There is more to bats' vision than meets the eye

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Flying Carollia perspicillata bat photographed at its breeding colony at the Goethe Universtiy Frankfurt/M and mounted onto a post-sunset natural background. Photo: Cornelia Hagemann, Goethe University Frankfurt/M, Germany.

The eyes of nocturnal bats possess two spectral cone photoreceptor types for daylight and colour vision. Reporting in the open-access, peer-reviewed journal *PLoS ONE,* scientists at the Max Planck Institute for Brain Research in Frankfurt and the University of Oldenburg have detected cones and their visual pigments in two flower-visiting species of bat.

With electroretinographic recordings, they found an increased sensitivity to UV light in cone-stimulating light conditions. The researchers conclude that bats' eyes are adapted for both daylight and UV vision.

The UV-sensitive cones may yield a number of advantages for bats, including improved visual orientation at twilight, predator avoidance and de tection of UV-reflecting flowers (a benefit for those that feed on nectar).

Bats are mammals in the order *Chiroptera,* which has two suborders: fruit bats (*Megachiroptera*) and microbats (*Microchiroptera*). Microbats (see images 1 and 2), also called 'true bats,' echolocate, while fruit bats do not. Microbats have small eyes and well developed visual centres in the brain. In bats, vision plays an important role in predator avoidance during foraging and homing and, in some species. in prey detection. Moreover, bats are exposed to different levels of ambient light during the day, depending on their roosting situation.

Portrait of a Carollia perspicillata bat, one of the investigated species. Photo: Cornelia Hagemann, Goethe University Frankfurt/M, Germany.

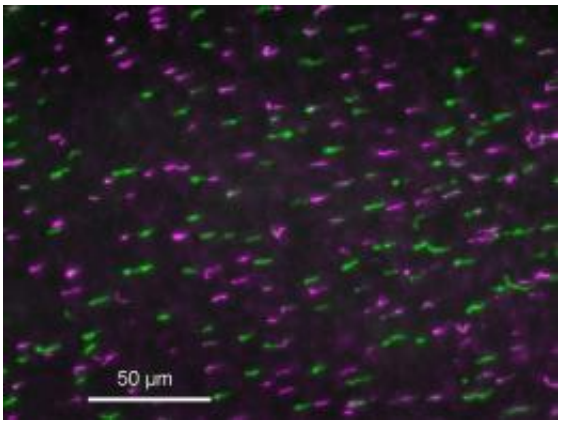
Mammalian retinas have rod photoreceptors for night vision and cone photoreceptors for daylight and colour vision. For colour discrimination, most mammals possess two cone populations with two visual pigments

(opsins) that have absorption maxima at short wavelengths (S, blue or ultraviolet) and long wavelengths (L, green or red).

The eyes of microchiropteran bats are small and their retinas are dominated by rods. This prompted Brigitte Müller and her colleagues at the Max Planck Institute for Brain Research in Frankfurt/Main to study the photoreceptors of flower-visiting bats using histological and molecular biological methods and, with the help of Josef Ammermüller's team at the University of Oldenburg, electroretinographic recordings.

To identify the different photoreceptor types, the researchers stained the retinas of two microbat species with opsin-specific antibodies. As expected, both species had high densities of rod photoreceptors, the prerequisite for nocturnal vision. In addition, they were shown to possess cone photoreceptors, comprising about 2-4 percent of the photoreceptors.

"This share of cones is rather small, but from studies of other nocturnal mammals like mice we know that it allows daylight vision", says lead author Brigitte Müller. For the two flower-visiting bats, *Glossophaga soricina* and *Carollia perspicillata* (endemic to Central and South America), the opsin labeling showed the two spectral cone types typical to mammals, the L cones and the S cones (see image 3). The UV sensitivity of the S cones was demonstrated by sequencing the tuning-relevant segment of the S opsin gene. Electroretinographic recordings confirmed the functional contribution of the cones and UV tuning of the S cones.



Double immunofluorescence labeling for the cone opsins in a flat-mounted retina of the long-tounged bat (Glossophaga soricina). Outer segments of L cone photoreceptors (green fluorescence) and S cones (magenta fluorescence) are visible. Photo: Brigitte Müller, Max Planck Institute for Brain Research, Frankfurt/M, Germany.

Some years ago, in a behavioural study of the flower bat Glossophaga soricina in dark-adapted conditions, scientists found no evidence for colour discrimination, but did detect UV sensitivity. They concluded that this was a property of the rod opsin, and that G. soricina lacked a separate shortwave-sensitive cone photoreceptor. Recent molecular studies found cone opsin genes in different bat species, but provided no evidence for their expression in retinal photoreceptors.

Considering all of these results, Müller and colleagues conclude that the increased sensitivity of the retina to UV light, in both of the species studied, derives from the significant proportion of cones expressing S opsin. Transmittance measurements of the corneas and lenses of *G. soricina* and *C. perspicillata* showed that UV light (wavelengths around 350 nm) in fact reaches the bat retina.

"The results of our study indicate cone-based UV sensitivity in

phyllostomid bats", says Brigitte Müller. "Moreover, with the two cone types, bats have the prerequisite for dichromatic colour vision, a condition common in mammals. The use of cone-based vision in addition to rod-based vision should improve the bats' capability to perceive visual information."

For bats, vision is important for foraging and homing, and for predator avoidance. Mesopic vision (at light levels that stimulate both the rods and the cones) is particularly relevant at dusk and dawn and on brightly moonlit nights. For flower-visiting and nectar-feeding bats like those studied here, UV vision should increase foraging success, as many flowers visited by bats show UV reflection.

More information: Müller B, Glösmann M, Peichl L, Knop GC, Hagemann C, et al. (2009) Bat Eyes Have Ultraviolet-Sensitive Cone Photoreceptors. PLoS ONE 4(7): e6390. doi:10.1371/journal.pone.0006390

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