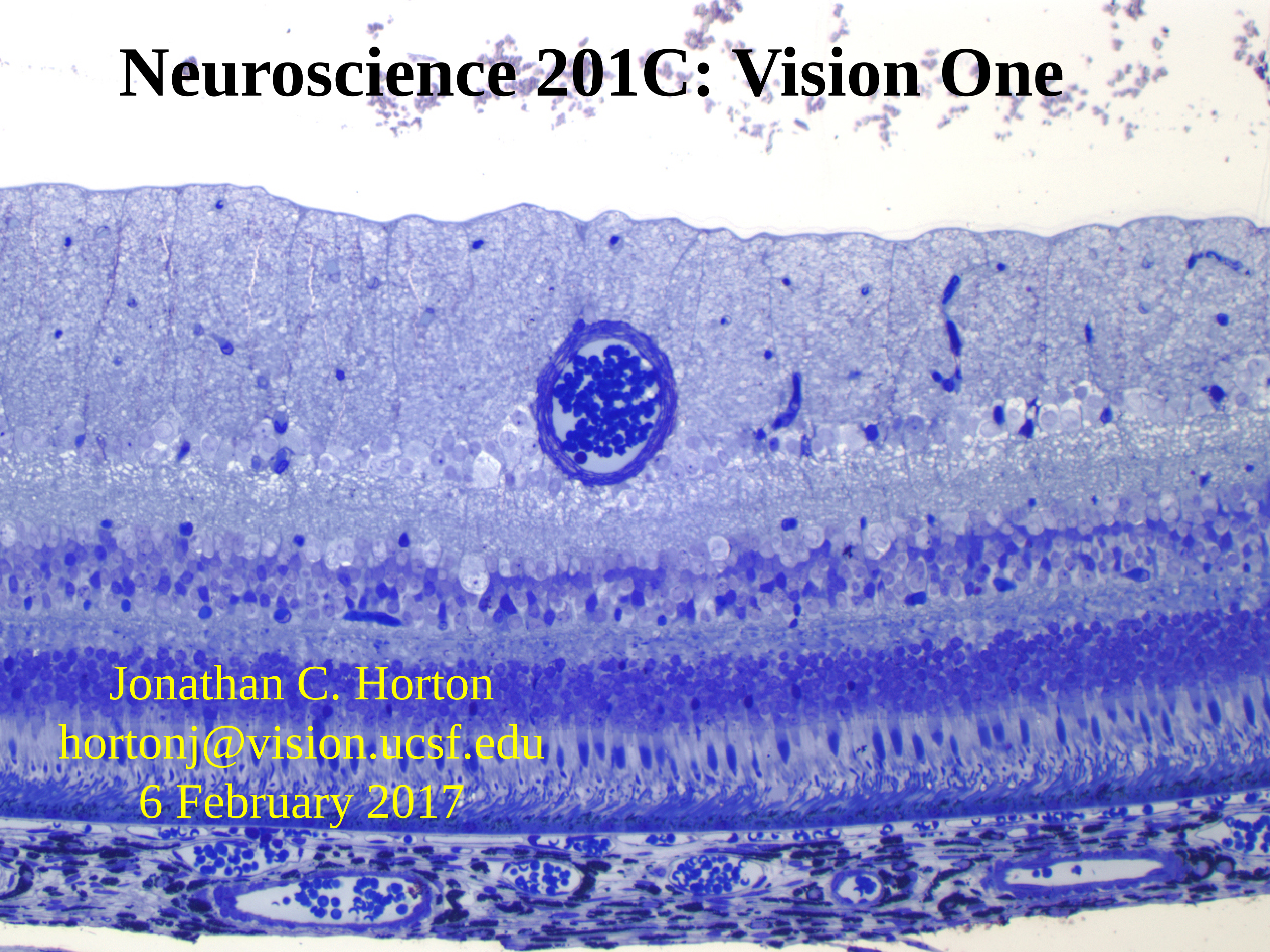
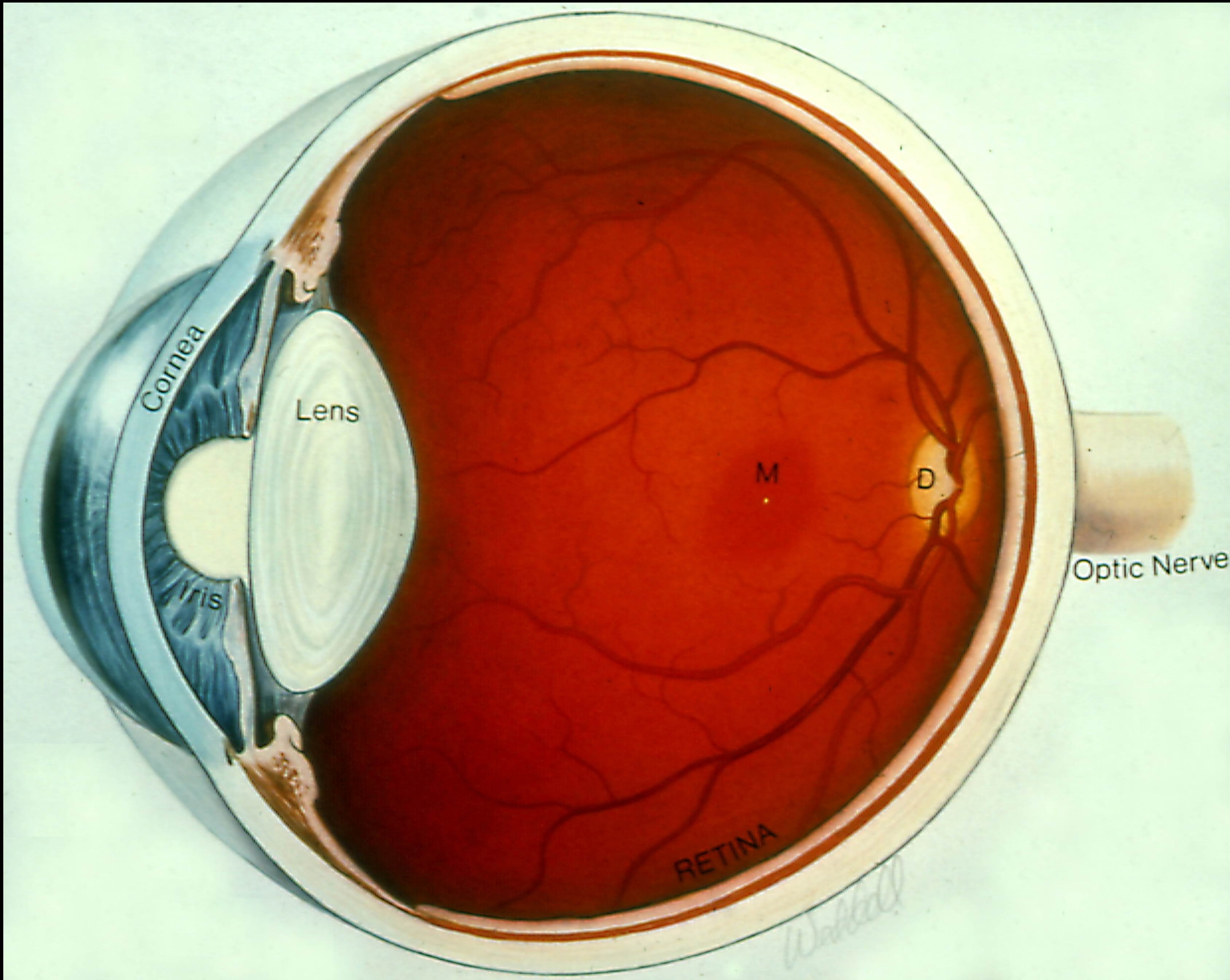
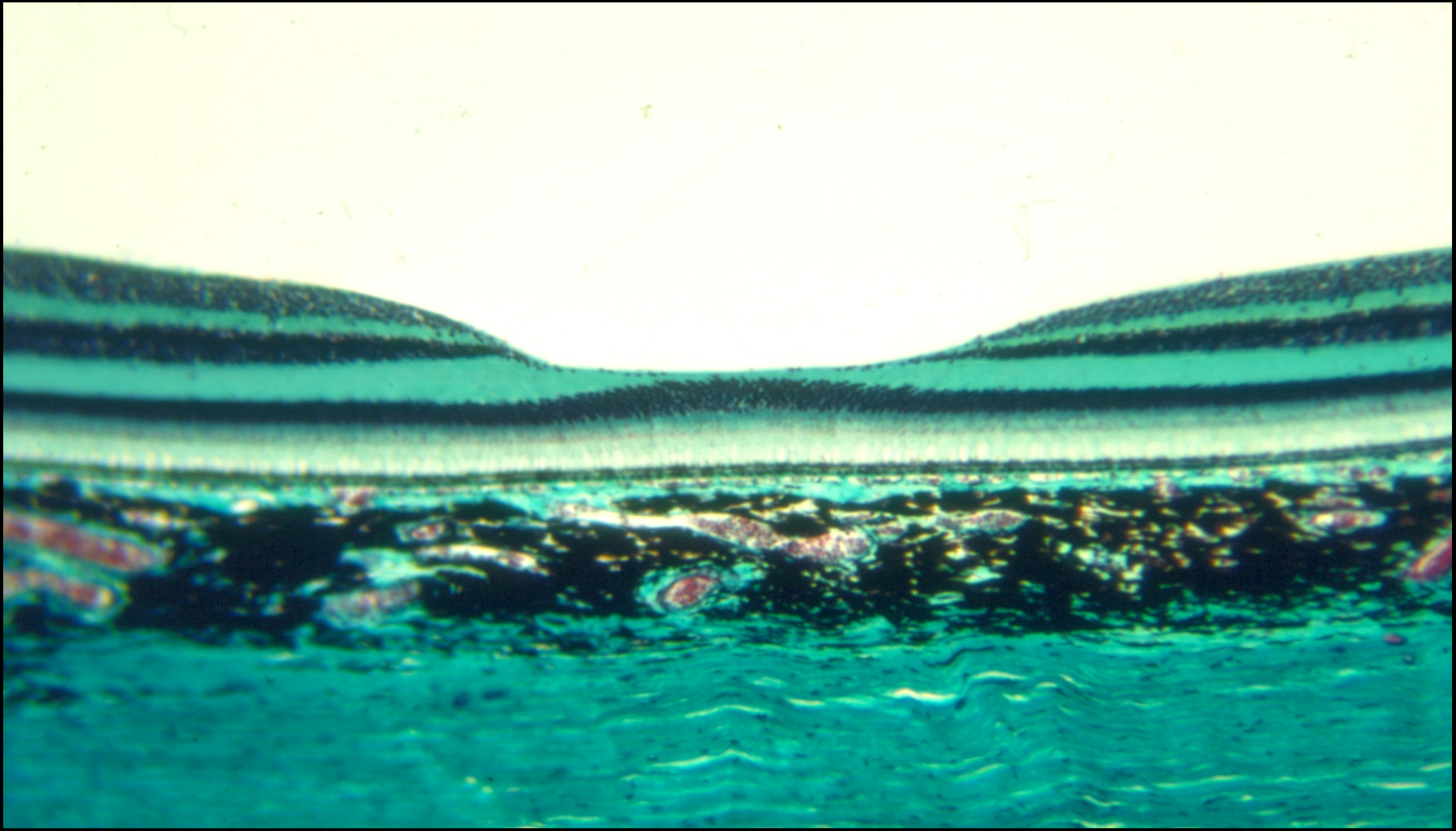
Neuroscience 201C: Vision One



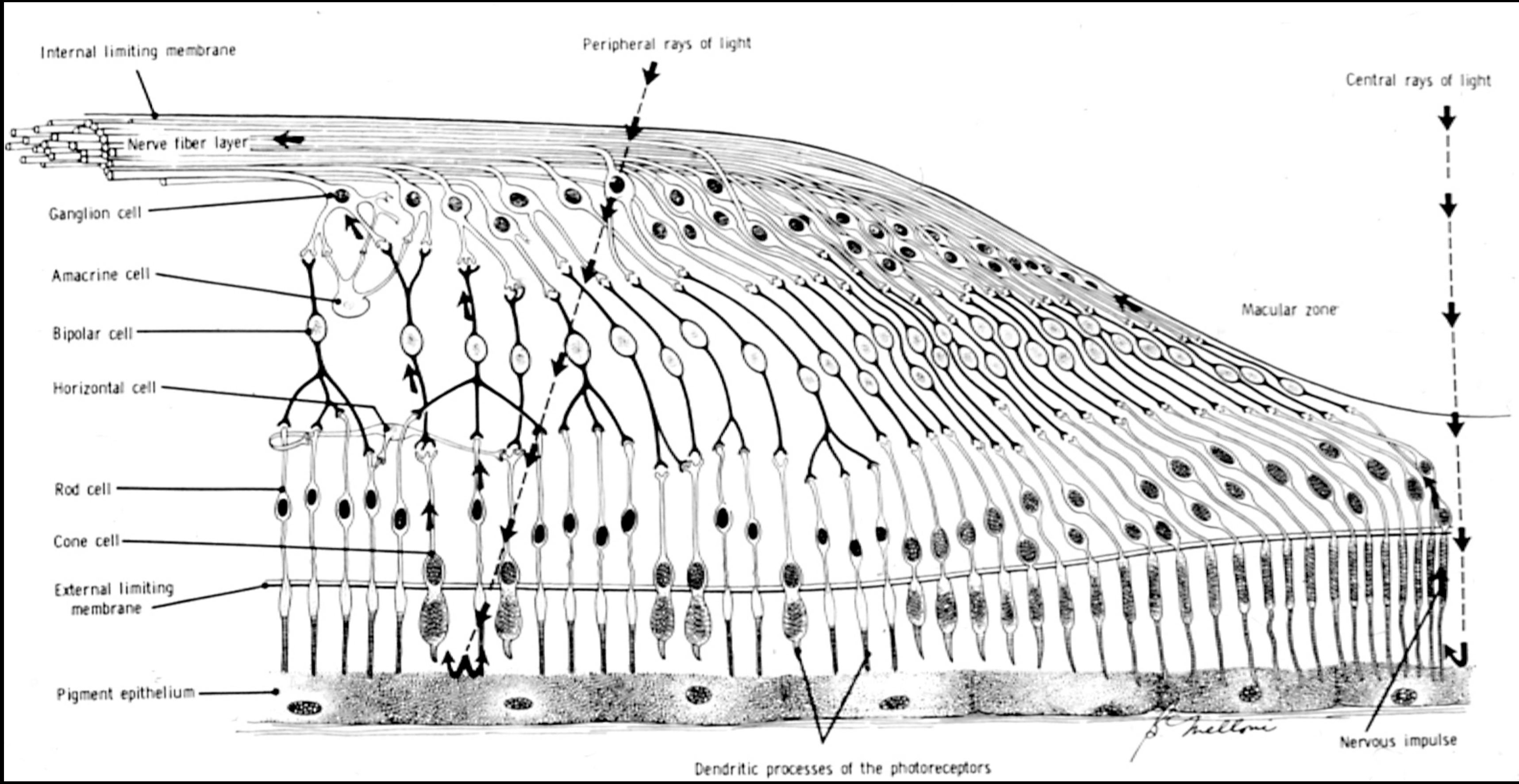
Jonathan C. Horton
hortonj@vision.ucsf.edu
6 February 2017


Cornea
Lens
Iris
M
D
Optic Nerve
RETINA


3/2/2012



Foveal Pit, Macaque Retina



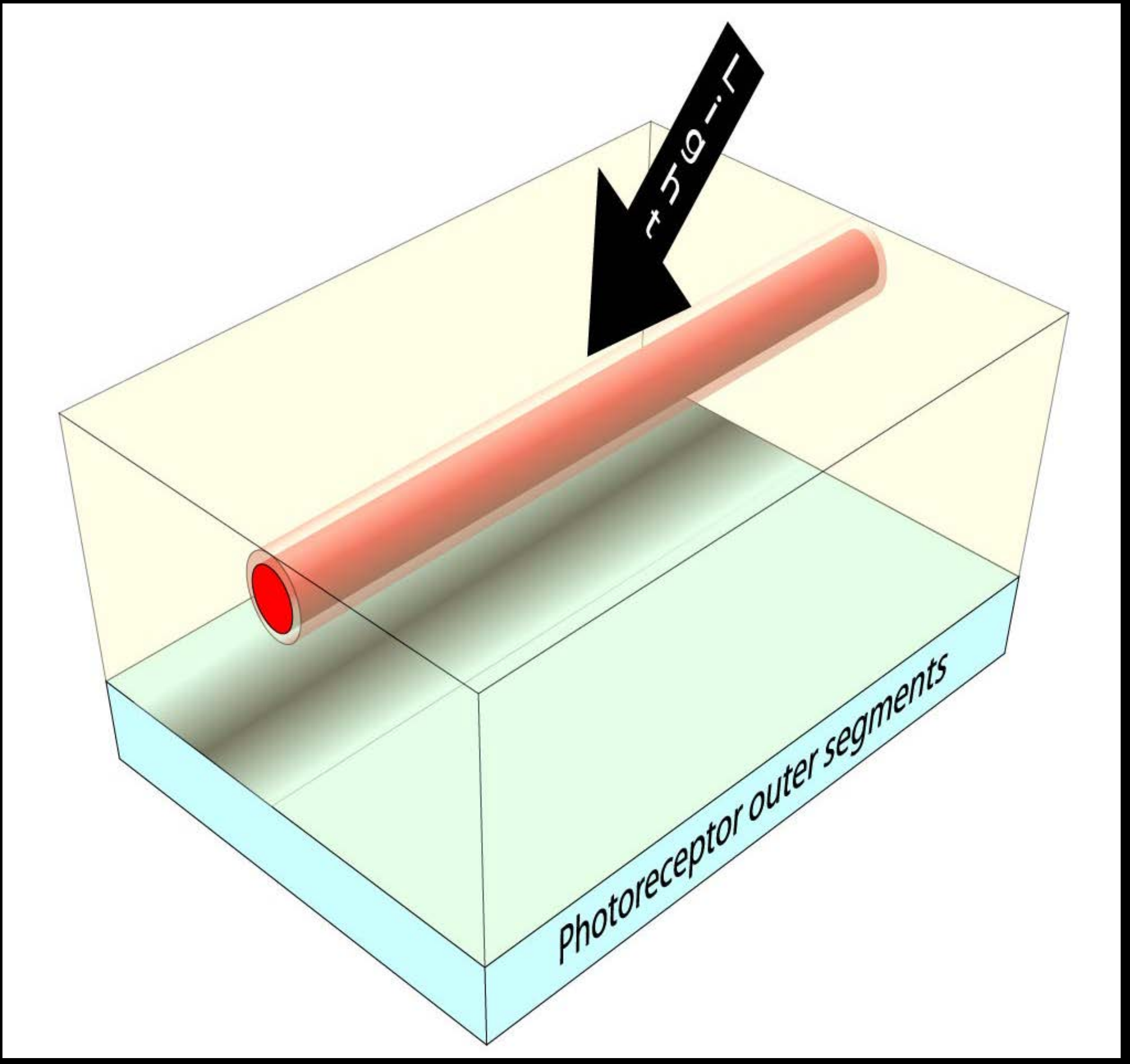
Specializations to Optimize Spatial Resolution in the Fovea

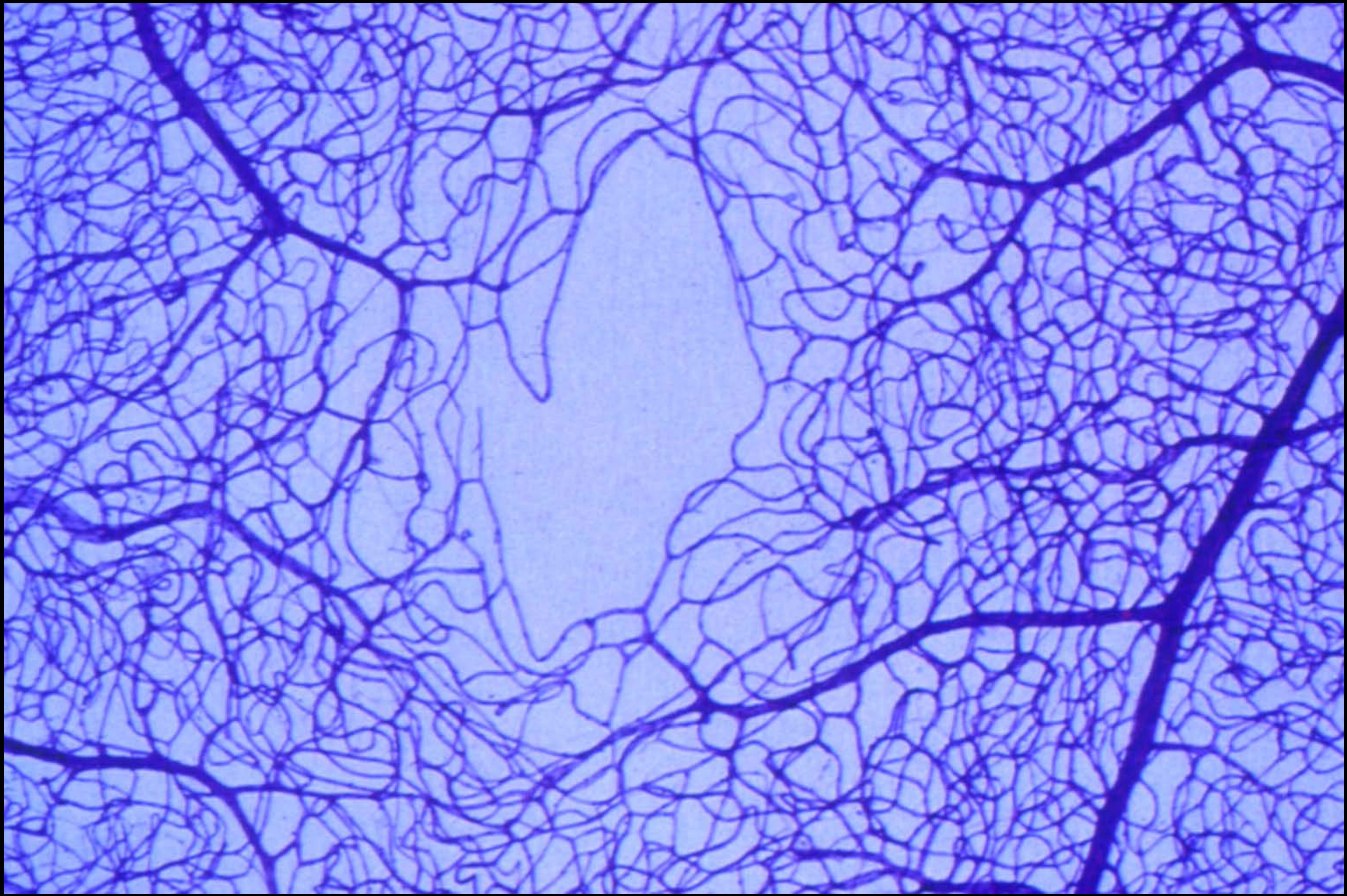
1) Foveal cones are the smallest and tallest in the retina.
2) No rods in the fovea.
3) "Private line" between individual cones and midget ganglion cells.
4) Inner retinal layers pushed aside.
5) No blood vessels in the center of the fovea.

Blood Vessels Cast A Shadow on Photoreceptors

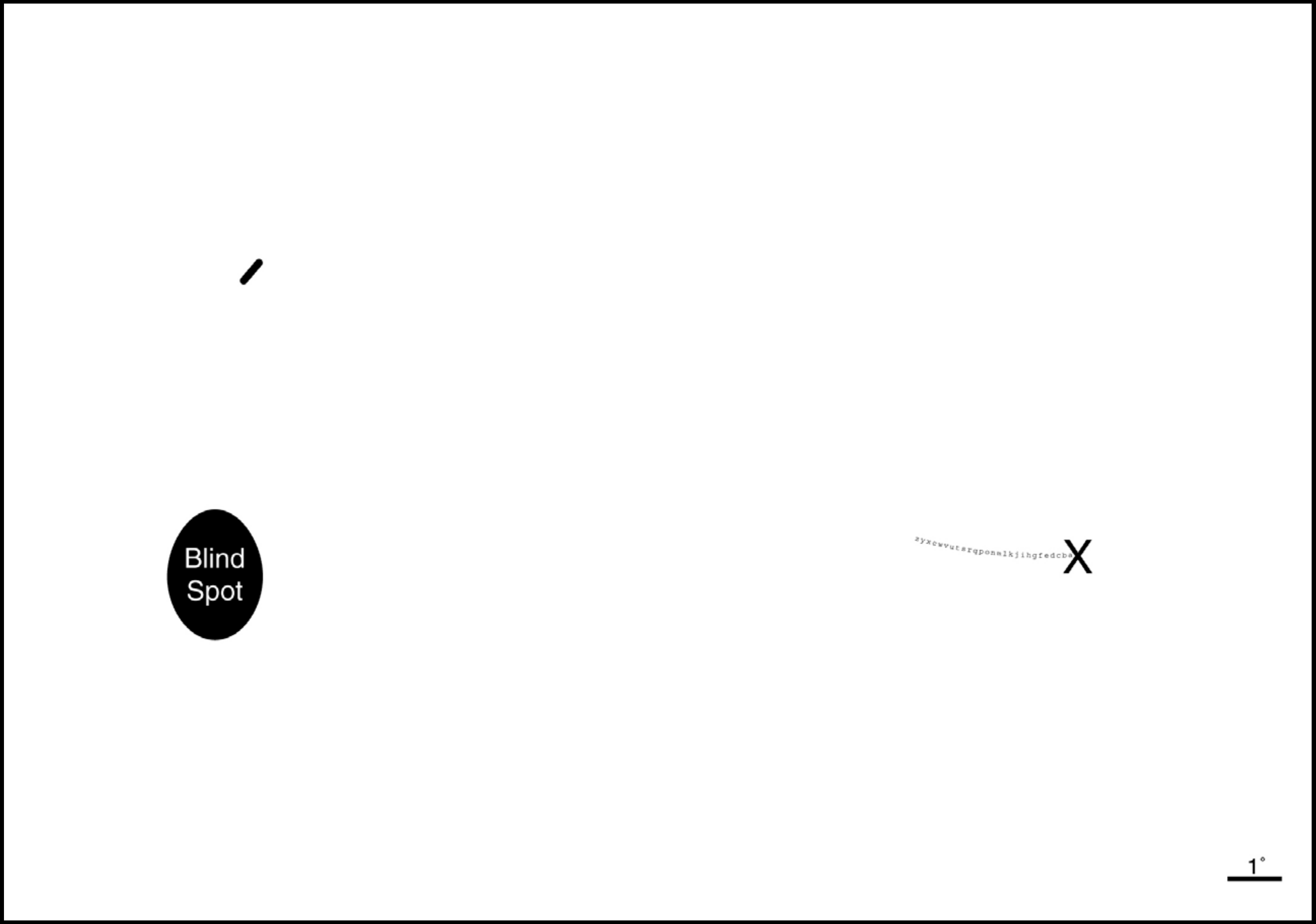
Blood vessels located in the nerve fiber layer, ganglion cell layer, and inner nuclear layer cast their shadow on the photoreceptors.

If sufficiently large, these vessels an occlude enough photoreceptors to produce blind regions in the visual field, known as “scotomas”.

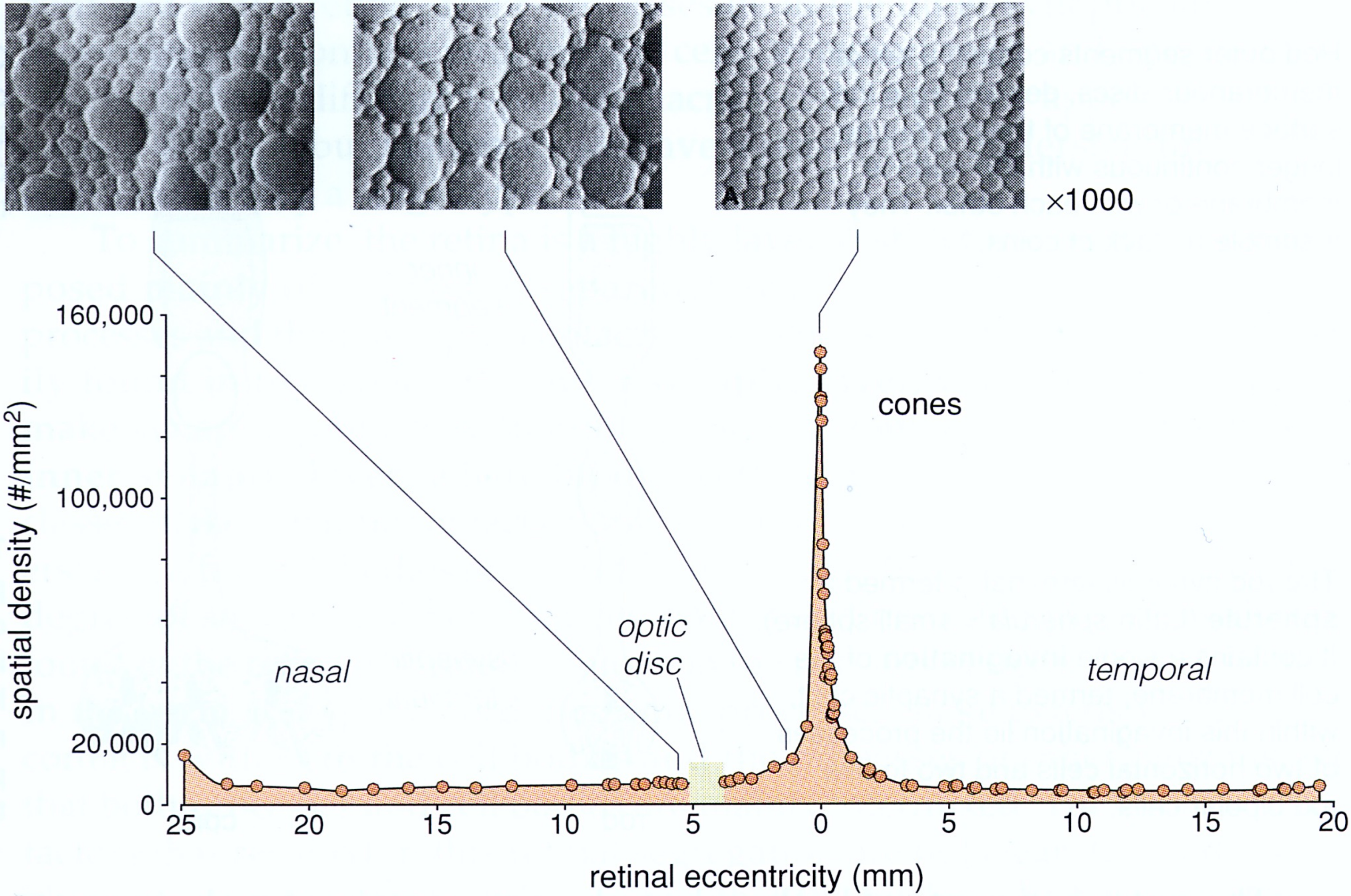




Foveal Avascular Zone in the Human Retina

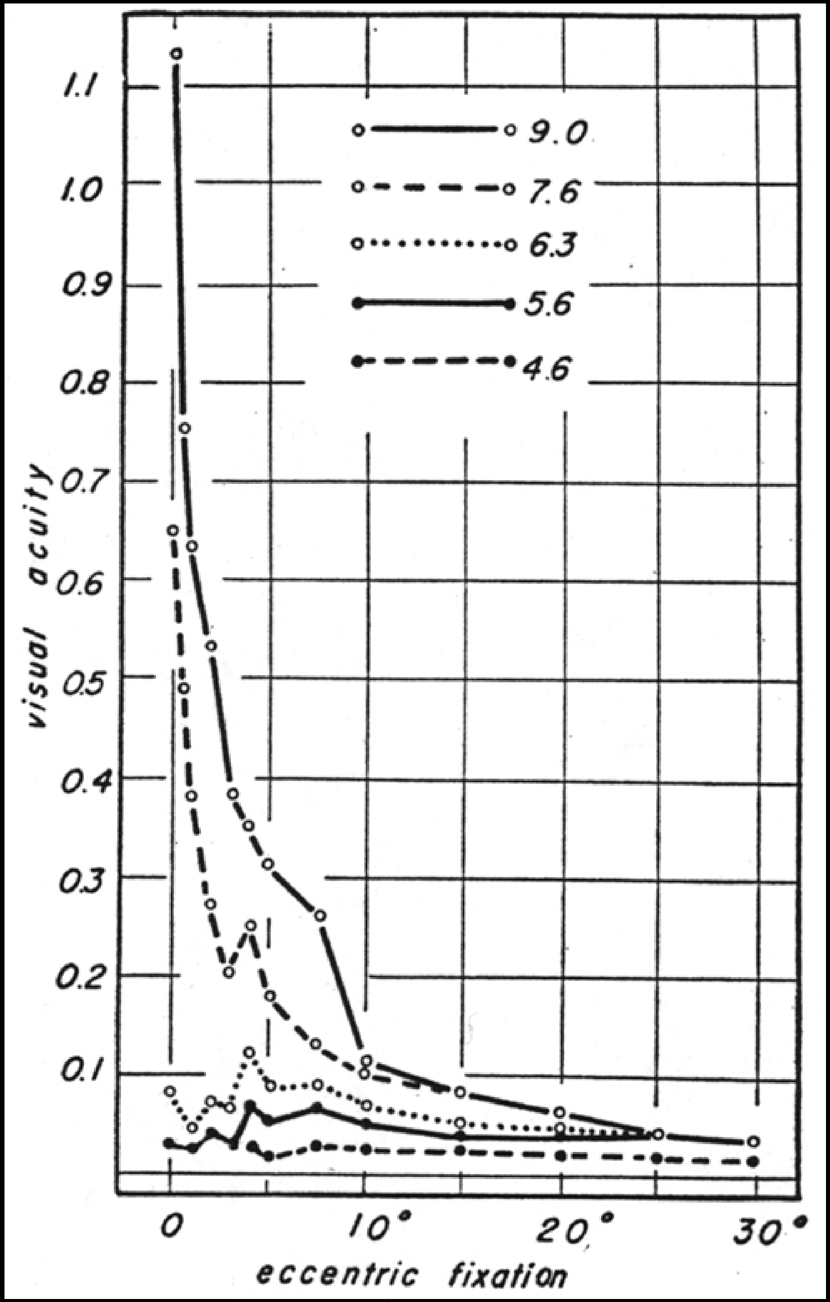


Demonstration of the Blind Spot and Angioscotomas



after Østerberg, 1935; as modified by Rodieck 1988;
micrographs from Curcio et al., 1990

Cone Density vs. Eccentricity

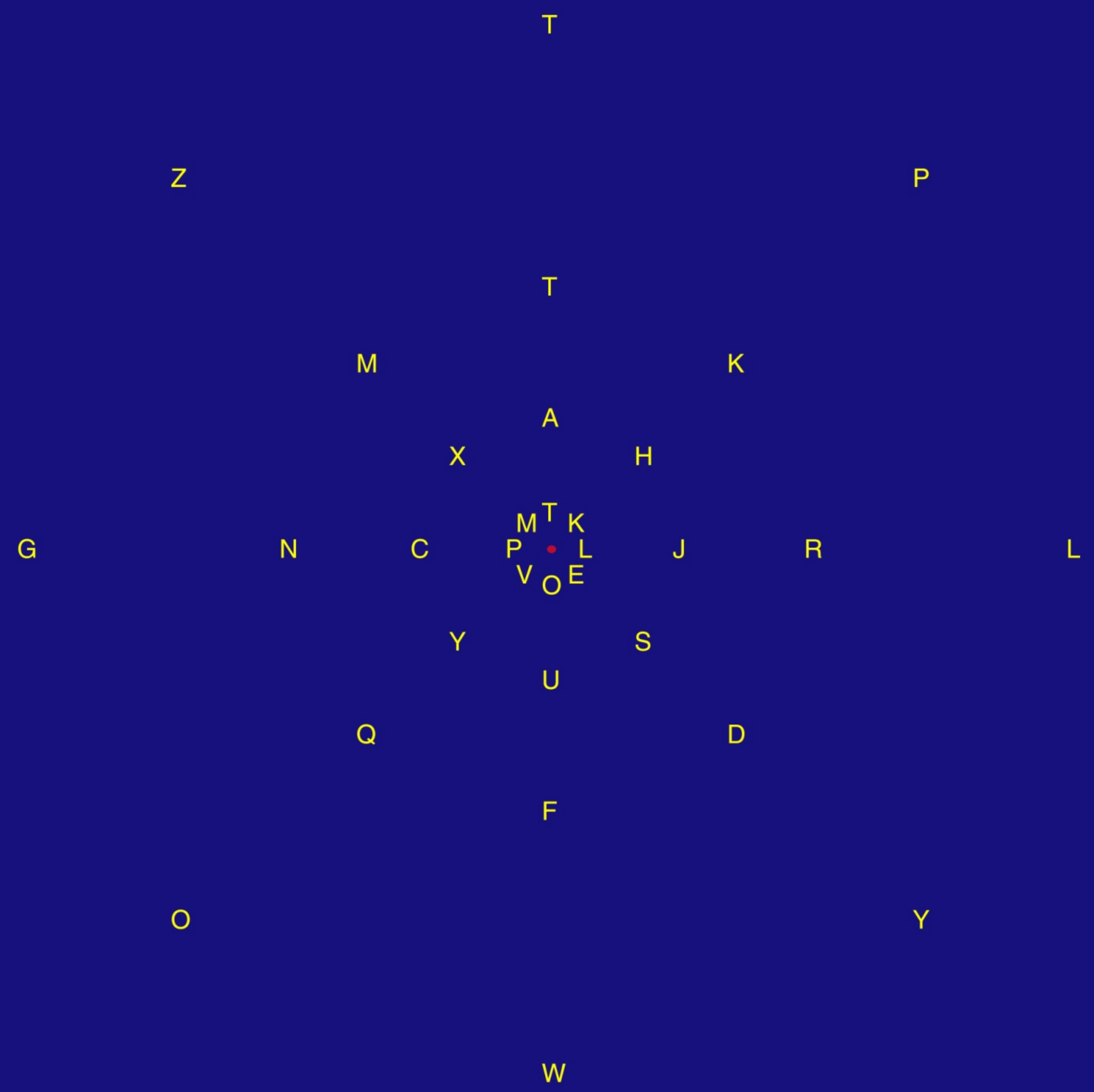


Visual Acuity Declines Logarithmically as Eccentricity Increases in the Visual Field

Luminance Values = Log µLamberts

Landolt C Rings

Mandelbaum & Sloan, Am J Ophthalmology, 30:581, 1947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Z P
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G N C P L J R L
V E
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Q D
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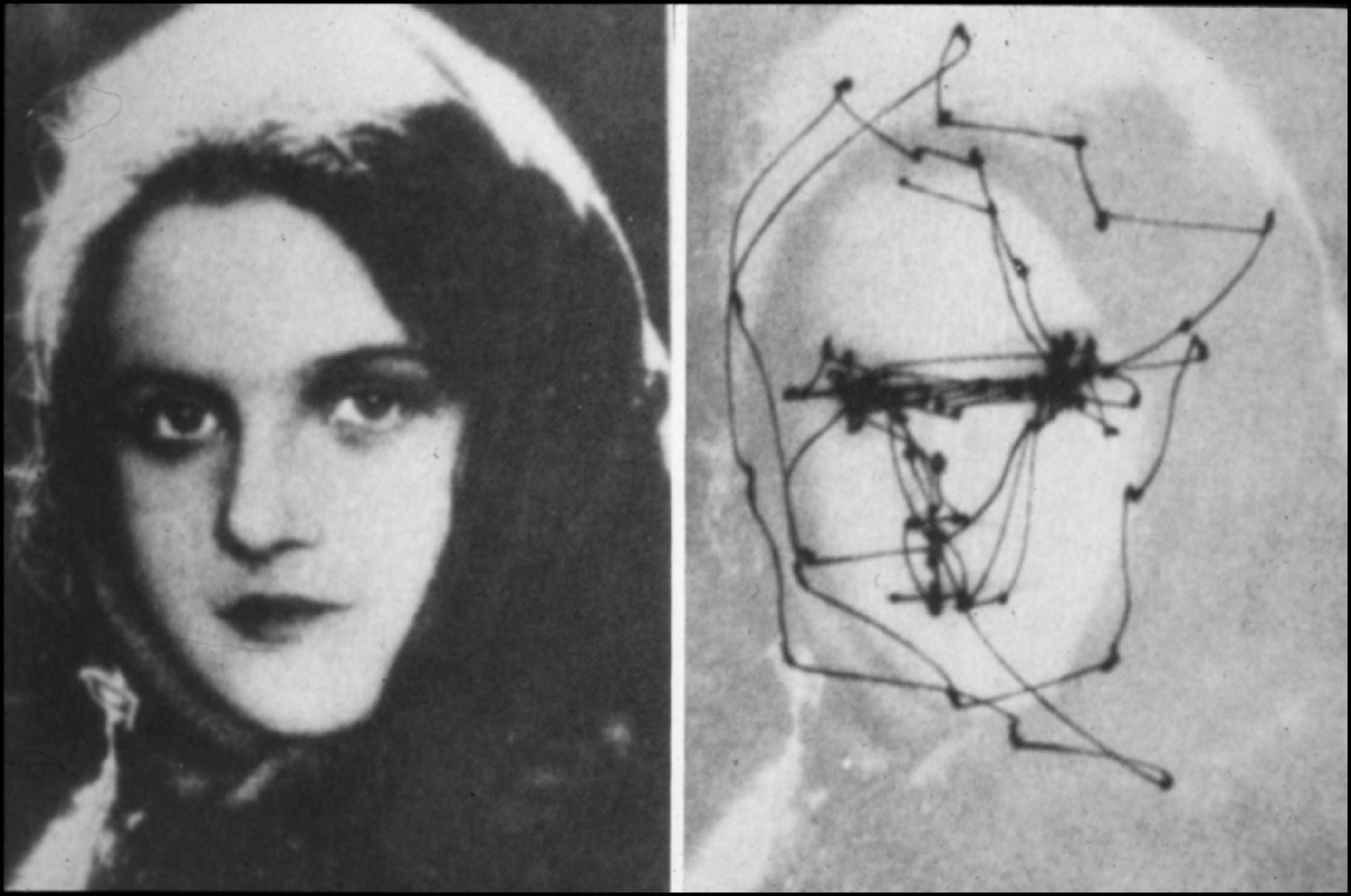
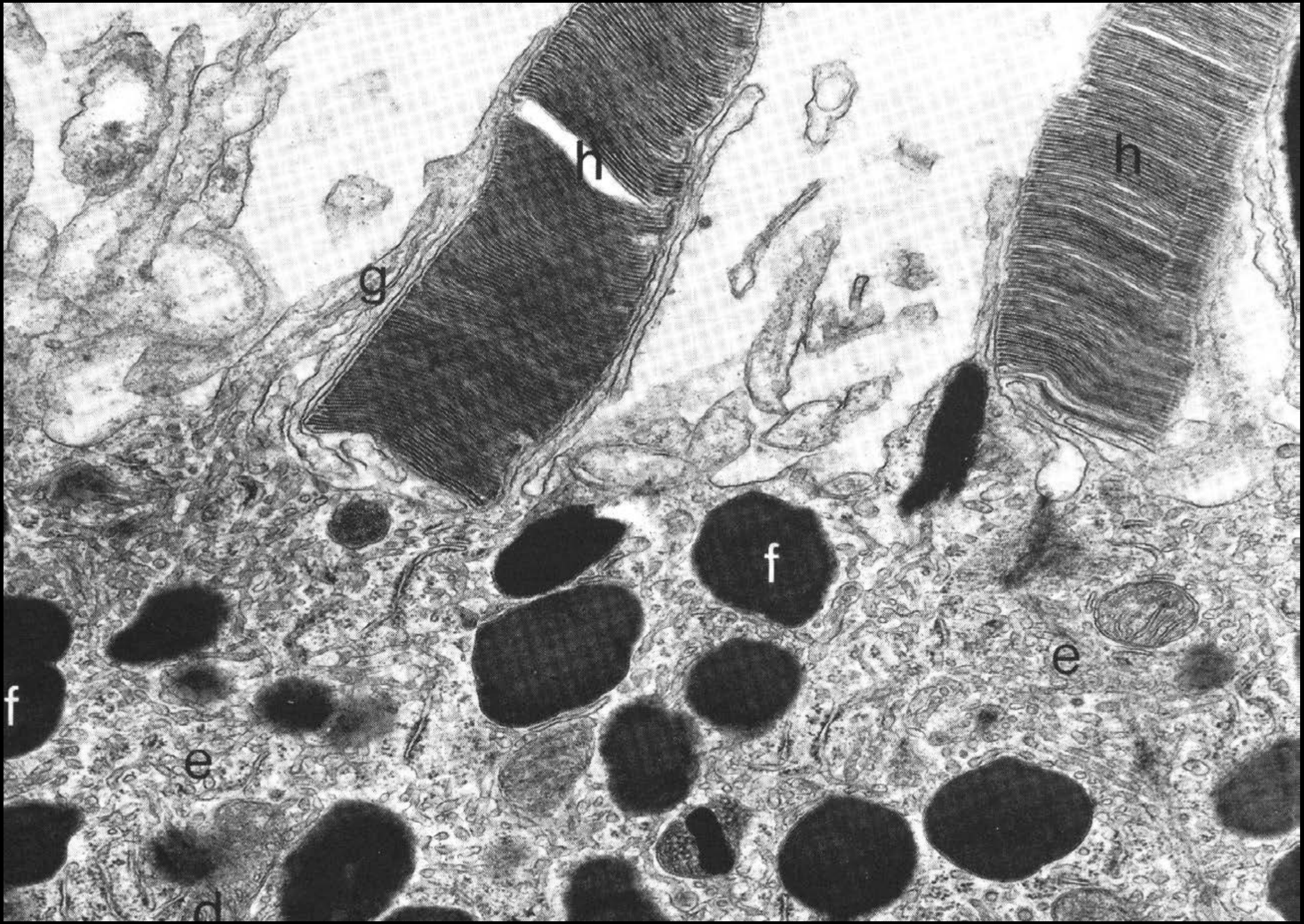
W


T P L Y W O G Z
T K R D F Q N M
A H J S U Y C X
T K L E O V P M

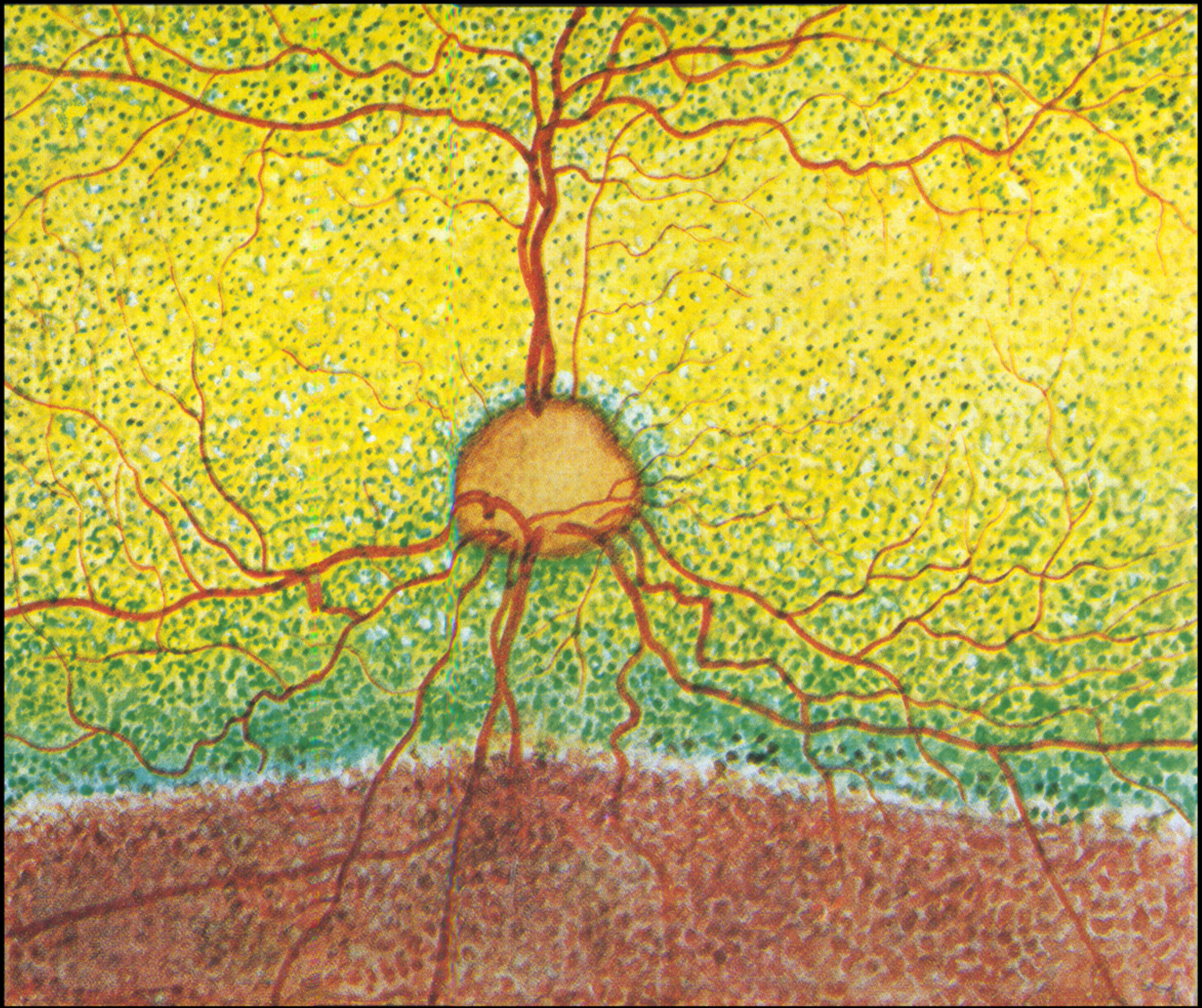


Human Scan Path (Yarbus, 1967)

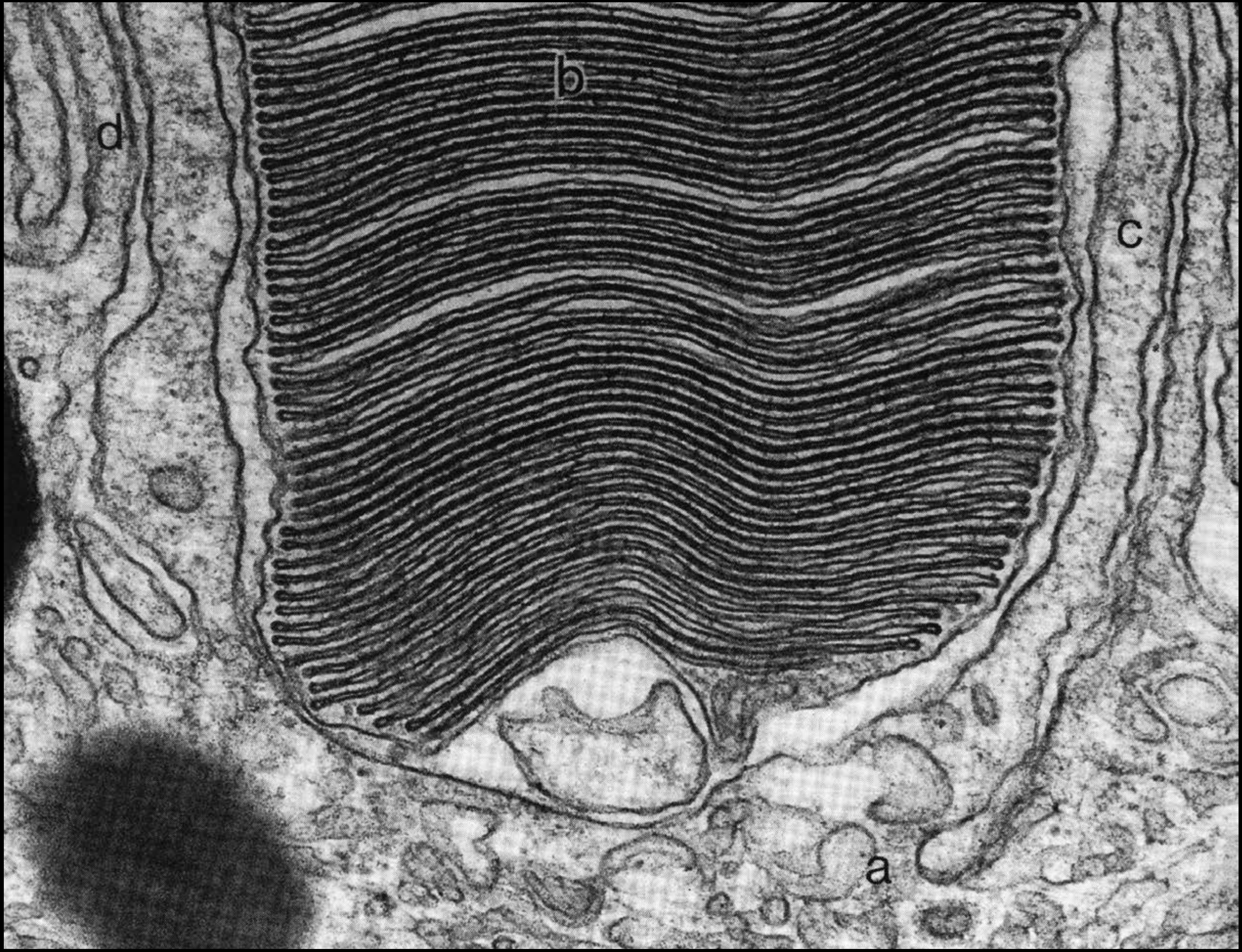
Macular Degeneration: Leading Cause of Blindness in the United States



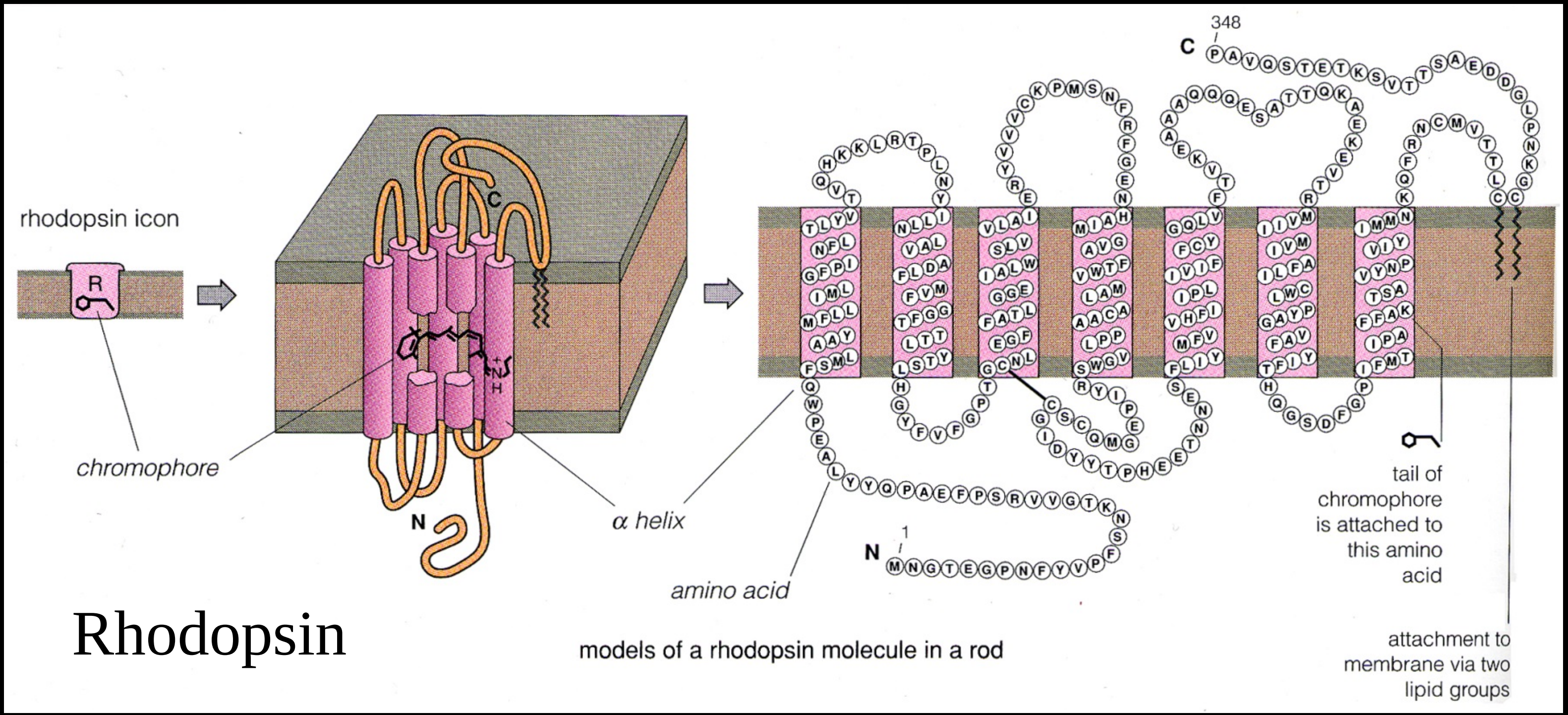
Retinal Pigment Epithelial Cells Phagocytose Shed Outer Segments and Absorb Light Missed by Photoreceptors. h = rod, f = melanosome



Cheetah Fundus with Regional Tapetum



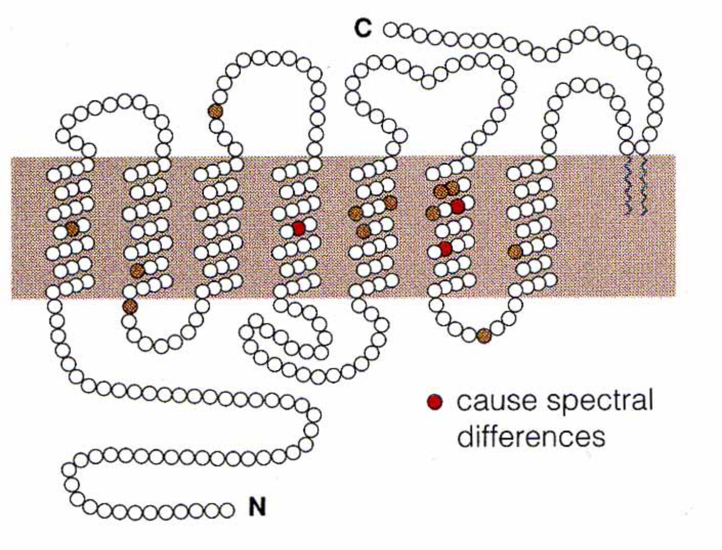
Stacks of Rhodopsin-Laden Membrane in a Human Rod



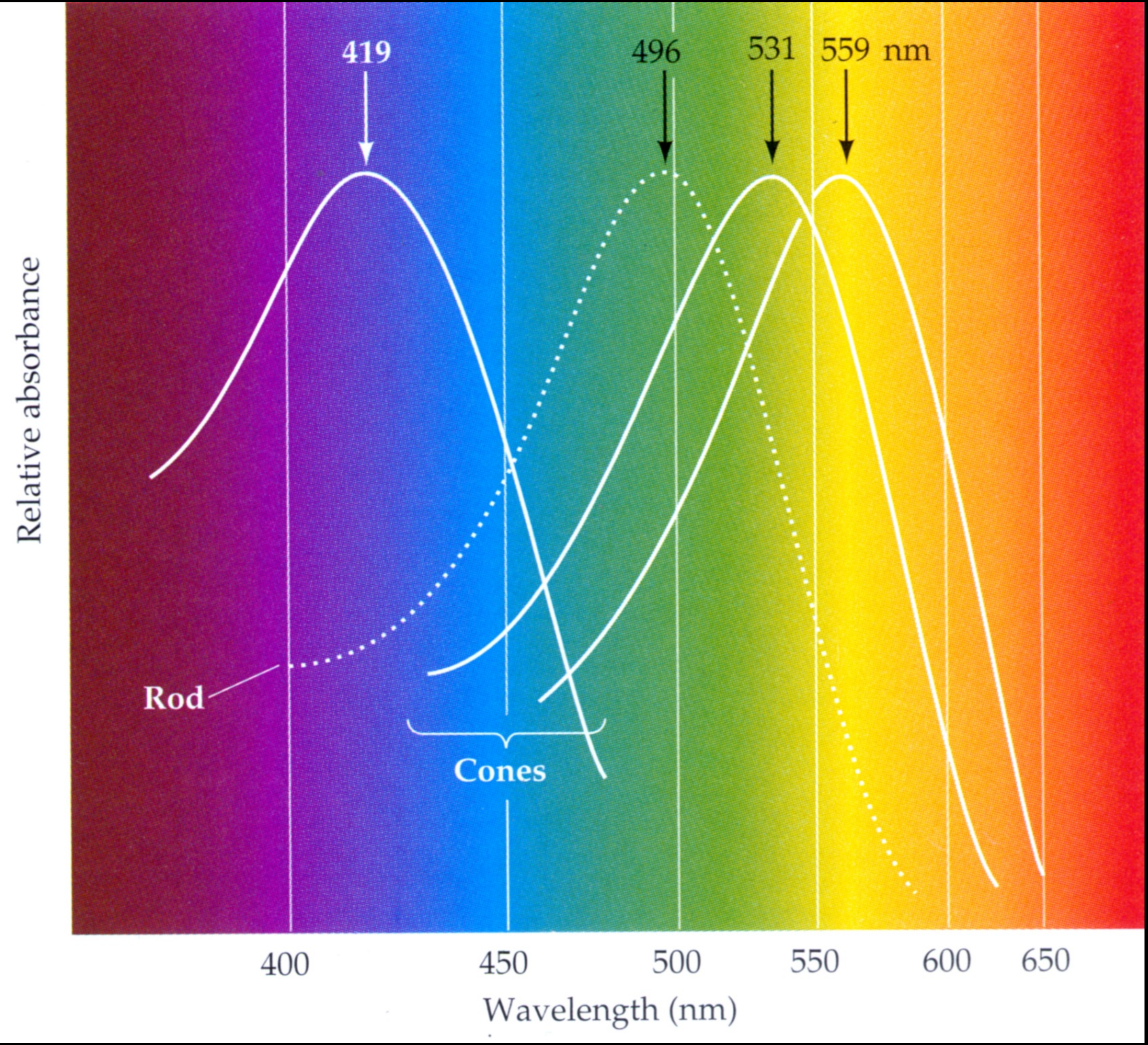
Rhodopsin

Red and Green Cone Opsins are Nearly Identical

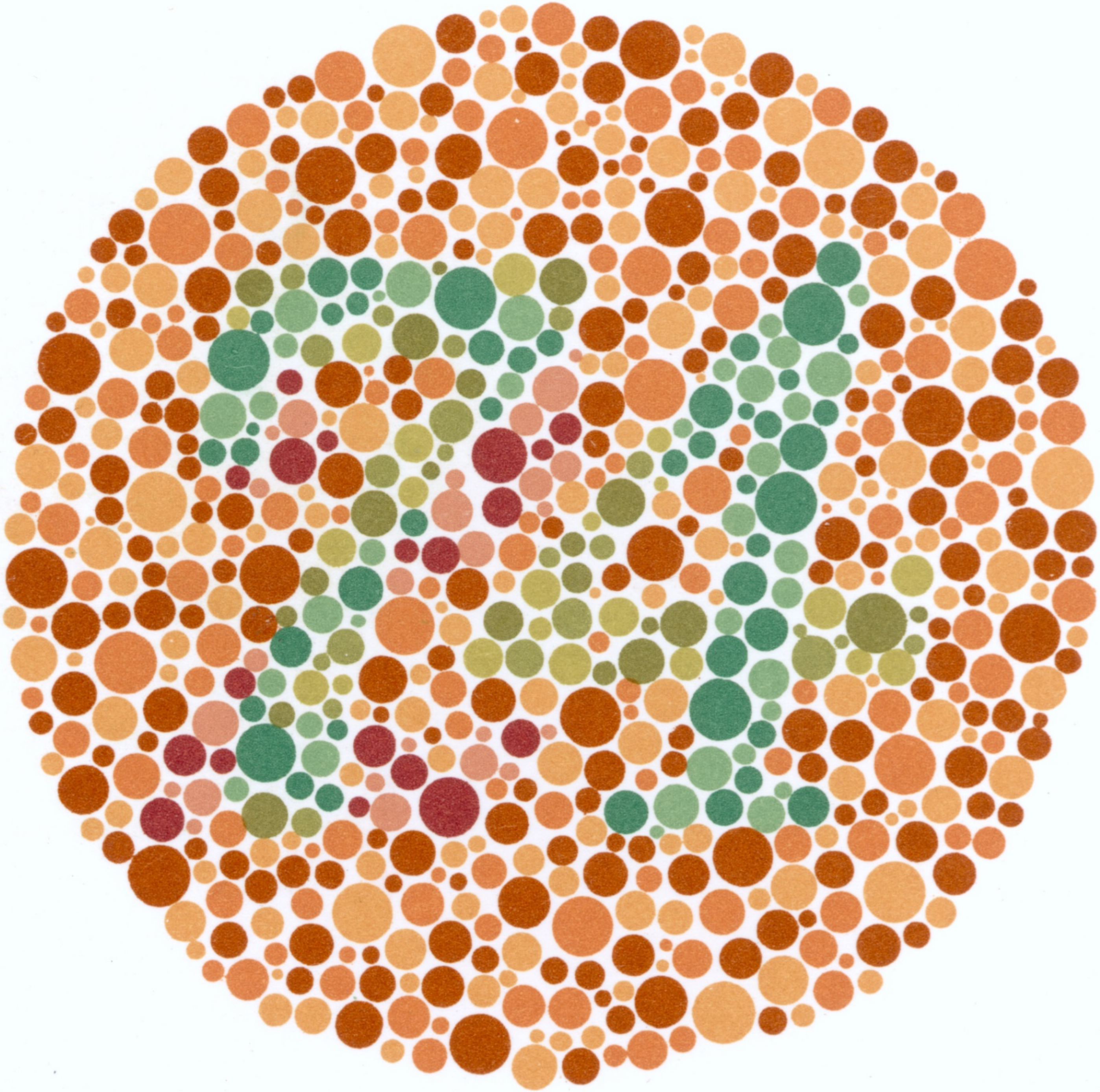
3/15 amino acid differences account for absorption shift

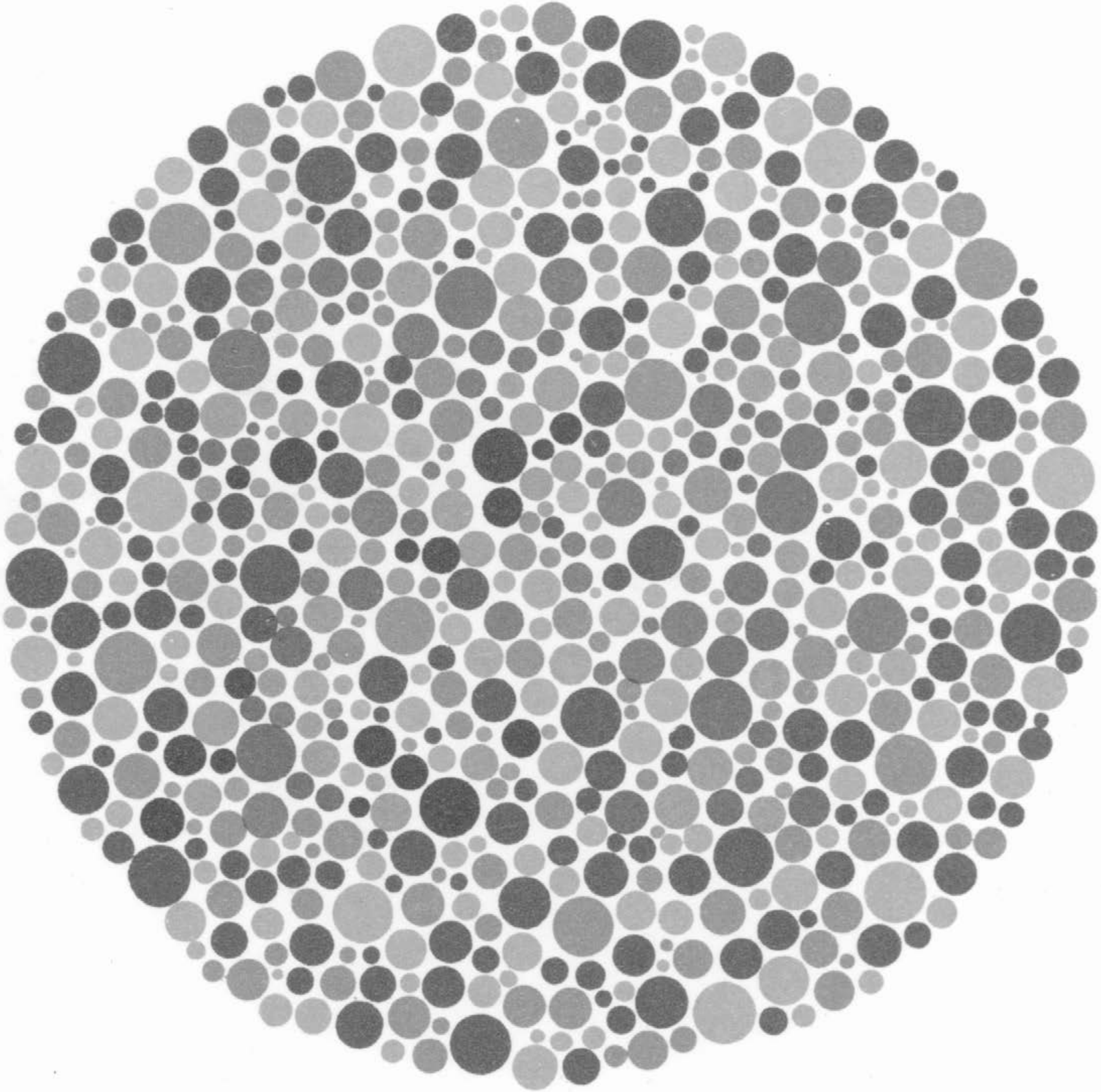


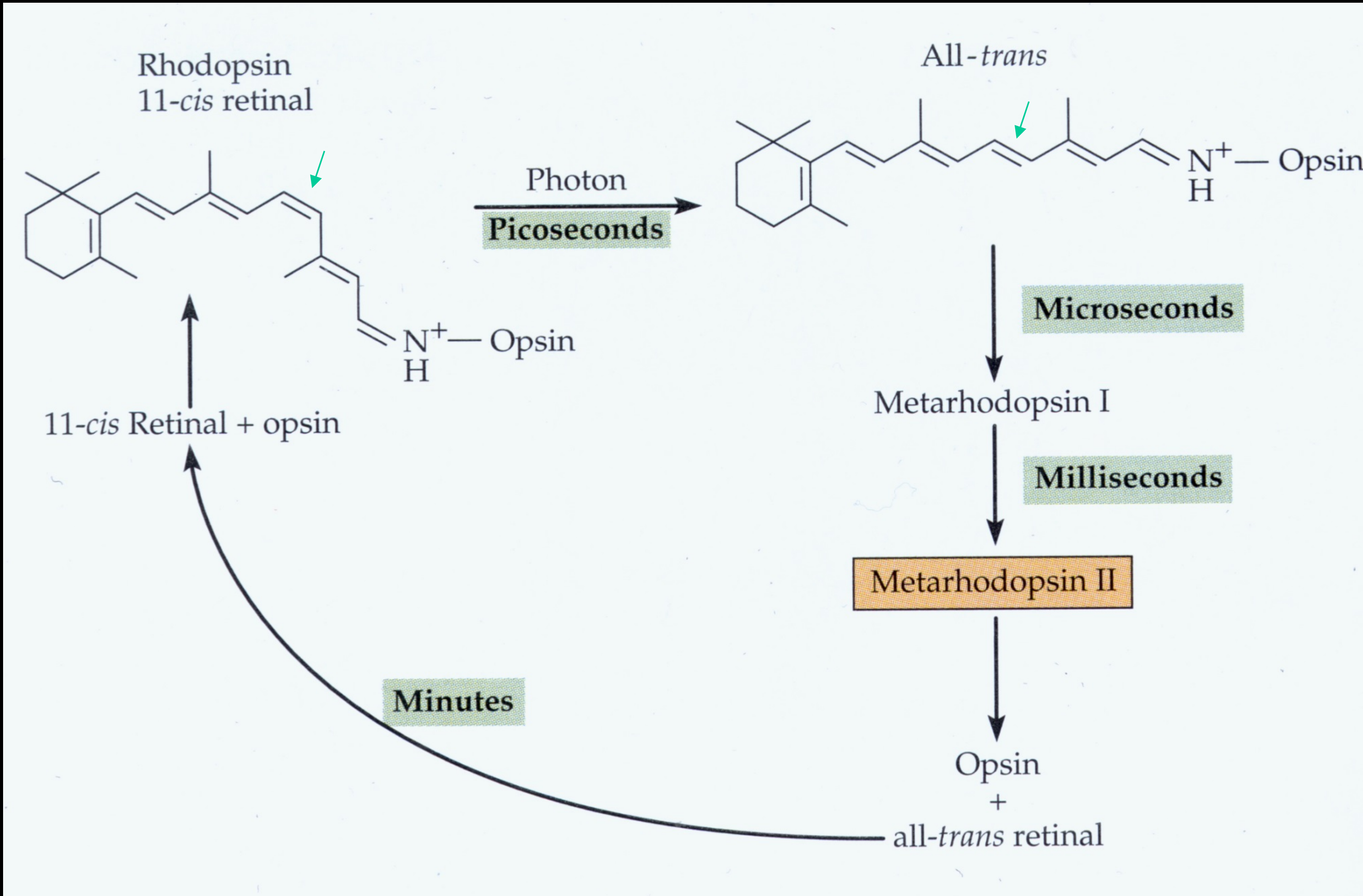
M and L cone differences



419
496
531
559 nm
Relative absorbance
Rod
Cones
400
450
500
550
600
650
Wavelength (nm)







Bleaching of Rhodopsin by Light Results in Uncoupling of Trans Retinal & Opsin. The Trans Retinal is Converted Back to Cis Retinal by the Pigment Epithelium

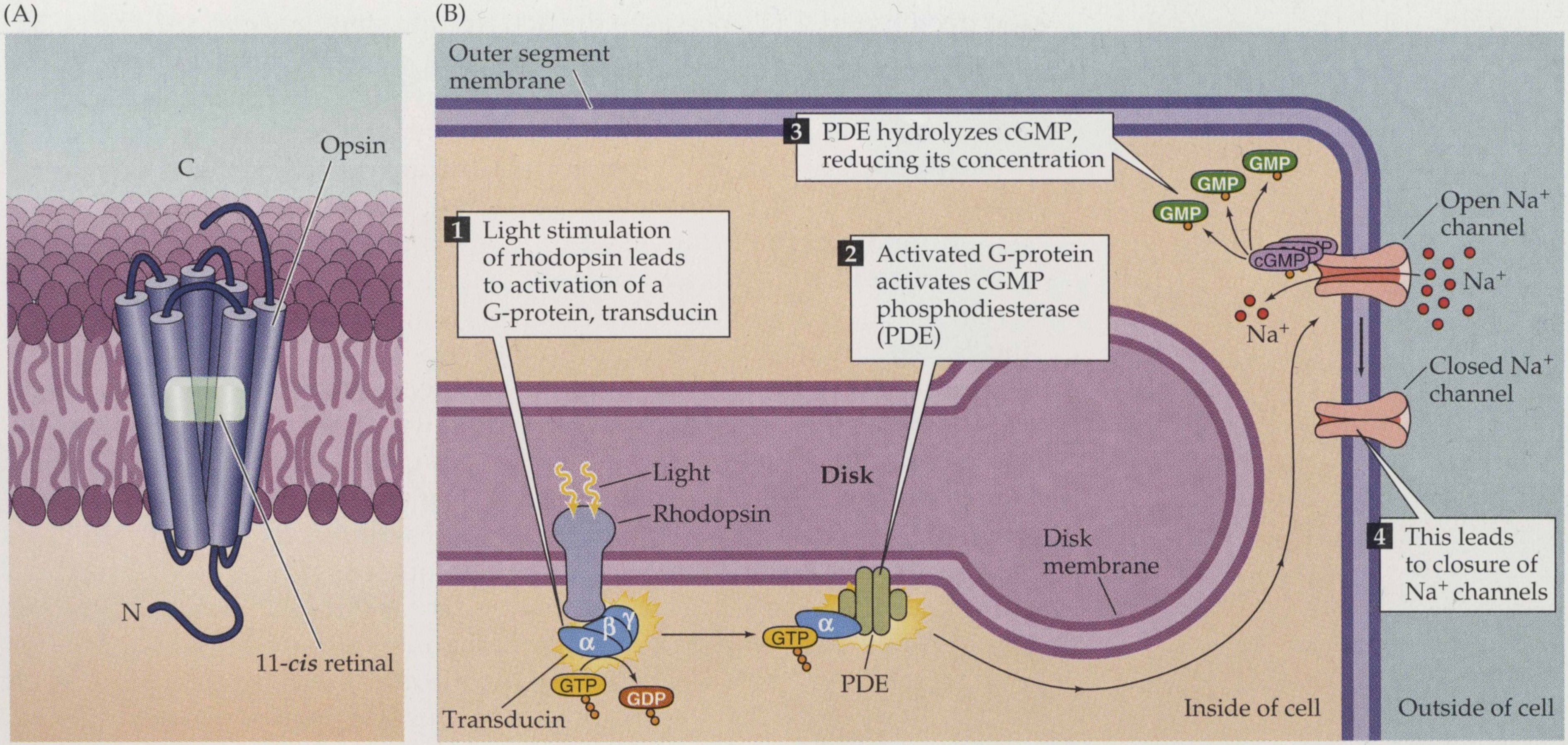


Figure 11.7 Details of phototransduction in rod photoreceptors. (A) The molecular structure of rhodopsin, the pigment in rods. (B) The second messenger cascade of phototransduction. Light stimulation of rhodopsin in the receptor disks leads to the activation of a G-protein (transducin), which in turn activates a phosphodiesterase (PDE). The phosphodiesterase hydrolyzes cGMP, reducing its concentration in the outer segment and leading to the closure of sodium channels in the outer segment membrane.

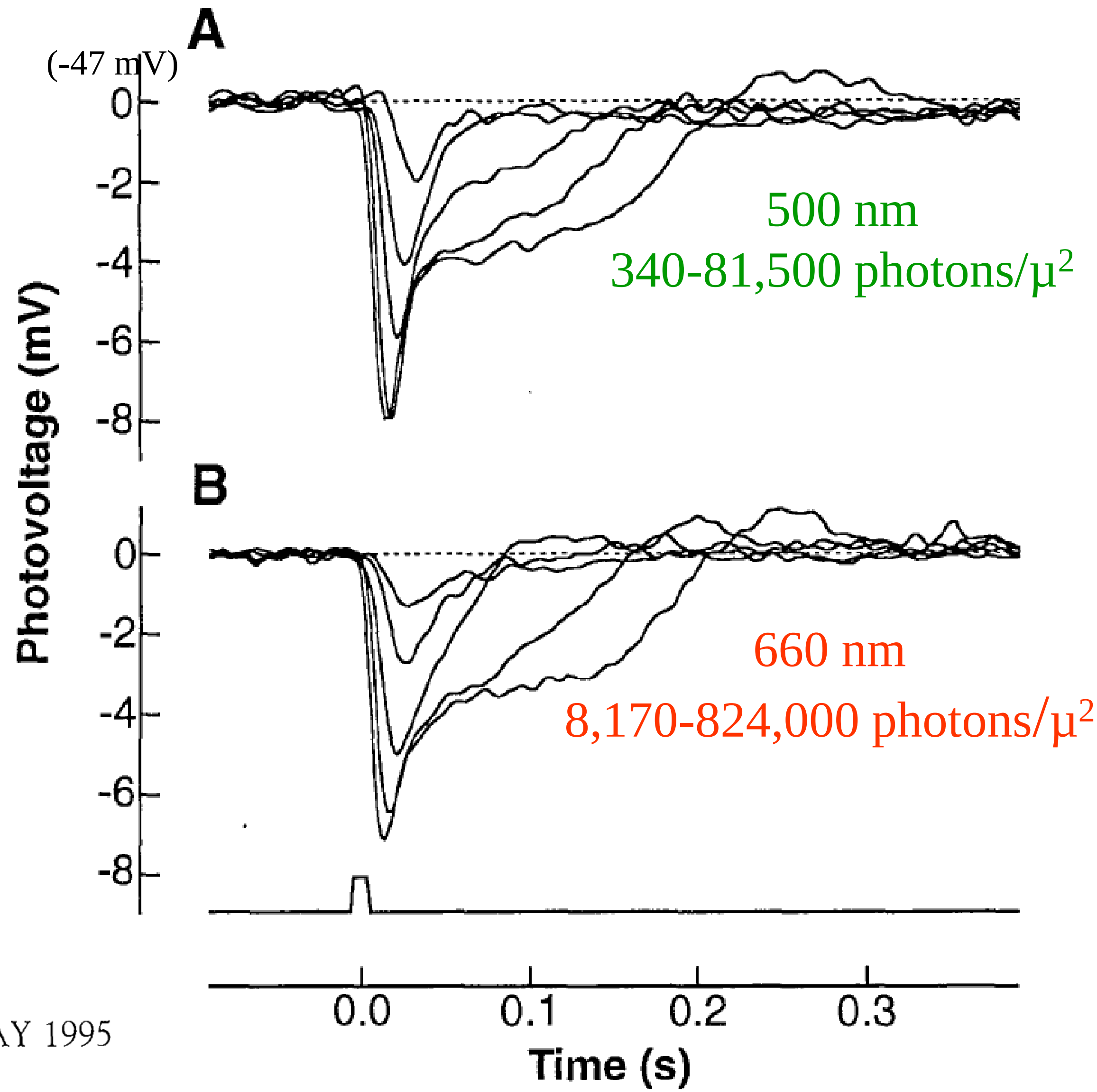
Purves et al, Neuroscience, 2001

Photovoltage of Rods and Cones in the Macaque Retina

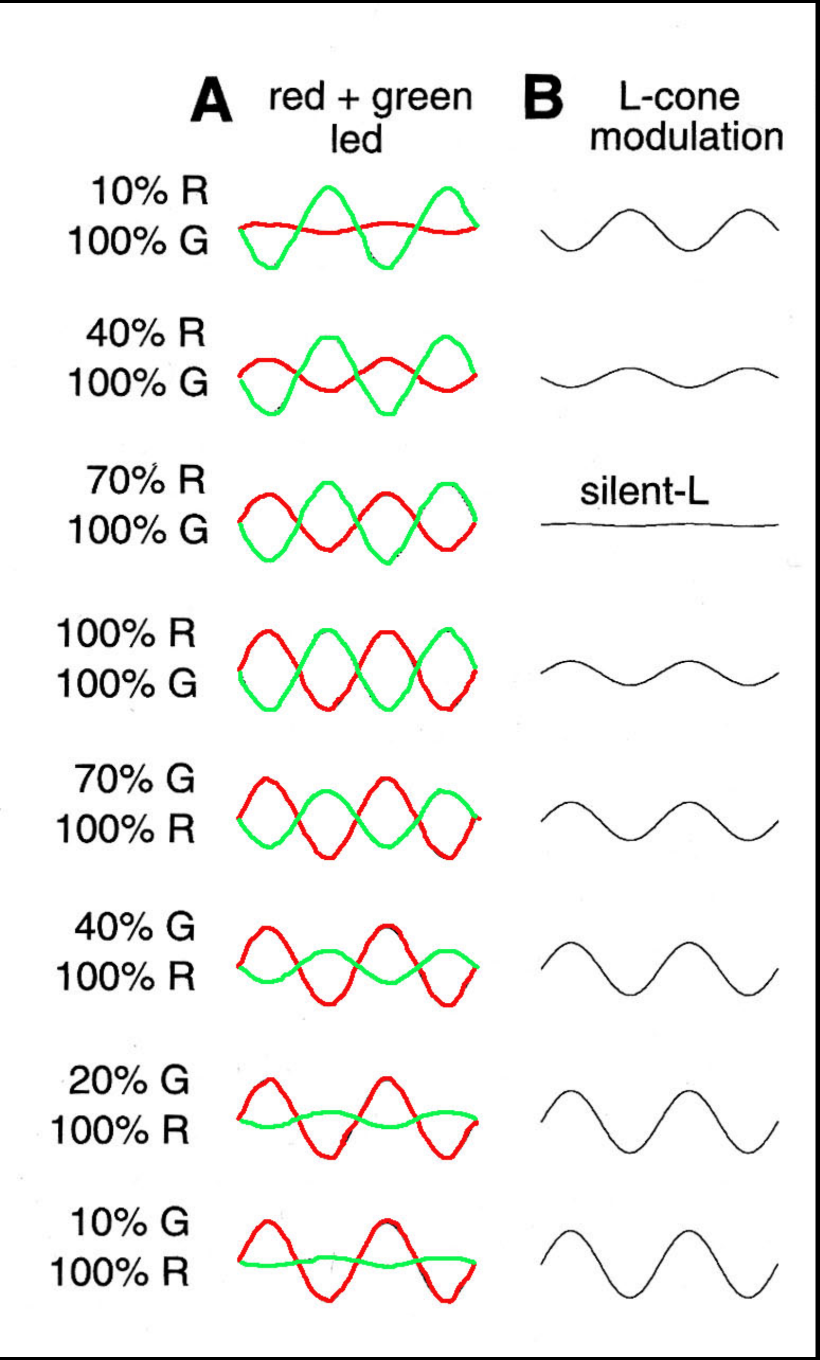
David M. Schneeweis and Julie L. Schnapf*

Hyperpolarization of a red cone to light.

Note that the cell is more sensitive to green light than red light.



SCIENCE • VOL. 268 • 19 MAY 1995



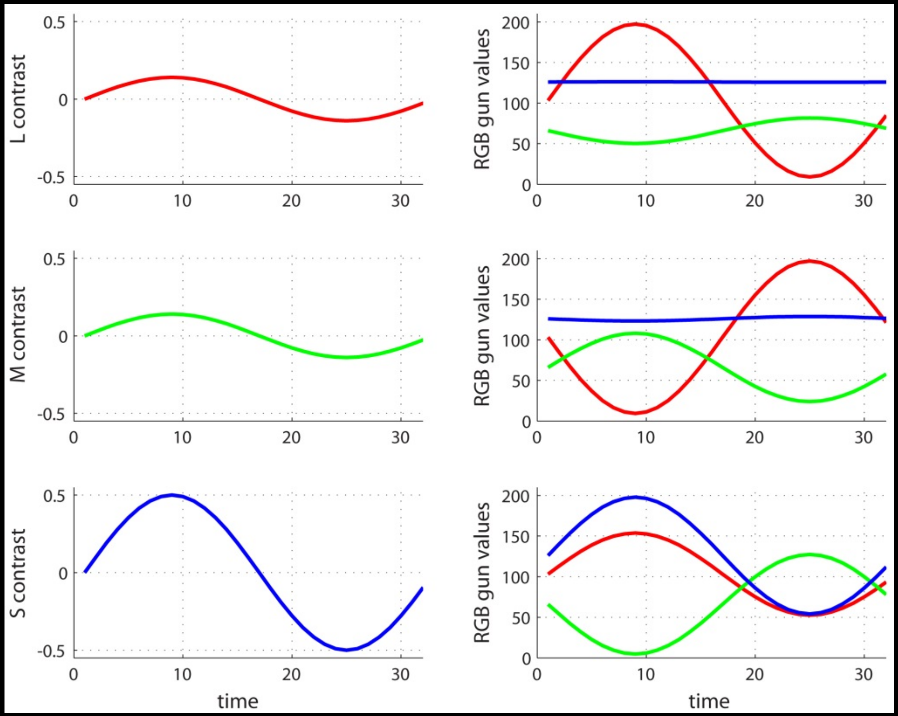
L-Cone Modulation

At 100% Red, 10% Green, the L-cones will modulate in phase with the red LED.

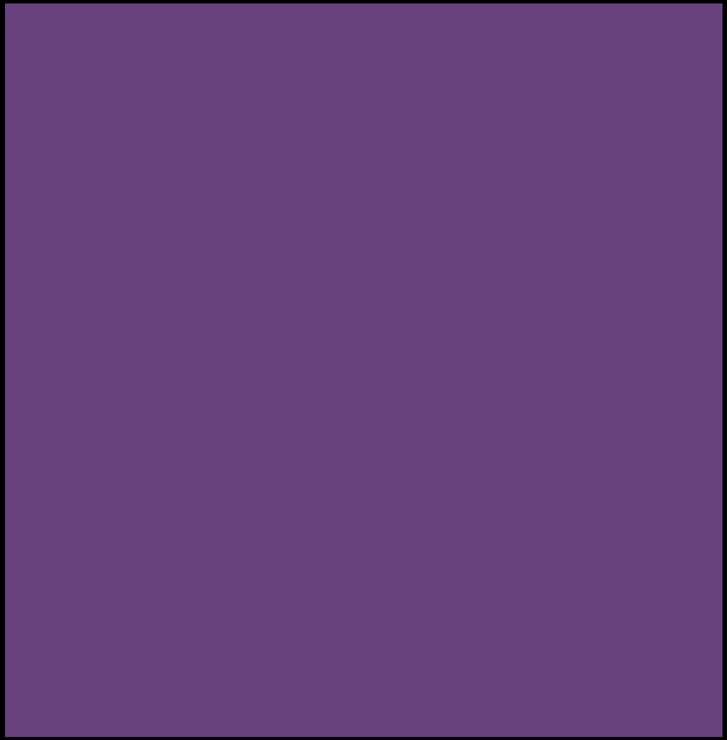
As the green LED gets stronger, the L-cones modulate more weakly, because the green LED is out of phase with the red LED.

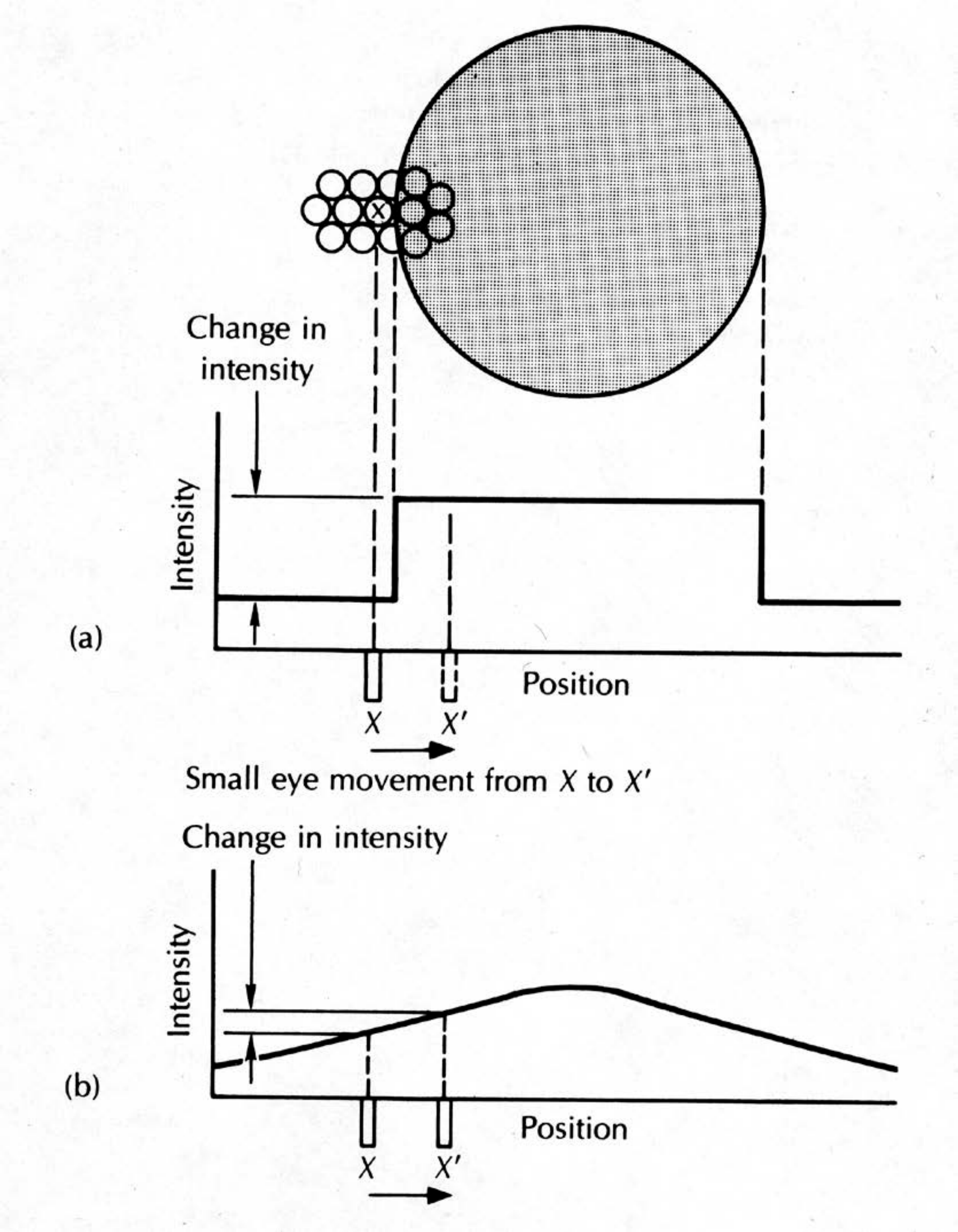
Eventually, the L-cones stop responding (the red LED modulation may need to be reduced to find this point). This stimulus is considered “M-cone isolating” because the L-cones are silent.

As the red LED modulation is reduced further, the L-cones begins to respond in phase with the green LED.

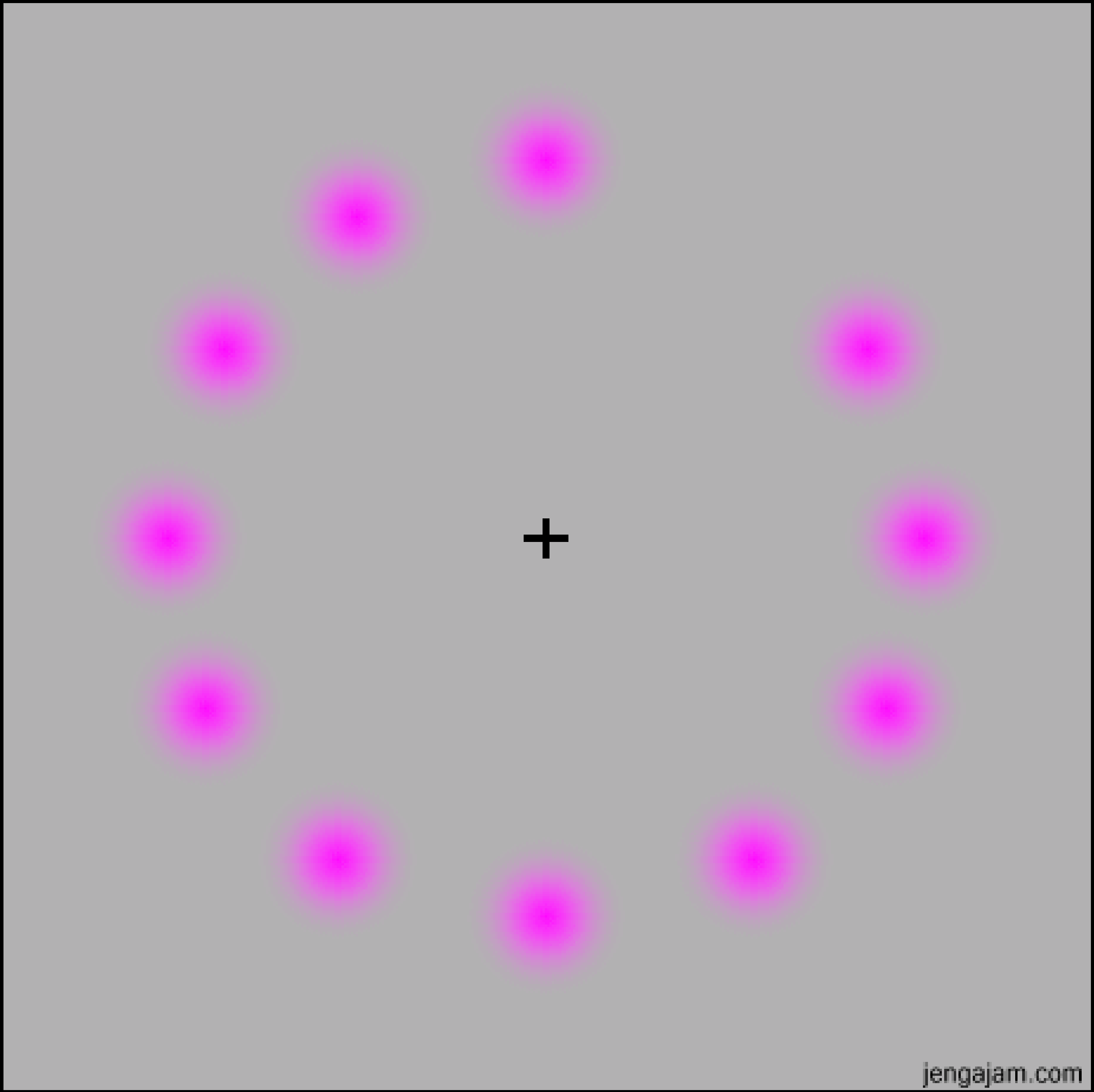


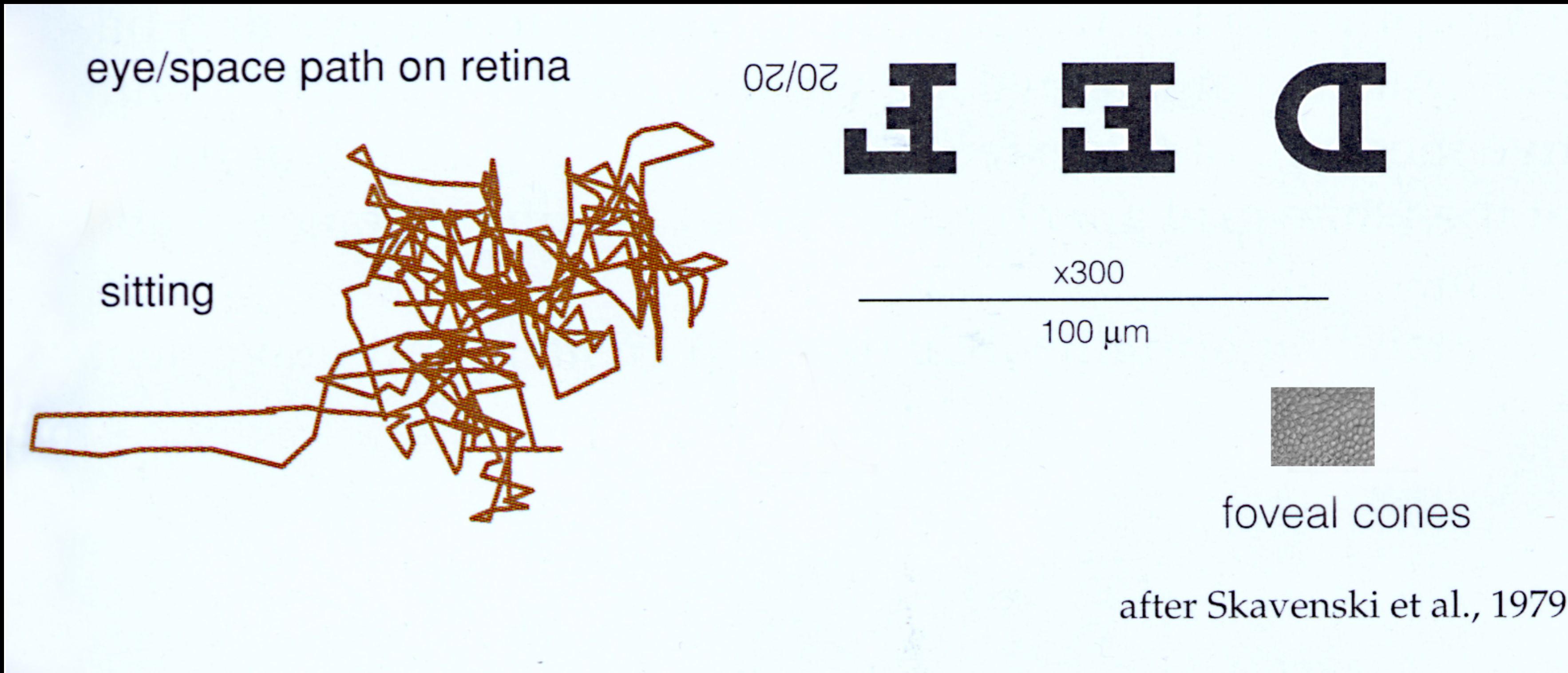
L cone



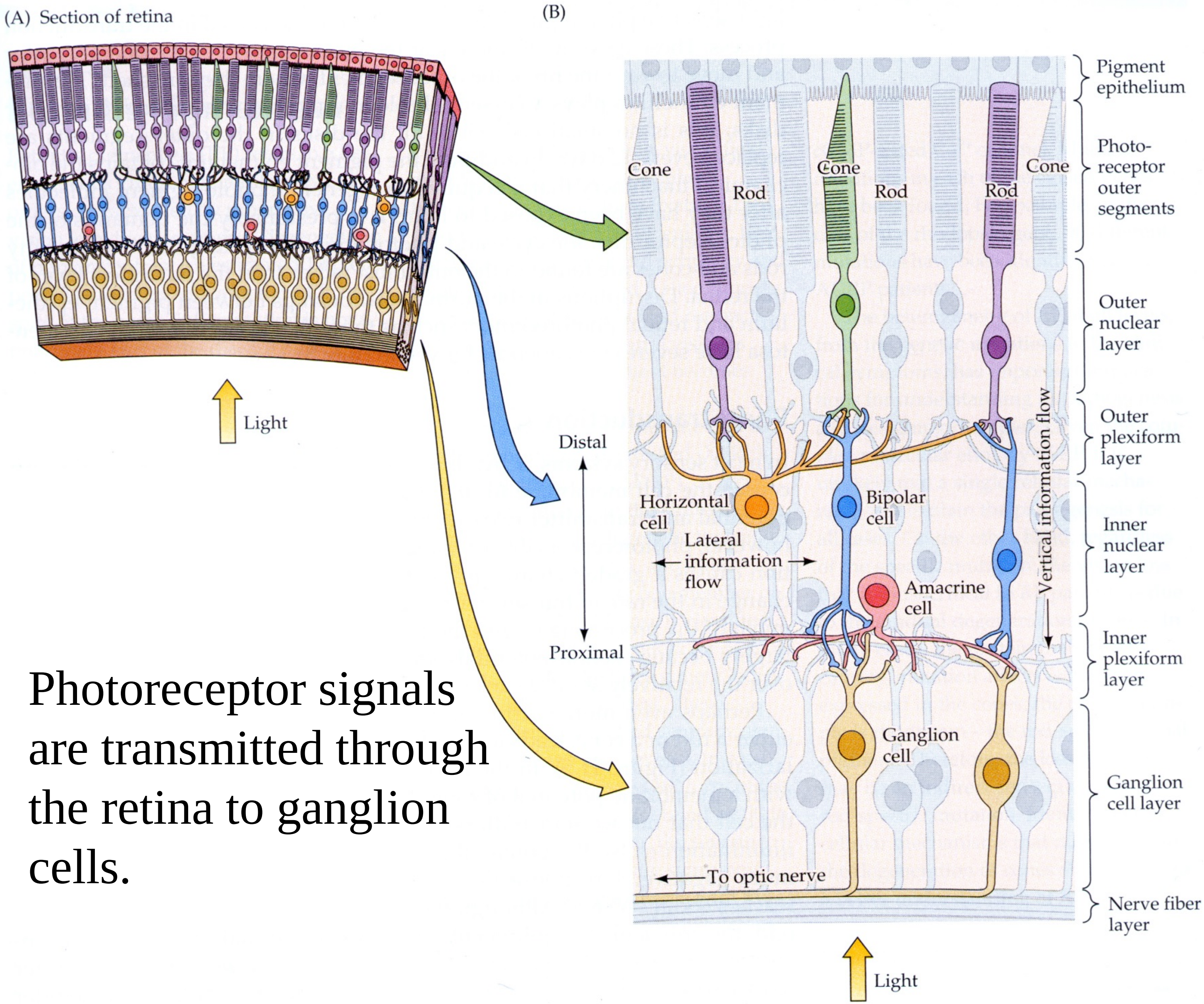


Cornsweet, TN
Visual Perception
Academic Press, 1970
Page 410

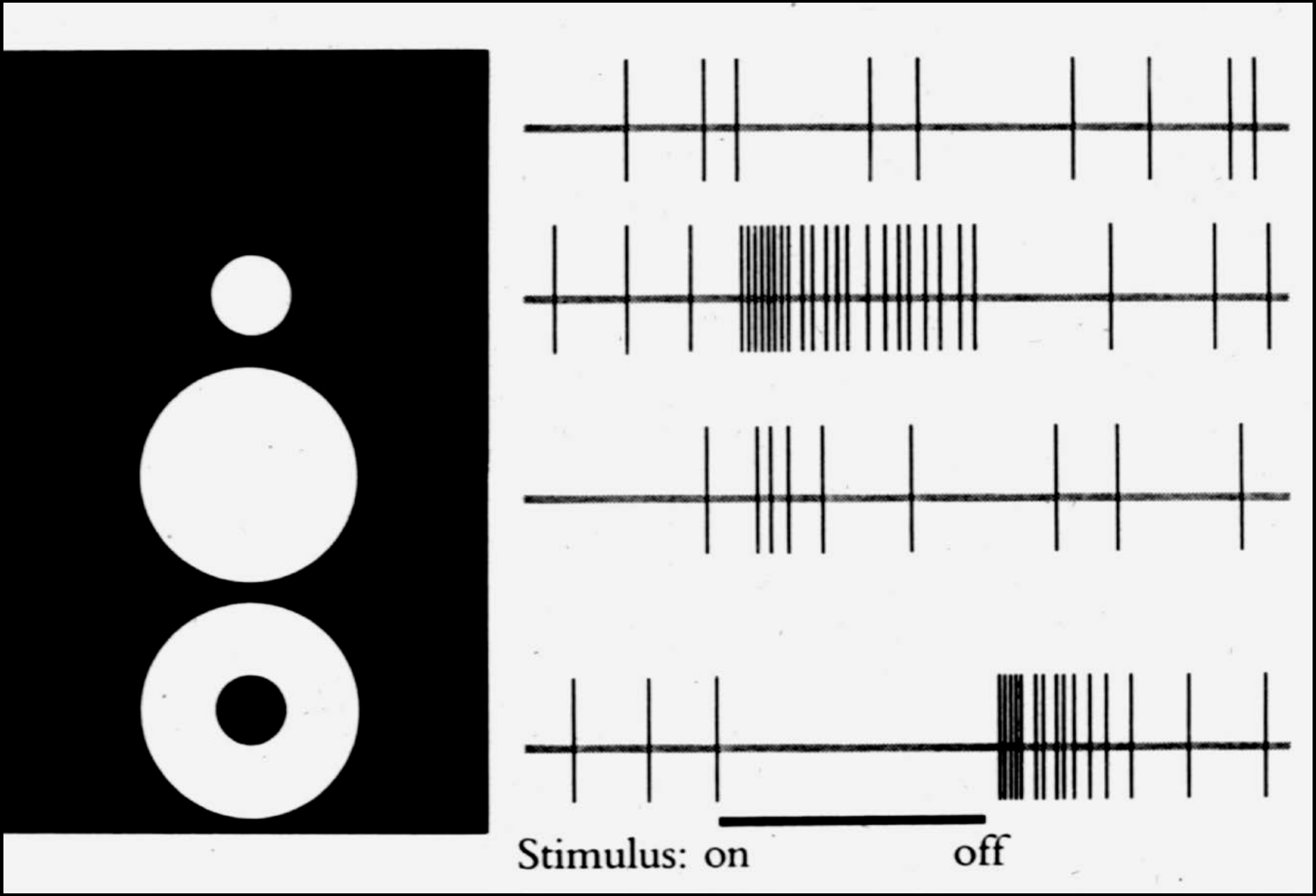

jengajam.com



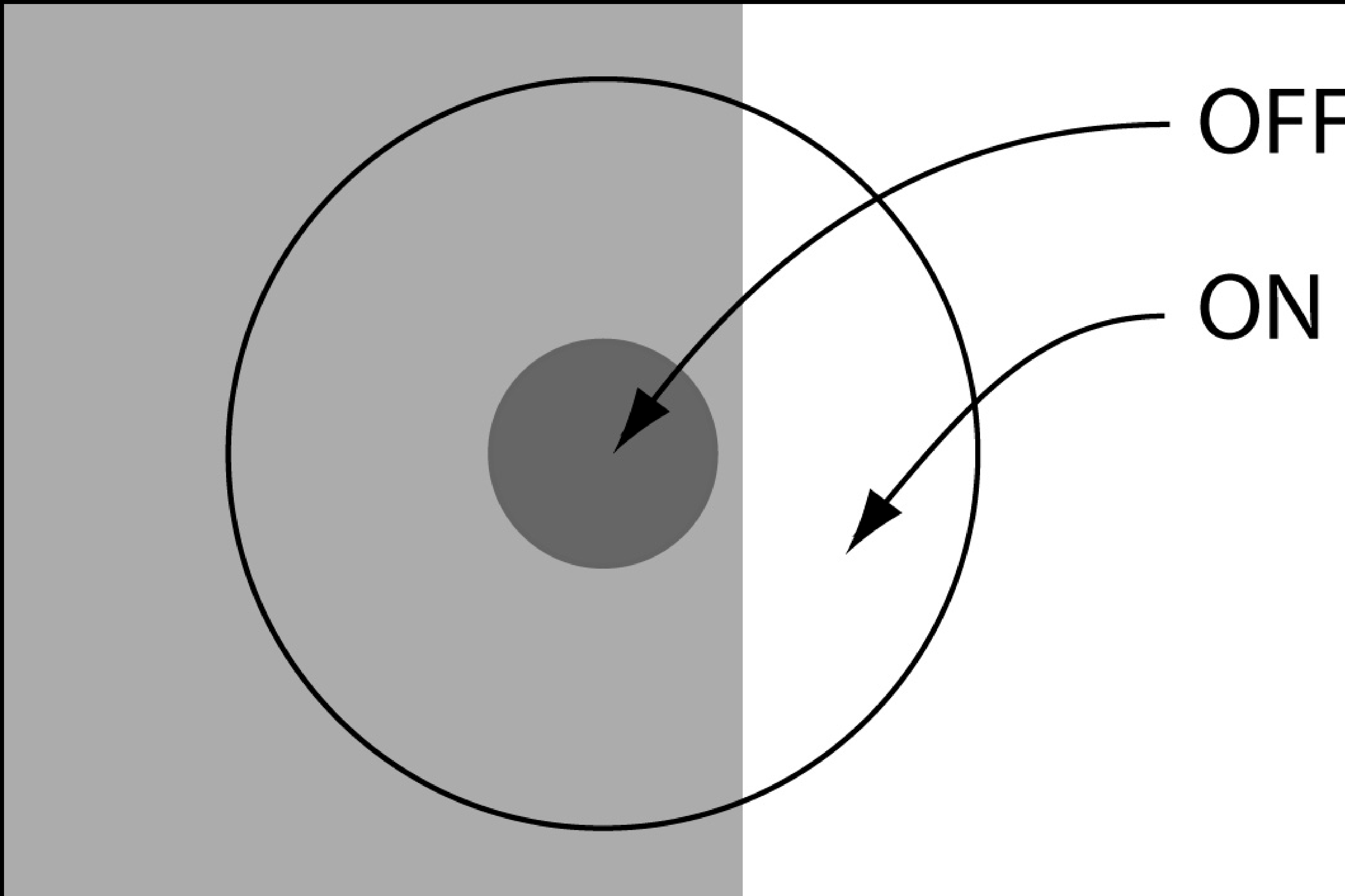
Microsaccades Prevent Image Fading by Avoiding Habituation of Photoreceptors

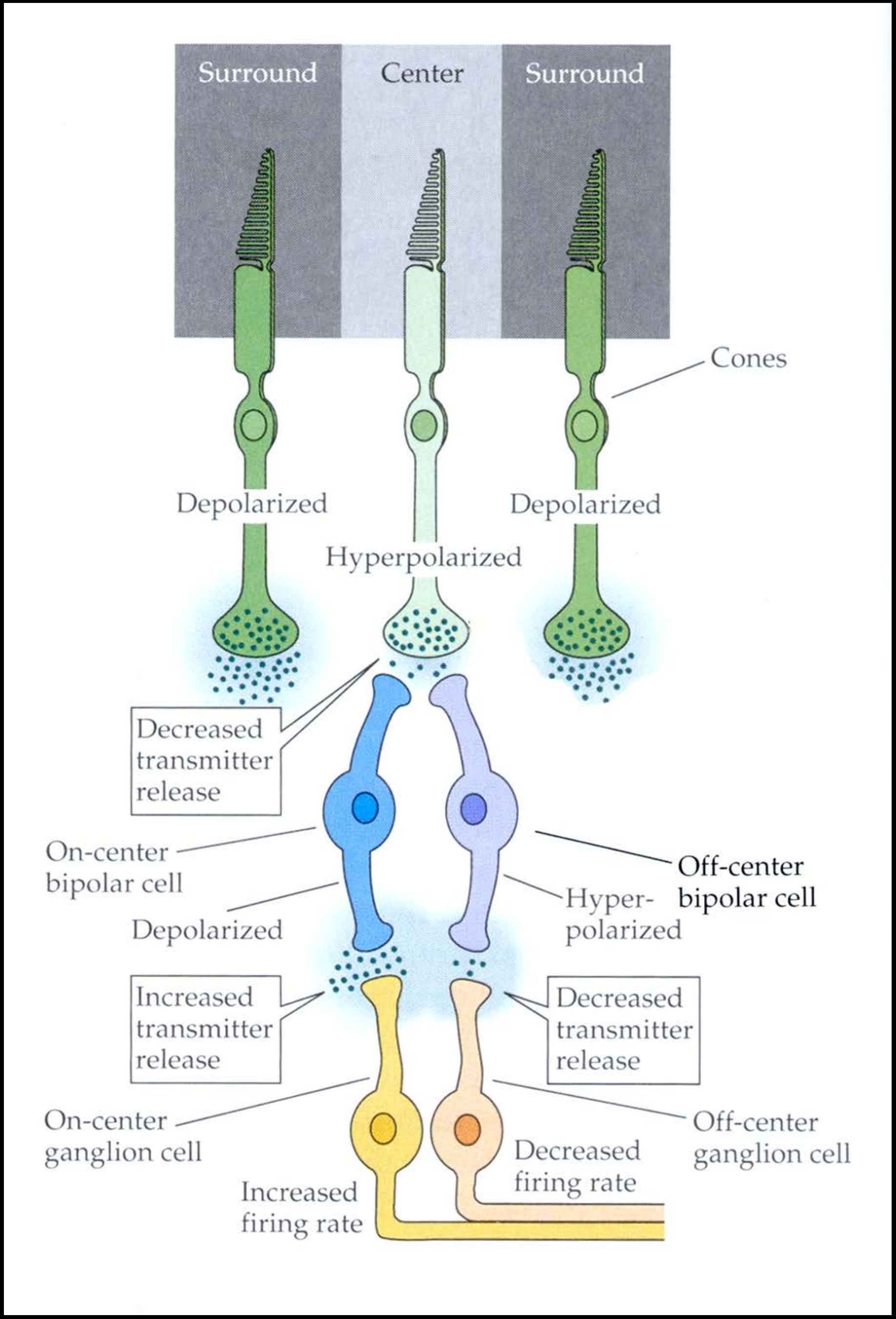


Photoreceptor signals are transmitted through the retina to ganglion cells.



On-Center Cell (from Kuffler, 1952)


OFF
ON



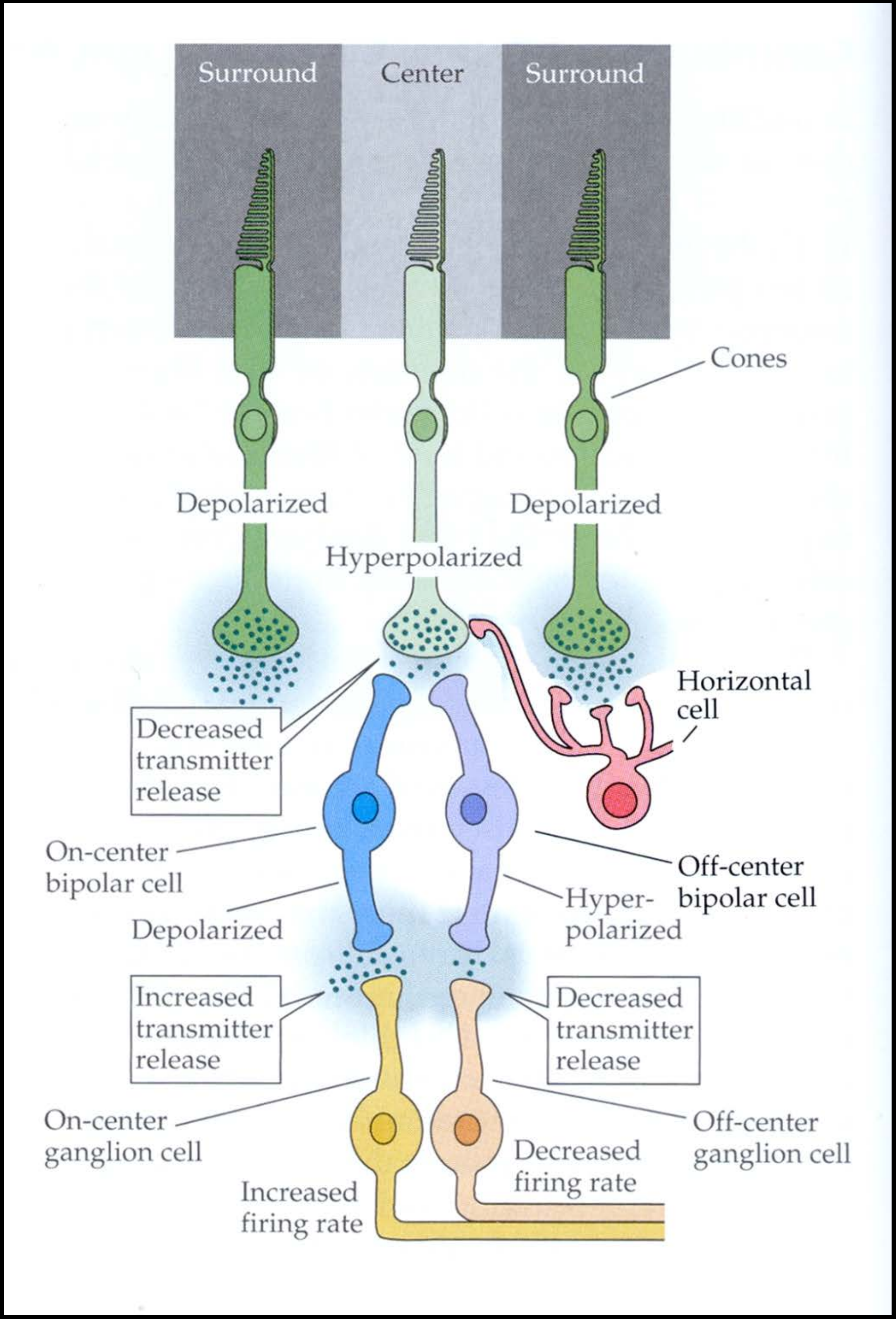
Ionotropic Receptors:

off-bipolar cells (AMPA, Kainate – sign conserving)

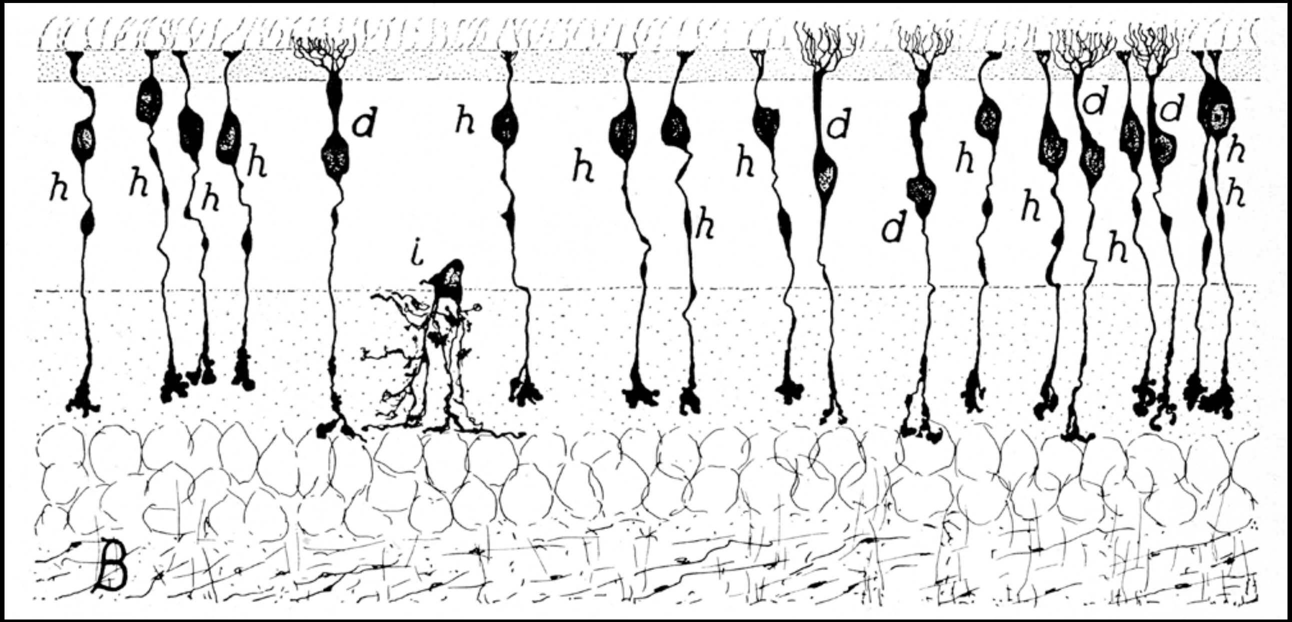
Metabotropic Receptors:

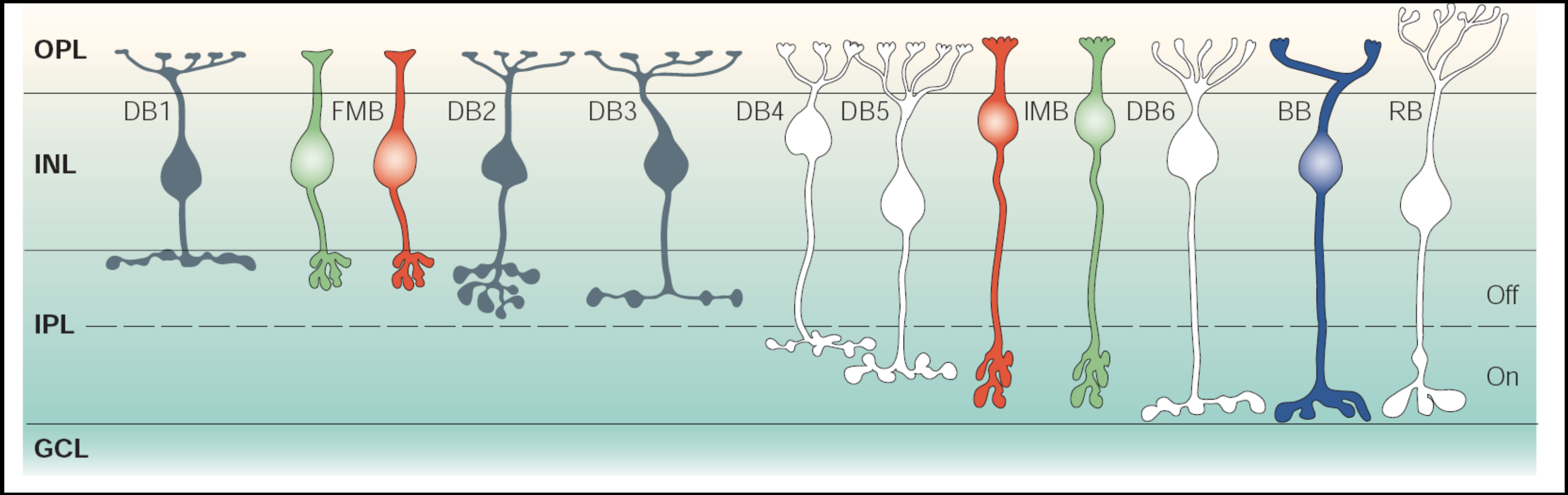
on-bipolar cells (mGluR6 – sign inverting)

How is the Opponent Surround Mediated in Ganglion Cells?

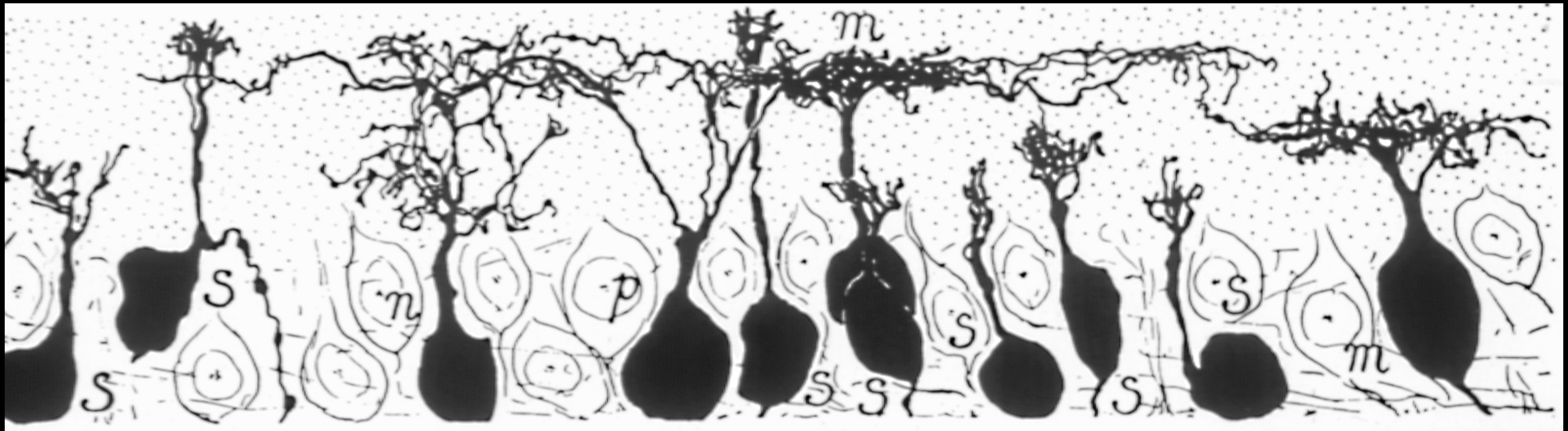


Bipolar Cell Types



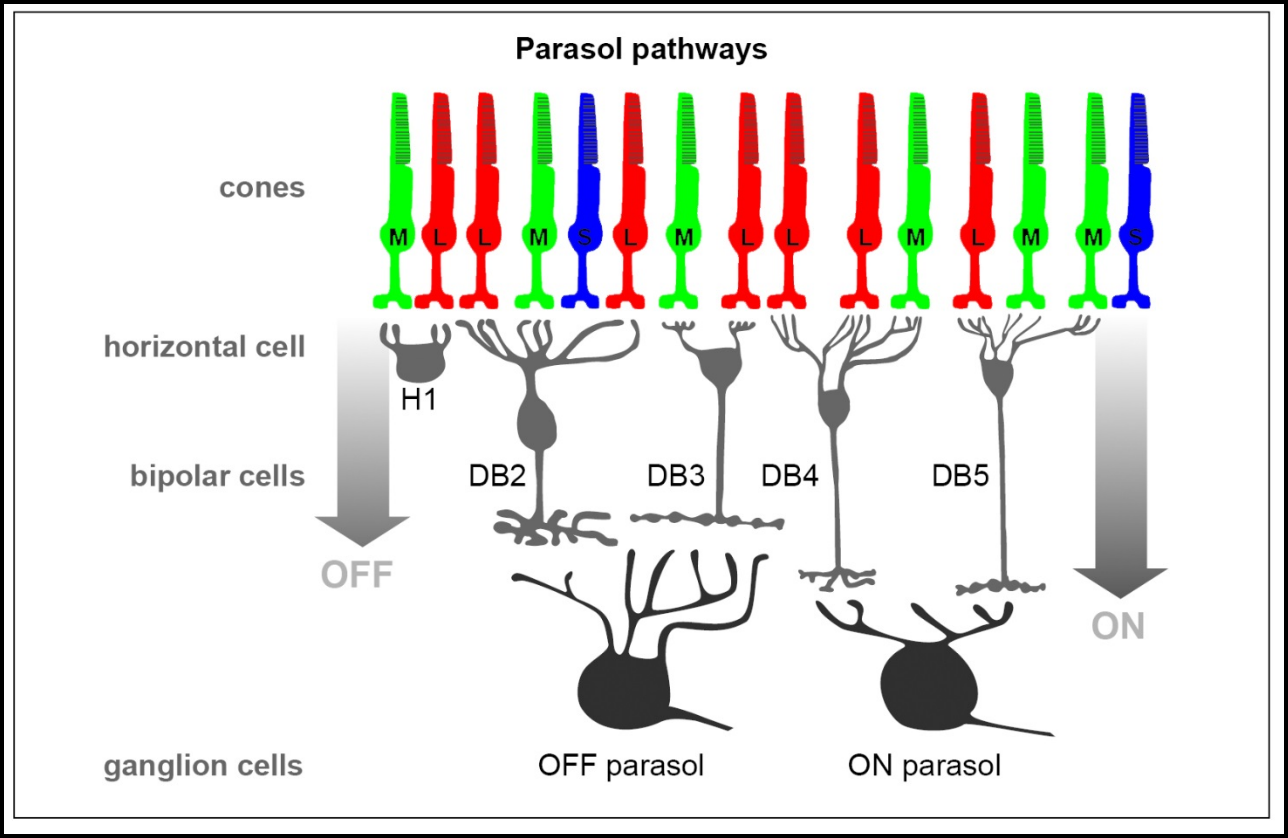


Wässle, H: Nature Reviews:5:747-757, 2004. DB = diffuse bipolar, FMB = flat midget bipolar, IMB = invaginating midget bipolar, BB = blue cone bipolar, RB = rod bipolar



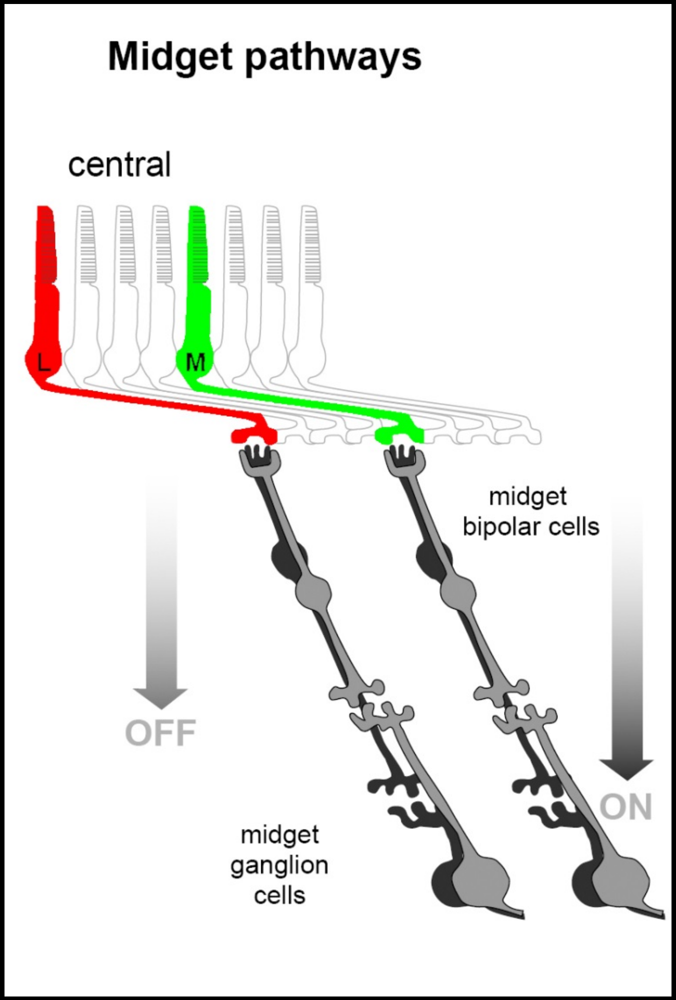
Polyak 1957

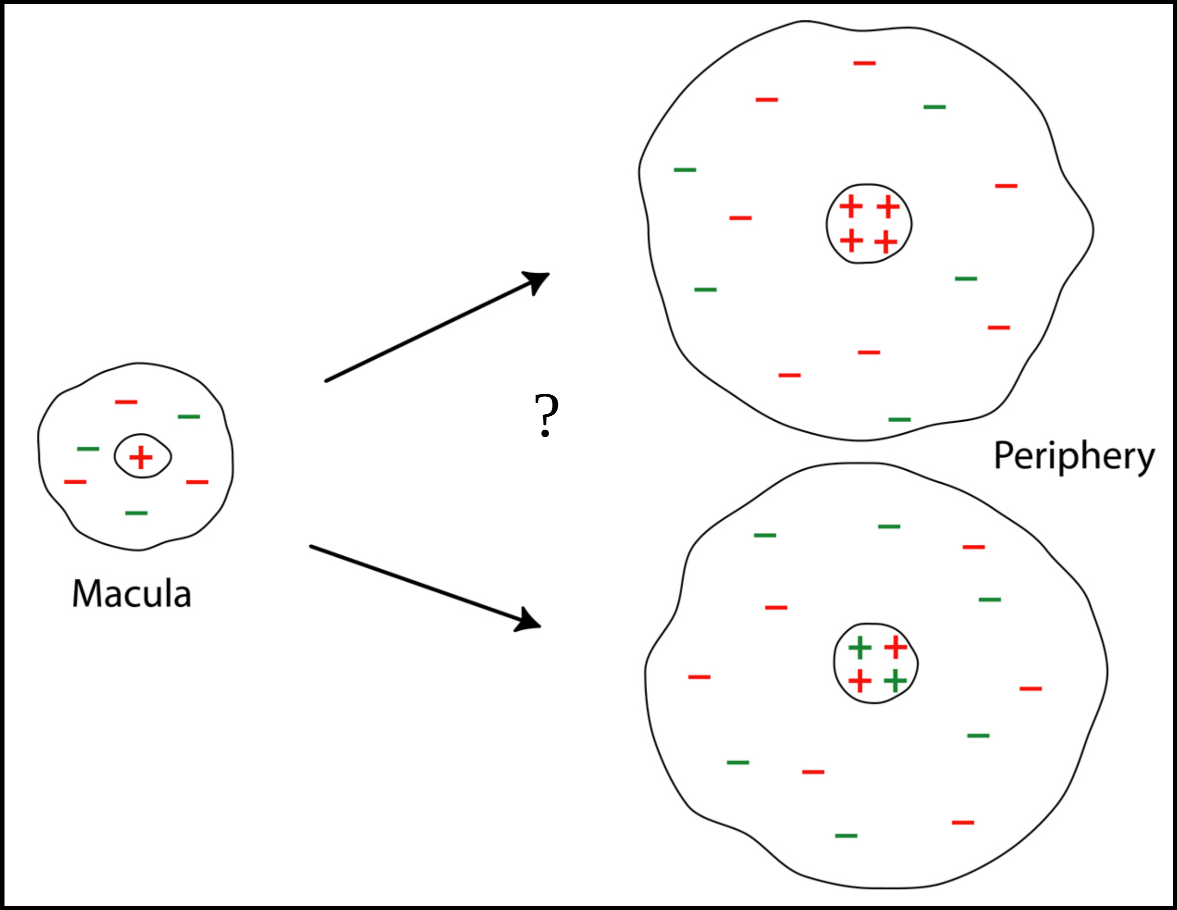
Parasol Cells Sum Inputs From All Cone Types



Parvo Red/Green Ganglion Cells

The color-opponent cell (top) modulates nicely as light covering the receptive field oscillates between red and green, even if the stimulus is always isoluminant.





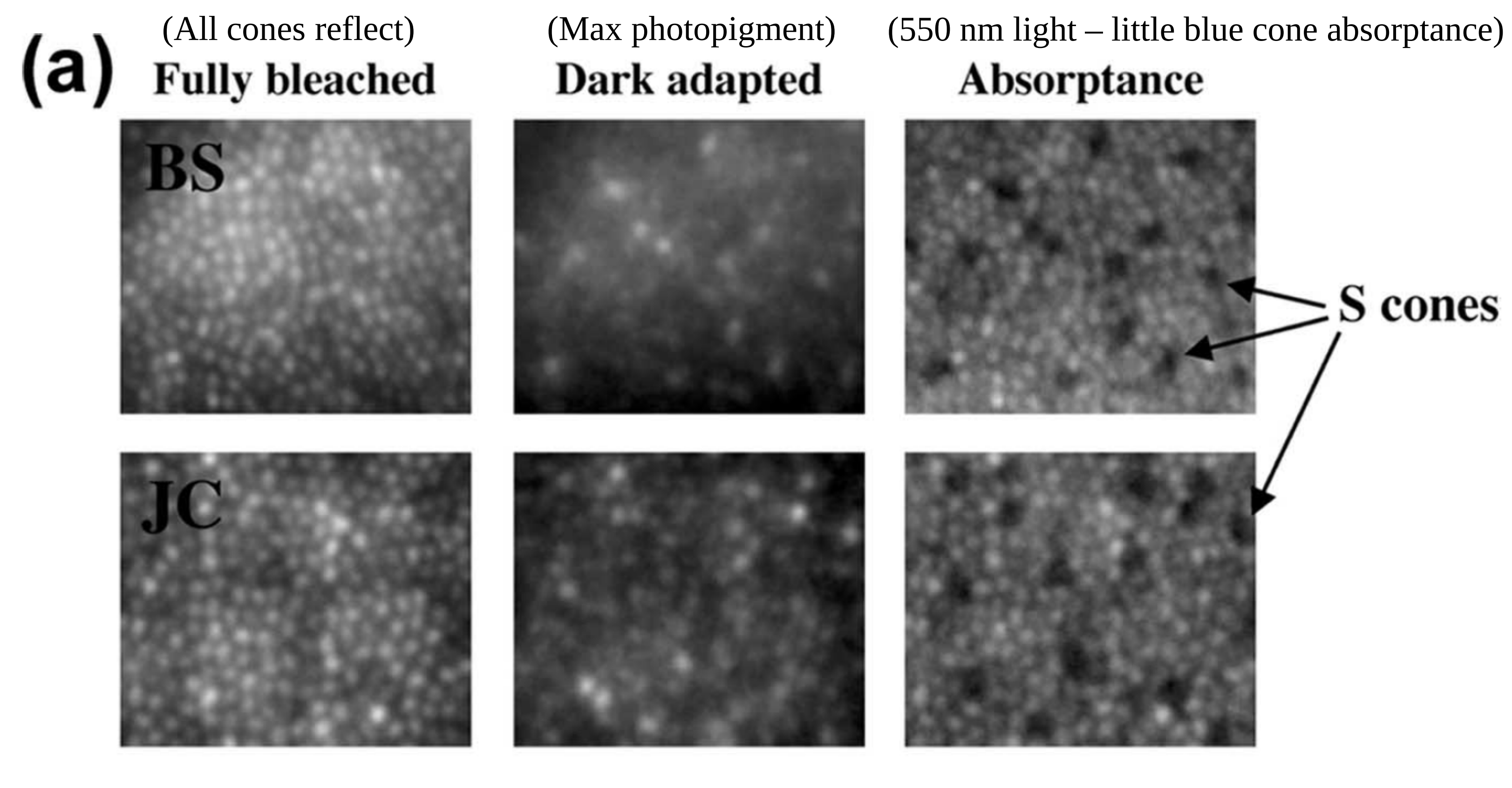
The non-opponent cell (bottom) does not modulate to isoluminant red versus green light, but it responds to altering the luminance of an isochromatic stimulus.

What Happens to Color Opponency in the Retinal Periphery?

The Journal of Neuroscience, October 19, 2005 • 25(42):9669 –9679

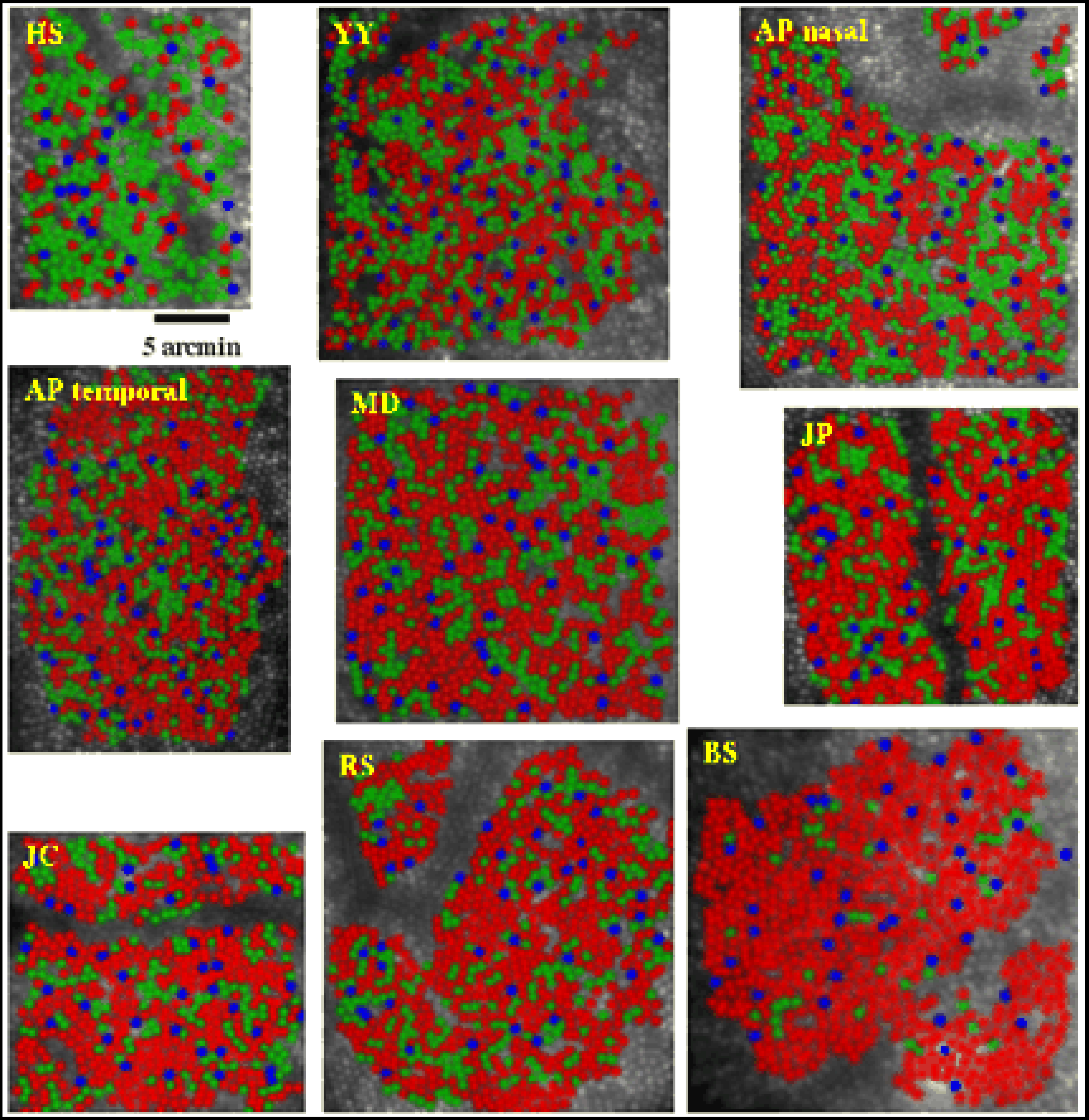
Organization of the Human Trichromatic Cone Mosaic

Heidi Hofer,[1] Joseph Carroll,[1] Jay Neitz,[2] Maureen Neitz,[2,3] and David R. Williams[1]



Red/Green cone ratio ranges from 94 to 53%

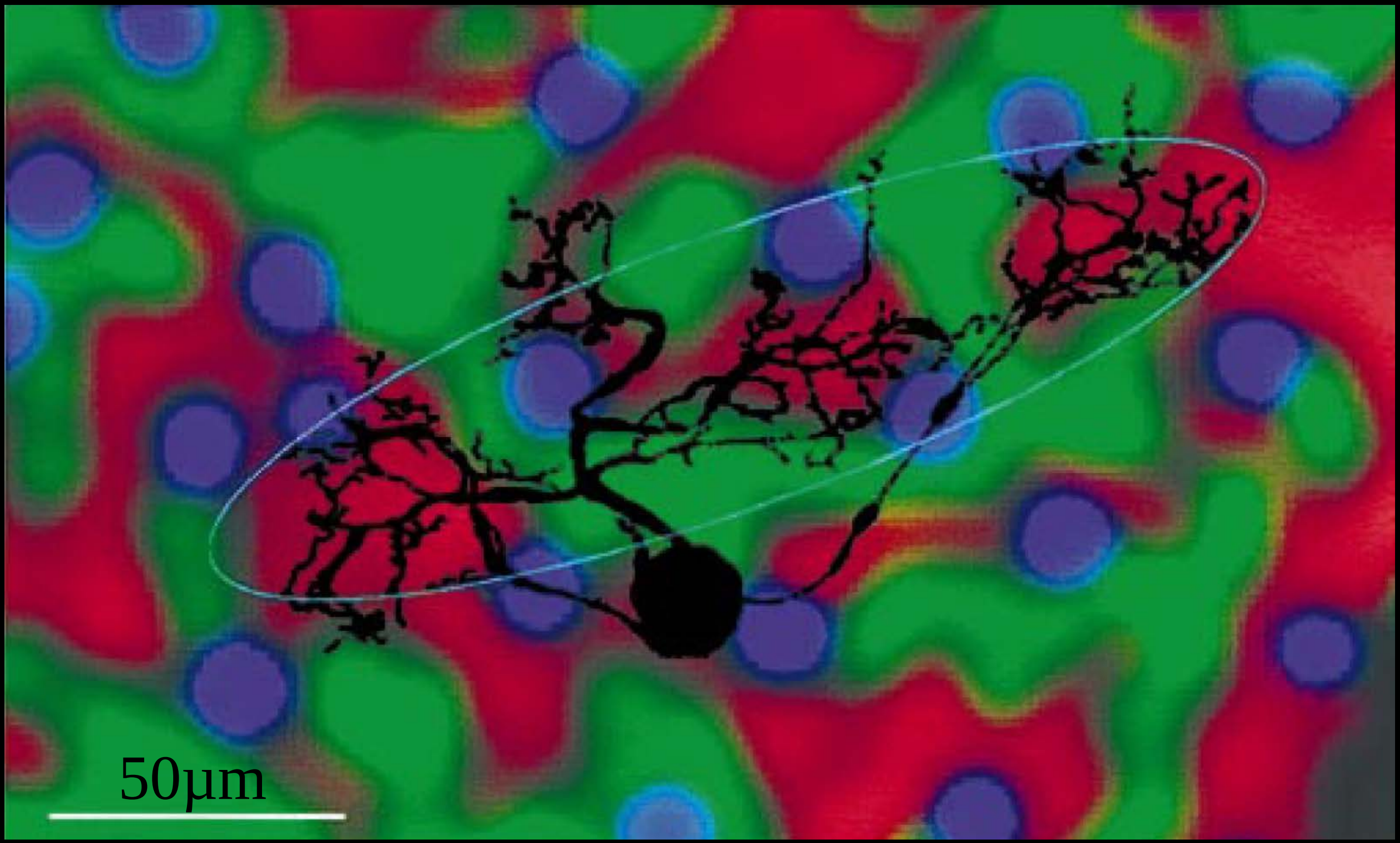
Subject HS has only 27% red cones, but is a protan carrier



Chromatic sensitivity of ganglion cells in the peripheral primate retina

Paul R. Martin*, Barry B. Lee†‡, Andrew J. R. White*,
Samuel G. Solomon* & Lukas Rüttiger†

NATURE | VOL 410 | 19 APRIL 2001 |



ARTICLE

doi:10.1038/nature09424

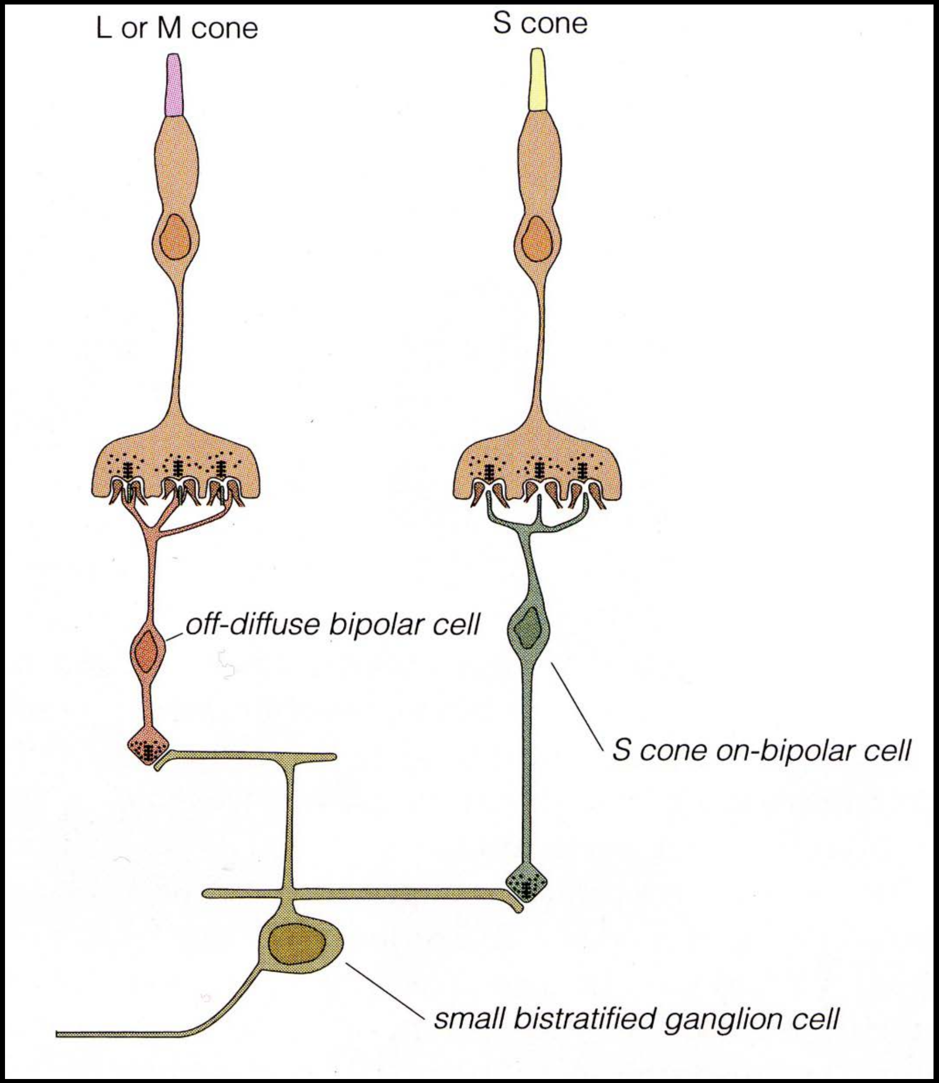
Functional connectivity in the retina at the resolution of photoreceptors

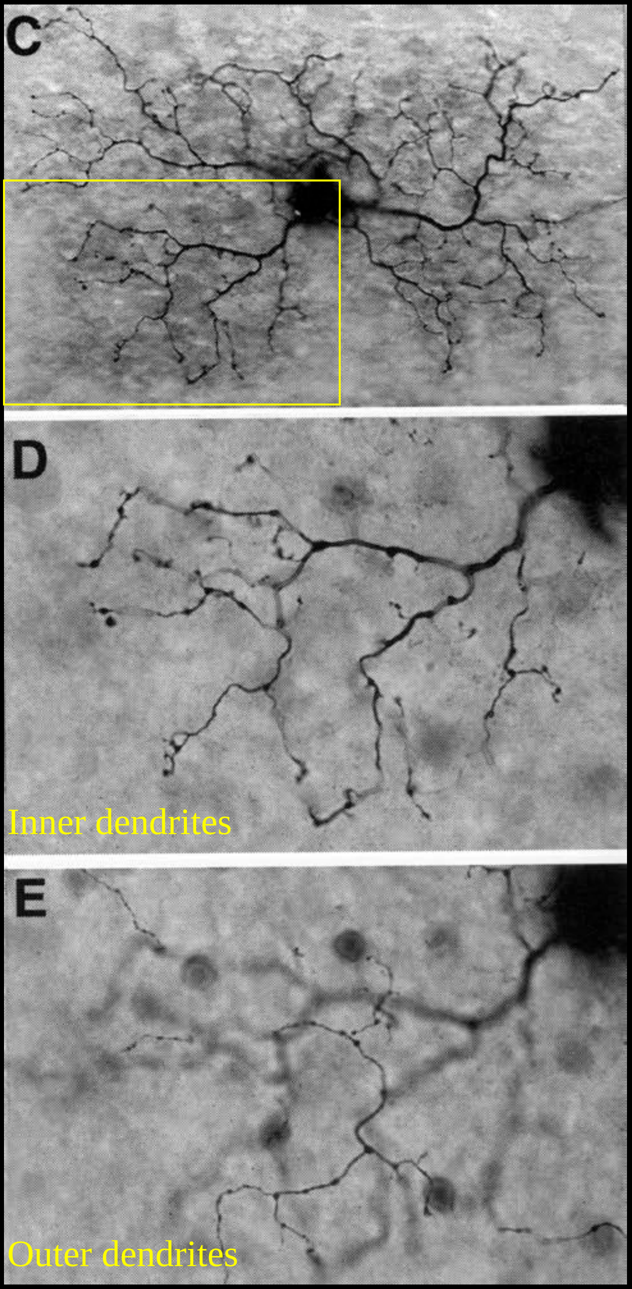
Greg D. Field[1]*, Jeffrey L. Gauthier[1]*†, Alexander Sher[2]*, Martin Greschner[1], Timothy A. Machado[1]†, Lauren H. Jepson[1], Jonathon Shlens[1], Deborah E. Gunning[3], Keith Mathieson[3], Wladyslaw Dabrowski[4], Liam Paninski[5], Alan M. Litke[2] & E. J. Chichilnisky[1]

7 OCTOBER 2010 | VOL 467 | NATURE

First Paper for Discussion Section

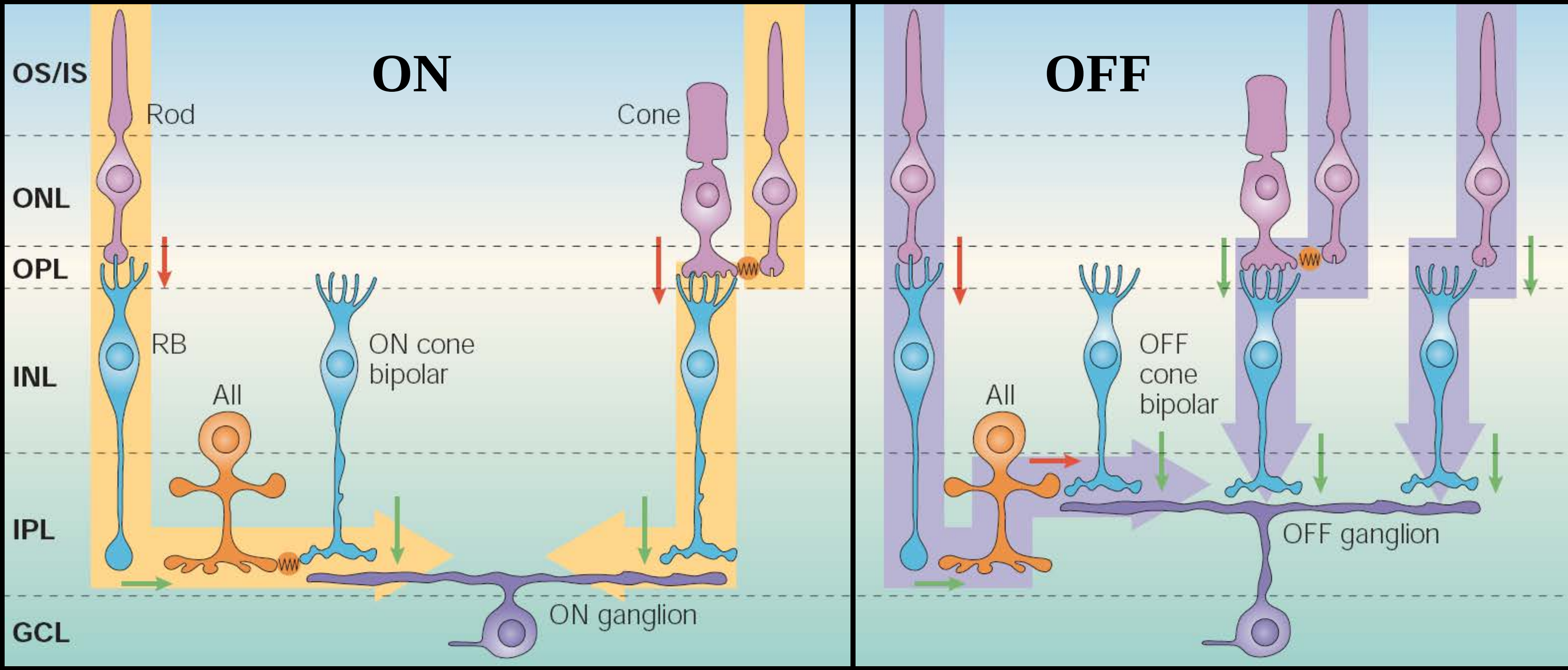
Blue-on/Yellow-off Pathway





The Rod Pathway (from Wässle 2004)

Sign Inverting Synapse   Sign Conserving Synapse



<u>First Pathway</u>: Synapse onto rod bipolar (the only type of rod bipolar, and it's "on"), synapse onto AII amacrine, gap junction onto on-cone bipolar, synapse onto on-center retinal ganglion cell.

<u>Second Pathway</u>: Gap junction to cone, synapse onto on-cone bipolar cell, synapse onto on-center retinal ganglion cell.

<u>First Pathway</u>: Synapse onto rod bipolar cell, synapse on AII amacrine cell, glycinergic synapse onto off-cone bipolar cell, synapse onto off-center retinal ganglion cell.

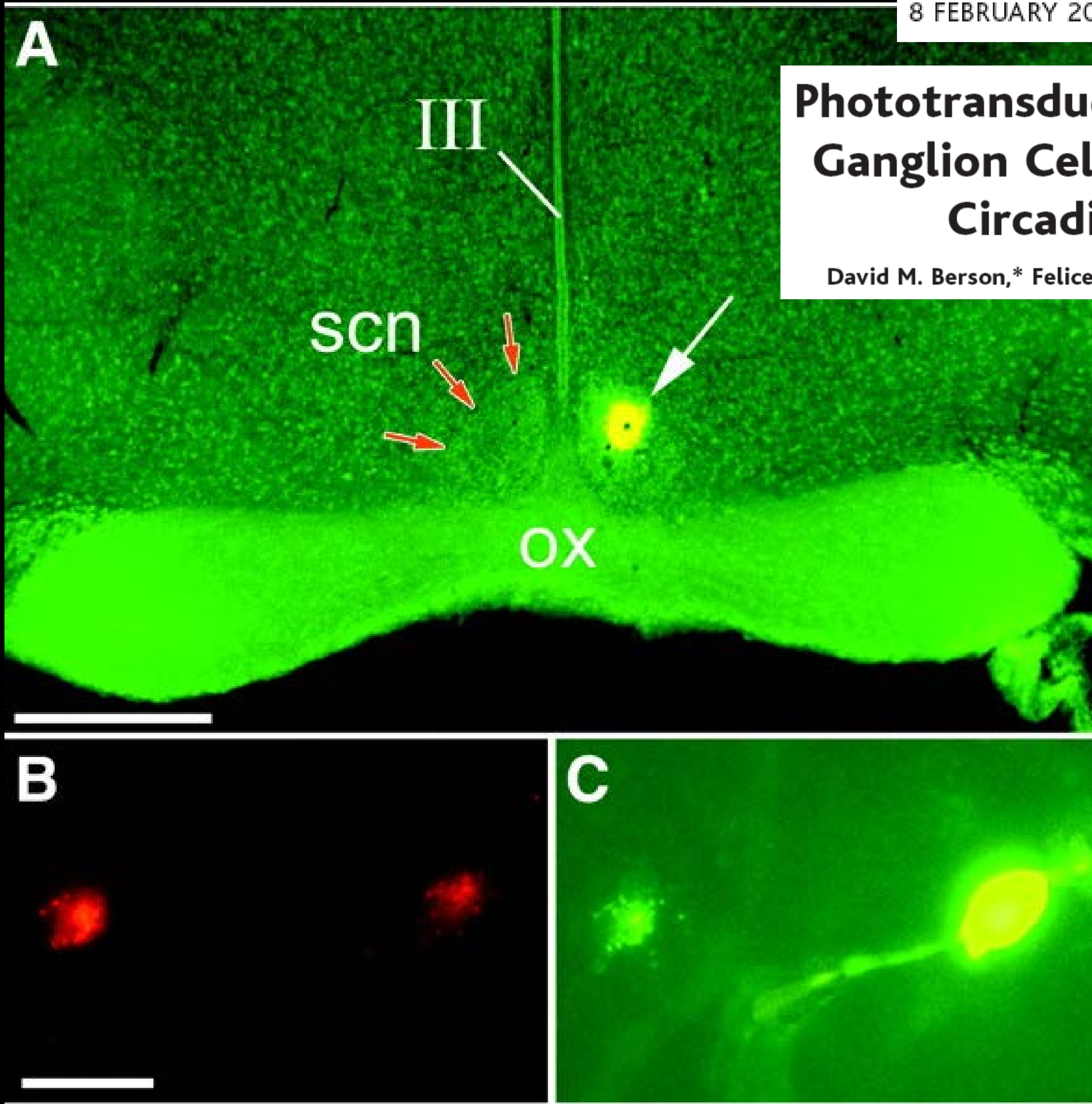
<u>Second Pathway</u>: Gap junction to cone, synapse to off-center bipolar cell, synapse to off-center ganglion cell.

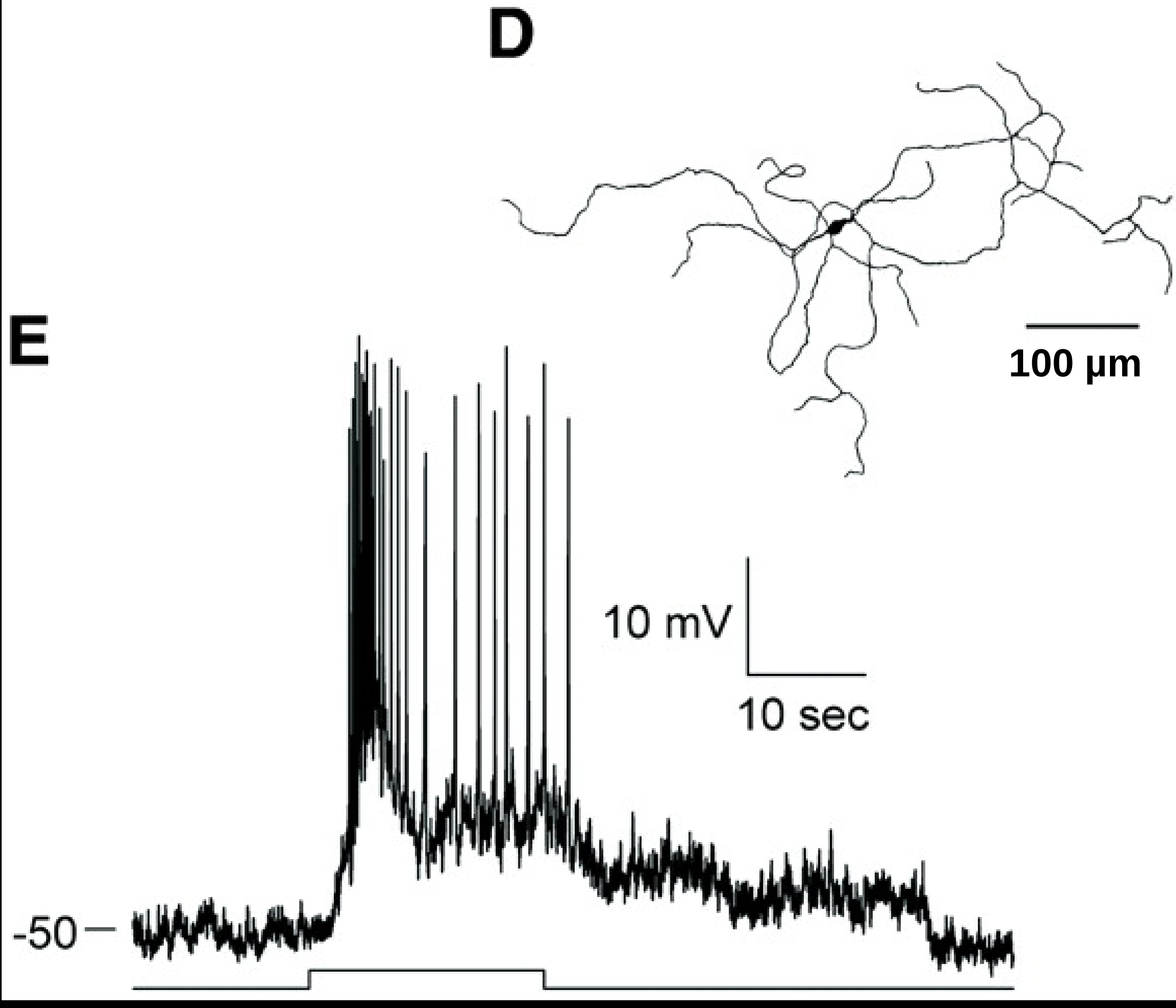
<u>Third Pathway</u>: Synapse onto off-cone bipolar, synapse onto off-center retinal ganglion cell.

8 FEBRUARY 2002 VOL 295 SCIENCE

Phototransduction by Retinal Ganglion Cells That Set the Circadian Clock

David M. Berson,* Felice A. Dunn,† Motoharu Takao†




D
E
100 µm
10 mV
10 sec
-50