As bearing upon future relations of science to government in the study of planning activities, one may not avoid calling attention to the probability that the materials of science will continue to increase at a rate not greatly different from that of recent decades. Especially in planning programs is it important that new material be taken into consideration. It is therefore necessary to have increasingly close touch between scientific research groups and agencies of the government concerned with activities of the forward-looking or planning type.

CONCLUSIONS

There is no responsibility of science relating to the future of the country greater than that which concerns development of such an interest in scientific truth and realities on the part of the people as is needed to guarantee that the highest values in life ultimately prevail. In this relation the specific responsibility of scientific agencies is very large. This will be met:

First, by increasing emphasis upon the most fundamental types of investigation for the advancement of knowledge in every department.

Second, by bettered means for interpretation of science and for education of the people as a whole regarding the status of scientific knowledge. In part this work must be done by scientists themselves.

Third, by improved means for securing application of results from science, and at the same time better control of materials secured but not at once applied.

One of the ultimate cautions to be expressed in considering the rôle of science concerns recognition of the fact that, although essentially science represents certain aspects of truth and reality, there are other phases of human interest, as in art and our fundamental philosophical and religious beliefs, which may be looked upon as having meaning at least comparable in importance to science. While it is necessary for us to define the realities and the truths represented by science, the elements sometimes called human values are realized largely through appreciation of what is involved by use of other coordinate or correlated modes of thought, such as those that have been mentioned. In considering their relations to government it may become a responsibility of scientists to join those concerned with study of these other aspects of thought if the ultimate human meaning of scientific truth is to be made clear.

The significance of science as an essential feature in the life of the nation will be kept in balance by the people according as experience and education establish standards of value in which science and its truths take their place along with other critical human necessities. The scientist will not lose sight of the idea that his subject is only one of several requisite groups of things. And while it is necessary to remember that he will be held responsible if he fails to set forth the worth of his discoveries, it is also important to realize that science will be held responsible if over-emphasis is given to isolated groups of facts without reference to their real human signfiicance. It is the responsibility of science to state the truth cautiously, and with care that harm be not done. The manner in which a thing is presented sometimes goes far to nullify the value of what may have great intrinsic importance.

Science should help to develop a clear appreciation of the needs of government, and so to organize and interpret its findings as to aid in solution of all possible problems. This means effort to learn what the application needs are, in order to be aware of the places to which new materials should go for the highest types of use.

The scientist should not necessarily expect to administer the results of his own work, and yet the relation to administration is extremely important. He can not avoid considering the broader implications of his contribution, any more than the student of human questions can avoid knowing something of the meaning of scientific problems if the results of science are to be fitted into the economic or governmental plan.

With these known factors concerning the value and opportunity of science appreciated by an intelligent, educated people, thinking continuously, constructively and unselfishly upon needs of the government, a great contribution would be made in guiding the nation along a safe course.

THE DUAL PRINCIPLES OF EVOLUTION[1]

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I APPRECIATE the opportunity, afforded by Director Redfield's invitation, of summarizing fifty-five years of reflection and observation in the battlefield of evolution, as well as of personal experiences with Hux-

[1] Paper presented to the Seminar of the Biological Laboratories, Harvard University, November 2, 1934. This is the twelfth contribution by the author on the Origin of Species and the principles of biomechanical adaptation as demonstrated in paleontology. The eleventh contribution on this subject was the Eleventh Sedgwick Memorial Lecture: "Aristogenesis, the Creative Principle in the Origin of Species," *Amer. Naturalist,* lxviii: 716, 193–235.

ley, Darwin, Haeckel, Weldon, Bateson, Poulton, Cope, Dall, Packard, MacBride, Lloyd Morgan, T. H. Morgan and other evolutionists.

Like a moth to the flame we are attracted to the eternal problem of the causes of adaptation. The nearer we get to adaptation the more our intellectual wings are singed until we end in agnosticism or despair. In the recent language of Bohr:

> On this view, the existence of life must be considered as an elementary fact that can not be explained, but must be taken as a starting point in biology, in a similar way as the quantum of action, which appears as an irrational element from the point of view of classical mechanical physics and, taken together with the existence of the elementary particles, forms the foundation of atomic physics.

A very sharp distinction must be drawn between the *modes of adaptation* which paleontology reveals with unique fullness and the *causes of adaptation* which paleontology still leaves an inexplicable blank.

First, let us briefly review the history of speculation as to the causes of adaptation.

If, in Bohr's opinion, life can not be explained, the adaptive evolution of the geneplasm is infinitely more inexplicable. Each of the four classic explanations originating in the brilliant intellects of the Greeks, modified, elaborated and experimented upon, down to the present time, appears naive and futile in the light of modern discoveries. Biologists, like religionists, congregate in schools and unconsciously adopt creeds. Volumes have been written and old friendships severed in the discussion of the relative merits of these four classic explanations.

Second, the entelechist steps in with his *petitio principi* of an internal perfecting principle. Paleontology does not support entelechy in the sense of Driesch. Paleontology does reveal an internally reacting adaptive principle in the sense of Aristotle. Paleontology also reveals a reacting creative principle unknown to Darwin and all his predecessors. The evidence for this duality may be epitomized for this afternoon's seminar.

Third, geneticists and experimentalists, while contributing brilliantly to the structural and functional bases of heredity, are not contributing at all to our knowledge either of the modes or of the causes of geneplasmic adaptation. Adaptation is secular rather than temporal, a matter of more or less rapid motion of an almost infinite number of coordinated organs. The motion of a bombarded gene or of a tortured and hybridized *Drosophila* is a temporal, ephemeral and lawless motion. The geneticists and experimentalists are unable to observe the secular or age-long motion or activation of the biomechanical geneplasm which we are now able to measure very accurately in mammalian phyla which extend through long periods of geologic time.

Fourth, anatomists, zoologists and paleontologists who are making marvelous discoveries in the *modes* of evolution rarely concern themselves either with the causes of adaptation or with the principles of heredity. *It is only by the combined observation of the principles of heredity and of the modes and principles of biomechanical evolution that the causes of adaptation may be intelligently explored.*

Variation: In these Mendelian days it is recognized that a very large part of the Variation studied with such precision by Weldon and others is due to tetraplastic modifications of the soma; it is only the geneplasmic Variations in Weismann's sense which count, as in fact was clearly recognized by Darwin. The old dogma that evolution is by Heredity, Variation and Selection, which still lingers in many text-books, means nothing now; it is an outworn biological creed.

Entelechy: The first of the four classic explanations is that of an internal perfecting principle. The biomechanical evolution of the Proboscidea proves that every single organ and every part of an organ progresses in adaptive direction and in accelerated motion, not according to an internal perfecting principle, but according to the amount of service which, under new conditions of life, it renders to the organism as a whole. For example, the specialization of the pair of inferior incisive tusks takes no less than thirteen different directions to serve the organism in thirteen kinds of plant feeding. Passing by entelechy as contrary to paleontology let us review the other chief lines of speculation and hypothesis since 1859.

Darwinism: Selection, the second of the four classic explanations, is not a bio-energetic process; it is outside of the energetic field; it is judge, jury and executioner in organs and organisms of every degree of fitness; it awards premiums to all changes of proportion which favor the struggle for existence; in these indirect senses only is it originative of species. It can now be proved from the evolution of the Proboscidea that many of the modes of motion and activation are independent of Selection. Selection, while not in the energetic cycle, is constantly standardizing the geneplasm and testing its adaptive or inadaptive reactions to habit and the organic and inorganic environment.

Lamarckism: There is, third, the classic bio-energetic explanation of the geneplasmic inheritance of the somaplasmic response to (a) the energy of physical environment, (b) the energy of living environment, (c) the energy of habit or function, (d) the energy of heredity. This fourfold somatic response is summed up in the word *tetraplasy,* signifying that every organism and its variants are a resultant of adaptive actions, reactions and interactions of four complexes of energy. Lamarck's explanation of the immediate geneplasmic inheritance of somatic adaptations to new habits is thoroughly disproved both by observers of heredity and observers of biomechanical evolution in paleontology. Apparent cases of Lamarckian inheritance are best accounted for by the Baldwin-Morgan-Osborn principle of coincident-variation (Lloyd Morgan) or organic-selection (Baldwin).

Buffonism: There is slowly accumulating evidence for Buffon's explanation of real geneplasmic modification under new physico-chemical stimuli; it is interesting to recall that French evolutionists of the Cuvier period appealed to America for proofs of the alleged principle that old-world animals and plants were being modified or *dénaturées* by new-world environment. This "direct-action-of-environment" principle is demonstrable experimentally, but still more strongly by field zoologists in the origin of new sub-species and, ultimately, of new species. It is self-evident that the chemical constitution of the geneplasm may mutate or evolve in a new chemical environment. Also, we observe in paleontology that a new secular environment stimulates activation of the geneplasm both in the modification of existing structures and in the origin of new aristogenic characters. Paleontology reveals new truths and principles drawn from the observation of the secular influence of the energy of habit or function upon the energy of heredity.

Weismannism: Conservation and stability of type seem to be the chief functions of the energy of heredity; in biomechanisms the slightest deviation from the standard biochemical type is apt to be punished by death and finally by extinction. How, then, is progressive heredity possible? Through the Selection of Variations or Mutations, however small, said Darwin. Through the selection of genetic mutations, say Morgan and Conklin.[2] Paleontology reveals the fact that beside the function of stability, the geneplasm possesses the potentiality of modifying all its existing biomechanisms and of originating new biomechanisms. How are these modifications and aristogenes brought about?

Zoologic Modes of Adaptation: In brief, ten chief modes of biomechanical modification of organs have been observed by zoologists, anatomists and embryologists from the times of Aristotle to those of Goethe and Dohrn. These are: (1) progression or development, (2) acceleration or hurrying forward, (3) retrogression or degeneration, (4) retardation or slowing down, (5) compensation or balance, (6) economy the adjustment to service, (7) alloiometry or change of proportion, (8) coadaptation, (9) coordination and correlation, (10) auto-adaptation, including change of function or neo-adaptation. All these ten modes of adaptation, first observed by anatomists and zoologists, are brilliantly illustrated in the biomechanical evolution of the Proboscidea over their sixty million year period.

It is these ten modes of the biomechanical adaptation of separate organs to which the four classic explanations of Darwin, of Lamarck, of Buffon, of Weismann are still being applied. You may verify this statement by a reperusal of the evolutionary speculations of Empedocles and Aristotle to Darwin, Weismann and Driesch, also by an examination of most of the modern text-books of zoology which take no account of the seven new modes of adaptation discovered in paleontology.

Secular Heredity: Geologic time reveals to the paleontologist the seventeen or more modes of adaptive motion in the geneplasm, which are hidden to the geneticist and experimentalist. The two charts of the Titanothere thirty million year phylogeny and of the Proboscidea sixty million year phylogeny are not mere representations of fossil Titanotheres or fossil elephants but are the visible or phenotypic expressions of geneplasmic adaptation. Secular heredity is an altogether different phenomenon from laboratory heredity.

Paleontologic Modes: Thirty-four years of intensive research on the Titanotheres and Proboscideans has not only confirmed and amplified to an incredible extent the above ten modes of zoologic adaptation, but has added seven modes of paleontologic adaptation which can be observed only in closely connected lines of ascent through longer or shorter periods of geologic time—in brief, through phylogeny as distinct from ontogeny. These recently discovered and confirmed modes of adaptation are:

(1) *Phylo-mutation or W. mutation* of Waagen, 1869, the slow origin and rise of a new character or "aristogene" over a long period of geologic time. (2) *"Mutations-richtung"* of Neumayr, the genetic trend of W. mutations, or "aristogenes" to go on increasing in an orthogenetic direction, sometimes termed "momentum." (3) *Genetic-continuity* or unbroken origin as contrasted with discontinuous or mutational origin of new adaptations or aristogenes. (4) *Genetic potentiality* or the independent origin of similar characters at different periods of geologic time from similar ancestral stocks. (5) *Genetic predetermination* closely connected with potentiality, as in the origin of horn rudiments in Titanotheres of similar stock in successive periods of geologic time. (6) *Aristogenesis* (Osborn, 1931) (*-rectigradations,* Osborn, 1889), the creative mode of origin of new adap-

[2] E. G. Conklin, *Proc. Amer. Phil. Soc.*, lxxiv: 1, 155, 1934.

tive biomechanisms. (7) *Reciprocal bio-mechanical reaction.* Mechanical reactions of the inferior grinding teeth of the Proboscidea are the reversed mechanical reactions in the superior grinding teeth. For example, all *convex* curves in the superior enamel foldings are opposed to *concave* curves in the inferior enamel foldings and *vice versa.*

Aristogenesis: (*a*) The seven modes of geneplasmic origin newly discovered through the intensive comparative study of fossils of three widely distinct mammalian stocks, assembled from all parts of the world, reveal in the geneplasm the *dual creative principle* unknown in the time of Darwin and unexplainable by any of the four classic explanations of the causes of adaptive modification. (*b*) These new characters are called "aristogenes" because they arise directly from the geneplasm; unlike modifications they are antecedent to function, use or habit; they add something entirely new to the organism; they demonstrate genetic potentiality; they arise through genetic predetermination; they slowly and continuously progress in an adaptive direction; they harmonize with the seven modes of biomechanical adaptation discovered in paleontology as well as with the ten modes of biomechanical adaptation observed in zoology. (*c*) On coming of age, namely, into coordinated use and function with the entire organism, aristogenes become subject to development or degeneration according to their service to the organism. (*d*) An aristogene is readily distinguishable from a D. mutation of DeVries, because it is wholly the product of law rather than the product of chance.

Aristogenesis, the creative origin of new characters, is a geneplasmic principle altogether new to biology. It is quite distinct from morphogenesis, the modifications of proportion and form, of intensity and degree, of plus or minus variation, of development or degeneration, of existing characters.

Modifications: The causes of modifications (a term proposed by Lloyd Morgan) are partly explainable at the present time. The causes of aristogenes are largely beyond us. Morphogenesis is a universal phenomenon; aristogenesis is relatively rare and infrequent. The differences between these dual principles, the creative and the modifying, are clearly illustrated in the comparison between the Titanothere and Proboscidean phylogeny. For example, the only aristogenes observed in the Titanotheres are the paired horns. These animals had a relatively brief geologic existence. In the Proboscideans the innumerable aristogenes in the grinding teeth, combined with adaptive alloiometrons or changes of proportion and function in the tusks, prolonged the individual existence of the elephant to a century and the racial existence of the Proboscidea to sixty million years.

Conclusions: While zoology and paleontology, during the past twenty-two centuries, have almost completely revealed the *modes of adaptation,* we have waited for relatively recent discoveries in biophysics, biochemistry and physiology for vistas into the bioenergetic causes of adaptation. We are hopeful that the invariable sequence of the origins of new adaptive aristogenes and of new adaptive alloiometrons may in time enable us to establish antecedent secular causes and subsequent secular origins of adaptations. This is the only outlook as to causation which the evolution of the Proboscidea reveals at present.

Hormones, Chalones: It is a very striking generalization that three of the ten principles of zoological adaptation may theoretically, in part or in whole, be connected with hormones as the accelerators of motion, or with chalones the retarders of motion, or with these endocrines as coordinators of motion. I have applied to Spemann for a hypothesis of paleontologic "organizers."

Osborn, Keith and others have applied hormone principles to the biomechanical differentiations of the human races; it well may be one hormone which makes a child or a race *brachysomatic* or broad in all its dimensions—skull, skeleton, limbs, hands and feet. It may be another hormone which makes every part of the skeleton *dolichosomatic*—narrow skull, tall narrow skeleton, long slender fingers and toes. I have examples of these two extremes in two of my granddaughters.

But such diffused broadening and shortening or narrowing and lengthening hormones can not explain the excessively localized shortened face and lengthened cranium of the Titanothere or the shortened cranium and lengthened face of the horse. In brief, incredibly localized metamorphoses lengthening or shortening, broadening or heightening, developing or degenerating, accelerating or retarding, are observed in closely contiguous organs or parts of organs. It is in this acceleration of one minute part of a complex grinding tooth and retardation of an immediately contagious part that all hormone, chalone and endocrine hypotheses fail. Accordingly disharmonic biomechanical adaptation is far more frequent than harmonic. Not only every single organ but every single constituent part of every single organ in the Proboscideans reacts to its own particular biomechanical task. Moreover, every single anatomical unit adaptively reacts to its own particular environmental conditions and problems. Equally incomprehensible in the adaptations of the Proboscidea are the causes of the perfected compensation and economy, even in parts which are very remote from each other.

None the less the basic hormone idea of chemical messengers which accelerate or retard or organize the motions of the individual parts is the only outlook we have into the possible causes of the modification principle of geneplasmic adaptation. We have not even a glimmer of a hypothesis as to the causes of the dual creative or aristogenetic principle in evolution.

Fortified with a complete knowledge of what may be actually observed and measured in anatomy and physiology, zoology and paleontology, the most hopeful line of escape from Bohr's agnostic position seems to be in biophysics, biochemistry and bioenergetics. The most hopeful outlook for the future of the Harvard Biological Laboratories, as I understand the wide scope of your personnel and the equally wide reach of your apparatus, is a collective creed that life and adaptation in all their aspects, past and present, present a single rather than a multiple problem which must be attacked by the combined synthetic research of all the adaptive phenomena of past as well as present time.

THE MEASUREMENT OF PERSONALITY

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THE measurement of personality is bound up with the question of psychological measurement in general. Hardly anything has so affected the aspect of experimental psychology during the last quarter century as the introduction and development of quantitative methods. Their influence on the whole has been good. The non-quantitative categories of descriptive psychology were frequently too ill-defined to be very meaningful or to offer fruitful points of departure for experimental work. More and more the descriptive approach is being abandoned in favor of procedures which are quantitative and often elaborately statistical.

It is well to remind ourselves, however, that the application of quantitative methods does not guarantee new psychological insights. Moreover, measurement enthusiasts too often lose sight of the inherent difficulties, even dangers, involved in the reduction of psychological data by the mathematical tools that are so indispensable in the physical sciences. Perhaps no saying of Thorndike's has been so often quoted as his statement that "whatever exists exists in some amount and can be measured." These words have been taken up by his followers and turned into a veritable battlecry in their assaults upon every psychological stronghold, including even those mysterious characteristics that go to make up what is known as "personality."

Is it really possible to measure personality in the strict sense of the word "measure," as the physicist, for example, is accustomed to use the term? To measure in this sense implies that we have a measuring scale with a zero point and with equal units throughout; a scale on which the score 20 is exactly twice the score 10, or the score 100 exactly five times the score 20. Every one acquainted with the literature of the subject knows that no such scale is available for the measurement of personality. In fact, no one so far seems even to have essayed the task of deriving a personality test that would "measure" in this strict sense of the word. Is any such goal attainable, either now or ever?

Let us turn to the field of intelligence, where quantitative methods have been so much more extensively cultivated than in the study of personality, and note what progress has been made since the early adventures of Galton in what he called "psychometrics." Binet, after many years of explorative work with mental tests, gave us a "measuring scale of intelligence." However, Binet was careful to point out that his scale does not, strictly speaking, measure intelligence, since it has neither a zero point nor equality of units. He tells us that instead of measuring intelligence in any absolute sense, his tests merely bring to light the hierarchy of developing intelligence. This is the sense in which the word measurement has been used by the majority of Binet's followers; it is the connotation which the present writer had in mind in entitling one of his books "The Measurement of Intelligence." Thorndike, on the other hand, in a more recent book bearing the same title, attempts to demonstrate that it is possible to measure intelligence in the same sense as a physicist measures distance or mass or time. His CAVD intelligence scale has what purports to be a zero point and units which are equal. The scores of the scale range from 0 to 43. Zero intelligence is just less that which leads one to spit out a substance that has a very bitter taste or to retain in the mouth a substance that tastes sweet. We will pass by the seeming arbitrariness of this standard, as well as the questionable procedure by which it was derived, and consider the results of applying the CAVD scale in the measurement of absolute intellectual differences. Score 43 represents approximately the intelligence of a college professor or the exceptionally gifted student. By the verdict of the CAVD scale the average child of six years has almost exactly three fourths this amount of intelligence, and the half-way point between zero and moderate genius (score 20) is repre-