ing, that we are witnessing potentiality rather than predetermination. One definition of the term potential, *i.e.*, "Latent, undeveloped, but capable of developing and becoming effective; existing in the germ . . . ," while a purely physical term, appears to apply to the latency of the aristogenes both in the grinding teeth of the Proboscidea and in the horns of the titanotheres. The presence of this genedynamy or latent power in the germ, is attested by the entire history of the grinding teeth of the mammals extending back to the single coned pro-mammals of the Triassic time.

### CONCLUSION

An interesting coincidence in the history of the evolution theory is that while William Bateson was working in Cambridge after his graduation (1882) from St. John's, under Weldon's direction he soon turned to the study of variation chiefly on the materials afforded in the Cambridge museums, and in the introductory pages to his well-known volume gave his preliminary conclusions: I. The forms of living things are various and, on the whole, are Discontinuous or Specific. II. The Specific forms, on the whole, fit the places they have to live in. How have these Discontinuous forms been brought into existence, and how is it they are thus adapted? This is the question the naturalist is to answer.

At the same time Osborn, studying in Cambridge (1879–1880) and Princeton (1881–1890), was also interested in the problem of variation, and in opening a discussion upon the Lamarckian principle before the American Society of Naturalists reached conclusions as to definite lines of blastogenic variation, as follows: "The conclusions we reach in this discussion must finally turn upon the existence of definite lines of blastogenic variation." Thus Osborn and Bateson laid out for themselves a program for future research based in Bateson's case on the concept of discontinuity between species, and in Osborn's case on the concept of the existence of definite lines of germinal variation still to be discovered.

The results of Bateson's research left him in a hopeless and agnostic mood. Osborn on the other hand is full of confidence.

Our knowledge of the chemical messengers which not only sustain the structural harmonies of the entire organism, but which hasten forward some processes and retard others, has advanced by leaps and bounds. We are still on the threshold of the biophysical messenger system, but the one fact that certain mammals are sensitive to slight changes in the barometric pressure of the atmosphere which heralds a coming storm is an indication of what we may anticipate in the physical sphere of action. The hard-won discoveries in aristogenesis which form the chief subject of the present address are entirely the outcome of the spirit of the "interpretation" of nature rather than the "anticipation" of nature, in the language of Bacon, the founder of inductive biology.

Nature is full of surprises; Nature seldom works according to the anticipations of man, even such semi-inductive anticipations as those of Charles Darwin and of Herbert Spencer. If, as we contend, the principle of Aristogenesis is firmly established by irrefutable paleontological evidence we are now in a new vantage point to attack the problem of the causes of biomechanical adaptations which have interested the mind and excited the imagination of man since the time of Empedocles. Let us summarize our present position for the direction of further research and experiment.

*In biomechanical evolution there are two distinct processes. The one long known consists in the alloiometric modification of existing adaptations as in changes of proportion and of function. The other, discovered in course of researches on the phylogeny of the horses, titanotheres and proboscideans, consists in the gradual geneplasmic origin of new and distinct adaptations; it is to the latter originative and creative process that the term Aristogenesis is applied. Both processes become part of the hereditary equipment of the organism.*

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# THE MECHANISM OF THE POLYMERIZATION AND DEPOLYMERIZATION OF OLEFINS[1]

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ALTHOUGH the polymerization of olefins is nearly as old as organic chemistry and in spite of the increasing industrial importance of this process, especially in connection with cracked gasoline, the theories which have been propounded to explain it have not been adequate. In most cases they have assumed types of changes which are entirely different from ordinary organic reactions. The theory presented in the present address is different from the preceding

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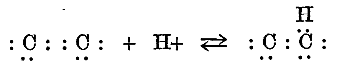
[1] Abstract of an address by the retiring vice-president and chairman of Section C—Chemistry, American Association for the Advancement of Science, Boston, December 29, 1933.

theories in that it assumes only successive additions of positive hydrogen ions and positive organic groups, corresponding to hydrogen ions, to molecules of olefins.

The suggestion for the present theory of polymerization came from some experiments in our rearrangement studies. The dehydration of a nonyl alcohol which was expected to give a nonene with the migration of a tertiary butyl group gave instead a pentene (trimethylethylene) and a butene (isobutylene). It thus became evident that the tertiary butyl group, instead of wandering with its electron pair during the rearrangement, had been deprived of the electron pair and left as a "positive" tertiary butyl group which immediately lost a hydrogen ion and became isobutylene. The formation of a pentene and a butene instead of the expected nonene was immediately recognized as a peculiar case of depolymerization. The suggestion became obvious that if this depolymerization consisted in the removal of a positive tertiary butyl group, then polymerization might consist in the addition of such a group to an olefin. This conception agrees with the experimental facts as recently determined in the case of the diisobutylenes and the triisobutylenes in this laboratory.

As will be recalled, the polymerization of olefins takes place most readily in the presence of acid catalysts. A great variety of substances which will give hydrogen ions will cause the polymerization of olefins. As is also well known, there is a great difference in the ease with which various olefins polymerize. Thus ethylene and propylene polymerize with considerable difficulty. The normal butenes polymerize somewhat more readily. Isobutylene polymerizes with extreme ease. The order of ease of polymerization of these substances is the same as the order of ease of addition of substances like hydrogen bromide. It has long been known that the first step in the reaction of an olefin consists in the addition of a positive group to one end of the double bond. This is believed to be due to the addition of the positive group to the extra electron pair of the double bond. After a positive group has added to the double bond, the other carbon is left with only six electrons and is, consequently, positive. This new positive fragment can add to another olefin in the same way to form a still larger positive fragment. Any one of these positive fragments can become stable by the loss of a positive hydrogen ion, thus leaving a double bond with the formation of an olefin molecule.

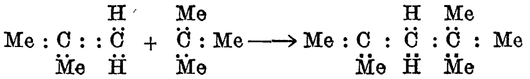
The condition existing at each step in the polymerization may be summarized by the following equation:



$$:\underset{..}{C}::\underset{..}{C}: \; + \; H+ \; \rightleftarrows \; :\underset{..}{C}:\underset{..}{\overset{\overset{H}{..}}{C}}:$$

In the first step the double bond is that of isobutylene, which unites [illegible]ydrogen ion to give a positive tertiary butyl radical. This positive tertiary butyl radical can add to a molecule of isobutylene to give a still larger positive fragment. This can either lose a hydrogen ion to give a diisobutylene or can add to another molecule of isobutylene to give a positive fragment related to the triisobutylenes. The diisobutylene and the triisobutylene, in turn, can react with positive tertiary butyl groups or even with larger positive groups in the reaction mixture. The regeneration of hydrogen ions from the positive fragments makes the polymerization truly catalytic.

This theory can be applied in detail to the polymerization of isobutylene. The first step is the addition of a hydrogen ion to the methylene group of the isobutylene to give a tertiary butyl group, the central carbon of which has only six electrons and is therefore positive. This process is reversible. The tertiary butyl group can then add to the methylene group of another isobutylene molecule to form a larger positive fragment. This process may be illustrated as follows:



$$Me:\underset{\overset{..}{Me}}{C}::\underset{\overset{..}{H}}{\overset{\overset{H}{..}}{C}} \; + \; \underset{\overset{..}{Me}}{\overset{\overset{Me}{..}}{C}}:Me \longrightarrow Me:\underset{\overset{..}{Me}}{C}:\underset{\overset{..}{H}}{\overset{\overset{H}{..}}{C}}:\underset{\overset{..}{Me}}{\overset{\overset{Me}{..}}{C}}:Me$$

The instability caused by the carbon with only six electrons may be overcome by the loss of a hydrogen ion, either from one of the adjacent methyl groups or from the adjacent methylene group. The loss of the hydrogen ion leaves a double bond in the corresponding position. The two olefins thus obtainable would be 2, 4, 4-trimethylpentene-1 and 2, 4, 4-trimethylpentene-2. These are actually the substances which exist in the mixture known as "diisobutylene," which was first made by Butlerow nearly seventy-five years ago.

The polymerization can proceed farther, either by the addition of the large positive groups to another molecule of isobutylene or by the addition of a positive butyl group to either of the two trimethylpentenes. The addition of the eight carbon positive fragment to the methylene group of another molecule of isobutylene, followed by the loss of a hydrogen ion, would give 2, 4, 4, 6, 6-pentamethylheptene-1 and the corresponding olefin with the double bond in the 2-position. These two olefins have recently been identified in this laboratory in the higher boiling fractions of "triisobutylene" formed by the polymerization of isobutylene or of tertiary butyl alcohol. If a tertiary butyl group added to the methylene group of 2, 4, 4-trimethylpentene-1 and a hydrogen ion was lost to give a double bond the products would be 2, 2, 4, 6, 6-pentamethylheptene-3 and unsymmetrical dineopentyl ethylene. These two substances have been identified in the lower boiling fractions of triisobutylene in this laboratory. Other workers have reported that "triisobutylene" contains substances which have two tertiary butyl groups on the same carbon. To form these, a positive tertiary butyl group would have to add to 2, 4, 4-trimethylpentene-2. No product of this kind has been found to date in our studies, although we have carefully fractionated 150 gallons of crude triisobutylene through the very efficient semi-commercial columns of Dr. M. R. Fenske and his colleagues. Apparently a positive tertiary butyl group will not add to an olefinic carbon which already has a tertiary butyl group attached to it.

Extended studies are being conducted on more complicated cases of the polymerization of olefins. The present theory of the mechanism of this process is proving very useful in these experimental studies.

# OBITUARY

## HENRY STEPHENS WASHINGTON

AFTER a long illness, Henry Stephens Washington, one of the most eminent and picturesque personalities in American science, died at his home in Washington, D. C., on January 7, 1934.

Washington was born in Newark, New Jersey, on January 15, 1867, the son of George and Eleanor Stephens Washington. After receiving from Yale University the degree of A.B. in 1886 and A.M. in 1888, he continued postgraduate studies at Yale, Leipzig and the American School of Classical Studies at Athens.

Always intensely interested in many intellectual fields, he spent a number of the earlier years of his career in archeological excavations in Greece, and later was assistant for several years in physics and mineralogy at Yale. Though in his later life he did not participate actively in archeological research, he retained his love for the subject, and was a fellow of the Archeological Institute of America. Without being a specialist, he possessed a remarkable store of knowledge regarding ancient peoples, their origins and mode of life, and their monuments, inscriptions and art. He was widely read, had a very retentive memory, and there were few topics on which he was not able to converse with much more than superficial knowledge. His familiarity extended to such varied subjects as botany, philology, literature, the development of social customs and culinary art.

The scientific field to which he devoted the greater part of his life and in which he became recognized as an eminent authority was that of geology and mineralogy; chiefly, but not wholly, were his interests directed toward the aspects of these subjects to which his skill as an analytical chemist contributed. He and Dr. W. F. Hillebrand, working independently but toward the same end, recognized and insisted upon the value of exact determinations of rock constituents, at a period when many published analyses left much to be desired. Largely as a result of their labors the general standard of excellence of rock analyses has become, in later years, of a very different order than formerly. Washington's treatise, "The Chemical Analysis of Rocks," has passed through several editions and has been a standard text-book everywhere for nearly a generation. It embodies not only tested methods of analytical procedure but gives instructions regarding details of manipulation that are most important. As a further contribution toward the ideal he had in mind, a number of years ago he set himself the prodigious task of assembling from the literature all rock analyses that seemed worthy of attention, and calculated the results in terms of "normative minerals." From his familiarity with the subject he was able to group the analyses into superior and inferior and to point out in what respect the latter were defective. A second and enlarged edition of this monumental work, published by the U. S. Geological Survey in 1917, is a quarto volume of 1,201 pages. It is known to every geologist in the world. To those of Washington's acquaintances unfamiliar with the more earnest side of his character the amount of patient investigation and even drudgery to which he was willing to devote himself in this work is almost unbelievable.

This work further embodied a classification of igneous rocks by chemical composition according to a quantitative scheme devised by Washington in collaboration with Dr. Cross and Professors Iddings and Pirsson. Though this system now has rivals in somewhat similar schemes devised by others, it probably represents the first serious attempt at classification in this manner.

Petrological and volcanological investigations carried Washington on extensive travels in Greece, Asia Minor, Italy, Hawaii, Brazil and the United States, and many valuable publications resulted. He was gifted with exceptional linguistic aptitude and became proficient in the conversational use of a number of European languages, and even acquired a knowledge of Arabic.

From 1906 to 1912 he was engaged in professional work as a mining geologist. In 1912 he became a member of the staff of the Geophysical Laboratory of the Carnegie Institution of Washington. Here he remained until his death, except for a period during the war years, when he served as chemical associate and scientific attaché at the American Embassy in Rome. During his association with the Geophysical Laboratory he was enabled to pursue his investiga-