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THE CHEMICAL SENSES OF BIRDS

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All living matter communicates chemically. Although we initially think of taste and smell when we discuss chemical senses, the body is a network of chemoreceptors. The carotid sinus, which regulates respiration, responds to the level of carbon dioxide in the circulating blood. Taste and smell are specialized chemoreceptors that respond to the chemistry of the environment.

You can see this communication in its most primitive form if you apply acid to an amoeba. The amoeba will withdraw from the acid. You may want to classify this response as irritability but it also is one of the most primitive examples of chemoreception. In the anemone the first differentiation of senses can be observed. One area responds to touch whereas there are specialized areas that respond to food stimuli. A piece of rotting meat in a stream will soon be covered with planaria. Apparently these flatworms use their chemical senses to guide them to the meat. The chemoreceptors in fish are located on the sides of the body. Catfish have some taste buds on their barbels-the ideal place for them-because when they turn their bodies they can chemically scan large areas for food. Blind fish exist in caves in Mexico. They have, in the water near the cave, first cousins that are not blind. The blind fish have many more taste buds than their sighted first cousins. These taste buds have developed in the blind fish to meet its greater dependence on the chemical senses. A frog has chemoreceptors in its buccal cavity; in addition frogs respond to some stimuli applied to the skin. All airbreathing animals have their taste buds concentrated in the mouth.

Birds are not concerned with the odors of their immediate environment. To a chicken, a starling or a cowbird, the odors of its environment are of little or no consequence. I am not saying that birds do not have the apparatus for olfaction, nor am I saying that no bird can smell. The kiwi of New Zealand is almost totally blind and does sniff. They do have "nostrils" on the tip of the bill. However, they are an unusual exception. If we place highly odoriferous material under one of two food choices and present them to domestic chickens or starlings, their choice behavior is not affected. Surgical ablation of the olfactory lobes in the domestic fowl does not alter its food preference behavior. The point here is that in most birds, odor is of little or no behavioral significance.

What do we mean by taste? When I talk about taste, I am not talking simply about taste, that is, a chemical stimulus affecting a gustatory receptor. I am talking about all the sensations one experiences when ingesting food. You cannot taste the difference between raw mashed potato and raw mashed apple if you close off your nose. When you say an apple tastes good, you really mean it smells good. You automatically incorporate olfactory information with taste information. You automatically incorporate temperature information. The temperature and pain receptors are near the taste receptors. You know that cold milk and hot milk taste differently, cold beer and hot beer, cold wine and hot wine. Even visual information will modify what you taste. Try to eat two fried eggs with black yolks or try to eat blue cereal. Even with no chemical difference in the stimulant many factors can modify your taste experience. The point I want to make is that variables have a special role related to the species. In birds, for instance, smell is of little consequence; however, temperature is very important. A bird will discriminate between two choices of water, one at room temperature and the other a degree or two above room temperature. Birds will suffer from acute thirst rather than drink water a few degrees above their body temperature. On the other hand, water close to freezing does not offend birds. Viscosity does not seem to affect the response of many birds to the acceptance of fluid. However, visual information is very important to the bird. It is the only domestic animal with color vision.

I can introduce you to the differences in taste worlds of animals with one illustration. If you take a 10 - 12% sucrose solution, and its equivalent in saccharine, you find that most humans will say that the solutions are sweet and pleasant tasting. But, a small percentage of humans have limited ability to taste sucrose, and a slightly higher percentage find a bitter component to saccharine.

If you offer these same solutions to laboratory rats, the rats will avidly select both, suggesting that their reactions are somewhat akin to our own. Psychologists until recently worked almost exclusively with rats, and their conclusion was that the sense of taste in most animals was similar to ours. However, a calf will respond to sucrose much better than we do. Low concentrations of sucrose solution (1%), which we find insipid or barely perceptible, will be chosen almost 100% of the time in a choice situation. Calves will not respond to saccharine at this concentration. Chickens, grackles, cowbirds or laughing gulls will respond to sucrose but saccharine at that level will offend them. Dogs have a sweet tooth and will select the sugar but a significant minority found the saccharine terribly offensive. Cats will not respond to either of these solutions. The point I am making here is that each animal species lives in its own sensory world which may or may not overlap with ours. You cannot use your own sensory judgment to predict how animals will respond to given stimuli.

One of the first experiments we did with taste some years ago was with pheasants, at Cornell. We sprayed prospective repellant on the feed in troughs. The birds would come over to the feeders and take one mouthful offered; since birds are not very bright they would shift their heads and take another mouthful. Then they would start wiping their beaks and move away from the feed. But a few birds enjoyed the fact that there was no competition at the feeder troughs and continued eating. It is obvious that the minority experienced a taste sensation different from that of the majority, in this case failing to perceive the offensive chemical.

Individual variability was tested more precisely with Japanese quail. We used ferric chloride because iron is one mineral that, if the animal does not use it, goes right through and is not absorbed. We tested 100 quail and their response provided a nice frequency distribution curve, that is, we had some very sensitive, the majority intermediate in response and some insensitive birds. We selected and bred the sensitive with the sensitive and the insensitive with the insensitive, and then rigidly culled out those with intermediate taste responses. Within five generations it was apparent that two strains were being developed.

Why is there so much difference in ability to taste and smell? Imagine the situation if all animals had exactly the same sense of taste and smell. All species would be competing for the same food. Ecologically it is sound to have diversity in taste responses between individuals and species in contrast to the universality of other physiological systems. This permits effective use of available food in an environment.

Birds have an interesting sense of taste. They have taste receptors like other animals, and their general structure is essentially the same as that in other vertebrates. The starling and chicken have a few dozen taste buds as compared to 25000 for the cow. The chicken has all the taste buds at the back of the tongue with the front half of the tongue highly cornified. In the chicken, the taste buds are so far back that it would appear that by the time it can taste something, it is too late to change its mind about swallowing it.

Most birds do not respond to what we describe as sweet. The parrot and some of the fruit-eating birds do, but the domestic and song birds do not respond to sugar as do humans. Blackbirds on an adequate diet do not appear to respond to sugars, certainly they do not avidly select dextrose, maltose or sucrose in water in a choice situation. They do, however, reject xylose which can cause an eye condition.

Birds responses to sour are different from ours. They are more tolerant of sour. Chickens will take acidic fluids down to a pH of 1.5, and the blackbird's response is somewhat similar. At slightly higher pH they exhibit a preference.

Commercial efforts to flavor chicken medicines are ludicrous. When an animal is sick, it stops eating, but the drive to drink continues for a period of time. Therefore, medicines are commonly administered in water. If medicines to be used for fowl are acid they are commonly neutralized and then sugar is added. The sugar does no good and neutralizing reduces the acceptability. To get medicine into a bird, the thing to do is put in the minimum amount of medicine so that the bird will not find it offensive. The other thing is that water should be cool or even cold; and the third is that the solution should be on the acid side. These three points will insure the maximum possible acceptance by the bird.

Birds don't share our world for bitter. Sucro octaacetate tastes bitter to humans but chickens will drink it indifferently. On the other hand, most of the common birds will reject quinine solutions. Birds are very sensitive to texture of feed, yet indifferent to the viscosity produced by sugar in solution.

Saltiness is an interesting situation. The bird's response is different from that generally encountered with mammals. Rats are indifferent to very low concentrations of salt. When they first perceive it, at about the concentration of physiological saline, they prefer it almost as much as sugar. As the concentration becomes greater they reject it. With birds the first response is indifference followed by rejection. There is no intermediate range where preference is demonstrated.

Some people have suggested that wild birds and chickens have periodically been killed by accidental salt intoxication; such a suggestion usually has no basis in fact. A chicken, if it has adequate water available, can tolerate the equivalent of your having a tumbler full of salt four times a day. They have an enormous capacity to handle salt, providing water is available continuously. Sea gulls because of their nasal salt glands are supposed to have a unique tolerance for salt. However, we have done some studies on the grackle, starling and cowbird, and they have a capacity to handle salt which approaches that of the sea gull.

In my opinion taste sensations constitute a continuous spectrum, however they must be described in terms we can understand. Sweet, salty, sour and bitter are not meaningful classifications for birds. The problem is further complicated by the bird's water sense. To us, water is wet and tasteless; to a bird water has a distinct taste. Water in itself is a strong stimulus for the bird. Therefore pure flavors tested in water solutions are actually mixtures.

In many cases salts are present in water and are uniquely offensive to birds. Chickens and sea gulls are uniquely offended by non-toxic iron salts in water at levels that are quite tolerable to most of us. There are some other salts, for example cadmium chloride and lithium chloride, which are poisonous; birds will accept them in water even at toxic levels.

If one is going to use the chemical senses to regulate bird populations, one must understand the physiological function they serve in the body. Thus, we will spend a few moments talking about the function of taste in the physiology of birds. If you take a fly and snip off its front legs, it will not respond to sugar water. Its taste buds are on its front feet. Until it gets taste information, its proboscis is not extended. After removal of the taste buds with the feet, the fly starves to death a-midst plenty.

A cow has its taste buds in the back of the tongue and they seem to be involved in initiating rumination. The foregoing are examples of the functions of taste.

Let's consider some of the general functions of taste. The first one that comes to mind is that taste serves to guide an animal in what it should eat. I have already referred to the fact that chickens do not drink xylose which causes cataracts. If they are deficient in thiamine and they are offered one of two solutions, they will choose the solution with thiamine. These choices suggest taste is the basis of nutritional wisdom. On the other hand, chickens avoid alfalfa despite its valuable vitamin content.

We have done several experiments with various feeds. If you replace corn with rye in a ground feed, the chicken will reject it in a choice situation and that is a good decision because the quality of the protein is not as good. However, if you replace the corn with barley they also will select the corn mixture despite the fact that the nutritional value of the barley is just as good as the corn. Apparently, the domesticated bird's taste response is not a reliable guide to the nutritional quality of the diet.

Birds will respond to water. Flavors will not increase the appeal of pure water for birds. Despite this sensitivity to water, if sodium arsenate is added to water and offered to blackbirds, they will kill themselves drinking it. You cannot depend on the inherent wisdom of an animal. With some stimuli they make the correct decision, but other times they do not.

We have tested a series of sweeteners on rats: xylose, saccharine, glucose, sucrose, fructose and so forth. Of course, the rats liked them. But in addition to using the white laboratory rats, we brought in wild rats caught at garbage dumps, tested them on all the sweeteners and the results were very interesting. Qualitatively their response is essentially the same as the laboratory rats to the sweeteners, but quantitatively there is a big difference. A wild rat doesn't take much xylose or saccharine. As a matter of fact, it is clear that with domestication an animal puts an increasing emphasis on the pleasurable aspects of the choice. The wild animal, however, is much more sensitive to the nutritional and the toxicological consequence of the choice. Perhaps, something similar has happened in humans.

Does taste influence the amount of food consumed by an animal? Only if the test is of short duration. Generally, if you offer a bird two food choices, and you add a chemical to one that is so offensive to them that they will not take any of it in a choice situation, and then give them no choice but the flavored food, food intake will be normal over a 14-day period. You have to increase the offensiveness 10-fold to reduce food intake by 10%. Taste offensiveness is of little consequence when the test is of reasonable duration. Both man and animals will rapidly adapt to what initially was offensive.

We compared the jungle fowl to its domestic counterpart and found that they will correct more accurately and rapidly for caloric dilution. The point here again is that while the domestic species are more readily available and easy to work with, you have to keep in mind that the selective pressures in these animals have been for other characteristics than the function of their sensory mechanisms.

While we are on the subject of food intake, there are a number of companies in the United States that sell "flavors" for bird and other animal feeds. The additives are supposed to increase food intake by making the food more appealing to the animals. We have not tested them all, but the ones we have tested totally failed to accomplish their advertised purpose. We found that the animals could not taste the flavor(s) at the recommended concentration(s). When we raised the dose to a level that the birds could perceive, we found that they rejected it. Even if they could perceive it and did like it, their food intake would probably not be influenced over an extended period. I do not know of any company that has done sophisticated research on feed "flavors" that are useful for birds.

Another major area of interest is investigation of the conditions under which the taste behavior of an animal changes. Do you encounter an abnormal change in the animal's behavior? Normally a rat rejects quinine, but if it is vitamin A deficient it will drink quinine indifferently. If you use a chelating agent to remove copper, and other (minerals) from an animal's system, its taste changes dramatically. A 100% change in threshold is not unusual. Chickens become very aggressive and exploratory when depleted of calcium. Normally, if you put your hand into a cage of chickens, they all run to the back of the cage, but if you deplete them of calcium and put your hand into the cage, they all run over and peck it. So if you have malnourished animals, deficient in vitamins, proteins or minerals you may get an alteration in behavior and in taste response.

Today there is substantial pressure to research the effects of taste and smell on efficiency of food utilization. I haven't done this on birds, but I have worked with dogs. We studied the effect of taste on the digestive system. Chronic fistulas were introduced into the stomach and the duodenum at the appropriate location. We were able to unscrew the cap on the tube in the intestinal fistula and go right in to intubate the pancreatic duct. If you apply clay to the dog's tongue, not much happens; but when you put lard on it, almost instantaneously there is an enormous increase in enzyme content and volume of pancreatic flow. This is evidence that the taste sensation affects the digestive secretions in the animal. Taste stimuli have an effect on the gastrointestinal activity as well as on the secretions along the entire tract.

As the world population explosion is commonly thought of only in terms of pressures on man, it is creating habitat and food problems for animals. Man's activities disturb, to various degrees, the chemical cues in the environment of wild animals. If wild animals are to survive, it is critically important that we come to terms with the wild populations. Understanding their sensory behavior, particularly as it relates to feeding and reproduction, could be most helpful.

The relationship of the structure of taste stimuli to taste sensation and function is largely undefined. The chemical phenomena involved at the receptor surface constitute a major scientific challenge. While we may not share the same sensory world, we do have common problems. Knowledge of the function of the sense of taste could contribute to the effective use of the world's food resources.