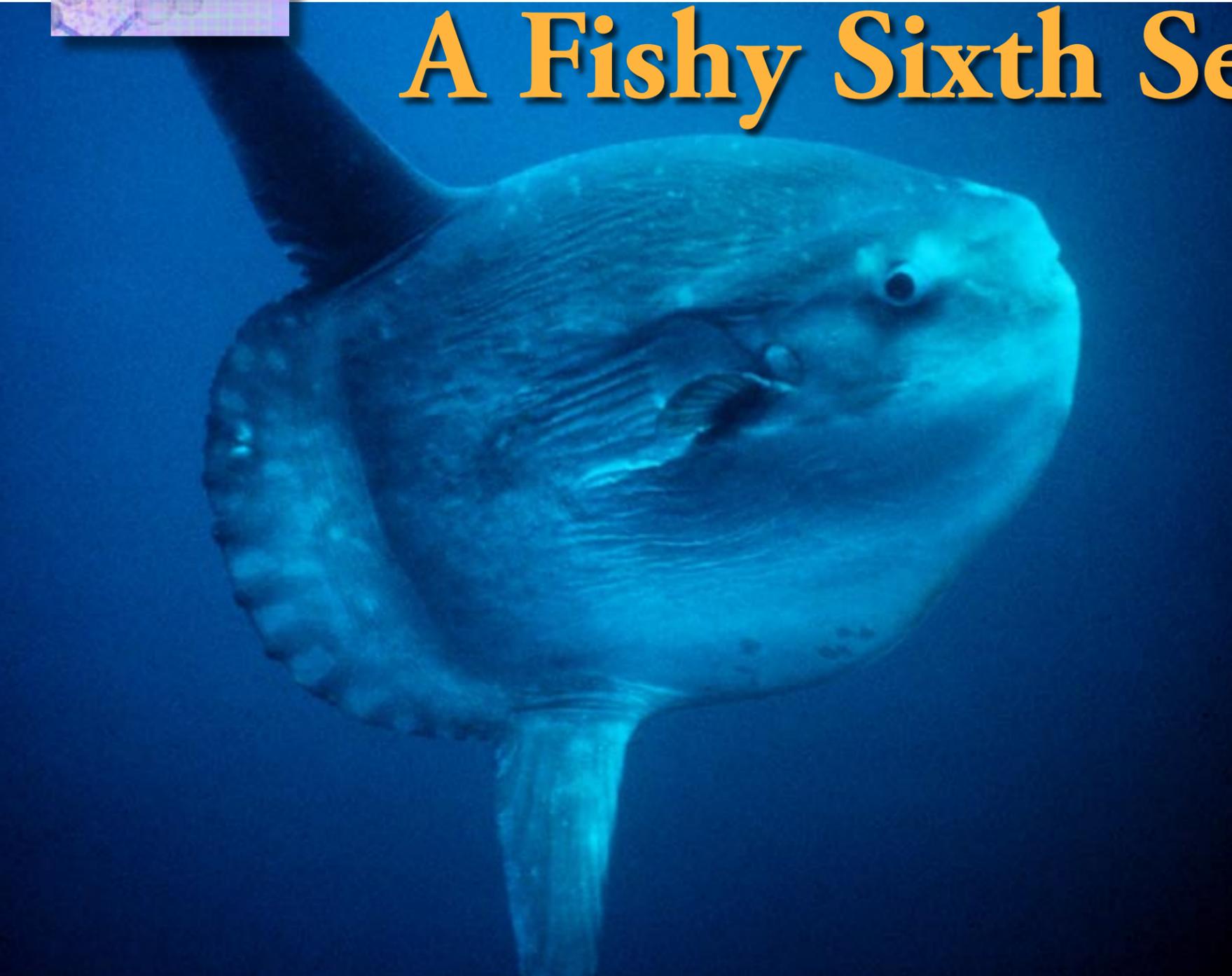


Text by Michael Symes
 Photos by Peter Symes, NOAA Photo Library, USDA Forest Service,
 Hawaii Biological Survey, Freshwater and Marine Image Bank

A Fishy Sixth Sense



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The ocean sunfish, or mola mola, is a deep sea fish found in the Gulf of the Farallones National Marine Sanctuary



USDA FOREST SERVICE

A rainbow trout in the shallows of a freshwater stream

The environments in which the many fish species have evolved are very diverse, ranging from the shoreline to the deep-sea depths, from fresh-water streams to tropical lakes. Because of the great variety of these habitats, the senses of these different species have consequently evolved quite differently, exhibiting a great diversity, with many senses not yet understood or even identified. There are thus still many mysteries regarding the behaviour of aquatic creatures. For example, how do eels find their way across the Atlantic ocean? Why is it so very difficult to swim up to a fish from behind without being detected? And even bank-side freshwater fish-

ermen, for example, know that the vibrations from footsteps can be detected by fish. But what sense or senses are being used by the fish in such cases?

The senses of fish

Fish have been shown to have the five, commonly accepted, human senses. In fish, however, their relative importance is different from that of human beings.

Vision

As the amount of light available below the surface generally is small, this is not the primary sense for fish. Some aspects of fish-sight were discussed in Xray Mag #3.

Smell

Generally, the sense of smell in fishes is very developed. Eels, for example, may detect a substance when only three or four molecules of it have entered its nose. It is probably that sense most used by fish in finding food.

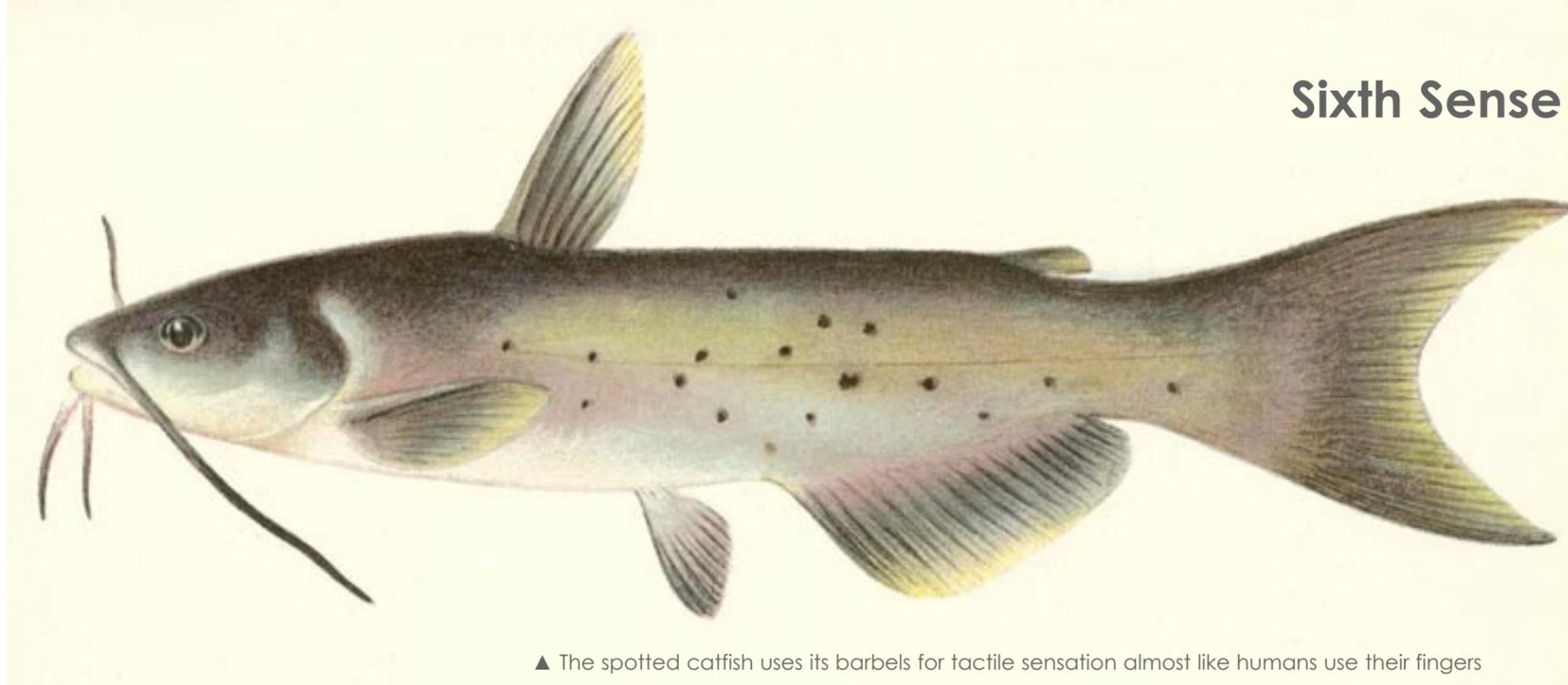


- ▲ The Needle Fish has a lateral line that runs very low on the sides
- ▶ The neon wrasse has a lateral line that has gaps along its length

PHOTO BY PETER SYMES



HAWAII BIOLOGICAL SURVEY



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▲ The spotted catfish uses its barbels for tactile sensation almost like humans use their fingers

Hearing

Hearing in fish is not very well understood, but seems mostly to be used for simple distance perception and sound source location.

Taste

Taste buds in fish are mainly located in the mouth, but also in the skin covering the head, body fins, barbels and lips. No response is obtained when a barbel is touched with an inert glass tip, for exam-

ple, but an immediate response is obtained when it is touched with a morsel of food.

Touch

Fish have a fine tactile sense, as is shown, for example, by certain catfish who can use their barbels almost as humans feel with their fingers.

However, good as some of these senses might be, none of them can account for even simple phenomena such as the detection of the vibrations from footsteps. Fish must therefore have at least one other sense which enables them to detect low frequency vibrations. Such a sense is located in their lateral line.

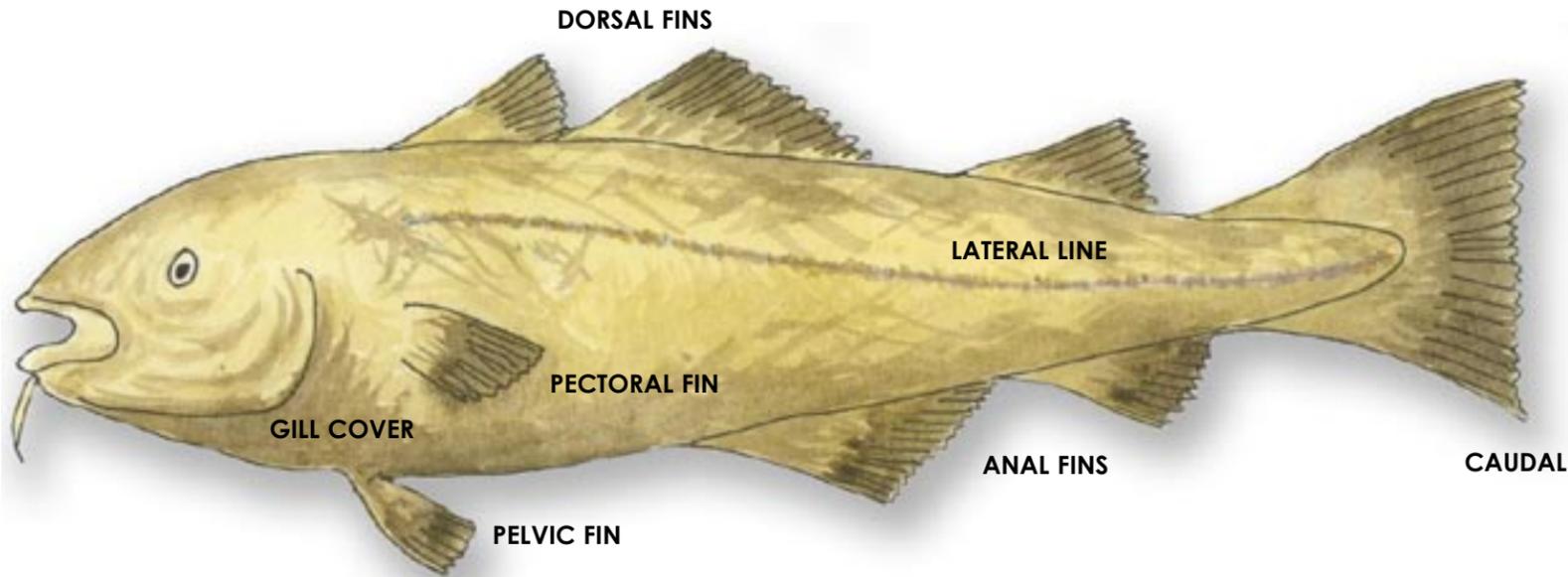
The lateral line

The lateral-line system is easy to observe in most fishes. There is usually only a single lateral line on each side of the body, but many variants of the typical lateral line may occur. For example, on the sides of the Belontiidae (Needle Fish), the lateral line runs very low on the sides. On some species the lateral line may be incomplete, or it may also be interrupted, meaning that it ends

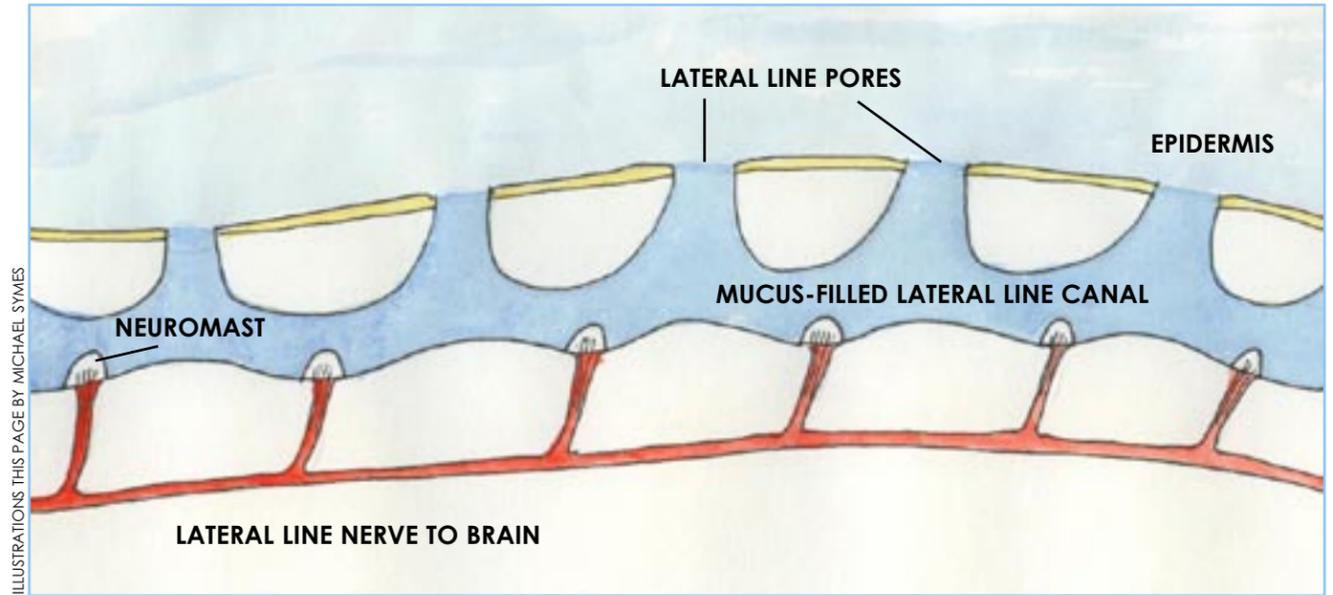
and then recommences after a gap, as in some of the Labridae (Wrasse) species. And in a number of families the lateral line may be absent altogether.

The lateral line consists of a linear series of sensory cells or neuromasts. In many fishes, the neuromasts can also extend along the fish's head as well as sides, although these are not always as obvious. These neuromasts are situated in a mucus-filled canal, situated just under the skin, which is in direct contact with the surrounding water through pores in the skin or scales. The incoming stimuli from the neuromasts are fed into a nerve parallel to the canal which then feed the stimuli to the fish's central nervous system.

The neuromasts can be thought of as very sensitive hydrodynamic transducers that can detect water disturbances. They consist of a base of sense cells with sensory hairs (cilia) that project into the canal. These hairs are capped with a gel-like cupula. Movement of the mucus in the canal, caused by flow of water, makes the cupula bend. This in turn causes bending of the hairs, which stimulate the sense cells, thus generating minute electrical signals which



▲ Diagram showing lateral line on cod fish



▲ Schematic diagram of lateral line

pass along nerve fibres to the brain.

There are actually two main types of neuromast: *canal neuromasts*, where the water displacements are transferred to the canal fluid via pore openings, and *superficial neuromasts*, which are directly exposed to the flowing water. In either case, when the neuromasts are at rest,

they send a continuous series of nerve impulses to the central nervous system.

In the case of the canal neuromasts, variations in water pressure between different pores along the canal cause a directional movement of the mucus through the canal. When pressure either increases or decreases due to a disturbance near a fish, the nerve impulse pattern changes, the fish registers the change, and takes appropriate action. In the case of the superficial neuromasts it is the drag of the water past the cupola that causes them to bend. The degree of this bending is directly related to the water velocity, i.e. to the velocity of the fish relative to the velocity of the water.

Similar to the human inner ear. For those with some knowledge of human anatomy, it will be clear that the structure of the cupola is homologous to the crista ampullaris of the human inner ear. Bending of the cupola by water currents and that of the crista ampullaris by dis-

turbance of the endolymph of the semi-circular canals causes excitation of sensory cells of both organs. Gerard (1936) inferred that the inner ear of vertebrates has phylogenically derived from a primitive lateral line system.

So, the lateral line can be considered as a sort of higher hearing sense, reacting to certain types of pressure changes in the surrounding water, just as the human ear reacts to pressure changes in the surrounding air. However, while the lateral line is a linear system of receivers, the ear functions just as a single receiver, although covering a range of frequencies. It does improve matters, though, that we do have two of them, giving stereo-directional hearing.

What can this sense be used for?

The lateral line system obviously greatly expands the area of tactile perception by making it possible for the fish to interpret its environment without actually touching an object. The lateral-line thus helps the fish in a number of ways.

Rheotaxis

Rheotaxis is a behavioural orientation

to water currents and is one of the most important functions of the lateral-line system.

The term, rheotaxis, comes from the Greek root *rheos*, meaning stream, flow or current; and *taxis*, meaning the movement of a cell or microorganism in a particular direction in response to an external stimulus, from the Greek via the New Latin *tassein*, to place in order.

Scientists at the University of Auckland, New Zealand, have demonstrated that some of the receptive cells in the lateral line are particularly well suited to provide information on water currents. It was found that the canal neuromasts are most sensitive to water acceleration whereas the superficial neuromasts are most sensitive to water velocity. Fish thus have one set of receptors designed to detect water acceleration and a second set to detect water velocity.

Rheotaxis is mostly mediated, however, by one specific receptor class of cells in the lateral line, the superficial neuromasts. These velocity-sensitive receptors seem to enable a fish to sense its orientation in relation to stream flow, even in the absence of other clues. Facing upstream

is highly advantageous, for not only does it present the most streamlined shape to the flow, but it also makes it easier for the fish to intercept food items drifting downstream.

Detection of food or enemies

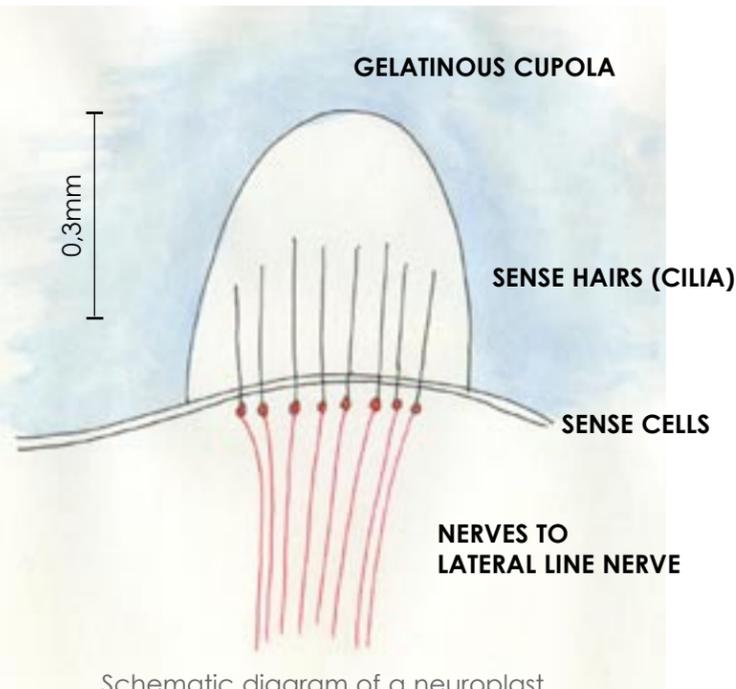
Sound passing through water creates variations in pressure. The lateral line system can thus detect sound, though only at a low frequency, such as that arising from footsteps, for example. Pressure waves are also caused by unseen prey such as a struggling insect, or the movements of an injured fish, so they can be located – and eaten!

Distances from stationary objects

The lateral line can serve as a sonar system with which distances from stationary objects may be determined. A bow wave precedes a swimming fish. This wave is reflected from the object back to the fish where it is detected by the lateral line system, thus enabling the fish to determine the distance to the object.

Communication

Typically the lateral line system can



Schematic diagram of a neuromast



PHOTOS THIS PAGE BY PETER SYMES

Sixth Sense

*Why are fish smart?
Because they are often in schools*

▼ Bigeye Jacks
Sipadan Island
Malaysia

The lateral line makes it possible for schooling fish to coordinate their movements and stay together. Some species of fish like the Blue Banded Snapper found in the Red Sea have a very strong sense of schooling



detect sound lower than 160 to 200 Hz. (The human ear can detect sounds down to about 10 Hz.) Many fish vocalisations are very low frequency crunches, grunts, and popping sounds. The lateral line system may thus play an important role in communication in some species of fish.

Schooling with other fish

The lateral line system makes it possible for schooling fish to coordinate their movements and stay together. The lateral line system is particularly good at detecting large disturbances in the water. Schooling fish often have a well developed lateral line. Sensing the movement of its schoolmates through water pressure variation, each fish can

synchronize its movements with the school.

Wake detection

Modern submarines can estimate the current position of an enemy submarine by detecting its wake. Like many other 'new technologies' evolution has preceded them. Recent research at the University of Konstanz, Germany, has shown that predatory catfishes use their lateral line for tracking the wake caused by prey as they swim after dark, and use past locations to predict the present position of their prey. Although the sense of taste is also used to detect chemical signatures produced by the prey fish, it was shown that stimulus of the lateral line was by far the most important factor.

All in all, then, it is clear that the lateral line system is a very complex and sensitive sense-organ. Or perhaps we should consider the lateral line as several different sense organs, for sensing motion, pressure, distance, etc.

In any event, it can therefore truly be said that fish do have, at the very least, a sixth sense, and a very complex one at that.

Do humans have an extra sense?

Although we must be careful to distinguish between sense and perception, it is obvious that we must more than five senses. For example, we can sense, and react to, pain, heat, pressure and movement. Even our sense of vision can be subdivided into one for light and one

for colour. But do we have as yet any undetected senses? Perhaps an amusing experiment, described in the *Electronic Naturalist*, may be of interest regarding this question.

Blindfold a person and let them move within a room, making sure there is some open space along one wall. The aim is for the blindfolded person to try and determine when he/she is really close to a wall by using senses other than the commonly accepted five.

Move the person around a bit so they lose track of exactly how far they are from the selected wall, then face the person towards the wall and let them

Are fish ticklish?

Probably not! But there is an ancient way of catching trout, called tickling that's even described in Shakespeare's twelfth-night, written 1599-1601, where Maria says " for here comes the trout that must be caught by tickling", the trout in question here being Malvolio.

Trout can be found in most fast running streams, but they hide very well. You will occasionally see one near the edge of a river but it is important to be very quiet and move slowly. Slowly move closer and bring a hand underneath the trout from behind and to the side. If you prod crudely the fish will take flight and dash to another hiding place; and do not touch its tail or it will be off in a flash. But if you are careful enough you will feel something swaying in the current and stroking your fingers like the soft touch of a feather. It is the fish's tail but do not try to grab it, for it will twist from your grip before you can get it out of water. Instead, the fish is rubbed gently so that it moves slowly backwards into your hand. Your palm slides gingerly over the dorsal fin and goes on till you feel the gentle waving of the pectorals. Then suddenly you grip a thumb and finger into the gills, and with one strong heave lift your fish from beneath its rock and throw it to the bank.

Well! That's what they say, but it does seem to be a very difficult skill. So you probably shouldn't count on getting your supper using it. ■

walk very slowly towards it. If the subject moves cautiously and carefully, just before arriving at the wall, they should be able to "feel" its presence just beyond their body. Not everyone is good at this but with a few trials many will be able to do this activity surprisingly well. Although people will be able to do this exercise, they will have trouble explaining just how they are able to do it.

So, perhaps we, too, have some vestigial extra sense, over and above those normally accepted. ■

