UCL

ANAT 3045 Visual Neuroscience
BIOS 3001 Advanced Visual Neuroscience

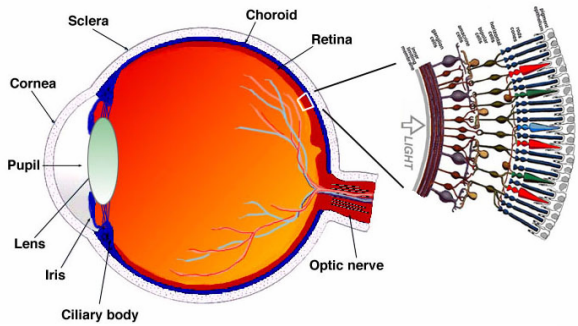
Introduction to the Retina

Professor Tom Salt
UCL Institute of Ophthalmology

t.salt@ucl.ac.uk

Institute of Ophthalmology

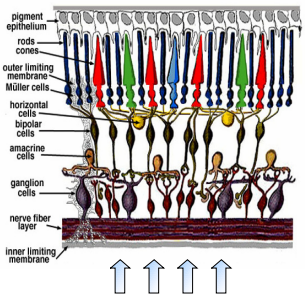
Human Eye



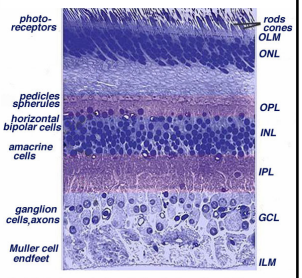
Section through the human eye with schematic enlargement of the retina

Human Retina

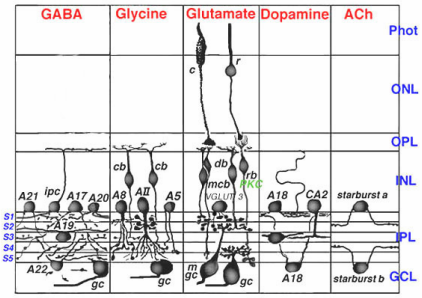
Schematic vertical section



Light Microscopic vertical section

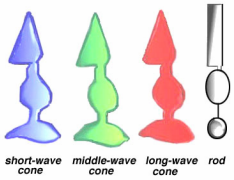


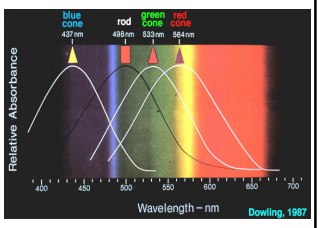
Neurotransmitters in Retina



Organisation of neurotransmitters according to cell type in mammalian retina

Photoreceptors



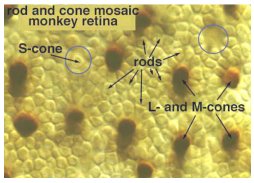


Four photoreceptor types in human retina:

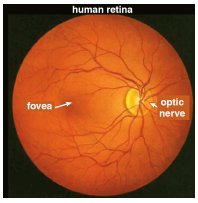
Short-wavelength (S, blue) cones, middle/medium wavelength cones (M, green), long wavelength cones (L, red) and rods.

Dim / Dark (scotopic) conditions – rod function dominates
Light / "normal" (photopic) conditions – cone function dominates

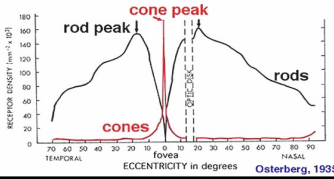
Rod / Cone Distribution



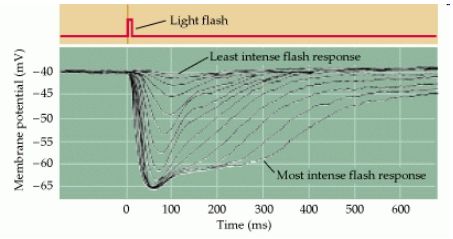
Rods always form a hexagonal packing around the cones and separate the cones from each other



Rods peak in density in a ring approximately 5mm (18 degrees) from the center of the fovea (human/rhesus monkey). Rods are present in greater numbers than cones from 2 mm from the fovea to the far periphery.



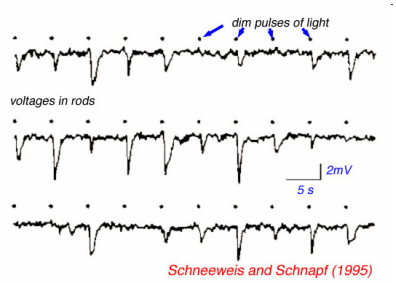
Photoreceptor responses



An intracellular recording from a single cone stimulated with different amounts of light (cone from the turtle retina).
Each trace represents the response to a brief flash that was varied in intensity.
At the highest light levels, the response amplitude saturates (at about -65 mV).
The hyperpolarizing response is characteristic of vertebrate photoreceptors.

(After Schnapf and Baylor, 1987.)

Photoreceptor responses - rods



Photovoltages recorded in monkey rods with suction electrodes.
The granularity of response to dim light stimuli is evident.

Photoreceptor responses - cones

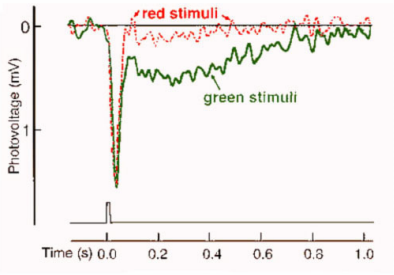


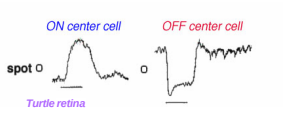
Fig. 30. Voltage recording from monkey cone with balanced red and green stiimuli. The green stimulus (solid trace) also evokes a slower hyperpolarizing phase after the initial response which the red stimulus (dotted trace) does not. This latter electrical wave has the characteristics of a rod signal. Schneeweis and Schnapf, 1995.

Photoreceptor responses - summary

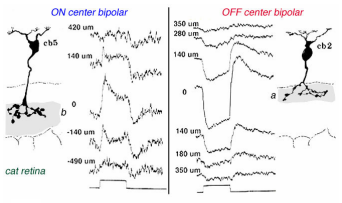
- In the dark (*i.e.* absence of light, *a.k.a.* **OFF**), photoreceptors have a depolarised cell membrane potential and are releasing their neurotransmitter (L-glutamate) continuously.
- Photoreceptors always respond to light ON with membrane potential hyperpolarisation: this results in a reduction of neurotransmitter release.
- Thus Photoreceptors can be considered to have an **OFF** response
- Photoreceptors synapse onto Bipolar Cells…….

Bipolar Cell Responses

Two types of Bipolar Cell Responses

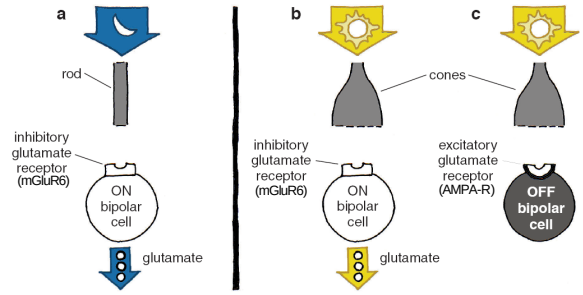


Intracellular membrane potential recordings showing responses to flashes of light from two types of bipolar cells in turtle retina (Ammermuller & Kiolb 1995)



Intracellular recordings from ON and OFF bipolar cells in cat retina. Size of the receptive field measured in μm.

ON and OFF bipolar cells

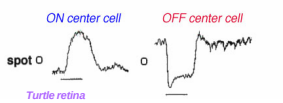


Photoreceptors release the transmitter glutamate in the dark, and stop releasing glutamate when stimulated by light.

Different bipolar cells respond differently to glutamate, depending on their type of glutamate receptor:
- ON bipolar cells have a depolarising receptive field (a, b)
- OFF bipolar cells have a hyperpolarising receptive field (c).

Bipolar Cell Responses

Two types of Bipolar Cell Responses



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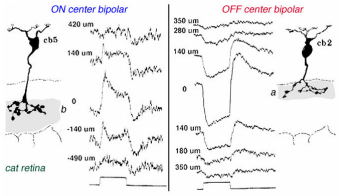
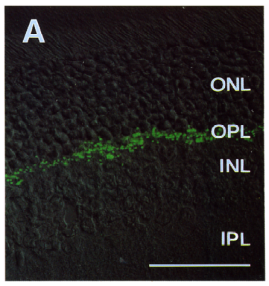
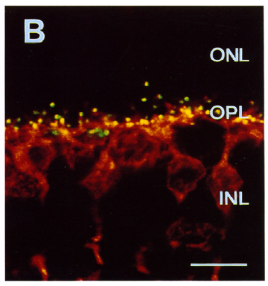


Intracellular recordings from ON and OFF bipolar cells in cat retina. Size of the receptive field measured in μm.

mGlu6 in bipolar cells



(A) Vertical sections of the adult rat retina were immunostained with the mGluR6 antibody, and a confocal micrograph superimposed on the Nomarski image of an immunostained section is indicated. A punctate labeling pattern (green) is restricted to the OPL. IPL, inner plexiform layer.



(B) Sections of the adult rat retina were immunostained with the mGluR6 antibody (green and yellow) and the PKC antibody(red), and a confocal micrograph of a double-stained section is presented. Intense punctate mGluR6 immunoreactivity is seen only at the dendritic termini of the PKC-immunoreactive bipolar cells.

Nomura *et.al.* (1994) Developmentally regulated postsynaptic localization of a metabotropic glutamate receptor in rat rod bipolar cells. Cell 77:361-369.

mGlu6 Receptor gated currents

Note

- mGlu6 is a Group III metabotropic glutamate receptor
- L-AP4 (formerly known as APB) is a Group III mGlu *AGONIST*.
- mGlu6 activation closes cation channels

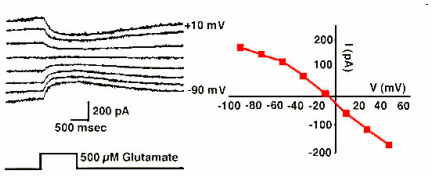


Fig. 10. Whole cell current traces (left) and the calculated current-voltage relationship (right) for APB receptor-gated currents. Glutamate acting on APB receptors closes non-selective cation channels resulting in a conductance decrease (from Grant and Dowling, 1996).

L-AP4 effects in the Retina

Note

- L-AP4 (formerly known as APB) is a Group III mGlu *AGONIST*.
- L-AP4 is a functional antagonist of the ON pathway.

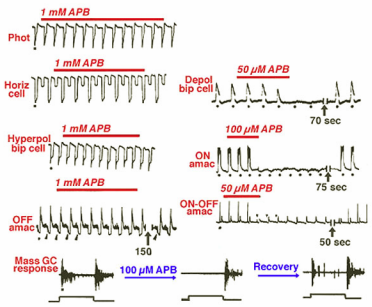
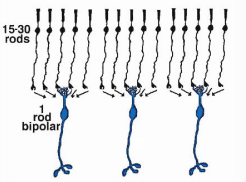
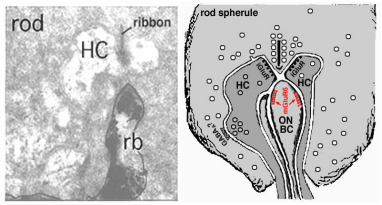


Fig. 11. intracellular recordings from different retinal neurons show that APB selectively antagonizes the ON pathway (right column). From Slaughter and Miller, 1981.

Rod Bipolar Cells



Convergence of rods onto rod bipolars

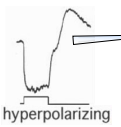


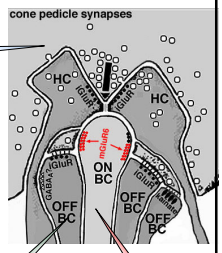
Electron micrograph and schematic of a rod spherule

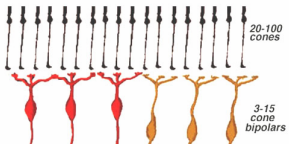
BC – Bipolar Cell
HC – Horizontal Cell

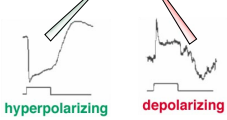
Cone Bipolar Cells

Connections of Cone photoreceptors to ON- and OFF- Cone Bipolar Cells

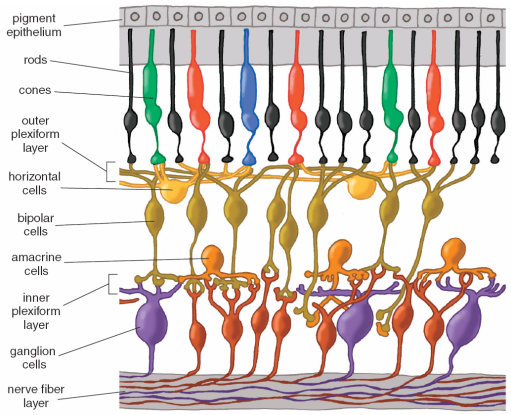




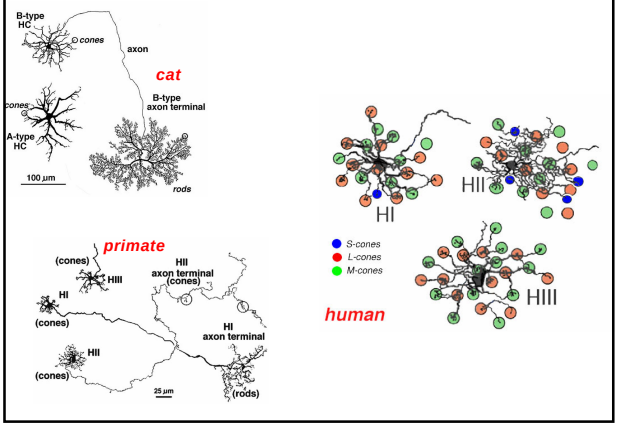




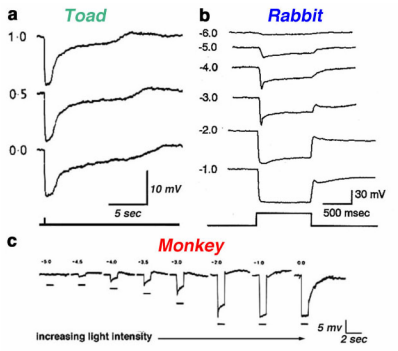
Retinal Circuitry



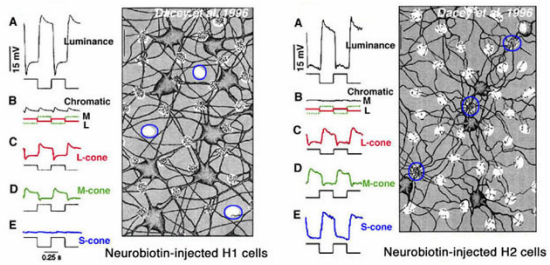
Horizontal Cell Types



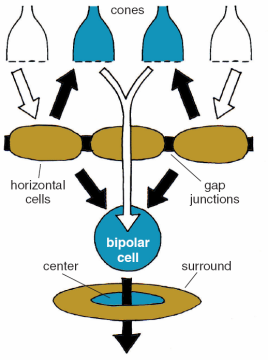
Horizontal Cell Luminosity responses



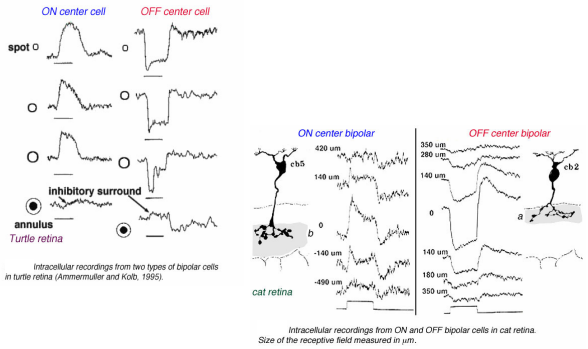
Horizontal Cells Chromaticity responses



Horizontal Cell Function

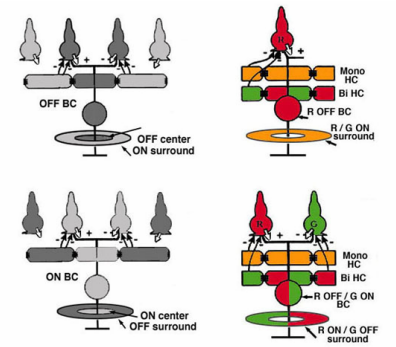


Bipolar Cell Responses- summation

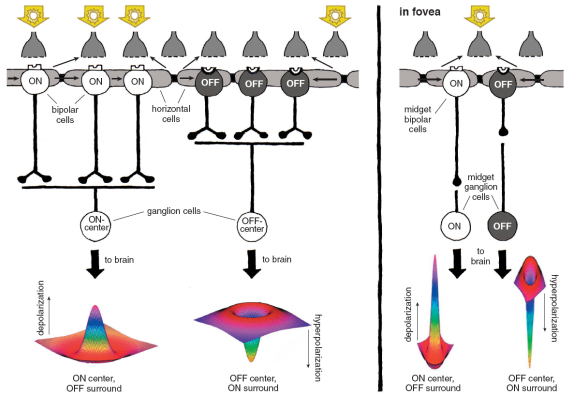


Horizontal Cell Function

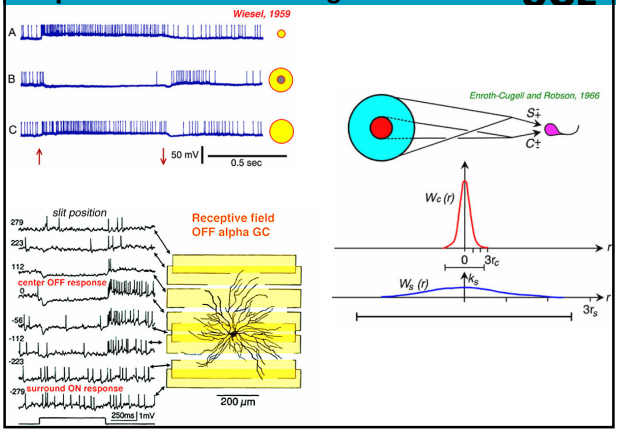
On/Off Surrounds Colour-opponent Surrounds



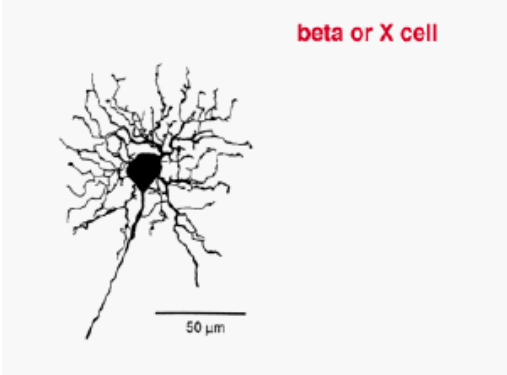
ON and OFF Cone paths to Ganglion Cells



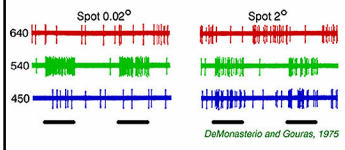
Responses of Retinal Ganglion Cells



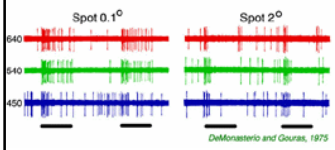
RGC Receptive Field



Responses of primate RGCs



Spectral responses of tonic ganglion cell in rhesus monkey retina. Stimulus wavelength in nm is given to the left of impulse discharge responses. The light stimulus is ON during the black bars at the bottom of the figure. This cell is a green ON-center red OFF-surround unit.



Spectral responses of phasic ganglion cell in rhesus monkey retina. Stimulus wavelength in nm given to left of impulse records. The light stimulus is ON during the black bars at the bottom of the figure. This cell is spectrally a luminosity type with ON-center and OFF-surround responses.

Summary of pathways through the retina

- Photoreceptors always respond to light ON with membrane potential hyperpolarisation, resulting in a reduction of neurotransmitter (Glutamate) release onto Bipolar Cells.
- Bipolar Cells respond to light with either **ON** or **OFF** responses. This is due to the expression of different Glutamate receptor types at the photoreceptor-bipolar cell synapse.
- Bipolar Cells utilise glutamate to synapse onto Retinal Ganglion Cells, conferring them with either **ON** or **OFF** responses.
- Retinal Ganglion Cells (RGCs) generate action potentials in responses to graded synaptic input potentials. Action potentials are conducted to the brain along the axons of RGCs running in the optic nerve.