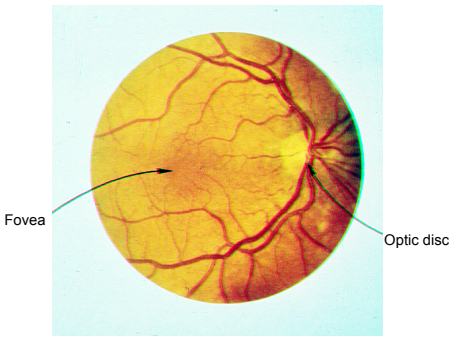
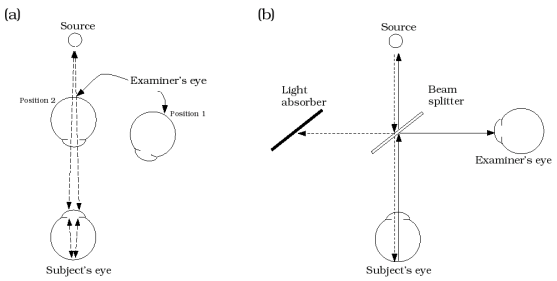
The retina

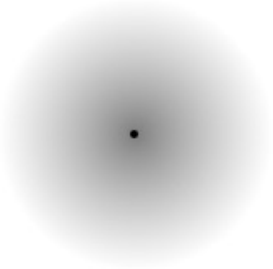
- Purkinje tree, ophthalmoscope, stabilized images
- Retinal layers and cells: photoreceptors, bipolar cells, horizontal and amacrine cells, retinal ganglion cells
- Properties: inhomogeneity, parallel pathways
- Light/dark adaptation, aftereffects, contrast coding

Purkinje tree (Johannes Purkinje c1850)



Helmholtz' Opthalmoscope



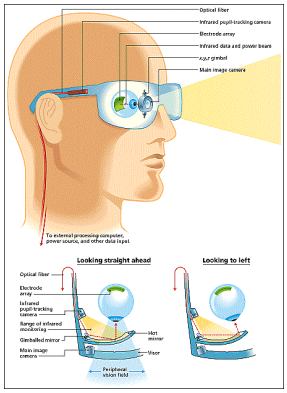


Eye trackers

Diseases of the retina

- macular degeneration
- diabetic retinopathy
- retinitis pigmentosa
- detached retina

Retinal implants



Cortical implants

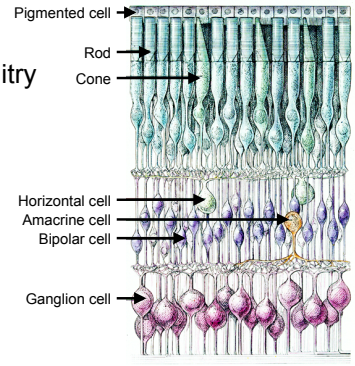
This 62 year old man, who has been blind since the age of 36, has been provided with limited vision by using a tiny camera wired directly to his the primary visual cortex of his brain. He can read large letters and navigate around big objects.

Neural circuitry in the retina

Parallel pathways:
1. Anatomically distinct
2. Physiologically/functionally distinct
3. Complete coverage
4. Recombine

Example: rods and cones

Neural circuitry in the retina



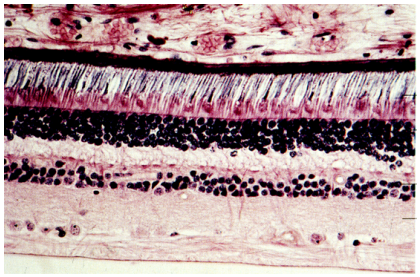
Retina cross-section

photoreceptors

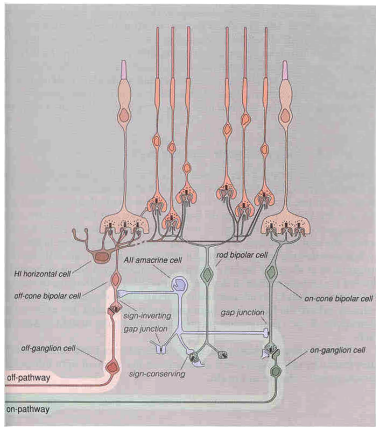
bipolar cells

ganglion cells

axons from ganglion cells



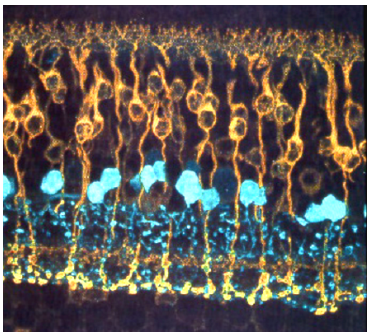
Neural circuits: rod pathway



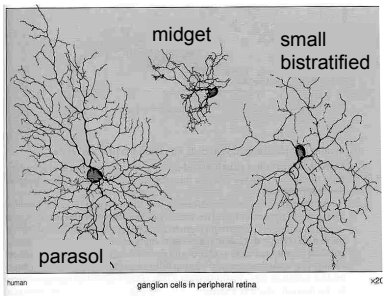
Neural circuits in the retina (monkey rod pathway)

Rod bipolar

AII amacrines



Some retinal ganglion cell types



Parallel pathways: ganglion cells

Parasol ganglion cell:
1. Inputs from many photoreceptors
2. Fast/transient responses
3. Poor spatial resolution
4. Combine all cones ("color blind")

Midget ganglion cell:
1. Inputs from few (or one) photoreceptors
2. Slow/sustained responses
3. High spatial resolution

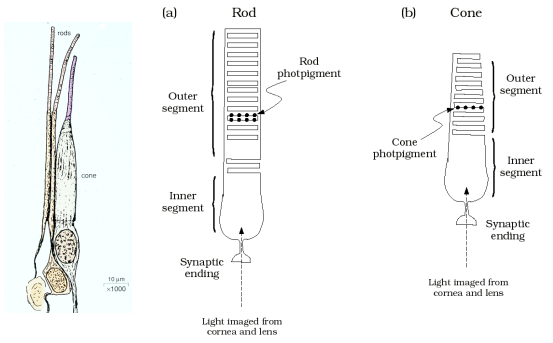
Functions of the retina

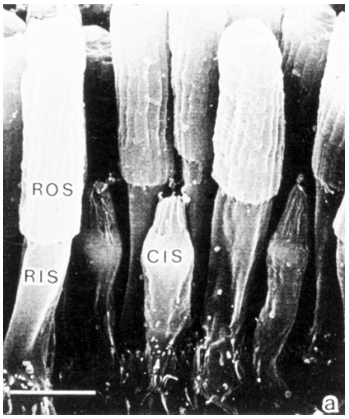
Retina performs five important jobs:

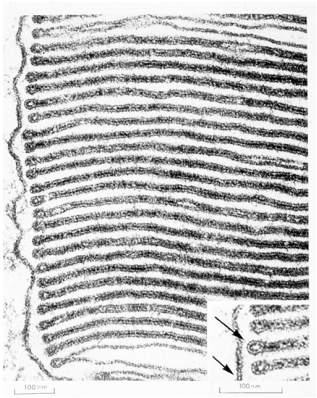
Today:
1. transduction
2. data compression
3. light/dark adaptation

Later classes:
4. spatial filtering
5. wavelength encoding

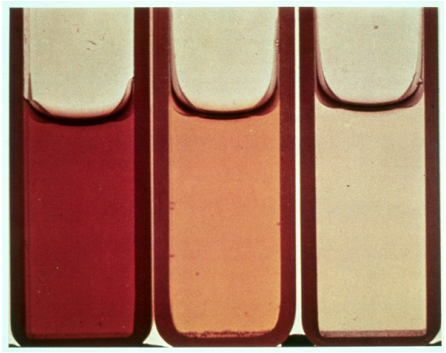
Photoreceptors: rods and cones







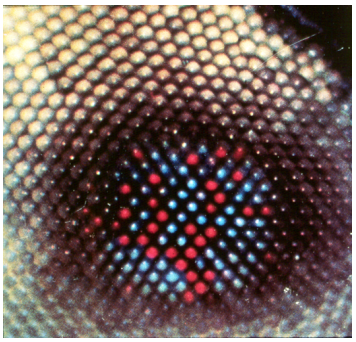
Rhodopsin



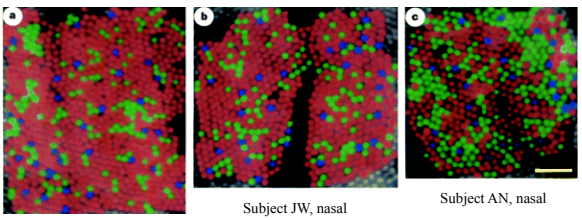
In the dark

Bleached by light

Butterfly eye



Human cone mosaic



Subject JW, temporal

Subject JW, nasal

Subject AN, nasal

one degree eccentricity

Functions of the retina

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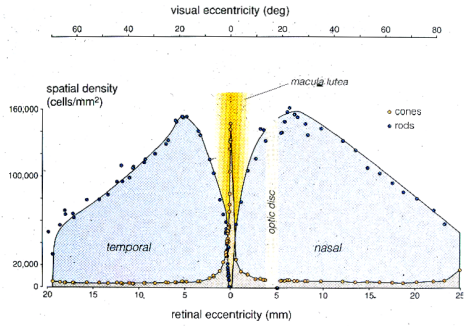
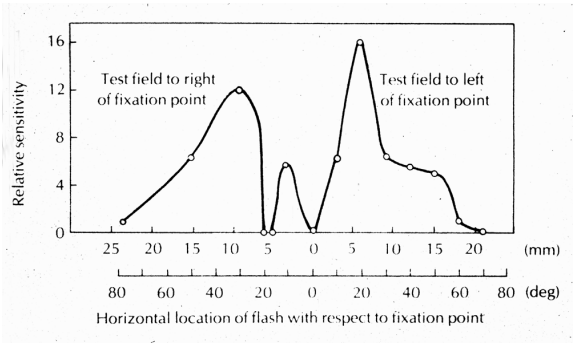
3. light/dark adaptation
4. spatial filtering
5. wavelength encoding

Retinal inhomogeneity

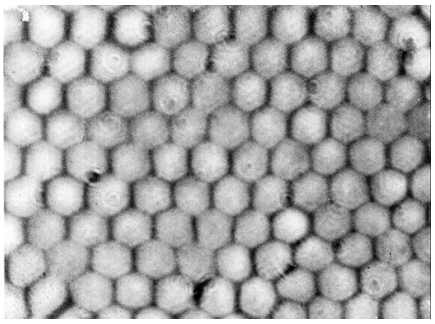
Simulations of the high spatial resolution in central vision coupled with the blurry low spatial resolution in the periphery.

Distribution of rods and cones

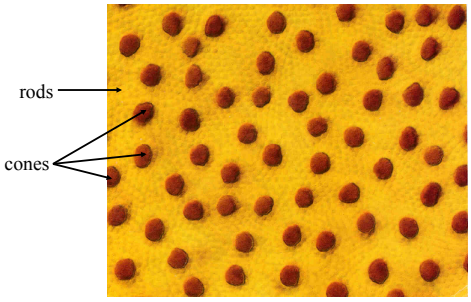




Foveal cone mosaic

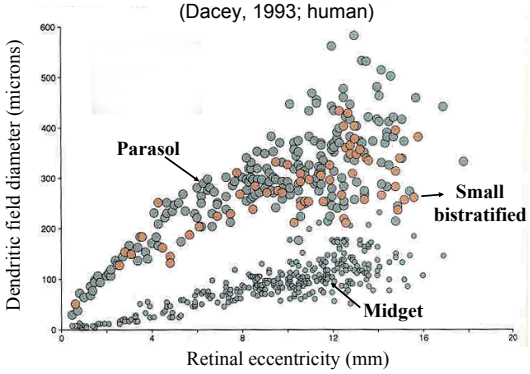


Near periphery photoreceptor mosaic



Dendritic fields increase with eccentricity

(Dacey, 1993; human)



Functions of the retina

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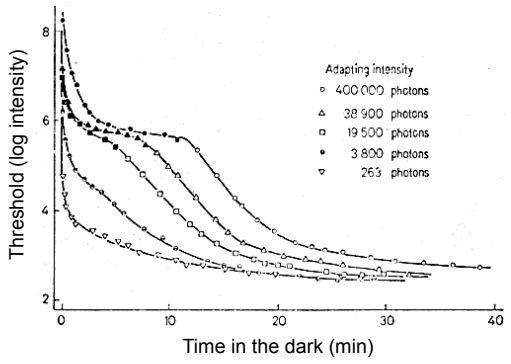
Surface luminance levels

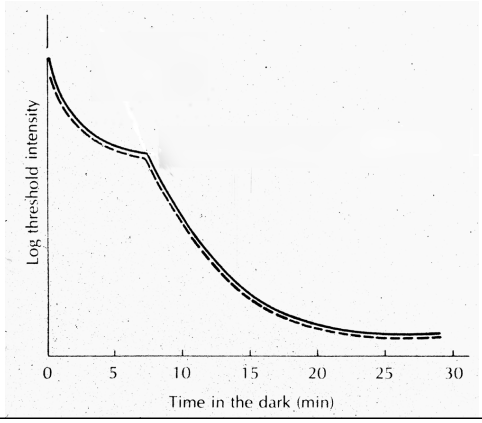
- Sunlight: 10^5 candelas/meter^2 (cd/m^2)
  - Approx. 10^{22} photons/m^2/sec
    - 3%-90% of photons are reflected as luminance
    - 3% for black surfaces, 90% for white surfaces
    - Only some of the reflected photons enter the pupil of eye
- Indoor lighting, CRTs: 10^2 cd/m^2
- Moonlight: 10^{-1} cd/m^2
- Starlight: 10^{-3} cd/m^2
- The eye can adjust to changes in light level by a factor of 100,000,000!
- Yet: firing rates only typically range from 0-400Hz

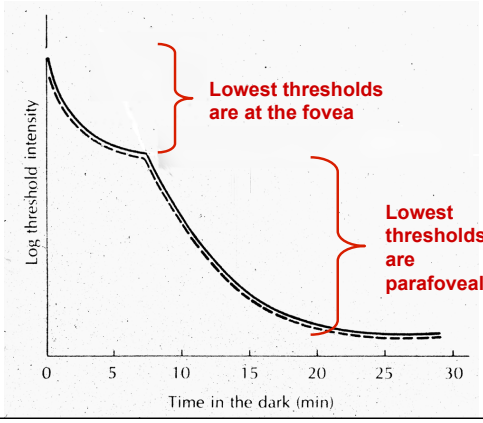
Dark adaptation

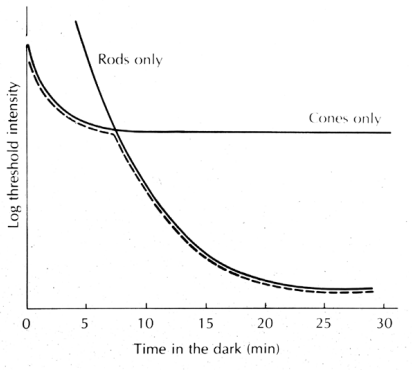


Dark adaptation

- Can it be due to change in pupil size?
  - Pupil goes from 1-2 mm to 8 mm diameter
  - Controls total light entering the eye by a factor of up to 64







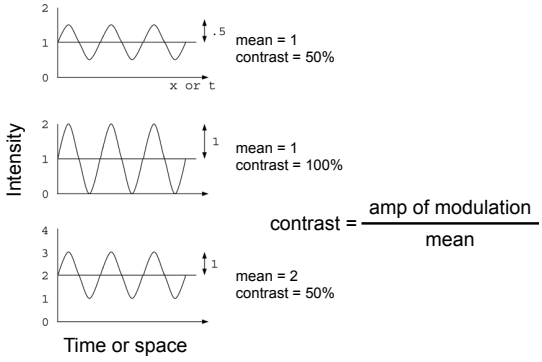
Mechanisms of dark adaptation

- Pupil size
- Switch from cone vision to rod vision
- Bleaching/regeneration of photopigment
- Feedback from horizontal cells to control the responsiveness of photoreceptors

Light Adaptation is Spatially Local

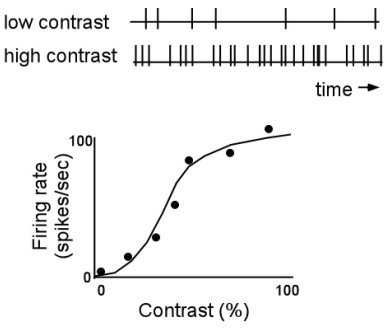
- Afterimages
- Dark afterimage on a light background
- Fades due to retinal stabilization

Contrast



$$\text{contrast} = \frac{\text{amp of modulation}}{\text{mean}}$$

Responses increase with contrast



Responses increase with contrast