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CONTENTS

The Beginnings of Intelligence: PROFESSOR S. J. HOLMES 473

The Galton Chair of Eugenics 480

Scientific Notes and News 481

University and Educational News 485

Discussion and Correspondence:—
The Air we breathe: WILLIAM KENT, WILLIAM J. CROWELL, JR., LOUIS CLEVELAND JONES. *University Fellowships:* PROFESSOR GUIDO H. MARX, DR. C. V. BURKE.. 486

Scientific Books:—
Kiebel and Mall's Human Embryology: PROFESSOR H. MCE. KNOWER 493

Special Articles:—
The Origin of Nine Wing Mutations in Drosophila: PROFESSOR T. H. MORGAN ... 496

The National Conference Committee on Standards of Colleges and Secondary Schools: PROFESSOR FREDERICK C. FERRY.. 499

Anthropology at the Providence Meeting: DR. GEORGE GRANT MACCURDY 500

The Fifth Annual Meeting of the Entomological Society of America: PROFESSOR ALEXANDER D. MACGILLIVRAY 507

Societies and Academies:—
Section of Biology of the New York Academy of Sciences: L. HUSSAKOF. *The New York Section of the American Chemical Society:* C. M. JOYCE. *The Helminthological Society of Washington:* MAURICE C. HALL 507

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THE BEGINNINGS OF INTELLIGENCE[1]

NOTHING shews more the force of habit in reconciling us to any phenomenon, than this, that men are not astonish'd at the operations of their own reason, at the same time, that they admire the *instinct* of animals, and find a difficulty in explaining it, merely because it can not be reduc'd to the very same principles. To consider the matter aright, reason is nothing but a wonderful and unintelligible instinct in our souls, which carries us along a train of ideas, and endows them with particular qualities, according to their particular situations and relations.—David Hume, "Treatise on Human Nature."

We all have a certain curiosity regarding the evolutionary history of our various powers and attributes, but from many points of view an unusual interest attaches to the first development of intelligence. The word intelligence is used in a variety of senses by writers on comparative psychology and any discussion of the origin of intelligence would be fruitless unless the meaning in which the term is employed be understood. One of the foremost of comparative psychologists, the acute Father Wasmann, defines intelligence as "the power of conceiving the relation of concepts to one another and of drawing conclusions therefrom. It involves abstraction, deliberation and self-conscious activity." Intelligence, according to Wasmann, is the God-given attribute of man alone; its possession separates man from brute by an impassable barrier.

Many comparative psychologists, among whom we may mention Lloyd Morgan, Forel and Loeb, adopt as a criterion of intelligence the power of forming asso-

[1] Read before the meeting of the Sigma Xi of the University of California, December 7, 1910.

ciations, or associative memory, and we shall follow the usage of these writers. It is obvious that the possession of this faculty marks an important step in advance upon the creatures whose actions are fatally determined by their instinctive make-up. From its beginning in forms in which the simplest associations are established only after a large number of experiences, intelligence has assumed a rôle of ever-increasing importance in the evolution of animal life, until in man, who is notoriously a weakling compared with the large beasts with which he has had to contend it became the main factor to which the human species owes its supremacy in the struggle for existence.

In considering the origin of intelligence one is naturally led to the subject of the relation of intelligence to instinct. Formerly it was the custom to contrast these two faculties as if they represented diametrically opposed types of activity. Instinct was regarded as something unalterably fixed, machine-like and practically perfect in its adaptation to the needs of the animal; intelligence was recognized as the anthithesis of all these qualities—variable, plastic and eminently fallible. With the establishment of the theory of evolution writers became more disposed to discover the kinship and filiation of instinct and intelligence and they have given us a variety of views as to the relation of these faculties.

Basing his theory on Lamarck's doctrine that instinct is inherited habit, G. H. Lewes attempted to explain instinct as "lapsed intelligence." Performances which are learned with difficulty come, after sufficient repetition, to be carried out automatically and without any intelligent guidance. If the acquired facility of performing these acts is inherited and the acts are repeated generation after generation, it is probable that they might finally be performed by an individual without any previous instruction at all; that is, they would become instinctive. An animal's instincts, according to this view, represent the stereotyped and mechanized behavior which its ancestors found to be profitable; their adaptiveness rests upon the wisdom acquired by ancestral experience. More recently this view has been upheld by Eimer, and in a less extreme form by Romanes, Wundt and many others.

One difficulty with the theory of lapsed intelligence is that it involves the acceptance of the doctrine of the transmission of acquired characters, which has come to be a very questionable biological theory. But another and more fundamental difficulty is revealed by recent work on the behavior of lower organisms. If instinct were derived from intelligence by a sort of mechanizing process we should expect, as Whitman has urged in his criticism of Lewes's theory, to find intelligence dominant in lower forms of life, and that acts which are instinctive in the higher animals would be intelligently performed by the lower ones. The work that has been done on the behavior of lower organisms enables us to state with confidence that such is not the case. In several large phyla of the lower invertebrates there has not, as yet, been demonstrated the least glimmer of intelligence; and, as we pass up the scale of life, intelligence gradually supersedes instinct, not the reverse. We can say with some degree of assurance that, however the transition may have been effected, intelligence has grown out of purely instinctive behavior.

It is not possible, however, to fix, except with the rudest approximation, the stage of evolution at which intelligence makes its first appearance. The transition from instinct to intelligence has been made, in all probability, not once, merely, but several times along different lines of descent. Intelligence in the vertebrates doubtless arose independently from that of the insects, and the intelligence exhibited here and there among the mollusks probably arose independently along a third line of development. Intelligence makes its appearance at a certain stage of organization along whatever line such a stage may have been reached.

Up to the point at which the power of associative memory becomes manifest there has been progress along many lines which has prepared the way for the evolution of this new faculty. Behavior has not only become more complex, but it has become more plastic and capable of easy modification to suit new conditions. The lower organisms do not always react in a particular way to a given stimulus. What reaction occurs may depend upon the number of previous stimulations, the supply of food, exposure to different environing conditions, and numerous other factors which influence the internal state of the organism. The behavior of many lower animals is plastic and adaptive to a remarkable degree, and to a superficial consideration often gives the appearance of a considerable degree of intelligence, without there being any detectable power of associative memory. This plastic and varied behavior not only simulates intelligence, but it secures for the organisms many of the advantages which intelligence confers. It adapts the animal to a more varied environment, and gives it the power of meeting a given situation in more than one way, so if one kind of response does not suit, another may be more successful. Let us glance briefly at some of the ways in which behavior may be modified.

A very general change of behavior in its organisms consists in the habituation to any stimulus which is repeated at sufficiently close intervals so that the organism no longer responds to it. This is shown even among the protozoa. A *Stentor* or a *Loxophyllum* subjected to a light mechanical stimulus at short intervals soon fails to respond as at first, but the duration of the modification so produced is very short; in *Loxophyllum* it probably does not extend over two or three seconds. Similar effects of repeated stimulation but of longer duration have been observed in *Hydra,* several species of sea-anemones, planarians, annelids and various other lower invertebrates. As a rule failure to respond may occur more quickly and the effects of the stimulus remain longer as we pass up the scale of animal life.

Occasionally the reverse phenomenon occurs when the response to a given stimulus is increased instead of diminished with repeated applications—a result which suggests the effect of the summation of stimuli. At times, as Bohn found in *Cerianthus,* there is an initial increase of responsiveness followed by a dulling of sensitivity. Bohn has attempted to subsume the effects of repeated stimulation under a general "law" to the effect that stimulation always produces at first increase of sensitivity to be followed later by a decrease. Sometimes, as Bohn claims, the initial increase is so short as to escape detection; which may be true, but the burden of proof is on M. Bohn.

Repetition of a stimulus may call forth not only quantitative differences of response, but it may evoke responses of very different character. Animals are frequently provided with several modes of reacting to a given stimulus which may be called into play one after the other. Jennings has shown that if a *Stentor* is subjected to a light mechanical stimulus by causing fine particles of India ink to fall upon its disk from a capillary pipette it usually reacts first by bending a little to one side. If the particles continue to fall on the disk the beat of the cilia covering the body may suddenly be reversed, thus creating a current tending to carry the offending particles away. If in spite of this the particles still impinge upon the disk the *Stentor* may contract one or more times. Finally, if all these reactions are tried in vain the infusorian may give a number of violent contractions, break loose from its place of attachment, and swim away.

It would be an error to interpret the varied behavior of this unicellular organism as a manifestation of intelligence, although it is not unlike what the behavior of an intelligent creature might be under the circumstances. No power of learning by experience has ever been discovered in *Stentor,* or indeed in any other protozoan. The organism is provided with a number of different modes of response, and which one is set in action depends upon internal factors which are influenced by the creature's previous activity. The organism which has responded to a stimulus has become transformed into a different mechanism which may respond more or less readily than before or radically change its method of behavior.

A striking illustration of varied responses to a given stimulus has been described by Jennings in the sea anemone *Stoichactis.* If a foreign body is placed upon its disk the anemone tries to rid itself of the object in various ways. The tentacles near the object collapse and the area between them extends, thus producing a relatively smooth surface so that the waves can readily wash the object away. If this does not occur the region under the object begins to swell, thus rendering the removal of the object still easier. If this reaction is unsuccessful the edge of the disk begins to sink so that a smooth sloping surface is formed from which the object can readily slide. Here, as in the case of *Stentor,* we have an organism capable of reacting in several ways to a given stimulus. What particular reaction is evoked depends upon previous stimulations.

Modification of behavior caused by different conditions of nutrition are found in the lowest members of the animal kingdom. Even the white blood cells after they have ingested a number of bacteria refuse to take in more. Whether there is a limit to the appetite of *Amœba* has not been determined, but many infusorians such as *Stentor,* after having swept in a certain amount of food, react to food particles in a quite different way than when in a hungry condition. *Hydra* when not fed for some time extends the body, sways about in various directions and keeps up a restless movement of its tentacles, thereby increasing its chances of contact with the small creatures which serve as its prey.

Instances of the non-intelligent modifications of behavior might be multiplied indefinitely. As we pass to higher forms the capacity for responding in different ways to a given situation becomes greatly increased. "Nature," says James in his admirable chapter on instinct, "implants contrary impulses to act in many classes of things, and leaves it to slight alterations of the conditions of the individual case to decide which impulse shall carry the day," and he points out that many animals lose the instinctive demeanor and appear to lead a life of hesitation and choice, not because they have no instincts, but because they have so many of them that they block one another's path. Intelligence in the acceptation of the term which we have accepted begins with the formation of associations. It does not make its appearance, so far as is known, until a comparatively high stage of organization has been attained. The evolution along the lines of complexity of instinct and ready modifiability of reactions to suit new conditions, affords a substantial basis for intelligent behavior. Without such evolution the power of associative memory would avail little. But with a large number of readily modifiable instincts, associative memory becomes the means of affording a much wider and closer adjustment to the environment.

The studies which have been made of primitive types of intelligence such as found in crustaceans, fishes and amphibians have shown that associations are formed by a gradual process of reinforcement or inhibition of a particular reaction to a given stimulus. The method followed is one which Lloyd Morgan has designated as "trial and error." It may be illustrated by the experiment of Yerkes on the formation of associations in the crayfish. In these experiments a box was employed into one end of which the crayfish was admitted through a narrow aperture. The other end of the box was divided by a median partition which gave the crayfish a choice of two routes to a tank of water at the other end into which the creature was naturally desirous of getting. One of the two ways to the water was closed by a glass plate at its farther end so that the crayfish was afforded a choice of a right and a wrong path to the water. Would the crayfish after a number of trials learn to choose the right path and avoid the closed passage? In the first ten experiments the crayfish went as often to the right as it did to the left, but in the next ten trials the percentage of correct choices was somewhat greater. Finally after a large number of trials the animal came to choose the right path to the water, making but rarely any mistakes.

Similar experiments with crabs, fishes and the frog have yielded similar indications of slow learning. In some respects such learning resembles the slow formation of a habit rather than the judgment of a consciousness which "sizes up" the situation and determines upon a certain course of action. It is quite probable that such a primitive form of learning does not include any association of ideas. It can be satisfactorily accounted for by assuming nothing more than an association of certain sense perceptions with particular movements. The animal may have no ideas to associate—nothing but sense impressions and motor impulses. Of course its mental content *may* include much more than this, but in interpreting the behavior of animals it is generally advantageous to follow the principle laid down by Lloyd Morgan—which is a sort of special application of the law of parsimony—that we should not assume the existence of a higher psychic function if the phenomena can be explained as well in terms of a lower one.

The step from sensori-motor association to the association of ideas is not, I believe, a wide one, and comes about as a natural consequence of the elaborateness and what Hobhouse has designated as the "articulateness" of the mental process of adjustment. It is foreign to our purpose, however, to trace the increase in the number, delicacy, quickness and complexity of the processes of association which we meet in the various stages of mental evolution. One problem at present lies in the initial step involved in the formation of a simple association. And it is a problem which, despite its apparent simplicity, involves the consideration of some vexed and subtle questions.

In learning we have to do with two opposite processes of reinforcement and inhibition. A chick after it pecks at a caterpillar which is wholesome and savory pecks at a similar caterpillar more readily on a second occasion. Something has apparently reinforced the connection between the visual impression produced by the caterpillar and the pecking impulse. If, on the other hand, the chick pecks at a caterpillar having a nasty taste it is apt to avoid pecking at it a second time. Something has happened to inhibit the response that would otherwise occur. We commonly explain such behavior by ascribing to the creature feelings of pleasure and pain. We say that the chick pecks at one kind of a caterpillar because of the pleasant taste it derives, and avoids another variety because its taste is bad. Pleasure and pain apparently function as agents for the reinforcement of certain reactions and the stamping out of others. It is a general rule, though not without certain exceptions, that what affords pleasure is conducive to organic welfare, while that which is productive of pain is injurious. The upshot is that the associations that are the outcome of the pleasure-pain response are of just the kind that minister to the animals' needs. Beneficent arrangement! Apparently we have to do with a selective agency which preserves and intensifies certain kinds of behavior and rejects others on the basis of their results—a kind of "sorting demon" in the realm of behavior. What could be more teleological!

The fact that what is pleasant is usually beneficial and what is painful is usually injurious may be explained with some plausibility as the result of natural selection, as was first contended by Herbert Spencer. Animals which took pleasure in doing things which were bad for them and which experienced pain in doing things which were good for them would be very apt to fare ill in the struggle for existence. Natural selection would ever tend to bring about a condition in which the pleasant means the organically good and the painful means the reverse. We should not expect the correspondence, if brought about in this way, to be complete, and it is rather in favor of the theory that we do not find it so.

But granting this contention of Spencer, there is the important question still left unanswered, namely, Why do animals follow what is pleasant and avoid what is painful? In other words, why does pleasure reinforce and why does pain inhibit? Here is another fundamental problem and we find that Spencer with his usual appreciation of fundamental problems was on the ground early with a theory. Pleasure, according to Spencer, is the concomitant of a heightened nervous discharge; pain the concomitant of a lessened nervous discharge. An act which brings pleasure causes an influx of nervous energy to the centers concerned in the movement; the lines of discharge become "more permeable," and upon a repetition of the conditions the same act follows with greater readiness than before. If the act is followed by pain with its concomitant of lessened nervous discharge, the diminution of nervous energy serves to prevent the performance of the act in response to the same conditions. Closely similar explanations of the physiology of the pleasure-pain response have been given by Bain and by Baldwin, the latter declaring that "pleasure and pain can be agents of accommodation and development only if the one, pleasure, carry with it the phenomenon of motor excess—and the other, pain, the reverse—probably some form of inhibition or of antagonistic contraction."

The physiological concomitants of pleasure and pain have afforded a subject for numerous laboratory studies and almost no end of theories. It has been impossible thus far to discover that either of these states is invariably accompanied by any definite physiological condition. The theory of Spencer and Bain is open to obvious criticism, for the man who steps on a tack undoubtedly has a "heightened nervous discharge," as much as a man who shouts for joy. And I believe I am safe in saying that no theory of the physiology of pleasure and pain is on a sufficiently firm basis to warrant its being regarded as anything more than a very tentative working hypothesis.

With our present knowledge of the psycho-physiology of pleasure and pain, the attempt to explain how these states or their physiological concomitants, whatever they may be, can act as agents of reinforcement and inhibition seems rather a fruitless one. The process which we meet at the beginning of intelligence in simple associative memory may be formulated as follows:

stimulus — reaction — pleasure — reinforcement
physiological state x
stimulus — reaction — pain — inhibition
physiological state y

Spencer, Bain and others have endeavored to show how the organic accompaniments of pleasure and pains modify the creatures' subsequent responses. But as the problem was interrupted by these writers our ignorance concerning the physiological states x and y brings us to a standstill.

In his valuable work on "Mind in Evolution" Hobhouse has presented a new point of view in considering this problem, which has the advantage of not involving any general theory of the physiology of pleasure and pain. It is essentially a theory of how behavior comes to be adaptively modified through the formation of associations. It makes no attempt to explain why pleasure is associated with certain experiences and pain with others. Such association may turn out to be as inexplicable as the problem why stimulation of the optic nerve gives rise to a sensation of light instead of some other kind of feeling. What it is feasible to attempt to explain is why certain responses tend to be repeated and others tend to be inhibited. And this can be explained with some plausibility as due to the congruity or incongruity of the reactions which come to be associated. For the sake of illustration let us consider again the chick which pecks at a nasty caterpillar. The irritation set up by the caterpillar in the chick's mouth evokes movements of withdrawal and ejection. The two responses of pecking and ejection become associated, but as the two movements are contradictory the result is inhibition. The pecking reaction no longer occurs in the presence of a second nasty caterpillar, not because of any stamping-out influence of the physiological concomitant of pain, but because it becomes joined with an antagonistic reaction.

In a previous paper by the writer the attempt was made to extend the theory of Hobhouse to account for the reinforcement commonly held to be caused by pleasure. The assumption was made that this process is due to an organic congruity of the reactions. If the caterpillar pecked at is a savory one there is set up the reflex of swallowing. Pecking and swallowing form the normal elements of a chain reflex; when one part of the structure concerned is excited it tends to increase the tonus of the associated parts, and thus reinforce the original response. I have found that in the crayfish stimulation of the antennules, which are important organs of smell, sets up chewing movements of the mouth parts and grasping movements of the small chelæ. Similarly stimulating the small chelæ evokes chewing movements of the mouth parts and twitching of the antennules, while stimulating the mouth parts directly may cause movements in both the other sets of organs. We have here as a matter of fact a number of reflexes which mutually reinforce one another. Suppose that in the chick the sight-pecking response and the taste-swallowing response are related as the feeding reflexes demonstrably are in the crayfish; the second response would thus tend to reinforce the first, and if this tendency persisted we would have a case of learning by experience.

Animals in the course of their instinctive responses encounter stimuli which bring about other responses. These become associated. According to the nature of the nervous pathways involved, there may be reinforcement of or interference with the original reaction. Experience brings about an extension of the range of adaptations by the assimilation of congruent reactions and the elimination of acts whose secondary consequences are in the nature of antagonistic and thereby inhibitory responses. Such we may say, by way of expressing a tentative view-point, is the nature of primitive intelligence.

But it will be seen that the capacity to form new adaptations rests upon the primary adaptiveness of the instinctive reactions. The power of formation of associations alone would never lead to improvement. The adaptiveness of intelligence is based upon the adaptiveness of instinct; it may be said that intelligence is a means of enabling an animal to live its life more completely and successfully, but instinct furnishes the fundamental springs of action. Even complex creatures like ourselves form no exception to this rule.

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THE GALTON CHAIR OF EUGENICS

We have noted that Sir Francis Galton, F.R.S., who died on January 17, aged 88, had left his residuary estate to the University of London for work in eugenics. This residuary estate will amount to about £45,000. In his will Sir Francis Galton describes the scope of his new foundation as follows:

I devise and bequeath all the residue of my estate and effects, both real and personal, unto the University of London for the establishment and endowment of a professorship at the said university to be known as "The Galton Professorship of Eugenics," with a laboratory or office and library attached thereto. And I declare that the duty of the professor shall be to pursue the study and further the knowledge of national eugenics—that is, of the agencies under social control that may improve or impair the racial faculties of future generations physically and mentally. And for this purpose I desire that the university shall, out of the income of the above endowment, provide the salaries of the professor and of such assistants as the senate may think necessary, and that the professor shall do the following acts and things, namely:

1. Collect materials bearing on eugenics.
2. Discuss such materials and draw conclusions.
3. Form a central office to provide information, under appropriate restrictions, to private individuals and to public authorities concerning the laws of inheritance in man, and to urge the conclusions as to social conduct which follow from such laws.
4. Extend the knowledge of eugenics by all or any of the following means, namely: (*a*) professorial instruction; (*b*) occasional publications; (*c*) occasional public lectures; (*d*) experimental or observational work which may throw light on eugenic problems.

He shall also submit from time to time reports of the work done to the authorities of the said university.

I also declare that the said university shall be at liberty to apply either the capital or income of the said moneys for any of the purposes aforesaid, but it is my hope that the university will see fit to preserve the capital thereof wholly or almost wholly intact, not encroaching materially upon it for cost of building, fittings or library. Also that the university will supply the laboratory or office at such place as its senate shall from time to time determine, but preferably in the first instance in proximity to the Biometric Laboratory. I state these hopes on the chance of their having a moral effect upon the future decisions of the senate of the university, but they are not intended to have