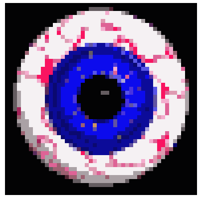
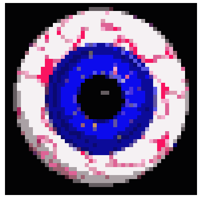
Crown 85: Visual Perception:
A Window to Brain and Behavior



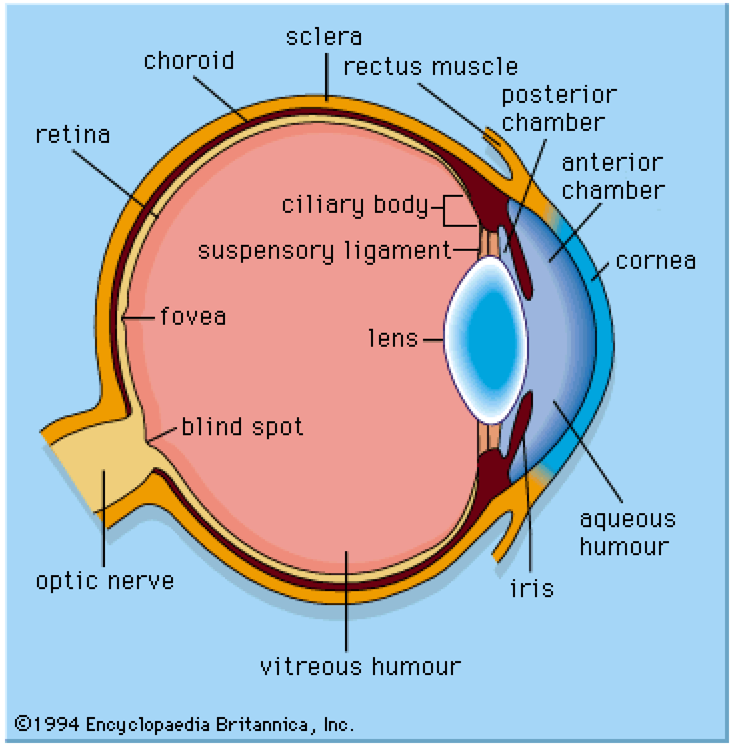


Lecture 5: Structure of and Information Processing in the Retina

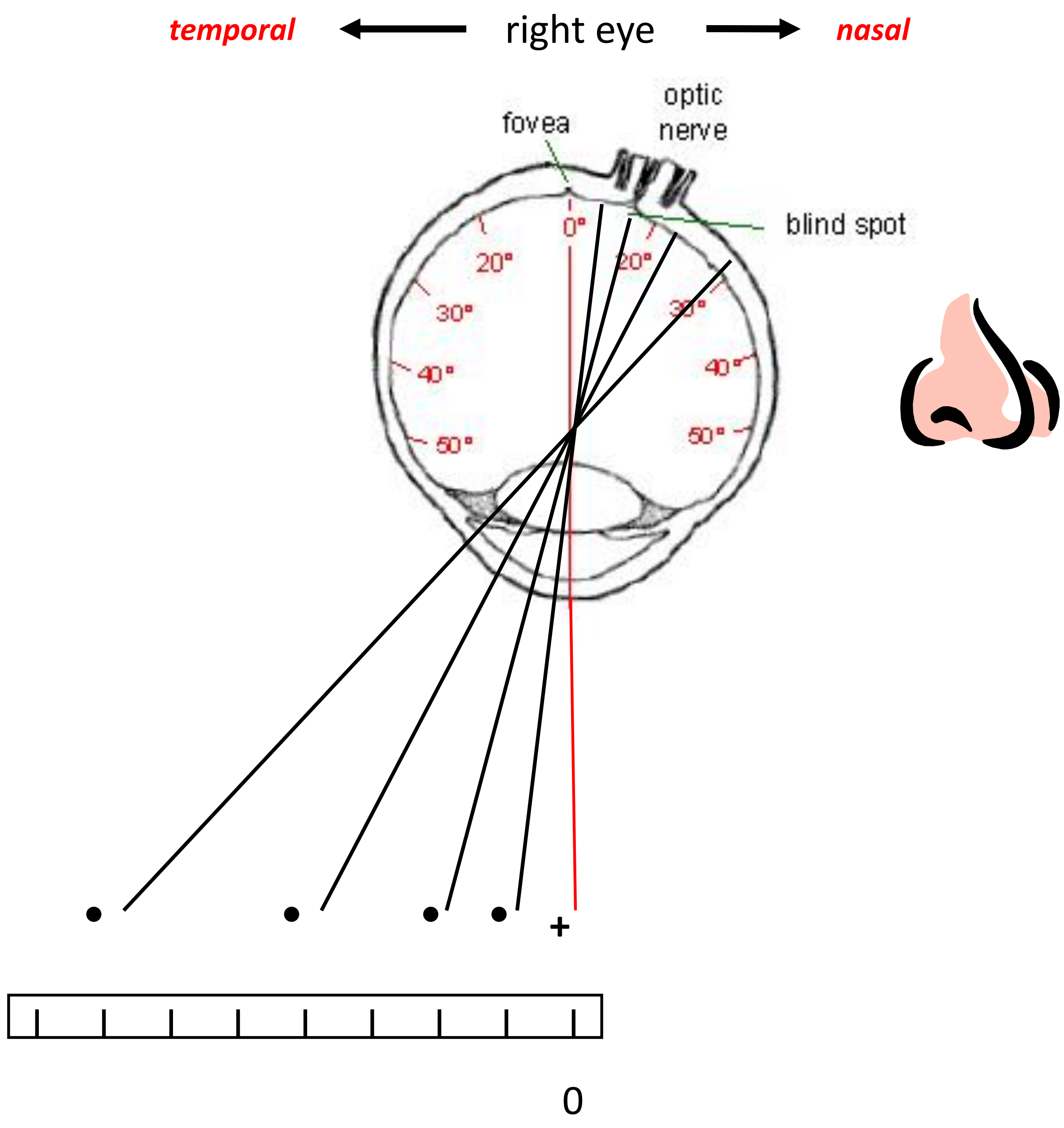
better make it a ***triple (3 x)***

blind spot demonstration (close left eye)

blind spot



sclera
choroid
rectus muscle
posterior chamber
retina
anterior chamber
ciliary body
suspensory ligament
cornea
fovea
lens
blind spot
aqueous humour
optic nerve
iris
vitreous humour
©1994 Encyclopaedia Britannica, Inc.


temporal
right eye
nasal
fovea
optic
nerve
blind spot
0°
20°
30°
40°
50°
20°
30°
40°
50°
+
0

pupil factoids

- controls amount of light entering eye
- depth of focus (vergence-accommodation-pupil reflex)
- often limits optics to center of cornea yielding fewer aberrations

Why do animal eyes have pupils of different shapes?	Prof. Marty Banks, et al, UCB NPR URL NPR Podcast Original Literature	~January 19th

lecture 5 outline

Crown 85 Winter 2016

Visual Perception: A Window to Brain and Behavior

Lecture 5: Structure of and Information Processing in the Retina

Reading: **Joy of Perception Retina**
Eye Brain and Vision
Web Vision
How the Retina Works (American Scientist) *[advanced]*

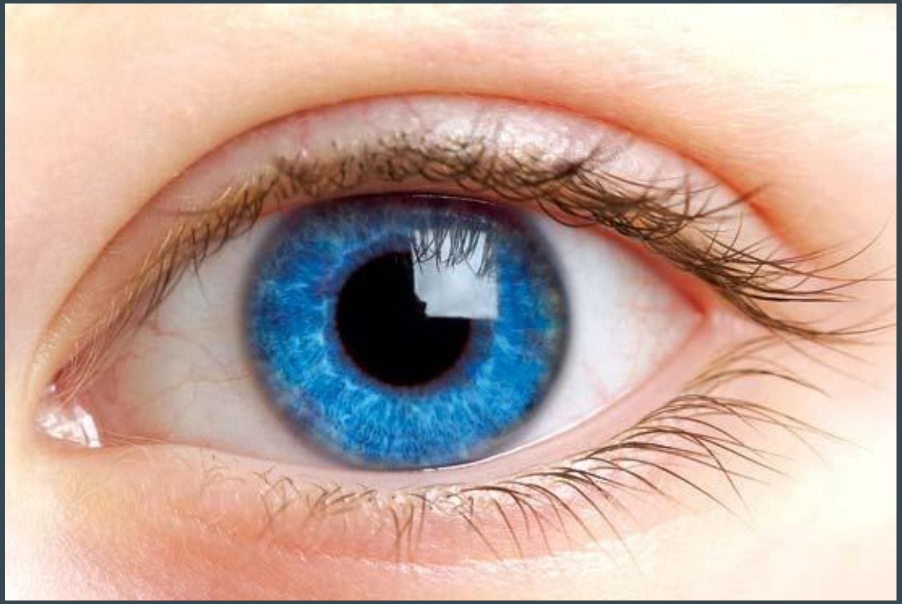
Looking: **Information Processing in the Retina (Sinauer)**
How Lateral Inhibition Enhances Visual Edges YouTube)

OVERVIEW: Once an image has been formed on the retina and visual transduction has occurred, neurons in the retina and the brain are ready to begin some serious information processing. In this lecture we will first discuss the structure of the retina and then look at the some perceptual phenomena related to the functioning of receptors and the transformations of visual information by neural networks found in the retina.

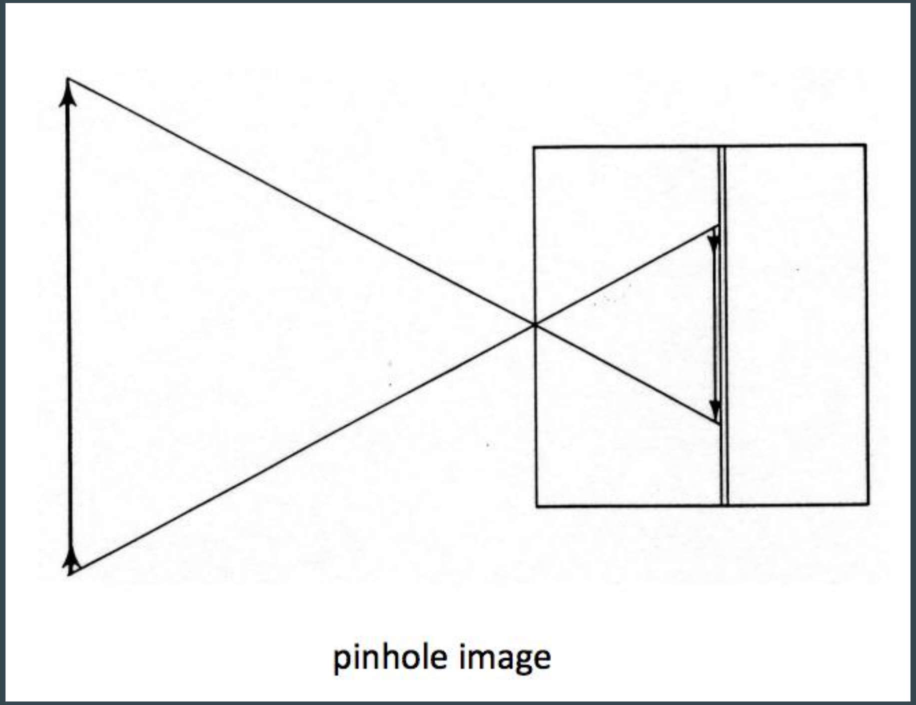
Why do animals have pupils of different shapes?

Ryann Miguel - Crown 85

Review



The pupil: hole in the middle of the iris through which light enters the eye



The size and shape of a pupil, such as a pinhole, affects what amount of light hits the back of the eye and the quality and strength of an image. Smaller hole = small aperture, = greater depth of focus

Different Types of Pupils

Focus: Land Animals

Vertically Elongated

Round

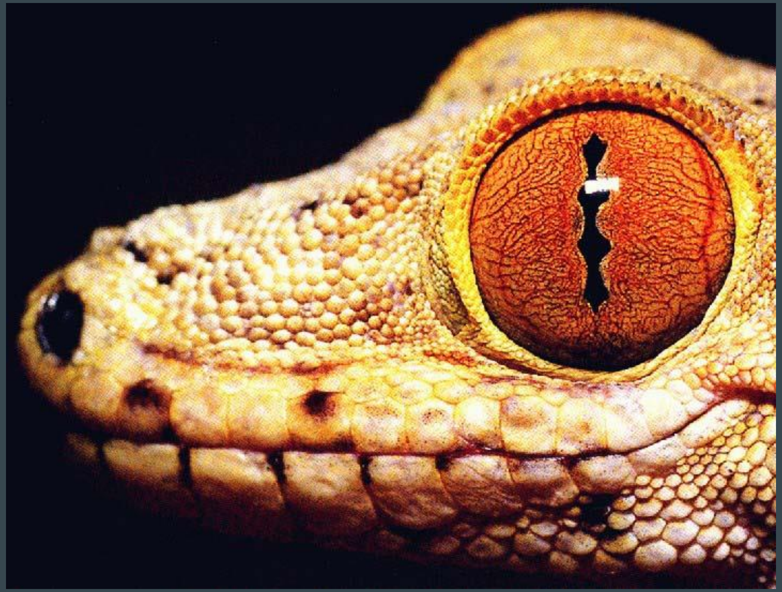
Horizontally Elongated

(House Cat)

(Tiger)

(Horse)

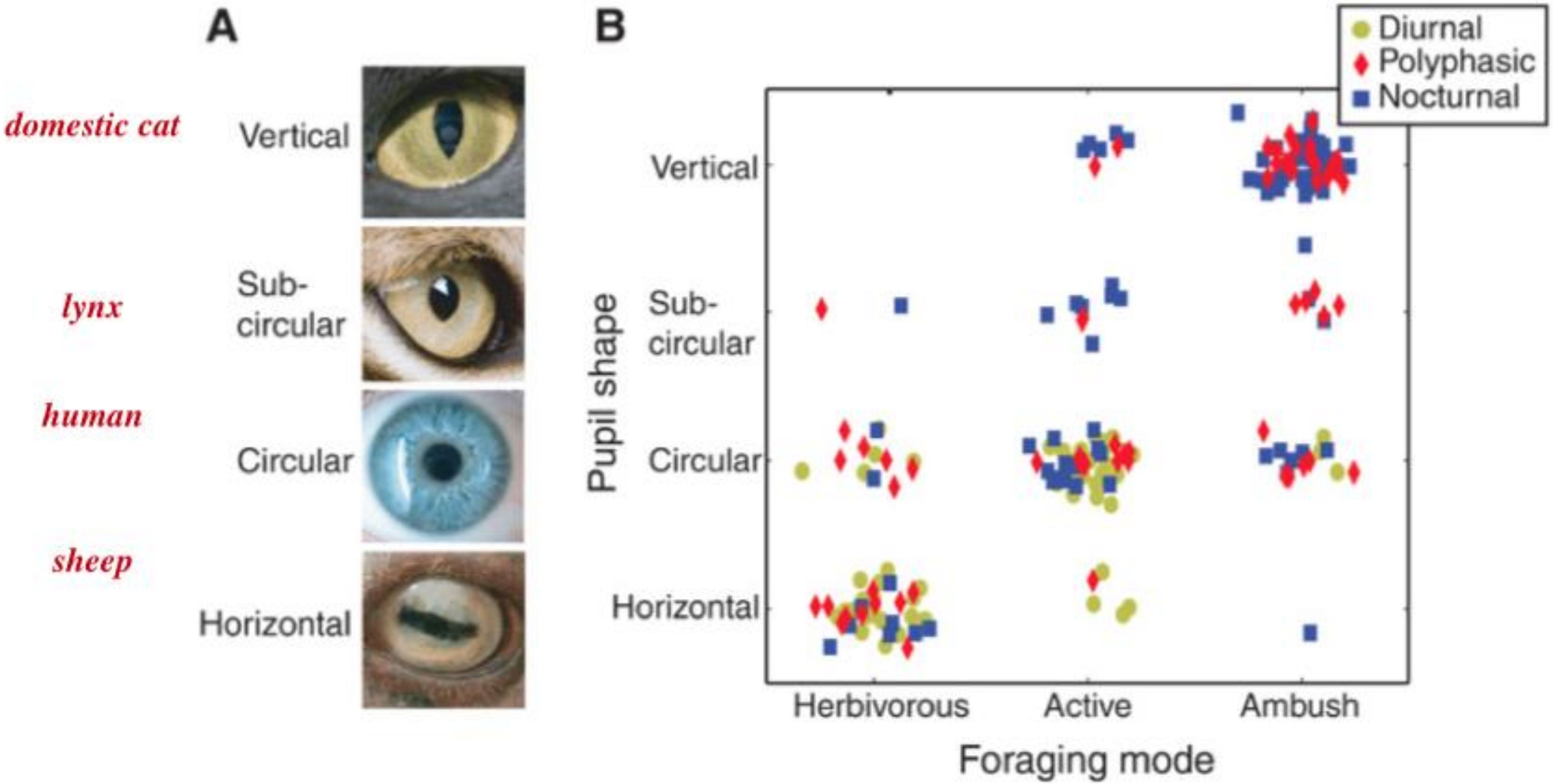
Retinal Illumination: Vertical vs Round



135 fold

300 fold

15 fold


A
B
domestic cat
lynx
human
sheep
Vertical
Sub-
circular
Circular
Horizontal
Diurnal
Polyphasic
Nocturnal
Pupil shape
Vertical
Sub-
circular
Circular
Horizontal
Herbivorous
Active
Ambush
Foraging mode

Vertically Elongated: Ambush Predators

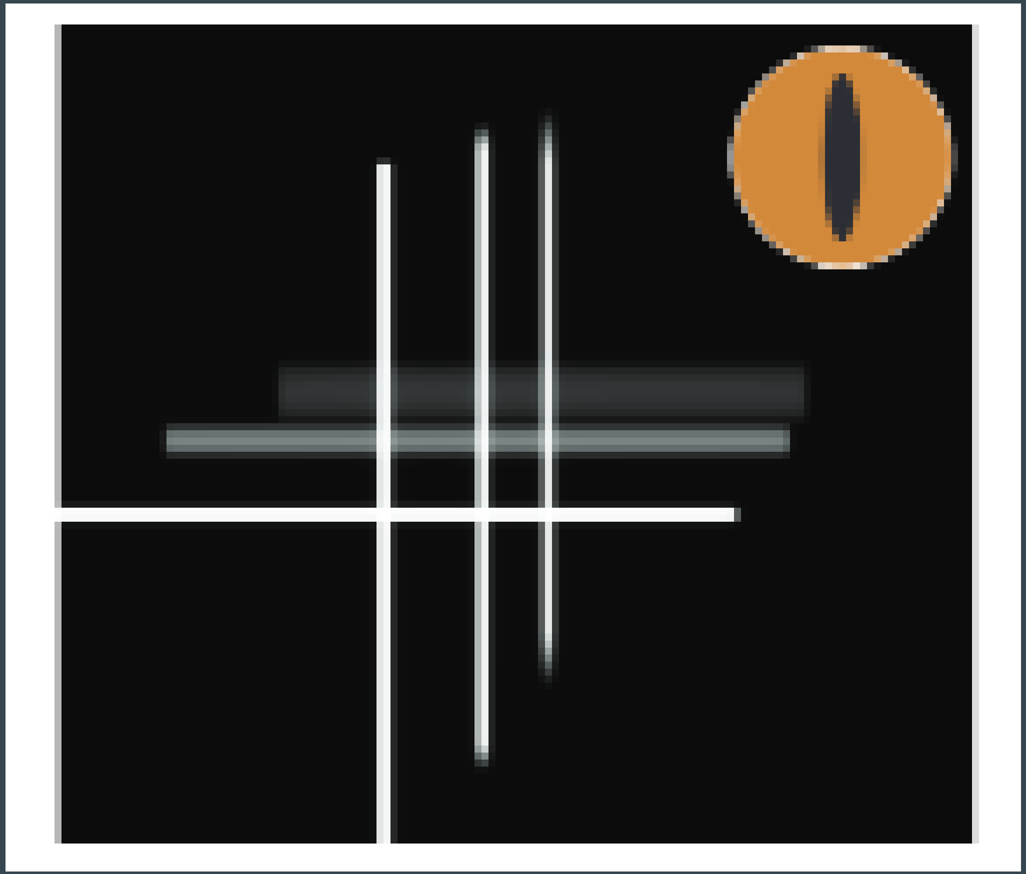
Front-eyed animals

Only applies to smaller, shorter ambush predators that live close to the ground and must be ready to “strike”




Astigmatic Factoids: Ambush Predators

- Vertically Elongated Slit
- Narrow opening horizontal direction
- Good depth of focus for widths of verticals
- ‘Stereopsis’ or depth perception
- Strong ability to gauge distance from predator to prey



Round: Pursuit Predators

Predators larger than the size of a normal house cat

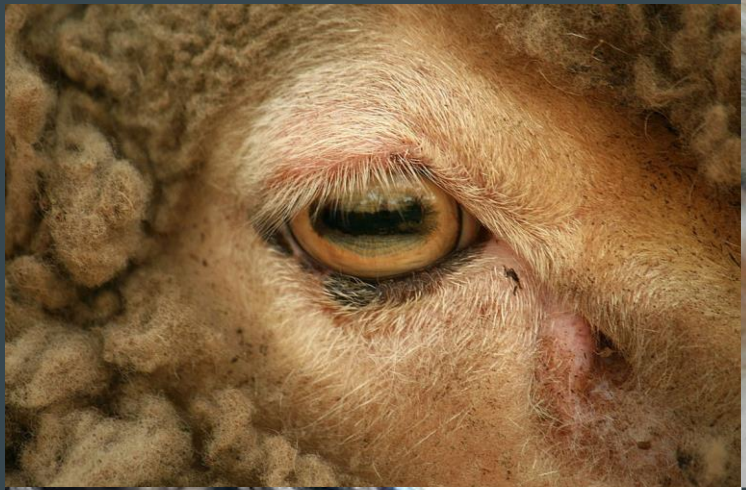
Ability to “pursue” rather than “strike” requires different abilities

Examples: human, bear, tiger

Horizontally Elongated: Prey

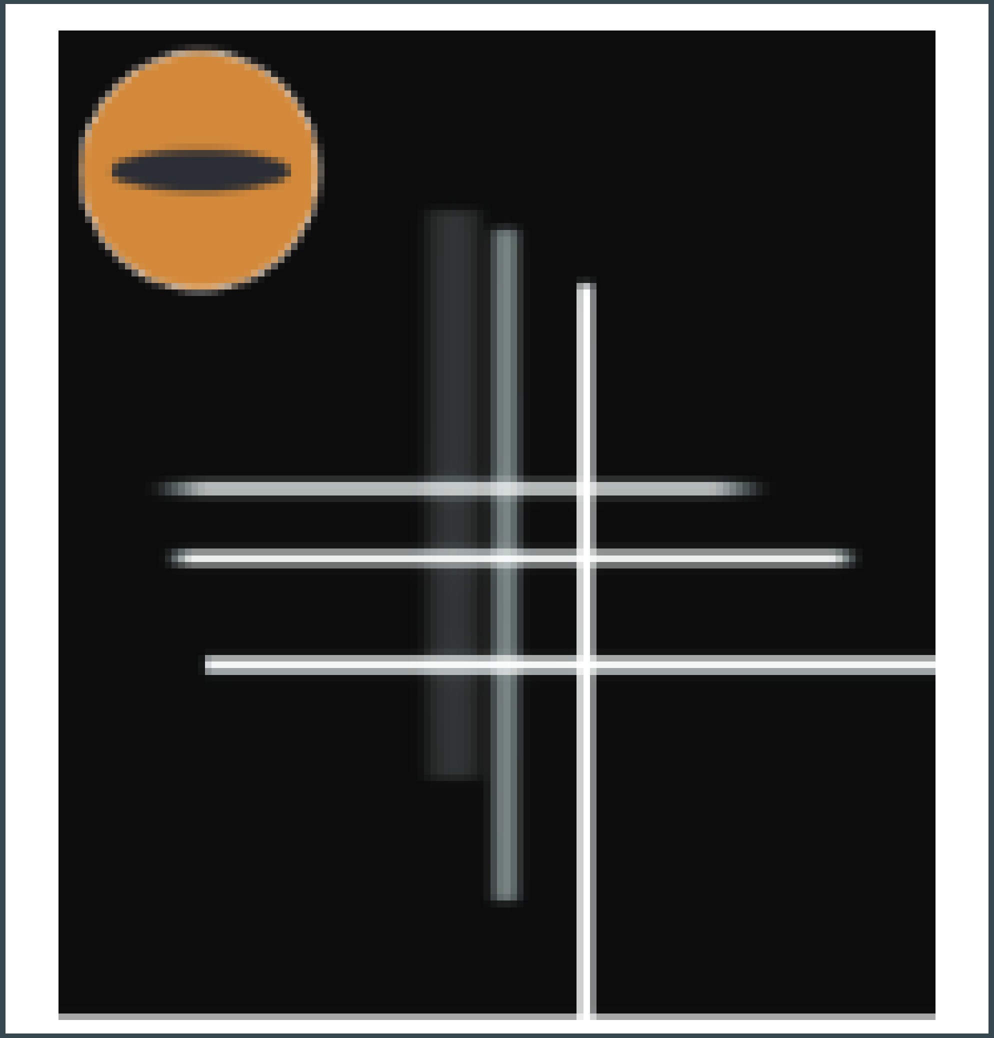
Usually have a boxy, rectangular elongation

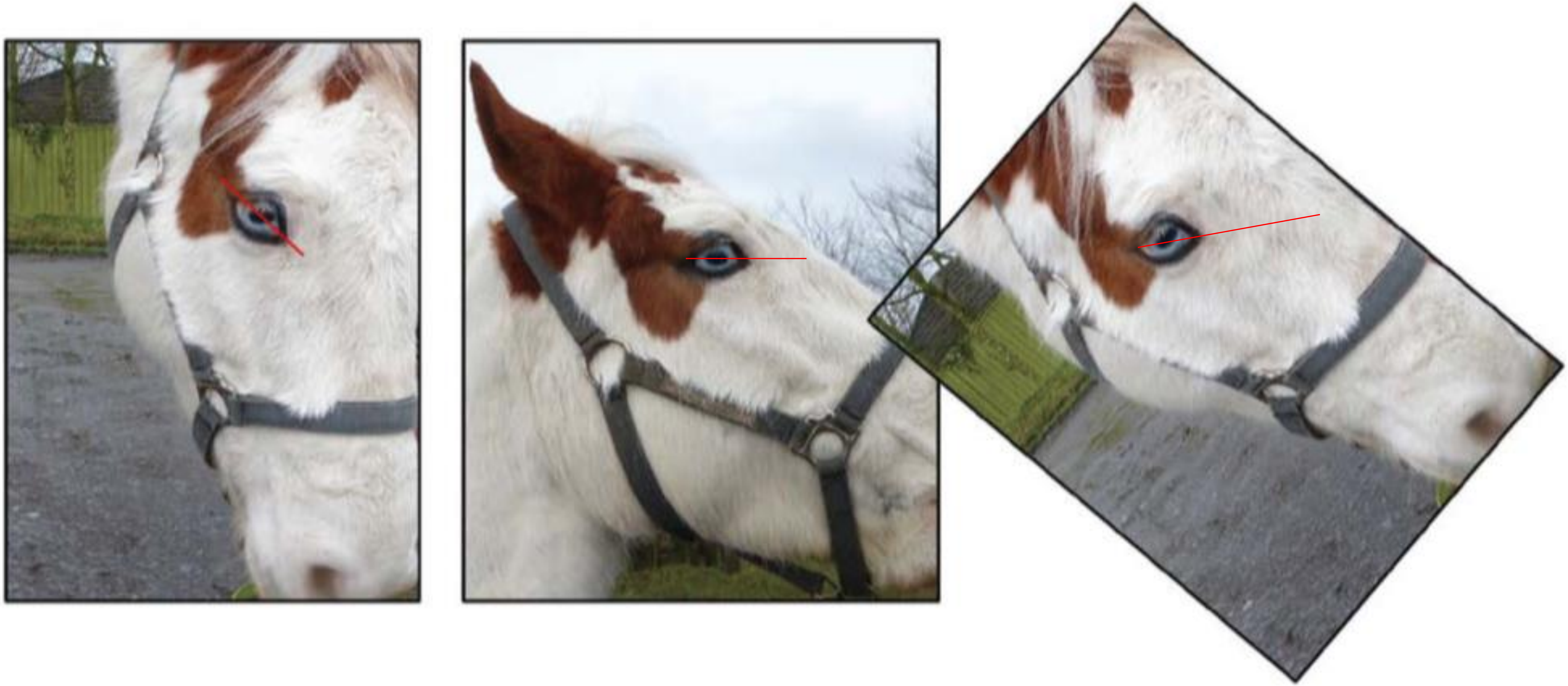
Normally eyes with these shaped pupils are situated more laterally, towards the sides of the head




Astigmatic Factoids : Prey

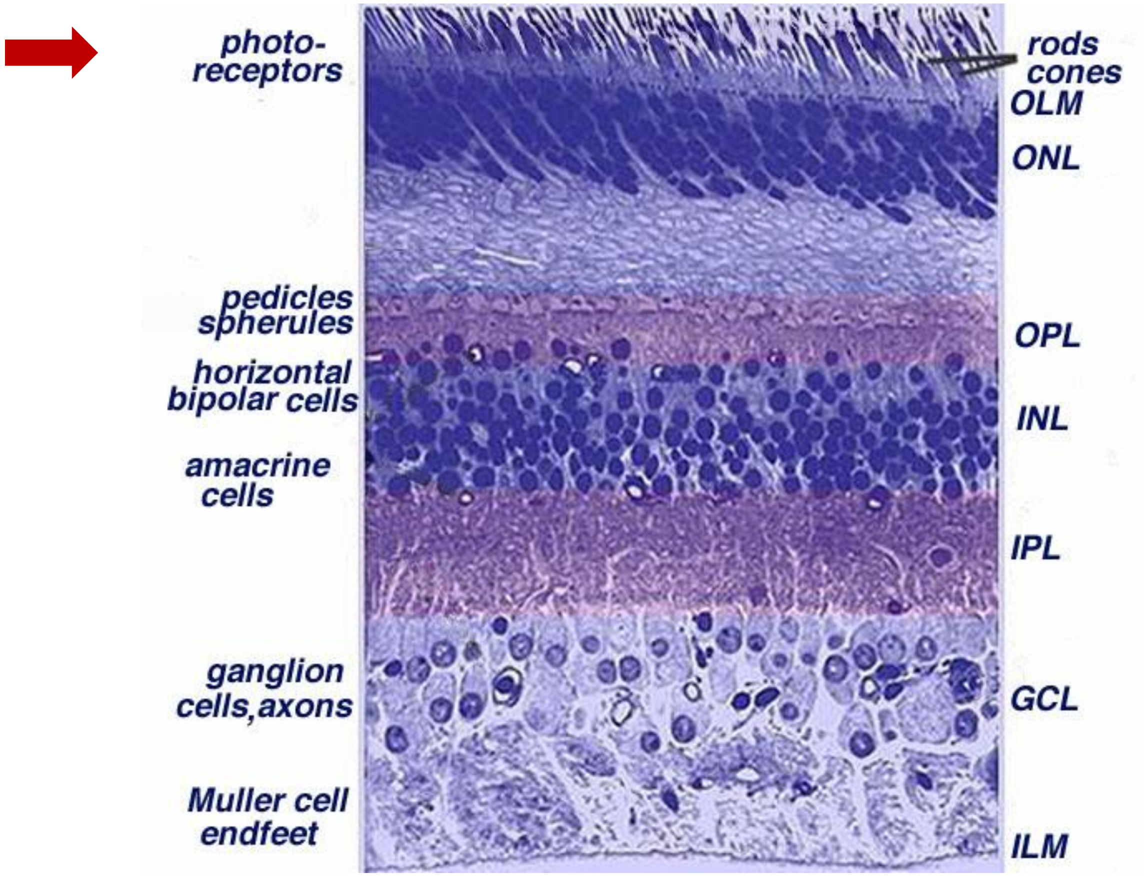
- Improves image quality for horizontal contours
- Narrow opening vertical direction
- Not good for stereopsis (depth perception), but allows more panoramic view
- Advantages lost if pupil not parallel to ground (animal must ‘cyclo rotate’ eye as it tilts head)



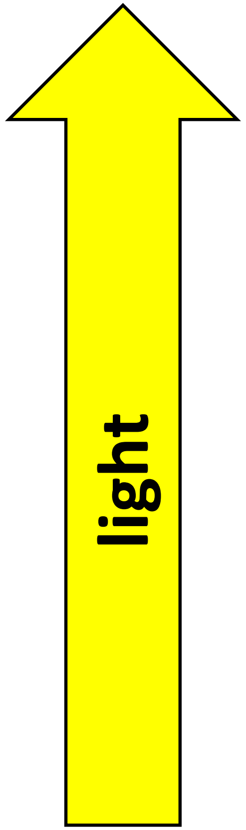


light microscope picture of the retinal layers

choroid



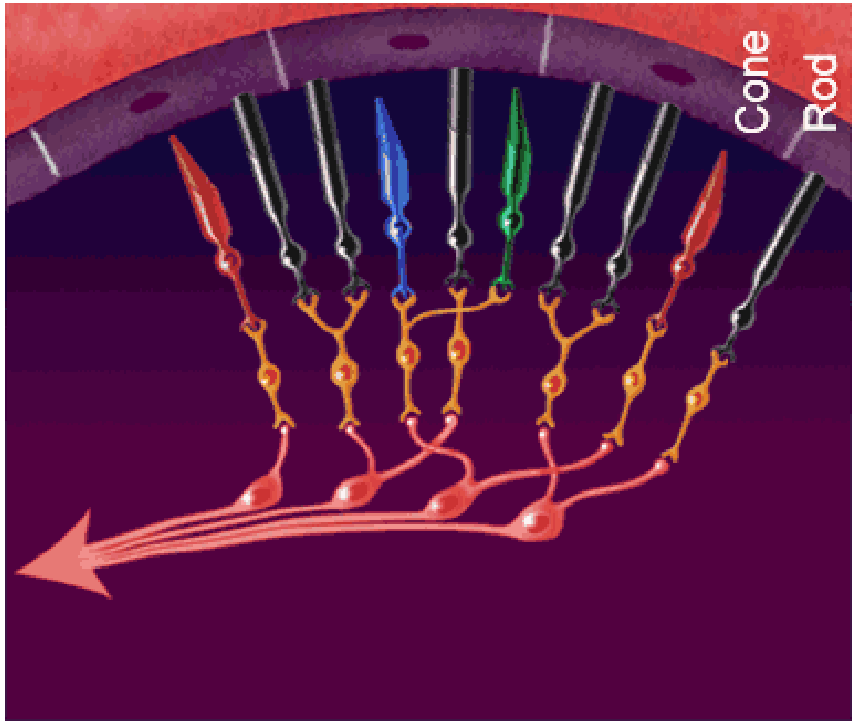
vitreous

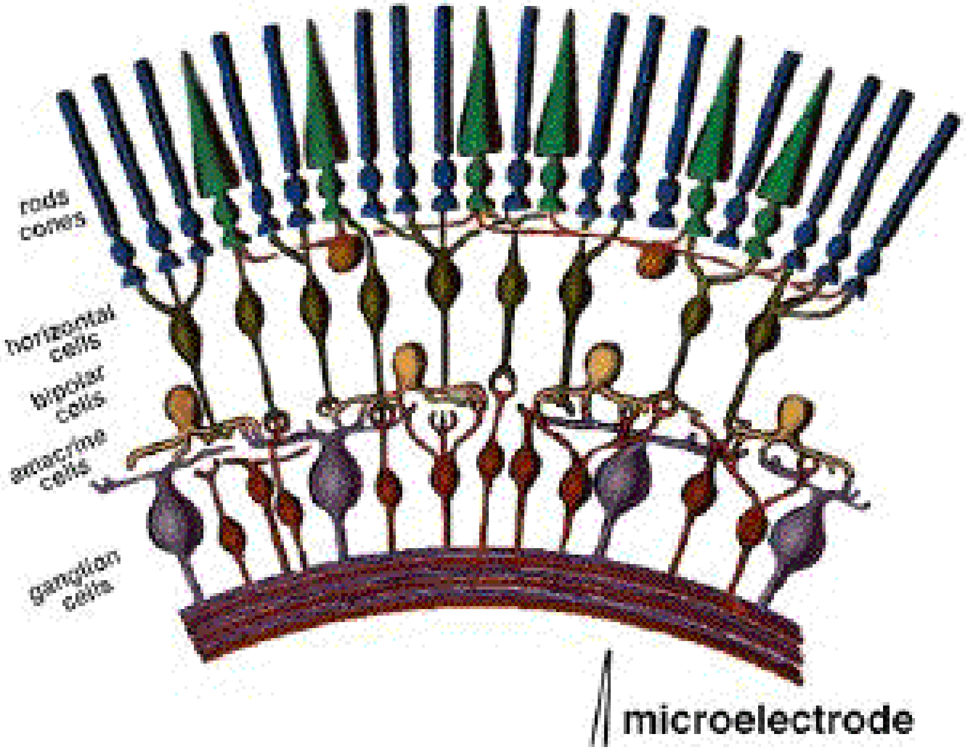


http://webvision.med.utah.edu/wp-content/uploads/2011/01/husect.jpeg

retina is "backwards"

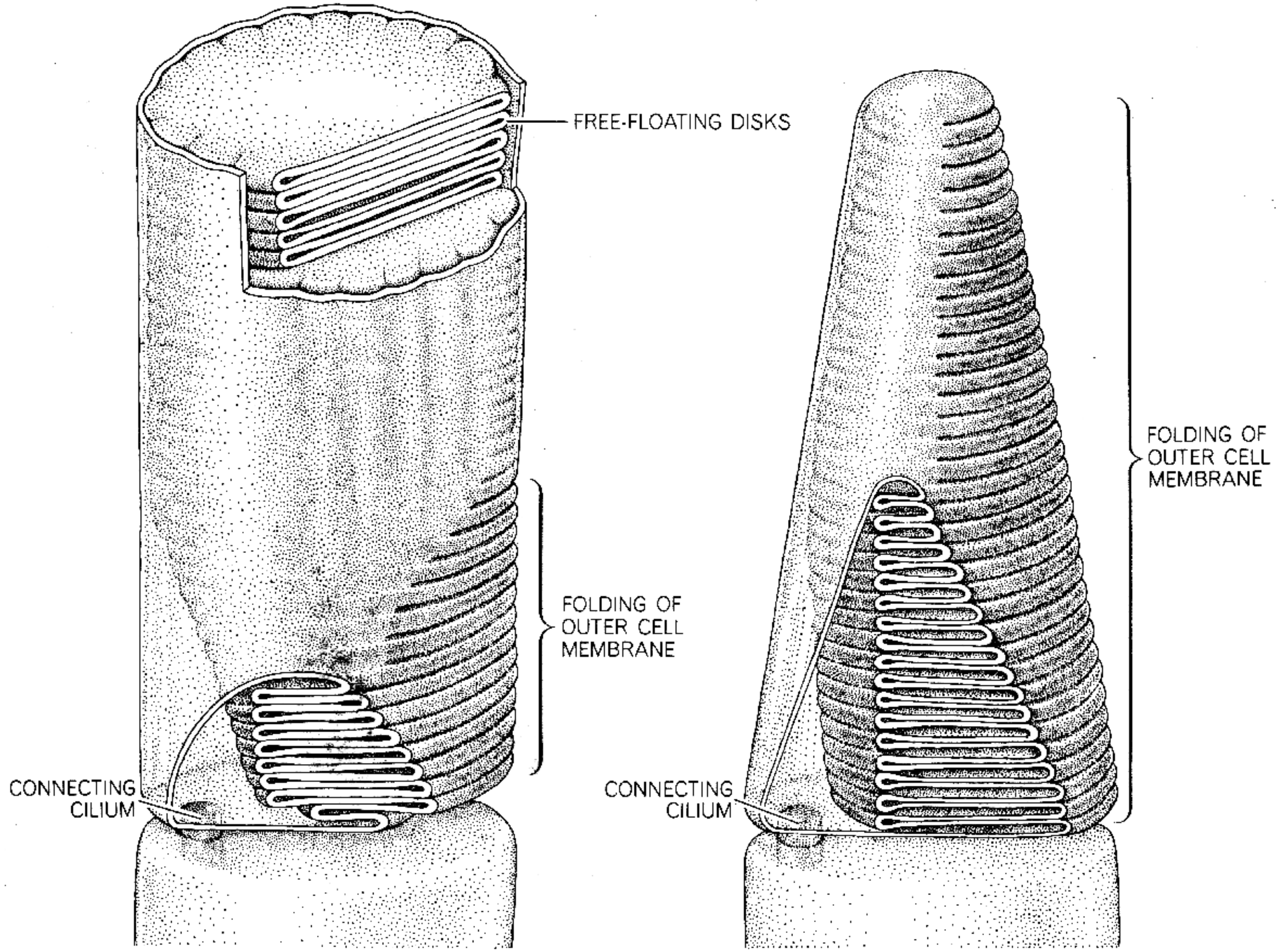
back of eye (choroid)



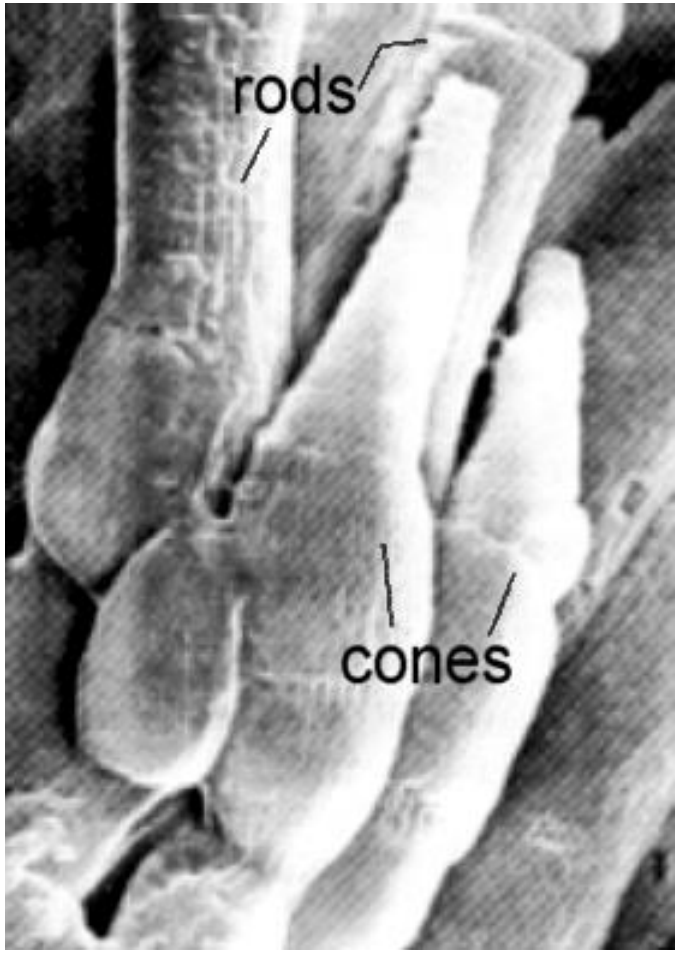


interior of eye (vitreous humor)

rods and cones



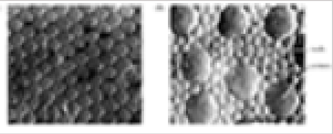
micrograph of rods and cones (≈ fig. 6.8 Kalat)



http://www.yorku.ca/eye/recept3.htm

rods and cones

1. What are the differences between the rod and cone receptors with respect to:
   a. size
   b. numerosity
   c. distribution across the retina
   d. scotopic and photopic vision
   e. color vision
   f. visual resolution

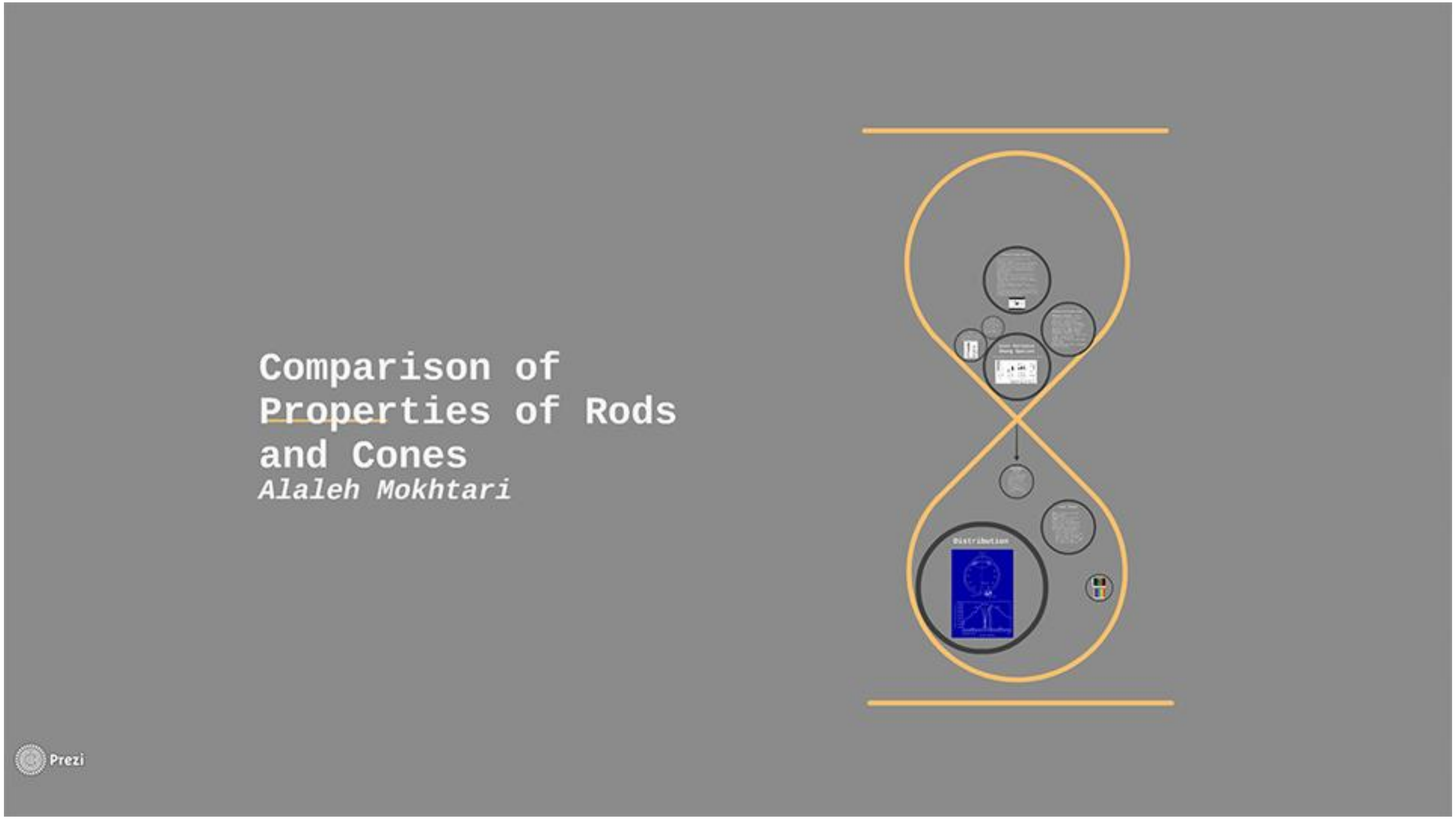


Comparison of the Properties of Rods and Cones

Comparison of Rods and Cones Report

~January 21th

Alaleh's report on properties of rods vs cones



https://prezi.com/fpuosgsctigb/rod-cells-located-in-the-retina-and-are-one-of-the-main-ph/

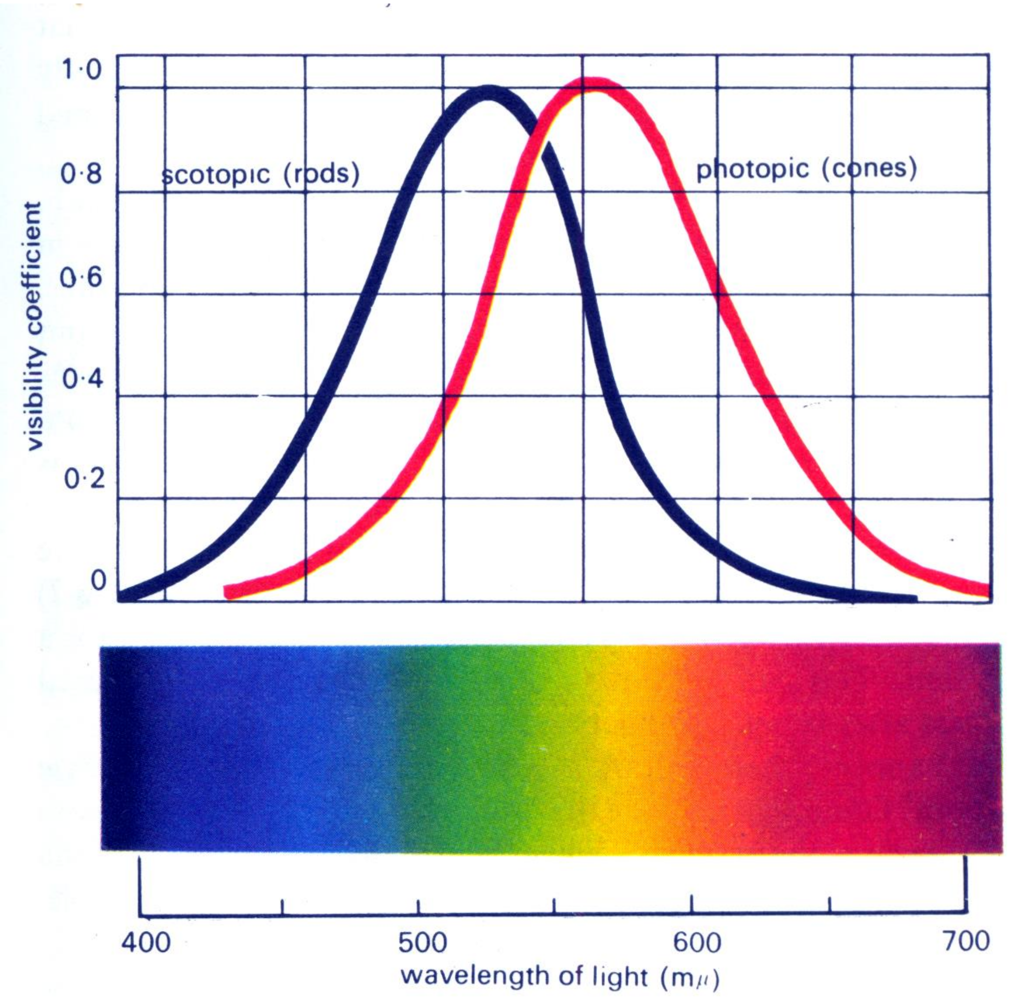
summary

Receptor Properties

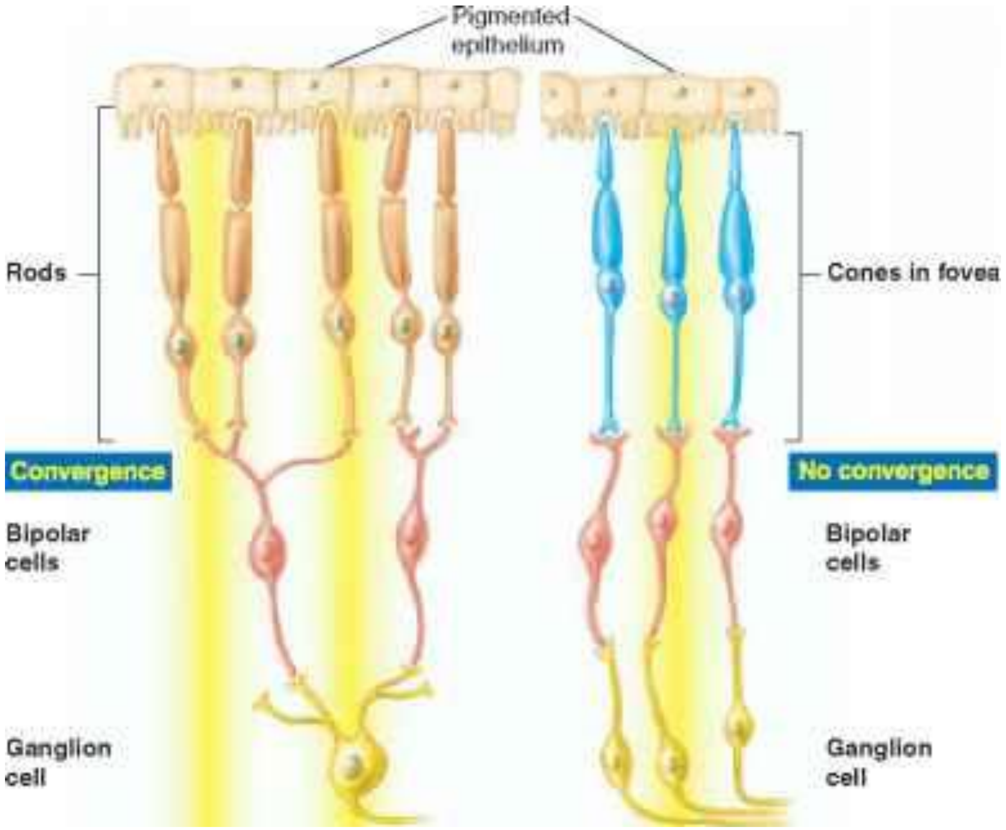
	Rods	Cones
size	2 x 10^{-6} m	2 x 10^{-6} m
number	120 million	6 million
light sensitivity	high in dim light SCOTOPIC	higher in bright light PHOTOPIC
distribution	periphery	fovea
connectivity/ acuity	many-to-one low	one-to-one high
photopigments	1 (rhodopsin) (no color vision)	3 † (color vision)

† 4-5 photopigments have recently been identified in humans

Figure 5.4   Eye & Brain Gregory scotopic [rods] vs photopic [cones] sensitivity



acuity (convergence of rods and cones to output cells)



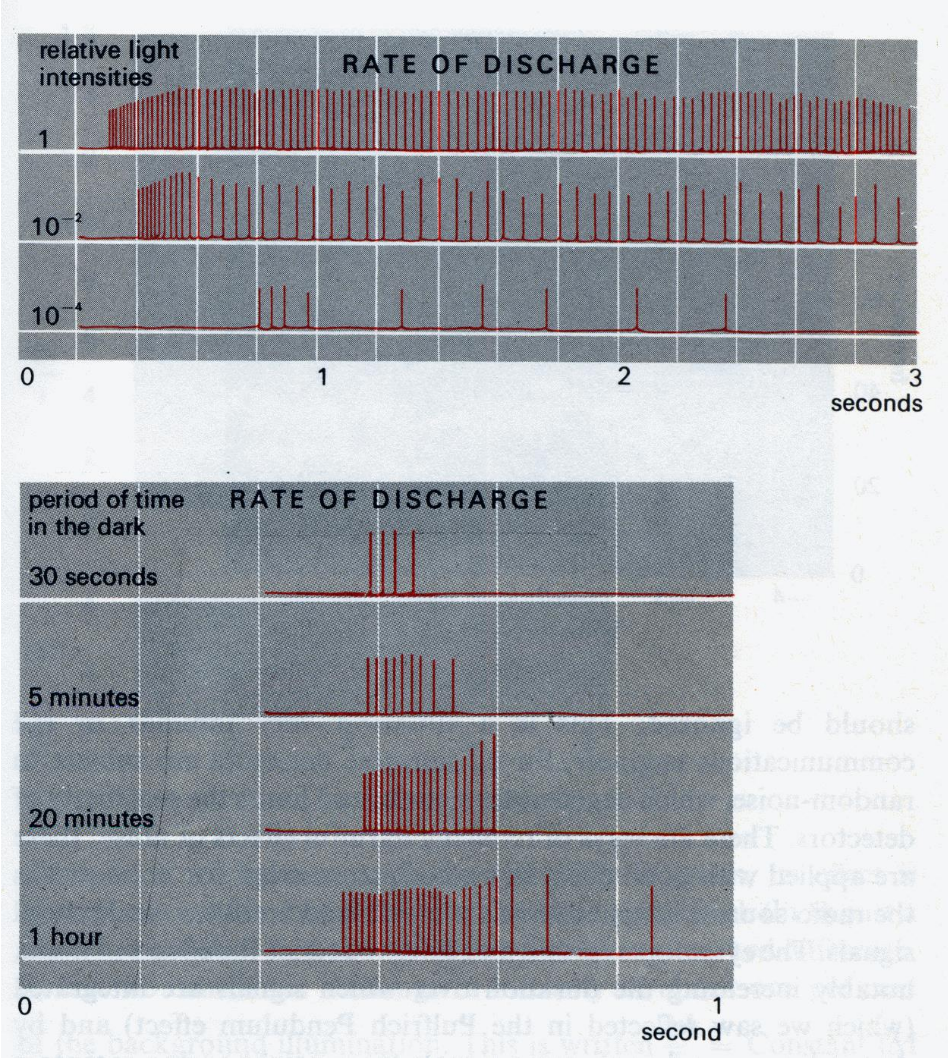
http://www.78stepshealth.us/human-physiology/visual-acuity-and-sensitivity.html

5. **Understand how the following psychophysical phenomena are related to processes occurring in the retina:**
   a. **dark adaptation**
   b. **Pulfrich pendulum**
   c. **Mach bands**

visual cell: firing rate vs intensity and recovery from light adaptation (Eye and Brain, Gregory fig. 5.6)

brighter

longer time in dark



more light

↓

greater firing rate

(given state of adaptation)

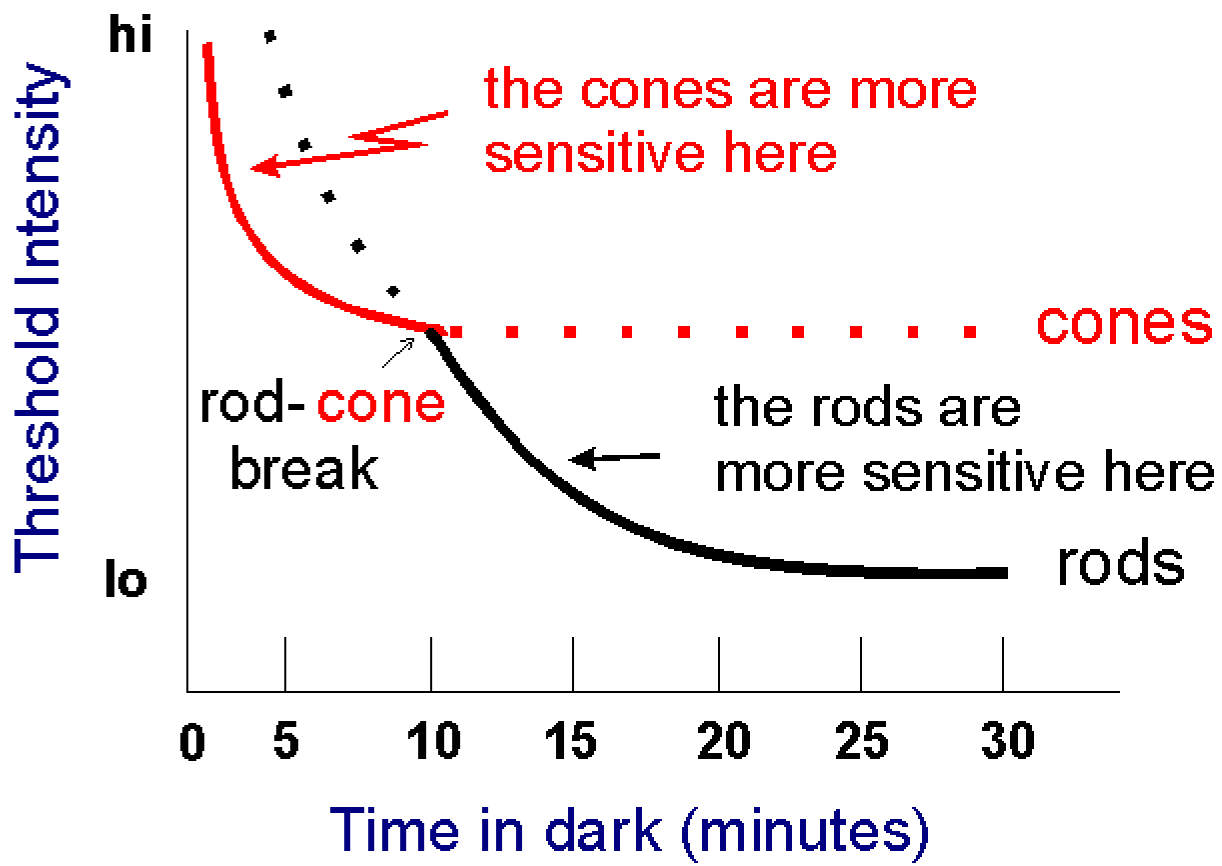
longer in dark

(greater 'dark adaptation')

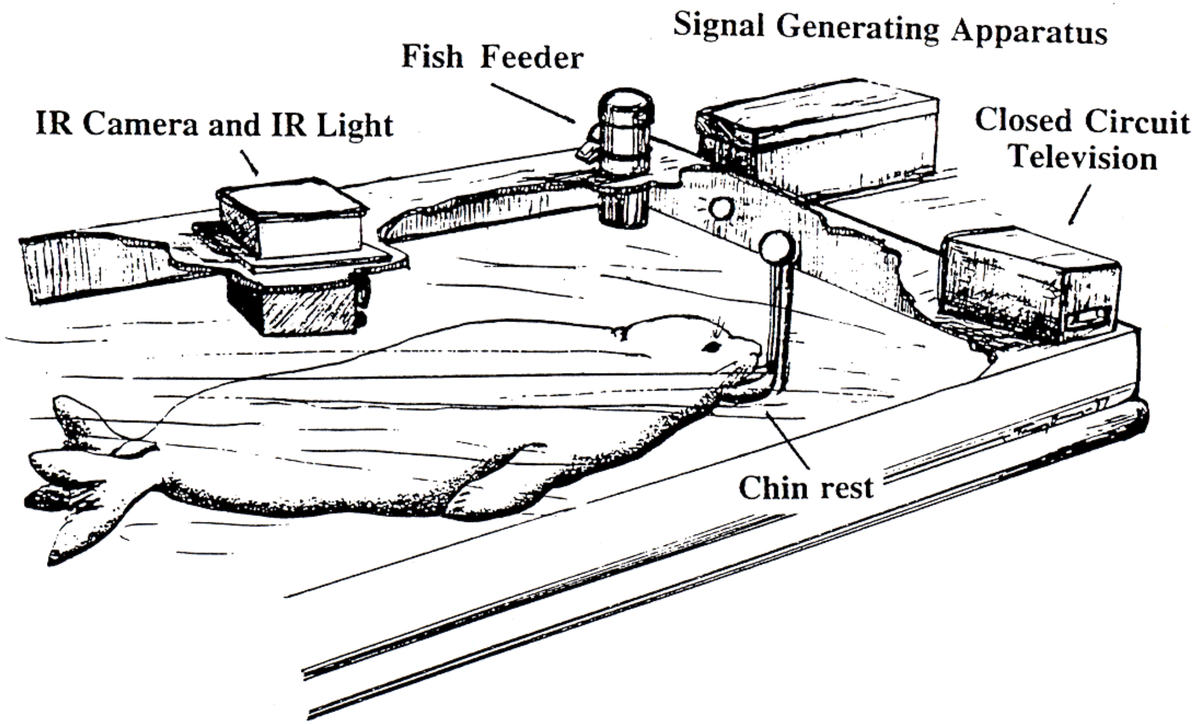
↓

higher sensitivity to light

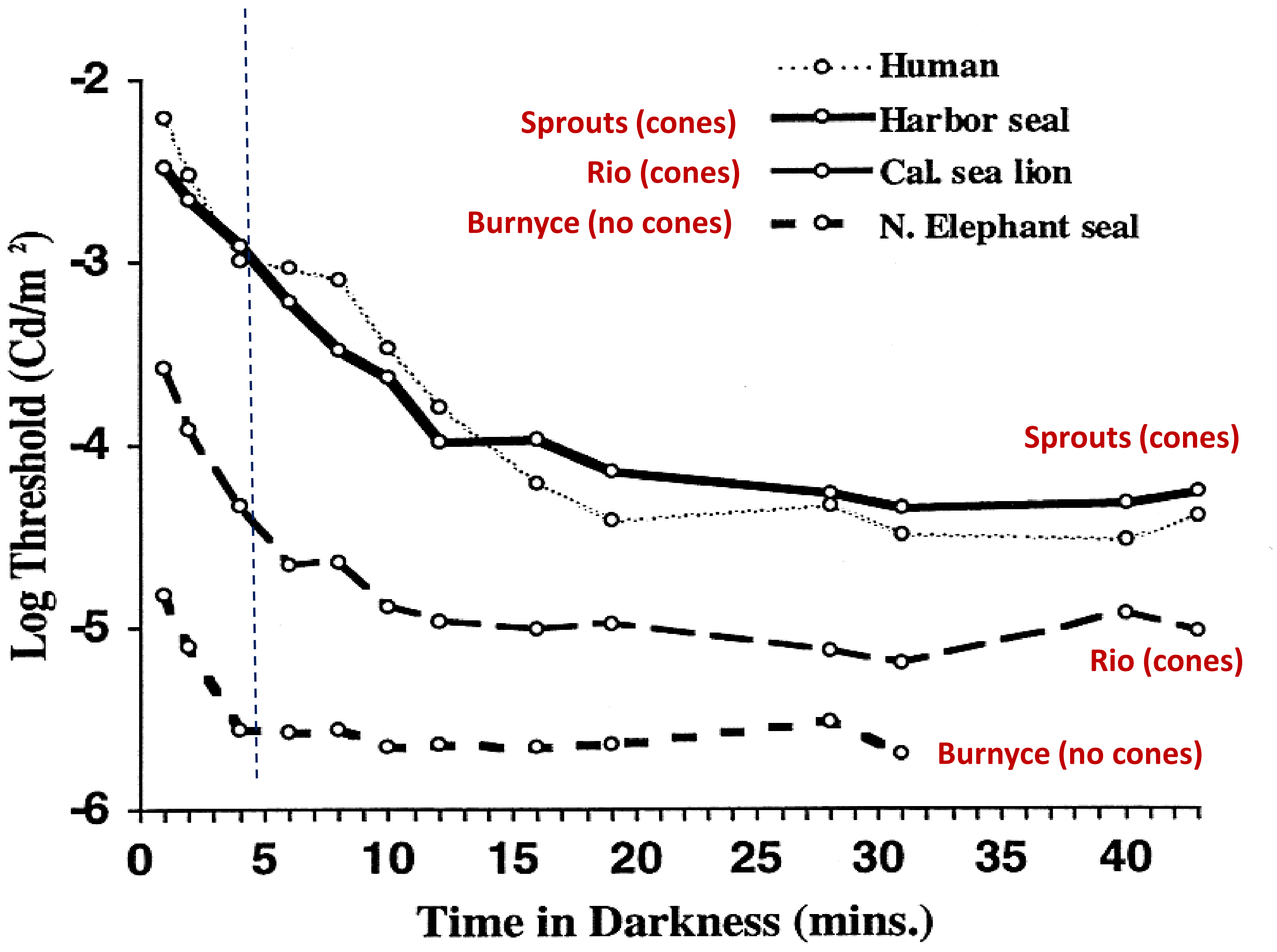
dark adaptation



sea lion psychophysics (Long Marine Lab)



do the marine mamals have cones as well as rods ??



2. **Know the following terms associated with the cells of the retina and retinal structure:**

   a. **rods**
   b. **cones**
   c. **horizontal cells**
   d. **bipolar cells**
   e. **amacrine cells**
   f. **ganglion cells**
   g. **fovea**
   h. **optic nerve**

cells of the retina

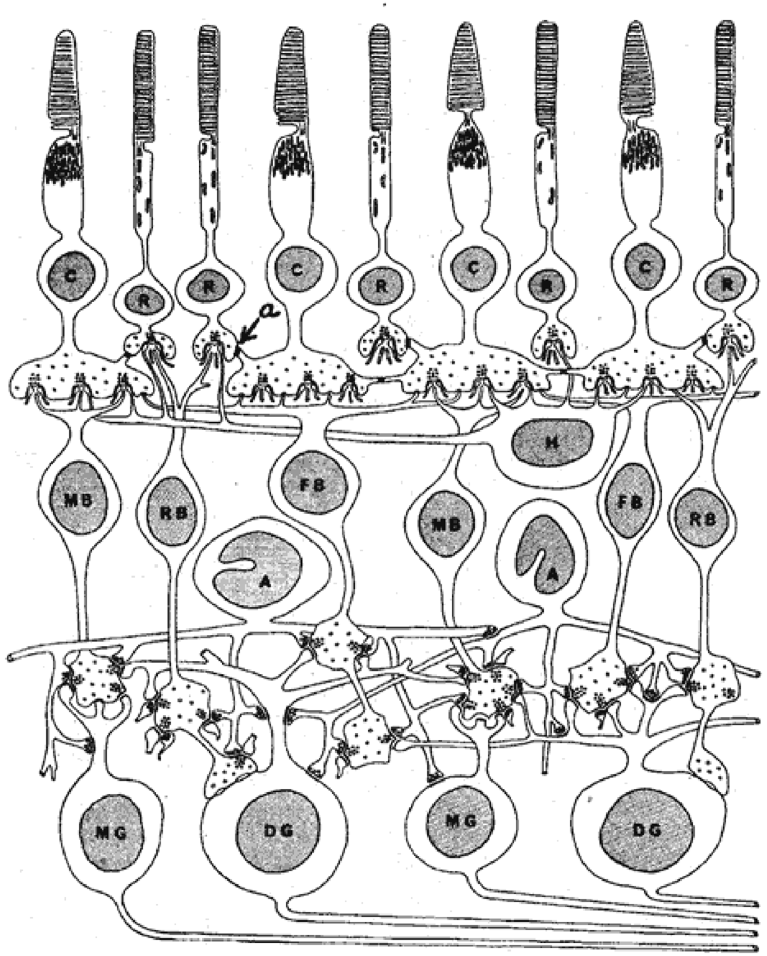
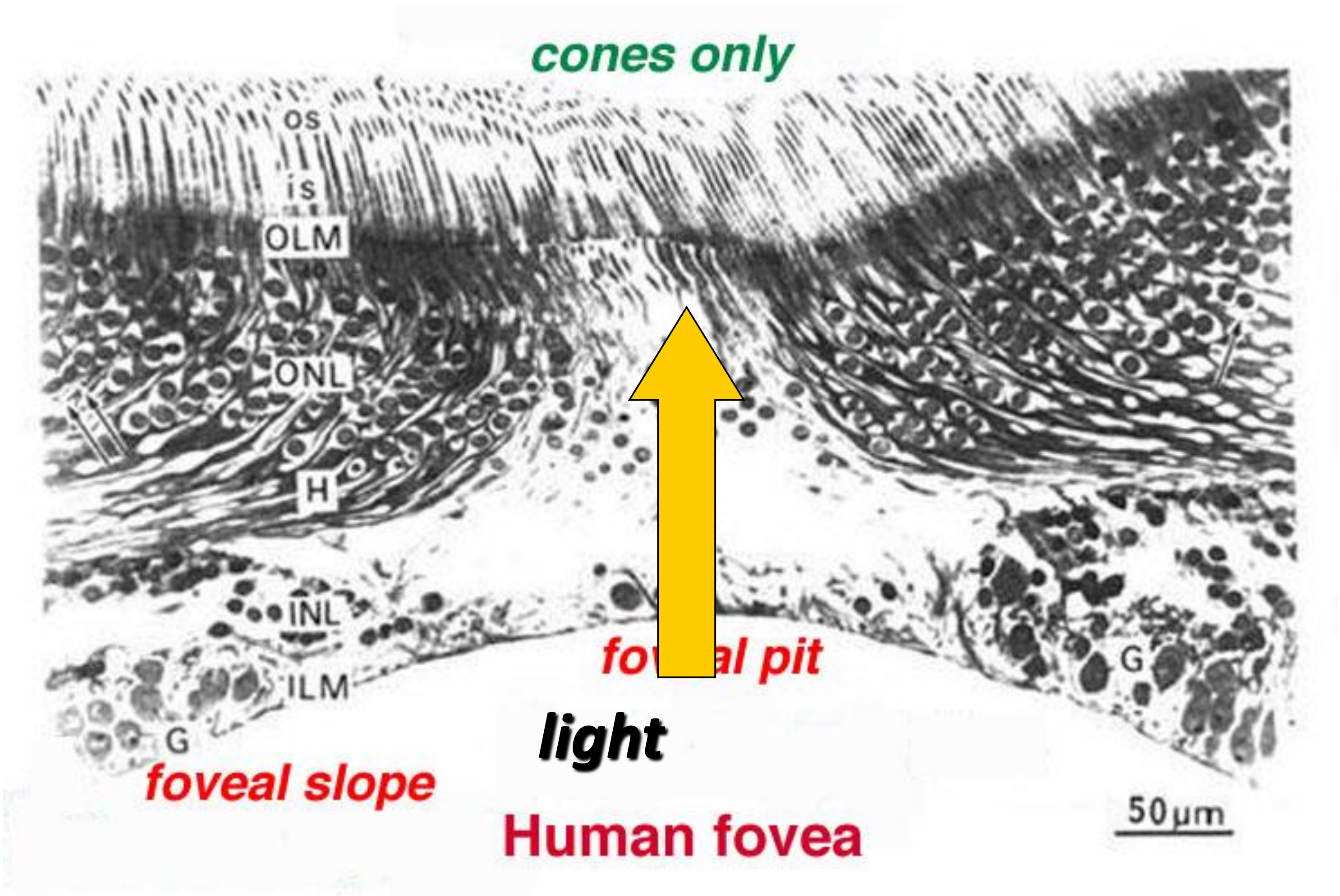


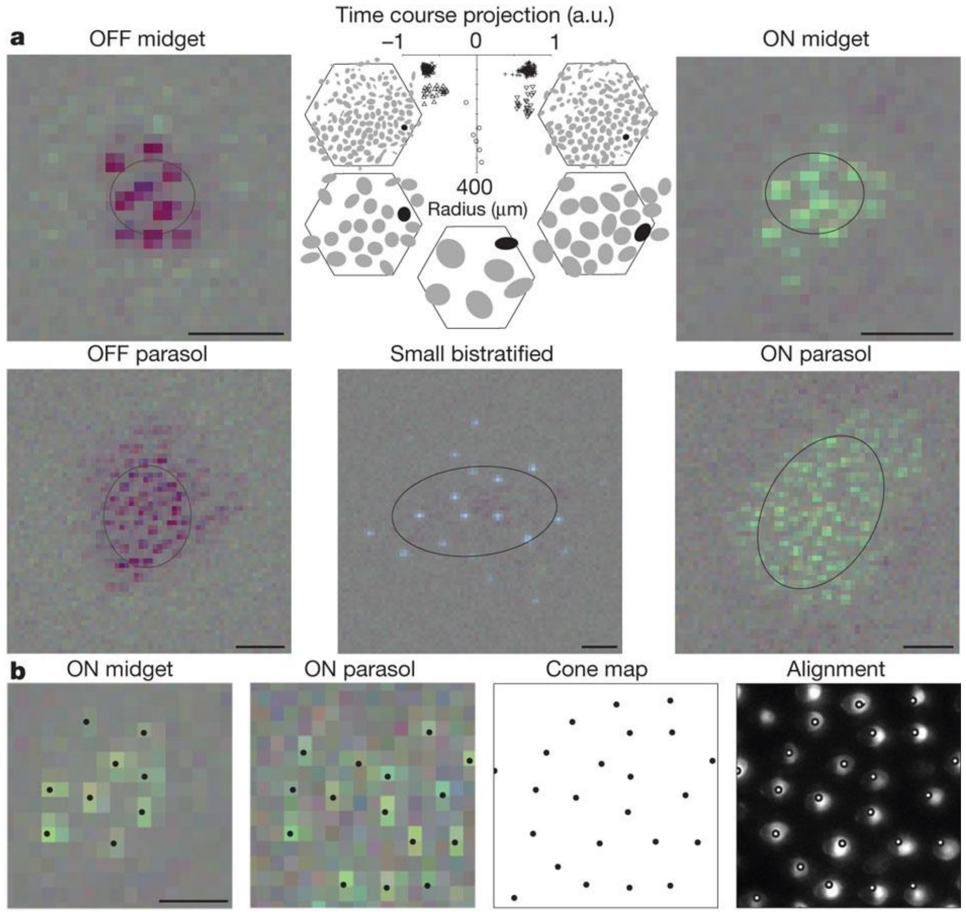
FIGURE 4.9 The schematic retina of Dowling and Boycott Z1966). R, rod; C, cone; MB, midget bipolar; RB, rod bipolar; FB, flat bipolar; H, horizontal cell; A, amacrine cell; MG, midget ganglion cell; DG, diffuse ganglion cell.

http://www.cis.rit.edu/people/faculty/montag/vandplite/pages/chap_8/ch8p3.html

cross section of fovea (note cones only and pit)



Nature 210 (many subtypes of retinal cells)



Functional connectivity in the retina at the resolution of photoreceptors

Greg D. Field, Jeffrey L. Gauthier, **Alexander Sher**, Martin Greschner, Timothy A. Machado, Lauren H. Jepson,Jonathon Shlens,Deborah E. Gunning,Keith Mathieson,Wladyslaw Dabrowski,Liam Paninski, **Alan M. Litke**& E. J. Chichilnisky

Santa Cruz Institute for Particle Physics, University of California, Santa Cruz, California 95064, USA

- Alexander Sher &
- Alan M. Litke

Prof. Alexander 'Sasha' Sher
Department of Physics and
SCIPP

Retinal Structure and Function
Retinal Regeneration
Advanced Multi-electrode
Recording Techniques

read more

2. Know the following terms associated with the cells of the retina and retinal structure:

   - ✓ a. rods
   - ✓ b. cones
   - ✓ c. horizontal cells
   - ✓ d. bipolar cells
   - ✓ e. amacrine cells
   - ✓ f. ganglion cells
   - ✓ g. fovea
   - ✓ h. optic nerve

3. **Response properties and interconnectivity among cells of the retina**

   a. **What are the synaptic connections among the cells of the retina?**
   b. **What is a ribbon synapse?**
   c. **In vertebrates, do receptors hyperpolarize or depolarize in response to light?**
   d. **Which retinal cells communicate by graded potentials and which by action potentials?**

synaptic connections in retina

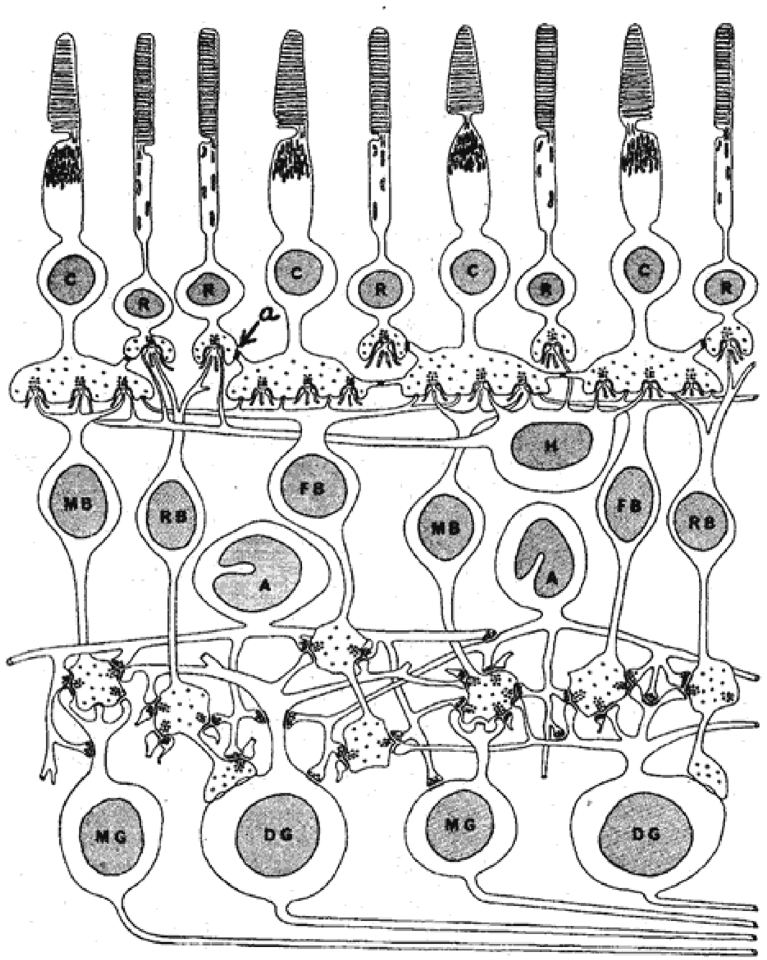
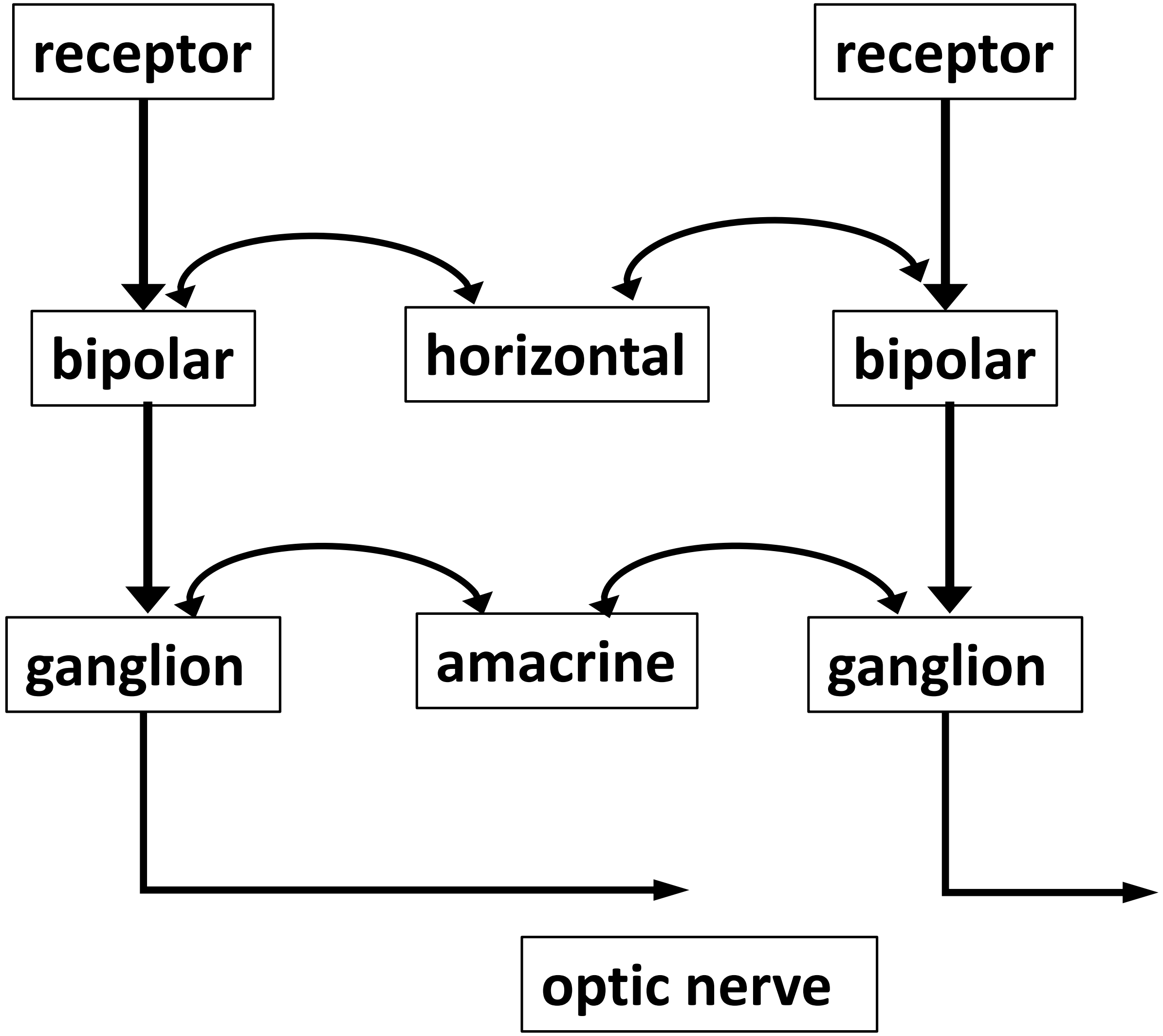
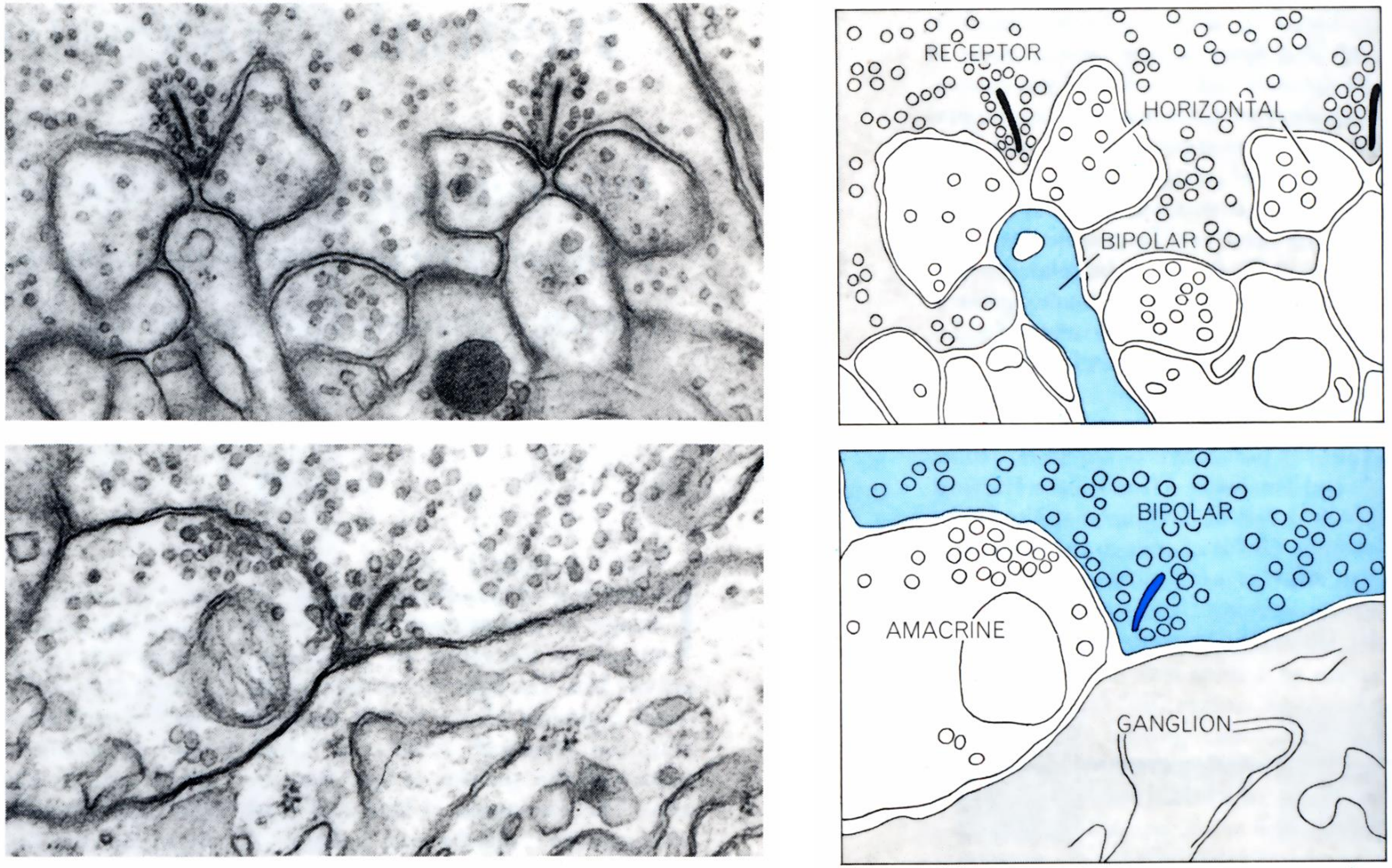


FIGURE 4.9 The schematic retina of Dowling and Boycott Z1966). R, rod; C, cone; MB, midget bipolar; RB, rod bipolar; FB, flat bipolar; H, horizontal cell; A, amacrine cell; MG, midget ganglion cell; DG, diffuse ganglion cell.

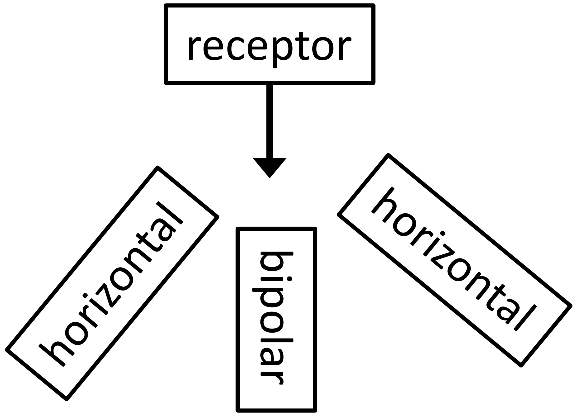
http://www.cis.rit.edu/people/faculty/montag/vandplite/pages/chap_8/ch8p3.html



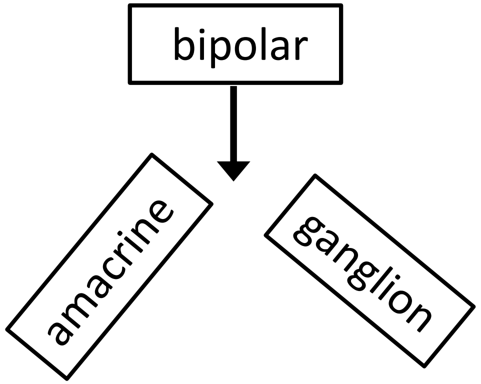
Ribbon Synapses



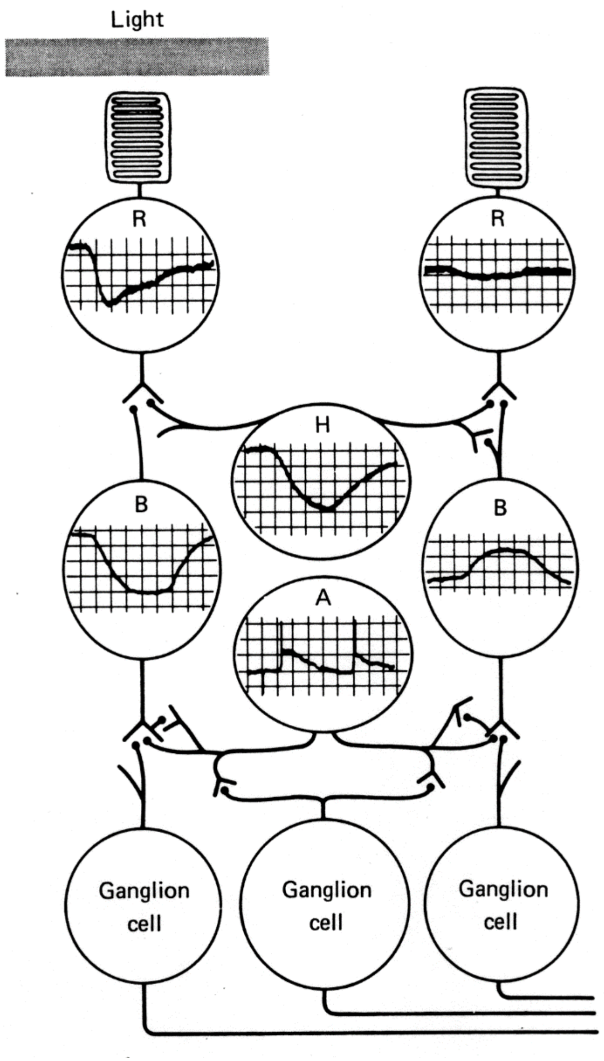
triad



dyad



electrical activity in retinal cells: graded vs action potentials



receptor hyperpolarizes in response to light (gee whiz)

horizontal and bipolar cells respond with hyperpolarizing or depolarizing graded potentials

amacrine cells graded, sometime spiking

ganglion cells send action potentials down the optic nerve

3. Response properties and interconnectivity among cells of the retina

✓ **a. What are the synaptic connections among the cells of the retina?**
✓ **b. What is a ribbon synapse?**
✓ **c. In vertebrates, do receptors hyperpolarize or depolarize in response to light?**
✓ **d. Which retinal cells communicate by graded potentials and which by action potentials?**

behavioral phenomena related to receptors

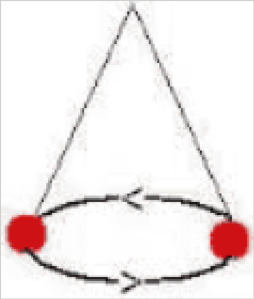
5. **Understand how the following psychophysical phenomena are related to processes occurring in the retina:**

✓ **a. dark adaptation**

b. Pulfrich pendulum

c. Mach bands

Pulfrich Pendulum

	Pulfrich Pedulum Class Demonstration	Pulfrich Pendulum Report	~January 25–27th

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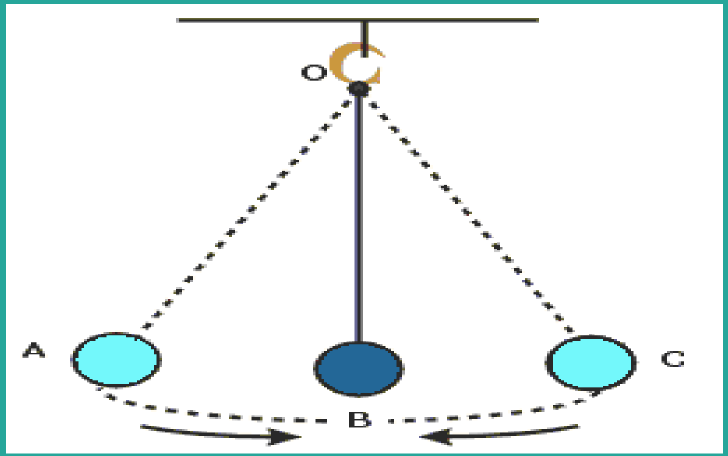


The Pulfrich Effect

—

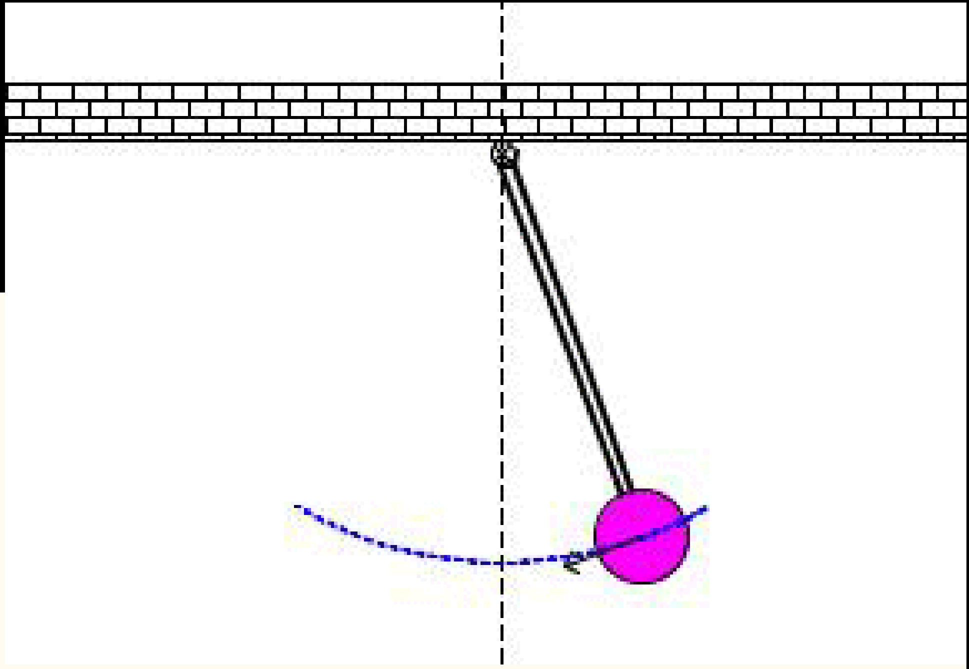
Christiana Kardamilas, Switkes, Crown 85:Visual Perception

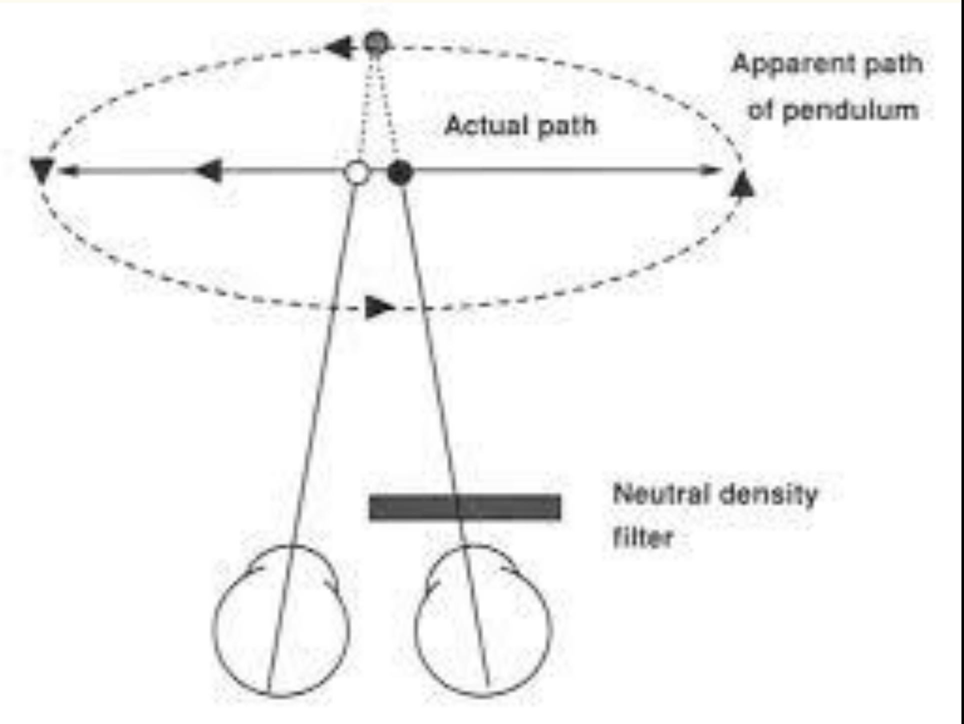
The Definition

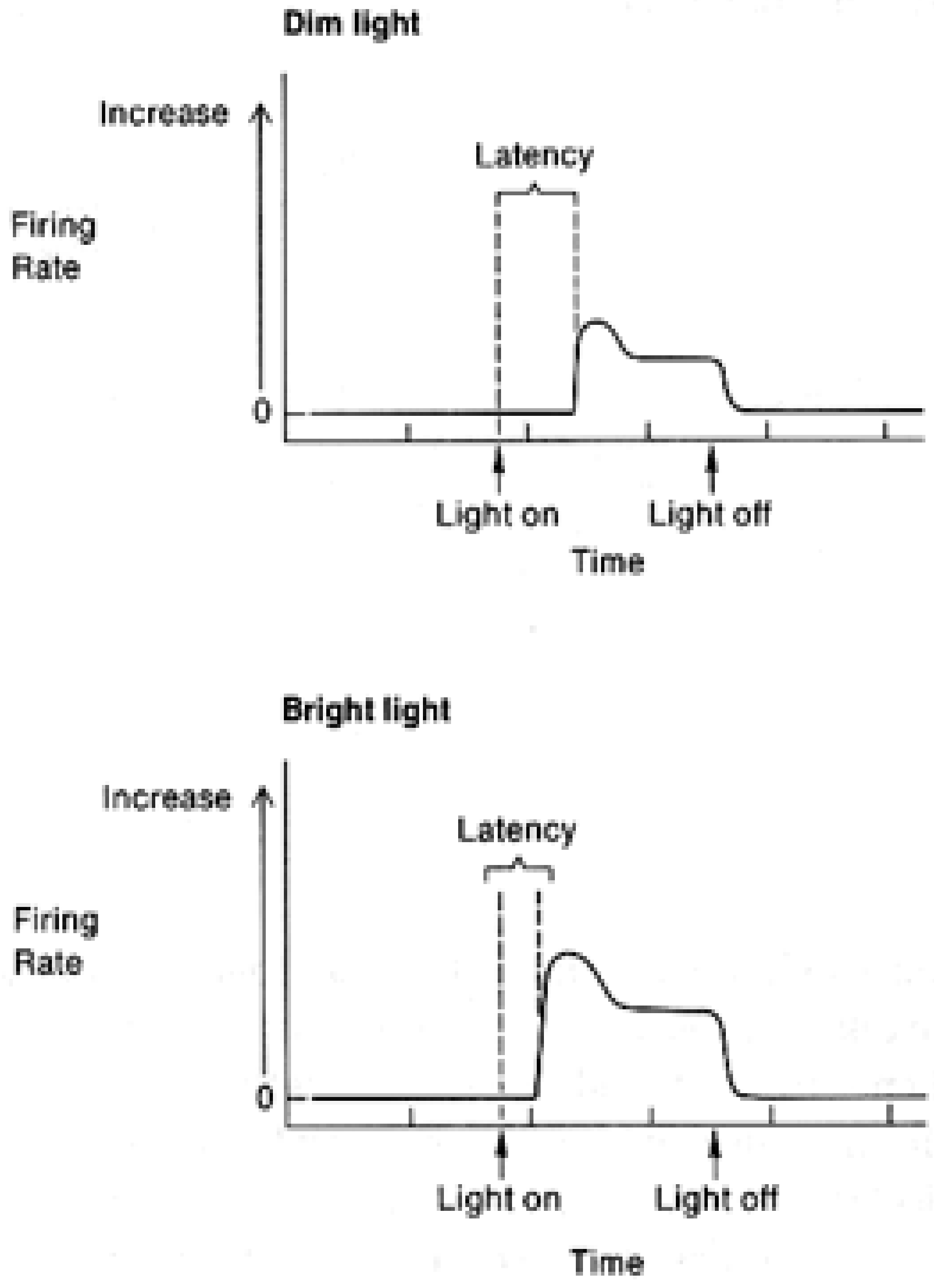
The Pulfrich Pendulum:

- The Pulfrich pendulum is an “illusion” that alters our perception of the depth, size, velocity and position of a moving pendulum.

- This is the result of a time lag in the processing of differing signals from the two eyes, one shaded and one not.







The Explanation

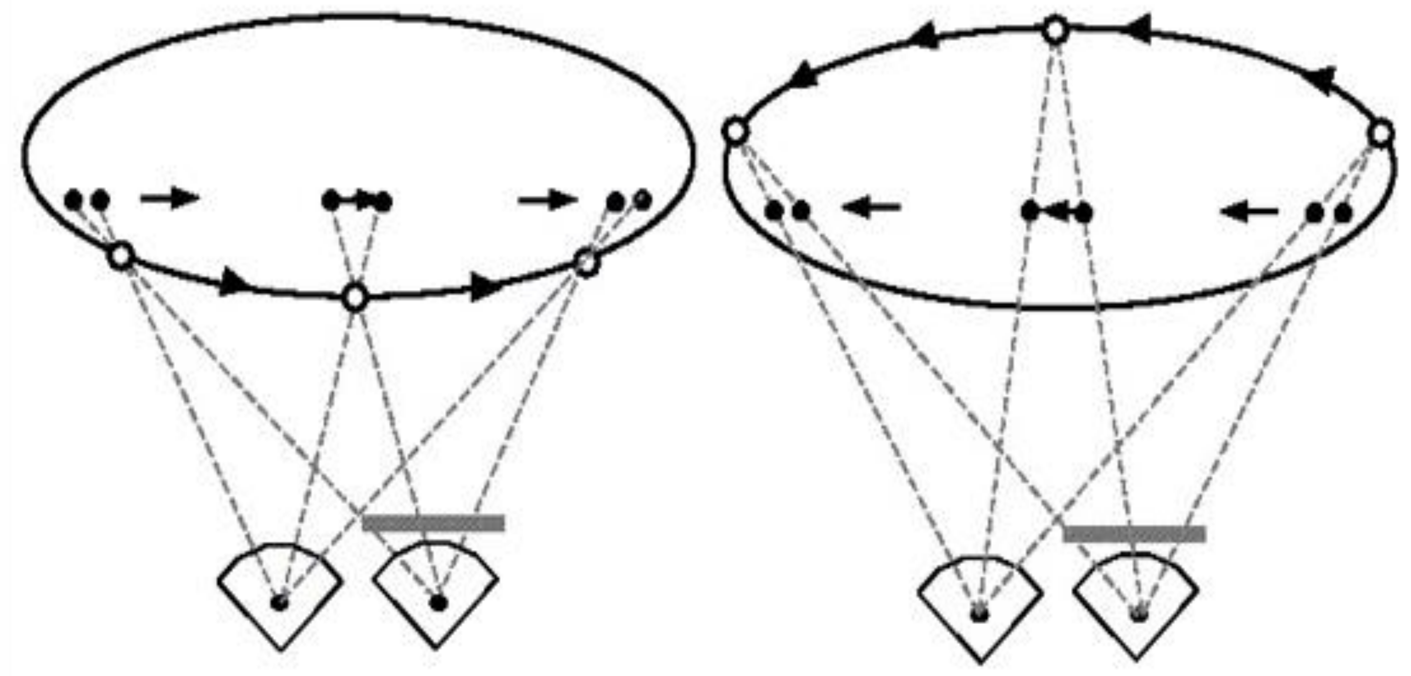
Light Intensity vs Latency

- Latency: the interval between the stimulation and the response.
- Firing rate: rate of signals being passed to the visual cortex.
- Higher light intensity means shorter latency period (A very good thing).
- In the covered eye the latency period is longer.

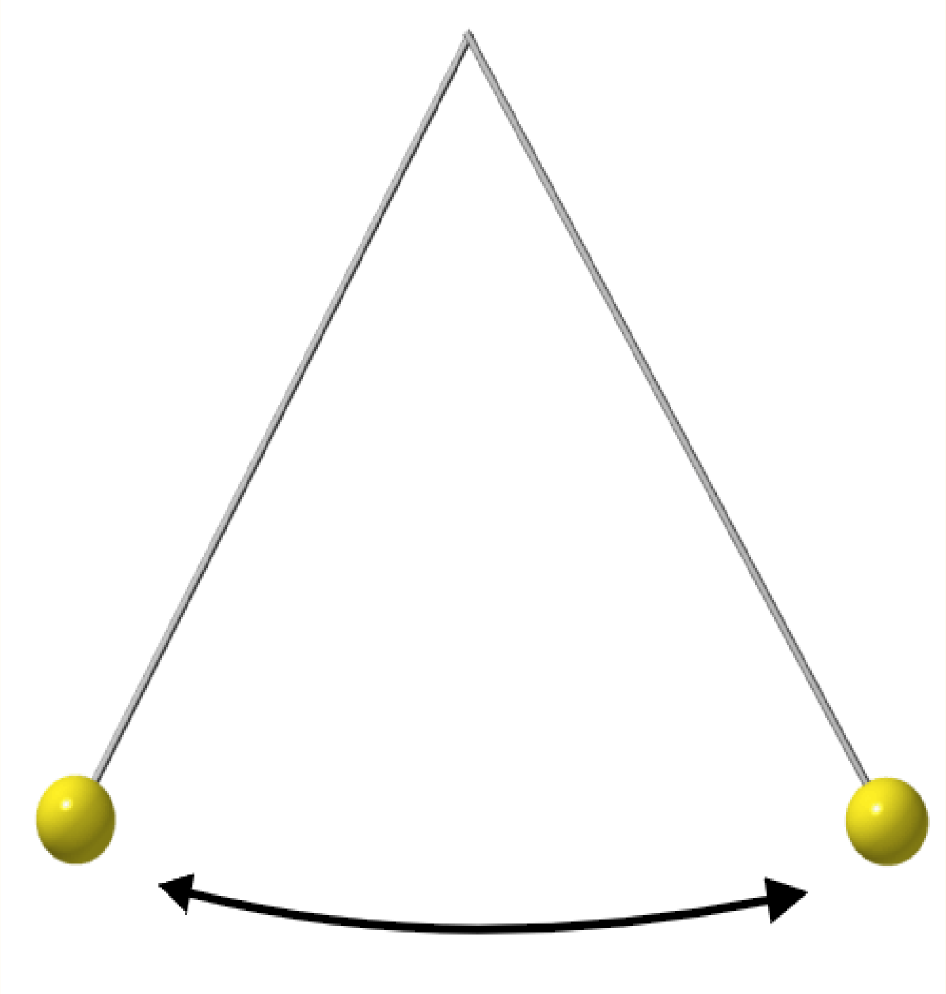
What That Means

- The covered eye takes longer to process the information (as the rods and cones in the retina of that eye take longer to respond than in the uncovered eye)

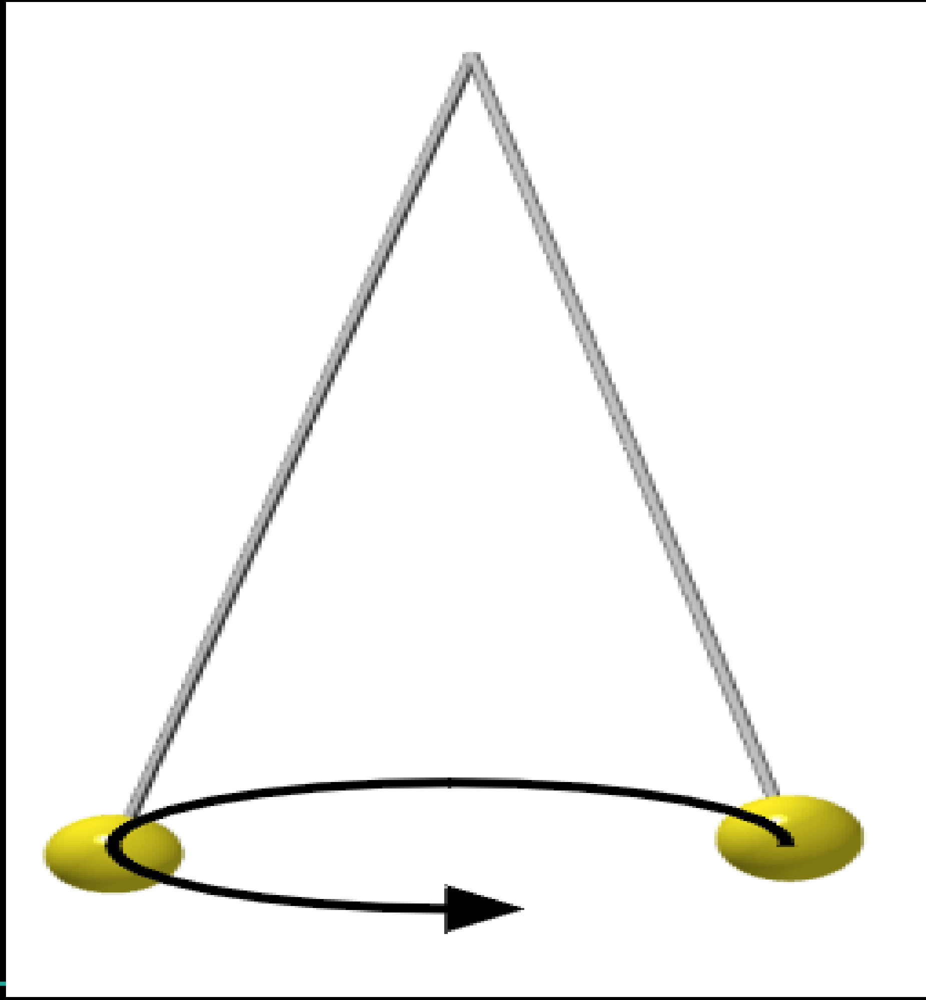
- The brain makes sense of this by combining the two images, interpreting the motion of the ball as an ellipse.



So with the Shade:

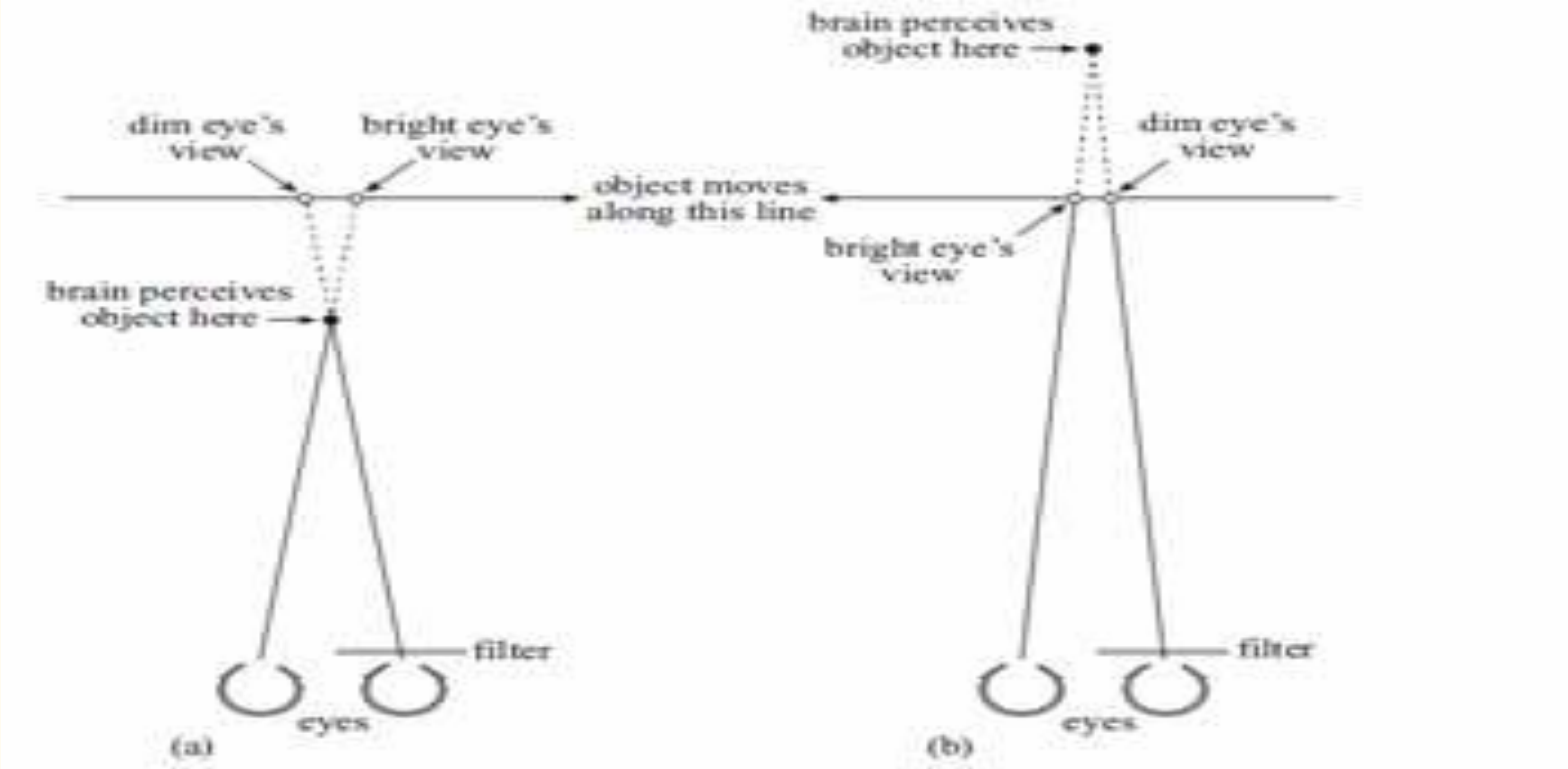


This

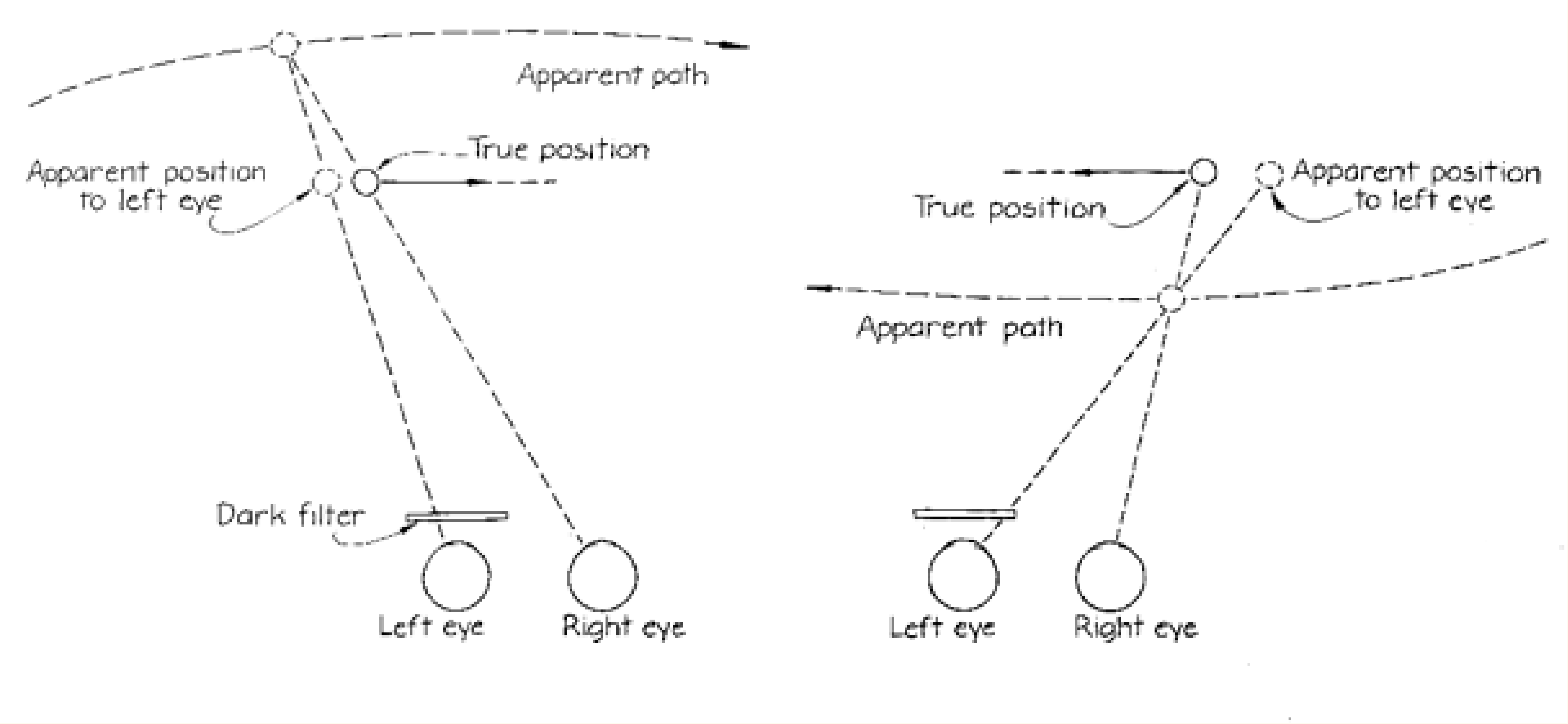


Turns into this

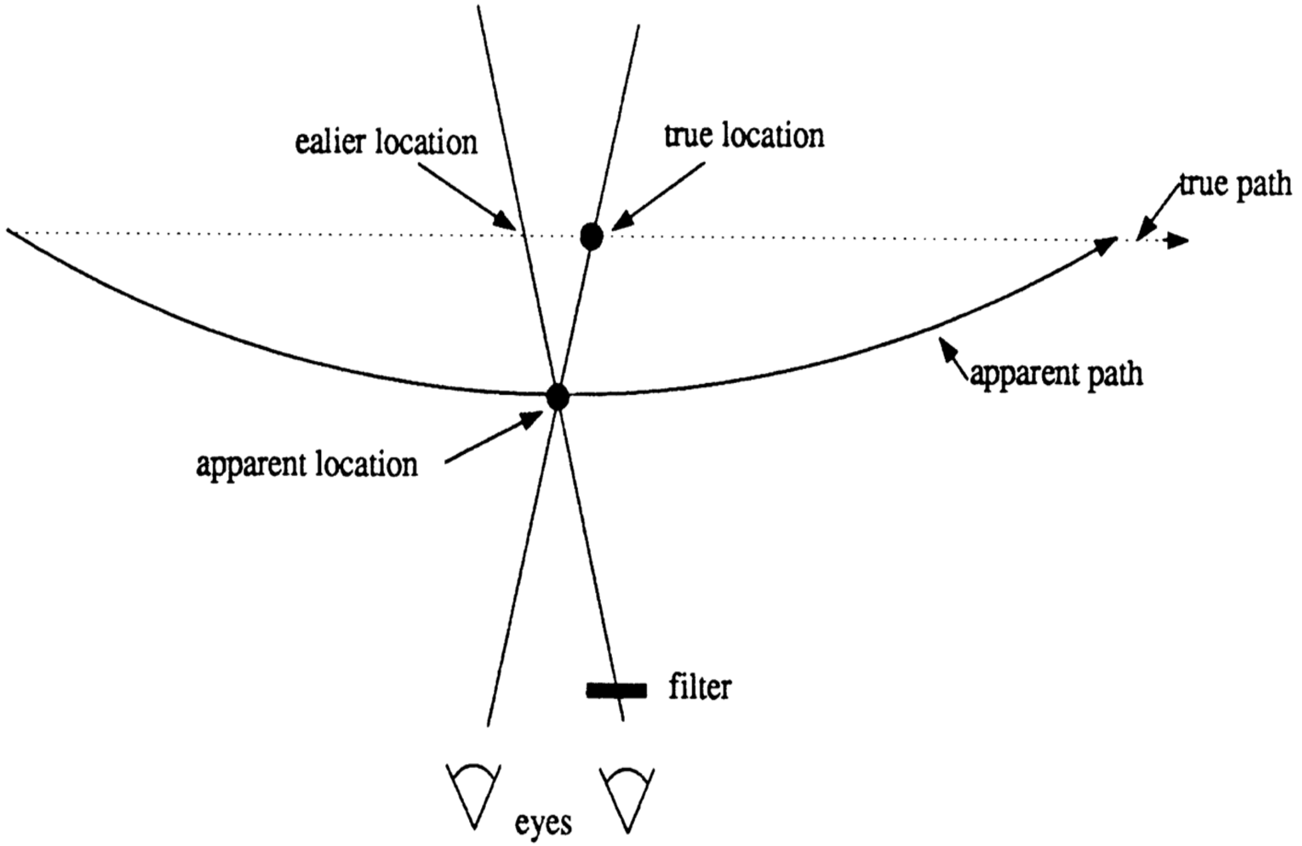
More Diagrams



. . . And More Diagrams



Final Diagrams



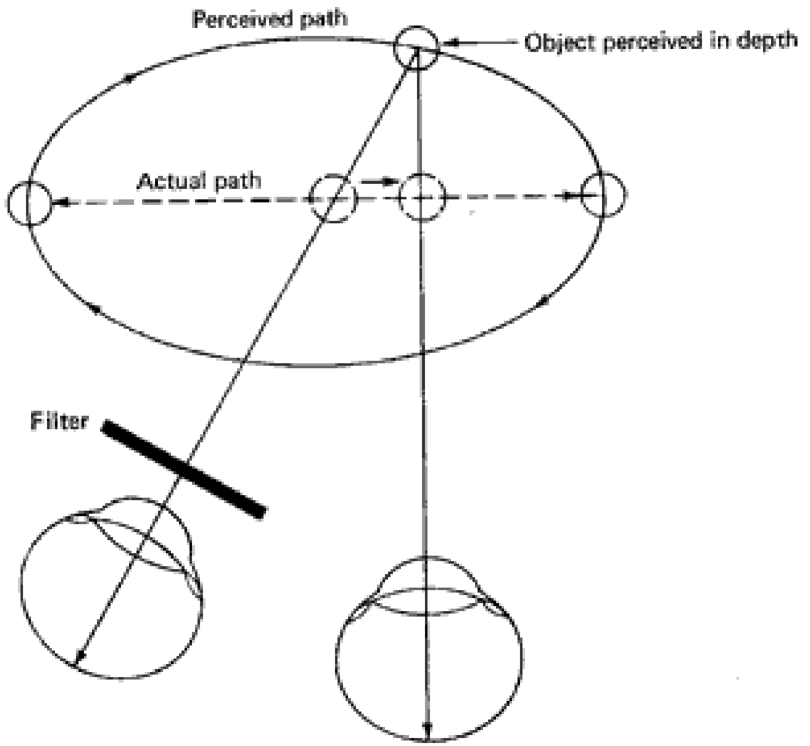
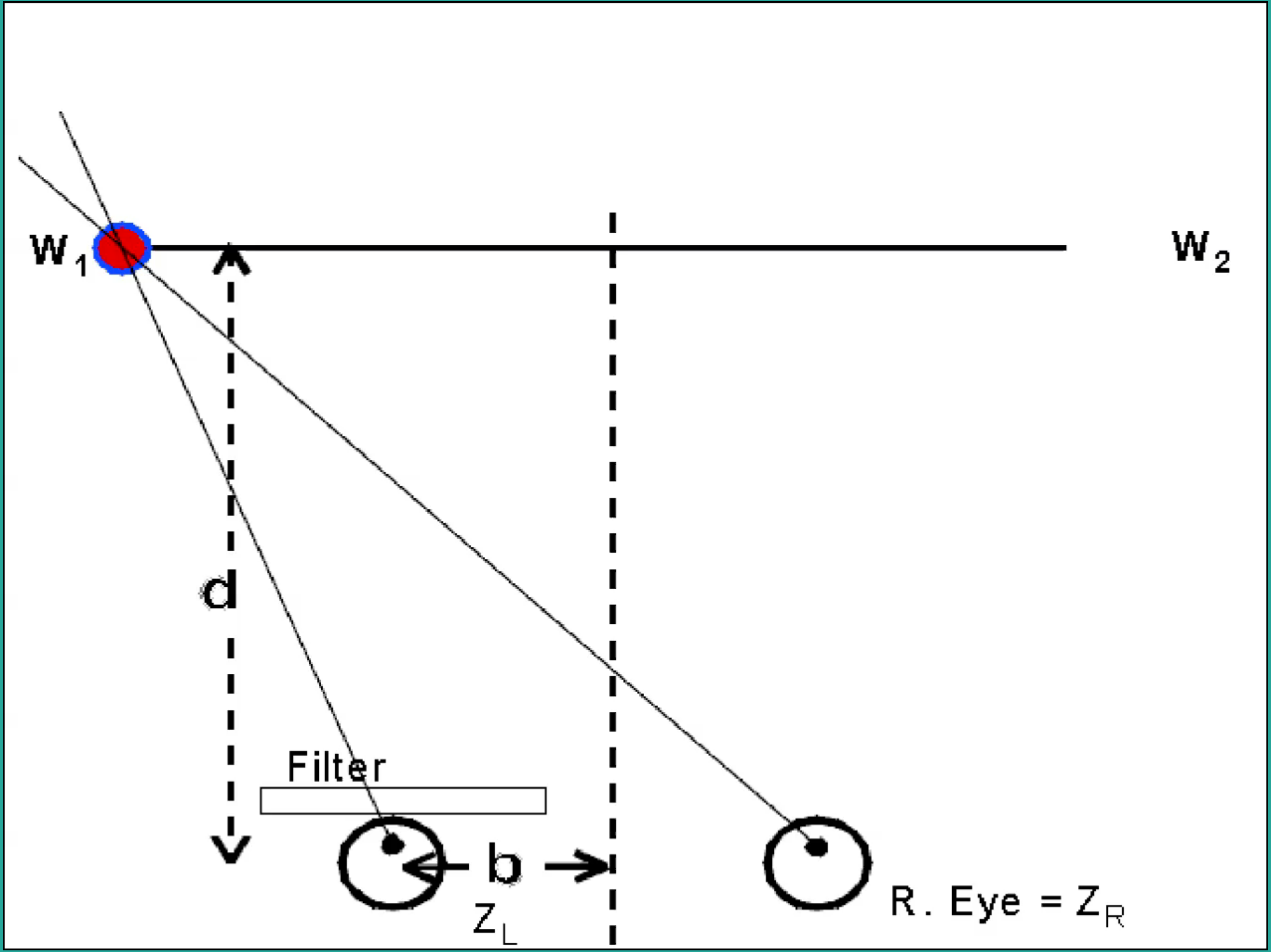


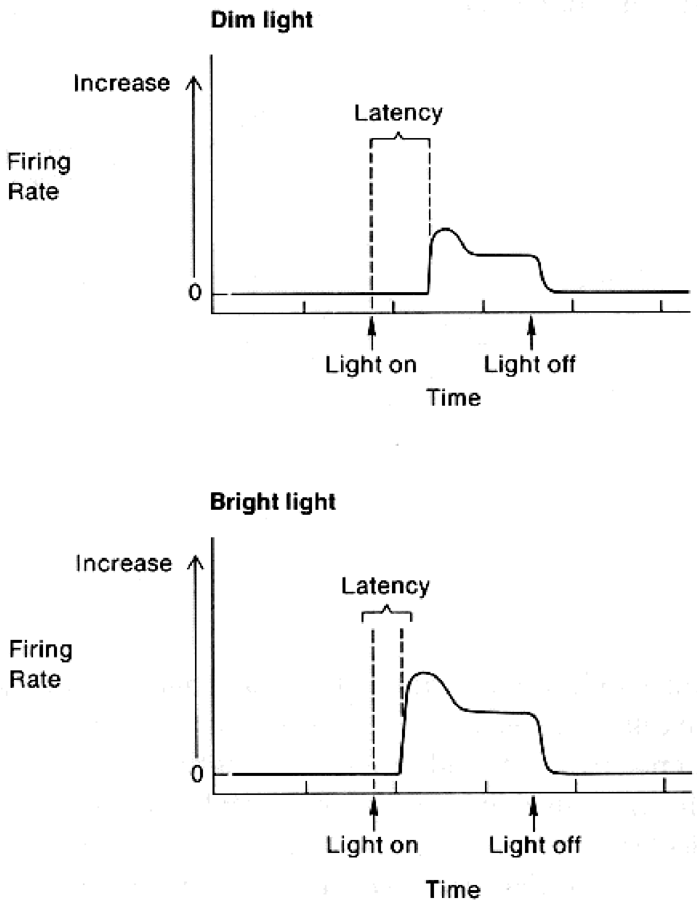
Fig. 13.7. The Pulfrich phenomenon. The attenuated eye perceives the pendulum ball as lagging behind the position as seen by the unattenuated eye. This is consistent with the ball actually traveling in an elliptical path, as shown.


W1
W2
d
Filter
b
ZL
R. Eye = ZR

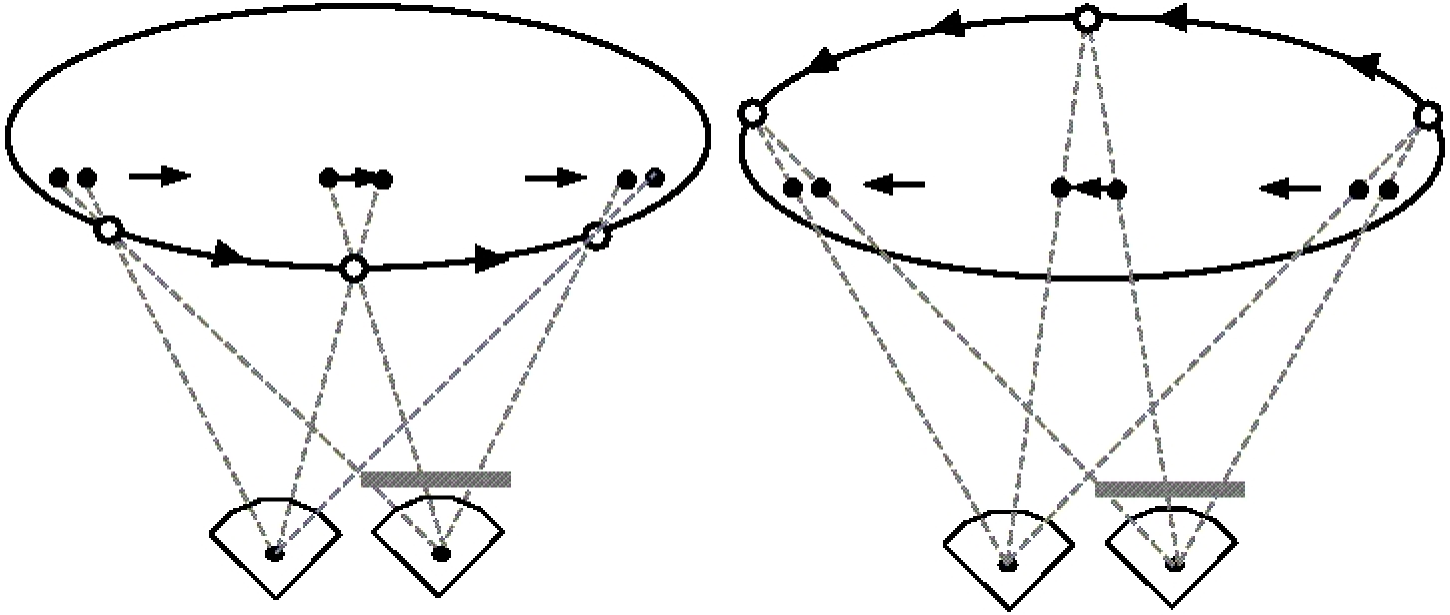
References to check out:

- http://pulfrich.siu.edu/Pulfrich_Pages/explains/expl_ani/explaina.html
- http://pulfrich.siu.edu/Pulfrich_Pages/explains/expl_ani/geom_big.htm
- https://prezi.com/all2ah4bqmfw/the-pulfrich-effect/
- http://berkeleyphysicsdemos.net/node/727
- https://www.youtube.com/watch?v=0Rv5DU-1FuE

Pulfrich pendulum: latency vs light intensity



Pulfrich Pendulum



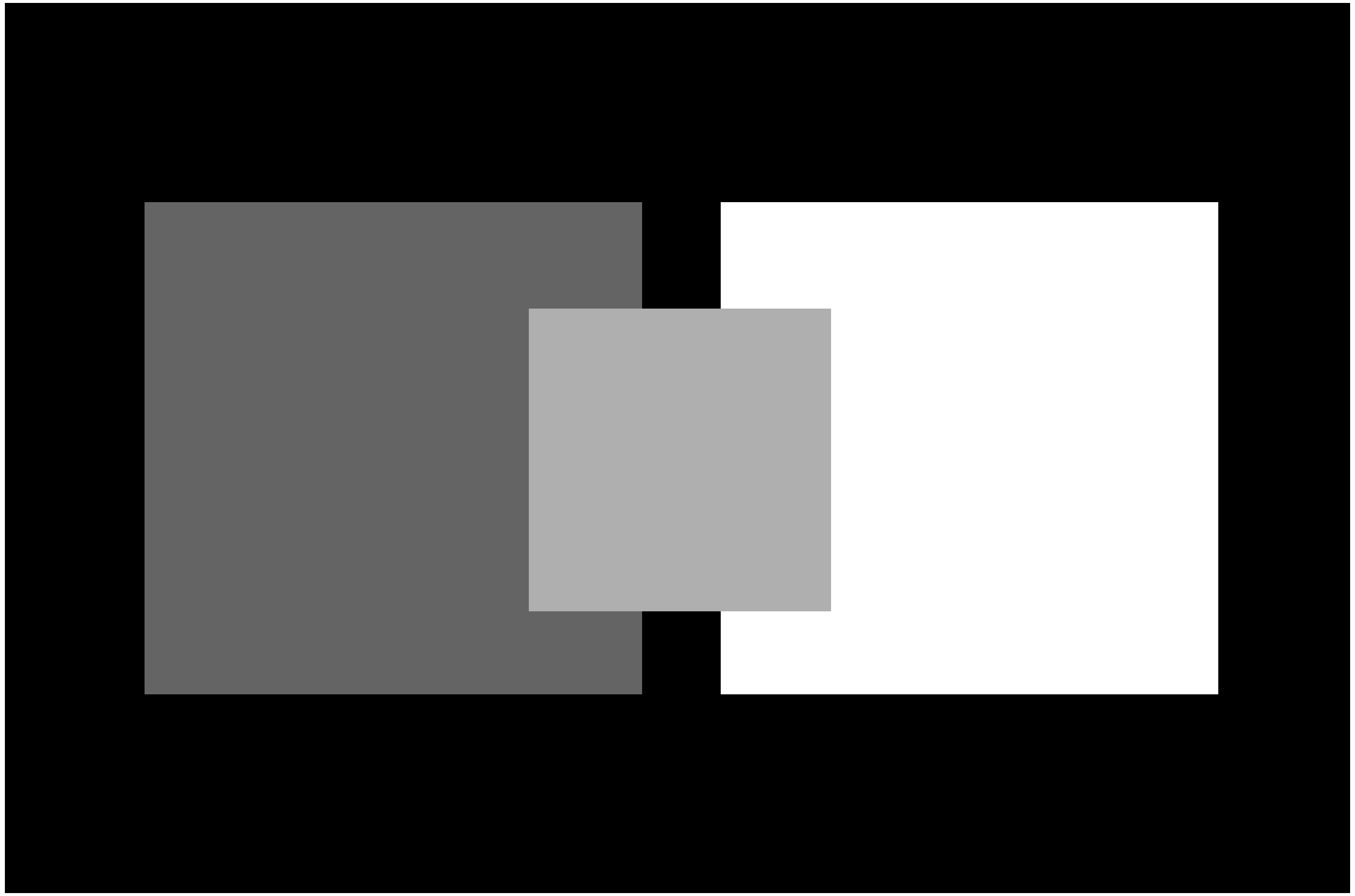
behavioral phenomena related to receptors

5. **Understand how the following psychophysical phenomena are related to processes occurring in the retina:**
   - ✓ **a. dark adaptation**
   - ✓ **b. Pulfrich pendulum**
   - **c. Mach bands**

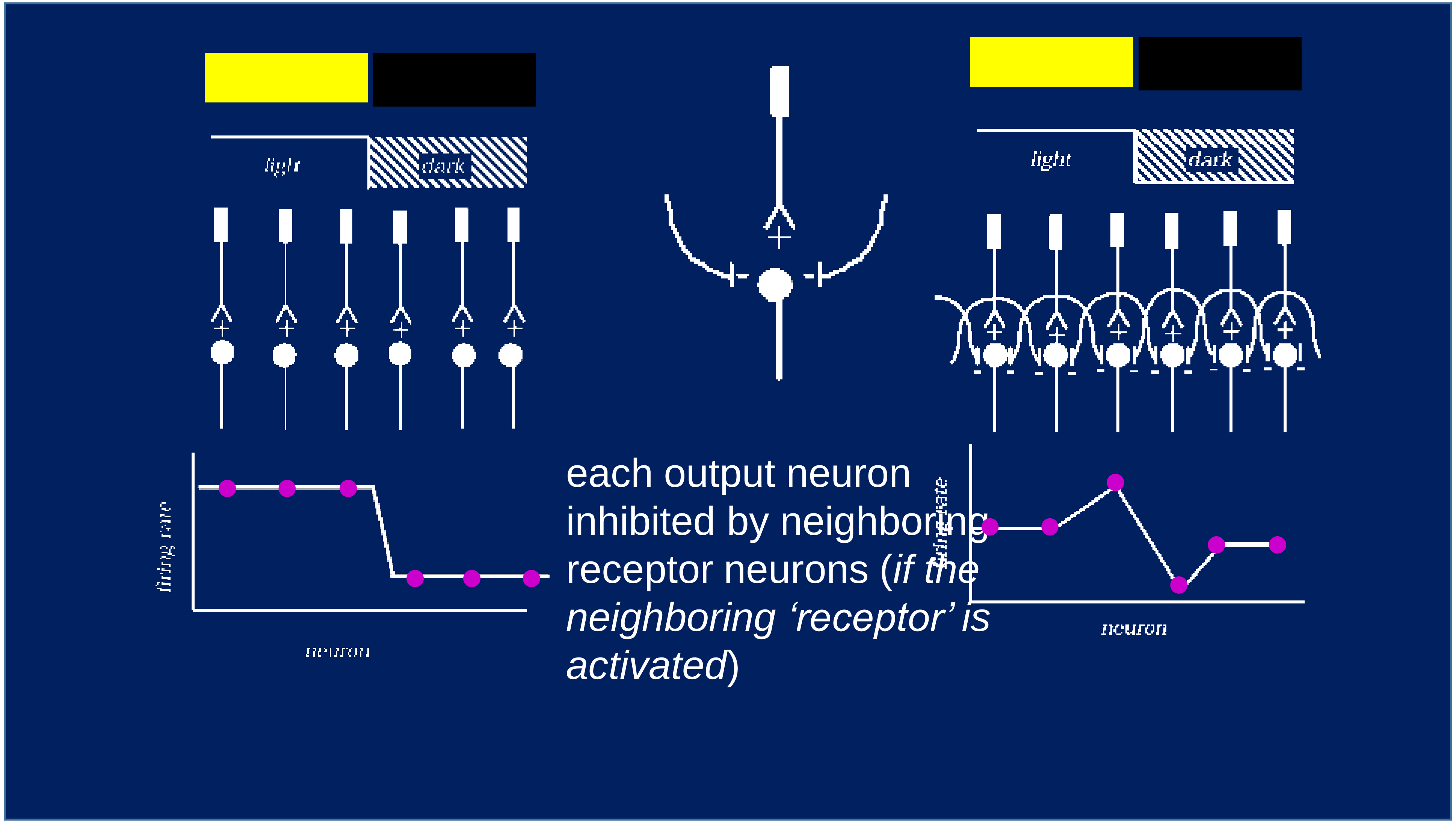
4. **Lateral inhibition is an important example of coding by neural networks.**
   Be sure to understand the how the “simple” network diagramed in class allows the visual system to emphasize the perception of contrast (spatial changes in luminance).

this illustrates: **contrast**

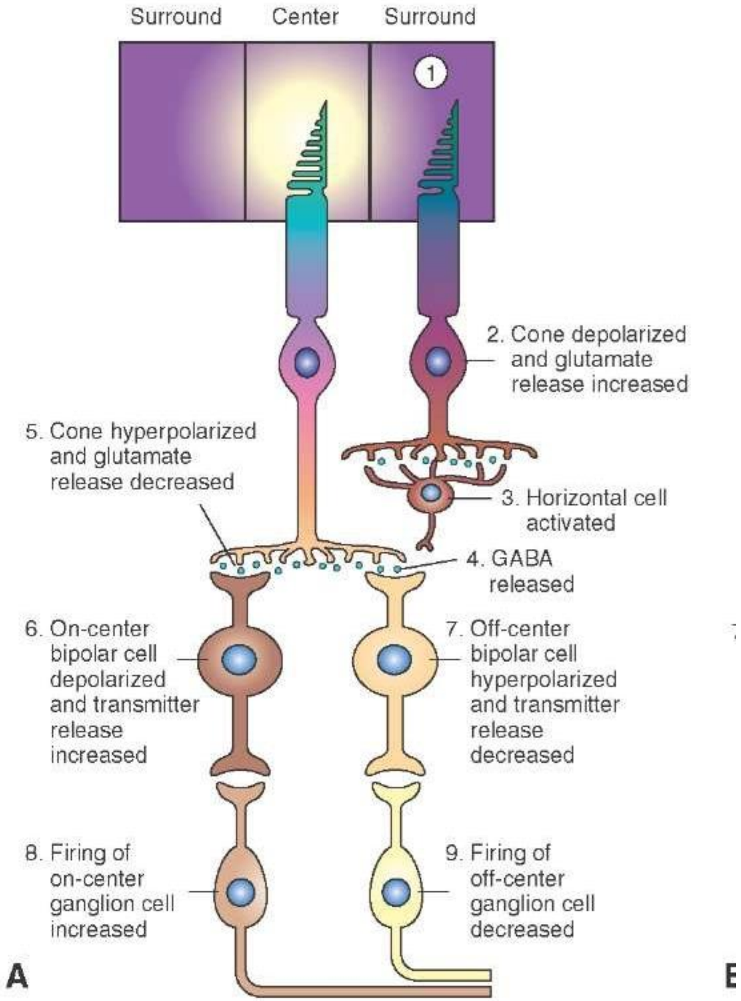
this illustrates: ***contrast***

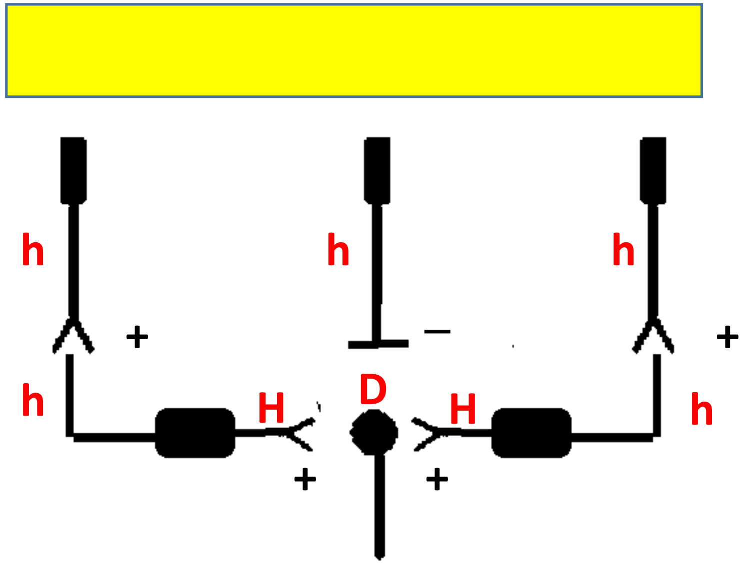


idealized neural network for: lateral INHIBITION



"real" retinal lateral inhibition network *[advanced]*



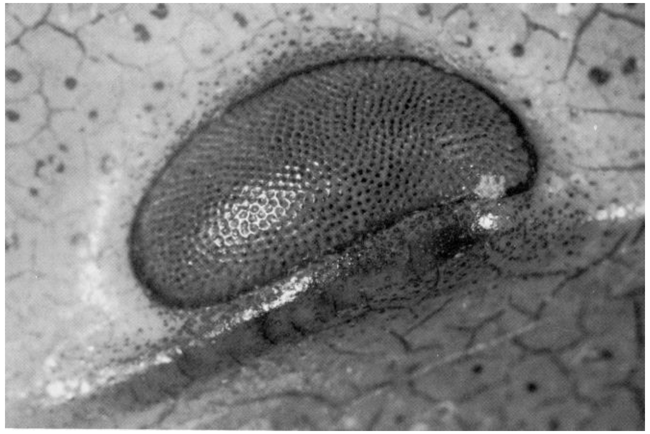


on-center bipolar

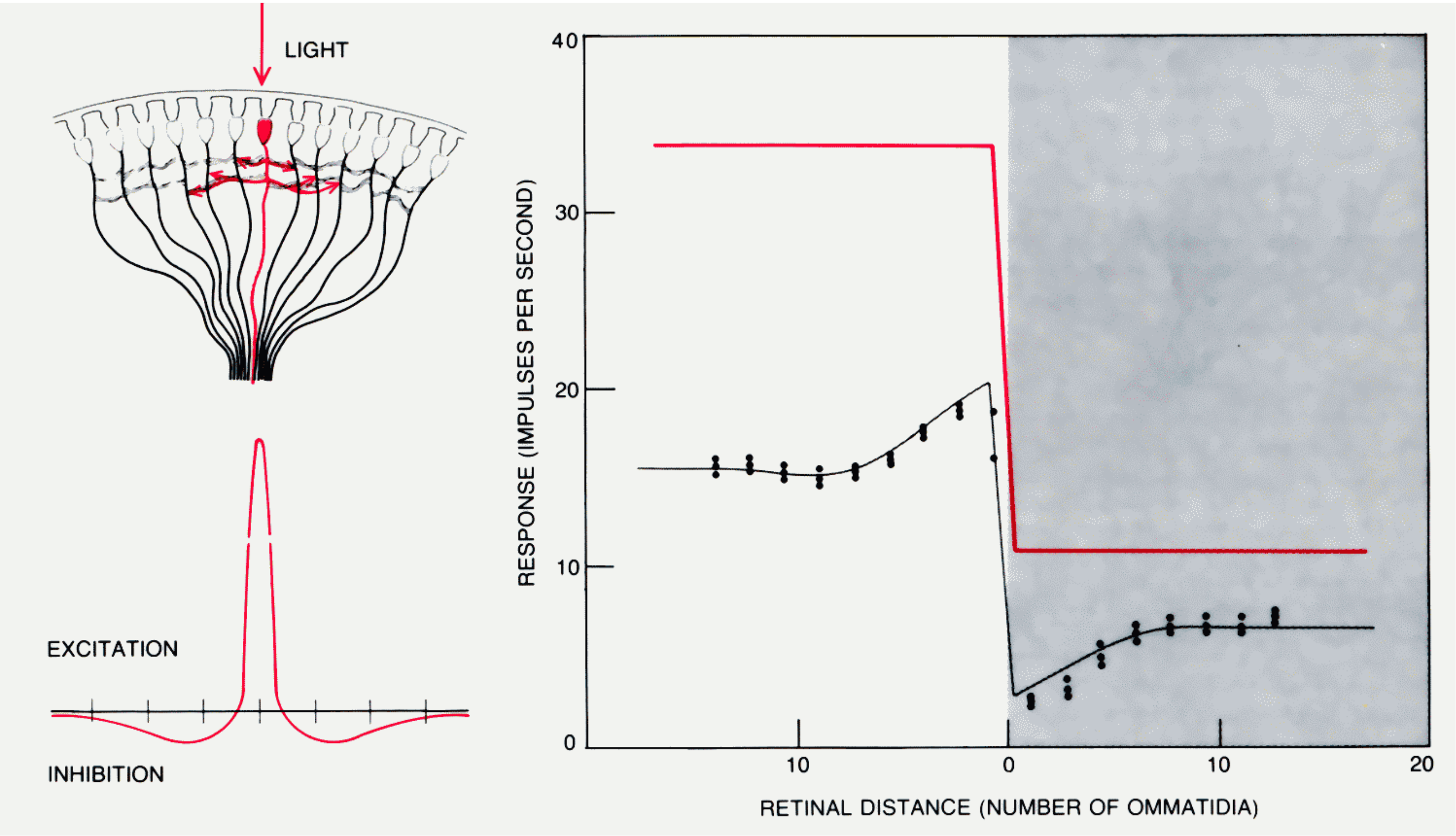
(depolarizes to light on central receptor; has hyperpolarizing glutamate receptors)

http://what-when-how.com/neuroscience/visual-system-sensory-system-part-2/

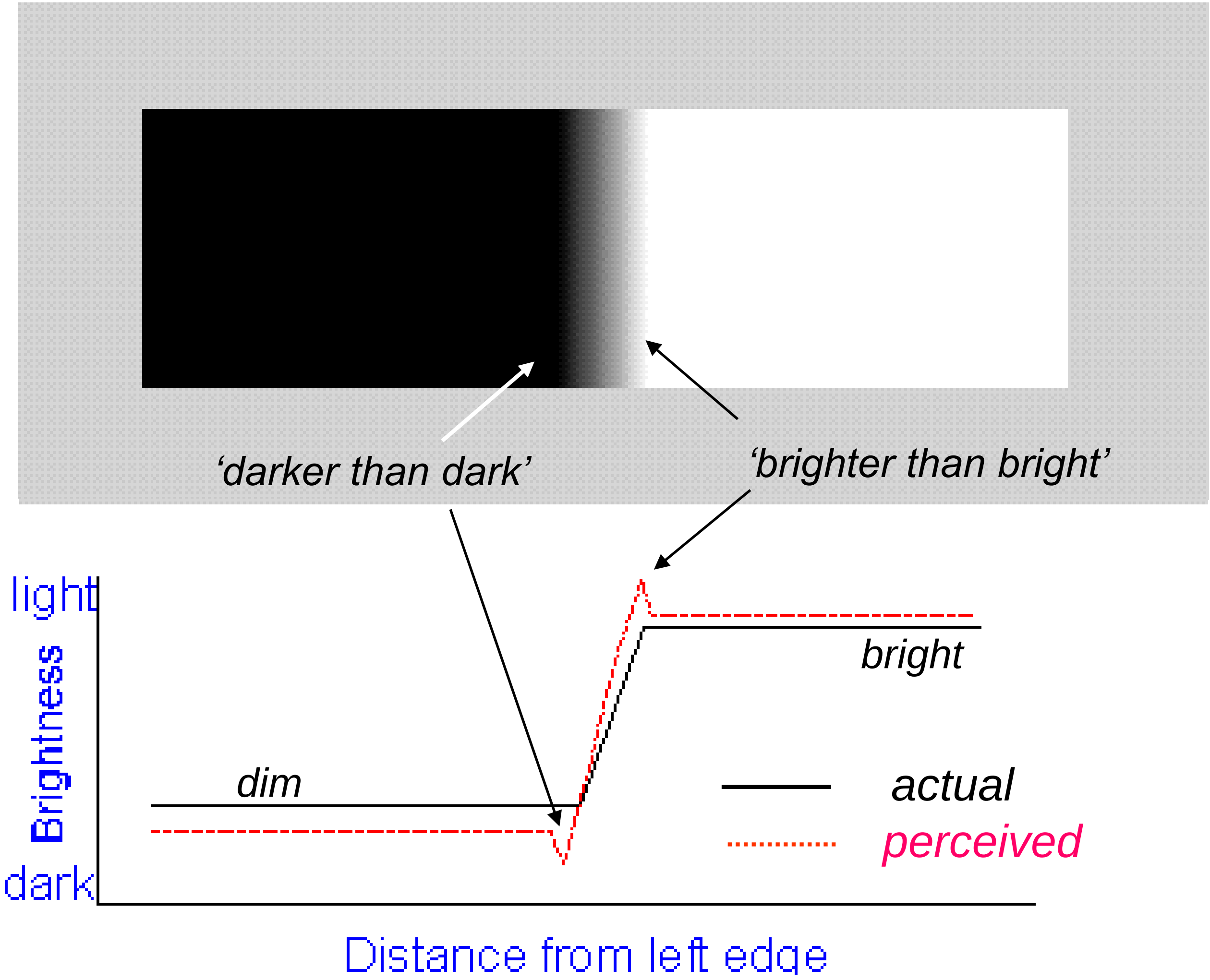
limulus– horseshoe crab



recording from limulus eye



Mach bands



'darker than dark'
'brighter than bright'
light
Brightness
dark
dim
bright
actual
perceived
Distance from left edge

and finally !!!

✓ 4. Lateral inhibition is an important example of coding by neural networks. Be sure to understand the how the "simple" network diagramed in class allows the visual system to emphasize the perception of contrast (spatial changes in luminance).

✓ 5. Understand how the following psychophysical phenomena are related to processes occurring in the retina:
   a. dark adaptation
   b. Pulfrich pendulum
   c. Mach bands

Finis

Table 2. Physical dimensions of the outer segment of mouse rods and cones. Salamander and primate photoreceptors are included for comparison purpose.

	Rods			Cones		
	Mouse	Primate	Salamander	Mouse	Primate	Salamander
Length (μm)	23.6	25	22	13.4	13	8
Diameter[a] (μm)	1.4	2	11	1.2	3_{bases}, 1_{tip}	4_{bases}, 2.5_{tip}
Volume (μm^3)	36	40	2000	14	30	70
References	(Carter-Dawson and LaVail, 1979)	(Baylor et al., 1984)	(Baylor and Nunn, 1986)	(Carter-Dawson and LaVail, 1979)	(Pugh and Lamb, 2000)	(Pugh and Lamb, 2000)

http://webvision.med.utah.edu/book/part-v-phototransduction-in-rods-and-cones/phototransduction-in-rods-and-cones/

receptors hyperpolarize with light !!!!