Human vision

Václav Hlaváč

Czech Technical University in Prague

Czech Institute of Informatics, Robotics and Cybernetics

160 00 Prague 6, Jugoslávských partyzánů 1580/3, Czech Republic

http://people.ciirc.cvut.cz/hlavac, vaclav.hlavac@cvut.cz

also Center for Machine Perception, http://cmp.felk.cvut.cz

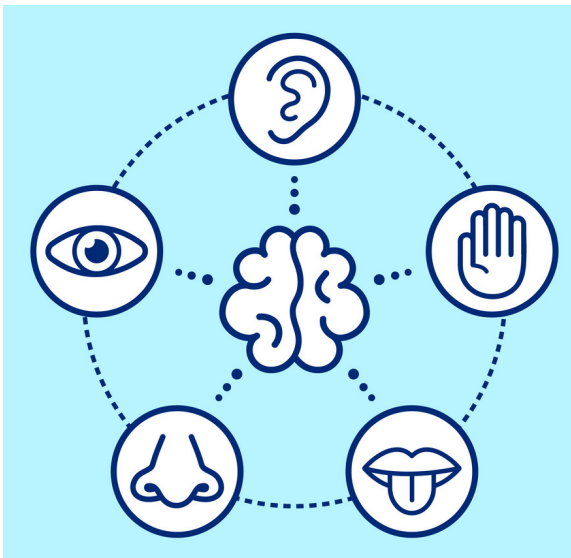
Courtesy: S. M. LaValle, Gordon Wetzstein, Wikipedia.

Outline of the talk:

- Relative importance of 5 senses.
- Human vision overview.
- Human eye.
- Retina.
- Visual: field, angle, acuity, etc.
- Meaning from what we see.

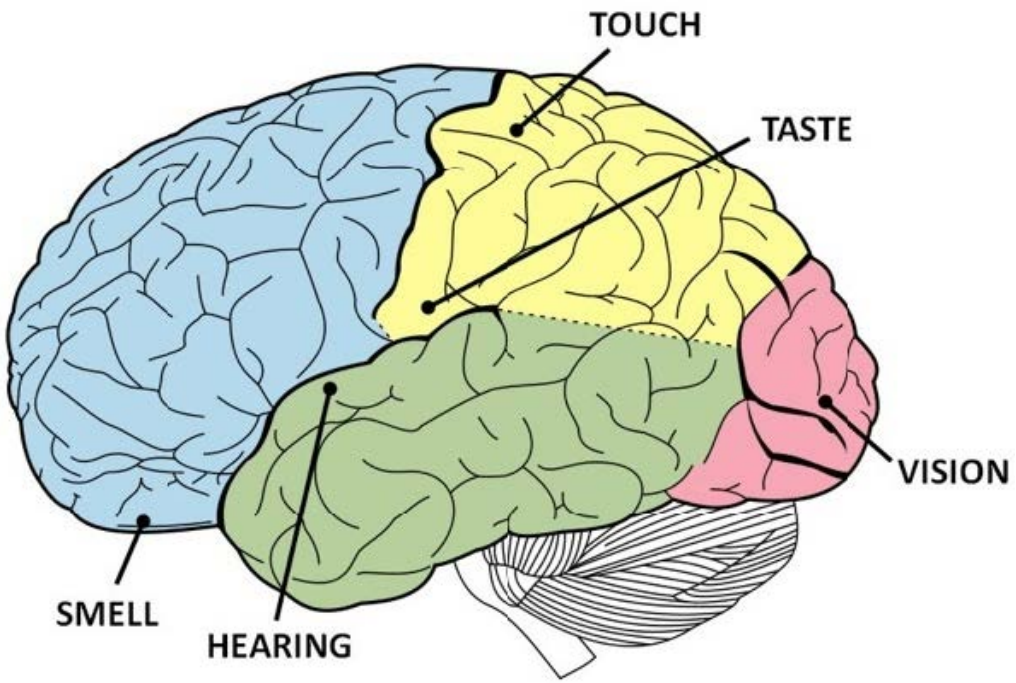
How do we humans perceive reality?

- Two basic processes:
  - Sensation – Gathering information
  - Perception – Interpreting information
- We understand the world through our senses: Sight, Hearing, Touch, Taste, Smell
  - Sensation part of Somatic Division of Peripheral Nervous System
  - Integration and perception requires the Central Nervous System



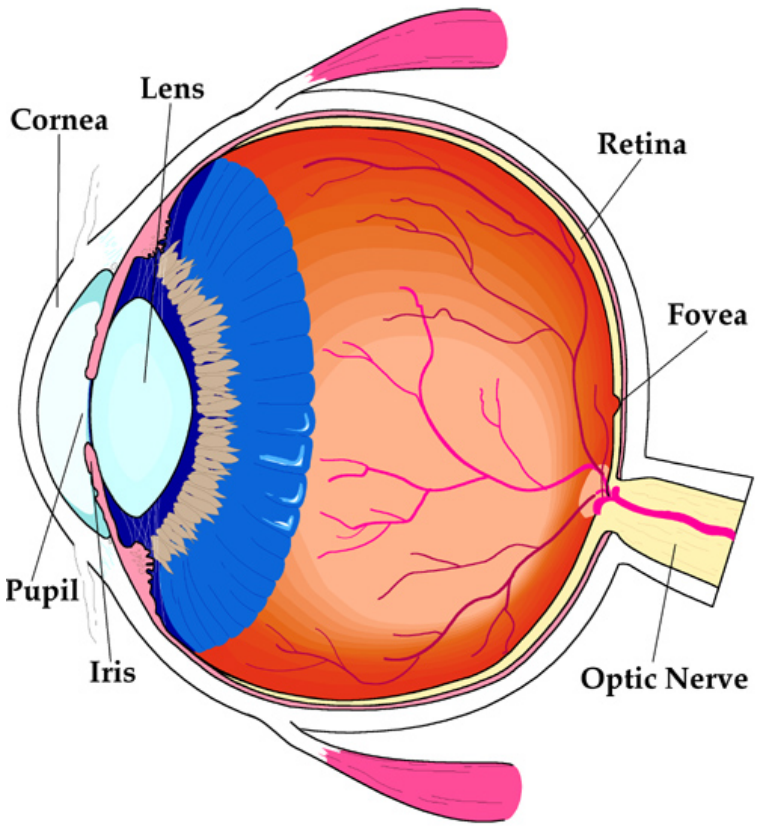
Relative importance of human five senses

- Percentage of neurons in brain devoted to senses
  - Sight – 30%
  - Touch – 8%
  - Hearing – 2%
  - Smell - $< 1\%$
- Over 60% of brain involved with vision in some way

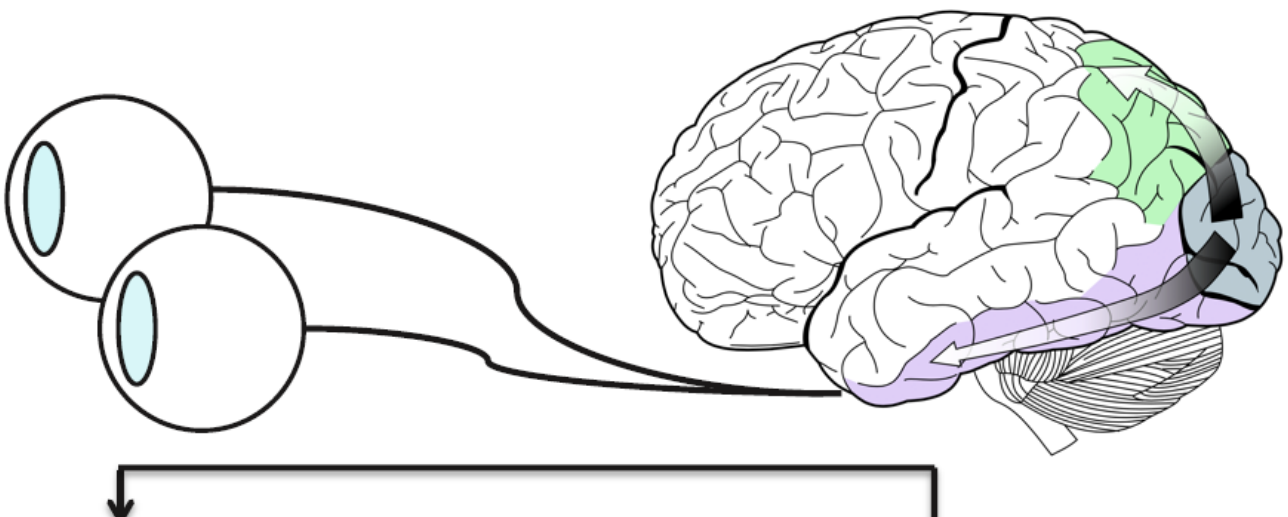


History of eye understanding

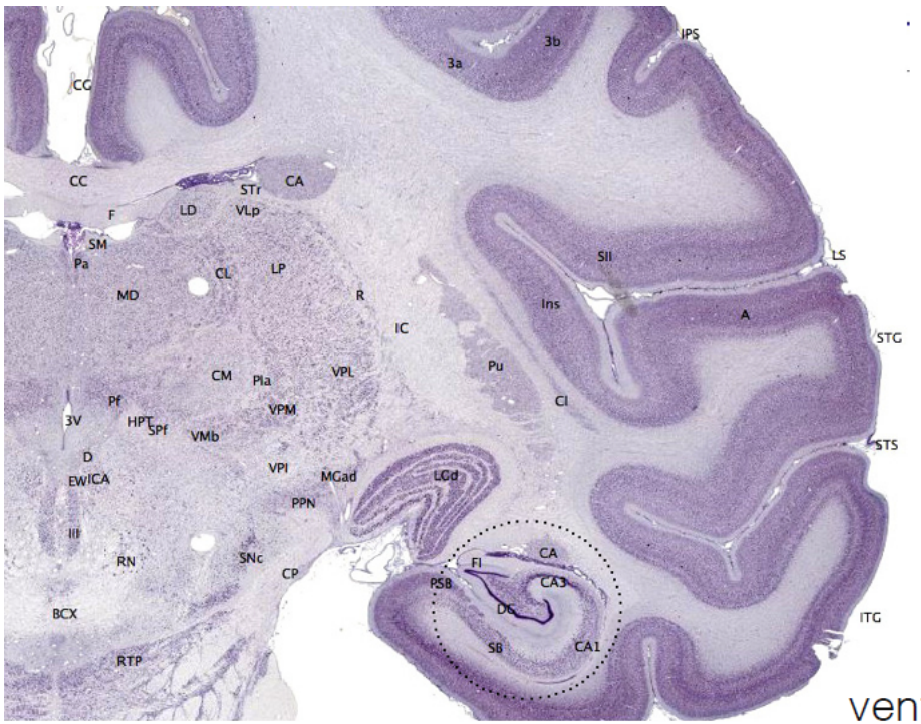
- Plato, 427-347 B.C. inner fire in the eye + emanated ray.
- Epicurus, 341-270 B.C., replicas of the object into the mind.
- Galen, 130-200, physiological details, rays out and in.
- Alhazen, Arabic philospopher, 965-1040, idea of pinhole camera.
- Jonannes Kepler, 1571-1630, knew about the lens, put it into an initial theory close to current one.

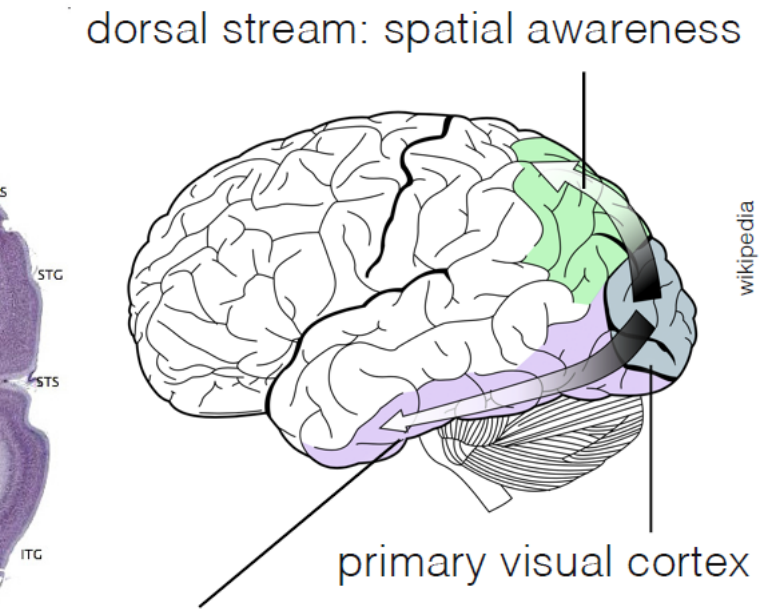


Human vision overview



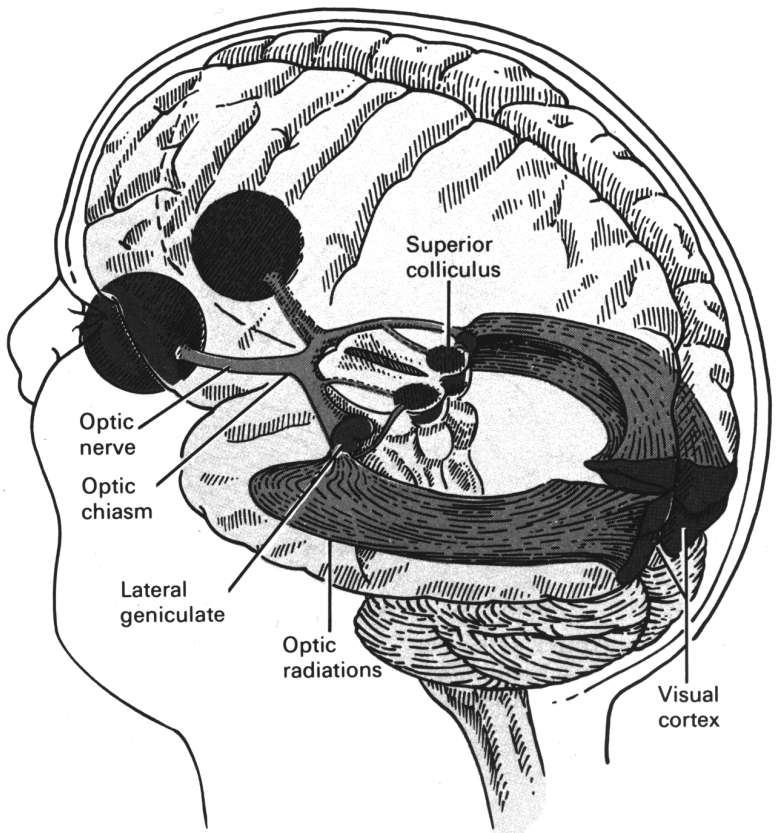
Human visual cortex



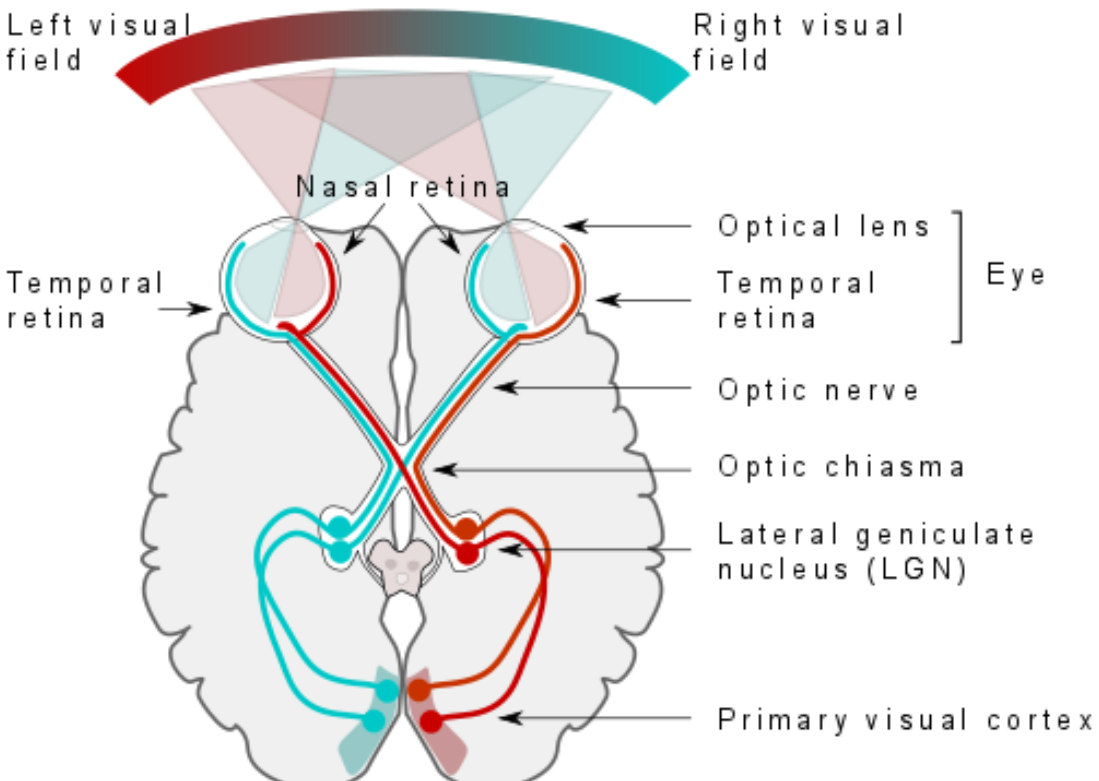


The visual cortex of the brain is that part of the cerebral cortex which processes visual information.

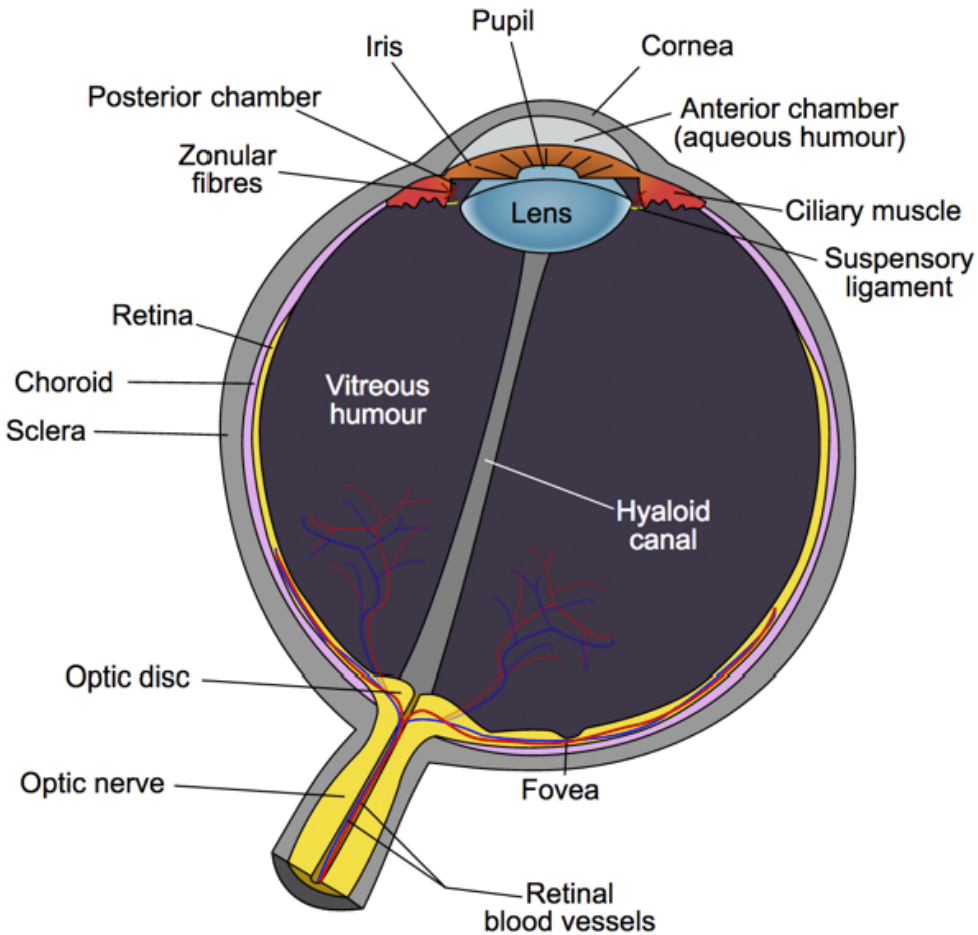
Human visual pathway 1



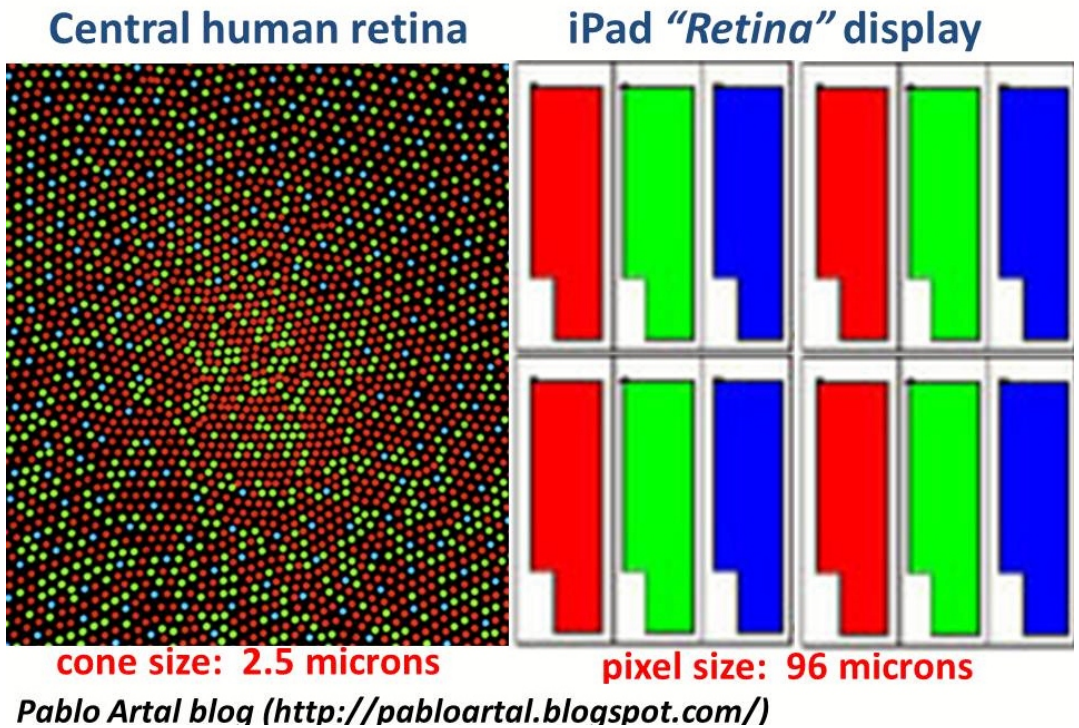
Human visual pathway 2



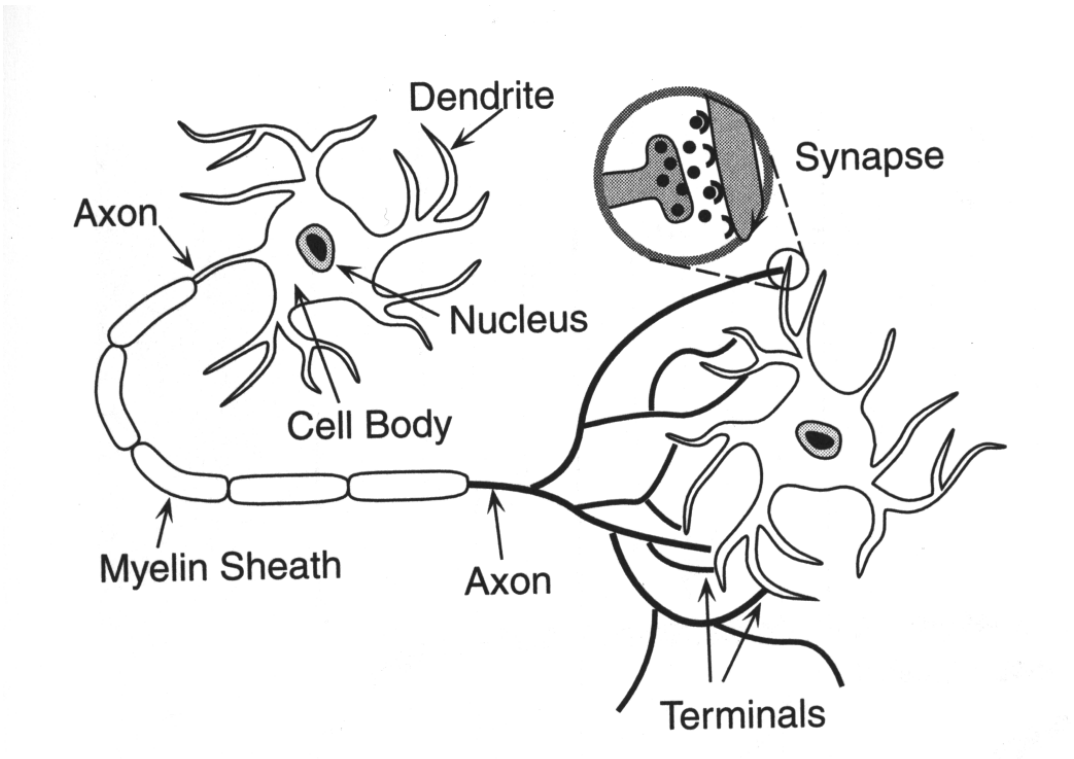
Human eye anatomy



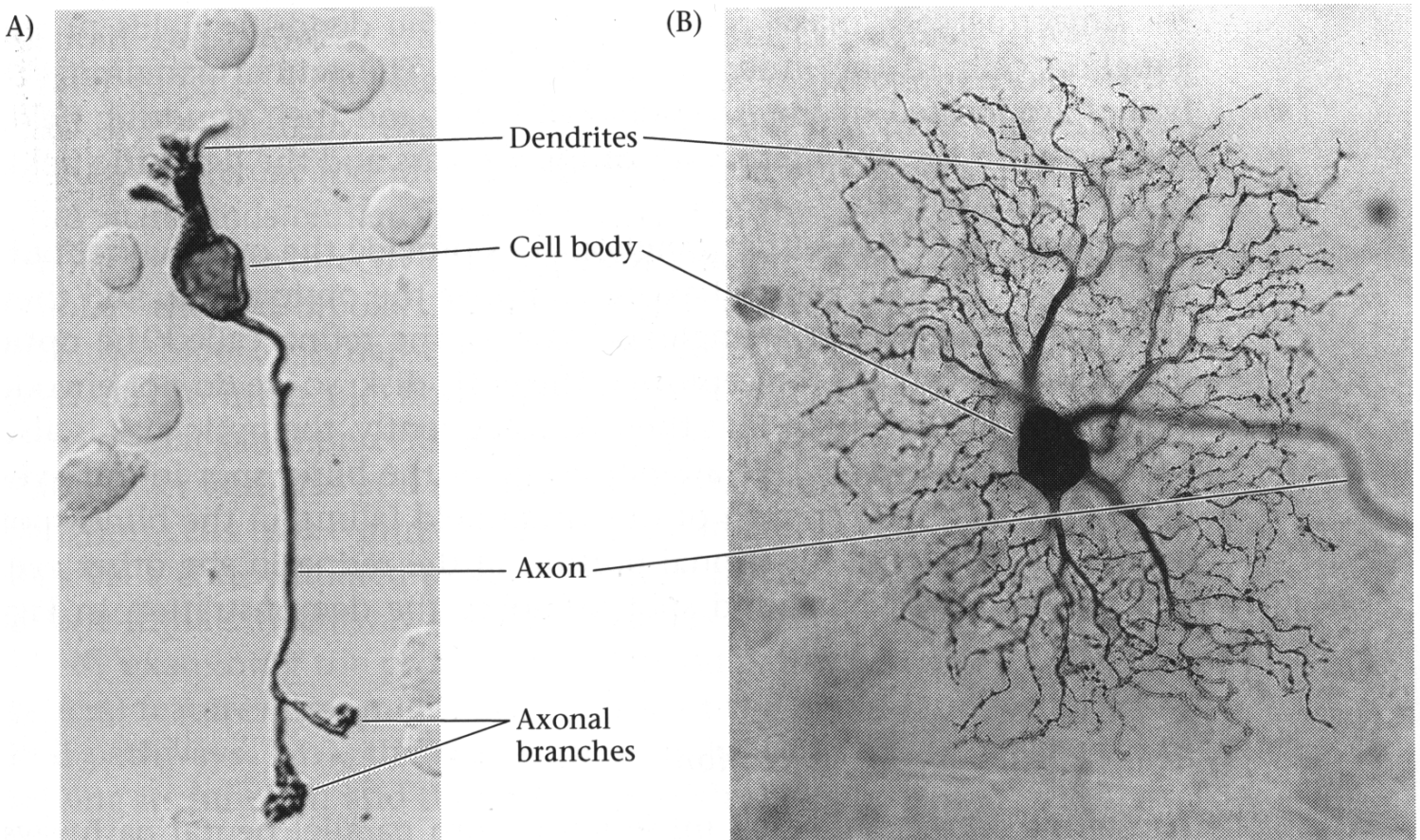
Human retina vs. iPad color sensor



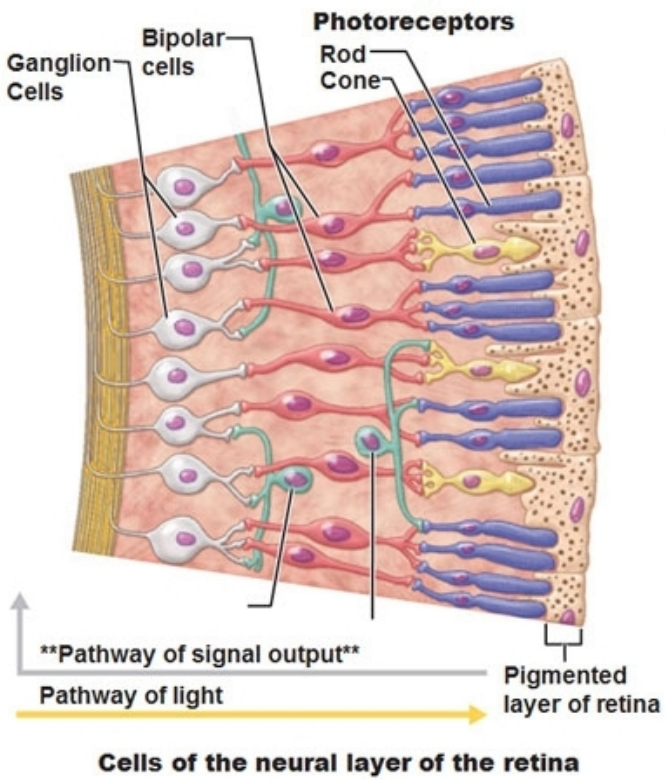
Neuron schematically



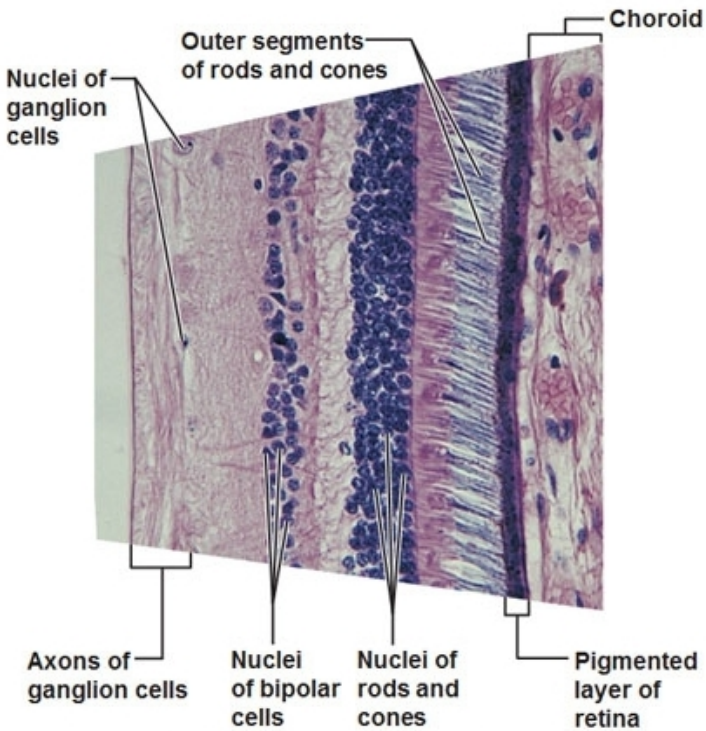
Real neuron



Microscopic anatomy of the retina

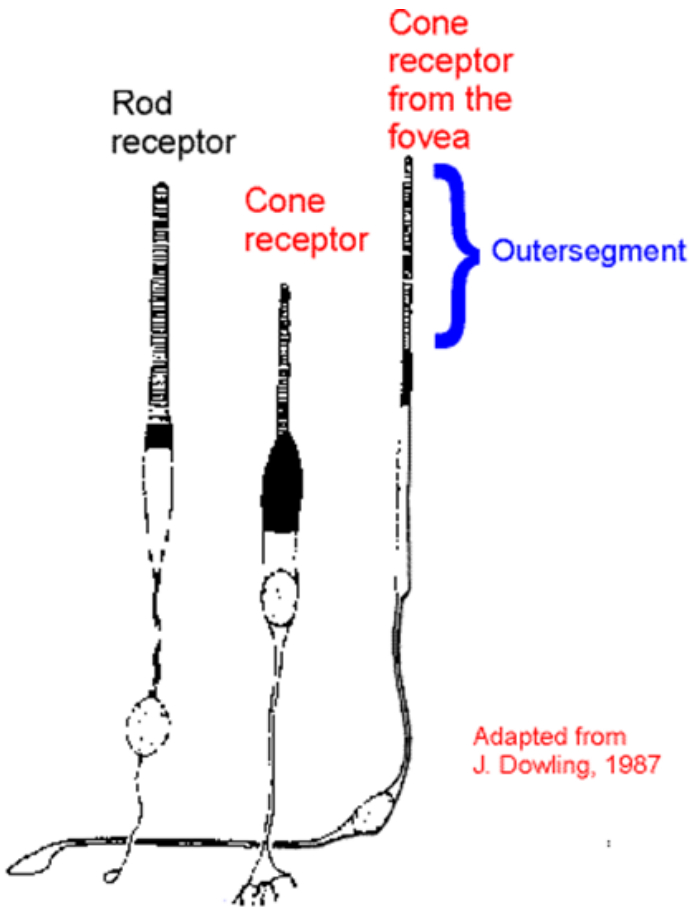


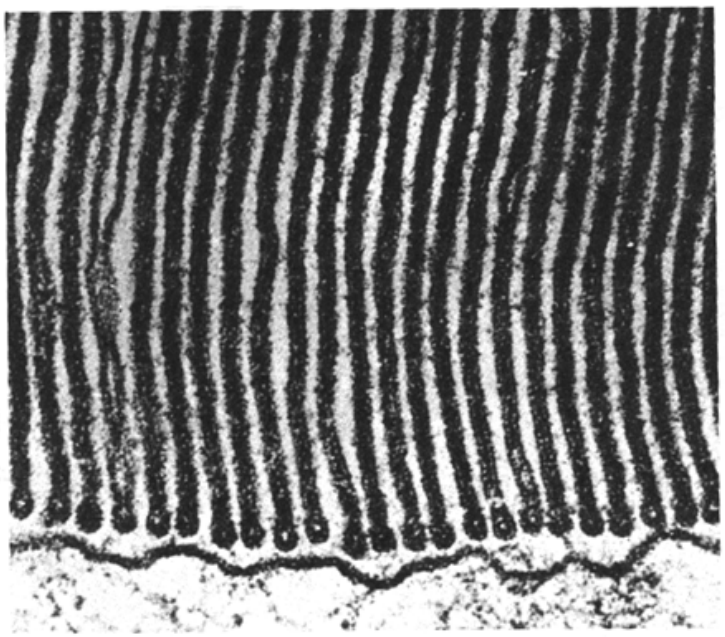
Cells of the neural layer of the retina



Photomicrograph of retina

Rod and cones





Light path

Inside the rod and the cone

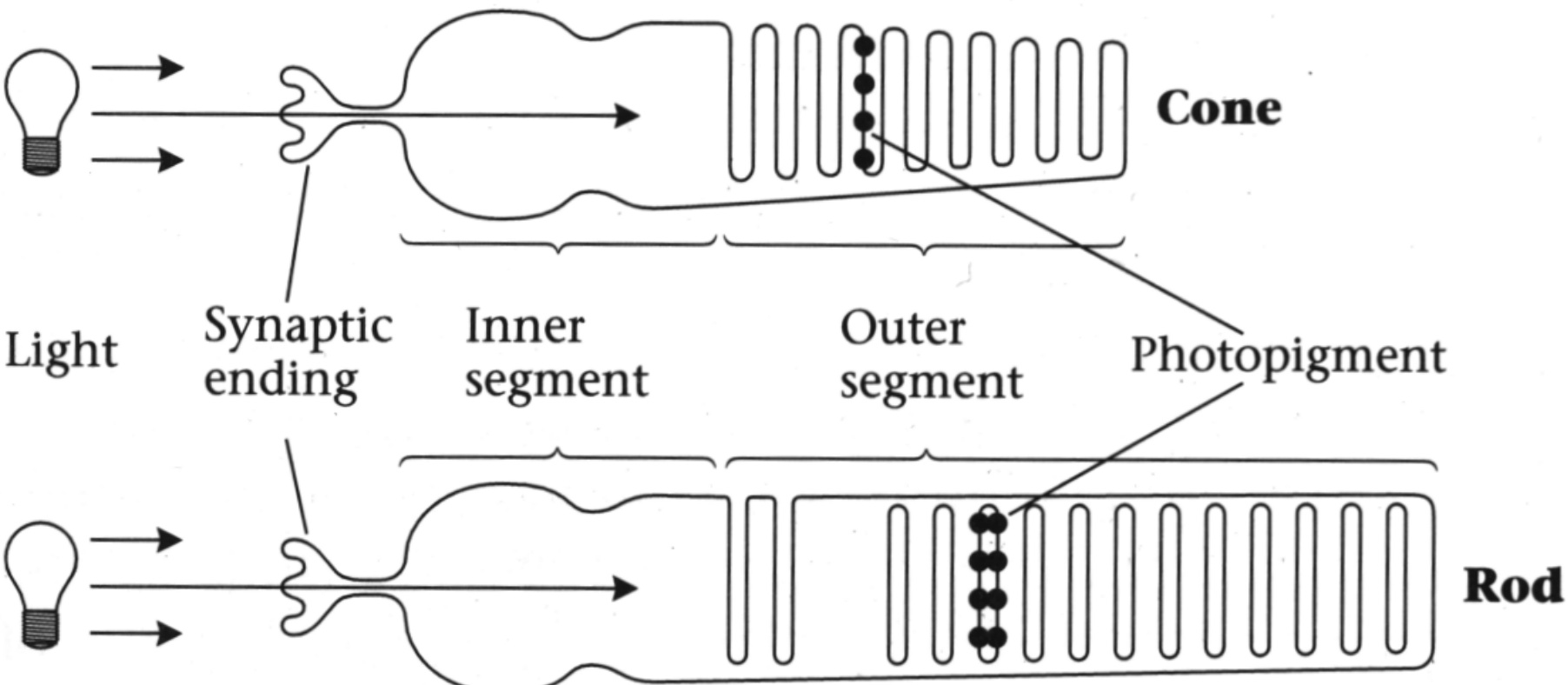
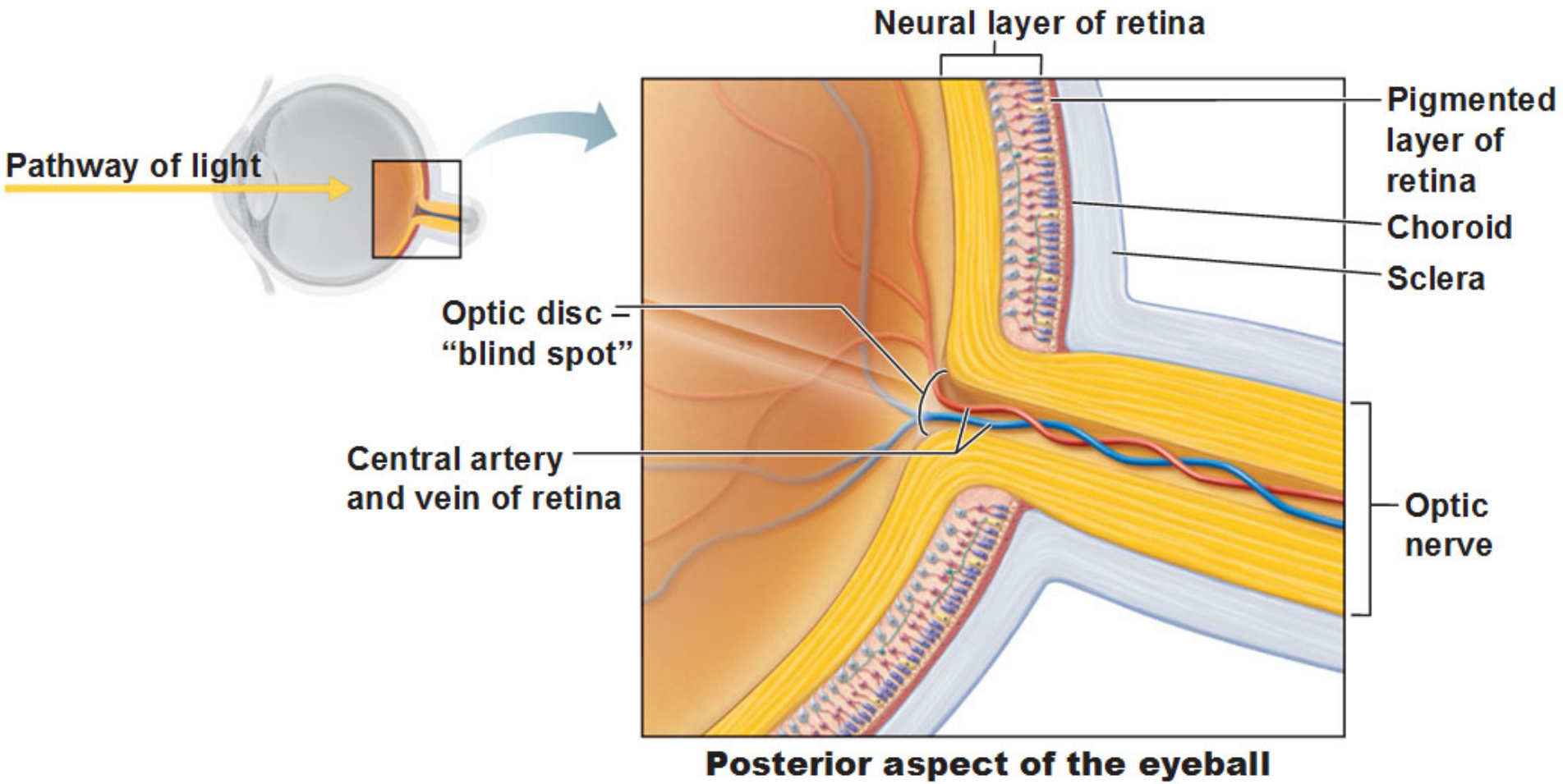


Image information going out of the eyeball



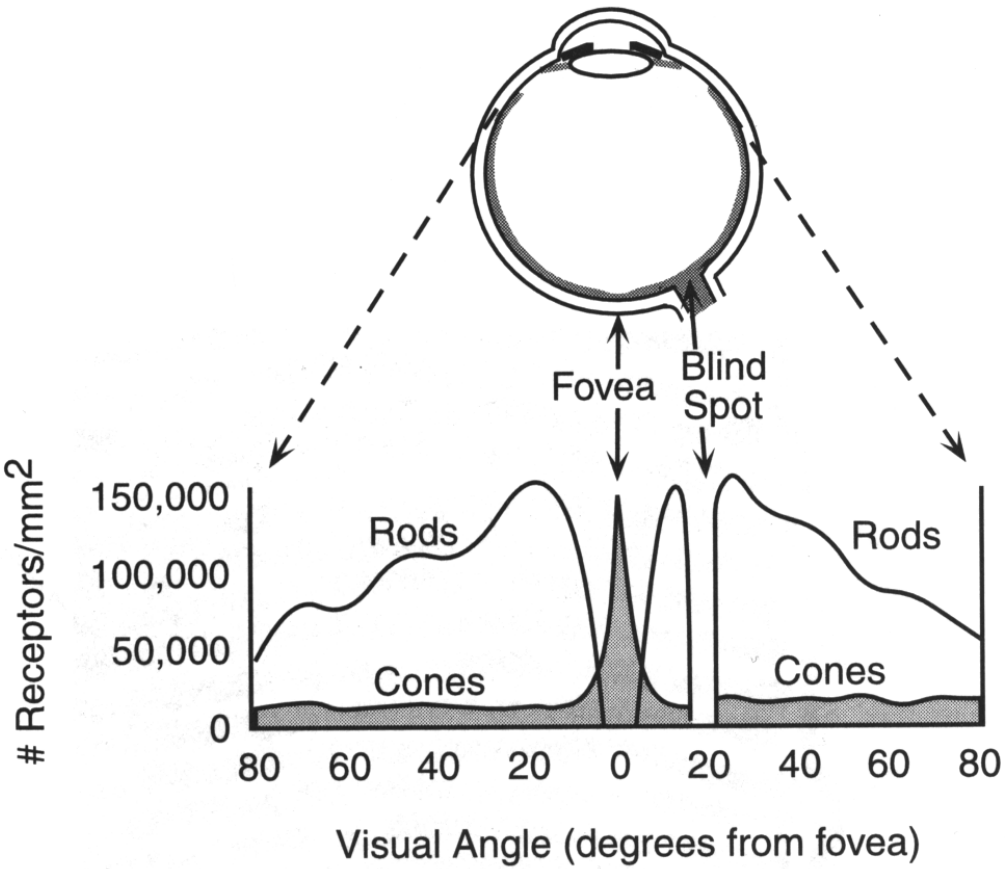
Retina, density of rods and cones

Rods

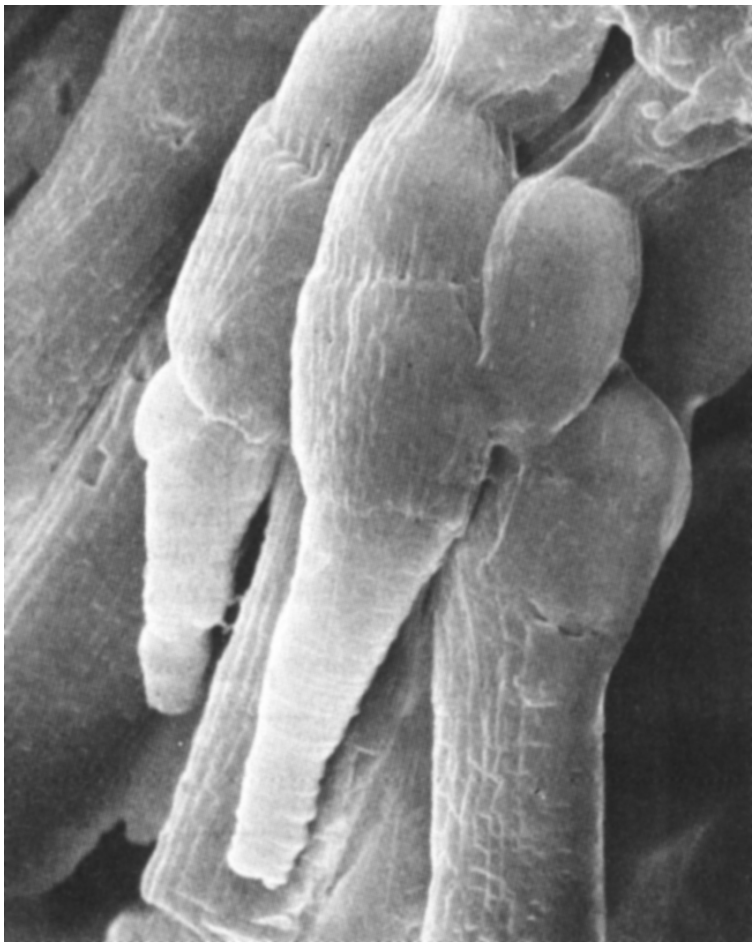
- Night vision.
- About 90 mil.

Cones

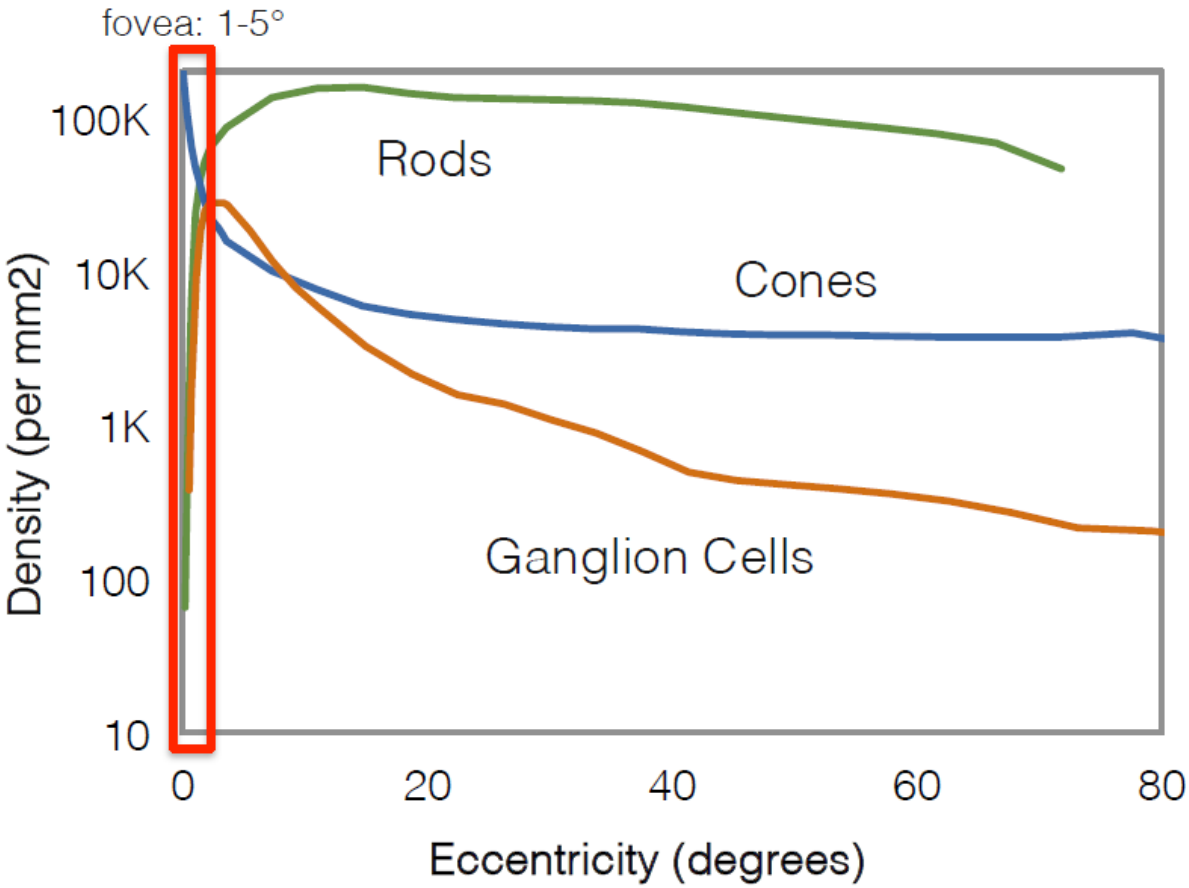
- Day vision.
- About 4.5 mil.
- Resolution comparable to recent digital cameras.

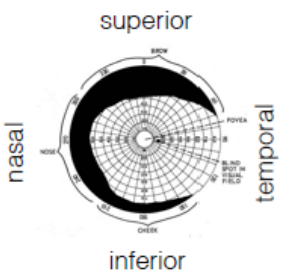


Cones under electron microscope

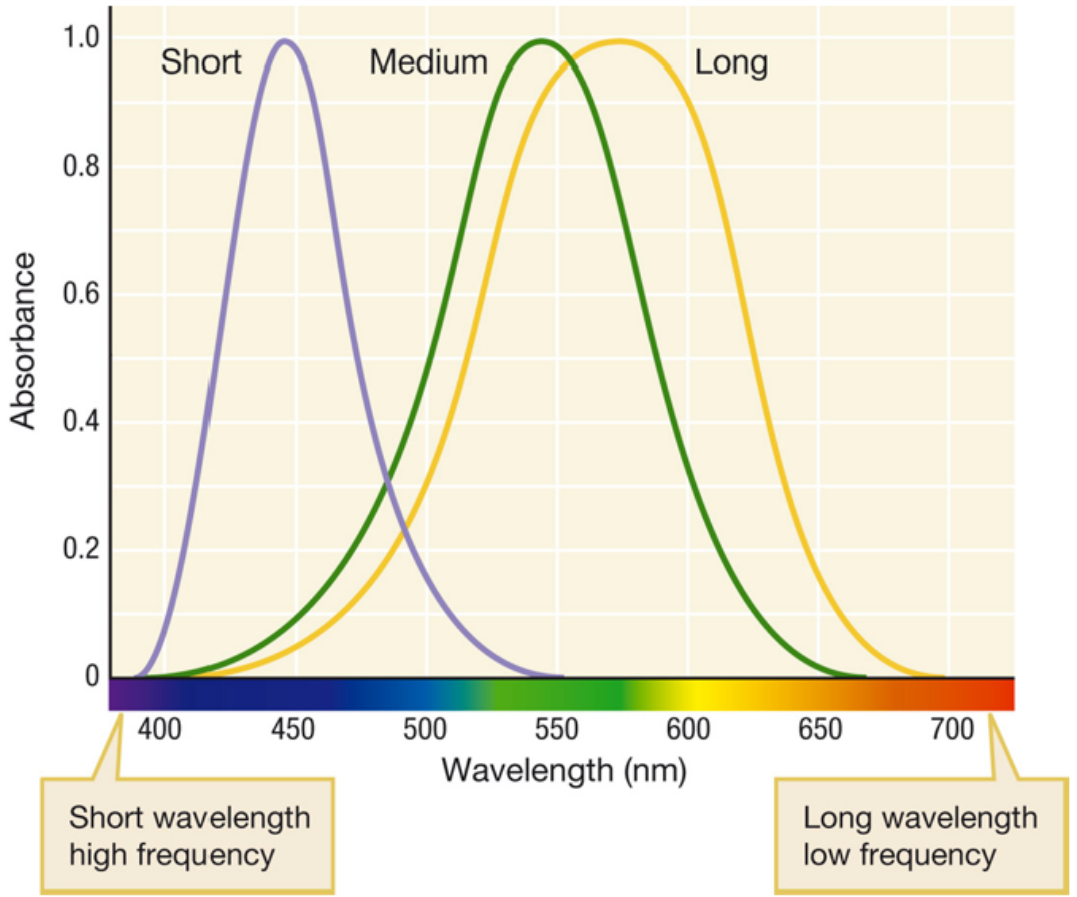


Density of photoreceptors on the retina

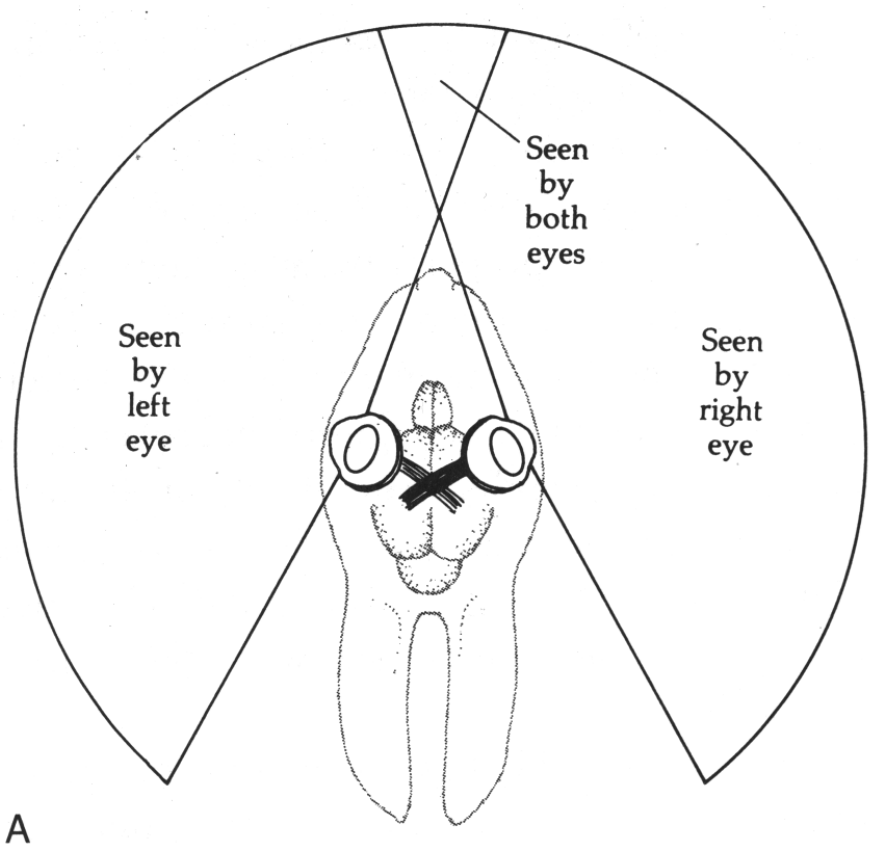


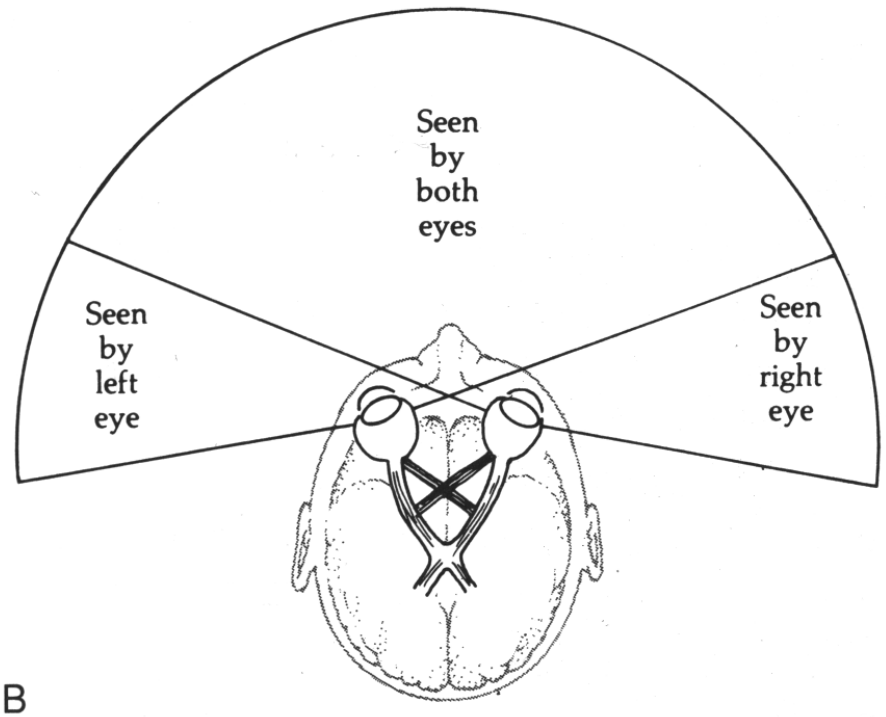


Sensitivity of color perceiving cones on the fovea



Rabbit, human – visual fields

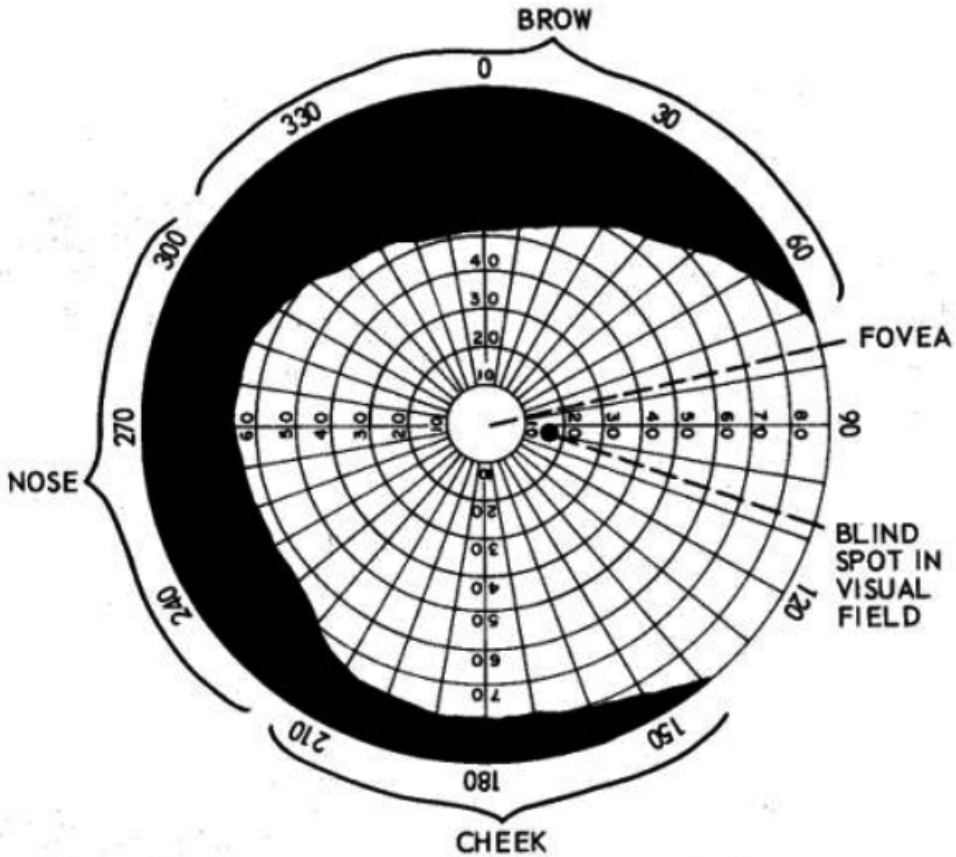




A – rabbit, pray

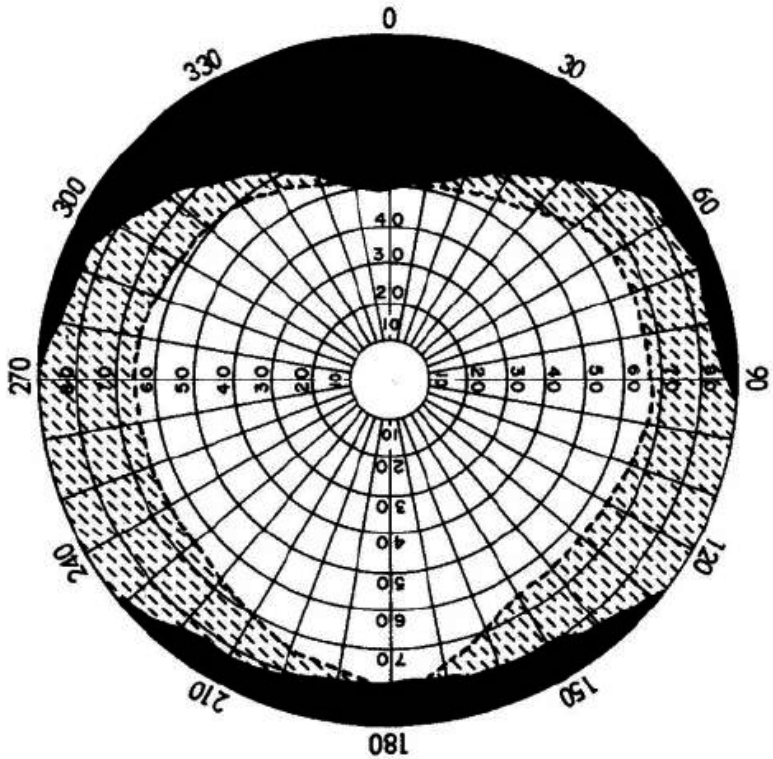
B – human, predator

Human visual field 1



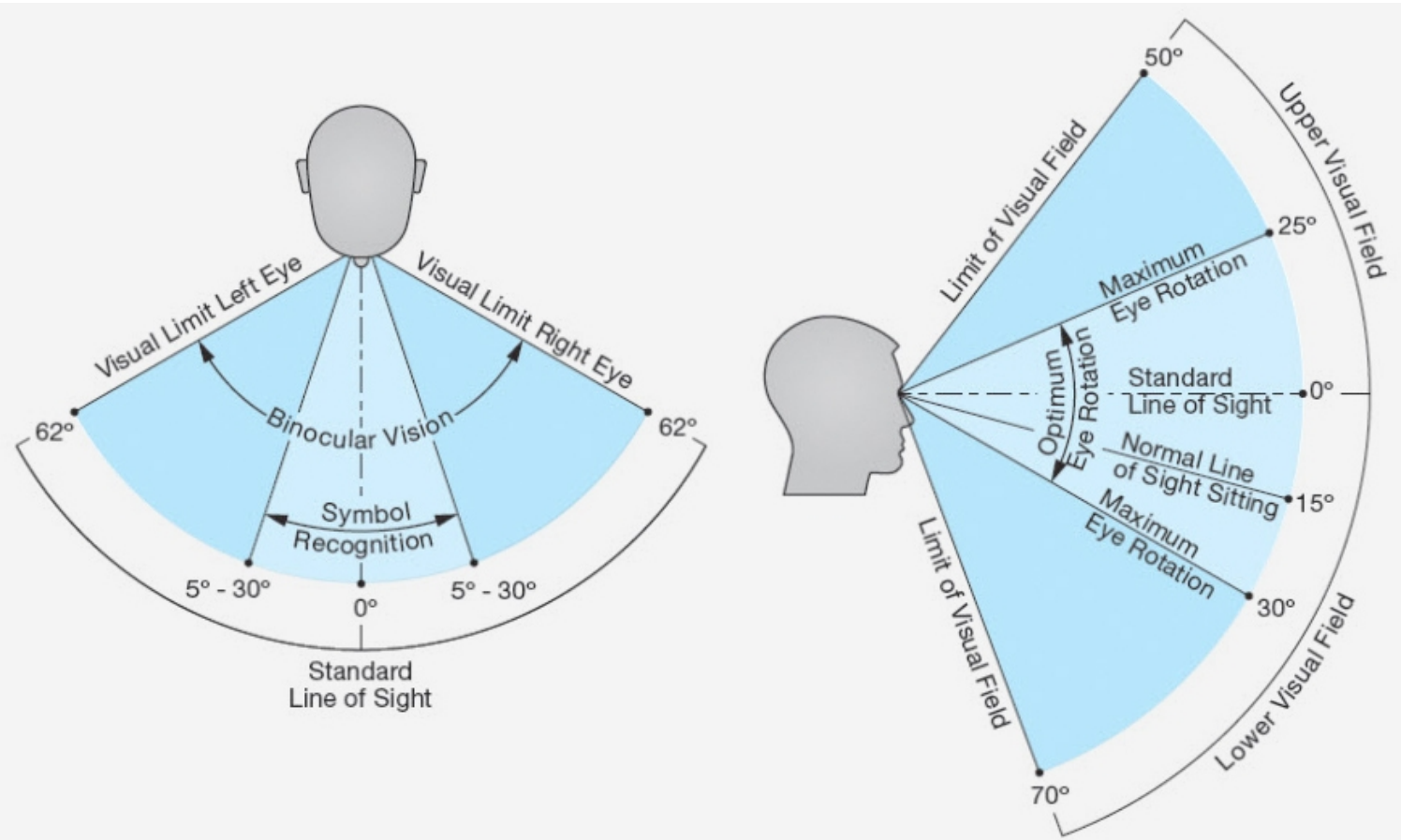
Ruch & Fulton, 1960

monocular visual field

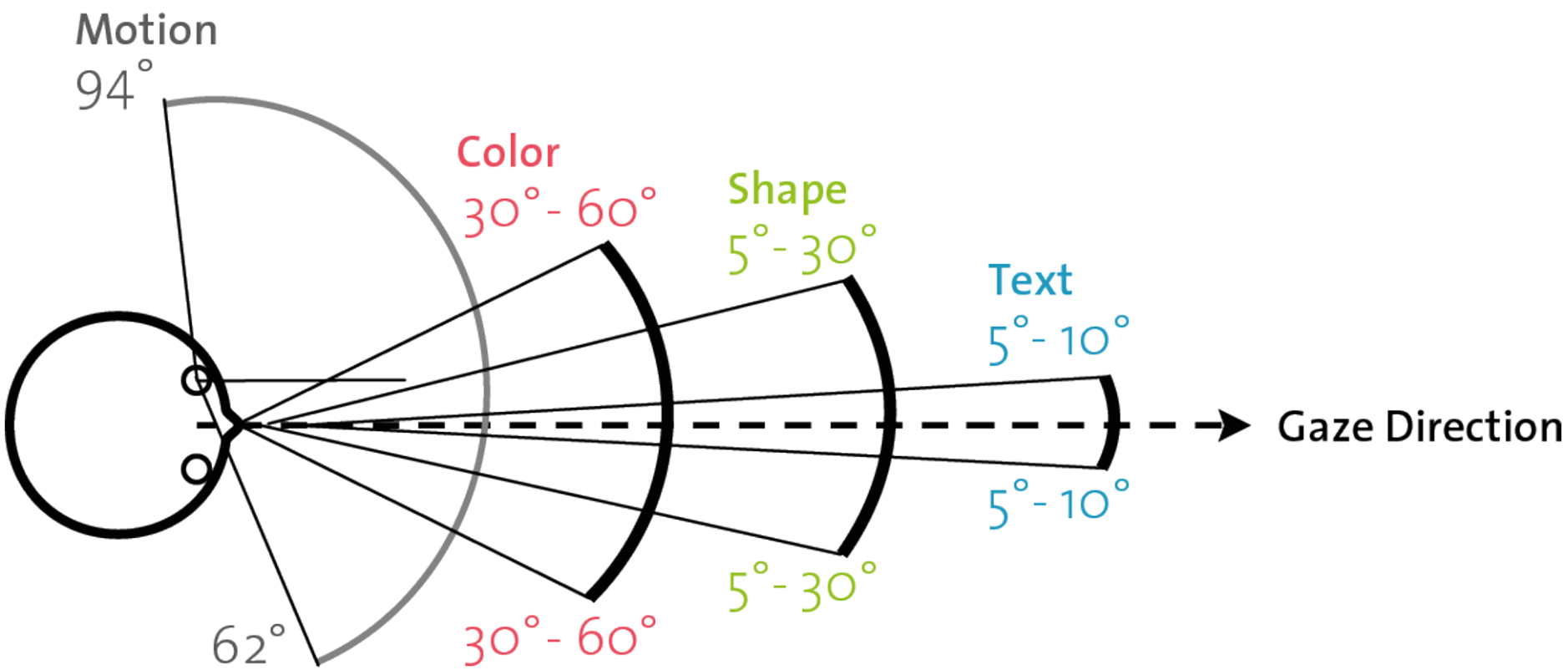


binocular visual field

Human visual field 2



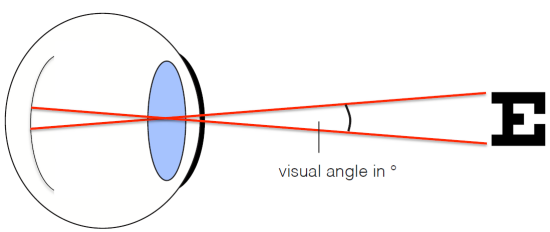
Visual perception depends on the field of view



Visual angle, visual acuity

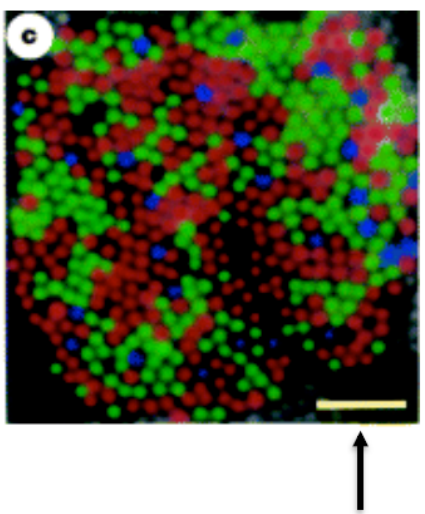
Visual angle

- Vision scientists often measure size in visual angle.
- Visual angle ≈ object size / object distance [in degrees].



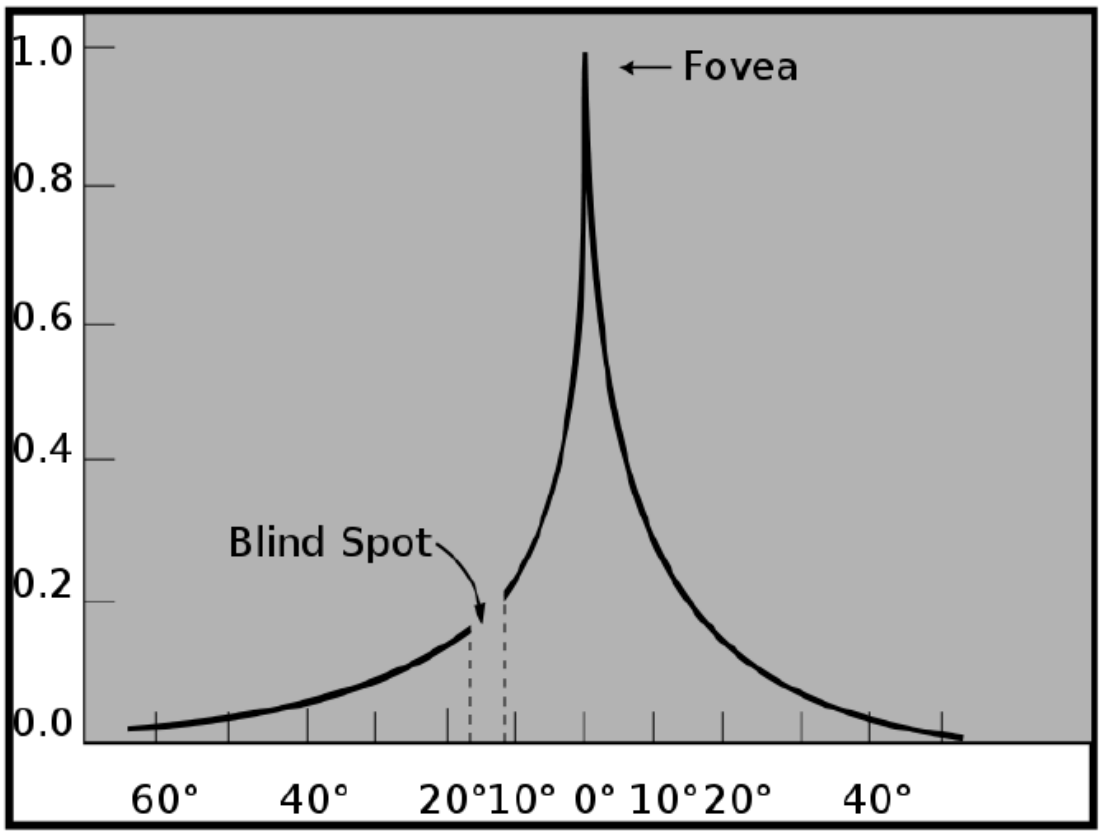
Visual acuity

- Each photoreceptor ≈ 1 arc minute (1/60 of a degree) of visual angle.



5 arcmin visual angle

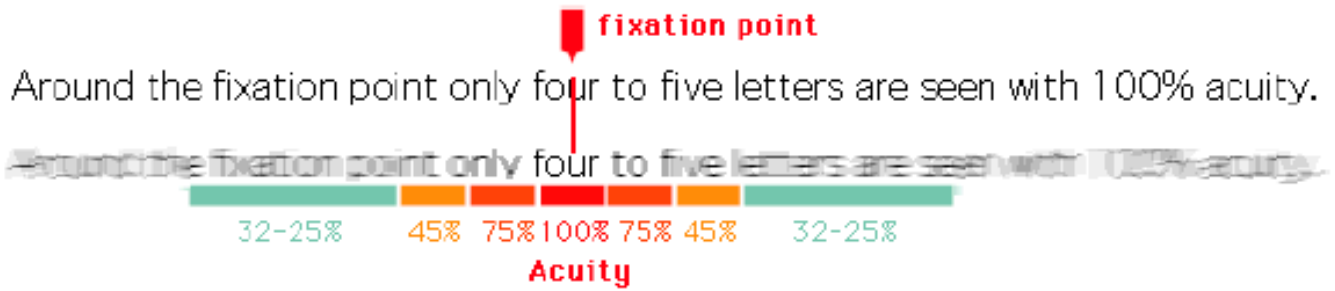
Relative acuity over retina eccentricity

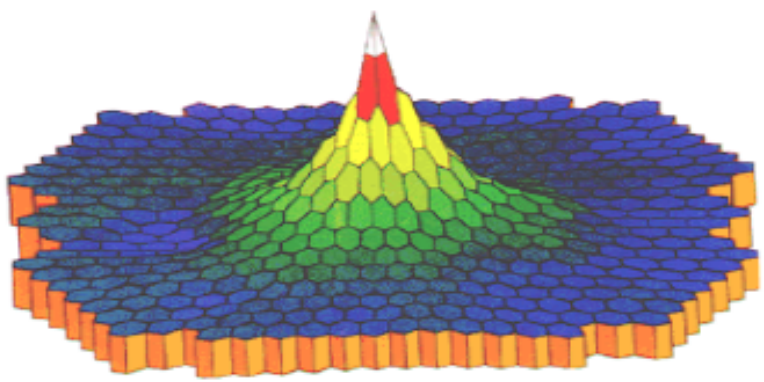


Eccentricity (i.e., distance to fovea in degrees of visual angle)

Foveation influences visual acuity

- Foveation angles the eyes to focus on an object of interest.
- Human visual system manages the captured level of detail by foveation.

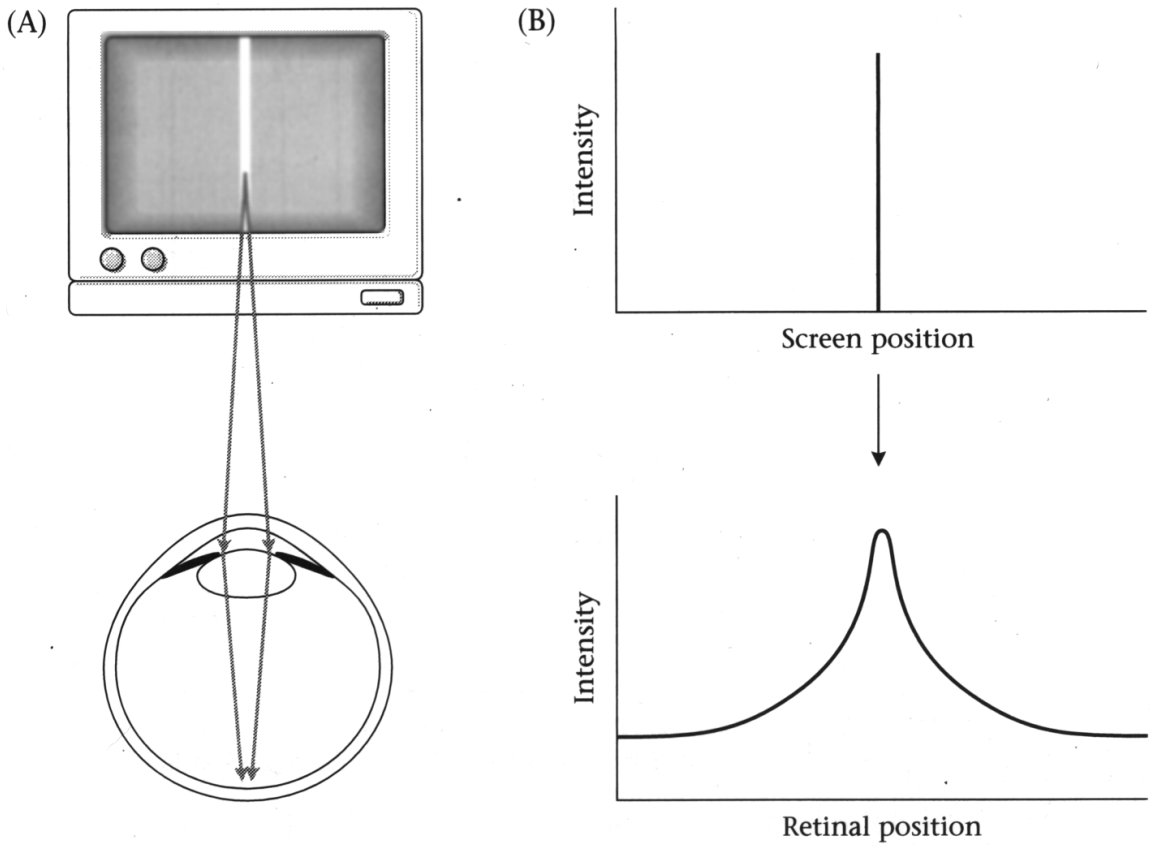




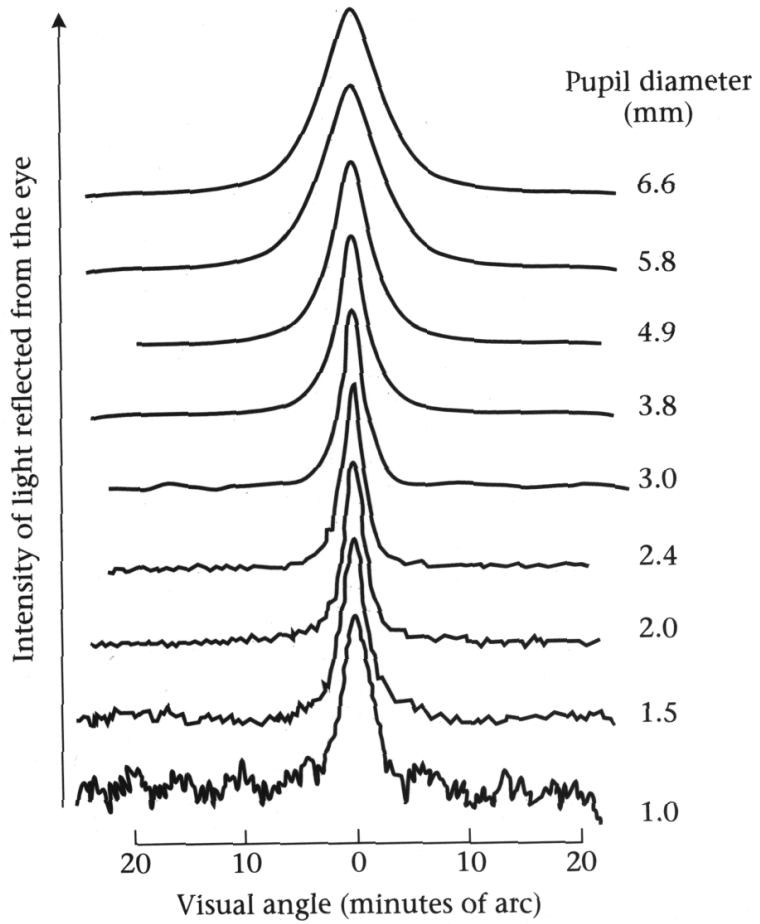
Herman Snellen's visual acuity chart, 1862

1	20/200	
2	20/100	
3	20/70	
4	20/50	
5	20/40	
6	20/30	
7	20/25	
8	20/20	← characters are 5 arc min of visual angle, need to resolve 1 arc min to read
9		
10		
11		

Response to a light slit

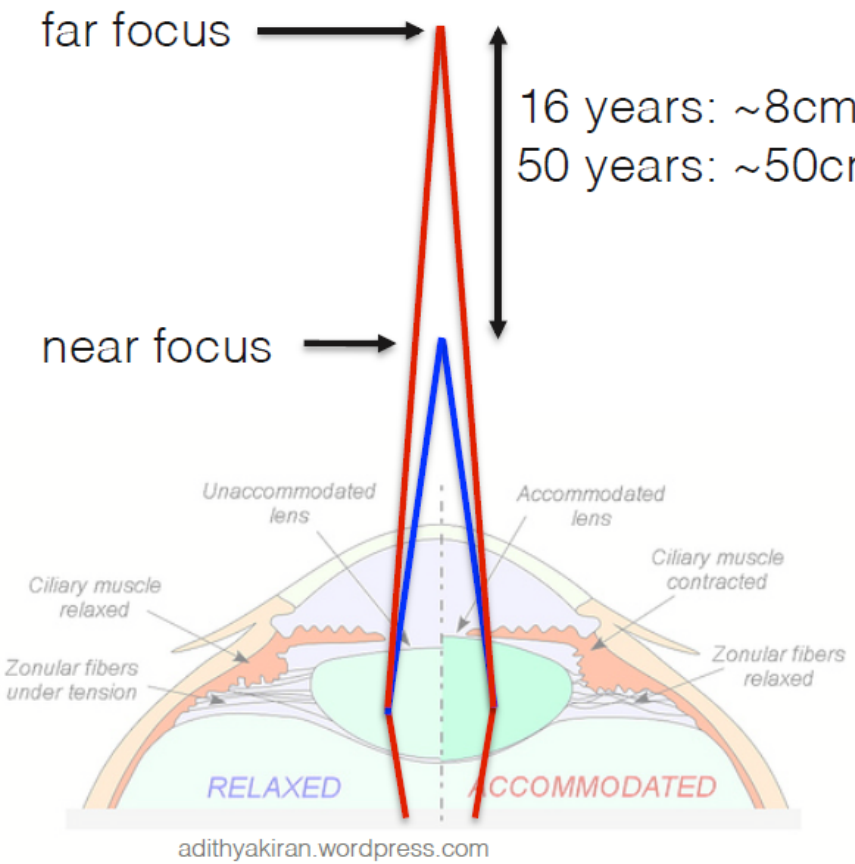


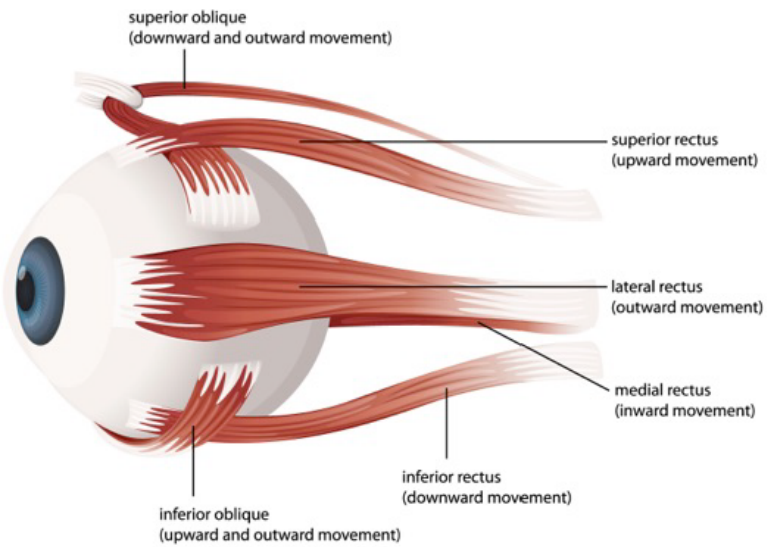
Iris change influences smoothing



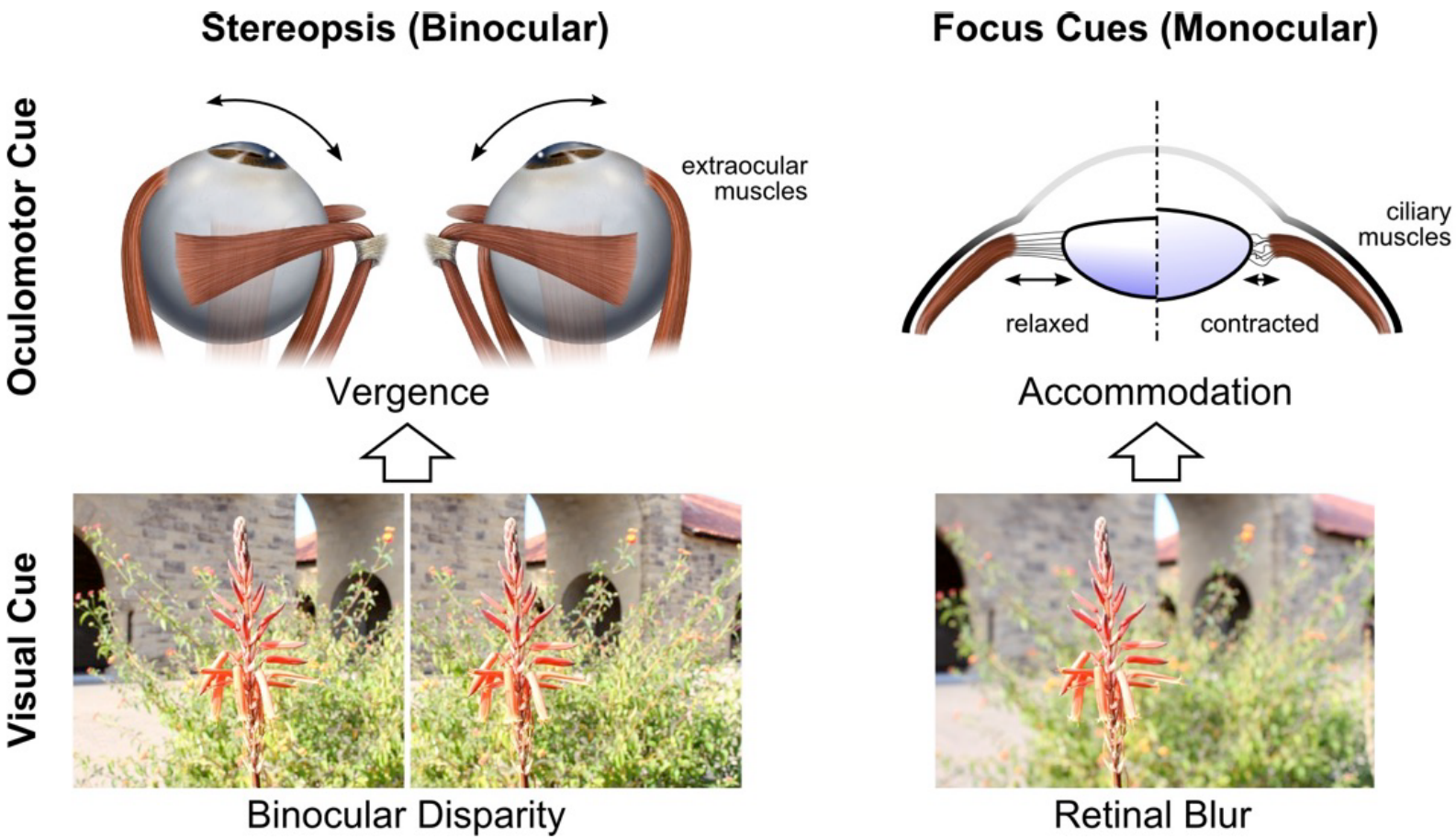
2.5 EXPERIMENTAL MEASUREMENTS of light that has been reflected from a human eye looking at a fine line. The reflected light has been blurred by double passage through the optics of the eye. Source: Campbell and Gubisch, 1966.

Oculomotor processes



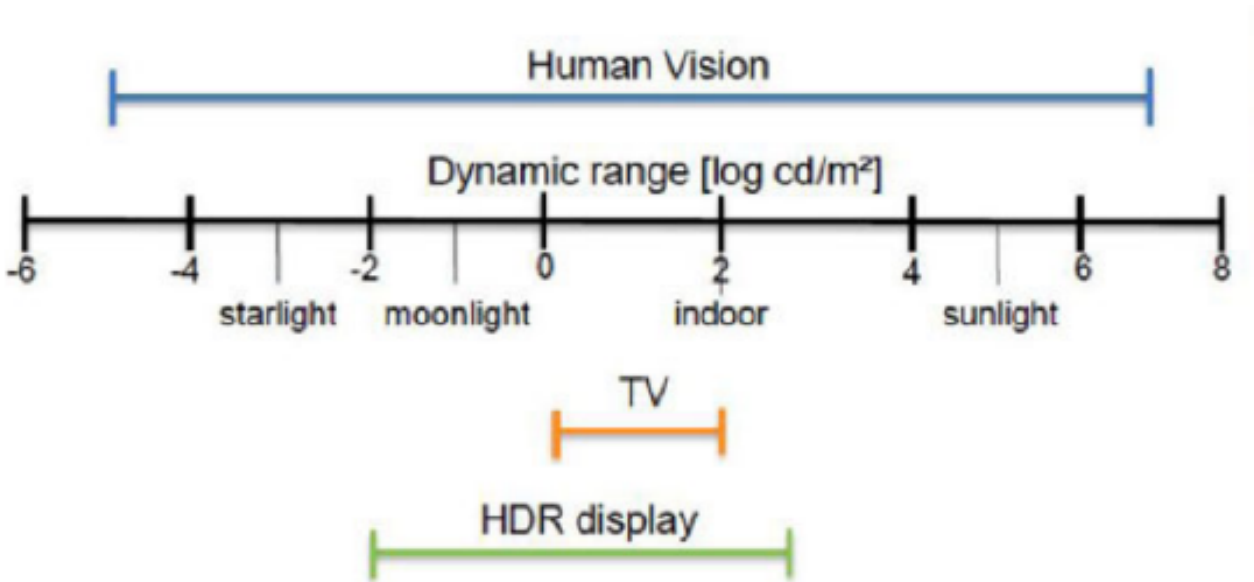


Human eye vergence and accommodation



Excellent dynamic range of the human eye

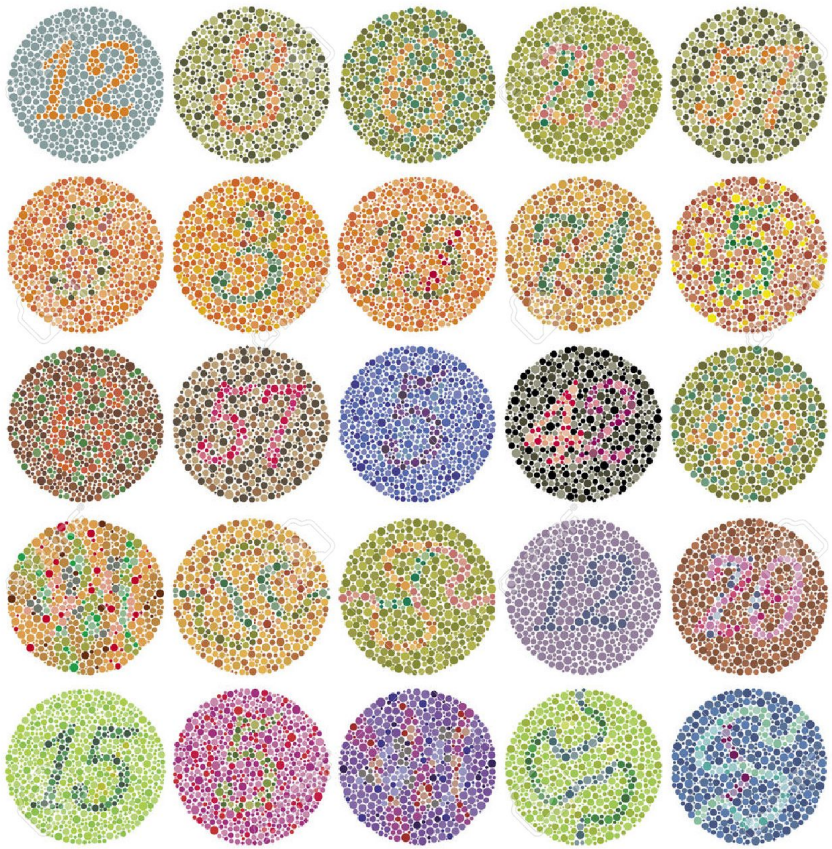
- Human vision dynamic range spans 12 decades (= decadic orders).
- Human vision has far higher dynamic range than any available display/camera technology.



Source: http://petapixel.com

Color blindness, Ishihara test

- Dr Shinobu Ishihara, 1879-1963.
- Japanese ophthalmologist, army surgeon.
- Test established in 1918.



We humans make meaning from what we see

- Humans as species are driven by a desire to find meaning. We are meaning makers, also “homo significants”.
- If one sees, e.g., eight dots in a line, the mind strives to find meaning of it. It is probably that you see four pairs of dots. Brains joins closer object together. Gestalt psychology explicates this observation further.