variations in molecular composition have as yet been realized. For some of these compounds, at the present time still hypothetical, theoretical considerations predict an endothermal and unstable state; other compounds, even if predicted to be thermodynamically stable, are likely to prove less stable than analogous products into which they can readily transform. Thus, AlCl is probably an exothermic compound and should exist, were it not for the fact that $AlCl_3$ is decidedly more stable; consequently, there is a tendency for the following reaction to occur spontaneously: $3\ AlCl = 2\ Al + AlCl_3$.

Thus, the manifestation of valence variation appears explainable in the case of such atoms which have their valence electrons distributed among 2 or 3 shells; explainable also in the case of atoms the valence electrons of which are all located in one shell, but the number of these electrons is more than 2. But how do the following instances of valence variation find their explanation: (1) In the second group metals—Mg, Ca, Sr, etc.—the two valence electrons are both in the same shell and both belong to the same subgroup; therefore, both electrons may be expected to enter into the formation of a bond with equal ease and therefore simultaneously. And yet we know, as cited in the early part of the paper, under certain conditions this is not the case. (2) Carbon, with its 4 electrons as 2.2, may be expected to function as bivalent and quadrivalent—but why trivalent? Similarly, why oxygen-univalent? (3) Why in chlorine, is valence variation by two—1, 3, 5, 7? How to explain the fact that fluorine, a member of the same group with chlorine, is always univalent, and no more?

You would not wish me to enter here upon the discussion of these and other similar questions. May I merely say that, in my judgment, no one can fail to be impressed by the cogency of the arguments which London, Heitler and others have built up during the last three or four years, on the basis of what is known as Pauli's Exclusion Principle. All the above-mentioned valence variations seem to be explainable in a satisfactory manner.

The above few illustrations may suffice to show that modern atomic structure theories are of great assistance to the chemist in explaining valence variation. What used to be a purely empirical fact becomes in the light of these theories an understandable concrete process. The occurrence of compounds with monovalent calcium or magnesium, divalent aluminum, trivalent carbon, and other cases of deficiency valence are not only compatible with these modern theories, but are predictable on the basis of the theories. The situation is not quite so satisfactory when we come to consider the coordination compounds, wherein elements exhibit what looks like excess valence. Nearly all attempts at explanation of these cases of valence variation make wide use of hypotheses, which in themselves may be legitimate and are plausible, but they do not rest on sufficiently clear-cut experimental evidence. It is not surprising, therefore, that two such eminent authorities as Sidgwick and Sugden do not agree whether a non-polar bond always requires for sharing a pair of electrons or whether a single electron will suffice; whether an octet of electrons around an atom is the limit, or whether ten, twelve and more electrons are also possible. The fundamental theory, however, of atomic structure is sound, and we may rest assured that these problems will in time also be solved.

CONCLUSION

In bringing to a conclusion these few scattered reflections concerning valence variation and atomic structure, may I be permitted to say this: He who is experimentally inclined may henceforth take heart and he need not be quite so timid in interpreting strange chemical reactions on the assumption of possible anomaly in the valence of the reactants. The physicist has no hesitation in speaking of the temporary existence, at the higher temperature employed in spectroscopic work, of such molecules as BaCl, AlO, (HO), CH^+, CH_2, MgF, etc. Is it not possible that under the influence of surface forces somewhat similar valence variation may not be excluded even at lower temperatures? That these strange compounds are thermodynamically unstable may be true. Nevertheless, they may function as the mysterious catalysts, or as initiators of chain reactions.

NEW CONCEPT OF EVOLUTION BASED UPON RESEARCHES ON THE TITANOTHERES AND THE PROBOSCIDEANS[1]

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THE new concept of evolution is not to be confused for a moment with the pre-observational "entelechy" of Aristotle, the "vitalism" of Driesch, the "évolution créatrice" of Bergson, the "emergence" of Lloyd-Morgan, the "holism" of Smuts, or any other of the age-long "internal-perfecting" hypotheses which are

[1]This is the seventh paper on the Origin of Species, and the newer aspects of the Evolution problem. The National Academy of Sciences, November 16, 1931.

more or less metaphysical anticipations of the order of nature. It is, on the contrary, purely inductive or post-observational.

The new concept is based on thousands if not hundreds of thousands of observations on invertebrate and vertebrate fossils. The mammals for the first time reveal the complete life history of a great hoofed family, the Titanotheres, during twelve million years, of a great hoofed order, the Proboscideans, during thirty million years, gathered from all the museums and all the countries of the world. The anatomical contrasts between these two groups of animals, namely, the arrest of tooth evolution in one and the marvelous progress of tooth evolution in the other, serve to absolutely establish the nine new principles of paleontology revealed since 1869.[2]

Recently the grinding teeth of the Proboscideans enable us for the first time to establish the rate of evolution in an extremely important adaptive organ, very slow even in the course of ten thousand years. This incredibly slow rate exposes the futility of modern experimental research which would produce a new character in a single year or in a few seconds.

In brief, the new concept of evolution is forced upon us by the discovery since the year 1869 of nine new principles of biomechanical evolution which were not only unknown to Charles Darwin but are antagonistic to one of his fundamental theses that Nature does anything by variation, by fortuity, by accident or by chance. It has taken sixty-two years of observation, namely since Waagen's observation of 1869, to demonstrate that organic like inorganic Nature does nothing by accident or by chance but only by means of universally prevailing adaptive principles which are only revealed in long secular periods of time. The very words adaptive action, reaction and interaction imply a chasm between biomechanism and inorganic mechanism, across which there is no bridge at present.

Moreover, as the principal point of the present address, we are compelled to return to a creational concept of evolution. Mark that the word *creational* is used without any of its old theological or philosophical implications; it is clearly distinct from the word *created;* there is no equivalent in the Greek language. For this concept the term "aristogenesis" is provisionally suggested until the classicists can furnish us with a single term signifying the *creative origin of the adaptive.*

A brief survey of the twenty-five centuries of observation and induction brings us face to face with this new concept.

[2] These nine principles are set forth in the British Association Centenary Address, September 25, 1931, to be printed in *The American Naturalist,* January–February, 1932.

DARWIN THE FOUNDER OF PALEONTOLOGY

After its brilliant inception by Cuvier at the close of the 18th century, paleontology lapsed during the first half of the 19th century into a merely descriptive and systematic science on the Continent and even in Britain under the genius of Hugh Falconer and Richard Owen. Despite great discoveries in India, Australia, South America and Europe, paleontology lacked any central principle; its philosophical potentialities were never released. Falconer and Leidy, who opened up the ancient fauna of the Siwaliks of India and of western America and who recognized ancestral affinities in the Proboscideans, horses and other mammals, spoke guardedly of descent because there was a hush on the old concept of evolution. It was Darwin, the disciple of Lyell and the observer of South American Pampean fossils, who reanimated this slumbering giant of Biology, and created modern paleontology, which reveals the life history of the earth's billion years, and furnishes the only absolutely incontrovertible proof for Darwin's "Origin of Species" and "Descent of Man."

Darwin worked altogether on the old variational concept; he lived too soon to see the fruits of the evolutionary paleontology, which he founded. Not a single *phylum* or actual line of descent, not an ascending or descending mutation, not a single specific origin, not a single character origin was known to Darwin. In invertebrate lines of descent Waagen (1869) led the way to the new concept of evolution closely followed by Neumayr, and Alpheus Hyatt. Among the vertebrates, Leidy, Cope, Marsh, Gaudry were the pathfinders of phylogeny and of continuous lines of ascent. But the pioneer in the Darwinian revolution was Waldemar Kowalevsky, the first to apply Darwin's survival of the fittest idea to single adaptive or inadaptive organs.

Among the *older hypotheses as to the modes of evolution or organs* paleontology proves that Lamarck was wrong in his main assumption that characters acquired by the soma are inherited; Darwin was wrong in adding Lamarckism to his original selection theory. Paleontology also reveals the fallacy in McBride's recent Lamarckian argument that habit is a driving factor in evolution; habit is not the driving factor but it is one of the guiding factors; grant the whole arguments of the Lamarckians, ancient and modern, the larger part of biomechanical evolution would still remain unaccounted for. Darwin knew not a single one of the nine paleontologic principles discovered since his time. DeVries was wrong in believing that species arise by the selection of fortuitous mutations. Darwin passed away just at the time when Weismann was establishing his cellular continuity of the germ-plasm principle; Weismann was

wrong in his subsidiary super-selection assumption that fortuitous variations of the germ-plasm give rise to new species. Darwin recognized the sub-species of birds and tortoises on the Galapagos Islands produced by geographic isolation, but he lived too soon to recognize Wagner's now well established principle of the origin of species and sub-species through geographic isolation. Darwin was doubtful of Buffon's factor of speciation through the direct action of environment; he was astonished at the pioneer case of *Saturnia* brought forward by Wagner. Darwin knew not a single case of intergradations between living species; we now know hundreds of intergradations in fishes, birds, reptiles and mammals.

As to the older hypotheses as to the origin of single characters, throughout Darwin's life period our attention was mainly concentrated on species rather than on single characters. In this after-period both zoologists and paleontologists are concentrating on the origin of single characters of which sub-species, species, genera and orders are by-products. Understand the origin, rise and fall of a single adaptive biomechanical character and you will understand the whole story. It is like Tennyson's "flower in the crannied wall."

In conversation with Dr. Hans Spemann recently, and knowing of his brilliant researches upon "living organizers," I asked him to produce a system of fossil organizers by which the nine new principles revealed by paleontology could be coordinated. He declared himself an agnostic as to the causes of evolution. I also am a complete agnostic, perhaps even more of an agnostic than Spemann, because, while he may be familiar with the eleven principles of biomechanical evolution revealed by zoology and comparative anatomy, we have through forty years of continuous observation become familiar with nine additional principles revealed by paleontology.

It does not detract one iota from Darwin's greatness as the founder of modern paleontology to say that it revolutionizes Darwin's old variational concept of the evolution process, even as Cuvier's paleontology of special-creation and successive-creation concepts was revolutionized by Darwin. Would that Darwin could return to earth to see his fossil offspring and to welcome the new concepts revealed in the extinct animal and plant kingdoms and of man.

SIX PRINCIPLES OF THE NEW CONCEPT

Certain of these six principles of biomechanical evolution were presented in the author's Hale Lectures before the National Academy in the year 1916, subsequently published in a volume entitled "The Origin and Evolution of Life." Others are here stated for the first time.

(1) *Uniformitarian rather than cataclysmal.*

Organic evolution conforms with the uniformitarian interpretations of Hutton and Lyell of the middle of the 18th century which had such a profound influence on the mind of Darwin. The uniformity of organic evolution proceeds with the uniformity of the physical and chemical environment.

(2) *Centrifugal rather than centripetal.*

Paleontology strengthens Weismann's epoch-making generalization of 1880, namely of the geneplasmic rather than somatic origin of all characters. No characters arise except from latent potentialities in the germ.

(3) *Creational rather than variational.*

Paleontology adds something far more important, namely, the adaptive origins of new characters from the germ for which the only term in our language at present is "creational." Paleontology strengthens the conclusions independently reached by zoologists that Darwin, from lack of evidence in his time, overstressed the principle of variation. Paleontology, moreover, demonstrates that variation of *kind* is temporary and fugitive, although plus and minus variation of *degree* is very important under selection.

(4) *Reactional rather than entelechistic.*

This creational process is, however, not wholly spontaneous, independent or emergent except perhaps in the evolution of the mind. The latent biomechanical powers of the germ are only evoked in the process of adaptive reaction either in the course of individual development or as a secular or age-long process.

(5) *Anti-energistic rather than syn-energistic.*

Life tends to borrow energy in order to resist energy—this is the distinctive feature of all living mechanisms—the root of the idea of the struggle for existence.

(6) *Evolution is prot-empirical rather than meta-empirical.*

Many of the biomechanical organs evolve in the geneplasm before there is any actual need for them rather than after the need for them arises. This is in opposition to the main thesis of Lamarck and of Herbert Spencer. Spencer believed that mind was built up through experience, but observed facts prove otherwise. We have found that much larger intelligence exists among primitive people than there is any actual need for, intelligence capable of grasping mathematical concepts among Eskimos who had no need even to count on their fingers.