A cetacean's perception of its environment

A few hundred million years ago, the terrestrial ancestor of cetaceans made its way into the aquatic environment. Over the course of evolution, several sensory adaptations developed to make it better adapted to life in the water. The way in which whales perceive their environment, which, it has to be said, is very different to our own, is presented here.

According to Darwin, the key to survival and to evolution is adaption to an environment. To make the most of their ocean environment, cetaceans had to develop new ways to navigate and to communicate. A few hundred million years ago, whales' ancestors were terrestrial mammals. These ancestors, living in a terrestrial and therefore air-breathing environment, like us, were presented with completely different environmental challenges in their transition into the water. There are many challenges associated with an underwater world! For example, among others, water is more dense than air (the force of gravity is thus weaker which explains why the biggest animals on the planet live in the ocean!), the viscosity of water is almost 50 times greater than that of air (this increases the resistance to movement which explains the hydrodynamic body shapes of cetaceans and their appendages adapted for propulsion in the water), the inaccessibility of air (the blow holes, positioned on the top of the head, allow the animal to breathe more easily at the surface) and the thermal properties of water (causing rapid heat loss). The ocean is in fact like a completely different universe to live in!

Touch

Cetacean skin is highly sensitive, and is therefore a powerful tool used to obtain information about their surroundings. Their skin has a high density of nerve endings and any contact with the skin results in an immediate transmission of information to the animal's cerebral cortex. As such, they are constantly aware of their position within their environment. Cetacean skin is also highly flexible which allows a more efficient flow of water over the animal's body. This helps to make the animals more hydrodynamic, thus limiting the drag associated with swimming. The sense of touch is also very important in terms of forming social bonds with other individuals of the same species. For example, calves will often rub themselves against their mother's heads. The top of the

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head, where the blow holes are located, is a particularly sensitive area as it is especially important for the animals to detect the change in environment at the surface when they breathe!

Cetaceans also have highly sensitive vibrissae. These short, stiff hairs on the upper and lower jaws of cetaceans work in the same way as the whiskers of cats and seals. These hairs are surrounded by a nerve sheath, so the slightest movements or contacts are detected and transmitted. It appears that the primary role of the vibrissae is to locate schools of krill and fish, and to evaluate their density. In this way, whales are able to assess the quantity of food in the area and therefore whether or not it is worth investing the energy to hunt.

Olfaction

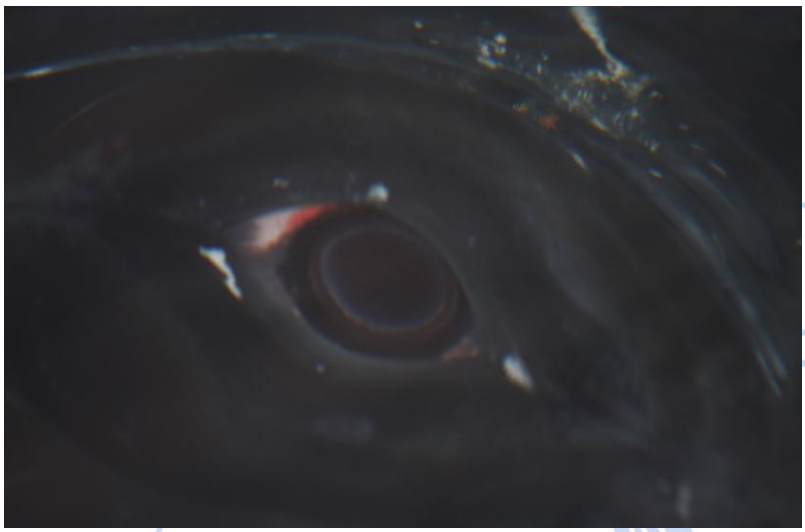
In a marine environment, it appears that the sense of smell is not particularly developed, and does not contribute to finding food or navigation. Smells are not easily dispersed in water, and are lost quickly through dilution. It is probably for this reason that the olfactory apparatus, and the areas of the brain used to analyse olfactory information have either completely disappeared, or are only weakly developed in cetacean species. However, through the necropsying of mysticetes (whales with baleen plates), biologists have discovered that their olfactory system is the most highly conserved of all the cetaceans. The hypothesis put forward to explain this anatomical difference is that, as they breathe at the surface, they are able to detect schools of krill that have a very specific smell carried in the air over the water. This is not their primary hunting technique, but it may be an additional adaptation that helps them to find their food more quickly. As fish and squid do not emit any smells detectable at the surface, odontocetes (toothed whales) no longer have any olfactory structures to allow them to detect odours.

Cetaceans still have the the vomeronasal organ which allows terrestrial mammals to detect reproductive hormones. The scientific community is still unsure of the chemoreceptive abilities of cetaceans, but it is possible that they are able to detect the pheromones released by sexually mature individuals that are ready to reproduce.

Taste

Contrary to what we might think, cetaceans are able to taste what they eat using highly sensitive taste buds. Through the analysis of the size and organisation of the structures associated with this system, it is thought that the sense of taste must be highly developed in cetaceans. Following experiments on dolphins in captivity, it was concluded that they are 10 times more sensitive to acidic and salty compounds than to sweet ones. In this way, cetaceans are able to detect changes in the salinity of the water and are therefore better able to orient themselves and recognise land marks as the undertake their annual migrations. For example, cetaceans are able to detect the change in salinity of the sea water as they approach the mouth of a river.

Sight

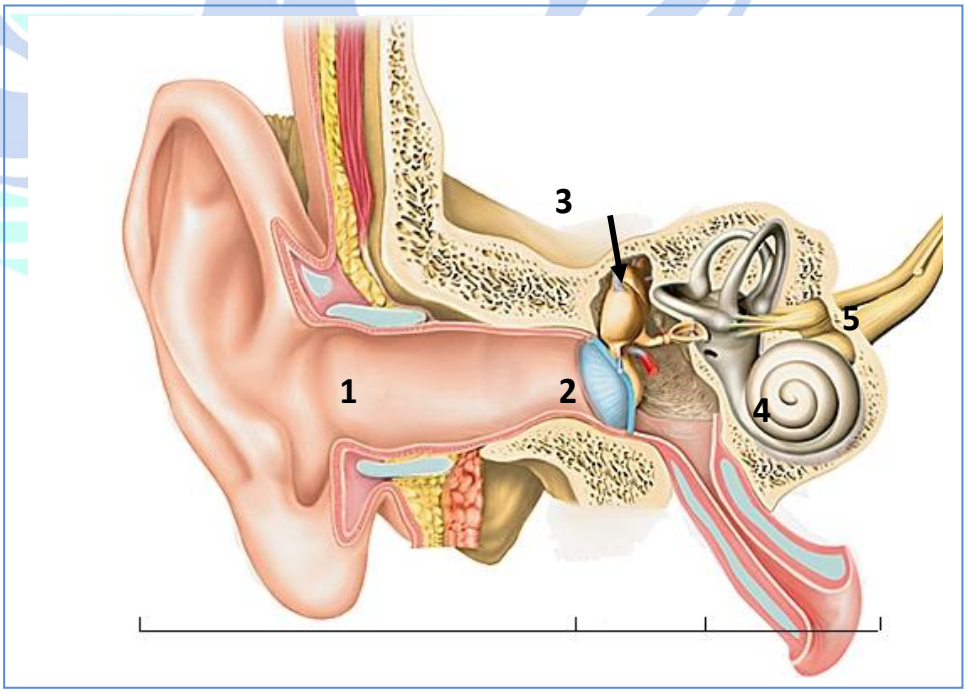


In an aquatic environment, sight is not the primary sense because the majority of the sun's rays are reflected at the water's surface. Those that do penetrate the water are then completely dissipated at a depth of 200m. In addition, the turbidity of the water (suspended particles of sand etc) also prevents light from penetrating down into deep water. Despite these constraints, cetaceans have good vision. Their retinas are primarily made up of rod cells which are light sensitive cells that are able to detect very low light levels. Cetacean eyes have only a small number of cone cells however, which detect different wave lengths of light, thus allowing colour vision. It is therefore speculated that whales mostly see in black and white. The iris is also extremely sensitive and its size can vary greatly as it adapts either to the darkness of deep water or to the light at the surface.

Cetacean's eyes are also relatively small compared to their size. If sight was as important for cetaceans as it is for humans, their eyes would be the size of a basketball, whereas in fact, it is only approximately the size of an orange.

Hearing

In general, sounds propagate much faster and much more easily in water than in air. As such, cetaceans principally use their sense of hearing to perceive their environment through listening and through echolocation.



In terrestrial mammals, when sound enters the ear canal (1), it generates vibrations that lead to pressure on the ear drum (2) causing the three tiny ear bones of the middle ear to move (3). The vibrations are then further propagated through part of the inner ear

called the cochlea (4) which converts these vibrations into a nervous signal sent to the brain via the auditory nerve (5). The signal is then processed and converted into an image in the temporal lobes of the brain (see the diagram). In cetaceans, the ear canal is in fact blocked by a wax plug. Its role is still debated among scientists, but it seems that it wouldn't prevent the animals from being able to hear. In odontocetes, sound vibrations in the water are also detected by fatty deposits in the lower jaw.

In contrast to terrestrial mammals, a cetacean's middle and inner ear is surrounded by a bone which allows them to detect where a sound source is coming from. This gives them better hearing capabilities under water as, for example, when a human dives they have the impression that they are surrounded by the sound and are unable to pinpoint its direction. This is because, in an aquatic environment, with no obstacles to block the sound, it reaches the two cochleas at the same time. It is therefore very difficult for us to determine the source and the nature of the sound. However, in cetaceans, sound waves will enter one ear a few milliseconds before the opposite ear because the bone structure surrounding the middle and inner ear isolates them. This is how they are able to determine the origin of potential dangers, locate prey and orient themselves in their environment. In addition, whales have a much wider hearing range than ours. They are able to hear frequencies ranging from -20Hz up to 250,000Hz. Humans can only hear between 20 and 20,000Hz. As cetaceans are so reliant on sound and their sense of hearing, it is unsurprising that their hearing range is so wide!

Références:

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ROMM (www.romm.ca)

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