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Oral Presentations
- Biophysics and bioengineering of sensory systems -

O11-1

The temporal structure of signal processing in the retina

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The vertebrate retina forms an intricate network of neurons with feed forward, feedback, and lateral connections. Visual stimuli elicit temporally structured responses in the retinal interneurons. This structure depends on neuronal type and the stimulus configuration. Consequently, the output signal of the retina, formed by action potential trains of the ganglion cells, is also temporally structured. For the design of a bioinspired visual prothesis, this temporal structure should be considered. Intracellular and multi-electrode, extracellular recordings were performed from all major interneurons and large ganglion cell populations of the turtle retina. Various light stimuli were applied and latencies, time to response peaks and temporal structure of ganglion cell spike trains were analyzed. The complexity of the temporal structure in ganglion cell spike trains increases with intensity, spatial extent and duration of the stimulus. It´s fine structure probably results from spike refractory period, whereas the coarse structure correlates to certain response features of the various types of retinal interneurons. Some features of this structure can be modelled with a simple contrast-gain model which includes delayed feedback lines. Since this structure occurs within the first 300 ms of the responses, we suggest that it might play an important role for object recognition during fixation periods, which also range between 100 and 500 ms in humans. Supported by CORTIVIS and DFG Am70.

O11-2

Active detection of sounds in the inner ear

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Hair cells of the inner ear detect mechanical stimuli by deflections of the hair bundle, which open tension-gated transduction channels in the cell membrane to admit cations from the surrounding fluid. Recent experiments have shown that the hair bundle has an active response and is not just a passive elastic structure. Indeed, spontaneous oscillations of the bundle have been observed in the absence of a stimulus. We have proposed the general concept of 'self-tuned criticality' to explain why such oscillations occur, and how they help the ear to hear. According to this idea, when working normally each hair cell is maintained at the threshold of an oscillatory instability. Poised on the verge of vibrating at a characteristic frequency, a hair bundle is especially responsive to weak periodic stimuli at that frequency. The concept of critical oscillators also sheds light on the transmission of acoustic energy within the cochlea. Classic experiments have demonstrated that a sound stimulus entering the inner ear excites a deformation of the basilar membrane which travels towards the apex and reaches peak amplitude at a location that depends on the frequency. We have put forward a model in which critical oscillators are ranged along the membrane, and are positioned so as to drive its motion. The basilar membrane is then an excitable medium which propagates an active traveling wave. The resultant nonlinear response accords with many of the observed features of cochlear tuning.

O11-3

The photochemistry of photobiology, with PYP and AppA as prime examples

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To properly respond to changes in fluency conditions, Nature has developed a variety of photosensors that modulate gene expression, enzyme activity and/or motility. Dedicated types have evolved, which can be classified in six families: rhodopsins, phytochromes, xanthopsins, cryptochromes, phototropins and BLUF proteins. Surprisingly, the latter three all use flavin as their chromophore. The photochemistry of rhodopsins, phytochromes and xanthopsins is based on *cis/trans* isomerization of an ethylene bond. In the flavin-containing families, exciting new types of photochemistry have been discovered. The basis of signal generation within the xanthopsins will be illustrated via Photoactive Yellow Protein from *Ectothiorhodospira halophila*. Its activation proceeds through *trans/cis* isomerization of the 7,8-vinyl bond of its hydroxycinnamic acid chromophore. This initiates a large conformational transition, leading to a phototactic response of the bacterium. Photoactivation initiates a photocycle (Ö = 0.35) with several intermediates, like pR and pB, formed after H+-transfer from E46 to the chromophore. The negative charge of E46 in the interior of the protein causes destabilization and subsequent partial unfolding. Refolding kinetics is dependent on the mesoscopic context of the protein. Much less is known about the anti-transcriptional regulator AppA, a BLUF-family member from *Rhodobacter sphaeroides*. Nevertheless, initial characterization revealed that its photochemistry is based on lightinduced deprotonation of its FAD chromophore, forming a signaling state which recovers with a rate of ~ 10-3 s-1. Furthermore, also this photoreceptor is partially unfolded in its signaling state. It is a challenge to resolve the to resolve the role of these partially unfolded signaling states for biological signal transfer.

O11-4

The use of insects as biosensors for the detection of volatile compounds

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Insects have evolved exquisitely sensitive olfactory sensors on their antennae and can perceive, with great specificity, very low concentrations of airborne volatiles For example, electrophysiological recordings from single antennal cells can detect 108 molcules per ml air. We have used this to detect volatiles present at an early stage of food deterioration. Recordings from the antennae of the fruit fly, *Drosophila melanogaster* demonstrate that it has olfactory cells which can discriminate between a healthy fruit and one which, although visually perfect, will begin to deteriorate within a few days. The cell is so sensitive that it can detect the difference between two punnets of tomatoes containing either 24 firm fruits, or 23 firm fruits plus one in an early stage of deterioration (not visible to the human eye). Similar specificity and sensitivity were found for the blowfly *Calliphor vomitoria* with volatiles from fish or meat, either fresh or in an early state of deterioration. The insect systems offer the prospect of developing biosensors, which are widely sought by the food processing and retail industries for early warning of loss of quality and safety. A biosensor incorporating preparations from insect antennae could comprise either a live insect or, in the longer term, the proteins which confer the molecular recognition. To this end we have cloned and expressed genes encoding the binding proteins responsible for initial interactions with the volatile signal chemicals in the insect antennae. These proteins are small, water-soluble and highly stable molecules suitable for incorporation into biosensors with enormous potential for many industrial applications.