factorial hypothesis can ever offer more than a purely formal explanation.

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The results here presented, though incomplete, serve to indicate that the genetic behavior of different organisms may in important respects be very diverse, even though in other respects far-reaching similarities appear between forms so far apart phylogenetically as bryophytes, flies, angiosperms and mammals. It follows that a comprehension of the facts of inheritance and variation, and a recognition of the fundamental features of their mechanism, require the assemblage of information from all available sources, including adequately representative members of all plant and animal phyla.

THE ORGANIC WORLD AND THE CAUSAL PRINCIPLE[1]

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SOME thirty centuries ago a Hebrew sage summed up the outcome of his observations by declaring that "there is no new thing under the sun." In those days man's knowledge of nature was absurdly limited. A contemporary critic might perhaps have challenged the dictum, but a final decision could not then be reached. As a matter of fact, Solomon, in those words, set forth a problem which has haunted the thinking man even to this very day. We are still asking the question: Does anything really new ever appear in the universe?

Taken superficially the statement is manifestly untrue. New aggregations of atoms are constantly taking place. Every fresh geological stratum, every individual organism, whether plant or animal, every chemical compound, is a new construction. But on the other hand, science is constantly demonstrating that these apparent novelties result, one and all, from the operation of certain general principles which hold throughout the entire known universe and which seem to have held throughout all time. The problem, as I see it, is really this: Granted that the material world is constantly changing, granted that all changes proceed according to certain rigid causal principles which we call the laws of nature and that these principles hold throughout the physical universe, we must ask: Has there appeared in the course of history any *new* principle—any mode of activity which is more than a direct corollary from these universal and eternal principles of cause and effect?

The answer is still very much in doubt. Those who incline to a mechanistic view of nature generally accept Solomon's conclusion. Vitalists and teleologists take the opposite position. They assume that new forces have somehow been brought into existence with the advent of organisms and conscious beings into the world. And there has recently come into prominence another conception of things, the theory of emergent evolution, which may take either a vitalistic or a mechanistic form, but which distinctly challenges the ancient aphorism. This theory also declares emphatically that new and unpredictable properties come into being from time to time as new systems of material units are generated.

With the vitalistic conception I have never had much sympathy. It may reasonably be assumed that most of the novelties which seem to emerge in the course of evolution are not strictly novelties at all—that the laws which govern the activities of these higher complexities of matter might have been formulated in advance, as corollaries from the fundamental causal principles. This remains for future experiment and logic to settle. What I wish to point out this afternoon is that the advent of the organism and its evolution have apparently given rise to two new principles of activity in the universe—principles which, so far as I can see, are not in any way deducible from the universal laws of causation. To this extent the conception of emergent evolution seems justified.

The various laws of cause and effect, so far as they have been discovered and formulated to-day, may be summed up, I take it, under the general principle of the conservation of energy. This principle is by no means self-evident. To the casual observer every activity requires expenditure of energy; in other words, work or effort seems at first sight to involve the disappearance of a certain amount of energy. It required the most delicate experimentation to demonstrate that the energy in question is not actually lost, but is merely transformed. However, the truth of the principle of conservation seems now well established. The total effect is believed to be exactly equivalent to the sum total of the causes; in every change that occurs, the total consequents are exactly equal to the total antecedents. This principle might appropriately be termed the law of the unvarying total.

[1] Address of the retiring vice-president and chairman of Section I—Psychology, American Association for the Advancement of Science, Des Moines, December, 1929.

My objection to vitalistic and teleological theories is that they seem to assume exceptions to this general causal principle. Their line of argument, so far as I am able to analyze it, seems to imply that in the organic world certain phenomena of growth and behavior involve changes in which the total later state is more than or essentially different from the totality of its antecedents. In fact, vitalistic biology and purposive psychology seem to cast doubt on the uniformity of nature, which is perhaps more fundamental than the principle of conservation. I shall not go into this question, which is really aside from our present topic. What I wish to bring out is that one may adopt a thoroughly mechanistic view of the world, which holds that the principle of the unvarying total is without exception, and at the same time believe that certain new principles of activity operate in connection with organic life.

The first of these supplementary principles is that of natural selection. There is nothing in the operation of natural selection that involves any exception to the universal causal principle. The changes that occur in connection with the growth of the individual organism and the changes of type which mark the evolution of species may all be brought under the principle of the unvarying total. And yet something new does occur in evolution. Organisms tend to become more adapted to the conditions of their environment: they respond to a larger number of stimuli; their responsive activities tend to afford them more and better assistance in keeping alive, in maintaining their status as organic units and in utilizing the surrounding world for their own welfare. Every step in progressive evolution proceeds, I take it, strictly according to the causal principle. At the same time, this process (or fact) of increasing adaptation is something quite novel: it does not occur—it has no meaning whatever—except in connection with those peculiar groupings of molecules which we call organisms.

Natural selection means simply that the fittest organisms tend to survive. They survive because they are more adapted to the general environment than other organisms. The principle is almost tautological. But could it operate in connection with any material except the biological organism or some unitary system which possesses the essential characteristics of the biological organism?

Selective evolution requires the continual production of complex individuals which resemble one another. It requires also that these individuals shall differ to some extent from one another. These conditions are fully met in biological organisms through their specific mode of reproduction. Since the offspring bear a close resemblance to the parent stock, the same types of organs and the same modes of behavior reappear generation after generation. Since the offspring differ in certain respects from the parents, there is opportunity for selective improvement in any of these organs and modes of behavior. It would be assuming too much to say that nowhere in the universe does selective evolution occur except among organisms such as exist on the earth. Other systems which fulfil these essential conditions may have been built up in other ways and out of other chemical elements on other planets. My point is that these conditions do not exist below the organic level. The principle of selective adaptation would seem to be a brand-new mode of activity, which does not operate in simple aggregations of matter or in any of the simpler systems of chemical compounds.

Let me apologize for presenting to this audience a form of argument which smacks of the philosopher rather than the scientist. My excuse is that the doctrine of emergent evolution itself is a philosopher's view of the world and has been bolstered up chiefly by philosophical evidence. The mechanist suspects, though he may not be able to prove, that the so-called new properties which emerge in new compounds and new systems are not really novel. Given sufficient knowledge of elementary properties, I believe that the properties of the higher compounds could be predicted—in other words, that the higher laws which we formulate with respect to their activities are merely corollaries from the fundamental principle of causation. But the principle of natural selection, or selective adaptation, does not seem to be in any sense a corollary from the causal principle.

It is perhaps unnecessary to-day to emphasize the importance of selective adaptation in promoting organic evolution. Through its means the organization of matter takes an entirely new trend. Spencer's mechanistic formula for evolution may cover the progressive changes of cosmic phenomena in general, but it proves inadequate to express the full import of organic evolution or the results that attend the interplay between organisms and their environment. The evolution of special organs for nutrition, circulation, responsive activity, reproduction, defense, social communication between organisms, introduces a novel feature into the material world. This new trend, according to the mechanist, represents no exception to the general principle of causation—it involves no modification of that principle. But it does indicate the operation of an additional principle, that of natural selection. In the jargon of the logician, the principle of selective adaptation may be said to be superimposed upon the principle of the unvarying total.

Of what interest is this to us as psychologists? It seems to bear on our branch in two important ways. In the first place, selective adaptation enables us to understand the evolution of behavior. Response to stimulation is an indirect reaction. In addition to the direct and immediate physical action-and-reaction which occurs when a force is applied to a body, we observe in the case of organisms a secondary and later reaction which takes place when the given force is applied as a stimulus to a receptor organ. And we note that this indirect reaction or response tends to be adaptive—it serves in most cases to promote the organic welfare of the creature. These adaptive responses depend upon the presence in the organism of certain specific organs for reception and for motor activity, and of a conducting system for establishing proper connections between these two groups of organs. The evolution of this entire behavior mechanism depends upon natural selection. It follows, then, that the real meaning of responsive behavior is bound up in the operation of selective adaptation, so that this principle concerns us fully as much as it does the biologists.

The second point of interest to psychologists lies in the fact that the selective principle does not complete our explanatory theory. I shall try to show that a still higher principle becomes effective in the later stages of organic evolution. In the more advanced animal species behavior may be a response not merely to present stimulation but to future situations. The phenomenon of anticipation or foresight is, to all appearances, something novel, which occurs only in organisms of a certain degree of complexity. The frog that snaps at a fly, the squirrel that buries a store of nuts and later retrieves them, the man who builds and furnishes a home for a prospective bride—all these are responding in a measure to future situations. A large part of human behavior has more or less definite reference to the future, and one could cite a host of such instances in subhuman species. The fact that responses are made in anticipation of future conditions is responsible for the rise of the teleological school of psychologists, which may be regarded as the counterpart of the vitalistic school in biology.

Now just as the evolution of organisms seems to admit of explanation on the basis of mechanistic causation, so the evolution of anticipatory responses and their mode of operation seems explicable in terms of the same general causal principle. But the anticipatory type of response depends upon certain special factors and conditions which come into play only in the higher organisms. In these higher species certain organs and mechanisms have evolved which enable them to respond in a preparatory way to stimuli which have not yet been applied and to situations which are still forming. Distance reception is one of these factors. The distance receptors enable a creature to see, hear or smell an object which is not in immediate contact with his body. If the object is approaching him, he may respond to the visual, auditory or olfactory stimuli in such a way as to be prepared for the contact of the object when it finally impinges upon his body. Furthermore, if the object happens to be a nutritious substance he may respond by locomotor activity, and hasten the advent of the tactual and gustatory stimuli by moving toward it. Or if the object is something injurious he may act so as to prevent the contact stimulus altogether.

Another factor which promotes anticipatory responses is the more or less permanent registration of the effects of past experiences in the nervous system. We are still in doubt as to the physiological mechanism of this registration. But the fact itself is perfectly evident. And it has this result. When a situation occurs which resembles a situation that the animal has previously experienced, the earlier response may be carried out more quickly and more precisely than it would if the situation were new. Not only this, but in many cases of repeated behavior the motor activity which takes place is a response to a phase of the situation which followed somewhat later on the previous occasion. Classical examples of this are the burnt child who withdraws his finger before actually touching the candle flame; and the bird who, after escaping from the trap, responds to similar baited objects by flying away. The literature of conditioned reflex experimentation is filled with examples of the effects of neural registration. In almost every case the result of conditioning is an anticipatory or at least a preparatory response. And whenever we examine the process by which these preparatory responses are acquired and trace the details of their operation, we find no indication of any modification of the causal principle—no exception to the principle of the unvarying total. In every case the movements and changes that occur are just what the physicist and chemist could have predicted, if they had had knowledge of all the immediate antecedents.

The teleologist, it should be noted, ascribes the fitness of anticipatory responses to a certain peculiar characteristic of consciousness which he calls awareness or insight or realization of the situation. But in practical experience we find that this awareness or insight has no power whatever to initiate the appropriate motor response unless the requisite neural connections are already established. If a man, by taking thought, can not oscillate his own ears, how can conscious reflection enable him to perform more complicated acts unless the proper neural connections are established? Conscious foresight, taken by itself,

seems incapable of explaining anticipatory responses. The principles of causation and selection, exemplified here in the learning process, furnish the basis for an adequate explanation. The teleological theory, then, seems to violate the canon of parsimony. It multiplies causes and agencies beyond our need.

And yet if we wish to understand these anticipatory phenomena completely, we must look beyond mere causation and adaptation. There is something further to be considered. We have not fathomed the entire significance of the phenomena when we have traced the evolution of the organs and their functions. Anticipation of the future is a fact which demands recognition. It does not seem to be in any way implied in natural selection, though it obviously depends upon the operation of that principle. Anticipatory adjustment is a novel type of response which is observed in certain highly complex organisms. The full meaning of their behavior is realized by the observer only if he recognizes that certain of their activities are more than mere responses to present stimulation.

Recently a tornado was reported in the Caribbean Sea moving in the direction of Florida. Preparations were made at once to prevent loss of life and minimize the damage to property. Ships altered their course. Buildings were shored up. Dwellers in the Everglades were transferred to more elevated ground. All these human activities were in response to what stimuli? In a measure they were reactions to present verbal stimuli—telegrams, storm signals, newspaper bulletins, radio messages, individual warnings by word of mouth. I have no doubt but that if a superscientist were to trace the cause-and-effect relations of this series of responses in the case of any person involved, he would find that the fundamental causal principle accounted fully for that person's activity. But this causal explanation does not exhaust the meaning of the behavior. The activity of some thousands of individuals in this instance had reference to a certain future situation as well as to the present. As a matter of fact, in cases like this the immediate antecedents (the verbal stimuli) may be regarded as merely incidental—the responses were primarily to stimuli which were yet to come.

A large part of human behavior is of this anticipatory type. In the majority of cases it may properly be called purposive, since the responsive activity is generally preceded by some conscious picture or imaging of the prospective situation. But we need not regard conscious purpose as a distinct type of preparatory response. It is merely more complex and more adaptive. In simpler instances, especially among subhuman species, the same type of response may occur without any prevision; the present stimulus serves to set off the response, and yet the response is obviously with reference to some future situation. The action of a dog in burying a bone is an example of this, or the act of a baseball fielder in raising his hands to catch a high fly. Either of these responses may occur without any conscious foresight. The conscious representation of the coming situation seems to involve merely the operation of a more highly organized neural adjustment, which is of the same anticipatory type as automatic preparatory adjustments. The significance of all such acts, whether consciously purposive or not, lies in the fact that they are preparatory responses. Are we not justified, then, in regarding anticipatory adjustment as a new principle of activity, which appears at a certain stage of organic evolution and supplements the principle of selective adaptation?

And now let me explain my reasons for discussing this topic. I have no idea of expounding a cosmic theory or a philosophic system. But I do feel that the theoretical implications of the evolutionary process fully deserve the attention they have received. The theory of vitalism in biology and the teleological or hormic theory in psychology are attempts to provide a suitable explanation of the progress of organic evolution. The more recent theory of emergent evolution is an attempt in the same direction. It is reasonable to ask whether any or all of these views are correct interpretations of the course of evolution. Since these views all hinge directly upon one's interpretation of the causal process, the problem of the causal relation must first be considered. Until recently the principle of conservation was by no means established. Transformations and inconsequences which to-day we would call magical were conceived as possible and were assumed as actually occurring. These magical interpretations of the causal process have now been abandoned by thinking men. The principle of the unvarying total is accepted as a general characteristic of the changes that take place in physical and chemical groupings.

The status of organic phenomena is not so well established. Vital force and purposive striving are accepted to-day by a number of biologists and psychologists in good standing. These views can be refuted only if we are able to show that the course of evolution can be fully explained in terms of mechanistic processes. Nor can they properly be characterized as magical or mystical unless we are able to demonstrate that a non-mechanistic explanation involves some exception to the causal principle of the unvarying total. I see no clear evidence at present that either of these theories involves magical or mystical assumptions. But I do believe we have considerable evidence for a thoroughly mechanistic interpretation of life and mind.

The process of natural selection seems able to ac-

count in a purely mechanistic way for the progressive trend of organic evolution toward greater adaptiveness of structure and function. We need not assume that a new type of energy, a vital force or entelechy, appears in the universe when organisms come into existence. The age-long causal principles still hold in the organic realm. But we may properly concede this much to the vitalists—they are right in suggesting that we must seek a new and broader view-point when we come to deal with organic phenomena. The organism may well be regarded as a new kind of system, whose distinctive characteristic is an ability to maintain its organic unity through dynamic interplay with the environment. The inherited similarity among organisms, and their variability, taken together, give rise to natural selection. And the result of the selective process is to improve the relations between the organism and its environment. Natural selection therefore should be considered not merely as a process, but as bringing about a very definite end-result: adaptation. The process of selective adaptation, then, should be recognized as a new factor which appears in connection with organic life. It is in no sense an exception to the causal principle of the unvarying total, but it does supplement this principle. It would appear impossible to have predicted in preorganic ages, from any knowledge of causal principles, the extraordinary variety and complexity of the organisms that have actually arisen, their manifold activities and tenacity of existence, or their numerical abundance. The principle of selective adaptation seems capable of accounting for all these facts. It explains the course of organic evolution without assuming the advent of a new kind of energy to operate these changes.

The same line of argument may be applied to the teleological psychology. This theory is useful in suggesting that a new and broader view-point is required when we come to deal with the phenomena of anticipatory behavior and prevision. But the assumption of a new kind of force to account for these activities seems needless and redundant. The universal causal principle and the principle of selective adaptation seem sufficient to explain the rise of preparatory responses and conscious purpose. The processes by which organic beings act with reference to future stimuli and coming situations may be described in purely mechanistic terms. But the significance of these phenomena must be sought in something that lies beyond these fundamental principles: their real meaning is summed up in the principle of anticipatory adjustment. There is no novelty involved in this principle, except that we have adopted a broader view-point.

And now we have reached the point where we can appraise the truth and error in the doctrine of emergent evolution. Many, if not all, of the so-called emerging properties which appear in the higher aggregations of matter could be predicted, I believe, from an intimate knowledge of physical principles. They are not really novel. They emerge only as new groupings or systems come into being. But we do find two new kinds of process developing at certain stages of evolution on the earth. With the advent of organic life the trend of progress is determined by the principle of *selective adaptation,* which seems to be a distinct novelty and not a mere corollary from the general principles of physics. At a later stage the responsive behavior of certain organisms to forces and situations in the environment is determined in part by a second novel principle—that of *anticipatory adjustment*—which assumes enormous importance in human life. These two principles, based upon the fundamental causal principle of the *unvarying total,* form a hierarchy. I believe they are needed to account fully for the organic stages of evolutionary progress. At least they lend new significance to this unique development. If the doctrine of emergent evolution means the recognition of general principles such as these, I believe it can be defended. If it means that new properties appear with the formation of new aggregations of matter, it is either a truism or it is open to grave question as implying an exception to the general uniformity of nature.

SCIENTIFIC EVENTS

THE WORLD PRODUCTION OF GOLD

SINCE the discovery of America, world production of gold has only slightly exceeded a billion ounces, approximately 1,003,500,000 ounces being indicated by study of available records, according to an economic review of gold production in the period 1493–1927, recently concluded by Robert A. Ridgway and the staff of the common metals division of the U. S. Bureau of Mines. Scattered production, of which there is no record, would probably add no more than one per cent. to this estimated total.

Mr. Scott Turner, director of the bureau, points out that more than half the grand total of gold production for the past 435 years, or 516,273,000 ounces, was produced in the first 27 years of the present century. Of the cumulative world production of gold since 1492, 467,000,000 ounces are estimated to exist in the form of monetary stocks, while 536,563,329 ounces