Underwater chemoreception

Sensing a Meal

Dr Tomasz Janecki, a hydrobiologist and scuba diver who has spent a total of more than 30 months in Antarctica, studies the impact of food-derived chemical signals on the metabolism and behavior of marine animals

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If animals were unable to harness the signals coming in from their environs, their lives would be a chaotic affair. In the special conditions that prevail in Antarctic waters, chemical signals represent a particularly important source of information that acts to organize their way of life on the sea floor

One of the channels through which animals obtain information about the world around them is known as *chemoreception*, i.e. the communication of chemical signals. As the most widespread (and in evolutionary terms likely the oldest) means whereby organisms communicate with their environment, chemoreception plays a particularly crucial role in the underwater environment - sea water being an excellent carrier of chemical information in view of the large quantity of various compounds dissolved in it. Chemoreception enables animals to seek food, collect information about the threat of predation, locate the most favorable environs, maintain contact with other members of the same species and form schools, establish social hierarchies, and identify the best partners for reproduction.

Even though scents spread much more slowly in the marine environment than in air, olfactory stimuli are nonetheless of great significance for water-dwelling animals. Their sense of smell is exceptionally acute, their distance receptors being much more sensitive and reacting to much lower concentrations of chemical substances. The crucial issue is being able to distinguish chemical signals from the environmental background "noise" of all the naturally present chemical compounds dissolved in the water. *Aquila aquila* eels, for example, are able to detect

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Benthic invertebrates in the cold waters of Admiralty Bay (King George Island) exhibit impressive diversity

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For many months, the Antarctic ice cover limits or even cuts off the light supply to deeper water layers. In such conditions, chemoreception is the primary means whereby animals communicate information

the scent of certain substances in concentrations of as little as several molecules per liter of water, while *Panuliris* rock lobsters react when the concentration of glicine amino acid surges by as little as 2%.

Marine animals are furthermore able to closely track gradations in the concentration of various chemical substances, using such information to evaluate a given signal's significance and to locate its source. By this means, predatory and carrion-feeding species are able to detect the source of a stimulus from even as far away as several hundred meters.

Attractive molecules

The chemical substances dissolved in water (ranging from simple hydrogen ions to complex amino acids and nucleic acids) that are released from food and secreted by various organisms are recognizable by marine animals and can stimulate behavior of various sorts. By watching how animals move towards food and gather near it, we can surmise that they react most of all to the chemical compounds that form part of their natural, stable food source. The first observations of such animal behavior were made back in the late 19th century, when it was noted that starfish lured with crab meat will follow the motion of a food source. Research on various species has conclusively shown that *trophochemoreception* (i.e. obtaining chemical signals concerning food) enables animals to intercept signals from their environs about the presence of potential food sources, their value and distance. The potential reactions to chemical attractors include a change in metabolic rate and/or a change in behavior, including movement to a different location.

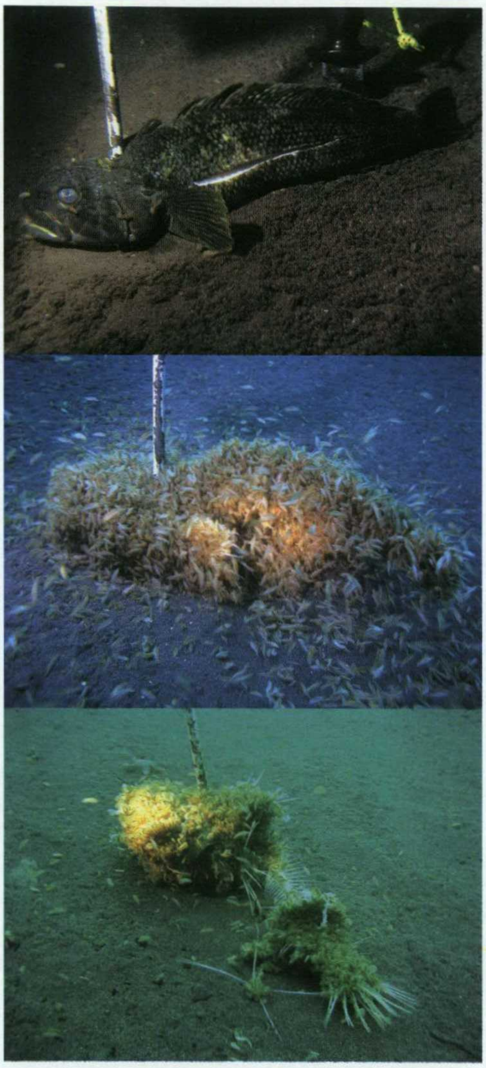
In recent years, physiologists' interest has been particularly drawn to how marine animals react to various amino acids - the basic building blocks of all proteins, which are also naturally present dissolved in sea water, having been given off by marine organisms or arising from the breakdown of dead organic material. Their concentration in the environment is low (ca. 10^{-8}–10^{-6} M), yet even a slight increase may be easily perceived by an underwater animal and treated as signaling the appearance of a potential protein source. This is of particular significance in the special environmental conditions of Antarctic waters, where organisms need organic food sources to survive.

Research to date has shown that various amino acids may affect the metabolic rate and behavior of marine animals of various taxonomic groups. Of all the amino acids, glutamic acid is considered the chief chemical attractant. It is one of the five amino acids (alongside glicine, aspartic acid, alanine, and serine) which account for some 80% of all amino acids dissolved in sea water, and can even constitute in excess of 15% of the protein in fish and zooplankton tissues in the Antarctic region. Glutamic acid also has an especially important function in transferring information on the molecular level and the central nervous system.

For certain Antarctic invertebrates (such as S. *polita*, G. *antarcticus*, A. *plebs* and O. *validus*), living within an exceptionally narrow range of temperature (from - 1.77 do 1.67°C) and salinity (from 33.41% to 34.16%) and in water with near 100% oxygen saturation, an essential role in the processes of trophochemoreception is played by the following amino acids: glutamic acid, arginine, histidine, isoleucine, leucine, lysine, serine, threonine, and tyrosine. The main amino acid that boosts the basic metabolic rate (by 30%–300% on average) of starved specimens of such species is glutamic acid. This increase can be explained in terms of the animal's metabolic preparation for moving to find and acquire food.

Modulated appetite

A range of factors may have an impact on animals' reception of chemical signals from



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Chemical signals arising from a food source (fish meat) draw in thousands of necrophagous crustaceans from far distances, mostly amphipods (*Amphipoda*), which make sort work of "getting to the last bite"

their environs. Firstly, it turns out that the very same chemical compounds can give rise to different, often opposite reactions for different groups of animals. For example, *Luidia clathrata* starfish are clearly attracted by isoleucine solution, while praline solution does not evoke any reaction from the species. *Marthasterias glacialis* starfish, on the other hand, react in a completely opposite fashion. *Acetas sibogae australis* shrimp will move towards sources of methionine, alanine, and leucine, without reacting at all to glicine, yet the latter amino acid clearly attracts the spiny lobster *Panulirus interruptus*. These differences may stem from the feeding preferences of the specific species, hereditary conditioning, and also the past experience gained by individuals specimens.

Confirmation of individual specimens' "memory" of flavors can be found in the case of *Orconectes sp.* crayfish, which were given an extract of a new type of food: the zebra mussel, *Dreissena polymorpha*. Only those specimens that had already previously been fed with this type of mussels reacted favorably.

It has also been noted that a higher concentration of a signal substance increases the likelihood of it causing a characteristic animal reaction, or renders this reaction more intense. Mixtures of "attractive substances" likewise act more strongly, evoking clearer and fuller reactions than the individual components.

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Antarctic waters are characterized by extreme, albeit stable environmental conditions (i.e. temperature and salinity)

***Glyptonotus antarcticus* (the giant isopod), the largest necrophagous crustacean encountered in Antarctic waters. Its body length can reach 12 cm**

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The physiological state of a given animal may also have an impact on how it reacts to chemical signals (whether attractive or repellant): for example, its level of satiation or length of starvation. Starved specimens from various species react more fully to chemical attractants than satiated ones. In six Antarctic invertebrate species studied by the author, starvation significantly reduced their metabolic rate by an average of 2.3 times (from 27 to 71%, depending on the duration of starvation) compared to fed specimens.

Eating and danger

Another important factor that modifies trophochemoreception processes is the presence of a predator. The scent of an *Esox lucius* pike changes the behavior of small fish from the carp family, such as the roach *Rutilus rutilus*, causing the latter to form schools, reduce its feeding intensity, and more frequently take cover within the underwater vegetation. This is likewise confirmed by facts pertaining to other groups of marine animals which fall prey to predators. The presence of the predatory crabs *Cancer irroratus* and *Hyas araneus* effectively deters their potential victim, the snail *Buccinium unduatum*, away from a lure it would otherwise be drawn to if there were no danger present.

Certain modifications of trophochemical reactions may help minimize the risk of meeting a predator. The very same chemical signals that attract specific species of animals to food sources enable other species to recognize the potential threat of predators drawn in by them, and take steps to avoid them. Such behavior has been observed in the sestonivorous/herbivorous sea urchins S. *neumayeri*, which sometimes fall victim to O. *validus* starfish. Glutamic amid, which acts as an attractor for the starfish, led the sea urchins to react by fleeing.

The wide diversity of the invertebrates in which glutamic acid has been seen to provoke significant metabolic and behavioral reactions enables one to conclude that this amino acid is a universal trophochemical signal for animals from a range of taxonomical groups.

Chemicals organize life

In the special environmental conditions that prevail in the waters of the Southern Ocean (with seasonal primary production and a limited or even nonexistent light supply caused by the seasonal ice cover), we can surmise that chemoreception plays a crucial role in aiding animal species to obtain information about their environs. Animals which demonstrate better perception of chemical signals, and which therefore more quickly find food sources and reproductive partners, while at the same time avoiding encounters with predators, stand greater chances of survival. Chemoreception processes may also be important on the level of whole populations, or even entire biological habitats. By streamlining the search for food, and thereby changing the location of animals within the environment, chemical signals may be a factor that modifies the spatial and temporal breakdown and organization of entire communities of organisms living on Antarctic sea floors. ■

Further reading:

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