The Human Retina

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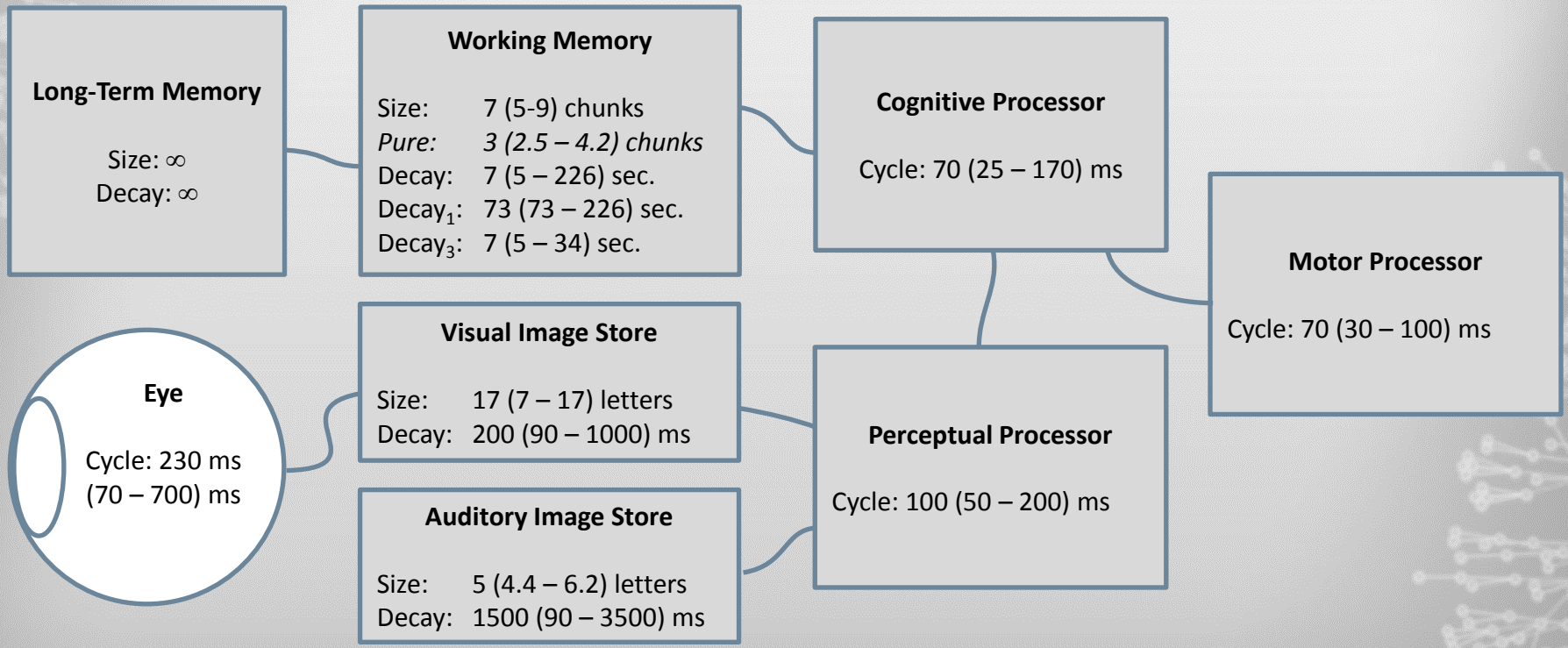
What Will We Learn?

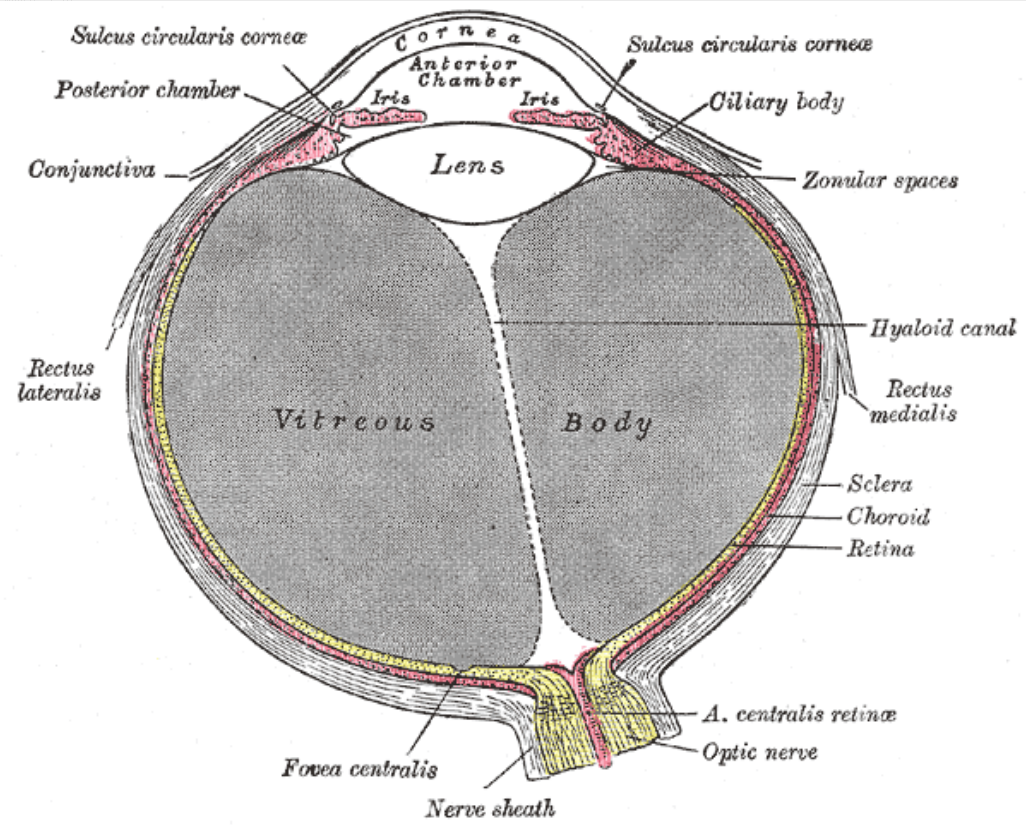
- How does the eye sense light?
- How small can the details in a visualization be?
- What colors should I use in a visualization?

The Model Human Processor



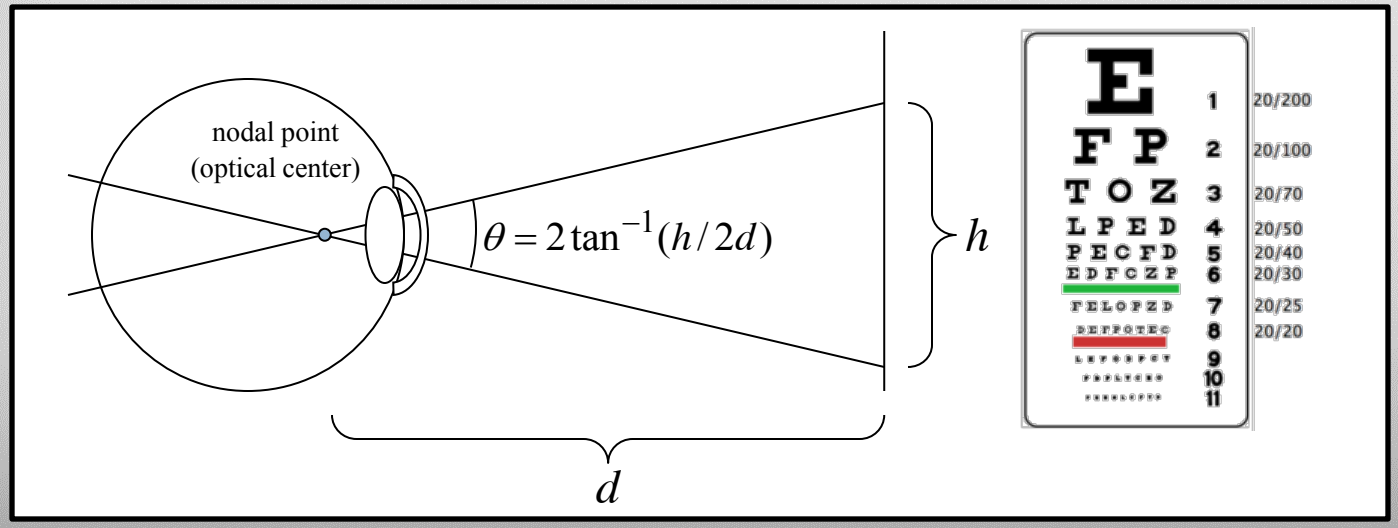
Card, Stuart K. "The model human processor: A model for making engineering calculations of human performance." In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 25(1),1981. pp. 301-305

The Eye


Sulcus circularis corneæ
Cornea
Anterior Chamber
Sulcus circularis corneæ
Posterior chamber
Iris
Iris
Ciliary body
Conjunctiva
Lens
Zonular spaces
Hyaloid canal
Rectus lateralis
Vitreous Body
Rectus medialis
Sclera
Choroid
Retina
A. centralis retinæ
Optic nerve
Fovea centralis
Nerve sheath

Acuity

- Angular resolution of retina
- Snellen ratio: 20/X means you distinguish at 20 feet what the average person distinguishes at X feet.
- 20/20 = distinguish two points 1 arc minute apart



Retinal Processing

Cornea, lens focus light onto *Retina*

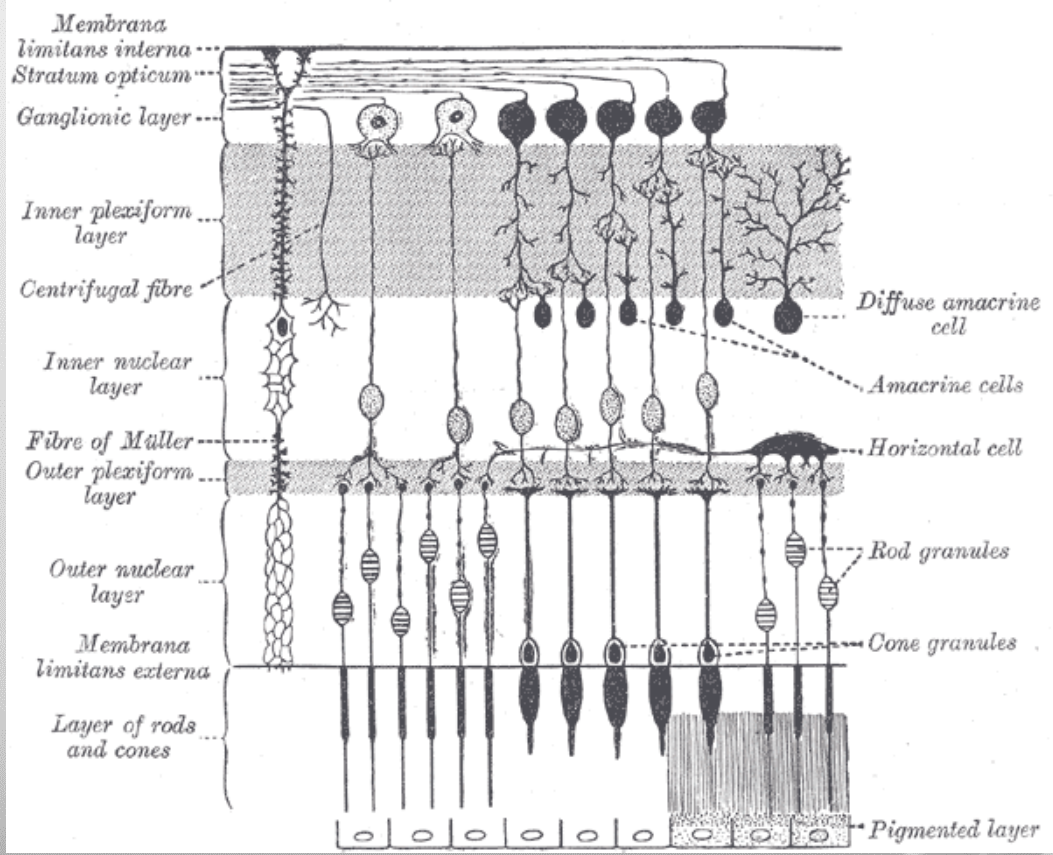
Photoreceptors

- *rods* - brightness
- *cones* – color (red, green, blue)

Ganglions – nerve cells

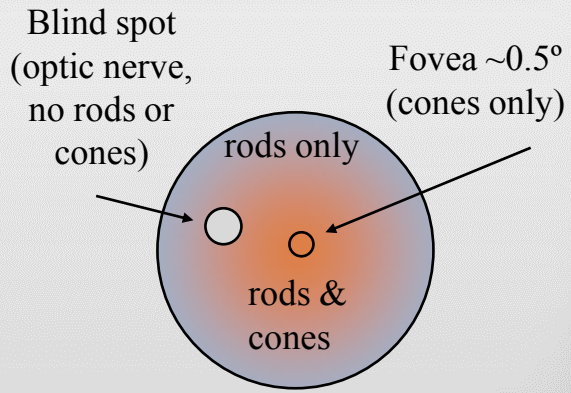
- (*X-cells*) detect pattern
- (*Y-cells*) detect movement

from Gray's Anatomy

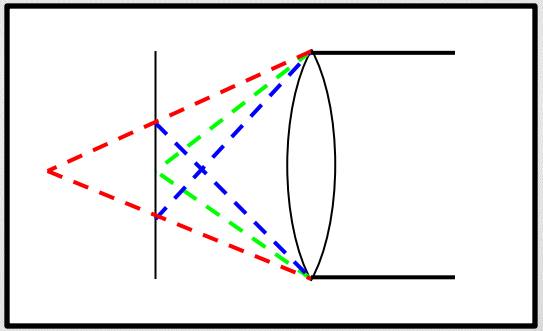


Rods & Cones

- Rods measure intensity
  - 80 million
  - Denser away from fovea
  - Astronomers learn to glance off to the side of what they are studying
  - sensitive, shut down in daylight
- Cones (sensitive to “red”, “green” & “blue”)
  - 5 million total
  - 100K – 325K cones/mm^2 in fovea
  - 150 hues
- Combined: 7 million shades



Chromatic Aberration



- Refractive index of lens material varies by wavelength
- Resulting dispersion causes focal plane to vary by color
- 1.5 diopters between focus of red and blue
- This is why amber sunglasses aid vision
- Never use pure blue (add at least a bit of red or green to aid in focusing on edges)

Red looks higher than blue

Most people see the red,

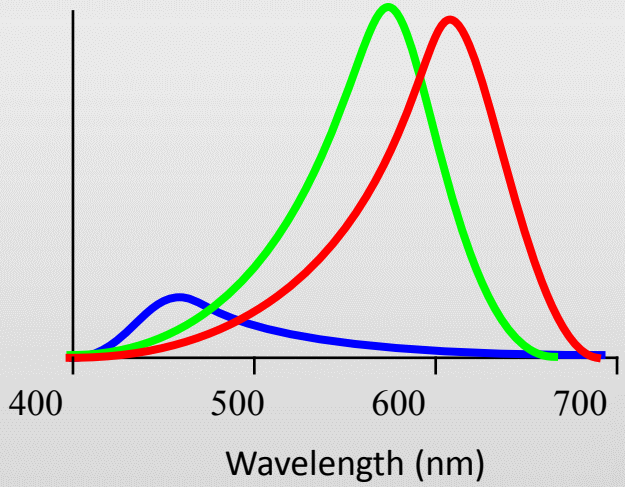
Closer than the blue.

Others see the opposite.

How about you?

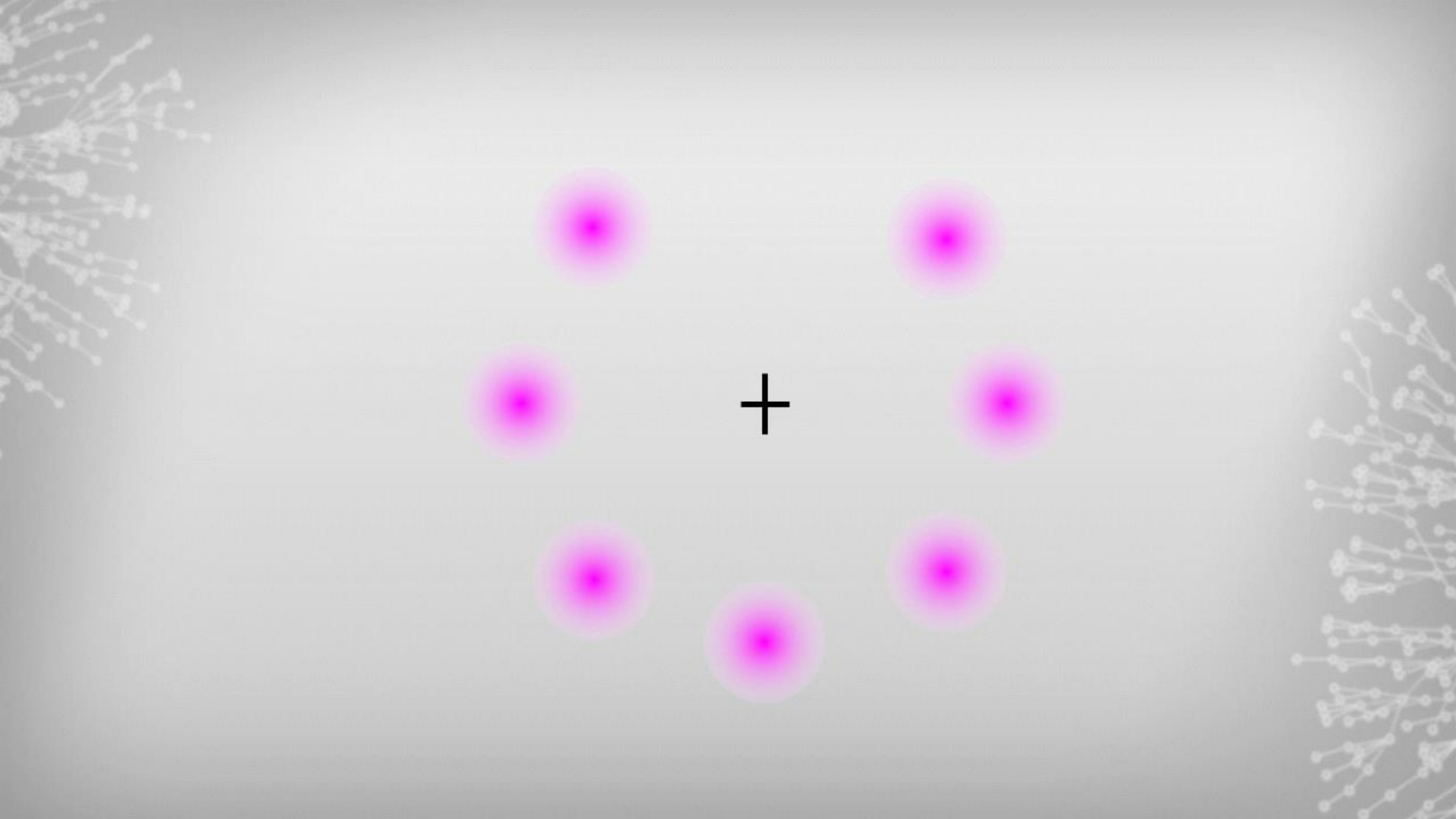
Color Perception

- L = 31% R + 59% G + 10% B
- 10% of males are color blind
- Pay attention to contrast!



- Eye color space

  Y = R + G, Y – B, R – G
- Color space is black⇔white, yellow⇔blue, red⇔green



What Did We Learn

- The retina senses brightness with rods and color with cones
- We have more cones near our center of vision, but more rods in our peripheral vision
- We tend to focus better on warmer colors and bring them to the forefront

Tips for data visualizaiton