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THE NEURO-EMBRYOLOGIC STUDY OF BEHAVIOR: PRINCIPLES, PERSPECTIVE AND AIM[1]

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EMBRYOLOGY as a scientific method arose in the domain of morphology. Although there were early physiological and chemical observations upon the embryo, these were relatively casual. It was in the interest of explaining the structure of the animal body that embryology acquired a technique of its own and attained to the dignity of a biological science. Embryology as a growing science, however, is now through and through physiological. Witness, for example, the experimental schools of Spemann, of Harrison, of Child, and the tomes of Needham on "Chemical Embryology." Embryology has in fact gone afield to explore every nook and cranny, every crook and turn of the developing organism experimentally, physiologically, chemically; and even the problem of animal behavior is now being attacked by numerous investigators with the method of this originally morphological science. It is this latter field of investigation that engages our attention at this time.

The behavior of embryos is not of exclusively recent interest. Movements of snails within the egg were studied by Swammerdam; mussels and oysters, by Leeuwenhoek (1695). Even earlier than this (1651) William Harvey gave an account of movements of the chick during the early days of incubation. After Harvey, however, a century elapsed before the next important contribution was made on the movements of the chick embryo. This was by Beguelin (1757), to whom is accredited the notable accomplishment of keeping the embryo alive in the opened egg for fifteen days. In the earlier part of the nineteenth century, von Baer (1828) experimented upon the sensitivity and contractility of the fetal membranes of the chick, although it remained for Vulpian (1857) to establish the distinction between

[1] Address of the president of the American Association of Anatomists, Cincinnati, April 13, 1933.

the active movements of the embryo itself and the passive movements caused by contractions of the amnion. Finally, this period of more than two centuries of fluctuating or intermittent interest in the behavior of the embryo culminated in the epochal work of Preyer (1885) on the movements of embryos, the results of which are incorporated in his "Specielle Physiologie des Embryo."

During this period a notable beginning was made in neuro-embryologic study of behavior, particularly by Remak, Lereboullet and Nussbaum. Remak (1854) discovered that muscle cells without nerves cause the contraction of the amnion; Lereboullet (1861) sought the explanation for the earliest movements of the trout, and concluded that they occurred before muscle fibers and motor nerves were developed, in this possibly anticipating Wintrebert, or he may have seen those movements in the blastoderm which have recently been described by Yamamoto; and Nussbaum (1883), on the basis of the behavior of the embryo of the trout after transections at various levels, discovered that the sensory and motor nerves are functional before they acquire the myelin sheath.

More recent investigations may be mentioned only in the briefest possible manner. Among those who, since Preyer, have studied the behavior of embryos without specific reference to neurology are: for invertebrates, Pearl on Limulus; for fishes, Tracy and Yamamoto; for birds, E. L. and E. R. Clark, and Kuo on the chick; for lower mammals, Swenson on the rat, Pankratz on the rabbit, Graham Brown, and Carnios on the cat; on the human fetus, Strassmann, Krabbe, Yanase, Bolaffio and Artom, and Minkowski. Among those who have undertaken to correlate anatomy with embryonic behavior are: Prosser on the earthworm; Wintrebert, Paton and Davenport Hooker on fishes and amphibians; Tuge on the turtle; Lane, Blincoe, East, Pankratz, Angulo and Windle and Griffin on lower mammals, and Davenport Hooker and Hogg on man. Minkowski, also, has made extensive neurological studies in reference to his unparalleled observations on the behavior of the human fetus; but it is not clear that these studies were made on the same individuals that were observed in action. Flechsig's work on myelinization might also be thought of in this connection; but here again the reference to behavior-capabilities may be made only in a general way. On the other hand, the current neurological studies of the development of behavior are based on anatomical material that has been tested for its behavioral capability under conditions that are as nearly as possible normal. Studied in this manner on the basis of physiologically tested material, neurology and behavior are reciprocally highly illuminating.

The neuro-embryologic study of behavior has proved to be not unlike hunting big game in a strange country: one finds many tracks of the game here and there before one comes upon the path which leads to its rendezvous. But, in this discussion, we shall pass by the promiscuous details of the field and take up some of the trails which are sufficiently defined to warrant our following them, tentatively at least, as guiding principles.

The principles which I have in mind for discussion on this occasion are statements of fact concerning the development of the nervous system of Amblystoma; they can be regarded as tentative only in their general application to vertebrates. On the neurological side of the problem they are, first, the primacy of a motor mechanism of total integration; second, the development of mechanisms of partial integration through localized acceleration of growth; and third, progressive organization of the nervous system from the whole to the part

There is in Amblystoma a motor mechanism which integrates all somatic movements into a unitary pattern of action. It is a longitudinal conducting system lying next to the floor plate on either side. After the development of Mauthner's fiber it occupies the space in the spinal cord between this fiber and the floor plate, and consists of caudally conducting neurons which provide the earliest motor innervation to the axial and appendicular muscles. In the rhombencephalon and mesencephalon this primary motor path clearly becomes the fasciculus longitudinalis medialis in its early stage of development We are justified, therefore, in the view that, in urodeles, the fasciculus longitudinalis medialis, beginning in the mesencephalon and extending the whole length of the rhombencephalon and spinal cord, is a mechanism of total integration.

In the higher vertebrates the fasciculus longitudinalis medialis is the first longitudinal conducting system to make its appearance. According to His, it is present in the human embryo of 6.9 mm. In point of time, therefore, it is the primary motor mechanism in the human brain. But as a discrete structure it does not extend the entire length of the spinal cord of the mammal as it does in the urodele, but it becomes confluent with the fasciculus proprius ventralis in the upper part of the spinal cord. This condition is correlated with the fact that in the mammal the axial muscles are not directly locomotor, but serve locomotion indirectly through posture, while the postural reactions are taken over largely by such tracts as the fasciculus proprius, vestibulo-spinal and rubo-spinal. Conjugate deflection of the eyes, on the other hand, although integrated with posture, is an independently moving somatic system primarily related to locomotion. Accordingly, in mammals the eye-muscles maintain their primitive relation with the mechanism of total integration.

But in higher vertebrates the fasciculus longitudinalis medialis does not constitute all this mechanism of total integration. For example, according to recent work by C. Judson Herrick, the interpeduncular nucleus is an important part of this system, even in Necturus. The importance of this nucleus arises from the fact that its efferent neurons form a component of the mechanism of total integration, while it is an end-station for the habenulo-peduncular, the mamillo-peduncular and the olfacto-peduncular tracts and the nervus terminalis. Through these conduction paths the mechanism of total integration is brought under the direct influence of the olfactory field at an exceedingly early period. These tracts, in fact, express the earliest physiological activities of the fore-brain. In Amblystoma the nervus terminalis is the first tract to become clearly differentiated in the forebrain. In man, according to His, the fasciculus mamillo-tegmentalis is present in the embryo of 10.9 mm, and the habenulo-peduncularis in the embryo of 15.5 mm. Accordingly, these tracts are laid down a relatively long time before the embryo at 20 mm in length begins to move. It is obvious, therefore, that the earliest influence of the forebrain on behavior acts, not through local reflex mechanisms, but through the mechanism of total integration.

Moreover, while comparative anatomy supports the validity of this principle in the evolution of the nervous system, it finds confirmation also in the field of psychology and psychopathology, for in his interpretation of posture, sleep and consciousness, Schilder[2] postulates a mechanism that conforms closely with the mechanism of total integration as here presented. But it would be an error to think of this mechanism as a fixed structure, for it is a growing organ; and in its growth it incorporates more and more of the higher portions of the nervous system, according to the position of the animal in the scale of behavior.

The second tentative principle raises the controversial point of equipotentiality. Probably there is no such thing as absolute equipotentiality in living organisms, for the functions of an individual cell would seem to require differentiation of parts and division of labor. But we do not know the absolute of anything; we use concepts, as we use things, when they are useful; and in this problem the concept of equipotentiality is useful because it expresses a condition which prevails in a very high degree in certain parts of the embryonic nervous system.

The motor mechanism of total integration in Amblystoma, excepting in its most rostral portion, appears to be an equipotential system when it begins to function, for all parts of it are doing the same thing—conducting impulses tailward and to the axial muscles. The same may be said of the primary sensory system, except that its cells are conducting headward from the receptors. Moreover, these primary sensory and motor cells are essentially alike in structure, for they are both neurons of central tracts, with peripheral branches functioning as nerves. Furthermore, with equipotential motor and sensory systems, the spinal cord itself, with the exception of its most rostral part, is, in the earliest functional condition, equipotential along its longitudinal axis, for every segment in this region is doing what all the others are doing, that is to say, conducting headward and tailward, and receiving sensory and sending out motor impulses of the same order.

This equipotential condition of the spinal cord in the region under consideration persists until about the time that the bud of the hind leg makes its appearance on the surface of the body. At this time proliferation of cells in the spinal cord undergoes acceleration according to a definite pattern which centers in the region that is destined to innervate the leg. The rate of proliferation in this center reaches its climax a considerable time before the leg begins to move as a part of the total pattern, and the highest rate is in the seventeenth segment, which is the middle one of the three which supply nerves to the leg. This localized acceleration in proliferation of cells is clearly allied with the development of the function of the leg as a whole, and expresses itself in an enormous increase in the number of cells and in the mass of gray substances in the region of the localized functions. Following this period of local acceleration of cell-division, the differentiation of white substance begins to accelerate in the same localized center, and this acceleration is also clearly correlated with the beginning of the localized function of the leg.

The spinal cord, owing to its relatively symmetrical organization along an approximately straight longitudinal axis, is especially favorable for studies of this kind, but the operation of the principle of localized acceleration of growth has been demonstrated in Amblystoma in the origin of localized functional centers of the medulla oblongata, the cerebellum, the mesencephalon, the diencephalon and the cerebral hemispheres. Furthermore, the description of the embryonic development of the three-layer and four-layer structure of the endbrain of the cat by Tilney and Kubie,[3] Langworthy's[4] description of the

[2] Paul Schilder, "Brain and Personality." New York and Washington, 1931.

[3] Frederick Tilney and Lawrence S. Kubie, *Bulletin of the Neurological Institute of New York*, Vol. 1, No. 2, pp. 229–313.

[4] O. R. Langworthy, Contribution to Embryology, No.

development of the cruciate gyrus in relation to its function in the kitten, and the early differentiation of the cerebral cortex of the human fetus as described by Bolton and Moyes,[5] give positive evidence that the localization of function in the cerebral cortex of mammals and man comes about according to the same principle that operates in establishing the simplest localized function in the spinal cord of Amblystoma—namely, not by accretion of independently functional mechanisms, but by localized acceleration of growth within a relatively equipotential functioning system.

In addition to the evidence drawn from embryology for this mode of ontogenetic development of localized or partial mechanisms of integration, there is conclusive evidence in comparative anatomy that the evolution of the nervous system has followed the same principle. This is shown particularly in extensive unpublished work by C. Judson Herrick on the forebrain of Amphibia. In the course of evolution, unitary centers of low degree of differentiation and relatively homogeneous in function have become differentiated into separate centers with different functional relation.

The principle of progressive organization from the whole to the part may be illustrated by the development of spinal ganglia in Amblystoma. Eleven pairs of these ganglia in ten successive stages of development have been studied to determine whether bilateral symmetry, in regard to numbers of cells, is attained first in the members of pairs of ganglia or in the total numbers of cells in all the ganglia on the opposite sides.

The method of treatment consisted in determining the mean number of cells in the ganglia of each pair and the departure of the individual ganglia of the pair from this mean, the total numbers of cells in all the ganglia on opposite sides of each specimen being treated in the same manner. As a result of this study, the maximum deviation from the mean is always found to be much greater for pairs of ganglia, in a given individual, than for the total numbers of cells of the two sides. This difference is greatest in the youngest specimen, and least in the oldest, with almost regular gradation between the youngest and the oldest. In the youngest specimen the maximum departure from the mean in individual pairs of ganglia is 54.8 per cent. of the mean, whereas the corresponding figure for the totals is 1.9 per cent. In the oldest specimen the departure for individual pairs of ganglia is 5 per cent.; and for the total, 0.3 per cent.

Furthermore, the segments of the spinal cord which correspond to these ganglia in the same animals were studied by the same method. The number of mitotic figures in each segment of the cord and the total numbers for the opposite sides of each individual were determined, with the result that organization within the spinal cord, as indicated by rates of mitosis, was found to proceed from larger to smaller divisions. Now, since the parts included in this study are those concerned with the innervation of a pair of limbs, we are justified in the statement that, in so far as the question has been investigated, the organization of a localized functional center of the nervous system progresses from the whole to the part. Symmetry of the whole is not acquired by the accretion of individually symmetrical parts; but the symmetry of parts is acquired by compensatory growth under the leadership of the whole.

We may now consider these neuro-embryologic principles in relation to behavior, which is their natural, physiological perspective.

The mechanism of total integration expresses itself in a total pattern of action without physiologically distinct parts. An action is regarded as total when it involves all the muscles of a functional system that are capable of responding at the time. In Amblystoma the development of the total reaction has been followed exhaustively. Action appears first in the anterior part of the axial musculature, and spreads thence tailward through the axial system, and then into the appendicular system, so that before an appendage can act on its own it acts only as an integral part of a whole, which is axial and appendicular. The appendage acquires the ability to act alone by individuation within this total pattern of action.

By way of definition, it should be noted that individuation used in this sense is not the equivalent of specialization or specification, for these processes constitute a functional adjustment of the organism to the environment. Individuation, on the other hand, brings about a definite and peculiar relation of a part of the organism to the organism itself as a whole. Individuation, like integration, is a purely intraorganismic process. It expresses itself, in part at least, through local acceleration of proliferation and differentiation of cells in a relatively equipotential growing system, according to the second neuro-embryologic principle I proposed a moment ago. Furthermore, it conforms to the third principle in the progressive organization from the whole to the part.

In accord, therefore, with these three neuro-embryologic principles—the primacy of a mechanism of total integration, the development of local mechanism by acceleration of growth within a relatively equipotential system and progressive organization from the whole to the part, behavior develops in Amblystoma

104; Carnegie Institution of Washington Publication, No. 380.

[5] J. S. Bolton and J. M. Moyes, "Brain," Vol. 35, Part I.

by the expansion of a primarily integrated total pattern of action and the individuation of partial patterns within the total pattern.

This plan of development is perfectly clear in Amblystoma from the earliest movement through the accomplishment of aquatic and terrestrial locomotion, feeding, optical fixation and the beginning of attention, or the "regarding reaction" of Gesell. This is a matter of fact. Whether or not behavior in other vertebrates follows this plan of development has become a question of leading interest in the study of behavior.

The strongest apparent evidence against this principle as applied to other vertebrates is in the work of Tracy on the toadfish, for he found that the integrated total pattern of action in this animal was preceded by local twitching of myotomes. It has not been demonstrated, however, that these local movements that antedate the total pattern are not myogenic. They give place to the total action pattern before the mechanism of total integration is in physiological connection with the exteroceptive or proprioceptive sensory system. They are, therefore, at no time a factor in a stimulus-response performance in the usual sense, and for that reason can not be reflexes.

The toadfish, it must be remembered, is a highly specialized vertebrate, and these early localized muscular contractions may express a very special adaptation of myogenic, or possibly even neurogenic, response to internal functional needs of the embryo. But even should these early local movements prove to be neurogenic, the situation regarding this principle of behavior would only be analogous to some of those variations in the formation of the germ-layers which are accepted as special adaptations in various species without invalidating the principle of germ-layers as such. Tracy designated these early localized movements as endogenous, but he found that the total pattern of action in the toadfish is also endogenous for a relatively long time before the sensory system "captures" it. Here certainly is a special adaptation to the needs of the particular species, for these early movements of total action serve aeration and respiration in the toadfish.

On the side of affirmative evidence for the validity of the principle of primary total integration in higher vertebrates there are the results of investigations on several species. Among these are the observations by Tuge on the turtle. In this animal, on account of the immobility of the trunk in locomotion, which is effected wholly by the appendages, one would expect to find, if anywhere, local patterns of action as the primary form of behavior. But in the turtle, as in Amblystoma, the earliest movements begin in the region of the head and progress caudad through the axial musculature and out into the limbs, so that the appendages are an integral part of a total pattern before they acquire independence of action.

Further affirmative evidence on the question is found in the embryo of birds. On the chick we have the early and extensive study by Preyer, and the recent exhaustive investigations by Kuo. An analysis of Preyer's records leaves no doubt in my mind that in the chick local action patterns emerge from a total pattern that expands through the growing organism as it does in Amblystoma; and Kuo explicitly indorses this interpretation. It is noteworthy that Kuo used nearly 3,000 embryos in his study on the chick.

The most comprehensive studies on fetal behavior in mammals has been made on the rat by Angulo, who has supplemented exhaustive stenographic notes from immediate observation with motion pictures very extensively. These pictorial records enable him to reexamine any phase of the behavior at any time. By this method he has demonstrated the progressive development of the total action pattern into postural reactions, feeding reactions and the beginning of locomotion. He has also demonstrated the individuation of many local reflexes within the growing total pattern of action.

The fetal behavior of the cat also has been extensively studied by Windle and Griffin. Although endorsing the idea of the total action pattern in general for later fetal behavior, Windle and Griffin express grave doubts concerning its primacy in application to certain early movements which they have observed. These movements, however, are, in my opinion, of the same order as the early localized movements of the toadfish, which are not the beginning of definitive local patterns. Angulo has observed similar movements also in the rat, but he finds that they mark the beginning of asphyxiation and that they do not occur under normal conditions. He does not believe that they should be regarded as the beginning of the behavior pattern as such. Certainly they are neither reflexes nor the beginning of definitive normal local patterns.

There is, also, substantial evidence that in the human fetus local reflexes are preceded by more extensive movements which approximate total reaction. According to the studies of Minkowski and others, a touch on the lip excited movement of the lip and legs in a fetus of 35 mm crown-rump length, whereas it was in a fetus of 110 mm total length that this stimulus excited a local movement of the mouth only. Also, in a fetus of 35 mm, a touch on the eyelid excited movements of the eyelids and legs, although it was in a fetus of 215 mm total length that a pure orbicularis palpebral reflex was first recorded. The plantar reflex in a fetus of 75 mm total length consisted of dorsal flexion of the foot and extension of the leg; in a fetus of 100 mm total length, this reflex consisted of movement of the toes only, but all of them in flexion and spreading together; whereas the isolated Babinski reflex was first observed in a fetus of 215 mm total length. It appears, therefore, that these typical reflexes in man develop through individuation out of much more extensive patterns of action.

For these correlations we depend chiefly upon observations by Minkowski, whose studies of the living human fetus have extended through many years. Obviously, however, Minkowski did not have in mind the principle of individuation of partial patterns of action within an integrated total pattern, for this principle has grown out of observations on lower vertebrates in comparatively recent years. It may be expected, on the other hand, that Davenport Hooker and his associates, who have only recently entered this field of study, will be able to test this principle specifically as applied to human behavior in its earliest phases of development.

And we must bear in mind that it is only in the early phases of fetal behavior that the process of individuation within an integrated total pattern can be seen clearly and conclusively. In man this period lies approximately between six weeks and six months of gestation. After six months, the simple local patterns become quickly obscured by complicated reactions, which can be analyzed only by knowing exhaustively what has preceded them in the process of their elaboration. In postnatal life the situation becomes still more complicated, and on the basis of infant behavior alone we can not hope for a clear and conclusive demonstration of the principle of individuation in its simplest terms. Nevertheless, that there is much in infant behavior which accords with the principle is obvious to one who is thoroughly familiar with early fetal behavior by direct observation. One who has exhaustive, immediate, personal acquaintance with the early fetal patterns of action can see in the growing infant up, say, to six months a progressive individuation of smaller out of larger patterns of action; and he can recognize the operation of the principle of individuation in the descriptions of early infant behavior as recorded by several investigators in this field. Especially convincing on this point is the development of the "regarding" reaction and prehension as described by Gesell[6] in infants from six weeks to a year old. The "regarding" reaction, or what may be termed the beginning of attention, is at first only visual fixation, which is effected, as I have already pointed out, by the mechanism of total integration. The reaction then expands through the motor mechanism, bringing head, trunk and arms into action, and finally prehension and grasping of the object of optical fixation is effected by individuation of the adaptive movement out of more general action.

This development of the process of optical fixation and prehension may be taken as a basic example of motor learning, and, in my judgment, the principle that is seen in operation here is involved in all motor learning. In non-motor learning, also, the principle becomes applicable if we bear in mind that knowing is a mode of doing—a thesis that is defended by Dewey[7] and that permeates the psychology of Ogden.[8] It is possible, therefore, that all learning consists of the expansion of a primarily integrated total pattern of action and of individuation of partial patterns within the total system.

Take, for example, the process of association. Since the work of Pavlov, this goes under the name of conditioning. Pavlov considers conditioning as the peculiar function of the cerebral cortex, but typical conditioning occurs in animals which have not even a vestige of a cortex. Conditioning, in fact, may occur in those parts of the brain which are ordinarily regarded as reflex centers. Moreover, the conditioned reflex of postnatal life develops in the same way that the unconditioned reflex develops in prenatal or embryonic life. This common process of development consists in progressive reduction of the reflexogenous zone of stimulation and progressive restriction of the motor response; and both these factors of conditioning or association are expressions of individuation within larger fields of action. This, indeed, seems to be the process through which symbolization and language are learned by the child; and it is probable that these patterns of action developed in the race, also, in the same manner.

Just one other consideration may be presented: the processes of integration of the whole and individuation of parts are antagonistic to each other in the development of behavior. The mechanism of total integration tends to maintain absolute unity and solidarity of the behavior pattern. The development of localized mechanisms tends to disrupt unity and solidarity and to produce independent partial patterns of behavior. In the interest of the welfare of the organism as a whole, partial patterns must not attain complete independence of action; they must be held under control by the mechanism of total integration. Parts become integrated with each other because they are integral factors of a primarily integrated whole,

6 Arnold Gesell, "The Individual in Infancy," "The Foundations of Experimental Psychology," Chapter 16, Worcester, Mass., 1929.

7 John Dewey, "The Quest for Certainty: A Study of the Relation of Knowledge and Action." New York, 1929.

8 R. M. Ogden and F. S. Freeman, "Psychology and Education." New York, 1932.

and they remain integrated, and behavior is normal, so long as this wholeness is maintained. But the wholeness may be lost through a decline of the mechanism of total integration or through the hypertrophy of mechanisms of partial patterns. This, I believe, is the biologic basis of that conflict in behavior which expresses itself widely in the field of psychopathology.

So much for the principles and the perspective of the neuro-embryologic study of behavior. What, now, of its aim? Of this I shall speak chiefly in the negative sense.

Certainly I have not at any time entertained the thought that it might be possible to explain every footprint of the action pattern of an animal in terms of the development of its nervous system; but I have from the beginning hoped that this method of treatment might throw a new light upon the important highways of behavior. This, I believe, has already been accomplished in the field of lower vertebrates, while here and there the same light is beginning to filter through upon the realm of higher animals and man. Nevertheless, even in lower forms there are many byways of behavior still to be explored with this method, and the whole subject of neuro-embryology of higher vertebrates should be reexamined in the light of the principles now well established for lower forms.

Furthermore, while I do not expect this method of study to explain all behavior in neurological terms, neither do I expect it to give a final explanation of anything in behavior. I recognize that a purely scientific discipline does not deal with the essence of things, the ultimate, or things immutable. The data of science are relational. Motion is a primary datum of science. For science, force is not an ultimate or immutable cause of motion; it is a space-time relation.

The long-prevailing confusion of metaphysics with scientific thought John Dewey[9] lays at the door of Newtonian physics. He holds that the Newtonian system is grounded in metaphysics, for its primary postulate is the immutability of particulate matter, a purely metaphysical concept. Obviously, in a system of immutable substance, force must be an agency of change in relations. In such a confusion of science and metaphysics, the mechanistic theory of behavior has its origin, with Newtonian immutability at its heart. This is the pitfall of the mechanistic doctrine, for it treats the organism as a succession of static space-relations which are transformed each into the succeeding by some immutable agency acting upon them. Consequently, Dewey's evaluation of Newtonian physics applies equally to mechanistic behaviorism; it is essentially metaphysical.

[9] John Dewey, *loc. cit.*

According to current thought, nothing is static; everything exists not only in a "frame" of space but also in a pattern of time. It becomes, then, a question not of matter *and* motion, but of matter *in* motion. Neither is it a question of structure *and* function; but it is a condition of structure *in* function; for all structure is in action, and the action of a structure is its function. Argument as to whether structure precedes function or function precedes structure, or in other terms, whether structure *causes* function or function *causes* structure is beside the mark, for neither can exist without the other at any point in space or time: they merge, in fact, into a space-time relation. Accordingly, if we think structure as static, we can attain in science only description that is infiltrated with metaphysics in the form of an anthropomorphic and mystical conception of cause and effect; but if we think structure *in* function as a space-time relation, as we must in a purely scientific discipline, we may hope to attain to all the understanding of behavior that science has to offer.

The embryological method illustrates the distinction I am trying to make. It has transformed anatomy into a science, in so far as it has correlated time-relations with the space-relations which constituted the anatomy of other days. Also, it is now engaged in a similar transformation of physiology through the contribution of such concepts as totipotence, pleuripotence, organizers, gradients, all of which have meaning only as the organism is regarded, not as a static pattern in space, but as a dynamic pattern in time. So, again, with the problem of behavior, which was formerly chained to the concept of the organism as a static pattern—involving physiological activity, of course, but being essentially the same in that activity at all times. The embryological method, on the contrary, reveals the behavior of the individual as a progressively changing continuum in which from beginning to end any particular pattern can be fully perceived only in the light of what precedes and follows.

In the sphere of living things, events are cyclic, and the organismic cycle, unlike the cosmic, lies within the life-span of man as an observer. For this reason, the living organism should constitute both the most available and the most conclusive information for the interpretation of those relations within a system which, according to the scientific method pure and simple, may be called cause and effect. Regarding this conception, the neuro-embryologic study of behavior shows that events within a behavioral system can be understood scientifically only as their relation is known to subsequent as well as to antecedent phases of the cycle. The antecedent tells a part of the story about the present, but not all of it; for within the present are events that have behavioral significance only in that which follows. Call this vitalism, if you will; I do not, for objection to it can not be grounded in any violation or contradiction of the scientific or the experimental method. It meets opposition only in that unconscious, or subconscious, mysticism which is the source of our concept of cause and effect. The purely scientific method, dealing exclusively as it does with space-time relations, can not reject the future from its explanation of the present in behavior, because any event in an organismic cyclic system is an integral part of both the future and the past. Whatever time may be in the absolute, as a function in behavior it works backward as well as forward. Working forward it is memory; working backward it is anticipation or imagination. In fact, one might say that, other things being equal, the position of an organism in the scale of behavior is directly correlated with the degree to which the past and the future are integrated with its present.

In this statement I am distinguishing between absolute time and time as a function in behavior, or between metaphysical postulate and scientific method. This distinction appeals to me as useful in clearing the way for an unadulterated science of behavior.

In closing a series of lectures on "The Moral Ideal," the late James Seth, who was finally professor of metaphysics in the University of Edinburgh, appealed to his class of young men in these words: "I would remind you how much greater is our life itself than any philosophy of it can ever be. By the very nature of the case, philosophy must always be disappointing; and from its abstract formula we turn with relief to literature, and, above all, to the tasks of life itself—from the discords of the schools to the great unanimities of life. The true insight into the meaning of life is as much moral as intellectual: it is the obedience of the will that clarifies the intellect. And if we have found the difficulty of a philosophic definition of the moral ideal, let us remember that the true definition is that of life itself."

This was the plea of a great metaphysician for the validity and supremacy of living in charting a philosophy of life. From such metaphysics there can be nothing to fear in regard to the survival of life's practical values. But every one of us is in his own way a philosopher, and my fear is that by the covert filtration of our peculiar philosophy into our science of life we may destroy the sources of the sweetness, the richness and the "great unanimities" of living. My own working hypothesis holds that the relation of cause and effect, in a purely scientific discipline, is a space-time relation within a unitary system, that the living organism is such a system, and that I can not fully perceive any phase of this relation or part of this system without perceiving the system as a whole. Upon this hypothesis my understanding of an event scientifically or experimentally requires knowledge of the future as well as of the past of the system in which that event occurs. If this be philosophy, I would call it a philosophy, not of *being,* but of *becoming;* not of *life,* but of *living*—which is itself my supreme experiment.

SCIENTIFIC EVENTS

THE INTERNATIONAL ORNITHOLOGICAL CONGRESS

Nature reports that the eighth International Ornithological Congress is to be held at the University of Oxford in July, 1934, under the presidency of Dr. E. Stresemann, of Berlin. The congress was originally held every five years, but at the last meeting at Amsterdam in 1930, when the president was Dr. E. Lönnberg, of Sweden, it was decided to hold it every four years. The last meeting of the congress in England was at the Imperial Institute, London, in 1905, with Dr. R. B. Sharpe as president. In 1910 it was held in Berlin, and it was proposed to hold the 1915 congress at Sarajevo, Yugoslavia, but in the meantime the war broke out and no further meeting was held until 1926, when, mainly through the efforts of Dr. Ernst Hartert, keeper at Tring Museum, it was resumed at Copenhagen. Preliminary arrangements have already been made for the 1934 congress at Oxford, and the Rev. F. C. R. Jourdain, of the British Ornithologists' Union, has been elected honorary secretary. Dr. P. R. Lowe, of the British Museum, has been elected chairman of the executive committee, which includes Lord Rothschild, Lord Scone, Dr. C. B. Ticehurst, Dr. Sclater and Messrs. Stuart-Baker and H. F. Witherby, president of the British Ornithologists' Union.

Delegates to the congress will include, according to *Nature,* the leading ornithologists from all parts of the world, including Australia, New Zealand, Argentina, Brazil, Japan, India, the United States, Canada and all European countries. The problem of oil pollution of the sea, whereby hundreds of sea-birds, including many rare species, are annually being destroyed, especially on the North Atlantic shores, will be a prominent feature of the section on bird protection, while the practise of "ringing" as a means of tracing bird migrations will also be discussed. One of the most important items is the project for founding an Institute of Ornithology at the University of Oxford, which it is hoped to develop out of the existing scheme of research in economic ornithology at Oxford, the grant for which expires in September,