COGS 101A: Sensation and Perception

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UCSD

Lecture 3:

The Retina – Chapter 2

Course Information

- Class web page: http://cogsci.ucsd.edu/ desa/101a/index.html
- Professor: Virginia de Sa
  - ⋆ I'm usually in Chemistry Research Building (CRB) 214 (also office in CSB 164)
  - ⋆ Office Hours: Monday 5pm
  - ⋆ email: desa at ucsd
  - ⋆ Research: Perception and Learning in Humans and Machines

For your Assistance

TAS:

- Jelena Jovanovic OH: Wed 2-3pm CSB 225
- Katherine DeLong OH: Thurs noon-1pm CSB 131

IAS:

- Jennifer Becker OH: Fri 9-10 or 10-11 CSB 114
- Lydia Wood OH: Mon 12-1pm CSB 114

Course Goals

- To appreciate the difficulty of sensory perception
- To learn about sensory perception at several levels of analysis
- To see similarities across the sensory modalities
- To become more attuned to multi-sensory interactions

Grading Information

- 25% each for 2 midterms
- 32% comprehensive final
- 3% each for 6 lab reports - due at the end of the lab
- Bonus for participating in a psych or cogsci experiment AND writing a paragraph description of the study

You are responsible for knowing the lecture material and the assigned readings. Read the readings before class and ask questions in class.

Academic Dishonesty

The University policy is linked off the course web page.

You will all have to sign a form in section

For this class:

- Labs are done in small groups but writeups must be in your own words
- There is no collaboration on midterms and final exam

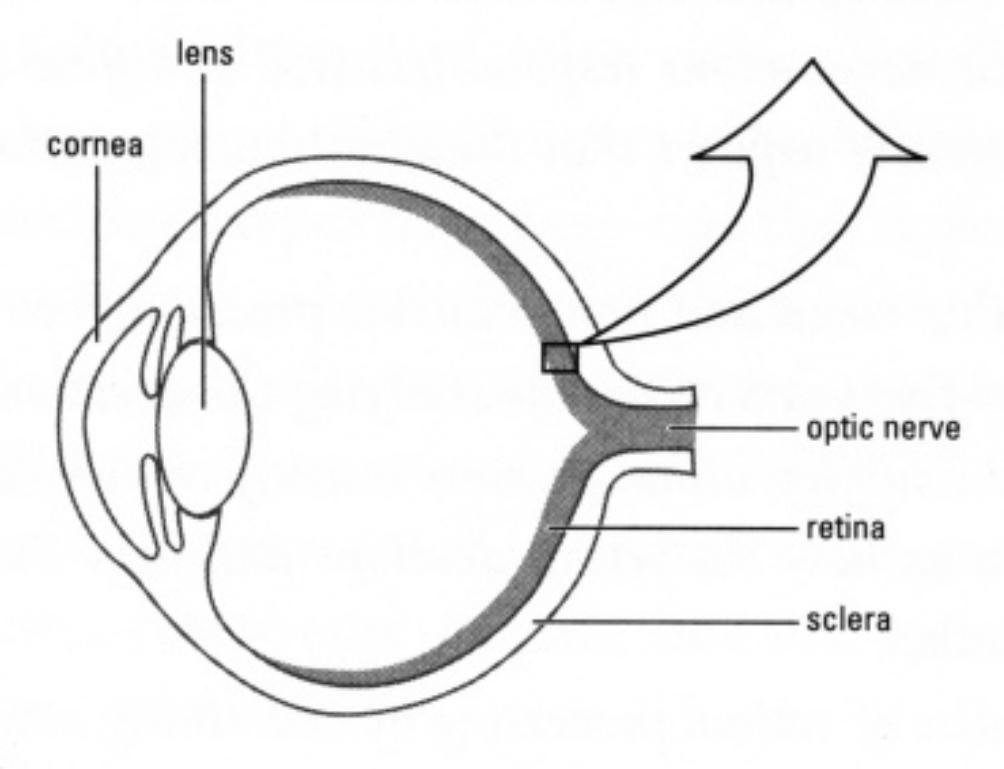
Last Class

We learned about the structure and evolution of the eye

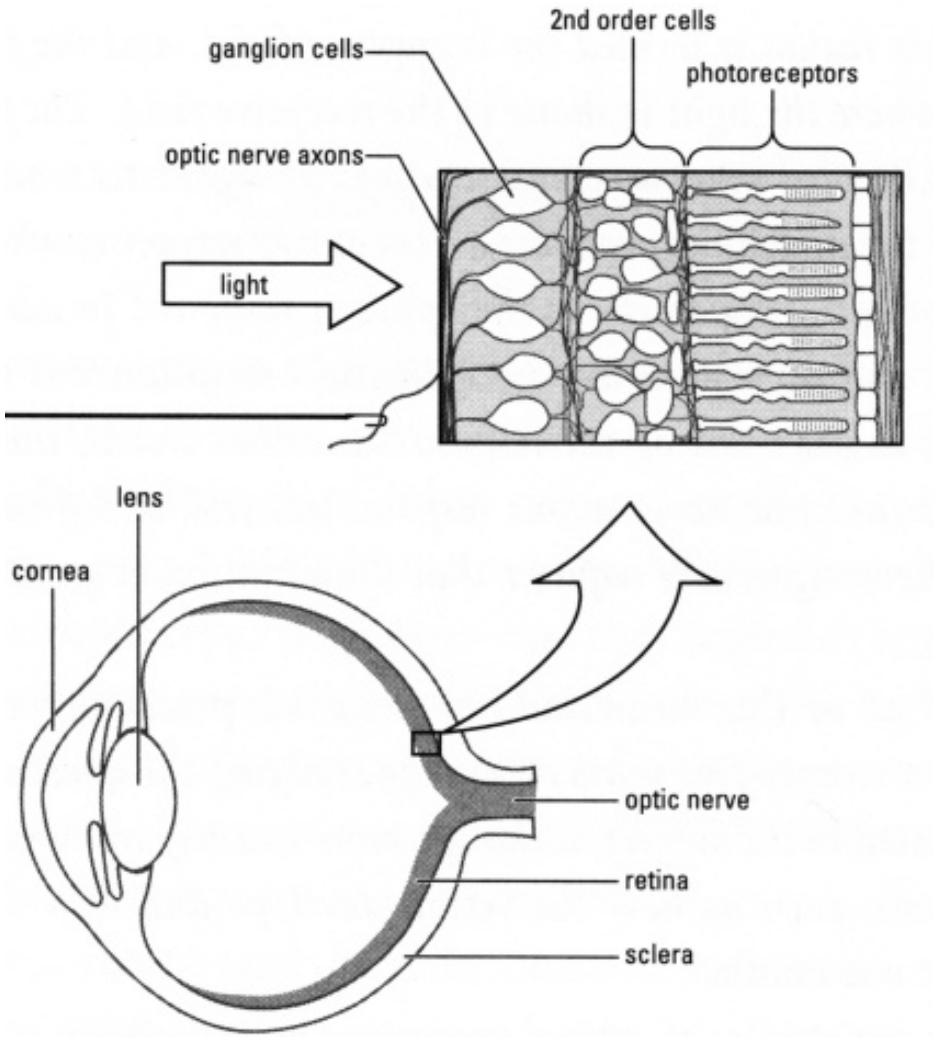
This Class

The Retina

The Eye

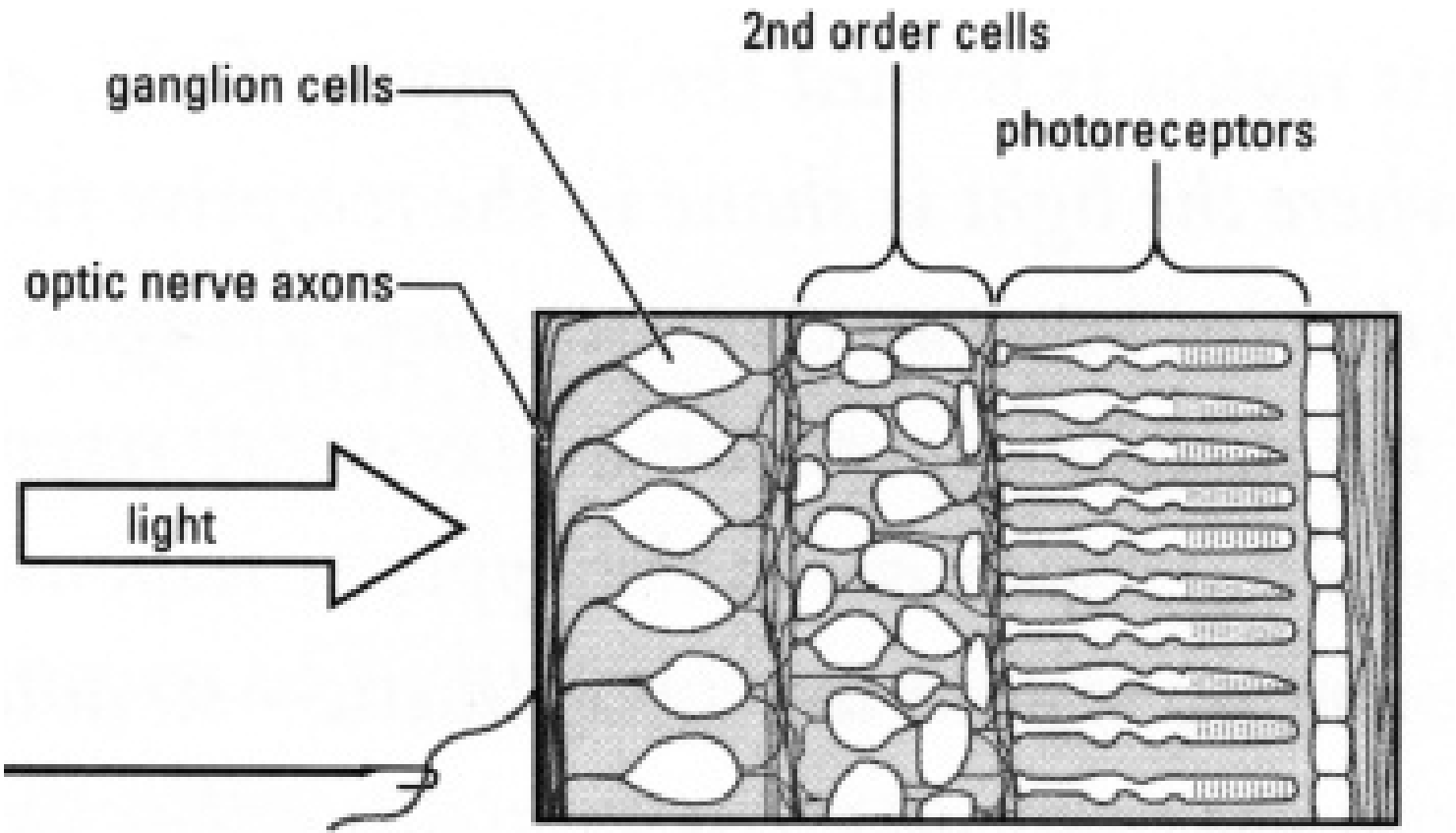


The Retina



retina -visual receptors and other neurons, covers rear of the eye

The Retina



Photoreceptors transduce the light to electrical signals

Transduction : the transformation of one form of energy to another the photoreceptors transduce light to electrical signals (voltage changes)

Human retina

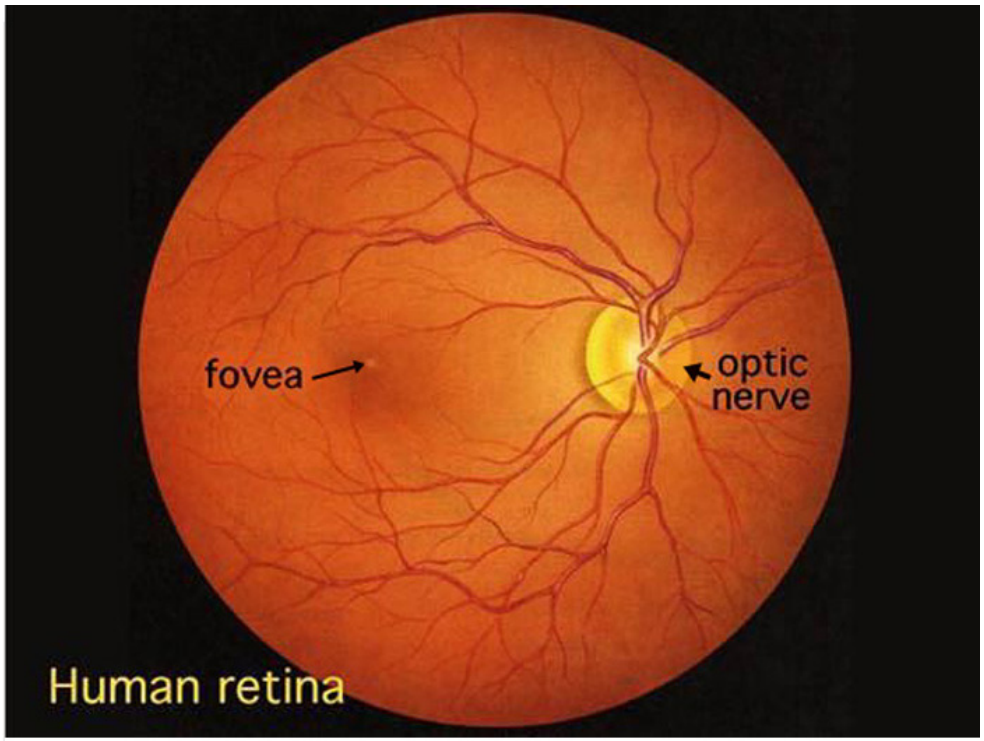


Fig. 1. Human retina as seen through an opthalmoscope.

http://webvision.med.utah.edu/imageswv/huretina.jpeg

The cells in the retina are neurons

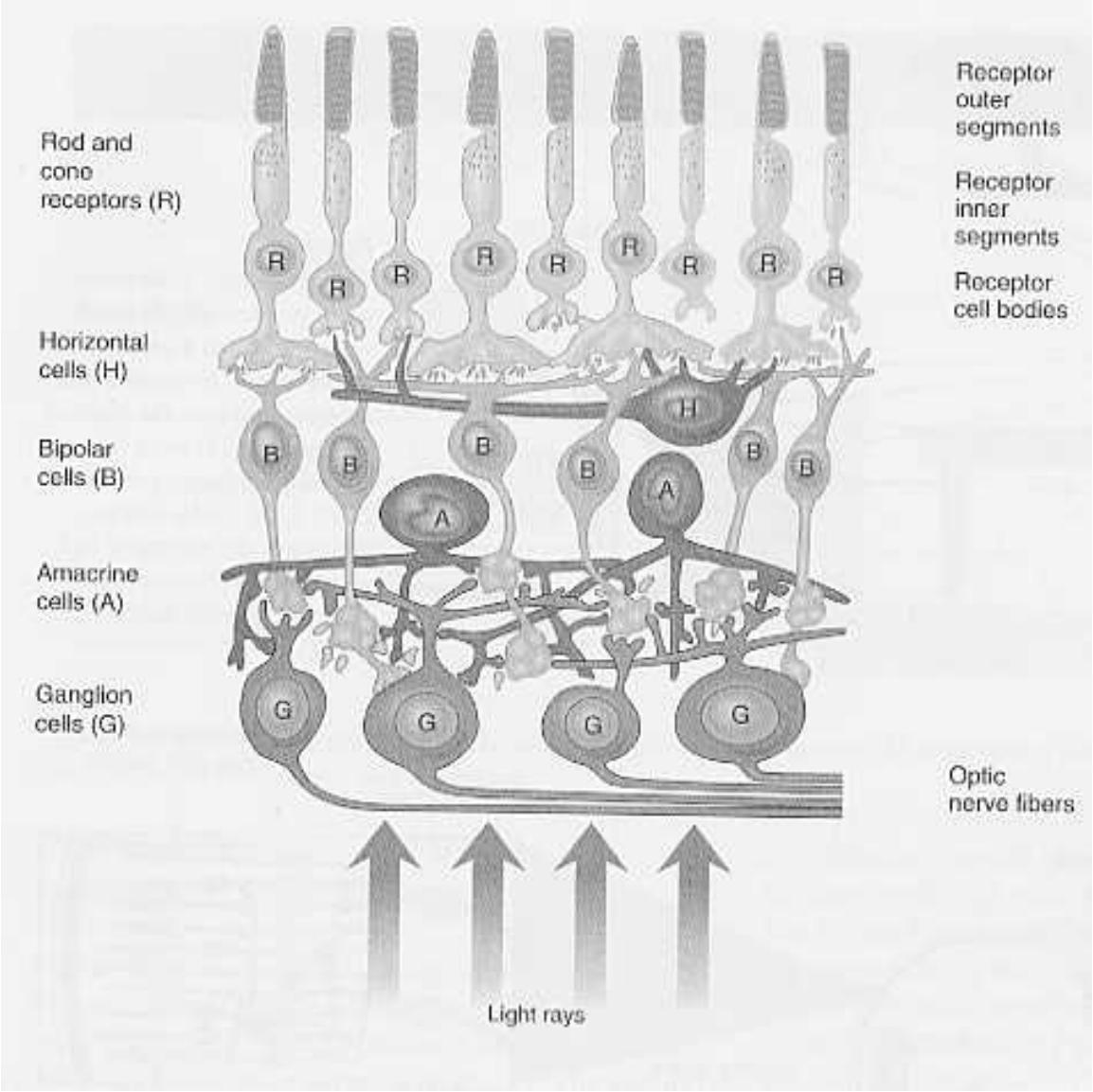
neurons are specialized cells that transmit electrical/chemical information to other cells

neurons generally receive a signal at their dendrites and transmit it electrically to their soma and axon.

At the axon terminals they release neurotransmitter that acts on the dendrites of the next set of neurons

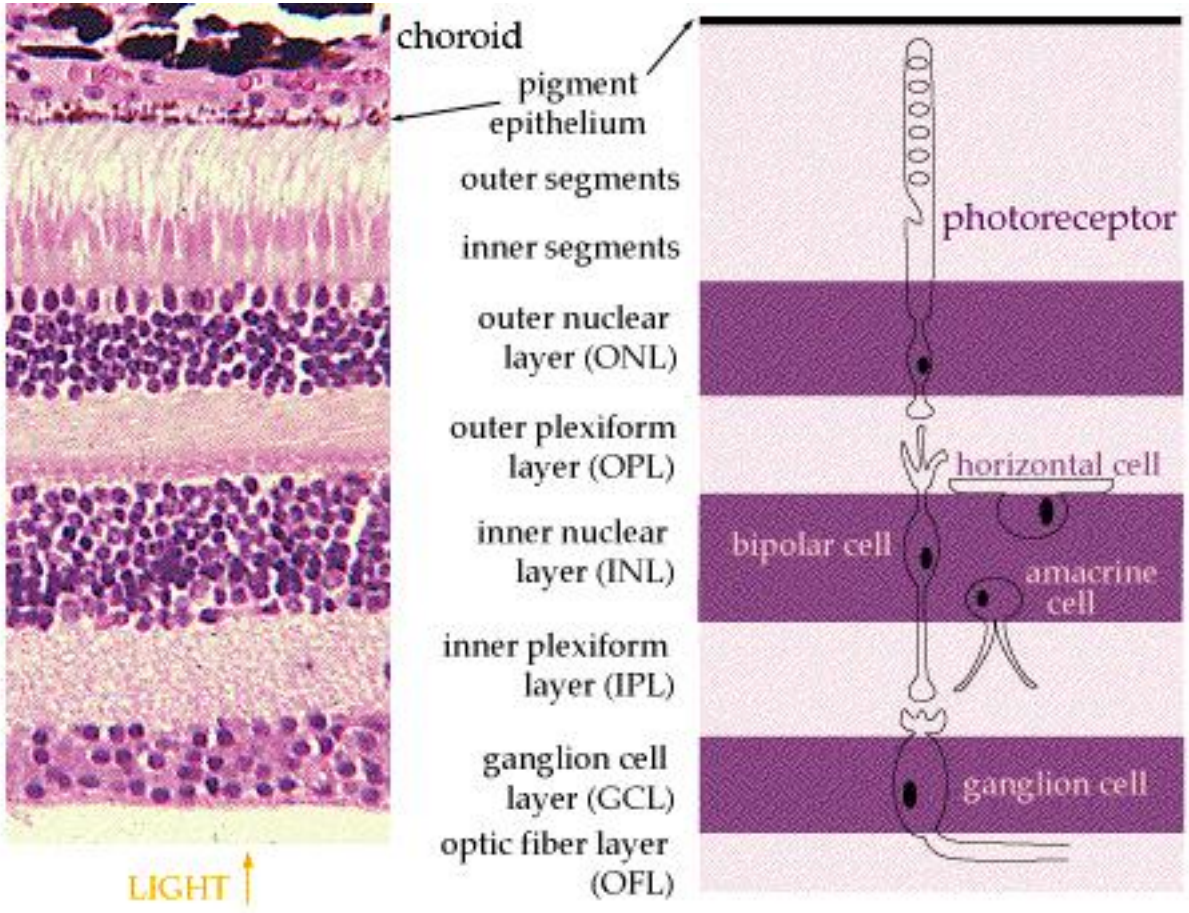
Neurotransmitter release can be graded or all/none (spikes, action potentials)

Let's look at the retina in more detail



Note the photoreceptors are farthest from the light.

The Retina



http://thalamus.wustl.edu/course/eyeret.html

Neurons in the Retina

Photoreceptors - farthest from the light, transduce the light signal and produce graded response

Bipolars - Next neurons in direct path also give a graded response

Ganglion cells -Output of the retina, gives action potentials. Axons of all ganglion cells combine to form **optic nerve**

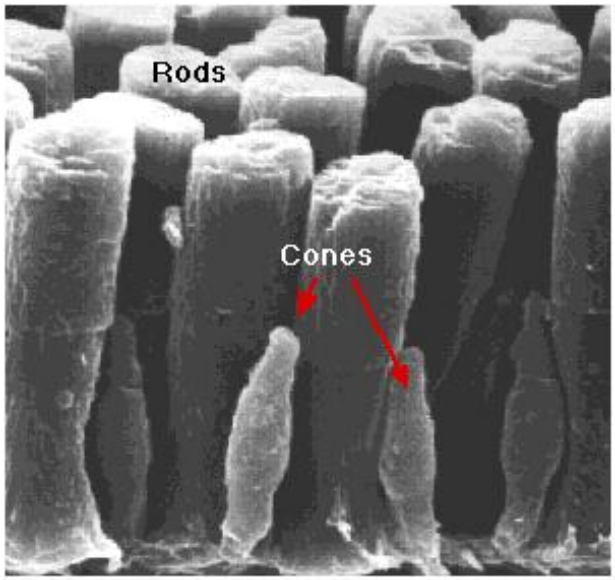
Horizontal cells - modify photoreceptor biploar interaction (graded signal)

Amacrine cells - modify bipolar ganglion interaction (graded signal some with action potentials)

Why do you think the Retinal Ganglion cells (RGC) code with action potentials and the others with graded potentials?

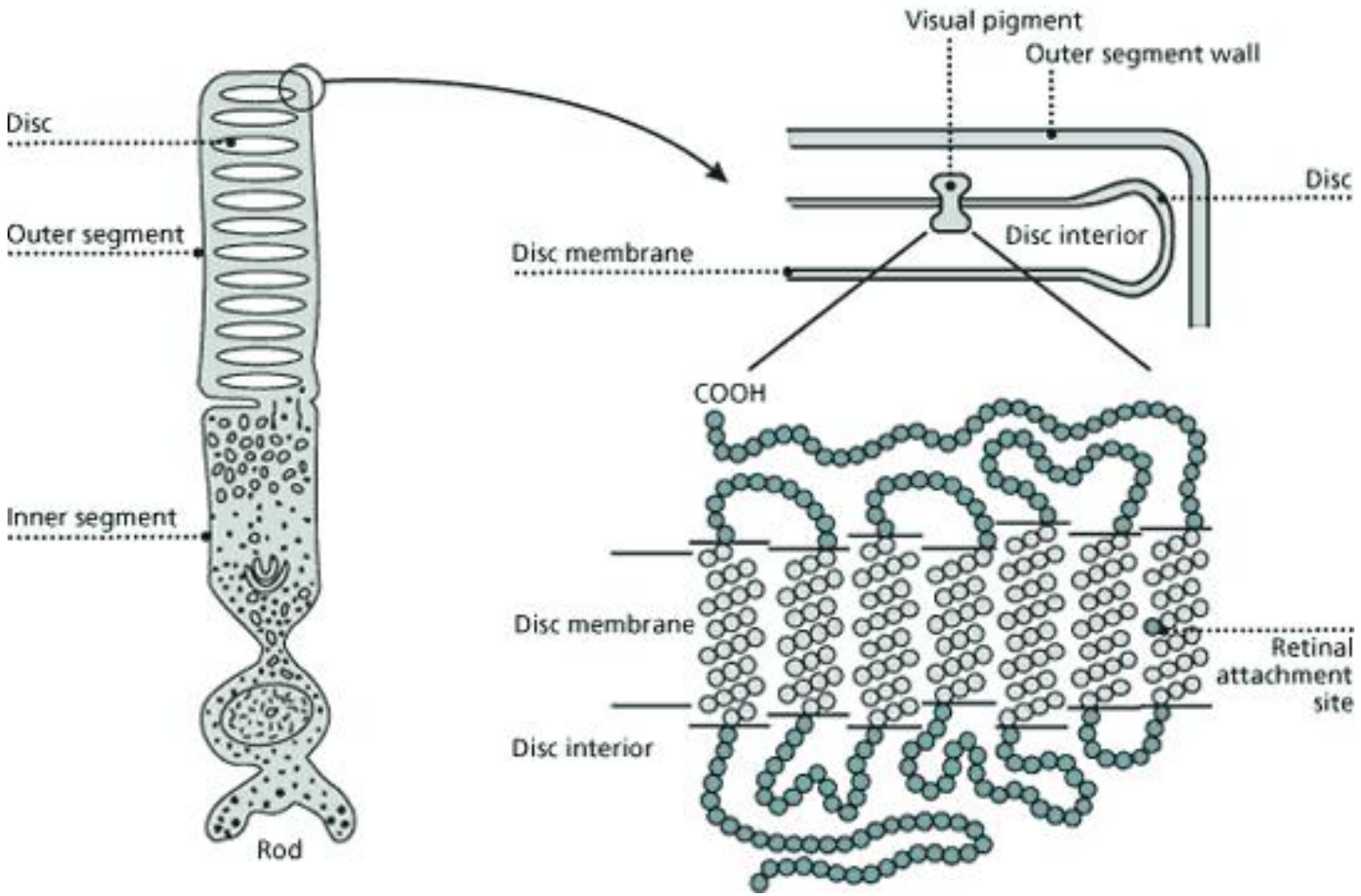
Rods and Cones

There are two types of photoreceptors: Rods and Cones



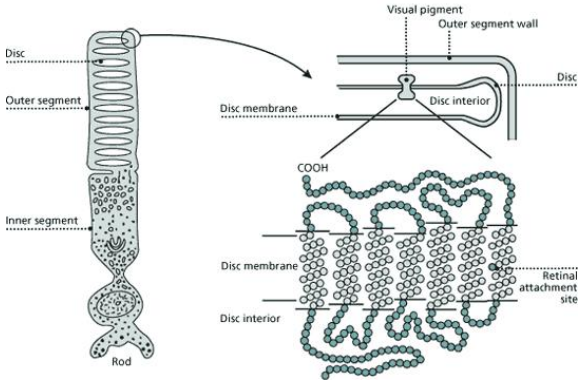
"This scanning electron micrograph (courtesy of Scott Mittman and David R. Copenhagen) shows rods and cones in the retina of the tiger salamander." http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/V/Vision.html"

Structure of Rod



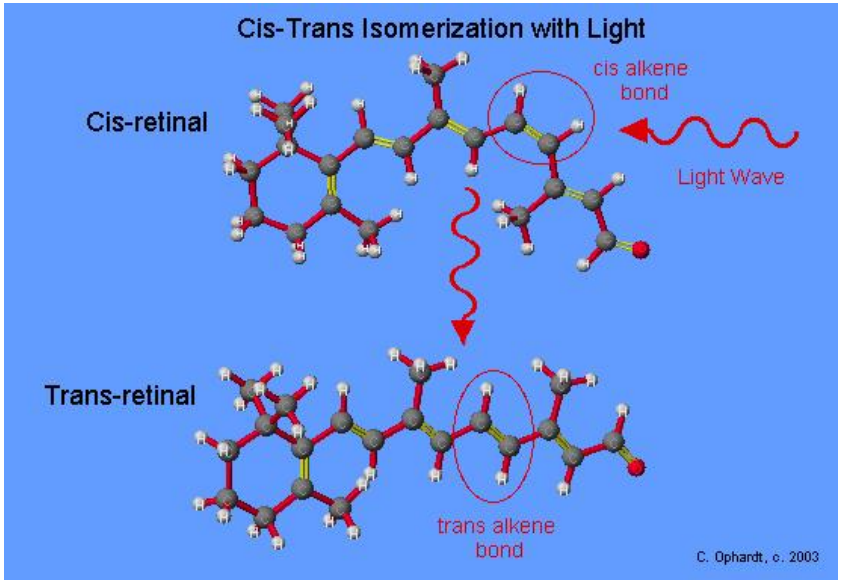
http://www.karger.com/gazette/64/fernald/art_1_3.htm

Structure of Rod



In the outer segment there are many discs containing pigment molecule : opsin (big) + retinal. In the rods this combination is called rhodopsin (more generally photopigment)

retinal (derivative of Vitamin A) reacts to light (absorbs a photon), changes shape **isomerization** and detaches from the opsin (retinal changes from 11-cis to all-trans)



http://www.elmhurst.edu/ chm/vchembook/533cistrans.html

Activated rhodopsin loses color **bleached** (also called starts a hugely amplified enzyme cascade of reactions resulting in a change in neurotransmitter release (before bleaching it is often called visual purple)

lovely demo

With time, energy and help frome the **pigment epithelium** the photopigment will regenerate. Before then light transucing capabilities are reduced

Interestingly light results in a decrease in transmitter release

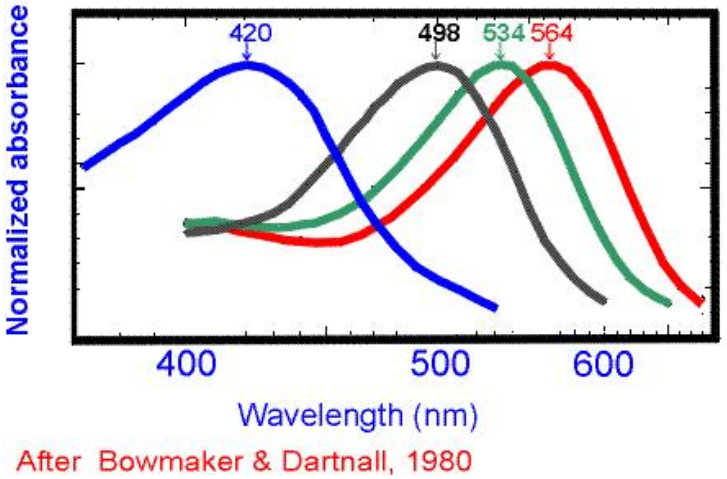
Isomerization

for much more detail

Cones

Cones have different varieties of opsin with different spectral absorption properties

Red, Green and Blue cones more accurately known as Long wave, Medium wave and Short wave sensitive cones (L,M and S cones)



http://www.yorku.ca/eye/specsens.htm

Cones require more light to activate (rod curve would go MUCH higher if they were all plotted on the same scale)

How are these measured?

Cones are used in daylight, Rods at night

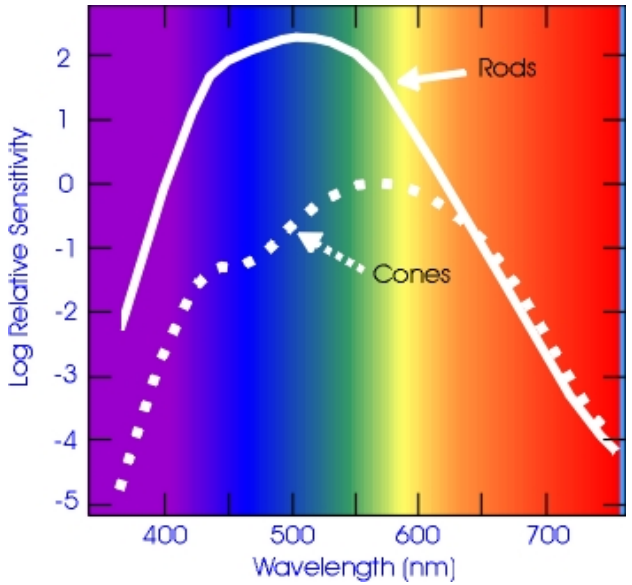
Cones and Rods operate in diffferent brightness ranges (with some overlap)
(Cones require more light to activate and Rods saturate at medium light levels)

photopic vision - with cones

scotopic vision - with rods

mesopic vision - with both

The different absorption spectra of the rod and cone systems relate to behavioral measurements - Spectral sensitivity curves

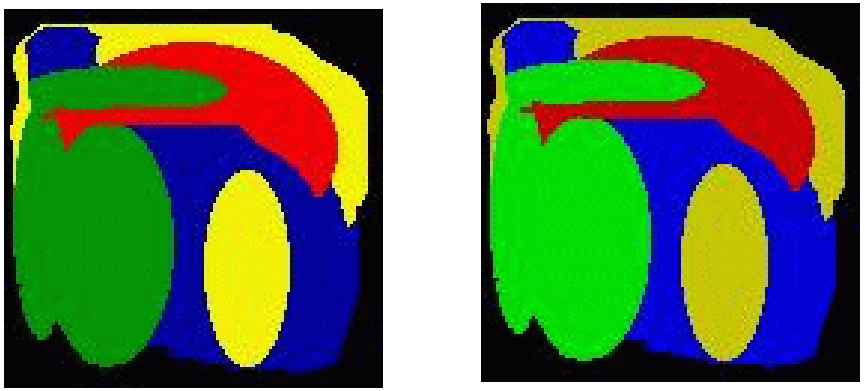


http://www.yorku.ca/eye/lambdas.htm

The difference in spectral sensitivity for rods and cones gives rise to the **Purkinje shift** – rods are more sensitive to short wavelengths.

In the day (photopic vision) rods are saturated and yellow is seen brighter than green (for same intensity), at dusk rods come on line (mesopic) and green is seen brighter than yellow

Simulated Example of Purkinje Shift



http://www.cquest.utoronto.ca/psych/psy280f/ch3/purkinje/ps.html

In the day (photopic vision) rods are saturated and yellow is seen brighter than green (for same intensity), at dusk rods come on line (mesopic) and green is seen brighter than yellow

Other interesting color tidbits

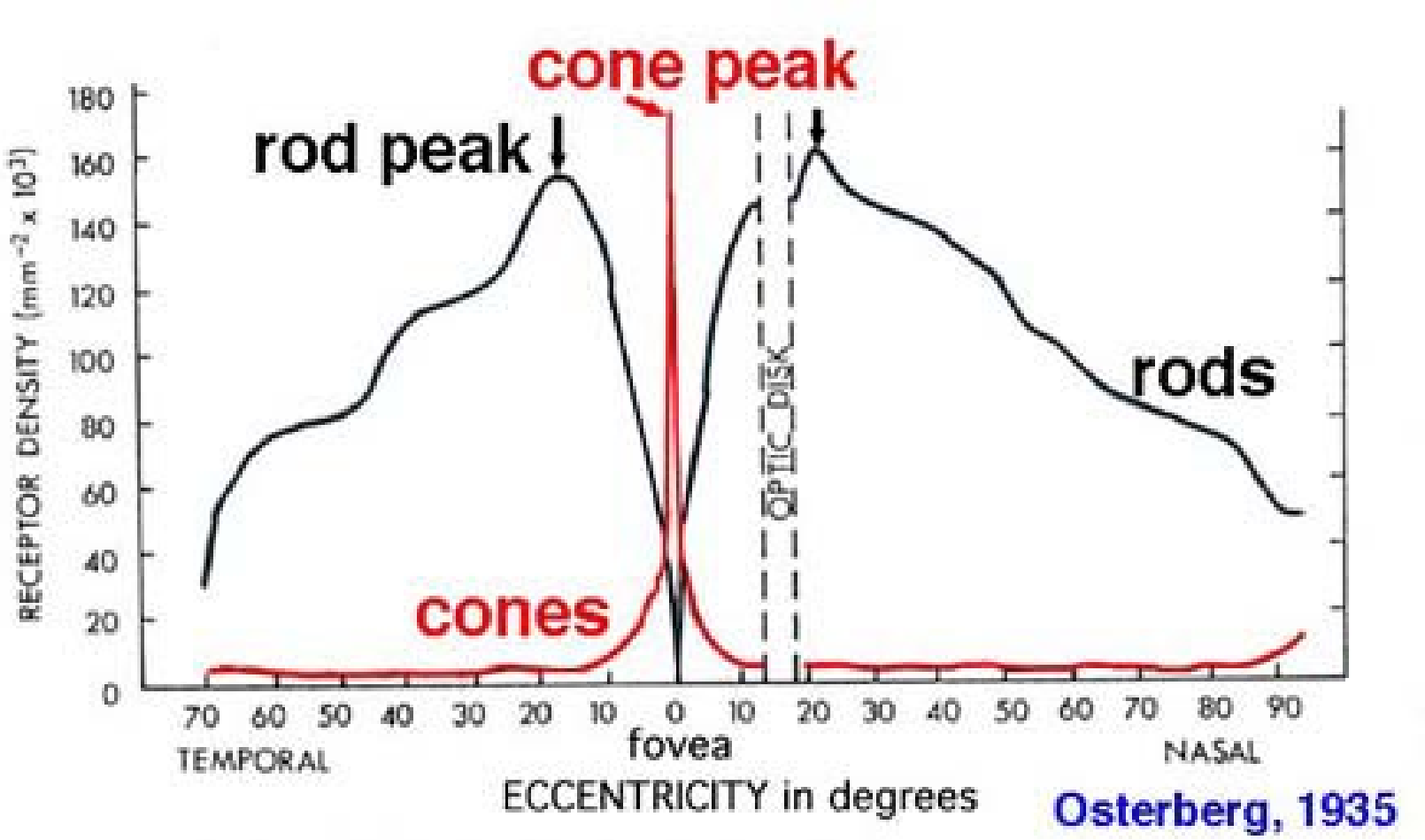
This is good for maintaining the rods in a dark-adapted state (for good sensitivity at night)

High wavelength light is scattered more than lower wavelength light (sky is blue) as a result the fovea does not have many blue cones (and the very center has none)

Comparing Rods and Cones (from Prof. Chris Johnson's notes)

	RODS	CONES
Shape	outer segment rod-like	outer segment cone-like
outer segment contents	discs with embedded photo pigment	folded sheet with embedded photopigment
size	larger(more photo pigment)	smaller
number	120 million/eye	6.5 million/eye
distribution	none in the fovea, high concentration in periphery	High in fovea, low in periphery
importance in color processing	No	code color thru differences in activation of different types
motion detection	excellent	poor
acuity	low	high (especially in fovea
light sensitivity	high(can operate in dim light)	Not as good(bright light)
connectivity	High convergence (many rods: 1 ganglion)	low convergence (1 or few cones: 1 ganglion)

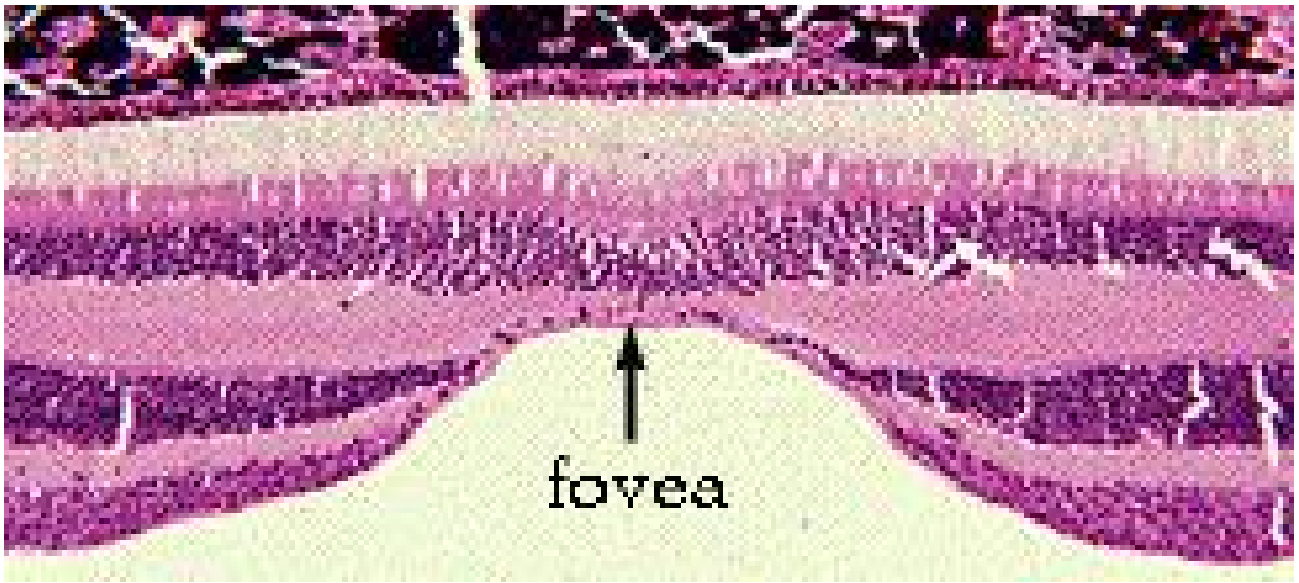
Distribution of Rods and Cones in the Retina



http://www.phys.ufl.edu/ avery/course/3400/vision/rod_cone_distribution2.jpg

Note – There are no photoreceptors where the optic nerve leaves the eye (optic disk) "blind spot". The blind spot is more nasal (towards the nose) than the fovea.

The fovea



http://thalamus.wustl.edu/course/eyeret.html

In the fovea: only cones and the cones connect almost 1:1 to ganglion cells

There is a dip because the other neuron types and blood vessels all avoid this area to give the best light access to the cones

Tight packing of cones in the fovea

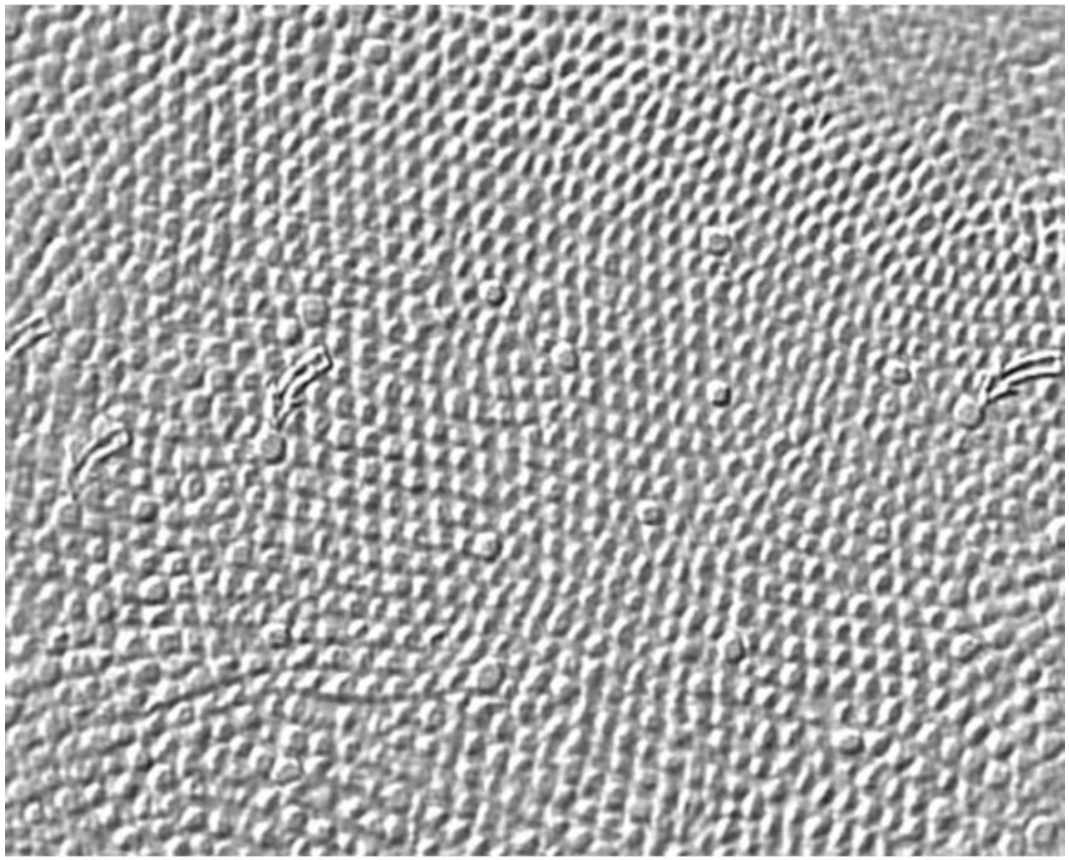


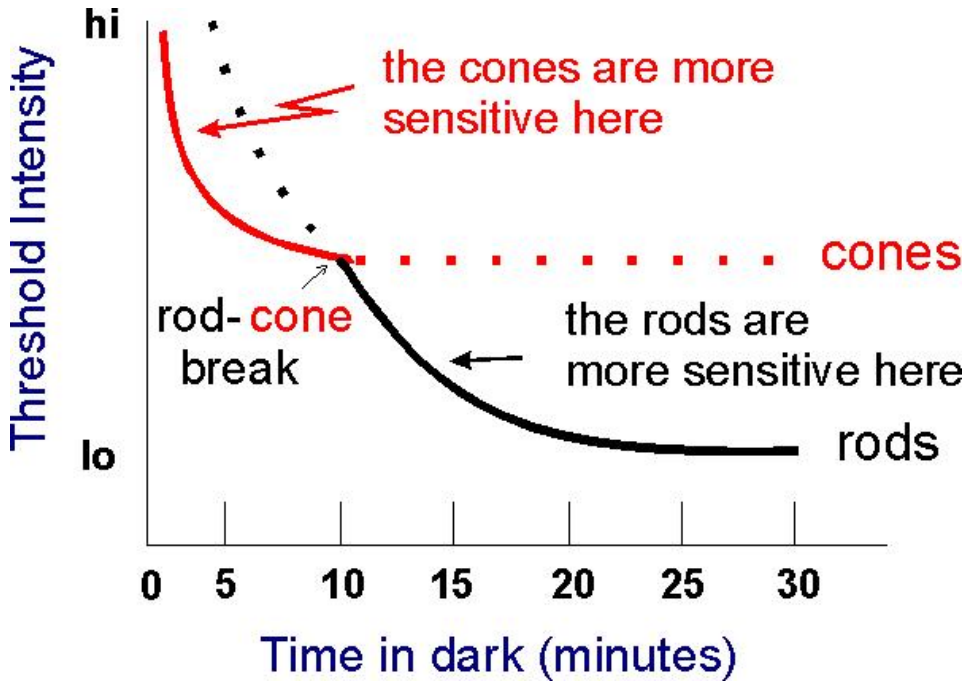
Fig. 13. Tangential section through the human fovea.
Larger cones (arrows) are blue cones.

http://webvision.med.utah.edu/sretina.html

Dark Adaptation

This will be relevant for your lab next week!

The pigment (and your light transucing ability) regenerates slowly over time and this can be measured with dark-adaptation curves



http://www.yorku.ca/eye/darkada1.htm

Rod pigment regenerates slower than cone pigments

A great set of flash lecture notes

link to notes

http://www.med.uwo.ca/physiology/courses/sensesweb by Tutis Vilis, University of Western Ontario, Canada

Review of Flash Notes

Ganglion cells have center-surround receptive fields

Center can be On-center or Off-center (and surround is opposite)

The surround inhibition is mediated by the horizontal cells (and possibly some by the amacrine cells)

Receptive Field

The **receptive field** of a visual neuron is the area of retina over which light stimuli change the response of that neuron (in general area over the receptor surface)

Measuring receptive field demo

Ganglion cell responses

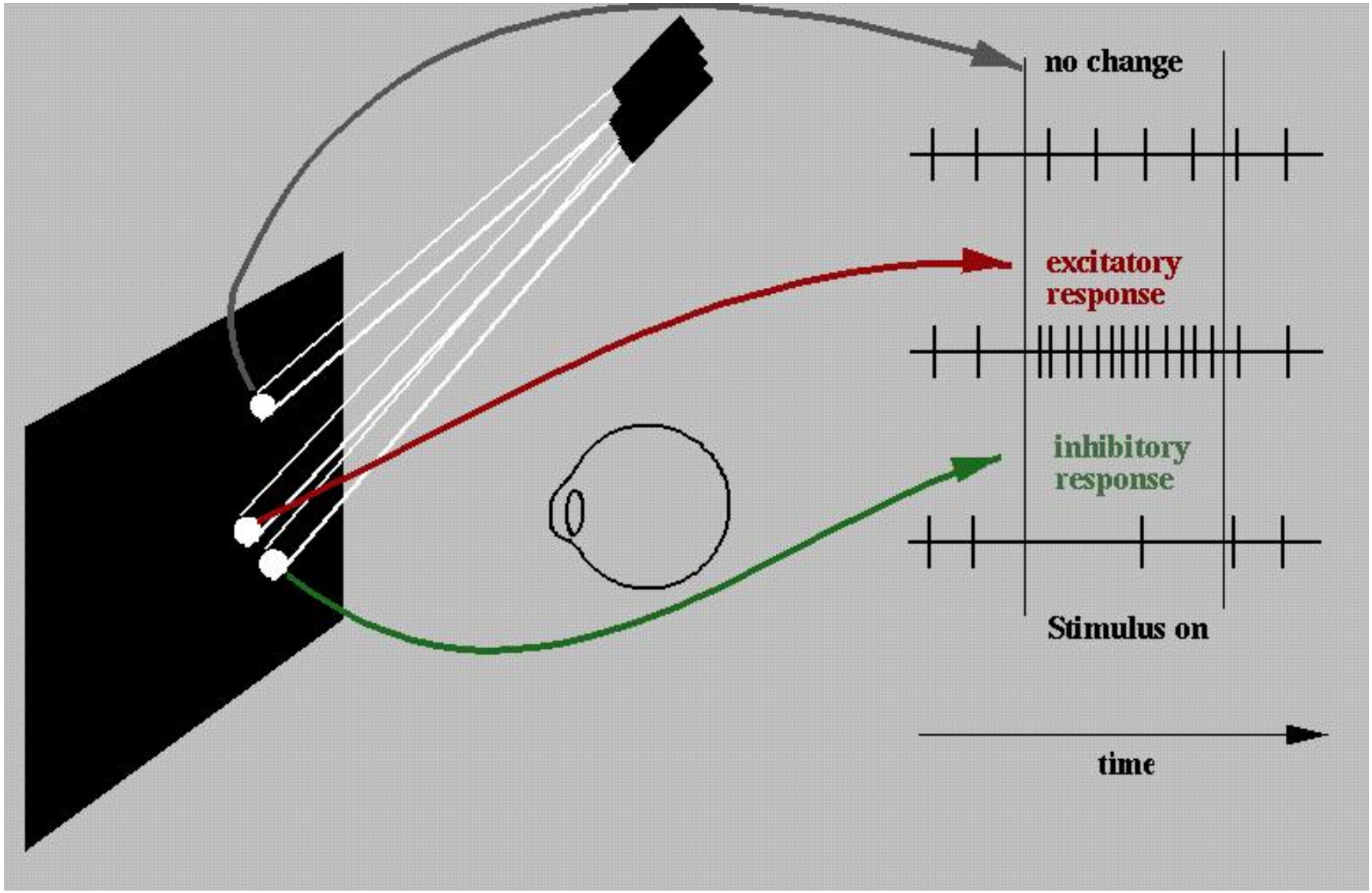
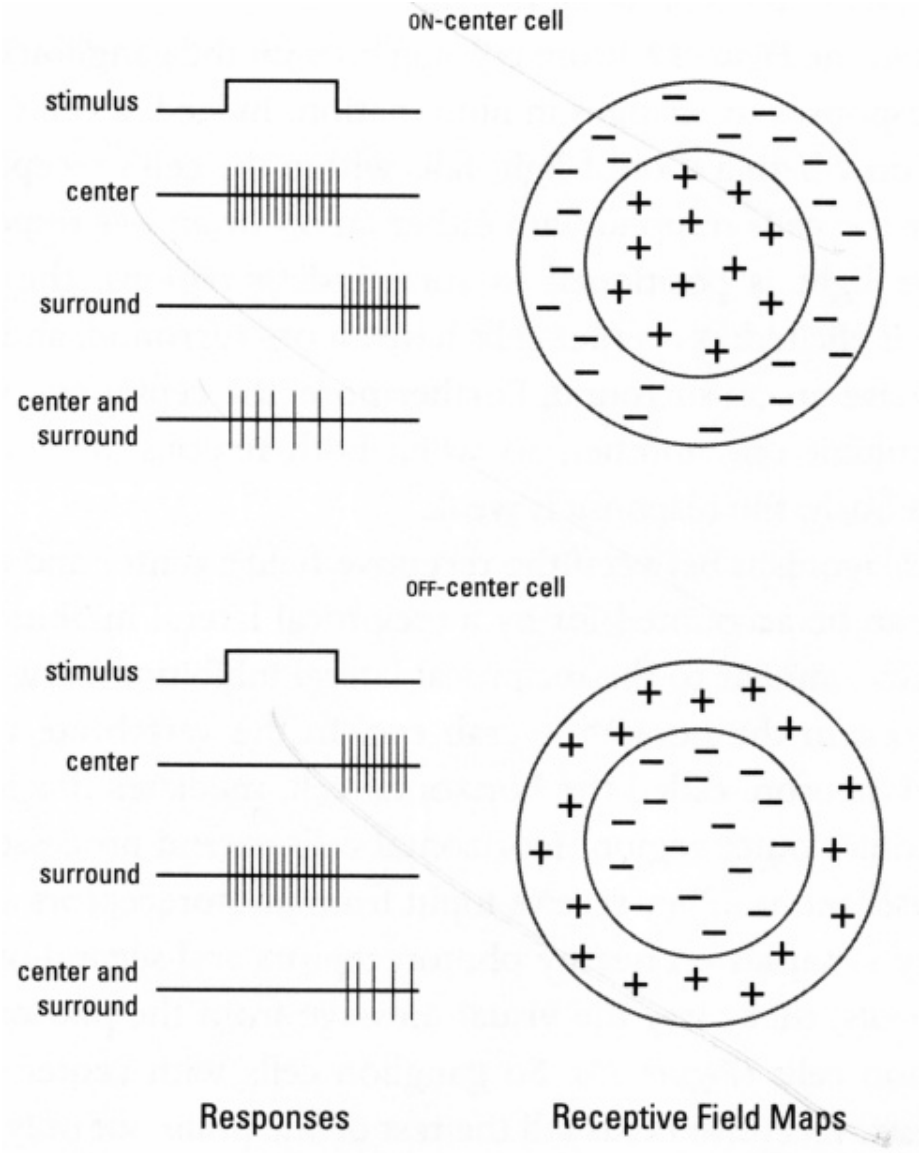


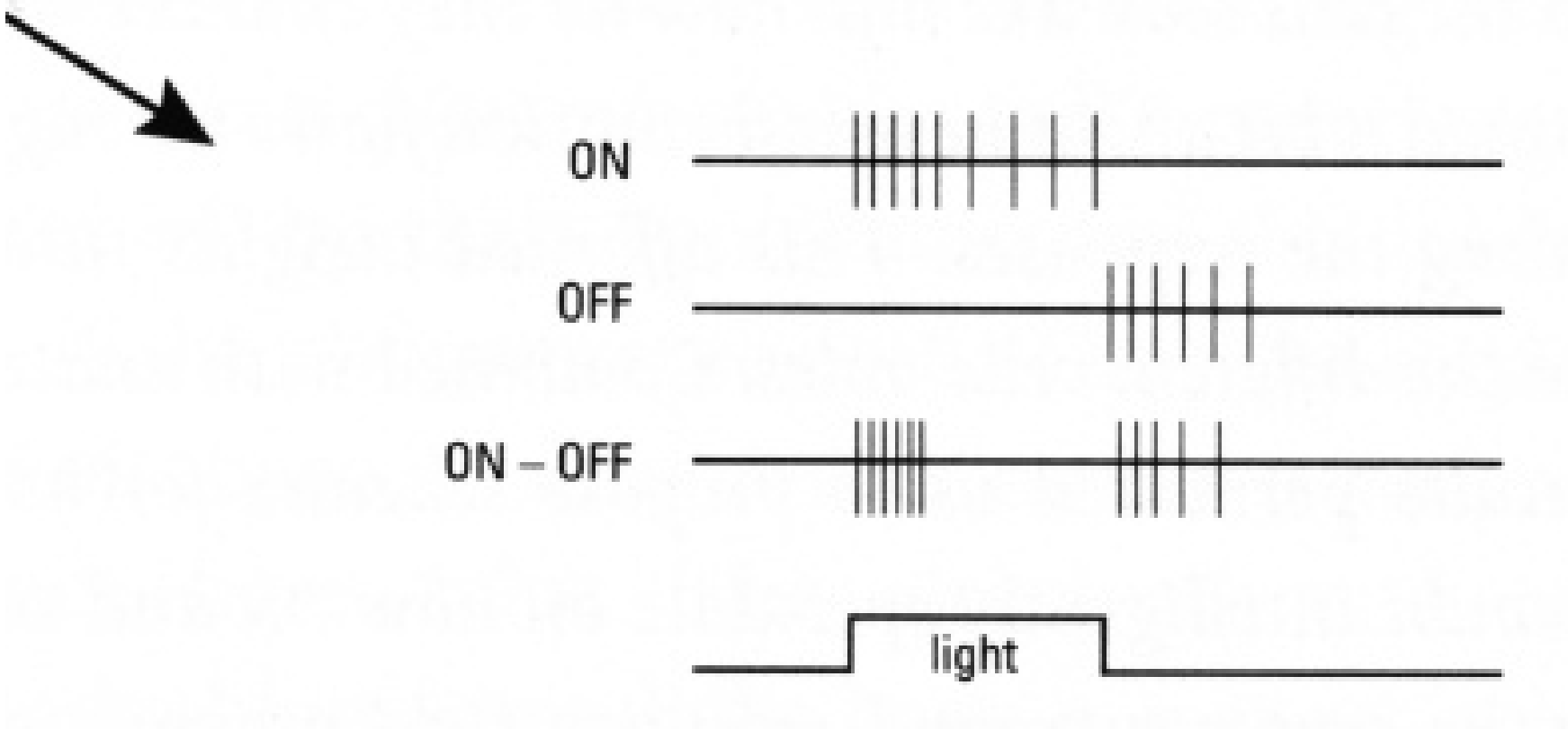
Figure from the web

Ganglion cell responses



http://zeus.rutgers.edu/~ikovacs/SandP/prepI_3_1.html

On and off responses



Connectivity pattern helps account for acuity and sensitivity differences

Rods - many rods converge on 1 ganglion cell

Cones - fewer cones/ganglion cell

Other factors influence sensitivity

- Isomerization more likely to alter neurotransmitter release in rods than cones (1 photon enough in rods)
- More rods – more likely to hit one
- Rods contain more pigment molecules

Next Class

We will learn more about center-surround physiology and what it means for perception