

The Organization of the Lamina ganglionaris of the Bee

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Bee, Vision, First Optic Ganglion

The lamina ganglionaris of the bee contains the first synaptic region in the optic tract. The nine retinula cells of one visual unit (ommatidium) either end in the lamina as *short visual fibres* or end as *long visual fibres* in the second optic ganglion (medulla). Each axon bundle of nine fibres from one ommatidium is associated with four different second order neurons (*L-fibres*) to form a single lamina cartridge. Processes of *additional fibres* invade single groups of cartridges.

The present investigation of the lamina on worker bee's eye employed the Golgi technique in light microscopy and electron microscopy. Serial sections reveal three important properties: the retina-lamina projection, the structure of the optical cartridge as well as the connectivity pattern of R-, L- and additional fibres.

The classes of retinula fibres (*R-fibres*) are distinguished by their shapes, by their axon diameters as well as by the regularly repeated arrangements in the axon bundles. The six *short visual fibres* (*svf*) of the retinula cells 1–6 (numbered according to Perrelet¹ and Menzel²) end as three different axon types in stratum A or B of the first synaptic region. The three other fibres from the retinula cells 7–9 run through the lamina and end as *long visual fibres* (*lvf*) in the distal layer of the medulla³.

The two *svf 1* (retinula cells 1 and 4) have tasel-like endings which reach the stratum B of the first synaptic region (Fig. 1). The *svf 2 and 3* end in stratum A of the first synaptic region. The two *svf 2* (retinula cells 3 and 6) have forked endings, the two *svf 3* (retinula cells 2 and 5) have tapering endings (Fig. 1). The three *long visual fibres* *lvf 1, 2 and 3* belong to retinula cells 7, 8 and 9. *Lvf 1 and 2* have tapering endings, *lvf 3* end in many branches.

The relative positions of fibres in the axon bundle remain almost the same from the basement membrane to the first synaptic region. The bundle rotates clock or anticlockwise with no regularity through an angle of 90–180° in different bundles.

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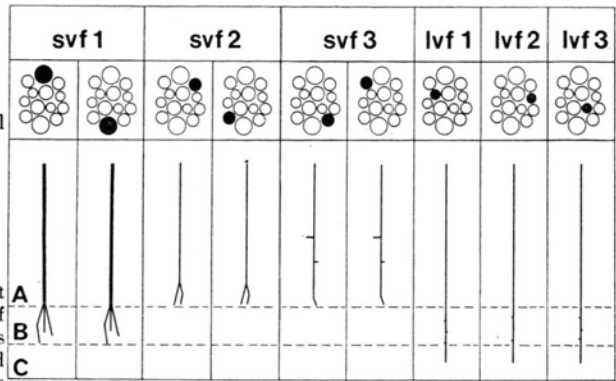


Fig. 1. The nine retinula fibres of one ommatidium end either as short visual fibres (*svf*) in the lamina or as long visual fibres (*lvf*) in the medulla. Retinula cells 1 and 4 end as *svf type 1*. Retinula cells 3 and 6 end as *svf type 2* and retinula cells 2 and 5 as *svf type 3*. The long visual fibres, *lvf type 1, 2 and 3* originate from retinula cells 7, 8 and 9. The position of the fibres in the lamina cartridge (level of stratum A) are marked with black dots.

The two *svf type 1* (diameter 2–2.4 μm) lie opposite each other parallel to the v-axis. The four *svf type 2 and 3* (diameter 1.4–1.8 μm) are arranged on either side of the *svf type 1*. The three *lvf* (diameter 0.8–1.2 μm) lie almost together in the centre of the axon bundle (Fig. 1).

The four *L-fibres* which join the nine R-fibres of one ommatidium to build an optic cartridge, can be distinguished by their different branching patterns. The *L-1* monopolar cell axon shows radial branches in all the three layers of the synaptic region (Fig. 2). Their branches in stratum A and B have postsynaptic contacts with all short visual fibres in the cartridge. In addition to the radial branches in stratum A, the *L-2* fibre has long collaterals which connect seven neighbouring cartridges (along the *z*, *-z*, *y*, *-y*, *x*, *-x* and *z/y* axes) (Figs 2 and 3). The small protrusions in stratum B make contacts only with the fibres on the same cartridge. The *L-3* type with radial branches in stratum B does not send any branches outside its own cartridge (Fig. 2). Postsynaptic contacts have been found only with the short visual fibre type 1. The monopolar cell *L-4* has long bilaterally arranged collaterals in stratum C. These branches reach six neighbouring cartridges along the dorso-ventral axis. The neighbouring cartridges which *L-4* contacts are positioned along the *v*, *-v*, *x*, *-x*, *y* and *-y* axes (Figs 2 and 3). The long collaterals of the *L-4* fibre have synaptic contacts with other L-fibres and additional fibres in the fibre dense zone of stratum C. Together with the three long visual fibres, the second order neurons *L1–4* of each cartridge project to the second optic region, the medulla.



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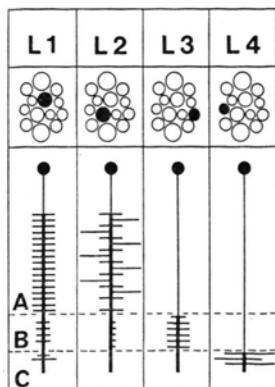


Fig. 2. The four *L*-fibres (second order neurons) of one cartridge. The branching pattern of the *L*-1 fibre is such that it connects fibres in the same cartridge in all three synaptic strata of the first synaptic region. The *L*-2 fibre with radial branches in stratum A connects fibres in the same cartridge. The few long collaterals reach 7 neighbouring cartridges. Small spines can be seen in stratum B. The *L*-3 monopolar fibre shows branches only in stratum B. The long collaterals of the *L*-4 fibre in stratum C are bilaterally arranged, perpendicular to the *z*-axis. Their branches reach six neighbouring cartridges in a dorso-ventral arrangement.

In addition to the R- and L-fibres each cartridge has 1–3 other fibres (distinguishable as *centrifugal*, *T*- or *tangential fibres*) which end in the synaptic region of the lamina. Some additional project to more than one cartridge. Their synaptic contacts with R- and L-fibres are distributed over wide areas of the first synaptic region.

¹ A. Perrelet, Z. Zellforsch. **108**, 530 [1970].

² R. Menzel and A. Snyder, J. Comp. Physiol. **88**, 247 [1974].

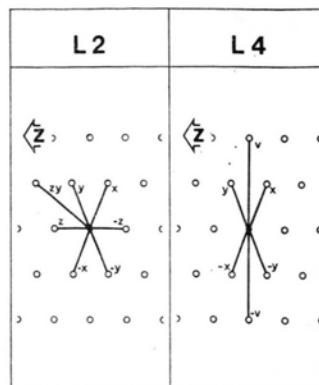


Fig. 3. The collaterals of the *L*-2 fibres connect neighbouring cartridges in the stratum A of the first synaptic region. Their branches reach neighbouring cartridges positioned along the *z*, $-z$, *y*, $-y$, *x*, $-x$ and *z/y* axes. The collaterals of the *L*-4 fibres connect neighbouring cartridges in the stratum C of the first synaptic region. These branches reach the neighbouring cartridges arranged along the *v*, $-v$, *x*, $-x$, *y* and $-y$ axes.

This light microscopy and Golgi-EM study of the arrangement of neurons and their synaptic connections in the first synaptic region are related to information processing of the lamina ganglionaris of the bee.

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³ W. Ribi, Adv. in Anatomy, Vol. 50/4 [1975].