

Masters Medizintechnik

Implantology

Retina basics 2:

The tricks of the retina -

Sophisticated image processing

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(comments, critics, suggestions)



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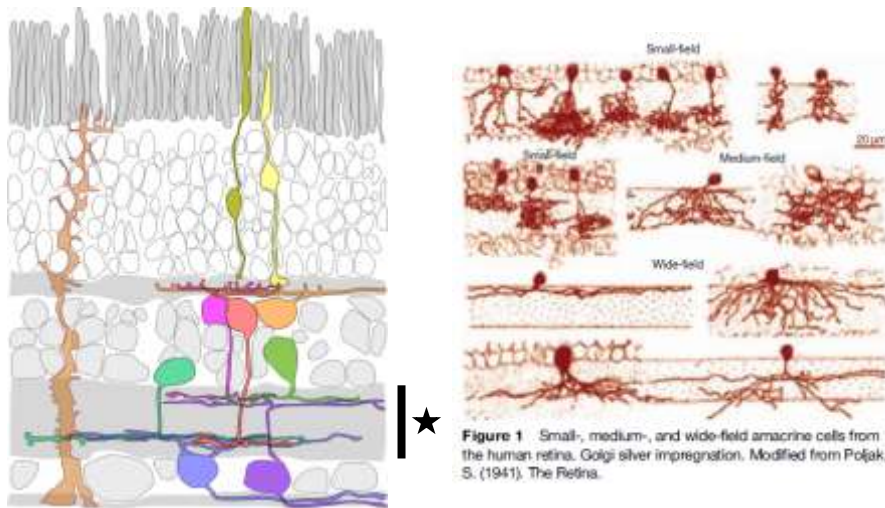
Learning goals

- **Diversity of image processing in the retina**
 - Many neural circuits specialized for specific functions (**feature extraction**)
 - Diversity of cell types (ganglion cells, amacrine cells)
 - Diversity of synaptic interactions
- **Retina as approachable part of the brain allows to study such interactions**
 - Examples for experimental approaches

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Amacrine cells – a diverse cell class



★ Inner plexiform layer (IPL)

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Outline – The tricks of the retina

Examples for sophisticated image processing: Analysis of image movement

- Direction Selectivity
- Object-motion sensitivity

Technical aspects:

Extracellular recordings and spike sorting

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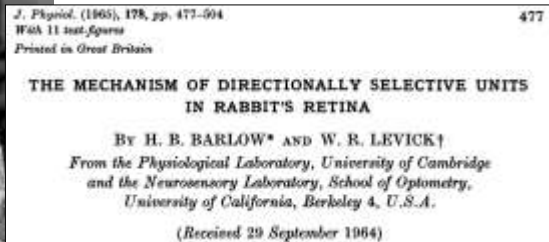
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Bill Levick

Horace Barlow

Detecting Motion Direction in the Retina

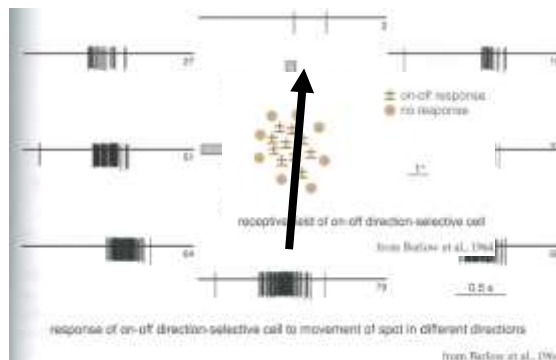


Barlow and Levick, 1965

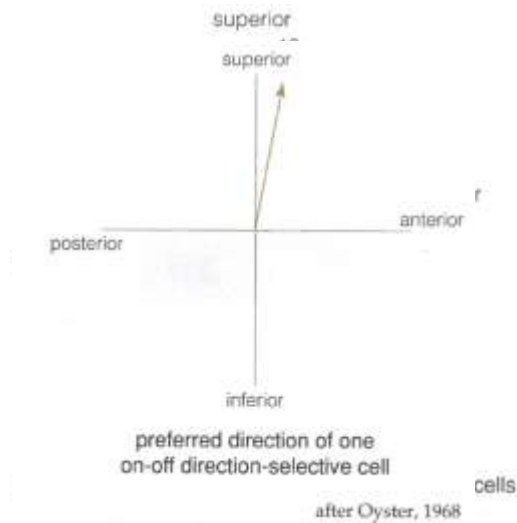
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Responses of DS ganglion cells



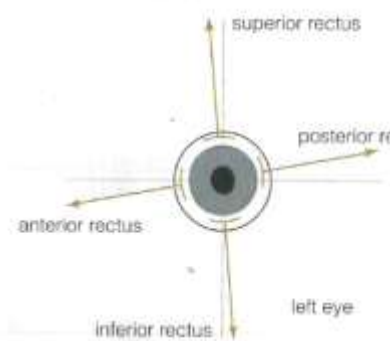
Responses of DS ganglion cells: 4 sub-types



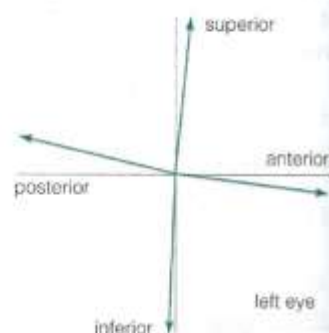
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Responses of DS ganglion cells: 4 sub-types



directions in which each of the rectus muscles move the left eye of the rabbit



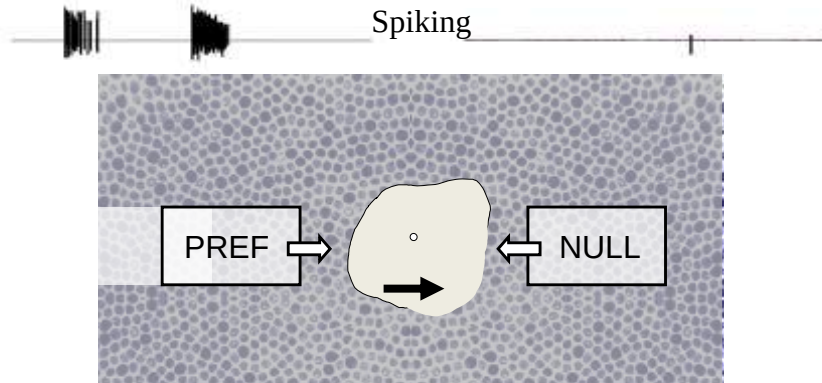
average preferred directions in the visual field for each type of on-off direction-selective cell in the left eye of the rabbit

after Oyster, 1968

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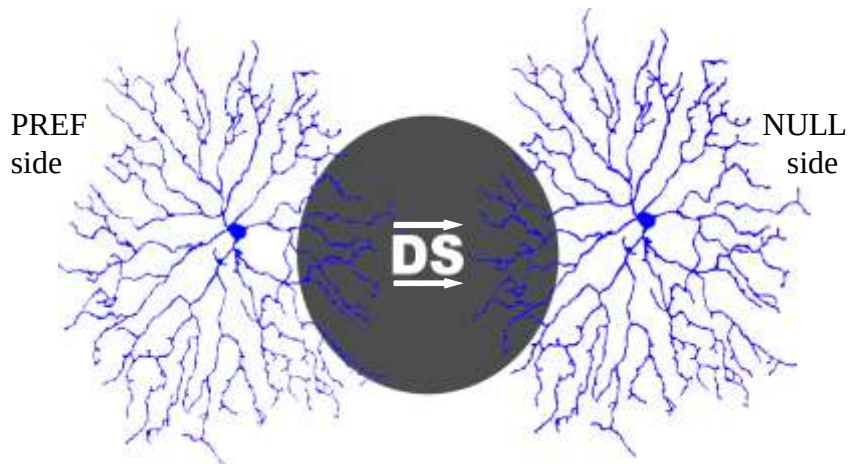
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Directional Asymmetries

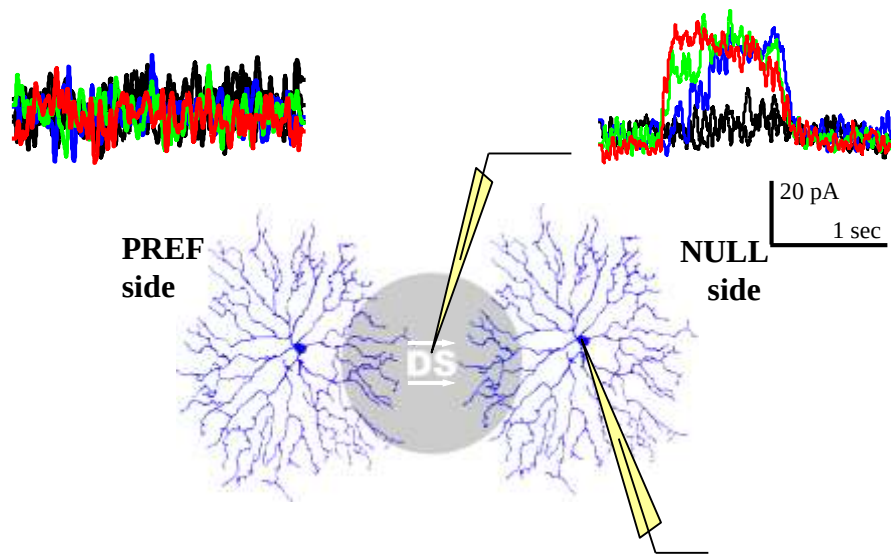


How is the directionally selective spiking generated?

Starburst amacrine cells

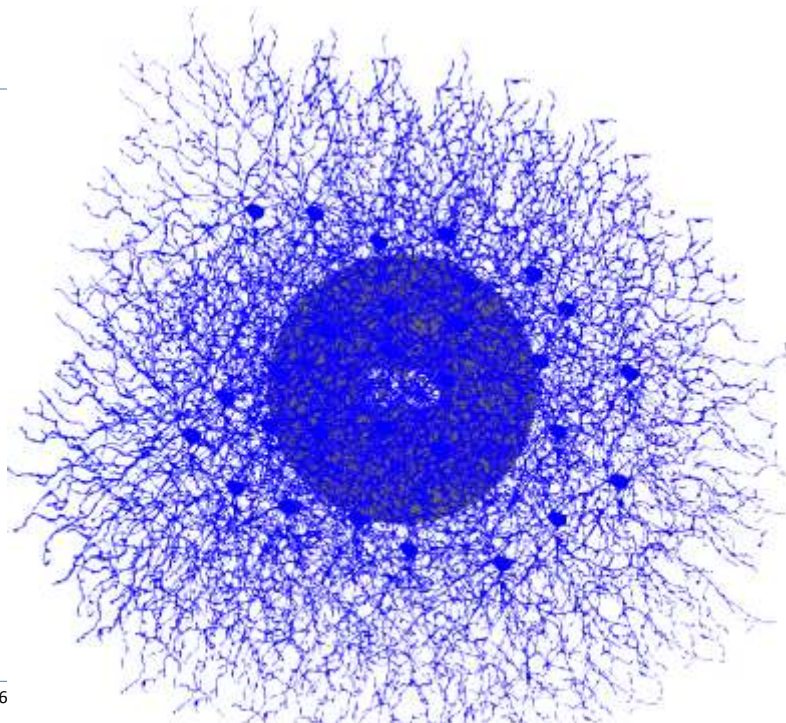


Starburst amacrine cells



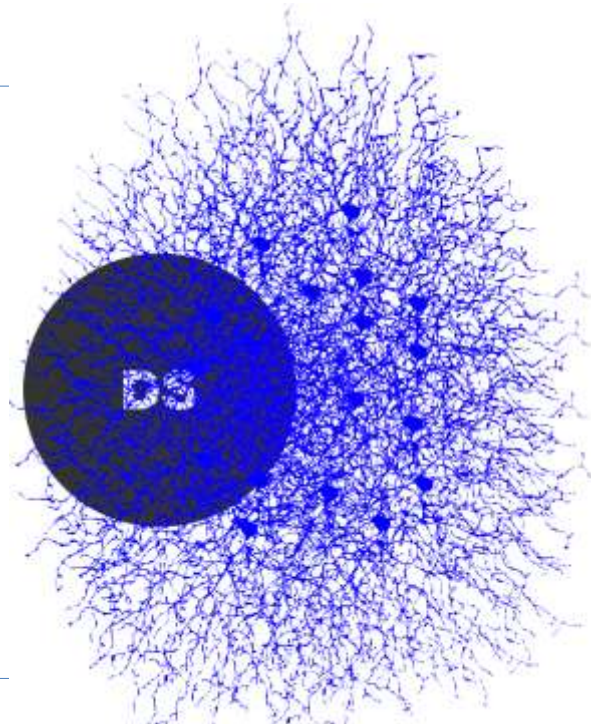
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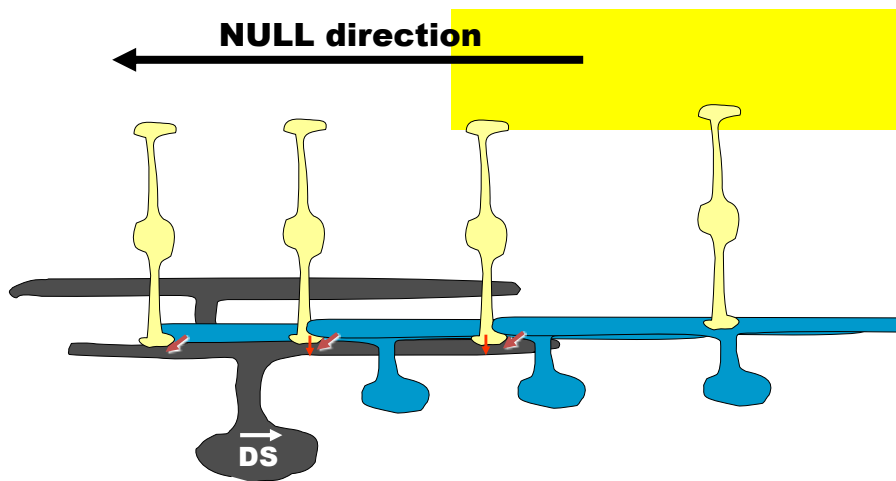
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Asymmetric inhibition



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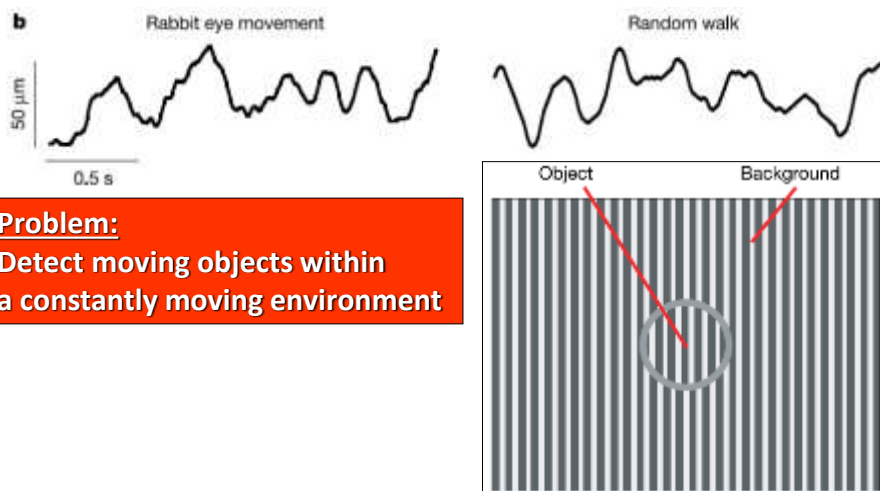
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Segregation of object and background motion in the retina

Dance P. Olvcsky^{1,2}, Stephen A. Lisman¹ & Markus Meister¹

NATURE | VOL. 423 | 22 MAY 2003

¹ Division of Health Sciences and Technology, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, Massachusetts 02138, USA
² Program in Neuroscience, Harvard University, 220 Longwood Avenue, Boston, Massachusetts 02115, USA
³ Department of Molecular and Cellular Biology, Harvard University, 8 Divinity Avenue, Cambridge, Massachusetts 02138, USA



Problem:

Detect moving objects within
a constantly moving environment

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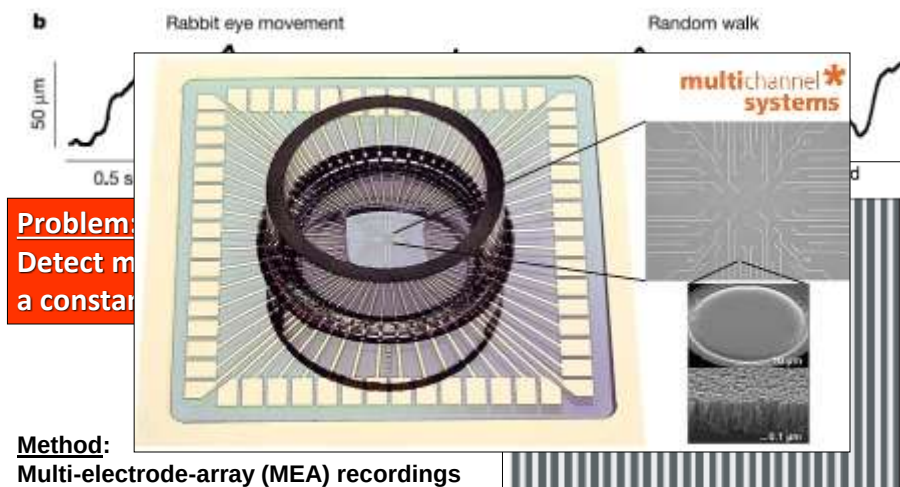
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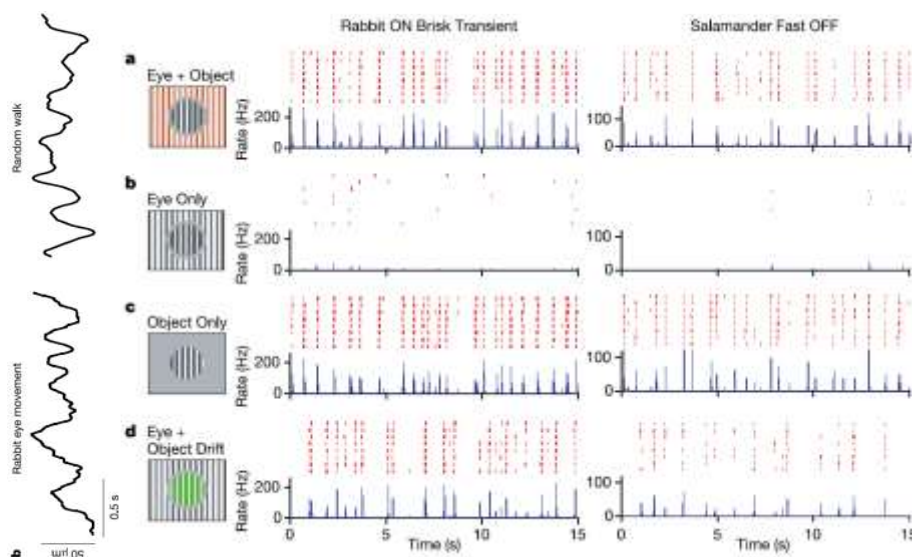
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Object motion sensitive ganglion cells



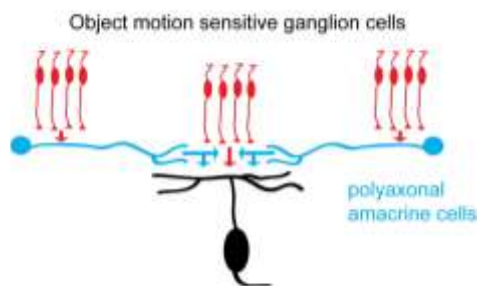
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Object motion sensitive ganglion cells

Problem:

Detect moving objects
within
a constantly moving environment



Bipolar cells

Strongly rectifying

Input

Output

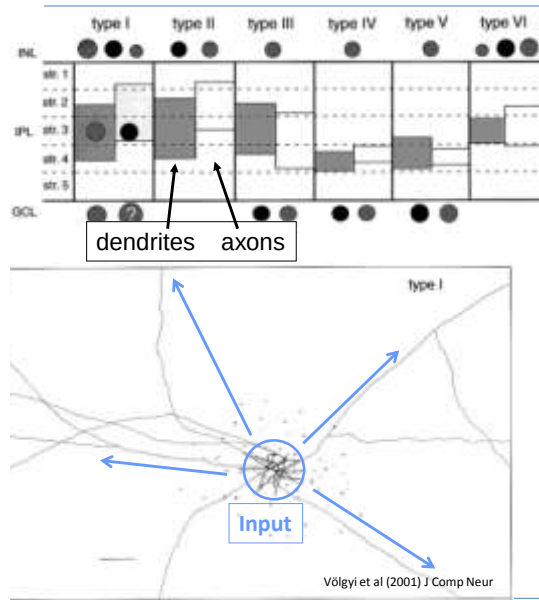
→ Sequence of temporally sparse events

Polyaxonal amacrine cells

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Object motion sensitive ganglion cells



Bipolar cells

Strongly rectifying

Input

Output

→ Sequence of temporally sparse events

Polyaxonal amacrine cells

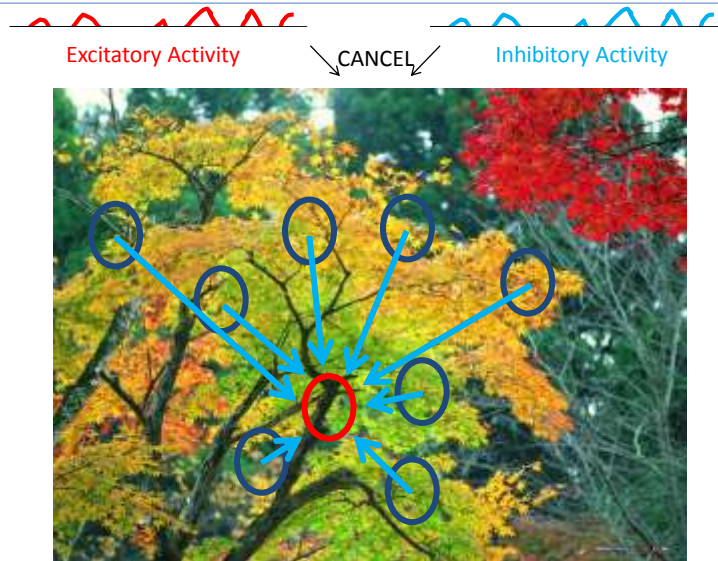
- large axonal fields
- coupled
- active properties (action potentials)
- high threshold

→ Sequence of temporally sparse events,
But ONLY if there is correlated activity
across large parts of the retina

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Object motion sensitive ganglion cells



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Object motion sensitive ganglion cells



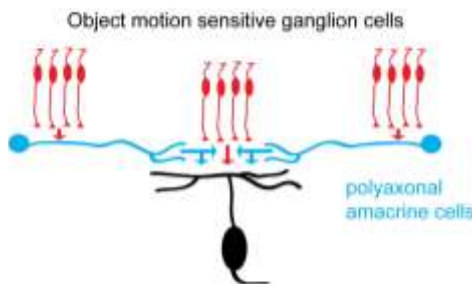
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Object motion sensitive ganglion cells

Problem:

Detect moving objects
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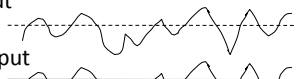


Bipolar cells

Strongly rectifying

Input

Output



→ Sequence of temporally sparse events

Polyaxonal amacrine cells

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Summary

Object-motion sensitivity

- Key inhibitory interneuron: polyaxonal amacrine cell
- inhibition (triggered by large, spatially coherent motion patterns) interferes with excitation if it is triggered by same motion pattern
- several ganglion cell types are OMS

Methodology:

**Retinal wholemount preparation, patterned light stimuli,
multi-electrode array recordings**

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MEA recordings:

- Extracellular recording technique
- Records changes in the electric field between recording electrode and a distant ground electrode
- “Flat” retinal anatomy allows recordings of ganglion cell activity with flat electrode arrays
- Most important factor influencing the data quality: Distance between cell and electrode

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pMEA layout (60pMEA200/30iR)



200 μm interelectrode distance

30 μm electrode diameter

59 recording electrodes

Base material: Polyimide foil

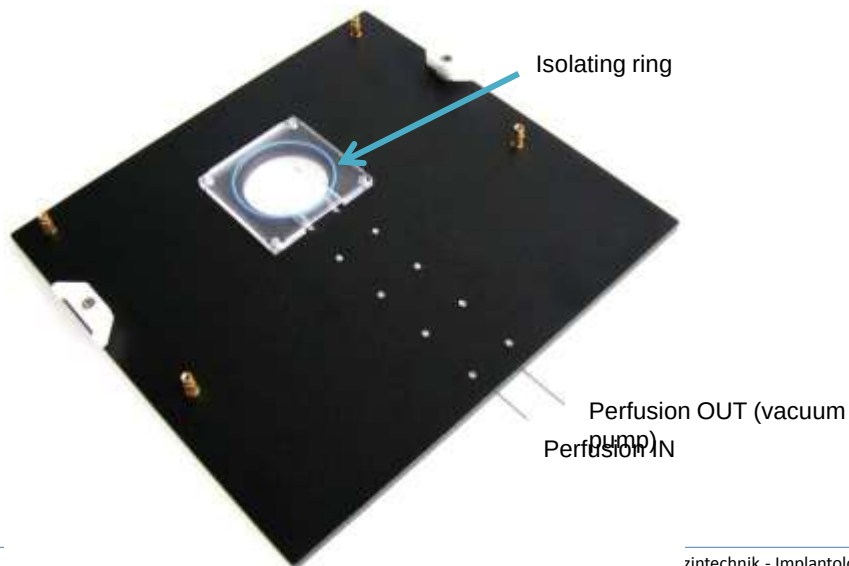
Hole diameter: 90, 75, 50, 30,
20 μm



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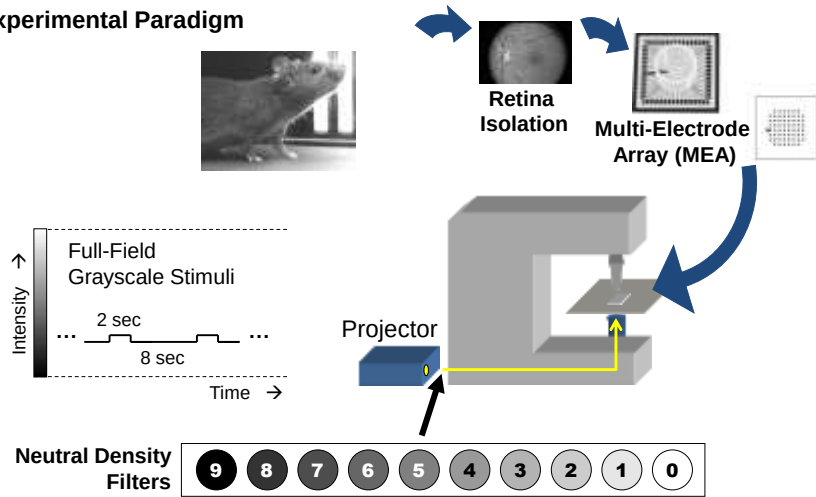
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Perfusion system: ground plate



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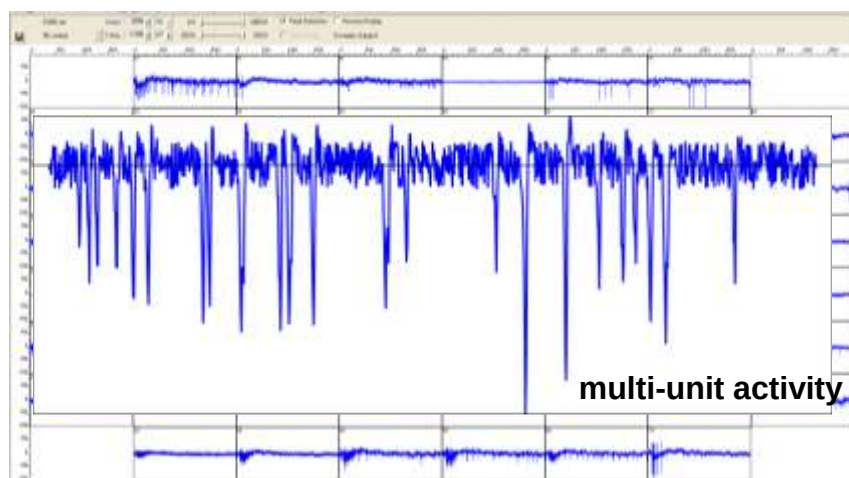
Experimental Paradigm



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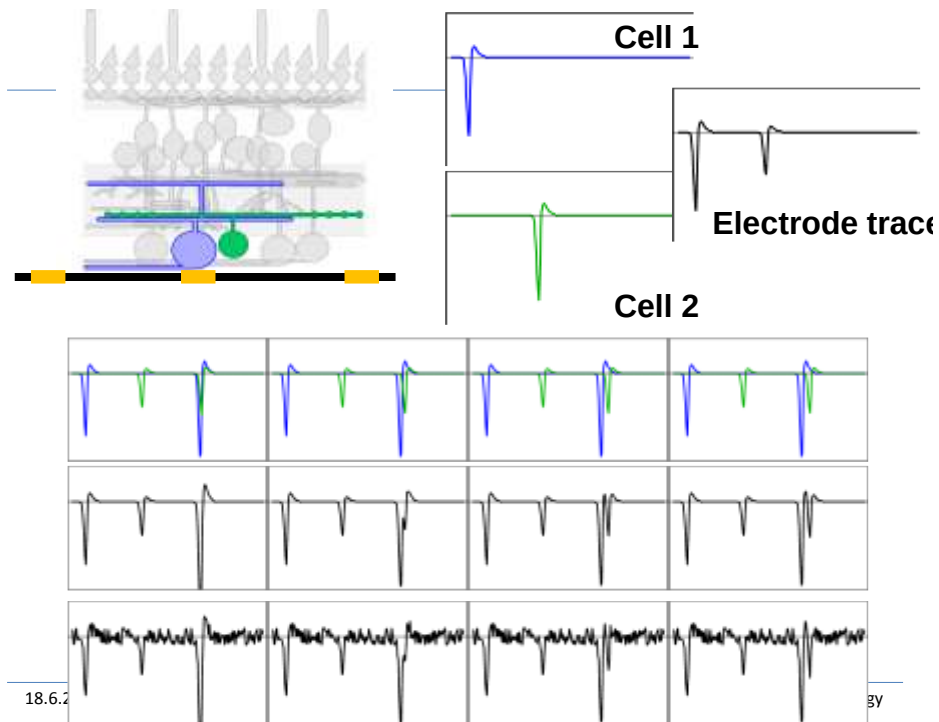
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Typical raw data



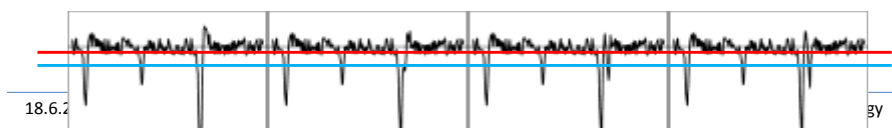
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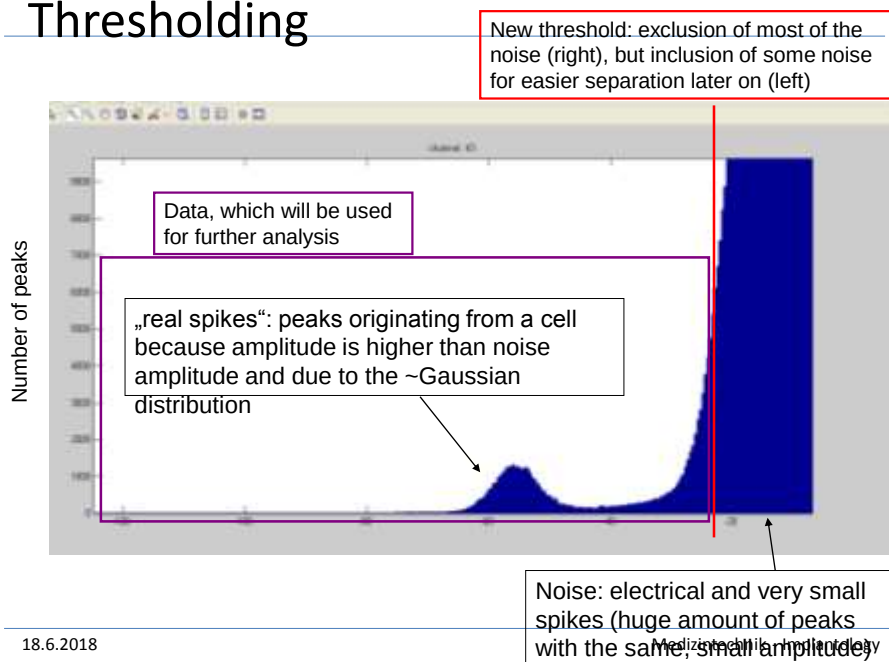


Processing

1. Preliminary Thresholding
2. Extract waveforms exceeding threshold
3. Plotting of the amplitudes of all these peaks and setting of threshold to exclude most of the noise.

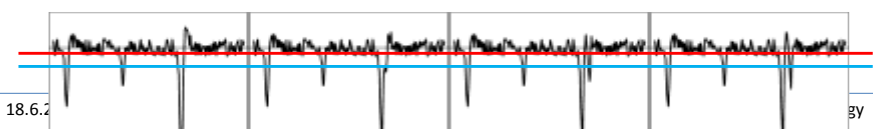


Thresholding



Processing

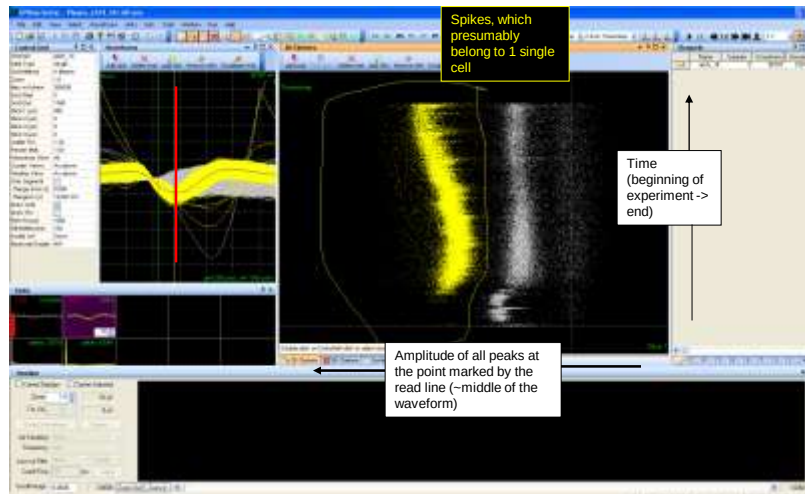
1. Preliminary Thresholding
2. Extract waveforms exceeding threshold
3. Plotting of the amplitudes of all these peaks and setting of threshold to exclude most of the noise.
4. Clustering (assigning of a spike to a cell) based on principal components and amplitude.



Clustering

Data from 1 electrode after thresholding.

Each point (middle) = 1 peak with a certain waveform (left) and a certain time point, when it occurred.

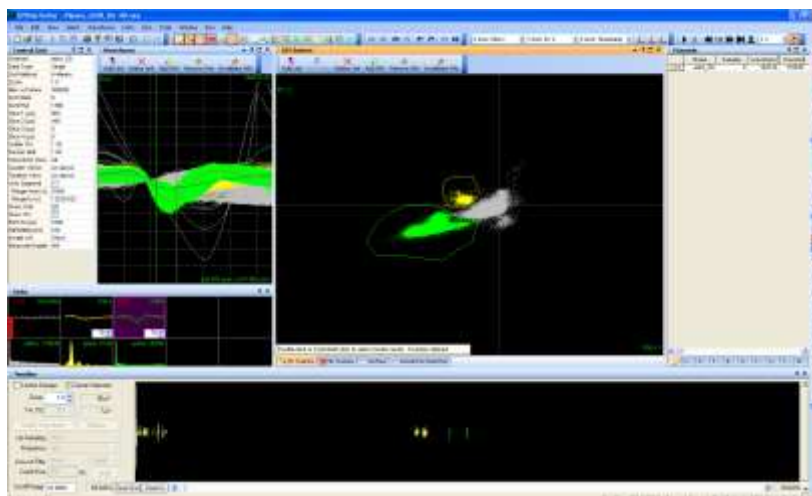


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Clustering:

Data from a different electrode: 2 separated units (~cells) in green and yellow. The left-over gray peaks are noise or spikes similar to noise.



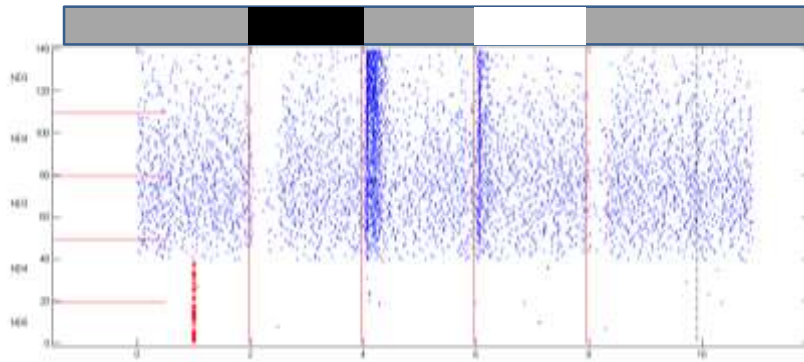
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After spike sorting...

Analysis of each unit (= spikes from 1 cell):

Characterization of the units by analysis of its responses to the different stimuli.



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