New study deepens understanding of how animals see, and what colors

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Researchers determined that animals adapted to land see more colors than animals adapted to water. Animals adapted to open terrestrial habitats see a wider range of colors than animals adapted to forests. Credit: Matt Murphy

Gathering vision data for hundreds of vertebrates and invertebrates, U of A biologists have deepened scientists' understanding of animal vision, including the colors they see.

Those researchers have determined that animals adapted to land are able

to see more colors than animals adapted to water. Animals adapted to open terrestrial habitats see a wider range of colors than animals adapted to forests.

However, evolutionary history—primarily the difference between vertebrates and invertebrates—significantly influences which colors a species sees. Invertebrates see more short wavelengths of light, compared to vertebrates.

Biological sciences doctoral student Matt Murphy and assistant professor Erica Westerman recently published these findings in *Proceedings of the Royal Society B: Biological Sciences*. Their article, "Evolutionary history limits species' ability to match color sensitivity to available habitat light," explains how environment, evolution and, to some extent, genetic composition influence how and what colors animals see.

"Scientists have long hypothesized that animal vision has evolved to match the colors of light present in their environments," Westerman said. "But this hypothesis is difficult to prove, and there is still so much we don't know about animal vision. Gathering data for hundreds of species of animals living in a wide range of habitats is a monumental task, especially when considering that invertebrates and vertebrates use different kinds of cells in their eyes to turn light energy into neuronal responses."

An animal's ability to detect visual information depends on the wavelengths and intensity of light in a given environment. Quantity and wavelength sensitivity of a family of retinal proteins, called opsins, govern the spectrum of light an animal sees—from ultraviolet to far red light.

However, invertebrates and vertebrates use phylogenetically distinct opsins in their retinae, and researchers have not determined whether

these distinct opsins influence what animals see or how they adapt to their light environments.

Murphy and Westerman collated vision data for 446 species of animals spanning four phyla. One of these phyla contained vertebrates—animals that have backbones, such as fish and humans. The rest of these phyla contained animals that were invertebrates—those that do not have backbones, such as insects, squid and jellyfish.

The researchers' study showed that while animals do adapt to environments, their ability to adapt can be physiologically constrained. While vertebrates and invertebrates broadly use the same cell type, opsins, to see, they build these cells differently. This physiological difference—what biologists call ciliary opsins in vertebrates and rhabdomeric opsins in invertebrates—might explain why invertebrates are better at seeing short wavelength light, even when habitat should select for vertebrates to also see short wavelengths of light.

However, the difference could be due to stochastic genetic mutations occurring in vertebrates but not invertebrates, Westerman said. These mutations could also limit the range of light in vertebrates' vision.

"Our study answers some important questions," Murphy said, "but it also generates more questions that could help us understand animal vision even better. We can do more to assess differences in the structure of the vertebrate and invertebrate retinae, or how their brains handle visual information differently. These are exciting questions."

More information: Matthew J. Murphy et al, Evolutionary history limits species' ability to match colour sensitivity to available habitat light, *Proceedings of the Royal Society B: Biological Sciences* (2022). DOI: 10.1098/rspb.2022.0612

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