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The "Love Spot"

Michael W. Perry and **Claude Desplan**

Department of Biology, 100 Washington Square East, 1009 Silver Center, New York University, New York, NY 10003, USA.

Is there really something called the "Love Spot"? At the risk of sounding uninformed... what is it?

The "Love Spot" is a male-specific region of the eye found in some insects that is used for detecting and chasing females. This dorso-frontal region is highly specialized for "small field, small target motion detection", and males use it to see and stay locked on to potential mates during aerial pursuit.

Is the Love Spot an obvious feature?

The Love Spot has been found in at least fifteen families of flies (Diptera) and in the mayflies (Ephemeroptera), where it is particularly dramatic. In some species, the eyes of males are clearly different from females, with enlarged unit eyes (called "ommatidia") in the Love Spot region. This difference can be very dramatic with the dorsal eye clearly distinct from the rest, containing huge ommatidia and corresponding changes in pigmentation (*e.g.* see **Figure 1**). In many species, though, the love spot is more subtle, and identification requires careful comparison between the sexes. For instance, in some species of flies, male eyes are "holoptic", meaning they meet in the middle, while female eyes are farther apart (**Figure 1**). In fact, this difference in spacing is often one of the easiest ways to tell males from females in the field. If the individual facets are also larger in the male dorso-frontal eye: success, you have identified a Love Spot.

What makes this region different from the rest of the eye?

This region is highly specialized for motion and contrast vision. The larger ommatidial lenses increase the amount of light gathered. Some species pack more ommatidia with narrower "acceptance angles" on a less curved eye to keep resolution high even though each individual unit eye is larger than normal. The holoptic, continuous visual surface makes it easier for the fly to place its target directly in its desired direction of travel during pursuit of a potential mate. In vertebrate predators such as hawks, forward-looking eyes allow binocular vision, while the eyes of prey are positioned more laterally for a wider field of view.

mp185@nyu.edu, cd38@nyu.edu

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Apart from these obvious external differences, the common house fly *Musca domestica* has been studied in more detail and several clever internal modifications have been discovered. In all Diptera, individual ommatidia contain eight light sensitive photoreceptors. Six "outer" photoreceptors called R1-R6 are used in motion vision and contain a light sensitive Rhodopsin that can detect a broad range of wavelengths. Their axons connect to the lamina, a region of the brain just under the retina specialized in motion vision. Inner photoreceptors R7 and R8 instead express Rhodopsins sensitive to more restricted wavelengths of light and make comparisons between each other for color perception. Their axons project deeper into the brain into a structure called the medulla. Thus the two "inner" photoreceptors are used for color vision and the six "outer" photoreceptors are used for motion and contrast vision.

In the *Musca* Love Spot, one of the inner photoreceptors normally used in color perception, R7, has been partially converted into an outer photoreceptor. This conversion sacrifices color vision in favor of improved sensitivity in motion detection. Love Spot R7s are modified in two main ways: first, they now respond to a broad spectrum instead of narrower ranges of color, and second, they connect to the motion-processing and spatial vision pathways of the brain – to the lamina instead of the medulla. This rewiring of the brain contributes one additional photoreceptor input per ommatidium toward motion processing and should in principle provide additional sensitivity, though perhaps as little as an 8% overall increase. It is possible that this additional sensitivity provides enough of an advantage to male *Musca* to be worth the loss of color vision across much of the visual field.

How else is the male visual system specialized for pursuit?

Measurements using electrodes inserted into individual photoreceptors have shown that the Love Spot is 60% faster than female photoreceptors in the same region. These are some of the fastest recorded response times for any animal. This increase in speed may be the result of speeding up the biochemical processes involved in phototransduction, though the precise mechanisms are unknown. The ability of individual males to shoulder this additional metabolic cost, and to sustain a strenuous chase may help indicate fitness to potential mates.

In addition to having faster photoreceptors, specialized male-specific processing neurons have been identified deeper in the optic lobes. Large, tree-like lobula plate tangential neurons function to integrate motion input from across the visual field and relay this information to the central brain. Additional neurons of this type have been characterized in *Musca* males in regions corresponding to input from the Love Spot. The special focus on this region of the visual field apparently extends to higher-level processing in the brain.

Could these specializations for extreme motion sensitivity and target tracking be useful in other contexts?

Possibly, yes. Another species in the *Musca* family (Muscidae) is known as the "Killer Fly", *Coenosia tigrina*. This predatory species sits and waits for prey to fly by. They are especially attentive to motion across the visual field in both males and females. Perhaps adaptations used for chasing and capturing mates could be useful here in both sexes; a sort of "Killer Spot" used instead for predation. Farther away from the Muscidae, the eyes of dragonflies also show clear evidence of Killer Spot-like features, with dorso-frontal eyes of both males and females exhibiting enlarged ommatidia and changes in pigmentation (**Figure 1**). Dragonflies are incredibly efficient flying predators. Both sexes also have specialized cells deeper in the brain that make use of motion vision information specifically from this modified region of the eye. It would be interesting to determine how the R7s are wired in the eyes of Killer Flies or in the specialized dorsal region of dragonflies, and to know which Rhodopsins they express.

Where can I find out more?

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Figure 1.

A female horse fly (family Tabanidae), left, is compared to a male of the same species, middle. Note the dorsally enlarged ommatidia and the "holoptic" eyes that meet in the middle. At right is an example dragonfly eye; both sexes have dorsally enlarged, Love Spot-like ommatidia used for hunting and capturing prey.