THE SENSE OF SMELL IN FISHES

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INTRODUCTION.

That fishes scent their food in the water much as many land animals do in the air is a belief that is held by many fishermen. This opinion has led to the practice of chumming or baiting up; i. e., of spreading bait in a region preparatory to fishing it, a practice that, in the case of sharks, mackerel, and bluefish, seems to be justified by the results. Such practice is based on the assumption that fishes have a sense of smell, but this opinion has been unsupported by physiological evidence, for up to the present time investigators of the subject have not been able to demonstrate any form of stimulation or reaction characteristic of the olfactory apparatus in water-inhabiting vertebrates. The observations of Aronsohn (1884, p. 164) that a goldfish which ordinarily will eat ant pupæ with avidity will not take these pupæ after they have been smeared with a little oil of cloves, are not conclusive evidence that the fish scents the oil, for it is entirely possible that this oil merely irritates the skin of the fish's snout and does not stimulate the olfactory apparatus at all. Nor is the discovery made by Steiner (1888, p. 47), that the spontaneous appropriation of food by the shark *Scyllium* ceases on the removal of the cerebral lobes or simply on cutting the connections between these lobes and the olfactory bulbs, satisfactory evidence that the olfactory apparatus in these fishes is an organ of smell rather than a receptor for taste or some closely allied sense.

Nagel (1894, p. 184) noted that the rostral portion of the head of *Barbus* was as sensitive to sapid substances after the olfactory tracts had been cut as before that operation, and Sheldon (1909, p. 291), studying the dogfish, demonstrated that the decided sensitiveness of the nostrils of this fish to weak solutions of oil of cloves, pennyroyal, thyme, etc., was not influenced by severing the olfactory crura, but disappeared on cutting the combined maxillary and mandibular branches of the trigeminal nerve. Evidently the nostrils of fishes, like those of the higher vertebrates, are innervated by fibers from the trigeminal nerve, and it is this nervous mechanism rather than the olfactory apparatus that is stimulated by the substances that have ordinarily been applied by experimenters. In fact, so far as the olfactory apparatus of the fishes and amphibians is concerned, we must agree with Nagel (1894, p. 61) that no one thus far has discovered anything positive concerning its function. It is, therefore, a matter of interest to record what seem to be unquestionable reactions dependent upon the olfactory apparatus of three of our common fishes: The fresh-water catfish (*Ameiurus nebulosus*), the smooth dogfish (*Mustelus canis*), and the killifish (*Fundulus heteroclitus*). The work on *Ameiurus* and *Fundulus* was done by G. H. Parker, that on *Mustelus* by R. E. Sheldon.

EXPERIMENTS WITH AMEIURUS.

Ameiurus nebulosus is a bottom-feeding fish possessing fair powers of sight and unusual gustatory organs located not only in the mouth and on the general outer surface of the body, but especially on the eight barblets about the mouth (Herrick, 1903). It is a hardy fish, living well in confinement and undergoing operations with success. It possesses near its anterior end a pair of nasal chambers, each of which is provided with two apertures, one anterior, the other posterior. The anterior aperture is nearly circular in outline and is located on a slight conical elevation somewhat anterior to the root of the dorsal barblet. The posterior aperture is slit-like in form and lies immediately posterior to the same barblet. The anterior aperture is apparently always open; the posterior one seems capable of slight closure, but is usually freely open.

By keeping catfishes a few days without food they can be made most eager for it, and if into an assemblage of such individuals a few fragments of fresh earthworms are dropped, the excitement that ensues will last some time after the final piece of worm has been swallowed. During this period the fishes swim about actively in the lower part of the aquarium, now in this direction, now in that, and frequently sweep the bottom with their barblets. As can be noticed when feeding actually occurs, the fishes seldom seize a fragment of worm until their barblets have come in contact with it. Yet before they have thus touched any food they show a marked degree of excitement and it is this initial nervous state that would lead an observer to suspect that they scented their food. This phase of their activity was, therefore, taken as the one to be tested in connection with their olfactory organs.

The nasal chambers of the catfish contain ciliated epithelium, the action of which is to draw water in at the anterior olfactory opening and discharge it at the posterior one. As can be demonstrated with carmine suspended in water, the passage through the chamber is accomplished in 8 to 10 seconds.

As a preliminary step in testing the catfishes, five normal fishes were placed in a large aquarium over night that they might become accustomed to their surroundings. In this aquarium were then hung two wads of cheesecloth, in one of which was concealed some minced earthworm. The fishes, which were swimming about near these wads, were then watched for an hour and their reactions in reference to the wads were recorded. The wad without worms was passed by the fishes many times and did not excite any noticeable reaction. The wad containing the worms was seized and tugged at eleven times in the course of the hour, notwithstanding the fact that from time to time this and the other wad were interchanged in position. Not only did the fishes thus openly seize this wad, but when in its neighborhood they would often turn sharply as though seeking something without success, a form of reaction seldom observed near the wad which contained no worms. Two other sets, of five normal fishes each, were tested in this manner and with similar results. It was perfectly clear to anyone watching these reactions that the fishes sensed the difference between the wad of cloth with worms and that without worms.

To ascertain what receptive organs were concerned in the reactions just described, two sets of 5 fishes each were taken from among the 15 normal fishes already tested, and each set was prepared differently by subjecting its members to a special operation. One set was etherized, and, through a small incision between the eyes, their olfactory tracts were cut, thus rendering their olfactory apparatus functionless. From fishes of the other set all the barblets were removed, whereby their external gustatory organs were partly, though not wholly, eliminated. After these operations both sets of fishes were liberated in the large aquarium, where they remained for over two days. At the expiration of this time, they were carefully inspected and tested. They swam about in an essentially normal way and members of both sets snapped bits of worm from the end of a hooked wire much as a normal fish does. Presumably they were in a satisfactory condition for experimentation.

The tests were begun by introducing into the large aquarium containing the 10 fishes a wad of cheesecloth within which were hidden some minced earthworms and recording the kind of fish that visited it and the nature of their reactions. During the first hour the wad was seized 34 times by fishes without barblets but with normal olfactory organs and, though often passed by fishes with cut olfactory tracts, it was "nosed" only once by one of these. A wad of cheesecloth without worms was next substituted for that with worms and the reactions of the fishes were recorded for a second hour. Though members of both sets frequently swam by this wad, none at any time during the hour seized it or even nosed it. These tests were repeated on the same fishes for two succeeding days and with essentially similar results. On the second day the wad with worms was seized 16 times during the test hour by fishes with normal olfactory organs and on the third day 54 times. On both these days the fishes with their olfactory tracts cut made no attempts on the wad with worms nor did any fish at any time nose the wormless wad. The movements of the two sets of fishes when in the neighborhood of the wad containing minced worms were characteristically different. The fishes with their olfactory tracts cut swam by the wads without noticeable change; those without barblets, but with their olfactory apparatus intact almost always made several sharp turns when near the wad as though seeking something, and then either moved slowly away or swam more or less directly to the wad and began to nose and nibble it. These reactions were so clear and so characteristic that when taken in connection with the conditions of the fishes, they lead inevitably to the conclusion that the olfactory apparatus of the catfish is serviceable in sensing food at a distance much beyond that at which the organs of taste are capable of acting; in other words, catfishes truly scent their food.

EXPERIMENTS WITH MUSTELUS.

The experiments here recorded were performed on the smooth dogfish, *Mustelus canis* (Mitchell). This was selected owing to its great abundance in Buzzard's Bay near Woods Hole, and also because previous experimentation (Sheldon, 1909) rendered many of its habits and reactions familiar.

Bateson, Nagel, and others believed that selachians recognize their food through the sense of smell; their evidence is, however, valueless in this connection owing to the fact that irritating substances were used as tests, or else no distinction between smell and other chemical senses was made. Mr. Vinal Edwards, collector for the Woods Hole Laboratory of the Bureau of Fisheries, states that it is the custom in fishing for dogfish to throw out in the tide lines baited with menhaden or alewives. For a time no dogfish will be seen, then they will appear in numbers, swimming around the bait in gradually diminishing circles until finally it is seized. Field (1907) finds that the dogfish carefully search the bottom for crabs. Finding one they turn on their sides to seize it, then dart off quickly, shaking the crab as a terrier would a rat. After swallowing the food, Field states that the dogfish keeps up its active swimming, often returning to the place where the crab was found.

Some experiments on the relation of the olfactory apparatus of the dogfish to its feeding habits were undertaken in the summer of 1908, but failed owing to the fact that the fishes refused to eat in captivity. These experiments and those of Field show that dogfish will not eat if kept in large tanks or even in the large cod cars of the station, even though they are kept in captivity to the point of emaciation. In order, therefore, to give them a habitat comparable to the normal, a portion of the large observation pool of the station was fenced off with meshed wire. This gave a pool 24 feet long, 8 feet wide at one end, and 10 feet wide at the other, with normal sea bottom, an irregular stone wall on three sides, and a depth of water of from 2 to 8 feet, depending on the portion of the pool considered and the height of the tide. Tufts of eelgrass, together with many other varieties of sessile marine life, grew on the botttom and sides. The pool, therefore, fulfilled to a reasonable degree the conditions of normal life, so far as the dogfish are concerned.

The individuals used were those caught in the traps from day to day and placed in the pool for a period of 10 days in order to bring about a state of hunger.

Spider or blue crabs were first offered the dogfish, but were always refused. The rock crab, *Cancer irroratus*, was next tried, with success, and used for all the experimental work. All experiments were conducted at low tide, when it was easy to observe the actions of the individual fishes. At first living crabs were used. These were found by the dogfish in from 10 to 15 minutes. Next, crabs were killed and a hole broken in the carapace, exposing the flesh. Such were found in from 2 to 5 minutes. These results suggest at the start that the food is recognized through the diffusion of animal juices into the water. Crabs killed, with the flesh thus exposed, were used for all further work.

In a total of about 40 experiments the method of feeding was the same in all cases. The dogfish spent most of the time swimming lazily around the pool, usually close to the sides. Now and then the direction was reversed, but at no time was there observed any search over the bottom or the rocks forming the sides of the pool. When a crab was placed in the pool, a few minutes was required, as noted, before any evidence of stimulation was to be seen. Then one of the dogfish which happened to be swimming within 3 or 4 feet of the crab seemed suddenly startled. It turned very quickly, and swimming with quick, nervous motions, instead of the calm, lazy movement of the unstimulated fish, began a systematic search over the bottom, investigating particularly grassy or uneven spots. The head was moved rapidly from side to side as the fish swam slowly, coursing, in gradually diminishing circles, 2 or 3 inches from the bottom. When within 2 or 3 inches of the crab the dogfish seized it suddenly, making off in a swift rush. As remarked by Field, the crab is shaken violently from side to side for a moment, as the shell is crunched and broken by the powerful jaws of the fish, after which it is quickly swallowed. Occasionally, however, the crab is dropped during the process; when this occurs, a search similar to the first follows until it is found again.

At no time did the dogfish appear to make any use of the sense of sight in feeding. A crab hidden in eelgrass is found as quickly as one lying on the open bottom; moreover, one is found with equal promptness whether lying on its venter, exposing the dark carapace, or on its dorsum, with the light-colored venter showing conspicuously. A dogfish, dropping a crab, is apparently unable to find it again excepting by means of the same sense which enabled recognition of food in the first place. It was observed, however, that a dogfish with food is usually followed by others in the vicinity, which endeavor to secure possession of it. Moreover, the fish will frequent for some time thereafter the region of the pool in which food was found. This is probably due to olfactory stimuli, although sight may be brought into play to a slight extent. It was often noted that a dogfish would circle around the spot where a crab had lain, often biting into the bottom at the exact spot; probably some body juices had escaped into the ground. Now and then a crab was placed on the bottom near the screen separating the experimental from the larger pool. If no fish capable of finding food were present in the former, it would often happen in a few minutes that 8 or 10 dogfish from the large pool would be swimming rapidly back and forth along the screen, endeavoring to find their way through.

Some experiments were tried with a hook and line baited with the flesh of a rock crab tied in cheesecloth. The dogfish here follow the same procedure as when the crab lies on the bottom. On noting the proximity of food the fish begin to swim, as before, in circles, but for a time persistently search the bottom beneath the baited hook. At length they gradually rise, turning somewhat sidewise, as stated by Field, to seize the bait. When the food is lying on the bottom this sidewise turning was never observed

Observation of the feeding habits of the dogfish would indicate, then, that it recognizes its food through some chemical sense. To test this the following experiments were performed:

Some fresh eelgrass was secured and two packets, closely resembling each other, were made, one containing a small stone, while the other inclosed a crab. Both were so tied that when placed in the water a foot apart a portion of the grass rose toward the surface, giving an appearance similar to the grass of the pool. In three sets of experiments the presence of food was detected in an average time of three minutes, the packet found by the usual procedure, torn apart, and the crab eaten. At no time did the packet containing the stone receive the slightest attention.

Next two packets of white cheesecloth of a similar size and appearance were made up. One of these contained a stone, the other a crab. This experiment was repeated four times on different days. The packet containing the crab was found in each case in from 3 to 5 minutes, while the one with the stone was never molested. The two packets were placed from 10 inches to 3 feet apart. Once or twice a dogfish which had eaten a crab would return and, circling about the spot where the crab had been found, would approach the packet containing the stone in an inquiring sort of way but at no time touched it. The packet containing the crab was always shaken and bitten until the food could be removed and eaten.

A crab was killed and a piece of white cheesecloth saturated in its juices. This was then attached to a small stone. In two experiments the presence of a food substance was noted in two minutes. The stimulus was located by the usual circling method and the stone, with its saturated cloth, seized again and again and shaken violently. After a half hour the fish took no further notice of it, probably because of a complete diffusion of the juices in the water.

In all the above experiments a number of different sets of dogfish were used. There were usually from 6 to 8 fish in the pool at a time. Normally only one or two experiments a day were performed, in order that there be no interference between them.

These observations show beyond doubt that the dogfish obtains its food through the use of a chemical sense. Experiments were now undertaken to find out what part the olfactory apparatus plays in these reactions.

Four dogfish which had eaten readily when in the normal condition were removed from the pool and their nostrils stuffed with cotton wool; in two of the cases the cotton was covered with vaseline. When returned to the pool such fish rush about violently for a few minutes, as do all dogfish which have been out of water. They soon, however, quiet down and swim about the pool as do the normal fish. Twenty-four hours later three crabs were placed, an hour apart, in the pool, which now contained, in addition, four normal fish. All were found, in the usual manner and length of time, by the fish without cotton in the nostrils. At no time did any of the individuals with the nostrils filled show the slightest interest in the crabs, although such often swam within a few inches of the food. Moreover, these fish made no attempt to follow those which had secured one of the crabs, although the food was occasionally dropped. It was often observed that two dogfish, one normal and the other with the nostrils filled, would be swimming along the wall side by side when they approached the vicinity of the crab; the normal fish would then make the usual sudden turn to search for food, while the individual with the cotton continued on its way with no change in the lazy swimming movement. As it was noted that vaseline or a close packing of the nostrils with cotton caused suppuration in time, this experiment was repeated three times with the cotton loosely packed. Results similar to the above were secured in all cases. Two tests were made, also, in which there were no normal fish in the pool. In these cases the crabs were left untouched for 24 hours, although the dogfish on the opposite side of the screen became much excited.

Three of the dogfish, all of which had eaten readily before the use of the cotton, but which had refused to do so thereafter, although tested for three successive days, were removed from the pool and the cotton withdrawn from the nostrils. These were returned to the pool, which now contained no normal fishes. The following day one of these ate readily in the usual manner, although there seemed to be slightly more difficulty than usual in finding the crabs, both in the first place and after one had been dropped. A day or two later all three ate as usual. This experiment was repeated twice with the same results.

These experiments indicate that the dogfish normally recognize the proximity and location of food through the use of the olfactory apparatus. It may be argued, of course, that the mere presence of the cotton in the nostrils renders the fish so uncomfortable that it refuses to eat, even though it act otherwise in a perfectly normal manner. To obviate this objection four dogfish were removed and one nostril only stuffed with cotton. These four only were now placed in the pool. One of these, within an hour thereafter, caught a crab after the usual preliminary procedure, but lost it and then seemed to take no further interest in the matter. The following day all four ate as usual. It was noticed in this experiment, also, that the dogfish had rather more difficulty than normally in finding the food, but that this wore off in a couple of days. These four fish were removed after four days, and seven others, fixed in the same way, were substituted. The results were the same. These tests show that the presence of the cotton is not sufficiently irritating to interfere seriously with the normal feeding habits of the dogfish. As remarked earlier, individuals with the nostrils plugged act, except in so far as the feeding habits are concerned, just as do the normal fishes. As both kinds swim about the pool, such could not be identified by an uninformed observer.

The nasal apparatus of the dogfish consists of a pair of large capsules, partially divided into two parts by means of a superficial and inclosed flap of skin rostrally and a fleshy ridge caudally. There are thus two incompletely separated apertures, a rostrolateral and a caudomedian, the latter closer to the mouth. (See Sheldon, 1909, fig. 3.) The capsules contain a double row of lamellæ, extending laterally from a median ridge much as do the barbs from the rachis of a feather. This ridge extends from the more lateral to the more medial opening. The lamellæ are innervated by an enormous number of short olfactory nerve fibers which terminate in the large olfactory bulbs, closely apposed to the capsules. The nervus terminalis of Locy also sends a few fibers into the lamellæ, while the capsules, in general, are innervated for tactile and general chemical sensation by the nervus maxillaris trigemini.

During the ordinary movements of respiration, as water is taken into the mouth, a current is, by suction, drawn through the nostrils, entering the more rostral and leaving at the more caudal aperture, to be drawn farther, to some extent, into the mouth. This may be easily demonstrated by fastening a dogfish on its dorsum and expelling, from a pipette, a colored solution rostrally of the nostrils. The current, then, follows the median ridge, a part being diverted laterad between the lamellæ. The shape and position of the fleshy ridge and flaps of skin are such, also, that a fish in forward locomotion forces water through the nostrils. A dogfish is, therefore, whether in motion or at rest, constantly receiving through its nasal capsules a current of water.

EXPERIMENTS WITH FUNDULUS.

The olfactory apparatus of the killifish, like that of the catfish, consists of a pair of sacs each provided with two apertures, one anterior, the other posterior. The anterior olfactory aperture is just above the upper lip and dorsal to the angle of the mouth. It is a small roundish opening not unlike one of the pores of the lateral line system and is on the summit of a low elevation. The posterior aperture is an elongated slit somewhat dorsal to the anterior limit of the eyeball. The mouth of the posterior aperture is partly occupied by a valve-like fold of skin.

If the quiescent head from a freshly killed *Fundulus* is examined in water, no motion is observable about the olfactory apertures. Suspended carmine is not carried into them nor discharged from them; in other words, there is no evidence of a ciliary current passing through the olfactory sacs such as is so easily demonstrated in the catfish. If a head in which the respiratory movements of the gills are still in progress is examined, well-marked currents can be demonstrated in the olfactory organs. Suspended carmine is taken in at the anterior aperture and discharged from the posterior one. With each respiratory movement, the valve in the posterior aperture opens, a small amount of water is discharged, and it then closes. This passage of water through the olfactory apparatus is apparently due to the changes of pressure produced by the rhythmic activity of the muscles of the gills probably acting in conjunction with valves within the olfactory sacs. The movement of the valve at the posterior aperture follows exactly that of the respiratory apparatus and its automatic character is obvious from the fact that if an anterior aperture in an active fish is closed by having its walls stitched together so that no current of water can enter the sac at that point, the posterior valve of the same side ceases to pulse, though that of the other side continues in normal activity. If, now, the closed aperture is reopened by removing the stitches, the valve previously quiescent begins again to pulse. Thus, though *Fundulus* has no continuous current through its olfactory sacs, such as the catfish has, it does have a well-developed intermittent current that is not inappropriately designated as respiratory, though this current is in no direct way concerned with the respiratory function. Apparently as long as the gill muscles of *Fundulus* carry out the respiratory movements, currents of water run through the olfactory sacs.

As a preliminary test to ascertain whether *Fundulus* could discover hidden food or not, packets of cotton cloth containing dogfish meat wrapped so as not to be visible and packets made of nothing but cotton cloth were hung in an aquarium in which there were a number of hungry *Fundulus*. After the packet had been thoroughly soaked in the sea water, the reactions of the fishes to them were watched. The packets without meat were occasionally approached and seized, but soon dropped. Those that contained meat were sooner or later surrounded by most of the killifish, which carried on a vigorous competition as to which would have possession of the packet. Frequently the first comer would not only seize the packet and tussle with it, but would often attempt to drive off other fish that had approached the region, attracted apparently by the movements of the first fish. These preliminary tests showed quite conclusively that the normal killifish responds very quickly and in a characteristic way to hidden food.

It was also quite evident from these tests that the killifish, in strong contrast with the catfish and dogfish, uses its eyes as well as its chemical senses in seeking and retaining its food. If a small piece of dogfish flesh is dropped into an aquarium in which there are hungry killifish, one is almost sure to pounce upon the fragment and swallow it quickly. This action is so sudden and begins when the fish is at such a distance from the bit of flesh that it is evidently controlled through the eye. That it is not entirely so, however, is seen from the fact that if a small ball of filter paper is thrown into the water, this too is pounced upon and taken into the mouth but soon discharged. Thus the sight of an object must be followed by an appropriate stimulus of smell or taste, if the object is to be swallowed.

It is the eye, apparently, that leads killifish to swim to a packet of plain cloth and seize it, even though it contains no food. The fact that the fishes do not remain about such a packet long, however, shows how clearly they distinguish it from a packet in which meat is hidden and around which they will gather and tussle for long periods of time. The use of the eye in the preliminary steps of search for food is shown in the amusing habit that these fish have of chasing drops of water down the glass face of an aquarium as if they were bits of food. The eye, then, in *Fundulus* is serviceable in the initial stages of procuring food, but whether the material is to be persistently nibbled and finally swallowed depends, as the preceding tests show, on senses other than sight.

The part played by the olfactory organs in reactions to hidden food can be determined by first eliminating these organs and then testing the fishes. The olfactory apparatus can be rendered inoperative by cutting the olfactory tracts in a position where they are easily accessible as, for instance, between the eyes. In this situation a small incision can be made through the thin bony roof of the skull and the two tracts can be cut by a single movement of a narrow blade. Twenty-four hours after such an operation the fish were fully active, took food, and in all obvious ways seemed normal. When two packets of cloth, one with dogfish meat hidden in it and the other without this food, were suspended in the aquarium in which the operated fishes were, these animals nibbled temporarily both packets in a way that made it impossible for an uninformed observer to distinguish one packet from the other. When these two packets were transferred to an aquarium of normal fish, the one containing the food was soon surrounded by a vigorously contesting assembly of fishes, whereas the packet without food was only occasionally nibbled. The evidence from these experiments favors the view that the olfactory organs are necessary to *Fundulus* in sensing hidden food. The severity of the operation, however, renders this evidence not wholly conclusive.

In order to carry out tests in which the objection could not be raised that the results might be due to the shock of cutting nerves rather than to the loss of a sense organ, the following procedure was employed: By taking two stitches of very fine silk thread, one on either side of the external olfactory aperture, it was comparatively easy to close this aperture, and thus to prevent any passage of water through the olfactory sacs. Killifish which previous to the operation gave markedly different and characteristic reactions to the two classes of packets already described reacted to both kinds of packets after their anterior olfactory apertures were closed, as they had previously done to the packets that contained no food. That this reaction was not to be directly attributed to the operation of stitching up the apertures was demonstrated in two ways. If, after the stitches were taken, the thread was not drawn up and tied so as to close the aperture, but the ends were allowed to remain free, the fish would react as normal fishes do to the two classes of cloth packets, thus showing that the mechanical injury due to the stitches themselves did not influence the fish in any essential way. Further, if fishes whose anterior olfactory apertures had been closed by stitching and tying, and whose discrimination for the two classes of packets had thereby been lost, had their olfactory apertures reopened by cutting and removing the thread, they very soon regained their capacity to distinguish packets with food from those without food; in other words, they soon returned to the condition of normal fishes. For these reasons it is believed that stitching up of the anterior olfactory aperture is in itself not a disturbing operation for the fish and that the loss of the ability to recognize the presence of hidden food is in reality due to the loss of the olfactory function.

CONCLUSIONS.

Whether such olfactory reactions as those that have just been described are really due to smell or not is regarded by some authors as an open question. Nagel (1894, p. 56), who has discussed this matter at some length, concluded on rather theoretic grounds that fishes could not possibly possess a sense of smell and that their so-called olfactory organs act more as organs of taste than of smell. Possibly the whole matter is merely one of definition. With human beings smell differs from taste chiefly in the concentration of the stimulating solution and not, as was formerly supposed, on the state of the stimulating material, for, though we usually say that we smell gaseous or vaporous materials and taste liquids and solids, all these substances are in reality dissolved on the moist surfaces of whichever sense organ they stimulate. The most striking difference between smell and taste with us is that we smell extremely dilute solutions and taste only very much more concentrated ones. As a result we recognize the presence of many distant bodies by smell and not by taste, for the very minute amount of material that reaches us from the distant body will form a solution on our moist surfaces that will be stimulating for our organs of smell, but not for our organs of taste. Hence our olfactory organs as compared with our organs of taste are what Sherrington (1906) has called distance receptors, a designation justly emphasized by Herrick (1908). Although this distinction between taste and smell is one of degree rather than of kind, it seems to us reasonably sound, and it certainly holds in the case of fishes much as it does with human beings, for these animals respond through their olfactory organs to solutions too dilute to affect their gustatory organs, and the nature of the response to olfactory stimulation (seeking food, etc.) is such that the olfactory organs in these fishes can be called appropriately distance receptors. We, therefore, believe that the fishes, although water-inhabiting animals, possess olfactory organs that are as much organs of smell as are the olfactory organs of the air-breathing vertebrates.

SUMMARY.

1. A current of water passes through the nasal chambers of many fishes in a direction from anterior to posterior. It may be produced by ciliary action (*Ameiurus*), by pressure due to the action of the respiratory muscles (*Fundulus*), or it may be a part of the true respiratory current (*Mustelus*).

2. By means of this current dissolved substances in the water are brought into contact with the olfactory surfaces.

3. Fishes distinguish packets containing hidden food from similar packets without food.

4. This power of distinguishing the two classes of packets is lost when the olfactory tracts are cut, when the anterior olfactory apertures are stitched up or when the apertures are plugged with cotton wool. It is revived on reopening the apertures by taking out the stitches or removing the cotton wool.

Mustelus and *Ameiurus* discover their food chiefly through the olfactory sense; *Fundulus* uses the eyes in addition to the olfactory organs for this purpose.

6. *Mustelus*, *Fundulus*, and *Ameiurus* use the olfactory organs to scent food much as land animals do; these organs are true organs of smell, i. e., distance receptors for the chemical sense.

POSTSCRIPT.

Since the preparation of this paper, confirmatory results have been obtained by Copeland (1912) on *Spheroides*, and our attention has been called to the earlier papers by Baglioni (1909, 1910) on *Balistes*, etc., in which, however, the reactions of the fishes are assumed, rather than proved, to be dependent upon the sense of smell.

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