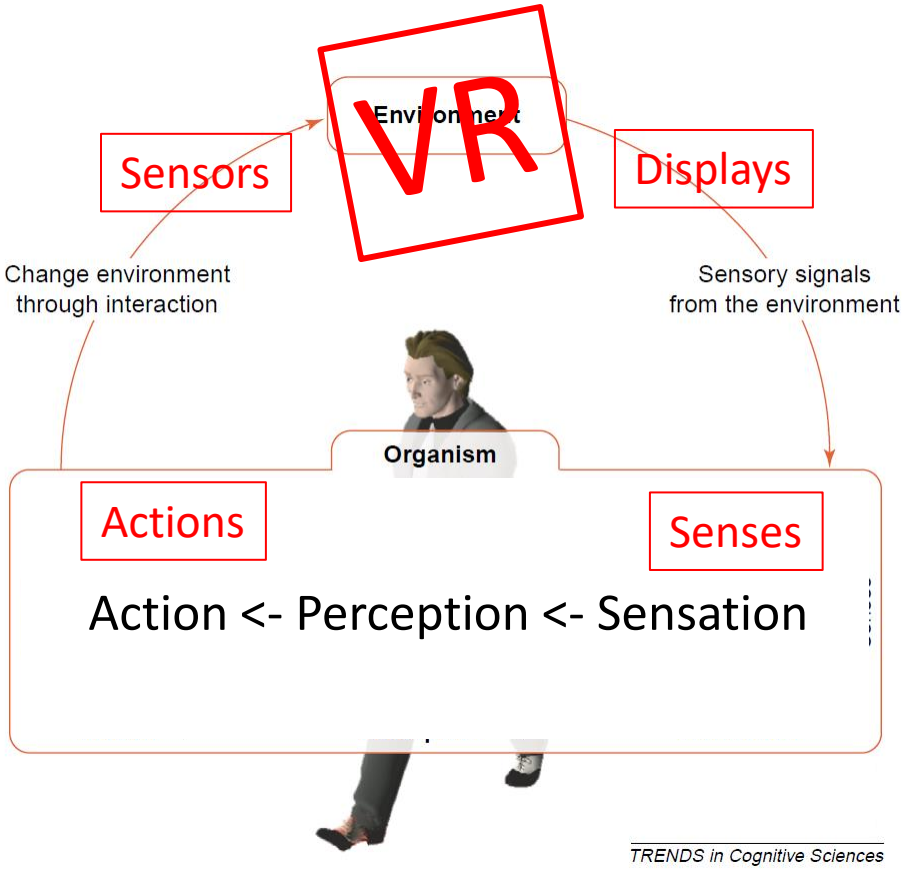
Human-machine interaction in virtual reality

Paul MacNeilage, Psychology
Eelke Folmer, Computer Science

Human-VR Loop



Communicating with Light

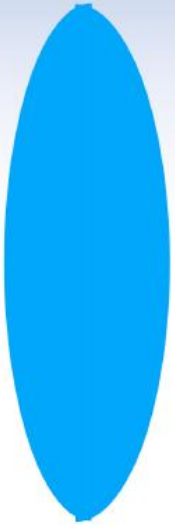
- Sending signals
- Receiving signals

- What is the content to be communicated?

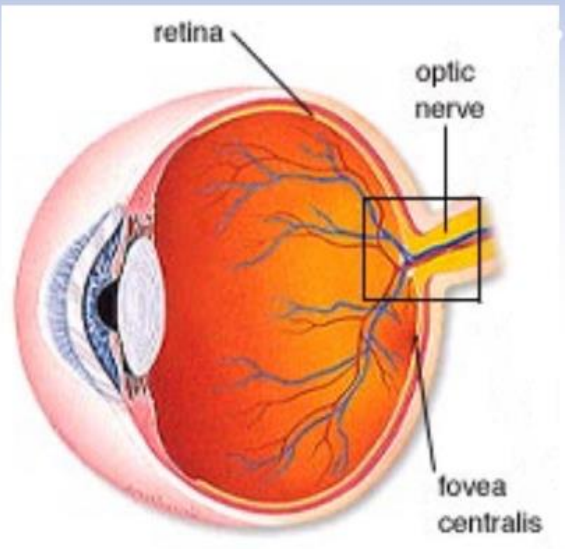
- Technically, how is this achieved?

Human Eye

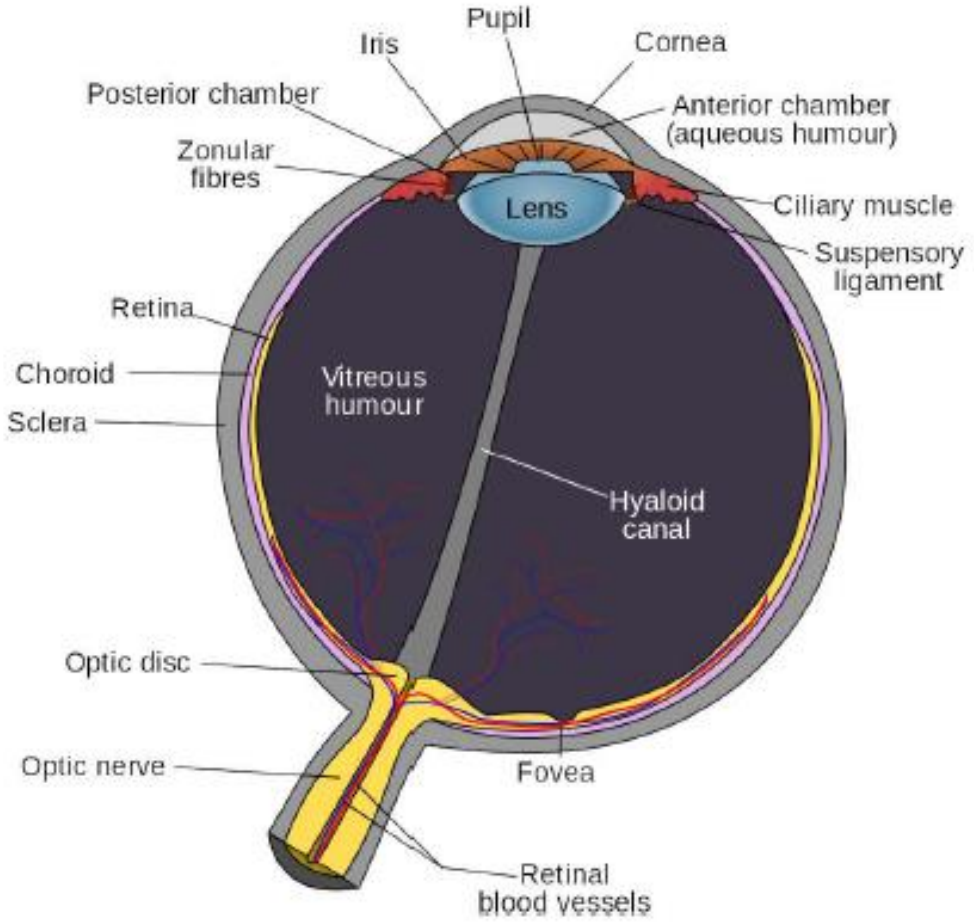
output pixels:



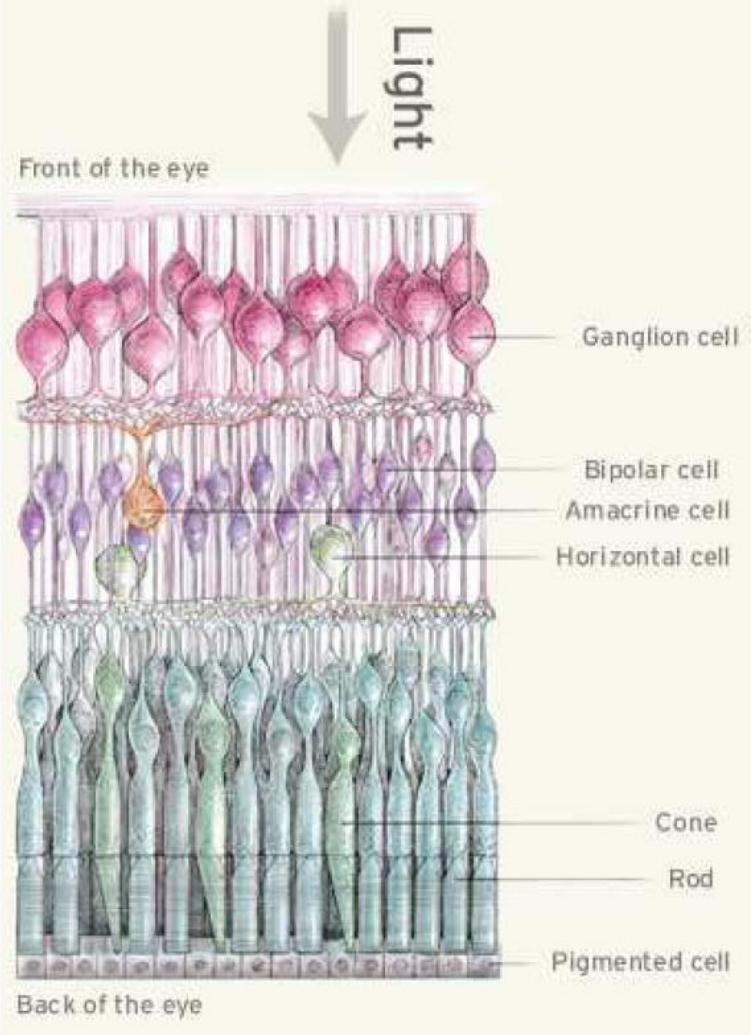
input pixels



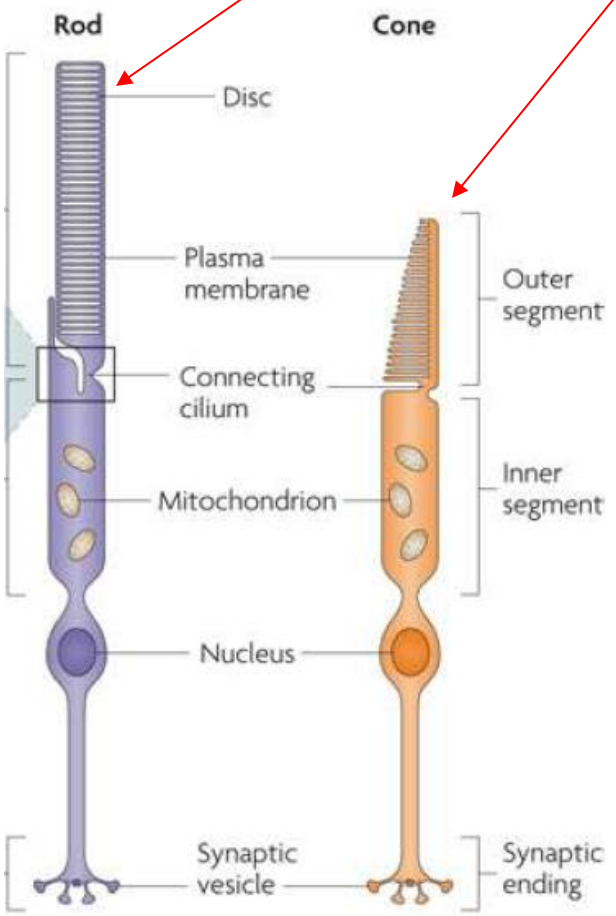
Anatomy of the Eye



Anatomy of the Retina

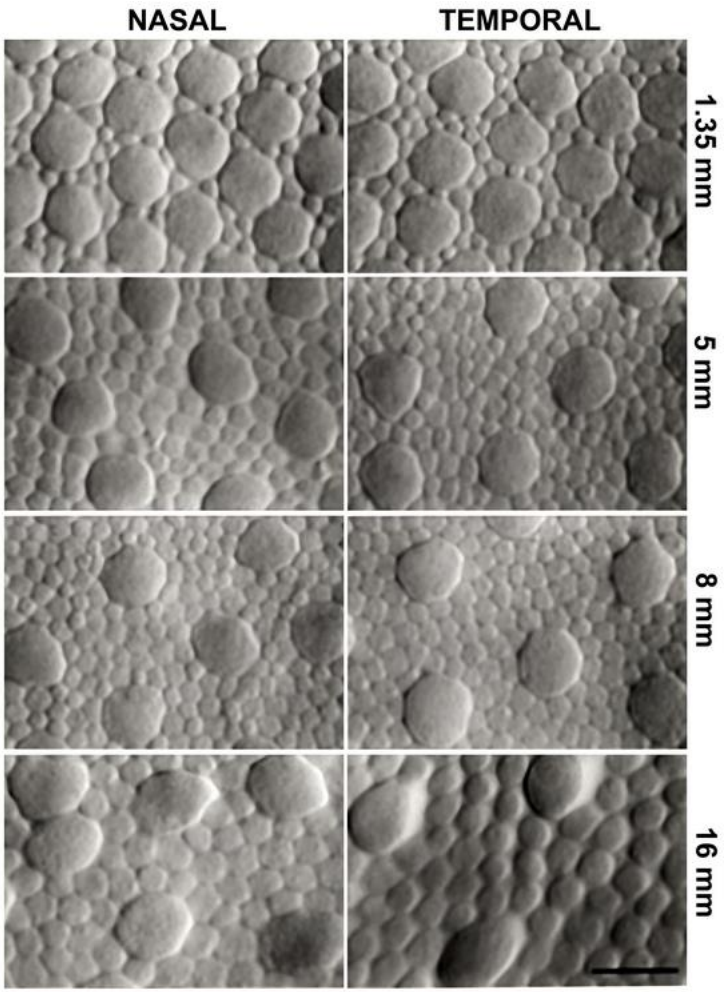


Rhodopsin photopigment

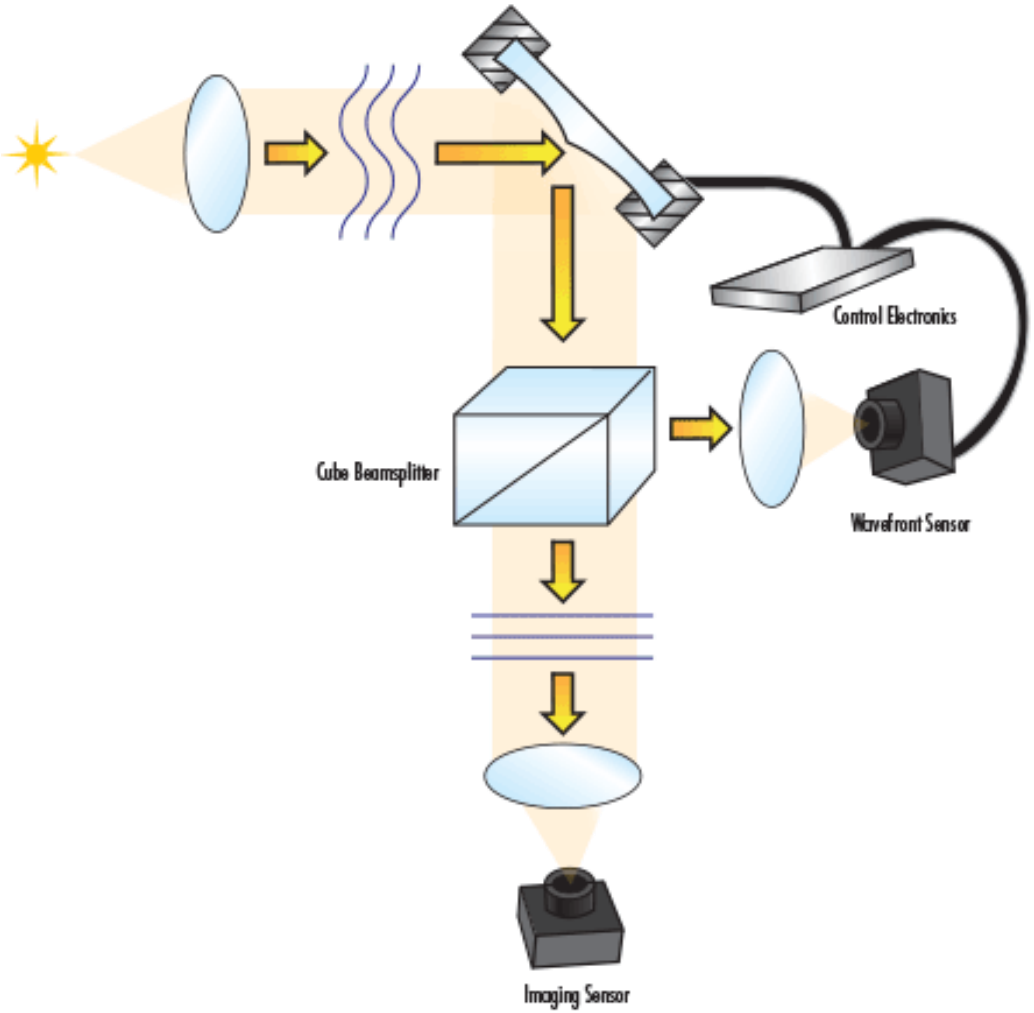


Photoreceptor Mosaic

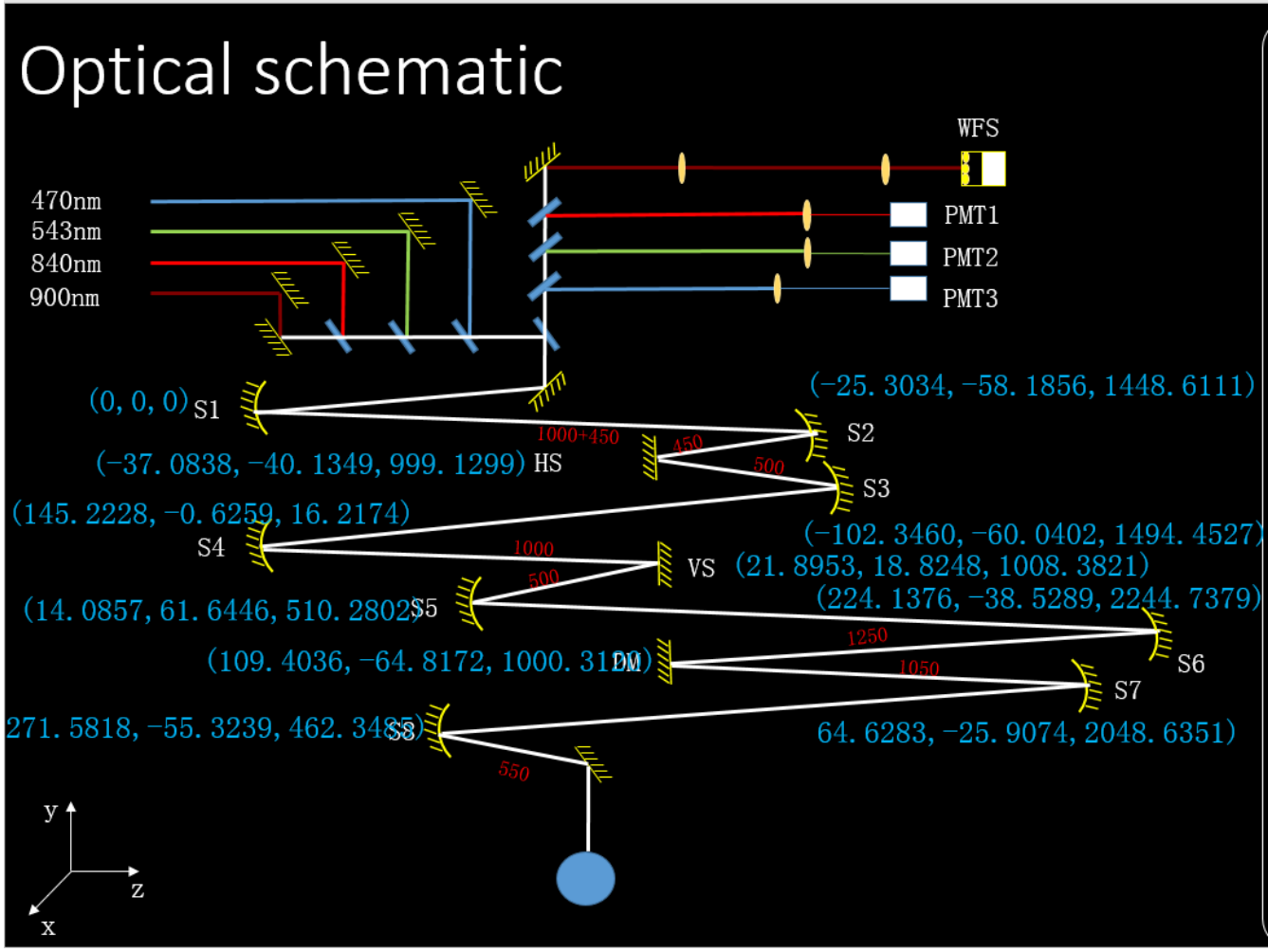
- Like pixels for sampling
- Density varies
- Fovea at the center
  - Greatest acuity
  - Most cones



Adaptive Optics



Scanning Laser Opthalmoscope



Parameters:

- Focal length (mm)

S1=1000; S2=450; S3=500;
S4=1000; S5=500; S6=1250;
S7=1050; S8=550.
L1=150; L2=150;
L3=125; L4=125; L5=150.

- Beam diameter (mm)

DM=13.5 (reference);
Entrance pupil=6;
Exit pupil(in front of the eye)=7.071;
Beam on WFS=6;

- Deformable Mirror(DM)

97 actuators

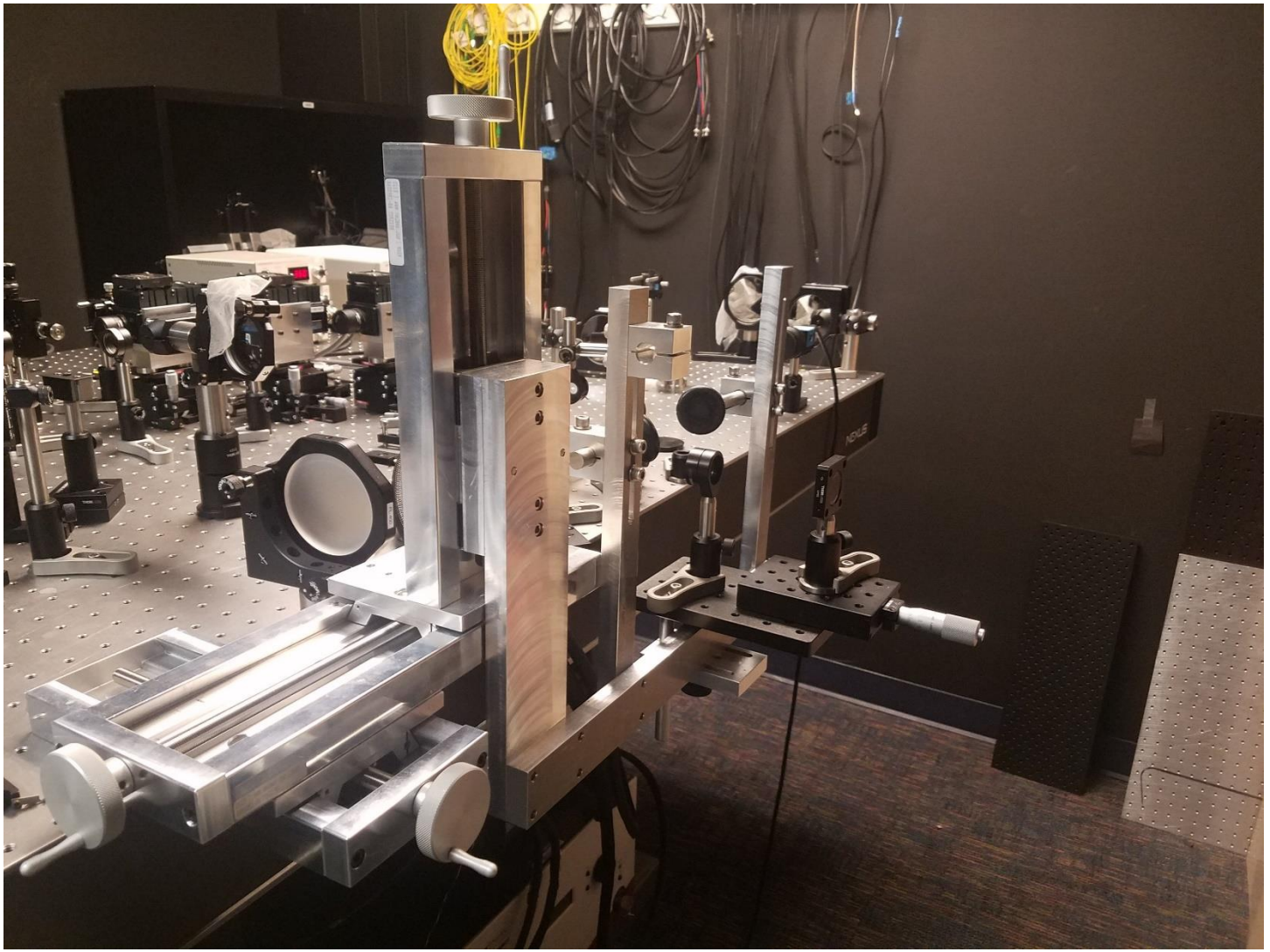
- Wavefront Sensor(WFS)

Ideal Focal length=8 mm;
Calibratied FL=7.374 mm;

Pitch=188 um;

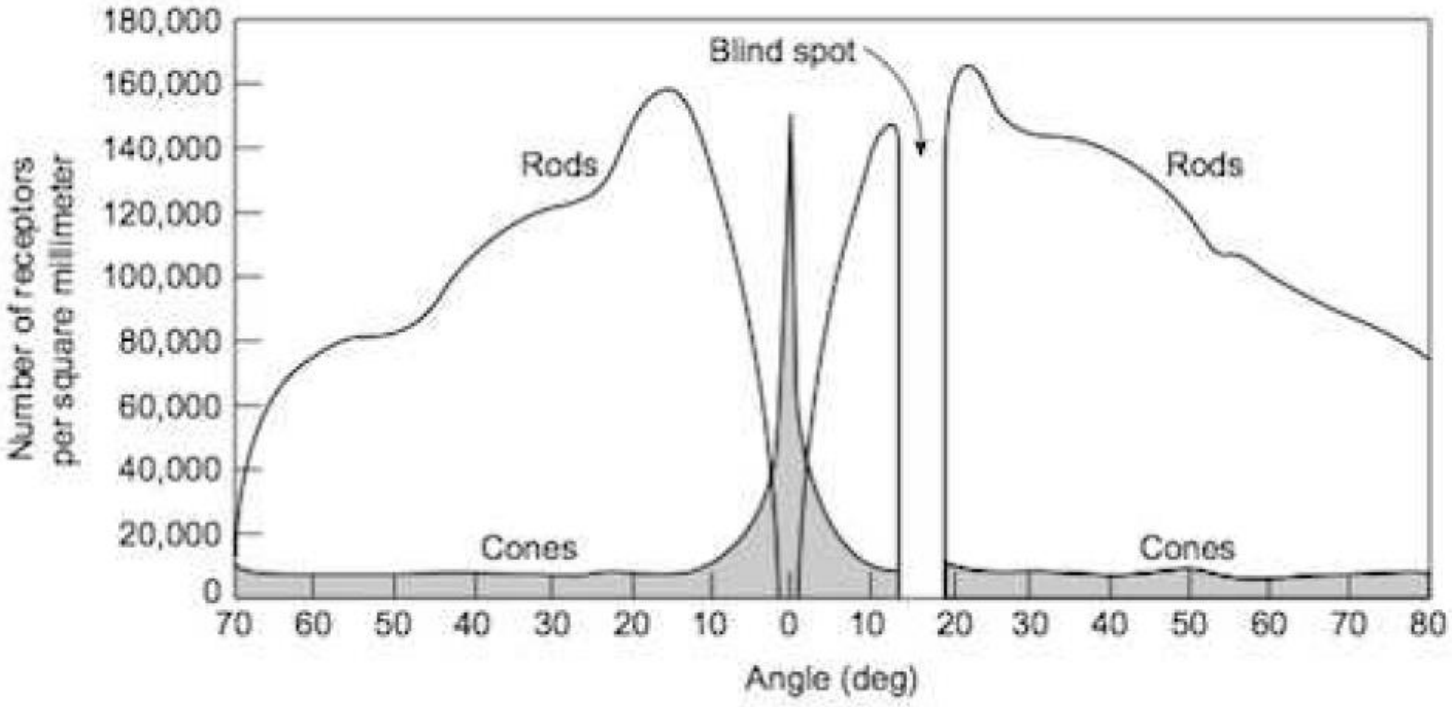
Microns/pixel on Camera=6.45 um;
Microns/pixel=12.9 um (Binning); (Current working mode)

Scanning Laser Opthalmoscope

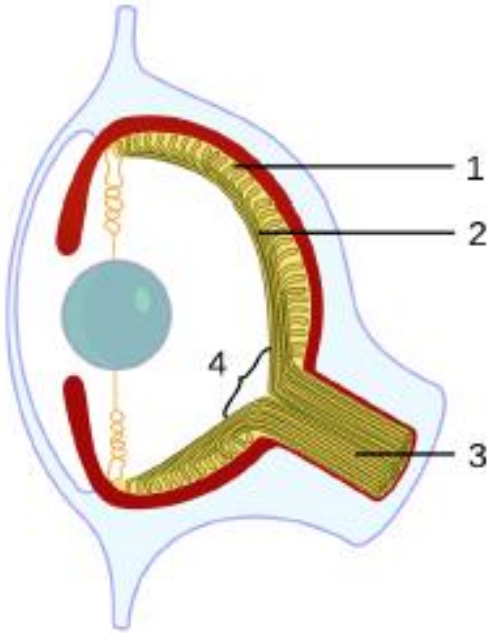


Sampling Density on Retina

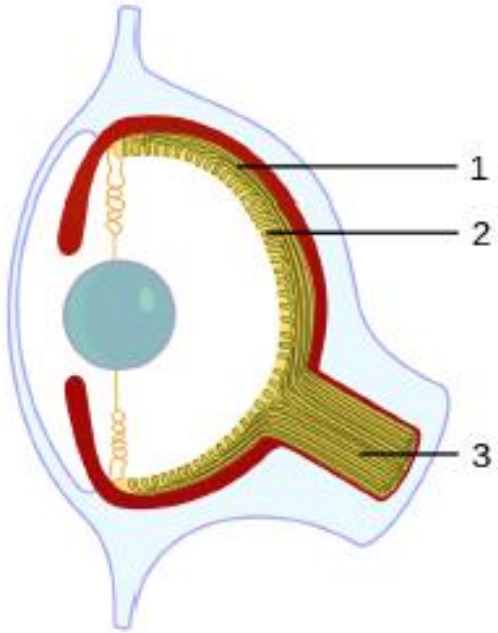
- Cones – color – daylight
- Rods – motion – low light levels



Blindspot?

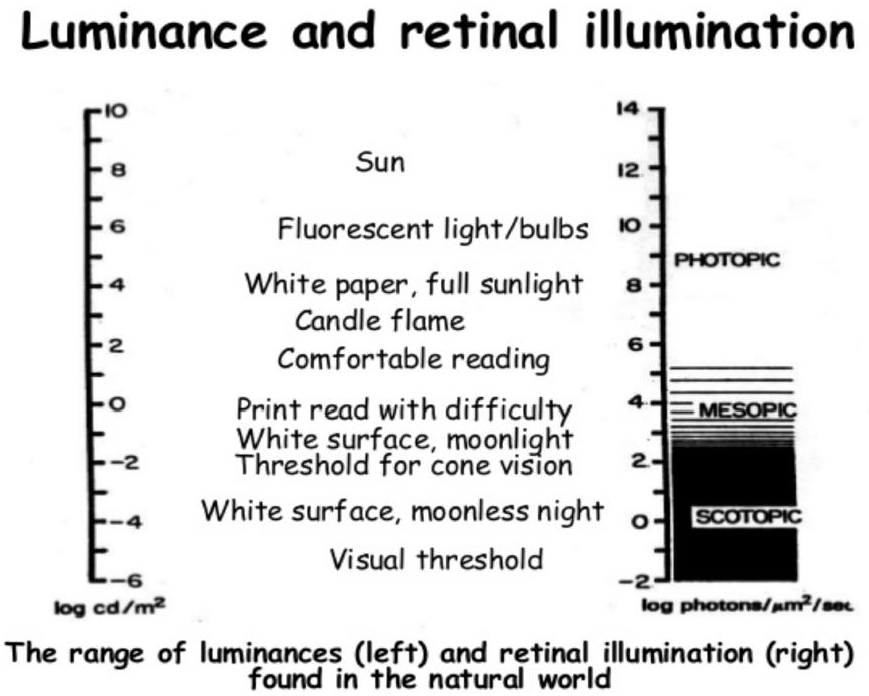


Vertebrate eye



Cephalopod eye

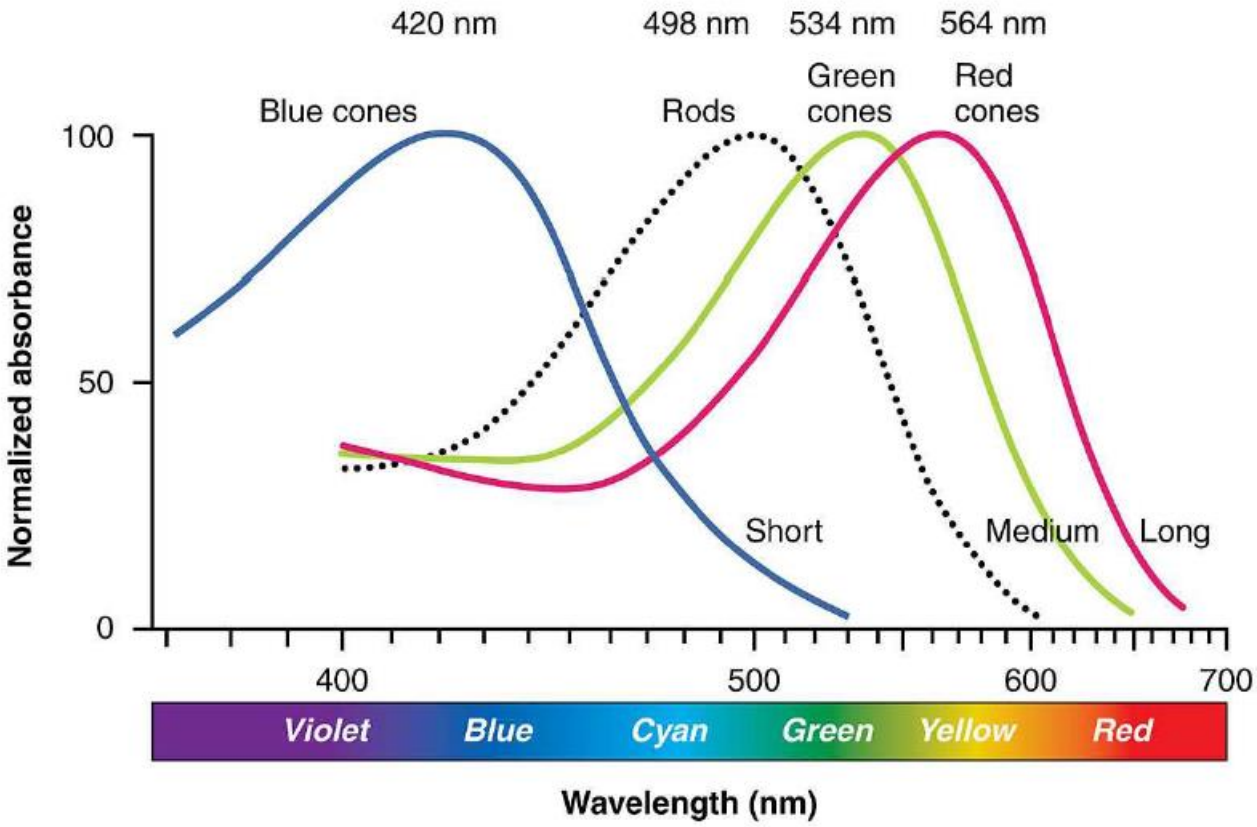
Dynamic Range



The range of luminances (left) and retinal illumination (right) found in the natural world

Light source	Luminance (cd/m^2)	Photons per receptor
Paper in starlight	0.0003	0.01
Paper in moonlight	0.2	1
Computer monitor	63	100
Room light	316	1000
Blue sky	2500	10,000
Paper in sunlight	40,000	100,000

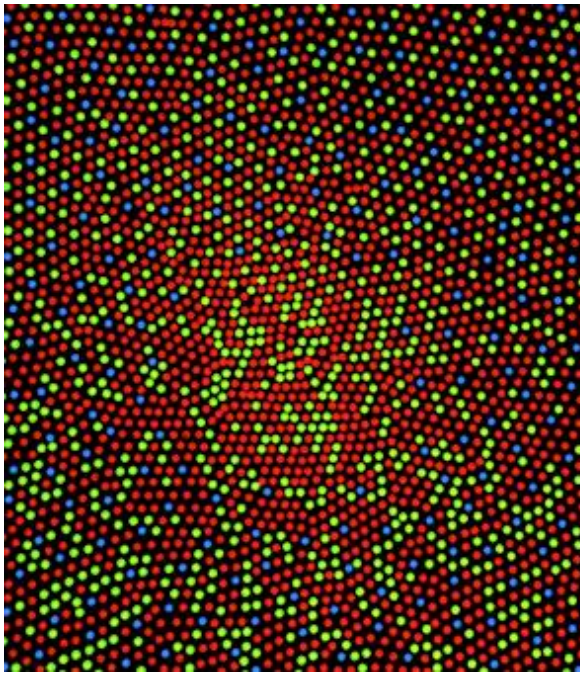
Types of Cones



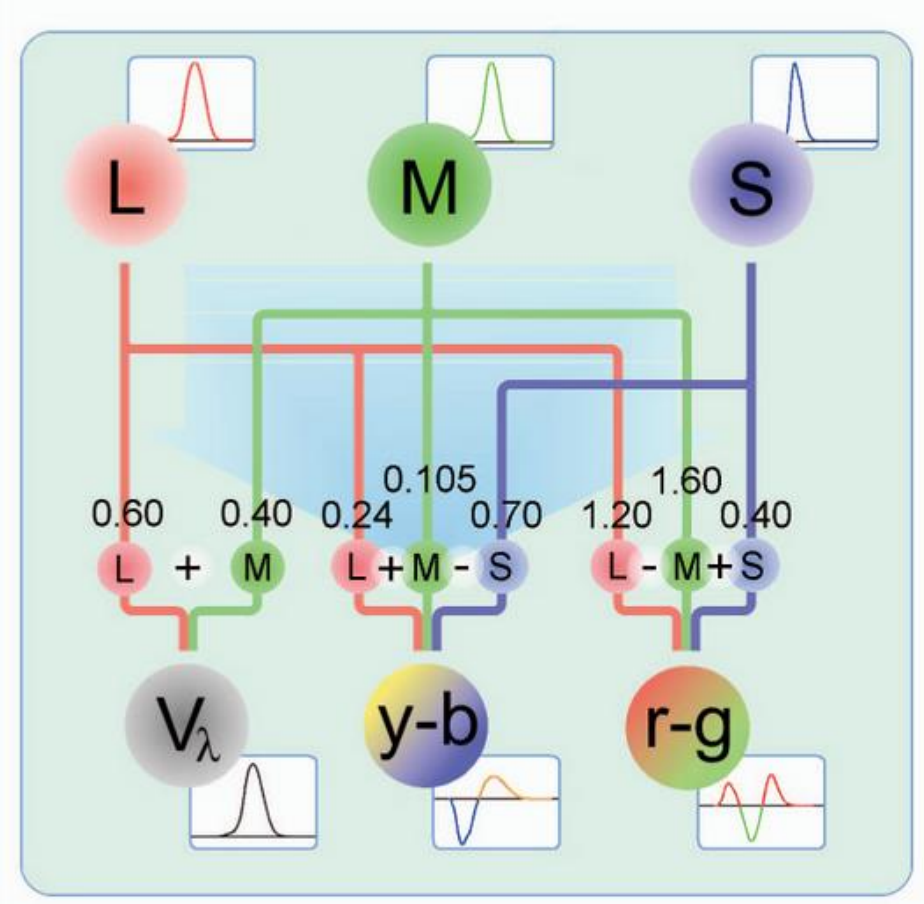
Photoreceptor Mosaic

Normal

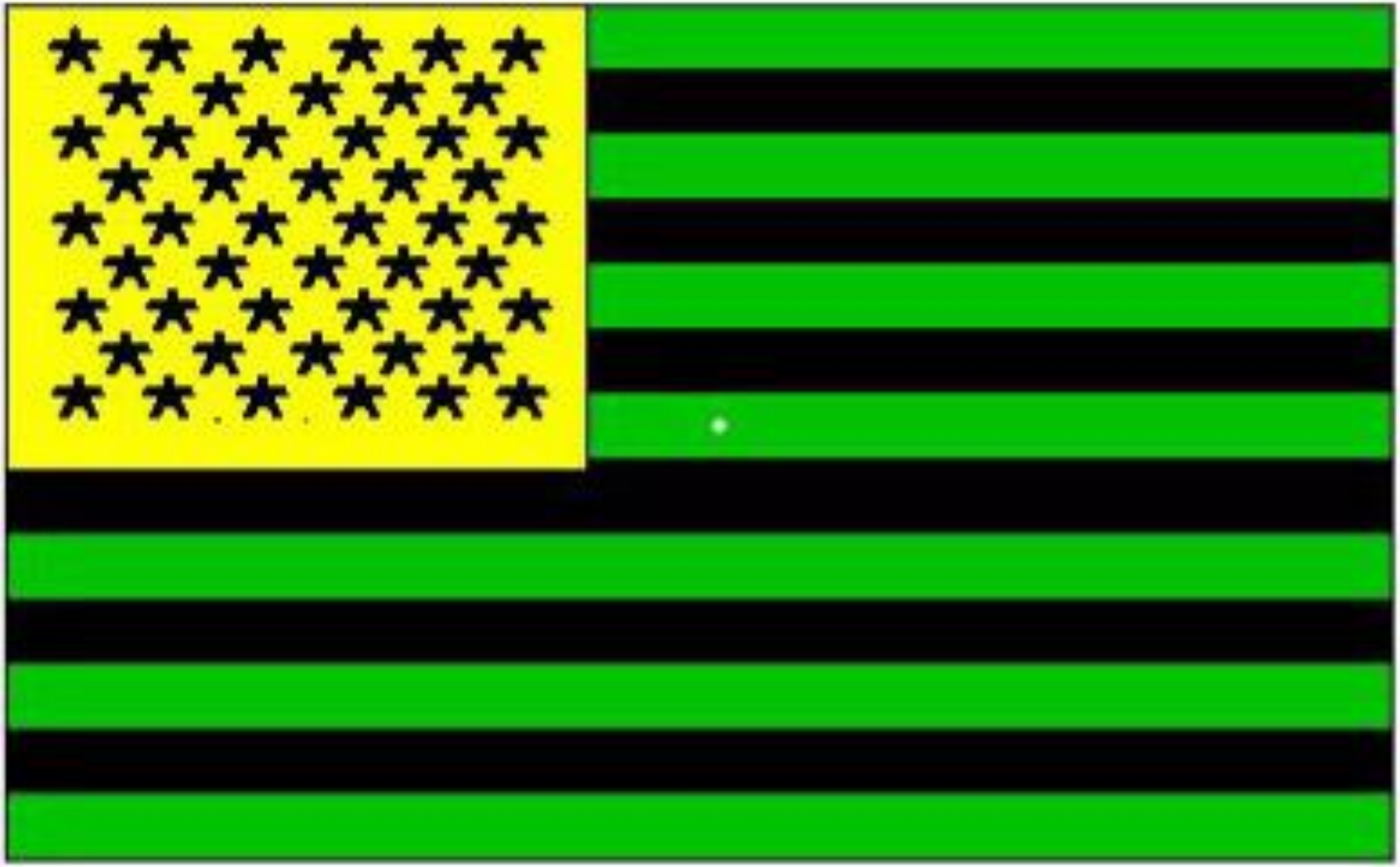
Colorblind



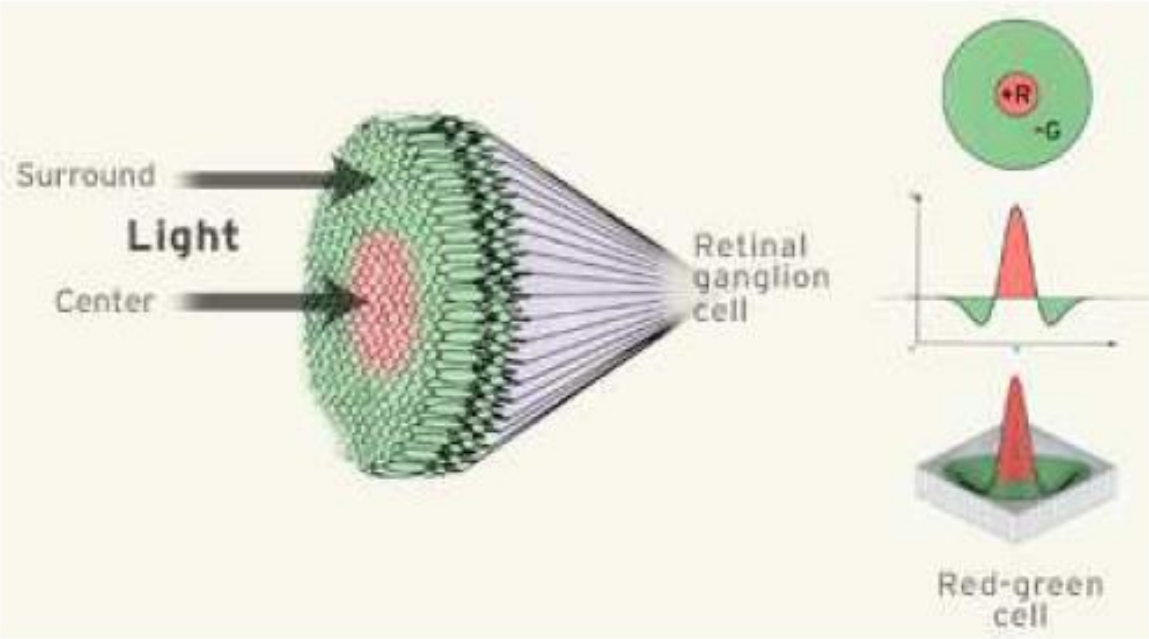
Opponent Color “Channels”



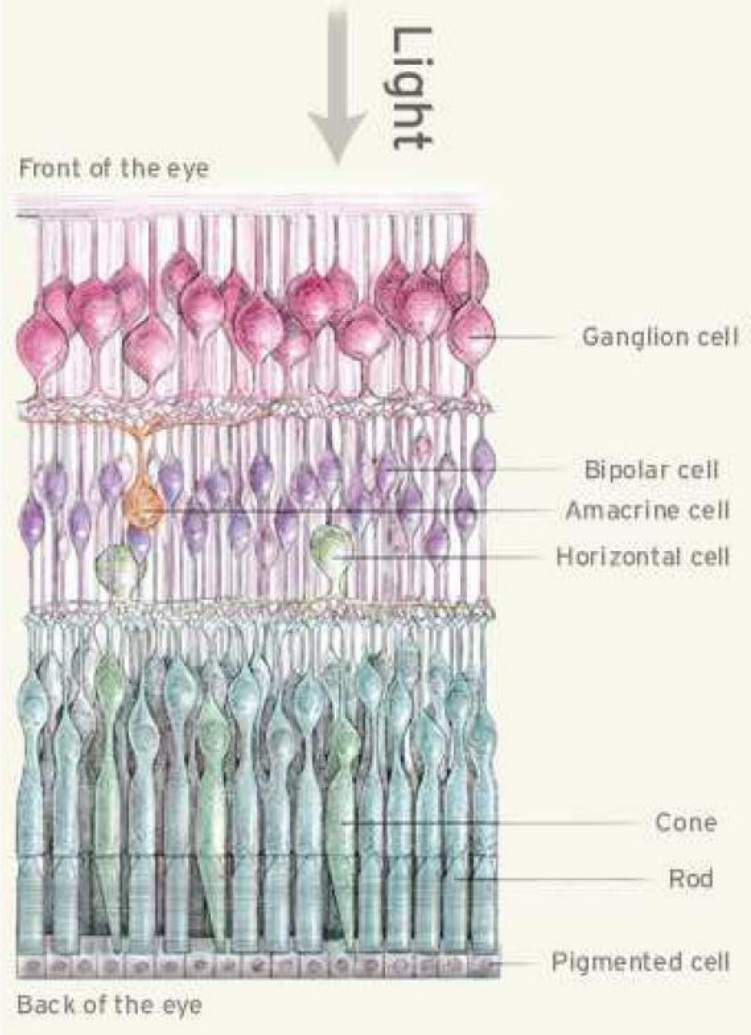
Adaptation

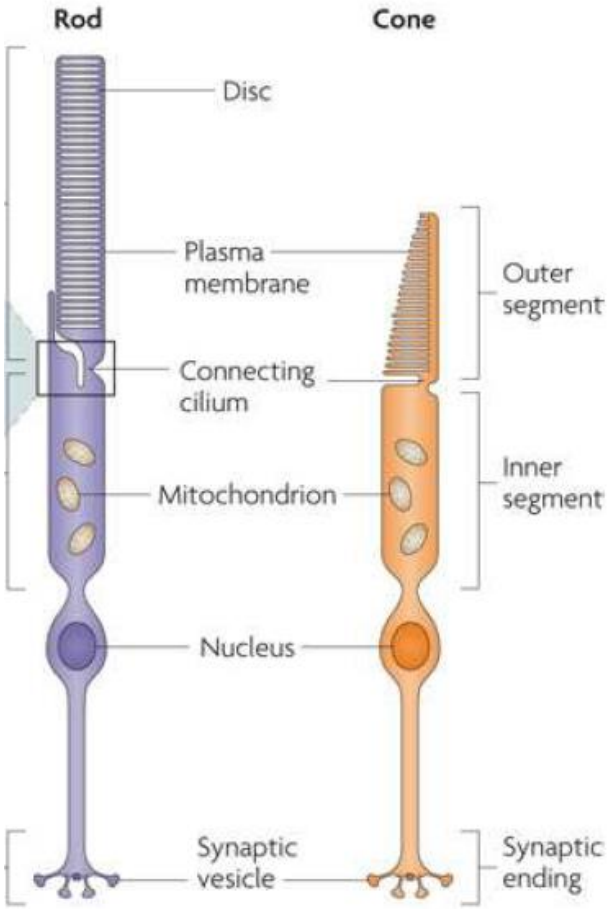


Neuronal Receptive Fields

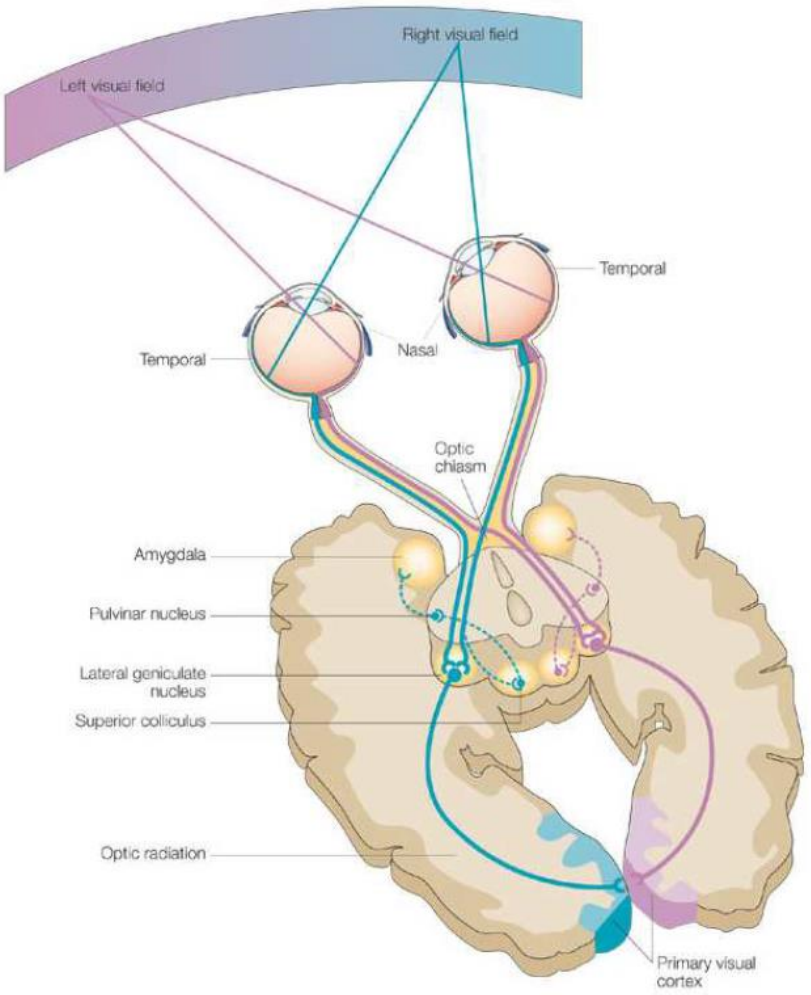


Anatomy of the Retina

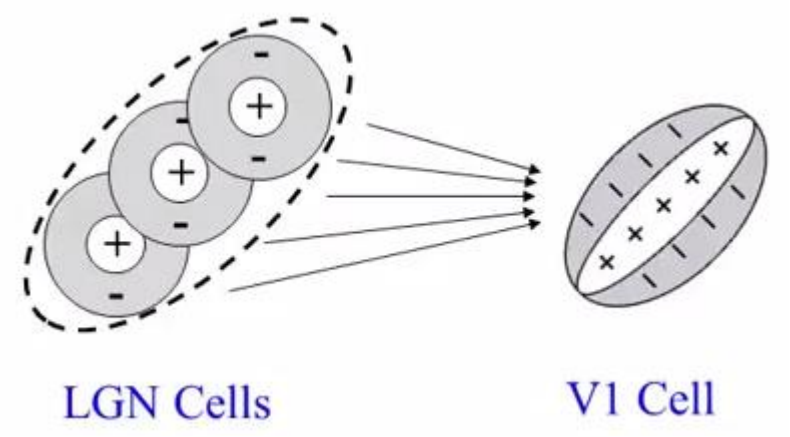


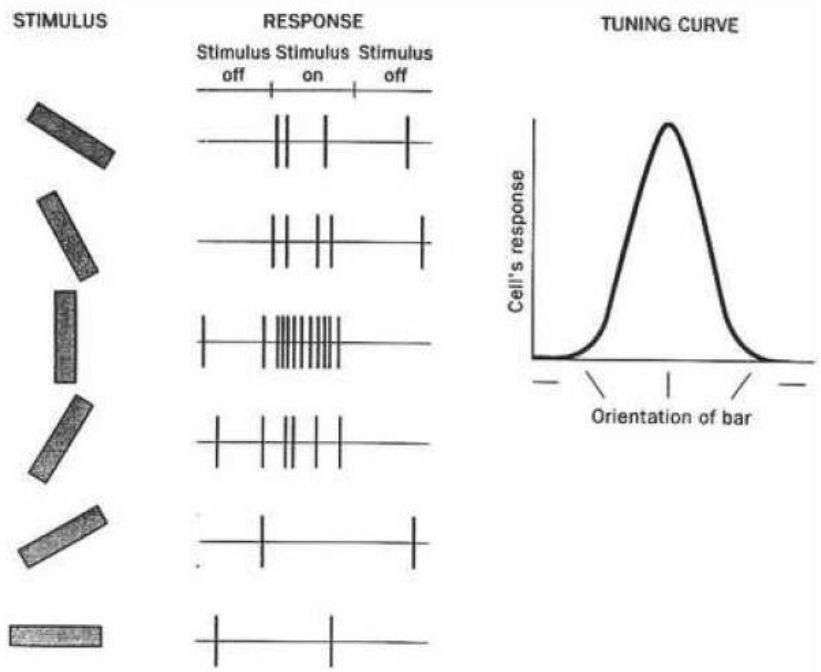


From Retina to Cortex



Cortical Receptive Fields

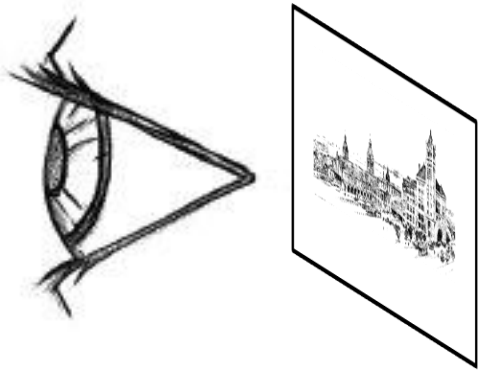




Discovered by Hubel & Wiesel, 1958 – Nobel prize 1981

Information is in the edges

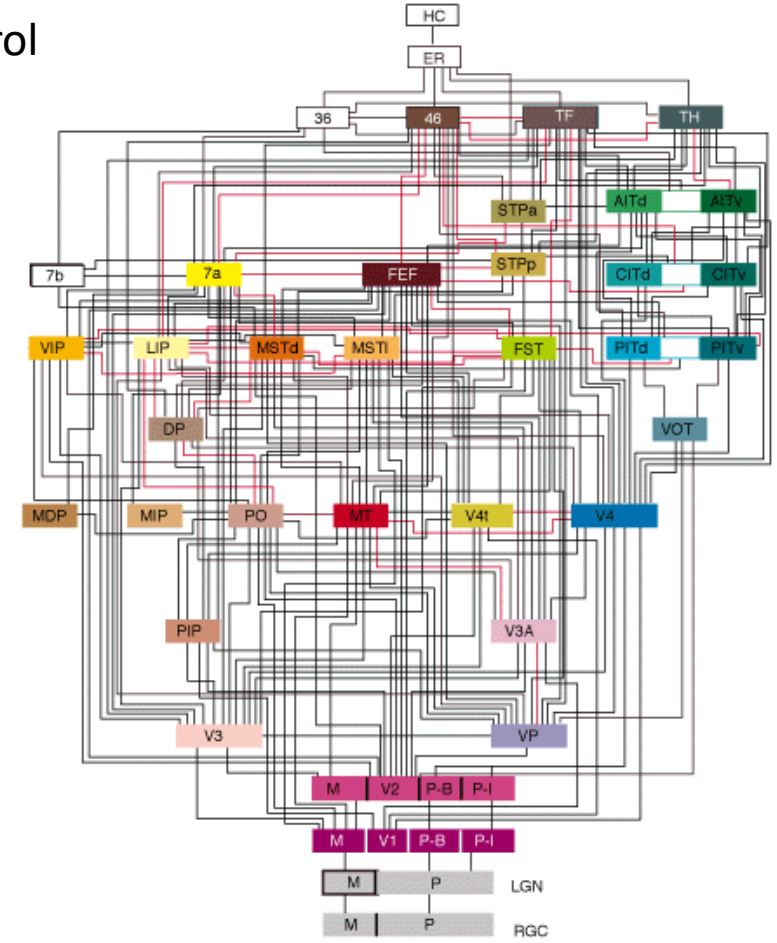
3D Real world



2D Image

The rest of the visual system

Eye movement control



Form/shape

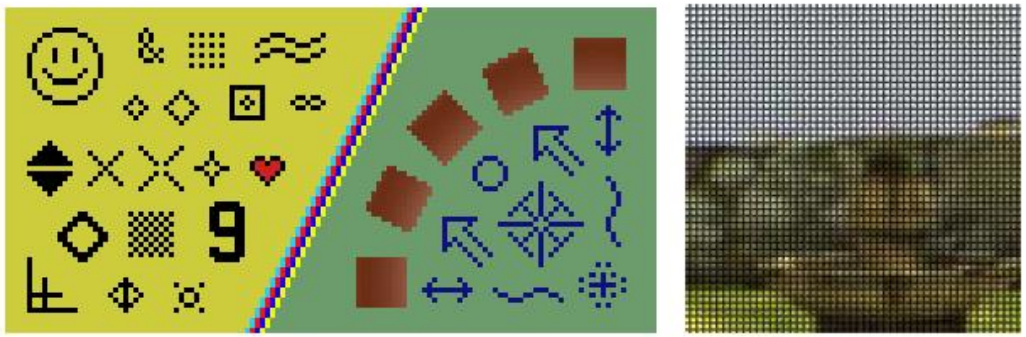
Motion

Implications for VR

- How good to displays have to be?
  1) Spatial resolution
  2) Intensity resolution and range
  3) Temporal resolution (covered later)

Spatial Resolution

- Too few pixels -> aliasing



(a) (b)

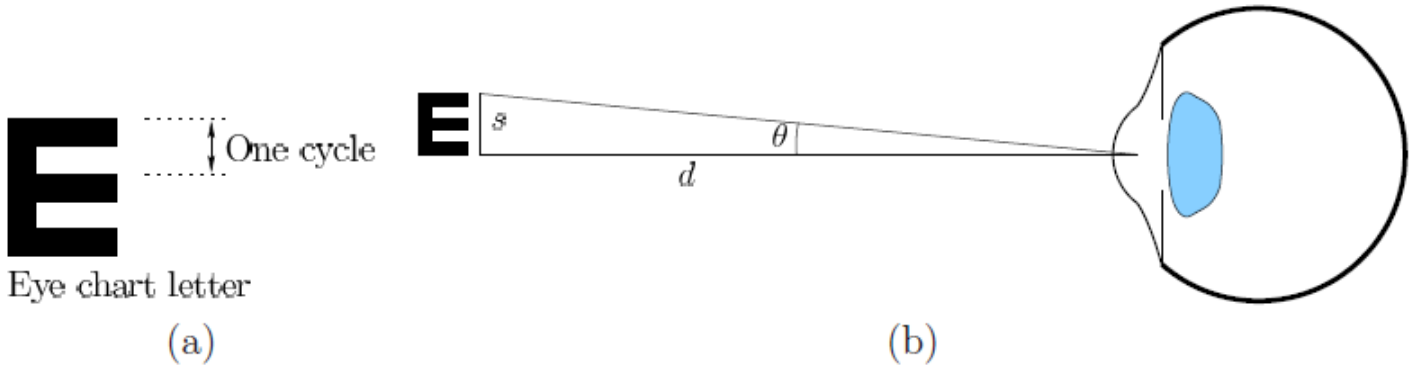
- What screen resolution is required?

Spatial Resolution

- Normal acuity (20/20):
  - 30 cycles/deg
  - 60 pixels/deg or more needed

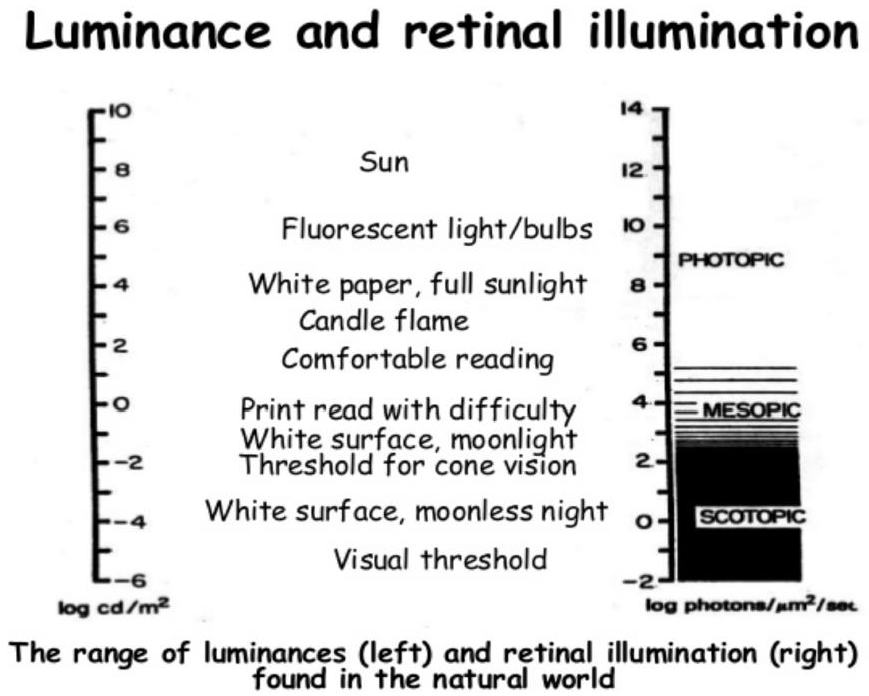
Size of 1 deg target $s = \tan(1) * d$

$ppi = 60/s$



- Screen at 20 feet; how many pixels per inch needed?
- HMD at 1.5 inches; how many pixels per inch needed?
- Retinal display -> 326 ppi; what viewing distance is needed?

Intensity: Dynamic Range



The range of luminances (left) and retinal illumination (right) found in the natural world

Light source	Luminance (cd/m^2)	Photons per receptor
Paper in starlight	0.0003	0.01
Paper in moonlight	0.2	1
Computer monitor	63	100
Room light	316	1000
Blue sky	2500	10,000
Paper in sunlight	40,000	100,000