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Digest

Digest: Life underground and sensory adaptations in caecilians (Gymnophiona)

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Abstract

Do caecilians retain some degree of vision? Navarrete Méndez et al. (2025) used an integrative approach to show that the long-wavelength-sensitive (*LWS*) opsin gene is present and that retinal morphology remains intact across all eight caecilian families investigated. This finding suggests that caecilians maintain some visual capacity, likely enabling day–night or color discrimination. More broadly, this study highlights key aspects of sensory adaptation in subterranean tetrapods.

Keywords: Subterranean lifestyle, olfaction, vision, mechanoreception, sensory trade-off

When studying sensory adaptation, the most commonly used proxy is the absolute or relative size of sensory organs, as a proportionally larger organ is generally assumed to allow for a more efficient or broader functional range (e.g., Martinez et al., 2020). From an evolutionary perspective, this makes sense since sensory structures can be energetically costly to develop and maintain, and larger organs are therefore expected to be more energetically demanding than smaller ones. However, sensory responses are complex multifactorial processes and may be pleiotropic (Mackay & Anholt, 2024). As a result, patterns of sensory function, whether increasing or decreasing, may sometimes be overlooked.

Caecilians (order Gymnophiona) are a group of legless amphibians that mostly live underground but exhibit a gradient of adaptations, ranging from leaf-litter species to strictly subterranean species, and also include semi- to fully aquatic forms. Previous comparative work on caecilian eyes identified substantial variation in size (Figure 1), including reductions and losses of associated muscles and nerves (Wake, 1985). Together with the observation that caecilian eyes are covered by skin (Figure 1), or even skin and bone, these findings have led to the common assumption that caecilians possess poor or nonfunctional vision.

Using an integrative approach combining genomics, transcriptomics, histology, and evolutionary model analysis, Navarrete Méndez et al. (2025) challenge this long-standing hypothesis. Notably, they consistently identified the long-wavelength-sensitive (*LWS*) opsin gene (encoding a red cone photopigment sensitive to yellow-orange light) across 13 caecilian species, spanning 8 of the 10 recognized families. However, transcriptomic analysis of eye tissue from *Caecilia orientalis* revealed that *LWS* transcripts are expressed at levels at least 80 times lower than the rod opsin *RH1* (one of the primary genes used for vision under low-light conditions). This pronounced difference in gene activity suggests that the visual system is specialized for detecting low-light signals, a pattern commonly observed in nocturnal or subterranean vertebrates. Despite evidence of relaxed selective constraint, the *LWS* gene may have been maintained under overall purifying selection for over 200 million years, supporting its continued physiological relevance. One of the authors' hypotheses is that this remaining functional vision may enable spectral discrimination, allowing caecilians to distinguish between day and night.

Further investigation is needed to better understand the variation in relative eye volume (Wake, 1985), its implications for functionality, and potential links to behavior and ecological adaptation. The renewed interest in sensory structures in amphibians, and in tetrapods more broadly, highlights how modern technologies can fill major gaps in our understanding of sensory adaptation and potential evolutionary trade-offs among different senses. Like many fossorial and subterranean tetrapods, caecilians exhibit eye reduction compared to their terrestrial relatives, suggesting a decreased reliance on visual cues for locating food, finding mates, or avoiding predators. This reduction is likely compensated for by other senses hypothesized to be highly developed in subterranean species, such as olfaction or mechanoreception (Catania, 2011; Schmidt & Wake, 1990). Some caecilians also possess a unique morphological innovation: the tentacle, an organ intimately linked with the eyes and likely involved in olfaction and/or mechanoreception (Himstedt & Simon, 1995; Schmidt & Wake, 1990).

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Figure 1. (Top) Photographs of two caecilian species with likely different degrees of reliance on vision: (top left) *Rhinatrema bivittatum* and (top right) *Herpele squalostoma.* (Bottom) Three-dimensional reconstruction of the head and eye of *Rhinatrema bivittatum*, showing the eye covered by skin. Reconstruction based on original diceCT data from David Blackburn and Edward Stanley (oVert project; Blackburn et al., 2024), using specimen BYU 48675 (Brigham Young Herpetology Collection). Photographs and segmentation by Quentin Martinez; copyright retained by the author.

Therefore, the work of Navarrete Méndez et al. (2025) not only challenges traditional views of caecilian vision but also opens new perspectives on sensory adaptation and morphological innovation in amphibians, and more broadly across vertebrates.

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Conflict of interest

The authors declare no conflict of interest.

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