This view of the purport, the meaning, and the higher function of the great and varied life-world brings us by a different route to what many of our better thinkers and teachers have tried to impress upon us—that our great cities are the "wens," the disease-products of humanity, and that until they are abolished there can be no approach to a true or rational civilisation.

This was the teaching of that true and far-seeing child of nature, William Cobbett; it is the teaching of all our greatest sanitarians; it is the teaching of Nature herself in the comparative rural and urban death-rates. Yet we have no legislator, no minister, who will determinedly set himself to put an end to the continued growth of these "wens"; which are wholly and absolutely evil. I will, therefore, take this opportunity of showing how it can be done.

There is much talk now of what will and must be the growth of London during the next twenty or fifty years; and of the necessity of bringing water from Wales to supply the increased population. But where is the necessity? Why provide for a population which need never have existed, and whose coming into existence will be an evil and of no possible use to any human beings except the landowners and speculators who will make money by the certain injury of their fellow-citizens? If the House of Commons and the London County Council are not the bond-slaves of the landowners and speculators, they have only to refuse to allow any further water-supply to be provided for London except what now exists, and London will cease to grow. Let every speculator have to provide water for and on his own estate, and the thing will be done—to the enormous benefit of humanity.

The same thing can, I presume, be done by Parliament for any other growing town or city. It can justly say: "When you have not a gallon of polluted water in your town, and when its death-rate is brought down to the average standard of rural areas, we will reconsider the question of your further growth." By that time, probably, there will be no public demand for enlarging our "wens" and a very strong and stern one for their cure or their abolition.
CHAPTER XIV

BIRDS AND INSECTS: AS PROOFS OF AN ORGANISING AND DIRECTIVE LIFE-PRINCIPLE

If we strip a bird of its feathers so that we can see its body-structure as it really is, it appears as the most ungainly and misshapen of living creatures; yet there is hardly a bird but in its natural garment is pleasing in its form and motions, while a large majority are among the most beautiful in shape and proportions, the most graceful in their activities, and often the most exquisite and fascinating of all the higher animals. The fact is, that the feathers are not merely a surface-clothing for the body and limbs, as is the hairy covering of most mammals, but in the wing and tail-feathers form an essential part of the structure of each species, without which it is not a complete individual, and could hardly maintain its existence for a single day. The whole internal structure has been gradually built up in strict relation to this covering, so that every part of the skeleton, every muscle, and the whole of the vascular system for blood-circulation and aeration have been slowly modified in such close adaptation to the whole of the plumage that a bird without its feathers is almost as helpless as a mammal which has lost its limbs, tail, and teeth.

Although birds are so highly organised as to rival mammals in intelligence, while they surpass them in activity and in their high body-temperature, yet they owe this position to an extreme retrogressive specialisation resulting in the complete loss of the teeth, while the digits of the fore limb are reduced to three, the bones of which are more or less united, and, though slightly movable, are almost entirely hidden under the skin.
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The earliest fossil bird, the Archæopteryx, had three apparently free and movable digits on the fore limbs, each ending in a distinct claw; while the two bones forming the forearm appear to have been also free and movable, so that the wing must have been much less compact and less effective for flight than in modern birds. This bird was about as large as a rook, but with a tail of twenty vertebrae, each about half an inch long and bearing a pair of feathers, each four inches in length and half an inch broad, while the wing feathers were nearly twice as long. The almost complete disappearance of the unwieldy tail, with the fusing together of the wing-bones, must have gone on continuously from that epoch. In the Cretaceous period the long tail has disappeared, and the wing-bones are much more like those of living birds; but the jaws are still toothed. In the early Tertiary deposits bird-remains are more numerous, and some of the chief orders of modern birds seem to have existed, while a little later modern families and genera appear.

The important point for our consideration here is that, in the very earliest of the birds yet discovered which still retained several reptilian characteristics, true feathers, both of wings and tail, are so clearly shown as to leave no doubt of their practical identity with those of living birds.

It is therefore evident that birds with feathers began to be developed as early as (perhaps even earlier than) the membranous-winged reptiles (Pterodactyles), and that these two groups of flying vertebrates began on two opposite principles. The birds must have started on the principle of condensation and specialisation of the fore limb exclusively for flight by means of feathers; the other by the extension of one reptilian digit to support a wing-membrane, while reserving the others probably for suspension, as in the case of the thumb of the bats.

The Marvel and Mystery of Feathers

Looking at it as a whole, the bird's wing seems to me to be, of all the mere mechanical organs of any living thing, that which most clearly implies the working out of a preconceived design in a new and apparently most complex
and difficult manner, yet so as to produce a marvellously successful result. The idea worked out was to reduce the jointed bony framework of the wings to a compact minimum of size and maximum of strength in proportion to the muscular power employed; to enlarge the breastbone so as to give room for greatly increased power of pectoral muscles; and to construct that part of the wing used in flight in such a manner as to combine great strength with extreme lightness and the most perfect flexibility. In order to produce this more perfect instrument for flight the plan of a continuous membrane, as in the flying reptiles (whose origin was probably contemporaneous with that of the earliest birds) and flying mammals, to be developed at a much later period, was rejected, and its place was taken by a series of broad overlapping oars or vanes, formed by a central rib of extreme strength, elasticity, and lightness, with a web on each side made up of myriads of parts or outgrowths so wonderfullly attached and interlocked as to form a self-supporting, highly elastic structure of almost inconceivable delicacy, very easily pierced or ruptured by the impact of solid substances, yet able to sustain almost any amount of air-pressure without injury. And even when any part of this delicate web is injured by separating the adjacent barbs from each other, they are so wonderfullly constructed that the pressure and movement of other feathers over them causes them to unite together as firmly as before; and this is done not by any process of growth, or by any adhesive exudation, but by the mechanical structure of the delicate hooked lamellæ of which they are composed.

The two illustrations here given (Figs. 108, 109) show two of the adjacent fibre-like parts (barbs) of which the web of a bird’s feather is composed, and which are most clearly shown in the wing-feathers. The slender barbs or ribs of which the web of the feather is made up can be best understood by stripping off a portion of the web and separating two of the barbs from the rest. With a good lens the structure of the barbs, with their delicate hooked barbules interlocking with the bent-out upper margins of the barbules beneath them, can be easily seen as in the view and section here given. The barbs (B, B in the figures) are
elastic, horny plates set close together on each side of the midrib of the feather, and pointing obliquely outwards; while the barbules are to the barbs what the barbs are to the feather—excessively delicate horny plates, which

Magnified View of the Barbs and Barbules forming the Web of a Bird’s Wing-Feathers (× 50)

Fig. 108.—View of a portion of two adjacent Barbs (B, B), looking from the Shaft towards the edge of the Feather.

bd, distal barbules; bp, proximal barbules.

Fig. 109.—Oblique Section through the Proximal Barbules in a plane parallel to the Distal Barbules of the upper Figure.

Letters as above; 1, 2, 3, barbicels and hamuli of the ventral side of the distal barbule; 4, barbicels of the dorsal side of the same, without hamuli.

(From Newton’s Dictionary of Birds.)

also grow obliquely outwards towards the tip of the barb. Laterally they touch each other with smooth, glossy surfaces, which are almost air-tight, yet allow of such slight motions as may be required during use, while remaining interlocked with the barbules of the adjoining barb in the manner just described. They are the essential elements of the feather, on which its value both for flight and as a protective clothing
depends. Even in the smallest wing-feathers they are probably a hundred thousand in number, since in the long wing-feather of a crane the number is stated by Dr. Hans Gadow to be more than a million.

What are termed the "contour-feathers" are those that clothe the whole body and limbs of a bird with a garment of extreme lightness which is almost completely impervious to either cold or heat. These feathers vary greatly in shape on different parts of the body, sometimes forming a dense velvety covering, as on the head and neck of many species, or developed into endless variety of ornament. They fit and overlap each other so perfectly, and entangle so much air between them, that rarely do birds suffer from cold, except when unable to obtain any shelter from violent storms or blizzards. Yet, as every single feather is movable and erectile, the whole body can be freely exposed to the air in times of oppressive heat, or to dry the feathers rapidly after bathing or after unusually heavy rain.

A great deal has been written on the mechanics of a bird's flight, as dependent on the form and curvature of the feathers and of the entire wing, the powerful muscular arrangements, and especially the perfection of the adjustment by which during the rapid down-stroke the combined feathers constitute a perfectly air-tight, exceedingly strong, yet highly elastic instrument for flight; while the moment the upward motion begins the feathers all turn upon their axes so that the air passes between them with hardly any resistance, and when they again begin the down-stroke close up automatically as air-tight as before. Thus the effective down-strokes follow each other so rapidly that, together with the support given by the hinder portion of the wings and tail, the onward motion is kept up, and the strongest flying birds exhibit hardly any undulation in the course they are pursuing. But very little is said about the minute structure of the feathers themselves, which are what renders perfect flight in almost every change of conditions a possibility and an actually achieved result.

But there is a further difference between this instrument of flight and all others in nature. It is not, except during actual growth, a part of the living organism, but a mechanical
instrument which the organism has built up, and which then ceases to form an integral portion of it—is, in fact, dead matter. Hence, in no part of the fully grown feather is there any blood circulation or muscular attachment, except as regards the base, which is firmly held by the muscles and tendons of the rudimentary hand (fore-limb) of the bird. This beautiful and delicate structure is therefore subject to wear and tear and to accidental injury, but probably more than anything else by the continuous attrition during flight of dust-laden air, which, by wearing away the more delicate parts of the barbules, renders them less able to fulfil the various purposes of flight, of body-clothing, and of concealment; as well as the preservation of all those colours and markings which are especially characteristic of each species, and generally of each sex separately, and which, having all been developed under the law of utility, are often as important as structural characters. Provision is therefore made for the annual renewal of every feather by the process called moulting. The important wing-feathers, on which the very existence of most birds depends, are discarded successively in pairs at such intervals as to allow the new growth to be well advanced before the next pair are thrown off, so that the bird never loses its power of flight, though this may be somewhat impaired during the process. The rest of the plumage is replaced somewhat more rapidly.

This regrowth every year of so complex and important a part of a bird's structure, always reproducing in every feather the size and shape characteristic of the species, while each of the often very diverse feathers grows in its right place, and reproduces the various tints and colours on certain parts of every feather which go to make up the characteristic colours, markings, or ornamental plumes of each species of bird, presents us with the most remarkable cases of heredity, and of ever-present accurately directed growth-power, to be found in the whole range of organic nature.

*The Nature of Growth*

The growth of every species of organism into a highly complex form, closely resembling one or other of its parents,
is so universal a fact that, with most people, it ceases to excite wonder or curiosity. Yet it is to this day absolutely inexplicable. No doubt an immense deal has been discovered of the mechanism of growth, but of the nature of the forces at work, or of the directive agencies that guide and regulate the forces, we have nothing but the vaguest hints and conjectures. All growth, animal or vegetable, has been long since ascertained to begin with the formation and division of cells. A cell is a minute mass of protoplasm, a substance held to be the physical basis of life. This is, chemically, the most complex substance known, for while it consists mainly of four elements—carbon, hydrogen, nitrogen, and oxygen—it is now ascertained that eight other elements are always present in cells composed of it—sulphur, phosphorus, chlorine, potassium, sodium, magnesium, calcium, and iron. Besides these, six others are occasionally found, but are not essential constituents of protoplasm. These are silicon, fluorine, bromine, iodine, aluminium, and manganese.\footnote{Verworn's General Physiology, p. 100.}

Protoplasm is so complex a substance, not only in the number of the elements it contains, but also in the mode of their chemical combination, that it is quite beyond the reach of chemical analysis. It has been divided into three groups of chemical substances—proteids, carbohydrates, and fats. The first is always present in cells, and consists of five elements—carbon, hydrogen, sulphur, nitrogen, and oxygen. The two other groups of organic bodies, carbohydrates and fats, consist of three elements only—carbon, hydrogen, and oxygen, the carbohydrates forming a large proportion of vegetable products, the fats those of animals. These also are highly complex in their chemical structure, but being products rather than the essential substance of living things, they are more amenable to chemical research, and large numbers of them, including vegetable and animal acids, glycerin, grape sugar, indigo, caffeine, and many others, have been produced in the laboratory, but always by the use of other organic products, not from the simple elements used by nature.

The atomic structure of the proteids is, however, so wonderfully complex as to be almost impossible of deter-
mination. As examples of recent results, haemoglobin, the red colouring matter of the blood, was found by Preyer in 1866 to be as follows—

\[ C_{900}H_{900}N_{154}Fe_{1}S_{3}O_{179} \]

showing a total of 1894 atoms, while Zinoffsky in 1855 found the same substance from horse's blood to be—

\[ C_{712}H_{1130}N_{211}O_{249}Fe_{1}S_{23} \]

showing a total of 2304 atoms. Considering the very small number of atoms in inorganic compounds, and in the simpler vegetable and animal products, caffeine containing only 23 \((C_7H_7(CH_3)N_4O_2)\), the complexity of the proteids will be more appreciated.

Professor Max Verworn, from whose great work on General Physiology the preceding account is taken, is very strong in his repudiation of the idea that there is such a thing as a "vital force." He maintains that all the powers of life reside in the cell, and therefore in the protoplasm of which the cell consists. But he recognises a great difference between the dead and the living cell, and admits that our knowledge of the latter is extremely imperfect. He enumerates many differences between them, and declares that "substances exist in living which are not to be found in dead cell-substance." He also recognises the constant internal motions of the living cell, the incessant waste and repair, while still preserving the highly complex cell in its integrity for indefinite periods; its resistance during life to destructive agencies, to which it is exposed the moment life ceases; but still there is no "vital force"—to postulate that would be unscientific.

Yet in his highly elaborate volume of 600 closely printed pages, dealing with every aspect of cell-structure and physiology in all kinds of organisms, he gives no clue whatever to the existence of any directive and organising powers such as are absolutely essential to preserve even the unicellular organism alive, and which become more and more necessary as we pass to the higher animals and plants, with their vast complexity of organs, reproduced in every successive genera-
tion from single cells, which go through their almost infinitely elaborate processes of cell-division and recomposition, till the whole vast complex of the organic machinery—the whole body, limbs, sense, and reproductive organs—are built up in all their perfection of structure and co-ordination of parts, such as characterises every living thing!

Let us now recur to the subject that has led to this digression—the feathers of a bird. We have seen that a full-grown wing-feather may consist of more than a million distinct parts—the barbules, which give the feather its essential character, whether as an organ of flight or a mere covering and heat-preserver of the body. But these barbules are themselves highly specialised bodies with definite forms and surface-texture, attaching each one to its next lateral barbule, and, by a kind of loose hook-and-eye formation, to those of the succeeding barb. Each of these barbules must therefore be built up of many thousands of cells (probably many millions), differing considerably in form and powers of cohesion, in order to produce the exact strength, elasticity, and continuity of the whole web.

Now each feather "grows," as we say, out of the skin, each one from a small group of cells, which must be formed and nourished by the blood, and is reproduced each year to replace that which falls away at moulting time. But the same blood supplies material for every other part of the body—builds up and renews the muscles, the bones, the viscera, the skin, the nerves, the brain. What, then, is the selective or directing power which extracts from the blood at every point where required the exact constituents to form here bone-cells, there muscle-cells, there again feather-cells, each of which possesses such totally distinct properties? And when these cells, or rather, perhaps, the complex molecules of which each kind of cell is formed, are separated at its special point, what is the constructive power which welds them together, as it were, in one place into solid bone, in another into contractile muscle, in another into the extremely light, strong, elastic material of the feather—the most unique and marvellous product of life? Yet again, what is the nature of the power which determines that every separate feather shall always "grow" into its exact shape?
For no two feathers of the twenty or more which form each wing, or those of the tail, or even of the thousands on the whole body, are exactly alike (except as regards the pairs on opposite sides of the body), and many of these are modified in the strangest way for special purposes. Again, what directive agency determines the distribution of the colouring matter (also conveyed by the blood) so that each feather shall take its exact share in the production of the whole pattern and colouring of the bird, which is immensely varied, yet always symmetrical as a whole, and has always a purpose, either of concealment, or recognition, or sexual attraction in its proper time and place?

Now, in none of the volumes on the physiology of animals that I have consulted can I find any attempt whatever to grapple with this fundamental question of the directive power that, in every case, first secretes, or as it were creates, out of the protoplasm of the blood, special molecules adapted for the production of each material—bone, muscle, nerve, skin, hair, feather, etc. etc.,—carries these molecules to the exact part of the body where and when they are required, and brings into play the complex forces that alone can build up with great rapidity so strangely complex a structure as a feather adapted for flight. Of course the difficulties of conceiving how this has been and is being done before our eyes is nearly as great in the case of any other specialised part of the animal body; but the case of the feathers of the bird is unique in many ways, and has the advantage of being wholly external, and of being familiar to every one. It is also easily accessible for examination either in the living bird or in the detached feather, which latter offers wonderful material for microscopic examination and study. To myself, not all that has been written about the properties of protoplasm or the innate forces of the cell, neither the physiological units of Herbert Spencer, the pangenesis hypothesis of Darwin, nor the continuity of the germ-plasm of Weismann, throw the least glimmer of light on this great problem. Each of them, especially the last, helps us to realise to a slight extent the nature and laws of heredity, but leaves the great problem of the nature of the forces at work in growth and reproduction as mysterious as
ever. Modern physiologists have given us a vast body of information on the structure of the cell, on the extreme complexity of the processes which take place in the fertilised ovum, and on the exact nature of the successive changes up to the stage of maturity. But of the forces at work, and of the power which guides those forces in building up the whole organ, we find no enlightenment. They will not even admit that any such constructive guidance is required!

*A Physiological Allegory*

For an imaginary parallel to this state of things, let us suppose some race of intelligent beings who have the power to visit the earth and see what is going on there. But their faculties are of such a nature that, though they have perfect perception of all inanimate matter and of plants, they are absolutely unable either to see, hear, or touch any animal living or dead. Such beings would see everywhere matter in motion, but no apparent cause of the motion. They would see dead trees on the ground, and living trees being eaten away near the base by axes or saws, which would appear to move spontaneously; they would see these trees gradually become logs by the loss of all their limbs and branches, then move about, travel along roads, float down rivers, come to curious machines by which they are split up into various shapes; then move away to where some great structure seems to be growing up, where not only wood, but brick and stone and iron and glass in an infinite variety of shapes, also move about and ultimately seem to fix themselves in certain positions. Special students among these spirit-inquirers would then devote themselves to follow back each of these separate materials—the wood, the iron, the glass, the stone, the mortar, etc.—to their separate sources; and, after years thus spent, would ultimately arrive at the great generalisation that all came primarily out of the earth. They would make themselves acquainted with all the physical and chemical forces, and would endeavour to explain all they saw by recondite actions of these forces. They would argue that what they saw was due to the forces they had traced in building up and modifying the crust of the
earth; and to those who pointed to the result of all this "motion of matter" in the finished product—the church, the mansion, the bridge, the railway, the huge steamship or cotton factory or engineering works—as positive evidence of design, of directive power, of an unseen and unknown mind or minds, they would exclaim—"You are wholly unscientific; we know the physical and chemical forces at work in this curious world, and if we study it long enough we shall find that known forces will explain it all."

If we suppose that all the smaller objects, even if of the same size as ourselves, can only be seen by microscopes, and that with improved instruments the various tools we use, as well as our articles of furniture, our food, and our table-fittings (knives and forks, dishes, glasses, etc., and even our watches, our needles and pins, etc.) become perceptible, as well as the food and drinks which are seen also to move about and disappear; and when all this is observed to recur at certain definite intervals every day, there would be great jubilation over the discovery, and it would be loudly proclaimed that with still better microscopes all would be explained in terms of matter and motion!

That seems to me very like the position of modern physiology in regard to the processes of the growth and development of living things.

_Insects and their Metamorphosis_

We now have to consider that vast assemblage of small winged organisms constituting the class Insecta, or insects, which may be briefly defined as ringed or jointed (annulose) animals, with complex mouth-organs, six legs, and one or two pairs of wings. They are more numerous in species, and perhaps also in individuals, than all other land-animals put together; and in either their larval or adult condition supply so large and important a part of the food of birds, that the existence of the latter, in the variety and abundance we now behold, may be said to depend upon the former.

The most highly developed and the most abundant of the insect tribes are those which possess a perfect metamorphosis, that is, which in their larval state are the most
completely unlike their perfect condition. They comprise the great orders Lepidoptera (butterflies and moths), Coleoptera (beetles), Hymenoptera (bees, ants, etc.), and Diptera (two-winged flies), the first and last being those which are perhaps the most important as bird-food. In all these orders the eggs produce a minute grub, maggot, or caterpillar, as they are variously called, the first having a distinct head but no legs, the second neither head nor legs, while the third have both head and legs, and are also variously coloured, and often possess spines, horns, hair-tufts, or other appendages.

Every one knows that a caterpillar is almost as different from a butterfly or moth in all its external and most of its internal characters, as it is possible for any two animals of the same class to be. The former has six short feet with claws and ten fleshy claspers; the latter, six legs, five-jointed, and with subdivided tarsi; the former has simple eyes, biting jaws, and no sign of wings; the latter, large compound eyes, a spiral suctorial mouth, and usually four large and beautifully coloured wings. Internally the whole muscular system is quite different in the two forms, as well as the digestive organs, while the reproductive parts are fully developed in the latter only. The transformation of the larva into the perfect insect through an intervening quiescent pupa or chrysalis stage, lasting from a few days to several months or even years, is substantially the same process in all the orders of the higher insects, and it is certainly one of the most marvellous in the whole organic world. The untiring researches of modern observers, aided by the most perfect microscopes and elaborate methods of preparation and observation, have revealed to us the successive stages of the entire metamorphosis, which has thus become more intelligible as to the method or succession of stages by which the transformation has been effected, though leaving the fundamental causes of the entire process as mysterious as before. Years of continuous research have been devoted to the subject, and volumes have been written upon it. One of the most recent English writers is Mr. B. Thompson Lowne, F.R.C.S., who has devoted about a quarter of a century to the study of one insect—the common blow-fly—
on the anatomy, physiology, and development of which he has published an elaborate work in two volumes dealing with every part of the subject. He considers the two-winged flies to be the highest development of the insect-type; and though they have not been so popular among entomologists as the Coleoptera and Lepidoptera, he believes them to be the most numerous in species of all the orders of insects. I will now endeavour to state in the fewest words possible the general results of his studies, as well as those of the students of the other orders mentioned, which are all in substantial agreement.

In those insects which have the least complete metamorphosis—the cockroaches—the young emerge from the egg with the same general form as the adult, but with rudimentary wings, the perfect wings being acquired after a succession of molts. These seem to be the oldest of all insects, fossilised remains of a similar type being found in the Silurian formation. Locusts and Hemiptera are a little more advanced, and are less ancient geologically. Between these and the four orders with complete metamorphosis there is a great gap, which is not yet bridged over by fossil forms. But from a minute study of the development of the egg, which has been examined almost hour by hour from the time of its fertilisation, the conclusion has been reached, that the great difference we now see between the larva and imago (or perfect insect) has been brought about by a double process, simultaneously going on, of progression and retrogression. Starting from a form somewhat resembling the cockroach, but even lower in the scale of organisation, the earlier stages of life have become more simplified, and more adapted (in the case of Lepidoptera) for converting living tissues of plants into animal protoplasm, thus laying up a store of matter and energy for the development of the perfect insect; while the latter form has become so fully developed as to be almost independent of food-supply, by being ready to carry out the functions of reproduction within a few days or even hours of its emergence from the pupa case.

At first this retrogression of the earliest stage of life towards a simple feeding machine took place at the period
of the successive moult, but it being more advantageous to have the larva stage wholly in the form best adapted for the storing up of living protoplasm, the retrogressive variations became step by step earlier, and at length occurred within the egg. At this early period certain rudiments of wings and other organs are represented by small groups of minute cells termed by Weismann *imaginal discs*, which were determined by him to be the rudiments of the perfect insect. These persist unchanged through the whole of the active larval stage; but as soon as the final rest occurs preliminary to the last moult, a most wonderful process commences. The whole of the internal organs of the larva—muscles, intestines, nerves, respiratory tubes, etc.—are gradually dissolved into a creamy pulp; and it has further been discovered that this is effected through the agency of white blood-corpuscles or phagocytes, which enter into the tissues, absorb them, and transform them into the creamy pulp referred to. This mass of nutritive pulp thenceforth serves to nourish the rapidly growing mature insect, with all its wonderful complication of organs adapted to an entirely new mode of life.

There is, I believe, nothing like this complete decomposition of one kind of animal structure and the regrowth out of this broken-down material—which has thus undergone decomposition of the cells, but not apparently of the protoplasmic molecules—to be found elsewhere in the whole course of organic evolution; and it introduced new and tremendous difficulties into any mechanical or chemical theory of growth and of hereditary transmission. We are forced to suppose that the initial stages of every part of the perfect insects in all their wonderful complexity and diversity of structure are formed in the egg, and that during the subsequent rapidly growing development of the larva they remain dormant; then, that the whole structure of the fully grown larva is resolved into its constituent molecules of living protoplasm, still without the slightest disturbance of the rudimentary germs of the perfect insect, which at a special moment begin a rapid course of developmental growth. This growth has been followed, step by step through all its complicated details, by Mr. Lowne and many
other enthusiastic workers; but I will call attention here only to the special case of the Lepidoptera, because these are far more popularly known, and the special feature which distinguishes them from most other insects is familiar to every one, and can be examined by means of a good pocket lens or microscope of moderate power. I allude, of course, to the wonderful scales which clothe the wings of most butterflies and moths, and which produce the brilliant colours and infinitely varied patterns with which they are adorned. Of course, the still more extensive order of the Coleoptera (beetles) present a similar phenomenon in the colours and markings of their wing-cases or elytra, and what is said of the one order will apply broadly to the other.

The wings of butterflies can be detected in very young caterpillars when they are only one-sixth of an inch long, as small out-foldings of the inner skin, which remain unchanged while the larva is growing; but at the chrysalis (or pupa) stage the wings expand to about sixty times their former area, and the two layers of cells composing them then become visible. At this time they are as transparent as glass; but two or three weeks before emergence of the imago they become opaque white, and a little later dull yellow or drab; twenty-four hours later the true colours begin to appear at the centre of each wing. It is during the transparent stage that the scales begin to be formed as minute bag-like sacs filled with protoplasm; the succeeding whiteness is caused by the protoplasm being withdrawn and the sacs becoming filled with air. The pupal blood then enters them, and from this the colouring matter is secreted. The scales are formed in parallel lines along ridges of the corrugated wing membrane. The more brilliant colours seem to be produced from the dull yellow pigment by chemical changes which occur within the scales. A few days before emergence the scales become fully grown, as highly complex structures formed of parallel rows of minute cells, each scale with a basal stem which enters a pocket of the skin or membrane, which pockets send out roots which seem to penetrate through the skin.  

1 This description is from Mr. A. G. Mayer's paper on the Development of the Wing Scales of Butterflies and Moths (Bull. Mus. Comp. Zool. Harv. Coll., June 1896), so far as I can give it in a very condensed abstract.
is the fact that the wonderful metallic colours of so many butterflies are not caused by pigments, but are "interference colours" produced by fine striæ on the surface of the scales. Of course, where eye-spots, fine lines, or delicate shadings adorn the wings, each scale must have its own special colour, something like each small block in a mosaic picture.

As this almost overwhelming series of changing events passes before the imagination, we see, as it were, the gradual but perfectly orderly construction of a living machine, which at first appears to exist for the sole purpose of devouring leaves and building up its own wonderful and often beautiful body, thereby changing a lower into a higher form of protoplasm. Its limbs, its motions, its senses, its internal structure, are all adapted to this one end. When fully grown it ceases to feed, prepares itself for the great change by various modes of concealment—in a cocoon, in the earth, by suspension against objects of similar colours, or which it becomes coloured to imitate—rests awhile, casts its final skin, and becomes a pupa. Then follows the great transformation scene, as in the blow-fly. All the internal organs which have so far enabled it to live and grow—in fact, the whole body it has built up, with the exception of a few microscopic groups of cells—become rapidly decomposed into its physiological elements, a structureless, creamy but still living protoplasm; and when this is completed, usually in a few days, there begins at once the building up of a new, a perfectly different, and a much more highly organised creature both externally and internally—a creature comparable in organisation with the bird itself, for which, as we have seen, it appears to exist. And, in the case of the Lepidoptera, the wings, far simpler in construction than those of the bird, but apparently quite as well adapted to its needs, develop a more or less complete covering of minute scales, whose chief or only function appears to be to paint them with all the colours and all the glittering reflections of the animal, the vegetable, and the mineral kingdoms, to an equal if not a greater extent than in the case of the birds themselves. The butterflies, or diurnal Lepidoptera alone, not only present us with a range of colour and pattern and
of metallic brilliancy fully equal (probably superior) to that of birds, but they possess also in a few cases and in distinct families, changeable opalescent hues, in which a pure crimson, or blue, or yellow pigment, as the incidence of light varies, changes into an intense luminous opalescence, sometimes resembling a brilliant phosphorescence more than any metallic or mineral lustre, as described in the next chapter.

And what renders the wealth of coloration thus produced the more remarkable is, that, unlike the feathers of birds, the special organs upon which these colours and patterns are displayed are not functionally essential to the insect’s existence. They have all the appearance of an added superstructure to the wing, because in this way a greater and more brilliant display of colour could be produced than even upon the exquisite plumage of birds. It is true that in some cases, these scales have been modified into scent-glands in the males of some butterflies, and perhaps in the females of some moths, but otherwise they are the vehicles of colour alone; and though the diversity of tint and pattern is undoubtedly useful in a variety of ways to the insects themselves, yet it is so almost wholly in relation to higher animals and not to their own kind, as I have already explained in Chapter IX. It is generally admitted that insects with compound eyes possess imperfect vision, and their actions seem to show that they take little notice of distant objects, except of lights at night, and only perceive distinctly what is a few inches or a few feet from them; while there is no proof that they recognise what we term colour unless as a greater or less amount of light.

But as regards the effect of the shading and coloration of insects upon the higher animals, who are almost always their enemies, there is ample evidence. Almost all students of the subject admit that the markings and tints of insects often resemble their environment in a remarkable manner, and that this resemblance is protective. The eye-like markings, either on the upper or under surfaces, are often seen to be imitations of the eyes of vertebrates, when the insect is at rest, and this also is protective. The brilliant metallic or phosphorescent colours on the wings of butterflies may serve to distract enemies from attacking a vital part, or,
in the smaller species may alarm the enemy by its sudden flash with change of position. But while the colours are undoubtedly useful, the mode of producing them seems unnecessarily elaborate, and adds a fresh complication and a still greater difficulty in the way of any mechanical or chemical conception of their production.
CHAPTER XV

GENERAL ADAPTATIONS OF PLANTS, ANIMALS, AND MAN

The adaptations of plants and animals, more especially as regards the cross-fertilisation of flowers by insects, forms a very important part of Darwin's work, and has been fully and popularly elaborated since by Grant Allen, Sir John Lubbock (now Lord Avebury), Hermann Müller, and many other writers. I have also myself given a general account of the whole subject both in my Tropical Nature, and my Darwinism; but as there are some points of importance which, I believe, have not yet been discussed, and as the readers of this volume may not be acquainted with the vast extent of the evidence, I will here give a short outline of the facts before showing how it bears upon the main argument of the present work.

Another reason why it is necessary to recapitulate the evidence is that those whose knowledge of this subject is derived from having read the Origin of Species only, can have no idea whatever of the vast mass of observations the author of that work had even then collected on the subject, but found it impossible to include in it. He there only made a few general, and often hypothetical, references both to the facts of insect-fertilisation, and to the purpose of cross-fertilisation. On the latter point he makes this general statement: "I have come to this conclusion (that flowers are coloured to attract insects) from finding it an invariable rule that when a flower is fertilised by the wind it never has a gaily-coloured corolla." Then a few lines farther on he adverts to beautifully coloured fruits and says: "But the beauty serves merely as a guide to birds and beasts, in order that the fruit may be devoured and the matured seed
disseminated; I infer that this is the case from having as yet found no exception to the rule that seeds are always thus disseminated when embedded within a fruit of any kind if it be coloured of any brilliant tint.”

Such general statements as those here quoted do not make much impression. The astonishment and delight of botanists and plant-lovers can, therefore, be imagined when, a few years later, by his book on the Fertilisation of Orchids by Insects, and his papers on the Different Forms of Flowers in the primrose, flax, lythrum, and some others; he opened up a vast new world of wonder and instruction which had hitherto remained almost unnoticed. These were followed up by his volumes on The Effects of Cross- and Self-Fertilisation (in 1876), and by that on Different Forms of Flowers on Plants of the same Species (in 1877), giving the result of hundreds of careful experiments made by himself during many years, serving as the justification for the few general observations as regards flowers and insects, which form the only reference to the subject in the Origin of Species.

The facts now admitted to be established by these various researches are: (1) that crosses between different individuals of the same species, either constantly or occasionally, are beneficial to the species by increasing seed-production and vigour of growth; (2) that there are innumerable adaptations in flowers to secure or facilitate this cross-fertilisation; (3) that all irregular flowers—Papilionaceæ, Labiates, Schrophulariaceæ, Orchidæ, and others—have become thus shaped to facilitate cross-fertilisation. Darwin’s general conclusion, that “nature abhors perpetual self-fertilisation,” has been much criticised, but chiefly by writers who have overlooked the term “perpetual.” He has also shown how the wonderful variety in form and structure, and the beauty or conspicuousness of the colours of flowers, can all be readily explained, on this theory, through the agency of variation and natural selection, while by no other theory is any real and effective explanation possible. But besides these there are very numerous other adaptations in flowers to secure them from injurious insects or from the effects of rain or wind.

in damaging the pollen or the stigmas, as beautifully shown
in Kerner's very interesting volume on Flowers and their
Unbidden Guests—a book that forms an admirable sequel
to Darwin's works, and is equally instructive and interesting.

Of late years writers who are very imperfectly acquainted
with the facts proclaim loudly that Darwin's views are dis-
proved, on account of some apparent exceptions to the
general conclusions he has reached. Two of these may be
here noticed as illustrative of the kind of opposition to which
Darwinism is exposed. The bee-orchis of our chalky
downs, though conspicuously coloured and with a fully-
developed labellum, like the majority of its allies which are
cross-fertilised by insects, yet fertilises itself and is never
visited by insects. This has been held to show that Darwin's
views must be erroneous, notwithstanding the enormous mass
of evidence on which they are founded. But a further
consideration of the facts shows that they are all in his
favour. In the south of Europe, while the bee-orchis is
self-fertilised as in England, several allied species are insect-
fertilised, but they rarely produce so many seed-capsules as
ours but, strange to say, an allied species (Ophrys scolopax)
is in one district fertilised by insects only, while in another
it is self-fertilised. Again, in Portugal, where many species
of Ophrys are found, very few of the flowers are fertilised
and very few ripe seed-capsules are produced. But owing
to the great number of seeds in a capsule, and their easy
dispersal by wind, the plants are abundant. These and
many other facts show that for some unknown cause, orchises
which are exclusively insect-fertilised, are liable to remain
unfertilised, and when that is the case it becomes advantageous
to the species to be able to fertilise itself, and this has
occurred, partially in many species, and completely in our
bee-orchis.

I may remark here that the name "bee-orchis" is mis-
leading, as the flower does not resemble any of our bees. But
the very closely allied "spider orchises" resemble spiders
much more closely. It occurs to me, therefore, that the
*general* resemblance to bee or spider may occasionally prevent
the flowers being eaten off by sheep or lambs, to whom
even spiders on their noses or lips would be disagreeable.
Mr. Henry O. Forbes observed, in Sumatra, that many tropical orchids with showy flowers, which were perfectly adapted for insect-fertilisation, yet produced very few seed-capsules, and in many cases none. Yet the great abundance of seeds, as fine as dust, in a single capsule, together with the long life of most orchids, is quite sufficient, in most cases, to preserve the various species in considerable abundance. When, however, there is any danger of extinction the great variability of orchids, which at first enabled them to become so highly specialised for insect-fertilisation, also enables them (in some cases) to return to self-fertilisation as in our bee-orchis. Should this continuous self-fertilisation at length lead to a weak constitution, then, occasional variations serving to attract insects by nectar or in other ways, with minute alterations of structure, may again lead to fertilisation by insects.

The other popular objection recently made to Darwin's views on the origin of the flowers is, that the colours and shapes of flowers are often such as to deter herbivorous animals from eating them, and that this is the main or the only reason why flowers are so conspicuous. The special case supposed to prove this is that some buttercups are not eaten by cattle because they are acrid or poisonous, and that the bright yellow colour is a warning of inedibility.

Even if these statements were wholly correct they would not in the least affect the general proposition that all conspicuous flowers attract insects which do actually cross-fertilise them. But, in the first place, there is much difference of opinion as to the inedibility of buttercups by cattle; and, in the second, our three most common yellow buttercups (*Ranunculus acris*, *R. repens*, and *R. bulbosus*) are so constructed that they can be cross-fertilised by a great variety of insects, and as a matter of fact are so fertilised. H. Müller grouped these three species together, as the same insects visit them all, and he found that they were attractive to no less than sixty different species, including 23 flies, 11 beetles, 24 bees, wasps, etc., and 5 butterflies.

Any readers who are not satisfied with Darwin's own statements on this subject should examine Müller's Fertilisation of Flowers (translated by D'Arcy W. Thompson), in
which details are given of the fertilisation of about 400 species of alpine plants by insects, while a General Retrospect gives a most valuable summary of the conclusions and teachings on the whole subject. As regards the general question of the uses and purposes of colour in nature, the late Grant Allen’s interesting and philosophical work on The Colour Sense should be studied. Any one who does so will be satisfied of the general truth of Darwin’s doctrines though there are a few errors in the details. As an example of the fascinating style of the book I will quote the following paragraph comparing insect-agency with that of man in modifying and beautifying the face of nature. After describing the great alterations man has made, and the large areas he has modified for his own purposes, the author thus proceeds:

“But all these alterations are mere surface scratches compared with the immense revolution wrought in the features of nature by the unobtrusive insect. Half the flora of the earth has taken the imprint of his likes and his necessities. While man has only tilled a few level plains, a few great river-valleys, a few peninsular mountain slopes, leaving the vast mass of earth untouched by his hand, the insect has spread himself over every land in a thousand shapes, and has made the whole flowering creation subservient to his daily wants. His buttercup, his dandelion, and his meadow-sweet grow thick in every English field. His thyme clothes the hill-side; his heather purples the bleak grey moorland. High up among the Alpine heights his gentian spreads itself in lakes of blue; amid the snows of the Himalayas his rhododendrons gleam with crimson light. The insect has thus turned the whole surface of the earth into a boundless flower-garden, which supplies him from year to year with pollen or honey, and itself in turn gains perpetuation by the baits it offers for his allurement.”

Although I wholly agree with my lamented friend in attributing the origin and development of flowers to the visits of insects, and the consequent advantage of rendering many species of flowers conspicuous and unlike others flowering at the same time, thus avoiding the waste and injury of the frequent crossing of distinct species, yet I do not consider that the whole of the phenomena of colour in nature is thereby explained.

In my book on Tropical Nature I devoted two chapters
to the Colours of Animals and Plants, and I opened the discussion with the following remarks, which indicate my present views on the subject. I will, therefore, give a few passages here:

"There is probably no one quality of natural objects from which we derive so much pure intellectual enjoyment as from their colours. The heavenly blue of the firmament, the glowing tints of sunset, the exquisite purity of the snowy mountains, and the endless shades of green presented by the verdure-clad surface of the earth, are a never-failing source of pleasure to all who enjoy the inestimable gift of sight. Yet these constitute, as it were, but the frame and background of a marvellous and ever-changing picture. In contrast with these broad and soothing tints, we have presented to us in the vegetable and animal worlds, an infinite variety of objects adorned with the most beautiful and the most varied hues. Flowers, insects, and birds are the organisms most generally ornamented in this way; and their symmetry of form, their variety of structure, and the lavish abundance with which they clothe and enliven the earth, cause them to be objects of universal admiration. The relation of this wealth of colour to our mental and moral nature is indisputable. The child and the savage alike admire the gay tints of flower, bird, and insect; while to many of us their contemplation brings a solace and enjoyment which is wholly beneficial. It can then hardly excite surprise that this relation was long thought to afford a sufficient explanation of the phenomena of colour in nature, and this received great support from the difficulty of conceiving any other use or meaning in the colours with which so many natural objects are adorned. Why should the homely gorse be clothed in golden raiment, and the prickly cactus be adorned with crimson bells? Why should our fields be gay with buttercups, and the heather-clad mountains be clad in purple robes? Why should every land produce its own peculiar floral gems, and the alpine rocks glow with beauty, if not for the contemplation and enjoyment of man? What could be the use to the butterfly of its gaily-painted wings, or to the humming-bird of its jewelled breast, except to add the final touches to a world-picture calculated at once to please and to refine mankind? And even now, with all our recently acquired knowledge of this subject, who shall say that these old-world views were not intrinsically and fundamentally sound; and that although we now know that colour has 'uses' in nature that we little dreamt of, yet the relations of those colours—or rather of the various rays of light—to our senses and emotions may not be another, and more important use which they subserve in the great system of the universe?"

The above passage was written more than forty years
ago, and I now feel more deeply than ever that the concluding paragraph expresses a great and fundamental truth. Although in the paragraph succeeding that which I have quoted from Grant Allen's book, he refers to my view (stated above) as being "a strangely gratuitous hypothesis," I now propose to give a few additional reasons for thinking it to be substantially correct.

The first thing to be noticed is, that the insects whose perceptions have led to the production of variously coloured flowers are so very widely removed from all the higher animals (birds and mammals) in their entire organisation that we have no right to assume in them an identity, or even a similarity, of sensation with ourselves. That they see is certain, but that their sensation of sight is the same as our own, or even at all closely resembling it, is highly improbable. Still more improbable is it that their perception of colour is the same as ours, their organ of sight and their whole nervous system being so very different, and the exact nature of their senses being unknown. Even a considerable percentage of men and women are more or less colour-blind, yet some diversity of colour is perceived in most cases. The purpose of colour in relation to insects is that they should distinguish between the colours of flowers which are otherwise alike and which have no perfume. It is not at all necessary that the colours we term blue, purple, red, yellow, etc., should be seen as we see them, or even that the sight of them should give them pleasure.

Again, the use of colour to us is by no means of the same nature as it is to insects. It gives us, no doubt, a greater facility of differentiating certain objects, but that could have been obtained in many other ways—by texture of surface, by light and shade, by diversity of form, etc., and in some cases by greater acuteness of smell; and there are very few uses of colour to us which seem to be of "survival value"—that is, in which a greater or less acuteness of the perception would make any vital difference to us or would lengthen our lives. But if so, the exquisite perception of colour we normally possess could not have been developed in our ancestors through natural selection; while what we call the "aesthetic sense," the sense of beauty, of harmony,
of indescribable charm, which nature's forms and colouring so often gives us, is still farther removed from material uses. Another consideration is, that our ancestors, the Mammalia, derived whatever colour-sense they possess almost wholly from the attractive colours of ripe fruits, hardly at all from the far more brilliant and varied colours of flowers, insects, and birds. But the colours of wild fruits, which have been almost entirely developed for the purpose of attracting birds to devour them and thus to disperse their seeds, are usually neither very brilliant nor very varied, and are by no means constant indications to us of what is edible. It might have been anticipated, therefore, that our perception of colour would have been inferior to that of birds and mammals generally, not, as is almost certainly the case, very much superior, and so bound up with some of our higher intellectual achievements, that the total absence of perception of colour would have checked, or perhaps wholly prevented, all those recent discoveries in spectroscopy which now form so powerful a means of acquiring an extended knowledge of the almost illimitable universe.

I venture to think, therefore, that we have good reason to believe that our colour-perceptions have not been developed in us solely by their survival-value in the struggle for existence; which is all we could have acquired if the views of such thinkers as Grant Allen and Professor Haeckel represent the whole truth on this subject. They seem, on the other hand, to have been given us with our higher aesthetic and moral attributes, as a part of the needful equipment of a being whose spiritual nature is being developed, not merely to satisfy material needs, but to fit him for a higher and more enduring life of continued progress.

**Colours of Fruits: a Suggestion as to Nuts**

As flowers have been developed through insects, so have edible fruits been developed and coloured so that birds may assist in the dispersal of their seeds; while inedible fruits have acquired endlessly varied hooks or sticky exudations in order that they may attach themselves to the fur of quadrupeds or the feathers of birds, and thus obtain extensive
dissemination. All this was clearly seen and briefly stated by Darwin, and has been somewhat fully developed by myself in the work already quoted: but there is one point on which I wish to make an additional suggestion.

In my Tropical Nature I referred to Grant Allen’s view (in his Physiological Aesthetics) that nuts were “not intended to be eaten”; and in my Darwinism (p. 305) I adopted this as being almost self-evident, because, though very largely edible, they are always protectively coloured, being green when unripe and brown when they fall upon the ground among the decaying foliage. Moreover, their outer-coverings are often prickly, as in the sweet-chestnut, or bitter as in the walnut, while their seed-boxes are often very hard, as in the hazel-nut, or intensely so, as in the Brazil-nut and many other tropical species.

But, on further consideration, I believe that this apparently obvious conclusion is not correct; and that nuts are, as a rule, intended to be eaten. I am not aware that this question has yet been discussed by botanists, and as it is one of much interest and exhibits one of the curious and indirect ways in which nature works for the preservation of species, both in the vegetable and animal world, I will briefly explain my views.

The first point for our consideration is, that most nuts are edible to some animals, and a large number are favourite foods even to ourselves. Then they are all produced on large trees or shrubs of considerable longevity, and the fruits (nuts, acorns, etc.) are produced in enormous quantities. If now we consider that in all countries which are undisturbed by man, the balance between forest and open country, and between one species and another, only changes very slowly as the country becomes modified by geographical or cosmical causes, we recognise that, as in the case of animals, the number of individuals of each species is approximately constant, and there is, broadly speaking, no room for another plant of any particular kind till a parent plant dies or is destroyed by fire or tempest. Imagine then the superfluity of production of seed in an oak, a beech, or a chestnut forest; or in the nut-groves that form their undergrowth in favourable situations. Countless millions of seeds are
produced annually, and it is only at long intervals of time, when any of the various causes above referred to have left a space unoccupied, that a few seeds germinate, and the best fitted survives to grow into a tree which may replace its predecessor.

But when every year ten thousand millions of seeds fall and cannot produce a tree that comes to maturity, any cause which favoured their wider dispersal would be advantageous, even though accompanied by very great destruction of seeds, and such a cause is found when they serve as food to herbivorous mammals. For most of these go in herds, such as swine, peccaries, deer, cattle, horses, etc., and when such animals are startled while feeding and scamper away, two results, useful to the species whose fruit they are feeding upon, follow. As the acorns, chestnuts, etc., usually lie thickly on the ground, some will be driven or kicked along with the herd; and this being repeated many times during a season and year after year, a number of seeds are scattered beyond the limits of the parent trees. By this process seeds will often reach places they would not attain by ordinary means, and may thus be effective in extending the range of the species. It would also often happen that seeds would be trodden into soft or wet ground and thus be actually planted by the devouring animals; and being in this case placed out of sight till the herds had left the district would have a better chance of coming to maturity.

Now one such success in a year would more than compensate to the species for millions of seeds devoured, and it would therefore be beneficial to a species to produce nuts or seeds of large size and in great quantities in order to attract numbers of mammals to feed on them. This is quite in accordance with nature’s methods in other cases, as Darwin has shown in the case of pollen. The very curious fact of the Brazil-nut having such a very hard shell to the triangular seeds and a still harder covering to the globular fruit, which falls from the very lofty trees without opening, and has to be broken open with an axe by the seed-collectors, is another example. This is said not to open naturally to let the seed escape for a year or more; and this fact, with its almost perfect globular form, would facilitate its being
scattered to a considerable distance by the feet of tapirs, deer, or peccaries, and when at last the seeds fell out, perhaps aided by the teeth or feet of these animals, some of them would almost certainly be trodden into the ground, and this would be facilitated by their sub-angular shape. If this is the mode of dispersal it has proved very successful, for the species is widely scattered in moderate-sized groves over a considerable portion of the Amazonian forests. The main facts and probabilities clearly point to the conclusion that the extensive group of nut-like fruits or seeds are intended to be eaten, not by birds while on the trees, but by ground-feeding animals—to be devoured wholesale, in order to disperse and save a few which may germinate and produce another generation of trees.

The Colours of Plants and Animals in relation to Man

The views of Haeckel and of the whole school of Monists, as well as of most of the followers of Spencer and Darwin, are strongly antagonistic to the idea that in the various groups of phenomena we have so far touched upon there has been in any real sense a preparation of the earth for man; and those who advocate such a theory are usually treated with scorn as being unscientific, or with contempt as being priest-ridden. Darwin himself was quite distressed at my rejection of his own conclusion—that even man's highest qualities and powers had been developed out of those of the lower animals by natural or sexual selection. Several critics accused me of "appealing to first causes" in order to get over difficulties; of maintaining that "our brains are made by God and our lungs by natural selection"; and that, in point of fact, "man is God's domestic animal." This was when I published my Contributions to the Theory of Natural Selection, in 1870, its last chapter on The Limits of Natural Selection as applied to Man, being the special object of animadversion, because I pointed out that some of man's physical characters and many of his mental and moral faculties could not have been produced and developed to their actual perfection by the law of natural selection alone, because they are not of survival value in the struggle for existence.
In the present work I recur to the subject after forty years of further reflection, and I now uphold the doctrine that not man alone, but the whole World of Life, in almost all its varied manifestations, leads us to the same conclusion—that to afford any rational explanation of its phenomena, we require to postulate the continuous action and guidance of higher intelligences; and further, that these have probably been working towards a single end, the development of intellectual, moral, and spiritual beings. I will now indicate briefly how the facts adduced in the present and preceding chapters tend to support this view.

Having shown in the last chapter that the phenomena of growth in the animal world, and especially as manifested in the feathers of birds and the transformations of the higher insects, are absolutely unintelligible and unthinkable in the absence of such intelligence, we must go a step farther and assume, as in the highest degree probable, a purpose which this ever-present, directing, and organising intelligence has had always in view. We cannot help seeing that we ourselves are the highest outcome of the developmental process on the earth; that at the time of our first appearance, plants and animals in many diverging lines had approached their highest development; that all or almost all of these have furnished species which seem peculiarly adapted to our purposes, whether as food, as providing materials for our clothing and our varied arts, as our humble servants and friends, or as gratifying our highest faculties by their beauty of form and colour; and as our occupation of the earth has already led to the extinction of many species, and seems likely ultimately to destroy many more except so far as we make special efforts to preserve them, we must, I think, assume that all these consequences of our development were foreseen, and that results which seem to be so carefully adapted to our wants during our growing civilisation were really prepared for us. If this be so, it follows that the much-despised anthropomorphic view of the whole development of the earth and of organic nature was, after all, the true one.

But if the view now advocated is not so wholly un-
scientific, so utterly contemptible as it has hitherto been declared to be by many of our great authorities, it is certainly advisable to show how various facts in nature bear upon it and are explained by it. I will therefore now add a few more considerations to those I have hitherto set forth.

On the question of the colour-sense I have already argued that though it may exist in birds and insects, it is hardly likely that it produces any such high aesthetic pleasure as it does in our own case. All that the evidence shows is, that they do perceive what are to us broad differences of colour, but we have no means whatever of knowing what they really perceive. It is a suggestive fact that colour-blind persons, though they do not see red and green as strongly contrasted as do those with normal vision, yet do perceive a difference between them. It is therefore quite possible that birds may see differences between one strongly marked colour and another without any sense of what we should term colour, and at all events without seeing “colours” exactly as we see them. It is now generally admitted that birds arose out of primitive reptiles, and from their very origin have been quite distinct from mammals, which latter probably diverged a little later from a different stock and in a somewhat different direction. The eyes of both were developed from the already existing reptilian eye, and their type of binocular vision may be very similar. But at that early period there were, it is believed, no coloured flowers or edible coloured fruits, and it is probable that the perception of colour arose at a much later period. It is therefore unlikely that a faculty separately developed in two such fundamentally different groups of organisms should be identical in degree or even in nature unless its use and purpose were identical. But birds are much more extensive fruit-eaters than are mammals, the latter, as we have seen, being seeders on nuts which are protectively tinted rather than on fruits, while their largely developed sense of smell would render very accurate perception of colour needless. It is suggestive that the orang-utan of Borneo feeds on the large, green, spiny Darian fruit; and I have also seen them feeding
on a green fruit which was repulsively bitter to myself. Our nearest relatives among existing quadrupeds do not therefore seem to have any need of a refined colour-sense. Why then should it have been so highly developed in us? It was one of the fundamental maxims of Darwin that natural selection could not produce absolute, but only relative perfection; and again, that no species could acquire any faculty beyond its needs.

The same arguments will apply even more strongly in the case of insects. They appear to recognise the colours, the forms, and the scents of flowers, but we can only vaguely guess at the nature and quality of their actual sensations. Their whole line of descent is so very far removed from that of the birds that it is in the highest degree improbable that there is any identity even in their lower mental faculties with those of birds. For the colour-sense is mental, not physical; it depends partly on the organ of vision, but more fundamentally on the nature of the nervous tissues which transform the effects of light-vibrations into the visual impressions which we recognise as colour, and ultimately on some purely mental faculty. But the colour-sense in insects may be quite other than the bird's or than our own, and may in most cases be combined with scent, and often with form to produce the recognition of certain objects, which is all they require.

Yet insects, birds, and the flowers and fruits which attract them, all exhibit to our vision nearly the same range of the colour-scheme, and a very similar intensity, brilliancy, and purity of colour in particular cases; which is highly remarkable if their respective needs were the only efficient causes in the production of these colours. Looking first at flowers, how very common and conspicuous are those of a yellow colour, yet far beyond the average are the rich orange petals of the Escholtzia and the glistening splendour of some of our buttercups; reds and purples are innumerable, yet in the Lobelia fulgens and some other flowers we reach an intensity of hue which seem to us unsurpassably beautiful; blues of the type of the campanulas or the various blue liliaceæ are all in their way charming, but in the blue salvia (Salvia patens) the spring
gentian (*Gentiana verna*), and a few others, we perceive a depth
and a purity of hue which seem to have reached the limits
of the possible. We may surely ask ourselves whether
these exquisite refinements of mere colour as well as the
infinity of graceful forms and the indescribable delicacies
of texture and of grouping, are all strictly utilitarian in
regard to insect-visitors and to ourselves. To them the
one thing needful seems to be a sufficient amount of
difference of any kind to enable them to distinguish among
species which grow in the same locality and flower at the
same time.

*Special Cases of Bird Coloration*

Coming now to birds, we find the colours with which
they are decorated to be fully equal in variety and purity of
tint to those of flowers, but extending still farther in modific-
tations of texture, and in occasionally rivalling minerals or
gems in the brilliancy of their metallic lustre. The exquisite
blues and vinous purples, reds and yellows of the chattering
and manakins, the glorious metallic sheen of the trogons, of
many of the humming-birds, and of the long-tailed paradise-
bird; the glistening cinnabar-red of the king-bird of paradise,
appearing as if formed of spun-glass; the silky orange of the
cock-of-the-rock and the exquisite green of the Malayan
crested gaper, are only a few out of thousands of the extreme
refinements of colour with which birds are adorned.

Add to these the marvellous ornaments with which the
males are so frequently decorated, the crests varying from
the feathery dome of the umbrella-bird, to the large richly
coloured crest of the royal fly-catcher of Brazil, and the
marvellous blue plumes from the head of the fern-bearing
bird of paradise (*Pteridophora Alberti*), with a thousand others
hardly inferior, and we shall more than ever feel the want of
some general and fundamental cause of so much beauty.

All this wealth of colour, delicacy of texture and exuber-
ance of ornament, has been explained hitherto as being utili-
tarian in two ways only: (1) that they are recognition-marks
of use to each species, more especially during its differentiation
as a species; and (2) as influencing female choice of the
most ornamental males, and therefore of use to each species
in the struggle for existence. The former I have, I think, proved to be a true cause; the latter I reject for reasons given in my Darwinism. I there give an alternative solution of the problem which I still think to be fundamentally correct and which has been arrived at by Weismann and others from theoretical considerations to which I may advert later on.

Coloration of Insects

Passing now to the order of insects which perhaps exhibits the greatest range of colour-display in the whole of the organic world—especially in the order Lepidoptera, we find the difficulties in the way of a purely utilitarian solution still greater. Any one who is acquainted with this order of insects in its fullest development in the equatorial zone of the great continents, will recognise how impossible it is to give any adequate conception of its wealth of colour-decoration by a mere verbal description. Yet the attempt must be made in order to complete the argument I am founding upon a consideration of the whole of the facts of organic coloration.

Even in the temperate zones we have a rich display of colour and marking in our exquisite little blues, our silver-spotted fritillaries, our red-admiral, our peacock, and our orange-tip butterflies, and on the Continent, the two swallow-tails, the Apollo butterflies, the fine Chaaxes Jason, and many others. But these are absolutely as nothing compared to the wealth of colour displayed in the eastern and western tropics, where the average size is from two to three times ours, and the numbers, both in species and individuals at least ten times as great. Not only is there every tint of red, yellow, blue and green, on ground-colours of black or white and various shades of brown or buff, but we find the most vivid metallic blues or silky yellows covering a large portion of the wing-surface or displayed in a variety of patterns that is almost bewildering in its diversity and beauty.

As a few examples, the Callithea sapphira of the Amazon is of a soft, celestial blue that the finest lobelia or gentian cannot surpass. The grand Ornithoptera Amphrisius and its
allies have the hind wings of an intense yellow with a silky lustre, while *O. Prianius* and many allied species are richly adorned with metallic green, deep orange, or violet-blue. *Papilio Ulysses* of Amboyna equals in size and colour the splendid blue morphos of South America; while these latter not only present us with every shade of blue on insects of the largest size, but in *Morpho cypris*, and several allied species, exhibit an intensity of colour and of metallic sheen that is equal to the highest efforts of nature in this direction on the caps or the gorgets of humming-birds, on the glittering shields of the Epimachidae of New Guinea, or on such precious gems as the emerald, the sapphire, the ruby, or the opal.

The exquisite combinations of brilliant colour and endless variety of pattern to be found among the small Lycaenidae and Erycinidae of both hemispheres must be passed over; as well as the somewhat larger Catagrammas whose diversified upper and under sides are a constant delight; while the vast groups of the Heliconidae and Danaidae, inedible to most birds and lizards, are often rendered conspicuous by bold contrasts of the purest white, yellow, or red, on a blue-black ground.

*Some Extremes of Insect Coloration*

There are some examples of tropical butterflies in which nature may be said to have surpassed herself, and to have added a final touch to all the beauty of colour so lavishly displayed elsewhere. These are to be found in a few species only in both hemispheres, and are therefore the more remarkable. The largest butterfly to exhibit this form of colour is the *Ornithoptera magellanus*, from the Philippines, whose golden-yellow wings, when viewed obliquely acquire the changing hues of polished opals, quite distinct from any of its numerous allies which possess the same colour but with what may be termed a silky gloss. In the same part of the world (the Bismarck Archipelago) there is a day-flying moth (*Burgena chalybeata*), one of the Agaristidae, whose wings change from black to blue and a fiery opalescent red. In tropical America there is a group of butterflies of the genus Papilio, which are very abundant both in species and individuals, whose velvet-black wings have a few bands
or spots of blue or green on the upper pair, while the lower have a band of spots near the posterior margin of a brilliant crimson. Among perhaps a hundred species with this general style of coloration, there are a few (perhaps a dozen) in which the red of the hind wings, when viewed very obliquely from behind, changes into opalescent and then into a curious bluish phosphorescence of intense brilliancy.

I am informed by Dr. K. Jordan (of the Tring Zoological Museum) that in these insects the black ground of the wing changes also into metallic blue, which seems to spread over the red and to aid in the production of the phosphorescent effect. This is so marked that Mr. Bates gave to one of the new species he described, the name of *Papilio phosphorus*. One of the small Eryciniidæ (*Euselasia praecala*) found in the Upper Amazon valley, is of a yellow buff colour, with a wonderful opalescent reflection which is said to be the most intense and brilliant in the whole order of Lepidoptera and probably the most brilliant colour known.

All metallic reflections in the animal world are what are called interference-colours, and are produced by excessively fine lines or rugosities on polished surfaces, or by equally thin transparent laminae. It is probable that in the remarkable changing glows now described, both these causes may come into play, producing, when viewed at certain angles, an intensity of hue resembling those of the finest opals, or sometimes imitating the most brilliant glow-worms or fire-flies by means of reflected light. It seems probable that these rare hues may be of a protective nature, since a pursuing bird might be startled by the sudden flashing out of so brilliant a light and thus allow the insect to escape; but that does not render it more likely that the infinitely complex arrangements by which such structures are produced and transmitted unfailingly to offspring, should have been brought about for this purpose alone, when thousands of other species arrive at the same end by simpler means.

Now if there was a difficulty in the view that all the wealth of colour and beauty in birds has been developed solely on account of its utility to themselves, that difficulty becomes greatly increased in the case of these insects. The described butterflies alone are already far more numerous
than birds, and there are certainly more to be discovered of
the former than of the latter. Bates well observed that the
expanded wings of butterflies seemed to have been used by
Nature to write thereon the story of the origin of species.
To this we may, I think, add that she has also used them,
like the pages of some old illuminated missal, to exhibit all
her powers in the production, on a miniature scale, of the
utmost possibilities of colour-decoration, of colour-variety,
and of colour-beauty; and has done this by a method which
appears to us unnecessarily complex and supremely difficult,
in order perhaps to lead us to recognise some guiding power,
some supreme mind, directing and organising the blind
forces of nature in the production of this marvellous
development of life and loveliness.

It must always be remembered that what is produced on
the flower, the insect, or the bird, is not colour, but a surface
so constituted in its chemical nature or mechanical texture
as to reflect light of certain wave-lengths while absorbing or
neutralising all others. Colour is the effect produced on
our consciousness by light of these special wave-lengths.
To claim that the lower animals, especially the mammals,
perceive all the shades and intensities, the contrasts and the
harmonies of colours as we perceive them, and that they
are affected as we are with their unequalled beauty is a
wholly unjustified hypothesis. The evidence that such
sensations of colour exist in their case is wholly wanting.
All we really know is, that they appear to perceive differences
where we perceive colour, but it has not been proved how
far this perception extends, since in the most intelligent of
these, dogs and horses, the sense of smell is so highly
developed as for many purposes to take the place of vision.

It is a very suggestive fact that the theory of the develop-
ment of the colour-sense through its utility, receives least
support from those animals which are nearest to us, and
from which we have been corporeally developed—the
mammals; rather more support from those which have had
a widely different origin—the birds; and apparently most
from those farthest removed from us—the insects, for whom
it has been claimed that we owe them all the floral beauty
of the vegetable kingdom, through their refined perception of
differences of form and colour. This seems to me to be a kind of *reductio ad absurdum*, and to constitute a disproof of that whole argument as a final cause of the colour-sense. On the other hand, it gives the strongest support to the view that the refined perception and enjoyment of colour *we* possess has not, and could not have been developed in us by its survival-value in our early struggle for existence, but that these faculties are, as Huxley remarked in regard to his enjoyment of scenery and of music, "gratuitous gifts," and as such are powerful arguments for "a benevolent Author of the Universe." ¹

CHAPTER XVI

THE VEGETABLE KINGDOM IN ITS SPECIAL RELATION TO MAN

It is obvious that, as animal life has from its very origin depended upon and been developed in relation to plant life, the entire organisation of the former would, by the continuous action of variation and survival of the fittest, become so harmoniously adapted to the latter, that it would inevitably have every appearance of the plant having been formed and preordained for the express purpose of sustaining and benefiting the animal. This harmonious co-adaptation cannot therefore be adduced as, of itself, being any proof of design, but neither is it any proof against it. So with man himself, so far as his mere animal wants are concerned, his dependence on plants, either directly or indirectly, for his entire sustenance by food, and therefore for his very life, affords no grounds for supposing that either of the two kingdoms came into existence in order to render the earth a possible dwelling-place for him. But as regards those special qualities in which he rises so far above all other animals, and especially those on which the higher races found their claim to be "civilised," there seem to be ample grounds for such an argument, as I hope to be able to show.

Taking first the innumerable different kinds of wood, whose qualities of strength, lightness, ease of cutting and planing, smoothness of surface, beauty, and durability, are so exactly suited to the needs of civilised man that it is almost doubtful if he could have reached civilisation without them. The considerable range in their hardness, in their durability when exposed to the action of water or of the soil, in their weight and in their elasticity, render them
serviceable to him in a thousand ways which are totally removed from any use made of them by the lower animals.

Few of these qualities seem essential to themselves as vegetable growths. They might have been much smaller, which would have greatly reduced their uses; or so much harder as to be almost unworkable; or so liable to fracture as to be dangerous; or subject to rapid decay by the action of air, or of water, or of sunshine, so as to be suitable for temporary purposes only. With any of these defects they might have served the purposes of the animal world quite as well as they do now; and their actual properties, all varying about a mean value, which serves the infinitely varied purposes to which we daily and hourly apply them, may certainly be adduced as an indication that they were endowed with such properties in view of the coming race which could alone utilise them, and to whose needs they minister in such an infinite variety of ways.

As one example of what such a different quality of timber as above indicated might mean let us remember that from before the dawn of history down to about the middle of the last century every ship in the world was built of wood. Had no wood existed suitable for sea-going vessels, the whole course of history, and perhaps of civilisation, would have been different. Without ships the Mediterranean would have been almost as impassable as was the Atlantic. America would be still unknown, as well as Australia and possibly South Africa; and the whole world would be for us smaller than in the days before Columbus. And all this might have happened had the nature of vegetable growth, while differing little in external form and equally well adapted for unintelligent animal life, not possessed those special qualities which fitted it for ministering to the varied needs of intellectual, inventive, and ever advancing man.

But, even with the whole vegetable world in its outward aspect and mechanical properties exactly as it is now, there are still a thousand ways in which it ministers to the needs of our ever-growing civilisation, which have little or no relation to the animal world which grew up in dependence on it. Leaving out of consideration the vast number of fruits, and cereals, and vegetables which supply him with
varieties of food, which may be of more importance to man in the future than they are now, let us take first the innumerable drugs which enable him to avoid some of the evils brought upon himself by his ignorance, his dissipations, or his willful neglect. The pharmacopoeias of every country and every age are crowded with the names of herbs and simples used with more or less success as remedies for the various diseases man was supposed to be heir to, and if many of these were altogether imaginary, very large numbers still hold their place as of real and often of inestimable value. To name only a few of the best known, we could hardly dispense with such common drugs as aloe, arnica, belladonna, calendula, cascara, gentian, jalap, ipecacuanha, nux vomica, opium, podophyllin, quinine, rhubarb, sarsaparilla, and a host of others.

To these we may add the various "balsams" so much used in ancient surgery—balm of Gilead, friar's balsam, balsam of Peru, benzoin, camphor, etc.

Then there are the ordinary resins and gums so useful in the arts—copal, dammar, mastic, kauri, gum-arabic, tragacanth, asafoetida, gamboge, etc.

Among the numerous dyes are arnotto, Brazil-wood, logwood, camwood, fustic, indigo, madder, turmeric, and woad.

Vegetable oils, used for cooking, lighting, perfumes, medicines, etc., are very numerous. Such are candle-nut, castor oil, coco-nut oil, colza oil, olive oil, cotton-seed, linseed, and rape-seed oils, cajeput oil, and innumerable others in every part of the world, known or yet to be discovered.

Perfumes and spices are also extremely abundant, such as caraways, cinnamon, cloves, mace, nutmegs, patchouli, peppermint, orris-root, sandalwood, sassafras, tonquin-beans, vanilla, and the many essential oils from highly perfumed fruits and flowers.

Of foods and drinks not used by the lower animals, are arrowroot, tapioca, sago, sugar, wine, beer, tea, coffee, and cocoa, the last six, when used in moderation, being among the choicest gifts of nature.

There remain a number of vegetable products invaluable for arts and manufactures—cotton and flax for clothing,
hemp for cordage, rattan and bamboo for tropical furniture, boxwood for wood-engraving, gutta-percha for machine belts and a great variety of economic uses, and lastly india-rubber, one of the greatest essentials of our chemical and mechanical arts, without which neither the electric telegraph, the bicycle, nor the motor-car could have reached their present stage of perfection, while no doubt many equally important uses remain to be discovered.

It may be objected that so many of these varied products have been shown to be of use to the plants themselves as protections against injurious insects or from being devoured in their young state by herbivorous mammals, that their utility to man is only an accidental result, and of no real significance. But this objection can hardly be a valid one when we consider the enormous number of beneficial drugs, highly agreeable scents and spices, useful oils, and delicious foods or drinks that are among the commonest of vegetable by-products. There seems no direct connection between juices or volatile oils which are distasteful to insects, and drugs which are valuable medicines in the case of human diseases. The leaves or stems of seedling plants needed only a temporary protection, while the juices which effect it not only increase in quantity during the whole life of the plant, but are transformed into such as are of unmistakable value to civilised man. It is almost inconceivable that the exquisite fragrance developed only by roasting the seed of the coffee shrub should be a chance result of the nature of the juices essential for the well-being of this particular species; or that the strange mechanical properties of india-rubber should be developed in a few only of the thousands of species having a protective milky sap.

*Indications of a Directive Mind*

Before leaving this branch of my subject, I must say a few words on the indications afforded by these varied products of plant-life, of the absolute necessity of a directive power and a mind of the highest organising intelligence for their production. Quite as clearly, perhaps even more clearly than for the development of the bird’s feather or the
insect's transformations, does the agency of such a supreme mind seem to be essential.

Let us consider first the extreme simplicity and uniformity of the conditions under which such marvellously diverse results are produced. A very large proportion of the vegetable products useful to man are obtained from the tropical forests, where the temperature is more uniform, the moisture more constant, and the trees less exposed to wind than anywhere else in the world. The whole organisation of the higher plants is, as compared with that of animals, extremely simple, and they are wonderfully similar in structure to each other, even in distinct genera and natural orders. The roots, the wood, the bark, the leaves, are substantially of the same type in thousands of species. All alike build up their structures out of the same elements, which they obtain from the water and the few substances it dissolves out of the soil; from the air and the carbonic acid and aqueous vapour it contains. Yet under these conditions what a seemingly impossible variety of products arise.

When the modern chemist attempts to bring about the same results as are effected by nature in the plant, he has to employ all the resources of his art. He has to apply great heat or great cold; he uses gas or electric fires and crucibles; he requires retorts for distillation, and air-tight vessels and tubes for the action of his reagents, or to preserve his liquid or gaseous products; but with all his work, carried out for more than a century by thousands of earnest students, he has only been able to reproduce in his laboratory a limited number of organic substances, while the more important of the constituents of living organisms remain far beyond his powers of synthesis.

The conditions under which nature works in the vegetable kingdom are the very opposite of all this. Starting from the ripened seed, consisting essentially of a single fertilised cell and a surrounding mass of nutritive material, a root is sent out into the soil and a shoot into the atmosphere, from which the whole plant with all its tissues and vessels are formed, enabling it to rise up into the air so as to obtain exposure to light, to lift up tons weight of material in the form of limbs, branches, and foliage of forest trees, often to
a hundred feet or more above the surface, by means of forces whose nature and exact mode of operation is still a mystery; while by means of the very same tissues and vessels those recondite chemical processes are being carried on which result in the infinitely varied products already very briefly referred to.

The living plant not only builds up its own marvellous structure out of a few elements supplied to it either in a gaseous or liquid state, but it also manufactures all the appliances—cells, vessels, fibres, etc.—needful for its complex laboratory-work in producing the innumerable by-products possessing so many diverse properties useful to man, but which were mostly unneeded by the remainder of the animal world.

Usually botanists as well as zoologists are satisfied to describe the minute structure of the organs of plants or animals, and to trace out as far as possible the changes that occur during growth, without any reference to the unknown and unintelligible forces at work. As Weismann has stated, the fundamental question—"the causes and mechanism by which it comes about that they (the gemmules or physiological units) are always in the right place and develop into cells at the right time"—is rarely or never touched upon. Modern theories of heredity take for granted the essential phenomena of life—nutrition, assimilation, and growth.

I find, however, that Professor Anton Kerner, in his great work on The Natural History of Plants, fully recognises this great fundamental problem, and even recurs to the much derided "vital force" as the only help to a solution of it. He says:

"The phenomena observed in living protoplasm, as it grows and takes definite form, cannot in their entirety be explained by the assumption of a specific constitution of protoplasm for every distinct kind of plant, though this hypothesis may prove useful when we enquire into the origin of new species."

Again he says:

"In former times a special force was adduced, the force of life. More recently, when many phenomena of plant-life had been success-

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1 The Germ-Plasm, p. 4.
fully reduced to simple chemical and mechanical processes, this vital force was derided and effaced from the list of natural agencies. But by what name shall we now designate that force in nature which is liable to perish whilst the protoplasm suffers no physical alteration and in the absence of any extrinsic cause; and which yet, so long as it is not extinct, causes the protoplasm to move, to enclose itself, to assimilate certain kinds of fresh matter coming within the sphere of its activity and to reject others, and which when in full action makes the protoplasm adapt its movements under external stimulation to existing conditions in the manner which is most expedient?

"This force in nature is not electricity nor magnetism; it is not identical with any other natural force; for it manifests a series of characteristic effects which differ from all other forms of energy. Therefore, I do not hesitate again to designate as 'vital force' this natural agency, not to be identified with any other, whose immediate instrument is the protoplasm, and whose peculiar effects we call life. The atoms and molecules of protoplasm only fulfil the functions which constitute life so long as they are swayed by this vital force. If its dominion ceases they yield to the operation of other forces. The recognition of a special natural force of this kind is not inconsistent with the fact that living bodies may at the same time be subject to other natural forces" (vol. i. p. 52).

And again, after discussing the various effects produced by that wonderful substance chlorophyll, he says:

"We see the effective apparatus, we recognise the food-gases and food-salts collected for working up, we know that the sun's rays act as the motive force, and we also identify the products which appear completed in the chlorophyll granules. By careful comparison of various cells containing chlorophyll, having found by experience that under certain external conditions the whole apparatus becomes disintegrated and destroyed, it is indeed permissible to hazard a conclusion about the propelling forces. But what is altogether puzzling is, how the active forces work, how the sun's rays are able to bring it about that the atoms of the raw material abandon their previous grouping, become displaced, intermix one with another, and shortly reappear in stable combinations under a wholly different arrangement. It is the more difficult to gain a clear idea of these processes, because it is not a question of that displacement of the atoms called decomposition, but of that process which is known as combination or synthesis" (vol. i. p. 377).

I have made these quotations from one of the greatest German writers on botany in order to show that a professor of the science, with a most extensive knowledge of every aspect of plant-life, supports the conclusion I had already
reached from a consideration of the broader phenomena of animal life and organisation. In the last paragraph quoted he even shows that phenomena occur during the growth of the plant, which are, with those of the metamorphosis of the higher insects, requiring the agency of some directive power for an adequate rational explanation of them.

I am quite aware that this view, of the earth and organic nature having been designed for the development of the human race; and further, that it has been so designed that in the course of its entire evolution its detailed features and organisation have been such as not only to serve the purposes of the whole series of living things but also in their final outcome, to serve the purposes and add to the enjoyments of man, is highly distasteful to a large proportion of scientific workers. They think, and some of them say, that it is a return to the old superstition of special creation, that science has nothing to do with first causes, whether in the form of spiritual or divine agencies, and that once we begin to call in the aid of such non-natural and altogether hypothetical powers we may as well give up science altogether. In my early life I should have adopted these same arguments as entirely valid, and should perhaps have thought of the advocates of my present views with the same contemptuous pity which they now bestow upon myself. But, I venture to urge, the cases are not fairly comparable, because both their point of view and my own are very different from those of our fellow-workers of the first half of the nineteenth century.

Let me recall the conditions that prevailed then as compared with those of to-day. Then the opposition was between science and religion, or, perhaps more correctly, between the enthusiastic students of the facts and theories of physical science in the full tide of its efforts to penetrate the inmost secrets of nature, and the more or less ignorant adherents of dogmatic theology. Now, the case is wholly different. Speaking for myself I claim to be as wholeheartedly devoted to modern science as any of my critics.
"I am as fully imbued with the teachings of evolution as they can be; and I still uphold, as I have always done, the essential teachings of Darwinism.

Darwin always admitted, and even urged, that "Natural Selection has been the most important but not the exclusive means of modification." He always adduced the "laws of Growth with Reproduction," and of "Inheritance with Variability," as being fundamental facts of nature, without which Natural Selection would be powerless or even non-existent, and which, then as now, were and are wholly beyond explanation or even comprehension. He elaborated his theory of Pangenesis for the purpose of rendering the many strange facts of inheritance more unintelligible, but even if it were proved to be an exact representation of the facts it would not be an explanation, because, as Weismann, Kerner, and many others admit, it would not account for the forces, the directive agency, and the organising power which are essential features of growth. This is felt so strongly by all the great workers in physiology, that even Haeckel has been driven to postulate "mind, soul, or volition," not only in every cell but in each organic molecule or physiological unit. And then, to save himself from the slur of being "unscientific," and of introducing the very organising power he had derided when suggested by others, he loudly proclaims that his "soul-atom," though it has "will," is yet wholly "unconscious." \(^1\)

I again urge, therefore, that our greatest authorities admit the necessity of some mind—some organising and directive power—in nature; but they seem to contemplate merely some unknown forces or some innate rudimentary mind in cell or atom. Such vague and petty suppositions, however, do not meet the necessities of the problem. I admit that such forces and such rudimentary mind-power may and probably do exist, but I maintain that they are wholly inadequate, and that some vast intelligence, some pervading spirit is required to guide these lower forces in accordance with a pre-ordained system of evolution of the organic world.

If, however, we go as far as this, we must go farther.

\(^1\) The Riddle of the Universe, p. 64.
If there is a ruling and creative power to which the existence of our cosmos is due, and if we are its one and unique highest outcome, able to understand and to make use of the forces and products of nature in a way that no other animal has been able to do; and if, further, there is any reasonable probability of a continuous life for us, in which we may still further develop that higher spiritual nature which we possess, then we have a perfect right, on logical and scientific grounds, to see in the infinitely varied products of the animal and vegetable kingdoms, which we alone can and do make use of, a preparation for ourselves, to assist in our mental development, and to fit us for a progressively higher state of existence as spiritual beings.
CHAPTER XVII

THE MYSTERY OF THE CELL

I have already (at page 292) given a short account of the chemical composition of protoplasm—the highly complex substance now held to be the physical basis of life, and by one school of biologists alleged to explain, as a result of that complexity, all the wondrous phenomena of growth and development. I now propose to give a very brief sketch of the physical characteristics of the living cell, of its internal structure, and of the extraordinary internal changes it undergoes during the growth or reproduction of all organisms.

One of the lowest or most rudimentary forms of life is the Amoeba, a living cell, just visible to the unaided eye as a little speck of floating jelly. This creature, being one of the most common of living microscopic objects, will have been seen by most of my readers. At first, under a low microscopic power, it appears structureless, as it was for some time described to be, but with increasing power and perfection of the microscope it is found to consist of three parts—a central body of a nearly globular shape slightly darker and more granular in texture, the outer jelly-like mass, and a small more transparent globular portion, which looks like an air-bubble, and is seen to undergo a slow motion of contraction and expansion; this is termed the “contractile vacuole,” which, when it has reached its full size, perhaps a quarter or a fifth of the whole diameter, suddenly disappears, and after a little while reappears and gradually grows again to its maximum size. The shape of the Amoeba varies greatly. Sometimes it is globular and immovable, but most frequently it is very irregular with arm-like processes jutting out in various directions. By
careful watching, these are seen to increase or diminish so as to change the whole shape in an hour or two. But more curious is its power of absorbing any particles of organic matter that come in contact with it by gradually enclosing them in its substance, where after a time they disappear. The Amœbae are found in stagnant water full of organic matter, and if they are transferred to pure water they soon diminish in size, proving that they require food and can digest it. The "contractile vacuole" is believed to have the function of expelling the carbonic acid gas and other waste products of assimilation.

This Amœba is one of the simplest forms of the lowest branch of the animal kingdom, the one-celled animals or Protozoa; all other animals being classed as Metazoa, as they are entirely built up of separate cells, which in all the more complex forms are countless millions in number. Every part of our bodies, from blood to muscles and nerves, from bones to skin, hair, and nails, is alike constructed of variously modified cells.

It might be thought that animals consisting of single cells could not be very numerous or very differently organised. Yet they are grouped into five classes, the first, Rhizopoda, comprising not only many kinds of Amœbae, but the beautiful Foraminifera, whose exquisite shells are such favourite microscopic objects. They are single amœboïd cells which yet have the power either of building up shells of small inorganic particles, or of secreting the more beautiful shells which seem to mimic the forms of those of the higher Mollusca. The fossils called Nummulites were Foraminifera with flat coiled shells, forming great masses of Eocene limestone. They are the largest of all, some equalling a half-crown in size. Radiolaria are rhizopods having a beautiful siliceous skeleton, and often living in colonies. Another class, the Mastigophora, have extremely varied shapes, often like sea-weed or flowers, having long, slender, whip-like processes. These and hundreds of other strange forms are still essentially single cells, though often grouped together for a time, and they all increase either by division or by giving off buds, which rapidly grow into the perfect form.
The remarkable thing in all these one-celled creatures is that they so much resemble higher animals without any of their organs. The writer of the article Cell in Chambers's Encyclopædia says: "The absence of a circulating fluid, of digestive glands, nerves, sense-organs, lungs, kidneys, and the like, does not in any way restrict the vital functions of a unicellular organism. All goes on as usual, only with greater chemical complexity, since all the different processes have but a unit-mass of protoplasm in which they occur. The physiology of independent cells, instead of being very simple, must be very complex, just because structure or differentiation is all but absent." All the one-celled animals and plants go through a series of changes forming the cycle of their life-history. Beginning as a nearly globular quiescent cell, they change in form, put forth growths of various kinds, then become quiescent again and give rise to new cells by subdivision or budding.

This fundamental fact, that all organic life-forms begin with a cell and are wholly built up either by outgrowths of that one cell or by its continued division into myriads of modified cells of which all the varied organs of living things are exclusively formed, was first established about the year 1840, and was declared by the eminent naturalist Louis Agassiz to be "the greatest discovery in the natural sciences in modern times." The cell is now defined as "a nucleated unit-mass of living protoplasm." It is not a mere particle of protoplasm, but is an organised structure. We are again compelled to ask, Organised by what? Huxley, as we have seen in Chapter XV., tells us that life is the organising power; Kerner termed it a vital force; Haeckel, a cell-soul, but unconscious, and he postulated a similar soul in each organic molecule, and even in each atom of matter. But none of these verbal suggestions go to the root of the matter; none of them suppose more than some "force," and force is a cause of motion in matter, not a cause of organisation. What we must assume in this case is not merely a force, but some agency which can and does so apply, and direct, and guide, and co-ordinate a great variety of forces—mechanical, chemical, and vital—so as to build up that infinitely com-
plex machine, the living organism, which is not only self-
repairing during the normal period of existence, but self-
renewing, self-multiplying, self-adapting to its ever-changing
environment, so as to be, potentially, everlasting. To do
all this, I submit, neither "life" nor "vital force" nor the
unconscious "cell-soul" are adequate explanations. What
we absolutely require and must postulate is, a Mind far
higher, greater, more powerful than any of the fragmentary
minds we see around us—a Mind not only adequate to
direct and regulate all the forces at work in living
organisms, but which is itself the source of all those forces
and energies, as well as of the more fundamental forces
of the whole material universe.

The necessity for some such far-reaching power and
directive agency will be even more apparent when we con-
sider the beautiful series of changes which occur in every
germ-cell of the higher animals (Metazoa) at the commence-
ment of growth into the perfect form, as detected by means
of a long series of observations by many embryologists, with
all the modern appliances of microscopic research, and
summarised in Professor A. Weismann's interesting volume
on The Germ-Plasm.

I will first quote a general description of such a cell
from Professor Lloyd Morgan's Animal Life and Intelligence,
and then give the further details as shown in the plate of
diagrams from Weismann's book. (Fig. 110.)

"The external surface of a cell is (usually) bounded by a film or
membrane. Within this membrane the substance of the cell is
made up of a network of very delicate fibres (the plasmogen), en-
closing a more fluid material (the plasm); and this net work seems
to be the essential living substance. In the midst of the cell is a
small round or oval body, called the nucleus, which is surrounded
by a very delicate membrane. In this nucleus there is also a
network of delicate plasmogen fibres enclosing a more fluid plasm
material. At certain times the network takes the form of a coiled
filament or set of filaments, and these arrange themselves in the
form of rosettes and stars. In the meshwork of the net, as in the
coils of the filament, there may be one or more small bodies
(nucleoli), which probably have some special significance in the
life of the cell." 1

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1 Animal Life and Intelligence, p. 10.
The accompanying series of diagrams from Professor Weismann's book already referred to are intended to show the essential features of what takes place in a cell previous to division, the detailed fibrous structure of the plasma being omitted for the sake of clearness. It must be understood, however, that much of what is described in the cells is quite invisible even in the highest powers of the best microscopes, owing to the fact that almost all the parts—the fibrous network and granules in the plasma, as well as the network in the nucleus—are transparent, and only become visible by the use of various chemical reagents and dyes, which stain some parts more than others and thus render them visible. The parts of the nucleus which are thus coloured and rendered visible are termed chromosomes or chromatin. I will now quote Weismann's description of what happens in such a cell. (Fig. 110, p. 343.)

"When the nucleus is going to divide, the chromatin granules, which till then were scattered, become arranged in a line and form a long thread which extends through the nucleus in an irregular spiral (Fig. 110 A), and then divides into portions of fairly equal length (the chromosomes). These have at first the form of long bands or loops, but afterwards become shortened, thus giving rise to short loops (B), or else to straight rods or rounded granules. With certain exceptions the number of chromosomes which arise in this way is constant for each species of plant or animal, and also for successive series of cells.

"By the time the process has reached this stage a special mechanism appears, which has till now remained concealed in the cell-substance. This serves to divide the chromatin elements into two equal parts, to separate the resulting halves from one another, and to arrange them in a regular manner. At the opposite poles of the longitudinal axis of the nucleus two clear bodies—the 'centrosomes,' each surrounded by a clear zone—the so-called 'sphere of attraction'—now becomes visible (A to D, e). They possess a great power of attraction over the vital particles of the cell, so that these become arranged around them in a series of rays. At a certain stage in the preparation for division, the soft protoplasmic substance of the cell-body as well as of the nucleus gives rise to delicate fibres or threads; these fibres are motile, and, after the disappearance of the nuclear membrane, seize the chromosomes—whether these have the form of loops, rods, or globular bodies—with wonderful certainty and regularity, and in such a way that each element is held on either side by several threads from
either pole (B, C). The chromatin elements thus immediately become arranged in a fixed and regular manner, so that they all come to lie in the equatorial plane of the nucleus, which we may consider as a spherical body."

Now follows another and even more remarkable stage in the process, which is thus described:

"The chromatin elements then split longitudinally, and thus become doubled (B), as Fleming first pointed out. It must be mentioned that this splitting is not caused by a pull from the pole threads (spindle threads), which attach themselves to the chromatin-ropes on both sides; the division arises rather from forces acting in the rods themselves, as is proved by the fact that they are often ready to divide, or indeed have already done so, some time before their equatorial arrangement has taken place by means of these threads.

"The splitting is completed by the two halves being gradually drawn farther apart towards the opposite poles of the nuclear spindle, until they finally approach the centre of attraction or centrosome (D), which has now fulfilled its object for the present, and retires into the obscurity of the cell-substance, only to become active again at the next cell-division. Each separated half of the nucleus now constitutes a daughter-nucleus, in which it (the chromatin) immediately breaks up, and becomes scattered in the form of minute granules in the delicate nuclear network, so that finally a nucleus is formed of exactly the same structure as that with which we started."

Weismann then discusses and explains the meaning of this strange phenomenon. He says:

"It is evident, as Wilhelm Roux was the first to point out, that the whole complex, but wonderfully exact, apparatus for the division of the nucleus exists for the purpose of dividing the chromatin substance in a fixed and regular manner, not merely quantitatively, but also in respect of the different qualities which must be contained in it. So complicated an apparatus would have been unnecessary for the quantitative division only. If, however, the chromatin substance is not uniform, but is made up of several or many different qualities, each of which has to be divided as nearly as possible into halves, or according to some definite rule, a better apparatus could not be devised for the purpose. On the strength of this argument we may, therefore, represent the hereditary substance as consisting of different qualities. . . . The statement that this substance is the hereditary substance can, therefore, hardly be considered as an hypothesis any longer." 

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1 The Germ-Plasm, p. 29.
After some further discussion of the views of other writers, he goes on to show that the chromatin substance is not only contained in the germ-cells, but also in all the cells of the entire organism in each phase of its development, which is effected by the constant division of the cells and their nuclei, the chromatin continuing to grow during the whole time. But in the body it enters on a long and complex process of growth, so as to build up the substance of all the varied organs and tissues, and also for the repair or renovation of these various tissues as they require it. He illustrates the successive changes which he supposes the chromatin to bring about, and for which purpose it is so accurately divided and subdivided from the very beginning, in the following passage:

"Even the two first daughter-cells (E) which result from the division of the egg-cell give rise in many animals to totally different parts. One of them, by continued cell-division, forms the outer germinal layer, and eventually all the organs which arise from it, e.g. the epidermis, central nervous system, and sensory cells; the other gives rise to the inner germinal layer and the organs derived from it—the alimentary system, certain glands, etc. The conclusion is inevitable that the chromatin determining these hereditary tendencies is different in the very first two daughter-cells."

Later on he shows in great detail how similar but even more complex changes take place in the newly fertilised germ-cell in which the male and female elements are combined, for the purpose of bringing about the accurate partition of these elements in all the cells which arise from them by subdivision, thus rendering possible the production, in all future generations, of males and females in nearly equal proportions. He also shows that there is a special provision for the production of slight variations in successive generations in a way too complex to be explained here. This, of course, is largely speculation, but it is based at every step on observed facts in the processes of fertilisation and cell-division.1

1 The reader will see that the diagrams referred to in Weismann's statements, quoted above, do not seem to represent accurately what he says. They must, therefore, be taken as "diagrams" only, not detailed "figures" of what is seen, which are often so complex that it is difficult to follow the essential details. They are for the purpose of indicating definite stages in the process of the
In Professor J. Arthur Thomson's most valuable and illuminating work on Heredity, in which he impartially expounds the theories and discoveries of all the great physiological writers of the world, he gives a very high, if not the highest, place to those of Weismann. I will therefore quote from his volume Weismann's latest short statement of his hypothesis as to the nature of the germ-plasm; and also Professor Thomson's very short summary of it, giving an explanation of Weismann's special terminology. Weismann's statement is as follows:

"The germ-substance owes its marvellous power of development, not only to its chemico-physical constitution, but to the fact that it consists of many and different kinds of primary constituents, that is, of groups of vital units equipped with the forces of life, and capable of interposing actively and in a specific manner, but also capable of remaining latent in a passive state until they are affected by a liberating stimulus, and on this account able to interpose successfully in development. The germ-cell cannot be merely a simple organism; it must be a fabric made up of many different organisms or units—a microcosm."¹

And Professor J. A. Thomson's Summary of Weismann's mechanics of the germ-plasm is as follows:

**Summary**

"The physical basis of inheritance—the germ-plasm—is in the chromatin of the nucleus of the germ-cell.

"The chromatin takes the form of a definite number of chromosomes or *idants* (Fig. 110, B, C, D, *id*).

"The chromosomes consist of *ids*, each of which contains a complete inheritance.

"Each *id* consists of numerous primary constituents or *determinants*.

"A determinant is usually a group of *biophors*, the minutest vital units.

"The biophor is an integrate of numerous chemical molecules."

In the preceding Summary I have italicised the technical terms invented by Weismann for the different stages of what

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FIG. 110.

DIAGRAM OF NUCLEAR DIVISION.

A. Cell with nucleus (n) and centrosomes (cs) preparatory to division. The chromatin has become thickened so as to form a spiral thread (chr).

B. The nuclear membrane has disappeared. Delicate threads radiate from the chromosomes, and form the "nuclear spindle," in the equator of which eight chromosomes or nuclear loops (chr = Jd) are arranged; these have been formed by the spiral thread of chromatin in A becoming broken up.

C. The chromosomes have each become split longitudinally into two, and are about to be drawn apart by means of the spindle threads. (For clearness four only of the eight chromosomes are shown.)

D. The daughter-loops pass towards the poles of the spindle.

E. The cell has divided, each new cell containing a centrosome and eight nuclear loops.

(From Weismann's Germ-Plasm, by permission of Walter Scott, Ltd.)
may be called the mechanical explanation of heredity by means of the successive changes observed in the growing and dividing germ-cells. But, as he himself admits, it explains nothing without taking for granted the essential phenomena of life—nutrition, assimilation, and growth; and these are admitted to be to this day quite unexplainable.

But the very first step of this process of growth—the division of the germ-cells, as described by Weismann himself and illustrated by his diagrams—is, as he himself almost admits, equally inexplicable. He speaks of a "complex, but wonderfully exact, apparatus for the division of the nucleus," of the purpose of that division being qualitative as well as quantitative, and of its evident adaptation to the building up of the future body, with all its marvellous complexities, co-ordinations, and powers. So that the farther we go in this bewildering labyrinth, as expounded in his works, in those of Professor Thomson, of Max Verworn, or in such general works as Parker and Haswell's Text-Book of Zoology, the more hopelessly inadequate do we find the claims of Haeckel, Verworn, and their school to having made any approach whatever to a solution of "the riddle of the universe," so far as regards its crowning problem, the origin and development of life.

The Plant Cell

So far I have taken the facts as to cell-division from the works of zoologists only; but almost exactly the same phenomena have been found to occur in plants, though they seem to have been rather more difficult to detect and unravel. In Professor A. Kerner's Natural History of Plants, already quoted, he gives the following short description of cell-division:

"When a protoplast living in a cell-cavity is about to divide into two, the process resulting in division is as follows:—The nucleus places itself in the middle of its cell, and at first characteristic lines and streaks appear in its substance, making it look like a ball made up of little threads and rods pressed together. These threads gradually arrange themselves in positions corresponding to the meridian lines upon a globe; but at the place where on a globe the equator would lie, there then occurs suddenly a cleavage of the
MYSTERY OF THE CELL

nucleus—a partition wall of cellulose is interposed in the gap, and from a single cell we have now produced a pair of cells" (vol. i. p. 48).

But later on we have a much fuller description, illustrated by four diagrammatic figures of the dividing cell, which show that the process in plants is substantially identical with that described and figured already from Weismann (vol. i. p. 581). This is most instructive, because it shows the absolute identity of the fundamental mechanics of life in the animal and vegetable kingdoms, though their ultimate developments are so wonderfully diverse.

Another interesting point is that, just as Weismann has stated, there is an identity in the number of certain elements in the cell for each species. Kerner's statement is:

"For every species of plant the number, size, and shape of the bodies arising in the interior of a cell by division are quite definite, though they vary from species to species. In the cell-chambers of some species several thousand minute protoplasmic bodies arise. In others, again, the number is very limited. If the number is large the individual masses are exceedingly small, and can only be recognised when very greatly magnified. If the number is limited the divided portions are comparatively large. The shape of the structures is exceedingly various. Some are spherical, elliptical, or pear-shaped; others elongated, fusiform, filamentous, or spatulate; some are straight, others are spirally twisted, and many are drawn out into a thread; others are provided over the whole surface with short cilia; others, again, with a crown of cilia at a particular spot, or with only a single pair of long cilia. In the majority of cases the small bodies exhibit active movements; but sooner or later they come to rest, and then assume another shape or fuse with another protoplasmic body."

• Referring to the theory that the structure of each plant is due to the specific constitution of the protoplasm of the species, Kerner says:

"What it does not account for is the appropriate manner in which various functions are distributed among the protoplasts of a cell-community; nor does it explain the purposeful sequence of different operations in the same protoplasm without any change in the external stimuli; the thorough use made of external advantages; the resistance to injurious influences; the avoidance or encompassing of insuperable obstacles; the punctuality with which all the
functions are performed; the periodicity which occurs with the greatest regularity under constant conditions of environment; nor, above all, the fact that the power of discharging all the operations requisite for growth, nutrition, renovation, and multiplication is liable to be lost. We call the loss of this power the death of the protoplasm" (vol. i. p. 51).

Growth by Cell-Division: What it Implies

As the account now given of the most recent discoveries as to what actually takes place in the living cell preparatory to its division and subdivision, which are the very first steps in the growth or building up of the highly complex and perfect animal or plant, is very technical, and will be perhaps unintelligible to some of my readers, I will now give a very short statement of the process with a few illustrations, and remarks as to what it all really means, and how alone, in my opinion, it can possibly be explained.

The egg is a single cell with a special central point or organ, called the nucleus, and it is this nucleus which makes the cell a germ-cell. That this is so has been proved in many ways,—in plants by grafting or budding, where the flower-bud which contains a germ-cell, when inserted in the bark of a different variety, and sometimes a different species of plant, reproduces the exact kind of flower or fruit that characterised the tree or bush the bud was taken from, not that of the plant of which it now forms a part, and whose sap forms its nourishment.

Again, Professor Boveri deprived an egg of a species of sea-urchin (Echinus microtuberculatus) of its nucleus, and then fertilised the egg with the spermatozoa of another species (Sphaerechinus granularis). The egg so treated developed larvae with the true characters of the latter species only, so that the main substance of the egg provided nutriment for the offspring, but did not transmit to it any of its parental characters. A similar illustration, at a later period of life, is that of an infant which from birth is fed on cow's milk, yet, if it lives, possesses only human characteristics.

This nucleus, therefore, which, when fertilised, has such marvellous powers and properties, is the seat of heredity and development. What is it that gives it this power? What
is the *agency* that sets in motion a whole series of mechanical, chemical, and vital forces, and *guides* them at every step to their destined end? Again, I urge, let us consider what we have to explain. The *matter* of the fertilised egg is the millionfold complex substance called protoplasm. It is also mainly *living* protoplasm. What power gave it life? It is also (in its essential part, the *nucleus*) already highly differentiated—it is *organised* protoplasm. What *power* organised it? It is a liquid or semi-liquid substance with slight cohesion; it gradually forms a cell, which divides and subdivides, till at a certain point the globular mass or layer of cells bends inward upon itself, forming a hollow sac with outer and inner walls. What power *determines* the cell-mass to take this or other well-defined shapes? Then, as cell-division and specialisation go on, the rudiments of muscle and bone are formed with totally distinct properties—the one with immense contractility and tensile strength, the other with great hardness and rigidity. Who or what *guides* or determines the atoms of the protoplasmic molecules into these new *combinations* chemically, and new *structures* mechanically?—combinations and structures which all the chemists and physicists of the world are powerless to produce even when they have the ready-formed protoplasm given them to start with? Then as the process goes on in an ever-increasing complexity which baffles the microscope of the observer to follow, never diverging at any one point from the precise mode of change which alone leads on to the completed living organism, we are asked to be satisfied with millions of "gemmules," "fundamental units," "determinants," etc., which actually *do* build up the living body of each organism in a prescribed and unchangeable sequence of events. But this orderly process is quite unintelligible without some *directive organising* power constantly at work in or upon every chemical atom or physical molecule of the whole structure, as one after another they are brought to their places, and built in, as it were, to the structure of every tissue of every organ as it takes form and substance in the fabric of the living, moving, and, in the case of animals, sensitive creation.

I will conclude this short sketch of cell-life and its
mystery, with a picturesque account of one striking example in the animal world, from Professor Lloyd Morgan's illuminating volume.

"There is, perhaps, no more wonderful instance of rapid and vigorous growth than the formation of the antlers of deer. These splendid weapons and adornments are shed every year. In spring, when they are growing, they are covered over with a dark skin provided with short, fine, thick-set hair, and technically termed 'the velvet.' If you lay your hand on the growing antler, you will feel that it is hot with the nutrient blood that is coursing beneath it. It is, too, exceedingly sensitive and tender. An army of tens of thousands of busy living cells is at work beneath that velvet surface, building the bony antlers, preparing for the battles of autumn. Each minute cell knows its work, and does it for the general good—so perfectly is the body knit into an organic whole. It takes up from the nutrient blood the special materials it requires; out of them it elaborates the crude bone-stuff, at first soft as wax, but ere long to become as hard as stone; and then, having done its work, having added its special morsel to the fabric of the antler, it remains imbedded and immured, buried beneath the bone products of its successors or descendants. No hive of bees is busier or more replete with active life than the antler of a stag as it grows beneath the soft warm velvet. And thus are built up in the course of a few weeks those splendid 'beams' with their 'tynes' and 'snags,' which, in the case of the wapiti, even in the confinement of the Zoological Gardens, may reach a weight of thirty-two pounds, and which, in the freedom of the Rocky Mountains, may reach such a size that a man may walk without stooping through the archway made by setting up upon their points the shed antlers."

In the eastern European forests the horns of the red deer reach a weight of 74 pounds, while in the recently extinct Irish elk the large, broadly palmated horns sometimes reached an expanse of 11 feet. These remarkable weapons were developed both for combats between the males and as a means of protecting the females and young from enemies. As organic outgrowths they are extremely simple when compared with the feathers of the bird or the scales of a butterfly's wing; yet as exemplifying the need for some guiding power, exerted upon the individual cells which carry out the work with such wonderful precision every year, they are equally striking. The blood, we know, furnishes the materials for every tissue in the body; but here a large
mass of bony matter, covered with a thin skin and dense hair, is rapidly built up to a very definite form in each species; then the skin and hair cease growing and fall away, while the horns persist for nearly a year, when they, too, fall off and are again renewed.

Concluding Remarks on the Cell-Problem

The very short account I have now given of what is known of the essential nature, the complex structure, and the altogether incomprehensible energies of these minute unit-masses of living matter, the cells—so far as possible in the very words of some of the most recent authorities—must, I think, convince the reader that the persistent attempts made by Haeckel and Verworn to minimise their marvellous powers as mere results of their complex chemical constitution, are wholly unavailing. They are mere verbal assertions which prove nothing; while they afford no enlightenment whatever as to the actual causes at work in the cells leading to nutrition, to growth, and to reproduction.

Very few of the workers who have made known to us the strange phenomena of cell-life in the Protozoa, and of cell-division in the higher animals and plants, seem to think anything about the hidden causes and forces at work. They are so intensely interested in their discoveries, and in following out the various changes in all their ramifications, that they have no time and little inclination to do more than add continually to their knowledge of the facts. And if one attempts to read through any good text-book such as Parker and Haswell’s Zoology, or J. Arthur Thomson’s Heredity, it is easy to understand this. The complexities of the lower forms of life are so overwhelming and their life-histories so mysterious, and yet they have so much in common, and so many cross-affinities among the innumerable new or rare species continually being discovered, that life is not long enough to investigate the structure of more than a very small number of the known forms. Hence very few of the writers of such books express any opinion on those fundamental problems which Haeckel and his followers declare to have been solved by them. All questions of antecedent purpose, of design in the course of development,
or of any organising, directive, or creative mind as the fundamental cause of life and organisation, are altogether ignored, or, if referred to, are usually discussed as altogether unscientific and as showing a deplorable want of confidence in the powers of the human mind to solve all terrestrial problems.

If, as I have attempted to do here, we take a broad and comprehensive view of the vast world of life as it is spread out before us, and also of that earlier world which goes back, and ever farther back, into the dim past among the relics of preceding forms of life, tracing all living things to more generalised and usually smaller forms; still going back, till one after another of existing families, orders, and even classes, of animals and plants either cease to appear or are represented only by rudimentary forms, often of types quite unknown to us; we meet with ever greater and greater difficulties in dispensing with a guiding purpose and an immanent creative power.

For we are necessarily led back at last to the beginnings of life—to that almost infinitely remote epoch myriads of years before the earliest forms of life we are acquainted with had left their fragmentary remains in the rocks. Then, at some, definite epoch, the rudiments of life must have appeared. But whenever it began, whenever the first vegetable cell began its course of division and variation; and when, very soon after, the animal cell first appeared to feed upon it and be developed at its expense,—from that remote epoch, through all the ages till our own day, a continuous, never-ceasing, ever-varying process has been at work in the two great kingdoms, vegetal and animal, side by side, and always in close and perfect adaptation to each other.

Myriads of strange forms have appeared, have given birth to a variety of species, have reached a maximum of size, and have then dwindled and died out, giving way to higher and better-adapted creatures; but never has there been a complete break, never a total destruction, even of terrestrial forms of life; but ever and ever they became more numerous, more varied, more beautiful, and better adapted to the wants, the material progress, the higher enjoyments of mankind.
The whole vast series of species of plants and animals, with all their diversities of form and structure, began at the very dawn of life upon the cooling earth with a single cell (or with myriads of cells) such as those whose structure and properties we have here been considering; and every single individual of the myriads of millions which have ever lived upon the earth have each begun to be developed from a similar but not identical cell; and all the possibilities of all their organs, and structures, and secretions, and organic products have arisen out of such cells; and we are asked to believe that these cells and all their marvellous outcome are the result of the fortuitous clash of atoms with the help of "an unconscious cell-soul of the most primitive and rudimentary kind!"

*The Fallacy of Eternity as an Explanation of Evolution*

It may perhaps not be out of place here to deal with what seems to me to be one of the common philosophical fallacies of the present day, the idea that you can get over the difficulty of requiring any supreme mind, any author of the cosmos, by assuming that it had no beginning—that it has existed, with all its forces, energies, and laws, from all eternity, and that it will continue to exist for all eternity.

I have already quoted Haeckel and some others on this point. I will now give a similar statement by two writers of to-day. Dr. Saleeby in an article on *The Life of the Universe*, in *The Academy* (March 25, 1905), after discussing the theory of dissipation of energy, the infinity of the universe, the littleness of man, and other matters, with his usual cleanness and vigour, concludes with this sentence: "Radium-clocks have been made that will go for a million years; but I believe that the Universe was never made and will go on for ever." This, of course, is vague, because, if the term "universe" is taken to mean "the all that exists," or rather, "all that exists, that ever has existed, or that ever will exist," it is a truism, because that includes all life and God. But "universe" is taken by Haeckel and his school to mean the material universe, and to definitely exclude spirit and God.

A great modern physicist, Professor Svante Arrhenius,
in the preface to his recent work, Worlds in the Making, concludes thus:

"My guiding principles in this exposition of cosmogonic problems has been the conviction that the Universe in its essence has always been what it is now. Matter, energy, and life have only varied as to shape and position in space."

This will be taken to mean, and I presume does mean, "matter" and "life" as we know them on the earth, and to exclude, as Haeckel does definitely, spirit and deity. The general conception of all these writers seems to be, that it is easier, simpler, more scientific, to assume that "matter, energy, and life" as we see them, have existed, the same in essence though in ever varying forms, from all eternity, and will continue to exist to all eternity, than to assume any intelligent power beyond what we see.

Now the idea, that positing eternity for matter and for organised life, and for all the forces of nature, overcomes difficulties or renders their existence at the stage they have now reached at all intelligible, is, I maintain, the very opposite of the truth, and arises from a want of real thought as to what "eternity" means. Take, first, "life" culminating in "man." It is admitted that there has been a continuous though not uniform progress from the first organic cell up to man. To arrive at that end it has admittedly occupied a very large portion of the duration of the habitability of the planet, and of the sun as a heat and life-giver. It is also assumed that, to ensure the persistence of life when suns cool and planets are unsuitable, either the germs of life must be carried through space (at the æra of temperature) from one solar system to another till they chance to alight upon one where the conditions of life are suitable, or they must have developed again out of dead matter. All this is overwhelmingly difficult,—but let us grant it all. Let us grant also that there are forces and energies capable of automatically building up progressively developing forms of sentient life, such as have been built up on the earth. Then, if these forces and energies have acted from all eternity, they must have resulted in an infinite life-development, that is, in beings inconceivably higher.
than we are. Now we, who, as they all tell us, are poor miserable creatures of a day, have yet got to know much of the universe, to apply its forces, and thus to modify nature—so, an eternity of progress at the same rate (and as there is progress there is no cause why it should stop) must necessarily have produced an infinite result—that is, beings which as compared with us would be gods. And as you cannot diminish eternity, then long ages before the first rudiment of life appeared upon the earth, long before all the suns we see had become suns, the infinite development had been at work and must have produced gods of infinite degrees of power, any one of whom would presumably be quite capable of starting such a solar system as ours, or one immensely larger and better, and of so determining the material constitution of an "earth" as to initiate and guide a course of development which would have resulted in a far higher being than man. Once assume a mind-developing power from all eternity, and it must, now, and at all earlier periods of the past have resulted in beings of infinite power—what we should term—Gods!

It may, I think, be stated generally, that whatever has an inherent power of increase or decrease, of growth, development, or evolution, cannot possibly have existed from a past "eternity" unless the law of its evolution is an ever-recurrent identical cycle, in which case, of course, it may, conceivably, have existed from eternity and continue through an eternity of future cycles, all identical; and, therefore, such cycles could never produce anything that had not been produced an infinite number of times before. Is this a satisfactory outcome for an eternal self-existent universe? Is this easier, simpler, more rational, more scientific, more philosophical, than to posit one supreme Mind as self-existent and eternal, of which our universe and all universes are the manifestations? And yet the "infinity and eternity" men call themselves "monists," and claim to be the only logical and scientific thinkers. With them matter, ether, life—(surely three absolutely distinct things)—with all the wonderful laws, and forces, and directive agencies which they imply, and without which none of them could for a moment exist, all are to be accounted for and
explained by the one illogical assumption, their eternity; the one complete misnomer, monism; the one alleged fundamental law which explains nothing, the "law of substance."

It will be seen that this alleged explanation—the eternal material universe—does not touch the necessity, becoming more clear every day, not for blind laws and forces, but for immanent directive and organising MIND, acting on and in every living cell of every living organism, during every moment of its existence. I think I have sufficiently shown that without this, life, as we know it, is altogether unthinkable. No "eternal" existence of matter will make this in the remotest degree imaginable. It is this difficulty which the "monists" and the "eternalists" of the Haeckel and Verworn type absolutely shirk, putting us off with the wildest and most contradictory assertions as to what they have proved!

I venture to hope and to believe that such of my readers as have accompanied me so far through the present volume, and have had their memory refreshed as to the countless marvels of the world of life; culminating in the two great mysteries—that of the human intellect with all its powers and capacities as its outcome, that of the organic cell with all its complexity of structure and of hidden powers as its earliest traceable origin—will not accept the loud assertion, that everything exists because it is eternal, as a sufficient or a convincing explanation. A critical examination of the subject demonstrates, as the greatest metaphysicians agree, that everything but the Absolute and Unconditioned must have had a beginning.
CHAPTER XVIII

THE ELEMENTS AND WATER, IN RELATION TO THE LIFE-WORLD

I have already (in Chapter XVI,) given the statements of two continental physiologists as to the great chemical complexity of the proteid molecule, involving as it does, in certain cases already studied, a combination of about two thousand chemical atoms. A more recent authority (Mr. W. Bate Hardy) is of opinion that this molecule really contains about thirty thousand atoms, while the most complex molecule known to the organic chemist is said to contain less than a hundred. One of the results of this extreme complexity is that almost all the products of the vegetable and animal kingdoms are what are termed hydro-carbons, that is, they consist of compounds of carbon, with hydrogen, oxygen, or nitrogen, or any or all of them, combined in an almost infinite variety of ways. Yet the compounds of these four elements already known are more numerous than those produced by all the other elements, more than seventy in number.

This abundance is largely due to the fact that the very same combination of carbon with the three gaseous constituents of the carbon-compounds often produces several substances very different in appearance and properties. Thus dextrine (or British gum), starch, and cellulose (the constituents of the fibres of plants) all consist of six atoms of carbon, ten of hydrogen, and five of oxygen; yet they have very different properties, cellulose being insoluble in water, alcohol, or ether; dextrine soluble in water but not in alcohol; while starch is only soluble in warm water. These differences are supposed to be due to the different
arrangement of the atoms, and to their being combined and recombined in different ways; and as the more atoms are used the possible complexity of these arrangements becomes greater, the vast numbers and marvellous diversity of the organic compounds becomes to some extent intelligible. Professor Kerner, referring to the three substances just mentioned, gives the following suggestive illustration of their diverse properties, of which I have only mentioned a few. He says:

"If six black, ten blue, and five red balls are placed close together in a frame, they can be grouped in the most diverse ways into beautiful symmetrical figures. They are always the same balls, they always take up the same space, and yet the effect of the figures produced by the different arrangements is wholly distinct. It may be imagined, similarly, that the appearance of the whole mass of a carbon-compound becomes different in consequence of the arrangement of the atoms, and that not only the appearance but even the physical properties undergo striking alterations."

Another and perhaps more interesting example, illustrated by a diagram, is given by Mr. W. Bate Hardy in his lecture already referred to. He says:

"Here is a simple and startling case. The molecules of two chemical substances, benzonitrile and phenylisocyanide, are composed of seven atoms of carbon, five of hydrogen, and one of nitrogen:

\[
\begin{align*}
\text{N} & \quad \text{C} \\
\text{C} & \quad \text{C} \\
\text{H} & \quad \text{C} \\
\text{H} & \quad \text{C} \\
\text{C} & \quad \text{H} \\
\text{H} &
\end{align*}
\]

Benzonitrile.

\[
\begin{align*}
\text{C} & \quad \text{N} \\
\text{C} & \quad \text{C} \\
\text{H} & \quad \text{C} \\
\text{H} & \quad \text{C} \\
\text{C} & \quad \text{H} \\
\text{H} &
\end{align*}
\]

Phenylisocyanide.

The only difference in the arrangement of the atoms is that those of nitrogen and carbon are reversed. But the properties of these two substances are as unlike as possible. The first is a harmless fluid with an aromatic smell of bitter almonds. The second is very poisonous, and its odour most offensive."

Here only three elements are combined, and in identical
proportions. We can imagine, therefore, what endless diversities arise when to these are added any of nine other elements, and these in varying proportions, as well as being grouped in every possible manner.

The fact of "isomerism," or of different substances, often with very different properties, having the very same chemical composition, is now so familiar to chemists as to excite comparatively little attention, yet it is really a marvel and a mystery almost equal to that of the organic cell itself. It is probably dependent upon the highly complex nature of the molecules of the elements, and also of the atoms of which these molecules are built up; while atoms themselves are now believed to be complex systems of electrons, which are held to be the units of electricity and of matter. It is these electrons and their mysterious forces that give to matter all its mechanical, physical, and chemical properties, including those which, in the highly complex protoplasm, have rendered possible that whole world of life we have been considering in the present volume.

Here, then, we find, as before, that the farther back we go towards the innermost nature of matter, of life, or of mind, we meet with new complications, new forces, new agencies, all pointing in one direction towards the final outcome—the building up of a living sentient form, which should be the means of development of the enduring spirit of man.

Important and Unimportant Elements

If we look at the long list of between seventy and eighty elements now known we shall see that a comparatively small number of these (less than one-fourth) seem to play any important part either in the structure of the earth as a planet, or in the constitution of the organised beings that have been developed upon it. The most important of the elements is oxygen, which is not only an essential in the structure of all living things, but forms a large part of the air and the water which are essential to their continued existence. It is also a constituent of almost every mineral and rock, and is estimated to form about 47 per cent of the whole mass of the globe. The next most abundant elements are silicon, aluminium, and iron, which form 25, 8, and 7 per cent
respectively of the earth-mass. Then follow calcium, magnesium, sodium, and potassium, contributing from about 4 to 2 per cent of the whole; while no other element forms so much as one per cent, and the majority probably not more than one-fiftieth or one-hundredth of one per cent.

The gases, hydrogen and nitrogen, are, however, exceedingly important as forming with oxygen the atmosphere and the oceans of the globe, which by their purely physical action on climate, and in causing perpetual changes on the earth's surface, have rendered the development of the organic world possible. These ten elements appear to be all that were necessary to constitute the earth as a planet, and to bring about its varied surface of mountain and valley, rivers and seas, volcanoes and glaciers; but in order to develop life, and thus clothe the earth with ever-growing richness of vegetation and ever-changing forms of animals to be sustained by that vegetation, four other elements were required—carbon, sulphur, phosphorus, and chlorine—but these being either gaseous or of very small specific gravity, and thus existing (perhaps exclusively) near the earth's surface, comparatively little of them was needed.

<table>
<thead>
<tr>
<th>Elements in Protoplasm in Order of their Abundance (approximately).</th>
<th>Elements in the Earth in Order of their Quantity (approximately). Per cent.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Hydrogen</td>
<td>1. Oxygen . . . 47</td>
</tr>
<tr>
<td>2. Carbon</td>
<td>2. Silicon . . . 25</td>
</tr>
<tr>
<td>3. Oxygen</td>
<td>3. Aluminium . . . 8</td>
</tr>
<tr>
<td>5. Sulphur</td>
<td>5. Calcium . . . 4</td>
</tr>
<tr>
<td>7. Phosphorus</td>
<td>7. Sodium . . . 25</td>
</tr>
<tr>
<td>8. Chlorine</td>
<td>8. Potassium . . . 25</td>
</tr>
<tr>
<td>9. Sodium</td>
<td>9. Hydrogen . . . (7) 0·1</td>
</tr>
<tr>
<td>10. Potassium</td>
<td>10. Nitrogen . . . (7) 0·1</td>
</tr>
<tr>
<td>11. Calcium</td>
<td>All others . . . (7) 0·8</td>
</tr>
<tr>
<td>12. Magnesium</td>
<td>100</td>
</tr>
</tbody>
</table>

The two elements in italics—Silicon and Aluminium—although forming a large proportion of the earth's substance, are not essential constituents of protoplasm, although occasionally forming part of it.

In the list of the more important elements here given, I have arranged them in two series, the first showing the
essential constituents of protoplasm; the second showing
the ten which are the most important constituents of the
earth's mass as known to geologists and physicists. The
four which are italicised in the first list do not appear in the
second, and cannot, therefore, be considered as forming an
essential portion of the rock-structure of the earth, although
without them it seems fairly certain that the life-world could
not have existed.

The Elements in Relation to Man

So far as we can see, therefore, the fourteen elements in
these two lists would have sufficed to bring about all the
essential features of our earth as we now find it. All the
others (more than sixty) seem to be surplusage, many
exceedingly rare, and none forming more than a minute
fraction of the mass of the earth or its atmosphere. All except
seven of these are metals, including (with iron) the seven
metals known to the ancients and even to some prehistoric
races. The seven ancient metals are gold, silver, copper,
iron, tin, lead, and mercury. All of these are widely
distributed in the rocks. They are most of them found
occasionally in a pure state, and are also obtained from their
ores without much difficulty, which has led to their being
utilised from very early times. But though these metals
(except iron) appear to serve no important purpose either in
the earth itself or in the vegetable or animal kingdoms, they
have yet been of very great importance in the history of
man and the development of civilisation. From very remote
times gold and silver have been prized for their extreme
beauty and comparative rarity; the search after them has
led to the intercourse between various races and peoples, and
to the establishment of a world-wide commerce; while the
facility with which they could be worked and polished called
forth the highest powers of the artist and craftsman in the
making of ornaments, coins, drinking-vessels, etc., many of
which have come down to us from early times, sometimes
showing a beauty of design which has never been surpassed.
Our own earliest rudiments of civilisation were probably
acquired from the Phœnicians, who regularly came to
Cornwall and our southern coasts to purchase tin.
Each of the seven metals (and a few others now in common use) has very special qualities which renders it useful for certain purposes, and these have so entered into our daily life that it is difficult to conceive how we should do without them. Without iron and copper an effective steam-engine could not have been constructed, our whole vast system of machinery could never have come into existence, and a totally distinct form of civilisation would have developed—perhaps more on the lines of that of China and Japan. Is it, we may ask, a pure accident that these metals, with their special physical qualities which render them so useful to us, should have existed on the earth for so many millions of years for no apparent or possible use; but becoming so supremely useful when Man appeared and began to rise towards civilisation?

But an even more striking case is that of the substances which in certain combinations produce glass. Sir Henry Roscoe states that silicates of the alkali metals, sodium and potassium, are soluble in water and are non-crystalline; those of the alkaline earths, calcium, etc., are soluble in acid and are crystalline; but by combining these silicates of sodium and calcium, or of potassium and calcium, the result is a substance which is not soluble either in water or acids, and which, when fused forms glass, a perfectly transparent solid, not crystallised but easily cut and polished, elastic within limits, and when softened by heat capable of being moulded or twisted into an endless variety of forms. It can also be coloured in an infinite variety of tints, while hardly diminishing its transparency.

The value of cheap glass for windows in cold or changeable climates cannot be over-estimated. Without its use in bottles, tubes, etc., chemistry could hardly exist; while astronomy could not have advanced beyond the stage to which it had been brought by Copernicus, Tycho Brahe, and Kepler. It rendered possible the microscope, the telescope, and the spectroscope, three instruments without which neither the starry heavens nor the myriads of life-forms would have had their inner mysteries laid open to us.

One more example of a recent discovery of one of the
rarest substances in nature—radium—and its extraordinary effects, points in the same direction. So far as known at present, this substance may or may not be in any way important either to the earth as a planet or for the development of life upon it; but the most obvious result of its discovery seems to be the new light it throws on the nature of matter, on the constitution of the atom, and perhaps also on the mysterious ether. It has come at the close of a century of wonderful advance in our knowledge of matter and the mysteries of the atom. Many other rare elements or their compounds are now being found to be useful to man in the arts, in medicine, or by the light they throw on chemical, electrical, or ethereal forces.\(^1\)

If now we take the occurrence of all these apparently useless substances in the earth's crust; the existence in tolerable abundance, or very widely spread, of the seven metals known to man during his early advances towards civilisation, and the many ways in which they helped to further that civilisation; and, lastly, the existence of a few elements which, when specially combined, produce a substance without which modern science in almost all its branches would have been impossible, we are brought face to face with a body of facts which are wholly unintelligible on any other theory than that the earth (and the universe of which it forms a part) was constituted as it is in order to supply us, when the proper time came, with the means of exploring and studying the inner mechanism of the world in which we live—of enabling us to appreciate its overwhelming complexity, and thus to form a more adequate conception of its author, and of its ultimate cause and purpose.

I have already shown that the postulate of a past eternal existence is no explanation, and leads to insuperable difficulties. A beginning in time for all finite things is thus demonstrable; but a beginning implies an antecedent cause, and it is impossible to conceive of that cause as other than an all-pervading mind.

\(^1\) While this chapter is being written I see it announced that two of the rarest of the elements, lanthanium and neodymium, have been found to provide (through some of their compounds) light-filters, which increase the efficiency of the spectroscope in the study of the planetary atmospheres, and may thus be the means of still further extending our knowledge of the universe.
The Mystery of Carbon: the Basis of Organised Matter and of Life

It is universally admitted that carbon is the one element which is essential to all terrestrial life. It will be interesting, therefore, to give a brief statement of what is known about this very important substance. Although it is so familiar to us in its solid form as charcoal, or in a more mineralised form as black-lead or graphite, it is doubtful whether it exists uncombined on the earth except as a product of vegetation. Though graphite (plumbago) is found in some of the earliest rocks, yet it is believed that some forms of vegetation existed much earlier. Graphite has also occurred (rarely) in meteorites, but I am informed by my friend Professor Meldola, that it cannot be decided whether this is derived from carbon-dioxide gas or from gaseous carbon. Sir William Huggins was also doubtful as to the state in which it exists in the sun and comets, whether as carbon-vapour or a hydrocarbon. But the most interesting point for us is that it exists as a constituent of our atmosphere, of which carbon-dioxide forms about \( \frac{3}{400} \) part, equal to about \( \frac{1}{70000} \) part by weight of solid carbon; and it is from this that the whole of the vegetable kingdom is built up. The leaves of plants contain a green substance named chlorophyll, which by the aid of sunlight can extract the carbon from the gas, and there is no other means known by which this can be done at ordinary temperatures. The chemist has to use the electric spark, or very high temperatures, to perform what is done by the green leaves at the ordinary temperatures in which we live.

The reverse operation of combining carbon with other elements is equally difficult. In Chambers's Encyclopædia we find the following statement: "At ordinary temperatures all the varieties of carbon are extremely unalterable; so much so that it is customary to burn the ends of piles of wood which are to be driven into the ground, so that the coating of non-decaying carbon may preserve the inner wood. Wood-charcoal, however, burns very easily, animal charcoal less so; then follow in order of difficulty of combustion coke, anthracite, black-lead, and the diamond."
two latter withstand all temperatures, except the very highest obtainable. These various states of carbon differ in other respects. Ordinary carbon is a good conductor of electricity; the diamond is a non-conductor.

Carbon unites chemically with almost all the other elements, either directly or by the intervention of some of the gases. It also possesses, as Sir Henry Roscoe says: "A fundamental and distinctive quality. This consists in the power which this element possesses, in a much higher degree than any of the others, of uniting with itself to form complicated compounds, containing an aggregation of carbon atoms united with either oxygen, hydrogen, nitrogen, or several of these, bound together to form a distinct chemical whole."

Carbon is also the one element that is never absent from any part or product of the vegetable or animal kingdoms; and its more special property is that, when combined with hydrogen, nitrogen, and oxygen, together with a small quantity (about 1 per cent) of sulphur, it forms the whole group of substances called albuminoids (of which white of egg is the type), and which, much diluted, forms the essential part of the blood, from which all the solids and fluids of organisms are secreted. It was on these special features of carbon that Haeckel founded his celebrated carbon-theory of life, which he has thus stated: "The peculiar chemico-physical properties of carbon—especially the fluidity and the facility of decomposition of the most elaborate albuminoid compounds of carbon—are the sole and the mechanical causes of the specific phenomena of movement, which distinguish organic from inorganic substances, and which are called life, in the usual sense of the word." And he adds: "Although this 'carbon-theory' is warmly disputed in some quarters, no better monistic theory has yet appeared to replace it."

What a wonderfully easy way of explaining a mystery! Carbon forms a constituent of the bodies and of the products of all living things; therefore carbon is the cause of life and all its phenomena!

But besides the carbon in the atmosphere an immense quantity exists in the various limestone rocks, consisting of
carbonate of lime \((\text{CaCO}_3)\). It is quite possible, however, that these are all results of animal secretions, as in coral reefs; or of the debris of the hard parts of marine animals, as in the Globigerina-ooze. Limestones exist among the oldest rocks, but as we know that marine life was very much older, this is no objection. All water holds in solution a large quantity of carbonic acid gas, so that both air and water are the source of the most essential elements for building up the bodies of plants and animals.

The ocean also holds a large amount of carbonate of lime in solution, and this is kept permanently dissolved by the large amount of carbonic acid gas always present, which is sufficient to dissolve five times the amount of carbonate of lime which actually exists. Deposits of inorganic limestone are, therefore, now never formed except by long-continued evaporation in isolated bodies of salt water. This renders it more probable that all pure limestone rocks are really very ancient coral-reefs consolidated and crystallised by heat and pressure under masses of superincumbent strata.

The altogether remarkable and exceptional properties of carbon are fully recognised by modern chemists, as well shown by Professor H. E. Armstrong’s statements in his Presidential Address to the British Association in 1909:

"The central luminary of our system, let me insist, is the element carbon. The constancy of this element, the firmness of its affections and affinities, distinguishes it from all others. It is only when its attributes are understood that it is possible to frame any proper picture of the possibilities which lie before us of the place of our science in the cosmos."

And a little farther on he says:

"Our present conception is, that the carbon atom has tetrahedral properties in the sense that it has four affinities which operate practically in the direction of four radii proceeding from the centre towards the four solid angles of a regular tetrahedron. . . . The completeness with which the fundamental properties of the carbon atom are symbolised by a regular tetrahedron being altogether astounding."

And again: