Selection of Food Among Lower Animals

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All animals must eat food in order to live. The higher animals usually do not eat anything that is not food, but some of the lower forms, such as the earthworm, eat a considerable amount of material that is not useful for food. In a general way it has been assumed that the further we go down the scale the less precise is discrimination between food and other materials. This idea has in the past been responsible for the notion that discrimination in food does not occur in the one-celled animals, for these stand at the bottom of the scale. The expectation was, then, that these low forms of animal life ate all the different kinds of particles that they happened upon, whether of food value or not. This opinion was expressed by some of our foremost students of the protozoa, and their opinions have been generally held for a long time.

It was with a view of determining the truth of this notion that I carried out a number of experiments on several of these lower forms. A considerable number of test substances were employed, some of which were good for food, others not. The principal question to be solved was: Can a one-celled animal tell the difference between food substances and those that are not good for food? And if they can tell the difference, how can they tell it?

I wish today to report on a few experiments on stentor and on ameba that were designed to throw some light on these questions. Both stentor and ameba are of about the same size, being just barely visible to the naked eye, and live amid the same general surroundings, in ponds and other bodies of fresh water. These organisms are entirely different in structure. While each consists of only a single cell with a single nucleus, their body structure is as unlike as it can well be.

The stentor has a definite and permanent body shape which is covered with small hair-like organs, the cilia, which function as locomotor organs and also to create a vortex of water directed toward its mouth, by means of which food and other particles are brought to it. The ameba on the other hand has no definite body shape, no definite organs of locomotion, no mouth; it has, indeed, no specialized organs of any sort. Another difference between these two forms is that stentor frequently attaches itself to some solid support, while at other times it swims freely through the water. But the ameba neither fastens itself nor swims in the water; it glides over the surface of submerged objects like a snail does; but unlike a snail, it changes its shape continually, and what is at any given time the head end will be gradually transformed into the tail end.

Of these two forms the ameba is commonly regarded as standing much lower in the scale of living beings than stentor; indeed it is frequently referred to as the simplest animal known. A reference to figures 1 and 2 will serve to make clear to some extent the main characters of these forms.

We shall first take up some of the experimental work on stentor. The method of feeding was simple. A number of particles of the desired kind were sucked up with some water into a pipette of very small bore. The particles were then very slowly dropped on the stentor's disk and the fate of each one, whether eaten or rejected, was noted and recorded. The work was done under a binocular microscope magnifying sixty-five diameters.

As a first experiment I fed a few small organisms, known under the name *Phacus triqucter*, which were ingested; then a number of grains of sulphur were fed, but all of these excepting one, were rejected. Then some more phacus were fed, followed by sulphur grains. Again the phacus were eaten and the sulphur rejected. The experiment showed that the food discriminative powers of stentor as far as they apply to sulphur and food organisms, are nearly perfect.

In other similar experiments stentor discriminated almost perfectly between food organisms and starch grains (which stentor cannot digest), and between food organisms and powdered glass or sand grains. The degree of accuracy in discrimination ranged from about 90 per cent to 98 per cent. The same degree of discrimination was exhibited when a mixed stream of several different kinds of indigestible particles and several different kinds of organisms were fed.

After it was clear that stentor can discriminate between food substances and indigestible particles, the question arose whether stentor selected certain food organisms in preference to other food organisms. To determine this, several different kinds of food organisms were fed in mixed order. At first all the different organisms were eaten, but as the stentor became less and less hungry, one kind after another of the organisms were rejected until some little time before the stentor was satiated, only one kind of organism was eaten. These various food organisms, while they differed but slightly in size, varied greatly in shape of body. The results of these experiments interested me to the extent that I desired to see how delicate the sense of discrimination is in stentor. To test this, I was fortunate in having cultures of two kinds of small organisms that were not closely related, but were almost exactly alike in size and shape. It required a trained eye to tell the difference between them. These two kinds of organisms were mixed in equal numbers and fed to the stentor one by one. At first both kinds of organisms were eaten. As the stentor became less and less hungry, many of both kinds of organisms were rejected. But finally when nearly replete, only now and then would an organism be eaten, and it is very remarkable to observe that all the organisms eaten when hunger had nearly disappeared, *were of one sort;* the organisms of the other sort were all rejected.

We may conclude then that stentor discriminates in food with a degree of precision that is matched only, so far as we know, by that of the higher animals. And the observation that stentor discriminates more and more precisely as hunger grows less, is also paralleled in the higher forms. Even in man does this observation hold. When hungry almost any kind of food is eaten, but when hunger has nearly vanished, only such things as desserts are capable of stimulating the eating mechanism. There is therefore a remarkable degree of similarity in the feeding behavior of the highest animals and of stentor.

The ability to discriminate in a high degree having been shown to exist, the question arises: How is it effected? Since stentor does not possess any of the sense organs we possess, so far as we know, it is interesting to know in what way stentor can tell the nature of the particle that strikes its disk. Can stentor "taste" the particles or "feel" them?

In popular usage the word taste includes a number of qualities which properly do not belong to it. We say commonly, that we taste our food, but in a strict sense there is very little truth in the statement. We taste sugar, a few salts, a few "bitter" substances, and a few "sour" substances. We smell a large number of substances which are practically always associated with our food, but which themselves exist only in small quantities. We smell the essential oils in many fruits, the meat extractives, peptones, etc., but all these are present in very small quantity in the food we eat, and their actual food value is negligible. Most of the proteins (the plant and animal albumins, for example), the starches (whether soluble or insoluble), have no taste in the pure form, and these make up the bulk of our food. It is well known that the cooked white of a hen's egg is not an attractive tasting substance, nor is it really disagreeable; it is merely tasteless. If we had never seen or tasted coagulated egg albumin, and should come upon a mass of it in a place where we would not expect to find food, such as inside of a rock, we would most certainly reject it if tested by taking it into the mouth and chewing it. The reason that we eat it, is that we have learned to eat it, because we have observed that it is non-toxic and that it sustains life. Now this is also the case with the other proteins and the starches. We do not taste these substances themselves, but only the volatile oils which are associated with them. If we ate only what we taste and smell in our ordinary food, we would starve to death or die of acute gastritis. The point is that a number of other factors are concerned besides taste and smell in food selection.

I have called attention to these facts merely to show that there is good ground for discussing the basis upon which selection in food is made.

In order to contribute to the solution of the question: Does stentor learn what is food by tasting and smelling it, or by feeling of it? I carried out a number of experiments on this point which I shall describe briefly.

The main object of the experimental work was to change the taste of the organisms, or to change their form, surface texture, etc., without, so far as possible, changing the taste, to see what the effect would be on the stentor. A number of food organisms, phacus, were cooked and washed. They were then fed with living phacus in a mixed stream. The result was that the hungry stentors ate all the phacus whether cooked or living; and those that were partially satiated ate a few of both sorts and rejected the greater number of both. Other phacus were treated with iodine, quinine, acids, dyes, etc., then washed and fed with living phacus in a mixed stream. But again there was no selection. Cooking phacus and treating them with various chemicals should change their taste; nevertheless whatever change was thus produced, was without effect in their discrimination of food.

In other experiments the living food organisms were mashed up into a jelly. The form of the organisms was thus completely destroyed. This jelly was rejected. Not any of it was eaten. But if the food organisms were cut up into quarters or eighths, the pieces were eaten. In a few experiments starch grains were soaked for a few minutes in the jelly of the organisms and then fed to the stentor without washing. None of the starch grains were eaten. Starch grains were also soaked in raw beef juice, pork juice, pepsin, Liebig's Extract of Beef, sugar, etc., but in no case was starch so treated eaten.

Now taking all these experiments together, we see that when the taste of the food objects was altered, no change in discrimination resulted; but when the form and texture of the food substances were changed, marked effects on discrimination were observed. This leads to the conclusion that the stentor selects its food by a tactual sense; that the chemical sense, if the stentor possesses any, plays little part in the process. This conclusion need not be surprising. For what sort of a taste may a living animal have when it is swallowed whole with a quantity of water? It is only the excretory products that diffuse out into the water from a living animal. The albumins and other proteins, carbohydrates and fats do not diffuse out into the water, and these substances are practically the only food substances in the animal.

Some attempts were made to analyze the basis of selection still further, but without much success. However, it is pretty certain

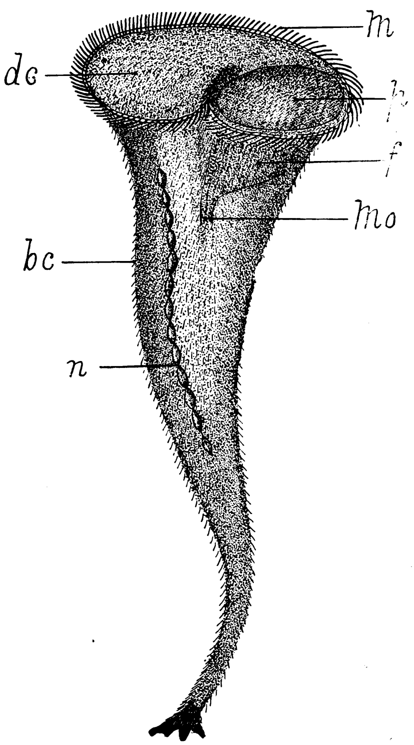

FIG. 1. The Blue Stentor (Stentor caeruleus Ehr.). *bc,* body cilia; *dc,* discal cilia; *m,* membranellae; *f,* funnel; *mo,* mouth; *p,* pouch; *n,* nucleus. A stream of water is brought against the disk by the action of the membranellae, *m.* Particles in the stream of water impinge upon the disk whence they are slowly carried to the pouch and funnel. If the particles are of food value they pass down through the mouth, *mo,* into the internal protoplasm; but if the particles have no food value, they are thrown out over the edge of the pouch. The stentor is shown in normal extended position attached to some solid support. Natural size of stentor, about three-quarters mm. long.

that selection is affected by more than a single quality affecting the tactual senses, such as weight, size, surface texture, form, etc. To stimulate the feeding mechanism, several of these factors must be present in a certain degree or form of expression; more than one of these factors serves as a basis of discrimination.

These experiments on stentor indicate that in the matter of food selection stentor compares favorably with the higher animals. The problem of food selection evidently does not begin with animals like stentor, for it is highly developed here. I was interested in knowing therefore whether in ameba, which as was said above, is supposed by many to be the simplest animal living, the problem of food discrimination begins; that is, whether there is any sign that the power of discrimination resides in ameba.

The method of work was as follows: A single particle of the substance which it was desired to test, was placed some distance ahead of the ameba, by means of very fine glass needles. Camera lucida drawings of the outline of the ameba were then made at intervals of about half a minute, as the ameba moved ahead. In this way a complete record of the behavior was obtained.

Instead of using living organisms for feeding ameba, isolated chemical substances were used. It was thought that by so doing the interpretation of the behavior would be simpler, for instead of having to do with a number of substances which are present in an organism, only one substance can be the cause of whatever changes are noticed. The number of variables and unknowns is thus reduced to the minimum.

The first question to be solved was: Does ameba possess the power of discrimination in food? It did not require many experiments to show that it does possess this power. In a general way we may say that, excepting carmine, which is eaten, only digestible substances are eaten. Not only does this hold true for organisms, living or dead, but for isolated proteins, such as the globulins and the albumins. Globulin, which is said to be insoluble, is readily eaten; but egg albumin, which is very soluble, is very seldom, if ever, eaten. Feeding experiments with ameba have not been carried as far as with stentor, but from the work that has been done, it seems safe to say that the power of discrimination is as highly developed in ameba as in stentor.

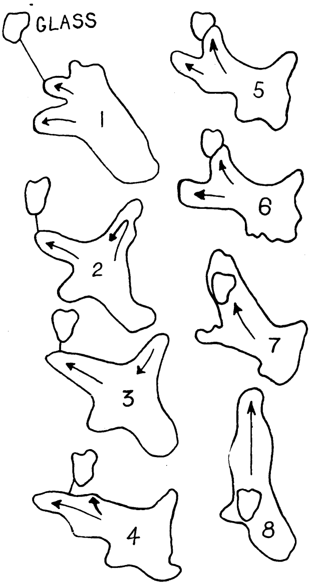

FIG. 2. Eight stages in the movement of an ameba (Amoeba proteus Leidy) drawn at intervals of about half a minute. A particle of glass was laid in the ameba's path, 1. The ameba became a little uncertain in its movement, 2. As the ameba moved forward past the glass, a small pseudopod was thrown out directly toward it, 4. This pseudopod became the main pseudopod through which the ameba moved away over the glass without any further change in behavior incident to the glass. Stage 4 illustrates the sensing of glass at a distance. Natural size of ameba, about one quarter mm. in length. The arrows indicate the direction of movement of the protoplasm.

More interesting than the fact that ameba can discriminate in food is the observation that an *ameba can sense objects at a distance.* Not only is this true of soluble particles, but of insoluble as well. A fragment of clean glass, one-twentieth millimeter in diameter, is sensed by an ameba at a distance of one-tenth millimeter. That is, the ameba moves toward the glass particle in a direct line after changing its direction, if the particle is placed to the side of the ameba's probable path. This has been observed in a number of cases, so it cannot be said that it is a matter of coincidence only.

Reaction to an object at a distance by an ameba is a remarkable phenomenon, for this animal has no specialized sense organs of any sort. This makes it difficult to determine how the presence of the particle of glass is sensed before contact is made. Glass is, of course, very slightly soluble, but it must be remembered that the observation was made with the ameba moving on a glass surface; so that even if the glass particle was soluble, its effect on the ameba was cancelled by the solubility of the glass surface over which the ameba moved, the glass particle being a fragment of the dish in which the experiment was made. See Fig. 2. Some work has been done to determine in what way the ameba senses insoluble particles at a distance, but no definite conclusions have been arrived at. This work is still in progress.

From the work on stentor and on ameba it may be concluded then that the unicellular animals possess the power to discriminate in food, and that they exercise this power in a high degree. The observations on ameba show also that an unlooked for sense, that of becoming aware of objects at a distance, is present in ameba.