recent additions to the American Museum from the Cope collection through the munificence of President Jesup. (For a fuller account see SCIENCE, N. S., XI., p. 77.)

Bashford Dean described the condition in seven eggs of *Myxine glutinosa* which he had received from Professor A. E. Verrill. These had been collected in 1880 on the Newfoundland banks in water of 90 and 150 fathoms. The egg membranes were regarded as more specialized than those of Bdellostoma.

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DISCUSSION AND CORRESPONDENCE.

DO THE REACTIONS OF THE LOWER ANIMALS AGAINST INJURY INDICATE PAIN SENSATIONS?*

IN a posthumous article with the above title by the lamented Professor Norman is contained the chief substance of what was to have been his doctorate thesis. It comprises new facts and a statement of those that are old in a way which will interest especially the psychologists and gratify to no small degree the physiologists—or some of them. While the author answers the titular question in the negative, as his main thesis, 'lower animals' indicates for him only those species up to and including the flounder. Moreover, the paper is remarkably free from opinions based on analogy, the evidence being weighed as its author thinks solely for what it is worth and regarding the particular species experimented upon alone.

The report begins with a proper adverse criticism of that mode of argument in a circle which bases presumption as to the mode of consciousness concomitant to movements, on these same movements taken as expressive of certain modes of consciousness. He follows rather the purely physiological method of considering movements as the immediate consequence of physical stimulation, the psychic factor not entering the problem at all. Certain experiments seem to the author to prove the correctness of this point of view.

The most striking and classic of these experiments were made on the common earthworm (*Allolobophora*). If such a low animal be divided at its middle transversely, only the posterior half shows those squirming and jerking movements which, anthropomorphically viewed, seem to indicate pain; the anterior half (containing the brain) crawls, as ordinarily, away. Now if each of these halves be halved, again the posterior segment of each squirms while the anterior halves crawl away. This same process may be continued with precisely like result until the pieces are no longer large enough to crawl independently. This striking phenomenon is explained in part by the two sets of muscular fibers in the worm, one longitudinal, causing the squirming and jerking, and the other circular, which produce the crawling. Why in the posterior segments the former set should be initially stimulated and in the anterior the latter set, Professor Norman says he does not know. For its purpose the experiment seems conclusive. Similarly, if a swimming leech be cut in two, both parts, after a pause, swim off as if nothing had happened. Like events take place with other species of worms, the anterior or brain part being regularly that undisturbed by the extraordinary stimulus.

The abdomen of a hermit crab may be cut in two without any 'but a very slight response' from any remaining movable organ. *Limulus* stops a few seconds when four or five abdominal segments are cut away, then proceeds quietly breathing as before. Its order of events is regularly: cessation of breathing, flexion of abdomen, pause, extension of abdomen, respiratory movements. *Geophilus* cut in two in the middle continues its crawling, the front half going forwards and the rear half backwards. Millipedes divided while walking do not hasten nor stop nor jerk. Dragon flies lose parts of their abdomens without any appreciable change in position. As was long ago pointed out, bees continue to eat when their abdomens are cut way during the process.

Lastly, sharks and flounders, provided a current of water circulate through their gills, will allow the most tedious and deep-going cutting operations on their heads without the slightest

* By the late Professor W. W. Norman, University of Texas, with Additional Note by Jacques Loeb. *American Journal of Physiology*, Vol. III., No. VI., 1 Jan., 1900. Pp. 270–284.

appreciable movement indicative of pain or even of sensation.

In the 'additional note,' Professor Loeb points out as the two chief results of the investigation: "(1) In a great number—perhaps the majority—of lower animals injuries cause no reaction which might be interpreted as the expression of pain sensations. (2) In the limited number of cases where injury is followed by motions which have been considered as the expression of pain sensations (as in the case of worms) a closer analysis shows that this interpretation is unjustified."

This article is noteworthy not least for what it neither says nor implies, namely, that animals other than those there considered probably do not feel pain. Notwithstanding this most commendable modesty of opinion on the part of its author, certain considerations present themselves therefrom, which are of too great moment both to psychology and to physiology to remain unanswered. The problem may be properly considered as insoluble—yet well worthy of debate. It will not be maintained that these animals do experience pain when they are injured, *but only that they may for all that experiments prove to the contrary.* Analogy and reasonable presumption are our only methods when inexperiencable sensations are in question and the former of these at least works both ways.

The lowness of the investigator's subjects in the animal 'scale' is worthy of preliminary notice. On this account it would at first sight seem that the author's and Dr. Loeb's opinion was more valid, on the common supposition that 'so low a grade of consciousness could not include actual, stinging pain.' The nervous systems of these worms and echinoderms and fishes seem undoubtedly too simple to allow of the presence of organs for pain such as on the whole seem probable in man and his congeners. The highest, highly differentiated animals require painful sensations as a means teleologically protective of their different organs; in the lowest orders, on the other hand, this need does not exist, for their relative simplicity of plan makes possible the regeneration of any lost part or organ or even the perfecting of an individual from a part artificially cut off from another individual. It is therefore extremely reasonable even from the pan-psychistic viewpoint to suppose that organs of pain would be undeveloped in these very lowly forms. The simplicity of neural structure in these orders makes it certain almost that much, present in higher forms as organs correlated to consciousness of various modes, would here be lacking. The worm and the starfish, simply because they are in a less degree, physiologically speaking, individuals than is a dog or a man, require fewer of those organs on which a continuance of individuality depends. But while this is so, perhaps, the sort of pain under discussion is not man's degree of pain, but rather that grade of painful consciousness proportionate to the needs of the animal in which it may or may not be experienced. The difference is not one of kind but one of degree, and a degree suitable to the biologic needs of the particular species may be present, commensurate not to the complexity of a nervous system even, but perhaps only to the necessity of the preservation of individuality—a necessity in some of the species experimented on obviously exceedingly small.

In view of the great similarity functionally between the neural structures of the higher animals and those of man, no one perhaps would seriously deny consciousness to, say, an elephant or an ape. To damaging stimulation these animals react much as does man, but it is a quite gratuitous presumption that the earthworm and the flounder would react to a destructive excitation in a manner even comparable to that in which these higher forms react. To suppose this would be to employ again only a sort of the objectionable anthropomorphism. Because the elephant or the cat with a remarkably elaborate system of innervated, muscled, and jointed limbs, reacts in a characteristic way to injury, there is no reason to expect the Nereis or the starfish to react similarly in any sense. The rabbit even, with essentially all the motor mechanism which man possesses, 'expresses' pain often times only by attempts to get away and by an increase in the breath-rate; indeed this dyspnœa is often the physiologic anæsthetizer's only sign that more ether is urgently demanded. It is not necessary then because the lowest forms of animals do not act

as mammals act under injury to presume on that account an absence of that degree of unpleasant consciousness which corresponds to the higher animal's pain. One might *à priori*, from difference in structure and in function both, expect wholly different reactions to stimuli or even none at all. Qualitatively as well as quantitatively the reactions of any two genera may differ to any indefinite degree.

Again that relative deficiency of simplicity of neural organs, natural to the low orders, may be and presumably is correlated with a like deficiency in the duration of the sensations represented by these organs. The time of continuance of a sensation occasioned by a momentary stimulation is perhaps determined by the number and extent of something comparable to association-currents running either between different parts of the neural unit or between these units extended spatially, or both. The former of these conditions may be simpler in the lowest orders, and the latter wholly or at least partly lacking. 'Reverberation,' in a word is less, the simpler the nervous organ. Professor Norman expressly noted in most of his experimental reports a period of quiet on the animal subject's part, representing nervous shock. It is a pure presumption to conclude that such a condition is not 'painful' to the animal. In all the higher animals severe pain is essentially asthenic in its effect on the organism. Limulus, cited by the writer, shows this especially well, and furthermore presents yet further evidence of painful or destructive sensation in the extreme abdominal flexion, the general concomitant of pain, noted in the experiments. This depressing period being past, and the perhaps only pseudo-individual being by the injury in no way incapacitated for its customary movements (because of lack of coördinating neural mechanism), these movements soon proceed as if nothing had happened, as indeed perhaps nothing had happened to more than an insignificant independent portion of the quondam individual.

Another consideration, quite old but on that account not less reasonable as it seems to the present writer, may be based on the biologic principle that nature does not act by leaps, that continuity is the all-pervading principle of evolution and so of psychophysical development. Man undoubtedly has consciousness and at times pain; the lowest organism has a minimum, but always some, of both, 'consciousness,' here indicating experience correlate with mechanical function, and 'pain' that sort of disadvantageous experience correlated with injury to the biologic egotism of the individual—very general terms, but therefore the more useful. Between these two zoologic extremes, the maximum and the minimum of developed life, all animal life has place and has accordingly, from this theoretical point of view, some degree or other of what, for want of a better term, is called pain. Each individual in its degree, be it man's degree or the earthworm's, has feeling, from this the philosophical view point, even as it has motion through space or within its organs. Let one who is disposed to deny this say with what genus sensation ends as one looks down the closely crowded scale of life—is it between man and the monkey or between the alligator and the flounder? However large the empirical gap at present between any two genera may be, the problem is not altered, for like biologic principles actuate them all, and strongest of these principles normally is the preservation of the individual. To this end, perhaps, pain developed, and to this end it everywhere, in the long run, works. This proposition is more than a mere speculative presumption, for observation inductively originated it and continually supports it. To get beneath it were to solve at length the great problem of Job, were to go deeper than empirical science can. It is a principle too firmly fixed in the philosophy of biology, so to say, to be shaken by the necessarily wholly negative result of experimentation where the conditions are so far from those of man, the judge.

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PLANT MATERIAL FOR LABORATORY USE IN THE SCHOOLS.

For more than a year there has been offered through the Ithaca Botanical Supply Co. plant material suitable for laboratory use in first courses, and for demonstrations of some of the organs and processes which it is rather difficult