MOVEMENT AND PROBLEM SOLVING IN OPHIURA BREVISPINA[1]

BY

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WITH FIVE FIGURES

INTRODUCTION

The observations and experiments which I shall describe and discuss in the following pages were made in the Marine Biological Laboratory at Wood's Hole, for the purpose of testing Preyer's conclusion that ophiurans are intelligent animals. In spite of the fact that there is still much difference of opinion as to what we mean by intelligence, all will agree, I think, that it involves at least the ability to learn and to modify behavior in accordance with experience. Jennings ('06, p. 291) has formulated in the law of the resolution of physiological states, the way in which behavior is modified in experience: "The resolution of one physiological state into another becomes easier and more rapid after it has taken place a number of times." I have attacked the problem of intelligence in Ophiura brevispina from the point of view afforded by this law of resolution.

PROGRESSION

Progression in ophiurans has been described by a number of observers, including Romanes ('85), Preyer ('86), von Uexküll ('05) and Grave ('00). These writers agree as regards the general method of locomotion in ophiurans, but they have not described all of the movements which these animals perform. All of these authors have noticed two types of progression, the first of which may be visualized by the aid of Fig. 1, in which the arms are numbered, and so distinguished by heaviness of line, that the most active is the widest, the least active the narrowest.

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In movements conforming to type *I*, Fig. 1, *A*, the two arms *1* and *3* are used as a pair, whose strong backward stroke drives the animal in the direction indicated by the arrow. Arm *2*, which projects forward rather stiffly, serves only the function of guiding, this being also the effect of *4* and *5*, which are dragged behind. A slight modification of type *I*, *A*, is found in type *I*, *B*, in which the distal end of arm *2* waves from side to side, and in this manner adds to the propelling force furnished by *1* and *3*. Type *I*, *C*, is a further modification of *I*, *A*, in which arm *2* instead of bending only distally makes a stroke as effective as either that of *1* or *3*, and bends either to the right or to the left, so that the animal is

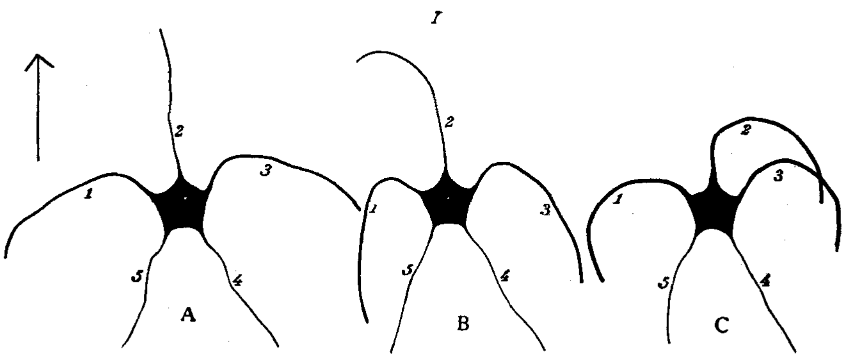

Fig. 1

propelled by two arms on one side and one on the other. The course is zigzag if regular alternations in the direction of the stroke of arm *2* occur but if this always falls on the same side the course is circular.

The movements that fall within this type are variable to an extent which has not been pointed out. *I*, *A*, represents in its pure forms one of the two types which all previous writers have noticed, though Grave ('00) has also observed the modification *B*, of which *C* is the extreme case. Von Uexküll ('05), who calls this type of movement Typus Unpaar voran, says: "Beim Bewegungstypus Unpaar voran, zeigt sich welch grosse Unterschied in der Bewegungsamplitude des ersten und zweiten Gangpaares besteht. Letzteres verhält sich beinahe passiv. Doch kann es gelegentlich auch stärker in Aktion treten." Both Preyer ('86) and Grave ('00) state that the "posterior" pair is dragged behind, and I have never observed more than insignificant movements in it.

Type *II* (Fig. 2), observed by all of the writers mentioned, and called Typus Unpaar hinten by von Uexküll, may be described as two pairs of arms working synchronously, or alternately, the anterior pair initiating movement at one time, the posterior at another, or the movement may be begun by arms *2* and *4*; by *1* and *3*; by *2* and *1*; or by *3* and *4*; the only constant factor is the behavior of arm *5* which is invariably dragged behind.

A third type of movement, Fig. 2, *III*, not previously recorded, involves the activity of all the arms in such a manner that the animal is forced forward by three arms on one side and a pair on the other. This type may be thought of as a modification of *I*, *C*,

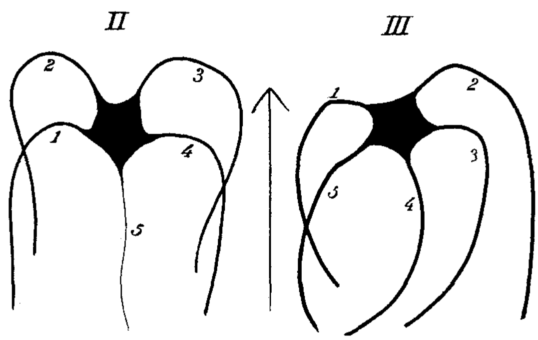

Fig. 2

in which arms *4* and *5* have become active, or as *II*, in which arm *5* has become active. Type *III*, is really *I*, *C*, plus an additional pair, and as in *I*, *C*, the course is zigzag if arm *2* alternates regularly from side to side, circular if the stroke falls always in the same direction.

It is not necessary to describe the finer variations to which these types of movements are subject; to point out, as has been done in von Uexküll's excellent paper ('05), how one may pass over into another, or how the course is affected by differences either constant or variable in the rate and strength of stroke of particular arms or particular combinations of arms. With the exception of type

Unpaar voran, in which according to von Uexküll effective movements occur in the two arms which are usually dragged passively behind, I have observed that Ophiura brevispina moves in practically all the ways in which it is possible for a pentaradiate animal of its construction to move.

INDIVIDUALITY

The movements described are directly dependent upon the pentaradiate symmetry, but this symmetry does not exhaust the possibilities of behavior. A little observation shows that each animal is unique at any given time and that while its movements fall within the system of classification proposed, they have peculiarities that distinguish them from other movements of the same type.

In general the movements may be either rapid or slow, and certain individuals seem on first acquaintance to be distinctly active or distinctly sluggish. More careful study shows, however, that very sudden changes of behavior occur, and that an active, rapidly moving animal may unexpectedly enter into a state of sluggishness that sometimes lasts for hours. I do not understand these sudden changes. They are not due to the conditions in the aquaria; they occur with great suddenness and not in all of the animals; they are not due to either gentleness or roughness in handling because either may or may not be followed by a change in the behavior of the same individual in successive trials. Possibly any sort of handling may, in certain physiological states, cause a change of behavior, but what the physiological state in which this occurs is, is hard to ascertain. In certain experiments in which I encumbered the arms with rubber tubes, after the manner of Preyer ('86), I frequently encountered the same sudden change from activity to passivity, and arms which were flexible and easily encumbered, would suddenly bend at their tips and stiffen, so that it was impossible to slip the tube over them. This stiffening might take place at the first trial, or some other one, and never again, or it might reoccur upon every attempt to encumber the arm.

Periodic changes from activity to sluggishness also occur.

Thus, in June of the present year, more than half of the animals I studied were very active and quickly responsive to stimuli during sometime of my acquaintance with them, but by August the whole race had changed. Perfectly fresh material brought into the laboratory in excellent condition and kept in large tanks of running sea-water, was so sluggish that I was forced to give up the experiments which I had planned for that month. None of the stimuli employed in June elicited reaction, and acids sufficiently concentrated to attack the skeleton, as well as the electrical current, resulted in nothing but a few spasmodic contractions with no attempt at progression or escape. What the reason for this change was is not certain. A sluggish individual almost always has very large bursal openings; in fact, it is possible to predict with considerable certainty the behavior of an individual by examining its ventral surface. The enlarged bursal openings may be consequences of the spawning process, and the periodic change of behavior of the breeding activities. O. brevispina begins breeding in June and ends in August. Late in June many individuals have spawned, and many have the enlarged bursal openings; by the middle of August all have spawned (Grave '00) and most of the individuals have the enlarged bursal openings. As the genital ducts lead into the bursæ—which in some species are used as brood-pouches—their enlargement may very well be due to sexual activity, which is a drain upon the animals, and undoubtedly leaves them in a state of physiological depression. If this view is correct, the enlarged bursal openings are the indices of a lethargic state following the breeding season.

Rapidity and sluggishness of movement have consequences of great importance in problem solving. Sluggish animals not only make fewer movements and take more time to perform them than active individuals, but they use in general fewer arms; their movements are less varied, and the arms very rarely come into contact with one another or cross. All this is very different with active individuals; their movements are quick and varied; they use relatively more arms, often move these through greater arcs than the sluggish animals; and, in addition, the arms touch and cross with great frequency. How "contacts" and "crosses" are related to activity and sluggishness is easy to see. An active individual using four arms in progression has a much greater opportunity to make "crosses" and "contacts" than if fewer arms were used. Very often when the animals move by means of two pairs of arms, the anterior pair is crossed by the posterior regularly. The same frequently happens when only three arms are used.

Contacts and crosses also depend on the length of the arms, as the chances that they will occur in long armed individuals are greater than in short. How important arm length is, is indicated in the following table in which are summarized observations on three individuals which were active, but differed in the lengths of their arms and also in the manner of using them. The effect of the latter factor emphasizes that of the former. The longest armed individual *A* used the "two pair of arms" stroke, only once in a total of 141 effective backward strokes, whereas the shorter armed individuals *B* and *C*, used this stroke eight times in 129 and four times in 126, respectively.

TABLE I

Individual	No. of Movements	Per cent Contacts	Per cent Crosses	No. of arms moved					
				1	2	3	4	5	
A	141	13	110	1	26	28	1	0	times moved
B	129	11	16	0	29	13	8	0	times moved
C	126	6	2	0	16	26	4	0	times moved

RIGHTING MOVEMENTS

Two types of righting movements were observed, only the first of which has been described by von Uexküll ('05) in an excellent paper illustrated by means of kinetoscope photographs, and by Grave ('00), who says: "Two adjacent arms straighten out so that together they form a straight line. On these arms as an axis the body revolves, being pushed over by the three remaining arms, but mostly by the median one of the three."

This description, correct as far as it goes, is incomplete. At the bases of the straightened arms, and in the interradial portion of the disc between them, movements occur whose effect is to bend the ventral surface in the direction indicated by the arrows. When this process, by which a small portion of the ventral surface is brought into the normal position (Fig. 3, *A*), has proceeded far enough, the animal is righted suddenly by its own weight, since while the process described has been going on, arms *3*, *4* and *5* have so elevated the dorsal surface of the disc that this falls into the normal position.

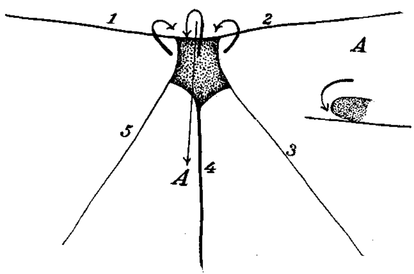

Fig. 3

In the second type of righting movement, Fig. 4, arm *2* curves near its base, and bends under the disc which, as in the previous case, is elevated by the other arms, particularly by *4* opposite *2*. The disc thus rotates on the base of *2* as a pivot, and after it has been sufficiently elevated, the animal falls into the righted position of its own weight.

The length of time required to execute the righting reaction was measured on eight individuals. I have summarized these results in Table II, in which are given the average time for each individual, as well as the maximum and minimum consumed. (See Table II.)

These averages of course do not show the differences between the successive individual rightings of any of the animals used. These differences were in some instances very large, and have had a great effect on the averages. (See Table III.)

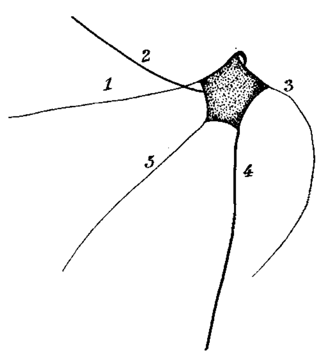

Fig. 4

These measurements show that the variations from the mean may be very great; that because an individual has righted itself very quickly a number of times is no reason for believing that it will continue to do so. In spite of those cases in which righting took place slowly, the

TABLE II

Average righting-times of eight animals

Date	Intervals	No. Trials	A	B	C	D	E	F	G	H
June 27	0	8	3.62″	3.62″	14.50″	4.12″				
27	5′	8	2.86	4.37	25.50	5.12				
27	3 hrs.	10	4.20	3.80	10.60	4.10	4.00″	16.20″	4.90″	3.60″
28	16 hrs.	10	5.10	5.60	6.40	43.30	5.10	10.30	5.10	4.40
30	64 hrs.	10		3.80	15.60	21.60	29.10	7.10	3.50	7.9
			Max. Min.	Max. Min.	Max. Min.	Max. Min.	Max. Min.	Max. Min	Max. Min.	Max. Min.
			8″ 2″	14″ 2″	43″ 4″	198″ 2″	89″ 3″	39″ 3″	12″ 2″	24″ 2″

TABLE III

Individual righting-times of eight animals in many successful trials

A	B	C	D	E	F	G	H
3	5	7	2	4	8	5	3
4	3	5	5	3	12	5	4
3	3	12	4	3	9	6	3
2	2	7	3	4	17	4	3
5	5	20	6	4	12	5	2
3	3	12	4	3	17	4	3
3	5	34	4	5	13	3	3
7	3	19	5	4	39	2	7
3	4	19	2	4	22	3	3
3	2	31	3	6	13	12	5
3	7	8	6	4	9	4	4
3	5	28	4	3	5	10	4
3	4	43	8	5	3	4	4
3	4	33	4	4	15	6	3
3	4	14	4	6	7	6	8
2	5	28	10	4	4	4	4
4	3	10	3	4	14	4	4
3	4	8	4	7	11	5	3
4	3	23	3	7	24	4	5
3	3	6	3	7	11	4	5
3	4	10	3	4	6	3	5
3	4	12	5	29	4	2	7
8	4	8	3	31	3	4	5
7	5	17	4	35	7	3	3
3	4	7	4	12	8	3	24
4	4	5	9	7	6	6	6
3	3	4	29	37	10	3	5
4	4	6	23	38	3	2	6
7	7	5	15	89	15	4	9
7	4	5	20	9	9	5	9
5	4	4	29				
6	5	6	40				
7	14	6	18				
5	6	9	198				
3	6	5	7				
4	3	14	5				
	3	8	4				
	5	5	11				
	4	27	25				
	4	6	45				
	3	21	11				
	5	27	12				
	4	12	14				
	4	20	14				
	3	24	41				
	3	6	39				

records when averaged show that these animals, on the whole, may be expected to right themselves in less than 45 seconds. One fact of considerable interest is clearly demonstrated by the averages as well as by the individual records—there is no reduction in the amount of time required to perform the righting act; in other words, under normal conditions, these animals do not improve by practice in the execution of their righting movements.

PROBLEM SOLVING

The expression "problem solving" is almost self-explanatory. Under this heading, I have placed such behavior as an ophiuran exhibited when stimulated by interference more or less unusual, and from which it was able sooner or later to escape. What I did was to observe the way in which the escape was made—the problem solved—and how much time was consumed in doing it.

The problem—the same as that employed by Preyer—was to rid one or more arms of the small pieces of loosely fitting rubber tubing with which I encumbered them. In the selection of individuals for experiment, my choice was guided by two considerations: whether all the arms were approximately equal in length, neither broken, nor recently regenerated; and whether the individuals were not too active to make the observations easy to record.

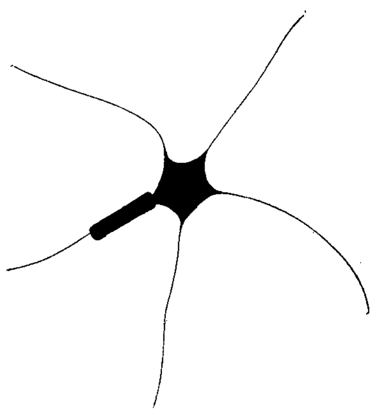

FIG. 5

When encumbered in the manner represented in Fig. 5, an ophiuran does many things, some of which are recorded in von Uexküll's photographs. At first it may pass through a brief latent period, during which it lies motionless on the bottom of the dish, and then it may crawl, dragging the encumbered arm behind it. Often the animal moves at an angle to the encumbered arm, or in rare cases in the direction of it. The progression may be of a very violent character involving many contacts and much crossing of arms, or the animal may simply writhe, without changing its location. If it does not move about, it usually waves one of its arms, especially the encumbered, in a horizontal plane, though the movements may also occur in a vertical plane and in circles. The encumbered arm is moved in a vertical plane oftener than the unencumbered ones; is frequently rubbed against the disc; against the adjacent arms; against the sides of the dish; and even against itself. Sometimes the encumbered arm is waved over the disc, much as a man waves a long whip, and then is "cracked," so that the encumbering tube moves nearer the distal end, and often slides off. When relieved the animal usually does not remain quiet, but continues its movements for a short time and makes several strokes that remove it from the place where the tube was gotten rid of. If at the instant of riddance the animal was not progressing, a short journey is begun at the moment of relief.

When encumbered on more than one arm, the latent period is longer than when only one arm is encumbered; the first movements are not through as great arcs, nor are they so long continued in any direction. One movement is succeeded rapidly, not by its duplicate, but by another in a different direction, and this by still another. The behavior changes constantly.

If all of the arms are encumbered, the above changes in behavior cease very soon, and an entirely different kind of action is begun. Instead of movements in the usual sweeping manner, the arms quiver and tremble. In one case, one arm (the first to be rid of its rubber tube) in particular attracted my attention by quivering when the rest of the animal was perfectly quiet. These quivering movements occur in a horizontal plane, and are so rapid, and many of them so slight, that it is impossible to record them accurately without special apparatus.

Of all these movements, several are more effective than many others in bringing about riddance. The most effective are the "whip movement," the "stripping movements;" certain of the "wavings," and violent progression which involves a number of different movements. Of these the whip movement is the rarest;

the violent progression next, whereas the strippings and the wavings are the commonest of all.

These observations open two ways in which the problem of resolution may be attacked; by studying the time taken to solve the problem and by noting the relative frequency of the most effective movements. The time and the frequency might both remain constant, or might change, or only one might change. As a reduction in the amount of time taken to solve the problem need not necessarily be due to an increase in the relative frequency of the most effective strokes, these two must be considered separately, although an increased frequency of strokes best fitted to solve the problem would involve a reduction in the amount of time. If a reduction in the amount of time required does occur, it means that the physiological state produced by the rubber tube has been resolved into the normal state more rapidly than it was resolved the first time. In other words, the animal has learned by experience.

The following Table IV contains my measurements of problem solving time. In every case the animal was given the same problem consecutively, viz: the same rubber tube was placed on the same arm, under the same conditions. As little time as possible was lost between trials.

TABLE IV*

Trials

Individual.......	1	2	3	4	5	6	7
A	3′ 45″	5′ 00″	2′ 00″	3′ 00″	6′ 00″		
B	0′ 30″	4′ 30″	1′ 00″	1′ 1′	4′ 00″		
C	0′ 45″	1′ 45″	0′ 1″	5″ 00″	1′ 30″		
D	2′ 00″	3′ 00″	7′ 30″	3′ 00″	3′ 00″	2′ 15″	3′ 30″
E	1′ 30″	0′ 45″	1′ 30″	1′ 40″	5′ 15″	3′ 30″	

*These measurements include the latent periods.

The number of trials recorded in Table IV is small. I was prevented from collecting more data by the sudden changes of behavior before alluded to. Other animals were tried but failed to react regularly even five times. The results as they stand, however, are worthy of confidence; they are representative of the whole behavior which is varied and uneven; like the measurements of righting time they neither increase nor decrease—the apparent increase being due to the failure to respond, for had this failure occurred sooner, some of the last measurements would have been smaller than the first. Fatigue played no part in the result, as the figures are too uneven.

The objection might be advanced that these cases which I have called "problems," were not such; that there was no reason why the animals should modify their behavior, and that what they did under the conditions of the experiment was nothing that they would not have done under normal conditions. This objection is met satisfactorily I believe by the following experiments.

A given arm was stimulated by encumbering it with a rubber tube, or by painting it with strong or dilute formalin or hydrochloric acid of different strengths. These trials, of which I made a great many, yielded very definite results. In only one case did an animal progress in the direction of the stimulated arm; in a few cases at an angle to it, using it as one of the propellers, whereas in the vast majority of cases it moved in the direction diametrically opposite the stimulated arm. If the stimulus was strong, the movements were very violent, but no difference in direction was noted in the case of weak and strong stimuli. Under ordinary circumstances it is impossible to predict the direction in which an ophiuran, all of whose arms are of the same size, will move, but if one of the arms be encumbered the prediction that the animal will move away from the stimulus will be verified in the vast majority of cases. I think it is justifiable to assert that the direction of progression has been determined in these cases, and if this is true there is a determining cause—a problem.

My second line of inquiry—whether encumbered animals showed a noticeable increase in the number of movements best adapted to solve the particular problem given, was begun by finding the percentage of crosses and contacts in the same animals under the two conditions stated. The results are summarized in Table V.

As contacts and crosses usually result from wavings I counted these in animal *II* unencumbered and with one arm encumbered. The results are summarized in Table VI

The general conclusion to be drawn from these experiments is that there is neither a decrease in the amount of time taken to solve the problem, nor an increase in the relative frequency of movements best fitted to solve it. In other words, the animals did not modify their behavior in accordance with the law of resolution, and consequently, so far as is objectively recognizable, learned nothing.

TABLE V

Animal	Arms Encumbered	Movements	Per cent Contacts	Per cent Crosses	Problems
I	0	231	4.0	2.0	0
I	1	202	3.9	1.9	3
II	0	267	13.8	10.8	0
II	5	553	9.2	11.2	5

TABLE VI

Animal	Arms Encumbered	Movements	Per cent Wavings
II	0	117	26.4
II	1	192	19.3

DISCUSSION

The facts which I have brought forward in the foregoing pages agree with those of Preyer and von Uexküll in showing that in problem solving the animal repeatedly changes its behavior, not persisting in a certain reaction when that is unsuccessful. If I venture to take issue with Preyer, and to assert that the behavior which both he and I observed does not warrant the conclusion that ophiurans are intelligent, I must rest my claim upon the validity of my interpretation of the facts, and this validity I shall now attempt to establish.

The behavior of Ophiura brevispina may be summarized by saying that this animal under normal conditions performs practically all the movements possible to a creature constructed as it is; that except for this limitation, its ordinary behavior is not predictable, and that even the righting movements, because of their variety occupy a place between the ordinary behavior and reflex behavior, for though more definite than the former, they are less precise than those highly perfected types of response which gave us our first idea of reflex action.

Regarding the manner in which ophiurans rid their arms of encumbrances, Preyer ('86, p. 125) says: "Aus den beschriebenen und ähnlich leicht zu variirenden Versuchen ergiebt sich zunächst, dass Ophiuren in 5-fach. verschiedener Weise sich gegen die beim Tasten und kriechen ihnen sehr hinderliche Bekleidung mit einem Schlauche vertheidigen: (1) streifen sie ihn ab durch Reibung am Boden wenn er locker ist, (2) schleudern sie ihn fort durch geissel. förmiges Hin und Herwerfen, (3) drücken sie ihn fest gegen den Boden mit dem freien Nachbararm, und ziehen den Arm aus dem dadurch fixirten Rohre heraus, (4) stemmen sie abwechselnd beide Nachbararme mit deren Zähnchen unten gegen dasselbe und schieben ihn ruckweise ab, (5) brechen sie durch Selbstamputation den Arm mit der unbequemen Bekleidung ab. Hilft dass eine Verfahren nicht, dann wird das andere angewendet. Sehe ich hier von dem letzten, der Autotomie, ab, von der noch die Rede sein wird, so beweist schon die 4-fache Art der Abwehr bei einem und demselben Individuum unter denselben aüsseren Verhältnissen, dass hier kein einfacher Reflex vorliegt. Vielmehr besitzen die Ophiuren die Fähigkeit sich ganz neuen, von ihnen noch niemals erlebten Situationen schnell anzupassen."

"Wenn Intelligenz auf dem Vermögen beruht, Erfahrungen zu machen, d. h. zu lernen, und das Erlernte in neuer Weise zweckmässig zu verwerthen, so müssen also die Ophiuren sehr intelligent sein."

Preyer's reasoning seems to be this: When encumbered on its arms the animal moves in different ways; failing to free its arms by these movements, it moves in other ways, and continues to change its movements until the encumbrances have been removed. The animal thus exhibits the process of discovery by elimination, learning in other words, and is therefore intelligent.

If this indeed be learning, then all movements which any organism may under any circumstances execute are outward signs of the process, for movements are never without cause, and the stimulus is aggravated, alleviated, or unchanged by them. Whatever be the result of the movement, the animal "learns" what has been the effect upon the stimulus, the cause of the movement. Two criticisms may be made of this point of view: In the first place, in behavior such as that of an ophiuran, movements which fail to solve a specific problem, or to contribute anything whatever to its solution, are often repeated immediately. If the animal learned anything from them, it forgot what it learned at the instant of learning, for the intervals between two successive movements which fail for the same reason may be less than one second; to forget as rapidly as to learn, can be objectively recognized as neither. In the second place, in ophiurans at least, it is the exception for an animal to perform only one movement at a time. Usually a considerable number, four, five, or six distinct movements are performed synchronously. All of these, on the assumption I am criticising, result in learning, but the knowledge which they give may be of two sorts; some of the movements may tell the animal how to solve the problem, the others, how it cannot be solved. It is impossible for me to believe, without striking evidence to the contrary, that an ophiuran can learn at the same instant half a dozen facts, belonging some to one, some to the other of two distinct categories.

If the idea that mere movement in various directions is a sign of learning, involves the serious difficulties which it seems to me to involve, we have nothing but behavior more or less permanently modified as the result of experience to fall back upon. I have shown that under ordinary circumstances Ophiura brevispina does not improve with practice, in its righting behavior, and in problem solving it shows no greater aptitude. I am, therefore, forced to the conclusion that neither intelligence nor even learning have as yet been demonstrated in this animal.

My experience with ophiurans also leads me to the conclusion that resolution will be very difficult to demonstrate, not only because of those sudden changes in behavior for which it is difficult to assign causes, but also because of the remarkable "action system" exhibted by these animals. This action system shows better than many others, that behavior is structure in motion, and that complexity of behavior depends on the complexity of that which behaves. An act performed by one arm may also be performed by any of the others. The arms may all do the same thing at the same time; some may do one thing and others another; and finally a single arm may execute different movements at different levels. As the disc itself may also execute varied movements, the number of possibilities is enormous. With this marked versatility to contend with, it is not surprising that resolution, demonstrated according to Jennings ('04, '05, '06) for Protozoa, Cœlenterates, and other forms lower in the scale of complexity than echinoderms, or as low, should remain undemonstrated for ophiurans. The number of movements possible to an ophiuran is immense; if the animal only acts, the chances that it will perform movements fitted to relieve a certain physiological state are better than the chances that such will be the case in most other animals. If one of the many movements that will serve is not performed, another will be, and we should not expect to find resolution, unless the fit things to be done are few. Any of the problems presented might have been solved in a variety of ways. One or more of these ways were superior to any of the others, but all served the purpose. Where the variety of solutions to a problem is great, there is no need of resolution, and it does not occur.

I have profited much by the elaborate criticism which Professor Jennings made of an earlier draft of this paper, and I take this occasion to thank him for his kindness.

University of Michigan
Ann Arbor, Mich.
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LITERATURE CITED.

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