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Fish eye development

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Abstract

The importance of the lens in eye development has been demonstrated using reciprocal transplantations between an eyed surface-dwelling fish and an eyeless cave fish of the same species.

Significance and context

In Mexico, there are over 30 varieties of the fish *Astyanax mexicanus.* Some populations of these fish live in surface waters while others live in unlit caves. The cave-dwelling varieties are eyeless, providing a unique opportunity to study the evolution of a developmental process in a single species, rather than in distantly related species. Using an eyed surface-dweller and an eyeless cave-dweller, Yamamoto and Jeffrey are able to show that an inductive signal from the lens influences eye formation.

In the surface-dwelling fish, eyes form by a process quite similar to that in other vertebrates. First, the optic vesicle buds out from the brain and contacts the overlying ectoderm, which forms the lens precursor. The optic vesicle folds to become the optic cup, while the lens develops and becomes internalized. The optic cup then differentiates into the retina and the ectoderm overlying the lens becomes the cornea. In the cave fish, the lens and optic cup develop normally for the first 24 hours; after this, however, the lens cells undergo programmed cell death or apoptosis. The cornea and iris do not form and the retina is extremely disorganized. Growth of the eye stops and photoreceptor cells never develop. The rudimentary eye eventually sinks back and is covered by skin.

The authors proposed two hypotheses for eye degeneration in the cave fish. In one, lens apoptosis is responsible for eye degeneration. In the other, the optic cup, which is diminished in the cave fish, produces insufficient amounts of some necessary signal, leading to the deterioration of the eye and lens.

Key results

Yamamoto and Jeffrey transplanted embryonic lenses from eyed fish into the optic cups of eyeless fish and vice versa. They found that a lens from a surface fish could induce normal-looking eyes in the blind cave fish, whereas the reciprocal transplantation caused a degeneration in the eye of the surface fish. In each case, the unmanipulated eye on the other side served as a control. To determine whether programmed cell death was responsible for this deterioration, the authors looked for apoptosis in the donor lenses. They found that the cave fish lens still underwent apoptosis when implanted in a surface fish embryo and the resulting eye was small and disorganized. In the opposite experiment, the surface fish lens did not undergo apoptosis and was able to stimulate normal eye development in the blind cave fish host, including differentiation of a lens, retina, iris and cornea. The restored cave fish eye also expressed the transcription factor Pax6, which is ordinarily present in the lens and corneal epithelia but is not detected in unmanipulated cave fish eye precursors. Yamamoto and Jeffrey then labeled the eyed fish donor tissue with a fluorescent dye prior to implantation to determine whether the rescued eye parts were from host or donor tissues. When they sectioned the embryos, only the lens was fluorescently labeled, revealing that the rescued eye parts were from the cave fish tissues. This showed that the implanted lens from the surface fish was capable of inducing the development of eye parts that were normally lost in the cave fish.

The authors also used molecular markers of retinal development to investigate the organization of the restored eye. Pax6, Prox1, proliferating cell nuclear antigen (PCNA) and rhodopsin mark different cell types within the retina. Pax6, Prox1 and PCNA were all expressed in the cave fish eye; however, the retinal layers were disorganized and very few cells expressed rhodopsin, which marks the rod cells. In the restored eye, the retina developed into distinct, organized layers, indicating that normal patterning, growth and differentiation of the eye can be induced in the cave fish.

Links

A comment on this paper appeared in the same issue of *Science* and is available to subscribers (Pennisi E, *Science* **289:**552b). A Supplementary figure to *Science* **289:**631-633 can be accessed freely from the *Science* website.

Reporter's comments

This study shows quite clearly that the lens can play an important role in patterning the eye. When the surface fish lens is implanted into the blind cave fish, normal eye development is restored, though it is unclear whether the restored eye is actually functional. The authors note that there are at least 30 *Astyanax* cave fish populations in north-east Mexico. Their results apply only to the Pachón cave fish used in their study. The other varieties of blind cave fish may have evolved by different mechanisms and further comparisons of these fish may provide insight into the evolution of developmental processes.

Table of links

Science

Pennisi E, *Science* **289:**552b

Supplementary figure to *Science* **289:**631-633

References

1. Yamamoto Y, Jeffrey WR: Central role for the lens in cave fish eye degeneration. Science. 2000, 289: 631-633. 0036-8075