THE ORGANIC CELL

Part I.—Its Methods of Division and Status in the Process of Heredity

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The term 'cell' is a biological misnomer, which, however, shows little sign of dying a natural death. Literally speaking a cell means a hollow chamber, bounded by distinct walls. It is only rarely we come across such hollow cells in organic life, the cell as found in Nature consisting essentially of a mass of protoplasm, a substance well described by Huxley as 'the physical basis of life' and admitted by all competent thinkers to be the field in which all vital phenomena are exhibited. However much cells may differ in appearance according to the particular tissue or organ they may go to form, they still possess features common to them all. In the higher organisms we have a composite structure built up of millions of units (cells).

There is, however, at the very bottom of the organic ladder a whole series of lowly forms, both plant and animal, consisting of a single cell, the type of which is the same as in the cells which go to build up the complex higher multicellular forms.

Examples of these one-celled organisms will be found in the infusoria, diatoms, and bacteria.

In these lower forms all the phenomena of life are exhibited by the single cell, while in the higher forms certain groups of cells perform certain definite functions, giving rise to the 'physiological division of labour' by which alone can be attained the most perfect exhibition of vital phenomena. To understand the complexity of cells forming the multicellular organism, one must go back to the single cell.

'It is to the cell that the study of every bodily function sooner or later drives us. In the muscle-cell lies the problem of the heart-beat, and that of muscular contraction; in the gland-cell reside the causes of secretion; and the secrets of the mind are hidden in the ganglion-cell. . . . If then Physiology is not to rest content with the mere extension of our knowledge regarding the gross activities of the human body, if it would seek a real explanation of the fundamental phenomena of life, it can only attain its end through the study of cell-physiology.' [1]

It seems strange that the above conceptions of the cell, originated by Schwann and elaborated by Kölliker, Virchow, and Häckel, did not for many years affect the speculative aspect of biology. In that great work 'The Origin of Species,' published in 1859, Darwin does not mention it except in regard to his provisional theory of pangenesis, about which I shall have more to say later.

The factor which brought the cell theory into line with the evolution theory was the series of researches (made twenty years later) on the early history of the germ cells, and the result of the union of the germ and sperm cells. Through the agency of these researches it became for the first time apparent that phenomena associated with embryology, heredity, and evolution are closely connected with cell structure; and that a full understanding of them can only be attained by the closest and most careful cytological research. Shortly after this it was clearly demonstrated that the nucleus of the cell contained the substance of inheritance, and at very nearly the same time the classical researches of van Beneden on the early changes taking place in the animal egg opened up a wide field for original work on the various details of cell phenomena.

To form an estimate of the full value of the discoveries made during this brilliant period it will be useful to very briefly examine the earlier opinions on embryology and inheritance. The modern thinker looks upon the germ as 'simply a detached portion of the substance of a pre-existing living body' carrying with it a definite structural organisation characteristic of the species. By the earlier embryologists, however, the matter was very differently regarded; for their views in regard to inheritance were vitiated by their acceptance of the Greek doctrine of the spontaneous generation of life. The great Harvey himself did not escape from this error. His

[1] Verworn, *Allgemeine Physiologie* (1895), p. 53.

mind was obscured by the fallacy of spontaneous generation. Neither could he have had any true idea of the nature of the egg, for the cellular structure of living things was not understood until two centuries later. For a century after Harvey's time desperate efforts were made to solve the mystery of the origin of the individual life. The extremists evolved what is known as the Preformation theory, which taught that the germ, whether ovum or sperm, contained a miniature organism, already preformed though invisible, which, on becoming unfolded, revealed the perfectly developed animal.

The egg was thus supposed to contain a minute model of the chick, which in its turn contained still minuter models *ad infinitum*. One enterprising fanatic calculated that Mother Eve must have contained at least 200,000 million homunculi. The ' Ovists,' believing that the ovum contained the miniature, held fierce discussions with the ' animalculists ' who championed the claims of the sperm.

This long-lived theory of Preformation received its deathblow when Caspar Wolff in 1759 demonstrated his theory of ' epigenesis ' by which he sought to show that there was a gradual development from a simple rudiment to a form of greater complexity. Wolff clearly showed in the chick the process of development from a simple rudiment, but having no idea of the uniqueness of the germ cells, was forced to fall back on the postulate of a *vis corporis essentialis*.

Thus the external nature of development was determined, but the structure of the egg and the process of inheritance remained in the dark for yet another century. Schwann and his followers, in 1839, established the fact beyond the possibility of doubt that the egg is a cell, having the same fundamental structure as other cells of the body. Then dawned the striking truth that a single cell may contain within itself the sum-total of the heritage of the species. It was in regard to the female sex that this conclusion was first arrived at; but the doctrine was soon extended to the male as well. Leeuwenhoek in 1677 showed that the fertilising fluid contained numberless minute motile bodies, possessing as a rule very active movement, and for this reason described by the early observers as parasites or infusoria, an idea which caused the origin of the term 'spermatozoa' by which they are even now generally spoken of.

An Italian naturalist (Spallanzani) showed that the fertilising power existed in the spermatozoa, and not in the medium in which they move, because, on filtering, the spermatic fluid loses its power.

The next step was the demonstration of the fact that the spermatozoa take their origin directly from the cells of the testis, that they therefore are not parasitic, but, like the ovum, are directly derived from the parent.

A little later it was shown that the spermatozoon consisted not only of a nucleus, but also contained cytoplasm. Its purely cellular nature was thus clearly shown, that though of extreme minuteness, and possessing a long tail and considerable motive power, still morphologically it was as true a cell as the ovum. Ten years later (1875) Hertwig showed that when fertilisation of the egg occurred this phenomenon was the result of its union with one spermatozoon, and only one. Thus in the process of sexual reproduction each parent supplies a single cell of its own body, which on uniting produce the offspring—a practical corroboration of the conclusions drawn by Galton and Darwin, that the sexes perform equal though not identical parts in the process of hereditary transmission. It is therefore evident that the questions of fertilisation and inheritance are cell problems.

The question now arises: How do the cells of the body originate? As early as 1835 it was known that cells arose by the division of pre-existing cells. There were two different methods by which cells were supposed to come into existence: (1) by division of a pre-existing cell; and (2) by what was known as 'free cell formation,' which supposed that cells could crystallise out from a nutritive substance called the 'cytoblastema,' and, strange to say, this latter method was supposed to be the more typical. After some years it was proved that 'free cell formation' was a fallacy and that such a method did not exist in Nature. In 1855 Virchow upheld the universal nature of cell division, stating clearly that every cell is the result of a pre-existing cell, concluding his statement with the now famous biological aphorism 'omnis cellula e cellula.'

The most recent research has placed this conclusion on an immovable foundation, and its absolute truth can be accepted unreservedly.

The first stage in development is the division of the egg into two portions, each of which is a perfect cell in every respect. The two divide to form four, these again to form eight, sixteen, and so on, until at last the original cell or egg comes to be divided up into a host of cells, each one of which is as perfect as the original egg from which they all arose. It is from this mass of cells that the embryonic rudiment is built and, finally, the fœtus, and then the full-grown individual. This splitting of the egg is called cleavage or segmentation. It must be remembered that cell-division does not begin with cleavage, but can be traced back into the foregoing generation, for it has been shown that the germ of the female and the sperm of the male arise by the division of cells pre-existing in the parent body. The germ and the sperm are therefore 'derived by direct descent from an egg-cell' or testis cell of the foregoing generation, and so on *ad infinitum.*

Thus we arrive at the conception of an endless series of cell divisions extending far back to the very commencement of all life. The body must be looked upon as an excrescence growing out from this 'endless chain, whose end is but to die,' the germ-cells, however, living on and on, 'carrying with them the traditions of the race from which they sprang, and handing them on to their descendants.' This is the modern standpoint of the problems of heredity and development.

The whole teaching of evolution rests on two factors, viz. variation and heredity. Variation causes the appearance of new characters, and by heredity these are carried on to future generations. In the 'Origin of Species' Darwin accepted two modes of variation in formulating his doctrine: (1) Inborn variations, which appear at birth, without having in any way been affected by environment; (2) Variations resulting from environment and produced during the individual life, e.g. the effects of use, disuse, &c. This second class of variation was accepted without hesitation by Lamarck, fifty years before Darwin, and is often spoken of as the Lamarckian factors. Around the question of the inheritance of the Lamarckian factors has raged a severe struggle. Darwin accepted the theory of their being inherited ; and, as an explanation of how it was possible for the effects of use and disuse, &c., to be inherited, he formulated his ingenious provisional hypothesis of pangenesis. This theory suggests that the germ-cells receive minute gemmules from every part of the body, and on this assumption explained the transmission of both inborn and acquired characters. This theory was the most speculative of all Darwin's writings, and, though discarded, it must always remain of interest from the wonderful skill used in its construction.

Brooks, in 1883, attempted to rejuvenate the theory of pangenesis. In the above year Professor A. Weismann startled the scientific world by issuing a sweeping challenge of the whole of the Lamarckian factors.[1] 'In my opinion this [the hereditary substance] can only be the substance of the germ-cells ; and this substance transfers its hereditary tendencies from generation to generation, at first unchanged, and always uninfluenced in any corresponding manner by that which happens during the life of the individual which bears it. If these views be correct, all our ideas upon the transformation of species require thorough modification, for the whole principle of evolution by means of exercise (use and disuse) as professed by Lamarck, and accepted in some cases by Darwin, entirely collapses.' Professor Weismann continues by stating the impossibility of the transmission of acquired traits, for it seems impossible to understand that changes in the body should affect the plasm of the germ cells so as to bring about corresponding changes in the offspring.

Weismann asserts that not a single case of transmission of acquired characters will stand a rigid scrutiny. Inheritance does not take place from the body of the parent to that of the child. 'The child inherits from the parent germ cell, not from the parent-body which bears it,' and the germ cell owes its characteristics not to the body which bears it, but to its descent from a pre-existing germ cell of the same kind. Thus the body is, as it were, an offshoot from the germ cell (see diagram).

[1] See *Essays upon Heredity*, vol. i., by A. Weismann (Clarendon Press, Oxford: 1891).

'As far as inheritance is concerned, the body is merely the carrier of the germ cells, which are held in trust for coming generations.' [1]

As an axiom in Weismannism let it be remembered that germ-plasm may be, and is, converted into body-plasm; but body-plasm can never become germ-plasm. In this simple statement lies the explanation of what is gradually becoming an accepted fact, viz. that any change affecting the body cells,

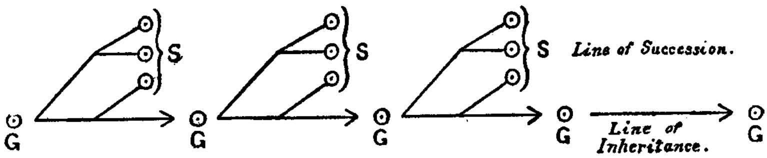

Diagram illustrating Weismann's theory of inheritance. G, the germ cell which by division gives rise to the body or soma (S) and to new germ cells (G) which separate from the soma, and repeat the process in each successive generation.

but not the germ cells, cannot be transmitted to future generations. Thus acquired characters (the Lamarckian factors) cannot be inherited. 'The germ-plasm of one generation being passed on to the next, and so on and on,' influences from without cannot reach them, they being far too deeply buried to be reached by such superficial influences; and thus acquired characters which cannot impress their influence on the germ cells cannot be inherited.

We must therefore look upon the body as a new formation, which soon ceases to exist, but which passes on to its offspring a portion of the original germ-plasm, the germ-plasm itself having existed far back through the ages that have been to the very commencement of all life.' [2]

In the next article in this series I propose dealing with the cell from its microscopical aspect.

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[1] *The Cell in Inheritance and Development*, by E. B. Wilson.
[2] *Mendelism in Theory and Practice*, by E. Wynstone-Waters.