Adapting to the darkness

by Kara Rosania

SCIENTIFIC NAME
Astyanax mexicanus

TAXONOMY
PHYLUM: Chordata
CLASS: Actinopterygii
ORDER: Characiformes
FAMILY: Characidae

Physical description

The Mexican tetra is a small fish (growing to a maximum overall length of 12 cm) widely distributed in northeastern Mexico and south Texas. Females tend to be larger and fuller-bodied than males and have a straight rather than slightly curved edge to their tail fins. The species consists of at least 29 different cave populations in addition to its surface-dwelling form, all of which are interfertile[1]. The surface-dwelling fish is silvery in color with a black band that extends along each side to the tail. The tail and lower fins of some individuals may be tinted yellow or red. In contrast, fish from blind cave populations have no eyes and are devoid of pigmentation, with pinkish-white-colored bodies. Their lack of eyes also causes some craniofacial differences between cave fish and surface fish[2].

Kim Caesar/Nature Publishing Group

Research résumé

A. mexicanus are particularly well-suited to studies of evolutionary development because the surface- and cave-dwelling populations can be compared side-by-side to examine how regulatory genes mediate the evolution of development[1]. More than once over the past 2–3 million years[3], surface-dwelling *A. mexicanus* have invaded caves, giving rise to multiple cave-adapted lineages[1,4]. In this way, each cave fish lineage represents a replicate experiment, providing a unique opportunity to study the developmental mechanisms underlying parallelism and convergence[4].

Several different cave fish populations have independently evolved a cluster of specific adaptations in response to the perpetual darkness of their habitat. Some of these changes are constructive, such as an enhanced feeding apparatus, including larger jaws and a greater number of taste buds and teeth, and a system of mechanoreceptors called neuromasts that are larger and greater in number and have longer cupulae than those of surface fish[1,5].

Cave fish also gained adaptive behaviors including attraction to vibrations, increased exploratory and food searching behavior, increased olfactory capabilities and a special feeding posture[6]. These enhancements likely developed in compensation for their blindness, which is the result of eye degeneration during development. Cave fish embryos form small primordial eyes, but 40 h after fertilization, the lens enters apoptosis, and cell death spreads to the neural retina, triggering the progressive degeneration of the entire eye[7].

Other regressive changes in cave fish include loss of pigmentation, which results from a loss of melanophores and a reduced capacity to synthesize melanin[1,2], and loss of sleep, schooling and aggressive behaviors[3,6]. A recent study showed that oscillation of clock genes in cave forms of *A. mexicanus* are substantially altered[8], and cave forms do not exhibit a circadian rhythm in metabolism unlike surface forms[4].

Several analyses have been done to determine the genetic underpinnings of trait differences between surface- and cave-dwelling forms of *A. mexicanus*, and especially of eye loss[1,2,5,7], with results indicating that multiple genetic modifications have contributed to an overall defect in lens biology. A genome[3] and a developmental transcriptome[9] of *A. mexicanus* have recently been reported, which will aid future research in identifying candidate genes underlying various behavioral and morphological trait differences.

1. Jeffery, W.R. Cavefish as a model system in evolutionary developmental biology. *Dev. Biol.* **231**, 1–12 (2001).
2. Jeffery, W.R. Evolution and development in the cavefish *Astyanax*. *Curr. Top. Dev. Biol.* **86**, 191–221 (2009).
3. McGaugh, S.E. *et al.* The cavefish genome reveals candidate genes for eye loss. *Nat. Commun.* doi:10.1038/ncomms6307; published online 20 October 2014.
4. Moran, D., Softley, R. & Warrant, E.J. Eyeless Mexican cavefish save energy by eliminating the circadian rhythm in metabolism. *PLoS ONE* **9**, e107877 (2014).
5. Jeffery, W.R., Strickler, A.G., Guiney, S., Heyser, D.G. & Tomarev, S.I. *Prox 1* in eye degeneration and sensory organ compensation during development and evolution of the cavefish *Astyanax*. *Dev. Genes Evol.* **210**, 223–230 (2000).
6. Elipot, Y. *et al.* A mutation in the enzyme monoamine oxidase explains part of the *Astyanax* cavefish behavioural syndrome. *Nat. Commun.* doi:10.1038/ncomms4647; published online 10 April 2014.
7. Hinaux, H. *et al.* Lens defects in *Astyanax mexicanus* cavefish: evolution of crystallins and a role for alpha-crystallin. *Dev. Neurobiol.* doi:10.1002/dneu.22239; published online 4 November 2014.
8. Beale, A. *et al.* Circadian rhythms in Mexican blind cavefish *Astyanax mexicanus* in the lab and in the field. *Nat. Commun.* doi:10.1038/ncomms3769; published online 14 November 2013.
9. Hinaux, H. *et al.* De novo sequencing of *Astyanax mexicanus* surface fish and Pachon cavefish transcriptomes reveals enrichment of mutations in cavefish putative eye genes. *PLoS ONE* **8**, e53553 (2013).