

In many fields of performance small brains, such as that of the fly, can completely outclass large ones, to say nothing of technical systems. One aspect is the rapidity of visual image processing. Thanks to a broad spectrum of research effort we are now beginning to understand the neuronal mechanisms underlying this process.

Anyone who has observed two flies chasing each other will be conversant with the breath-taking aerial acrobatics these tiny pilots can produce. Whilst the human eye is scarcely capable of even following their flightpaths, the pursuer fly is quite capable of catching its speeding prize. To do this it relies to a great extent on its large, faceted eyes, which give it almost all-round vision. The continuous images these eyes deliver to its brain are evaluated in fractions of a second and transformed into navigating signals.

In order to learn what the fly sees during these breath-taking manoeuvres let us imagine we are sitting in the fly's cockpit. Immediately after take-off our environment starts to move past both our eyes from

# In the Cockpit



# of the Fly

Small brains can completely outclass large ones in their performance. Thus the fly has proved to be an outstanding model system for image processing in the brain

make up to ten sudden turns per second, during which they reach angular velocities of up to 5,000 degrees per second – velocities which no human body could even begin to withstand.

The fly has proved to be an outstanding model system for tracing the activities in the brain which serve to process image-flows proceeding from the eyes. On the one hand, the visual system of the fly is optimised for the performance of this task and, on the other, experimental analyses can be conducted here employing a broad spectrum of methods. Every method of investigating neuronal circuits can be applied to a largely intact creature, thus making it possible to study the processes occurring in the brain during the actual reception of its natural sensory inputs.

**W**e are now at least able to study basic aspects of the neuronal circuits which evaluate the moving images on the retina of a fly. These moving images are not perceived directly by the eye. The fly's eye rathermore sees

---

with maximum strength to movement in a given direction. The information from numerous local motion detectors is summated by integrating neurons. These are able to recognise characteristic relationship situations, such as occur, for instance, when a flying body changes direction.

We gained our knowledge about this from studies based on relatively simple stimuli, such as black bars moved in front of the fly's eyes, whereby the neural networks for visual image processing were subjected to electrophysiological analysis. For this analysis, fine measuring probes are introduced into individual nerve cells to register their electrical activity. However, these experiments cannot tell us how information relating to the environment

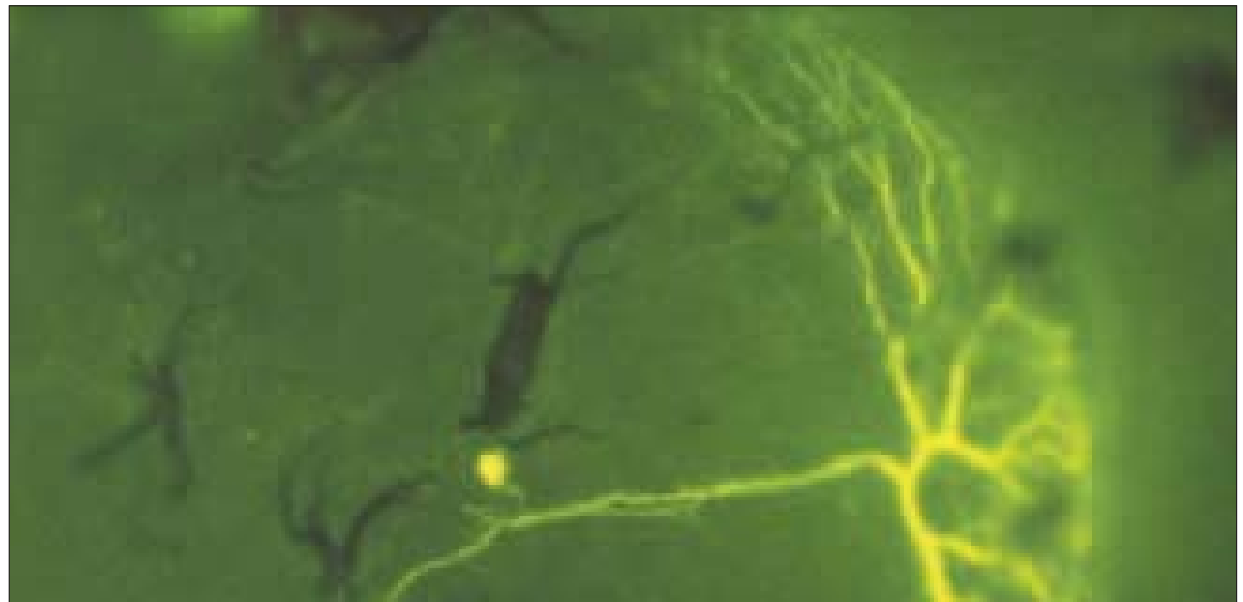
reliable, in other words, they react very differently to the repeated presentation of a stimulus. Secondly, visual stimuli in real behavioural situations are not, as in an experiment, predetermined by an external source, but are determined by the manner in which the creature moves.

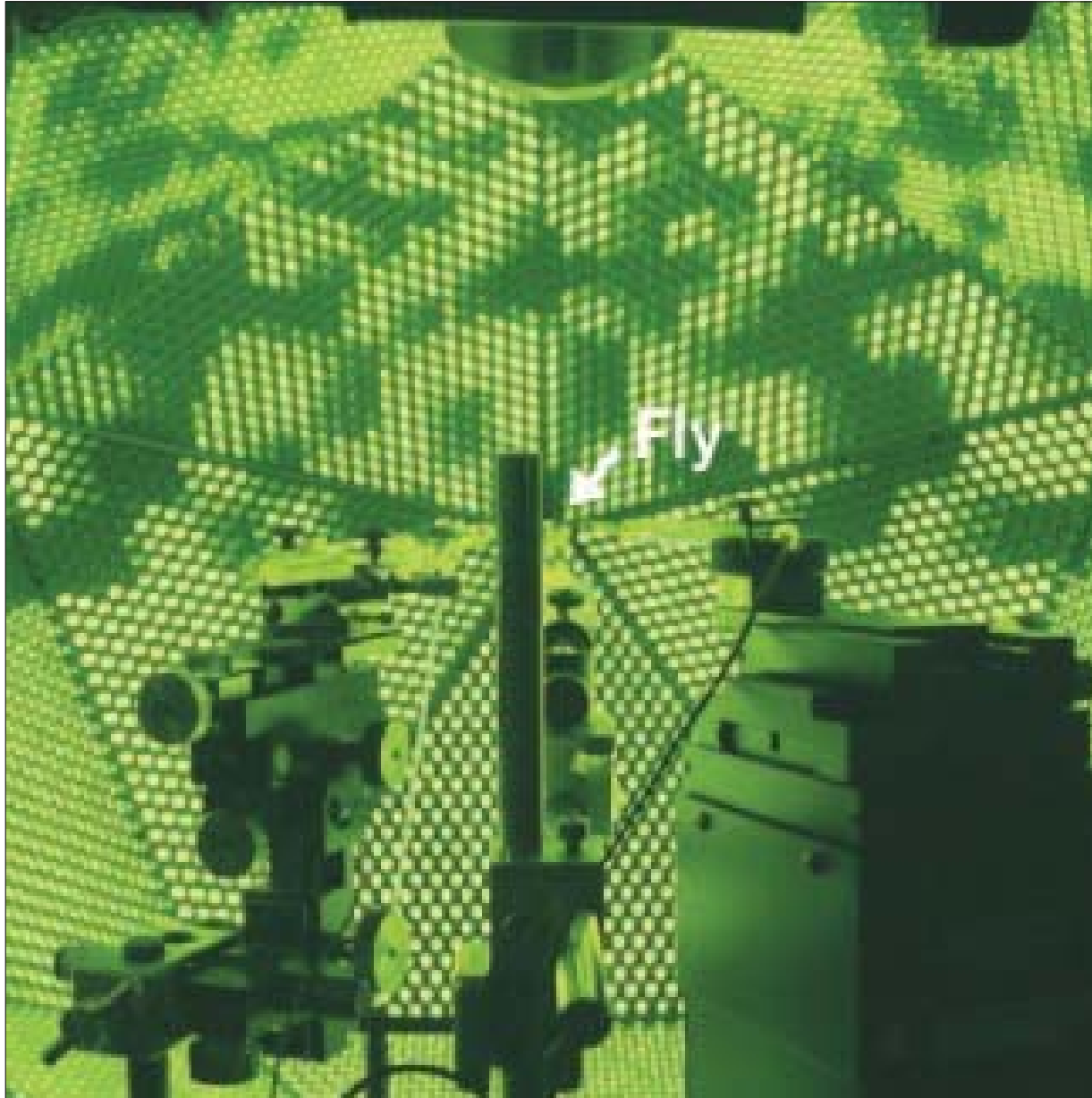
In order to study the neuronal processing of natural visual stimuli we developed a sort of panorama cinema for flies ("FliMaX"), which now, for the first time, permits the image-flow seen by flies in free

images is much greater than that of a human being. Hence the film in our "FliMaX" is played at a speed of 370 images per second. At this speed the image sequences fuse in the fly's eye to a natural impression as would be seen by the eyes during a rapid flight manoeuvre.

Current studies in the "FliMaX" suggest that the mechanisms for visual image evaluation in flies are only able to present the brain with the necessary information on the environment so rapidly and efficiently because they require rela-

The nerve cell of a fly has been filled with a fluorescent dye. The stained cell is most sensitive to small moving objects. Below: An image-creating process elucidates neuronal information processing. Left, the ramified exit region of a nerve cell





The “FiMaX” panorama cinema was developed specifically for studying the brain performance of flies. The fly is located at its centre and looks onto the screen. Fine measuring probes are introduced into its brain from behind.

ing in normal behavioural situations. At the moment, we are continuing this development to transform our “virtual fly” into an autonomously acting agent capable of navigating in complex environments with degrees of efficiency and virtuosity similar to those of a real fly.

Even if the development of this “virtual fly” is being pursued primarily for reasons of scientific interest, the mechanism of biological information processing could provide valuable leads for the development of technical systems. This has, in fact, already happened in diverse study groups in Europe and the USA, where scientists are using models developed for parts of the motion vision system of flies to develop computer chips for use in robot control. Despite this, there is