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COUPLING AND CONTROLLING RETINAL NEURONS WITH SEMICONDUCTOR CHIPS

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The trivial prerequisite studying the relevant electric signals in a neuronal population is the measurement of these signals. Today's experiments reflect a gap between the number of recorded and theoretically recordable neurons in brain tissue because of the relatively low number of electrodes and the large separation between them. Silicon-based multi-electrode arrays (NeuroChips) with 16384 sensors/mm2 provide sufficient sampling density to record from hundreds of neurons at once. The sampling density further enables us to image the propagation of individual neuronal signals along axons. And third, NeuroChips can be used to induce electrical activity in neurons by capacitive stimulation.

In this lecture I will discuss the application of NeuroChips in retina research with the focus on retinal diseases. The axons of retinal ganglion cells form the optic nerve that transmits the visual information from the eye to higher brain areas. In different optic nerve neuropathies, including glaucoma, axons in the optic nerve degenerate leading to incurable blindness. We make use of a simple protocol to crush the optic nerve and measure the conduction velocity within individual ganglion cell axons one to four weeks after surgery. Our preliminary results indicate that although the conduction velocity decreases other electrical functionalities of individual ganglion cells remain intact over a long time period.

As a second example the hereditary disease of retinitis pigmentosa will be discussed. Here, the loss of photoreceptors is accompanied by extensive morphological changes in the neural retina, but detailed knowledge of physiologic changes is just emerging. We measure, in agreement with previous studies, aberrant rhythmic activity in a large number of retinal ganglion cells. Using pharmacological blockade of the input of these cells we identify presynaptic neurons responsible for the physiological changes.

Diverse neuroprosthetic devices are developed to bring back some vision to blind patients. Electrical neuroprosthetic devices rely on the efficient and safe stimulation of the remaining neural retina. In the last part I will present results on capacitive stimulation of retinal ganglion cells using the NeuroChip. The results will be compared to the Lapicque' and Blair's theory of electrical stimulation of excitable tissue.