HEREDITY EVOLUTION AND VITALISM

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HEREDITY, EVOLUTION, AND VITALISM:

SOME OF THE DISCOVERIES OF MODERN RESEARCH INTO THESE MATTERS— THEIR TREND AND SIGNIFICANCE

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TO

PROFESSOR J. ARTHUR THOMSON,

AN EMINENT BIOLOGIST AND AN INSPIRING WRITER.

PREFACE.

THE laws of heredity and evolution have made the world of life what it now is, and determine what it may yet be. Of recent years we have learned to understand these laws better, and our knowledge of them has become both of deep theoretic interest, and of great practical importance.

The author accordingly believes that all thoughtful men should have some knowledge of the latest researches of science in these fields, and some acquaintance with the various problems they solve or suggest, and he has endeavoured in the following pages to give a fair summary of what we now know concerning embryonic growth, parental inheritance, and evolutionary change. His endeavour has been to expound scientific facts, and also to indicate certain novel conclusions to which they seem to lead—conclusions which so far appear to have escaped notice, and which are nevertheless of the greatest philosophic and theologic importance.

He points out that recent biological discoveries have quietly undermined the foundations of

Darwinism, and have suggested other evolutionary principles, which render it again possible to believe in special creation, and even in the special creation of Man ; and he outlines a new theory of evolution which seems to him to be in accordance with present biological knowledge.

Further, he tries to show that a mechanical explanation of the phenomena of life can no longer be accepted, and that the functions and forms of animate things are as certainly the work of mind as are the words and the sentences and the paragraphs of a book.

R. C. M.

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ERRATA.

Page 26, line 6, for *curdle* read *digest*.
,, 75, lines 21 and 22 should be transposed.
,, 105, third line from foot of page, for *woman* read *female*.

HEREDITY, EVOLUTION, AND VITALISM

CHAPTER I.

LIVING MATTER.

"HAVE not all souls thought
For many ages that our body is wrought
Of aire and fire and other Elements?
And now they think of new ingredients;
And one Soule thinkes one, and another way
Another thinkes, and 'tis an even lay.

* * * *

What hope have wee to know ourselves when wee
Know not the least things which for our use be."
(*Donne.*)

"WE are fearfully and wonderfully made!" So exclaimed the Psalmist more than two thousand years ago. Yet the Psalmist had only the vaguest conception of the mysterious and intricate mechanism of the body; and we are far more fearfully and wonderfully made than he imagined. Indeed, how marvellously we are made we are still continually discovering, and the miracle of the human body is still full of mystery, and still full of surprises.

The inimitability of the living body.

The beautiful Greek myth of Pygmalion and Galatea tells how a sculptor toiled to achieve the statue of a beautiful woman, and at length made it so perfect that the marble became alive. And even the dull modern imagination is willing to entertain the fancy that a statue might be made such a perfect replica of the human body, that the mere addition of that subtle something called a soul might bring it to life. But such a fancy is absolutely fantastic, for the most life-like creations of art are infinities removed from life.

Nothing can be made by man that even remotely approaches the inimitable intricacy and the infinite complexity of the human machine. We have not learned to make anything truly life-like. Regiomontanus made an iron fly which fluttered round the room and returned to his hand. Vaucanson made a flute-player, and a tambourine-player, and a famous duck that quacked, and ate, and drank. Roger Bacon is said to have made a brazen head that talked. Droz exhibited in Germany some years ago such a marvellous writing-boy that no one could comprehend its complicated mechanism, and both boy and mechanist were suspected of the Black Art and seized by the Spanish Inquisition. And many other instances of wonderful mechanical toys might be quoted. But though these may have had power of motion, not one of them was truly life-like, and even the little amœba crawling about in the ditch-water, and the tiny tubercle bacillus browsing on the lung, are incomparably more intricate and marvellous machines than anything the most ingenious science and art have ever manufactured.

Even such a seemingly simple thing as a bone is unique. One would think that one could mould bones out of lime salts, and have at least a skeleton ready; but bones are much more than "cunning casts in clay," and any skeleton we could make would have only a superficial and fictitious resemblance to the real thing, and would not do at all in the machine of life.

And the structures of life are unique and inimitable, not only because they are infinitely complex in their composition, but also because their ultimate particles are in multitudinous motion.

Most of us do not know, or do not realize, the seething myriad unrest of the living body. We

The myriad unrest of the living body.

know, of course, that the muscles can contract, and the fingers twitch, and the eye roll, and the chest heave, but not only do such motions, *en masse*, occur, but the little molecules (and there are millions in a speck as large as a comma) are throbbing and vibrating; and each molecule again, as we have recently discovered, is made up of infinitesimal particles (*electrons, corpuscles*) spinning and gyrating with enormous velocity in definite orbits.

Does not all this give new and deep meaning to Leibnitz's wise sayings, "Actualia dependent a Deo, tum in existendo, tum in agendo"—

"Neque male docetur conservationem divinam esse continuatam creationem, ut radiis continue a sole prodit"? All existence is action; every molecule is a maelstrom; and in the *vis motus* we must recognize the Power in whom we live and move and have our being.

The mechanism is a mystery. We may stop a clock and take it to pieces, and put it together again, and make it go again; but we cannot take a heart, or an eyelid, or a lily leaf to pieces, and put it together again, and make it go again. We know nothing or almost nothing of the mechanics of the minuter wheels in the machinery of life. Moreover, the wheels of life, like Catherine wheels, are in constant flux; every particle of every wheel is constantly flying away and as constantly being replaced by similar particles; and the body is like a flame which keeps its shape and its average chemical constitution, and yet consists of little fugitive, throbbing, incandescent particles—"a mild white furnace in the thorough blast of perfect spirit."

The mystery of the mechanism of the human body.

The *nature* of the ultimate infinitesimal corpuscles which compose the body, and indeed all matter, is not fully understood; but it is known that they are akin to electric charges and move with almost infinite velocity.

The ultimate basis, then, of the structure and function of the body is inexplicably intricate, depending on the multitudinous yet orderly motion of infinitesimal particles. The more deeply we investigate the machinery of life, the more multiplex and mysterious does it appear, and the more do we realize that there are wheels within wheels, and that the beating heart and the moving limbs are merely manifestations of much subtler and more complex motions.

Of the deeper dynamics of living matter we know nothing, nor does it help us in the least to point out that the chemical elements of living matter are found also in dead matter, and that the vital substance is probably formed in much the same way, and under the same laws, as other chemical compounds. Nothing is explained by pointing out these similarities. The cause and nature of the movements within the chemical elements, the cause and nature of chemical combination, and the relation of these to anatomical structure and physiological function, remain problems unsolved, and probably unsolvable. Though the body may be an integral part of the universe, and though the stomach may exhibit the same chemical laws as the stars, yet these facts in no way simplify the problem of the structure and function of either stomach or star. In both cases, analysis leads us back to bewildering constellations of infinitely small, infinitely numerous particles ; and the elaboration of these into the complexes of living and dead matter remains a mystery and a marvel. Well might Walt Whitman exclaim,

> "Why, who makes much of a miracle?
> To me every hour of the light and dark is a miracle,
> Every square yard of the surface of the earth is spread with
> the same,
> Every foot of the interior swarms with the same."

Yet, although the ultimate basis of living and dead matter be a mystery, it does not follow that we cannot find structural and functional relationships, and principles of some interest and importance, among living parts of more than corpuscular magnitude. Even though we may not understand the mechanism of a clock, we may notice that the second hand moves faster than the minute hand, and the minute than the hour hand. And so, though we cannot tell how certain molecules are made and how they compose a substance with powers of locomotion, assimilation, and reproduction, yet we can investigate the general chemical composition and visible characters of living matter. We can consider living matter morphologically and functionally as a *cell*, and chemically as a conglomeration of molecules and atoms. In our next chapters we shall regard it from those standpoints.

CHAPTER II.

THE CELL.

> "NATURE is whole in her least things expressed,
> Nor know we with what scope God builds the worm."

The cellular theory.

THE scientific conception of the cell as the indivisible unit of living matter, and of the higher organic bodies as corporations of cells (independent yet co-operative) is of comparatively recent date. The primitive microscopes of the seventeenth century must have hinted the idea; for blood cells were seen by Swammerdam in 1658, and by Malpighi and Leeuwenhoek a few years later; while in 1665 Robert Hooke (who first gave a useful form to the compound microscope) described the honeycomb appearance of the bark of a tree seen through the microscope. Malpighi, indeed, seems to have actually propounded the doctrine of the cellular composition of organic bodies. But the idea was not developed; all through the eighteenth century it remained dormant; and not till the middle decades of last century did it come to full fruition.

In 1809 Oken suggested, as the basis of life, an *Urschleim* composed of minute vesicles, but this was merely a fanciful hypothesis without foundation of fact. More scientific was de Candolle's statement in 1812, that, seen through strong microscopes, "plants the most dissimilar in their outward form show a truly extraordinary internal resemblance. . . . The cellular tissue regarded *en masse* is a membranous tissue formed by a great number of cells or closed cavities which may be roughly and correctly enough compared to the froth of beer or to cells of honeycomb." That was near enough to the truth, and soon thereafter Schleiden, Schwann, and Virchow scientifically demonstrated cellular structure, and scientifically formulated the cellular theory.

Schleiden. Schwann. Virchow.

Schleiden, whose great work was published in 1838, taught that all plants are built up of cells, and that "each cell leads a double life: an independent one pertaining only to its own development, and an incidental one, in so far as it has become an integral part of a plant."

Schwann, whose work appeared a year later, showed that animals, like plants, were composed of cells, and that "the whole organism subsists only by means of the reciprocal action of its single elementary parts."

Virchow (1858) applied the cellular theory to disease and still more precisely formulated it. "Just as a tree," he wrote, "constitutes a mass arranged in a definite manner, in which in every single part, in the leaves as in the root, in the trunk as in the blossom, cells are discovered to be the ultimate elements, so is it also with the forms of animal life. Every animal presents itself as a sum of vital entities, every one of which manifests all the characteristics of life." Virchow also established the important law that every cell is born of a parent cell—*omnis cellula e cellula*.

The essence of the cellular theory.

The essence of the cellular theory was its analysis of the higher organisms into congeries of smaller self-contained particles, each living its own life, and capable of assimilation, growth, and reproduction. These particles were named by the histologists *cells*, and taken singly are found to be fundamentally the same structurally and functionally as simple microscopic organisms. As a single cell, indeed, all multicellular organisms begin, and the development of a multicellular organism is merely a matter of coherent multiplication. But the cells, be it noted, are not merely bunches of molecules; they consist of molecules definitely and complexly arranged, so as to show under the microscope definite structural differentiation. To talk of living matter, then, as if it could be cut up into lengths, is about as absurd as to talk of an engine in such a fashion. There is no living matter that *we* can divide, even as there is no locomotive capable of division. When cells divide, their division is duplication: it is as if a steam-engine changed into two steam-engines.

Living matter artificially indivisible.

It is true that Nägeli, Weismann, de Vries, and many other biologists have been fain to assume that the cell is composed of much smaller living particles. Nägeli would postulate particles, which he calls "micellæ," so small that a hundred billion would be contained in a minute cell; and Weismann's biophors and de Vries' pangens must be about equally minute. Quite simple and homogeneous in structure, these particles are supposed to have powers of assimilation and reproduction, and therefore to be alive. But even assuming—and there is good ground for assumption—that in the living cell there are particles (such as determinants) which are capable of assimilation and reproduction, it by no means follows that, out of their context in the cell, they would be capable of such functions. Because a minute wheel revolves in a watch, we have no reason to believe that taken out of the watch it would still revolve. Further, if such particles of life were capable of independent existence and multiplication, they would surely form colonies large enough to be discovered by a microscope.*

Seeing that all assimilation, and growth, and division we know, are associated with complex structure and movements, it is rash to assume

* Lately ultra-microscopic particles, which have been named *Chlamydozoa,* and which have been supposed to be micro-organisms, have been described, but their vital character has still to be demonstrated.

that such marvellous physiological processes could occur in smaller particles without structure at all. Granted that particles divide in the cell, it is more reasonable to assume that the division is part of the reciprocal life of the whole cell, and is conditioned by its general physico-chemical mechanism. A correlated multi-particulate structure seems essential to the machinery of life.

CHAPTER III.

THE MINUTE STRUCTURE OF THE CELL.

"Put by the telescope,
  Better without it man may see,
Stretched awful in the hush'd midnight,
  The ghost of his eternity.
Give me the nobler glass that swells to the eye
The things that near us lie,
  Till Science rapturously hails
In the minutest water-drop
  A torment of innumerable tails."
(*Coventry Patmore.*)

In man there are many varieties of cells microscopically and chemically distinguishable. Thus, there are skin cells, and bone cells, and cartilage cells, and nerve cells; cells round, and cells elongated; cells flat, and cells branched, cells that secrete bile, and cells that carry oxygen; fixed cells and wandering cells; and all of them work in harmony as a co-operative company.

A cell is usually a microscopic object; nevertheless, even in a tiny cell the number of molecules is enormous. It has been calculated that a liver cell contains 300,000,000,000,000 atoms of varying size and quality grouped together in almost infinite variety into 64,000,000,000 molecules. It has further been calculated that a sperm cell $\frac{1}{500}$ in. in diameter contains 2,500,000,000 molecules, each composed of several atoms, and that a

Number of molecules in cells.

microscopic egg cell contains 1,728,000,000,000,000 molecules composed of 8,640,000,000,000,000,000 atoms. We need not be surprised therefore to find that, even in cells, there are wheels within wheels, and that the process of cell division is of a very complicated character.

Structural features of cell.

When we examine a cell microscopically, we find, as we have said, that it is not homogeneous, but that it has special structural features. We find that, as a rule, it has a granular or reticulated appearance, that it is invested by a membrane, the *cell-wall*, and that somewhere in its centre there is a little knot-like object which stains better than the general substance of the cell, and is known as the *nucleus*.

The cell-wall.

The *cell-wall* is undoubtedly of great physiological and chemical importance: it insulates the cell substance and actively influences its environmental interchanges.

The nucleus.

The *nucleus* is one of the most marvellous and mysterious objects in the whole microscopic world. It seems the very citadel of life, and if one could solve its secrets one might solve the riddles of birth and heredity.

The chromatin.

It is found usually to have a vague delimiting wall which separates it from the rest of the cell, and some of its substance, arranged usually in net-work fashion, is found to stain especially well. This substance, because of its staining quality, has been called the *chromatin* of the nucleus, and when it is watched it is seen to behave in an amazing manner, and to be in some way connected with the division of the cell.

Under ordinary conditions, as we have said, the chromatin is arranged in net-work fashion; but before the cell divides, it re-arranges itself in a very mysterious way. Firstly, it usually becomes a long looped and coiled thread, and eventually the thread breaks up into a number of loops or rods of equal length and thickness, which become arranged in the equatorial plane, and are known as *chromosomes*. At the same time, a small rounded body (known as the *centrosome*), lying just outside the nucleus, divides into two, and seems to give origin to a system of fine fibrils which radiate through the cell, and ultimately take the shape of a spindle, in close relation to the chromosomes. Secondly, the chromosomes split longitudinally into two, and the halves, seemingly directed in some way by the fibres of the spindle, move in different directions, and become agglomerated into two new nuclei of the original reticular character. Concomitantly, the general body of the cell divides into two, so that one half contains the one new nucleus and the other half the other. The effect of this mode of division of the original nucleus is plainly to

The chromosomes and how they divide.

The centrosome.

divide its chromatin equally between the two new nuclei; and the nucleus and centrosome are apparently essential to division, for in their absence division seems never to occur.

We have explained that before the division of a cell, the chromatin divides into equal pieces, and the extraordinary fact was soon noticed that the chromatin of every cell of the millions and millions of cells formed by any organism always (except in a few anomalous cases) divides into exactly the same number of pieces. Thus, in the onion, in the ox, in the guinea-pig, every cell forms sixteen chromosomes. In snails there are thirty-two, in sharks thirty-six, in the mouse, trout, and lily, twenty-four; in the grasshopper, twelve; in the threadworm, two or four; in the little salt-water crustacean artemisia, no less than one hundred and sixty-eight. In man there are probably thirty-two (some say twenty-four) chromosomes. Every cell in man's body contains, or has contained, these thirty-two chromosomes. The cells of man's liver, the cells of his brain, the cells of his bones, the cells of his skin, all agree in this essential; and not a single cell normally divides without the preliminary ceremonies we have described.

Characteristic number of chromosomes.

What is the meaning of this numerical precision none can say, but it is evidently of vital importance, and it is bewildering to think that for millions and millions of generations this process

Significance of numerical constancy.

of numerical division has been going on, probably without a single error. That a cell should give birth to millions and millions of cells is wonderful enough; but that the division should in each case be such an intricate arithmetical and architectural matter is more wonderful. And still more wonderful are the manœuvres of the chromosomes, which go through their performance like conscious purposeful beings. There is certainly no phenomenon in the world of inorganic matter to which this phenomenon can be compared, and it seems almost impossible to account for the co-ordinated phenomena of the division, fission, segregation, and molecular and molar movements of the chromosomes by any theory of gradual evolutionary selection. Every detail is evidently of vital importance, and every detail so co-ordinated that a failure in one item must mean failure in all. The cell is not a simple mixture of molecular complexes; it is differentiated into parts which work independently, yet in harmony, and which seem "impelled to do certain things to a certain end"—"to some far off divine event."

We cannot understand much about these mysterious processes—how the chromosomes are partners in a common purpose—but it is impossible to believe that such co-ordinated processes, so worthless separately, and with only prospective value, could have been produced by any additive and selective evolution, by any intracellular selection. Very little indeed can we understand the mysteries of the cell; but, as we shall see in a later chapter, it is possible that the division of the nuclear element into two equal halves provides in some way at once for the transmission of likeness and the production of variation.

CHAPTER IV.

THE CELL: ITS CHEMICAL COMPOSITION.

"Willst du dich am Ganzen erquicken
So musst du das Ganze im Kleinsten erblicken."
(*Goethe.*)

The chemical composition of the living body.

When we analyze cells, vegetable or animal, large or small, we find that, chemically speaking, they consist mainly of the elements carbon, oxygen, nitrogen, hydrogen, and sulphur.

Now here we reach facts of much interest. Of these five elements all living beings are made. All living things are compounded of these five elements: the flesh of a lobster, the leaf of a lily, the heart of man, are all made of this same chemical material. There are dozens of other elements—gold, and silver, and platinum, and tin, and so on—but out of none of them is living tissue ever composed: the compound which exhibits vital functions *must* be composed of the particular quintet—carbon, hydrogen, oxygen, nitrogen, and sulphur.

The chosen elements have nothing very remarkable about them, nor could we expect their wedding to have such momentous consequences. *Carbon* is found singly in coal and diamond; and, in combination with oxygen, it occurs in the gases carbon dioxide and carbon monoxide. *Hydrogen* is found in the gases of volcanoes, and in conjunction with oxygen it forms water. *Oxygen* is one of the gases of the air, and it is also found, as we have said, in carbon dioxide, carbon monoxide, and water. *Nitrogen* is found in the air, and occurs in combination in ammonia and nitric acid. *Sulphur* is found in large quantities in the neighbourhood of volcanoes. Earth, air, and ocean, therefore, contain tons of the elements that go to the making of living tissues, and there seems nothing very noteworthy about them.

The characteristics of the elements composing living tissues

Oxygen, nitrogen, and hydrogen are all gases at ordinary temperatures, and their volatility may have something to do with the versatility and mobility of living tissue. Carbon has an extraordinary power of linking atoms together, and this may make for complexity of structure and function. Nitrogen, though inert, is an explosive element, and its explosive tendencies may facilitate tissue change. Oxygen is a most sociable element, and no doubt its sociability favours atomic combinations. But this is about all that can be said.

And yet these five common and commonplace elements, when wedded in certain proportions and mingled with certain salts, become *alive*, and begin to creep, and crawl, and walk, and swim, and feed, and breed, and love, and think.

"A few gallons of water," writes Oliver Wendell Holmes, "a few pounds of carbon and lime, some cubic feet of air, an ounce or two of phosphorus, a few drams of iron, a dash of common salt, a pinch of sulphur, a grain or more of each of several hardly essential ingredients, and we have man according to Berzelius and Liebig. We have literally 'weighed Hannibal,' or his modern representative, and are ready to answer Juvenal's question. The wisest brain, the fairest face, and the strongest arm, before or since Ulysses, and Helen, and Agamemnon, were, or are, made up of these same elements, not twenty in number, and scarcely a third of the simple substances known to the chemist. The test-tube, and the crucible, and the balance which 'cavils on the ninth part of a hair' have settled that question."

Carbon particularly proper to life.

If we are to pick out any one of the elements we have mentioned as particularly proper to life, we must choose *carbon*. "The peculiar chemico-physical properties of carbon," says Haeckel, "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."

Regarded stereo-chemically, Ehrlich says that protoplasm, the organic material of life, "may be pictured as made up of a large number of curls like a judge's wig—all in intercommunication through some centre, and connected here and there, perhaps, by lateral bonds of union." But the picture does not help us much.

Living matter not homogeneous

The precise combination of carbon, hydrogen, oxygen, nitrogen, and sulphur, which manifests vital functions is not known; and it is probable indeed that living matter is not homogeneous but heterogeneous in its chemical composition, and that it consists of a varying complex of nitrogenous compounds in colloid form. Certainly, even the smallest living organisms we know show structural differentiation.

Difficulty of deciding the chemical composition of living matter.

The difficulty of deciding the chemical composition of living matter is largely increased by the fact that organic matter can be analyzed only *after* death, and death certainly implies profound chemical change. It has been supposed that each molecule of living material must contain eight hundred or nine hundred molecules, and it has been calculated that the smallest living organism known contains about 4,000,000,000 molecules. A recent authority, Mr. W. Bate Hardy, estimates that the molecule contains no less than thirty thousand atoms. All this, however, so far as *living* matter is concerned, is mere theory, and it seems to the writer quite possible that in living matter the atoms may be impelled by special energy, and may be partly broken up into corpuscles (electrons), or may combine and recombine in manners quite unknown in so-called dead matter, even as it has been found that substances in solution acquire new atomic simplicity.

Atoms in living matter may be in special kinetic condition.

What we *do* know is simply that living tissue can always be analyzed, when dead, into compounds of carbon, hydrogen, oxygen, nitrogen, and sulphur, that it contains certain salts and about 75 per cent of water, free and combined, and that it always shows a differentiated structure.

Here, we may remark, *en passant*, that to consider all living tissues as composed of identical nitrogenous substances (the so-called *protoplasm*) is hardly scientific. Analysis of organic matter when dead shows differences in the chemical constitution of its proteins, and a very small chemical difference in a carbon compound means great physiological alteration. Thus, benzonitrile, a harmless aromatic fluid, and phenylisocyanide, a poisonous offensive fluid, are both built up of seven atoms of carbon, five of hydrogen, and one of nitrogen, and the difference between

Living matter varies to some extent in chemical composition.

A small chemical difference may mean great physiological difference.

them depends simply on the mutual arrangement of two of their atoms. So starch, gum, and cellulose all consist of six atoms of carbon, ten of hydrogen, and five of oxygen. Verily "all flesh is not the same flesh; but there is one flesh of men, another flesh of beasts, another of fishes, and another of birds."

The artificial manufacture of living matter.

In the latter decades of last century, as chemists began to find it possible to synthesize organic substances, such as indigo and urea, from inorganic compounds, the hope was born that they would in time be able to build up the special compound on which the vital functions depend, and thus be able actually to create a living organism. It was assumed that the properties of multiplication, movement, etc., shown by living matter were of chemical origin and followed the ordinary chemical laws, and it was assumed that by compounding elements in the right proportions, under the right conditions, the compound would behave exactly in the same way as living matter. The assumption was not unjustifiable, and the hope not unwarrantable. Regarded chemically, the living matter had nothing to differentiate it very decisively from dead matter, and it was quite possible that its unique behaviour was due merely to its greater molecular complexity. Certainly, various ordinary chemical processes, such as oxidation, reduction, diffusion, hydrolysis, katalysis, were plainly at work in living things, and many facts favoured the suggestion that the living body was merely a chemico-physical machine, and that living matter was compounded by the ordinary forces of chemical affinity. Misled, no doubt, by this theory, Huxley identified a slimy matter, Bathybius, found in the dredgings of the *Challenger*, as primitive life material; but the matter turned out to be merely a mineral deposit, and Huxley frankly admitted his mistake.

More recent science has been less optimistic, for it has been found that nature never seems to form life substance anew; but that each new piece of life substance is always formed by the division of a cell. It has been found also that the cell is not quite so simple chemically and structurally as was formerly thought, and that the division of the cell is much more than an ordinary chemical reaction.

Even though Fischer, and Grimaux, and other scientists have succeeded in building up substances like albumins, we are yet infinities away from the manufacture of a living cell. Even if it were in the power of a chemist to form that hypothetical simple particle known as a "micella" or "biophor," we should be far away from a cell, for even a moneron of 6 mm. diameter must contain, *ex hypothesi*, about 100 billions of such particles, and such particles—if such particles there be—must be arranged in a structural and kinetic scheme of quite incomprehensible complexity. Nor, indeed, can any theory of historic evolution of such particles, through differentiation and selection—through any *Kampf der Teile*—throw much light on the final nature of vital structure and function.

Chemical versatility of the cell.

The chemical versatility of the cell is one of its most characteristic features. So long as a cell is alive, it is a chemical laboratory, and in certain cells there are more chemical processes going on than in any laboratory in the world. Moreover, the chemical processes are often quite inimitable—inimitable not only in their general result—the establishment of that condition of unstable equilibrium associated with the vital functions of the body, but also in their particular methods of chemical synthesis and analysis, and in their bye-products.

Chemical processes in living cell of the nature of fermentation.

Almost all chemical processes carried on by the living cell seem to be of the nature of fermentations. When yeast is added to grape sugar, the mixture ferments; it breaks up into alcohol, carbonic acid, and some other substances. This is a chemical change quite like the chemical changes that occur in dead matter; but the yeast is alive, and it produces the changes in a particular way. It produces a substance known as a "ferment," and this ferment, in a way not understood, breaks up the sugar in the grape juice; and the wonderful thing is that the ferment itself is quite unchanged, however much fermentable sugar it may have broken up. The ferment *rennin* has been proved to curdle almost a million times its weight of milk ; and the ferment *pepsin* has been proved to curdle half a million times its weight of fibrin. It is through the ferments of the gastric and intestinal cells that the body is able to break up and assimilate food. The chlorophyll cells of the plant, with the assistance of sunlight, easily, and quietly, and continually break up the carbon dioxide molecule. Only by difficult potent processes can chemistry effect the same disruption. The little nitrite-manufacturing bacterium can emulate and perhaps outvie the lightning in its power of combining oxygen and nitrogen.

Only living cells can produce substances (ferments, enzymes) that act in this way, and it is probable that the chemistry of the living cell is almost wholly of this nature. " It is perhaps too sweeping a generalization," says Professor Bourne, " to assert that the life of any given animal is the expression of the sum of the enzymes contained in it, but it seems well established that the activities of cells are, if not wholly, at all events largely, the result of the actions of the various kinds of enzymes held in combination by their living protoplasm. These enzymes are highly susceptible to the influence of physical and chemical media . . ."

The process of assimilation, by which a cell selects certain substances and builds them up into the labile and motile substance of life, is one of those mysteries far beyond human understanding. Why cells of the human body should accept hydrogen, nitrogen, and carbon in the form of certain foodstuffs, and should reject them in other forms—why certain unicellular organisms should take silica from sea-water, and others carbonate of lime, we do not know; but the ultimate result of the synthetic process, so far as life is concerned, is to maintain a nitrogenous colloid compound in a state of such unstable equilibrium that the slightest stimulus causes it to break down again, with the evolution of heat and other forms of energy.

But in multicellular organisms, assimilation has still another remarkable aspect. Assimilation must go hand in hand with disassimilation and elimination. A cell assimilates, but it also eliminates; and so exquisite is the adaptation that what one cell colony eliminates another cell colony elects—one cell's poison is another cell's meat. The cells of the stomach, for instance, throw out on the one side digestive juice, and by various chemical processes assimilate food into their own substance, while they pass on (through the blood and lymph) their leavings; and these leavings, though really excreta of the stomach cells, exactly suit the requirement of subsequent cells; and so on, seriatim. Even in the act of digestion the cells are working for other cells; no cell lives for itself; each fulfils a useful part in the general economy. It is a case of

> "Jack Sprat could eat no fat;
> His wife could eat no lean;
> And so between them both, you see,
> They made the platter clean."

CHAPTER V.

DEVELOPMENT.

"How do the tiny seeds transform
To living gold the leaden sod?
How is the dead made quick and warm?
O mystic alchemy of God!"

"Fearful and wondrous is the skill which moulds
Our body's vital plan,
And from the first dim hidden germ unfolds
The perfect limbs of man.
Who, who shall pierce the secret—tell us how
Something is drawn from nought—
Life from the lifeless mass? Who, Lord, but Thou,
Whose hand the whole hath wrought.
Of this corporeal substance, still to be,
Thine eye a survey took,
And all my members yet unformed by Thee
Were written in Thy book."

It has been established that all living organisms are simple cells, or complexes of cells, and that every cell is the product of a former cell; but the dynamics of even the simpler forms of cell-division, as we have seen, are very complicated and mysterious processes. We might try to explain the division of a cell by alterations in surface tension, and no doubt surface tension may have something to do with it; but there is far more than mere division to explain: the orderly movement and redistribution of the chromatin, the preservation of likeness, the production of variation, etc., equally require explanation; and though all the processes may eventually be shown to follow the chemical and physical laws at work in dead matter, yet the co-ordination of all the processes *to an end* will still require explanation.

Duplication in unicellular organisms.

In unicellular organisms division *duplicates.* When the cell that produces dysentery divides into two, it is not a simple matter like the division of a globule of mercury into two. The division is preceded by all the mysterious intracellular processes we have described in Chapter II., and results in the production of another cell with similar complicated dynamical and chemical powers. However often the cell divides, it yet retains its hereditary characters, and its power of slaying these immense colonies of cells known as men. So, in the case of the cell known as the "tubercle bacillus," division always results in a cell capable of causing consumption. In every instance, division of the cell of unicellular organisms produces organisms like the original parent—like not only in general characters, but in detail, with exactly the same number of chromosomes, and under like conditions, with exactly the same chemical powers.

Differential division in multicellular organisms.

In multicellular organisms, on the other hand, the fertilized ovum cell as it divides gives rise to groups of cells of diverse structure and function. Thus, in the human body we have liver cells which secrete bile, and do many other wonderful things ; brain cells which are in some way associated with thought, and feeling, and movement ; red blood cells which carry oxygen ; white blood cells which digest germs ; bone-cells which secrete the bony matter of bones, even as coral polyps secrete the limy matter of coral ; and many other cells with equally specific functions.

In mammals, the original cell which divides into all these different cells is really compound, for it is formed by the conjunction of a male cell (sperm cell) with a female cell (egg cell or ovum). When the male cell has joined with the female cell, the female cell is said to be fertilized, and, under suitable conditions, it begins to grow and to divide, and in time forms the wonderful mechanism of the body—eyes, and ears, and brain, and heart, etc. The cells which conjugate are known as "gametes," and after they have joined the compound cell is known as a "zygote."

The fertilized ovum.

It is very strange that a little association of carbon, hydrogen, oxygen, and nitrogen should have the power of adding to their number, and it is stranger still that the addition should take such shape, and produce such a mechanism as a multicellular organism. If a brick were to grow into a pile of bricks, and if the bricks were to arrange themselves in the form of a cathedral, what a miracle it would seem ; yet every day single cells grow into heaps of cells, and the heaps of cells arrange themselves into trees, and flowers, and birds, and beasts, and men, and no one seems particularly surprised. Well might Huxley remark that as we watch the cells of the ovum arrange themselves into a living body, it seems almost as if an unseen hand were moulding them into shape.

Microscopic details of fertilization.

The conjunction of the egg cell and sperm cell is evidently of great importance in the development of multicellular animals, for in the higher animals there can be no conception without fertilization. If we look for a moment at the microscopic details of the process of fertilization in the higher animals, we discover many remarkable facts.

The ovum.

The ovum of the higher animals is usually a round piece of protoplasm about $\frac{1}{120}$ of an inch in diameter—rather more than the average diameter of a human hair—having in its centre, like other cells, a nucleus containing the particular number of chromosomes characteristic of the species.

The sperm cell.

The sperm cell is usually much smaller, and consists mainly of a nucleus, also with the special number of chromosomes.

Now, since fertilization consists essentially in the conjunction of the ovum and sperm cell, with commingling and wedding of the two nuclei, it might seem that the result would be a doubling of the number of chromosomes. But the number is found not to be doubled in the double nucleus, but to remain constant, and the constancy is maintained by the following remarkable preliminary manœuvres.

The first step in the process of maturation is a reversal of the process of ordinary division.

Maturation.

Instead of each chromosome splitting longitudinally into two, each two chromosomes amalgamate longitudinally into one—a process known as *synapsis*. The number of chromosomes is thus halved.

Secondly, each double chromosome is divided *by cross section* into two, and the halves segregate and form two nuclei, which go to two new cells, one large and one small. The small one is known as a polar body, and is of no obvious importance. This is known as the reduction division. The larger cell divides into two again, but this time the chromosomes split longitudinally. Again one cell is large and one small. In accordance with the aforesaid method of division, each cell contains only half the original number of chromosomes. The larger cell is known as the mature ovum.

This may be rather difficult to follow, and the details are, indeed, differently described by different observers ; but the gist of the matter is this, that at a certain stage prior to fertilization, an egg cell is produced with only half the ordinary number of chromosomes characteristic of the species.

In the case of the sperm cells a similar reduction in number is somewhat similarly effected.

The matured ovum contains only half ordinary number of chromosomes.

And thus, when the nuclei of the egg and sperm cells conjoin, the new composite nucleus contains only the normal number of chromosomes—a number carefully preserved during its subsequent divisions by the device of splitting before bipartition.*

This prelude to development—this apparently prescient departure from the ordinary mode of division—is surely one of the most extraordinary facts in biology, and its mechanism and meaning are only very dimly and partially understood, but it is evident that its effect is to contribute equal numbers of maternal and paternal chromosomes to the mature ovum, with probably resultant commingling of maternal and paternal traits in the offspring.

It has commonly been held that fertilization quickens the ovum, and that, without commingling

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* Within the last few years it has been shown that in many insects the body cells of the male contain an odd number of chromosomes—one less than the even number in the body cells of the female—and that when the sperm cell divides at the reducing division one of the two gametes formed is minus a chromosome. When such a gamete joins a female gamete containing its full even number of chromosomes, a zygote is again formed containing an odd number of chromosomes and develops into a male organism. When again the *better* half of the sperm cell witn even number of chromosomes joins a female gamete with same number of chromosomes, a female zygote with even number of chromosomes is produced.

of sperm nuclei, development is impossible; but of recent years many remarkable discoveries have controverted this theory. It has been discovered, for instance, that the ova of certain bees, lice, crayfish, and other animals are capable of development without fertilization, and recent researches have shown that the eggs of starfish may be stimulated to development by treatment with chloride of magnesium, and that many other eggs may be made to develop by physical and chemical stimulation. It has even been demonstrated that the nucleus of the sperm cell will develop in the absence of the egg cell.

Development without fertilization.

The significance of fertilization, then, is very obscure. In most cases, however, and in all mammals, the process of fertilization precedes development, and takes place in the complicated manner we have described.

It is a remarkable fact that the ova of all mammals are about the same size, and almost indistinguishable from each other. "Even when we use the most powerful microscope," says Haekel, "we can detect no material difference between the ova of men, the ape, the dog, and so on." For a considerable time the dividing human ovum shows no signs of its human character, and up to the end of the first month there are "no features by which the human embryo materially differs from that of the hare, the ox, or the horse—in

Resemblance between ova of mammals.

a word, of any higher mammal." It is not, indeed, till the last four months of fœtal life that the human embryo becomes unmistakable.

When we study the development of ova we find that the development of lower and higher animals always proceeds along the same path in the same manner, and that the final result, roughly speaking, is just a question of the point at which development ceases.

In the simpler animals, the ovum divides into a mulberry mass, and remains such a mass. In more highly developed animals the mulberry mass becomes a hollow ball, the cells being fitted side by side in a single layer, and the hollow ball becomes invaginated and forms a double-walled cup (such as might be made by pressing-in a hollow indiarubber ball to make a cup). In animals still more highly developed the double wall of the cup divides into four layers, and various organs are formed out of these.

Recapitulation of evolutionary history in development.

But however highly developed the animal may be, its development always seems to go step by step through the stages of development reached by less highly developed animals, and thus, a lancelet, developmentally speaking, seems just a more highly developed polyp, and a man a more highly developed lancelet. Further, according to current theory, the developmental forms and stages recapitulate the evolutionary history of the animal; and even man's descent can be followed in the embryo. Man began, so say the evolutionists, as a single cell: hence the ovum. The cell became in time a polyp, as is recorded in the double layer of the blastoderm. In the later stages, recapitulation still continues, and we find, in the human embryo, such broad hints of its ancestry as the gill arches of a fish and the tail of an ape.

Indeed, the embryo in the womb goes through a sort of pageant of the past history of the race. Such features (e.g., the tail) as man no longer retains, disappear in the course of embryonic growth; other features are kept and accumulate, and the final result, the human embryo, is just a patchwork made up of useful survivals from various ancestors. "Thus," says Haekel, "we have inherited the oldest organs of the body, the external skin and the internal coat of the alimentary canal, from the gastræads (polyp-like organisms), the nervous and muscular systems from the platodes (flat worms), the vascular system, the body cavity, and the blood from the vermalia (true worms); the chorda and the branchial gut from the prochordonia (organisms like sea-squirts); the articulation of the body from the acronia (lancelet-like fish); the primitive skull and the higher sense organs from the cyclostomes (fishes like lampreys and hagfishes); the limbs and jaws from the salachia (shark-like fish); the five-toed foot from the

The phylogeny of man.

amphibia; the palate from the reptiles; the hairy coat, the mammary glands, and the external sexual organs from the promammals (primitive mammals)."

Very few biologists now-a-days would care to endorse this genealogical table, but still it will serve to illustrate the nature of the theory of the so-called "fundamental biogenetic law."

Most of the ancestral inheritances which go to the making of the human body have survived because in some way serviceable; but we have also many relics of the past that seem quite useless. For instance, we have the appendix, relic of a larger organ very useful to apes; and we have a useless remnant of the third inner eyelid seen in sharks; and we have muscles, now quite superfluous, to move our ears.*

The theory of recapitulation of the past in the embryo is not only fascinating, but it is supported by the facts of heredity. Not only do we find instances where individual development certainly does recapitulate the individual's racial evolution; but, as Archdall Reid has so clearly shown, if there have been evolution, the very fact of inheritance necessitates such recapitulation. Reid considers a lineage of individuals A, B, . . . L, M. "Clearly," he says, "since

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* Within the last year or two Dr. Gaskell has endeavoured to prove from embryological considerations that the king crabs are species in the direct line of descent of mammals, and that the brain of man is a development of a king crab's stomach.

each individual down to M recapitulates the development of his parent and makes in addition another step (a variation), the development of B *must* consist in a recapitulation of A followed by his own variation. C, again, since he recapitulates B, must first recapitulate A, *then* proceed to B's variation, and *then* to his own. D, in turn, must recapitulate A, then the variation *in order* of B and C, and then, and then only, proceed to his own variation. M, the last of a race in whom a progressive variation occurs, must found his variation on a recapitulation of A, plus a recapitulation in orderly succession of the variations of all the intervening ancestors. Given the unquestionable fact that the child recapitulates the development of the parent, any method of development other than by a recapitulation of the life-history of the race is not only impossible but actually unthinkable."

Nevertheless embryogeny can seldom be shown to be an epitome of phylogeny; and in most cases, indeed, we have no phylogeny to compare; while further, it would be quite easy to argue that, granted a molecular similarity in ova, they would be likely to develop, to different degrees, along the same line, even though not genetically related.

The idea of recapitulation has been naturally extended to include the mental development of the individual and the mental evolution of the race, and it has been maintained that we can trace in the various stages of development of the child's mind the various stages passed through by mankind from primitive to modern times.

Looked at in its chemical and embryological aspects, the human body is verily a wonderful thing. A little speck of protoplasm, consisting mainly of carbon, hydrogen, oxygen, and nitrogen atoms, collects other atoms from the mother's blood, and grows and multiplies, and the cells, as they are formed, arrange themselves in groups and layers suggestive at first of polyps, and fishes, and worms, and apes, but finally developing into a baby.

How wonderful the transformation is we do not always quite realize. But suppose a being from another world, who knew nothing of human embryology and morphogenesis, were shown a microscopic speck of jelly-like material and were told that under certain circumstances it would become a Shakespeare or a Napoleon, would it not seem to him quite impossible? Think of the speck becoming able to move a pen or command a Dreadnought. Does not the prodigy fill us with a sense of mystery and a sense of power? It seems to me that our lack of wonder is really due to our plenitude of belief, for we tacitly and unconsciously assume that a Divine Power to whom all things are possible is at work.

CHAPTER VI.

THEORIES OF DEVELOPMENT.—THEORIES IN GENERAL.—WEISMANN'S THEORY.

"Before the beginning of years,
  There came to the making of man,
Grief, with a gift of tears;
  Time, with a glass that ran;
Pleasure, with pain for leaven;
  Summer, with flowers that fell;
Remembrance, risen from heaven;
  And madness, fallen from hell."

(*Swinburne.*)

"Although it be a known thing subscribed by all, that the fœtus assumes its origin and birth from the male and female, and consequently that the egge is produced by the cock and henne and the chicken out of the egge, yet neither the schools of physicians nor Aristotle's discerning brain have disclosed the manner how the cock and its seed doth mint and coine the chicken out of the egge." (*Harvey.*)

The problem of the architectonic mechanism of growth.

We have seen that the higher organisms are colonies of cells produced by the multiplication of a single cell; we have seen that fertilization usually precedes development; we have discovered many facts, but, so far, we have not faced the question of the architectonic mechanism of growth. It is evident that no mere process of cell division will produce a living creature, unless the cells, as produced, have certain different definite characteristics, and become marshalled and arranged in a fixed orderly fashion. The problem of the manner of the production of the organism from the egg has been narrowed but not solved by the cell theory.

The problem of the architectonics of development is a fascinating one, and since the time of Aristotle it has been the aim of biologists to solve it; but to this day it is unsolved.

Attempts at solution have been made chiefly from two standpoints—from the standpoint of the theory of *preformation*, and from the standpoint of the theory of *new-formation* or *epigenesis*.

Preformation and Epigenesis.

The theory of preformation supposed that the animal existed in miniature in the egg, and that development was mainly if not entirely a matter of growth—a manifestation through growth of the invisibly minute; it resembled the theory of Topsy, who asserted that God made her so long, and that she growed the rest. To give this theory consistency it was necessary to suppose that the first egg contained miniatures of all its posterity; hence it sometimes is known as the "pill-box" theory.

Preformation.

The first preformationists maintained that Eve had stored in her ova miniatures of all human beings; and Haller indeed calculated the number to be 200,000 million. When, however, the Dutch microscopist Leeuwenhoek discovered the male sperm cells, *these* were supposed by many to hold the miniatures, and the preformationists divided into two factions, the *Animalculists* and the *Ovulists*. "Both schools, however, still agreed in the general idea that microcosm lay within microcosm, germ within germ, like the leaves within a bud awaiting successive unfolding, or like an infinite juggler's box, to the evolution of which there was no end."

The Animalculists and Ovulists.

Well might Erasmus Darwin quaintly comment that the embryos assumed by this theory "must possess a greater degree of minuteness than that which was ascribed to the devils who tempted Saint Antony, of whom twenty thousand were said to have been able to dance a saraband on the point of a needle without the least incommoding each other."

The other rival theory of epigenesis, as ancient as Aristotle, held that the parts of the body were formed consecutively, and that the heart appeared first.

Epigenesis.

Harvey maintained this proposition, holding that "the first concrement of the future body grows, gradually divides, and is distinguishable into parts: not all at once, but some produced after others, each emerging in its order." Swedenborg, too, maintained that development was epigenetic. He denied that there was any "realis effigies maximi in minimo, seu in aliquo primo typus futuri corporis, qui simpliciter expanditur," and held that "singula membra successiva seu unum post alterum producuntur." Not, however, till the publication of Caspar Friedrich Wolff's "Theoria Generationis" was the epigenetic theory put on a scientific basis, and not till the work of von Baer in the 19th century did it gain anything like general acceptance.

Wolff put the matter too crudely and strongly, saying that "the germ at the outset was nothing but unorganized matter," which became gradually organized in consequence of fertilization. In this crude form epigenesis cannot be now held, for we know that the cell is highly organized, containing nucleus, chromosomes, centrosphere, and other structural parts.

Most modern theories of development may be called evolutionary, and are a modification and combination of preformationist and epigenetic views: they hold that the organism is not preformed *as such*; though its parts may be conditioned and represented by particles, pre-existent in the cell. They hold that there is no homunculus in either the egg or sperm cell of the human species, but nevertheless such an organized and organizing mechanism as results in a procession of forms, ending finally in a man.

Modern theories of development. Combination of the preformationist and epigenetic views.

Various theories have been promulgated as to the nature of the organized and organizing mechanism.

Part played by the nucleus in cell architectonics.

It is evident that the nucleus plays a very important part in the process of cell division and cell architectonics. Not only is division always preceded by the complicated divisional changes in the chromosomes which we have already described; not only is a nucleus necessary to division, but it has been shown that the nucleus, more than the general material of the cell, determines the specific nature of the embryo. This being so, most modern theories have sought in the nucleus the explanation of development.*

Weismann's theory of determinants.

The most famous of such *nuclear* theories is that elaborated by Weismann. Weismann, arguing from the facts of inheritance and trying to explain these facts, assumes that each part of the body capable of independent variation is represented in the maternal and paternal chromosomes of the fertilized ovum by a determining particle. These particles, or *determinants*, are not arranged in the nucleus as in the finished body, nor do they structurally resemble the parts they determine; nevertheless they are the determining material agents. He conceives the fertilized nucleus therefore not as a nation of

* The nucleus, however, is not everything. Driesch showed that a defective larva is produced if a certain mass of protoplasm is cut away from the ovum of the ctenophore, even if the nuclear material is quite undamaged and intact.

homunculi, but as a monster zigzag puzzle, or rather perhaps as pockets of assorted seeds—"genitalia corpora rerum." How the zigzag pieces—how the seeds—that go to the making of man are arranged in the chromosomes, he does not pretend to state, but they are all conveniently and compactly packed in the nucleus.

More than two thousand years ago, Empedocles imagined that the several organs of animals—legs, eyes, heads, trunks—whirled about in chaos till they fortunately and fortuitously joined into normal organisms; and now recent science paints quite a similar picture.

But Weismann's conception of the architectonic antecedents of the multicellular individual is more complicated still. He maintains, on quite reasonable and logical grounds, that the ovum nucleus and the sperm nucleus each contains *several* alternative complete sets, or *ids*, of the parts of an individual. When, then, maturation takes place, several paternal and maternal sets are rejected, and when fertilization occurs, the *several* conserved maternal sets of determinants join with the *several* conserved paternal sets of determinants, and these all compete for a place in the patchwork of the organism. Conceived in this light, man is a mosaic, but the parts are, so to speak, standardized, and there are alternative pieces, maternal, paternal, and ancestral, for each patch. And the character of the offspring depends on the

Man as a mosaic.

selection from a considerable stock of determinants contained in the conjoint germ plasm. Thus the offspring shows maternal, paternal, and ancestral idiosyncrasies, separately or compounded. Long ago Huxley foresaw this possibility. "It is conceivable," he wrote, and indeed probable, that every part of the adult contains molecules derived from the male and from the female parent; and that, regarded as a mass of molecules, the entire organism may be compared to a web, of which the warp is derived from the female and the woof from the male." "What has since been gained," says Professor E. B. Wilson, "is the knowledge that this web is to be sought in the chromatic substance of the nuclei, and that the centrosome is the weaver at the loom."

Struggle of determinants *inter se.*

Since the determinants, *ex hypothesi*, are alive, they are able to feed, and grow, and multiply, and they must be subject to the same laws of struggle with regard to food and multiplication that hold in the case of other vital units. Some determinants, therefore, will multiply and become stronger, and others will dwindle away. "From the relative vigour or dynamic status of the particles of the germ plasm an ascending line of variation will thus spontaneously arise, precisely as the facts of evolution require." But the conception of the nucleus of the ovum as a house of belligerent representatives does not seem to throw much light on the ultimate, complicated, co-ordinated composition of the body. It is as if we sought to explain the genesis of a book by the assumption that all the letters of the alphabet were in the ink bottle, feeding, fighting, multiplying.

Even granting the *particules représentatives*, we have still to explain how they go to the making of man. It is here, perhaps, that the theory fails. Weismann supposes that, as the ovum divides, the representative particles are variously divided among the dividing cells, and govern their development. The first daughter cells have all the various kinds of representative particles in equal shares, and each therefore has exactly the same potentialities as the ovum, and must be, in fact, itself an ovum. This has been frequently demonstrated by showing that in some cases each of the first few cells can develop into a complete organism. After the first few divisions, however, the cells are known to acquire different potentialities, and have divergent destinies, and this Weismann explains by assuming that in the later division the determinants have been differentially apportioned, and that only such characters as the differently allotted determinants govern can afterwards be evolved. It is mainly a question of equal and unequal division. Those cells dividing in such a way as to share all their determinants equally among their offspring will have daughter cells resembling each other, while every cell division involving a difference in the determinant contents of new nuclei will imply and produce a cell with new characters. "Such differential divisions will continue to occur until the determinant architecture of the *ids* is completely analyzed or segregated out into different kinds of determinants, so that each cell ultimately contains only one kind of determinant, the one by which its own particular character is determined. This character, of course, consists not merely in its morphological structure and chemical content, but also in its collective physiological capacity, including its power of division and duration of life."

When the determinant has reached its divisional destination it may remain latent in the nucleus; but if it is to play an *active* part it is supposed to migrate under a liberating stimulus from the nucleus into the cell substance.

Weismann supposes that in many cases cells carry latent determinants to meet accidental contingencies such as mutilation. Thus a small piece of a sea anemone can grow into an entire organism.

CHAPTER VII.

A CRITICISM OF WEISMANN.

"ALLE Gestalten sind ähnlich, doch keine gleichet der andern
Und so deutet der Chor auf ein geheimes Gesetz
Auf ein heiliges Räthsel."

(*Goethe.*)

Difficulty in the way of Weismann's theory of determinants.

WEISMANN'S theory is *consistent with many of the facts of inheritance; but it cannot be said to throw much light upon the facts of development;* and, indeed, certain facts of development seem opposed to it. No architectural or mechanical principles we know, would serve to differentiate and distribute the living multiplying determinants in such orderly succession, that each cell as formed should acquire its particular determinant, especially since the differentiation and distribution seem able to adapt themselves to different conditions.

Even were such a distributing machine possible, the theory merely substitutes one difficulty for another, for we can conceive of no kind of material particles which could determine such things as secretion, duration of life, size; these are characters and functions which surely must be determined by the *whole* architectural structure and metabolic activity of the cell. Further, if the determinants determine the cell, *what determines the determinants*, and what stimuli are so specific as to liberate the particular determinant at the right moment? If, for instance, cells are to divide differentially so as to distribute determinants in such a foreseeing manner, it is surely obvious that each cell must have a determinant to determine its differential nuclear division; but such determinants would themselves require determinants to distribute them correctly, and so on *ad infinitum*. "*Quis custodiet ipsos custodies?*" It is very doubtful if the theory of the particulate predestination of the ovum contents throws much light on developmental mechanics.

Opponents of Weismann.

Among the chief opponents of Weismann's theory may be specially mentioned Hertwig.

Hertwig.

Hertwig holds that the embryological development of an organism is no mosaic work of self-contained pieces, but that the parts of an organism develop in relation to each other, and that the development of a part depends upon the development of the whole. He instances how typical organs can be formed in abnormal situations by abnormal stimuli, how either end of the stalk of a polyp may form a new head; how even the tissue of a leaf turned into a gall may produce roots; how any of the first embryonic cells may suffice to produce a perfect organism; how the earliest cells of certain echinoids may be pushed out of place without producing malformations in the embryo; and from these, and other instances, he argues that *all the cells of every organism have equal potentiality, and that their individual characters are not predetermined by different determinants, but vary just in so much as they are subjected to different stimuli.* He points out that in the course of development inorganic matter is perpetually becoming organic, and that the egg and the adult "are separated from each other by an almost inconceivably long series of connecting intermediate states," and that it therefore is a mistake to assume that all the characters present in the last cells of the series had material antecedents or determinants in the first.

Equi-potentiality of all the cells of multicellular organisms.

There are not determinants serially and severally distributed; but "the self-multiplying systems of units always binding themselves into higher complexes continually enter into new interrelations, and afford the opportunity for new combinations of forces producing new characters."

Seeming superfluity of determinants so far as development is concerned.

So far as the facts of *development* are concerned, it seems to the writer that determinants are superfluous. Granted the power of growth and division, it surely follows from the law of the instability of the homogeneous that each new cell must have new characters and new environment.

No homogeneity can possibly persist in a delicately-balanced substance when polarity, gravitation, light, the stimulation of fertilization, and other forces are at work; and, granted only growth and division, each new cell will *necessarily* have a new constitution and new characters. To chop is to change.

Further, each division will multiply differentiating influences. The first cell will be alone in the world. The second cell will have a neighbour, implying an interchange of chemical influences. In the cup stage, when there is an internal and an external layer, the external layer will live on material that has been eliminated by the cells of the external layer, and will accordingly acquire idiosyncrasies in their chemical characters and consequent developmental conduct. In the more complicated organisms intracellular assimilation and secretion will be still further reciprocally differentiated by propinquity and chemical interchange, and will tend to a differentiation in the cells as they are serially produced. The intracellular secretion of any group of cells will affect not only their genealogical and spatial neighbours, but may be passed on from cell to cell and affect the developmental career of cells quite at a distance. Thus, as Driesch puts it, the prospective value of an embryonic cell "is a function of its location." That slight chemical alterations produce structural and

Structural and functional effects of slight chemical alterations.

functional effects is seen every day. A child, for instance, ceases duly to develop, and shows structural and functional abnormalities, if the little gland in the neck, known as the thyroid gland, does not secrete sufficiently. By the action of different insects upon the same plant different galls are produced. Loeb has shown that sea-urchins' eggs may develop without fertilization if chloride of magnesium be added to sea-water. Herbst has shown that the same eggs will develop into strange monstrosities if the sodium of the sea-water be replaced by lithium. Stockard, by adding magnesium chloride to sea-water in the proportion of 6 grams of the former to 100 c.c. of the latter, altered the position of the optic vesicles in the eyes of the minnow, *Fundulus heraclitus*, and produced 50 per cent of Cyclopean monsters. Even more suggestive than these facts are the facts of sexual development. It is well known that the fertilized eggs of the queen bee develop into either workers or queens according to the food the embryos are given. If they are given rich food they become queens; if poor food, workers; and if worker larvæ be supplied in time with a richer diet they become queens. A similar polymorphism in ants is probably to be similarly explained.

Not only is sex sometimes a matter of diet, and hence of chemistry, but in many cases the intracellular chemistry of the sexual glands themselves has marked structural consequences.

Thus old hens, in which the ovarian secretion is deficient, crow and develop cock feathers, and old women frequently develop moustaches and other masculine characters. Darwin notes that stags never renew their antlers after castration; and that castration reduces the horns of sheep, antelopes, and oxen. The swelling on the index finger of the male frog, the shape and size of the abdominal segments of crabs, are also intimately connected with germ-cell secretions.

To multiply illustrations is unnecessary, for even these will suffice to show that the developmental career of a cell largely depends on chemical influences, and especially on the influences of the intracellular secretions of its predecessors, neighbours, and comrades. Even as the infinitesimal quantity of a cellular secretion, such as anthrax toxin, may kill millions and millions of cells, so also an infinitesimal quantity of another cellular secretion may stimulate proliferation and development.

The minute amount of chemical substances sufficient to produce physiological reactions.

As Richet has pointed out, "the quantities of substances which come into play in physiological reactions are often in such minute proportions that they may be called imponderable." The ten-millionth of a milligram per litre of vanadium salts will influence lactic acid fermentation; "and as there are in a litre which is fermenting a hundred thousand milliards of cells, and perhaps more, it follows that the quantity of vanadium which acts on each cell is indicated by a fraction of a grain so small that twenty-five zeros would be needed to express it." "Certain infusoria contain in their cells some granules of chlorophyll. Now, if these infusoria are made to live in a liquid containing bacteria, and they are exposed for only a second to a ray of the sun, at once all the bacteria are seen precipitating themselves towards the chlorophyllian infusorium. This is because the infinitesimal quantity of chlorophyll exposed to light during a second has decomposed a particle of the dissolved carbonic acid, and liberated oxygen, which attracts bacteria. And, of course, in such a case we have to do with an imponderable quantity. But this quantity has been sufficient to make the bacteria precipitate themselves with violence towards this thousand-millionth part of a gram and a still smaller quantity of oxygen that has been given off."

The specificity of chemical imponderables.

The specificity of these chemical imponderables is most amazing. A thousand-millionth part of a gram of the albuminoid substance of horse serum injected into a guinea-pig will so alter its cellular chemistry that at the end of a month an injection of horse serum, harmless to a normal guinea-pig, will kill it in a few minutes, and yet to all other serums it will react normally.

Uhlenhuth has demonstrated that if guinea-pigs are injected with drops of blood of unknown origin, each will die if injected a month later with the same blood. Thus, if we find that one guinea-pig dies when injected with the blood of a tortoise, and another when injected with the blood of a dog, we can conclude with certainty that the first had been previously injected with tortoise's blood, and that the second had been previously injected with dog's blood. Guinea-pigs injected with watery extract of various tissues from an Egyptian mummy over 3000 years old, died when injected a month later with modern human albumins.

Such facts illustrate how subtle and specific is the chemistry of the living cell, and certainly suggest that the multitudinous changes, structural and functional, which occur in the living body between fertilization and death, may be a series of chemical reactions and nothing more; and make it easy to believe that development in its differential aspect may be essentially due to the cumulative complications, correlations, and interactions of intracellular chemistry as conditioned by the original chemical constitution of the developing cell and by its environment.

As Professor Geddes puts it, "If the reproductive elements start with a specific protoplasm continuous with that of the combined mother ovum and fertilizing sperm—that is, with a concentrated accumulation of characteristic anastates and katastates—the simple fact that the products of protoplasmic change must be fixed, definite, and continuous, as in all chemical processes, gives us at once a protoplasmic basis from which to explain the constant and necessary symmetry of segmentation and development."

Nevertheless, admitting the sufficiency of chemical processes to explain the process of development, they cannot be held to explain heredity. As Weismann points out, "Chemical substances are not vital units which feed and reproduce, which assimilate, and which bear a charm against the assimilating power of the surrounding protoplasm. They would necessarily be modified and displaced in the course of ontogeny. . . ."

CHAPTER VIII.

HEREDITY AND WEISMANNISM.

"The body in which we journey across the isthmus between the two oceans is not a private carriage but an omnibus."—(*O. W. Holmes.*)

"With antecedents,
With my fathers and mothers, and the accumulations of past years—
With all, which had it not been, I would not now be here as I am."
(*Walt Whitman.*)

Every satisfactory theory of development must explain, not merely the general facts of development, but also the particular facts of heredity.

Some facts of heredity.

Let us look first at some of the facts of heredity.

We find that every offspring of two parents has obvious resemblances to one or both parents, and also characters obvious in neither. We find, too, in a general way, that the likeness between offspring and parents may be of three kinds: (*a*) The offspring may have characters derived from both parents, e.g., a dog may have one grey eye from a grey-eyed mother, and one brown eye from a brown-eyed father; or a piebald foal may have patches of its mother's and patches of its father's hair. (*b*) The offspring may have paternal and maternal characters blended, e.g., a black father and white mother may have a mulatto child. (*c*) The offspring may almost exclusively resemble one parent.

Certain traits seem particularly persistent. Thus the Romans had families—Nasones, Labeones, Buccones, and Capitones—distinguished respectively by peculiarities of nose, lip, cheek, and head; and a small pit in the skin of the ear, or a white lock among dark hair, may be transmitted to several generations. To multiply instances is unnecessary; but the following interesting cases mentioned by J. A. Thomson ("Heredity") may be quoted. "A gentleman had a peculiar formation of the right eyebrow. It was strongly arched, and some of the hairs in the centre grew upwards. Three of his sons have the same peculiarity; one of his grandsons has it also; so has his great-granddaughter; and, if we are to believe the artists, this gentleman's grandfather and great-grandfather had the same peculiarity."

Interesting cases of heredity transmission.

"There was a family in France, of whom the leading representative could, when a youth, pitch several books from his head by the movement of the scalp alone. His father, uncle, grandfather, and his three children possessed the same power to the same unusual degree. This family became divided eight generations ago into two branches, so that the head of the above-named branch was cousin in the seventh degree to the head of the other branch. This distant cousin resided in another part of France, and, on being asked whether he possessed the same faculty, immediately exhibited his power."

"A woman with blonde hair, a birthmark under the left eye, and a lisp, married a man with dark hair and normal utterance. There were nineteen children, none of whom showed any of the mother's characters. Nor among the numerous grandchildren was there any trace. In the third generation, however, there was a girl with blonde hair, a mark below the left eye, and a lisp."

Now, there are many such facts of inheritance to be explained, and it is certainly difficult to explain them on such general chemical principles as might explain development, nor can it be said that any very satisfactory explanation has yet been suggested.

The theory of complete preformation with its corollary of *emboîtement*, though superficially satisfactory, has been quite discredited by modern embryological research; and there remain only the various pangenetic theories and Weismann's theory.

Pangenesis.

Pangenesis was suggested by Democritus, who held that the "seed" of animals was made up of contributions from the various parts of the body; and Hippocrates, Paracelsus, and Maupertuis made similar suggestions. The idea was resuscitated by Buffon, who regarded the germs as mingled extracts from all parts of the body, or as collections of samples from the various organs. Herbert Spencer's theory of physiological units was on similar lines. In the hands of

Darwin the theory was ably maintained in the following form, as given by Professor J. A. Thomson: "(1) Every cell of the body, not too highly differentiated, throws off characteristic gemmules; (2) These multiply by fission, retaining their characteristics; (3) They become specially concentrated in the reproductive elements in both sexes; (4) In development the gemmules unite with others like themselves, and grow into cells like those from which they were originally given off, or they may remain latent during development even through several generations."

Theories of pangenesis, like the theory of preformation and emboîtement, have been overthrown by increasing knowledge; and now, perhaps, the only theory in the field is Weismann's theory of the continuity of the germ plasm—a theory previously suggested by Owen, Haeckel, Brooks, Galton, Nussbaum, and others.

The continuity of the germ-plasm.

Weismann maintains that hereditary likeness depends on the genetic continuity of the germ-plasm. He defines the germ-plasm as the special substance in the nucleus of the fertilized egg which contains the determinants; he identifies this substance, as we have previously said, with the chromatin of the chromosomes, and he maintains that not *all* of this substance is expended in the process of individual development; but that part of it is kept in reserve (as the sperm cells or ovum cells) in the individual to go to the making of a new individual. To quote Weismann's own words, "In each development a portion of the specific germ-plasm which the parental ovum contains is not used up in the formation of the offspring, but is reserved unchanged for the formation of the germinal cells of the following generation." Or, as Professor Thomson puts it, "If a fertilized egg cell have certain characters, *a, b, c, x, y, z,* it develops into an organism in which these characters, *a, b, c, x, y, z,* are expressed; but at the same time, the future reproductive cells are early set apart, retaining the characters, *a, b, c, x, y, z,* in all their entirety, to start a new organism again with the same 'capital.'" The germ-plasm is thus continuous down the ages, handed from parent to child—"Et quasi cursores vitai lampada tradunt."

To express it more concretely: The son is a product of the mixed germ-plasms of his father and mother. Part of this mixed germ-plasm is retained intact in his germ-cells, and (compounded with maternal germ-plasm) will go to form offspring in whom, in turn, part of the new compound germ-plasm will be reserved for purposes of propagation, and so on. The individual does not produce the germ-plasm; it produces him; and a reserve portion stored in him goes to the making of his offspring, and so on. Adam and King George are in a very scientific sense made of the same clay.

> "With Earth's first Clay they did the First Man knead,
> And there of the Last Harvest sowed the Seed;
> And the first Morning of Creation wrote
> What the Last Dawn of Reckoning shall read."

As the runners of a strawberry explain the likeness between individual plants, even if the runners be cut, so does the genetic continuity of the germ-plasm explain the likeness between related individuals even though there be no material bond.

According to this theory, the son does not inherit characteristics from his father and mother; he merely inherits portions of the germ-plasm that went to their making—germ-plasm, therefore, which is likely enough to tend to reproduce paternal and maternal qualities. All that can be transmitted are the determinants contained in the dual germ-plasm, and simply because the son is a chip of the old block does he resemble his father, and chiefly because to chop is to change does he vary from his father. There is no transmission of actual characters, be it plainly understood, but merely transmission of reserved portions of certain germ-plasms that under certain conditions produced certain characters, and under like conditions may do so again.

The son literally a chip of the old block.

The biplexity of the germ-plasm of the fertilized ovum.

The biplexity of the germ-plasm of the fertilized ovum naturally complicates matters. We have seen how the chromosomes in the fertilized ovum (zygote) consist of equal contributions from the chromosomes of the nuclei of the egg and sperm cells. The germ-plasm, therefore, that goes to the making of the child is composed half of paternal and half of maternal germ-plasm, and characteristics of both parents are potentially in the zygote. Again, both paternal and maternal germ-plasm are compounded of contributions from a long line of ancestors.

It might, at first sight, seem legitimate to consider all prepaternal and prematernal contributions to the zygote as inert and negligible, and to assume that the paternal and maternal contributions will again approximately produce them; and the question would resolve itself into a question of the conflict, interaction, or co-operation of two sets of determinants determining known characters, in the determinations of the development of the new individual. We would simply have to decide on what principles the *known* paternal and the *known* maternal character augment, neutralize, alter, modify, or oust each other in the final composition. We would simply have to solve such questions as: Given a red-haired mother and a black-haired father, what colour of hair will offspring have?

But we cannot make this simplification: the problem is more complicated: the paternal and maternal contributions to the zygote cannot be assumed to produce, or to tend to produce, simply *known* paternal and maternal characters. The paternal body is the product of the interaction and equilibration of the determinants in thirty-two chromosomes; likewise the maternal body is the product of thirty-two chromosomes; but in the process of maturation the paternal gamete and the maternal gamete each eject sixteen chromosomes. Now if, as Weismann maintains, there are separable particulate determinants for individual parts of the body, both paternal and maternal potentialities must be altered by the rejection of the determinants in the sixteen rejected chromosomes; and the paternal and maternal contributions to the zygote can no longer be assumed to represent the patent, extant, paternal and maternal characters; very probably fresh concatenations of chromosomes and determinants, and so of characters, will be produced. Certainly numerous variations from both the paternal and maternal must follow, and these variations are particularly likely to reproduce prepaternal and prematernal characters.

A concrete illustration of maturation.

On this theory, maturation may be compared to the abstraction of half the cards from many packs of cards previously shuffled, and fertilization may be compared to the combination in one heap of two such expurgated collections of cards, while the embryo may be considered a pack selected from the new combination, and will be like and yet unlike the paternal and maternal packs.

The number of different permutations and combinations which may be effected by the shuffling processes of maturation and fertilization is surprising. It has been calculated that two gametes, each with thirty-two chromosomes, can halve in so many ways that they can form, on conjunction, no less than 601,080,390 different zygotes — even if each gamete have identical chromosomes. Since the chromosomes of the paternal and maternal gametes differ, a still greater number of different combinations is theoretically possible.

Number of permutations and combinations produced by maturation and fertilization.

It is probable, however, that all the theoretical combinations are not physiologically possible, and that all the chromosomes are so alike that they can undergo many expurgations and recombinations without *much* disturbance of their aggregate determinant capacity. Thus, the average racial characters persist in spite of all re-arrangement of chromosomes, and thus must, on the average, be equally represented in any batch of sixteen chromosomes.

On the other hand, many characters vary, increase, diminish, come and go, from generation to generation, and these variations are probably mainly due to the varying dominance of determinants as conditioned by the subtractions and additions of maturation and fertilization. Certain characters may be well represented in numerous maternal or paternal chromosomes, or, even if poorly represented, may escape rejection at maturation, and thus may be transmitted from generation to generation. Other characters may be poorly represented and may be quickly eradicated, or quickly reduced to dormancy, by the mischances of maturation and fertilization. Other characters again may be augmented and, if dormant, made manifest by the conjunction of fertilization. When dormant determinants are reinforced so that the characters previously patent which they represent become again patent, or when they are freed by maturation of opposing determinants that have kept them impotent, there will obviously be a return to ancestral characters.

Mother and father not always equally represented in the offspring.

Accordingly, as we have already stated, though a zygote be half paternal and half maternal, it does not by any means necessarily follow that the child, therefore, manifests his father's and mother's characters in equal proportions, either particulately or blended, nor does it follow that he is manifestly compounded only of character manifested formerly by them. For the father transmits to the offspring only half of the chromosomes that went to his making, and the mother transmits only half the chromosomes that went to her making, nor can either half be assumed to be adequately and efficiently representative of the determinants *potent* in the parent. And even if we could assume that just those determinants particularly potent in the manifest making of each parent were conserved and transmitted, even then we must allow for the likelihood that, in combination in the zygote, they may neutralize or supersede each other, or may produce new alliances producing new characters, or reproducing ancient ones.

Limitations to our power of prophecy.

Our power of prophesying, therefore, is very limited, and all we can say is simply that since some half of the father's and some half of the mother's patent and latent characters compose the zygote, it is likely that a good many maternal and paternal characters patent in father and mother will reappear in the offspring, together with new characters and ancestral characters. It is plain, too, that the offspring is likely to resemble his father twice as much as he resembles his grandfather, since half his determinants are identical with those of his father, and probably only a quarter of them identical with those of his grandfather.

Of late years, as we shall see in another chapter, an application of certain principles discovered by Mendel has increased our powers of prediction.

Owing to the interweaving of paternal and maternal and ancestral characters, the new individual may be conceived as a sort of a mosaic.

"Vom Vater hab' ich die Statur,
Das Lebens ernsten Fuhren;
Von Mutterchen die Frohnatur
Und Lust zu fabuliren.

"Urahnherr war der Schönsten hold
Das spukt so hin und nieder;
Urhn frau liebte Schmuck und Gold,
Das zuckt wohl durch die Glieder.

"Sind nun die Elemente nicht
An dem Complex zu trennen;
Was ist denn an dem ganzen Wicht,
Original zu trennen?"

(*Goethe.*)

Mosaic conception of heredity.

Of this mosaic conception of heredity Galton gives a very picturesque illustration.

"Many of the modern buildings in Italy are historically known to have been built out of the pillaged structures of older days. Here we may observe a column or a lintel serving the same purpose for a second time, and perhaps bearing an inscription that testifies to its origin, while as to the other stones, though the mason may have chipped them here and there, and altered their shape a little, few, if any, came direct from the quarry. . . . This simile gives a rude, though true, idea of the exact meaning of particulate inheritance—namely, that each part of the new structure is derived from a corresponding piece of some older one, as a lintel was derived from a lintel, a column from a column, a piece of wall from a piece of wall. . . . We appear to be severally built up out of a host of minute particles, of whose nature we know nothing, any one of which may be derived from any one progenitor, but which are usually transmitted in aggregates, considerable groups being derived from the same progenitor. It would seem that while the embryo is developing itself, the particles more or less qualified for each post wait, as it were, in competition to obtain it, also that the particle that succeeds must owe its success partly to accidents of position, and partly to being better qualified than any equally well-placed competitor to gain a lodgment. Thus the step-by-step development of the embryo cannot fail to be influenced by an incalculable number of small and mostly unknown circumstances."

Explanation of reversion on crossing.

On Weismann's theory, it is possible to explain the reversion produced by crossing. In crossing unlike races and breeds, ancestral determinants, which in the ordinary combinations are subordinate, become potent. They become potent because they are identical in each parent (since both parents sprang from a common stock), and thus augment each other, while the determinants of the particular, unlike, parental characters, being more or less contrasted, neutralize each other, unless—as we shall explain later—they *mendelize*.

In like manner, the general effect of marriage is to prune away variations from the ancestral type.

According to the germ-plasm theory, then, likeness is due to the continuity of the germ-plasm; while variation depends on differential division in the germ-plasm, on the struggle of the determinants *inter se*, and on the new combinations produced by fertilization.

Difference in persistence of variations.

Variations produced by variations in the nutritional vigour of the determinants will be progressive, and will endure at least as long as the nutritive and other conditions which affected the determinants persist. Variations produced by the processes of maturation and fertilization may be great, but are somewhat liable to be counteracted and annulled by subsequent processes of a similar nature.

The theory of the continuity of the germ-plasm adds considerably to the difficulties of conceiving a satisfactory scheme of *progressive* evolution. On this theory, the germ-plasm is continuous, and the germ-plasm which goes to the making of offspring is contemporary with the germ-plasm that went to the making of the parents, and antecedent to the parents' bodies.

So long as there was no definite distinction made between the body and the germ-plasm, so long as the egg and sperm cells were thought to be in serial genetic continuity with the bodies of the parents, and to be impressionable to bodily changes, it was easy to find a reason for progressive continuity, in variations ; but now, when it has been discovered that the body does not produce the germ-plasm, but is rather a casket containing germ-plasm formed before itself, the problem becomes more difficult.

If variations are to be persistent and progressive, an ante-natal progressive growth of determinants in the germ-plasm, an ante-natal unanimity in the ejections of maturation, and a very stringent and consistent post-natal selective process must, some or all, be postulated.

Such, then, is Weismann's theory of heredity ; and though it has been rather elbowed aside by Mendelian and other theories, there can be no doubt that in many ways it is the best working hypothesis that has yet been proposed ; it is consistent with Galton's and Pearson's statistical results, and in some cases, where Mendelism fails, it seems to fit in with the facts.

CHAPTER IX.

GALTON'S AND PEARSON'S CONTRIBUTIONS TO THE SCIENCE OF HEREDITY.

"Thou dost this body, this enhavocked realm,
Subject to ancient and ancestral shadows;
Descended passions sway it; it is distraught
With ghostly usurpation, dinned and fretted
With the still tyrannous dead; a haunted tenement
Peopled from barrows and outworn ossuaries."
(*Francis Thompson.*)

"Born into life, man grows
Forth from his parents' stem
And blends their bloods, as those
Of theirs are blent in them.
So each new man strikes root into a far fore time."
(*Matthew Arnold.*)

Statistical expression of proportionate inheritance of parental and ancestral characters.

Whatever the germinal reason may be why parental and grandparental characters, rather than characters of more remote ancestors, tend to reappear in offspring, the fact remains that it is so, and various attempts have been made to find and formulate a statistical expression giving the proportions which parental and ancestral characters contribute in the composition of an average individual.

Quetelet.

The first to apply statistical or biometric methods to the problem of heredity was Quetelet, who, in 1846, addressed a series of letters to the Duke of Saxe-Coburg and

Gotha, showing that the Law of Probabilities applied to moral, political, and biological problems; but not till the time of Galton did statistical methods produce much fruit. In 1869, from a careful statistical study of the inheritance of colours in pedigree basset hounds, Galton came to the conclusion that the proportionate contribution of ancestors to their progeny could be simply stated in arithmetical terms; and in 1897 he enunciated his famous Law of Ancestral Heredity.

Galton's law of ancestral inheritance.

The law is as follows: "The two parents between them contribute, *on the average*, one half of each inherited faculty, each one contributing one quarter of it. The four grandparents contribute between them one quarter, or each of them one sixteenth; and so on, the sum of the series $\frac{1}{2} + \frac{1}{4} + \frac{1}{8} + \frac{1}{16} + \ldots$ being equal to 1, as it should be. It is a property of this infinite series that each term is equal to the sum of all $\frac{1}{4} = \frac{1}{8} + \frac{1}{16} + \ldots$ and so on. The pre-potencies those that follow: thus $\frac{1}{2} = \frac{1}{4} + \frac{1}{8} + \frac{1}{16} \ldots$ or sub-potencies of particular ancestors in any given pedigree are eliminated by a law that deals only with *average* contributions, and the varying pre-potencies of sex in respect to different qualities are also presumably eliminated."

Galton's law consistent with Weismann's theory.

This law is evidently quite in keeping with Weismann's conception of the ancestral germ-plasm, and is certainly suggested by the phenomena of maturation and fertilization. This was remarked by Galton, who wrote: "It should be noted that nothing in this statistical law contradicts the generally accepted view that the chief, if not the sole, line of descent runs from germ to germ and not from person to person. The person may be accepted on the whole as a fair representative of the germ, and being so, the statistical laws which apply to persons would apply to the germs also, though with less precision in individual cases. Now this law is strictly consonant with the observed binary subdivisions of the germ cells, and the concomitant extrusion and loss of one-half of the several contributions from each of the two parents to the germ cell of the offspring. The apparent artificiality of the law ceases on these grounds to afford cause for doubt; its close agreement with physiological phenomena ought to give a prejudice in *favour* of its truth rather than the contrary."

Pearson's biometric calculations.

By more elaborate biometric calculations, Karl Pearson has obtained quite comparable figures, for he finds the proportional contribution of parents, grandparents, and great-grandparents to be 0·6244, 0·1988, 0·0630 respectively.

Difference of opinion with regard to value of Galton's law.

The value of Galton's Law has been much debated. Pearson, who has developed Galton's statistical and mathematical methods, declares: "The law of ancestral heredity is likely to prove one of the most brilliant of

Mr. Galton's discoveries; it is highly probable that it is the simple descriptive statement which brings into a single focus all the complex lines of hereditary influence. If Darwinian evolution be natural selection combined with heredity, then the single statement which embraces the whole field of heredity must prove almost as epoch-making to the biologist as the law of gravitation to the astronomer."

Pearson's opinion.

Professor Weldon likewise approves it: "The results so far achieved make it probable that Mr. Galton's original prediction will be verified for the large class of cases to which he intended it to apply, and that the influence of the different generations of ancestors, as measured by regression coefficients between these and existing individuals, will be found to diminish with the remoteness of the ancestors according to the terms of a single geometric series, which is sensibly the same at least for all those characters among the higher animals which have been properly examined."

Weldon's opinion.

On the other hand, Bateson writes: "Though there was admittedly a statistical accord between Galton's theory and some facts of heredity, yet no one familiar with breeding, or even with the literature of breeding, could possibly accept that theory as a literal or adequate presentation of the facts. . . . His formula should in all probability be looked

Bateson's criticism.

upon rather as an occasional consequence of the actual laws of heredity than in any proper sense one of those laws."

"That method of representing the phenomena of heredity and all modifications of it are based on the false assumption that any individual can transmit the characteristics of any ancestor, and especially of any recent ancestor. When this conception was shown to be untrue, the structure which the biometricians have offered to the world as a scientific study of heredity ceased to have meaning or value. Statistical examination of ancestral composition may, as we have seen, occasionally give a prediction in good correspondence with fact ; but this is due to coincidence, and not to any elements of truth in the ratiocination by which the prediction was reached."

The statistical method of Galton has been largely extended by the biometrical labours of Pearson, who maintains that the best means of reaching truth in questions of heredity is to proceed "from inheritance in the mass to inheritance in narrower and narrower classes, rather than attempt to build up general rules on the observation of individual instances," for "the very nature of the distribution . . . seems to indicate that we are dealing with that sphere of indefinitely numerous small causes, which in so many other instances has shown itself only amenable to the calculus of chance, and not to the analysis of the individual instance."

Pearson and the biometrical school have laboured chiefly to ascertain and denote by quantitative measurements, where such measurements are possible, the range and general behaviour of variation, particularly in its relation to the problems of heredity and species formation. By such measurements it has been established that most quantitative variations are "continuous," that is to say, that the gamut of variation is gradual, so that between the largest and smallest every gradation in size occurs. By such measurements, too, it has been established that most continuous variations accord with the law of the frequency of error.

Accordance of continuous variations with the law of frequency of error.

The law of the frequency of error can be illustrated by the distribution of bullet-marks on a target. Granted that the marksmen have skill, the greater number of bullet-marks on a target will be crowded near the bull's-eye, and the farther from the bull's-eye the fewer will be the bullet-marks. In like manner it is found that in cases of continuous variation in size, one size is more frequent than any other, and that as the other variations diverge from this size they become less numerous. Thus, it is found that most men have a height of about 67 inches, and that men of other statures progressively diminish in number as they diverge upwards and downwards from the standard height. The size found most frequently is known as the "mode."

By comparing parental and filial deviation from the mode of the general population, the intensity of inheritance has been more or less accurately estimated. It is evident that if sons deviate from the general mode of any character as much as their fathers deviate, inheritance must be intense in the case of that character, and that, generally speaking, the ratio between the deviation of parents and the deviation of their sons with respect of any character will be a measure of the intensity of inheritance for that character. The ratio is called the "coefficient of correlation" for that character.

Intensity of inheritance measured by comparing parental and filial deviation from mode of the general population.

Coefficient of correlation.

Professor Pearson has worked out the "coefficient of correlation" between parents and offspring in respect to many measurable characters, and has found that in most cases the average offspring exhibits about half the deviation of the parent. Thus, if a father be six inches taller than the *mode* of the population, his sons average only three inches taller. This relation may be expressed by stating that the average coefficient of correlation between one parent and offspring is ·5.

Pearson's estimate of correlation coefficients.

Professor Pearson has further estimated the correlation coefficient between grandchild and grandparent as ·33, and that between great-grandchild and great-grandparent ·22, the correlation coefficient with an ancestor of each generation being $\frac{2}{3}$ of that of the next below.

Similar correlation has been shown in regard to mental characters.

The following two tables from Pearson will give some idea of the results he has obtained.

TABLE OF INTENSITY OF PARENTAL INHERITANCE IN DIFFERENT SPECIES.

Species	Character	Mean Value	No. of Pairs used
Man ..	Stature	·506	4886
	Span	·459	4873
	Forearm	·418	4866
	Eye colour	·495	4000
Horse ..	Coat colour	·522	4350
Basset hound	Coat colour	·524	823
Greyhound ..	Coat colour	·507	9279
Aphis ..	Ratio of right antenna to frontal breadth (non-sexual reproduction) ..	·439	368
Water-flea ..	Ratio of basal joint of antenna to body-length (non-sexual reproduction)	·466	96

Character	Brothers	Sister	Brother and Sister
Vivacity	0·47	0·43	0·49
Assertiveness	0·53	0·44	0·52
Introspection	0·59	0·47	0·63
Popularity	0·50	0·47	0·49
Conscientiousness	0·59	0·64	0·63
Temper	0·51	0·49	0·51
Ability	0·46	0·47	0·44
Handwriting	0·53	0·56	0·48
Mean	0·52	0·51	0·52

The law of retroversion to the mode would seem to be almost a necessary consequence of inheritance if, as Weismann and Galton maintain, about half the determinants of the germ-plasm are atavistic, and if every character is a result of the compounded tendencies of the determinants. Galton reasons thus: "In every population that intermarries freely, when the genealogy of any man is traced far backwards, his ancestry will be found to consist of such varied elements that they are indistinguishable from a sample taken at haphazard from the general population. The mid-stature M of the remote ancestry of such a man will become identical with P (the mean of the present population); in other words, it will be mediocre." Similarly, Pearson writes: "A man is not only the product of his father, but of all his past ancestry; and unless very careful selection has taken place, the mean of that ancestry is probably not far from that of the general population. In the tenth generation a man has (theoretically) 1024 tenth great-grandparents. He is eventually the product of a population of this size, and their mean can hardly differ from that of the general population. It is the heavy weight of this mediocre ancestry which causes the son of an exceptional father to regress towards the general population mean; it is the balance of the sturdy commonplaces which causes the son of a degenerate father to escape the whole burden of the parental ill. Among mankind we trust largely, for our exceptional men, to extreme variations occurring among the commonplace ; but if we could remove the drag of the mediocre element in ancestry, were it only for a few generations, we should sensibly eliminate regression, or create a stock of exceptional men. This is precisely what is done by the breeder in selecting and isolating a stock until it is established."

CHAPTER X.

MENDEL.

WE have seen how much light Weismann, Galton, and Pearson have shed upon the obscure problems of heredity. But, unknown to them, and before their day, a German priest, Gregor Johann Mendel, experimenting with peas in his cloister gardens, had in some respects penetrated even more deeply into the arcana of inheritance.

Both Weismann and Galton conceived of organisms as mosaics, with various characters contributed by various ancestors; but years before, Mendel had both demonstrated the mosaic nature of inheritance, and had discovered some of the laws that in some cases regulated the composition of the mosaic.

In 1865 Mendel announced his discoveries; but they attracted no attention, and only within the last ten or eleven years has their paramount and far-reaching importance been realized.

Mendel's experiments with peas.

Mendel's experiments consisted in crossing peas differing in certain definite comparable characters, with a view to discovering the behaviour of the characters in the hybrid, and also in the progeny of interbred hybrids. He selected for experiment such characters as the form of the ripe seed, the form of the ripe pods, the position of the flowers, the length of the stem; and crossed peas which contrasted in such characters.

He found that the hybrid *showed* only one of any two contrasted characters. The characters that appeared in the hybrid he called *dominant*; the character that did not appear he called *recessive*. For instance, he crossed tall peas and dwarf peas. The hybrids were all tall; hence he called tallness *dominant*, and dwarfness *recessive*.

Statement of results.

When he interbred the hybrids he found that one plant in four again developed the recessive character, while the other three retained the dominant character. "In this generation (the first generation bred from the hybrids) there reappear, together with the dominant characters, also the recessive ones with their peculiarities fully developed, and this occurs in the definitely expressed average proportion of three to one, so that among each four plants of this generation three display the dominant character and one the recessive. This relates without exception to all the characters which were investigated in the experiments. . . . *Transitional forms were not* observed in any experiment."

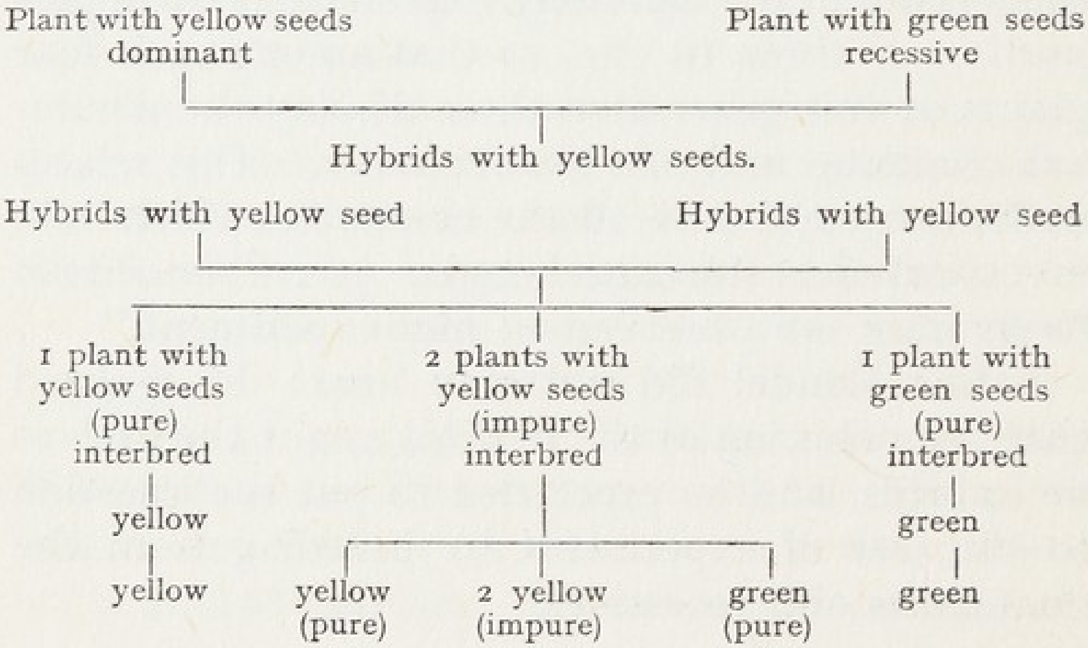
But Mendel did not stop here: he realized that the offspring of the hybrids might themselves be hybrids, and he proceeded to put the question to the test of experiment by breeding from the dominants and recessives.

Statement of further results.

By such experiment he found that "those forms which in the first generation (bred from the original known hybrids) *exhibit* the recessive character, do not further vary in the second generation as regards this character: they remain constant in their offspring.

"It is otherwise with those which possess the dominant character in the first generation (bred from the hybrids). Of these, *two*-thirds yield offspring which display the dominant and recessive characters in the proportion of 3 to 1, and thereby show exactly the same ratio as the hybrid forms, while only *one*-third remains with the dominant character constant."

The proportion in which the descendants of the hybrids develop and split up in the first and second generations presumably holds good for all subsequent progeny. To take a concrete instance:



Mendel next proceeded to investigate what occurred when hybrids were bred which included *several* pairs of contrasted characters. For instance, he crossed peas with round yellow seeds with peas with wrinkled green seeds. Here, round and wrinkled, yellow and green, constituted two pairs of contrasted characters (what are now called *allelomorphs*). In such a case he found that not only were round yellow and wrinkled green peas produced, but also wrinkled yellow and round green, all in definite proportions. And by a series of experiments he proved that "the constant characters which appear in the several varieties of a group of plants may be obtained in all the associations which are possible according to the laws of combination, by means of repeated artificial fertilization."

Crossing of several pairs of contrasted characters.

Allelomorphs.

These were novel, interesting, and important discoveries; but Mendel went further still, and crowned his work by suggesting a reasonable physiological basis for the phenomena he had discovered.

Physiological explanation of results.

He suggested that the various combinations and ratios could be explained by assuming that the members of pairs of contrasted characters in the hybrid went separately to separate gametes, in such a way that each gamete contained one representative of every pair, and in such a way, too, that all possible combinations that could be so made were produced in equal numbers, and were joined in conjunction to form new zygotes according to the laws of chance.

Accordance with laws of chance.

Thus—to take the simplest possible case—if we assume that a hybrid purple pea, containing the contrasted characters purple and white, produces equal numbers of purple and white egg cells and pollen cells, and if we further assume that these gametes join by chance, then we should get one purple × purple zygote, one white × white zygote, and two purple × two white zygotes or one pure purple pea, one pure white pea, and two hybrid purple × white peas—which is just exactly what we do get.

Again, if we assume that a hybrid with two contrasted pairs of characters, e.g., a cross made of a tall purple pea and a short white pea, produces gametes containing all possible combinations of these (provided always that no *two* contrasted characters go to the same gamete) in equal numbers, then we ought, *ex hypothesi*, to get tall purple, short white, short purple, and tall white gametes in equal number ; and were these gametes joined by chance the conjunctions would result in 9 purple tall, 3 purple short, 3 white tall, 1 white short, which are exactly the combinations and ratios we do find.

Mendel's law a basis for inference and prediction.

Mendel's theory then gives an explanation of certain known facts, and offers a basis for inference and prediction. By the light of his theory of gametic combinations of alternative characters, we can foresee the results of any cross whose pairs of contrasted characters we know, and we can anticipate and predict simply by doing a little sum in permutations and combinations. Thus, we can foretell that by interbreeding hybrids with four pairs of contrasted characters (one member of each pair being dominant, i.e., eclipsing the other when present with it, we will obtain sixteen visibly distinct types, and we can even foretell how many of each type there will be, and how many of each will breed true to its type.

Ejection of complete set of allelomorphs at maturation.

It is pretty safe to maintain that at every maturation reduction of chromosomes a different complete set of alternative characters (or *allelomorphs,* as they have been called) are ejected, and that when the paternal and maternal chromosomes join together prior to the maturative reduction, they interchange alternative characters. Almost in no other way could the combinations and permutations be effected.

But however they are effected, they certainly seem to take place; and Mendel's theory has certainly thrown great light on the phenomena of hybridization and of hereditary transmission in general.

Bateson's eulogy of Mendel's discoveries.

Bateson, who, more than any other biologist, has developed Mendel's theory, writes: "As a consequence of the application of Mendel's principles, that vast medley of seemingly capricious facts which have been recorded as to heredity and variation is rapidly being shaped into an orderly and consistent whole. A new world of intricate order previously undreamt of is disclosed. We are thus endowed with an instrument of peculiar range and precision, and we reach to certainty in problems of physiology which we might have supposed destined to continue for ages inscrutable."

After such a discovery, it is obvious that old ideas must be revised. Systematists debating the limits of "specific rank" or the range of variability, morphologists seeking to reconstruct phylogenetic history, physiologists unravelling the interaction of bodily functions, cytologists attempting to interpret the processes of cell-division—each of these classes of naturalists must now examine the current conceptions of his study in the light of the new knowledge. The practical breeder of animals or plants, basing his methods on a determination of the Mendelian units and their properties, will, in many of his operations, be able to proceed with confidence and rapidity. Lastly, those who as evolutionists and socialists are striving for wider views of the past or of the future for living things, may by the use of Mendelian analysis attain to a new and as yet limitless horizon."

Do *all* characters mendelize?

Whether animals and plants can be regarded as exclusively built up of separate and interchangeable unit characters must be considered still an open question. "What would be left," asks Lock, "if we could imagine all the separable characters of a living creature as having been taken away? Would there or would there not be any residuum?" The question has been best answered by Weismann, who was the first to develop, in his theory of determinants, the idea of unit characters. He holds that such parts as are capable of independent variation must be regarded as unit characters separately heritable. And if we agree with this proposition we can allow very little residuum.

> "Sind nun die elemente nicht
> An dem Complex zu trennen.
> Was ist denn an dem ganzen Wicht
> Original zu nennen?"

But whether all of these unit characters *mendelize* is another story. Some biologists, indeed, maintain that mendelization is the exception, and not the rule.

It has been found that in plants, tallness and dwarfness, branching habit and unbranched habit, hairiness and glabrousness, much-serrated and little-serrated leaves, hollow and solid straw (wheat), susceptibility and resistance to rust disease (wheat), long and short styles (primula), and many other characters are inherited in the alternative manner discovered and explained by Mendel.

In animals colour-characters and a few other characters exhibit alternation in inheritance. In man "a considerable number of diseases and malformations have been shown to behave usually as dominants." "Of normal characteristics, eye-colour is the only one yet studied sufficiently to justify a positive statement as to the existence of a Mendelian system of descent."

There can be no doubt, as Professor J. A. Thomson asserts, that "as Mendel's discovery is extended it is bound to have a great influence on the breeding of animals and the cultivation of plants. Wherever it is applicable it will afford a solid basis for action, enabling the breeder to reach his desired result more surely, more rapidly, and more economically."

Illustrations of economic importance of Mendel's discoveries.

To illustrate the immense economic importance of Mendel's discovery, we may quote two cases as related by Mr. R. H. Lock, in his book, "Variation, Heredity, and Evolution."

There is much difficulty in cultivating in England varieties of wheat which produce wheat grains with the *strength* necessary for baking purposes. One of the few varieties of strong wheat that can be grown is the mixed wheat known as *Manitoba Hard*; and the variety unfortunately does not yield a large crop. To endeavour to increase its crop-yielding power, Biffen crossed it with a prolific weak English wheat—*Rough Chaff*.

The result of the cross was a hybrid which produced grains fully as *strong* as those of the Manitoba hard.

"These grains were sown, and it was found that some of the resulting plants produced strong grains, and others weak ones, and that the former were to the latter in the numerical ratio of 3 to 1.

"Samples of the strong and weak grains were sent to an expert, and were identified as Manitoba hard and weak English wheat. It was evident, therefore, that the characters, strength and weakness, had been inherited alternatively, as dominants and recessives, in Mendelian ratios.

"In the next generation, certain of the dominant plants, as was to be expected, bred true, and amongst them were individuals which combined with strength of grain the other desirable qualities of the second parent. The problem has, therefore, been completely solved, and there can be little doubt that when new types are brought into general cultivation, the profit obtainable from the growing of wheat in this country will be increased by several shillings to the acre of crop grown."

The second case related by Mr. Lock is still more striking: "Among a great number of strains of wheat grown on the Cambridge experimental farm, several types showed marked differences in the degree of their immunity from, or susceptibility to, the attacks of *Puccinia glumarum* (yellow rust). Among them Mr. Biffen found one which was apparently quite immune, and, though grown in the midst of numbers of rusted plants, itself never showed a trace of infection. Of another type, known as Michigan Bronze, no single individual ever escaped the rust, and so badly were the plants of this strain diseased that very few ripe grains could ever be obtained from them.

"Biffen crossed these two types together. In the first generation every plant without exception was badly rusted, but fortunately a considerable number of ripe grains was obtained, and these were sown to produce the second generation. When the plants of this generation had grown up, it was observed that among a majority of badly rusted plants certain individuals stood out fresh and green, being entirely free from infection. On examination it was found that every plant could be placed in one or other of two categories—either it was badly rusted, or it was entirely free from rust; and the numbers of the two kinds of plants were as follows: 1,609 infected, 523 immune.

"It is clear, then, that immunity and susceptibility to the attacks of yellow rust behave as a simple pair of Mendelian characters, immunity being recessive. And it is, therefore, possible to obtain by crossing, in three generations, a pure rust-free strain containing any other desired quality which is similarly capable of definite inheritance."

Application of Mendelian principles to breeding of animals.

Professor J. A. Thomson suggests that if Mendelism apply in the case of animals, it should be possible to re-invigorate an inbred stock by crossing it with new blood, without any risk of permanently affecting the pure breed.

But seeing that if Mendelism do apply, it would apply to a multitude of contrasted characters in the cross, and would imply the possibility of an enormous number of new zygotic combinations, it is very unlikely that the exact original combination should be reproduced again.

Indeed, this is just one of the points where Mendelian inheritance in the higher animals seems incompatible with any permanence of type, or with any consistency in selection, for unless we postulate a huge number of offspring, types very like the parents might never appear, and those that might appear might be very unlike the parents. But it is possible that this may be partially counterbalanced if, as has been suggested, the types most like their parents have greater survival value. The dwarf *Œnothera cæta* bears two kinds of pollen grains—allelomorphic with respect to tallness and dwarfness,—but only the dwarf pollen grains are functional. And such differentiation may be at work in other cases.

CHAPTER XI.

SOME CRITICISMS OF THE MENDELIAN THEORY OF HEREDITY.

Limitations of Mendelianism.

PLAUSIBLE, ingenious, illuminating though the Mendelian theory be, and valuable though some of its practical fruits be, yet it seems to have its weaknesses and limitations.

In the first place, it is difficult to conceive of any process in the course of maturation and conjugation adequate to produce the permutations and combinations which the theory implies.

More pairs of contrasted characters than chromosomes.

In the process of maturation and reduction, as we have seen, there is a selection of half of the chromosomes; and it might be assumed that at this time one of each pair of contrasted characters is reserved and the other one rejected. But there are often more pairs of contrasted characters than there are chromosomes, and therefore more possible permutations and combinations of allelomorphs than the permutations and combinations of chromosomes can effect. Further, we do not find that the most variable and most complicated organisms have the most numerous chromosomes.

Only in two ways can we get over this difficulty. We must either assume that the allelomorphs are borne both by the general cell substance (cytoplasm) and by the chromosomes, and that the allelomorphs in the cell substance segregate in some quite unknown manner, or we must assume that each chromosome carries several allelomorphs, and that the rejected and conserved chromosomes (of the reduction division) can and do interchange allelomorphs before they are divided asunder.

C. E. Walker's theory.

C. E. Walker, in his most interesting book, "Hereditary Characters," argues that racial characters are borne by the cytoplasm, and that only individual characters are borne by the chromosomes; but in the first place, it is questionable whether any valid distinction can be made between racial and individual characters (since presumably all racial characters emerged as individual characters); and in the second place, even unicellular organisms possess chromosomes; and in the third place, a very complicated division of the nucleus takes place in *every* case; and in the fourth place, even if we attribute to the chromosomes only distinctly individual variational characters, and allow for *coupled* allelomorphs, even then, in many cases, the allelomorphs outnumber the chromosomes.

The second assumption seems the more reasonable. There is little doubt that, before reduction, the two sets of chromosomes which are to be afterwards sundered do temporarily conjoin (the so-called *synapsis*), and during conjunction it is quite possible that they exchange allelomorphs they carry. This is quite a *possible* operation; but how they can arrange to make such exchanges as will produce the *equal* numbers of each combination that the theory demands, requires explanation. It must be remembered that even with four pairs of allelomorphs there are sixteen different quartets, each with a representative of every pair.

Exchange of allelomorphs during synapsis.

These difficulties are, of course, physiological or physical, and since we know little of the mechanism of cell division, and of allelomorphic distribution, we are not entitled to deny the alternation simply because it is difficult to conceive of a mechanism competent to carry it out.

But then in the case of the higher animals there are still more serious difficulties to be faced. If we grant that each gamete is a set of allelomorphs, that there are as many gametes as there are possible combinations of allelomorphs, and that the individual varies with the allelomorphs in the gamete, we assume not only an enormous number of varying individuals (which were a likely enough assumption), but unless we restrict the combinations we must also assume

Difficulties in the application of Mendelian principles in the case of higher animals.

vast differences between individuals—differences that must exceed their resemblances and must stultify the law of hereditary likeness. For instance, suppose that in the parental zygote there are the allelomorphs A, B, C, D, E, F, G, H, a, b, c, d, e, f, g, h. Then one gamete may be composed of A, B, C, D, E, F, G, h, and another of a, b, c, d, e, f, g, H.

Moreover, almost every character in the more complicated organisms must be multiplex, and must be most intricately correlated; and simple allelomorphism must be very rare. Tallness and shortness, for instance, in animals depends on a multitude of independently variable structures.

Difficulty in correlated characters.

It must be noted also that even in such comparatively simple cases as have been studied, many exceptions and discrepancies in the behaviour of crossbreeds have been discovered. Thus, in the hybrid generation, the relative dominance and recessiveness of allelomorphs in hybrids seem to depend on whether they are contributed paternally or maternally, and also seem to be affected by health, race, and environment. Further, there are the following difficulties to be faced: (1) In the progeny of some interbred hybrids only *pure* dominants and *pure* recessives occur. (2) Dominants and recessives of the second and third generation are rarely without traces of the alternative characters.

Exceptions to Mendelian law in the case of hybrids, etc.

(3) The Mendelian ratios in which dominants, hybrids, and recessives should appear in the progeny of conscentive hybrids, are often deranged. (4) In most cases of crossing we have blending, and not a mosiac of the allelomorphic type.

Archdall Reid's attitude towards Mendelianism.

In view of these and other facts, it has been maintained by Archdall Reid that inheritance of characters on Mendelian principles is the exception and not the rule, and that alternation of characters is due, not to segregation of allelomorphs in the gamete, but to alternate latency and patency of allelomorphs associated in the zygote. According to Reid, *both* allelomorphs occur in the gametes of the hybrid, but each allelomorph is alternately latent and patent.

Alternation of the sexes and of secondary sex characters.

The most familiar phenomena of alternatives is the alternation of the sexes, and of secondary sex characters. In this case it is very likely that the individual is originally dowered with the determinants of both sexes, and that in a male the female characters are latent and the male patent, while in a female the male characters are latent and the female patent. It is well known that under certain circumstances females develop secondary male characters.

" The male characters of aphides are transmitted through a long series of parthenogenetic females," and the unfertilized ova of queen bees produce male only. The hag-fish is apparently at first a male, and produces sperms, while later in life it produces ova and is functionally a female. In some species of the nematodes the female produces both eggs and sperms; while in other species the male produces both sperms and eggs.

Yet again, it seems that in some animals the sex of the offspring may be altered long after fertilization by external conditions, and, as is well known, some animals (e.g., snails, tadpoles) and many plants are hermaphrodite and produce both ova and sperm.

Both sexes potentially present in each individual.

All these facts seem to indicate that both sexes are potentially present in the individual, and that each sex is a hybrid and contains the opposite sex characters in a latent condition, and that the alternation of sex and sex characters is merely a case of alternate latency and patency. Archdall Reid, taking this view of the matter, further maintains that the Mendelian alternation is not a matter of allelomorphic separation, but merely an exceptional instance of alternate latency and patency such as occurs in the case of sex. "Now the presumption is that the inheritance of the Mendelian characters is of the same type as that of the sexual characters, and therefore, that instead of segregation and gametic purity, what really occurs is patency and latency."

Mendelian alternation merely alternate latency and patency of characters.

Reid points out that characters, which according to Mendelian law should have been eliminated from a race, often reappear when a new cross is made, and even reappear without crossing. For instance: "In purely bred races (of pigeons) of every kind known in Europe, blue birds occasionally appear having all the marks that characterize *Columba livia,* and a Sebright gold-laced bantam hen has been known to assume masculine characters derived from the first progenitors of the breed removed by a period of about sixty years."

Such reproduction of ancestral traits by pure-bred races is considered by Reid as a "decisive proof that the Mendelian phenomena are due to alternate patency and latency, not to segregation."

Reid further maintains that the majority of Mendelian characters "are sexual in the sense that, as attractions or otherwise, they are concerned with reproduction." Finally, he comes to the conclusion that the Mendelian mode of transmission is very rare, and is seen only when there are wide differences such as are arranged by breeders between mating individuals, and he maintains that Mendelian characters are merely characters abnormally reproduced in the alternative manner, in which sexual characters are reproduced, i.e., by alternate latency and patency of each allelomorph.

That Reid has made out a strong case for latency and patency cannot be denied; but, on the other hand, he has failed to explain why latency and patency should alternate with such regularity, and sometimes, at least, produce the Mendelian ratios in dominants, hybrids, and recessives.

Reid's failure to explain Mendelian ratios.

Whether his theory be right or wrong, it is pretty certain that the complex correlated mosaic of compound allelomorphs that occurs in animals cannot produce such definite simple ratios as are seen in the case of peas. So many types are theoretically possible, so many complications occur, so few offspring comparatively are born, that each family must be a law to itself, and only by extensive statistical investigations and mathematical reasoning can any general laws be discoverable.

Pearson and Mendelianism.

By such statistical investigations and mathematical reasoning, Pearson came to the conclusion that Mendelian inheritance is the exception rather than the rule.

Morgan and Mendelianism.

Quite lately, Professor T. H. Morgan has suggested that the facts of Mendelian inheritance may be interpreted as the result of quantitative differences in the representation of characters in the gametes. It would require too much space here to explain his scheme, but, as he claims, it certainly "seems to work as well as the pure gamete assumption; it avoids certain difficulties encountered by the latter; and appears to explain further a class of cases inexplicable on the pure gamete hypothesis, namely, the graded series of forms so often met with in experience and so often ignored or roughly classified by Mendelian workers." According to Morgan's suggested hypothesis, "alternate inheritance and blended inheritance appear only to be extremes of the same process."

On the whole, it appears as if the strict ratios of Mendelian inheritance only occur, and can only occur, in certain definite instances, and that the general facts of average inheritance are better explained by Weismann's hypothesis and better formulated by Galton's and Pearson's statistical results. Probably in animals true allelomorphic characters are few, though it is possible that all new characters that arise act *at first* as allelomorphs.

CHAPTER XII.

DETERMINATION OF SEX.

Two hundred and sixty-two groundless theories of sex.

In discussing Archdall Reid's criticism of Mendelism, we have already referred to the relevant question of the inheritance of sex, and have suggested one theory of sex inheritance. But in no question do more theories compete. In the time of Drelincourt there were said to be two hundred and sixty-two groundless theories of sex, and though now-a-days there may not be quite so many, yet there are quite enough to suggest that we have not yet found a true one.

Sex considered from the standpoint of Weismann's theory of determinants.

If we approach the problem from the standpoint of Weismann's theory of determinants and of the continuity of the germ-plasm, then we must assume that the unmatured sperm, being part and parcel of the same germ-plasm that grew to a male, should, under like conditions, determine a male, and that the unmatured ovum, being part and parcel of the same germ-plasm that grew to a woman, should, under like conditions, determine a female; and even after the reduction division of maturation the same sex-bias might, on the average, be assumed to obtain in a weaker or stronger degree.

On conjugation, then, the sex determinants of the two gametes, like the determinants of other characters, must compete for dominance in the zygote. Evidently the battle must be an even one, since the ancestral plasm has been built up, all down the ages, of contributions of both male and female germ-plasm; and probably the issue frequently depends on environment, and might therefore be controlled for a time by alterations in air, diet, etc. In some of the lower animals, such as bees, it is known that sex can be altered by nutritional alterations. The issue must all depend to some extent on the feminity or masculinity of the ancestral contributions. If, for instance, females have been more numerous for generations in the families of the father and mother, it is very probable that their offspring will be female. In man and the higher animals, no means of determining sex have yet been discovered, but it is always within the bounds of possibility that means may be found.

Thomson's and Geddes' theory of sex, and author's suggestion that increased oxidation might increase production of males.

Thomson and Geddes, in their standard work on the "Evolution of Sex," emphasize the fact that the male is essentially the more metabolic organism; and, while it seems rather unlikely that the metabolic activity of a zygote can be altered *after* segmentation, yet, on the principle of adaptability to possible contingencies, it seems quite possible to the writer that a quickening of metabolism in the germ-plasm during gametogenesis, by means of increased oxidation, might favour the development of determinants of male characters, and so result in a crop of gametes with male bias more marked. This, at least, is quite in keeping with Weismann's theory of intra-germinal struggle and selection.

It is not impossible that even in the newly-formed zygote, sex bias may be alterable by increase of oxidation.

It would be interesting to make experiments to test the effect of increased oxidation. For instance, animals might be given inhalations of oxygen before and during their breeding period, and spawn of various kinds might be treated with oxygenated water.

As some slight support of this notion it may be remarked that in time of war, when increased muscular activity implies increased respiratory exchange, male children seem to be more numerous, and that on the high plateaus of the South African veldt, where the dry air favours oxidation, the same preponderance of males is found. On the other hand, females always preponderate in vertebrates of low respiratory exchange, such as fishes and frogs.

In several animals it has been shown that the body-cells of the female possess at least one chromosome more than the body-cells of the

Difference in the number of chromosomes in the body-cells of the males and females of certain animals.

male. In such cases, the female has an even number of chromosomes, and the cells of the female therefore allow of the ordinary production at maturation of ova containing equal numbers of chromosomes. But the male cells, since they contain an uneven number of chromosomes, necessarily produce, when the germ-plasm divides, two kinds of sperms—one lot each containing as many chromosomes as the ova, and the other lot each containing one chromosome less. Accordingly, when a sperm containing the even number of chromosomes joins an ovum, the zygote has an even number of chromosomes, whereas when a sperm containing the uneven number of chromosomes joins an ovum, a zygote with a deficient and uneven number of chromosomes is formed. In the first case the organism develops into a female, in the second case into a male. In such cases as these, with two kinds of sperm, it is plain that the determination of sex is purely a matter of chance, and cannot be influenced unless we have means of selecting the kind of sperm.

It is stated that a relationship of this kind between chromosomes, sperms, ova, and sex has been found in over a hundred species of insects; but the facts are not quite established, and, in any case, it does not follow that such a relationship is universal.

Mendelian interpretations of sex.

Attempts have been made to interpret sex alternation on Mendelian lines, and the mode of differentiation we have just outlined certainly suggests and permits Mendelian combinations.

If, for instance, we suppose that the female is a sex hybrid and contains both male and female, and that the male is pure male, and if we suppose further that the female is dominant, then this hypothesis would be quite in accordance with many of the facts, and males and females would be produced in equal numbers, provided only that eggs of both kinds were produced in equal numbers. But the supposition fails to account for the masculinity of unfertilized eggs, since, according to this theory, the egg contains both male and female chromosomes, unless we add the further supposition that in the reduction division the female chromosome is invariably rejected by the unfertilized egg. But if we add this further supposition, then fertilization by the male which *ex hypothesi* is a *pure* male could not produce females, *which it does*.

Correns suggested that the male is hybrid, containing both male and female, and that the female is purely female, and that male is dominant to female. In this case, as in the last, the result of conjugation would evidently be to produce equal numbers of males and females. But this hypothesis would not explain the parthenogenetic production of males, for the females *ex hypothesi* do not contain male characters.

A third theory is the one we have already mentioned in connection with Archdall Reid's criticism of Mendelism, viz., that both sexes are sex hybrids—that the male contains the female, and the female the male, either male or female dominating according to the relative dominance of egg and sperm. Thus if egg were dominant, a female egg with a male sperm would produce a female hybrid, and a male egg with a female sperm would produce a male hybrid; while if the sperm were dominant, *its* sex would dominate the hybrid. This hypothesis assumes a selective conjugation wherein no male or female sperm joins an ovum of its own sex. But surely the essence of Mendelism is that it explains the ratios of various combinations as the product of *all* combinations according to the laws of chance. Further, the theory would not explain the sexes of bees. The male bee is produced by an unfertilized ovum, which is therefore presumably a male egg which has eliminated the female tendency. All the sperms of the male bee will be male accordingly. But the unfertilized egg which is male, fertilized with male sperm which is male, produces females. Which is surely a *reductio ad absurdum*.

It seems therefore impossible to find any strictly Mendelian interpretation of the facts that will satisfactorily explain sex.

For reasons which we have already noted in the previous chapter, it seems almost certain that both male and female are sexual hybrids; and though the last theory we have mentioned which assumes this hybridity is not quite satisfactory, it is probable that sex and sex determination must be interpreted and explained on such a basis.

Probably such a quantitative theory as we have deduced from Weismannism will be found most satisfactory, and Professor Morgan has lately propounded a quantitative theory that seems in accordance with the facts of the case.

Morgan's theory of sex.

In the American *Naturalist* of February, 1911, Morgan gives his theory as follows: "By means of the following formulæ we can meet the requirements that the situation seems to me to demand. If we admit that in the first class, one of the genes (sex determinant or sex chromosome) has become larger than the other female genes, and if we admit that in the second class one of the female genes has become smaller than its sister genes, we can account for the results, as the following formulæ show."

	Gametes.
F m f m = Female	F m f m
f m f m = Male	f m f m
(F denoting a larger quantity of feminity than f).	F f m m (female) and f f m m (male).

	Gametes.
F m F m = Female	F m F m
F m f m = Male	f m f m
	F F m m (female) and F m f m (males).

Both these formulæ are evidently representative relationships such as we have already suggested.

Morgan considers that they have certain advantages over those now in vogue: "First, because the male gene is not ignored as a factor in sex determination; second, that its presence, both in males and females, explains how under certain conditions the male or the female may assume the characters of the opposite sex; third, that the paradox of the female being the heterozygous form in one class and the male in the other class is, in part at least, resolved; fourth, that the ease with which species pass from the hermaphrodite condition to that of sexual dimorphism and the reverse is understandable; fifth, that the production of males by parthenogenetic females can be accounted for by the loss of one of the female genes in the polar body; and lastly, we see how there may be two kinds of eggs, as in *Dinophilus apatris*, both of which can be fertilized, for in such cases the sperms should be all alike." This is evidently a return to the quantitative theory of Weismann.

CHAPTER XIII.

THE TRANSMISSION OF ACQUIRED CHARACTERS.

Innate and acquired characters.

ALL modern theories of development and heredity draw a distinction between so-called "acquired" and so-called "innate" characters, and, round the question of the transmission of "acquired" characters, a battle royal has raged. The question is not merely academic, it is of great practical importance. "A right answer," says Herbert Spencer, "to the question whether acquired characters are or are not inherited underlies right beliefs not only in biology and psychology, but also in education, ethics, and politics."

Problem not clearly conceived nor correctly stated.

Yet, amazing to relate, the problem has seldom if ever been lucidly conceived or correctly formulated, and most of the difficulties that have prevented its solution have been due to foggy thinking and "terminological inexactitude." The moment the question is precisely defined, its answer is evident, and a thousand contradictions and perplexities vanish.

Lamarck.

Failing to see any difficulty of definition, Lamarck, the great pioneer of evolution, held that "all that has been acquired or altered in the organization of individuals during their lifetime, is conserved by generation, and transmitted to the new individuals born of those that have undergone such changes," and on this principle he could explain such progressive evolution by progressive changes due to use modifications. Thus the fleetness of deer could be explained by progressive increase of speed, generation by generation, owing to the efforts of deer to outrun their enemies. And thus the elongation of snakes could be explained: "The snakes sprang from reptiles with four extremities, but having taken up the habit of moving along the earth and concealing themselves among bushes, their bodies, owing to repeated efforts to elongate themselves and to pass through narrow spaces, have acquired a considerable length out of all proportion to their width. Since long feet would have been very useless, and short feet would have been incapable of moving their bodies, there resulted a cessation of use of these parts, which has finally caused them totally to disappear, although they were originally part of the plan of organization in these animals."

For nearly a hundred years such crude Lamarckism dominated scientific theories. Upon its foundations both Darwin and Spencer built. Spencer, indeed, went so far as to say, "Close contemplation of the facts impresses me more strongly than ever with the two alternatives—either there has been inheritance of acquired characters, or there has been no evolution."

Lamarckism fallen into disrepute.

But now, in its crude form at least, Lamarckism has quite fallen into disrepute. No one now believes that a blacksmith's son will have a larger arm because the blacksmith hammered horseshoes. No one now believes that giraffes acquired long necks because their progenitors stretched their necks to reach leaves. In such a form the doctrine is dead; it has been attacked inductively by statistics, and deductively by inferences from the development of the germ-plasm. We find, upon the one hand, that blacksmiths' sons have not progressively larger arms, and we find that the germ-plasm which goes to the making of the son was forged long before his father wielded a hammer, and could not, therefore, be affected by his father's muscles.

"Nor can the inheritance of such so-called acquired characters be supported by any theory of pangenesis. How completely the germ-plasm is removed from ordinary somatic influences is shown in many ways. Professor Castle, for instance, transplanted ovaries from a black guinea-pig to a white one previously castrated, and found that the white guinea-pig thereafter produced, in three successive litters, six young, all black."

Acquired characters and pangenesis.

Crude Lamarckism is dead, and rightly dead; but nevertheless we hold that the statement "acquired characters are not inherited" is inaccurate, and that the whole question requires redefinition and reconsideration.

All characters acquired and all characters innate.

If we accept any evolutionary theory of development, it is evident we must maintain that *all* characters are *acquired* by the ovum, in the course of its development, by interaction between its molecular chemistry and its environment; and it is equally evident that to draw a line, as is sometimes done, between congenital and post-natal characters, is to draw a line without rhyme or reason. All characters from first to last, strictly speaking, are "acquired," since no character is preformed in the ovum, and also *all* characters, strictly speaking, are innate, for any evolutionary interpretation of heredity must postulate determinants of some kind or other for *all* characters at whatever distance from the germplasm. Every character is *acquired* by development of the *innate*; every character is therefore both acquired and innate, and to draw a distinction between the acquired and the innate is to make a totally unphilosophical and unscientific distinction that must end in confusion.

Illustrations: the little water ranunculus.

Take, for instance, the case of the little water ranunculus. "In the young state the whole plant is submerged beneath the surface of the water, and bears leaves so finely divided or dissected into minute segments as to resemble a camel's-hair pencil when removed from the water. Sooner or later the growing terminal bud reaches the surface, and rises above it into the air. As soon as this happens, the rudimentary leaves just beginning to swell within the bud entirely change their course of development. They grow now into flat-lobed blades which float upon the surface of the water. The change of environment from water to air has worked such an alteration in form that no one who was not in the secret would suppose that these two kinds of leaves could possibly have been borne upon the same plant." Surely both shapes of leaf are equally innate and equally acquired.

Primula sinensis.

Again, a variety of *Primula sinensis* when kept in a moist greenhouse bears red flowers at 30° C. and white flowers at 20° C., and the same plant of clover may have leaves with five lobes and four lobes. Which is the innate and which is the acquired ?

Again, the *Papaverum somniferum monstruosum* may have 150 supernumerary carpels, or it may have only a few rudiments. Which is the innate form, which the acquired ?

Still more illuminating are such cases as these.

Herbst's and Stockard's experiments.

Herbst has shown that if the egg of a sea-urchin be reared in sea water minus magnesium sulphate and magnesium, the number and relative positions of the characteristic calcareous spicules in the larva are altered, and changes are produced in other organs. Similarly, Stockard has shown that a small excess of magnesium chloride in sea water gives rise to profound changes in the optic vesicles of the minnow, *Fundulus heteroclitus*, and in 50 per cent of the embryos produces Cyclopæan monsters.

Now, the normal structure of the sea urchin and minnow would generally be considered *innate*, and the modifications due to alterations in the sea water would generally be considered *acquired*, according to the ordinary use of the terms. But suppose that the sea usually had the composition of the water in the experiments, then we should call the modified forms innate, and the forms now considered innate we should call acquired. In the light of such illustrative cases it is obvious that all forms are equally innate and equally acquired, and that the term innate signifies merely *the more common form acquired under the more common conditions*.

All environmental effects or acquisitions are manifestations of the innate, and all manifestations of the innate are acquired through environmental stimulus.

To contrast innate and acquired characters, then, or to talk of the transmission of acquired characters as contrasted with innate characters, is absurd.

Still, there does seem to be a difference between the inheritability or transmissibility of different characters, and if it do not correspond to a difference between the acquired and innate, to what does it correspond? Such a character as a dimple is inherited, such a character as Caruso's musical larynx seems not to be inherited. Such a character as a finger-nail is inherited, such a character as an enlarged biceps seems not to be inherited.

Why apparent difference in heritability?

If all characters are innate, and therefore heritable, why then this apparent difference in heritability?

Complexity and simplicity of character.

The apparent difference is due simply to two circumstances: firstly, certain characters are simple, and certain other characters complex; secondly, certain characters are developed under the inevitable and ordinary conditions of life, and certain other characters require extraordinary and specific developmental stimuli, over and above these.

Question of specific stimulus.

The so-called acquired characters and use modifications, which are supposed by most modern biologists to be uninheritable, are, and must be, inheritable like all other characters, and the apparent failure in their inheritability is merely or mainly a failure in the specific stimulus or stimuli required to develop them.

In the case of such an inheritable organ as Caruso's larynx, so many parts are co-ordinated (e.g., lungs, rib muscles, throat muscles, respiratory centres, hearing centres), and so many stimuli are concerned in the development of each part, that the perfect hereditary transmission of all determinants and the due action of all the stimuli can hardly be expected.

Naturally, characters whose developmental stimuli are as inevitable as oxygen, and bread and butter, reappear more often and usually more early than other characters whose development depends on less instant and catholic stimuli.

A character, such as a nose, which develops as the result of the reaction between certain cells and those elements of environment necessary to life, e.g., air, food, will seem inheritable; while a character that can be evoked only by casual, incidental, or contingent stimuli will seem non-inheritable.

Accordingly, to say that a nose is inherited and the power of speech or song non-inherited, is to see very little beyond the point of one's nose. The difference is merely a difference in kind of stimuli and time of stimulation. The nose does not appear till such time as its developmental stimuli evoke it; and the power of speech or song does not appear till at a much later stage *its* stimuli evoke *it*; but both are acquired, and both are innately inheritable and inherited.

Misapprehension of question by acute scientific minds.

As an illustration of the remarkable manner in which the question of the inheritance of acquired characters has been obfuscated and misapprehended even by acute scientific minds, we may quote a passage from Kellogg's admirable work, "Darwinism To-day."

"Now," writes Kellogg, "what is the condition that exists in the body after a somatic part is modified by use or disuse or by other functional stimulus, as when a muscle is enlarged by exercise, the sole of the foot calloused by going barefoot, the ear more finely attuned by training? We have a definite physical change in a definite organ, but is the germ-plasm in any way changed or affected by this superficial or specific somatic modification, or, if changed, is it so changed that it will reproduce in its future development a similar change in the same organ of the future new individual? What possible mechanism have we in the body to produce or insure such an effect on the germ-plasm? The answer is obvious and flat; we certainly know of no such mechanism; in fact, what we do know of the relation of the germ cells to the rest of the body makes any satisfactory conception of such a mechanism as yet impossible."

These are the words of an able, lucid thinker, and yet surely in this instance he has quite lost his way. Why in the name of all that is logical should the germ-plasm be changed so that it will reproduce a similar change. Surely, if it produced the change once it will naturally produce it again. The germ-plasm is the same in son as in father, and if it produced an enlarged muscle, or a callous heel, or an attuned ear in the father, why should it require to be changed in order to produce the same modifications in the son? Under the same conditions it *will* produce the same modifications.

It is true that the modification characters will not be produced fully at once, but what characters *are* produced fully at once—hair, teeth, bones, muscles, balance—are all produced gradually under appropriate stimuli. Of course the germ-plasm contains the determinants of the modifications unless they have been lost at the maturation division, and they require no mysterious mechanism to make them develop in the children as they developed in the parents.

The point at issue, if point at issue there be, is not whether acquired characters are inherited, which is a foolish question altogether; but *whether structural and functional modifications of the body known to be primarily evoked and developed under particular specific conditions of exercise, temperature, etc., do so influence and alter the germ-plasm that in the offspring of the modified individuals the same modifications will appear under the ordinary conditions which ordinarily evoke and develop no such structural and functional modifications.*

The real point at issue.

In most cases this is certainly not so. In most cases the specific stimuli or specific conditions which have evoked a modification are still required to evoke it.

We know quite well that a blacksmith's son will not develop the muscular power of his father unless he subject his muscles to the developmental stimulus of labour. We know that the son of a sunburnt man will not develop a brown skin if he keep out of the sunlight. We know that the son of a great singer will not be able to sing unless he practise singing. We are pretty certain that the eggs of Herbst's abnormal sea urchins and Stockard's abnormal minnow will not develop similar abnormalities in normal sea water.

It seems, indeed, most unlikely that any alterations produced by specific stimuli in the body cells of an individual should so affect its germ-plasm that its offspring should develop the same modifications without the same specific stimuli. We cannot conceive how pigmentation of the skin due to light could affect the germ-plasm in such a way that future offspring should reproduce the pigmentation even in absence of sunlight. We cannot conceive how a biceps enlarged by exercise could affect the germ-plasm in such a way that future offspring should without exercise develop enlarged biceps. Such consequences must seem most unlikely now that we understand the continuity and self-containedness of the germ-plasm.

In fact it would require overwhelming evidence to establish such an anomaly as the suggested reciprocity between body and germ-plasm. For the reciprocity suggested seems to contradict the laws of cause and effect. The bodily modification is developed from certain determinants by certain stimuli, e.g., a callosity is developed on the heel by friction. In what manner then can we suppose that identical determinants in the germ-plasm can be induced by the callosity to develop to another callosity without identical or nearly identical stimuli? It is as if we were to suppose that a seed taken from a bag and sown and grown to a flower, could induce another seed to grow to flower without being sown. It is almost incredible.

Experiments to prove or disprove reciprocity between bodily modifications and germ-plasm.

Nevertheless, of late years many experiments have been made to prove or disprove this proposition of reciprocity between bodily modifications and germ-plasm, and many interesting facts have been discovered.

Experiments by Weismann and Standfuss.

Weismann and Standfuss subjected the pupæ of the small tortoise-shell butterfly to cold, and produced changes of colour in the butterflies that reappeared in their progeny even when reared at normal temperatures. Fischer obtained similar results with a moth.

But this likeness between the results exhibited in the butterfly and its progeny cannot be interpreted to mean that the modifications in the butterfly produced by cold caused such modifications of the germ-plasm that the progeny exhibited the same modifications under normal conditions. The correct interpretation of the facts is simply that the determinants (enzymes) of colour in the pupa, and the determinants of colour in the germ-plasm were similarly altered by the cold, and that in the case of the germ-plasm the alteration was perpetuated.

Tower's experiments.

Tower's experiments on the potato beetle have revealed similar facts that must be similarly interpreted.

Tower found that changes in temperature produce changes in the colour of potato beetles; but that the changes reappear under normal conditions in their offspring, only if the temperature changes act upon the imagos of the beetles *at the time the ova are being formed,* and that if one batch of ova are developed in the imago at a high temperature, and a second batch at a normal temperature, only the progeny of the former batch exhibited the colour-change—thus showing that the change of temperature affects the germ-plasm of the growing ova directly, and that the changed colour of the offspring does not mean transmission of the alterations in the parents.

Tower further found that other modifications not shown by the parents could be produced by changes in the environment of the imagos acting directly on the germ-plasm, and he also showed that some of these modifications when crossed with the parent species behaved like Mendelian allelomorphs.

All these beetle and butterfly experiments are interesting and instructive, but they do not support the idea that somatic changes due to environment affect the germ-plasm in any specific manner.

Other experiments.

Other experiments seem to give some support to the idea of such reciprocal specific influence, but the evidence is not conclusive. We may instance some of it.

(*a*). " A *Capsella* was found growing at an elevation of 2000 to 2400 metres in Asia Minor which had hairy stems 2 to 4 cm. long, xerophytic leaves, and reddish flowers. This plant had evidently been introduced from the lowlands by man along a route that has been in use for more than 2000 years. The *Capsella* of the lower plains forms a stem 30 to 40 cm. high, has whitish flowers and broad leaves ; when its seeds are taken to elevations with climates comparable to the above, individuals are developed duplicating those of the highlands, so that the characteristic features of this alpine form are clearly somatic reactions ; and that they have become fixed and fully transmissible is demonstrated by the fact that in a series of generations grown at lower levels the stem characters, as well as those of the reproductive branches and floral organs, retained their alpine acquired characters, although the leaves, as might be expected, returned to the mesophytic form with broad laminæ."

We cannot agree that the characteristic features of the alpine form are clearly direct somatic reactions. On the contrary it would be difficult to prove that they are not germ-plasm reactions to soil. And the same criticism may be made with regard to other evidence of this kind.

Woltereck's experiments.

(*b*). Woltereck, by overfeeding certain crustaceans, increased the size of their head helmets, and found that the larger helmet persisted in their offspring even under ordinary nutrient conditions.

But it is surely not unlikely that the larger helmet was merely one of the consequences of well-nourished germ-plasm, and was not in any sense transmitted to the offspring.

Sumner's experiments.

(*c*). Sumner found "that the offspring of warm-room and cold-room mice, although themselves reared under identical temperature conditions, presented differences of the same sort as had been brought about in their parents through the direct effect of temperature, viz., differences in the mean length of tail, foot, and ear."

Here again, as Sumner himself admits, both the body cells and the germ-plasm may be simultaneously altered by specific chemical substance formed in the blood under the influence of heat.

Much more evidence of like nature might be quoted, but none of it is conclusive, and it is safe to assume that "acquired characters are not transmitted," if we give that foggy phrase the only possible sense that renders transmission in any way questionable.

Interaction between body and germ-plasm.

But it must be particularly noticed that to deny such specific interaction between bodily modification and germ-plasm does not mean that there is *no* interaction between body and germ-plasm. That would be a quite impossible position. The germ-plasm, it is true, forms the body, and not the body the germ-plasm: the germ-plasm, it is true, is continuous from Adam to King George; but nevertheless the germ-plasm is kept in the body, and is fed by the body, and is in chemical relation to the body. No doubt in most cases it is amazingly stable, and no doubt it has marvellous powers of restitution when disturbed; but still there are plenty of proofs, some of which we have already quoted, that it is not charmed from changing—that it can be permanently and radically changed by changes in the chemistry of the body. Some of these induced changes no doubt are along evolutionary lines, but other changes are retrogressive and destructive. The most notorious of detrimental changes are those produced by such chemical poisons as lead and alcohol.

Lead and alcohol.

These poisons act, not by producing specific heritable variations, but rather by perverting the course of normal metabolism. But it must be realized that the resistance of the germ-plasm to poisons is two-fold. In the first place, it is not readily perverted; and in the second place, it has great restitutive capacity. Though the germ-plasm requires nourishment, its nutritional behaviour is anomalous in many ways. For a varying number of years, up to the age of puberty, it remains a constant quantity and does not multiply, whereas after puberty it is in a state of continual flux. Its nutritional conditions before and after puberty must therefore differ. It is difficult to say how far it is open to the attacks of poisons before puberty; but since it is apparently in a condition of latent or arrested vitality, it is probably almost immune. After puberty, again, its constant flux must tend to preserve it, to some extent at least, from permanent evil effects in the case of passing nutritional poisons, and it seems to be established that gametes forming at a time of toxæmia may be perverted, while those formed soon thereafter may be quite healthy. Thus, with respect to alcohol, Forel makes the following interesting statement. "The recent researches of Bezzola seem to prove that the old belief in the bad quality of children conceived during drunkenness is not without foundation. Relying on the Swiss census of 1900, in which

Resistance of germ-plasm to poisons.

Interesting statement by Forel with regard to alcohol and germ-plasm.

there figure nine thousand idiots, and after careful examination of the bulletins concerning them, this author has proved that there are two acute annual maximum periods for the conception of idiots (calculated from nine months before birth). In the wine-growing districts the maximum conception of idiots at the time of vintage is enormous, while it is almost *nil* at other periods. Moreover, these two maximum periods come at the time of the year when conception is at a minimum among the rest of the population; the maximum of normal conceptions occurring at the beginning of summer. . . . We may, therefore, assume that when a germinal cell leaves its gland at the moment when it is impregnated with alcohol, and achieves conjugation, it is unable to return to its normal condition for want of opportunity to be completely and promptly cleansed by nutrition and the circulation."

A racial poison which initiates nutritional disturbance at the time of gametogenesis may of course continue in action through the whole antenatal life, with correspondingly great degeneration of the offspring.

In the case of lead, death is the most common consequence. In extreme cases of alcoholism, epilepsy, idiocy, drunkenness, and an early tendency to crime are the most common fruits.

CHAPTER XIV.

VOLITIONAL CHARACTERS AND THEIR INHERITANCE.

> "THOU not cast'st us new
> Fresh from thy craftship, like the lilies' coats,
> But foist'st us off
> With hasty tarnished piecings negligent,
> Snippets and waste
> From old ancestral wearings,
> That have seen sorrier usage ; remainder flesh
> After our fathers' surfeits ; nay, with chinks,
> Some of us, that if speech may have free leave
> Our souls go out at elbows."

WE have already pointed out that differences in the inheritability of characters depend mainly on the relative prevalence of the stimuli required to elicit them—to develop their determinants.

Now, many of the so-called acquired characters in men are volitional : they require for their development and manifestation more or less persistent volitional impulses, and these impulses again require their own specific stimuli. But the specific stimuli of most of the higher volitional impulses are not always to hand, like air and food, and hence these volitional modifications, even though their determinants may be duly transmitted, often fail to reappear in consecutive generations. The

Variability of volitional stimuli.

variability of volitional stimuli, as compared with the inevitability of some other stimuli, readily accounts for the apparent failure of transmission of volitional characters.

Nevertheless, the characters are there *as determinants*, and may be transmitted from generation to generation till suitable stimuli again call them forth. An athletic race will remain an athletic race, even though for generations its members may be tied to office stools. A musicianly stock will readily learn music, even though a few generations have been debarred from musical opportunities.

Determinants in absence of stimuli may remain latent and be transmitted.

The fact that a volitional character is undeveloped does not mean that it is not transmitted. Individuals may be developed or undeveloped, but they transmit to their descendants the same determinants of characters, vital and volitional, that they themselves received.

On the other hand, many volitional characters are very complex, and require a number of precisely co-ordinated determinants and a number of precisely regulated stimuli for their production, and they are therefore very apt to be aborted and abbreviated in transmission, as well as badly and inadequately developed after transmission.

Complexity of volitional characters.

The only manner in which we can test and manifest the innate is by multiplying environmental stimuli; and early education should consist largely in the provision of experimental stimuli.

Mill on nature.

In his "Principles of Political Economy," Mill asserts: "Of all vulgar methods of escaping from the effects of social and moral influences on the mind, the most vulgar is that of attributing the diversities of conduct and character to inherent natural differences;" and Buckle, in his "History of Civilization," makes a similar assertion: "Whatever, therefore, the moral and intellectual progress of men may be, it resolves itself not into a progress of natural capacity, but into a progress, if I may say so, of opportunity; that is, an improvement of the circumstances under which that capacity after birth comes into play. Here then lies the gist of the whole matter. The progress is one not of internal power, but of external advantage. The child born in a civilized land is not likely, as such, to be superior to one born among barbarians; and the difference which ensues between the acts of the two children will be caused, so far as we know, solely by the pressure of external circumstances, by which I mean the surrounding opinions, knowledge, associations,—in a word, the entire mental atmosphere in which the two children are respectively nurtured."

We admit that the differences in volitional characters which, under present social conditions, *do* appear in individuals and classes, are certainly chiefly environmental: simply owing to the fact that under present social conditions the differences in mental environment are very marked. But equalization of environment would not abolish differences. Were all individuals given the same environment, and a fairly stimulating environment, the innate differences would probably be greater still. When the same education is given to a number of children, they are differentiated, not equalized. This was clearly perceived by Ruskin, who puts the case well and clearly in the following paragraphs:

Whatever stimuli provided, individual differences appear.

"Education was desired by the lower orders because they thought it would make them upper orders, and be a leveller and effacer of distinctions. They will be mightily astonished, when they really get it, to find that it is, on the contrary, the fatallest of all discerners and enforcers of distinctions; piercing even to the division of the joints and marrow, to find out wherein your body and soul are less or greater than other bodies and souls, and to sign the deed of separation with unequivocal seal."

"In the handful of shingle which you gather from the sea beach, which the indiscriminate sea, with equality of fraternal foam, has only educated to be, every one, round, you will see little difference between the noble and the mean stones. But the jeweller's trenchant education of them will tell you another story. Even the meanest will be the better for it, but the noblest so much better, that you can class the two together no more. The fair veins and colours are all clear now, and so stern is nature's intent regarding this, that not only will the polish show which is best, but the best will take most polish. You shall not merely see they have more virtue than the others, but see that more of virtue more clearly; and the less virtue there is, the more dimly you shall see what there is of it.

"And the law about education which is sorrowfullest to vulgar pride, is this—that all its gains are at compound interest, so that, as our work proceeds, every hour throws us farther behind the greater men with whom we began on equal terms. Two children go to school hand in hand, and spell for half an hour over the same page. Through all their lives never shall they spell from the same page more. One is presently a page ahead, two pages, ten pages—and evermore, though each toils equally, the interval enlarges—at birth nothing, at death infinite."

Even if such a multifarious environment were to be provided for all, as to offer stimuli for all the potentialities of each, there would be still more marked *individual differences.* Further, though there can be nothing truer than that diversities of conduct and character are often due to differences in environment, yet, in the case of man, differences in environment are themselves largely due to differences

Differences in environment largely due to differences in conduct and character.

in conduct and character. Thus, it might be supposed that the reduced stature of the industrial classes is due to bad environment; but it is probable that in most cases it is innate, and that the environment is selected by the workers because suited to their poor physique. Even granting that in the world, as we see it, many great divergencies in volitional character manifestations among individuals are due to divergencies in environment, yet it is certain that only in so far as the divergencies in character are germinal divergencies can they be permanent and progressive, and become the foundation of racial variations. Environment can certainly equalize the innately unequal and differentiate the innately equal, but such equalization and differentiation are fickle, fictitious, and superficial: the radical likenesses and differences rooted in the germ-plasm remain.

Racial value of germ-plasm a more or less fixed quantity.

Differences in character due to environment will come and go as environment changes, but the real racial value of the germ-plasm will remain more or less a fixed quantity. "The rank is but the guinea stamp, the man's the man for a' that." We may decorate or neglect our minds, but "there's a divinity that shapes our ends, rough-hew them how we will."

Relative importance of nature and nuture.

The relative importance of nurture and nature has often been debated, but it must be remembered that nurture is itself natural, and that a deficiency in the nurtural means a previous deficiency in the natural. If I bring up a monkey to eat with a knife and fork, it will not alter the fact that men and monkeys do naturally eat in different ways, and the nurturally acquired character will not be equivalent in this case to the naturally acquired character.

Πίθηκος ὁ πίθηκος κἂν χρυσᾶ ἔχῃ σάνδαλα.
A monkey remains a monkey even wearing golden sandals.

In the same way nurture by the State can never equal natural paternal and maternal nurture. In direct opposition to Buckle, therefore, we may say: "Whatever, therefore, the moral and intellectual progress of men may be, it resolves itself not so much into an improvement in the circumstances under which his natural capacity comes into play, but into a germinal improvement in the natural capacity, which again implies improvement in circumstances. The progress is not so much a progress of external advantage as of internal power. The child born of civilized parents in a civilized land is likely, as such, to be superior to one born of barbarians in the same land, and the difference between the comparable acts of the two children will be caused not so much by the pressure of external circumstances, as by innate difference in themselves and their race."

All true racial progress in volitional and other characters is germinal.

According to this theory of inheritance which we have advanced, all true racial progress in volitional, as in other characters, is germinal; and environment, though it may improve the individual, cannot directly affect the breed. The germ determinants of volitional characters being equal, the characters of adult individuals may vary within considerable limits depending on education and other volitional stimuli; but any permanent racial change must be predetermined in the germ-plasm, and volitional variations must be selected on ordinary evolutionary principles by germinal and personal selection. Individuals may do what they please with themselves; but they transmit to their descendants just what they themselves received, that is to say, determinants of characters vital and volitional.

The proposition that "acquired" characters are inherited is obviously of great importance to eugenic theory and practice. Though the meaning of the proposition is now restricted, and it maintains that there can be no progressive evolution by the volitional cultivation and augmentation of acquired characters, it nevertheless contends that the higher characters of man are inheritable, and it insists on the paramount importance for the individual, if not for the race, of their cultivation. Though it maintains that the higher volitional characters are often unmanifested, yet it must also maintain that they may be perpetuated by breeding from the fortunate individuals who do manifest them; for if, on the one hand, non-manifestation be only latency, manifestation certainly implies an inheritable primordium. What is not patent may be latent; but what is patent certainly is permanent, germinal, and heritable.

Moral significance of above interpretation.

The moral significance of this interpretation of the facts of heredity is easy to discover. The old view which explains progressive evolution as due to the inheritance of functional modifications, put posterity in respect to its higher faculties almost entirely at the mercy of the will of man. If the fathers ate sour grapes, the children's teeth were set on edge even to the third or fourth generation.

For years this view permeated sociology. Then came the modern view, that the higher acquirements are not inheritable, and that each child starts life with equal potentialities.

Between these two theories comes the theory we have propounded. Children do not start where their parents left off, nor do they start at a higher or lower level because of the acquirements of their parents; but children start in these matters where their parents started, i.e., at determinants in the germ-plasm, and start at various levels because of differentiation in germ-plasm due to germinal and personal selection during previous generations. Man cannot control the future; only the present is in his hands, and the present is a product of the past. All radical differences are due to differential division of the germ-plasm by a mechanism we do not understand.

Present-day education.

The aim of present-day education seems to be to produce uniformity by providing stimuli for such characters as men possess in common and in comparatively equal measure. The fault of present-day education is its failure to recognize the immense differences in innate potentiality, and to provide for these. Walter Scott was considered a dunce at school because he did not respond to the commonplace stimuli of education. Shelley had no use for Oxford. Newton was a fool at theology. Alfred Russel Wallace believes in spiritualists. Ehrlich was hardly able to pass his medical examinations. Darwin found the medical lectures at Edinburgh University "intolerably dull," and he registered a terrible vow, "never as long as I lived to read a book on geology, or in any way to study the science." When Tolstoi was a student at the University of Kazan, the report on his work was as follows:—

"Penal Code: Poor progress, insufficient application.
General History: Student always absent, extremely indolent.
Russian History: Student invisible, very indolent."

And yet under the right stimuli all these developed great faculties and did great work. The duty of education is first to discover the innate, and then to make the most of it, and it is folly to bind all young minds to the Procrustean bed of a rigid and regular curriculum, and to estimate brain-power by the percentage of marks made in examinations. It is true that in secondary education some provision is made for the development of diverse individual talents; but the differentiation should be made in the elementary schools, if not in the nursery.

It is the innate that mostly matters. When we considered that "*acquired characters*" so affected the germ-plasm that their acquisition in future generations was assured, or facilitated, and so long as we believed that characters could be acquired by the mind almost irrespective of the original contents of the germ-plasm, so long we were bound to put our faith in education as a means both of manufacturing the individual and the race. Then were we bound to believe that generation by generation the race could be improved by education.

Again, when the Neo-Darwinians denied even the transmission (the *transmission*, quite apart from any effect on the germ-plasm that might facilitate their transmission) of so-called acquired characters, education ceased to have much racial importance.

But *now*, when it would seem that the so-called "acquired" characters are transmitted under the same conditions as the so-called innate characters; now that we understand that acquirements do not affect the germ-plasm, and that their determinants in the germ-plasm are transmitted unchanged by any somatic developments ; now, when we realize the innate basis of the acquired, we must hold a middle position. On the one hand, we cannot believe that any education of parents will either educate their offspring or facilitate the education of their offspring; but, on the other hand, we must believe that the educational capacities of the parents are transmitted to offspring, in accordance with the ordinary laws of heredity, i.e., that the child begins just about the point at which its parents began, and is equally dependent on specific stimuli.

And this suggests the educational segregation of stirps (stocks). Between man and man, and class and class, there are often very great known differences in educability and in kinds of educability, and there can be no doubt that at present attempts are being made to educate those incapable of education. It would be well to make an attempt to differentiate between educable and uneducable children, and in making this attempt it would surely be well to take into account the known educational characters of their parents. No characters, it is true, seem so unpredicable and so capricious in their crosses as intellectual and moral characters ; but their vagaries are often superficial, due not so much to innate differences as to environmental variations, and in a broad way at least it seems pretty certain that, *ceteris* *paribus*, special abilities will be found to run in special families.

According to Pearson, we can predict mental and moral characters, and in many cases at least, pre-eminence can be shown to be inherited. But of course, in order satisfactorily and successfully to conserve intellectual characters, assortative mating is more or less necessary and more or less impossible.

Whether prediction be possible or not, discrimination is possible, and it certainly is time that educationalists realized that to cram a child's unwilling mind with facts that it neither desires nor digests, is as absurd as to try to make him an athlete by affixing artificial calves or bicipes. The mind must have natural appetite, natural assimilative vigour, natural manipulative and elaborative energy, if it is to be developed to any good purpose ; and to cram the average child's mind with Latin or geometry is about as sensible as teaching a monkey to eat with a knife and fork.

In nothing so much as in the fine arts, music, painting, sculpture, poetry, is innate difference exemplified. These intellectual characters in some cases seem to develop on the least provocation ; but in other cases no provocation will suffice to develop them.

CHAPTER XV.

HEREDITY AND EVOLUTION.

"The world was once a fluid haze of light,
Till towards the centre set the starry tides,
And eddied into suns, that, wheeling, cast
The planets." (*Tennyson.*)

"Where wast thou when I laid the foundations of the earth? Declare if thou hast understanding. Who hath laid the measures thereof, if thou knowest? Or who hath stretched the line upon it? Whereupon are the foundations thereof fastened, or who laid the corner-stone thereof, when the morning stars sang together, and all the sons of God shouted for joy?"

Evolution in the widest sense.

EVOLUTION in the widest sense of the term is the history of the genesis of the cosmos, and especially the history of the genesis of our solar system.

The earliest cosmogonies.

The first cosmogonies of all nations were merely poetical imaginings; yet many of them contained the germ of the evolutionary idea. Almost all the old Greek philosophers, for instance, considered the world, and all that is therein, as the product of growth from very embryonic and elemental beginnings. Anaximander seemed to have an intuitive notion of Spencer's heterogeneity from homogeneity; Leucippus, Democritus, Epicurus, and Lucretius even went so far as to postulate a progressive development of all things from atoms ; while Lucretius certainly had an inkling of the uniformity and sufficiency of natural law.

Descartes.

It was left to Descartes, however, in the wonderful seventeenth century, to deliver the great idea of cosmic evolution into the actual hands of Science. He maintained that, given only matter and motion, the genesis of a world having the characters and contents of the present world naturally followed.

Swedenborg.

About a hundred years later Swedenborg asserted " that the sun is the centre of a vortex ; that it rotates upon its axis ; that the solar matter concentrated itself into a belt or zone, or ring at the equator, or rather at the ecliptic ; that by the attenuation of the ring it became disrupted ; that upon the disruption parts of the matter collected into globes . . . that the globes of solar matter were projected into space ; . . . that in proportion as the igneous matter thus projected receded from the sun, it gradually experienced refrigeration and consequent condensation ; that hence followed the formation of the elements of ether, air, aqueous vapour, etc., until the planets finally reached their present orbit ; that during this period the earth experienced a succession of geological changes, which originated all the varieties in the mineral kingdom, and laid, as it were, the basis of the vegetable and afterwards of the animal kingdoms."

In 1749 was published Leibniz's "Protogæa," which taught that the earth must have been originally in a molten state, and that the present structure of the earth is due to the successive action of fire and water.

Leibniz.

In 1755 Kant enunciated his famous cosmogony; and in 1796 Laplace brought forward his famous nebular hypothesis.

Kant.
Laplace.

Thus, before the end of the eighteenth century the theory of inorganic evolution had obtained a fairly firm footing in the minds of men.

But the idea of organic evolution was of somewhat tardier growth. A crowd of thinkers—Leibniz, Spinoza, Lessing, Schelling, Kant, Diderot, Bonnet, Robinet, Oken, Treviranus, Buffon, Goethe, Erasmus Darwin, St. Hilaire, and Lamarck—all adumbrated the notion of organic evolution; but belief in special creation was very stubborn, and the audacious hypothesis was not welcomed by the world at large.

Organic evolution.

We have not space here to deal at length with these early speculations; but a representative quotation from Treviranus may be given. "In every living being," he writes, "there exists a capacity for endless diversity of form; each possesses the power of adapting its organization to the variations of the external world, and it is this power, called into activity by cosmic changes, which has enabled

Treviranus.

the simple zoophytes of the primitive world to climb to higher and higher stages of organization, and has brought endless variety into nature."

Lamarck.

The most influential of the earlier preachers of organic evolution was certainly Lamarck, who not only preached that doctrine, but endeavoured, by providing a causal explanation, to put it upon a scientific and logical basis. He was the first to develop the idea of a branching genealogical tree, and to suggest that functionally produced modifications are inherited in such a way as to lead to their progressive augmentation. As we have seen, his theory is founded on a false distinction between the functionally produced and the innate, and on a false analysis of the inter-related facts of development and inheritance; but nevertheless it had great influence on evolutionary thought, and it still struggles to survive.

Chambers' "Vestiges of Creation."

In 1844 appeared Robert Chambers' "Vestiges of the Natural History of Creation," which "contained a very clear and popularly intelligible statement of the genetic or developmental hypothesis as applied to cosmic, geological, and organic phenomena." As Merz remarks, "the publication of this book unsettled the popular mind in this country, and prepared it for a really able, dispassionate, and exhaustive exposition of the whole subject, and especially of the crucial problem to which it was narrowed down, the question regarding the fixity or variability, the historical origin and development, or the sudden creation and persistence of animal and vegetable species."

Darwin's "Origin of Species."

In 1859 the "able, dispassionate, and exhaustive exposition" appeared in the shape of Darwin's "Origin of Species."

Kellogg's epitome of Darwinism.

Darwin showed that by natural and sexual selection of variations new species might be formed. The Darwinian position is so succinctly and lucidly epitomized by Kellogg ("Darwinism To-day") that we cannot do better than quote his epitome.

"The Darwinian explanation rests on certain observed facts and on certain deductions from these facts.

"The observed facts are: (1) The increase by multiplication, in geometrical ratio, of the individuals in every species, whatever the kind of reproduction which may be peculiar to each species, whether this be simple division, sporulation, budding, parthenogenesis, conjugation, and subsequent division, or amphimixis (sexual reproduction); (2) The always apparent slight (to greater) variation in form and function existing among all individuals, even though of the same generation and brood; and (3) The transmission, with these inevitable slight variations, by the parent to its offspring of a form and physiology essentially like the parental.

" The inferred (also partly observed) facts are: (1) A lack of room and food for all these new individuals produced by geometrical multiplication, and consequently a competition (active or passive) among those individuals having any œcologic relations to one another, as for example, among those occupying the same locality, or needing the same food, or needing each other as food; (2) The probable success in this competition of those individuals whose slight differences (variations) are of such a nature as to give them an advantage over their confrères, which results in saving their life at least till they have produced offspring; and (3) The fact that these 'saved' individuals will, by virtue of the already referred to action of heredity, hand down to the offspring their advantageous condition of structure and physiology (at least as the 'mode' or most abundantly represented condition, among the offspring)."

Between individuals and species, the struggle to survive is threefold in character. "(1) An active struggle or competition with other individuals of its own kind for space in the habitat, sufficient share of the food, and opportunity to produce offspring in the way peculiar and common to its species; (2) An active or passive struggle or competition with the individuals of other species which may need the same space and food as itself, or may need *it*, or its eggs or young, for food; and (3) An active (or more usually passive) struggle with the physico-chemical external conditions of the world it lives in, as varying temperature and humidity, storms and floods, and natural catastrophes of all sorts."

"This repeated and intensive selection leads to a slow but steady and certain modification through successive generations of the form and functions of the species, a modification always towards adaptation, towards fitness, towards a moulding of the body and its behaviour to safe conformity with external conditions. The exquisite adaptation of the parts and functions of the animal and plant as we see it every day, to our infinite admiration and wonder, has all come to exist through the purely mechanical, inevitable weeding-out and selecting by Nature (by the environmental determining of what may and may not live) through uncounted generations in unreckonable time."

Since Darwin's day many have tinkered at his theory in efforts to improve it; but, if we except Wagner's and Gulick's work on the influence of isolation in the formation of species, Darwin's theory must stand or fall very much in the shape he left it.

Wagner and Gulick.

Of the plastic potency of Darwin's formative factors there can be no doubt at all. That marriage and death do select and adapt is an unquestionable fact. And yet it is probable that Darwinism and Neo-Darwinism have exaggerated

All-sufficiency of selection probably exaggerated.

the all-sufficiency of selection, and recent discoveries render it at least doubtful whether the meticulous and delicate adaptation of the parts and functions of animals and plants has been produced by a purely mechanical, inevitable weeding-out process.

To discuss the question at length would require a volume; but here we should like to point out what seem to some the main difficulties in the way of the Darwinian explanation of evolution, especially in the light of recent research in the province of heredity.

Some of the main difficulties in the way of Darwinism.

Though the theory of evolution does not depend on the adequacy of Darwin's explanation of its mechanism, yet carried to its logical conclusion the doctrine of the origin of species by natural selection does imply the evolution of the higher animals from the lower organisms.

A man, according to Darwinism, is just an amœba plus certain selected adaptive variations. But the selected variations which separate a man from an amœba are almost infinite in number, many of them are co-ordinated, many of them are non-adaptive, and most of them symmetrical.

Even supposing that all the variations are adaptive, even supposing that co-ordination may be attained by selection, would it be possible for so many adaptations to become *candidates* by chance, and could selection possibly have been so versatile and so stringent, could environment possibly have been so multitudinously differential, as to select so many differing variations? It must be remembered that Darwin postulated only those variations known as fluctuating, and though it might be possible for fluctuating variations, if selected and augmented, to build up a man from an amœba, is it possible that ten thousand fluctuating variations should each have such serial and consecutive survival value as to persist and progress through a myriad generations? In the first place, the tendency of fluctuating variations, as we have seen, is to oscillate between extremes, and to have definite limits; and in the second place, different variations must have different survival values, and out-value each other in turn, according to quite chance circumstances. Granted that the rudimentary eye fluctuates in certain directions, and that certain variations, however light, might be more useful than others, is it conceivable that their usefulness should invariably have life and death value, so that individuals should be selected by eyesight, for centuries and generations sufficient to produce man's finished eye? How do we find men selected nowadays? One by his bank account; one by his biceps; one by his club foot; one by his resistance to infantile enteritis; one by his piety; one by his impiety, and so on. How, then, can any one variation be progressively improved by selection when selection is so capricious in its criteria? Why, infantile enteritis alone would put an end to selection, that might be proceeding satisfactorily, on fifty different lines. It is almost impossible to believe that any one organ or character can have survival-value long enough, or often enough, to ensure its own elaboration and perpetuation in a complicated and varying environment, selecting now this, now that.

It must be noted, too, that adaptation is nearly always a specific and complicated matter, and that often there is no adaptation until the variation has progressed for a considerable distance. How does the right and specific *so often* and so opportunely arise when there are thousands of useless variations possible, and when the right would often seem to require much foresight and ingenuity to discover it ? How, then, are the early variations saved and selected ? How, again, has *one* world produced hundreds of thousands of species each with diverse adaptations ? Why should a moth and an armadillo, a lobster and a jelly-fish, have gone such very different ways ? And how has it happened that there are many adaptations that have arisen without selection ? For instance, among ants " it is the workers who feed and clean the helpless emerging larvæ, who put them in places of safety, who carry the pupæ into the warm sunshine, and afterwards back again to the sheltered nest, who make this nest itself, and keep it in order, after having collected or prepared the material for it ; it is they alone who defend the colony against the attacks of enemies, who undertake predatory expeditions, attacking the nests of other ants, and engaging in obstinate combats with them." But the workers do not reproduce, and therefore no selection of them can account for the adaptations they exhibit.

Retrogression to a mean.

Even if we waive all other difficulties, we must face the fact we first mentioned that the tendency of fluctuating variations is always retrogression to a mean, and, even granting that by consistent and continuous selection the mean might be raised, yet all experiments go to prove that progress in any direction is limited, and that it ceases as soon as selection ceases. By selecting sugar-beets, beets containing a higher average percentage of sugar (about double the original average) have been produced; but the maximum of variation in this respect seems to have been reached; it can only be maintained by continual selection, and, as de Vries remarks, "there is nothing which is in the remotest degree like the origin of a new species, nor anything that could lead us to expect that any form of the systematic value of a species could arise in this way." All other improved races, improved by selection of fluctuating variations, and show like limitations. "We may lay it down as a general rule," says de Vries, that a doubling or a halving of the original mean is about the most that can be attained by selection." As soon as selection ceases, there is rapid retrogression. "Continued selection by no means fixes the character chosen, but, by separating the race further from the type from which it sprang, continually adds to the risk of regression. The maintenance of an improvement depends on the continuance of selection ; for nature is continually striving to reduce the new mean to the original one. This mean is a state of equilibrium from which skilful practice can only temporarily raise the characters of a plant."

Weismann's theory of intra-germinal selection.

Weismann, seeing the difficulty of explaining progressive variation by selection of fluctuating variations, introduced the conception of intra-germinal selection. He assumes that every progressive variation is the result of accumulative nutritional advantages on the part of certain determinants. The determinants so favoured grow stronger and claim still more nourishment, and thus the tendency is for every variation to increase, provided that it is to the advantage, or at least not to the deadly disadvantage, of the animal exhibiting it. This rather theoretical explanation might account for *progressive* variation, but it does not account for the fact that variations that are *useful adaptations* are so often presented, and it does not get over the difficulty that fluctuating variations, such as differences in intra-germinal nutrition *might* produce, are, *as a fact*, found always to be at the mercy of panmixia, and are, *as a fact*, found always to be very limited in their extremes of progress.

Unless there be synchronous crops of similar variations, they are bound to be either swamped by panmixia or deleted by personal selection; for even if a variation be a useful one, twenty individuals lacking it are more likely to survive than one person possessing it. A little extra fertility, or a little extra luck, may cover and perpetuate a multitude of sins, and compensate for many disadvantages.

Further—and this is a point that has been invariably neglected—if we are to make selection the great formative factor in living bodies, why ignore the most stringent selection of all, the selection of the gamete. In the trout only two eggs in 6000 become mature fishes. In the sturgeon only two eggs in 100,000,000 reach maturity. If selection be a formative factor, surely this preliminary elimination must be of vast importance. Again, if selection has such evolutionary value, how comes it that the sturgeon has such stability of characters?

Selection of the gamete.

The fact seems to be that, on the whole, selection is very much a matter of chance, and proceeds on very erratic and inconsistent lines. The pig or squirrel that eliminates the acorn, the germ or railway accident that eliminates the man, are not at all likely to make for progress in any specific direction by the consistent selection of any specific variations; and when one considers the multitude of eliminating agents each destroying on different principles, the survival value of any slight fluctuating variation in the hands of selection seems very dubitable.

Selection by breeders not comparable to natural selection.

It is true that breeders do produce breeds by selecting certain variations ; but here selection is a *constant* factor, *always* selecting the *same* feature in the same way, and the feature is usually not one of the ordinary fluctuating variations, but what is nowadays called a *mutation.* As Darwin remarks, man " often begins his selection by some half-monstrous form, or at least by some modification prominent enough to catch the eye or to be plainly useful to him." This leads us to the question, Is it possible then that nature acts by selecting mutations, instead of by selecting " the slightest differences of structure and function," as Darwin supposed ?

Mutations.

To answer this question it will be necessary to consider the whole matter of mutations in their relevance to the origin of species, and to this we shall devote the next chapter.

CHAPTER XVI.

DE VRIES AND MUTATION.

Most variations tend to regress to a mean.

Most quantitative variations capable of precise measurement which have been investigated by biometricians have been found to be fluctuating and continuous in character, and to be distributed on each side of a mean according to the law of error; and, as we have seen, in a mixed population parents who depart from the mean produce offspring that regress towards the mean. Thus, so far as continuous fluctuating variations are concerned, species tend to be stable; and therefore, as we have already said, it is difficult to understand how continuous fluctuating variations can originate species.

Discontinuous variations or mutations.

But besides such common continuous fluctuating variations, other variations known as *discontinuous* variations or *mutations* are recognized, and have been specially defined and studied by de Vries. The essential feature of these so-called mutations is that they do not conform to the law of filial regression, but are inherited as constant characters in Mendelian fashion. They are usually larger than fluctuating variations; they are often a complex of characters: they always appear in isolated individuals (hence the term discontinuous), but their essential feature is the Mendelian unregressive manner of their inheritance. Their manner of inheritance and their isolated occurrence suggest a radical distinction between them and continuous variations. Continuous variations are just such oscillating variations as we should expect to occur in almost identical determinants under the oscillating stimulation of everyday environment, and they behave in heredity as we should expect such environmental variations to behave, i.e., they oscillate within definite limits and tend to preserve an average. Mutations, on the other hand, are just such variations as we should expect to occur through actual alteration in the germ-plasm, and they behave in heredity as we should expect such germinal idiosyncrasies to behave, i.e., they occur only discontinuously in isolated individuals, and in crosses they mendelize.

Essential feature of mutations.

In a criticism of de Vries' theory of mutations, F. A. Dixey objects: "To say with de Vries that selection of individual differences is powerless to raise permanently the mean of a species, seems perilously like begging the question. As soon as the mean has been permanently raised, the result would be claimed as a mutation." But there is no begging the question; since the biome-

Dixey's objection.

tricians have proved that individual differences *do* fluctuate about a mean, and therefore cannot be permanently raised.

Mutations suggested long ago.

The notion of mutations in the sense of permanent saltations was suggested long ago. Lock quotes a writer, Dr. Thomas Browne, who as long ago as 1650 wrote: "We may say that men became black in the same manner that some foxes, squirrels, lions, first turned of this complection, whereof there are a constant sort in diverse countries; that some chaughes came to have red legges and bills, that crows became pyed; all which *mutations*, however they began, depend upon durable foundations, and such as may continue forever."

Huxley.

Huxley, too, had an inkling of the same fact, for in a review of "The Origin of Species," he says: Mr. Darwin's position might, we think, have been even stronger than it is if he had not embarrassed himself with the aphorism, 'Natura non facit saltum,' which turns up so often in his pages. We believe . . . that Nature does make jumps now and then, and a recognition of the fact is of no small importance in disposing of many minor objections to the doctrine of transmutation."

Galton.

Still more definite and accurate was Galton's idea of stable and unstable variations illustrated by a polygon pushed over on to consecutive faces.

But it was de Vries who first clearly conceived the existence of mutations as we have defined them, and who first clearly formulated the proposition that such mutations are the formative factors of varieties and species.

There can be little doubt that continuous variations are merely differences of germinal response to a fluctuating environment, and that no process of selection applied to such variations can originate new permanent varieties or species. And there can be little doubt also that the discontinuous variations or mutations imply actual germinal alterations, and are therefore permanent, and therefore can and do originate new varieties and new species. If a single character mutate, a new variety is produced: if a set of characters mutate, a new species is produced.

The evening primrose.

De Vries, indeed, observed new species in the act of originating. In a disused potato field near Hilversum he found a species of the evening primrose, *Œnothera Lamarckiana*, in the act of mutating. He selected nine plants, planted them in the botanical garden in Amsterdam, and sowed their seeds. In seven generations he grew from seed 50,000 plants, and of these 800 were mutants, which could be classed in seven new species.

De Vries' laws of mutation.

From a study of these mutants he formulated the following laws of mutation: (1) New elementary species arise suddenly, without transitional forms; (2) New elementary species are, as a rule, absolutely constant from the moment they arise; (3) New elementary species appear in large numbers at the same time, or at any rate during the same period; (4) The mutations to which the origin of new elementary species is due appear to be indefinite; that is to say, the changes may affect all organs and seem to take place in almost every conceivable direction; (5) Mutability appears periodically.

No observations can compare with de Vries' in scope and thoroughness, but of course several other cases of species produced by mutations are known. The Shirley poppy, for instance, arose suddenly without transitional forms; and McDougal has produced mutants artificially by injecting weak solutions of different chemical substances into the seed capsules of plants. Classical examples of mutations in animals mentioned by Darwin are the Ancon and Mauchamp sheep.

Examples of mutation.

"In some few instances new breeds have suddenly originated; thus in 1791 a ram-lamb was born in Massachusetts having short crooked legs and a long back like a turnspit dog. From this one lamb the *otter*, or *ancon*, a semi-monstrous breed was raised. As these sheep could not leap over the fences, it was thought they would be valuable, but they have been supplanted by merinos, and thus exterminated. The sheep are remarkable from transmitting their characters so truly that Colonel Humphreys never heard of 'but one questionable case' of an ancon ram and ewe not producing ancon offspring When they are crossed with other breeds, the offspring, with rare exceptions, instead of being intermediate in character, perfectly resemble either parent ; even one of the twins has resembled one parent and the second the other. Lastly, the ancons have been observed to keep together, separating themselves from the rest of the flock when put into enclosures with other sheep.' "

"A more interesting case has been recorded in the Report of the Juries for the Great Exhibition (1851), namely, the production of a merino ram lamb on the Mauchamp farm, in 1828, which was remarkable for its long, smooth, straight, and silky wool. By the year 1833 M. Graux had raised rams enough to serve his whole flock, and after a few more years he was able to sell stock of his new breed. So peculiar and valuable is the wool, that it sells at 25 per cent above the best merino wool : even the fleeces of half-bred animals are valuable, and are known in France as Mauchamp-merino."

Other cases of well-known mutations are the hornless Paraguay cattle and the polled Herefords ; and within recent years Castle has been able to establish races of mutant four-toed and mutant long-haired guinea-pigs. Most of the races, too, of domesticated animals are certainly mutations selected by man.

McDougal's summary of his experiments.

In some cases, as in McDougal's injections and Tower's experiments with beetles, and Gager's experiments with œnothera, the disturbing factors which give rise to mutations are actually known. McDougal summarizes his experiments thus: "The action of reagents, having an osmotic and a chemical effect, has resulted in the induction of mutants in the progeny of *Raimannia odorata* and *Œnothera biennis*. The mutants thus induced have been tested to the second and third generation, and found to come true to their newly assumed characters.

"The induction of mutants by the action of reagents is a conclusive demonstration of the fact that hereditary characters may be altered by external forces acting directly upon the reproductive mechanism. The action of the re-agents used experimentally is simulated by many conditions occurring in nature."

Tower's summary of his experiments.

And Tower thus summarizes his experiments on beetles: "I conclude in the light of these experiments that the production of heritable variations, slight or extreme, represents in these beetles the response of germ-plasm to stimuli. In my experiments these stimuli were external, but there is no *a priori* reason why they might not also be internal."

Known instances of mutations are comparatively few, and we might be inclined to hold with Kellogg that "species-forming by sports and discontinuous variations is obviously no theory to presume to offer itself as a species-forming substitute for natural selection." But the proof of the pudding is not its size but the eating of it; and it is certain that mutations do in some cases produce species, and it is almost certain that continuous variations are incompetent to produce them. Whether mutations be many or few, it is obvious that only germinal alterations such as they are defined to be can produce permanent heritable varieties and species.

A *heritable* difference of response to the same environment constitutes the difference between two species, and the origination of a heritable difference of response implies mutation in the original germ-plasm; and, if organic evolution be a fact, all the heritable differentiating characters between species and species must have arisen, as mutants, from mutating germ-plasm.

Probably species have their mutating periods—the germ-plasm remains unchanged for a certain time and then undergoes kaleidoscopic changes, and probably at mutating times there is a crop of the same mutants.

It does not seem to have been noticed that if evolution proceed by mutation, embryonic growth must also proceed by mutation, and that the differentiation of the zygote into the various cells represents a process of mutation. Certainly, in consistency, the changes, the *heritable* changes, that must have taken place when a unicellular organism became a multicellular organism, and when the cells of multicellular organisms began to differentiate into unlike cells, could hardly be called instances of continuous variation, and must surely be regarded as mutational. And if cellular differentiation be mutation, it would almost seem as if the essence of mutation was differential division of the germ-plasm. It is a bold theory, but the writer suggests that the evolution of a multicellular organism illustrates the evolution by mutation of species. Even as a certain somatic cell after a certain number of proliferations gives birth to mutants (liver cells, or nerve cells, or any other kind of cell, as the case may be), so the germ-plasm periodically mutates, and gives birth to mutants which originate varieties and species. Why the somatic cell mutates we do not know; but we have suggested in a previous chapter that it is due to chemical and nutritional stimuli; and there seems a certain amount of evidence (e.g., McDougal's experiments with injection) which suggests a similar cause for germinal mutation. The different cell groups of the body then may be regarded as different species produced by mutation.

The majority of known mutations are larger than the infinitesimally small continuous variations, but there are doubtless many small mutations that have not been detected, and in a few cases they may exhibit a sort of continuous serial succession, and be difficult to distinguish from the continuous fluctuating variations to which they themselves are subject. It is indeed probably the admixture of continuous fluctuating variations with small mutations that renders statistical analysis so difficult to interpret.

Johannsen.

Johannsen has recently shown that populations of plants are composed of the fluctuating progenies of many mutants. Considered in aggregate, they show continuous variation; but individual groups have their own particular mode and their own limits of variation, and these are constant. The apparently continuous variation is due simply to the overlapping environmental fluctuations of small mutations. In such a case, if we can isolate mutants at either end of the scale, they breed true to their own mode, and will not fluctuate back to the mean of the mixed population.

The theory of mutations is essentially a theory of species formation by the addition of unit characters. Since these unit-characters appear in only one or in very few individuals, they must usually (unless in hermaphroditic forms) cross with unmutated forms. Now what will happen in such crosses? What chance of survival will the mutant have, provided always it is fit to propagate and fit to survive till its

How will mutants survive in crosses?

propagative maturity? When the unit character crosses with the parent species, it must act either as a dominant or as a recessive, and will reappear in Mendelian proportions, and if it be not detrimental to the individuals possessing it, will in time take a place in the world's population.

CHAPTER XVII.

ADAPTATION AND EVOLUTION.

"Was wär ein Gott der nur von aussen stiesse,
Im Kreiss das all am Finger laufen liesse,
Ihm ziemt die Welt im Innern zu bewegen.
Natur in Sich, Sich in Natur zu hegen,
So dass was in ihm lebt und webt und ist
Nie seine Kraft, nie seine Geist vermisst."
(*Goethe.*)

"There's a divinity that shapes our ends,
Rough-hew them how we will."

Each species essentially a bundle of adaptations.

WHATEVER evolution be, it is more than a mere cumulative addition of new characters, for each species is essentially a bundle of adaptations, and adaptation has to be explained. The great attraction of the Darwinian theory of natural selection was just that it seemed to offer an explanation of adaptations. According to Darwinism, the germ-plasm made minute tentative variations; and, in the long run, variations of vital advantage that favoured the life or matrimonial career of their owners were by that very fact more frequently propagated; while variations that were of vital disadvantage to their owners were by that very fact less frequently propagated. Thus, by degrees, the right variations or adaptations would be added and augmented, and give rise to new species.

We have seen that the great difficulty in the way of the Darwinian theory lay in the selection and conservation of characters which in their incipient stages could have had no survival value, and that even if we accept the Weismannian hypothesis of intragerminal selection, we are faced with a still greater difficulty—the difficulty of finding differences in environment sufficient to give such different *life and death* value to variations as separately to select the thousands of divers adaptations and bundles of adaptations we find in plants and animals. We have seen that even if fluctuating variations were capable of indefinite progression, as Weismann suggests, there is not, in the world, machinery of selection at once consistent enough, and multiform enough, to *select* all the varying adaptive characters of different species. At best, Darwinian selection would be fitful and fickle; it would destroy to-morrow by fire what it had selected yesterday by water.

Still further, we have seen that even if there were environmental machinery able to select to such good purpose as to select a man from the fluctuating variations of an amœba, we should be merely transferring the miraculous from the germ-plasm to its environment, and the environmental machinery would surely require explanation, as much as the mould of a coin.

Suppose that a man's face and figure in silhouette were to appear on this page, and I were to say that it was not designed, since the ink had been spilt by chance and had formed an amœbiform blot from which the face and figure had been elaborated by elimination and selection, would my explanation be an explanation at all? How then can any theories of environmental selection presume to offer a similar explanation of much more wonderful apparitions?

Plausible and fascinating though the Darwin-Wallace theory of selection be, it is not sound, it is not satisfactory; for fluctuating variations *will* fluctuate, and even if they did not, neither marriage nor death possesses sufficiently sharp and potent tools to differentiate about a million species of animals and plants. Darwinian selection in the hands of man and in the hands of Nature can do much, but not all that evolution requires.

Giving up, then, the Darwinian theory of evolution by selection of fluctuating variations, let us see whether de Vries' mutations offer a better explanation of the adaptational differences which divide species.

The conception of evolution by mutations surmounts certain difficulties which are stumbling-blocks to the Neo-Darwinian hypothesis. It explains the persistence of useless characters, which selection on Darwinian principles would fail to conserve. It explains the occurrence of complicated and co-ordinated characters which, according to Darwinian principles, could not have been built up gradually, because as rudiments their elements could not have had survival value, or at least consistent and coincident survival value.

Further, since we have defined *mutations* as germinal variations, and since, granted the same or a similar environment, germinal variations persist and mendelize, mutations are inherited not regressively but *in toto*, and are therefore competent to originate such permanent inheritable differences as differentiate species. Permanent differences of indefinite degree they *ex hypothesi* are, and any number of species might be formed by means of them, but the question remains, why should the variations so often take *adaptational* form? why should they show such versatile adaptability to diverse contingencies and sometimes to contingencies far ahead?

Mutations competent to originate permanent inheritable differences such as differentiate species.

According to the theory of mutations, every species represents a mutation, and every mutation represents a species; and therefore, if there have been any selection at all, it must have been a selection of species, and if we are to explain adaptation by selection, we can only explain the adaptational character of species by assuming that organisms exhibit mutation in all directions, and that selection eliminates the unfit mutations, thus giving species adaptational characters, and causing discontinuity between them. In such a case mutations would play the same part as fluctuations. But we have no evidence of indiscriminate mutability in all comparable directions. On the contrary, almost all the evidence we have points to single and sudden mutations—the only exceptions being the mutations known as "pure lines," which certainly resemble continuous fluctuations.

No evidence of indiscriminate mutability.

Indiscriminate mutations, moreover, would allow much more latitude to variation than we find to be the case; for since we know that mutations breed true, and are inherited without regression, the result of indiscriminate mutation would be a continual crop of progressive, unadaptational monstrosities that would in time be eliminated, but which, under conditions of less stringent selection, might persist for generations. There are about 400,000 known species of plants, but we do not find that an oak tree ever mutates in a single leaf to a rose tree, nor do we find such inter-racial interchange of mutations as indiscriminate mutation would imply. Since, according to the theory of indiscriminate mutation, all the characters of all species are indiscriminate mutations of one original germ-plasm, it seems strange that such a multitude of species, when formed, should be so mutually exclusive, and so little apt tentatively to repeat each other's mutations. But even if we assume indiscriminate mutations weeded by selection, we are met by the same difficulties which confronted us in the case of fluctuating variations, and in the end put such responsibility on selection as only an infinite Mind could exercise.

When we consider the tremendous variety of *means* to an end or an adaptation, when we consider the ingenuity and complexity of adaptations, we feel that they can have been brought about only as human adaptations are brought about, e.g., by prescience, and by consciousness of an end to be attained. It is inconceivable that a reptile's scale could be mutated into a bird's feather by any chance selection of chance mutations, even if all the elective and eliminative capacity of natural processes were for thousands of years focussed and concentrated on selection of the features of the feather from the variations of a scale. No doubt the word Archæopteryx *could* be mutated into the word Pterodactyle simply by mutating and selecting letters ; but one cannot believe that the mutation could be actually effected unless either the mutation or the selection were teleological and in the hands of mind. And in the case of a feather, and of most of the adaptations of life, the mutation equally seems to require mind. And when we consider any adaptation in all its adaptational relations, the necessity of a directive power and of a mind seem even more evident. One has only to read Alfred Russel

Ingenuity and complexity of adaptations suggest a mind at work.

Wallace's description of the mystery and marvel of feathers to realize this. He points out "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." He points out, too, the exquisite perfection of the barbs and barbules of the feather. "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." The feathers "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 shelter from violent storms and blizzards. Yet,

The mystery and marvel of feathers.

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." Further, since the feathers are apt to experience wear and tear, provision is made for their renewal by the process of moulting, which is itself arranged so as to take place without destroying power of flight. Weismann adds the remarkable fact discovered by Sigmund Exner, "that the feathers become positively electric in their superficial layer, and negatively electric in their deeper layer, whenever they rub against one another and strike the air. But they are rubbed whenever the bird flies or moves, and the consequence of the contrast in the electric charging of the two layers is that the covering feathers are closely apposed over the down-feathers, while, on the other hand, the similar charging of the down-feathers makes them mutually repel each other, with the result that a layer of air is retained between them, and thus there is between the skin and the covering feathers a loose thicket of feathers uniformly penetrated by air—the most effective warmth preserver imaginable."

Now, is it conceivable that these millions of barbs and barbules arranged with such precision to such good purpose, and that utilization of electrical phenomena, should be the result of natural selection acting upon chance mutations in reptilian scales?

Mutations of a scale could have had no survival value unless they were already feathers in co-ordination with a very complicated muscular mechanism. The mutations that could make a bird of a reptile must have been immense, ingenious, and miraculous. And, after all, why call in selection in a vain endeavour to explain away a miracle, when every day we see the same miracle performed, in the development of a feather from an epithelial scale (since as an epithelial scale all feathers commence). The mere statement that it has been transmitted by heredity in no wise explains the mechanism of the transmutation or makes the second and third growth more explicable than the first. Mutations occur in the same way that growth occurs, and we must explain growth to explain mutation, and explain mutation to explain growth. Why does an epithelial scale grow into a feather now, and why did an epithelial scale mutate into feathers æons ago, are cognate questions and cognate mysteries. But certain it seems to be that mutations take place not altogether at random, and almost always with reference to the eternal fitness of the variation to the circumstances of the case. We do not find that the epithelial scales of a man tentatively mutate to feathers.

Mutations almost always suitable to the exigencies of the case.

All through nature we see apparent prescience of contingencies; and the variations that occur are seldom or never monstrous or incongruous, but have always reference to the particular nature of the organism and of its environment.

Thus, it has been discovered that many deep-sea animals have luminous organs, sometimes merely glands that secrete a luminous substance, sometimes "complex organs, 'lanterns' which are controlled by the will of the animal, and suddenly evolve a beam of light and project it in a particular direction, like an electric searchlight." In crustaceans, shrimps, molluscs, and many fishes such organs are found . . . . "one species of cephalopod has about twenty large luminous organs, like gleaming jewels, ultramarine, ruby-red, sky-blue, and silvery, while in another the whole surface of the belly is dotted over with little pearl-like luminous organs."

Instances of suitability of characters to the circumstances.

Weismann declares: "That this sort of structure should have arisen all at once through a 'mutation' is inconceivable; it can have originated only from simple beginnings by a gradual increase of its structure, along with continual strict selection among the variations which cropped up. They all depend upon complicated 'harmonious' adaptations, and cannot possibly have been derived from mutations, that is, from ready-made structural 'constellations,' unless we are to call in the aid of the miraculous." But, as we have already indicated, selection of fluctuating variations could never select such organs. In their beginning they could not have had exclusive life and death value, and could not therefore have been material for stringent selection. We have to explain not only their complicated harmony, but their *opportune* appearance. We do not find that dogs, and cats, and men, or even shallow-water fishes, exhibit such startling mutations: only those animals to whom such mutations have utility. It is perfectly true that in dogs and cats such luminosity might be fatal; but still, does nature seem even tentatively to produce it? Mutation therefore seems not to be indiscriminate, but in most cases quite discriminating. We have, in any case, whether we choose fluctuations, or mutations, "to call in the aid of the miraculous," and the mere fact that fluctuations may seem less miraculous is no reason to ignore their incompetence.

Take, again, the other case of deep-sea adaptation cited by Weismann. Many deep-sea fishes have enormous eyes, or eyes elongated into cylinders which project far beyond the level of the head. We must, as we have seen, surrender Weismann's theory of selection of fluctuations, and must assume that these eyes have been produced by mutations; but how did mutations hit upon the very variation required to adapt the eyes to the dim luminosity of the deep sea? We do not find such mutations in whales, or elephants, or guinea-pigs. We must call in the aid of the miraculous.

Or take the case of the whale. We find the whale to be a mountain of adaptations. Its ancestors, according to theory, had four legs and a coat of hair; but the modern whale has fore-legs transformed into flippers, and hind-legs reduced to rudiments, and a hairless skin. It is spindle-shaped like a fish, and has an enormous tail-fin. The muscles of its ears have disappeared: its teeth are rudimentary, its nostrils are in its forehead, it has an enormous mouth cavity. All these and many other features are adaptations to aquatic life. But if they arose by mutation, how came it that they all arose in the right animal at the right time? We must call in the aid of the miraculous.

Or take a more striking instance still. The caterpillar "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 organized creature both externally and internally—a creature comparable in organization with the bird itself."—("The World of Life," A. Russel Wallace).

Now here is an amazing revolution—a butterfly constructed from the *débris* of a caterpillar! The caterpillar is not transformed by the selection of fluctuations or mutations into a butterfly: it is broken down—the whole of its internal organs—muscles, intestines, nerves, respiratory tubes, etc., are broken up into a creamy pulp. And the most extraordinary feature of the case is that they are dissolved by the caterpillar's own white blood corpuscles, and serve as food for the growing butterfly, which develops from a few cells of the larva left intact amid the general dissolution.

By what possible chance mutations could such phenomena be produced? Could it be the result of an indiscriminate mutation that the white blood corpuscles should dissolve all the elaborate structure of the larva and leave the germs of the butterfly intact? Could it be a mere chance coincidence that the detritus serves as food for the growing butterfly? The man who is able to believe that such concatenations to an end are mere chance coincidences selected by the exigencies of environment, the man who can believe that such a conspiracy of toward events is a matter merely of chance mutations and lucky hits, seems to us to be beyond the reach of reason. Mutations are just as likely to work together to such an end as letters tumbled at random out of a box are likely to compose a poem. There is prescience and a mysterious architectonic principle behind all organic changes. Chance and coincidence are insufficient explanation of co-ordination to an end of adaptation to contingencies. The white blood corpuscles devour the larva under exactly the same impulse as impels the stars—the impulse of a Will.

Instances of adaptations which cannot be explained by selection of mutations are also well seen in the adaptations of carnivorous plants.

Some more remarkable adaptations.

The bladderworts, plants which float on the water, have some leaves under the water modified into traps to catch small water animals. The traps are hollow bladders with a narrow neck. Bristle-like hairs project outwards from the neck and keep out larger animals, and within the orifice is a valve opening inwards but not outwards, so that when small animals such as water-fleas enter they are trapped. The trapped insects are digested by special cells and serve to nourish the plant.

In the case of the pitcher-plant, *Nepenthes villosa*, the gorgeous colour of the pitcher-shaped flower and the honey it contains attract insects, "but the thick, swollen rim of the pitcher is as smooth as if it were made of polished wax, and resembles the petals of those magnificent large orchids the *Stanhopeæ*. The inner surface of the pitcher below the margin is also smooth, so that insects which creep about seeking honey are apt to slip and fall to the bottom. Even if many of them are not at once killed by the digestive fluid, but are able to climb up the smooth wall again, they cannot escape, for beneath the swollen rim, which projects inwards, there is a circle of strong bristles or teeth, with the points directed downwards, which, like thorns, prevent the captives' escape. Thus the pitchers of *Nepenthes* secure and digest a large number of insects." In Borneo a little lemur learned to attract insects from the pitcher, and one species of the pitcher plant grows two strong prickles from the lower side of the base of the lid—surely a remarkably opportune mutation!

The sundew (*Drosera rotundifolia*) has another way of trapping insects. All over its leaves are set hairs like pins in a pincushion. On the head of each pinlike hair is a dew-like drop of sticky fluid. When insects settle on a hair they are caught by the sticky fluid, and all the hairs round the insect bend towards it and embrace it and pour digestive juice upon it.

The Venus's fly-trap (*Dionæa muscipula*) shows even more remarkable adaptations. The two halves of a leaf hinge on the midrib, and gently close together if an insect touch one of six jointed hairs that grow upon them. The edges of each half of the leaf bear strong spinous processes, and when the leaf shuts up, the spinous processes of each half interlock like fingers of two hands. Insects are thus securely trapped, and are then digested by a digestive juice secreted by glands in the leaf.

These are certainly remarkable adaptations, and it seems to us quite impossible to explain them by assuming chance mutations, since the adaptation is complex and co-ordinated, consisting of co-operative parts and functions that could not possibly have come together by mere coincidence. Why did they all crop up together just where they happen to be useful? There would not be much use for traps unless there were flies to catch, not much use in catching flies unless there were digestive juice to digest them. In every case there seems a logical nexus between the parts and functions, and also an intelligent and ingenious anticipation of correspondences and contingencies such as the human mind is wont to exercise.

In a word, then, if we are to accept evolution by mutation—and accept it we must—we must also accept the miraculous, which Darwinism for a time more or less successfully evaded.

CHAPTER XVIII.

ADAPTATION AND EVOLUTION.—*Continued.*

"Wer kann der Raupe die am Zweige kriecht
Von ihrem Künft'gen Futter sprechen,
Und wer der Puppe die am Boden liegt.
Die zarte Schale helfen durchzubrechen?
Es kommt die Zeit, sie drängt sich selber los,
Und eilt auf Fittigen der Rose in den Schooss."

(*Goethe.*)

We cited in the last chapter several cases of extraordinary adaptative co-ordination, but nature is full of them—full of organisms with functions and structures which singly are useless, and which are of utility only when completed by other functions and structures, which chance mutations, even assisted by selection, could never have associated into their effective complexes. All the universe, indeed, may be rightly considered just such an integrated, co-operative, co-ordinated complex: "Seven snowdrops sister the Pleiads," and "You cannot touch a flower without troubling of a star."

Sitaris humeralis beetle.

Take the well-known case of the *Sitaris humeralis* beetle. The female beetle lays about 2000 eggs near the entrance to the nest of a burrowing bee. The larvæ have six legs, and are able to spring actively. When any hairy insect approaches they spring upon it, and cling to its hairs, and naturally a few larvæ become attached to female bees. The female bee builds a cell, fills it with honey, and lays an egg upon it, whereupon the clinging larva leaves the bee, and attaches itself to the egg, and eats it. Having eaten the egg it becomes changed into a form like a vesicle adapted for floating, with breathing tubes on its upper surface. Thus it escapes drowning, and is able to devour the honey at its leisure. Having finished the honey, it becomes metamorphosed once or twice again, and finally becomes a mature beetle.

Now mark all the factors working to a far-off end, and all requisite to the final result—the large number of eggs, the place where they are deposited, the agility of the larvæ, the strange instincts that make them leap to hairy insects, and that make them leave the bee and eat first the egg and then the honey, the adaptation to a floating life, etc. Unless all these things worked together, each would be useless. But how did such remarkable co-adaptations in habits, functions, and structures appear so opportunely, so coincidently and co-ordinately in bee and in larva? The facts really could not be explained by Darwinism, and still less can they be explained by mutations. How *can* the ingenious and far-fetched way in which the beetle gets an egg and honey diet for its larva—how can the way in which the larva rises to the occasion—be chance mutations? They presuppose mind, and a knowledge surpassing the knowledge of man.

The Yucca and the moth Pronuba.

Look again at the most remarkable co-adaptation between the plant yucca and the moth Pronuba. It is thus described by C. E. Gibson ("Hereditary Characters"): "The Yucca has a large white flower, which emits a strong perfume, particularly at night, when it is visited by the moths. The female at first collects the pollen. This she rolls into a pellet, using for this purpose maxillary appendages specially modified and found only in this genus. She continues doing this until she has made a pellet about three times as large as her head. She then proceeds to lay her eggs inside the ovary of *another* flower. She does this by means of an ovipositor, which is sufficiently sharp to penetrate the tissues of the ovary and sufficiently long to reach the inside. Having deposited her eggs, she climbs up the stigma, the natural entrance to the interior of the ovary, into which she presses the ball of pollen, thus sealing it up. Of course this also fertilizes the ovules, and, moreover, as she always lays her eggs in a different flower from that which yielded the pollen, cross-fertilization is secured. The moth lays only a few eggs in each ovary, which hatch out into larvæ, which feed upon the fertilized ovules of the yucca. As, however, the ovules of the plant are very numerous, there are plenty, both to provide food for the larvæ of the moth, and also for the reproduction of the plant."

It is quite plain that the moth could not have reached success in such a complicated matter by any process of chance mutations. By no lucky hit could it ever make a ball of pollen and press it upon a stigma so as to provide food for eggs previously deposited. The moth might mutate in its habits till doomsday before it hit on such a concatenation of fruitful actions, and we are compelled to compare its behaviour with the behaviour of a thinking being. Certainly the moth does not think and scheme. But some Mind does.

Pupation.

Or take the adaptations of pupation as described so well by Weismann ("Evolution Theory"). "The caterpillar first spins, in a suitable place, a small round disk of silk threads, to which it then attaches the posterior end of its body so securely that it cannot be easily torn away. More complicated still is the securing of the pupa when it does not hang freely, but is to be pressed against a wall or a tree, as is the case in the Papilionidæ and the Pieridæ. In this case the caterpillar must, in addition to the usual cradle, spin a thread of silk, in an ingenious way diagonally across the thorax, so that it may cross about the middle of the wing rudiments, and not be too loose lest the pupa fall out, yet not too tight lest the thread cut too deeply into the wing rudiments." By what possible mutations in structure can the thread of silk come so usefully into being, and by what possible mutations of spinning can the caterpillar learn to use it so skilfully and with such foresight? And why should the silk and the weaving power appear together?

Stag beetle.

More wonderful still is the case of the stag beetle. It "undergoes its pupal metamorphosis in the earth and makes a large hard ball of clay, hollow inside, and as smooth as if polished, and its cavity is exactly the size of the future pupa, or, to speak more precisely, of the fully-formed beetle. For, as Rosel von Rosenhof in his day 'observed with amazement,' the balls in which the males lie have a much larger cavity than those built by the females, and for this reason, that when the fully-formed beetle emerges from the pupa it must, if it be a male, have room to stretch out its horns, which have till then laid upon its breast. . . . The male larva thus makes a much longer pupa-house than the female larva in anticipation, so to speak, of the enormous size of the jaws which will grow out later!" Could such prescient preparation for coming events be merely a chance mutation?

"Not less significant is the case of the silk-cocoons. The cocoons spun by the silkworm are egg-shaped, and consist of a single thread many thousand yards in length, which is wound round the spinning caterpillar so that not a space is left uncovered. The web is firm, tough, and very difficult to tear; therefore we must grant that the pupa resting within will enjoy a very considerable degree of security against injury. But the moth must be able to get out, and that this may be possible, the caterpillar is impelled by instinct to make its spinning movements such that the cocoon is eventually looser at the anterior end, so that the insect, when it is ready to emerge, can tear it asunder with its feet and make a way out for itself. For this very reason, because the silk must be torn and spoilt by the emerging insect, silk-breeders kill the pupating insect before it begins to make its way out."

"But there are species whose cocoons are provided from the very start with an outlet, for the caterpillar spins the silk round itself in such a way that a round opening is left. But this opening would be not only a convenient door for the butterfly to emerge by, but an equally convenient entrance for all its enemies. It is therefore closed up. In the case of the emperor moth (*Saturnia carpini*) this is effected by means of a circle of stiff bristles of silk on the inside, the points of which bend outwards like those of a weir-basket; from the inside the emerging moth can easily push aside the bristles, while the threatening enemy from without is scared off by the stiff points of the bristles."

Weismann proceeds: "Such a cocoon is

comparable to a work of art in which every part harmonizes with the rest, and all together are adapted as well as possible to their purpose. And yet it is all accomplished without the caterpillar having the remotest conception of what it is aiming at, when it winds the endless silken thread about itself in the artistic and precisely prescribed coils. Nor has it any time for trying experiments or for learning: it must make all the complex bendings and turnings of the head which spins the thread, and of the anterior part of the body which guides the thread, quite correctly and exactly the first time, if a good cocoon is to be produced. Here every possibility of interpreting this instinct as 'an inherited habit' is excluded, for each caterpillar becomes a pupa only once; and it is just as impossible to suppose that it can be directed by intelligence, since it can neither know that it is about to become a pupa, nor that, in the pupa stage, it will be in danger from enemies which will attempt to force their way into the cocoon, nor that the hedge of bristles will protect it from its enemies. Our only clue to an interpretation is in the slow process by which minute useful variations in the primitive instinct of spinning are accumulated through selection; and it is wonderful to see how exactly these spinning powers are adapted to the particular life-conditions of individual species."

The clue Weismann offers is surely a false one, since no selection of variations (even supposing they might be cumulative) could ever successfully select a number of co-ordinated variations which have no common basis of survival value, but which are quite different in kind and which become of utility at different times. The caterpillar does not know that it is about to become a pupa; it does not know of its future enemies; it does not plan the protective hedge; but it is in the hands of the Great Spirit

> "Whose dwelling is the light of setting suns,
> And the round ocean and the living air,
> And in the heart of man."

To take two final instances.

Wonderful wasps.

The larvæ of the wasp *Ammophila* feed upon caterpillars. The female makes a nest, drags a caterpillar to it, lays her eggs on the caterpillar, and seals up the nest. But the matter is far more marvellous than that. When the female catches the caterpillar she paralyses it by stinging the nerve centre in each separate segment of the caterpillar's body. This not merely facilitates carriage of the caterpillar; but it also ensures that the caterpillar will not devour the larva instead of the larva devouring the caterpillar; and further, it provides the larva with fresh instead of with decaying meat, for the paralysed caterpillar lives without food for several weeks.

The *Sphex* wasp, again, provides grasshoppers and crickets for its larvæ. The motor centres of grasshoppers and crickets are three nerve ganglia situated in the thorax ; and when the female sphex catches her prey she stings it in these nerve ganglia, and actually picks out a "particular point where the tissues are soft and the nerve centres are easily reached from the surface."

To analyse these instances in detail, and to show the intricacy of coincidence that these adaptations of structure and function involve, would require too much space; but surely it is self-evident that no mutations could be so effective and co-operative by chance—surely it is evident that individually the mutations have not even sufficient life and death importance to undergo much selection.

The instincts of bees and ants have been so often described that it is unnecessary to dwell upon them here.

Altogether, the adaptations of instinct are too remarkable, too varied, too many-sided, to be explained as the manufacture of indiscriminate mutations, however stringently selected. The organisms must have looked before leaping, and not only must have looked but must have taken a logical and comprehensive view of all the circumstances of the case.

Even such a selection of fluctuating variations as Darwin assumed could not explain such achievements of evolution, and the theory of mutations which we must now accept is equally impotent to explain them. We must fall back on the miraculous and supernatural.

CHAPTER XIX.

CONTINUOUS EVOLUTION.

"Everything possible to be believed is an image of the truth."
(*Blake.*)

" The power of becoming altogether transcends parental inheritance, or there had been no evolution."—(*Greville Macdonald.*)

" Then the round earth grew furrowed and grew frore,
And the encircling steam,
Condensing in a stream,
Hissed boiling, bubbling, on a barren shore,
Till the Word spake, and then
There blossomed flowers, and beasts, and souls of men."

To reject the theory of the evolution of organisms by *selection* of fluctuations is not necessarily to reject the doctrine of a serial continuous evolution of the many from the one. It is true that the explanation which Darwin offered of species-transmutation gave more plausibility to such a doctrine of evolution; but evolution may be a fact, even though we reject Darwin's theory of its mechanism, and even though we may be compelled to postulate a mind-like mainspring.

Evolution independent of Darwinism.

Quite apart from the question of Darwinian evolution stands the question—Is continuous evolution a fact? *Is* continuous evolution a fact? In how far does the overthrow of Darwinism affect the credibility of the theory?

Consistently held, continuous evolution starts with a nebula, and ends in man. The spectroscope shows us that atoms are evolved from electrons; chemistry reveals that all matter, organic and inorganic, is composed of atoms; comparative anatomy and physiology declare that all animals and all plants can be arranged in an ascending series, with only small gaps between the species; embryology discovers a recapitulation of phylogeny in embryogeny; palæontology informs us that species succeeded to species in the history of the world; genetics proves to us that in some cases at least species have actually originated by mutations. Astronomy, chemistry, comparative anatomy, comparative physiology, embryology, palæontology, and genetics all strongly suggest progressive genetic continuity, and suggest it quite apart from the Darwinian theory of evolution.

Evolution deprived of its material and machinery much less cogent.

But suggestion is not proof, and if we deprive evolution of its material in the shape of fluctuating variations, and of its machinery in the shape of natural selection, we deprive it also of much of its cogency. For the evolution theory, in the orthodox Darwinian acceptation of the term, is acceptable chiefly because it eliminates or mitigates the supernatural. "The possibility," wrote Du Bois-Raymond, "ever so distant, of banishing from nature its seeming purpose, and of putting a blind necessity everywhere in the place of final causes, appears therefore as one of the greatest advances in the world of thought, from which a new era will be dated in the treatment of these problems. To have somewhat eased the torture of the intellect which ponders over the world-problem will, as long as philosophical naturalists exist, be Charles Darwin's greatest title to glory." Darwinism dispensed with the supernatural, whereas evolution (as we now must conceive organic progress), by prescient mutations and without manifest machinery, retains a supernatural character, and is therefore not so acceptable to the reason.

The mere fact that animals can be arranged in an arborescent fashion does not necessarily prove genetic connection. Since there are about 400,000 species of animals, it is almost necessary that each should approximate another, and there is room in such multitudes both for special creation and for transformation.

The mere fact, again, that animals seem to exhibit in their embryogeny forms of animals from which they are supposed to be genetically derived, does not prove genetic derivation; for development may be considered the dynamical result of protoplasmic chemistry, and, if that be so, we should expect a similarity of developmental processes in all species derived from protoplasmic ova even if not genetically continuous.

As Bergson puts it:—"Roads may fork or byeways may be opened along which dissociated elements may evolve in an independent manner, but nevertheless it is in virtue of the primitive impetus of the whole that the movement of the parts continues. Something of the whole, therefore, must abide in the parts; and this common element will be evident to us in some way, perhaps by the presence of identical organs in very different organisms" (e.g., the eye of man and the eye of a pecten).

Nor does the fact of certain palæontological sequence prove much—at most, it renders probable a genetic connection between a small number of groups of species.

No, the moment we reject the Darwinian material and the Darwinian machinery, we render continuous evolution of the many from the one much more dubitable, because much more obviously miraculous.

What Darwinism did was to dispense with a *Deus ex machina*, or at least to disguise his working. It is true, as we already have seen, that to explain that an amœba grew into a man in the course of ages by the selection of fluctuating variations, does not make the transformation any less a miracle; but still the miracle was comminuted: it was mitigated by time, it was qualified by the misfits and mis-hits that were supposed to be its concomitants. The mind felt less amazement at the co-ordinations and adaptations of living organisms, if it could conceive them as the automatic result of infinite time and infinitesimal fluctuating variations. Given sufficient time, and sufficient variation, biology imagined that, like Laplace, it could say of Deity, "Sire, je n'ai pas besoin de cette hypothèse."

But now that we know that fluctuating variations are incompetent to form species, and that in any case they could not be selected by environment so coincidently and proportionately as to form such complex co-ordinations as we have already described—now, if we are to hold that evolution proceeds by leaps large and small, that are immediately adaptive and co-ordinate, the miracle of creation cannot be disguised, and it seems to matter little whether we suppose the process to be one continuous genetic miracle from amœba to man, or whether we start with twenty, or twenty thousand, or four hundred thousand, specially created species.

The moment we surrender the pseudo-automatic selection process of Darwin, and the accessory machinery suggested by Lamarck, we are in much the same position as Cuvier, and can postulate as many beginnings, as many original trees of life, as many special creations, as we please. Nay, further, the moment we surrender Darwinism and Lamarckism, the broad genetic probabilities of the case seem rather to point to a multitudinous primæval parturition of the inorganic than to a continuous evolution from moneron to man.

Multitudinous primæval parturition.

Indeed, to consider life as originating at a point of time, in a point of space, as a speck of protoplasm, or as a bunch of biophors, is surely to be guilty of a very narrow use of the imagination.

Think of the antecedents of life—a firemist, a molten globe in an atmosphere of carbon dioxide. If conservation of energy, if continuity of cause and effect, mean anything, life began in such a fiery womb. That concourse of atoms which bustled in the brain of Shakespeare, or that directs the karyokinesis of a cell, must have derived its original energy of motion from the terrific energy of dissociated electrons—such energy as we see in the corpuscles of radium. From that energy of corpuscular motion, and from the subsequent heated and battered atoms, all energy must have proceeded; and the energy of life—the energy of these protoplasmic molecules that wax and wane, and seize and surrender, like the molecules of a flame,—must be imagined back into the furnace of the sun.

Energy of life may have begun in the firemist.

That under these extraordinary initial conditions, constellations and combinations of nascent atoms would be formed, such as are never formed under present thermal conditions, may be accepted as an axiom, *and we suggest that while some atoms* (*as the heat energy, which succeeded the corpuscular energy, radiated away*) *would form* *stable inorganic substances, others would give rise to those other more energetic compounds that now show the phenomena we know as vital, and that respond by specific molar and molecular motion to environmental stimuli.* This is surely what the scientific imagination demands—life blossoming multitudinously from flame, not moulded out of tepid, torpid mud. The *living* compounds we know, *live* only at moderate temperatures, but nevertheless that particular atomic energy they exhibit must be conceived as energy derived from the sun millions of years ago. Even as crystals crystallize out of solutions as they cool, so can we imagine that the molecules of cells and cellular organisms aggregated and acquired novel chemico-physical character as the earth cooled. Without much stretch of imagination, indeed, we may believe that the molecular combinations that metabolize in the chromosphere of the sun, and which certainly must be in very active adaptive gaseous interrelation, may represent conscious entities with a consciousness far transcending ours. Without much stretch of our imagination we may believe that the sun is aflame with souls. And without stretching our imaginations at all, we can believe that the compounds and structural compositions of life are consequences of tremendous thermal energy of a specific kind and degree. The synthetic

Early differentiation of the organic and inorganic.

The sun perhaps aflame with souls.

influence of thermal energy is illustrated even now in vital metabolism. It is light that finishes the compounding of that marvellous organic substance known as hæmoglobin: it is light that co-operates with the chlorophyll to tear asunder the carbon and the oxygen of the carbon dioxide and to build up the starch that is the basis of life as we know it. We know that light, heat, and electricity, which are all akin, and which all emanate from the sun, have great chemical and physical potency; but there may be myriads of other ether waves at work of which we know nothing, and it is not merely poetry to imagine that all living things are blossoms of the sun.

The synthetic influence of thermal energy illustrated still in vital metabolism.

Professor Pflüger, of Bonn, has brought forward a similar theory of the thermal origin of life, and has shown that such a theory is quite congruous with what we know of proteid metabolism. He points out that proteid is the fundamental substance of life; and that proteid as it behaves in the living body is much more labile and unstable than the proteid we know when dead, and he suggests that this difference is due to the presence in the living proteid of the radicle *cyanogen*, which is a radicle possessing a great quantity of internal energy, and therefore capable of imparting energetic internal motion to the proteid. He points out further that cyanogen

Theory of Pflüger.

Cyanogen.

is formed at an incandescent heat. "Accordingly, nothing is clearer than the possibility of the formation of cyanogen compounds when the earth was wholly or partially in a fiery or heated state. . . . If, now, we consider the immeasurably long time during which the cooling of the earth's surface dragged slowly along, cyanogen, and the compounds that contain cyanogen and hydro-carbon substances, had time and opportunity to indulge extensively their great tendency towards transformation . . . and to pass over, with the aid of oxygen, and later of water and salts, into that self-destructive proteid, living matter. . . . The first proteid to arise was living matter, endowed in all its radicles with the property of vigorously attracting similar constituents, adding them chemically to its molecule, and thus growing *ad infinitum.*"—("History of European Thought in the Nineteenth Century.")

All matter originally alive.

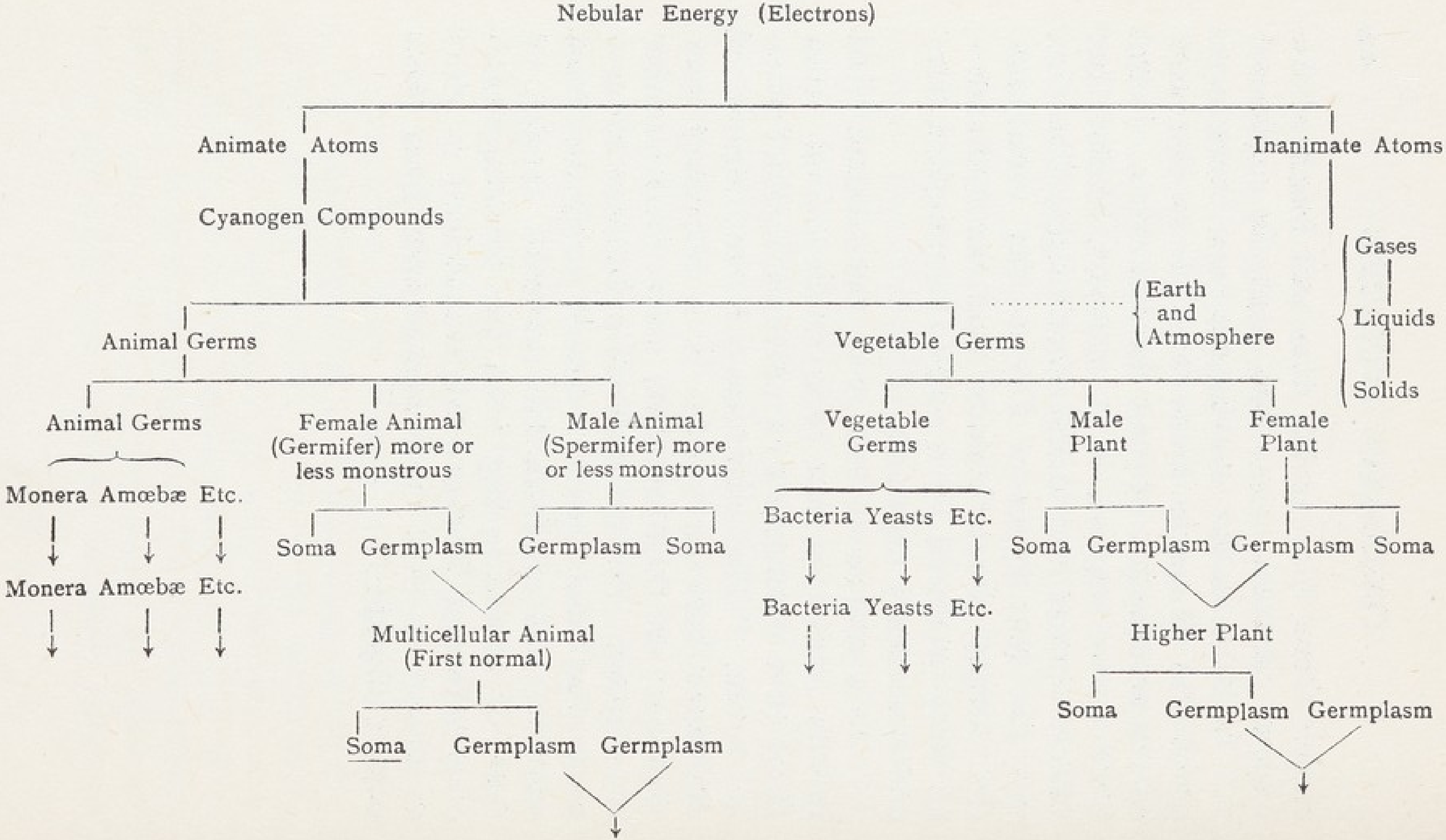
Professor Preyer has gone so far as to suggest that all matter was originally living, and that the dead is the product of the living.

Now then, if we assume such specific origin of life, such beginning and branching of atomic energy in the firemist, there is no advantage, rational or evolutionary, in supposing that only one group of atoms became endowed with vital energy: it is more likely that there were groups of all kinds and sizes that found at different times the conditions requisite for their development. Thus the varying flora and fauna of the various palæontological eras might be explained.

In brief, so far as evidence goes, there is no proof that all species arose from one species, and, on the assumption of such thermal origin of vital force as we suggest, it is, *a priori*, likelier that various species had independent origin, than that say, the four types of Cuvier—the vertebrata, the radiata, the articulata, and the mollusca—all were produced by a series of mutations from one elementary organism.

As a matter of fact, too, the natural mind revolts from the idea of a single animal stem. Kant gave utterance to a universal instinct when he wrote, "The slightness of the degrees of difference between species is a necessary consequence of their number, since their number is so great. But a *relationship* between them—such that one species should originate from another, and all from the universal species, or that all should spring from the teeming womb of a universal Mother—this would lead to ideas so monstrous that the reason shrinks from them with a shudder."

SCHEME OF EVOLUTION SUGGESTED BY AUTHOR.



N.B.—The main streams and the streamlets of energy though divaricate yet inosculate, and give and take.

CHAPTER XX.

VITALISM.

"I the grain and the furrow,
The plough-cloven clod,
And the ploughshare drawn thorough
The germ and the sod.
The deed and the doer, the seed and the sower, the dust which is God.

"Hast thou known how I fashioned thee,
Child, underground?
Fire that impassioned thee,
Iron that bound,
Dim changes of water, what thing of all these hast thou known of or found?

"Canst thou say in thine heart,
Thou hast seen with thine eyes,
With what cunning of art
Thou wast wrought, in what wise,
By what force, of what stuff, thou wast shapen, and shown on my breast to the skies?"

Is there sufficient reason to assume a kinetic differentiation of thermal energy?

SATISFACTION of the scientific imagination and of "the natural mind" does not suffice to establish a hypothesis, and our theory that the energy of the animate and the energy of the inanimate were thermally differentiated æons ago obviously requires further discussion. What reason have we to suppose that the vital energy had a primæval separate origin? What reason have we to suppose that life cannot originate in some simple form through a complex conjunction of inanimate atoms and of the ordinary chemical energies of inanimate atoms, and gradually evolve into the higher organisms by ordinary mutational changes? For centuries it was believed that life could originate spontaneously in this way, and even now it is argued by some scientists that the energies, and the results of the energies, we see in the inanimate, are competent to account for life's simpler manifestations. "The morphological or structural biologist pictures to himself very much more complicated arrangements of molecules than the carbon tetrahedron of Van't Hoff or the benzine ring of Kekulé, yet formed on similar principles; and by continuing in his mind these combinations, which, as they become more complex, also become more unstable, he arrives ultimately at a very complex and continually changing chemical structure which he imagines to be the beginning of the living process, the element of organization." Is there anything impossible in this picture, or unlikely, or untrue?

Are not the energies of the animate the same energies that activate the inanimate?

Are not the energies, formative and functional, of life after all merely the chemical and physical energies which we see at work in dead matter? And if so, why suggest remote kinetic differentiation? We may not understand, it is suggested, the more complicated manifestations of energies;

yet if their simple beginnings can be interpreted as chemical and physical phenomena following the same laws as chemical and physical phenomena seen in the inorganic world, then their complicated manifestations may be assumed capable of similar interpretation, and there is no need to postulate an original differentiation of energy.

Let us examine this question more carefully.

As we have already seen, living organisms are made of quite ordinary elements. "A few gallons of water, a few pounds of carbon and lime, some cubic feet of air, an ounce or two of phosphorus, a few drams of iron, a dash of common salt, a pinch of sulphur, a grain or more of each of several hardly essential ingredients, and we have man according to Berzelius and Liebig." And if we separate and examine the elements, we find that they behave in a quite ordinary and undistinguished way. We could cure fish with the salt, or kill rats with the phosphorus, or make sulphuretted hydrogen with the sulphur. The hydrogen of the sun, the hydrogen of a tallow candle, the hydrogen of a blue eye, have all exactly the same spectroscopic signature. All the elements taken from the organic exactly resemble in all their chemical and physical characters the same elements taken from inorganic substances.

Living organisms made of quite ordinary elements.

"Imperial Cæsar, dead and turned to clay,
Might stop a hole to keep the wind away."

Again, Berthold showed that "the arrangement of cells in organic tissues follows the same type as does the arrangement of the single bubbles of a soap-lather, and Bütschli added to this the discovery that the minute structure of the protoplasm itself is that of a foam also. Of course, it is not one fluid and one gas which make up the constituents of the structure in the organisms, as in the case of the well-known inorganic foams, but two fluids, which do not mix with one another. One general law holds for all arrangements of this kind—the so-called law of least surfaces, expressed by the words that the sum of all surfaces existing is a minimum; and again, it is a consequence of this law, if discussed mathematically, that four lines will always meet in one point and three planes in one line. This feature, together with a certain law about the relation of the angles meeting in one line to the size of the bubbles, is realized most clearly in many structures of organic tissues, and makes it highly probable, at least in some cases, that capillarity is at work here."—(Driesch, "Science and Philosophy of the Organism.")

Berthold and Bütschli.

As far back as 1869, Engelberg maintained that changes and shape in so-called contractile cells are due to alterations in surface tension, and Bütschli later showed that a drop of an emulsion of olive oil and potassium carbonate will creep about like an amœba for hours owing to alterations in surface tension. Muscular contractility, the excretory behaviour of certain cells, and even cell-division, have been explained in the same way; and J. Willard Gibbs, Sir J. J. Thomson, and Professor Macallum have shown that there is a close relationship between surface tension and the distribution of salts through a fluid.

Osmosis, which is closely related to surface tension, also has been called in to explain physiological processes; oxidation certainly plays a prominent part in all vital functions; and we have already shown that development is largely a chemical matter.

All these attempts to bring physiological processes of living organisms into comparison with the physical and chemical processes that are seen apart from life are of great interest; but they cannot be said to explain the coordinated energies, the *essential* morphogenetic and functional and adaptive features of living organisms.

An amœba or moneron not really simple.

It may seem natural to postulate the beginnings of life as simple and microscopic; but there can be little simplicity in an amœba or moneron assumed to contain in itself the potentiality not only of 400,000 existent species, but of millions of unfit species that perished of their unfitness. And even if we divest an amœba or moneron of such phylogenetic potentiality, it yet remains a most complicated organism, containing in itself not only all the structures and functions proper to life, but all that mysterious power of hereditary transmission, and consisting not only of very complex and prodigiously energetic chemical substances, but having the intricate structure and the complicated conduct we have already described.

It has been calculated that in a germ cell there are 8,640,000,000,000,000,000 atoms grouped into 1,728,000,000,000,000 molecules. A liver cell has been calculated to contain 300,000,000,000,000 atoms, in 64,000,000,000 molecules, and has been compared in its mechanical complexity to a Mauretania full of chronometers. The shell of a diatom is as wonderful as the skeleton of a dinosaur: it is "of extraordinary complexity and most singular beauty"; and the work done by a proliferative bacterium is quite comparable to the energy of a rhinoceros: as we have frequently insisted, living organisms are never merely colossal molecules; they are chemical and *structural* complexes. There is no escaping from the conclusion of E. B. Wilson that "the study of the cell has, on the whole, seemed to widen rather than to narrow the enormous gap that separates even the lowest forms of life from the inorganic world."

We cannot consider as in any way simple even the simplest forms of life, and the more carefully we consider their physiological characters the more we find that they differ from the characters of the inanimate things.

Vital force, considered quantitatively, is much less exhaustible than the forces we find at work in dead bodies. We can heat a stone, and so long as heat radiates away, it is available active energy. We can loosen a stone at the top of a hill, and until it reaches the bottom it is a centre of active force. We can put together two chemical substances that wed into one, and until the wedding is complete, active energy is given out. But the life energy seems inexhaustible. A little cell is capable of dragging tons of atoms into itself, and of duplicating and reduplicating itself apparently for ever.

Vital force seemingly inexhaustible.

Punnett calculates that in a year a rotifer might multiply to such an extent that its progeny would form "a solid sphere of organic matter greater than the probable limits of the known universe," and Cohn calculates that a cholera bacillus might in a few days multiply to a mass of bacteria as large as the moon. When we consider what work in horse-power or foot-pounds this turnover of matter represents, we get some idea of the energy of life; and we realize that it can never arise spontaneously in a test-tube. It is true that we know now that even the dead atom is full of energy—full of prodigious energy. It has been estimated that there is enough intra-atomic energy in a copper one-centime piece "to work a goods train along a horizontal line equal in length to a little over four and a quarter times the circumference of the earth"—as much energy, that is to say, as would be produced by about three million kilogrammes of coal costing about seventy thousand francs. Sir J. J. Thomson calculates that a few grains weight of hydrogen has within it sufficient force to raise a million tons to a height of more than three hundred feet. But the intra-atomic energy of dead atoms is statical; it is all employed in maintaining the orbital integrity of the electrons that compose the atom or molecule, and, except in the case of radium, it is hardly available for any other purpose.

The energy in the atoms of inanimate bodies fully employed in maintaining integrity of the atoms.

For some thousands of years, the question of the spontaneous origin of life has been debated, and, within the last few years, Bastian, a very distinguished and able scientist, has reasserted that life can arise, *de novo*, in sterilized media. Bacteriologically speaking, he has made out a strong case that deserves every attention; but biologically and physically speaking, his contention is incredible.

Bastian and spontaneous origin of life.

Life represents enormous energy: *ex nihilo nihil fit*.

How then does Bastian expect to endow the dead atoms with the amazing kinetic energy of life which effects locomotion, assimilation, reproduction, mutation, etc.? He does not even provide the conditions of the most primæval life: he has no atmosphere of carbon dioxide: he boils the oxygen out of his culture medium, and he precludes the actinic rays of light. But even if he provided most of the subsidiary conditions of life, he could never produce the kinetic energy of life; and it seems possible to the writer that the micro-organisms which Bastian finds in his culture media are forced by atmospheric pressure through the glass, owing to the partial vacuum produced in the tube, under the conditions of his experiment.

A top will write a book only if we give it the correct initial rotations, and if we are to create life we must begin, not with a saline solution superheated to 145° C., but with lightning-swift electrons, and with spinning worlds going twenty miles a second and heated to 6000° C.

Vital force not only inexhaustible but a force *sui generis*.

And vital force is not only more active and more inexhaustible than the energy of dead bodies, but it acts in ways that always suggest the actions of thinking beings, as we have experience of these, and even its most elementary energies make this suggestion.

Take the inexhaustible energy that manifests itself as cell-division. It may be shown that cell-division is associated with certain changes in surface tension, salt distribution, etc.; but as we know, cell-division, even in the case of a unicellular organism, is much more than cross-section: it is preceded by a systematic division of the chromosomes, and by a remarkable movement of these relative to each other and to spatial extension—such a movement as is never found in the parts of dead matter unless under the guidance of a mind. Further, the cell is not divided into two, as we might bisect an apple by a knife: it forms two complete apples. When we consider the process of cell-division and cell-conjunction in multicellular organisms, we find not only these vital peculiarities we have mentioned, but that the cells assume a certain apposite arrangement, and alter character in a certain opportune way—in such a way as to resemble very complex rational operations, and in a way quite unlike anything that occurs in inanimate nature.

Nothing at all equivalent to the opportune and apposite motions of the animate seen in the inanimate.

We can imagine a substance capable of indefinite growth and division simply by some elaboration of the ordinary chemical processes that are at work in the compositions of dead matter, but we cannot subsume, under any known chemical or physical processes at work in dead matter, such orderly systematic rearrangement and re-orientation of the parts of a whole, as are seen in the chromosomes of a dividing cell, or such duplication of a structural complex as results from cell-division. Nor can we subsume, under any chemical or physical laws derived from inorganic phenomena, such apposite addition and such opportune differentiation as are exhibited in the embryogeny of a multicellular organism. These processes are rightly distinguished as *vital*, since they can be compared to nothing in nature except to the purposive changes in matter brought about by human intelligence. There certainly seems to be a force at work in these things we call *living*, which is not at work in these things we call *dead*—a force different not only in degree but in kind. As Huxley said long ago, "We are forcibly reminded of a modeller in clay."

Vital processes can be compared only to changes in matter brought about by human intelligence.

The more minutely we examine living cells, the more clearly we find in them complicated motions with effective results, the more clearly we perceive the autonomy of vital functions. We realize that these functions cannot have evolved from the chemical processes found in the inorganic, but must have had a separate impulse of a very particular kind—a *vis a tergo* before the solidification of the world—we perceive that death and life are brother and sister, not father and son.

Let us consider embryogeny for a moment. When we examine in detail some such simple embryogeny as that of a sea-urchin, we find that it really is not simple at all. Quite apart from the reiterated

Embryogeny.

complicacies of karyokinesis, we find that growth proceeds by as anomalous methods as the growth of a picture under a painter's brush, or the growth of a statue under a sculptor's chisel. There is no question of tentative variations, but there are means to an end constantly changing in substance and spirit. Now new material is provided, now a new process improvised, now a new organ initiated, very much after the manner of human manufactures and creations.

After extremely complicated operations of maturation and fertilization (which we have already described, and which are themselves dynamical mysteries with psychical suggestions), the egg begins to divide. But it does not divide anyhow; it divides in certain planes (cleavage planes), and in such a way that as a result of three cleavages a square figure of eight cells is formed, four cells being superposed on four. Cleavage still continues, but four of the eight cells formed by the cleavage of the aforesaid lower cells are smaller than the others and are known as micromeres, and the offspring of the micromeres are always small cells. When 808 cells have been formed by cleavage, they will be found to be arranged in the form of a hollow sphere walled with a single layer of cells. Next, *all* these cells acquire small hair-like processes (cilia) on their outer aspect, and these hair-like processes *move* and propel the sphere (which is called a blastula) through the water.

Now look at these facts. They are really quite as wonderful and inexplicable as the adaptations of insects that we have already admired. It may be gravity, and the stimulus of light, and other so-called natural forces that produce these mutations that have such a fortunate manipulative locomotive effect ; but the mutations must have been there to be produced, and the mere fact that they are the product of two factors, the inherent dynamical tendencies of certain molecules, and the stimulus of environmental conditions, does not make them less wonderful. But it is not gravity that gives *all* the cells cilia and that makes the cilia move, and that makes them move in such a co-ordinate way as to propel the blastula through the water. Whatever the result is due to, it must be due to a concatenation of numerous causes acting on a substance capable of numerous appropriate responses, and the very fact that the aggregate result is of such a co-ordinated kind, suggests, just as the higher vital functions and all vital functions suggest, the action of an intelligent will that arranged the factors (innate and environmental) to produce the product. It is just because we, by what we call will in action, can produce such complexes, that we are inclined to attribute them to Will and Mind.

But to proceed with the embryogenetic details. About fifty of the smaller cells, descended from the micromeres, get into the interior of the cell in some mysterious way, and form a little wart-like heap on the inside of the cell-wall. Soon these cells rearrange themselves as a triangle with rounded angles, and two of the angles have each a little group of cells which afterwards go to form the skeleton of the animal.

Next, at that part of the cell-wall which is included and delimited by the triangle, a narrow tube of cells grows inwards right across the hollow sphere. From this tube the intestine of the animal is afterwards formed.

The formation of the skeleton of the animal is particularly amazing. About thirty cells from each group of skeleton-forming cells which we have mentioned work at the skeleton. They wander in the interior of the blastula, which at this time is filled with a sort of gelatinous matter, and as they wander they lay down the calcareous skeleton, much as workmen might lay down bricks —" one forms one part and one another, but what they form altogether is one whole."

Eventually a form known as the *pluteus* is built up; but it is not a permanent form, and many fundamental changes are made before the adult sea-urchin is formed.

Again, we can only comment that these operations are comparable only to the manufactures of mind: they are mento-moto-volitional in the fullest sense of that word.

The most simple of living things, then, are far from simple in their structure and behaviour;

and they exhibit energies which could not originate from the energies of the inanimate, and which probably had separate origin in the thermal activities of the fire-mist. Further—and this is the point on which we would now insist—the most elementary processes and proceedings of living matter are the processes and proceedings of mind, and are quite as extraordinary as the processes and proceedings of the higher organisms such as man, and the power behind them would seem quite competent to create any number of separate species, higher or lower, without any such pseud-automatic machinery as Darwin postulated and as later thinkers have denied.

CHAPTER XXI.

VITALISM.—*Continued.*

FURTHER ARGUMENTS IN FAVOUR OF VITALISM AND MULTIFORM PARTURITION.

"How did the Chaos bourgeon into life?
Did it imagine, when the toil began,
'Twould blossom into stars and moon and sun
Rolling to rhythmic music? Toil seemed vain:
Mistily, vaguely, dizzily it spun,
Racked with strange pain,
In fiery rain,
Through black abysses, while the cosmic power
Compelled it into bird and beast and flower."

"And yet the Soul in Whom all beings are,
Discerns so deep, foresees so far,
He plans the beauty of a star
Before the stellar mist is made,
And in the fire
He moulds to His desire
The tiny blossom and the tender blade."

If the normal dynamics of cell-growth and cell-division suggest a directive mind, and compel comparison with the intelligent creative acts of man, even more so do the abnormal dynamics of morphogenesis, under abnormal experimental conditions.

Roux killed one of the first two cells formed by a frog's egg in the process of embryogeny, and found that only a half embryo was formed. But Driesch found that one of the first two cells formed by a sea-urchin's egg was capable of forming a small *pluteus* by itself. Driesch describes his experiment thus: "It (the isolated cell) went through cleavage just as it would have done in contact with its sister-cell, and there occurred cleavage stages which were just half of the normal ones. The stage, for instance, which corresponded to the normal sixteen-cell stage, and which, of course, in my subjects, was built up of eight elements only, showed two micromeres, two macromeres, and four cells of medium size, exactly as if a normal sixteen-cell stage had been cut in two; and the form of the whole was that of a hemisphere. So far there was no divergence from Roux's results.

Driesch's experiment with sea-urchin's egg.

"The development of our echinus (sea-urchin) proceeds rather rapidly, the cleavage being accomplished in about fifteen hours. I now noticed, on the evening of the first day of the experiment, when the half-germ was composed of about two hundred elements, that the margin of the hemispherical germ bent together a little, as if it were to form a whole sphere of smaller size, and indeed the next morning a *whole* diminutive blastula was swimming about. I was so much convinced that I should get Roux's morphogenetic result in all its features, that, even in spite of this whole blastula, I now expected that the next morning would reveal to me the half organization of my subject once more. The intestine, I supposed, might come out quite on one side of it, as a half-tube, and the mesenchyme ring might be a half one also.

" But things turned out as they were bound to do, and not as I had expected. There was a typically *whole* gastrula on my dish the next morning, differing only by its small size from a normal one, and this *small but whole* gastrula was followed by a whole and typical small pluteus-larva."

Driesch further found that any one, or any two, or any three of the first four cells was capable of forming a complete pluteus.

Now, here surely is a very remarkable versatility and adaptability. It is quite plain that the same design is carried out by a varying number of cells, and that each cell, as formed, must arrange its work according to the number of the other cells at work, and according to its own spatial and serial position and possibilities with respect to the organism-to-be. It is the plan of the organism-to-be that decides what each cell shall be and do, and if there are too few cells to carry out the full-size plan, they make it smaller, but still radically the same. It almost exactly resembles the case of a tailor cutting a coat always of the same pattern, but large or small according to the cloth. In an intelligent community all working to achieve a certain elaborate structure, one workman may do the work of another who is ill or dead, and the community may decide to make the structure smaller if there be lack of artisans; but how can cells show such prescient and intelligent adaptability and versatility if they are bound by the rigid chemical and physical laws that rule dead atoms? Even the cells that wander about in the gelatinous material in the interior of the blastula apportion the work among themselves according to their number; yet they are not even in touch with the mainland of the organism.

When we look at processes of repair, we find a similar prescient versatility. Cells that never did such a thing in their life before, reconstruct organs and tissues according to correct plan, and even invent new ways of reconstruction if the old way be debarred, and different cells may effect the same reconstruction.

Remarkable instances of repair.

If the lens of the eye of the triton be removed, it is reconstructed by the cells of the iris cells, which are of quite different origin from the cells of the original lens. "What is more, in the

Salamandra maculata.

Salamandra maculata, if the lens be removed and the iris left, the regeneration of the lens takes place at the upper part of the iris; but if this upper part of the iris itself be taken away, the regeneration takes place in the inner or retinal layer of the remaining region. Thus, parts differently situated, differently constituted, meant normally for different functions, are capable of performing the same duties, and even of manufacturing, when necessary, the same pieces of the machine."

Tubularia.

Take the case of the hydroid polyp *Tubularia*. The tubularia has a flower-like head bearing two rings of tentacles placed on the top of a long stem. If the head be cut off at any level, the cells of the stem proceed to form a new head, and to form it according to scale in proportion to the length of the stem, with the rings of new tentacles of correct proportionate size at the right proportionate distance apart. The cells of the stem collaborate in this reconstruction, but different cells form different parts of the head according to the level at which the stem is bisected.

The two rings of tentacles begin as raised linear ridges placed vertically round the stem. Now, if the upper ring of ridges be removed before they have become complete tentacles, the stem still proceeds to produce that ring of tentacles. It proceeds, too, in various ways. It may produce the missing ring by budding it forth from the head after it is otherwise finished. It may divide the remaining ring of ridges into two rings by bisecting it by a circular groove. Or it may erase the ring of ridges already formed, and begin the reconstruction afresh.

Such is the resourcefulness and ingenuity of the cells in the stem of the tubularia!

The sea-squirt *Clavellina* shows still more extraordinary restitutional processes. If the clavellina be cut in two so that its intestinal sac is in one half and its bronchial apparatus in the other half, each half may regenerate the missing half by a process of budding. In the case of the half containing the bronchial apparatus, however, restitution of the complete organism may take place in another manner. The half with the bronchial apparatus may lose almost all its organization and become a small white sphere, and this sphere may become reorganized and form a complete little clavellina. It is almost as if we should cut off a man's nose, and the nose, after becoming a little white sphere, should grow into a complete miniature man.

Clavellina.

If the bronchial apparatus be cut into two pieces, two little clavellinas will be similarly formed. "So we see," says Driesch, whose account we follow, "that not only is the bronchial apparatus of our animal capable of being transformed into a whole animal by the co-operative work of all its parts, but even each *part* of it may be transformed into a small *whole*, and it is quite at our disposal how large this part shall be, and what sort of a fragment of the original bronchial apparatus it shall represent."

A similar kind of regeneration after differentiation is shown by the flatworm *Planaria*. If a large piece of the pharynx of this worm be cut away, the remainder of the pharynx is first undifferentiated into a mass

Planaria.

of cells, and then from these cells a smaller pharynx is constructed.

Even in the simplest forms of life then we find instances of inexplicably prescient, intricate adaptations such as are never found in dead matter; and when we add to the instances of adaptive instincts we have already cited, and when we consider the mysterious processes of development, heredity, and evolution, we must admit, it seems to me, that living matter has other energies than those that move dead matter; and that living matter is not evolved from inorganic compounds, but is the resultant of a form of energy—a mode of motion probably initiated in the fire-mist, and possibly finding its first material manifestation in energetic cyanogen compounds.

To attempt to evolve life from the dead by any composition of dead atoms and their energies is to attempt an impossibility. The functions of life are resolvable, as Descartes declared, into matter and motion, or rather into motion and matter, *but the motion and therefore the matter are not the motion and matter of the cool crust of the world.* Bichat defined life as the totality of the functions which resist death; but life might perhaps be better defined as the totality of the functions which distinguish the living from the dead. There is a distinction, as we have shown, and a difference of more than degree: "There are," as Bichat himself put it, "in nature two classes of things, two classes of properties, two classes of sciences. Things are organic or inorganic, their properties are vital or non-vital, their sciences are physical or physiological."

Great objection has been taken to the term "vital"; but the term is quite legitimate, either as a taxonomic term to classify particular groups of phenomena, or as a dynamical term to express the particular form of energy which manifests itself in living things. As Virchow said long ago, "Nevertheless, we cannot see how the phenomena of life can be understood simply as an assemblage of the natural forces inherent in those substances: rather do I consider it necessary to distinguish, as an essential factor of life, an impressed derived force in addition to molecular forces. I see no objection to designating this force by the old name of vital force."

Term "vital" quite legitimate.

No doubt all energy or force is one, but it may flow in different channels with different effects. The planets whirling round the sun, the electrons whirling in an atom, the atoms throbbing in an inorganic molecule, the chromosomes manœuvring in an organic cell, are all no doubt inspired by the same force; but the forms of motion are different, may have been differentiated at different times, and may be distinguished by different names.

The great mistake that has been made has been the endeavour to explain the particular form of energy seen in living bodies by reference to the composition and the character of the components of organic tissues when out of their vital context. But the energy is the maker of the cell, not the cell the maker of the energy. "Die Pflanze bildet die Zellen, nichte die Zellen die Pflanze," says a German writer. "Cells," says Huxley, are "no more the producers of the vital phenomena than the shells scattered in orderly lines along the sea-beach are the instruments by which the gravitative force of the moon acts upon the ocean. Like these, the cells mark only where the vital tides have been, and how they have acted." "The influence of animal or vegetable life [vital energy] on matter," says Lord Kelvin, "is infinitely beyond the range of any scientific enquiry hitherto entered upon. About twenty-five years ago I asked Liebig if he believed that a leaf or a flower could be formed or could grow by chemical forces. He answered, I would as readily believe that a book on chemistry or on botany could grow out of dead matter by chemical processes."

Life is the cause and not the consequence of organization, and to say, as Huxley afterwards said in his anti-vitalistic days, that when certain elements "are brought together under certain conditions they give rise to the still more complex body, protoplasm, and this protoplasm exhibits the phenomena of life," is surely to reason rather rashly. Even Huxley had to admit that the protoplasm and its vital properties appeared only "under the influence of pre-existing living protoplasm," that is to say, under the influence of vital force. In face of the vital phenomena we discover in even the so-called "lower organisms," we cannot regard the organic as compositions of inorganic energies, and if the organic was not produced by the inorganic we must find another source of energy; and the almost inevitable conclusion is the proposition we primarily stated, that the organic is the manifestation of a particular stream of thermal energy that branched off from the thermal energy of the young world probably before its inorganic structure was formed. To put it briefly and finally otherwise: living and dead matter have such diverse modes of energizing, are such diverse manifestations of energy, that we are led to believe that matter was differentiated in the fire-mist by the imposition on certain atoms and molecules of two kinds of motion—the atomic and molecular motion of dead matter, and the atomic and molecular motion of living matter. All matter, as Ostwald says, is a complex of gravitational, kinetic, and chemical energies; but to account for the dynamical difference between the living and the dead, we must assume two different endowments of energy—on the one hand, such intra-atomic energy as we find in so-called dead matter, on the other hand, such kinetic energy as we find in living matter. On this hypothesis we preserve the conception of unity of initial impulse, and we escape from the necessity of postulating either an intermittent action of creative force or a sudden interposition of Providence. If we do not accept this theory, we must, it seems to me, accept the theory that the inanimate atoms of carbon, hydrogen, oxygen, nitrogen, and sulphur, perhaps all the inanimate atoms, are really de-energized atoms that at one time possessed such energies as are manifested in vital phenomena ; for it certainly cannot be maintained that the energies seen in the dead are equal to producing the energies seen in the living.

The molecular nuclei of life were probably formed and energized long before the cooling of the world ; but the cooling of the world probably allowed the manifestation of their kinetic energies in the assimilation and arrangement of dead atoms.

Accepting the theory of the separate thermal origin of life, we must also accept its corollary of possible multitudinous primæval parturition. The whole object of postulating the beginnings of life as a simple micro-organism was to explain the passage from the inorganic to the organic. Since, then, there are no simple micro-organisms, and since the very fact that the micro-organisms were, *ex hypothesi*, capable of such marvellous evolution made them infinitely complex, the explanation was no explanation. Still, it was as an explanation that it was acceptable ; and now that no explanation is necessary—now that it seems better not to assume a genetic connection between dust and diatoms, mud and monera—now that we may logically derive life separately from the multitudinous and prodigious energy of the sun—now that we must assume species-formation by adaptive mutations—*now* we are free to begin life on as vast and various lines as we please; and the multitudinous parturition we have already suggested can include mastodons as well as amœbæ if we will.

After all, if we are to allow that life can bud in an amœba (even without miraculous phylogenetic potentialities) there is no reason to deny that it might also bud in a mastodon. It is really no more difficult, scientifically speaking, to conceive of the ontogenetic development of a mastodon from a nebular nucleus than to conceive of its ontogenetic development from an ovum, or of its phylogenetic development *via* molluscs and fishes. Indeed, it is easier for the imagination to believe that a midge and a mastodon were separately created from separate vital nuclei, than to believe that they both are the product of the same germ-plasm, and are serial members of long lines of mutated species; and it is *a priori* more probable that many kinds of vital nuclei were formed than that one kind only was produced. Even as centres of ordinary atomic energy of many kinds were made, so probably also were there centres of vital atomic energy. At least it is a perfectly legitimate scientific conception. We must give up the theory of life from dead dust (unless we postulate divine intervention); we must give up the theory of automatic selection (since fluctuating variations are proved futile); but we may keep the theory of evolution, and, keeping it, may hold either that all the species mutated from one species under the impulse of a specific thermal energy (vital force), or that the thermal energy produced numerous specific centres of vital force, each of which in due season found manifestation in different organisms. Personally we prefer the latter theory.

Not so wild after all is Milton's picture :

> " The earth obeyed, and straight
> Op'ning her fertile womb, teemed at a birth
> Innumerous living creatures, perfect forms,
> Limbed and full grown. Out of the ground uprose,
> As from his lair, the wild beast, where he wons
> In forest wild, in thicket, brake or den:
> Among the trees they rose, they rose and walked;
> The cattle in the fields and meadows green:
> Those rare and solitary, these in flocks
> Pasturing at once, and in broad herds upsprung.
> The grassy clods now calv'd; now half appear'd
> The tawny lion, pawing to get free
> His hinder parts, then springs, as broken from bonds,
> And rampant shakes his brindled mane."

And not so wild after all is Oken's speculation: " Man also is the offspring of some warm and gentle seashore, and probably rose in India, where the first peaks appeared above the water. A certain mingling of water, of blood-warmth, and of atmosphere must have conjoined for his production, and this may have happened only once and at one spot."

Certainly there is poetical licence in both cases; but there may also be scientific truth, and we venture to suggest that the main lines of living animals may have arisen at once, "perfect forms, limbed and full grown,"—we venture seriously to suggest as a new credible theory of the origin of life that even the multicellular organisms arose as saltations. The first forms of multicellular gametic organisms must of course have been different, and may have been vastly different from these organisms as they are now formed (they may, in fact, have been mere sexual monstrosities) since *ex hypothesi* they would be formed not in a womb but in the mud; but provided they had male and female characters, i.e., were germifers and spermifers ("male and female created He them"), there would be no difficulty in believing that the very first offspring of sexual congress were "perfect forms, limbed and full grown." In many of the lower species still we find a sexual and a vegetative form, and our suggestion simply is that the higher organisms originated as unique vegetative forms which at once gave birth to higher organisms resembling those that we now know. On this hypothesis, the embryonic rudiments of gills may be considered hereditary reminiscences of man's original fire and mud ancestor, and not of shark-like fishes.

The conception of the full-grown parturition of various multicellular forms in no-wise precludes a further evolution of these by mutations, while it provides man with an escape from a monkey ancestry, and accounts for the absence of the mutational monstrosities, and of the mutational transition forms, which evolution as ordinarily conceived *ought* to have produced.

A theory of parturition, by the mud, of larger animals, seems to require more courage than a theory which begins with a microscopic speck of protoplasm; but this is simply because the human mind has a misconception of size, and is wont to imagine that smallness means simplicity. But smallness in the case of living organisms, as we have shown, does not mean simplicity.

It requires a bolder imagination perhaps to imagine a "tawny lion pawing to get free," than to imagine a few million million molecules aggregating into an amœba; but intellectually and scientifically, as we have shown, the one case is as easy of credence as the other, and the conception of an urancestor of the lion arising from magic miocene mud is no whit more marvellous than its present origin from a microscopic ovum.

"Everything possible to be believed is an image of the truth," and the theories we have suggested, though scientifically unproven, are, in the light of recent research, scientifically more credible than the Darwinian theory.

Perhaps after all the Almighty did make man in His own Image. Perhaps the cyanogen nucleus of man was already conceived in the fire-mist long before the time of monkeys or even the time of amœbas.

CHAPTER XXII.

ORGANISMS MORE THAN AUTOMATA.

"Boundless inward in the atom, boundless outward in the whole." (*Tennyson.*)

"Mens agitat molem et magno se corpore miscet." (*Virgil.*)

"Hæ omnes creaturæ in totum ego sum, et præter me aliudens non est." (*Veda.*)

"All are but parts of one stupendous whole,
Whose body Nature is and God the whole." (*Pope.*)

All our investigations of the problems of development, of heredity, of adaptation, and of evolution, have led us to the conclusion that the phenomena of life are comparable to the mechanical creations of man. Life, indeed, seems to construct organisms by a fitting together of organisms and functions, much as man constructs machines, and the parts of organisms work together to an end, much as machines do. Are living organisms then to be considered machines?

The resemblance of organisms to machines has struck many minds, and a mechano-physical theory of life has often been propounded. "Thus," writes Leibniz, "the organic body of each living being is a kind of divine machine, or natural automaton, which infinitely surpasses all artificial automata. For a machine made by the skill of man is not a machine in each of its parts. For

Leibniz.

instance, the tooth of a brass wheel has parts and fragments which for us are not artificial products, and which do not have the special characteristics of the machine; whereas the machines of nature, namely, living bodies, are still machines in their smallest parts *ad infinitum*. It is this that constitutes the difference between nature and art, that is to say, between the divine art and ours."

Descartes propounded similar mechanical views of living things, and was prepared to make all things out of matter and motion.

Descartes.

Coming to more recent days, we find Huxley declaring in the *Encyclopædia Britannica* (1875) that "a mass of living protoplasm is simply a molecular machine of great complexity, the total results of the working of which, or its vital phenomena, depend—on the one hand upon its construction, and on the other upon the energy supplied to it; and to speak of 'vitality' as anything but the name of a series of operations, is as if one should talk of the horology of a clock." And we find Sachs asserting in his "Lectures on Plant Physiology" (1887) that "The organism is only a machine put together out of different parts; . . . in a machine, even if only made by human hands, there lies the result of deepest and most careful thought and of high intelligence so far as its structure is concerned."

It is quite evident that in many respects organisms do resemble machines: they are so constructed that their parts work in harmony, and change one form of energy into another, with a definite aggregate result. In a locomotive steam-engine the intramolecular energy of coal is converted by oxidation into the energy of heat, and the energy of heat is converted into the energy of steam, and the energy of steam is converted into the motion of pistons, and the straight impulse of pistons is converted into the rotational motion of wheels, and the wheels move the engine. In a man the intramolecular energy of food is converted by oxidation into the energy of muscles, and the whole energy of man can be shown to be merely the energy educed from substances oxidized in his body. The means by which the oxygen is supplied to the body—the bellows-like mechanism of the lungs, the pump-like action of the heart—are also strictly mechanical. Digestion, too, the means by which the combustible fuel is provided to the tissues, can be shown to be mainly a chemical and osmotic process. In fine, digestion, respiration, circulation, motion, are all largely chemical and physical functions.

But yet, as we have already indicated in other connections, living beings are autonomic, and cannot be considered merely machines; they are built on a plan on which no machine is built; for they are not built by the assemblage of parts; but the big machine of each body is all built up by a microscopic machine, the ovum, and all the parts of the big machine are themselves self-contained going machines. There is no machine that we know, that can automatically turn out millions and millions of other machines, some like it, some unlike it; yet each a perfect miniature machine, and all working together as a harmonious whole. Further, there is no chemical apparatus we know that can imitate the chemical processes of life, such as the decomposition of carbon dioxide, and the construction of starch as effected by the green plant, and the particular synthetic operations of living organisms.

Originality of organic syntheses.

As admitted by Bunge, "All our artificial syntheses can only be achieved by the application of forces and agents which can never play a part in vital processes, such as extreme pressure, high temperature, concentrated mineral acids, free chlorine-factors which are immediately fatal to the living cell."

From these points of view, living organisms differ from and surpass any machines we know; but the great dividing difference between living organisms and machines lies in the fact that machines are made to work to a certain end only under definite fixed conditions, whereas the organisms of life, as we have already pointed out, manifest, both in morphogenesis and in physiological functions, a complex power of adapting their functions to a varying complex of contingencies and emergencies, such as we find in machines only when *directly* under the will and mind of man. We have seen that fact very plainly in some of the adaptive facts of insect and plant life we have already discussed, but it is to be discerned in every item of structure and conduct. Without power of adaptation to contingencies, both structure and function would be vain, and it is this power of adaptation to contingencies that distinguishes living beings from machines. The correspondence between conditions, and organs, and functions, is never simple; it is always manifold and multiplex, and has reference—and this is the essential feature—to the future and to the unforeseen.

It is the infinitely complex co-ordination between function and structure and the things that emerge *in time* that makes a living body; and the energy that drives so many million separate and inter-toothed wheels in harmony—with a varying environment—is certainly not the energy that moves the molecules of inanimate bodies, or that we employ to move machines. No, the organism is built of its parts by a unique form of energy, and is moved in its parts by a unique form of energy. Of course, as Huxley said, vital phenomena depend on the one hand upon the construction of the body, and on the other hand upon the energy supplied to it; but that is begging a good deal. The writing on this page depends, on the one hand, on the construction of my fingers, and of my pen and of my brain, and of a multitude of other things, and on the other hand, on the energy supplied to them ; but the energy supplied to them is of a particular kind, manifested in particular results, and the kind of energy manifested in such results may quite aptly be distinguished, by the term *vital*, from such energy, say, as the energy of a waterfall eating away a rock.

But it may be said that many machines are made to adapt themselves automatically to certain contingencies, and that living beings are simply very perfect machines adapted to many contingencies. Indeed, it is obvious that if we consider the body as a machine, we must logically consider all the universe in its relationship to the body as part of the machine ; and we must consider all things as a definite predetermined mechanism. We may see only certain wheels of the machine at any one instant, but, *ex hypothesi*, the machine is complete, all is predetermined, and if we had an infinite horizon of time we should see all things working mechanically as a whole.

"An intellect," said Laplace, "which at a given moment knew all the forces with which nature is animated, and the respective situations of the beings that compose nature—supposing the said intellect were vast enough to subject these data to analysis—would embrace in the same formula the motions of the greatest bodies in the universe and those of the slightest atom ; nothing would be uncertain for it, and the future, like the past, would be present to its eyes."

"If," said Huxley, "the fundamental proposition of evolution is true, that the entire world, living and not living, is the result of the mutual interaction, according to definite laws, of the forces possessed by the molecules of which the primitive nebulosity of the universe was composed, it is no less certain that the existing world lay, potentially, in the cosmic vapour, and that a sufficient intellect could, from a knowledge of the properties of the molecules of that vapour, have predicted, say the state of the fauna of Great Britain in 1869, with as much certainty as one can say what will happen to the vapour of the breath on a cold winter day."

"All our poetry," said Tyndall, "all our science, all our art, Plato, Shakespeare, Newton, and Raphael, are potential in the fires of the sun."

With such a consistent mechanical theory of all things, we might, it is true, consider creation as a big machine, and organisms as parts of the big machine. But such a theory neglects *duration in time* as an essential element of consciousness as we know it. If we try to empty consciousness of the conception of emergence and sequence in time, we stultify our mind-picture altogether. We cannot conceive of all things as a statical stationary whole without stopping the action of the mind, without separating the subjective

We cannot bound the universe without stopping our mind, which is part of it, and without illegitimately severing mind and universe.

and the objective in a quite impossible way, without performing the impossible feat of getting outside our consciousness and considering its contents without adding to them. Addition and duration are facts we must eternalize to infinity. As Bergson expresses it, "Radical mechanism implies a metaphysic in which the totality of the real is postulated complete in eternity, and in which the apparent duration of things expresses merely the infirmity of a mind that cannot know everything at once, But duration is something very different from this for our consciousness, that is to say for that which is most indisputable in our experience. We perceived duration as a stream against which we cannot go. It is the foundation of our being, and, as we feel, the very substance of the world in which we live. It is of no use to hold up before our eyes the dazzling prospect of a universal mathematic; we cannot sacrifice experience to the requirements of a system."

Bergson.

Creation, then, is more than a big machine, and organisms are supplied with more than mechanical energy; they are supplied with a particular form of creative energy—"vital force." The force in all living things, so far as we can adjudge it, is of the same kind as the force that moves our limbs, and builds our houses, and writes our books: it is not automatic; it is not mechanical; it is original, creative, *contingently teleological*, and *eternally new*.

We must postulate a concept--an "entelechy," a "psychoid," "a soul," call it what you will—that possesses means of meeting contingencies and adapts the means to the new contingencies *as they arise.* We can make a teleological Teddy-bear that will walk across the Strand, but not a Teddy-bear that will avoid the traffic. Not even omniscience could have foreseen the traffic, and could have energized the Teddy-bear to make the right movements at the right time. Even omniscience can see only what exists, and, as we have just pointed out, to postulate that all the future already exists is to deny the great fact of emergence in time.

We find that in living matter one cell grows into two cells; and, inferring from our own creative experience, we are inclined to argue that the second cell must have been in the first cell as determinants, or in some other material form; we are inclined to lay down as a law that "the present contains nothing more than the past, and that what was found in the effect was already in the cause." But such argument is not sound, for organic life may be considered as a continual creation, and if we entertain the conception of Infinite Cause we must entertain also the conception of creative evolution of the new. The World to come is not already ready-made; it is not in the womb of the present; it is *to come.* If we premise an infinite past we must premise also an infinite creative evolution in the future.

The Final Cause of adaptation is volition—the desire of something, and the perception of means by which it may be obtained. We know this of our own material adaptations; we *infer* it of adaptations due to a power not ourselves. There are two parallel streams through Time: living matter with *its* energy, and dead matter with *its* energy, and it is idea with volition that adapts each to each.

Ages ago, Aristotle taught a modified doctrine of the teleology of life, though chiefly in opposition to the doctrine of chance variation. "Yet it may be said," he wrote, "that they (the teeth) were not made for this purpose, but that this purposive arrangement came about by chance; and the same reasoning is applied to other parts of the body in which existence for some purpose is apparent. And it is argued that where all things happened as if they were made for some purpose, being aptly united by chance they were preserved, but such as were not aptly made, these were lost, and still perish, according to what Empedocles says concerning the bull-species with human heads. This, therefore, and similar reasoning, may lead some to doubt on this subject.

"It is, however, impossible that these parts should arise in this manner, for these parts, and everything which is produced in Nature, are either always or for the most part thus (adaptively) produced, and this is not the case with anything which is produced by fortune or chance, even as it does not appear to be fortune or chance that it frequently rains in winter. . . ." "Similarly it may be argued that there should be an accidental generation of the germs of things; but he who asserts this subverts Nature herself, for Nature produces these things which, being continually moved by a certain principle contained in themselves, arrive at a certain end."

Plato's idea.

This was a modified form of teleology. But it was left to Plato to suggest Idea (ἰδέα) as the Final Cause; and to Idea as the Final Cause both of form and function philosophical science must return. Descartes declared that one thinks metaphysically, but one lives and one acts physically: "On pense métaphysiquement, mais on vit et on agit physiquement;" but that is perhaps just where Descartes was wrong. We act metaphysically as well as physically, since every conscious action is preceded by its notion in the mind. "*In the Beginning was the Word.*" From the metaphysical we cannot escape, for our sensations, our ideas, our volitions, are all metaphysical. It is idea and volition that produce what we call purposive results, and if we see purposive results in *all* living organisms, we must assume idea and volition as elements in the forces that produced them. We can interpret no forces in the world so intelligently and fully as the forces we ourselves exercise, and it is surely legitimate to interpret other forces by the light of our inner consciousness. Well does Bunge say, "The mystery of life lies hidden in activity. But the idea of action has come to us from the observation of will as it occurs in our consciousness, and as it manifests itself to our internal sense." . . . "Physiological enquiry must commence with the study of the most complicated organism, that of man. Apart from the requirements of practical medicine, this is justified by the following reason, which leads us back to the starting-point of our remarks—that in researches upon the human organism we are not limited to our physical senses, but also possess the advantage afforded by the 'internal sense,' or self-observation. . . . The essence of vitalism does not lie in being content with a term and abandoning reflection, but in adopting the only right path of obtaining knowledge which is possible—in starting from what we know, the internal world, to explain what we do not know, the external world."*

We must interpret force by the light of objective experience.

Still more clearly does Sir John Herschel express the necessity for a subjective interpretation of Force. "In that peculiar mental sensation," he writes, "clear to the apprehension of everyone

Sir John Herschel.

* (Quoted by Merz, "History of European Thought in the Nineteenth Century," from Bunge's Text-book on "Physiological and Pathological Chemistry.")

who has ever performed a voluntary act, which is present at the instant when the determination to do a thing is carried out into the act of doing it (a sensation which, in default of a term more specifically appropriated to it, we may call that of *effort*), we have a consciousness of immediate and personal causation which cannot be disputed or ignored ; and when we see the same kind of an act performed by another, we never hesitate in assuming for him that consciousness which we recognize in ourselves ; . . . in every such change we recognize the action of *Force*. And in the only case in which we are admitted into any personal knowledge of the origin of force we find it connected (possibly by intermediate links, untraceable by our faculties, but yet indisputably *connected*) with volition, and by inevitable consequence with *motive*, with *intellect*, and with all those attributes of mind in which personality consists."

Life a manifestation of conscious intelligent volitional force.

There is the matter in a nutshell: that is the special energy that inspires all living things—the same kind of energy that we ourselves exercise in our conscious volitional actions. Matter is now recognized to be force, and the manifestations of life are the manifestations of that force which we know as intelligent force. We cannot empty the idea of force of its psychical significance. The term and the idea are derived from our own conscious action. The moment we identify matter with force, we identify it with Conscious Will and Conscious Being. There is no way out of it. What was formerly called the substance of matter is now known to be Force, and the Force, from its manifestations in living matter, must be recognized as the Soul and the Will of God, in much the same way as certain movements and dispositions of matter are recognized to be manifestations of the soul and will of man.

Many acute and great minds have reached this same conclusion by other paths. "I consider," says Schopenhauer, every natural force as a will (i.e., *conscious* will). Will is essentially identical with all forces which act in Nature, the various manifestations of which belong to the species of which will is the genus. It is the direct consciousness which we have of will which alone conducts us to the indirect knowledge of other forces."

Under this interpretation, both the living and the dead are actuated by mind; but at the moment, for our present purposes, we would lay most emphasis on its subproposition that *Intelligent* Will inspired by an idea must be especially recognized as the specific and Final Cause of the particular phenomena of *life*, simply because these most closely resemble the *intelligent* operations of the mind of man. Matter is will; living matter is intelligent will; and if our theory of evolution be sound, intelligent will did not gradually manifest itself in increasing degree in dead matter, but began to manifest itself in certain thermal activities of nascent atoms before the making of the world.

Even the motions of the chromosomes—the most elementary of all molar movements—have all the characters of volitional motions. I do not mean to suggest that they will to move: I say they are willed to move. It matters not whether the will acts by fingers or by surface tension: there is a purposive movement in space, a re-orientation of the parts of a whole to each other such as is not found in dead matter, and such as we ourselves do produce in battalions, or chessmen, or bricks, or bullets, by the operations of our will under the inspiration of ideas. The building up of a multicellular organism from an ovum is even more volitional and ideational in its phenomena—so much so that Huxley says that "we are forcibly reminded of a modeller in clay;" and though for a time the automatic selection theory of Darwin seemed to give a mechanical explanation of the processes of morphogenesis and regeneration, it really did not do so, for many of the adaptations could not have been the result of any pruning and eliminative processes; they were answering correspondences, not dovetailing correspondences, not a fitting together of similar materials, but a unique reply to an original question. In what sense can the ear be considered an adaptation to the air?

Far more true is George Macdonald's mystic faith—

> "Where did you get that pearly ear?
> God spoke, and it came out to hear."

How could there be an adaptation of matter to serve the sense of hearing, which has no material ultimate so far as we can discover? Even granting—as in the light of recent researches cannot be granted—that adaptations are automatically selected from casual variations, and finally take the shape and assume the relationships we know, even granting that, we should have to attribute to the shaping environment a prescient preparedness such as we find only in tools in the hands of a sculptor, moving to the inspiration of an idea. These things have all been *thought out*.

> "Die Rose die allhier dem irdisch Auge siehet.
> Die hat von Anbeginn in Gott also geblühet."

> "War nicht das Auge sonnenhaft
> Wie könnt es denn das Licht erblicken."

Consider the restitutional processes we described in Chapter XXI. Consider the cases of the triton, of the clavellina, of the tubularia. Consider the development of the butterfly from the caterpillar. Consider the many wonderful prescient processes and co-ordinated adaptations we have cited, and then say whether any explanations save the explanation of a Mind and Will can be accepted. Again, in the great philosophical words of the Hebrew seer, "In the beginning was the Word, and the Word was God." It is the idea behind the egg that makes it into a living man, even as it is the idea behind this pen that moves it over the paper It may be true that the idea of the egg began perhaps in wild whirling atoms, and it is equally true that the motion of this pen began by a plunge in the inkpot; but the idea and volition are none the less the *vis a tergo* that produces the ultimate result.

Accordingly, life is much more than a mechanism, and living things much more than machines, and now, indeed, that the Darwinian automatic explanation of the forms and functions of life must be given up, we must return to some form of teleology—to some form of psycho-physics. "Whoever," as Du Bois Reymond says, "does not place all activity wholesale under the sway of Epicurean chance, whoever gives only his little finger to teleology, will inevitably arrive at Paley's discarded 'Natural Theology,' and so much the more necessarily, the more clearly he thinks and the more independent his judgment. . . . The physiologist may define his science as the doctrine of the changes which take place in organisms from internal causes. . . . No sooner has he, so to speak, turned his back on himself than he discovers himself talking again of functions, performances, and actions of the organs."

Teleological in some sort science must be, but scientific teleology must be philosophical.

Scientific teleology must be philosophical.

It will not do to try to identify the teleological and the personally utilitarian. It will not do to assert that the sheep was made to provide man with mutton, and that the grass was made to provide the sheep with food, and so on. We cannot pulverize the purpose of a purposive universe. The purpose of the grass, and of the sheep, and of the man is to play co-ordinated parts in the scheme of an infinite ever-growing whole, and all we can do is to discover such arrangements in certain parts of the whole as indicate the inspiration of idea. If, for instance, we watch a typewriter at work, and if we discover that the first letters make a word, and the first words make a sentence, we have a right to assume that there is a mind behind the movements of the keys; but the purpose of the mind is not merely to put adjectives beside nouns to make a sentence, but to develop a thought which may not become apparent till many words and sentences are written. And the world of consciousness may be regarded as an infinite book without beginning and without end. We do not know its infinite purport, but we find words and sentences, just as we ourselves write, and therefore have a right to assume that there is a Mind at work. That is the only teleology we have a right to assert —an imperfect teleology without any finality.

> "All are but parts of one stupendous whole,
> Whose body Nature is and God the soul."

Yet again, in view of the specific and wonderful nature of the adaptations and functions of living beings, and in view of preparedness of living organisms for original contingencies, we see no difficulty at all in admitting the possibility of the special creation of any number of species from organic nuclei of the cyanogen order; nor do we see the least difficulty in admitting the likelihood of big mutations reaching at a bound adaptations apparently miraculous in their fitness to survive.

CHAPTER XXIII.

DARWINISM AND THEOLOGY.

Opposition to Darwinian evolution.

WE have become so accustomed to a mechanical theory of the universe, and to an automatic theory of evolution, that it is difficult now-a-days to realize how only fifty years ago these theories had to fight for a footing in the face of the fiercest opposition and the most inveterate prejudice. So much of life is now mechanical and automatic that there seems to most little necessity to postulate anything else; the horse has been ousted by the automobile; the hand-loom has been superseded by the "spinning-jenny," and it now seems natural enough to include the shining stars and the beating heart under chemical equations and mechanical formulæ. But it was not always so; materialistic views, so-called, obtained a footing in the world only by hard fighting, for, to the majority of mankind, materialism seemed to be anti-Christ—an evil spirit to be turned out of the land by bell and exorcist, a perilous thing to be burned out of the land with fire and faggot. Foot by foot, modern scientific views of life and matter had to battle their way into credence, and only by the labours of such giants as Bruno, Galileo, Leibniz, Descartes, Darwin, Wallace, Haeckel, Huxley, Tyndall, did they ultimately gain the victory.

It was a hard, fierce fight, and the remarkable thing is that in the last decades of the nineteenth century all rancour had vanished, all passion flickered out, and men quietly and almost universally accepted views that had formerly been anathema to more than half the world.

Such a rapid and complete *volte face* suggests insincerity and requires explanation. How are we to account for it? Had the protagonists of the new doctrines become convinced of the error of their ways, or what had happened?

The truth is that the foes of the new science, and not only the foes of the new science but all the world, were simply hypnotized into belief by the intellectual ardour and force of the new great thinkers. Darwin was an encyclopædia, Huxley a Boanerges, Tyndall the greatest popular writer of science that ever lived. They were strong, patient, honest men, of great intellect and of high character, and they had facts on their side.

How Darwinian views were ultimately accepted.

Such advocacy was irresistible, and unconditional surrender was inevitable. And yet we venture to assert that the great victory of the evolutionists was a matter for tears. No one wept, it is true, and there is no weeping now; but the reason simply is that men when they surrendered shut their eyes to the spiritual sacrifices the new beliefs necessarily involved. They rightly and honestly admitted that facts were against them, but they stultified all their previous passionate opposition by saying that it did not matter. But they were right in the original spirit of their opposition, for it did matter, it did matter a great deal, as the history of belief from that time on shows very clearly. They faced the apparent facts, though they dared not face the spiritual consequences of the facts; they shut their eyes to them.

Let us look into this.

Darwinism a spiritual disaster.

There can be no doubt at all that Darwinism was a spiritual disaster, and that the fear it inspired in theological circles was really quite right and reasonable, even though the attempts to overthrow it were neither wise nor effective. The theory that nature threw out variations more or less at random, and that all the wonderful adaptations that we see in the world of life are simply the result of a selection of such variations by environment, did inevitably lead to a colder and less theistic conception of the world. It may not have banished a Maker from the world, but it at least hid him in a mist of chance behind a mountain of machinery. Who can honestly and sincerely say God bulks as largely in the theory of Darwinism as in the theory of special creation as propounded in the first chapter of Genesis ?—

"And God said, Let the waters bring forth abundantly the moving creature that hath life, and fowl that may fly above the earth in the open firmament of heaven.

"And God created great whales, and every living creature that moveth, which the waters brought forth abundantly, after their kind, and every winged fowl after his kind: and God saw that it was good.

"And God blessed them, saying, Be fruitful, and multiply, and fill the waters in the seas, and let fowl multiply in the earth.

"And the evening and the morning were the fifth day.

"And God said, Let the earth bring forth the living creature after his kind, cattle, and creeping thing, and beast of the earth after his kind: and it was so.

The Hebraic account of creation.

"And God made the beast of the earth after his kind, and cattle after their kind, and every thing that creepeth upon the earth after his kind: and God saw that it was good.

"And God said, Let us make man in our image, after our likeness: and let them have dominion over the fish of the sea, and over the fowl of the air, and over the cattle, and over all the earth, and over every creeping thing that creepeth upon the earth.

"So God created man in his own image, in the image of God created he him; male and female created he them.

"And God blessed them, and God said unto them, Be fruitful, and multiply, and replenish the earth, and subdue it; and have dominion over the fish of the sea, and over the fowl of the air, and over every living thing that moveth upon the earth.

"And God said, Behold, I have given you every herb bearing seed, which is upon the face of all the earth, and every tree, in the which is the fruit of a tree yielding seed; to you it shall be for meat.

"And to every beast of the earth, and to every fowl of the air, and to every thing that creepeth upon the earth, wherein there is life, I have given every green herb for meat: and it was so.

"And God saw every thing that he had made, and, behold, it was very good. And the evening and the morning were the sixth day."

That is certainly an anthropomorphic view of divinity, and a quite erroneous view of evolution; but can anyone deny that God as a Maker, with a planning Mind, bulks more largely in this chapter than in the Darwinian creed?

As we have previously pointed out, the desire of Darwin was to escape from the miraculous and præternatural, and to substitute for design and forethought the automatic working of a mechanical system. The fear of God is the beginning of all wisdom, but it was a fear of God —a fear of a formidable conception that dwarfed the intellect and paralysed the imagination—that made the great thinkers of the materialistic school endeavour to escape from the Almighty.

But " Fear wist not to evade, as Love wist to pursue," and man, patiently and honestly seeking after truth, has traced truth back again to the mind of a Maker.

So quietly and patiently has the work been done, that though its results are really revolutionary, few have perceived its trend and its triumph and its logical and spiritual outcome. Men have worked without any ulterior philosophic or theologic aim, have rested so confidently on the doctrines of Darwin, and have perceived so little the subtle deadliness of the doctrines, that they have neither noticed the death of Darwinism, nor exulted in their escape to more spiritual possibilities.

Darwinism is dead, for Pearson has shown that the fluctuating variations, on which Darwin chiefly relied, are incompetent to produce evolutionary adaptations. Darwinism is dead, for de Vries has shown that nature can arrive at its goals in a succession of successful leaps. Darwinism is dead, for many thinkers have shown that bilateral symmetry, and anticipatory adaptations, and many other biological facts, cannot be explained by his evolutionary doctrine, and that we must assume prescience and a mind that works, as the mind of man works, with some foresight of contingencies.

Death of Darwinism unnoticed by the Church.

And yet, strange to say, the same Church that fought tooth and nail against Darwinism has apparently heard no rumour of its death, or, if it has heard, has considered the news of no theologic importance. Yet if Darwinism was dangerous fifty years ago it is dangerous to-day, for the comfortable belief professed by the defeated that Darwinism after all had no theologic consequences was as insincere and cowardly as it was unsound. Darwinism, as we have already said, had and has theologic consequences that should have been frankly and bravely confessed. It did empty the world of mystery and marvel; it did substitute intermediary automatic causes for divine intention and intervention; and much of the spiritual paralysis that attacked intellectual minds in the closing decades of last century was due to its influence. To make Chance such a formative power in the world, to find that the Almighty, in a rather fortuitous way, produced man out of an anthropoid ape, can hardly be held to be conducive to spiritual pride or to spiritual aspiration. The new doctrines did deaden the spiritual senses of the world, and all the sciences, geology, chemistry, embryology, etc., fell into line, and tacitly ignored the supernatural—so much so that to the present day it is considered by scientists almost a crime to suggest that there is a Mind behind Law, or to give any emotional and imaginative meaning to scientific facts.

The downfall of Darwinism certainly does compel us to postulate a Mind behind the forms and functions of the animate world; it allows us, if we choose, to disclaim a simian ancestry; and it enables us to believe that in the loins of life are far more wonderful things than could ever be produced by the action of environment on fortuitous fluctuating variations. More and more will science help men to make the most of the material things of life; but more and more also will she be compelled to admit that behind the material is the spiritual.

The time is ripe for a great scientific spiritual renaissance and revival. Is it not time that the Church discovered the spiritual applications of modern biological science and the spiritual consequences of the overthrow of Darwinism?

CHAPTER XXIV.

WOMAN AND HEREDITY.

RECENT investigations into the laws of heredity and evolution have shed considerable light on one of the most interesting of modern controversies—the controversy as to the social relationship of man and woman. The controversy, unfortunately, is a popular one, and the whole matter has been darkened and obscured by the unscientific statements of many of the controversialists. Thus, it is not at all uncommonly stated, by ignorant advocates of female suffrage, that the inferior talents of women in certain respects are due to the fact that women have been debarred for centuries from the due exercise of these talents. This bold statement meets us on the very threshold of enquiry, and is accepted by many as an axiom; yet it is bristling with fallacies; it shows a deep and almost invincible ignorance both of logic and science, and it is flatly contradicted by the elementary facts of heredity. In the first place, it makes the ignorant and foolish assumption that disuse of a faculty causes its deterioration in the offspring; and it doubles the ignorance and folly of the assumption, by further assuming that such deterioration in the mother would be transmitted only to the daughters. There is no evidence whatsoever that disuse of any faculty disables that faculty in the offspring, and still less is there any evidence of one-sided transmission. The mathematical genius of Newton had nothing to do with the use or disuse of the mathematical faculties of his forefathers. The brilliant literary career of George Eliot cannot be ascribed to the literary industry of her foremothers.

Transmission of faculties not one-sided.

As we have before explained, both mother and father go to the making of the son, and both mother and father go to the making of the daughter, nor can use or disuse of talents by either parent affect the transmission of the talents to offspring of either sex.

When we come to consider, in a really scientific way, whether the paternal or maternal bulks more largely in offspring, and whether the father preponderates in the son, and the mother in the daughter, or the mother in the son, and the father in the daughter; and whether, again, the father usually transmits intellectual, and the mother moral qualities—when we begin, seriously and scientifically, to consider questions like these, we find that they are very difficult questions, and that we know very little about the matter.

Do we know anything at all?

Goethe declared that he got his stature and serious way of taking life from his father, and his gaiety and inventive faculties from his mother, Huxley stated that "mentally and physically (except in the matter of the beautiful eyes) I am a piece of my mother;" and many such instances of parental likenesses can be collected; but when we try to formulate a general law to express the part played by father and mother in the composition of offspring, we find that we cannot. It is true that many breeders believe that external form depends on the father, and temperament and visceral organs depend on the mother; but this is not really the case; and equally erroneous is the dog-fanciers' axiom, "Chien de chienne, et chienne de chien."

Our knowledge in the matter is well summed up by Professor J. A. Thomson in the following words: "Apart from a few cases well established statistically, such as the prepotency of the father as regards stature in British families, it is at present illegitimate to make general statements as to exclusive inheritance. Whether the offspring takes after the father or the mother in respect to particular characters probably depends on the more or less unpredictable relative strengths of the corresponding parental contributions to the inheritance."

Professor J. A. Thomson's statement.

This being so, and the daughter being no more maternal than paternal, and the son no more paternal than maternal, it might be supposed that son and daughter have equal mental, moral, and physical heritages. Have they not? Apart from the few distinctive features of sex, are they not almost identical? Is there a nerve, a bone, and muscle, that a man possesses which is not equally possessed by a woman? Are not the heart chambers alike? Are not the liver fissure and lobes, the brain fissure and lobes, exactly similar?

In all these obvious features, men and women are alike, and their parts are inherited equally from their fathers and mothers, and yet the difference between man and woman is much greater than the few structural and physiological differences that we can discover. A man with a grain of opium in his veins is very different from a man with normal blood; a woman with some thyroid secretion in her system is widely different from a woman with none; and between man and woman there is such a difference, of just such a degree, and such a kind, for the whole psychology of a man and the whole psychology of a woman are so influenced by what we may call the organic chemistry of each. Up to the age of sexual maturity, boy and girl are very alike, and the girl may be more manly than the boy; but at the age of sexual maturity a few small physiological changes effect great constitutional alterations in each organism. Outwardly the boy gets his beard and the woman her curves; inwardly both are

Difference in the organic chemistry of women and men.

intellectually and morally differentiated by new reflexes and by the new chemical contents of the blood, and they can never again see eye to eye. No longer are they duplicates, but complements.

The woman may have just as much brain as the man; but her brain has different food, and therefore acts otherwise. The man may have just as much heart as the woman, but his heart has different diet, and therefore different feelings.

Were it possible to change the chemistry of man and woman so that the so-called intra-cellular products in the blood of each should be rendered identical, then, in muscular activity, in mental and moral character, the two sexes would approximate. Of this we have some evidence in eunuchs and amazons and other creatures whose organic chemistry has been altered by design, or accident, or disease; and, as is well known, it is not uncommon for woman to develop certain manly characters, such as a beard and a bass voice.

Though then the facts of heredity inform us that males and females are compounded of paternal and maternal elements, and that a girl may have her father's brain and her father's heart, yet, despite brain and heart, the girl must be a woman, and see life with the eyes of a woman, so long as brain and heart are under the influence of certain reflexes and of certain ferments. She can no more alter that psychological fact than she can alter her muscular metabolism, which again has its own characteristic feminine qualities, as even a little lime-water can prove. Under normal conditions, the difference is always there.

Psychological differences of the sexes good.

It is good that there should be this difference, for it tends to specialize the heart and head work of men and women, so that both play companionable and complementary parts in the world. The man by the very exigencies of his physico-chemical system is energetic and enterprising, polemical and political; the woman more emotional, more æsthetic, more domestic. *He* fights and wins bread; *she* makes the home and tends the children.

On this biological relationship, love, marriage, child-rearing, empire-making—the whole social economy is founded, and the nation who would do violence to it cannot survive. The world as we know it is man-made; the boundaries between empire and empire have been cut by the sword of man; the ships that knit the continents of the world together were made by men and manned by men; the railways that link east and west, north and south, were engineered by men; the cities that are clustered over the face of the globe have been built by men; all the great financial machinery of the world—banks, business, etc.—has been constructed by men, and is managed by men. By the blades and battleships of men, by the courage of men, by the ambitions of men, have the great nations found places in the sun, and on the sense of justice of man have their laws been founded. It was a man who wrote "Hamlet"; it was a man who painted the Sistine Madonna; it was a man who conceived the Elgin marbles; it was a man who composed the "Moonlight Sonata"; it was a man who showed that the earth goes round the sun; it was a man who showed how the planets are held in their places; it was a man who discovered the circulation of the blood; it was a man who invented the telegraph, the telephone, the steam-engine, the aeroplane; it is a Man whom we worship as the God of the Universe. And even in spheres of life where feminine activities have been at work for centuries—in such things as dressmaking, dairywork, cooking—men are pre-eminent. To answer a list that might be drawn out to volumes by mentioning Madame Curie, and Florence Nightingale, and a few others, is no answer. To say that women have done less than men because men have kept women down is absurd. For centuries in civilized countries women have had far more leisure for work than men, nor has the greatest work in the world been accomplished by men with the greatest opportunities, but by men who have had to fight for opportunity in the face of opposition.

Between normal men and women there is no question of rights, no question of rivalry, no question of jealousy, no question of antagonism; but the natural, mutual give and take that their mental, moral, and æsthetic constitutions require. On this give and take, on this complementary relationship, as we have said, society, and home, and love, and all the best things in life are founded. To talk of man oppressing women is not only untrue but the antithesis of truth. So long as men are men and women are women, men will feel specially tenderly towards women and women towards men: it is so; it ought to be so; it always will be so; and even this lamentable spirit of sex-antagonism so subtly inculcated by the propaganda of the so-called "feminists" can never wholly eradicate this deeply-rooted physico-psychological fact. We see it in small things, such as the dressing of wounds in a hospital ward; we see it in large things, such as the wreck of the "Titanic." To realize how absurd is the accusation that men oppress and repress women, one has merely to walk down Regent Street or Bond Street—one has merely to glance at the hat shops, and milliners' shops, and jewellers' shops. The differences we see in the sexes are not due to repression or oppression of women by man, but are the natural outcome of their different characters as conditioned by physico-psychical laws over which we have no control. And from fire-mist to man, be it remembered, the essence of progress has been differentiation, and differentiation of the mental functions of men and women has taken place *pari passu* with the advance of civilization.

Essence of progress differentiation.

The modern cry for equality, the desire of certain modern women to participate in all masculine activities, are simply signs and symptoms of organic abnormality and deficiency. The advocates of women's "rights" are often called *feminists*, but the whole trouble is that they are not feminists but *epicenes*. Indeed, a very small acquaintance with the modern feminine revolt cannot fail to suggest, to the observant medical eye, that sex rivalry and sex antagonism are often psycopathic—that they are often due to physiological abnormalities with psychological consequences. The feminists are so constituted that they do not feel as normal women do towards men, and are unable to understand the chivalrous feeling of men towards women; their views of the relative position of men and women are the inevitable fruit of the deficiencies of their own nature; they do honestly believe that all differences between the sexes are artificial, and that men and women are equivalent in all the activities of life.

Feminists really epicenes.

Not all the feminists, of course, are products of such organic abnormality; many are drawn to the feminist movement by occasional causes, such as disappointment in love, hysteria, ambition; but the mainspring of the movement is certainly an epicene failure to appreciate the differential and complementary relationship of the sexes.

The result is that the feminist movement fails to appreciate the great and growing importance of love between man and woman in the world machine, for the very same causes and circumstances that separate men and women mentally, emotionally, morally, physically, attract them to each other, and bring them together into the complementary relationships of love—on the very differences the feminists deny or deprecate love is based and love is sustained. Even little differences in garments, in hair-dressing, in gait, serve to attract as they serve to differentiate, and it is noteworthy and suggestive that many of the advanced women who claim sex equivalence do not understand or approve these distinctions.

Physiology, expediency, experience, instinct, all deny—cheerfully and emphatically deny—the mental, emotional, moral and physical equivalence of men and women; but to deny equivalence is not to deny equality.

Men are the swords, and knives, and wheels, and turbines, in the great financial and political organization of society; women are the light, the music, the beauty, the love that make life worth living; they are "The rose upon truth's lips, The light in wisdom's eyes."

Women supreme in love.

Above all, women are the Love of the world. In love women are supreme. From the days of their dolls, to the days of their grandmotherhood, their lives are beautified and enriched by love. Poetry and history are full of tales of the devotion women have given, and of the passion they have inspired, and so long as they love, "the hand that rocks the cradle will rule the world."

Let not women sell their thrones for a vote, on the false idea that men care less for women than women care for each other; on the false idea that women's minds are meant rather for competitive combat than for complementary comradeship; on the false idea that differentiation of function is in some way a denial of equality; on the false idea that they can put wrong things right more effectively by getting a vote than by getting a voter.

It is true that a certain very small percentage of women, sometimes by their own fault, sometimes by the fault of others, sometimes by nobody's fault, are *forced* to live epicene lives, often hard, combative, loveless lives. For these we must feel great sympathy; but we must not let sympathy with their misfortunes blind us to the fact that they are only exceptional cases; that the best in the world is founded on the love existing between men and women, and that this love again is based on the psychophysical differences between them which draws them together in heart, even while it differentiates the natural manifestations of their physical or mental energies.

The country's great asset is love, and if it be bankrupt in love it cannot prosper.

CHAPTER XXV.

THE CELL IN MICROBIC DISEASE. A NEW THEORY.

" Der Luft, dem Wasser, wie der Erde,
Entwinden tausend Keime sich
Im Drocken, Feuchten, Warmen, Kalten."

THE multicellular colony known as the human body slowly and continuously burns away, and only by renewing its tissues with the protoplasmic substance of other cells can it maintain integrity of function and structure. It *eats* other cells, dissolves them by analytic ferments, and then by synthetic ferments uses some of the dissolved substances to repair its own wear and tear, or to supplement its own store of combustible material.

But not only do men devour other animals and cells; other animals and cells also devour man, and all down the ages he has had to fight for his life both with his fists and his ferments. In the early days he had to combat such mighty conglomerations of cells as mammoths, and woolly rhinoceroses, and sabre-toothed tigers, but now, strangely enough, his most dangerous enemies are little single microscopic cells.

For ages these little single cells had man more or less at their mercy. Their very minimissitude was in itself a peril, for they are so small that he could not see them, and could not evade them—so small that like St. Anthony's angels they could dance a saraband on the point of a needle. And they were everywhere. They lurked in the Campagna marshes; they hid in the mediæval mud-huts; they insinuated themselves into his milk and cream; they fermented his wine and fuddled his brain; they fermented his blood and disordered his functions. They made aeroplanes of the dust, and employed the proboscis of a flea or of a mosquito as an injection needle. Without mercy they marred, and maimed, and massacred. Nor could man understand what was going on; of the war waged between cell and cell he knew nothing until within the last fifty years. Now, however, man knows a good deal, and increasing knowledge has given him greater power to resist and destroy the invisible enemy.

The ubiquity of microbes.

When certain cells, known as "microbes," come into contact with the cells of the body, the microbe cells and body cells necessarily begin to cause certain chemical changes in each other, and these changes may be fatal or injurious to one of the two parties. Many of the microbes we inhale and ingest are quickly destroyed and absorbed, and it is so much the worse for the microbe. Microbes are constantly alighting on the lining membrane of the nose, and usually about as quickly as they alight they are devoured, "and nothing said." In other cases, however, the microbes are not so easily defeated; there is a pitched battle, and the higher organism which is attacked suffers certain physiological changes known as disease. With this matter of microbic disease we wish now specially to deal.

In most cases where microbes cause disease, not only, be it noted, is the body diseased, but also the microbes, for this is the very essence of the battle between them. *Both* are fighting to destroy, both are damaged by the battle.

When, for instance, typhoid germs invade the human body, the body cells suffer from certain changes known as typhoid fever; but the typhoid germs in turn suffer from certain changes which might be called anthropoid fever. The body cells and the typhoid cells are equally hurt, and irritated, and perturbed by unsuitable ferments, and by new relationships to which they are unaccustomed. In most cases, after a longer or shorter time, the typhoid cells die, and the body cells are then found to have acquired such properties that they are immune to further attacks of the disease.

Explanation of immunity.

Now this immunity which follows recovery from most microbic diseases is a very amazing fact. How is it to be explained? How does it happen that the body cells manage to find and to secrete exactly the right juices necessary to kill off the invaders?

Various subtle theories have been suggested; but it seems probable to the writer that immunity is produced in three simple ways.

The invaders may die from exhaustion of the food supply in the blood, or they may so alter the food supply in the blood by their toxins, and by the effect of their toxins on the excretions of the body-cells, that no longer is food material produced fitted to nourish them, but rather a poisonous substance calculated to kill them. In this latter case, the whole metabolism of the body cell is altered so that it continues to secrete anti-toxins, opsonins, agglutinins, precipitins, lysins, and so forth, for its natural lifetime. Immunity to common colds and influenza is probably of this nature—a direct chemical reaction of the body cells to the chemical products of the microbes.

How is life-long immunity to be explained?

But the lifetime of somatic cells is limited, and, since acquired characters are not transmitted as mature characters, we cannot, as is usually done, explain immunity that lasts for years on this basis, and such immunity requires a special explanation. How then is life immunity to be explained? Life-long immunity can be explained only on the principle of the survival of the fittest.

When disease-cells invade our bodies, and when the fight is severe, the death-rate and the birth-rate of the fighting cells are exceedingly high. The same irritation that causes death also causes multiplication, and the cells both die at a great rate and multiply at a great rate. Further, each generation has its own crop of variations, and, under such conditions of stringent selection, each variation lives or dies, according to its fitness to survive. It is not, as is usually asserted, a case of education of the cells. The term education in such a connection has little meaning and explains nothing; the only things educed are new varieties, and after eduction it is simply a case of the survival of the fittest. So long as we believed in Lamarckism we might believe that perpetuity of immunity could be established by the perpetual transmission of characters experimentally acquired; but now that we know that acquired characters are not inherited, except under the same circumstances that conditioned their original acquisition, we must surrender this theory. It is almost impossible to believe that individual cells make a series of chemical experiments, and finally hit upon a victorious chemical equation; and in view of our knowledge of the principles of heredity, it is quite impossible to believe that even if they did hit upon it, they would transmit the same toxicological accomplishment to their offspring. According to the established laws of heredity, the cell offspring would have to perform the same series of experiments that their fathers performed, and immunity would last only for the lifetime of a single generation of cells. The theory of chemical experiments by individual cells was never scientific and must be given up, and it seems strange to the writer that this theory of cell multiplication and selection has not been previously propounded.

Continued immunity a matter of multiplication and selection.

Continued immunity, then, we suggest, is in many cases simply a matter of multiplication and selection. Under the stimulus of the toxins resistant strains are selected and weak strains killed off, and thus the combat is eventually a combat between "picked" cells on both sides. Not only, it must be noticed, are the body cells selected, but also the microbe cells; and the effect of such selection in raising the virulence of microbes, is well seen in strains of microbes that have been passed through several bodies in succession. During such passage the weakly microbes are killed off and only the more resistant and more virulent microbes survive. It is not a case of chemical experiment by an individual, but of chemical experiment upon generations of varying individuals, and, though it may seem a wonderful thing that in the course of generations variants should usually eventually arrive capable of resisting a specific toxin, yet, after all, it is not more wonderful than the fact that in the history of the race populations should appear with adaptations fitted to the many unfavourable situations in which they may find themselves—

no more wonderful than the whale's blubber-lining, or the lizard's prehensile tongue. The beauty, indeed, of the theory we propose is that it puts toxicological adaptations of cells on the same basis as the other larger adaptations found in the fauna and flora of the world—on a basis that assumes both a certain amount of prescience of contingencies, and also of selection and elimination.

The theory, moreover, offers a new and plausible explanation of the definite time factor found in infective disease, for it implies time for selection and variation, and only after a certain number of generations, requiring a fairly definite time for their production, will the conquerors be born and will it be possible for either side to win the battle.

Once a strong resistant strain has been bred by lethal selection and has won its battle, it is likely to breed true for a number of generations, though, as we see in small-pox and some other diseases, the strain may degenerate with cessation of selection and the body cells may again be susceptible to the disease.

The excessive and rapid multiplication of cells due to the stimulation of toxins which we have suggested as the basis of acquired immunity, is well seen in cases of superficial septic inflammation and ulceration. In every such case millions and millions of cells are produced and destroyed on both sides, until eventually a breed of cells is produced by the body chemically competent to resist and slay the microbes, or until a breed of microbes is produced that the body cells cannot conquer. The body cells which take part in this competitive multiplication are chiefly the white blood corpuscles and connective tissue cells, for these would seem to be the soldiers and toxicologists of the corporeal commonwealth. The suppuration, the flow of pus that accompanies septic inflammation, is more than an aggregation of dead cells killed by the toxins of the microbes; it is a holocaust of the unfit of cells that have been tried and found wanting, and, until fitter cells are born, the holocaust continues. But in time, as a rule, even if the microbes are not killed by antiseptics, a breed of cells is produced more immune to the toxins, and repair takes place, for usually somewhere in the loins of the cells of the human body there are cells fitted to cope with most bacterial possibilities—another instance of the anticipation of contingencies which we have already so frequently indicated.

Interpretation of suppuration.

In all cases of inflammation and suppuration of mucous membranes, such as acute bronchitis, the copious discharge is probably a sign and symptom of a process of lethal selection. Part purpose of the discharge may be to carry off invaders, but its more important purpose is to remove the weakly members of the cell-community, with the view to the breeding of a good resistant race.

Even the pustules in small-pox and chicken-pox may be localized battlefields and breeding-places where great fighters are selected.

On this theory of immunity, poultices and fomentations act not so much by mobilizing phagocytes and defensive cells, as by incubating them, and thus hastening multiplication and evolutionary selection.

It may be enquired how, on this theory of immunity, we can explain the action of anti-toxins, such as diphtheritic antitoxin. But an explanation on this basis is quite simple, and, indeed, helps to elucidate the action of the anti-toxins. Antitoxins are perhaps, properly speaking, not antitoxins at all, but stimuli that cause a proliferation of cells in the neighbourhood of the injection, with the production of a certain proportion of cells showing favourable variations, and these favourable varieties and their progeny in the blood act as auxiliary forces and ensure victory by their secretions. In this way and on this principle we can understand how such a small quantity of antitoxin can go such a long way and persist such a long time, for "a little leaven leaveneth the lump."

If this explanation be correct, the best treatment by antitoxins should be multiple injections, so as to establish numerous breeding-places.

Let us look in this light for a moment at the tuberculin treatment of consumption. It is very probable that the battle of tuberculosis is mainly a war between the tubercle bacilli and the leucocytes of the body. In the course of the fight, many leucocytes perish, as the pustular discharge clearly proves, yet, on the whole, there is a tendency for the disease, as time goes on, to become more chronic. The weaker bacilli, the weaker leucocytes, have been destroyed, and the two opposing forces are about equally matched.

Tuberculin treatment of consumption.

Now in what way can the injection of tuberculins in the course of pulmonary tuberculosis affect the combat?

Whatever form of tuberculin may be chosen, it contains, in some shape, some of the toxins which produced death and proliferation at the seat of disease in the lungs. It will accordingly produce a similar proliferation at the site of injection, and the proliferation will similarly tend to produce a race of cells capable of resisting, by opsonins or otherwise, the assaults of the tubercle bacilli. The number of resistant cells produced may be small, but still it must be remembered that they are capable of multiplication, and that even infinitesimally small quantities of certain cellular products may have great chemical potency. Further, there is this great advantage, that the resistant cells are bred without any compensatory and reciprocal breeding of resistant microbes, as must be the case if they are bred at the site of the disease in competition with each other.

It would seem to follow as a corollary of this principle that the most efficacious administration of tuberculin would be by a series of small injections; but experiments in this way have yet to be made.

The fact that proliferation under the stimulation of microbic toxins does usually eventually lead to the generation of an immune race of body-cells suggests that in future years these immune cells may become generated at once, with the result that microbic disease will in time become extinct. No doubt many microbic diseases have vanished or become less in the course of centuries, and very probably this may be the rationale of their extinction or attenuation.

We see even in the life history of individuals that increasing age brings increasing immunity, e.g., to ringworm or tuberculosis, and it is quite possible that the same proliferation that takes place under the stimulus of toxins takes place under the normal direction of vital stimuli, so that in time, even without exposure to disease, the resistant generations are produced.

GLOSSARY OF SCIENTIFIC TERMS.

Amœba.—A very elementary micro-organism consisting of a microscopic particle of protoplasm, which can grow, can multiply by dividing into two, and can move about by protrusion and retraction of arm-like extensions of its own substance.

Atoms.—Ultra-microscopic particles of matter which were formerly believed to be indivisible. Lately it has been shown that these particles are made up of still smaller particles, known as electrons or corpuscles.

Anastates.—The series of substances produced in the process of the natural building-up of living matter.

Allelomorphs.—Contrasted pairs of characters occurring in conjugating organisms. Thus, if we fertilize tall white sweet-peas with dwarf red sweet-peas, tallness and shortness and whiteness and redness are allelomorphs.

Arborescent.—With branches like a tree.

Blastoderm.—The primary layer of cells formed by the division of the ovum.

Cephalopod.—A class of molluscs including the octopus.

Chlorophyll.—The green colouring matter of plants.

Chromatin.—That part of the substance of the cell which is found to stain especially well. It is often in the form of a mesh-work or of short rods. (See page 14.)

Chromosomes.—Threads or rods consisting chiefly of chromatin. (See page 14.)

Cytology.—Study of the cell.

Colloid.—Are substances, such as albumin, which pass with difficulty or not at all through animal membranes.

Dynamics.—Science of force.

Echinoids.—Sea-urchins.

Electrons.—A name given to the ultimate particles of atoms.

Enzymes.—Otherwise known as "ferments," are substances that cause chemical change in other substances without themselves incurring change. Thus the enzyme of saliva converts starch into sugar, and itself remains unchanged. (See pages 25 and 26.)

Fission.—Division into two or more pieces.

Gametes.—Sexual cells which unite in pairs to form zygotes—the compound cells which give rise to the multicellular individual. A gamete derived from a male is known as a sperm-cell; a gamete derived from a female is known as an egg-cell or ovum.

Genetics.—The science that deals with the principles of generation.

Germ-cell.—See *Gamete*.

Germ-plasm.—The substance of a gamete.

Hydrolysis.—A chemical process of combination with water which results in the breaking down of larger molecules into smaller ones. Thus cane-sugar combines with water and divides into the smaller molecules known as dextrose and levulose.

Imago.—The final stage in the transformations of an insect.

Infusoria.—Micro-organisms that swim about in infusions of decaying organic matter.

Karyokinesis.—The complicated phenomena which occur in cells previous to cell-division.

Katalysis or Catalysis.—The breaking up which occurs in certain substances when brought into contact with certain enzymes. (See *Enzyme*.)

Katastates or Catastates.—The series of substances produced in the course of the changes which occur in living matter.

Kinetic Energy.—Energy in the form of motion.

Lancelet.—A skull-less fish, the lowest of all vertebrates.

Mesophytes.—Plants that require a moderate amount of water, as contrasted with Xerophytes, which require almost none.

Micromeres.—The smaller of the cells resulting from the division of certain cells.

Molar.—Pertaining to the mass, as contrasted with molecular.

Molecule.—The smallest part of a substance that can exist separately, and yet retain its composition and specific properties.

Moneron.—A lowly unicellular organism.

Morphogenesis.—Growth of structure.

Morphology.—The science of structure.

Mutation.—A wide and stable departure from the normal type.

Œcology.—The science of the relation of organisms to one another or to the world around them.

Ontogeny.—The evolution of the individual as contrasted with the evolution of the species, which is known as phylogeny.

Osmosis.—The mixture of two gases or fluids by passage through a membranous or porous partition separating them. In such a case the partition is found to be under a certain pressure known as osmotic pressure.

Palæontology.—The study of extinct organisms, especially as revealed in fossils.

Pangenesis.—The theory that qualities are transmitted to the offspring by means of minute particles (pangens) which are derived from all the cells of the body, and which are brought to the germ-plasm by the circulation.

Panmixia.—Promiscuous interbreeding, leading to admixture of qualities.

Parthenogenesis.—Production of offspring by unfertilized eggs.

Phylogeny.—The evolution of the species as contrasted with ontogeny, the evolution of the individual.

Polymorphism.—The occurrence of several types of structure in the same group of organisms.

Polyp.—A group of small aquatic animals of which the sea anemone is perhaps the best known.

Protein.—The most important and characteristic substance found in animal and vegetable tissues. It is a complex compound of carbon, hydrogen, oxygen, nitrogen, and sulphur.

Somatic.—Pertaining to the body proper, as contrasted with the germ-plasm, *i.e.* with the cells in the body capable of producing another body.

Taxonomic.—Classificatory in a scientific sense.

Teleological.—With reference to an aim or purpose—purposive.

Urschleim.—Primitive material of life.

Xerophytic.—Requiring little water—applied to plants growing in arid soil.

Zygote.—The egg formed by the junction of two gametes. (See *Gamete.*)

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