INTRODUCTION

"*Jedes Thier erscheint als eine Summe vitaler Einheiten,* von denen jede den vollen Charakter des Lebens an sich trägt." VIRCHOW.[1]

DURING the half-century that has elapsed since the enunciation of the cell-theory by Schleiden and Schwann, in 1838–39, it has become ever more clearly apparent that the key to all ultimate biological problems must, in the last analysis, be sought in the cell. It was the cell-theory that first brought the structure of plants and animals under one point of view, by revealing their common plan of organization. It was through the cell-theory that Kölliker, Remak, Nägeli, and Hofmeister opened the way to an understanding of the nature of embryological development, and the law of genetic continuity lying at the basis of inheritance. It was the cell-theory again which, in the hands of Goodsir, Virchow, and Max Schultze, inaugurated a new era in the history of physiology and pathology, by showing that all the various functions of the body, in health and in disease, are but the outward expression of cell-activities. And at a still later day it was through the cell-theory that Hertwig, Fol, Van Beneden, and Strasburger solved the long-standing riddle of the fertilization of the egg and the mechanism of hereditary transmission. No other biological generalization, save only the theory of organic evolution, has brought so many apparently diverse phenomena under a common point of view or has accomplished more for the unification of knowledge. The cell-theory must therefore be placed beside the evolution-theory as one of the foundation stones of modern biology.

And yet the historian of latter-day biology cannot fail to be struck with the fact that these two great generalizations, nearly related as they are, have been developed along widely different lines of research, and have only within a very recent period met upon a common ground. The theory of evolution originally grew out of the study of natural history, and it took definite shape long before the ultimate structure of living bodies was in any degree comprehended. The evolutionists of the Lamarckian period gave little heed to the finer details of internal organization. They were concerned mainly with the more

[1] *Cellularpathologie*, p. 12, 1858.

obvious characters of plants and animals — their forms, colours, habits, distribution, their anatomy and embryonic development — and with the systems of classification based upon such characters; and long afterward it was, in the main, the study of like characters with reference to their historical origin that led Darwin to his splendid triumphs. The study of microscopical anatomy, on which the cell-theory was based, lay in a different field. It was begun and long carried forward with no thought of its bearing on the origin of living forms; and even at the present day the fundamental problems of organization, with which the cell-theory deals, are far less accessible to historical inquiry than those suggested by the more obvious external characters of plants and animals. Only within a few years, indeed, has the ground been cleared for that close alliance between students of organic evolution and students of the cell, which forms so striking a feature of latter-day biology and is exerting so great an influence on the direction of research. It has, therefore, only recently become possible adequately to formulate the great problems of development and heredity in the terms of cellular biology — indeed, we can as yet do little more than so formulate them. Yet the fact that these two great lines of research, both concerned with the deeper problems of life, yet having their beginnings so far apart, have at length converged to a meeting-point, is one of the more striking evidences of progress that modern biology has to show; and it sufficiently justifies an attempt to treat the cell from the standpoint of the general student of development.

Let us at the outset briefly outline the cell-theory as thus regarded, and indicate the manner of its historical connection with the general problems of evolution.[1]

[1] Schleiden and Schwann are universally and justly recognized as the founders of the cell-theory; but like every other great generalization the theory was based on a long series of earlier investigations beginning with the memorable microscopical researches of Leeuwenhoek, Malpighi, Hooke, and Grew in the second half of the seventeenth century.

Wolff, in the *Theoria Generationis* (1759), clearly recognized the "spheres" and "vesicles" composing the embryonic parts both of animals and of plants, though without grasping their real nature or mode of origin, and his conclusions were developed by the botanist Mirbel at the beginning of the present century. Nearly at the same time (1805) Oken foreshadowed the cell-theory in the form that it assumed with Schleiden and Schwann; but his conception of "Urschleim" and "Bläschen" can hardly be regarded as more than a lucky guess. A still closer approximation to the truth is found in the works of Turpin (1826), Meyen (1830), Raspail (1831), and Dutrochet (1837); but these, like others of the same period, only paved the way for the real founders of the cell-theory. Among other immediate predecessors or contemporaries of Schleiden and Schwann should be especially mentioned Robert Brown, Dujardin, Johannes Müller, Purkinje, Hugo von Mohl, Valentin, Unger, Nägeli, and Henle. The significance of Schleiden's, and especially of Schwann's, work lies in the thorough and comprehensive way in which the problem was studied, the philosophic breadth with which the conclusions were developed, and the far-reaching influence which they exercised upon subsequent research. In this respect it is hardly too much to compare the *Mikroskopische Untersuchungen* with the *Origin of Species*.

During the past thirty years the theory of organic descent has been shown, by an overwhelming mass of evidence, to be the only tenable conception of the origin of diverse living forms, however we may conceive the causes of the process. While the study of general zoölogy and botany has systematically set forth the results, and in a measure the method, of organic evolution, the study of microscopical

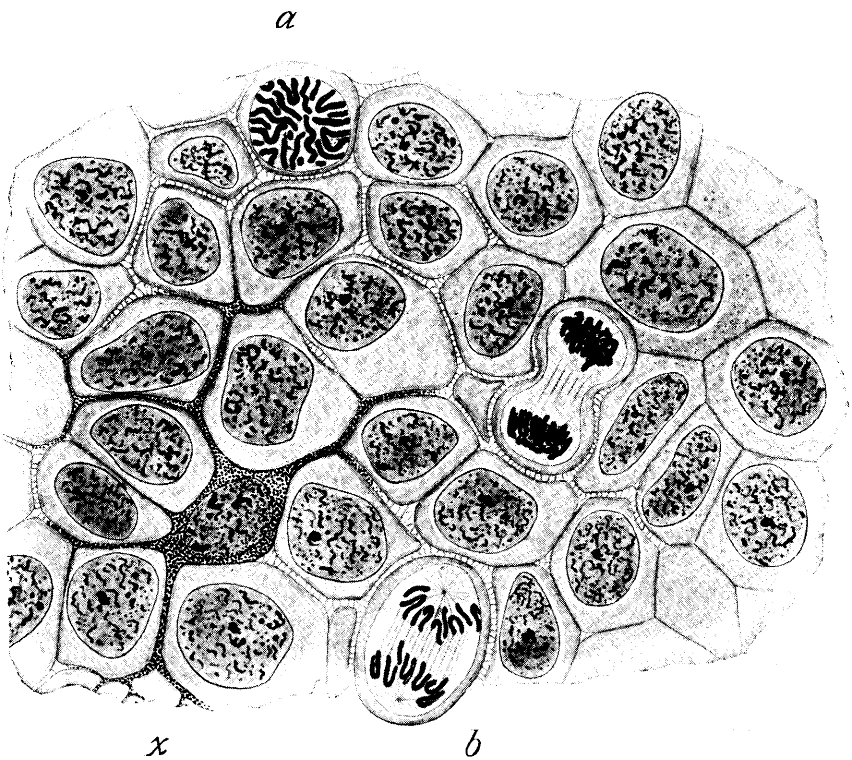

Fig. 1. — A portion of the epidermis of a larval salamander (*Amblystoma*) as seen in slightly oblique horizontal section, enlarged 550 diameters. Most of the cells are polygonal in form, contain large nuclei, and are connected by delicate protoplasmic bridges. Above x is a branched, dark pigment-cell that has crept up from the deeper layers and lies between the epidermal cells. Three of the latter are undergoing division, the earliest stage (*spireme*) at a, a later stage (mitotic figure in the anaphase) at b, showing the chromosomes, and a final stage (*telophase*), showing fission of the cell-body, to the right.

anatomy has shown us the nature of the material on which it has operated, demonstrating that the obvious characters of plants and animals are but varying expressions of a subtle interior organization common to all. In its broader outlines the nature of this organization is now accurately determined; and the "cell-theory," by which it is formulated, is, therefore, no longer of an inferential or hypothetical character, but a generalized statement of observed fact which may be outlined as follows : —

In all the higher forms of life, whether plants or animals, the body may be resolved into a vast host of minute structural units known as *cells*, out of which, directly or indirectly, every part is built (Figs. 1, 2). The substance of the skin, of the brain, of the blood, of the bones or muscles or any other tissue, is not homogeneous, as it appears to the unaided eye, but is shown by the microscope to be an aggregate composed of innumerable minute bodies, as if it were a

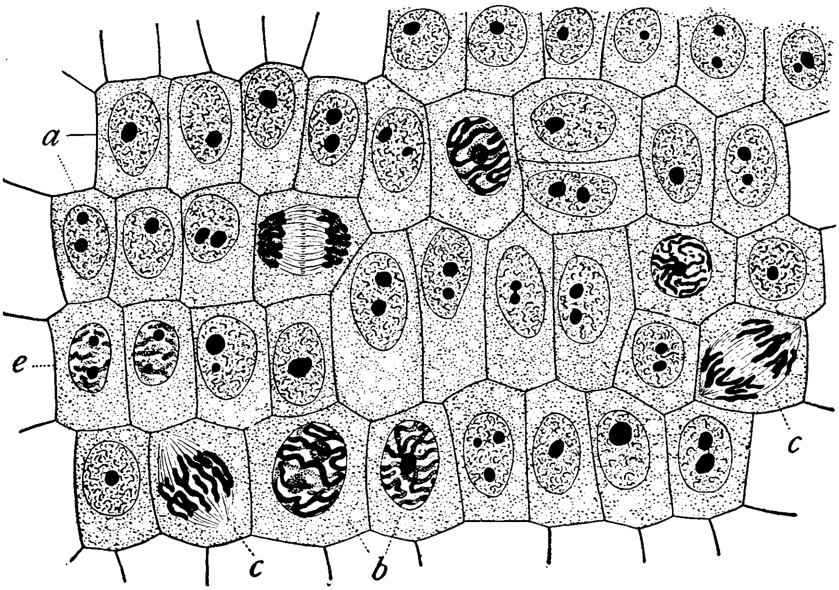

Fig. 2. — General view of cells in the growing root-tip of the onion, from a longitudinal section, enlarged 800 diameters.

a. non-dividing cells, with chromatin-network and deeply stained nucleoli; *b.* nuclei preparing for division (spireme-stage); *c.* dividing cells showing mitotic figures; *e.* pair of daughter-cells shortly after division.

colony or congeries of organisms more elementary than itself. The name *cells* given to these bodies by the early botanists, and ultimately adopted by nearly all students of microscopical anatomy, was not happily chosen; for modern studies have shown that although the cell may assume the form of a hollow chamber, as the name indicates, this is not one of its characteristic or even usual features. Essentially the cell is a minute mass of *protoplasm*, a substance long since identified by Cohn, Leydig, Max Schultze, and De Bary as the essential active basis of the organism, afterward happily characterized by Huxley as the "physical basis of life," and at the present time universally recognized as the immediate substratum of all vital activity.[1] Endlessly diversified in the details of their form and structure, these protoplasmic masses nevertheless possess a characteristic type of organization common to them all; hence, in a certain sense, they may be regarded as elementary organic units out of which the body is compounded. This composite structure is, however, character-

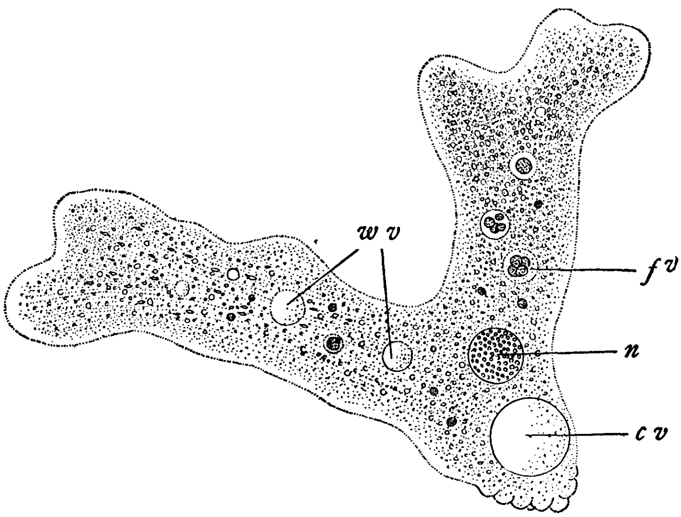

Fig. 3. — *Amœba Proteus*, an animal consisting of a single naked cell, × 280. (From Sedgwick and Wilson's Biology.)

n. The nucleus; *w.v.* water-vacuoles; *c.v.* contractile vacuole; *f.v.* food-vacuole.

istic of only the higher forms of life. Among the lowest forms at the base of the series are an immense number of microscopic plants and animals, familiar examples of which are the bacteria, diatoms, rhizopods, and Infusoria, in which the entire body consists of a single cell (Fig. 3), of the same general type as those which in the higher multicellular forms are associated to form one organic whole. Structurally, therefore, the multicellular body is in a certain sense comparable with a colony or aggregation of the lower one-celled forms.[2] This com-

[1] The word *protoplasm* is due to Purkinje (1840), who applied it to the formative substance of the animal embryo and compared it with the granular material of vegetable "cambium." It was afterward independently used by H. von Mohl (1846) to designate the contents of the plant-cell. The full physiological significance of protoplasm, its identity with the "sarcode" (Dujardin) of the unicellular forms, and its essential similarity in plants and animals, was first clearly placed in evidence through the classical works of Max Schultze and De Bary, beside which should be placed the earlier works of Dujardin, Unger, Nägeli, and Mohl, and that of Cohn, Huxley, Virchow, Leydig, Brücke, Kühne, and Beale.

[2] This comparison must be taken with some reservation, as will appear beyond.

parison is not less suggestive to the physiologist than to the morphologist. In the one-celled forms all of the vital functions are performed by a single cell. In the multicellular forms, on the other hand, these functions are not equally performed by all the cells, but are in varying degree distributed among them, the cells thus falling into physiological groups or tissues, each of which is especially devoted to the performance of a specific function. Thus arises the "physiological division of labour" through which alone the highest development of vital activity becomes possible; and thus the cell becomes a unit, not merely of structure, but also of function. Each bodily function, and even the life of the organism as a whole, may thus in one sense be regarded as a resultant arising through the integration of a vast number of cell-activities; and it cannot be adequately investigated without the study of the individual cell-activities that lie at its root.[1]

The foregoing conceptions, founded by Schwann, and skilfully developed by Kölliker, Siebold, Virchow, and Haeckel, gave an impulse to anatomical and physiological investigation the force of which could hardly be overestimated; yet they did not for many years measurably affect the more speculative side of biological inquiry. The *Origin of Species*, published in 1859, scarcely mentions it; nor, with the important exception of the theory of pangenesis, did Darwin attempt at any later period to bring it into any very definite relation to his views. The initial impulse to the investigations that brought the cell-theory into definite contact with the evolution-theory was given nearly twenty years after the *Origin of Species*, by researches on the early history of the germ-cells and the fertilization of the ovum. Begun in 1873–74 by Auerbach, Fol, and Bütschli, and eagerly followed up by Oscar Hertwig, Van Beneden, Strasburger, and a host of later workers, these investigations raised wholly new questions regarding the mechanism of development and the *rôle* of the cell in hereditary transmission. Through them it became for the first time clearly apparent that the general problems of embryology, heredity, and evolution are indissolubly bound up with those of cell-structure, and can only be fully apprehended in the light of cytological research. As the most significant step in this direction, we may regard the identification of the *cell-nucleus* as the vehicle of inheri-

[1] *Cf.* pp. 58–61. "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; in the epithelial cell, in the white blood-cell, lies the problem of the absorption of food, 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*" (Verworn, *Allgemeine Physiologie*, p. 53, 1895).

tance, made independently and almost simultaneously in 1884–85 by Oscar Hertwig, Strasburger, Kölliker, and Weismann,[1] while nearly at the same time (1883) the splendid researches of Van Beneden on the early history of the animal egg opened possibilities of research into the finer details of cell-phenomena of which the early workers could hardly have dreamed.

We can only appreciate the full historical significance of the new period thus inaugurated by a glance at the earlier history of opinion regarding embryological development and inheritance. To the modern student the germ is, in Huxley's words, simply a detached living portion of the substance of a preëxisting living body[2] carrying with it a definite structural organization 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 equivocal or spontaneous generation of life; and even Harvey did not escape this pitfall, near as he came to the modern point of view. "The egg," he says, "is the mid-passage or transition stage between parents and offspring, between those who are, or were, and those who are about to be; it is the hinge or pivot upon which the whole generation of the bird revolves. The egg is the terminus from which all fowls, male and female, have sprung, and to which all their lives tend — it is the result which nature has proposed to herself in their being. And thus it comes that individuals in procreating their like for the sake of their species, endure forever. The egg, I say, is a period or portion of this eternity."[3]

This passage appears at first sight to be a close approximation to the modern doctrine of germinal continuity about which all theories of heredity are revolving. In point of fact, however, Harvey's view is only superficially similar to this doctrine; for, as Huxley pointed out, it was obscured by his belief that the germ might arise "spontaneously," or through the influence of a mysterious "*calidum innatum*," out of not-living matter.[4] Neither could Harvey, great physiologist and embryologist as he was, have had any adequate conception of the real nature of the egg and its morphological relation to

[1] It must not be forgotten that Haeckel expressed the same view in 1866 — only, however, as a speculation, since the data necessary to an inductive conclusion were not obtained until long afterward. "The internal nucleus provides for the transmission of hereditary characters, the external plasma on the other hand for accommodation or adaptation to the external world" (*Gen. Morph.*, pp. 287–289).

[2] *Evolution in Biology*, 1878; *Science and Culture*, p. 291.

[3] *De Generatione*, 1651; Trans., p. 271.

[4] Whitman, too, in a brilliant essay, has shown how far Harvey was from any real grasp of the law of genetic continuity, which is well characterized as the central fact of modern biology. *Evolution and Epigenesis*, Wood's Holl Biological Lectures, 1894.

the body of which it forms a part, since the cellular structure of living things was not comprehended until nearly two centuries later, the spermatozoön was still undiscovered, and the nature of fertilization was a subject of fantastic and baseless speculation. For a hundred years after Harvey's time embryologists sought in vain to penetrate the mysteries enveloping the beginning of the individual life, and despite their failure the controversial writings of this period form one of the most interesting chapters in the history of biology. By the extreme "evolutionists" or "præformationists" the egg was believed to contain an embryo fully formed in miniature, as the bud contains the flower or the chrysalis the butterfly. Development was to them merely the unfolding of that which already existed; inheritance, the handing down from parent to child of an infinitesimal reproduction of its own body. It was the service of Bonnet to push this conception to its logical consequence, the theory of *emboîtement* or encasement, and thus to demonstrate the absurdity of its grosser forms, pointing out that if the egg contains a complete embryo, this must itself contain eggs for the next generation, these other eggs in their turn, and so *ad infinitum*, like an infinite series of boxes, one within another — hence the term *emboîtement*. Bonnet himself renounced this doctrine in his later writings, and Caspar Friedrich Wolff (1759) led the way in a return to the teachings of Harvey, showing by precise actual observation that the egg does not at first contain any formed embryo whatever; that its structure is wholly different from that of the adult; that development is not a mere process of unfolding, but involves the continual formation, one after another, of new parts, previously non-existent as such. This is somewhat as Harvey, himself following Aristotle, had conceived it — a process of *epigenesis* as opposed to *evolution*. Later researches established this conclusion as the very foundation of embryological science.

But although the external nature of development was thus determined, the actual structure of the egg and the mechanism of inheritance remained for nearly a century in the dark. It was reserved for Schwann (1839) and his immediate followers to recognize the fact, conclusively demonstrated by all later researches, that *the egg is a cell* having the same essential structure as other cells of the body. And thus the wonderful truth became manifest that a single cell may contain within its microscopic compass the sum-total of the heritage of the species. This conclusion first reached in the case of the female sex was soon afterward extended to the male as well. Since the time of Leeuwenhoek (1677) it had been known that the sperm or fertilizing fluid contained innumerable minute bodies endowed in nearly all cases with the power of active movement, and therefore regarded by the early observers as parasitic animalcules or infusoria, a view which gave rise to the name *spermatozoa* (sperm-animals) by which they are still generally known.[1] As long ago as 1786, however, it was shown by Spallanzani that the fertilizing power must lie in the spermatozoa, not in the liquid in which they swim, because the spermatic fluid loses its power when filtered. Two years after the appearance of Schwann's epoch-making work Kölliker demonstrated (1841) that the spermatozoa arise directly from cells in the testis, and hence cannot be regarded as parasites, but are, like the ovum, derived from the parent-body. Not until 1865, however, was the final proof attained by Schweigger-Seidel and La Valette St. George that the spermatozoön contains not only a nucleus, as Kölliker believed, but also cytoplasm. It was thus shown to be, like the egg, a single cell, peculiarly modified in structure, it is true, and of extraordinary minuteness, yet on the whole morphologically equivalent to other cells. A final step was taken ten years later (1875), when Oscar Hertwig established the all-important fact that fertilization of the egg is accomplished by its union with one spermatozoön, and one only. In sexual reproduction, therefore, each sex contributes a single cell of its own body to the formation of the offspring, a fact which beautifully tallies with the conclusion of Darwin and Galton that the sexes play, on the whole, equal, though not identical parts in hereditary transmission. The ultimate problems of sex, fertilization, inheritance, and development were thus shown to be *cell-problems*.

Meanwhile, during the years immediately following the announcement of the cell-theory, the attention of investigators was especially focussed upon the question: How do the cells of the body arise? The origin of cells by the division of preëxisting cells was clearly recognized by Hugo von Mohl in 1835, though the full significance of this epoch-making discovery was so obscured by the errrors of Schleiden and Schwann that its full significance was only perceived long afterward. The founders of the cell-theory were unfortunately led to the conclusion that cells might arise in two different ways, viz. either by division or fission of a preëxisting mother-cell, or by "free cell-formation," new cells arising in the latter case not from preexisting ones, but by crystallizing, as it were, out of a formative or nutritive substance, termed the "cytoblastema"; and they even believed the latter process to be the usual and typical one. It was only after many years of painstaking research that "free cell-formation" was absolutely proved to be a myth, though many of

[1] The discovery of the spermatozoa is generally accredited to Ludwig Hamm, a pupil of Leeuwenhoek (1677), though Hartsoeker afterward claimed the merit of having seen them as early as 1674 (Dr. Allen Thomson).

Schwann's immediate followers threw doubts upon it,[1] and as early as 1855 Virchow positively maintained the universality of cell-division, contending that every cell is the offspring of a preëxisting parent-cell, and summing up in the since famous aphorism, "*omnis cellula e cellula*."[2] At the present day this conclusion rests upon a foundation so firm that we are justified in regarding it as a universal law of development.

Now, if the cells of the body always arise by the division of preexisting cells, all must be traceable back to the fertilized egg-cell as their common ancestor. Such is, in fact, the case in every plant and animal whose development is accurately known. The first step in development consists in the division of the egg into two parts, each of which is a cell, like the egg itself. The two then divide in turn to form four, eight, sixteen, and so on in more or less regular progression (Fig. 4.) until step by step the egg has split up into the multitude of cells which build the body of the embryo, and finally of the adult. This process, known as the *cleavage* or *segmentation* of the egg, was observed long before its meaning was understood. It seems to have been first definitely described in the case of the frog's egg, by Prévost and Dumas (1824), though earlier observers had seen it; but at this time neither the egg nor its descendants were known to be cells, and its true meaning was first clearly perceived by Bergmann, Kölliker, Reichert, Von Baer, and Remak, some twenty years later. The interpretation of cleavage as a process of cell-division was followed by the demonstration that cell-division does not begin with cleavage, but *can be traced back into the foregoing generation;* for the egg-cell, as well as the sperm-cell, arises by the division of a cell preexisting in the parent-body. *It is therefore derived by direct descent from an egg-cell of the foregoing generation, and so on ad infinitum.* Embryologists thus arrived at the conception so vividly set forth by Virchow in 1858[3] of an uninterrupted series of cell-divisions extending backward from existing plants and animals to that remote and unknown period when vital organization assumed its present form. Life is a continuous stream. The death of the individual involves no breach of continuity in the series of cell-divisions by which the life of the race flows onwards. The individual body dies, it is true, but the germ-cells live on, carrying with them, as it were, the traditions of the race from which they have sprung, and handing them on to their descendants.

[1] Among these may be especially mentioned Mohl, Unger, Nägeli, Martin Barry, Goodsir, and Remak.

[2] *Arch. für Path. Anat.*, VIII., p. 23, 1855.

[3] See the quotation from the original edition of the *Cellularpathologie* at the head of Chapter II., p. 63.

We have thus arrived at the form in which the problems of heredity and development confront the investigator of the present day. It remains to point out more clearly how they are related to the general problems of evolution and to those post-Darwinian discussions in which Weismann has taken so active a part. All theories of evolu-

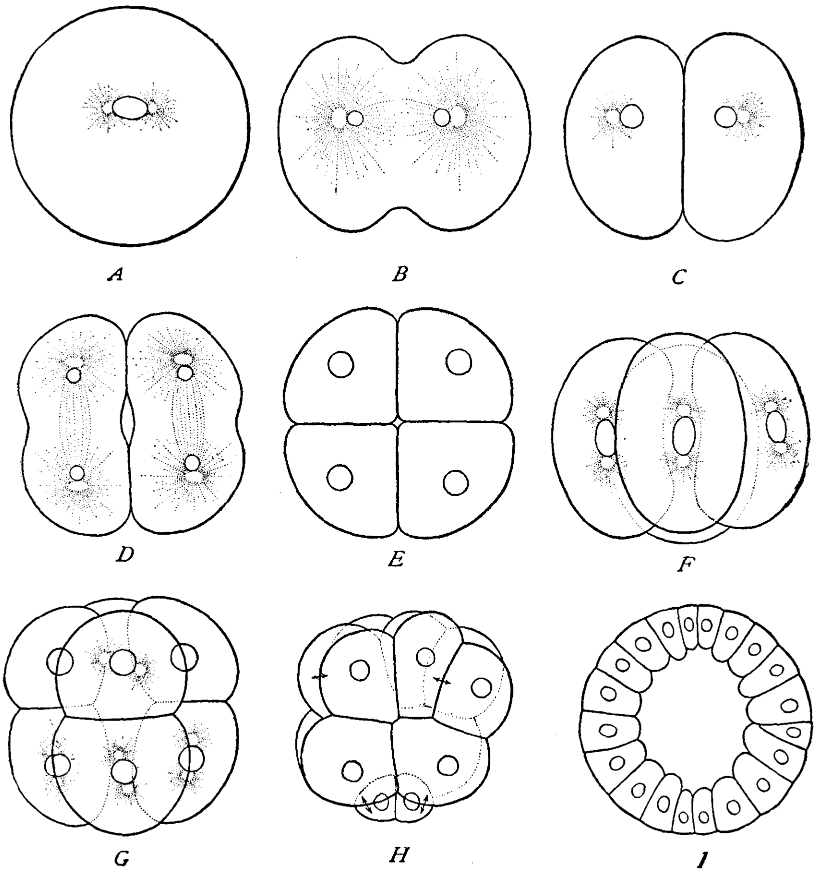

Fig. 4. — Cleavage of the ovum of the sea-urchin *Toxopneustes*, × 330, from life. The successive divisions up to the 16-cell stage (*H*) occupy about two hours. *I* is a section of the embryo (blastula) of three hours, consisting of approximately 128 cells surrounding a central cavity or blastocœl.

tion take the facts of variation and heredity as fundamental postulates, for it is by variation that new characters arise and by heredity that they are perpetuated. Darwin recognized two kinds of variation, both of which, being inherited and maintained through the conserving action of natural selection, might give rise to a permanent transformation of species. The first of these includes congenital or inborn variations, *i.e.* such as appear at birth or are developed "spontaneously," without discoverable connection with the activities of the organism itself or the direct effect of the environment upon it, though Darwin clearly recognized the fact that even such variations must indirectly be due to changed conditions acting upon the parental organism or on the germ. In a second class of variations were placed the so-called acquired characters, *i.e.* definite effects directly produced in the course of the individual life as the result of use and disuse, or of food, climate, and the like. The inheritance of congenital characters is now universally admitted, but it is otherwise with acquired characters. The inheritance of the latter, now the most debated question of biology, had been taken for granted by Lamarck a half-century before Darwin; but he made no attempt to show how such transmission is possible. Darwin, on the other hand, squarely faced the physiological requirements of the problem, recognizing that the transmission of acquired characters can only be possible under the assumption that the germ-cell definitely reacts to all other cells of the body in such wise as to register the changes taking place in them. In his ingenious and carefully elaborated theory of pangenesis,[1] Darwin framed a provisional physiological hypothesis of inheritance in accordance with this assumption, suggesting that the germ-cells are reservoirs of minute germs or gemmules derived from every part of the body; and on this basis he endeavoured to explain the transmission both of acquired and of congenital variations, reviewing the facts of variation and inheritance with wonderful skill, and building up a theory which, although it forms the most speculative and hypothetical portion of his writings, must always be reckoned one of his most interesting contributions to science.

In the form advocated by Darwin the theory of pangenesis has been generally abandoned in spite of the ingenious attempt to remodel it made by Brooks in 1883.[2] In the same year the whole aspect of the problem was changed, and a new period of discussion inaugurated by Weismann, who put forth a bold challenge of the entire Lamarckian principle.[3] "I do not propose to treat of the whole problem of heredity, but only of a certain aspect of it, — the transmission of acquired characters, which has been hitherto assumed to occur. In taking this course I may say that it was impossible to avoid going back to the foundation of all phenomena of heredity, and to determine the substance with which they must be connected. In my opinion this can only be the substance of the germ-cells; and this substance trans-

[1] *Variation of Animals and Plants*, Chapter XXVII.

[2] *The Law of Heredity*, Baltimore, 1883.

[3] *Ueber Vererbung*, 1883. See *Essays upon Heredity*, I., by A. Weismann, Clarendon Press, Oxford, 1889.

fers 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" (*l.c.*, p. 69).

It is impossible, he continues, that acquired traits should be transmitted, for it is inconceivable that definite changes in the body, or "soma," should so affect the protoplasm of the germ-cells as to cause corresponding changes to appear in the offspring. How, he asks, can the increased dexterity and power in the hand of a trained piano-player so affect the molecular structure of the germ-cells as to produce a corresponding development in the hand of the child? It is a physiological impossibility. If we turn to the facts, we find, Weismann affirms, that not one of the asserted cases of transmission of acquired characters will stand the test of rigid scientific scrutiny. It is a reversal of the true point of view to regard inheritance as taking 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, and the germ-cell owes its characteristics not to the body which bears it, but to its descent from a preëxisting germ-cell of the same kind. Thus the body is, as it were, an offshoot from the germ-cell (Fig. 5). As

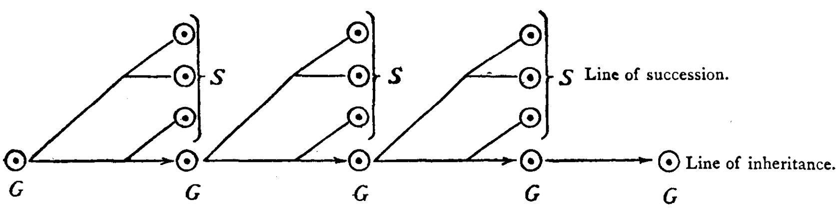

Fig. 5.— Diagram illustrating Weismann's theory of inheritance.

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.

far as inheritance is concerned, the body is merely the carrier of the germ-cells, which are held in trust for coming generations.

Weismann's subsequent theories, built on this foundation, have given rise to the most eagerly contested controversies of the post-Darwinian period, and, whether they are to stand or fall, have played a most important part in the progress of science. For aside from the truth or error of his special theories, it has been Weismann's great service to place the keystone between the work of the evolutionists and that of the cytologists, and thus to bring the cell-theory and the evolution-theory into organic connection. It is from the point of view thus suggested that the present volume has been written. It has accordingly not been my primary object to dwell on the *minutiæ* of histology, still less to undertake an exhaustive description of all the modifications of cell-structure and cell-action; and for these the student must refer to other and more extended treatises. Yet the broader questions with which we have to deal cannot profitably be discussed apart from the concrete phenomena by which they are suggested, and hence a considerable part of the text is necessarily given over to descriptive detail; but I hope that the reader will not lose sight of the relation of the part to the whole, or forget the primary intention of the work.

We shall follow a convenient, rather than a strictly logical, order of treatment, beginning in the first two chapters with a general sketch of cell-structure and cell-division. The following three chapters deal with the germ-cells, — the third with their structure and mode of origin, the fourth with their union in fertilization, the fifth with the phenomena of maturation by which they are prepared for their union. The sixth chapter contains a critical discussion of cell-organization, completing the morphological analysis of the cell. In the seventh chapter the cell is considered with reference to its more fundamental chemical and physiological properties as a prelude to the examination of development which follows. The succeeding chapter approaches the objective point of the book by considering the cleavage of the ovum and the general laws of cell-division of which it is an expression. The ninth chapter, finally, deals with the elementary operations of development considered as cell-functions and with the theories of inheritance and development based upon them.

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[1] See also Literature, I., p. 61.

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