



CS 498 VR

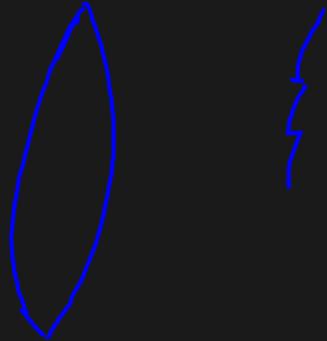
Lecture 13 - 3/7/2018

go.illinois.edu/VRlect13

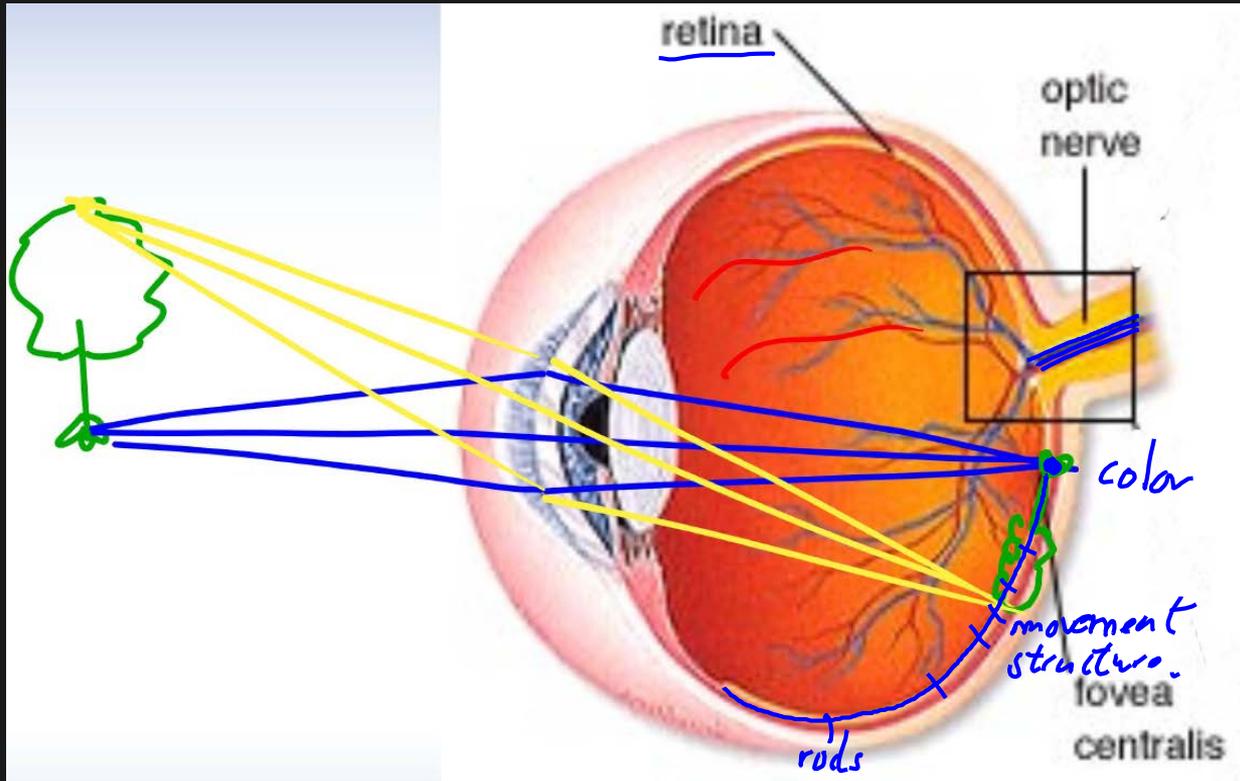


Review

- How do we perceive the color of an object? And how does the color of the light source itself change how we perceive color?
- How do Fresnel lenses cut costs in comparison to spherical lenses?



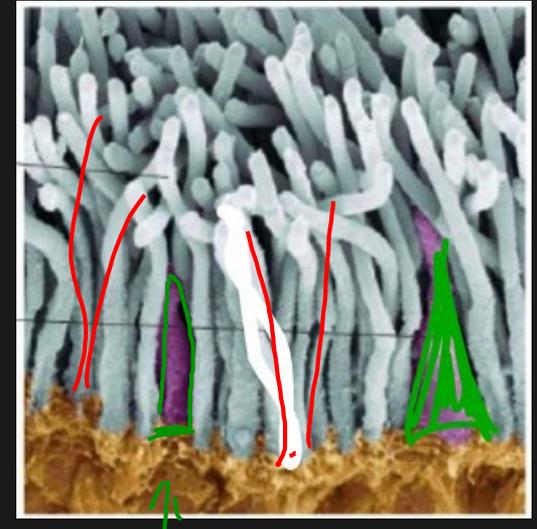
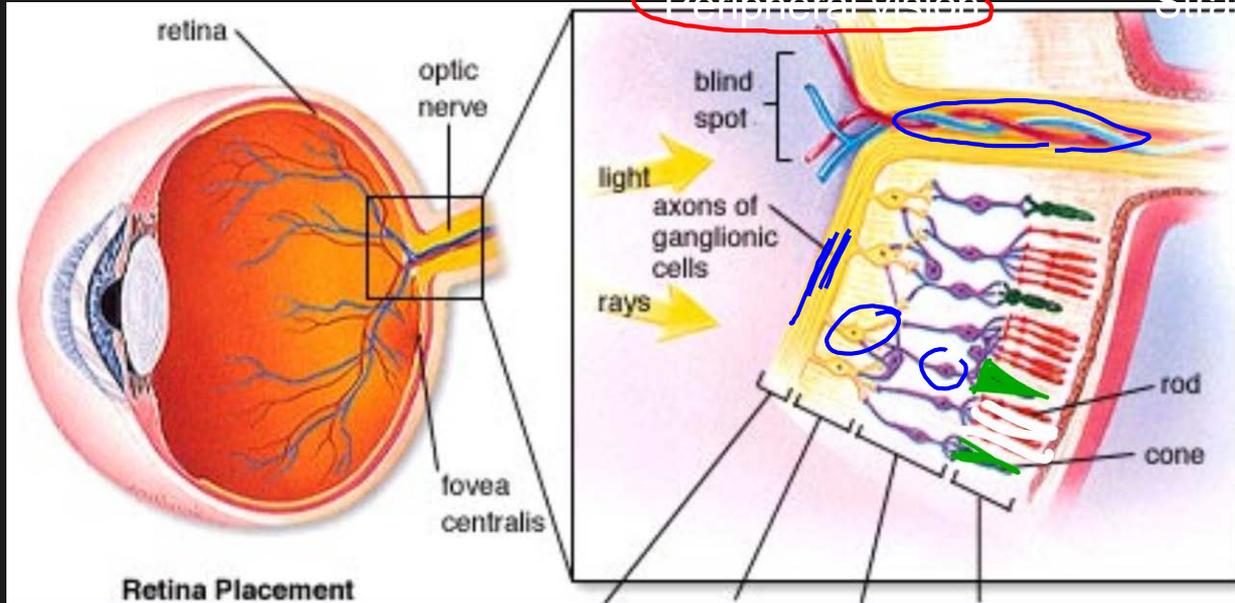
Peripheral Vision



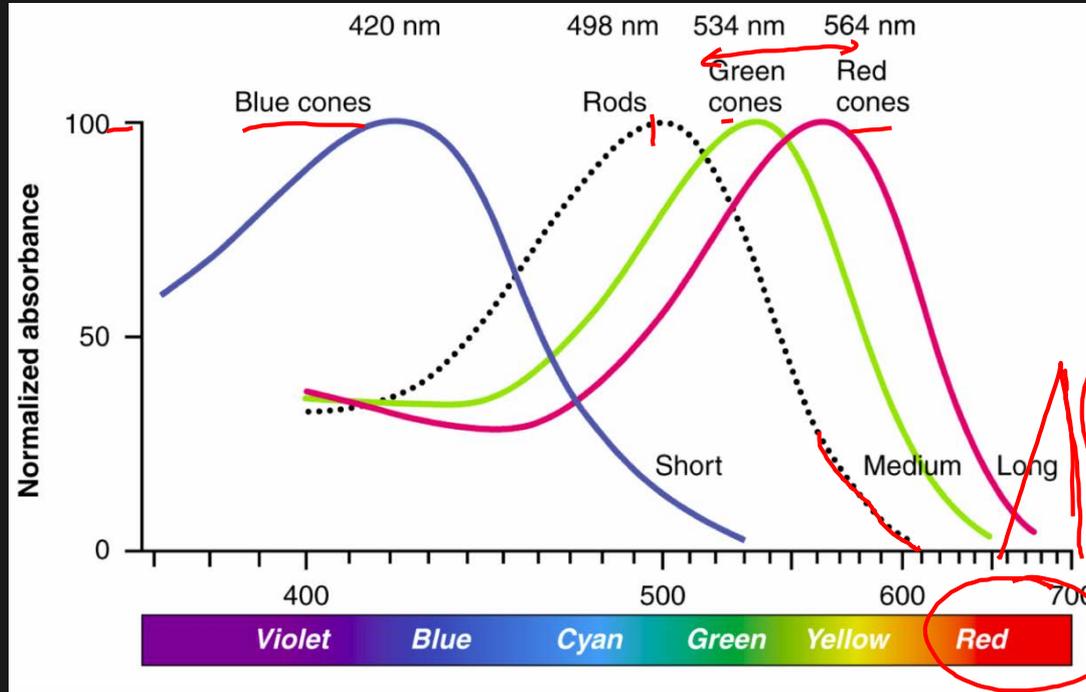
Photoreceptors

There are two types:

Rods	Cones
120,000,000	6,000,000
000	0
Low light	Bright light
Black/white	Color, RGB
Peripheral vision	Straight, high-res



Rods and Cones Sensitivity

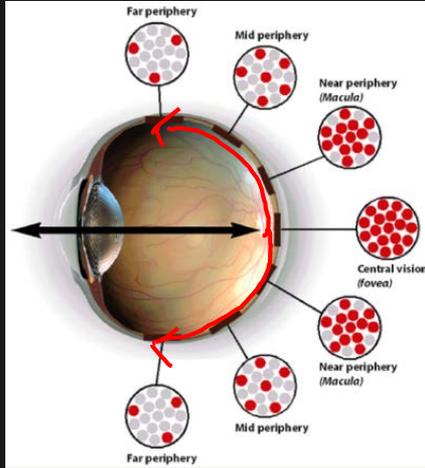


Photopic

Scotopic.
"Rods"

- Examples:
1. We do not see colors at night, or on periphery
 2. Red rose at dusk
 3. Green leaf at dusk

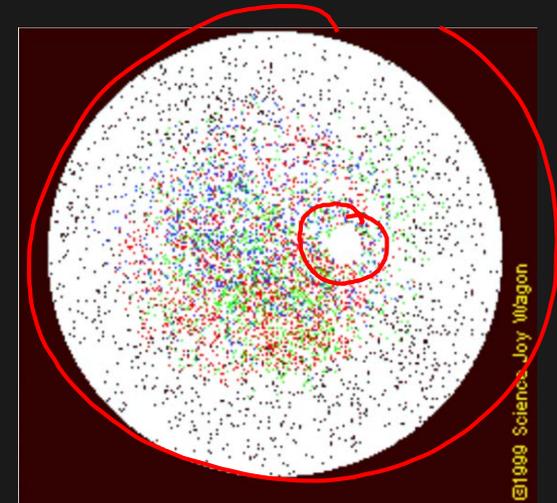
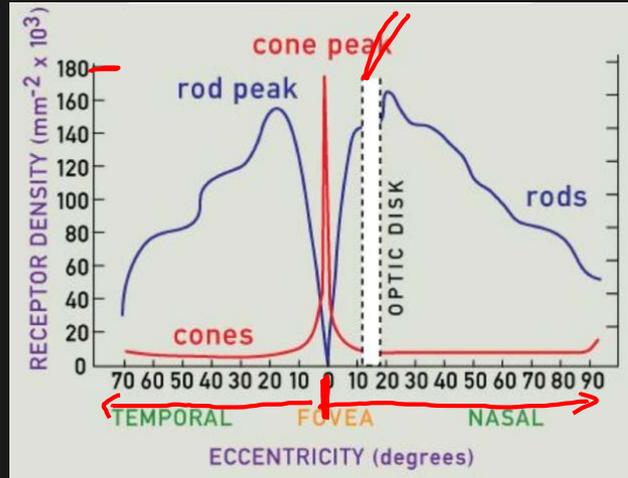
Rods and Cones Placement



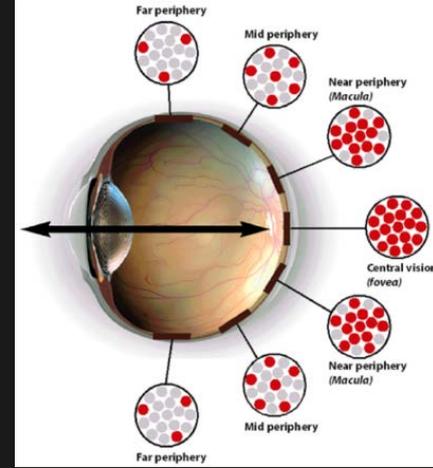
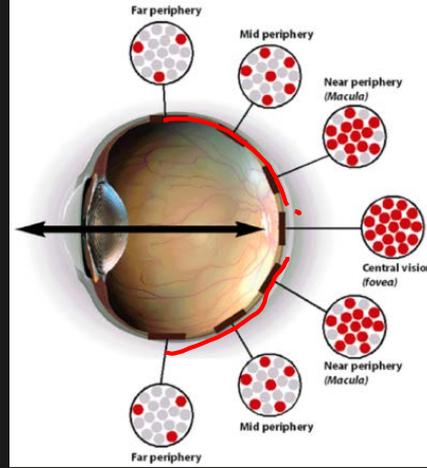
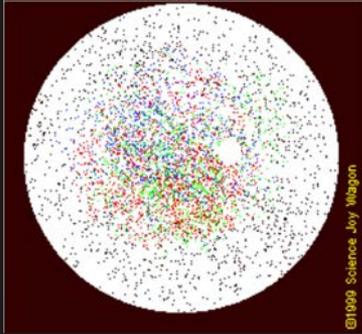
Which eye is this? *Left*

Why is there asymmetry?

Density at fovea: $\sim 200,000$ rec/1 mm²



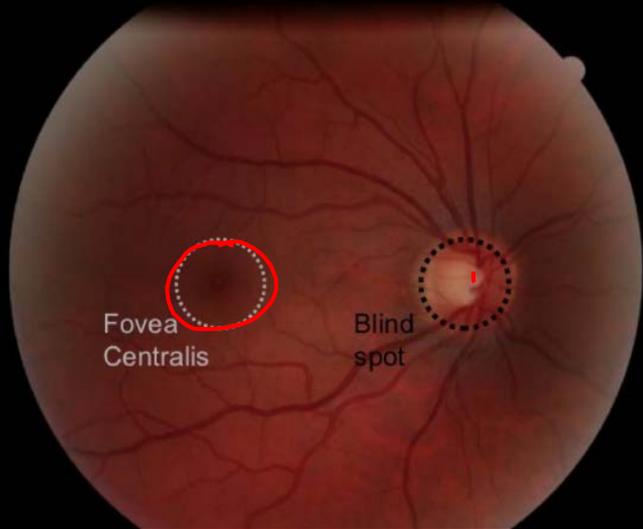
Examples



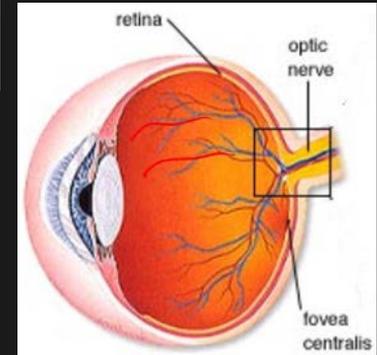
Examples	Day, light	Dusk, night
Straight	Color hi-res	~ Blind
Periphery	BPW low res	BPW low res
Damaged rods	"Tunnel vision"	Blind
Bright red charts	Visible	color (Fovea) BPW (Periphery)
Faint red charts	visible	Blind to red

How to see “stuff” blocking photoreceptors

Right Eye



Hypothesis: We only see moving stuff!





How to see “stuff” blocking photoreceptors

A lot is not known about the human eye



Concentrate on the 4 dots for 30 secs.
Then, shift your eyes to the wall and blink.
Who do you see???

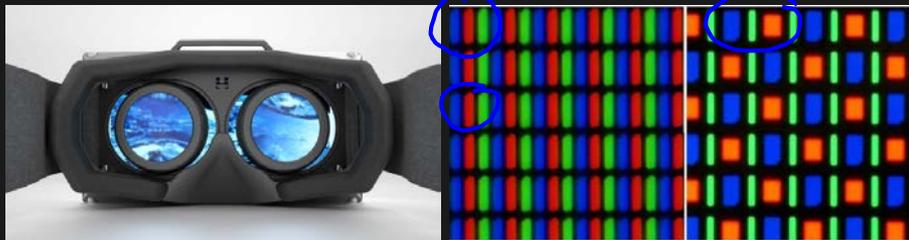
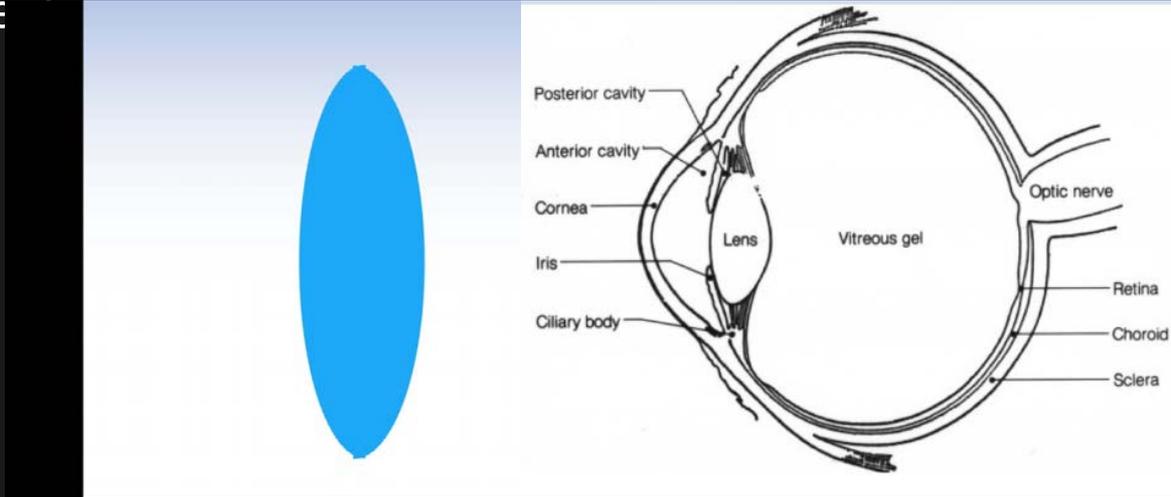
How much display resolution is enough in VR?

Output pixels: RGB

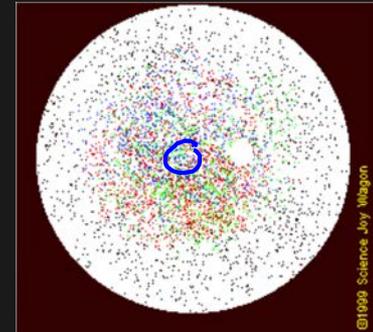
Interface

Input pixels:

Photoreceptors



Is 1080p per eye enough?



How much display resolution is enough in VR?

Conservative estimate:

photoreceptors = # pixels

$$\text{Resolution} = \sqrt{\# \text{ pixels}} = 11k \times 11k$$

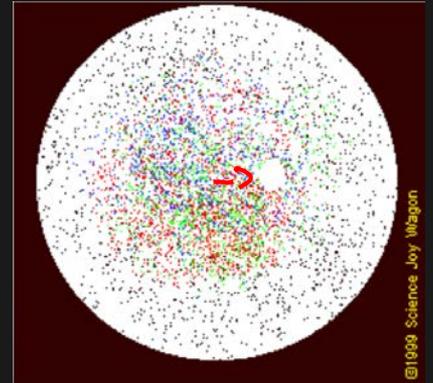
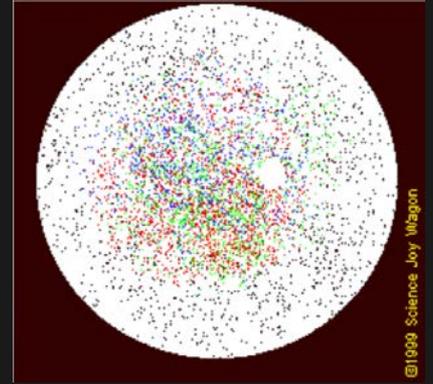
Current resolution?

CV1 res is 1080x1200 per eye, 2160x1200 total

Overkill? $200,000 / \text{mm}^2$

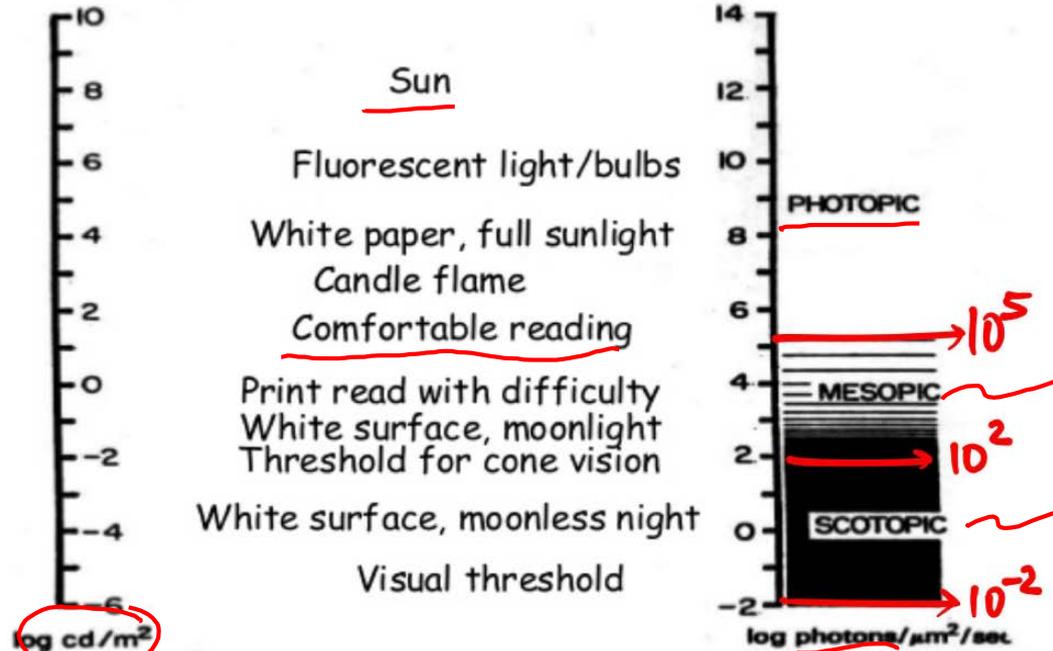
pixels = highest density/mm² x Retinal area (mm²) 1160 mm^2

$$\text{Resolution} = \sqrt{\# \text{ pixels}} = 14k \times 14k$$



Light Intensity

Luminance and retinal illumination



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

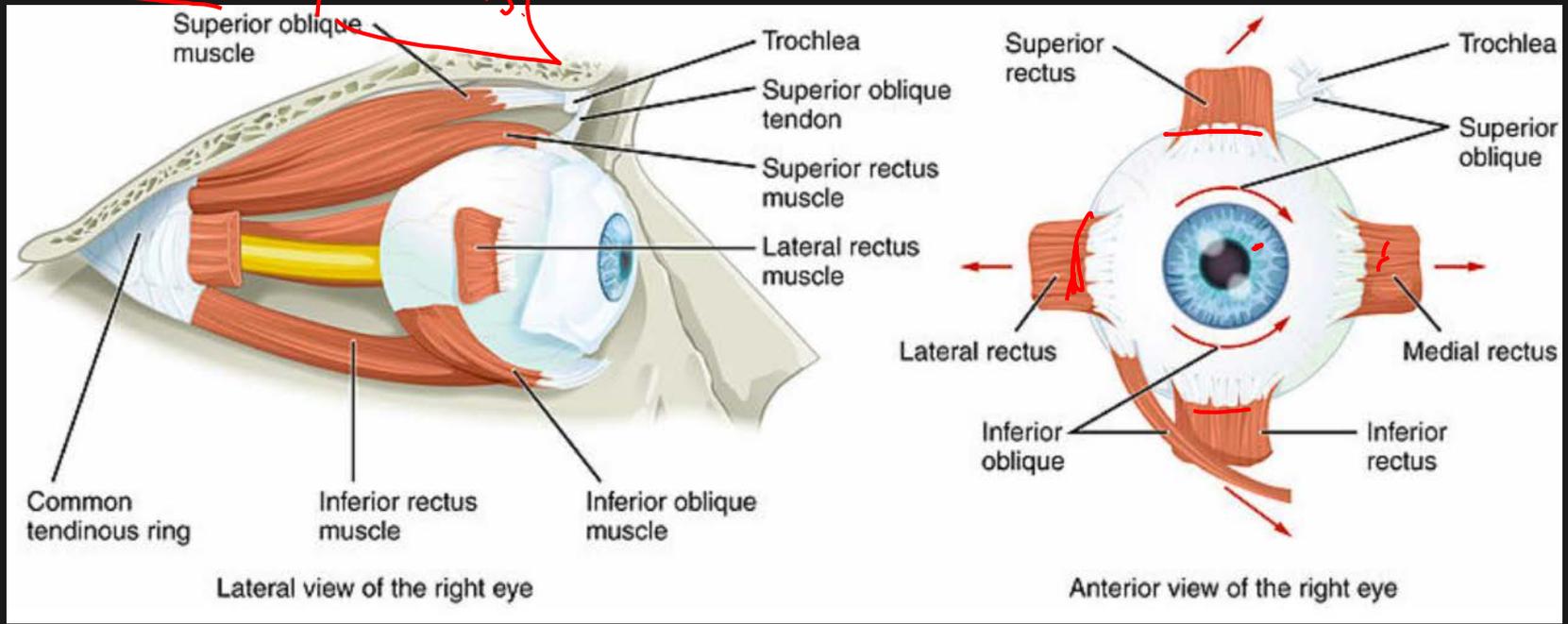
Scotopic vs. Photopic Vision

	Scotopic Vision	Photopic Vision
Photoreceptors	<u>Rods</u>	<u>Cones</u>
<u>Light levels</u>	$< 10^2$ ph/ μm^2 /sec	$> 10^5$ ph/ μm^2 /sec
Color	<u>Monochromatic</u>	<u>Trichromatic</u>
Adaptation	<u>35 mins</u>	<u>10 min</u>

saccades. 40mins

Eye Muscles

900°/s



- Implications for VR:
- 1) Uncanny Valley
 - 2) Foveated rendering

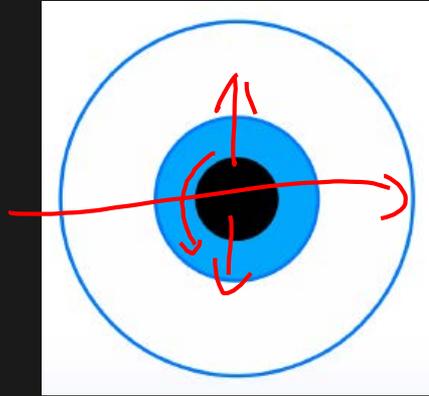


Eye Muscles

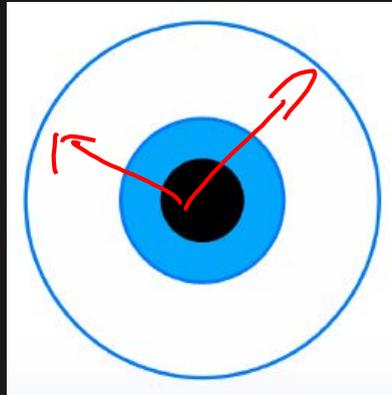
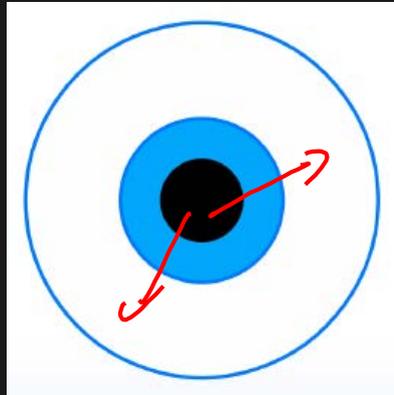
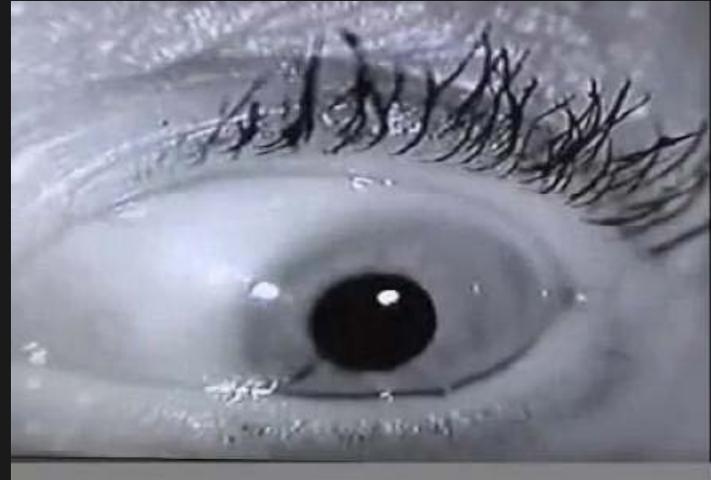
VR is an interdisciplinary topic

- **VR** is **NOT** a purely CS topic.
- If you work in a VR company, expect to work side by side with computer scientists, engineers, psychologists, optical engineers, optometrists, neuroscientists and artists.
- Most of the design questions in VR are open problems, almost everything is **unchartered territory**.
- Pick any field, you probably can make a difference there with VR.
- A great place to make impact and change the world.

Sanity Check: DOFs



3 dof





Eye Motion Modes

Eye Motion Modes

	Conjugate	Disjunctive
<u>Voluntary</u>	<u>Saccades</u> <u>Pursuit</u>	Vergence (Convergence + divergence)
Involuntary	<u>Vestibulo-ocular</u> <u>reflex (VOR)</u> Optokinetic <u>Microsaccades</u>	N/A

Review

1 photon

color
"Trichrom."

120m

6m

- Explain the four main differences between rods and cones
- Why are many navigation lights colored bright red?
- How long will it take for us to start seeing things really well when going from a room with really bright light to very dark light? Which mode of vision is this?

scotopic

Announcements

- MP 4 due March 26th - but start early!
 - Takes a long time to do & lab will be full closer to due date so start now!
- From now on, you will have **mandatory weekly final project meetings** - TA for your project will contact you
- Your attendance will be logged and work you completed will be kept track of. You could get a lower grade than the rest of your team if you don't contribute equally to the final project

Read LaValle, **Chapter 4, 5**

