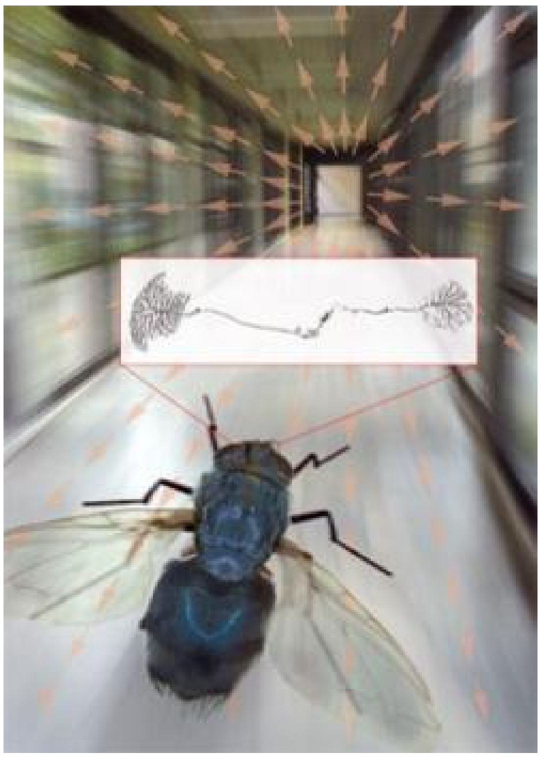
Two nerve cells in direct contact

November 7 2006



A fly, flying along a corridor, produces through its movement a constant shift of the pictures of the environment on its eyes (illustrated with arrows). This "vector field" must be analysed on a higher level of the visual centReR, called the Lobula plate, so as to control and correct the flight course. Turns are controlled by the direct connection of two nerve, the HSE cell (right) and the H2-Zelle (left). Credit: MPI for Neurobiology - Robert Schorner

For the first time, scientists at the Max Planck Institute for Neurobiology in Martinsried near Munich (Germany) have been able to show how two nerve cells communicate with each other from different hemispheres in the visual centre. This astoundingly simple circuit diagram could at a later date provide a model for algorithms to be deployed in technical systems.

Movements in space create in humans and animals so-called optical flow fields which are characteristic for the movement in question. In a forward movement, the objects flow by laterally, objects at the front increase in size and objects further away hardly change at all. At a higher level in the visual centre in the brain, there must be a computation of the visual information, so that animals can differentiate between their own movement and movement of their environment and are able to correct their course if necessary.

It is important for the analysis of flow fields that the movement information from both eyes is merged so that the whole flow field can be assessed. In their current study, Karl Farrow, Jurgen Haag and Alexander Borst have for the first time proved the direct link between two nerve cells, one in each half of the brain, combining the movement signals from both the facetted eyes of a fly.

In the blow fly, the nerve cells that analyse optical flow fields, called tangential cells, are located in the lobula plate. There are only 60 of these tangential cells for each half of the brain and each of these 60 cells can be identified individually. The scientists in Martinsried have looked closely at one cell, the H2 cell. This cell exhibits a strong preference for rotational flow fields such as that which arises when the fly turns around its body's vertical axis. Interestingly, this cell seems initially to react only to the movements in front of its own eye (ipsilateral), but remain blind to movements in front of the other eye (contralateral). However, if the ipsilateral movement stimuli are combined with the contralateral, it is seen that the latter do indeed modulate the reactions to ipsilateral movement stimuli. "The preference of the H2 cell for rotational stimuli is due to a non-linear coordination of the movement stimuli from both eyes, and it was this non-linearity that we wanted to investigate further," said Alexander Borst.

The next step was to analyse the circuit diagram of the tangential cells of the lobula plate in detail. This was based on a multitude of experiments in which the connections between the cells within one lobular plate and those between the two hemispheres were examined. In the end it turned out that there were two ways in which movement information from one half of the brain could reach the H2 cell in the other: firstly, directly from the so-called HSE cell, which is electrically linked to the H2 cell in the opposite hemisphere and secondly, indirectly via the CH cell, which receives information via several intermediate stops from the other half of the brain and which inhibits the H2 cell on the same side with chemical synapses. Both connections were in principle suitable for achieving the effect described; however the question remained: which of the two is the crucial one?

The Max Planck scientists therefore blocked the two possible routes selectively with laser ablation (the cell is filled with fluorescent dye which has a toxic effect when strongly stimulated) and tested sensitivity to rotation in the H2 cell. A long series of these technically very difficult experiments provided unambiguous proof: if the ipsilateral CH cell was destroyed, no effect was seen on the rotation sensitivity of the H2 cell. However, if the contralateral HSE cell was removed from the circuit, the rotation sensitivity of the H2 cell disappeared. It was blind to the movement stimuli in front of the other eye, irrespective of whether it was combined with the ipsilateral movement stimuli.

Alexander Borst enthused about the discovery: "The genius of this circuitry is in its simplicity: with a single electrical link between two cells from the halves of the brain, one cell is selective for rotation flow fields." Whether nature has constructed similarly simple mechanisms in mammals is still unclear - the circuitry of the nerve cells in the relevant areas in the cerebral cortex has not yet been sufficiently explained to allow experiments of this nature to be carried out. And it is rather doubtful whether removing a single cell from the many billions of cells in the cerebral cortex would have an effect.

Clearly, however, this does not mean that the findings made by the fly researchers in Martinsried will be without consequence for other areas of science. For example, engineers developing navigating robots and driving assistance systems rely on simple and robust algorithms such as those realized by nature in insects. The mechanisms of optical flow field analysis are supremely suitable for technical implementation. As part of two projects supported by the Federal Ministry for Education and Research (the Bernstein Center in Munich and "Cognition in Technical Systems" (CoTeSys)) the neurobiologists in Martinsried, in collaboration with their colleagues from the Technical University in Munich, will be working more intensively on this area over the next few years. The Neuronal Information Processing department under the leadership of Alexander Borst has recently participated in the graduate training program "School of Systemic Neurosciences" at the Ludwig Maximilian University in Munich.

Citation: Karl Farrow, Jürgen Haag & Alexander Borst, Nonlinear, binocular interactions underlying flow field selectivity of a motion-sensitive neuron, *Nature Neuroscience*, October 10, 2006

Source: Max Planck Institute of Biochemistry