evidence, however, can be led to contradict the answer in the latter case, unless it refer to a previous conviction, or to circumstances tending to throw doubt on the impartiality of the witness. A witness may in cross-examination, and a witness proving hostile or adverse to the party calling him, may, in examination-in-chief, be asked whether he had not on a former occasion made statements inconsistent with his present statements. The credit of a witness may also be impeached by the other party calling witnesses to swear that they believe him to be unworthy of belief, and counter-evidence may be given in reply. The theory of the proceedings is that a witness will tell his story in the most favourable way for the party calling him and against his opponent.

The improper admission or rejection of evidence was formerly a frequent ground for applications for new trial; under the Judicature Act a new trial will only be granted on such ground when some substantial wrong has been occasioned thereby.

The following are the most important writers on the law of evidence:—John Pitt Taylor (two vols. 8vo, 6th edition, London, 1872); Henry Roscoe (*Digest of the Law of Evidence on the trial of actions at Nisi Prius*, 13th edition, by Day and Powell, London, 1875) A. M. Best (*On the Principles of the Law of Evidence, with elementary rules for the interrogation of witnesses*, 6th edition, London, 1875); Edmund Powell (*Principles and Practice of the Law of Evidence*, 4th edition, London, 1875); Sir J. F. Stephen (*Digest of the Law of Evidence*, London, 1877); S. Greenleaf (*On the Law of Evidence*, 3 vols. 13th edition, Boston, 1876). (E. R.)

questions are improper if the imputation would not affect, or would affect in a slight degree, the opinion of the court as to the credibility of the witness on the matter to which he testifies; (3) Such questions are improper if there is a great disproportion between the importance of the imputation made against the witness's character and the importance of his evidence."

EVOLUTION

1. Evolution in Biology.

In the former half of the 18th century, the term "evolution" was introduced into biological writings, in order to denote the mode in which some of the most eminent physiologists of that time conceived that the generation of living things took place; in opposition to the hypothesis advocated, in the preceding century, by Harvey in that remarkable work[1] which would give him a claim to rank among the founders of biological science, even had he not been the discoverer of the circulation of the blood.

One of Harvey's prime objects is to defend and establish, on the basis of direct observation, the opinion already held by Aristotle; that, in the higher animals at any rate, the formation of the new organism by the process of generation takes place, not suddenly, by simultaneous accretion of rudiments of all or the most important of the organs of the adult; nor by sudden metamorphosis of a formative substance into a miniature of the whole, which subsequently grows; but by *epigenesis*, or successive differentiation of a relatively homogeneous rudiment into the parts and structures which are characteristic of the adult.

"Et primò, quidem, quoniam per *epigenesin* sive partium superxorientium additamentum pullum fabricari certum est: quænam pars ante alias omnes exstruatur, et quid de illa ejusque generandi modo observandum veniat, dispiciemus. Ratum sane est et in ovo manifestè apparet quod *Aristoteles* de perfectorum animalium generatione enuntiat: nimirum, non omnes partes simul fieri, sed ordine aliam post aliam; primùmque existere particulam genitalem, cujus virtute postea (tanquam ex principio quodam) reliquæ omnes partes prosiliant. Qualem in plantarum seminibus (fabis, putà, aut glandibus) gemmam sive apicem protuberantem cernimus, totius futuræ arboris principium. *Estque hæc particula veluti filius emancipatus seorsumque collocatus, et principium per se vivens; unde postea membrorum ordo describitur; et quæcunque ad absolvendum animal pertinent, disponuntur.*[2] Quoniam enim *nulla pars se ipsam generat; sed postquam generata est, se ipsam jam auget; ideo eam primùm oriri necesse est, quæ principium augendi contineat (sive enim planta, sive animal est, æque omnibus inest quod vim habeat vegetandi, sive nutriendi),*[3] simulque reliquas omnes partes suo quamque ordine distinguat et formet; proindeque in eadem primogenita particula anima primario inest, sensus, motusque, et totius vitæ auctor et principium." (*Exercitatio* 51.)

Harvey proceeds to contrast this view with that of the Medici," or followers of Hippocrates and Galen, who, "badly philosophizing," imagined that the brain, the heart, and the liver were simultaneously first generated in the form of vesicles; and, at the same time, while expressing his agreement with Aristotle in the principle of epigenesis, he maintains that it is the blood which is the primal generative part, and not, as Aristotle thought, the heart.

In the latter part of the 17th century, the doctrine of epigenesis thus advocated by Harvey was controverted on the ground of direct observation by Malpighi, who affirmed that the body of the chick is to be seen in the egg before the *punctum sanguineum* makes its appearance. But from this perfectly correct observation a conclusion which is by no means warranted was drawn; namely, that the chick as a whole really exists in the egg antecedently to incubation; and that what happens in the course of the latter process is no addition of new parts, "alias post alias natas," as Harvey puts it, but a simple expansion or unfolding of the organs which already exist, though they are too small and inconspicuous to be discovered. The weight of Malpighi's observations therefore fell into the scale of that doctrine which Harvey terms metamorphosis, in contradistinction to epigenesis.

The views of Malpighi were warmly welcomed on philosophical grounds by Leibnitz,[4] who found in them a support to his hypothesis of monads, and by Malebranche while, in the middle of the 18th century, not only speculative considerations, but a great number of new and interesting observations on the phenomena of generation, led the ingenious Bonnet, and Haller,[6] the first physiologist of the age, to adopt, advocate, and extend them.

Bonnet affirms that, before fecundation, the hen's egg contains an excessively minute but complete chick; and that fecundation and incubation simply cause this germ to absorb nutritious matters, which are deposited in the interstices of the elementary structures of which the miniature chick, or germ, is made up. The consequence of this intussusceptive growth is the "development" or "evolution" of the germ into the visible bird. Thus an organized individual (*tout organisé*) "is a composite body consisting of the original, or *elementary*, parts and of the matters which have been associated with them by the aid of nutrition;" so that, if these matters could be extracted from the individual (*tout*), it would, so to speak, become concentrated in a point, and would thus be restored to its primitive condition of a *germ*; "just as, by extracting from a bone the calcareous substance which is the source of its hardness, it is reduced to its primitive state of gristle or membrane."[1]

"Evolution" and "development" are, for Bonnet, synonymous terms; and since by "evolution" he means simply the expansion of that which was invisible into visibility, he was naturally led to the conclusion, at which Leibnitz had arrived by a different line of reasoning, that no such thing as generation, in the proper sense of the word, exists in nature. The growth of an organic being is simply a process of enlargement, as a particle of dry gelatine may be swelled up by the intussusception of water; its death is a shrinkage, such as the swelled jelly might undergo on desiccation. Nothing really new is produced in the living world, but the germs which develop have existed since the beginning of things; and nothing really dies, but, when what we call death takes place, the living thing shrinks back into its germ state.[2]

The two parts of Bonnet's hypothesis, namely, the doctrine that all living things proceed from pre-existing germs, and that these contain, one inclosed within the other, the germs of all future living things, which is the hypothesis of "*emboîtement*;" and the doctrine that every germ contains in miniature all the organs of the adult, which is the hypothesis of evolution or development, in the primary senses of these words, must be carefully distinguished. In fact, while holding firmly by the former, Bonnet more or less modified the latter in his later writings, and, at length, he admits that a "germ" need not be an actual miniature of the organism; but that it may be merely an "original preformation" capable of producing the latter.[3]

But, thus defined, the germ is neither more nor less than the "particula genitalis" of Aristotle, or the "primordium vegetale" or "ovum" of Harvey; and the "evolution" of such a germ would not be distinguishable from "epigenesis."

Supported by the great authority of Haller, the doctrine of evolution, or development, prevailed throughout the whole of the 18th century, and Cuvier appears to have substantially adopted Bonnet's later views, though probably he would not have gone all lengths in the direction of "emboîtement." In a well-known note to Laurillard's *Éloge*, prefixed to the last edition of the *Ossemens fossiles*, the "radical de l'être" is much the same thing as Aristotle's "particula genitalis" and Harvey's "ovum."[4]

Bonnet's eminent contemporary, Buffon, held nearly the same views with respect to the nature of the germ, and expresses them even more confidently.

"Ceux qui ont cru que le cœur étoit le premier formé, se sont trompés; ceux qui disent que c'est le sang se trompent aussi: tout est formé en même temps. Si l'on ne consulte que l'observation, le poulet se voit dans l'œuf avant qu'il ait été couvé."[5]

"J'ai ouvert une grande quantité d'œufs à differens temps avant et après l'incubation, et je me suis convaincu par mes yeux que le poulet existe en entier dans le milieu de la cicatrule au moment qu'il sort du corps de la poule."[6]

The "moule intérieur" of Buffon is the aggregate of elementary parts which constitute the individual, and is thus the equivalent of Bonnet's germ,[7] as defined in the passage cited above. But Buffon further imagined that innumerable "molecules organiques" are dispersed throughout the world, and that alimentation consists in the appropriation by the parts of an organism of those molecules which are analogous to them. Growth, therefore, was, on this hypothesis, partly a process of simple evolution, and partly of what has been termed syngenesis. Buffon's opinion is, in fact, a sort of combination of views, essentially similar to those of Bonnet, with others, somewhat similar to those of the "Medici" whom Harvey condemns. The "molecules organiques" are physical equivalents of Leibnitz's "monads."

It is a striking example of the difficulty of getting people to use their own powers of investigation accurately, that this form of the doctrine of evolution should have held its ground so long; for it was thoroughly and completely exploded, not long after its enunciation, by Caspar Frederick Wolff, who in his *Theoria Generationis*, published in 1759, placed the opposite theory of epigenesis upon the secure foundation of fact, from which it has never been displaced. But Wolff had no immediate successors. The school of Cuvier was lamentably deficient in embryologists; and it was only in the course of the first thirty years of the present century, that Prévost and Dumas in France, and, later on, Döllinger, Pander, Von Bär, Rathke, and Remak in Germany, founded modern embryology; and, at the same time, proved the utter incompatibility of the hypothesis of evolution as formulated by Bonnet and Haller, with easily demonstrable facts.

Nevertheless, though the conceptions originally denoted by "evolution" and "development" were shown to be untenable, the words retained their application to the process by which the embryos of living beings gradually make their appearance; and the terms "Development,"

[1] The *Exercitationes de Generatione Animalium*, which Dr George Ent extracted from him and published in 1651.
De Generatione Animalium, lib. ii. cap. x.
De Generatione, lib. ii. cap. iv.

[2] "Et primò, quidem, quoniam per *epigenesin* sive partium superxorientium additamentum pullum fabricari certum est: quænam pars ante alias omnes exstruatur, et quid de illa ejusque generandi modo observandum veniat, dispiciemus. Ratum sane est et in ovo manifestè apparet quod *Aristoteles* de perfectorum animalium generatione enuntiat: nimirum, non omnes partes simul fieri, sed ordine aliam post aliam; primùmque existere particulam genitalem, cujus virtute postea (tanquam ex principio quodam) reliquæ omnes partes prosiliant. Qualem in plantarum seminibus (fabis, putà, aut glandibus) gemmam sive apicem protuberantem cernimus, totius futuræ arboris principium. *Estque hæc particula veluti filius emancipatus seorsumque collocatus, et principium per se vivens; unde postea membrorum ordo describitur; et quæcunque ad absolvendum animal pertinent, disponuntur.*[2] Quoniam enim *nulla pars se ipsam generat; sed postquam generata est, se ipsam jam auget; ideo eam primùm oriri necesse est, quæ principium augendi contineat (sive enim planta, sive animal est, æque omnibus inest quod vim habeat vegetandi, sive nutriendi),*[3] simulque reliquas omnes partes suo quamque ordine distinguat et formet; proindeque in eadem primogenita particula anima primario inest, sensus, motusque, et totius vitæ auctor et principium." (*Exercitatio* 51.)

[3] "Ce mot (germe) ne désignera pas seulement un corps organisé *réduit en petit*; il désignera encore toute espèce de *préformation originelle dont un Tout organique peut résulter comme de son principe immédiat.*"—*Palingénésie Philosophique*, part x. chap. ii.

[4] "Cependant, pour revenir aux formes ordinaires ou aux âmes matérielles, cette durée qu'il leur faut attribuer, à la place de celle qu'on avoit attribuée aux atomes pourroit faire douter si elles ne vont pas de corps en corps; ce qui seroit la métempsychose, à peu près comme quelques philosophes ont cru la transmission du mouvement et celle des espèces. Mais cette imagination est bien éloignée de la nature des choses. Il n'y a point de tel passage; et c'est ici où les transformations de Messieurs Swammerdam, Malpighi, et Leewenhoek, qui sont des plus excellens observateurs de notre tems, sont venues à mon secours, et m'ont fait admettre plus aisément, que l'animal, et toute autre substance organisée ne commence point lorsque nous le croyons, et que sa generation apparente n'est qu'une développement et une espèce d'augmentation. Aussi si je remarqué que l'auteur de la *Recherche de la Verité*, M. Regis, M. Hartsoeker, et d'autres habiles hommes n'ont pas été fort éloignés de ce sentiment." Leibnitz, *Système nouveau de la Nature*, 1695. The doctrine of "Emboîtement" is contained in the *Considérations sur le principe de vie*, 1705; the preface to the *Theodicée*, 1710; and the *Principes de la Nature et de la Grace* (§ 6), 1718.

[5] "Il est vrai que la pensée la plus raisonnable et la plus conforme à l'experience sur cette question très difficile de la formation du fœtus; c'est que les enfans sont déja presque tout formés avant même l'action par laquelle ils sont conçus; et que leurs mères ne font que leur donner l'accroissement ordinaire dans le temps de la grossesse."—*De la Recherche de la Verité*, livre ii. chap. vii. p. 334, 7th ed., 1721.

[6] The writer is indebted to Dr Allen Thomson for reference to the evidence contained in a note to Haller's edition of Boerhaave's *Prælectiones Academicæ*, vol. v. pt. ii. p. 497, published in 1744, that Haller originally advocated epigenesis.

[1] *Considérations sur les Corps organisés*, chap. x.

[2] Bonnet had the courage of his opinions, and in the *Palingénésie Philosophique*, part vi. chap. iv., he develops a hypothesis which he terms "évolution naturelle;" and which, making allowance for his peculiar views of the nature of generation, bears no small resemblance to what is understood by "evolution" at the present day:—

"Si la volonté divine a créé par un seul Acte l'Universalité des êtres, d'où venoient ces plantes et ces animaux dont Moyse nous decrit la Production au troisieme et au cinquieme jour du renouvellement de notre monde?

"Abuserois-je de la liberté de conjectures si je disois, que les Plantes et les Animaux qui existent aujourd'hui sont parvenus par une sorte d'évolution naturelle des Etres organisés qui peuplaient ce premier Monde, sorti immédiatement des Mains du Createur? . . . .

"Ne supposons que trois révolutions. La Terre vient de sortir des Mains du Createur. Des causes preparées par sa Sagesse font développer de toutes parts les Germes. Les Etres organisés commencent à jouir de l'existence. Ils étoient probablement alors bien différens de ce qu'ils sont aujourd'hui. Ils l'etoient autant que ce premier Monde différoit de celui que nous habitons. Nous manquons de moyens pour juger de ces dissemblances, et peut-être que le plus habile Naturaliste qui auroit été placé dans ce premier Monde y auroit entièrement méconnu nos Plantes et nos Animaux."

[3] "Ce mot (germe) ne désignera pas seulement un corps organisé *réduit en petit*; il désignera encore toute espèce de *préformation originelle dont un Tout organique peut résulter comme de son principe immédiat.*"—*Palingénésie Philosophique*, part x. chap. ii.

[4] "M. Cuvier considérant que tous les êtres organisés sont dérivés de parens, et ne voyant dans la nature aucune force capable de produire l'organisation, croyait à la pré-existence des germes; non pas à la pré-existence d'un être tout formé, puisqu'il est bien évident que ce n'est que par des développemens successifs que l'être acquiert sa forme; mais, si l'on peut s'exprimer ainsi, à la pré-existence du *radical de l'être*, radical qui existe avant que la série des évolutions ne commence, et qui remonte certainement, suivant la belle observation de Bonnet, à plusieurs generations."—Laurillard, *Éloge de Cuvier*, note 12.

[5] *Histoire Naturelle*, tom. ii. ed. ii. 1750, p. 350.

[6] *Ibid.*, p. 351.

[7] See particularly Buffon, *l.c.* p. 41.

"Entwickelung," and "Evolutio" are now indiscriminately used for the series of genetic changes exhibited by living beings; by writers who would emphatically deny that "Development" or "Entwickelung" or "Evolutio," in the sense in which these words were usually employed by Bonnet or Haller, ever occurs.

Evolution, or development, is, in fact, at present employed in biology as a general name for the history of the steps by which any living being has acquired the morphological and the physiological characters which distinguish it. As civil history may be divided into biography, which is the history of individuals, and universal history, which is the history of the human race, so evolution falls naturally into two categories,—the evolution of the individual, and the evolution of the sum of living beings. It will be convenient to deal with the modern doctrine of evolution under these two heads.

1. *The Evolution of the Individual.*

No exception is, at this time, known to the general law, established upon an immense multitude of direct observations, that every living thing is evolved from a particle of matter in which no trace of the distinctive characters of the adult form of that living thing is discernible. This particle is termed a *germ*. Harvey[1] says—

"Omnibus viventibus primordium insit, ex quo et a quo proveniant. Liceat hoc nobis *primordium vegetale* nominare; nempe substantiam quandam corpoream vitam habentem potentiâ; vel quoddam per se existens, quod aptum sit, in vegetativam formam, ab interno principio operante, mutari. Quale nempe primordium, ovum est et plantarum semen; tale etiam viviparorum conceptus et insectorum *vermis* ab Aristotele dictus: diversa scilicet diversorum viventium primordia."

The definition of a germ as "matter potentially alive, and having within itself the tendency to assume a definite living form," appears to meet all the requirements of modern science. For, notwithstanding it might be justly questioned whether a germ is not merely potentially, but rather actually, alive, though its vital manifestations are reduced to a minimum, the term "potential" may fairly be used in a sense broad enough to escape the objection. And the qualification of "potential" has the advantage of reminding us that the great characteristic of the germ is not so much what it is, but what it may, under suitable conditions, become. Harvey shared the belief of Aristotle—whose writings he so often quotes, and of whom he speaks as his precursor and model, with the generous respect with which one genuine worker should regard another—that such germs may arise by a process of "equivocal generation" out of not-living matter; and the aphorism so commonly ascribed to him, "*omne vivum ex ovo*," and which is indeed a fair summary of his reiterated assertions, though incessantly employed against the modern advocates of spontaneous generation, can be honestly so used only by those who have never read a score of pages of the *Exercitationes*. Harvey, in fact, believed as implicitly as Aristotle did in the equivocal generation of the lower animals. But, while the course of modern investigation has only brought out into greater prominence the accuracy of Harvey's conception of the nature and mode of development of germs, it has as distinctly tended to disprove the occurrence of equivocal generation, or abiogenesis, in the present course of nature. In the immense majority of both plants and animals, it is certain that the germ is not merely a body in which life is dormant or potential, but that it is itself simply a detached portion of the substance of a pre-existing living body; and the evidence has yet to be adduced which will satisfy any cautious reasoner that "omne vivum ex vivo" is not as well established a law of the existing course of nature as "omne vivum ex ovo."

In all instances which have yet been investigated, the substance of this germ has a peculiar chemical composition, consisting of at fewest four elementary bodies, viz., carbon, hydrogen, oxygen, and nitrogen, united into the ill-defined compound known as protein, and associated with much water, and very generally, if not always, with sulphur and phosphorus in minute proportions. Moreover, up to the present time, protein is known only as a product and constituent of living matter. Again, a true germ is either devoid of any structure discernible by optical means, or, at most, it is a simple nucleated cell.[2]

In all cases, the process of evolution consists in a succession of changes of the form, structure, and functions of the germ, by which it passes, step by step, from an extreme simplicity, or relative homogeneity, of visible structure, to a greater or less degree of complexity or heterogeneity; and the course of progressive differentiation is usually accompanied by growth, which is effected by intussusception. This intussusception, however, is a very different process from that imagined either by Buffon, or by Bonnet. The substance by the addition of which the germ is enlarged is, in no case, simply absorbed ready-made from the not-living world and packed between the elementary constituents of the germ, as Bonnet imagined; still less does it consist of the "molecules organiques" of Buffon. The new material is, in great measure, not only absorbed but assimilated, so that it becomes part and parcel of the molecular structure of the living body into which it enters. And, so far from the fully developed organism being simply the germ *plus* the nutriment which it has absorbed, it is probable that the adult contains neither in form, nor in substance, more than an inappreciable fraction of the constitutents of the germ, and that it is almost wholly made up of assimilated and metamorphosed nutriment. In the great majority of cases, at any rate, the full grown organism becomes what it is by the absorption of not-living matter, and its conversion into living matter of a specific type. As Harvey says (Ex. 45), all parts of the body are nourished "ab eodem succo alibili, aliter aliterque cambiato," "ut plantæ omnes ex eodem communi nutrimento (sive rore seu terræ humore)."

In all animals and plants above the lowest, the germ is a nucleated cell, using that term in its broadest sense; and the first step in the process of the evolution of the individual is the division of this cell into two or more portions. The process of division is repeated, until the organism, from being unicellular, becomes multicellular. The single cell becomes a cell-aggregate; and it is to the growth and metamorphosis of the cells of the cell-aggregate thus produced, that all the organs and tissues of the adult owe their origin.

In certain animals belonging to every one of the chief groups into which the *Metazoa* are divisible, the cells of the cell-aggregate which results from the process of yelk division, and which is termed a *morula*, diverge from one another in such a manner as to give rise to a central space, around which they dispose themselves as a coat or envelope; and thus the morula becomes a vesicle filled with fluid, the *planula*. The wall of the planula is next pushed in on one side, or invaginated, whereby it is converted into a double walled sac with an opening, the *blastospore*, which leads into the cavity lined by the inner wall. This cavity is the primitive alimentary cavity, or *archenterom;* the inner, or invaginated, layer is the *hypoblast*, the outer the *epiblast;* and the embryo, in this stage, is termed a *gastrula*. In all the higher animals, a layer of cells makes its appearance between the hypoblast and the epiblast, and is termed the *mesoblast*. In the further course of development, the epiblast becomes the ectoderm or epidermic layer of the body; the hypoblast becomes the epithelium of the middle portion of the alimentary canal; and the mesoblast gives rise to all the other tissues, except the central nervous system, which originates from an ingrowth of the epiblast.

With more or less modification in detail, the embryo has been observed to pass through these successive evolutional stages in sundry Sponges, Cœlenterates, Worms, Echinoderms, Tunicates, Arthropods, Mollusks, and Vertebrates; and there are valid reasons for the belief, that all animals of higher organization than the *Protozoa* agree in the general character of the early stages of their individual evolution. Each, starting from the condition of a simple nucleated cell, becomes a cell-aggregate; and this passes through a condition which represents the gastrula stage, before taking in the features distinctive of the group to which it belongs. Stated in this form, the "gastræa theory" of Haeckel appears to the present writer to be one of the most important and best founded of recent generalizations.

So far as individual plants and animals are concerned, therefore, evolution is not a speculation but a fact: and it takes place by epigenesis.

"Animal . . . per *epigenesin* procreatur, materiam simul attrahit, parat, concoquit, et eâdem utitur; formatur simul et augetur. . . primum futuri corporis concrementum . . . prout augetur, dividitur sensim et distinguitur in partes, non simul omnes, sed alias post alias natas, et ordine quasque suo emergentes."[1]

In these words, by the divination of genius, Harvey, in the 17th century, summed up the outcome of the work of all those who, with appliances he could not dream of, are continuing his labours in the 19th century.

Nevertheless, though the doctrine of epigenesis, as understood by Harvey, has definitively triumphed over the doctrine of evolution as understood by his opponents of the 18th century, it is not impossible that, when the analysis of the process of development is carried still further, and the origin of the molecular components of the physically gross, though sensibly minute, bodies which we term germs is traced, the theory of development will approach more nearly to metamorphosis than to epigenesis. Harvey thought that impregnation influenced the female organism as a contagion; and that the blood, which he conceived to be the first rudiment of the germ, arose in the clear fluid of the "colliquamentum" of the ovum by a process of concrescence, as a sort of living precipitate. We now know, on the contrary, that the female germ or ovum, in all the higher animals and plants, is a body which possesses the structure of a nucleated cell; that impregnation consists in the fusion of the substance[2] of another more or less modified nucleated cell, the male germ, with the ovum; and that the structural components of the body of the embryo are all derived, by a process of division, from the coalesced male and female germs. Hence it is conceivable, and indeed probable, that every part of the adult contains molecules derived both 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. And each of these may constitute one individuality, in the same sense as the whole organism is one individual, although the matter of the organism has been constantly changing. The primitive male and female molecules may play the part of Buffon's "moules organiques," and mould the assimilated nutriment, each according to its own type, into innumerable new molecules. From this point of view, the process, which, in its superficial aspect, is epigenesis, appears, in essence, to be evolution, in the modified sense adopted in Bonnet's later writings; and development is merely the expansion of a potential organism or "original preformation" according to fixed laws.

2. *The Evolution of the Sum of Living Beings.*

The notion that all the kinds of animals and plants may have come into existence by the growth and modification of primordial germs is as old as speculative thought; but the modern scientific form of the doctrine can be traced historically to the influence of several converging lines of philosophical speculation and of physical observation, none of which go further back than the 17th century. These are:—

1. The enunciation by Descartes of the conception that the physical universe, whether living or not living, is a mechanism, and that, as such, it is explicable on physical principles.

2. The observation of the gradations of structure, from extreme simplicity to very great complexity, presented by living things, and of the relation of these graduated forms to one another.

3. The observation of the existence of an analogy between the series of gradations presented by the species which compose any great group of animals or plants, and the series of embryonic conditions of the highest members of that group.

4. The observation that large groups of species of widely different habits present the same fundamental plan of structure; and that parts of the same animal or plant, the functions of which are very different, likewise exhibit modifications of a common plan.

5. The observation of the existence of structures, in a rudimentary and apparently useless condition, in one species of a group, which are fully developed and have definite functions in other species of the same group.

6. The observation of the effects of varying conditions in modifying living organisms.

7. The observation of the facts of geographical distribution.

8. The observation of the facts of the geological succession of the forms of life.

1. Notwithstanding the elaborate disguise which fear of the powers that were led Descartes to throw over his real opinions, it is impossible to read the *Principes de la Philosophie* without acquiring the conviction that this great philosopher held that the physical world and all things in it, whether living or not living, have originated by a process of evolution, due to the continuous operation of purely physical causes, out of a primitive relatively formless matter.[3]

The following passage is especially instructive:—

"Et tant s'en faut que je veuille que l'on croie toutes les choses que j'écrirai, que même je prétends en proposer ici quelques unes que je crois absolument être fausses; à savoir, je ne doute point que le monde n'ait été créé au commencement avec autant de perfection qu'il en a; en sorte que le soleil, la terre, la lune, et les étoiles ont été dès lors; et que la terre n'a pas eu seulement en soi les semences des plantes, mais que les plantes même en ont couvert une partie; et qu' Adam et Eve n'ont pas été créés enfans mais en âge d'hommes parfaits. La religion chrétienne veut que nous le croyons ainsi, et la raison naturelle nous persuade entièrement cette vérité; car si nous considérons la toute puissance de Dieu, nous devons juger que tout ce qu'il a fait a eu dès le commencement

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[1] *Exercitationes de Generatione.* Ex. 62, *Ovum esse primordium commune omnibus animalibus.*

[2] In some cases of sexless multiplication the germ is a cell-aggregate—if we call germ only that which is already detached from the parent organism.

[1] Harvey, *Exercitationes de Generatione.* Ex. 45, *Quænam sit pulli materia et quomodo fiat in Ovo.*

[2] Not yet actually demonstrated in the case of the phænogamous plants.

[3] As Buffon has well said:—"L'idée de ramener l'explication de tous les phénomènes à des principes mecaniques est assurement grande et belle, ce pas est le plus hardi qu'on peut faire en philosophie et c'est Descartes qui l'a fait."—*l. c.* p. 50.

toute la perfection qu'il devoit avoir. Mais néanmoins, comme on connôitroit beaucoup mieux quelle a été la nature d'Adam et celle des arbres de Paradis si on avoit examiné comment les enfants se forment peu à peu dans le ventre de leurs mères et comment les plantes sortent de leurs semences, que si on avoit seulement considéré quels ils ont été quand Dieu les a créés : tout de même, nous ferons mieux entendre quelle est généralement la nature de toutes les choses qui sont au monde si nous pouvons imaginer quelques principes qui soient fort intelligibles et fort simples, desquels nous puissions voir clairement que les astres et la terre et enfin tout ce monde visible auroit pu être produit ainsi que de quelques semences (bien que nous sachions qu'il n'a pas été produit en cette façon) que si nous la decrivions seulement comme il est, ou bien comme nous croyons qu'il a été créé. Et parceque je pense avoir trouvé des principes qui sont tels, je tacherai ici de les expliquer."[1]

If we read between the lines of this singular exhibition of force of one kind and weakness of another, it is clear that Descartes believed that he had divined the mode in which the physical universe had been evolved; and the *Traité de l'homme* and the essay *Sur les Passions* afford abundant additional evidence that he sought for, and thought he had found, an explanation of the phenomena of physical life by deduction from purely physical laws.

Spinoza abounds in the same sense, and is as usual perfectly candid—

"Naturæ leges et regulæ, secundum quas omnia fiunt et ex unis formis in alias mutantur, sunt ubique et semper eadem."[2]

Leibnitz's doctrine of continuity necessarily led him in the same direction; and, of the infinite multitude of monads with which he peopled the world, each is supposed to be the focus of an endless process of evolution and involution. In the *Protogæa*, xxvi., Leibnitz distinctly suggests the mutability of species—

"Alii mirantur in saxis passim species videri quas vel in orbe cognito, vel saltem in vicinis locis frustra quæras. Ita *Cornua Ammonis*, quæ ex nautilorum numero habeantur, passim et forma et magnitudine (nam et pedali diametro aliquando reperiuntur) ab omnibus illis naturis discrepare dicunt, quas præbet mare. Sed quis absconditos ejus recessus aut subterraneas abysses pervestigavit? quam multa nobis animalia antea ignota offert novus orbis? Et credibile est per magnas illas conversiones etiam animalium species plurimum immutatas."

Thus in the end of the 17th century the seed was sown which has at intervals brought forth recurrent crops of evolutional hypotheses, based, more or less completely, on general reasonings.

Among the earliest of these speculations is that put forward by Benoit de Maillet in his *Telliamed*, which, though printed in 1735, was not published until twenty-three years later. Considering that this book was written before the time of Haller, or Bonnet, or Linnæus, or Hutton, it surely deserves more respectful consideration than it usually receives. For De Maillet not only has a definite conception of the plasticity of living things, and of the production of existing species by the modification of their predecessors; but he clearly apprehends the cardinal maxim of modern geological science, that the explanation of the structure of the globe is to be sought in the deductive application to geological phenomena of the principles established inductively by the study of the present course of nature. Somewhat later, Maupertuis[3] suggested a curious hypothesis as to the causes of variation, which he thinks may be sufficient to account for the origin of all animals from a single pair. Robinet[4] followed out much the same line of thought as De Maillet, but less soberly; and Bonnet's speculations in the *Palingénésie*, which appeared in 1769, have already been mentioned. Buffon (1753–1778), at first a partisan of the absolute immutability of species, subsequently appears to have believed that larger or smaller groups of species have been produced by the modification of a primitive stock; but he contributed nothing to the general doctrine of evolution.

Erasmus Darwin (*Zoonomia*, 1794), though a zealous evolutionist, can hardly be said to have made any real advance on his predecessors; and, notwithstanding that Goethe (1791–4) had the advantage of a wide knowledge of morphological facts, and a true insight into their signification, while he threw all the power of a great poet into the expression of his conceptions, it may be questioned whether he supplied the doctrine of evolution with a firmer scientific basis than it already possessed. Moreover, whatever the value of Goethe's labours in that field, they were not published before 1820, long after evolutionism had taken a new departure from the works of Treviranus and Lamarck—the first of its advocates who were equipped for their task with the needful large and accurate knowledge of the phenomena of life, as a whole. It is remarkable that each of these writers seems to have been led, independently and contemporaneously, to invent the same name of "Biology" for the science of the phenomena of life; and thus, following Buffon, to have recognized the essential unity of these phenomena, and their contradistinction from those of inanimate nature. And it is hard to say whether Lamarck or Treviranus has the priority in propounding the main thesis of the doctrine of evolution; for though the first volume of Treviranus's *Biologie* appeared only in 1802, he says, in the preface to his later work, the *Erscheinungen und Gesetze des organischen Lebens*, dated 1831, that he wrote the first volume of the *Biologie* "nearly five-and-thirty years ago," or about 1796.

Now, in 1794, there is evidence that Lamarck held doctrines which present a striking contrast to those which are to be found in the *Philosophie Zoologique*, as the following passages show :—

685. Quoique mon unique objet dans cet article n'ait été que de traiter de la cause physique de l'entretien de la vie des êtres organiques, malgré cela j'ai osé avancer en débutant, que l'existence de ces êtres étonnants n'appartiennent nullement à la nature; que tout ce qu'on peut entendre par le mot *nature*, ne pouvoit donner la vie, c'est-à-dire, que toutes les qualités de la matière, jointes à toutes les circonstances possibles, et même à l'activité répandue dans l'univers, ne pouvaient point produire un être muni du mouvement organique, capable de reproduire son semblable, et sujet à la mort.

686. Tous les individus de cette nature, qui existent, proviennent d'individus semblables qui tous ensemble constituent l'espèce entière. Or, je crois qu'il est aussi impossible à l'homme de connôitre la cause physique du premier individu de chaque espèce, que d'assigner aussi physiquement la cause de l'existence de la matière ou de l'univers entier. C'est au moins ce que le résultat de mes connaissances et de mes réflexions me portent à penser. S'il existe beaucoup de variétés produites par l'effet des circonstances, ces variétés ne dénaturent point les espèces; mais on se trompe, sans doute souvent, en indiquant comme espèce, ce qui n'est que variété; et alors je sens que cette erreur peut tirer à conséquence dans les raisonnements que l'on fait sur cette matière.[1]

The first three volumes of Treviranus's *Biologie*, which contains his general views of evolution, appeared between 1802 and 1805. The *Recherches sur l'organisation des corps vivants*, which sketches out Lamarck's doctrines, was published in 1802; but the full development of his views, in the *Philosophie Zoologique*, did not take place until 1809.

The *Biologie* and the *Philosophie Zoologique* are both very remarkable productions, and are still worthy of attentive study, but they fell upon evil times. The vast authority of Cuvier was employed in support of the traditionally respectable hypotheses of special creation and of catastrophism; and the wild speculations of the *Discours sur les Révolutions de la Surface du Globe* were held to be models of sound scientific thinking, while the really much more sober and philosophical hypotheses of the *Hydrogeologie* were scouted. For many years it was the fashion to speak of Lamarck with ridicule, while Treviranus was altogether ignored.

Nevertheless, the work had been done. The conception of evolution was henceforward irrepressible, and it incessantly reappears, in one shape or another,[1] up to the year 1858, when Mr Darwin and Mr Wallace published their *Theory of Natural Selection*. The *Origin of Species* appeared in 1859; and it is within the knowledge of all whose memories go back to that time, that, henceforward, the doctrine of evolution has assumed a position and acquired an importance which it never before possessed. In the *Origin of Species*, and in his other numerous and important contributions to the solution of the problem of biological evolution, Mr Darwin confines himself to the discussion of the causes which have brought about the present condition of living matter, assuming such matter to have once come into existence. On the other hand, Mr Spencer[2] and Professor Haeckel[3] have dealt with the whole problem of evolution. The profound and vigorous writings of Mr Spencer embody the spirit of Descartes in the knowledge of our own day, and may be regarded as the "Principes des Philosophie" of the 19th century; while, whatever hesitation may not unfrequently be felt by less daring minds, in following Haeckel in many of his speculations, his attempt to systematize the doctrine of evolution and to exhibit its influence as the central thought of modern biology, cannot fail to have a far-reaching influence on the progress of science.

If we seek for the reason of the difference between the scientific position of the doctrine of evolution a century ago, and that which it occupies now, we shall find it in the great accumulation of facts, the several classes of which have been enumerated above, under the second to the eighth heads. For those which are grouped under the second to the seventh of these classes, respectively, have a clear significance on the hypothesis of evolution, while they are unintelligible if that hypothesis be denied. And those of the eighth group are not only unintelligible without the assumption of evolution, but can be proved never to be discordant with that hypothesis, while, in some cases, they are exactly such as the hypothesis requires. The demonstration of these assertions would require a volume, but the general nature of the evidence on which they rest may be briefly indicated.

2. The accurate investigation of the lowest forms of animal life, commenced by Leeuwenhoek and Swammerdam, and continued by the remarkable labours of Reaumur, Trembley, Bonnet, and a host of other observers in the latter part of the 17th and the first half of the 18th centuries, drew the attention of biologists to the gradation in the complexity of organization which is presented by living beings, and culminated in the doctrine of the "échelle des êtres," so powerfully and clearly stated by Bonnet; and, before him, adumbrated by Locke and by Leibnitz. In the then state of knowledge, it appeared that all the species of animals and plants could be arranged in one series; in such a manner that, by insensible gradations, the mineral passed into the plant, the plant into the polype, the polype into the worm, and so, through gradually higher forms of life, to man, at the summit of the animated world.

But, as knowledge advanced, this conception ceased to be tenable in the crude form in which it was first put forward. Taking into account existing animals and plants alone, it became obvious that they fell into groups which were more or less sharply separated from one another; and, moreover, that even the species of a genus can hardly ever be arranged in linear series. Their natural resemblances and differences are only to be expressed by disposing them as if they were branches springing from a common hypothetical centre.

Lamarck, while affirming the verbal proposition that animals form a single series, was forced by his vast acquaintance with the details of zoology to limit the assertion to such a series as may be formed out of the abstractions constituted by the common characters of each group.[4]

Cuvier on anatomical, and Von Baer on embryological grounds, made the further step of proving that, even in this limited sense, animals cannot be arranged in a single series, but that there are several distinct plans of organization to be observed among them, no one of which, in its highest and most complicated modification, leads to any of the others.

The conclusions enunciated by Cuvier and Von Baer have been confirmed in principle by all subsequent research into the structure of animals and plants. But the effect of the adoption of these conclusions has been rather to substitute a new metaphor for that of Bonnet than to abolish the conception expressed by it. Instead of regarding living things as capable of arrangement in one series like the steps of a ladder, the results of modern investigation compel us to dispose them as if they were the twigs and branches of a tree. The ends of the twigs represent individuals, the smallest groups of twigs species, larger groups genera, and so on, until we arrive at the source of all these ramifications of the main branch, which is represented by a common plan of structure. At the present moment, it is impossible to draw up any definition, based on broad anatomical or developmental characters, by which any one of Cuvier's great groups shall be separated from all the rest. On the contrary, the lower members of each tend to converge towards the lower members of all the others. The same may be said of the vegetable world. The apparently clear distinction between flowering and flowerless plants has been broken down by the series of gradations between the two exhibited by the *Lycopodiaceæ*, *Rhizocarpeæ*, and *Gymnospermeæ*. The groups of *Fungi*, *Licheneæ*, and *Algæ* have completely run into one another, and, when the lowest forms of each are alone considered, even the animal and vegetable kingdoms cease to have a definite frontier.

If it is permissible to speak of the relations of living forms to one another metaphorically, the similitude chosen must undoubtedly be that of a common root, whence two main trunks, one representing the vegetable and one the animal world, spring; and, each dividing into a few main branches, these subdivide into multitudes of branchlets and these into smaller groups of twigs.

As Lamarck has well said[5]—

Il n'y a que ceux qui se sont longtemps et fortement occupés de la détermination des espèces, et qui ont consulté de riches collections, qui peuvent savoir jusqu'à quel point les *espèces*, parmi les corps vivants se fondent les unes dans les autres, et qui ont pu se convaincre que, dans les parties où nous voyons des *espèces* isolés, cela n'est ainsi que parcequ'il nous en manque d'autres qui en sont plus voisines et que nous n'avons pas encore recueillies.

Je ne veux pas dire pour cela que les animaux qui existent forment une série très-simple et partout également nuancée; mais je dis qu'ils forment une série rameuse, irrégulièrement graduée et qui

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[1] *Principes de la Philosophe*, Troisième partie. § 45.

[2] *Ethices*, Pars tertia, Præfatio.

[3] *Système de la Nature. Essai sur la Formation des Corps Organisés*, 1751, xiv.

[4] *Considérations Philosophiques sur la gradation naturelle des formes de l'être; ou les essais de la nature qui apprend à faire l'homme*, 1768.

[1] *Recherches sur les causes des principaux faits physiques*, par J. B. Lamarck. Paris. Seconde année de la République. In the preface, Lamarck says that the work was written in 1776, and presented to the Academy in 1780; but it was not published before 1794, and at that time it presumably expressed Lamarck's mature views. It would be interesting to know what brought about the change of opinion manifested in the *Recherches sur l'organisation des corps vivants*, published only seven years later.

[1] See the "Historical Sketch" prefixed to the last edition of the *Origin of Species*.

[2] *First Principles* and *Principles of Biology*, 1860–1864.

[3] *Generelle Morphologie*, 1866.

[4] "Il s'agit donc de prouver que la série qui constitute l'échelle animale réside essentiellement dans la distribution des masses principales qui la composent et non dans celle des espèces ni même toujours dans celle des genres."—*Phil. Zoologique*, chap. v.

[5] *Philosophie Zoologique*, première partie, chap. iii.