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**Figure 1** | A *Drosophila* larva. The photoreceptors that mediate light avoidance are labelled green, with the posterior epidermal cells of each segment labelled red.

## NEUROSCIENCE

# Feel the light

**How is light perceived? The answer that might immediately come to mind is, through the eyes. Fly larvae, however, can ‘feel’ light using specialized neurons embedded under the cuticle encasing their bodies. [SEE ARTICLE P.921](#)**

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Light perception is a highly useful skill. Like other animals, we humans rely on vision to navigate, to locate food and mates, and to avoid predators. But biological applications of light perception go well beyond vision — from basic light-avoidance to circadian rhythms<sup>1</sup>. What’s more, photoreceptive cells are located not only in the eyes, but also in various non-ocular locations, ranging from the skin in molluscs<sup>2</sup> to the hypothalamus deep within a bird’s brain<sup>3</sup>. Even overtly eyeless animals, such as the soil-dwelling nematode *Caenorhabditis elegans*, possess photosensitive neurons that help them to avoid the daylight<sup>4</sup>.

In this issue, Xiang *et al.*<sup>5</sup> (page 921) extend the analysis of non-ocular photoreception to the fruitfly *Drosophila melanogaster*. They describe a set of dermal photoreceptors that, surprisingly, had previously escaped notice in this well-studied organism, and uncover a molecular mechanism of phototransduction that has not been previously encountered in the fly.

The lives of *Drosophila* larvae are highly focused on burrowing. As they increase in size in preparation for adulthood, the larvae must feed ravenously, and immersing themselves in the nutritious goo of rotting fruit is an excellent way to access a surfeit of calories in a hurry. In addition, the larvae are highly vulnerable to predation when exposed, because their squishy bodies crawl along rather slowly. Burrowing helps them keep out of harm’s way. Tunnelling therefore provides a singular solution for the larva’s need for both feeding and defence.

One of the cues that fly larvae use to orient

the crucial drive towards the interior is light. Young fly larvae are highly photophobic, and this behaviour involves a pair of primitive eye-like structures inside the larva, near its anterior<sup>6</sup>. These structures, called Bolwig organs, resemble the compound eye of the adult fly in many respects, including their expression of light-sensing rhodopsin pigments<sup>7</sup>. But whereas Bolwig organs can lead larvae out of the light, their anterior location raises a potential problem: once the larval anterior is submerged, the light-driven force for burrowing should diminish. This could leave the larva in the awkward position of posterior exposure, like the proverbial ostrich with its head in the sand.

Xiang *et al.*<sup>5</sup> elegantly attack this ethological conundrum. By genetically ablating the Bolwig organs, the authors show that, although Bolwig neurons are crucial for avoiding low light intensities, the requirement for these cells wanes as light intensities approach those of direct sunlight — around 1 mW per mm<sup>2</sup>.

This observation suggests that flies contain additional photoreceptors. Suspecting that these photoreceptors could be analogous to dermal photoreceptors described in other creatures<sup>8,9</sup>, the authors systematically scanned the sensory neurons along the larval body wall for physiological responses to light. They note that one particular set of sensory neurons — the class-IV da neurons — is strongly activated by light (Fig. 1). Satisfyingly, these neurons remain light responsive even when grown in isolation in culture, confirming their intrinsic light sensitivity. Flies therefore contain dermal photoreceptors.

Do these dermal photosensors mediate avoidance of high-intensity light? Xiang and colleagues’ genetic-ablation experiments indicate that they do. Killing class-IV neurons significantly reduced avoidance at all light intensities. Somewhat surprisingly, however, killing just these neurons, but leaving Bolwig organs intact, dramatically decreased responses to high-intensity light. This suggests that, rather than having overlapping, redundant functions, these two classes of photosensors drive behaviour over different ranges of light intensity.

Intriguingly, previous studies<sup>10–12</sup> have shown that class-IV da neurons also participate in aversive responses to noxious heat and mechanical force. Together with the present results, it seems that these neurons serve as multi-purpose triggers of avoidance. On activation by light, they may provide that extra jolt the larva needs to ensure that its entire body is fully protected.

More surprises were in store when Xiang *et al.* probed the phototransduction machinery of class-IV da neurons. Activation of these cells by light was unaffected when the researchers eliminated proteins on which other fly photoreceptors depend, such as the photon-detecting rhodopsins. Instead, it depended on another G-protein-coupled receptor, Gr28b.

Initially classified as a gustatory receptor, LITE-1 — a nematode relative of Gr28b — was recently discovered<sup>4,13</sup> to mediate phototransduction in *C. elegans*. But although Gr28b and LITE-1 are related, initial evidence suggests differences in the phototransduction pathways in which they are involved. LITE-1

## ASTROPHYSICS

# A strange ménage à trois

**The two Magellanic Clouds may have joined our Milky Way quite recently. It turns out that this trio of galaxies is remarkably unlike most other galaxy systems — both in the luminosity of the clouds and in their proximity to the Milky Way.**

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acts through the cyclic nucleotide cGMP to activate cyclic-nucleotide-gated ion channels<sup>4</sup>. Xiang and colleagues' pharmacological data suggest, however, that these channels might not be required for Gr28b activity. Instead, phototransduction in the class-IV da neurons relies on a member of the TRP family of cation channels, TRPA1.

*Drosophila* TRPA1 is known to act as a molecular sensor of temperature<sup>14–16</sup> and of reactive electrophiles<sup>17</sup>, such as the wasabi ingredient allyl isothiocyanate. TRPA1 is also distantly related to the TRP channels that act downstream of rhodopsins in the fly, although this protein was not previously implicated in photodetection. Precisely how TRPA1 cooperates with Gr28b to mediate phototransduction remains to be determined, but activation by G-protein signalling seems a reasonable possibility.

A key issue this paper<sup>5</sup> raises is the mechanism(s) by which proteins such as LITE-1 and Gr28b participate in phototransduction. When misexpressed, LITE-1 can make cells photosensitive<sup>4,13</sup>, suggesting that it could participate in photon detection. Whether Gr28b shares this capability is not known, but it raises the question of how photons might interact with these molecules, and whether the mechanisms used by rhodopsins might have some relevance here. As Gr28b and LITE-1 have additional relatives in flies, worms and other invertebrates, related pathways may be deployed elsewhere in these animals. From a broader evolutionary perspective, one wonders about the origins of these light sensors and the extent to which their functional analogues may occur in other present-day organisms, but have simply escaped our notice — as was the case for so long in *Drosophila*. ■

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We are all Copernicans now. So we expect to be living in a typical galaxy in a normal neighbourhood. The first of these expectations is fulfilled: our Milky Way is a relatively normal giant galaxy with fairly loosely wound spiral arms (Hubble type Sbc), or perhaps a spiral giant with a central bar-shaped region of stars (SBbc). But the second expectation is not fulfilled: the Galactic neighbourhood is unusual and quite different from what might have been expected. True, the Local Group that we belong to is a small cluster, like many others in nearby regions of the Universe. However, the nearest neighbours to our home Galaxy have been observed to exhibit remarkable peculiarities. Two papers, one in *Monthly Notices of the Royal Astronomical Society*<sup>1</sup> and the other a recent preprint<sup>2</sup>, now reinforce these observations.

For most galaxies, including Andromeda<sup>3</sup>, the nearest neighbours are elliptical galaxies or lenticulars (an intermediate type between an elliptical and a spiral galaxy), whereas the more distant companions are spirals with loosely

bound spiral arms or galaxies with an irregular shape. However, the Milky Way's two closest big companions, the Large Magellanic Cloud (LMC; Fig. 1) and the Small Magellanic Cloud (SMC), are irregular galaxies. This anomaly suggests<sup>4</sup> that the Magellanic Clouds might not always have been close satellites of the Galaxy, but instead that they might be objects formed in the outer reaches of the Local Group and that just happen to be passing close to the Milky Way at present. Recent calculations<sup>5</sup> suggest that there is a probability of about 72% that the Magellanic Clouds were accreted onto the Milky Way within the past billion years, and a roughly 50% probability that they were accreted together.

The second anomaly among the closest large companions to our Galaxy is that the LMC is extraordinarily luminous for a Magellanic-like irregular galaxy. In nearby regions of the Universe, there are only two Magellanic-like irregular galaxies (NGC 4214 and NGC 4449) that even come close to rivalling the LMC in luminosity. In other words, the LMC seems to be close to the upper luminosity limit for Magellanic-like irregular galaxies. This is



**Figure 1 | The Large Magellanic Cloud.** Calculations by James and Ivory<sup>1</sup> and by Liu et al.<sup>2</sup> suggest that the a priori probability of the Milky Way having a nearby satellite galaxy as luminous as the Large Magellanic Cloud is very low.

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