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RECENT REVIVALS OF DARWINISM[1]

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BEFORE us are four recent volumes, the "Huxley Memorial Lectures," "The Causes of Evolution," by J. B. S. Haldane, "Problems of Relative Growth," by Julian S. Huxley, and "The Scientific Basis of Evolution," by Thomas Hunt Morgan, which bring us up to date in the latest British and American thought as to the nature and causes of evolution. They are popularly written and the chief impression they convey is their reversion to more or less pure Darwinism, especially surprising on the part of one of the authors, T. H. Morgan, who some years ago wrote a severe critique of Darwin's theory of adaptation.

We thus have presentations by a distinguished physiological chemist, by the leader of the experimental and genetic school, by an experienced zoologist, P. Chalmers Mitchell, and by one of the leading British authorities on animal life, Julian Huxley. The point of view shown in Julian Huxley's volume should be supplemented by his article in the recent edition of the "Encyclopaedia Britannica."

Preceding a critique of these volumes may we point out four historic explanations of the modes and causes of evolution.

EMPEDOCLES–DARWIN HYPOTHESIS

This bit of absolutely inductive research has a 2,500 year speculative background because about 600 B. C., as described in my volume, "From the Greeks to Darwin," the Greeks began to speculate not only on the modes or kinds of evolution but on the hypothetical causes of evolution. Thus Empedocles of Agrigentum, a Sicilian town, anticipated what may be known as pure Darwinism, namely, that out of many kinds of accidents and variations more or less spontaneously occurring in animals, nature permits the survival only

[1] Address before the Osborn Research Club in the American Museum of Natural History, December 13, 1932.

of those which happen to fit in with the environmental times. This original very crude idea has come down through the ages of human thought, being modernized step by step until it finds its present refinement and up-to-date re-definition and re-statement in the four volumes before us. After many vicissitudes Darwinism is now once more flourishing.

Erasmus Darwin–Lamarck Hypothesis

Similarly, the second great hypothesis as to the modes and causes of evolution, now known as Lamarckism, was adumbrated in Greek time because, as pointed out by Brooks in his "The Foundations of Zoology," the notion that bodily improvement, through the universally acknowledged individual adaptation which comes about through the skilful use of parts, as well as the counteraction of bodily degeneration through disuse of parts, has been discussed down through the centuries and reached its apogee in the mind of Erasmus Darwin, of Lamarck, its modernized ideas in the speculations of Herbert Spencer, and its mechanical climax in the writings of our own Cope. Relative to the ever-growing and verdant Darwinism, Lamarckism is decidedly moribund. It received its death thrust in 1880 when Weismann challenged every kind of evidence for the inheritance of acquired characters. It seems cowardly to attack a dying principle, but I may claim in self-defense that the Titanothere Monograph as well as the more recent Proboscidea Memoir give Lamarckism its final *coup de grace.*

Buffon–St. Hilaire Hypothesis

The third great historic explanation of the nature and causes of evolution appears to have dawned upon the human mind at a relatively recent period, namely, that of the direct action of a favorable or unfavorable, or even of a new environment, on the body and indirectly on the germ as well, although it must be recalled that in all early speculations the sharp distinction which Weismann was the first to draw between the body cells and the germ cells was not clear. Nevertheless, the dictum of Buffon that the mammals of the New World were *dénaturés* as compared with their relatives in the Old World, followed by the violent physicochemical transformation involved in the speculations of Geoffroy St. Hilaire, fully foreshadows the modern speculations, experiments and observations not only on the final inheritance by the germ of the modifying influences of climate but also on the reaction of the germ and consequent origin of hereditary mutations under more or less violent physicochemical agencies.

Aristotle–Driesch Hypothesis

The fourth great principle is purely speculative. It is not truly an induction from observed facts like the others. It is rather a deduction. Hydra-headed, it appears under new designations from the "entelechy" of Aristotle (384–322 B. C.) to the modern "holism" of Smuts or the "emergence" of C. Lloyd Morgan. Perhaps the most expressive designation is that of "vitalism," namely, that there is in life a mysterious self-perfecting principle, charmingly designated by Bergson the "élan vital." Needless to say, this is what the Latins called a *petitio principi;* it is begging the question and avoiding the difficulties by assuming the presence of this internal perfecting tendency. It is something like the assumption by older chemists of "phlogiston" as an explanation of the internal heat and of motion of the body.

Again, while stoutly maintaining that the entelechy of Aristotle and his successors is a theoretic assumption, we should by no means shut out the possibility of further observational or inductive demonstration that there is in life something in the nature of an internal perfecting principle. It is certainly rash at the present moment to deny the possibility of such future discovery. Certainly if there is an *élan vital* it should appear in the creative origin of new parts and organs, as, for example, in the beautiful eyes of the scallop *Pecten* which, as Bergson showed, present so many analogies to the human eye in the position of the lens and retina.

Trends of Recent Thought

Unlike pure Darwinism, which is still greatly debated as an adequate explanation of evolution, and unlike Lamarckism, which is moribund except in the minds of a very few of its living advocates, the Buffon-St. Hilaire principle of direct environmental action both on body and germ is now universally admitted as one of the great causes of evolution. As shown in the experiments of Sumner, one of my former students, it is directly responsible for speciation in animals like *Peromyscus.* Sumner has positively demonstrated that modifications in color and form and proportion, traceable to the prolonged direct action of environment, are hereditary and therefore true germinal characters. Perhaps the best established zoological generalization of modern times is that subspeciation, and ultimately full speciation, is the inevitable result of prolonged change of environment especially visible in color, in proportion, and inevitable in habit which is the invariable precursor of change of form.

The three above principles—Darwinian, Lamarckian and Buffonian—rest upon both a purely speculative and a largely observational basis, and great zoologists, like Edward B. Poulton, who have devoted their entire lives to observations tending to establish pure Darwinism, firmly believe that the pure Darwin principle explains not only color evolution as seen in protective and aggressive mimicry, but that *all evolution of every kind is explainable by Darwinism.* This is very evident in the years of early correspondence which I enjoyed with Poulton, and our opposing views ripened into full presentation at the centenary of the British Association held in the British Museum a year ago.

My own position with respect to these three historic explanations has been frequently and clearly stated, but I may now briefly summarize it, namely, that pure Darwinism never sought to explain the origin of new characters. In fact, Darwin invariably used the word "chance" but open-mindedly declared that "chance" was a term which might simply express the ignorance of his time as to principles of origin which might subsequently be discovered. Since Darwinism is the only explanation of certain kinds of adaptations and since it is universally admitted that the survival of the fittest is a universal principle and that this applies to fitness in every organ of the body, we all gladly embrace pure Darwinism as one of the great factors of evolution.

As to Lamarckism, the case is quite different. The immediate inheritance by the next generation of the effects of individual adaptation is absolutely disproved, but in the age long or secular biomechanical adaptations of animals we do perceive a great principle which comes within the generic conception of Lamarckism, if not within the specific conception of Lamarckism which the great French naturalist advocated.

As regards the third great principle, namely, the direct action of environment, it seems to be no longer debatable. It is equally evident in every type of animal and plant which we may observe, but, like Darwinism, so far as we know at present it is confined to the modification of existing organs rather than to the origin of new organs, and even as regards the modification of existing organs, the direct action of environment is rather limited.

As a youthful observer I was first strongly impressed by Lamarckism and my early writings led to my classification with Cope as a neo-Lamarckian, but whereas Cope stuck to this explanation of the origin of all biomechanical adaptations to the very end of his life I soon abandoned it and took the speculative ground that there was an entirely unknown factor of evolution awaiting discovery. Fifty years of continuous and very close observation, often of the most laborious and tedious kind, aided by such a splendid assistant as William King Gregory, have only confirmed and strengthened my youthful conviction that the real underlying causes of evolution are entirely unknown, and my present feeling is that they are not only unknown but may prove to be unknowable. The universally and marvelously adaptive principle in the origin and development of biomechanical fitness may be something of the same nature as Newton's principle of gravitation. We may observe all its modes, workings and laws and be able to formulate them in detail even to the great test of prediction. But we may never know the underlying nature of the thing itself. As in gravitation so it may be in biology, some Einstein may succeed a Newton, and yet leave gravitation still in its simpler expression like,—the force that holds the moon in a constantly stable relation to the earth,—something unknown and unknowable, a fact which we can observe but never explain. That is my own present feeling about the whole evolution process.

Having dropped speculation very early in my biologic and paleontologic career, I settled down to the only absolutely safe course for a naturalist, namely, to continual and unremitting observation—day after day, night after night, month after month, year after year. I stick to observation as a shoemaker sticks to his last, through thick and thin, and all the generalizations which I have been able to make are in part confirming generalizations previously made by others, in part discovering entirely new principles hitherto unsuspected. I estimate that 90 per cent. of my time has been given to my own observation and less than 10 per cent. to reading the observations of others. In fact, I am somewhat ashamed of having done comparatively little reading. When I find some one has anticipated me I am only too glad to give him the fullest possible credit, but anticipations are rare because no one in the world has ever had the opportunity afforded me through the splendid financial resources of this museum and the dauntless corps of explorers, field collectors and coworkers who have built up the unrivaled collections in the department of vertebrate paleontology in the American Museum. Such actual documentary records of evolution as have never been accessible before to any naturalist or any observer, however keen, have opened the way to all which may be claimed as new discovery.

Recently Julian Huxley visited the Hall of the Age of Mammals and I showed him the small case two feet square which contains the entire fossil vertebrate collection of the Tertiary, of the year 1891. Then when I told him of the six great exhibition halls of the Life History of the Earth which will be overcrowded when all our existing collections are displayed in them, he was simply amazed. It is not the magnitude of these collections, but the exhaustive and refined way in which they have been assembled with extremely precise field records both as to locality and as to geologic level, which is of inestimable value. This minute observation of geologic sequence, first in America and then in the Tertiaries of India by Barnum Brown, has brought us to the point where we can demonstrate beyond refutation the absolute origins and continuous developments of new characters. Such observations were undreamt of by Buffon, by Lamarck or by Darwin.

THE VALUE OF THE DETERMINATION OF FREE ENERGY CHANGE FOR ORGANIC REACTIONS[1]

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IT is only within recent years that the importance of free energy determinations of organic compounds has been realized.[2]

The study of any chemical reaction resolves itself primarily into two fundamental questions: first, how nearly to completion does it go under various conditions, and second, how rapidly does it approach this limit in the presence of various catalysts. The answers to these two quesitons are to be found by means of free energy values.

The well-known formula $\triangle F.^\circ = -RT \ 1n \ K$ gives the relation between the equilibrium constant (K) and the change of free energy for the particular reaction under certain definite conditions. The value $\triangle F.^\circ$ is of more general significance than the value K and that is why this particular physical constant is usually sought. The factor R in the equation is the gas constant and T the absolute temperature

It is not necessary to determine the equilibrium constant directly under certain definite conditions in order to find $\triangle F.^\circ$ It is usually quite feasible to perform operations with various chemical equations in free energy terms, so that a numerical value of $\triangle F.^\circ$ is obtained.

It is sometimes quite expedient to use another well-known formula for the determination of $\triangle F.^\circ$ This is: $\triangle F^\circ = \triangle H - T \triangle S$.[3] In this case use is not made of the gas constant R and the equilibrium constant K, but the heat term $\triangle H$ and a change in entropy $\triangle S$. The term $\triangle H$ is a quantitative value of the heat given off or taken up during the reaction. This heat term is usually measured while the system is at constant pressure. The reaction, however, may be from one physical state to another and not necessarily chemical.

The change in entropy $\triangle S$ is made up of a series of $\triangle S$'s from the absolute zero up to the temperature existing at equilibrium for each constituent. For example, a solid in heating up from absolute zero to some higher temperature acquires an entropy value equal to the integral of the function $\frac{Cp}{T}$ over the temperature range, where Cp is the specific heat at constant pressure. When the solid changes from the solid state to liquid state the heat of fusion divided by the absolute temperature of melting will constitute the entropy change for that change in state. From then on the specific heat of the liquid is the determining factor until the boiling point of the liquid is reached and then the latent heat of evaporation must be taken into consideration. In this way it is possible to determine from specific heats and latent heat data the S for any particular chemical compound at any definite state and condition. The $\triangle S$ for a reaction is calculated from the S values of individual compounds in exactly the same manner as $\triangle F$. In other words, the $\triangle S$ value for the reaction is calculated by subtracting the sum of the S values of the reactants from the sum of the S values of the products.

It should be possible theoretically to measure the equilibrium constant of any chemical reaction and from this to obtain easily a $\triangle F.^\circ$ value. We would then have an answer to the question, what are the equilibrium conditions of the reaction, and thereby be able to determine whether or not the reaction was suitable for any particular purpose. Unfortunately, there are a great many practical difficulties that arise, especially with organic reactions.

Reactions studied by the equilibrium method have been those that, first, gave a measurable concentration of product and left a measurable concentration of reactant; second, involved relatively simple methods of analysis; third, had no complicating side reactions. With the exception of ionic reactions, as great a proportion of inorganic as organic reactions satisfy the first requirement—although that proportion is very small indeed. Analytical methods are much better developed for inorganic than for organic compounds. As for side reactions, the distinctive ability of carbon to combine with itself tends to cause much greater

[1] Read before the Natural Academy of Sciences, University of Michigan, on November 14, 1932.

[2] See American Chemical Society Monograph No. 60, entitled "Free Energies of Some Organic Compounds," by Parks and Huffman, recently published by the Chemical Catalog Company in New York.

[3] $\triangle F = \triangle H - T \triangle S$ under any conditions. $\triangle F = \triangle F^\circ$ when all reactants and products are under one atmosphere pressure.