of the disc at the centre is nil, and its motion at the circumference quite marked, and the times of identical clocks at these two points will therefore vary to the moving observer. And similarly the rate of any identical clock will vary according to the distance of its position on the surface of the disc from the centre, as the motions of all points on the disc will differ according to their distance from the centre. He then proceeds to apply identical measuring rods and finds the same continual variation. He finds that the identical measuring rods vary in length according to their position on the disc; one placed on the circumference is shorter than one placed near the centre. And the differing lengths of the rods will measure up different spaces. The observer will become utterly confused, and will finally conclude that the spaces on the disc are not the same everywhere and in all directions, but appear to vary in all directions and to be twisted, warped, and curved. Or, as we would say, the space of the disc is not straight-line homogeneous uniform Euclidean space, but curved and non-Euclidean. Taking the variations of the spaces and times on the rotating disc together, we conclude that the disc is not a Euclidean space but a non-Euclidean Space–Time continuum.

As we have seen that the phenomena of acceleration (including rotation) and gravitation are equivalent, these considerations in reference to the rotating disc apply also to every gravitational body. We know that gravitation acts at a distance from the centre of the gravitational body; in fact every such body is surrounded by a gravitational field far larger than itself. Therefore the non-Euclidean characters will also distinguish the Space–Time continuum in this field. In other words, movements and happenings in this field will not follow the law of a uniform time and a homogeneous identical space in all directions. They will take place in curves, exactly as on our rotating disc. A body falling in space through such a field will on entering it and while in it, follow not a straight path, but the curve which coincides most closely with its original straight path; a ray of light passing through the field will similarly follow the nearest curve instead of a straight line. And indeed any physical event within that field will, in so far as it is of a translational character, follow the curve on which it happens to take place. These deductions from theory have been experimentally verified in the most important particulars.

According to this theory the mysterious "attractive" power of matter, which is called gravitation, assumes quite a different character. The apparent attraction is simply due to the movements in the universe of masses charged with energy, which (except as pushes and pulls on our bodies) we ourselves do not particularly notice as we happen to partake of the same movements as the observed phenomena. This, however, does not make of gravitation an unreality, due to the subjective vagaries of the observer. Gravitation, as we have seen, now becomes the curves of the real Space–Time world; it marks the inevitable paths which all events must follow in the physical universe. So far from being subjective or merely relative to the observer, gravitation becomes the very structure of the real world and connotes the stratification which characterises the vast fields of the Space–Time continuum. Our whole conception of the universe is altered. Instead of conceiving the universe as consisting of material bodies floating in a medium of uniform homogeneous space, we now look upon the vast variable masses of "matter" associated with high-speed energies as developing huge "fields" called Space–Time, in which the curves of the lines can be calculated and the course of events happening in them can be predicted. For events follow the curves and their future course can be calculated, once their position on the curves is determined. The physics of Nature thus becomes in part an annexe of the geometry of Space–Time, and a new power is placed in the hands of man, limited only by the limitations of his mathematical insight and genius. The distance between mind and matter is immeasurably reduced, and matter appears to become plastic to the moulding power of mind. The concept of the "field" becomes all-important in science and in thought. The "field" of matter is simply the curved structure of the real Space–Time, which extends far beyond sensible matter itself. Throughout its vast "fields" the universe assumes a form not very much unlike the curved contours and unevennesses which we associate with the physical appearance of this globe. The contours of the unseen universe of our field which surrounds us follow very much the lines which meet our eye on sea and land. But these lines are not mere empty form. They are not mere curves of beauty; they are real and causal, for they determine the course of events in the universe. The peripheries of rotating bodies are such curves, the planets move round the suns in such curves; light is propagated along such curves; in fact these curves are the pathways of the physical universe which all physical events must follow. The inmost nature of the universe is active Energy or Action and involves the interplay of tremendous activities, whose result is expressed in these curves; and these curves are nothing but the actual orientation or direction of events in the Space–Time framework of the universe.

What is or would be the situation beyond the material universe and its vast fields? There we pass beyond the bounds of gravitation, where there is neither rotation nor acceleration, where "bodies" (if such astral abstractions could be imagined) persist in their state of rest or of uniform motion in a straight line according to Newton's First Law. There Space–Time, if it could be imagined to exist, would not be curved, but would be homogeneous and continuous, and would be exactly the form of empty nothingness. In fact, homogeneous Euclidean Space–Time beyond all real fields is simply a limiting conception of thought and would correspond to nothing that we have any knowledge of in our universe.

It may be interesting, in conclusion, to point out the difference between this conception of Space–Time in the Relativity Theory, and the conceptions of Space and Time formulated by Newton and Kant. For Newton both Space and Time were absolutes; that is to say, were real invariable permanent characters of things and events. They were each homogeneous and continuous and therefore adequately expressible by the geometry of Euclid. There was nothing subjective about them. For Kant, who in other respects profoundly admired the Newtonian system, the great problem of knowledge was how to determine the relative contributions made to our knowledge of the world by the subjective and objective factors respectively, and especially how much and what the mind brought into the common pool of knowledge and experience. His answer in effect was that the action of the mind was creative in experience and that it contributed to our knowledge—(*a*) the elements of Space and Time which are nothing but the mind's own sensuous forms of intuition or perception imposed on the materials of sense and experience, and (*b*) the general conceptual system of knowledge which follows from the categories of the Understanding, and (*c*) certain ultimate regulative principles of the human Reason. According to this view, therefore, Space and Time are nothing but the necessary forms of man's sensuous perception; they do not exist in external reality, but are imposed by the mind on all objects of sense. While accepting the homogeneous universal Euclidean characters which Newton ascribed to Space and Time, Kant denied that they were characters of things or events. If these characters belonged to things, Kant failed to understand how the *a priori* synthetic character of mathematical knowledge was possible, and he could only explain this fact by making the sensuous form of things a subjective contribution of the mind itself. The universal forms of Space and Time in knowledge were due, not to the things or the world to which they seemed to belong, but purely and simply to the perceiving mind which invested all things with them.

In contradistinction to both these theories, Space and Time in the theory of Relativity as conjoint co-ordinate forms belong both to the mind and to things; and the whole effort of Einstein was to separate the subjective appearance from the objective reality, to separate the relative, variable and disturbing contribution made by the observing mind from the real permanent Space–Time factor which is inherent in the physical universe. If the confirmation of theory by facts means anything it must be admitted that Einstein has been singularly successful in his analysis and evaluation of these two subjective and objective aspects of the Space–Time concept. That Space and Time were not, on the one hand, merely subjective conditions of experience as Kant held, nor, on the other, merely objectively given elements for experience as Newton held, but that they were both subjective and objective contributions to experience, might have been the discovery of a sound psychology or epistemology. But that these two factors of Space and Time have been fused into one synthesis, from which both the subjective and objective elements have been properly sorted out and isolated and valued and rigorously determined, is an achievement of the most outstanding importance not only for science but also for philosophy. It is unnecessary to point out that in the *Theory of Relativity* Space and Time are not metaphysical conceptions or forms. The infinite homogeneous Space and Time which to Kant were mental presuppositions and preconditions of all sensuous experience, and to Leibniz the pre-established permanent universal order of co-existence and succession among things, are to Einstein mere limiting pseudo-concepts, metaphysical abstractions without relation to our real experience. In our experience Space and Time are given elements just as colour, weight, and the rest. The task of science is to co-ordinate these elements in an intelligible form, and in doing so Einstein has simply explored them as if they were real physical experience like the rest. The result is the elimination of certain historic errors from the concepts of Space and Time, and the determination of their physical qualities in line with the rest of our physical experience and concepts. The Space–Time continuum, instead of being a vague, homogeneous, formless, metaphysical concept, becomes a part of physical reality, becomes the " field " of the material world, with a definite structure of its own. Structure, real differentiated structure, becomes the inmost form of the real Space–Time world. The close bearing of this on the main argument of this work will appear from the following chapters.

CHAPTER III

THE REFORMED CONCEPT OF MATTER

Summary.—Coming now from the Space–Time continuum to Matter we find the feature of structure much more conspicuous and important. The physical and chemical constitution of matter is almost entirely a matter of structure. Chemistry has traced matter to its ultimate units or atoms, and to the combination of these into molecules and substances according to structural schemes dependent on the placing and spacing of the different units in the various chemical combinations. The New Physics has carried the process a step further back by analysing atoms into their constituent electrons and protons, or units of negative and positive electricity. These units are so arranged structurally as to approximate to the form of more or less complicated solar systems, with central positive nuclei and revolving planetary electrons. The explanation of the physical and chemical properties of matter has been traced to the structural arrangements in these atomic systems and the number and changes in position of their various units. Matter is thus a structure of energy units revolving with immense velocities in Space–Time, and the various elements arise from the number and arrangement of the units in an atom; as these can be varied, the transmutation of elements becomes possible, as in Radioactivity. The peculiar serial character of the Periodic Table of the elements is thus due to the number of units and their architecture in the atoms. Atomic Weights and Atomic Numbers reflect this inner arithmetical character of the atoms.

The states of matter, as gaseous, liquid or solid, are also the results of the residual surface forces in atoms and molecules, due to their inner structure. Crystal structure is another result of inner atomic structure. But perhaps the most remarkable state of matter is a combination of the other states; this is called the colloid state, in which very minute particles of one material are dispersed throughout another. This colloid state is much more universal than commonly thought, and is specially important because the protoplasm of cells is organised in this state. The minuteness of the dispersed particles means the exposure of a maximum surface area compared to their mass. These surfaces bring into play the surface forces and show peculiar affinities or

selective properties of various kinds, and in this way certain chemical and physical reactions are facilitated at these surfaces, which make them useful in the industries as well as in the processes of organic life. In fact, some reactions in the colloid state approximate strangely to the biological type.

From the above analysis of the structural energetic constitution of matter certain conclusions can be drawn which very much narrow the gulf between matter and life.

In the first place, the old view of matter as inert and passive disappears completely. Matter like life is intensely active, indeed is Action in the technical physical sense; the difference is not between deadness and activity, but between two different kinds of activity. Through their common activities the fields of matter and life thus overlap and intermingle, and absolute separation disappears.

In the second place, Radioactivity in matter plays a somewhat analogous rôle to Organic Descent in life. Both render fluid the old fixed entities and forms; although the difference between them must not be minimised. Especially must it be recognised that Radioactivity is regressive, while Organic Descent is progressive. But this may be due to the extreme age of matter as compared with the youth of life in the history of the earth.

In the third place, the Periodic Table of Chemistry has a distinct resemblance to the Systems of Botany and Zoology; the concepts of families, genera and species could be applied to both. This shows that the characters of activity, plasticity and probably of development and genetic relationships apply to both the organic and inorganic domains.

In the fourth place, the structural character of matter indicates that it is also creative, not of its own stuff, but of the forms, arrangements and patterns which constitute all its value in the physical sphere. Just as life and mind are creative of values through the selective combinations and forms which they bring about, so matter also, instead of being dispersive, diffusive and structureless, effects through its inner activities and forces structural groupings and combinations which are valuable, not merely to humans, but in the order of the universe. But for its dynamic structural creative character matter could not have been the mother of the universe.

In the fifth place, matter in its colloid state in protoplasm discloses properties and manufactures substances, such as chlorophyll and hæmoglobin, which are necessary for the functions of life, and which go far toward bridging the great gap between the two. In its colloid state we thus see matter reaching up to the very threshold of life. A great leap may have taken place across what remained as a gap. A great "mutation" may have occurred. But as life probably began on a much lower level than the lowest forms we know to-day, the mutation may after all not have been so great. In any case a close scrutiny of the nature of matter, as revealed by the New Physics, and especially colloid chemistry, brings it very near to the concept of life.

Let us now proceed to consider how recent advances in our knowledge of the constitution of matter have emphasised the importance of this same feature of structure in the physical universe. Chemistry had for a century been exploring with great success the structure and constitution of matter, but the New Physics of Radioactivity has during the last twenty years proved a most powerful aid to Chemistry and led to discoveries which are little short of revolutionary. To Chemistry was due the analysis of matter into a certain number of elements, each with its own physical and chemical properties; the discovery of the atom as the ultimate unit of each element of matter; the union of atoms of each element into simple molecules of that element, and the union of atoms of various elements into compound molecules. The combinations of elements in definite quantitative proportions was explained as the union of one or more of the atoms of these elements with each other. From this it might be inferred that the combinations of Chemistry were like the combinations of Arithmetic, and that the whole numbers of Arithmetic might properly represent the atoms of Chemistry and their combinations into compounds. This inference has, however, only been actually verified by the recent physical discoveries. It was not only the fact of numerical or quantitative structure that was important to Chemistry; the spatial or positional structure of matter, the order of placing and spacing of the atoms in the chemical substance, the architecture of matter became almost equally important, and in many cases the properties of a substance could only be explained on the basis of its real or supposed inner structure and configuration. Thus molecules of carbon could be either coal or graphite or diamond, and this great dissimilarity in the same chemical substance was explained as the result of the difference of structure in the placing and spacing of the atoms in the carbon molecule. Sulphur and many other elements show a similar polymorphous or, as it is called, allotropic character. It was, however, when chemists had to explain the different characters of quite distinct chemical compounds, which yet had the same chemical composition, that the importance of "structure" and constitution became most highly accentuated. Such compounds are called isomers. So important is structure to matter that without it one may safely say that organic chemistry becomes unintelligible. The more complex the composition of substances (as in organic chemistry), the larger the number of permutations and combinations that are possible in the relative positions and placings of atoms or groups of atoms in the make-up of matter, the more important does the phenomenon of isomerism become, and the greater is the part played by structure and configuration in the building up of matter. The chemical formula is no longer sufficient, it is a mere abstract notational shorthand which may be thoroughly misleading in the absence of a diagrammatic representation of the constitution or structure of the compound substance. The crystal forms of solids illustrate not only the structural character of chemical substances, but also the invariable way in which the same substance follows the same pattern of structure. To Chemistry structure, or the proper representation of relative positions of atoms or their groups in the three dimensions of space, has become indispensable. And the New Physics has now gone a step further and shown that this minute structure of the chemical atom and compound is not static in space, but dynamic and intensely active in that Space–Time continuum which we have already found dominant in the relations of astronomical bodies and events. Space–Time prevails at both ends of physical infinity and everywhere between.

To Chemistry the atom was a hard indivisible unit, the constitution of which (if there was any) could not be known; nor could it explain chemical affinity or why atoms combined into molecules; nor could it explain the strange serial character of the Periodic Law in reference to the atomic weights and the properties of atoms. These triumphs were reserved for the New Physics, and they have traced structure back into the innermost recesses of the atom. The discovery of Radioactivity by Becquerel in 1896 at Paris was the first indication that the atom was not indivisible and could break up spontaneously in nature. The discovery in the previous year of the X-rays by Röntgen for the first time revealed the existence of invisible rays whose wave-length was as small as atoms, and the elaboration of the spectrum of these rays has provided an instrument of incredible power and accuracy in the investigation of the almost infinitesimally small phenomena of atomic structure. Then followed in 1899 the isolation by Sir J. J. Thomson of the ultimate unit of negative electricity in the electron; and in the following year Max Planck of Berlin University discovered what came to be known as the *quantum,* the unit of radiant action emitted by all radiant bodies or even dark bodies. The application of these new ideas and means of investigation by a number of brilliant researchers has led to the elucidation of the nature and constitution of the atom of matter in the theory which is specially associated with the names of Sir Ernest Rutherford and Professor Niels Bohr. Without entering into details which do not concern us, and simply to illustrate the element of " structure " in the atom with which we are dealing, I shall summarise the salient points in this theory. According to it, an atom is an electrical constellation somewhat like our gravitational solar system; the centre of the system being a minute very massive nucleus positively electrified, round which revolve equally minute electrons or negative particles of very small mass—so small that in the Hydrogen atom, for instance, the nucleus has 1835 times the mass of the electron. The electrons revolve at various rates in their different orbits, all of which can be measured through their X-ray spectrum; and an electron can suddenly and all at once jump from one orbit to another, increasing its orbit when it receives one or more quanta of radiation from some outside body, or decreasing its orbit and taking one nearer the central nucleus, and in the act of doing so releasing one or more quanta of radiation. It is these quanta of radiation, released when the electron jumps to a narrower orbit in the atom, that account for the light which comes from the sun and the stars, and in fact all radiant bodies; and it is the definite quanta of radiation so emitted which account for the peculiar spectrum of the elements in the spectroscope. Why atomic light should be emitted in these definite amounts or quanta is not yet known, but it is known that the quanta follow a scale somewhat similar to the notes in music, and we may therefore think of light as the music of the spheres, in which the total harmony or light effect is made up of definite discontinuous notes instead of continuous variations of light. The wonderful thing is that in regard to all these matters we have the most minute and accurate knowledge: the amount of a quantum; the mass, velocity and orbits of an electron; the mass and velocity of rotation of a nucleus, and the total sphere of an atom, with its small nucleus and electrons and vast empty spaces, comparable to the empty spaces in our solar system. The electron is by now very well known, and indeed all electric currents are nothing but streams of free electrons. But of the corresponding positive unit which is called a proton next to nothing is known, as the proton has never yet been isolated. Now the nucleus of an atom may be simple or complex; it may be a proton, as in the case of the Hydrogen atom, or it may consist of several protons, some of which, again, may be neutralised by closely associated electrons, and some remain unneutralised, so that the nucleus as a whole always remains positively electrified. In the Hydrogen atom there is one proton in the nucleus, and hence there is one electron revolving round it. In the Helium atom, again, there is a nucleus of four protons, two of which have electrons in association with them, and two not; the nucleus, therefore, has two positive units, to which correspond two electrons which revolve round the nucleus in the atom. The combination of four protons and two electrons in the Helium nucleus appears to persist in other nuclei, so that the nuclei of the other elements appear to be a combination of simple

(Hydrogen) and complex (Helium) nuclei. The number of revolving electrons in an element always corresponds to the number of unsatisfied positive units in the nucleus, which is called the atomic number of the element, and which is always an integer; and thus the atomic numbers of the elements run from 1 in the case of Hydrogen to 2 in the case of Helium, 3 in the case of Carbon, and so on to 92 in the case of Uranium, the heaviest of all the known elements. Of these 92 possible elements, 5 or 6 have not yet been isolated, although their atomic numbers and weights and positions in the Periodic Table and their approximate properties are known.[1] Atomic weights are in every case integers, the apparent exceptions being cases where we have to do with isotopes or elements of which the atoms are not all identically the same but slightly different in their electron contents. Thus the New Physics has incidentally explained the mystery of the Periodic Table.

The mystery of the atom has now largely narrowed down to the nucleus, which consists of an inner revolving system of protons of which comparatively little is known except that they rotate round their centre with an enormous velocity —probably not much less than that of light—and that the quantum law as well as the mass law of Relativity holds with regard to them. As space or volume contracts with velocity in Space–Time, the mass of the nucleus increases with high speeds out of all proportion to its size, and the positive nucleus of the atom is therefore its virtual mass, the rest of the atom being either empty space or very light insubstantial electrons. Owing to its massiveness the nucleus of protons is therefore coming to be identified with matter, as if matter were ultimately only high-speed densely massed positive electricity. The proton may thus yet prove to be the fundamental unit of matter. The significance of this view is that it reduces matter simply to a form of energy,

[1] If the claims to the recent discoveries of Hafnium, Masurium, and Rhenium are allowed only a couple of further elements await discovery.

or rather Action, and therefore still further simplifies the scheme of the universe.

There is another fact which shows the intimate relation between energy on the one hand and structure or mass on the other. The mass or atomic weight of the free Hydrogen atom has been determined as 1.0077. In the Helium nucleus, as we have seen, there are four protons or Hydrogen nuclei, but here their mass only appears as one. In other words, the free Hydrogen atoms or protons (they are practically identical as regards mass) suffer a diminution of mass when they are concentrated into the Helium nucleus, as if in this nucleus, which is itself an inner constellation system, the protons and electrons are so close as to jam each other, and therefore move more slowly and thereby decrease their mass or matter. When the Helium nucleus is again split up into Hydrogen protons, this loss of mass would be recoverable in the form of energy, which, small as it is in the Helium nucleus, must be enormous in the world, as in all matter the nuclei are composed either of Hydrogen protons or Helium protons (their compressed form) or both. Should this energy ever become economically available, the greatest potential source of energy in the universe will be opened up for the benefit of mankind.

This would involve the artificial breaking up of matter, and this is the phenomenon which we actually witness in a natural spontaneous form in Radioactivity. In Radioactivity the nuclei of the heavier elements (Uranium, Thorium, and Radium) spontaneously break up and eject Helium at an invariable slow rate, which is regular enough to be a geological clock, now being used as a measure to calculate the age of the oldest rock-formations of the earth.[1] Thus the Periodic Table shows that the expulsion of three Helium atoms from Uranium will convert it through Thorium into Radium; the expulsion of one more Helium atom will convert Radium into an

[1] The age of these oldest formations, the Algonkian mountains of Canada, has thus been calculated as 1400 million years. Thus on this basis we obtain the lowest limit for the age of the earth.

element called Radium Emanation; and so on until eight Helium atoms have been expelled, when Lead will be reached. If the process of expulsion could be continued, Mercury will next be reached, and next after that Gold. The alchemists were then not so far out when they guessed that Mercury could be transmuted into gold! Unfortunately (or rather I should say fortunately as a citizen of the greatest gold-producing country) this spontaneous break-up of matter has not yet been observed to proceed beyond lead. And the artificial break-up of matter in the laboratory has only just begun in the experiments of Sir Ernest Rutherford, who by bombarding Nitrogen gas with α particles from Radium C has succeeded in splitting the Nitrogen atom into Hydrogen atoms and a residual apparent combination of Helium nuclei which might result in Carbon according to the Periodic Table, but which is more likely to split up into Helium atoms. To what extent this artificial destruction of the elements is possible, and whether, if possible, it would be economically feasible, are questions for the future to answer.

We have seen that the positive charges of the nucleus have to be balanced by the corresponding number of negative electrons grouped in their orbits round the nucleus. On the number and grouping of these planetary electrons the external physical and chemical properties of the atom will depend. If the orbits followed impose a strain on the equilibrium of the atom, a quantum adjustment to a different orbit will be made. If the number of electrons and their orbit distributions produce complete equilibrium the atom will be very stable internally and inert or inactive externally; it will belong to one of the inert group (Helium, Argon, Neon, Krypton). On either side of this inert group of elements in the Periodic Table we find elements whose atoms have one electron too many or too few; in other words, they are not internally in equilibrium and have a negative or positive charge unsatisfied; they will therefore combine with any other element which has an opposite charge unsatisfied. At another remove from the inert elements in the Periodic Table we find elements with two negative or positive charges unsatisfied, which will again combine with another element which has two opposite charges unsatisfied. And so on to the elements which have three, four or five charges unsatisfied. In this way both chemical affinity and the valency (monovalency, divalency, etc.) of the elements are accounted for. In every case the external properties of the element are simply the expression of its internal structure and its condition of stable or unstable equilibrium in respect of its inner elements.

Not only the combination of atoms into molecules, but the formation of the most complex compounds rests on this condition of unstable equilibrium due to unsatisfied negative or positive charges in the combining elements. The compound, instead of being a single system of the solar type, is a far more complex affair, and represents the case where suns with their attendant planets again revolve round a greater central sun, or where several solar systems are linked together externally and not by a common centre. In either case the distribution and equilibrium of the moving internal electric units determine the structure of the substance as matter as well as its physical and chemical properties, while the movements of the substance as a whole and of its parts relatively to each other create the gravitational field or curved Space–Time system which forms the medium and the field of the substance. There is thus structure through and through, not only in matter or the energies which in their extreme concentration and velocity assume the massive form of matter, but also in the field which surrounds this matter.

The gaseous, liquid and solid forms of matter are also the result of this inner condition of electrical stability in the atom and molecule. If the positive and negative charges are quite equal and properly distributed the result, as we have seen, is an inert element. And this element will also be a gas, as the inner satisfaction of the charges and balance of the system will make it inactive or inert externally. All gases are states of matter where the inner balance of equilibrium in the atoms and molecules is such that there is no residual force to work externally; the atoms (in inert elements) and molecules (in others) therefore move freely and unhampered. If the inner balance of charges is not quite complete, there will be some external residual force as between the molecules, and the liquid state will result. If this inner satisfaction is lessened still further, the resultant external strain among the molecules will increase, they will attract each other still more strongly and tend to closer aggregation, and thus the solid form will appear. The negative or positive electrical condition of the gas, liquid or solid will be an index of the still unsatisfied charges residing in the substance in that state. The free and unhampered movement of atoms in an inert gaseous element and of molecules in other gases makes the question of the particular forms of such elements or gases immaterial; they have as gases no particular form. In the case of liquids, however, the resultant residual forces of the atoms and molecules will, as is the case in electrical bodies, act mostly at the surface, where the resulting force between the molecules of the surface layer, or the surface tension, as it is called, will give a particular form or shape to the liquid (as in a drop of water). The molecules inside a liquid appear to be stratified into layers loosely superimposed on each other. And in the case of solids the still larger residual force will result in arranging the molecules in a definite crystal structure on the pattern of a lattice, which is the special and specific form of solid chemical substances. Crystal structure is to solid compounds what the planetary structure is to the atom—not only a specific ordering of inner units, but the index and source of all external properties and activities. One of the most interesting recent discoveries is that in crystals there is a unit body or minute structure consisting of two or more molecules which is of atomic or radicle character in that it always acts as a unit in the upbuilding of the crystal.

Besides the gaseous, liquid, and solid phases of matter just discussed there is a fourth, to which in recent years an ever-increasing amount of attention has been and is being devoted. This is the colloid state, in which one substance is dispersed throughout another in very minute particles which are yet larger than molecules. Originally substances were divided into colloids and non-colloids; but more recently it has been shown that non-colloids (like mineral salts) can under certain conditions be reduced to the colloid state. And now this division has been abandoned, and the colloid state is recognised as a fourth form of material aggregation applying to substances generally under certain conditions. Much of the earth and the air exists in the colloid state; but the colloid state is specially important because it seems to be distinctive of all life-forms—the protoplasm of all organic cells being organised in the colloid state. The protoplasm of the cells contains solid substances in most minute form dispersed throughout its jelly-like fluid, and this colloid state seems to link the inorganic with the organic elements in the cell.

Owing to their minute size, particles in the colloid state expose the maximum surface area in comparison with their mass; and the colloid state in consequence brings into action the play of surface energies more than any other phase of matter. In all forms of aggregation the surface molecules of matter are specially orientated; the active sides of the molecules being turned inwards, and the outer surface thus consisting of the weak ends of these molecules. This orientation affects the surface tensions, chemical behaviour and energies of the surface molecules; and as colloids expose a maximum of such surfaces they show properties which are of a distinctive character. Thus at these surfaces loose unstable combinations with other special substances are easily formed, and colloids appear in consequence to have a peculiar and almost mysterious selective action for other substances. The phenomenon is called "adsorption"; the selected substances being adsorbed at the colloid surfaces. Colloids are thus used in many industrial processes to separate other substances from each other, to remove impurities, and in other ways to act as a selective separator of mixed substances. They also act as catalysts; that is to say, at their surfaces chemical actions take place and combinations are effected which otherwise would not be brought about. The colloid surface is apparently a special field of force or influence, in which other chemical or physical reactions besides selective adsorption are facilitated. The enzymes, for instance, in the protoplasm of the cell are complex chemical substances in very minute colloid form, with the surface molecules or radicles specially orientated so as to facilitate in a most marvellous way the chemical and physical processes which are necessary for the organic activities of life. But enzymes are very particular in their action, and each particular process has its own particular enzyme to bring it about. Thus enzymes transform the sugar or sugar-like contents of certain plants into alcohol; but each plant has its own enzyme, which will only operate on the material of that plant. Similarly chlorophyll is a complex chemical compound probably in colloidal dispersion in the protoplasm of leaf cells and other green cells, and its colloidal surfaces are "fields" in which the energy of sunlight can synthesise the carbon dioxide of the air into organic compounds which ultimately take the form of sugar, starch and cellulose. No laboratory has ever been able to make sunlight perform this wonder; but the colloidal surface "field" of chlorophyll can do it, and in that way provide for the sustenance of all organic life on this globe.

The marvellous behaviour of matter at its surfaces in the colloid state, and especially its mysterious "selective" power, has raised the hope that here the bridge may yet be found between the inorganic and the organic. Thus Dr. S. F. Armstrong says: "Enough has been said to show how the conception of an orientated active structure at the surface of a colloid aggregate might endow it with selective power of so fine a nature as almost to merit the description of intelligence; the further prosecution of research on these lines may well serve to bridge the gap between us and the full understanding of vital activity." [1]

It has been usual to distinguish "physical" from "chemical" combination. The New Physics has, however, made it clear that there are two types of chemical change,

[1] *Chemistry in the Twentieth Century*, p. 17.

involving two types of chemical combination and structure. The one type, which prevails among the salts, acids, and bases of inorganic chemistry, is a much looser, less rigid combination or union than the other, which prevails among the carbon compounds of organic chemistry. Thus common salt, which is a combination of sodium and chlorine, is now understood to be a more or less loose aggregation of free positive sodium atoms or ions held in equilibrium by an equal number of free negative chlorine atoms or ions; the equilibrium being fairly stable, without any actual union of the atoms such as was assumed by orthodox chemists. In organic compounds, however, the linkage of the constituent atoms is real, and the compound is not a system of free ions in equilibrium, but a real combination or fixed structure of the atoms concerned. Organic compounds thus display an advance in respect of chemical structure in substances. While in inorganic salts and similar substances the looser arrangement of the atoms or ions approximates to the type of "physical" combination, in organic substances, on the other hand, the chemical union is more thorough and intense, and leads to a closer structural character, linked together by common electrons. In this connection it is important to remember that organic compounds are the mechanisms of life: we may therefore say that as we approach life we witness a more intense element of structure in chemical compounds.

Life may have arisen in—at least it now uses as its mechanisms—chemical substances of a subtler structure than that which characterises inorganic compounds.

In connection with the explanation of the structure of the atom given above the question arises whether the structure of the atom is really as above indicated, or whether we have merely to do with a hypothesis to explain the known facts. The question is important, because it raises one instance of the general method of scientific explanation. Science deals with sensible phenomena and tries to co-ordinate them in accordance with known physical laws, and in doing so has often to interpret the sensible phenomena in a particular way in order to effect the necessary intelligible co-ordination. Thus, in the case of the atom, its existence as a fact is no longer disputed, but its structure on the model of a planetary system is no more than an inference from well-grounded sensible phenomena; and we cannot, therefore, say for certain that the above is the actual structure of the atom. The sensible phenomena are quite different from the inferred structure, but they are quite definite, and have been most minutely measured or calculated. The electron and the nucleus have not been observed, but certain light effects, which they accurately express, have been observed, and from these effects their mass and other properties have been calculated. The sensible phenomena actually observed include light effects, which are explained on the hypothesis of their transmission in particular wave-lengths; these explanations accord with the observed effects, and again form the basis of the supposed velocities, rotations and orbits of the electrons and nuclei, which are not directly observed but calculated with extraordinary minuteness and accuracy on the basis of the observed light effects. Similarly the light from the atom comes in definite observed quantities, which it has hitherto only been possible to interpret intelligently as sudden changes in the orbits of the rotating electrons. The observed phenomena are light effects of various definite qualities and quantities; the rest is theory or hypothesis, in which the elements of quality and quantity in the sensible phenomena are so minutely analysed and translated into elements of time and space as to result in the structure of the atom above given. And this structure is then tested by all the phenomena which call for explanation, and it is only finally accepted when it affords a complete explanation of them all. The electrons, the nucleus, the revolutions of the electrons round the nucleus, the sudden leaps of the electrons from one orbit to the other: these are not observed realities or sensible phenomena, but they all rest on a basis of sensible light effects, which have been most meticulously determined and tested by reference to other observed phenomena. They are therefore not sensible realities but scientific realities. They are not directly observed, but deduced from observations. They are the reflection, so to say, of the sensible phenomena in the human mind with its particular conceptual equipment. And if they are not the actual forms of nature, they are so close to them and measure and represent them so completely, that for us humans they are accepted as true and correct, that is, in experimental accord with the deliverances of our senses. Thus the apparently unrelated and unintelligible data of sense in a particular case are converted by the mind into the structure of the atom; and the atoms with all their inner units and arrangements become the conceptual or scientific entities which correspond to, reproduce, and represent the data of sense. In other words, the conceptual or scientific order arises on the basis of the sensible order, and as long as the two are in complete accord we accept them both together as the explanation of Nature. While thus according complete respect to both orders, we should always bear in mind that the sensible order is the governing factor to which the conceptual order has to conform. As long as it does so conform we accept it, not as sensible reality, but as an accurate measure and expression and completion of sensible reality. The hypothetical structure of the atom reproduces and expresses the observed facts; without such structure the observed facts are unintelligible and inexplicable. We therefore accept the structure as a true and accurate explanation of the observed facts, even though it has not been directly observed as a structure.

I conclude this chapter with a few general reflections on the nature of matter which will serve to emphasise and interpret the results of the foregoing discussion.

As indicated in the first chapter, the object of this work is to make a modest contribution towards the reform of the fundamental concepts of matter, life and mind, to assist in breaking down the apparently impassable gulfs between them, and to interpret them in such a way as to present them as successive more or less continuous forms and phases of one great process, or as related progressive elements in one total coherent reality. In pursuance of that general object my aim in this chapter is to pave the way for a reform of the concept of matter, to break down the old concept of matter as something inert, passive, barren, dead, as something with absolute contours and nothing beyond, as something presenting an impassable barrier to the kingdoms of life and mind beyond. This cannot be done by general philosophical reflections on the nature of matter as an object of thought, nor by launching a general invective against it, but only by a careful consideration of the concept of matter by the light of all the available physical knowledge. This must be my excuse for having referred to the Relativity Theory and the New Physics at some length. Certain general results emerge from our discussion which have an important bearing on the concept of matter.

In the first place, the old concept of matter as dead, passive, inert is clearly inconsistent with the recent developments of physical science. The old contradictory notion of dead matter as the vehicle and carrier of life must disappear in the light of our new knowledge. The difference between matter and life is no longer measured by the distance between deadness or absolute passivity on the one hand, and activity on the other—a distance so great as to constitute an impassable gulf in thought. The difference between them is merely a difference in the character of their activities. So far from matter being pure inertia or passivity, it is in reality a mass of seething, palpitating energies and activities. Its very dead-weight simply means the push of inner activities. Its inertia, which is apparently its most distinctive quality and has been consecrated by Newton in his First Law, has received its death-blow at the hands of Einstein. From the new point of view the inertia of matter is simply the result of the movement of Nature's internal energies; its apparent passivity is merely the other side of its real activity. Matter itself is nothing but concentrated structural energy, energy stereotyped into structure. As space contracts with velocity, so mass or the inertia of matter increases through that contraction, and both the mass of matter and its quality of inertia or passiveness are therefore mere variable dependent aspects of Nature's high-speed energies. From this point of view matter is but a form of energy, concentrated by its exceeding velocity, and structured to appear massive or substantial. The very nature of the physical universe is activity or Action. The Law of the Quantum rules all.

The repercussion of all this on the old concept of matter is deadly. Once the new point of view is thoroughly realised and assimilated into popular thought, the bugbear of matter will cease to trouble our peace. We shall no longer continue to stare at a hopeless irreconcilable contradiction in experience. With the dissolution of the old traditional concept of matter the dead-weight of its utter passivity will disappear from men's minds, and one of the greatest partition walls in knowledge will fall down. The contacts with life may still be very difficult to establish. But at any rate the impassable gulf will have disappeared. With the contours of matter razed, its field will itself point the way for the transition to the kingdom of life beyond. For the fields of matter and life will overlap, intermingle, and interpenetrate each other, the fruitful contacts will be established, and the enriched and broadened concepts of matter and life will appear as what they are—different phases in the evolution of an essential unity. The breakdown of the old concept of matter will have prepared the way for a great advance towards a new synthetic world-conception.

In the second place, another advance of the New Physics has perhaps even greater significance in effecting a *rapprochement* between matter and life. I refer to the effect of Radioactivity in destroying the permanence of the natural elements, and in explaining the genesis of the elements from one another. Radioactivity has done a somewhat similar work for matter as Darwin's theory of Organic Descent did for life two generations ago. The fixity of the types of matter has followed the fixity of the types of life to the limbo of the obsolete. Of course there are marked differences in the operation of Radioactivity and Organic Descent. In one respect Radioactivity has not proved as powerful a factor as Organic Descent, for it holds out no promise of the creation of new species or elements beyond those already known. The Periodic Table does indeed indicate the vacant places for half a dozen more guests yet to arrive. But the number of elements is definitely and narrowly limited, and we have no reason to look forward to any large increase beyond those already known. In another important respect Radioactivity differs from Organic Descent. Organic Descent professes to show how new and future species arise through variation and selection from those already existing. Radioactivity operates in the opposite direction and indicates how by elimination of certain unit constituents from a complex element there may be established a regress to another simpler known element. In the time-series Organic Descent professes to move forward, while the process of Radioactivity appears to be backward, or to retrace evolutionary steps taken in the past. In still another respect Radioactivity appears to be even more effective than Organic Descent, for it exhibits before our eyes the process of the transmutation of elements, while it is not yet definitely established that any natural species has yet been raised in the laboratory or will ever be raised in any period of time short of geological periods. In a final respect there is a striking similarity between the two factors in that they both appear to proceed by definite substantial increments or decrements in effecting transmutations. Radioactivity expels definite numbers of Helium nuclei as steps in the transmutation of elements. According to De Vries and others the process of advance from old to new species or varieties is by way of definite marked mutations, and not by the slow summation of minute discontinuous variations. And the present-day Geneticists emphasise this similarity still more by identifying all organic variations with differences of chromosomes or genes in the nuclei of varying or mutating species.

The above differences in the operation of the two factors of Radioactivity and Organic Descent arise partly no doubt from inherent differences between matter and life, but also partly from other possible differences in their circumstances of a less fundamental character. Thus life is a mere child on this globe and is yet in the heyday of its growth and increase. As yet it recognises no limit or barrier in its first flush of youth. It spends with a lavish prodigality, which is in striking contrast to the frugality and conservatism of matter, for which the laws of Conservation and of Least Action have become the last word of wisdom and the unbroken rule of action. But then matter is old, old as the beginning, so old that its wrinkles are the fundamental curves of the Space–Time universe. Life has only just begun, since the yesterday of Eozoic times, in the upbuilding of its new forms and types, and in this task it can proceed for millions of years to come. Matter, on the contrary, had completed its active race probably more than a thousand million years before life began. It had built up slowly and laboriously in nebular and solar heat, and amid conditions beyond the possibility of our knowledge or imagination, the elements from their simplest to their most complex forms, and from these again substances and compounds in rising complexity until at last protoplasm was reached. And in the favouring bosom of protoplasm life could be nurtured from its simple chemical beginnings and launched on its great career, most of which is still before it. The work of matter is done; in the great Space–Time curve it is now regressing from the more complex to the simpler types or elements, just as in organic Evolution we see a tendency for the most highly evolved and differentiated types to hark back for stability to simpler and stronger types. Radioactivity is doing to-day what Organic Descent (when it will indeed have become a descent) will do in the fullness of its time, when Life's spirit of adventure will have abated, and its aim will be safety and conservation rather than progress.

When all allowance has been made for the differences in character and operation of Radioactivity and Organic Descent, there still remains a striking and unmistakable similarity between them. And between the Periodic Table of Chemistry on the one hand and Systematic Botany and Zoology on the other there remains something very much like a family resemblance. The concepts of orders, genera and species could be applied to both; and in both cases there is a fluidity and plasticity of types which proves that, although they are in different kingdoms, yet they are in the same world of forms and geneses. One rises from a study of the Periodic Table and the New Physics with the feeling that matter can quite justifiably claim some distant relationship with life, and that life need not be quite ashamed of the rock whence she was hewn.

The intimate character of structure which the material universe and its field discloses justifies another general observation as bearing on the concept of matter. We have already seen that, properly understood, the ideas of activity, plasticity and development apply to matter in a sense not entirely dissimilar to that in which they apply to life. I am going to make a more daring suggestion and to indicate that in another even more important respect matter approximates to life. The structure of matter indicates that matter is also in a sense creative—creative, that is to say, not of its own stuff, but of the forms, arrangements and patterns which constitute all its value in the physical sphere. It is creative in a sense analogous to that in which we call life or mind creative of values. Remember that according to the new point of view we have not to judge of matter from the outside and as indifferent external spectators. We have to identify ourselves with the point of view of matter, so to speak. We have humbly to get into that closed cage; we have to take our post on that plane circular rotating disc. We have to interpret matter from the inside, from a point of view which is that of matter and not remote from and indifferent to it. And from that intimate angle matter is seen to create its structures and patterns and values very much as life or mind does on another much higher plane. Hitherto the idea of creativeness has been confined to the organic and mental aspects of the universe. Those who have called the universe creative have implicitly referred to the activity of life and mind in creating new arrangements, meanings and values. It has not been suggested that, from another point of view, the physical universe is also creative. The principles of the conservation of matter and energy have effectively barred any such idea. Novelty, originativeness and creativeness are quite inconsistent with the ordinary point of view and the popular ideas of matter as well as the more rigid mechanistic conceptions of science. Nobody, however, could have followed the above exposition of the structural character of matter without beginning to appreciate that in its evolution or creation of the forms, structures and types which characterise it from beginning to end, matter or the physical element in the universe is in a sense as truly creative as is organism or mind. The "values" of matter or the physical universe arise purely from these structures and forms. If the stuff of matter or energy or action were not definitely structural but diffuse throughout space, the entropy of the universe would be absolute, and its value for this cosmos from all points of view would be nil. The efficiency, utility and beauty, in short the values of matter, arise from the structures which are the outcome and the expression of its own inherent activities. In a very real sense the idea of value applies as truly and effectively in the domain of the physical as in that of the biological or the psychical. In both cases value is a quality of the forms and combinations which are brought about. Whether they are structures resulting from the activities of matter, or works of art or genius resulting from the activities of the mind, makes no real difference to the application of the ideas of creativeness and value in either case. Once we get rid of the notion of the world as consisting of dead matter, into which activity has been introduced from some external or alien source; once we come to look upon matter not only as active, but as self-active, as active with its own activities, as indeed nothing else but Action, our whole conception of the physical order is revolutionised, and the great barriers between the physical and the organic begin to shrink and to shrivel. Organism has by its inner activities and the influences of the environment evolved its own forms and types, and this great life-process is still going on before our eyes. As I have already suggested, a similar evolution of material structures and elemental types may have gone on during the practically infinite period of past time. And it may even be that, although new elements will no more be evolved, derived structures are still being created under suitable conditions. It is interesting to note, for instance, that under novel laboratory conditions, new substances are continually being synthetically produced. The whole romance of the Aniline dyes is a tribute to the still active "creativeness" of matter under the proper external conditions.

These considerations, in so far as they have any force, must influence our concept of matter and tend towards reducing the utter heterogeneity which marks our traditional concepts of matter and life. Of course a great difference remains between these two concepts, between the chemical compound on the one side and the organic cell on the other. It would be futile to attempt to argue away this difference. It is and remains great, but its character has been fundamentally transformed. We may put the conclusion of our discussion in this way. In organic Evolution we come across mutations—not absolute breaks with the past, but sudden long steps of advance on the past, where one species or variety leaps forward from and in advance of another. In the advance from matter to life there is a leap forward, not as between species, but as between kingdoms. And we may conclude by saying that, instead of the old impassable gulf between matter and life, between the chemical compound and the cell, we have found on closer scrutiny only a mutation—the greatest mutation of all undoubtedly in the whole range of science, but essentially nothing more than a mutation. They present the faint lineaments of a family resemblance, and as science advances and our philosophy looks more deeply, the resemblance will become clearer and more unmistakable.

Lastly, we have seen that matter in its colloidal state discloses properties and shows a behaviour which seem in some way to anticipate the processes and activities of life in its most primitive forms. In any case it begins to lay the basis of those physical and chemical reactions which are specially required for vital activities. It shows a certain power of selectiveness, which may be related to chemical affinity, but which seems to have a farther reach and to partake of the character of life. It begins to manufacture substances, such as chlorophyll and hæmoglobin, which are the special mechanisms of life, and without which life as we know it could not be. These substances are the links which connect material structure with the life structures which are to follow in the course of Evolution. They are themselves inorganic chemical substances, but they are the special instruments and the very basis of life, so to say. At their colloidal surfaces the energies of Nature are utilised to convert the inorganic material of Nature into the most complex organic substances required for the sustenance of life; and the conversion is brought about by processes which, however simple and direct apparently, have hitherto defied all attempts at imitation in our most highly equipped laboratories. We therefore see matter in this colloidal state reaching up to the very threshold of life, so to speak. A gap remains; a great leap may have taken place across it. But beyond a doubt some forms of matter in their colloidal state are fairly close to life in their properties. And it may even be that life began with much more primitive forms and structures than any of which we have knowledge to-day. Thus the gap may not have been so wide nor the leap so great as would appear to us to-day.

CHAPTER IV

THE CELL AND THE ORGANISM

Summary.—The cell is the second fundamental structure of the universe. It is possible that both before and after the origin of atoms and cells, as well as in between, other structures arose in the course of cosmic Evolution. If so, they have passed away, and we have now only these two permanent survivals which we can scrutinize for clues as to the basic character of the universe.

In the study of animate nature Evolution or Organic Descent has till recently attracted most attention. But more recently the study of the structure and functions of the cell has come rapidly to the front and now probably forms the principal centre of interest in Biology.

That all plants and animals consist of cells; that cells contain certain peculiar bodies called nuclei; that all higher organisms arise from cell-fusions in which the nuclei play a prominent part—all these facts have been discovered only in comparatively recent years; and our knowledge of cells is therefore still in its earliest stage. But Cytology is now, with much-improved methods and appliances, making rapid strides, and great discoveries are confidently looked forward to.

Besides the nucleus the cell consists principally of a rapidly circulating jelly-like fluid, enclosed in a more or less well-marked wall or membrane of a permeable character; and the fluid contains numerous exceedingly complex chemical compounds in solution or in the colloid state. The structure of a cell is therefore most complex, and in fact comparatively little is yet definitely known about it. Its functions are even more mysterious, for they include practically all the activities which we see in developed organisms—birth, growth, breathing, feeding, digestion, self-healing, reproduction, and death. Its most distinctive function is metabolism, which means that it thoroughly alters and transforms all food materials before assimilating them; that all its apparently physical activities are of this transformative metabolic character instead of being simple mechanical operations. It appears to form complex chemical compounds, called enzymes, which in their colloid state enable these distinctive radical transformations to be effected. The apparently simple physical processes such as osmosis in the

cell are really much more complicated, as they are effected through enzyme action, which is a physico-chemical mechanism distinctive of organisms. The laboratory attempts to repeat organic processes throw, therefore, little light on the exact nature of these processes.

The origin of the cell is the origin of life and is still a profound mystery. However, the reproduction of cells seems to admit us to the inner secrets of life, and the cell-divisions which precede cell-fusions in reproduction have an extraordinary semblance to electrical situations, and seem somehow to connect the electrical structure of the atom with a possible electrical origin of the cell. It is now, however, impossible to follow up this clear semblance further, as the original electrical processes have probably become overlaid with other developments which have transformed them.

Judging from the action of sunlight in the growth of plants it is not improbable that the cell of life arose when the sun was both warmer and richer in chemically active rays, and when the waters of the earth still contained many substances in solution and colloid dispersal. The adhesion of cells to each other would account for the origin and development of multi-cellular organisms; and the divisions of cells, which we now see in growth and reproduction, may have arisen originally from the breakdown of cells or groups which had become too complex to be stable.

The reproduction of plants and animals, including the reduction division of the sexual cells, follows largely the same plan; and it is therefore probable that this wonderful organic mechanism was evolved before the bifurcation of life into the plant and animal forms took place, and thus dates back to the early beginnings of life on this globe. The plant type arose from its dependence for food on air and earth, which was consistent with fixed positions; while animals, needing organic foods, required mobility, and in consequence developed a motor system with a nervous system to work it, and ultimately a brain to direct and control it.

The cell differs from the atom or molecule in its far greater complexity of structure and function, in the differentiation and specialisation of its parts and organs, and in the system of co-operation among all its parts which makes them function for the whole. This co-operative system exists not only in the single cell but among the multitudinous cells of organisms. The system of organic regulation and co-ordination among an indefinitely large number of parts which makes all the parts function together for certain purposes is a great advance on the system of physical equilibrium in atoms and compounds, and is yet quite distinct from the control which, at a later stage of Evolution, Mind comes to exercise in animals and humans. Mind as we know it must therefore not be ascribed to the cell or the lower organisms; but organic regulation seems on that lower level to be even more effective than Mind is at a later stage.

This organic regulation and synthesis of functions is seen not only in all the ordinary functions of organisms, but more especially in their capacity for self-restoration in case of mutilation. In such phenomena there seems to be something more in actual operation than merely the parts; the parts appear to play a common part and to carry out some common purpose or to act for the common well-being. They seem to respond to some central pressure. There seems to be a central regulator. We have seen a factor in matter making for structure; we now see a factor in organism making for central regulation and co-ordination of all parts. We are evidently in the presence of some inner factor in Evolution which requires identification and description. That will be attempted in the next chapter.

THE atom and the cell are the two fundamental structures in the universe that we at present know of—the atom being the unit of the world of matter, the cell the unit of the world of life. In the last chapter we considered the structure of the atom and showed how the external properties of the atom were the expression and resultant of its internal energies and their structural grouping inside the atom. We saw the atom as a little complex world of its own, underlying the outward properties as well as the field of that little world. We now pass on to consider the vastly more complicated little world of the cell and its field. In the science of life the two most significant conceptions are Evolution and the Cell, the one being the unit structure and the other the general character and trend of the activities or functions of life. Round the investigation and development of these two governing conceptions most of the progress and interest in biological science since the middle of the nineteenth century have centred; and the results hitherto obtained have been most important, and practically revolutionary for our entire world-conception. And the end is by no means in sight yet. In the first chapter we saw that there were still deep-seated misunderstandings of the nature of Evolution, and that a proper appreciation of Evolution would mean a recasting not only of biological concepts but also, and above all, of our concept of matter. Let us now turn to the cell as the other and no doubt the real governing factor of the situation of life, and see what light it throws on the nature and concept of life.

A few introductory words in regard to the history of our knowledge of the cell may not be out of place here. It will be seen that accurate information even of what little we do know about the cell is of very recent date, and that we are only at the beginning of what may yet prove a great story.

In the second half of the seventeenth century Robert Hooke observed with the crude microscope then in use that cork and other vegetable substances had a vesicular appearance and he called the apparent cavities "cells." A few years later Grew and Malpighi independently observed in plant tissues these same cavities filled with fluid and surrounded with firm walls, as well as what appeared to them to be tubes likewise with walls and filled with fluid. Towards the end of the eighteenth century Treviranus showed that these tubes were cells placed in a row and elongated in the direction of the row and with the partitions between them lost. Then followed in 1831 Robert Brown's great discovery of the nucleus in the cell in plants, and in 1838 Schleiden's elucidation of the great part which the cell with its nucleus plays in the structure of plants, and shortly afterwards the application by Schwann of the new knowledge of the cell to the structure of animals also. Both Schleiden and Schwann attached great importance to the cell wall and looked upon the cells as having crystallised out of some mother substance. The contents of the cells Schleiden called vaguely "vegetable slime"; and it was not till about the middle of the nineteenth century that the great German biologist von Mohl correctly explained the contents of both vegetable and animal cells as nucleated masses of what he called "protoplasm," which was not a chemical crystallisation from other substances, but always came into being as the offspring or daughter cells from other pre-existing cells. Hence arose the formula: *omnis cellula e cellula.* This paved the way to the correct understanding of sexual fertilisation as the union of two cells, the discovery of cell-divisions, and the part played by the nucleus with its chromosomes in these divisions, and of the origin of embryos through repeated cell-divisions. And finally a concentrated effort was made by many investigators in many countries to discover in cell divisions and fusions, and especially in the part played by the nucleus, the physical mechanism of heredity. During this century the re-discovery of Mendelism by De Vries and others, and the rise of the new science of Genetics, have led to redoubled efforts to find the explanation of the many peculiar phenomena of heredity in an analysis of the parts played by the nucleus and the other elements in the protoplasm of the cell, and at present experimental cytology is being vigorously prosecuted with numerous improved methods and appliances.

Let us now consider the structure of the cell and the part it plays in organisms. I shall only summarise its most general and outstanding features, with a view to illustrating the considerations and speculations which will be advanced later. I am trying to find concepts for vital phenomena, which will be coherent not only with those phenomena but also with wider aspects of knowledge and reality, and a reference to the scientific facts and results is therefore necessary. The time is past when a philosophy of life could be evolved without a knowledge of or reference to the scientific facts and view-points.

All plants and animals consist of cells, these cells being again usually composed of various chemical substances, some of which have a very complex constitution. The number of cells in an organism varies according to its size and complexity, some of the lowest, most primitive organisms being unicellular or composed of comparatively few cells, while at the other end the higher plants and animals may contain untold millions of cells. The human brain alone is estimated to have about 9000 million cells! These cells again are of a most diverse character, the cells which build up the various parts and organs of the body being different from each other. Thus the cells of the nerves and the bones and the muscles and indeed of all parts of the animal organism differ markedly from each other, and the number of the different kinds of cells that go to the making up of a body may be indefinitely large. All these almost innumerable cells of all kinds and degrees of differentiation and complexity are arranged in a stable, orderly structure in the plant or animal body; and this structure is not stationary but in continual movement and development. The structural order which we have seen characterising the inorganic element or compound is even more characteristic of the vastly more complex organic body with its continuous mobility and transformations.

A plant or an animal can be considered from the point of view of its structure or its functions, that is to say, the activities performed by the structure as a whole or the parts of which it is composed. Viewing it merely as a structure we see the same orderly combination and arrangement of parts as in the inorganic body, only the constituent parts and the structural arrangements are far more complex than in the inorganic body. In water, for instance, or any other chemical compound, all molecules are more or less the same, and the body consists simply of a repetition of the fundamental molecule, and the structures in which the molecules are arranged are likewise of a repetitive character; while in an organic body there may be an indefinite number and variety of cells, and the varieties of arrangements and structures according to which these cells are combined in the several parts and organs of the body may also be indefinite in number.

But the difference between inorganic and organic bodies lies not only in their structures, but even more in their functions, especially the functions of the organic cells, to which there is apparently nothing corresponding in the inorganic world. About these cells we at present know comparatively little except that their functions and activities are the basis of the functions and activities of the organisms which they compose, all being co-ordinated into a single system of a new type called "life." In the march of Evolution from the inorganic to the organic the cell is the real innovation, to which nothing corresponding in the inorganic has yet been discovered. To use a metaphor, the cell is the point where matter or energy aroused itself from its slumbers and became active from within, with activities and functions which reveal its inner character and nature, so to say. It is a new structure in which energy becomes or is transformed into a new form of activity, becomes functional, becomes in some inexplicable way endowed with a power of self-help and self-control, with special characters of selectiveness and reproduction, which constitute a unique departure in the universe.

Let us summarise briefly some of the points that are known of the structure and the functions of the cell; and as the plant cell is simpler than the animal cell let us take that as the type. It consists of chemically very complex substances called in the aggregate protoplasm, which is the physico-chemical basis of all forms of life. Comparatively little is known of its composition or chemical structure. In the plant cell (less so in the animal cell) it secretes a containing wall or membrane for itself from which the cell derives its name. Inside the wall the protoplasm appears as a jelly-like fluid and consists principally of a small nucleus, which contains certain chromatin bodies of a rich protein character, and of a larger body of cytoplasm surrounding the nucleus and reticular in structure, that is to say, consisting of a network of spaces which contain various cell-saps and solutions and even minute particles of crystals and other inorganic bodies. The whole constitutes a colloidal system, as we saw in the last chapter. The cell walls are semi-permeable, admitting of the osmosis through them of certain substances and not of others, so that suitable food and other substances can be passed through the cell walls from one cell to another. There is a constant circulation and agitation of the cell fluid, which gives it the appearance of a stream, and is much more than the usual promiscuous Brownian movement in inorganic colloidal mixtures. The movement of protoplasm, whether it is Brownian or something different, has much more of the character of definite specific direction; and this is probably only an expression of that selectiveness and directiveness which are inherent and universal characteristics of all life-forms. Although little is definitely known of the details of cell-structure, the functions it performs are so many-sided, delicate, and complex that one may safely say that the cell must have an immensely complex organisation, and that the details of its constitution may never be fully known or even adequately pictured by the human mind. It represents, at the one end of the scale of existence, a minute detailed complexity which is in some sense comparable to the wonders of the astronomical universe at the other end. And all this intricate and complex little system is maintained in a state of active, moving equilibrium; it is dynamic through and through and incessantly active in all its details, and its almost innumerable activities are finely adjusted to each other and co-ordinated into a harmonious process, which not only maintains its balanced functioning for its individual life, but increases and improves it in the duration of innumerable generations. Looking at this baffling mystery of active, continually changing and developing organisation, with its continuous delicate readjustments of innumerable moving parts into one co-ordinated forward movement, we find that ordinary physical categories of description fail us. We feel in the presence of an entirely new phenomenon, which we call life, and we may even feel tempted to go further and to say that the cell has not only life but also mind. To do so would, however, be going too far, as I shall explain later.

To appreciate the position more fully let us look at some of the functions of the cell. It is very difficult to realise it, and yet it is the fact, that the little microscopic or ultra-microscopic cell probably does all or most that the plant or animal is known to do. It literally breathes or respires; it takes in, manipulates, digests and assimilates its food; it reproduces its kind; it grows, decays and dies; it heals itself when sick and restores itself when a breakage takes place. It develops special means and mechanisms to assist it in carrying out these operations, and it co-ordinates and regulates all its manifold activities in a way which implies some wonderful central control of all these functions. Let us look at these operations with a little more detail.