BRAIN RESEARCH

Dolphins are Colour-blind

Most mammals can see colours. The basis for this is two types of cone photoreceptors in the retina, the blue and green cones, each with different spectral sensitivity. Scientists at the Max Planck Institute for Brain Research in Frankfurt-on-Main, the Alfred Wegener Institute in Bremen and the University of Lund in Sweden have discovered that the blue cones are missing in whales and seals (EUROPEAN JOURNAL OF NEUROSCIENCE, vol. 13, pp. 1520–1528, April 2001). These marine mammals only possess green cones and are, therefore, colour-blind since it is impossible to distinguish colours with only one type of cone. By contrast, relatives of the whales and seals living on land still possess both types of cone.

Humans and many other primates can see colours very well. This is made possible by three types of cone photoreceptors (light-perceptive cells) with different spectral sensitivity in the retina of the eye: the blue, green and red cones (trichromatic colour vision). The capability of most other mammals is somewhat less developed. They only possess two types of cone: blue and green cones. Some species only have blue and red cones. This dichromatic colour vision is so to speak the basic equipment in the building plan of mammals. However, two large groups of marine mammals, whales and seals, fall completely outside this pattern. Whales and seals lack the blue cones; they possess only the green cones. Since it is not possible to distinguish colours with only one type of cone, whales and seals are, therefore, colour-blind (cone monochromats). Furthermore, their perception of brightness and contrast is severely restricted in the blue band of the spectrum. The defect seems paradoxical to the scientists since the light becomes increasingly blue in clear seawater as the depth increases.

When examining the eyes of various marine mammals, Leo Peichl from the Max Planck Institute for Brain Research, Günther Behrmann from the Alfred Wegener Institute of Polar and Marine Research in Bremen and Ronald Kröger from the Zoological Institute of the University of Lund (Sweden) came across a surprising deficiency: the blue-sensitive cones are missing in all 14 species of the toothed whales (dolphins), seals and sea lions examined; their retinas contain only the green cones and the rod photoreceptors essential for twilight vision. The defect was demonstrated by means of immunocytochemistry using antibodies against the visual pigments (opsins) of the cones. This method makes it possible to examine the preserved eyes of marine mammals that have been stranded or have died in zoos.

Based on their taxonomically broad random samples, Peichl, Behrmann und Kröger suspect that all whales and seals have the blue cone defect. Whales and seals are not phylogenetically related. The whales originate from land-living even-toed ungulates, their nearest terrestrial relative is the hippopotamus. The seals have developed from land-living beasts of prey (carnivores); amongst their close relatives are the wolf, the ferret and the river otter. The research group found blue cones in all these terrestrial relatives. The loss of the blue cones in the marine representatives of these two so disparate groups of mammals argues in favour of an evolutionary adaptation (convergent evolution) to the marine habitat and thus of an adaptive advantage to the defect. ►

PHOTO: ZOOLOGICAL INSTITUTE OF THE UNIVERSITY OF LUND / RONALD KRÖGER

Bottlenose dolphin: The blue cones are missing in the eyes of these marine mammals; they only possess green cones. The evolutionary advantage of the loss of blue cones is unclear since in clear seawater light becomes increasingly blue as the depth increases.

However, the matter becomes puzzling due to the phenomenon that during the propagation of light in clear water, such as in the open sea for example, the long-wave fractions are scattered in preference and therefore, as the depth of water increases the short-wave, blue fractions dominate more and more – an effect with which every diver is familiar. Under these conditions loss of the blue cones would seem to be a particularly poor adaptation. Even if colour vision (on the basis of at least two types of cones) is not very useful in a monochrome blue underwater world, surely the type of cone that can best make use of the available light for perception of contrast and brightness ought to be retained. Thus many fish that live under comparable light conditions have blue cones.

The researchers assume that loss of the blue cones occurred at an early stage of evolution when the first representatives of whales and seals on their way back to the sea initially only inhabited coastal waters. There the light under water is longer-wave because of the higher content of organic and inorganic matter causing turbidity and contains only low fractions of blue. In these conditions the loss of "idle" blue cones would have been a beneficial or at least harmless development.

The loss of colour vision may have simplified the processing of visual information in the brain, thereby releasing capacities for other sensory outputs. Thus many whales have developed an echolocation system and seals can perceive the water movements generated by their quarry with their whiskers.

For the species that still live near the coast today, the loss of blue cones would continue to be an advantage. In contrast, the species that have conquered the open seas in the course of evolution would probably profit now from blue cones but the genetic defect that happened during evolution is probably so serious that it cannot be undone. "Perhaps the colour-blindness of the whales and seals is the price that these mammals had to pay for access to the abundance of food in the seas," summarizes Leo Peichl. ●

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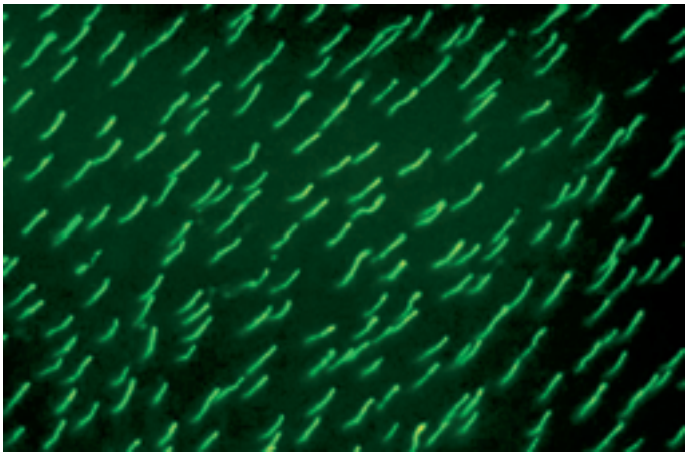

Photo: MPI for Brain Research / Leo Peichl

Cone photoreceptors in the retina of a ringed seal, stained with an antiserum against the visual pigment of the green cones. Seals and whales only possess this green-sensitive type of cone. The space between the cones is filled with the more numerous rod photoreceptors that convey twilight vision.