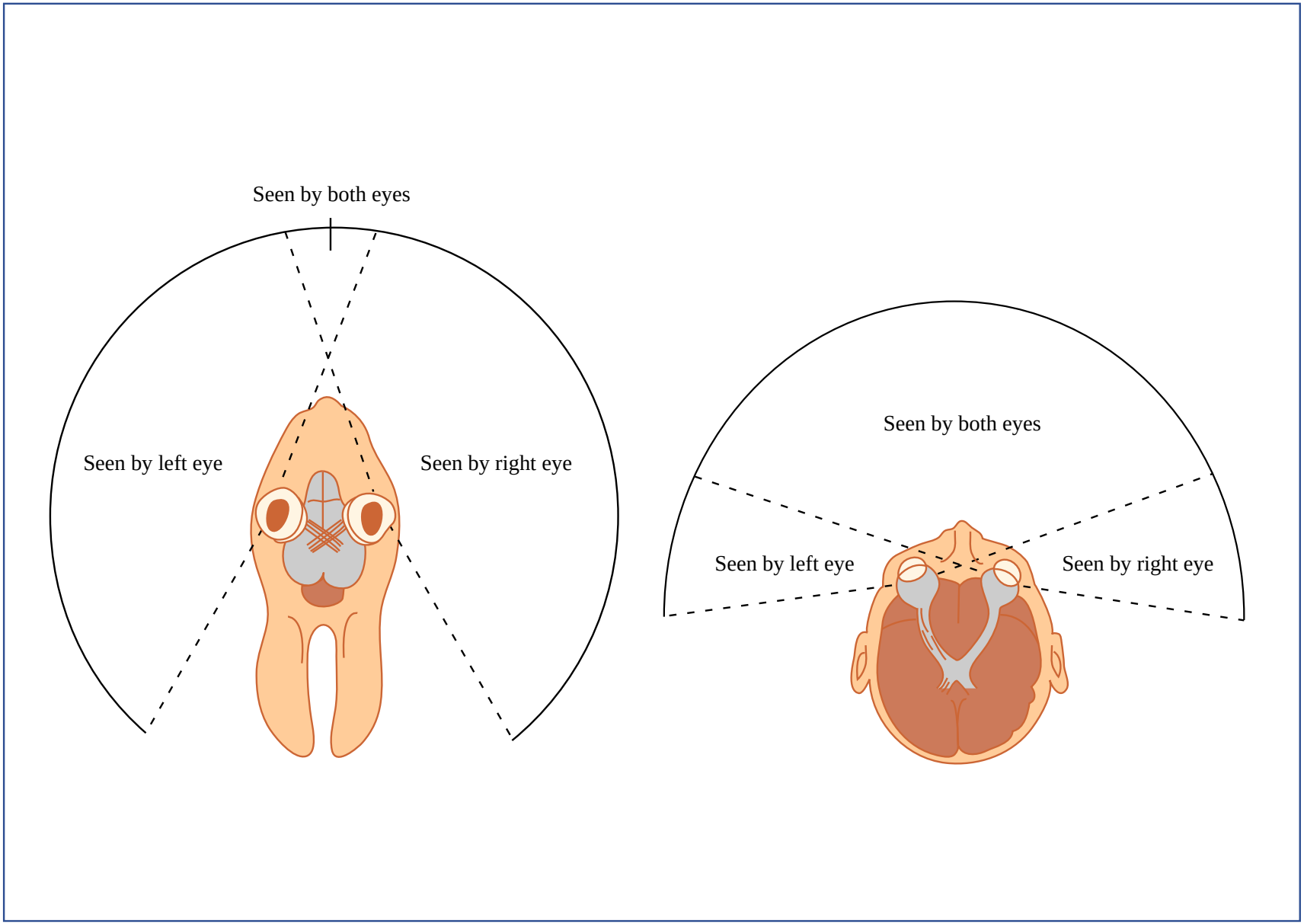
September 9, 2013:

The layout of the visual system, the retina and the lateral geniculate nucleus

Basic Wiring of the Visual System

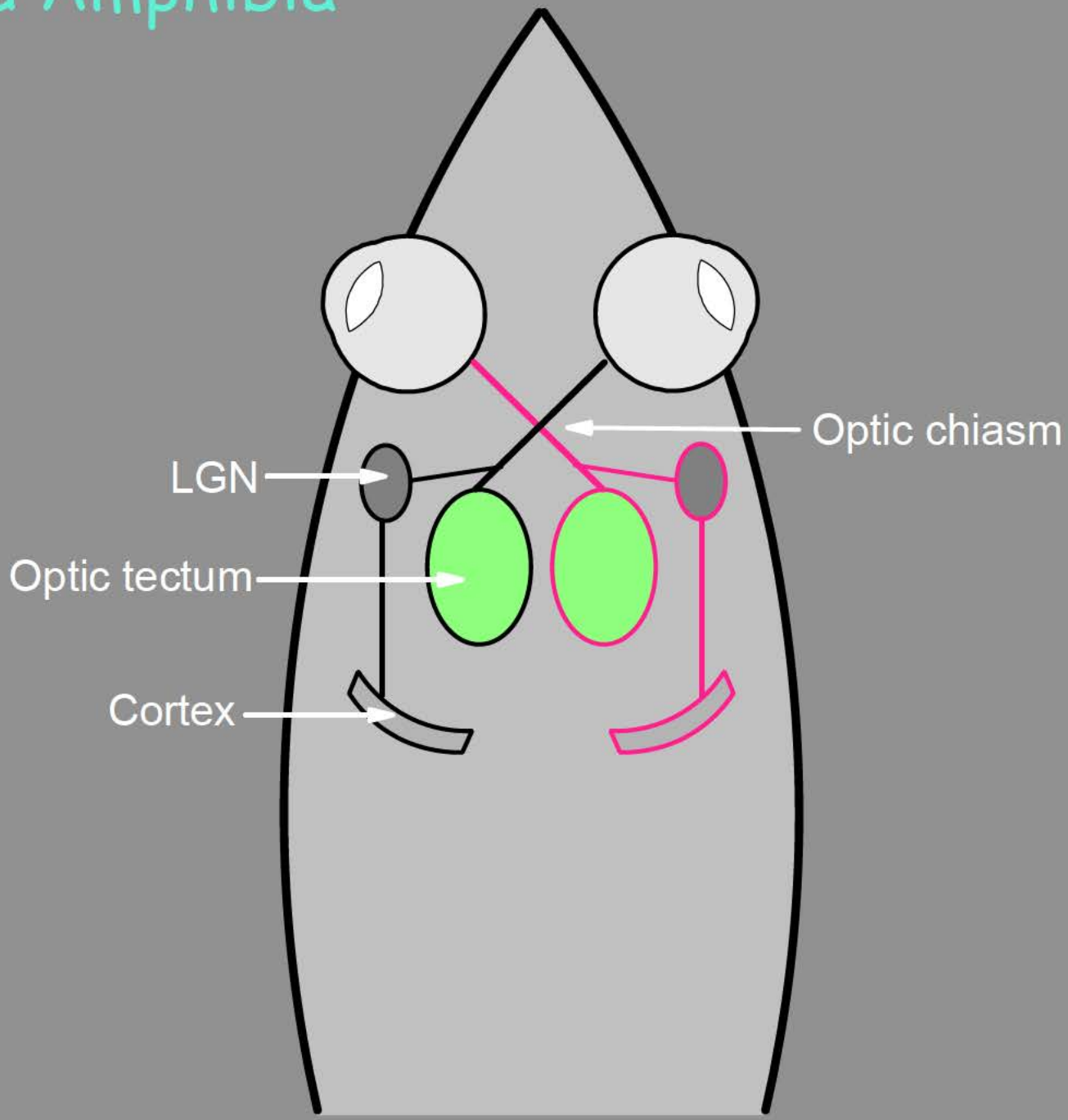
The world seen by the two eyes



rabbit

human

Fish and Amphibia



Primates

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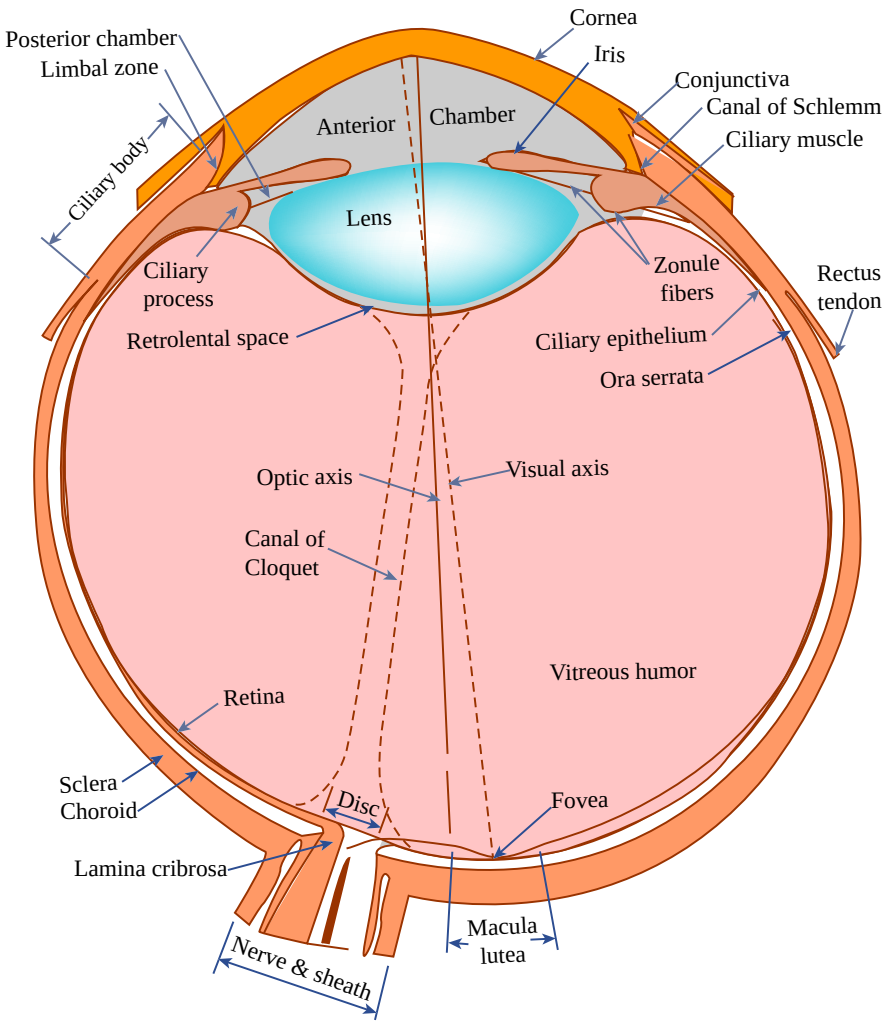
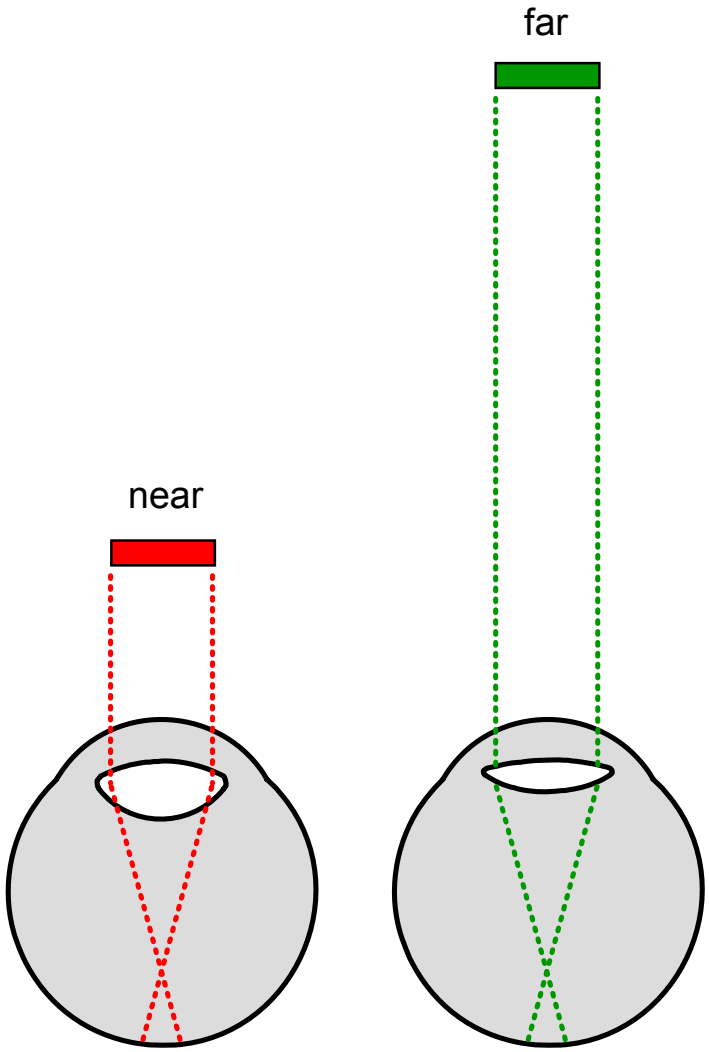
Please refer to lecture video or Figure 3 from Schiller, Peter H., and Edward J. Tehovnik. "Visual prosthesis." *Perception* 37, no. 10 (2008): 1529.

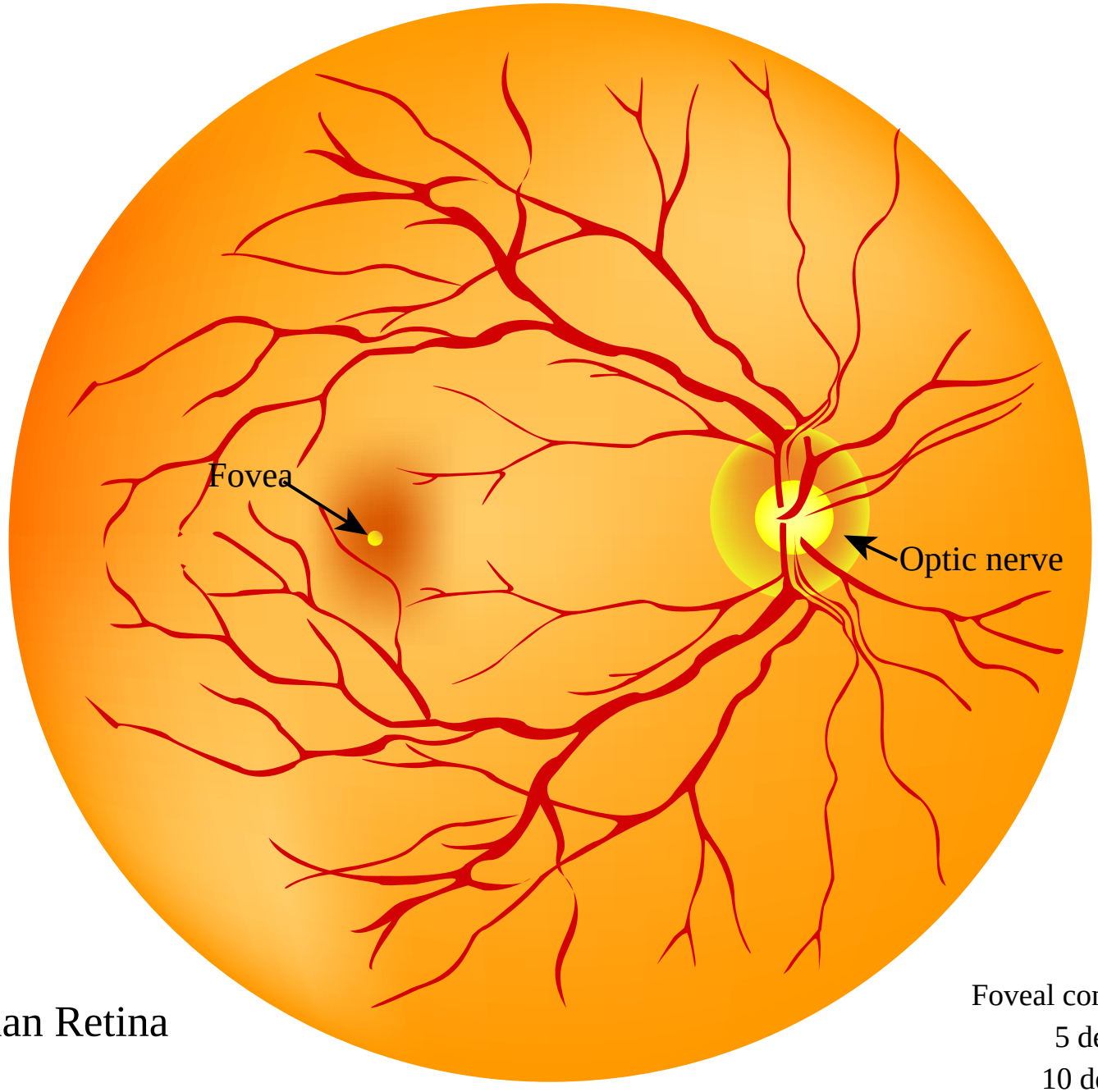
Basics of Retinal Connections and Retinal Ganglion Cells



Horizontal section of the right human eye.

Image by MIT OpenCourseWare.





Human Retina

Foveal cone density: 200,000/sqmm
5 degrees out: 20,000/sqmm
10 degrees out: 10,000/sqmm

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Please refer to lecture video or to Polyak, Stephen Lucian. T*he Vertebrate Visual System: Its Origin, Structure, and Function and its Manifestations in Disease with an Analysis of its Role in the Life of Animal and in the Origin of Man.* Edited by Heinrich Kluver. University of Chicago Press, 1957.

Retinal ganglion cells, cross section, Golgi label

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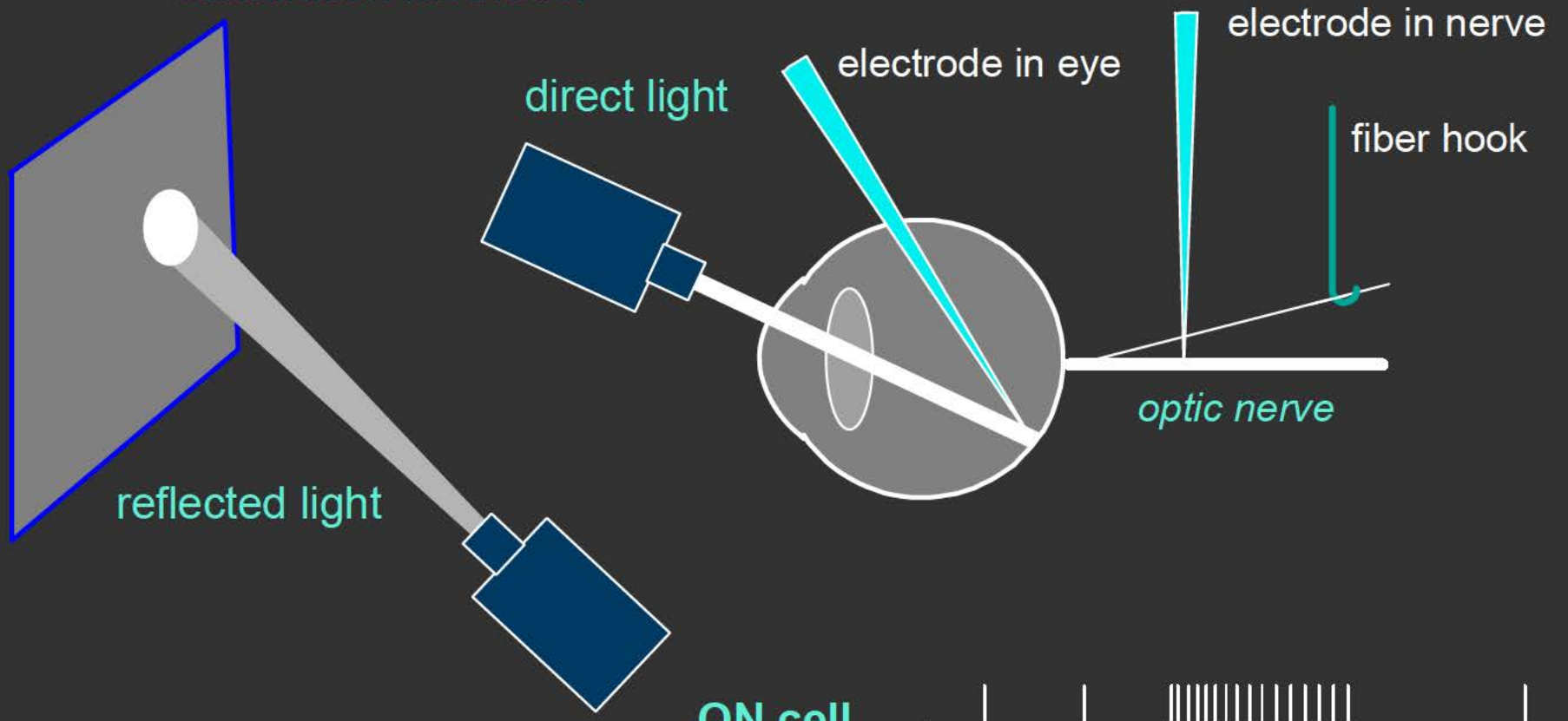
Please refer to lecture video or Figure 4 from Schiller, Peter H. "Parallel information processing channels created in the retina." *Proceedings of the National Academy of Sciences* 107, no. 40 (2010): 17087-17094.

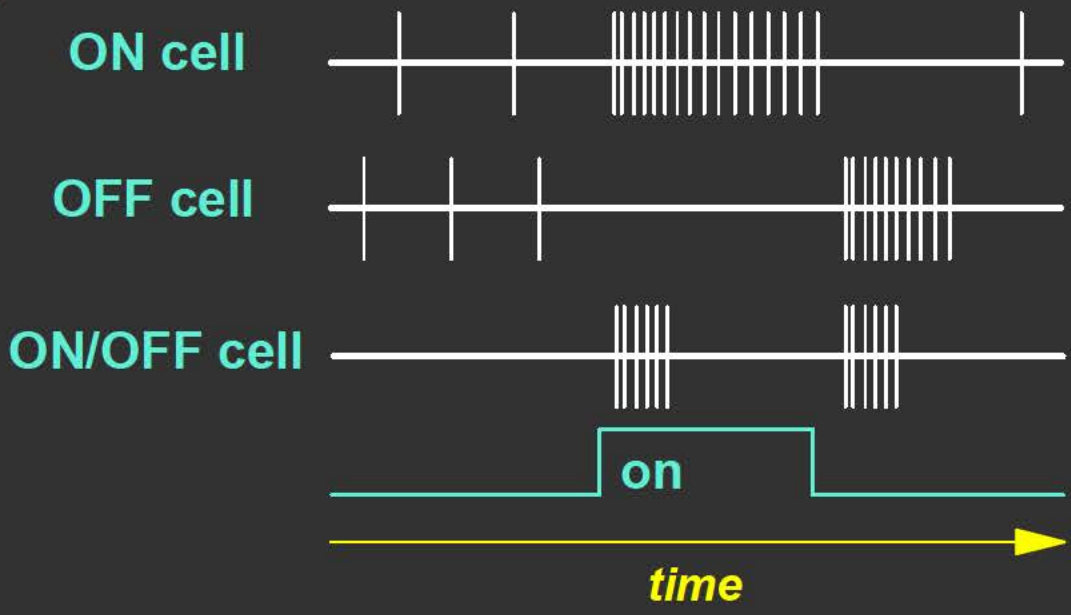
by Polyak

Physiology of retinal ganglion cells

Recording Methods:

Stimulation Methods:





The receptive fields of three major classes of retinal ganglion cells

Whole mount cat retina, Nissl stain

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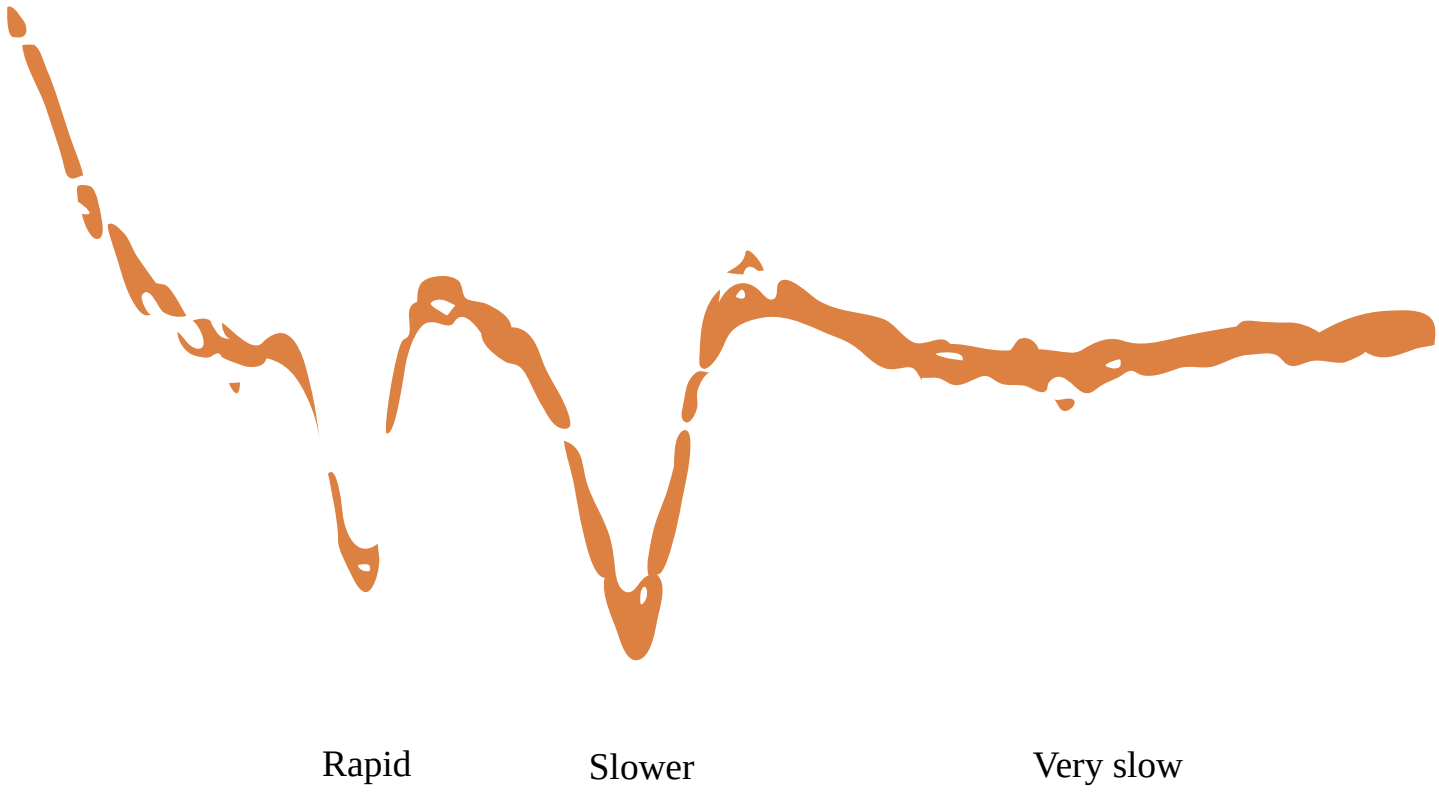
Please see lecture video or Figure 1 from Wassle, H., W. R. Levick, and B. G. Cleland. "The distribution of the alpha type of ganglion cells in the cat's retina." *Journal of Comparative Neurology* 159, no. 3 (1975): 419-437.

Conduction velocity in optic nerve fibers



Three populations of fibers

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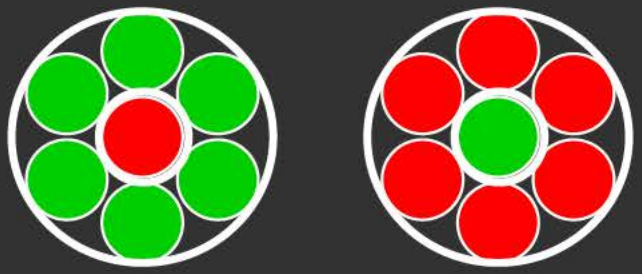
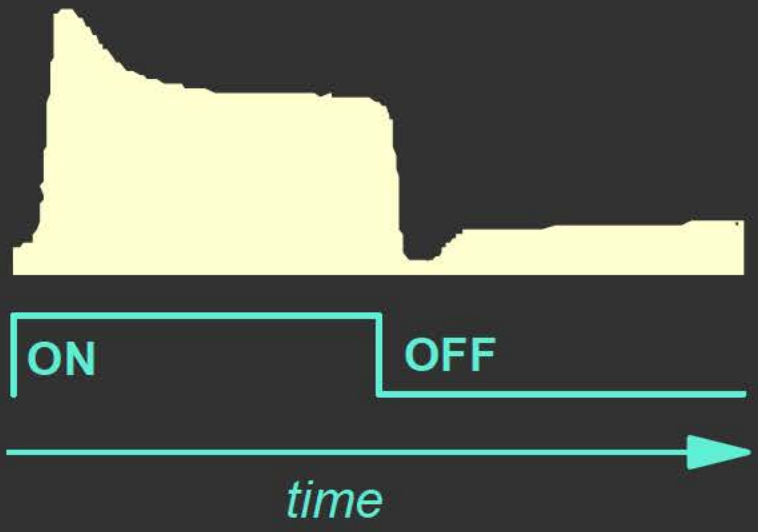
Please see lecture video or Figures 2 and 3 from Watanabe, M. and R.W. Rodieck. "Parasol and midget ganglion cells of the primate retina." *Journal of Comparative Neurology* 289, no. 3 (1989): 434-454.

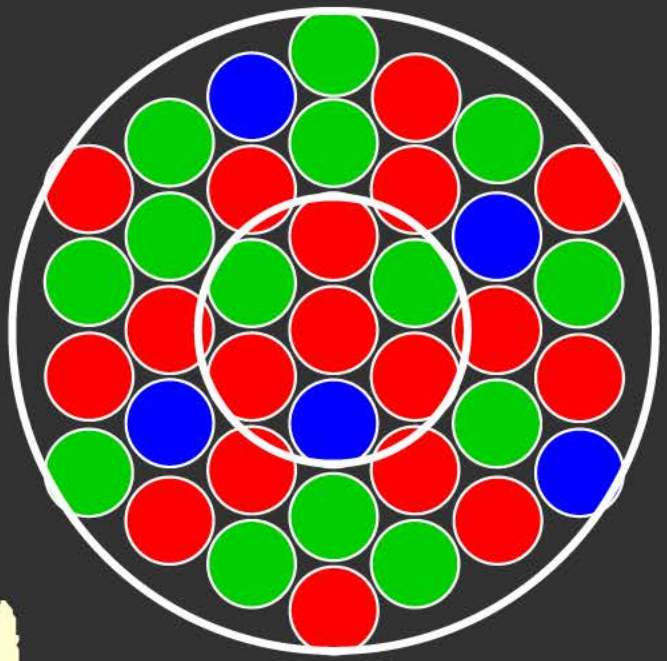
MIDGET SYSTEM



neuronal response profile



PARASOL SYSTEM



Photoreceptors

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Please refer to lecture video or Figure 1 from Schiller, Peter H., and Edward J. Tehovnik. "Visual prosthesis." *Perception* 37, no. 10 (2008): 1529.

Rods and cones in periphery

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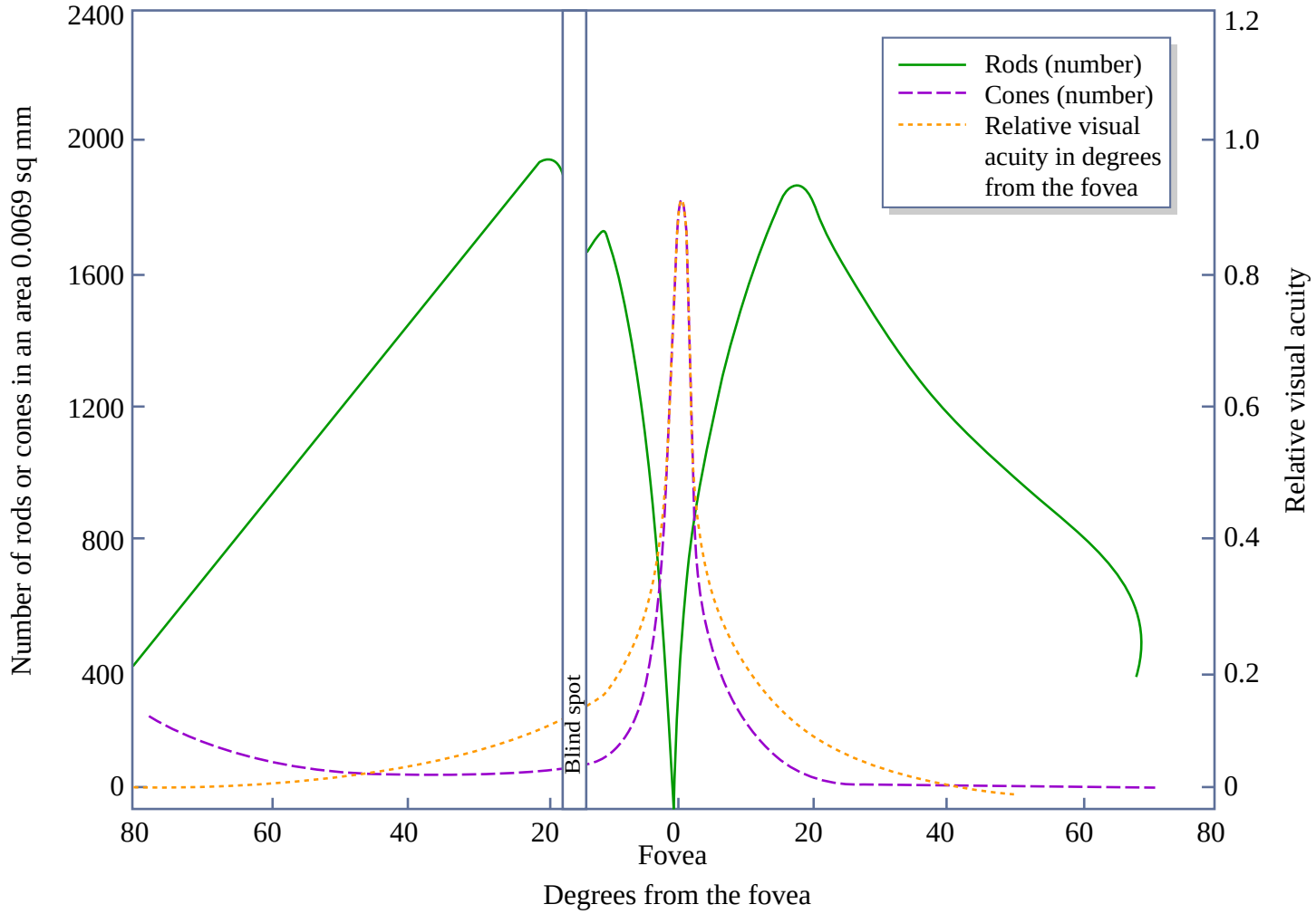
Please see lecture video or Figure 1 from Winkler, Kenneth C., and Pasko Rakic. "Distribution of photoreceptor subtypes in the retina of diurnal and noctournal primates." *The Journal of Neuroscience* 10, no. 10 (1990): 3390-3401.

In human retina there are about 120 million rods and about 5 million cones

Distribution of rods and cones on the retina



Distribution of rods and cones along a horizontal meridian. Parallel vertical lines represent the blind spot. Visual acuity for a high luminance as a function of retinal location is included for comparison.

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Please see lecture video or Figure 2 from McCrane, E. P., F. M. De Montasterio, S. J. Schein, and R. C. Caruso. "Non-dluorescent dye staining of primate blue cones." *Investigative ophthalmology & visual science* 24, no. 11 (1983): 1449-1455.

Blue cones labeled with procion black

McCrane et al., Investigative Ophthalmology and Visual science, 1983, 24, 1449-55

Some basic facts about the receptor array:

1 degree = 200u on retina

Intercone distance in fovea = 2.4u (0.7 min)

200,000 cones per sq.mm. in fovea

20,000 cones per sq.mm. 5 degrees out

Thumbnail at arm's length = 1 degree

The 12 font letter "I" activates about 80 cones at 23 cm

Each rod has 1,000 disks, each with 10,000 molecules

Only 1 of 8 cones is blue. Red and green are equal.

Monoclonal antibody label of light activated rods

Bipolar cells

Cat bipolar cells

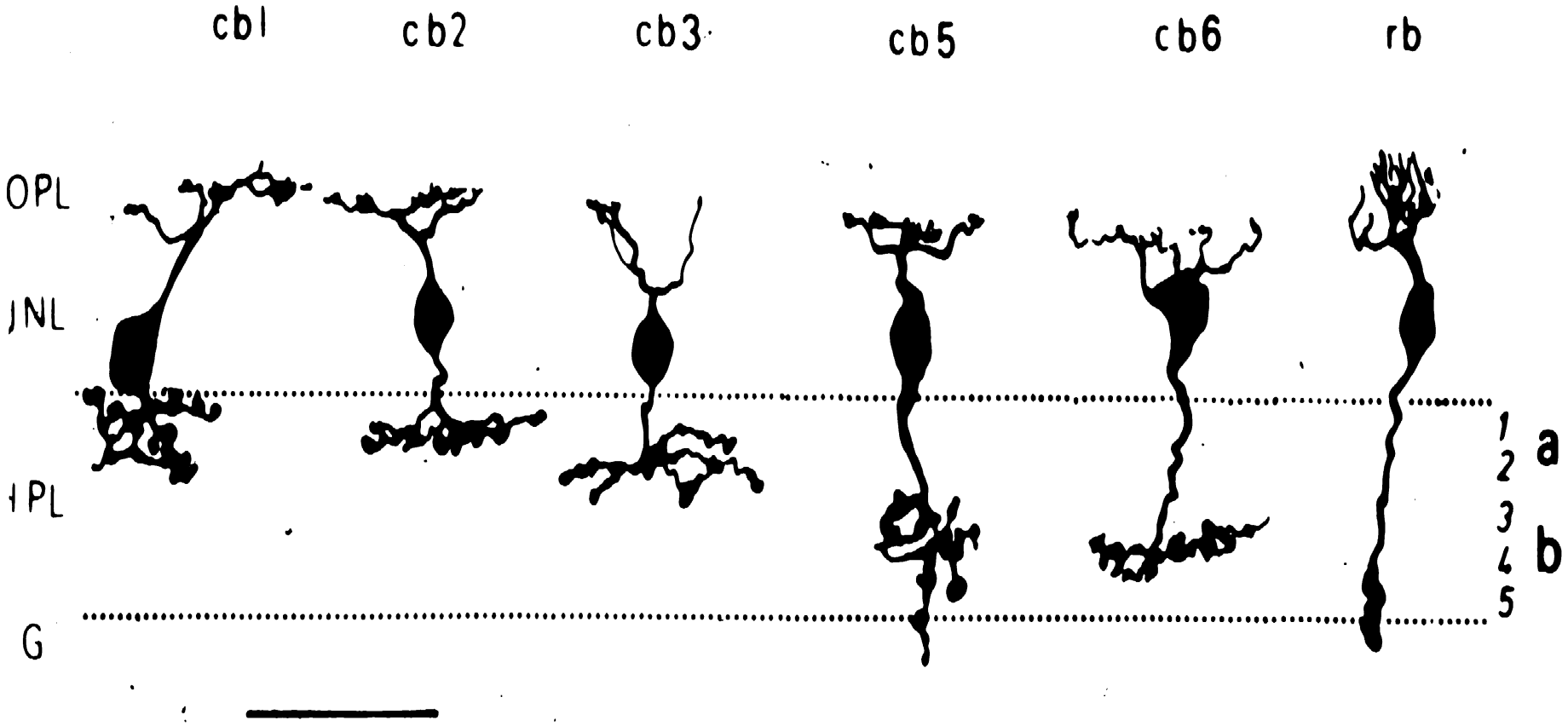

Fig. 1. Bipolar cells of the cat retina as seen in vertical sections of a Golgi-impregnated retina. Cb1, cb2, cb3, cb5 and cb6 are cone bipolar cells whereas rb is the single type of rod bipolar cell. See text for detailed descriptions of the cells. All cells are 7 mm from the area centralis (a.c.). Dotted lines indicate the boundaries of the IPL. Sublaminae a and b and strata S1-S5 are indicated. Scale bar 30 μm.

Horizontal cells

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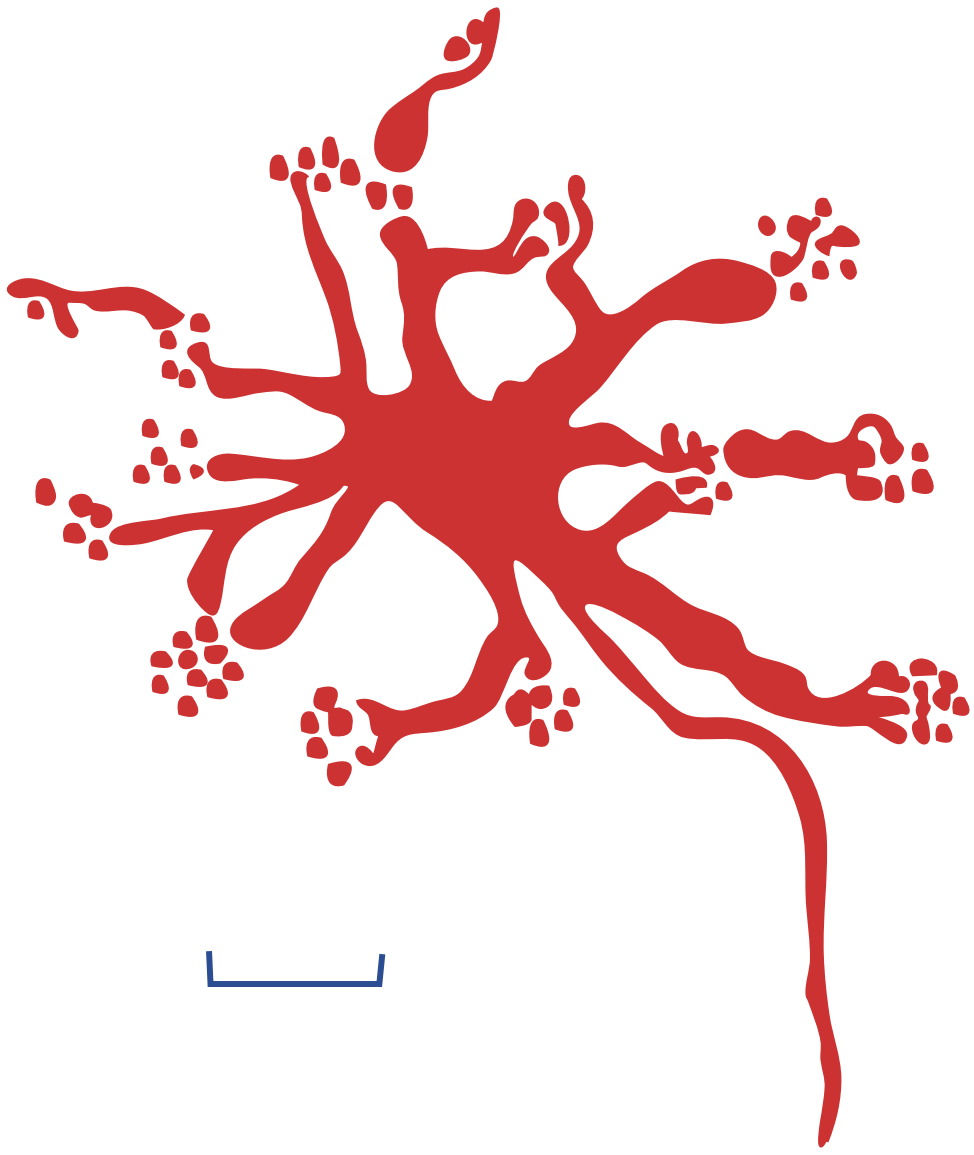
Please refer to lecture video or to Polyak, Stephen Lucian. T*he Vertebrate Visual System: Its Origin, Structure, and Function and its Manifestations in Disease with an Analysis of its Role in the Life of Animal and in the Origin of Man.* Edited by Heinrich Kluver. University of Chicago Press, 1957.



A Horizontal cell with regularly arranged dendrites that is connected to 15 cones in a cone density region of 20.

Amacrine cells

Labeled and injected cholinergic amacrine cell

Images removed due to copyright restrictions.

Please see lecture video or Figure 2 of Masland, Richard H. "The functional architecture of the retina." *Scientific American* 255, no. 6 (1986): 102-11.

cholinergic cell

All cell

dopaminergic cell

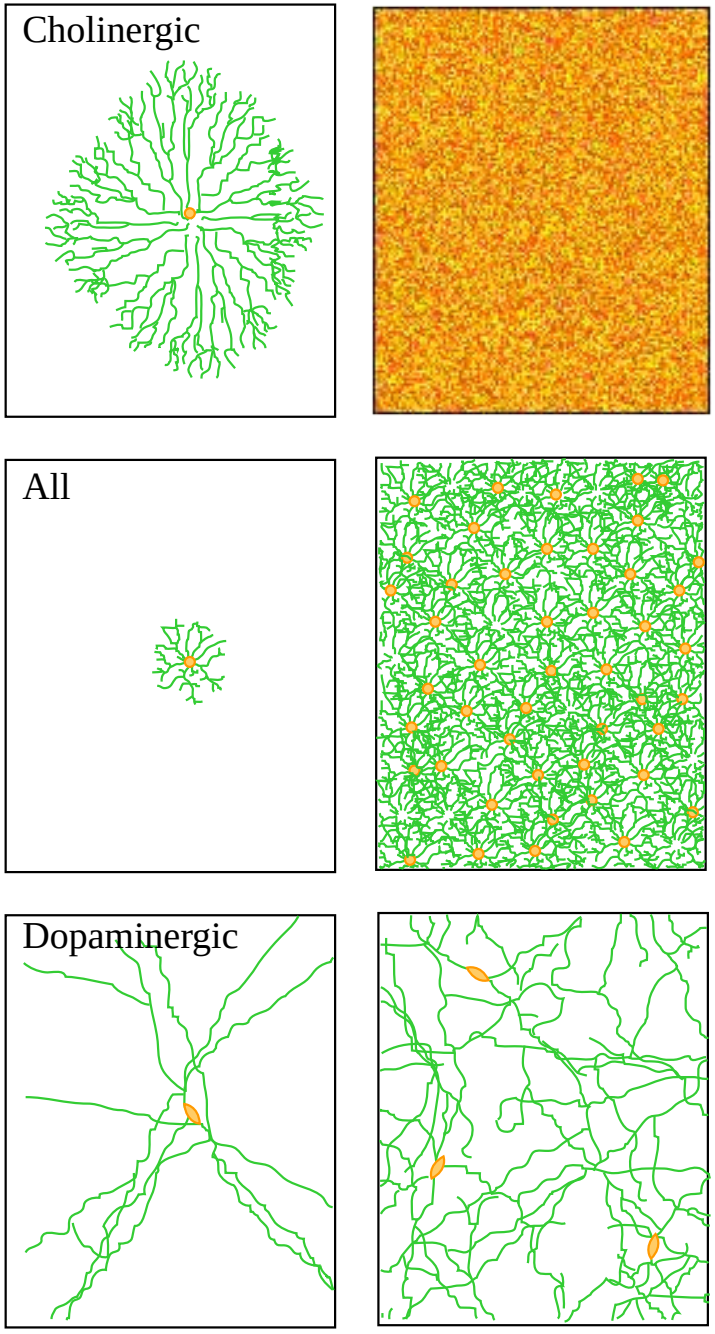
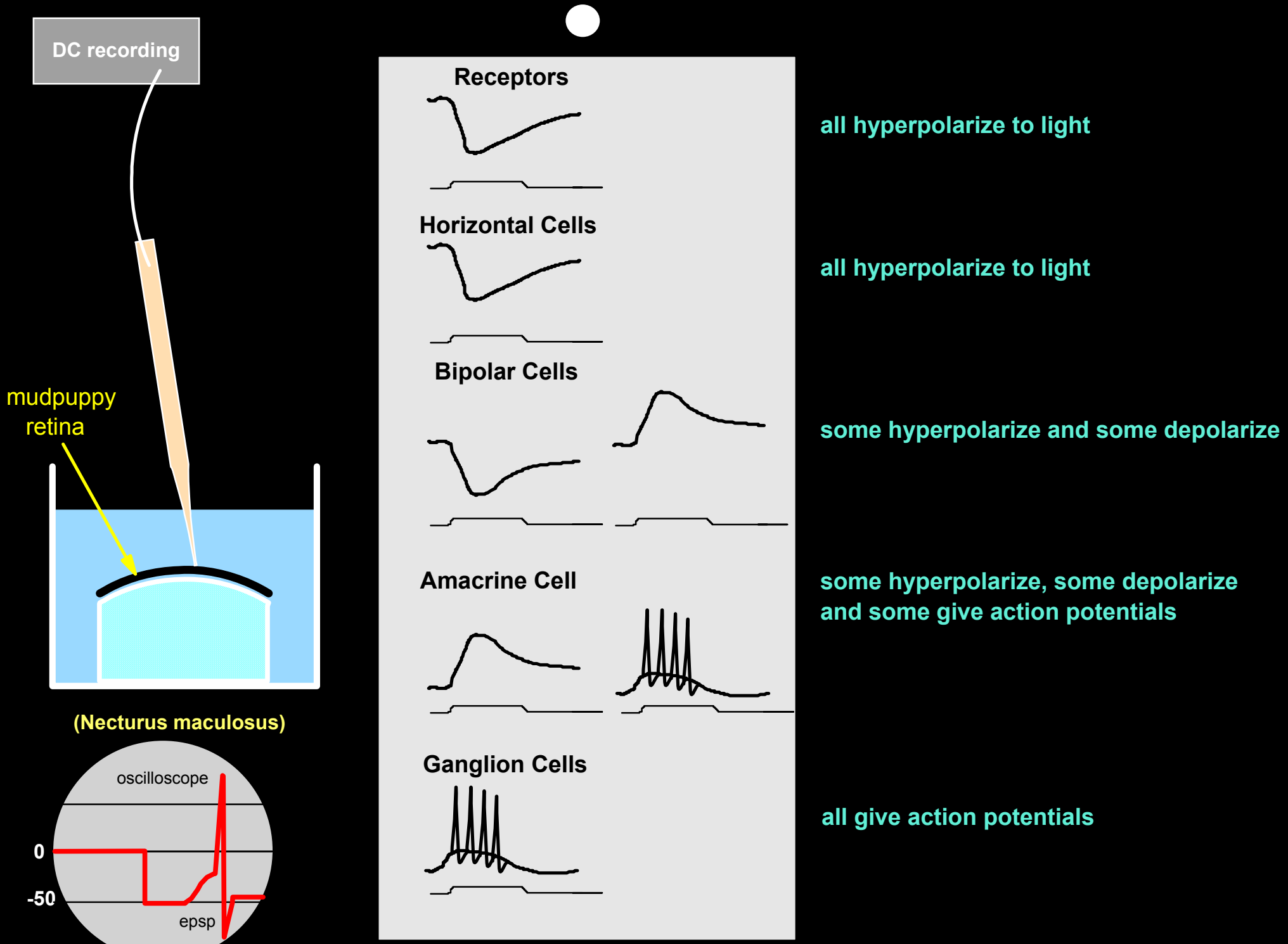
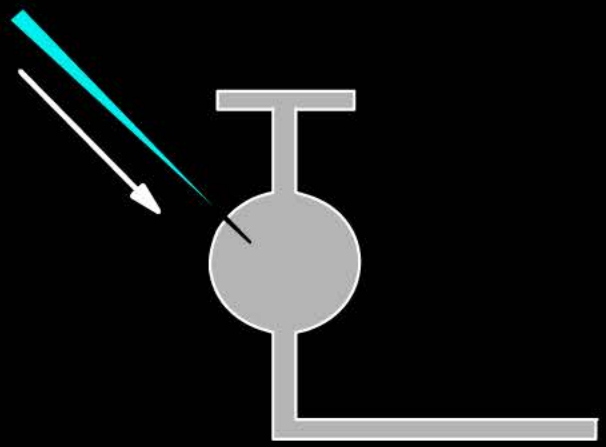


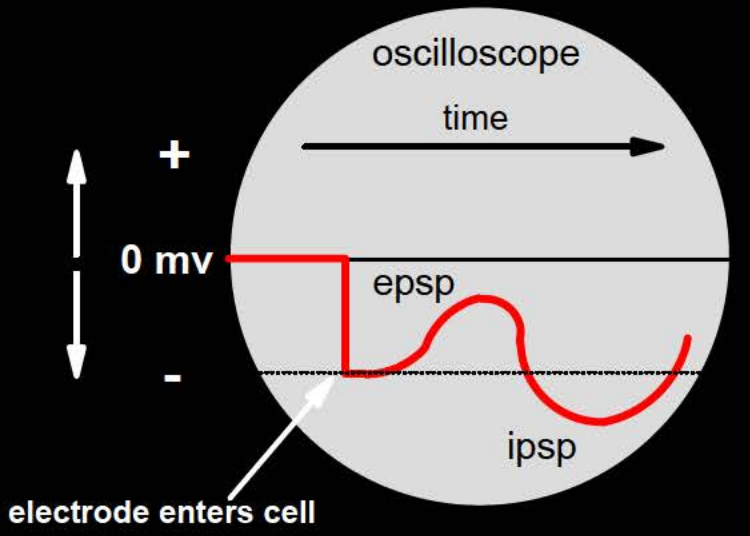
Image by MIT OpenCourseWare.

Electrical responses in the retina





cell with graded potentials

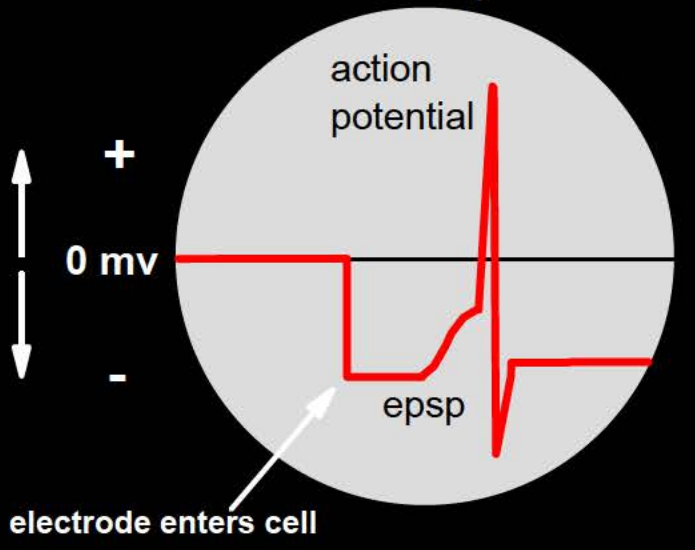


epsp = excitatory post synaptic potential

ipsp = inhibitory post synaptic potential

Neurotransmitter is released in cells when they depolarize (epsp).

cell with action potentials



Photoreceptors hyperpolarize to light. Therefore, glutamate is released when there is a decrease in illumination.

Photoreceptor basics:

1. All photoreceptors hyperpolarize to light.

2. Depolarization of the photoreceptor releases glutamate.

3. Photon absorption by the photopigment results in isomerization of the chromophore from 11-cis to all-trans. This causes hyperpolarization thereby reducing neurotransmitter release.

4. Two classes of bipolars are the ON and the OFF. The synaptic junction of OFF bipolars is sign conserving; that of the ON bipolar is sign inverting.

5. The ON bipolar receptor is mGluR6. Its activation leads to closing of channels causing hyperpolarization.

9.04 Sensory Systems

Fall 2013