

Lecture 2.7 – How We See

Learning Objectives:

3.6.1 Understand the basic way our brain processes light stimuli into sight.

3.6.2 Understand the role of contrast in low-level visual processing.

3.6.3 Understand the organization of the ‘what’ and ‘where’ visual processing systems.

Monologue from *The X-Files*
“Jose Chung’s From Outer Space”

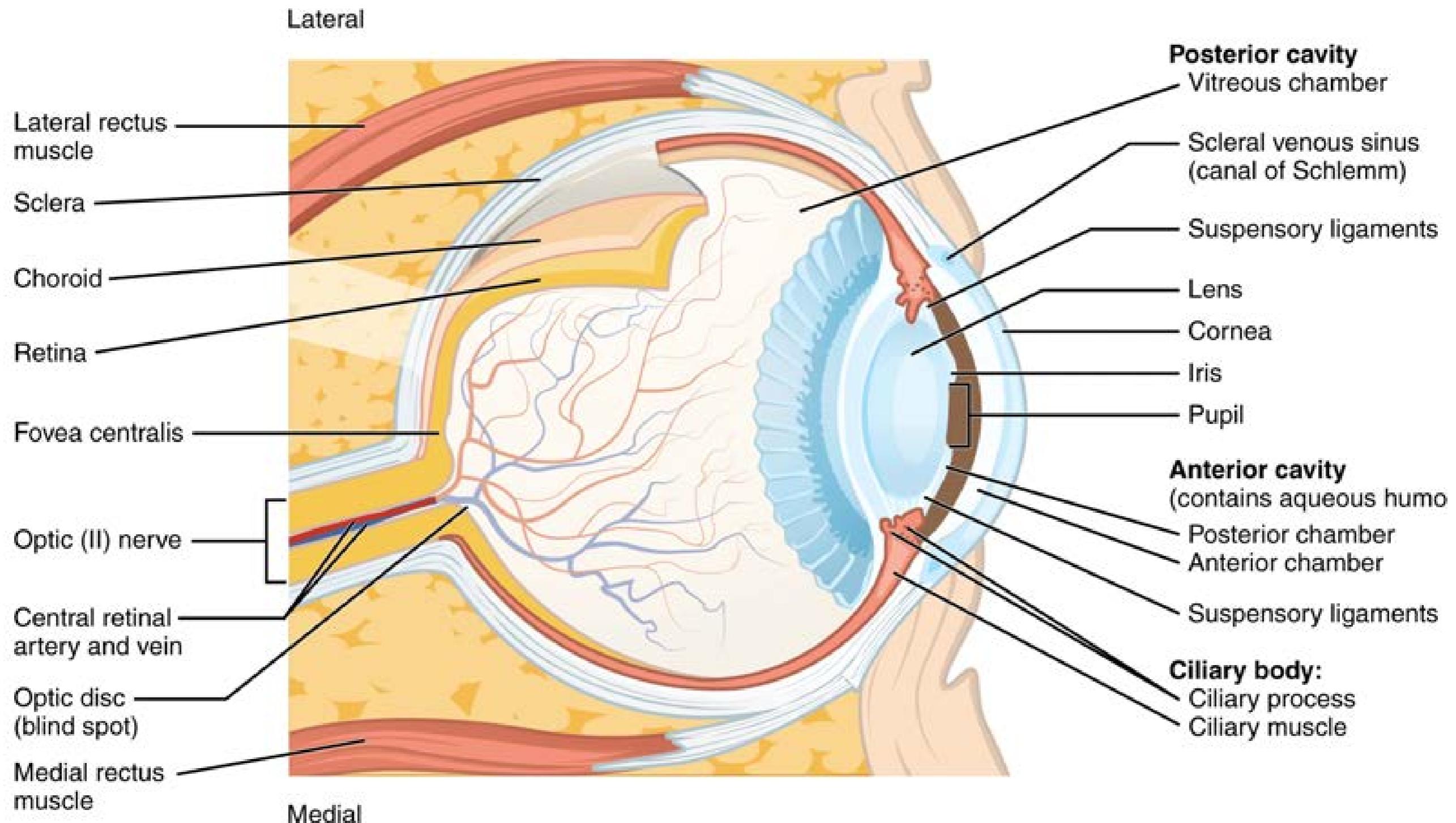


How We See

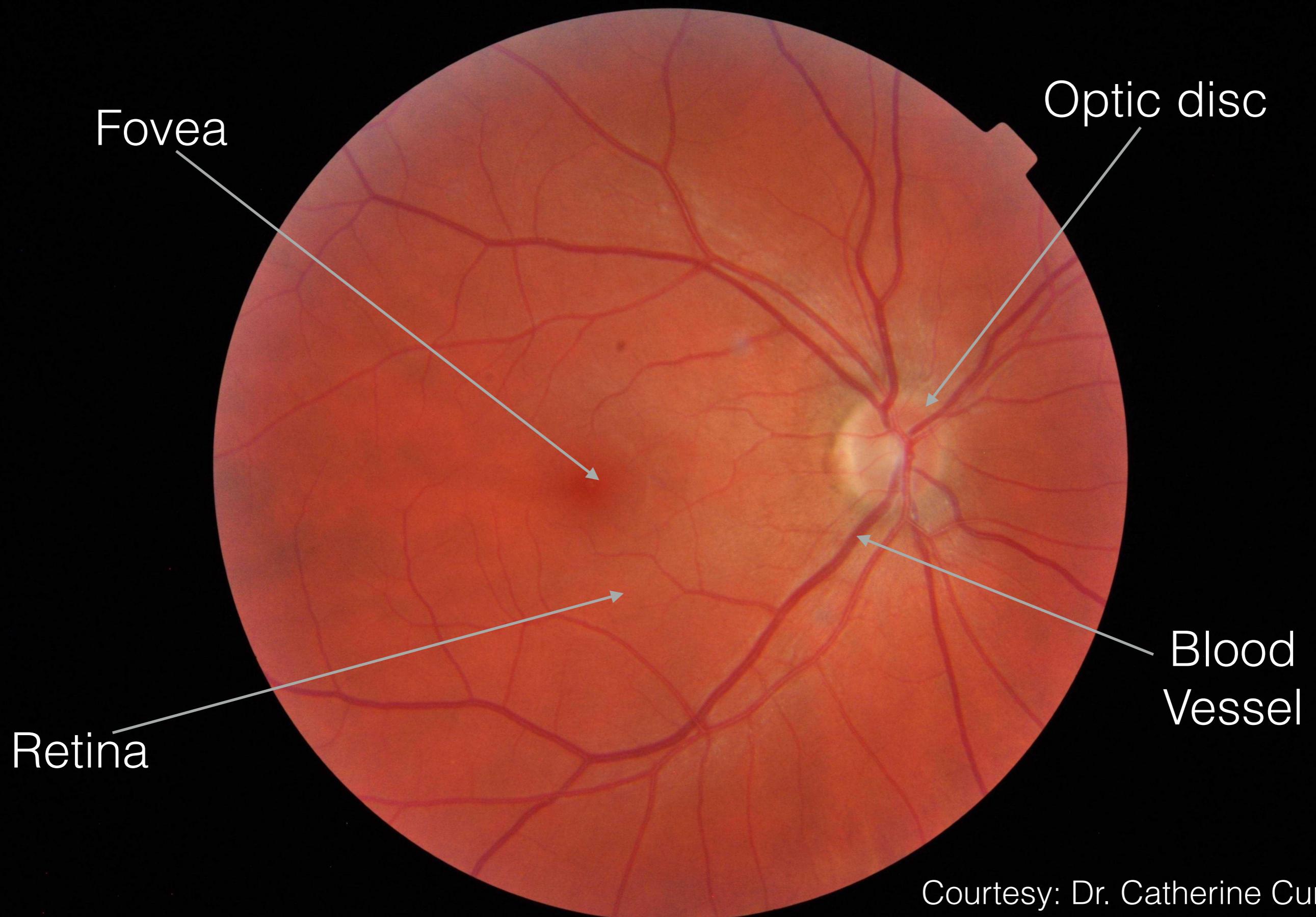
- 1. Our visual systems are built primarily on contrast
(not just sensing light).**

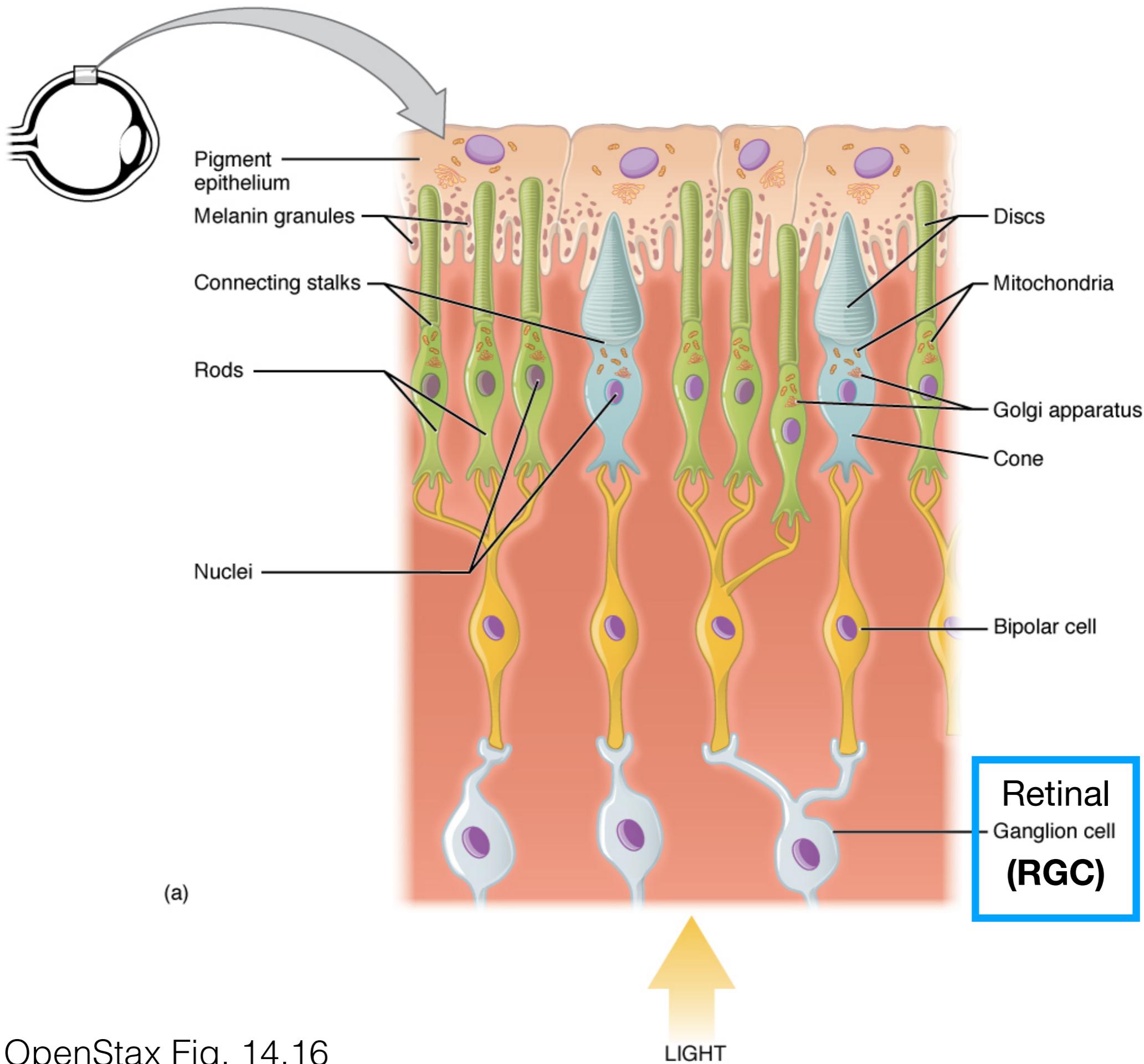
- 2. We see based on visual processing
(not image transmission).**

Anatomy of the Eye



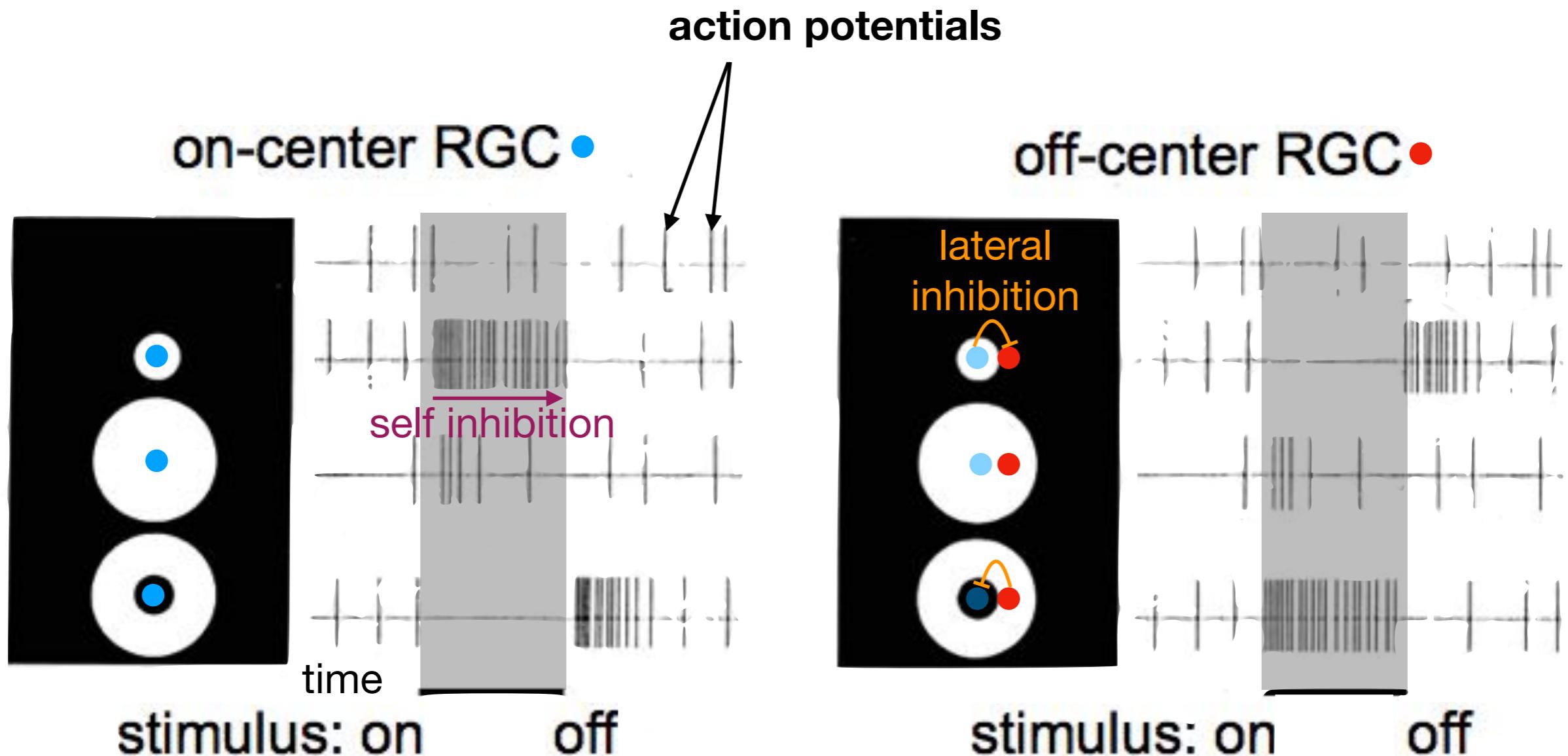
My Eyeball!





OpenStax Fig. 14.16

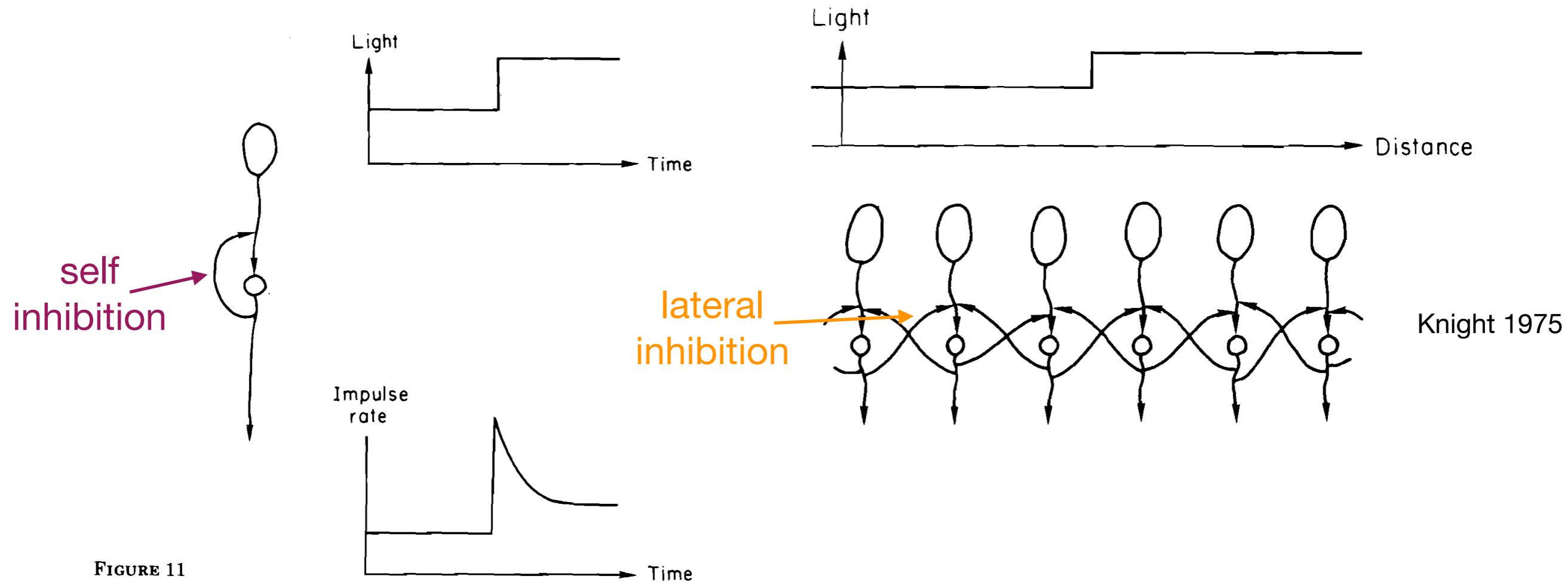
How Contrast Works



- Retinal ganglion cells (RGC) respond strongest to light near edges of dark.
 - Light sensing cells inhibit themselves (self inhibition)
 - Light sensing cells inhibit their neighbors (lateral inhibition)

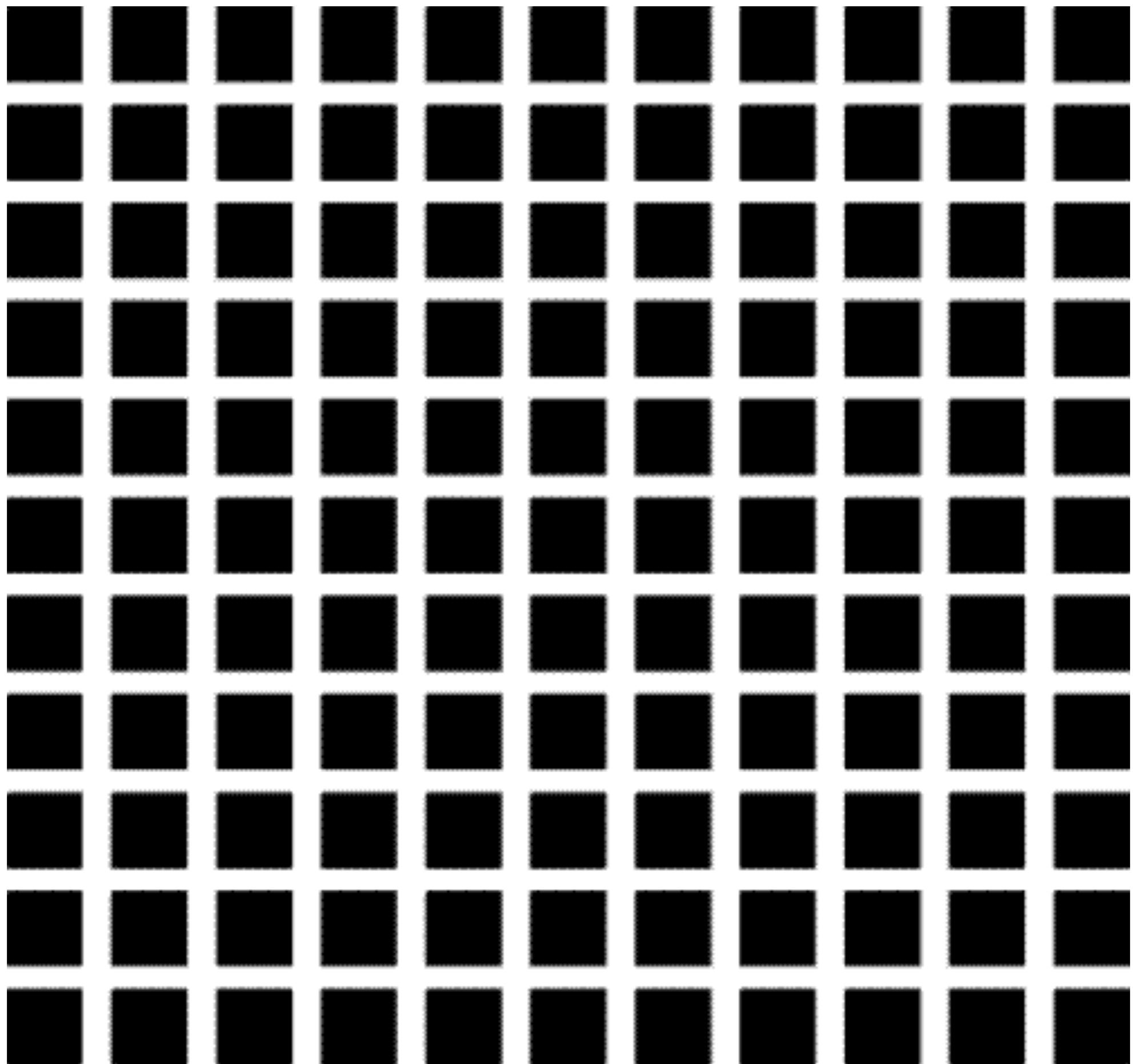
How Contrast Works

- **Self inhibition** and **lateral inhibition** cause Mach banding



**Chevreul Illusion or
“Mach banding”**





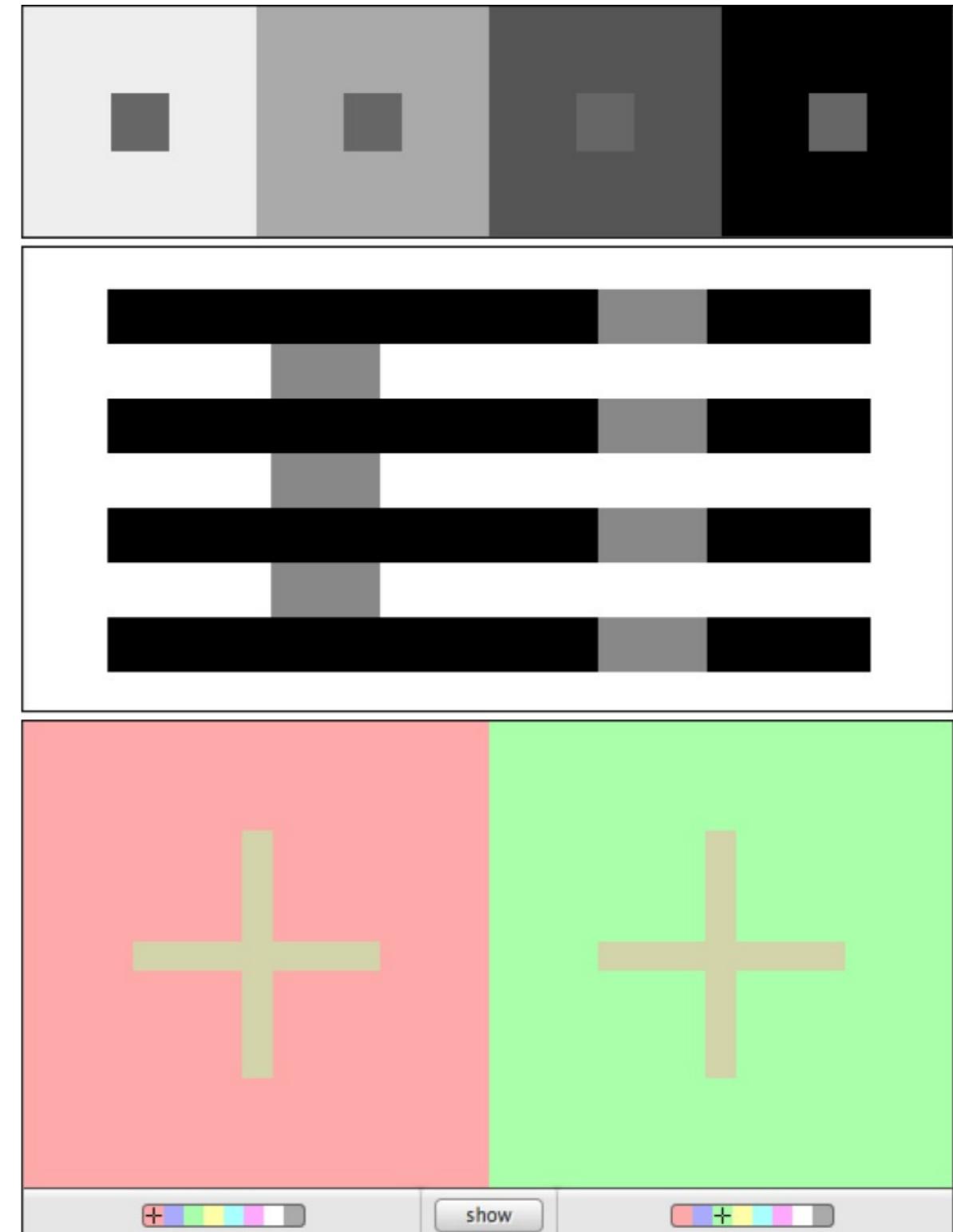
We only see contrast: everything is relative



This is white

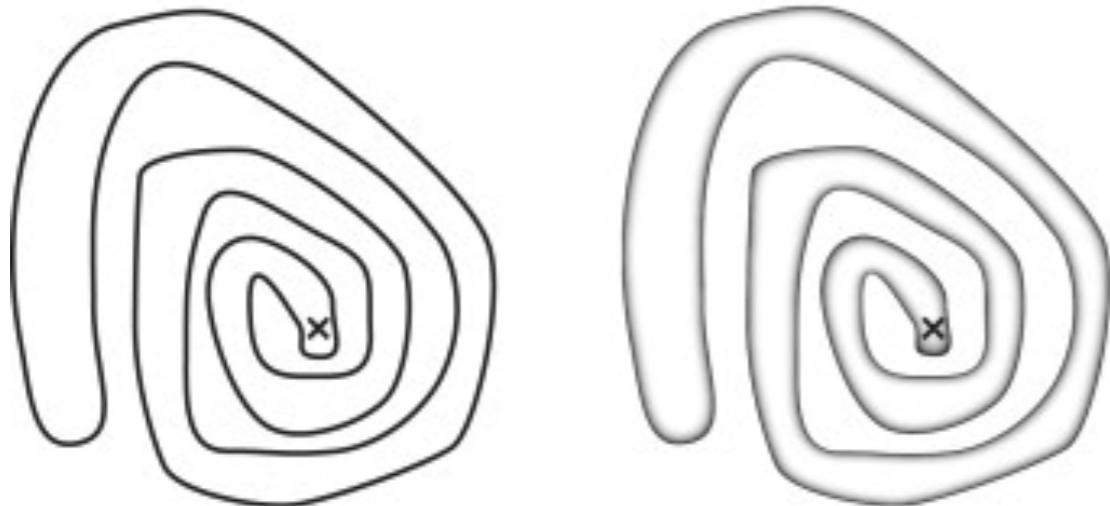


This is also white



Contrast can improve understanding or be misleading

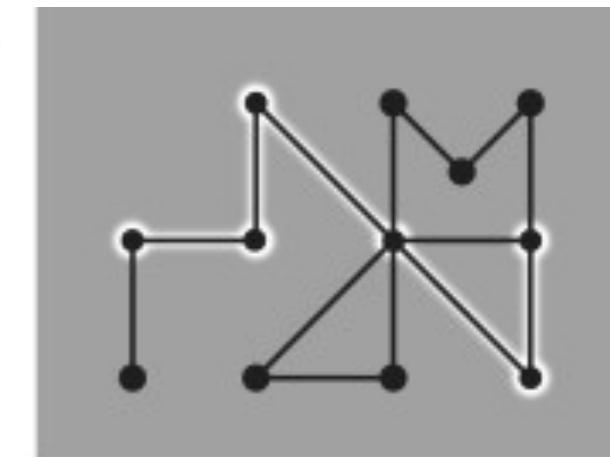
Cornsweet contours help identify shapes



Improving background contrast improves readability



(a)



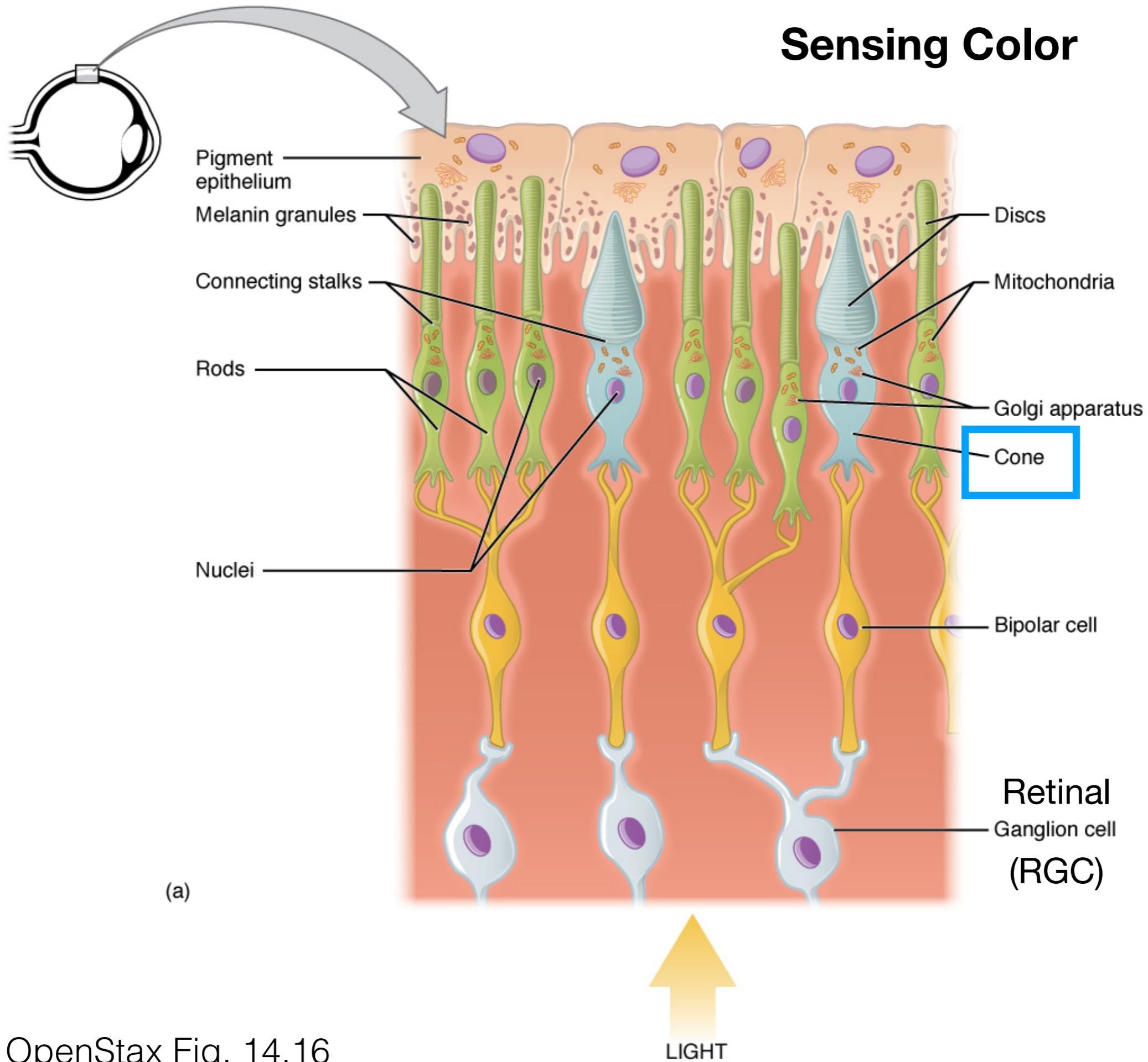
(b)

Chevreul Illusion or “Mach banding”



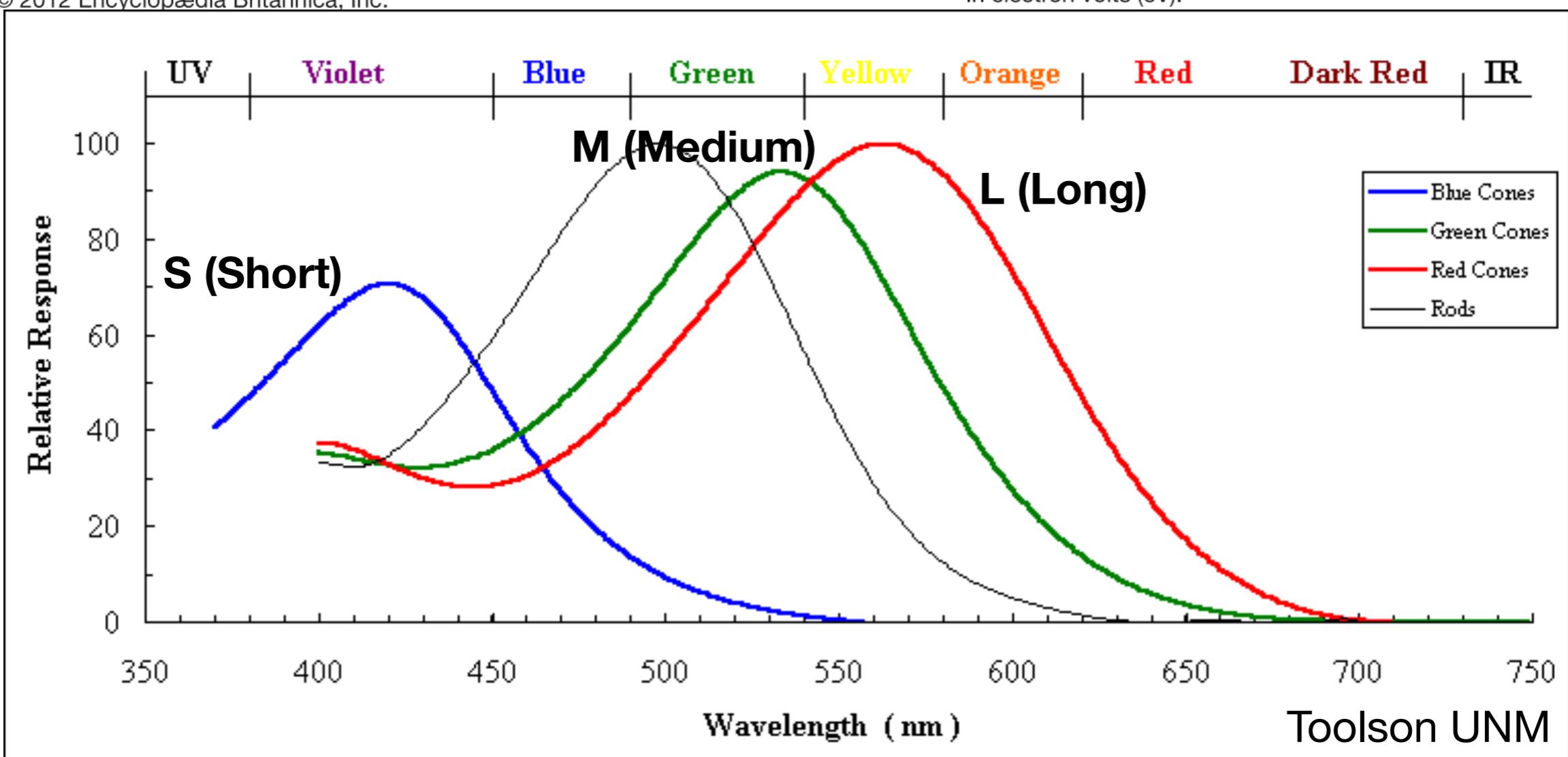
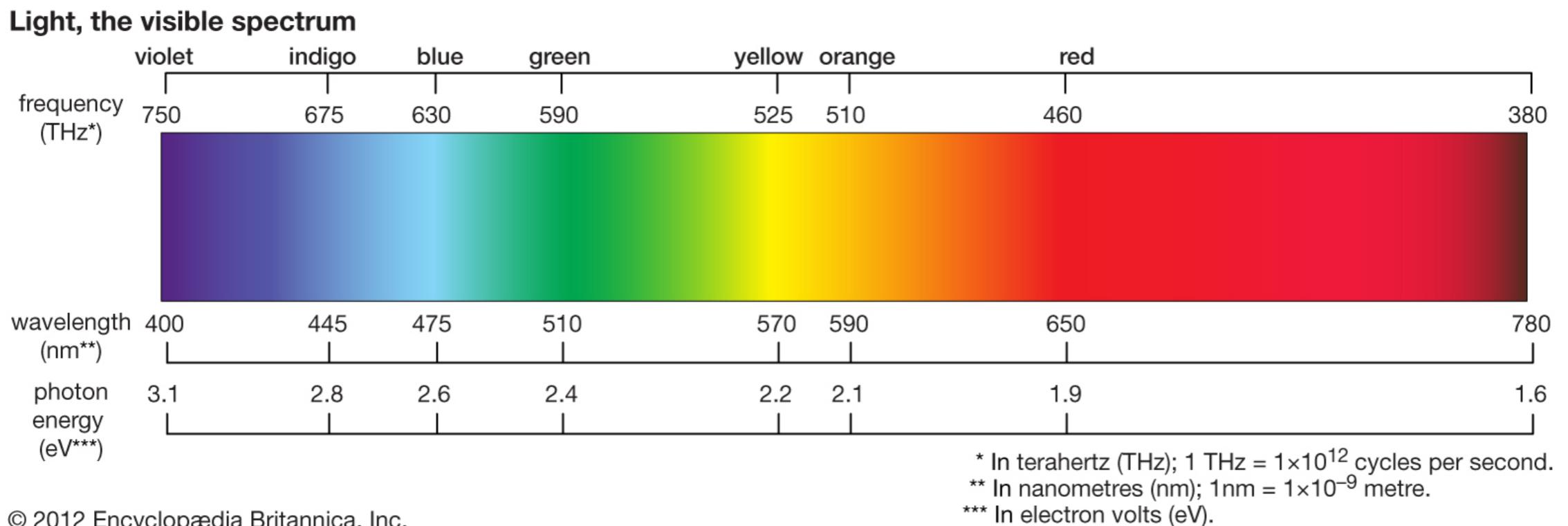
Can mislead viewers of color scales!

Sensing Color

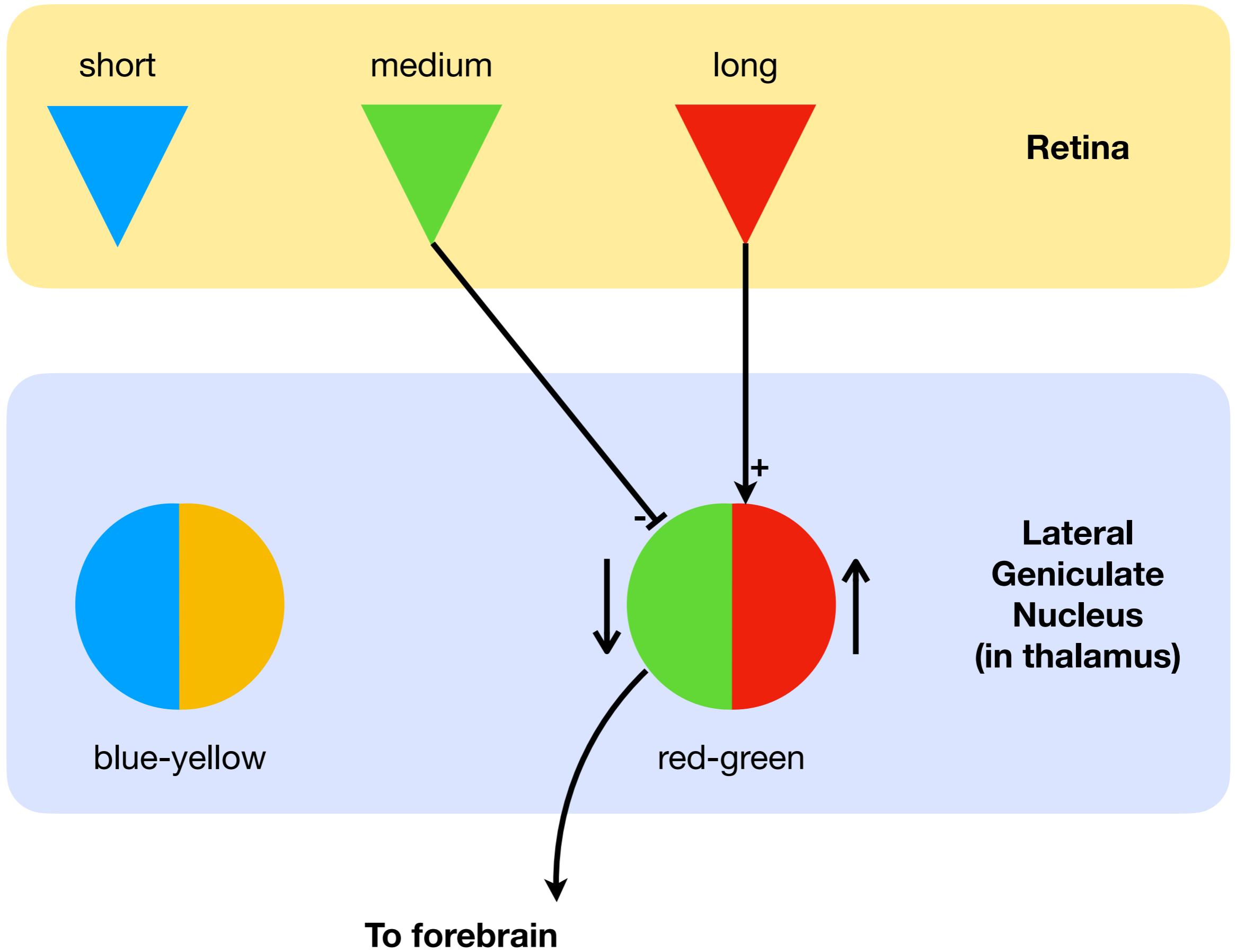


OpenStax Fig. 14.16

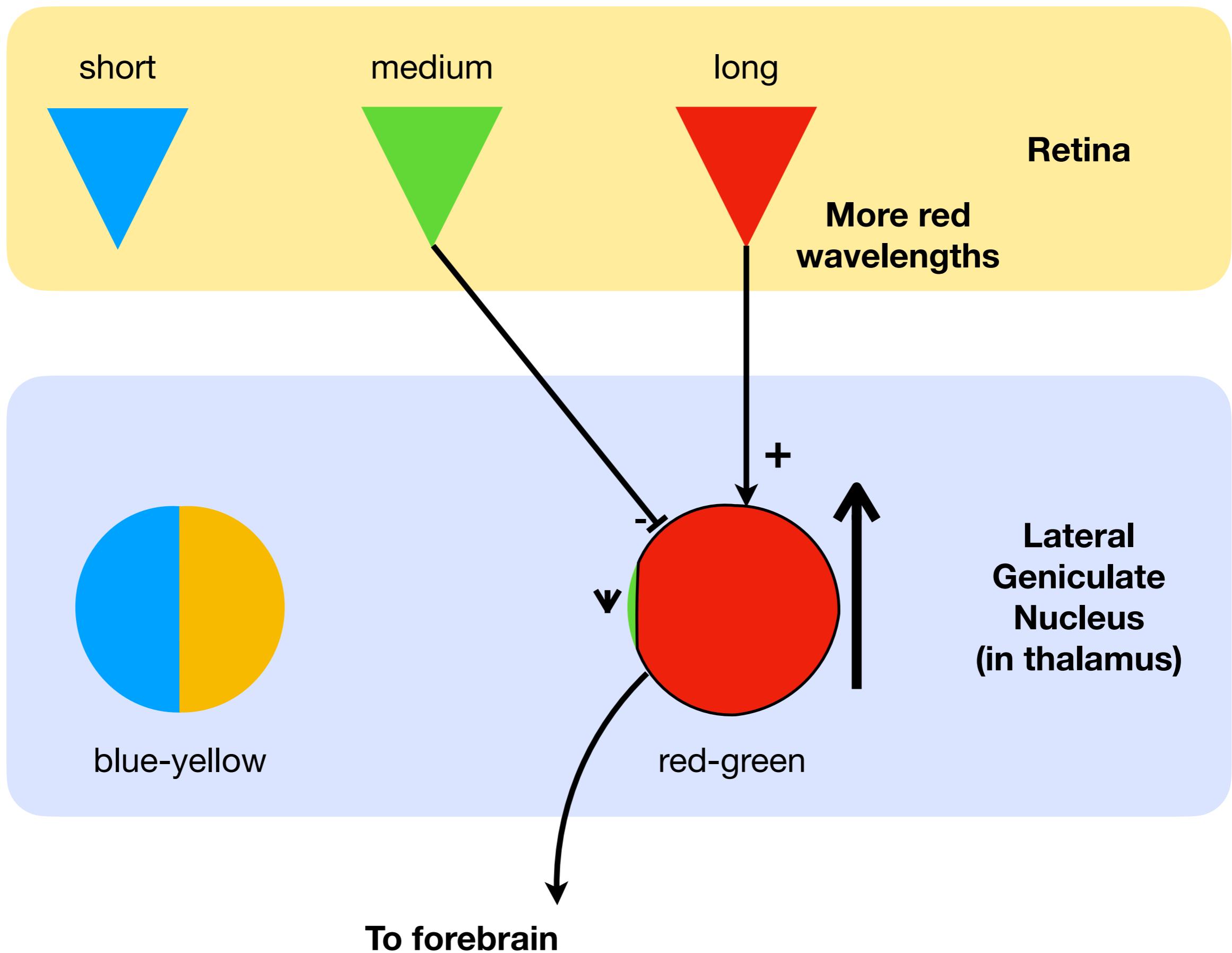
Cone types



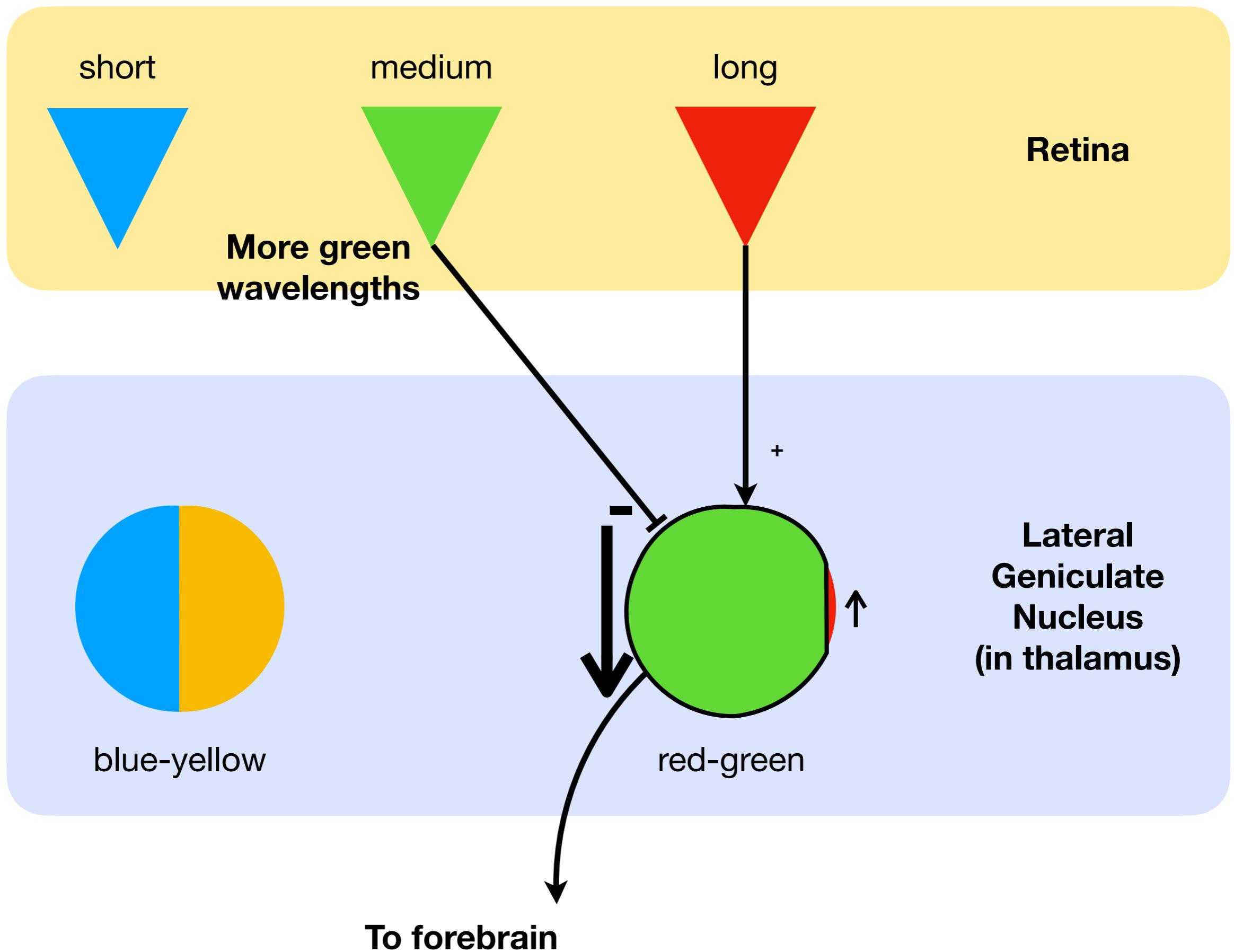
Opponent-Process Theory of Color (Chromatic)



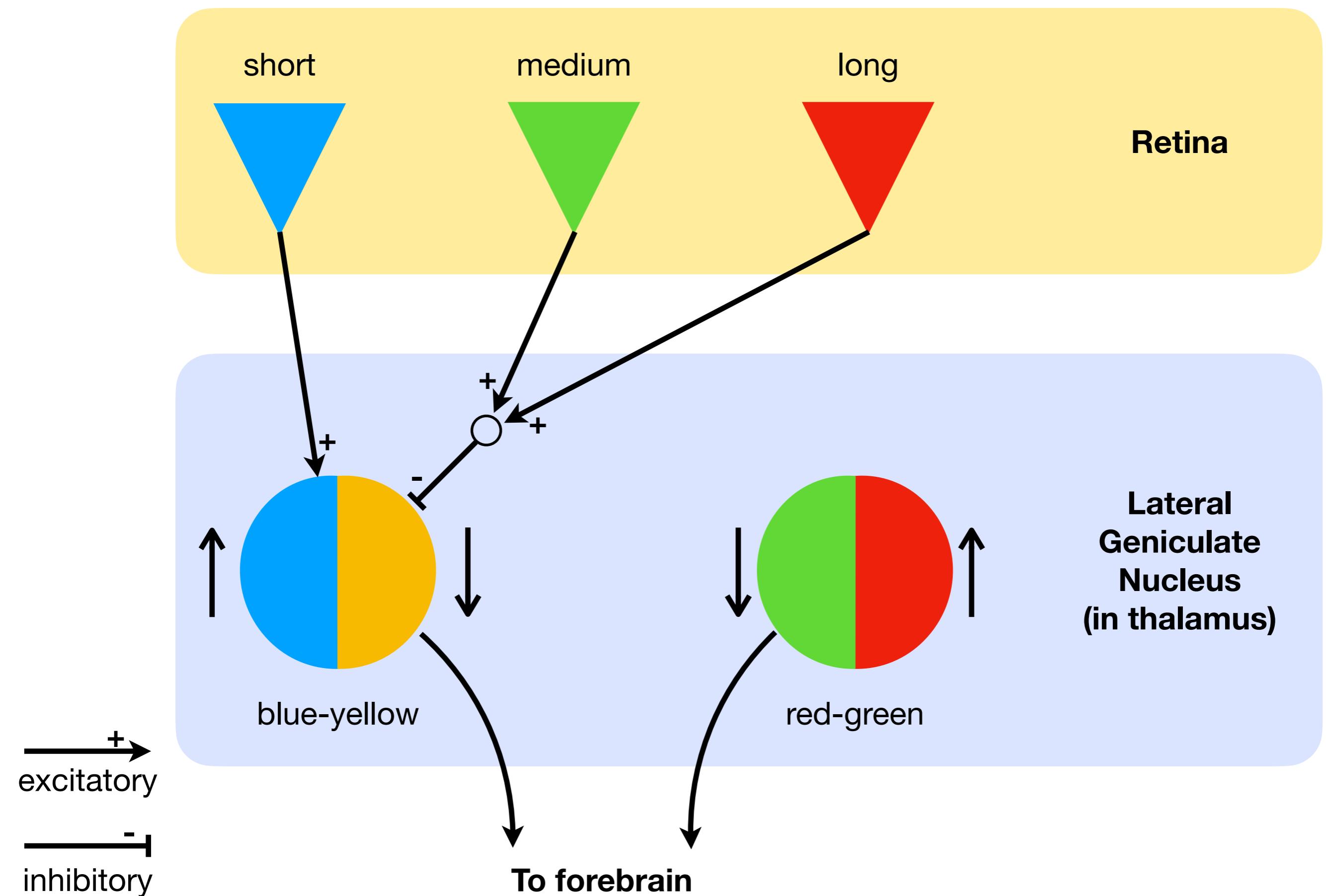
Opponent-Process Theory of Color (Chromatic)



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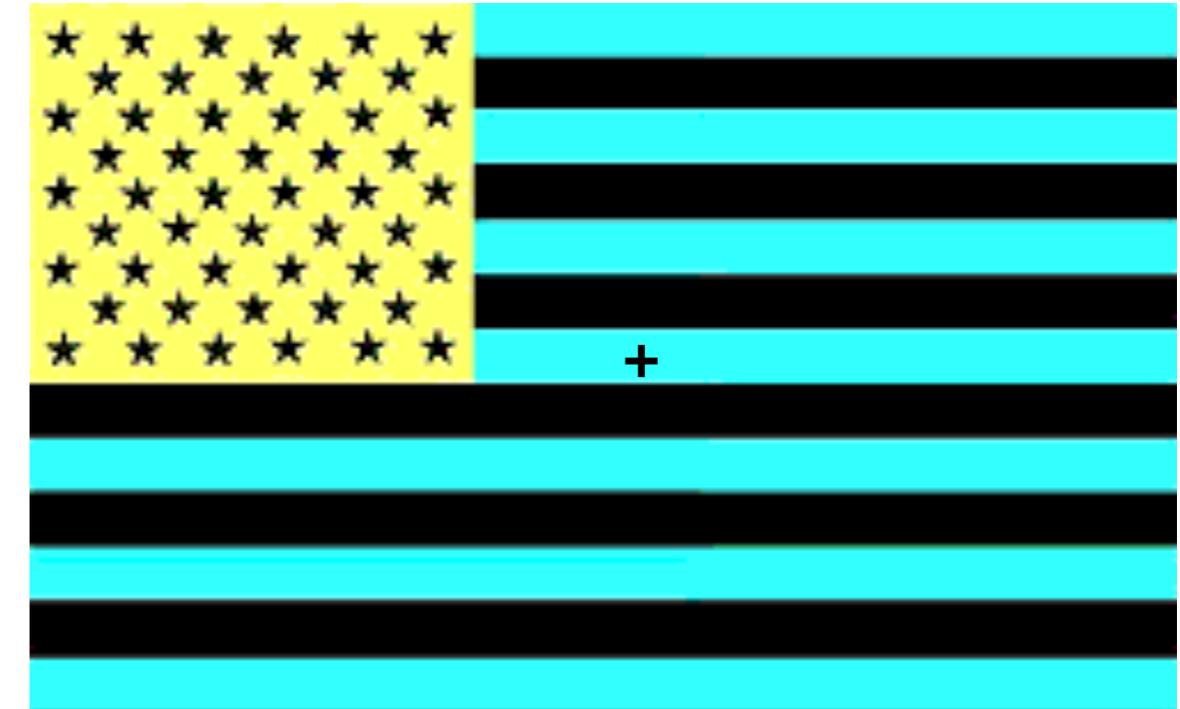
Opponent-Process Theory of Color (Chromatic)



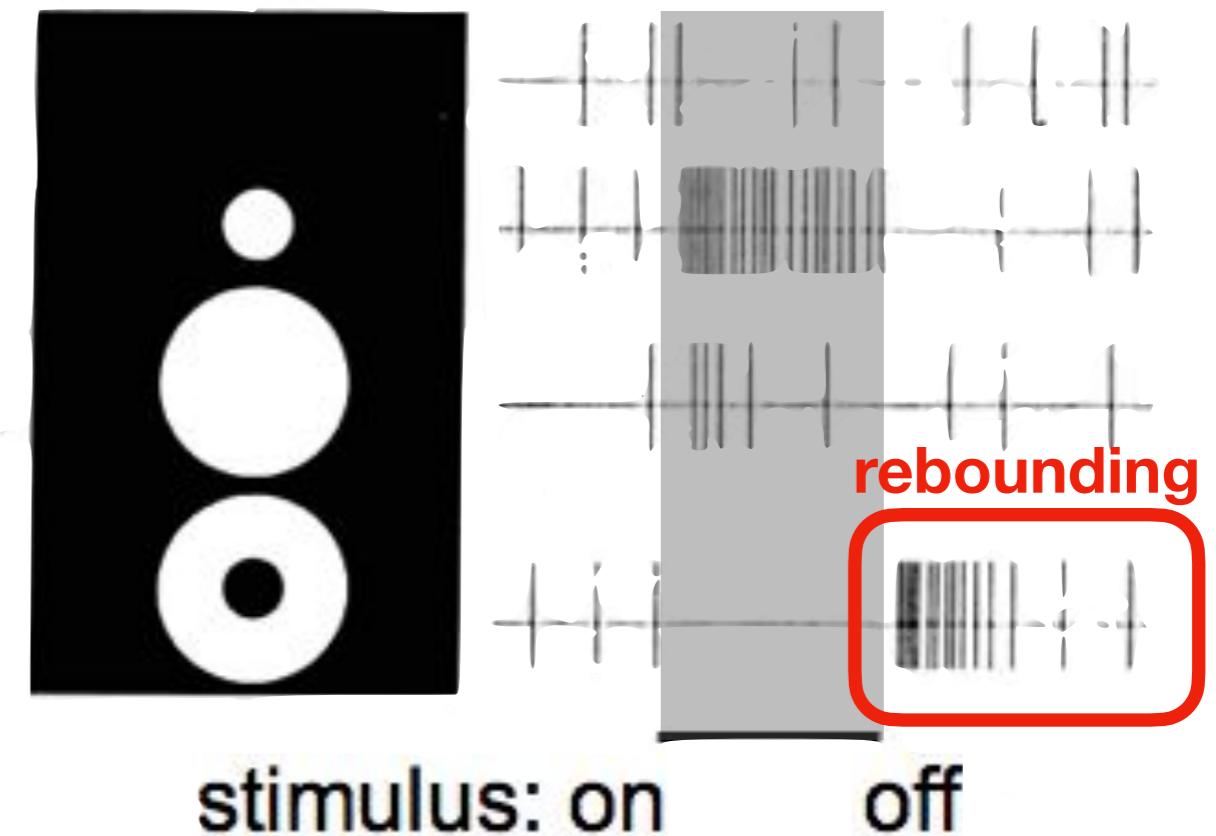
Complementary Color illusions

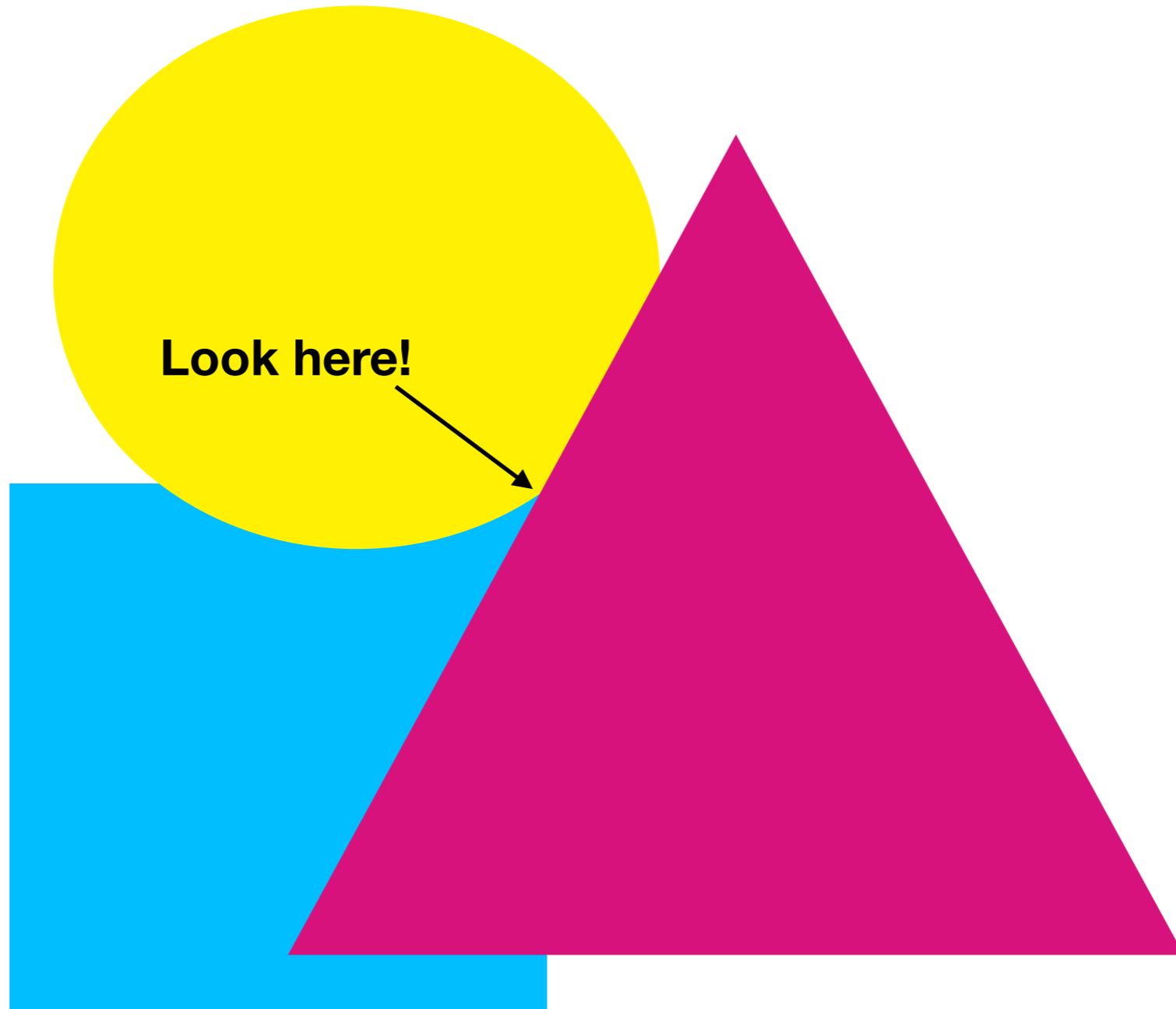
“Lilac Chaser”

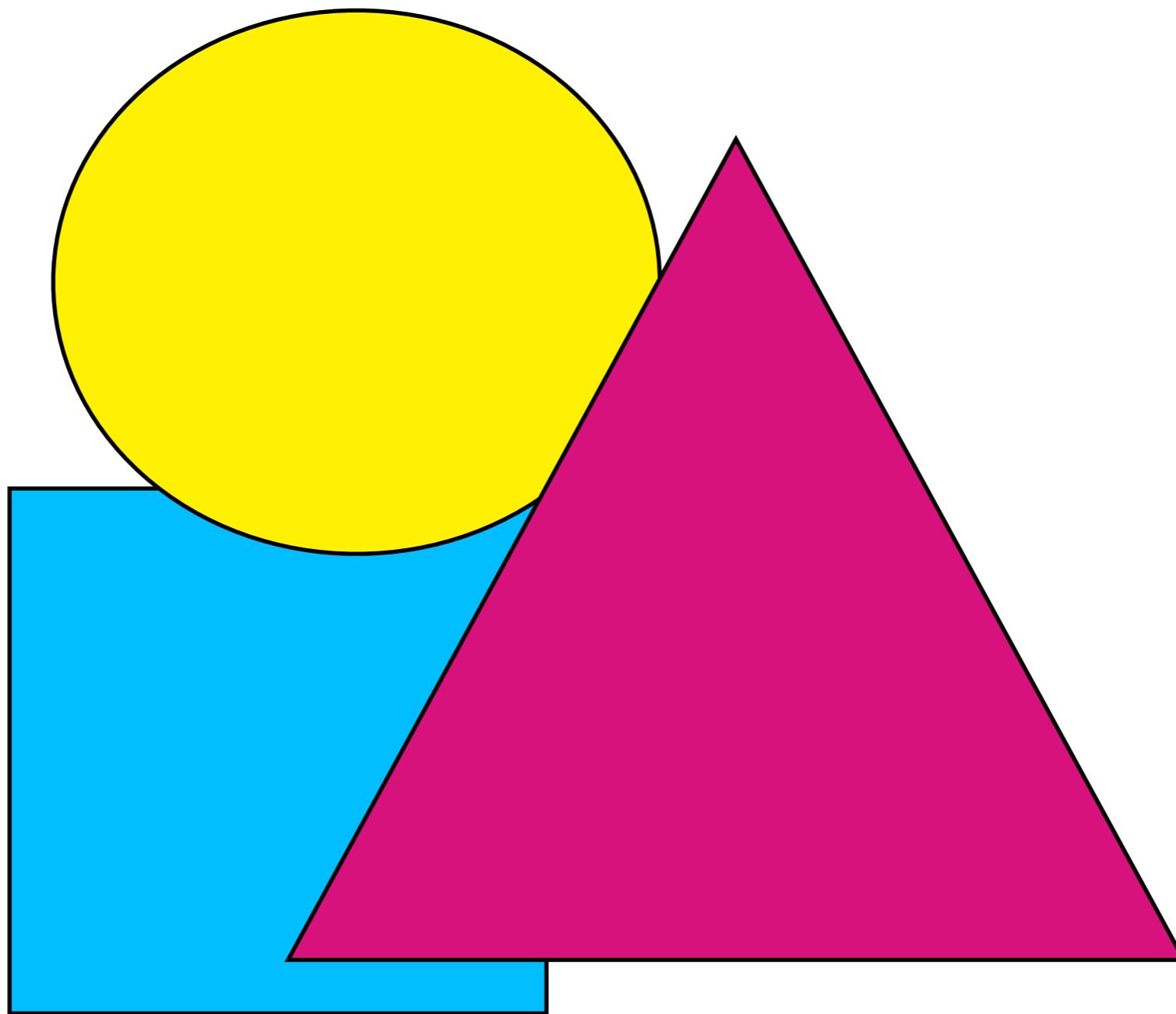
https://en.wikipedia.org/wiki/Visual_adaptation



on-center RGC







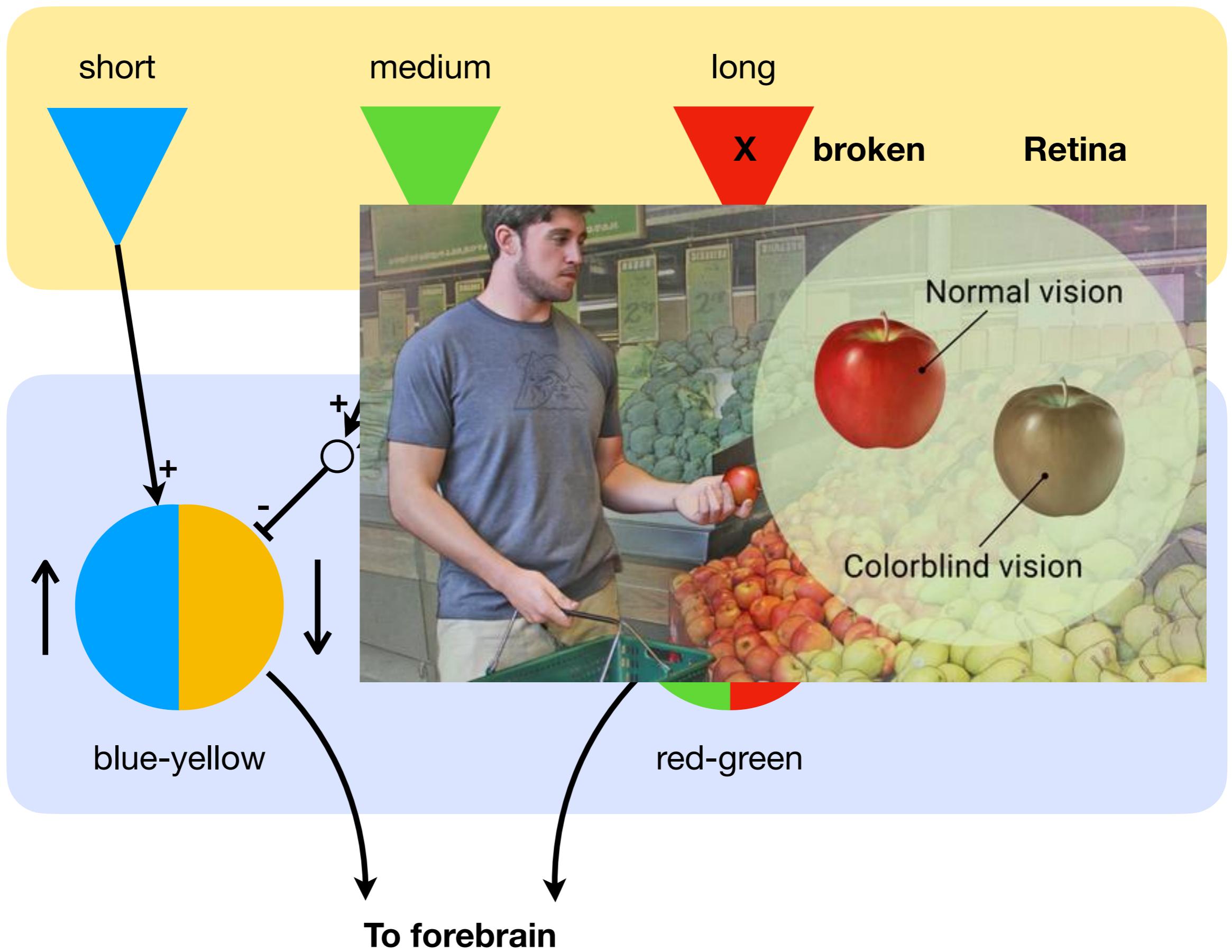
Livingstone 2014 reproduction

We only see contrast

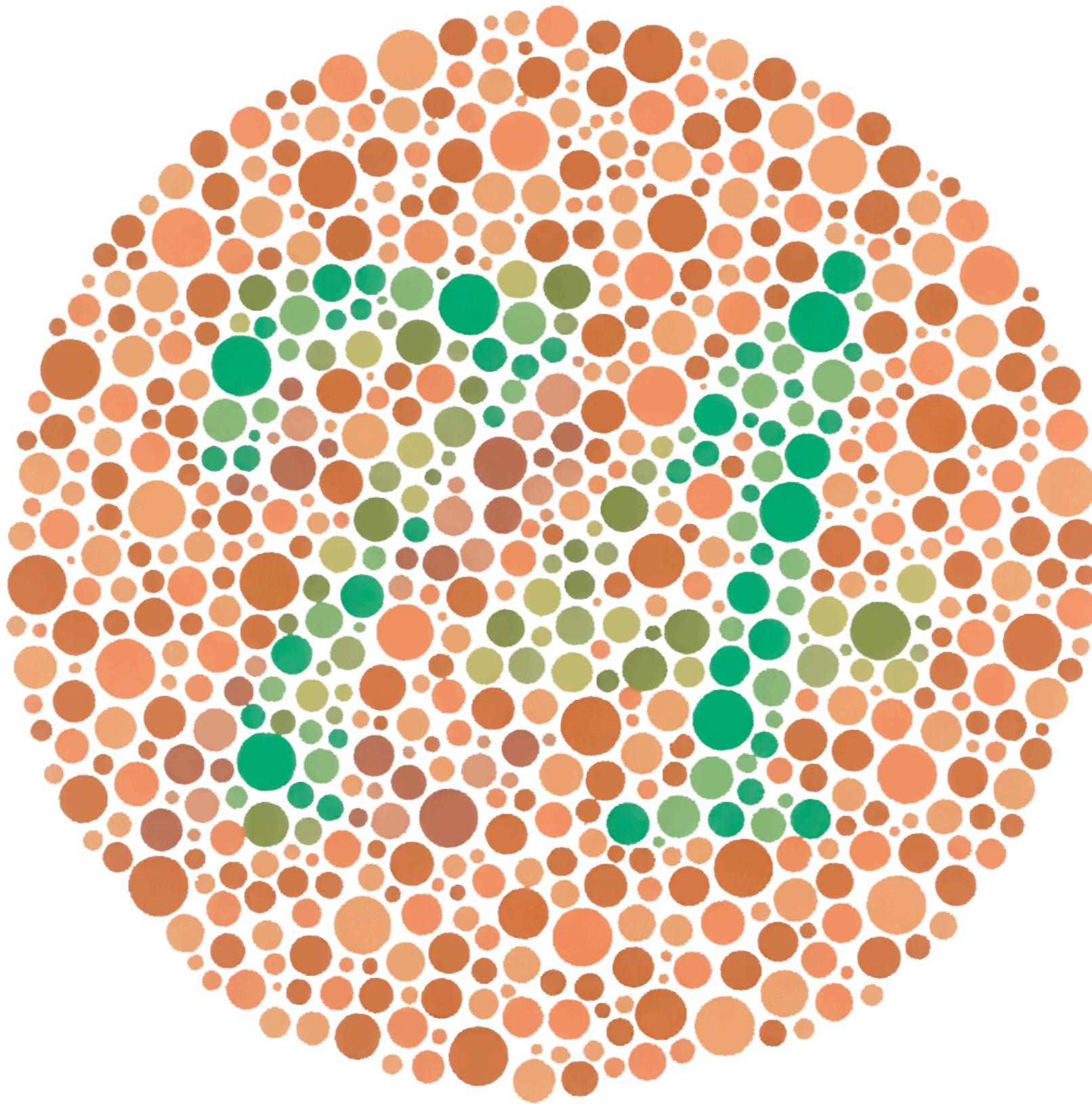
“The Dress”



What happens in color blindness?



Ishihara Plate 9 (Color blindness Test)



74 or 21

Colorblindness simulator: <https://www.color-blindness.com/coblis-color-blindness-simulator/>

Be careful of color contrast!

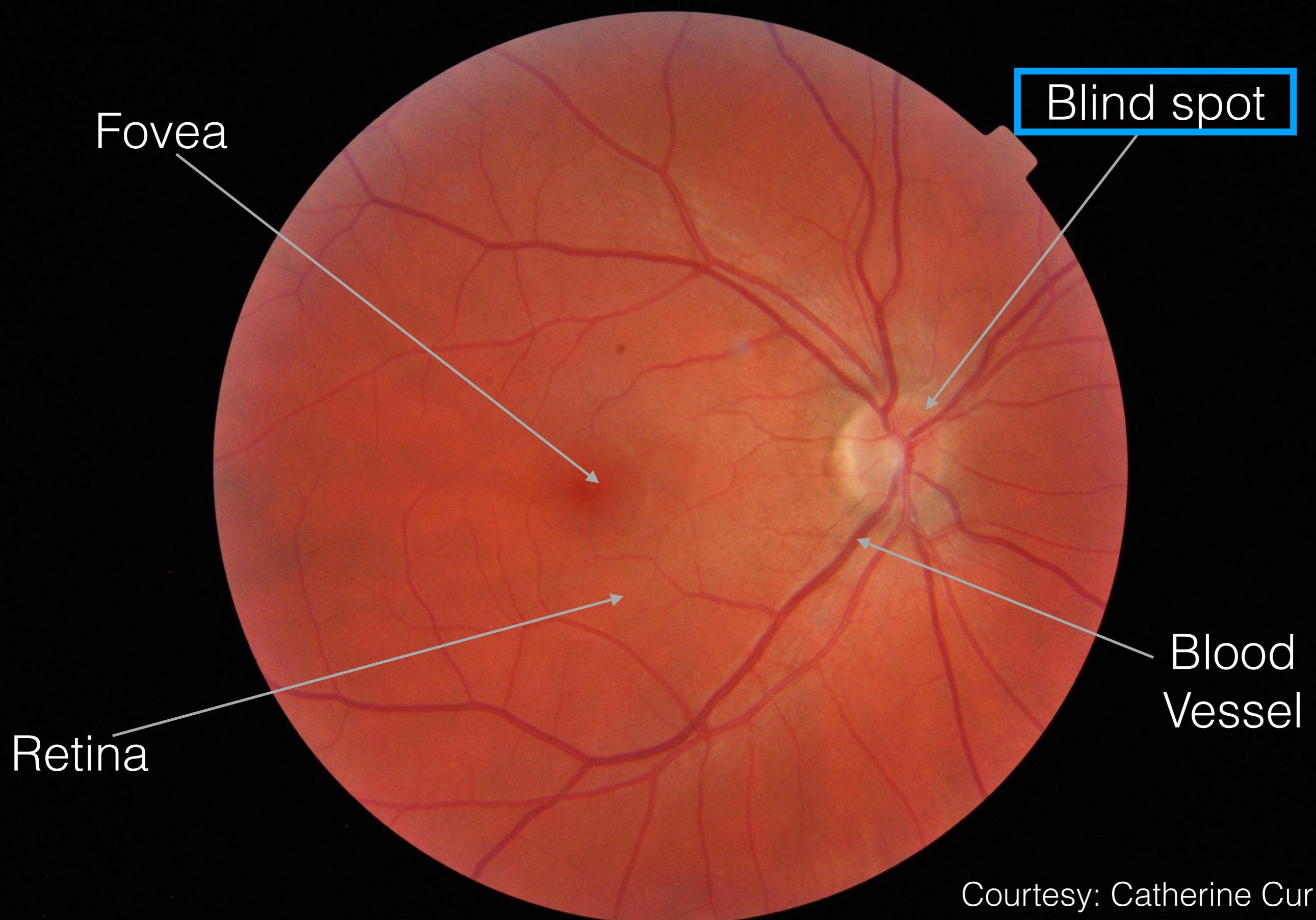
Text, lines, and other design elements should not be of equal or close luminance (grayscale) to the background. Near-equal luminance objects are very hard to pick out, and near-equal luminance text is very difficult to read. Use luminance contrast that is sufficiently different to avoid problems.

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Contrast is Key

- Contrast ranks #1 in importance for our visual systems.
 - Be sure your visualizations have **high contrast** elements.
 - Be sure to avoid Mach Banding with color & gray scales (no more than 5 unique shades when value is important).
 - Make your visualizations accessible to people with colorblindness by
 - 1) avoiding red and green together, and
 - 2) using high luminance (gray scale) contrast.

2. We see based on visual processing (not image transmission)



Find Your Blind Spot

O

X

Your brain makes up stuff all the time 🤯



Vishal Gondal ✅ @vishalgo... · 7/27/21 · ...

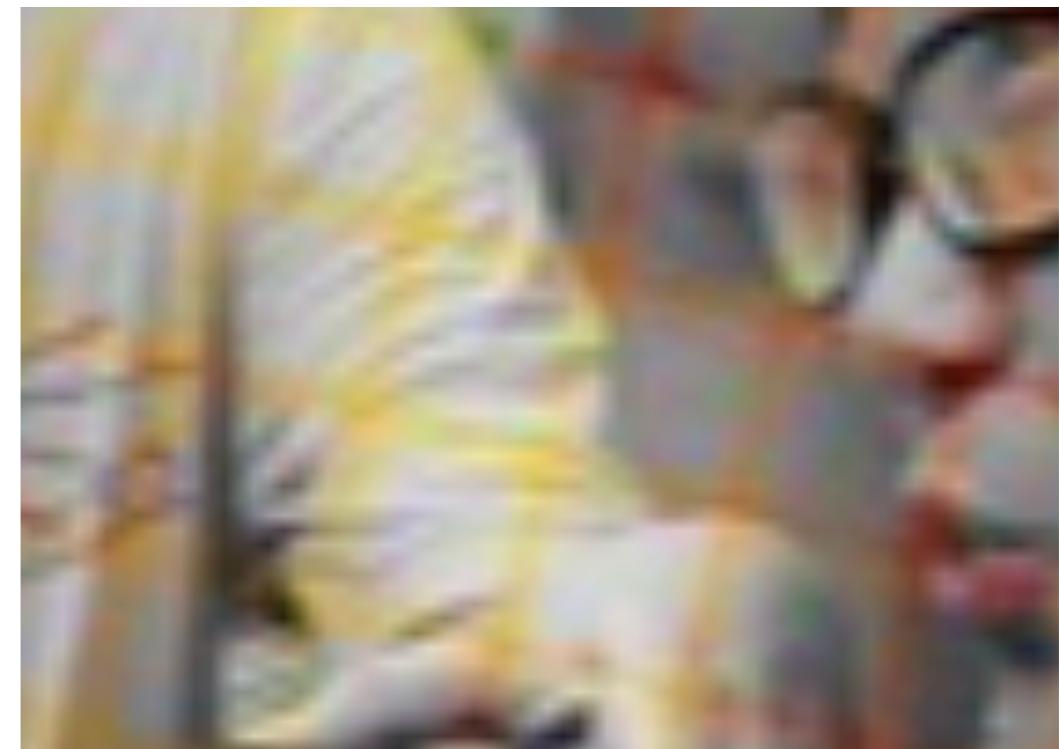
This photograph is black and white picture. An artist has drawn some colour lines through it. The human brain is filling the rest of the colours even though they aren't there. zoom in look closely. We tend to fill in using the availability heuristic which is a cognitive bias.



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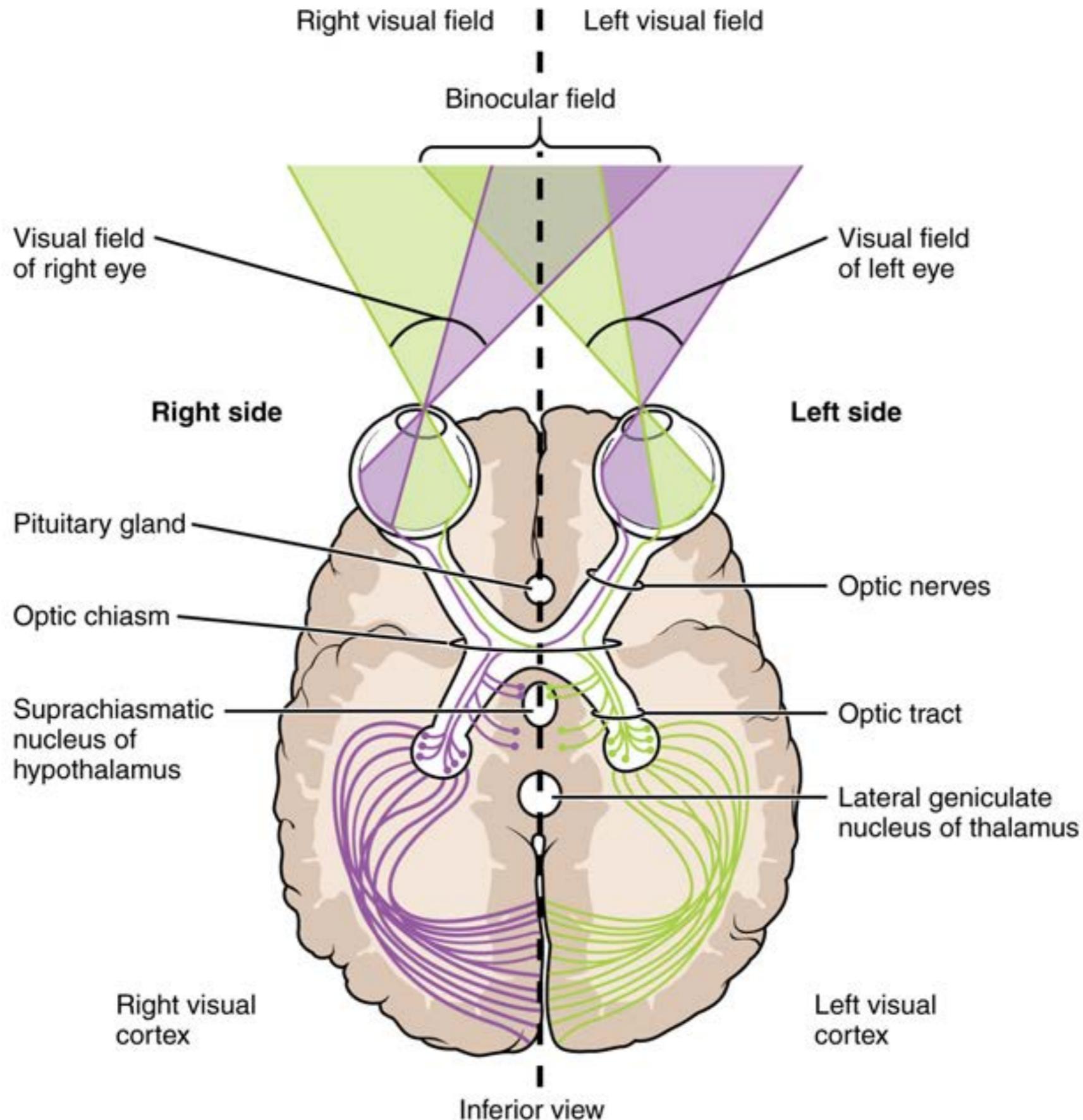
3,367

9,482

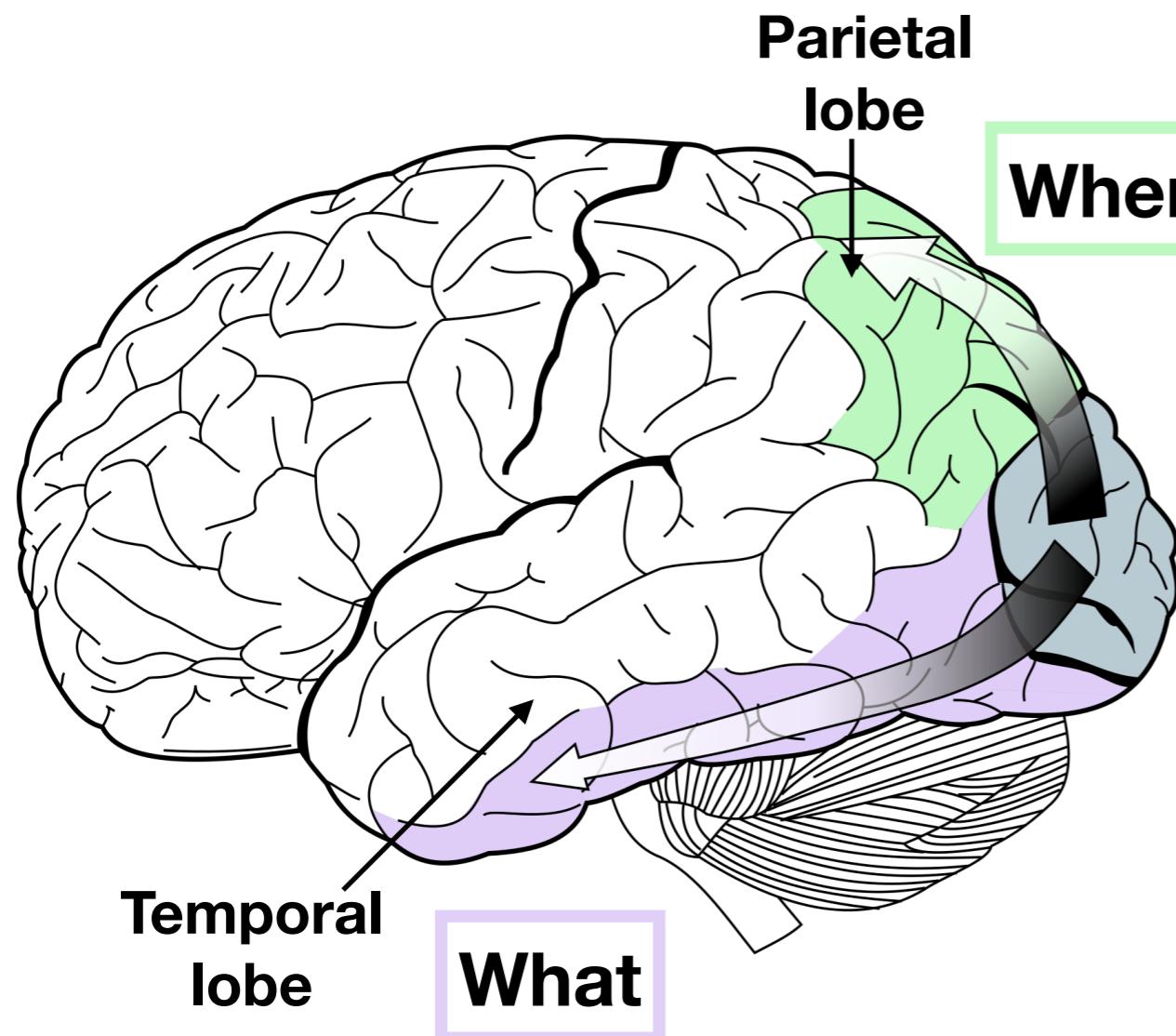


We see based on visual processing, not image transmission.

Visual Field Tracts



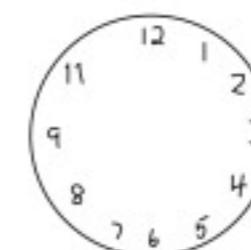
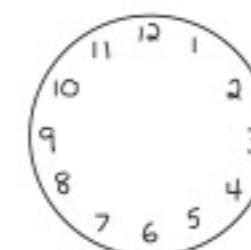
Visual Field Processing



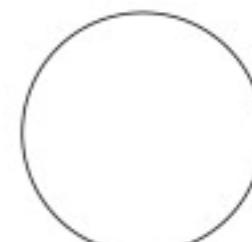
Where system
Visual guiding
Motion
Colorblind
Calculated across retina

Breaks

Normal patterns:



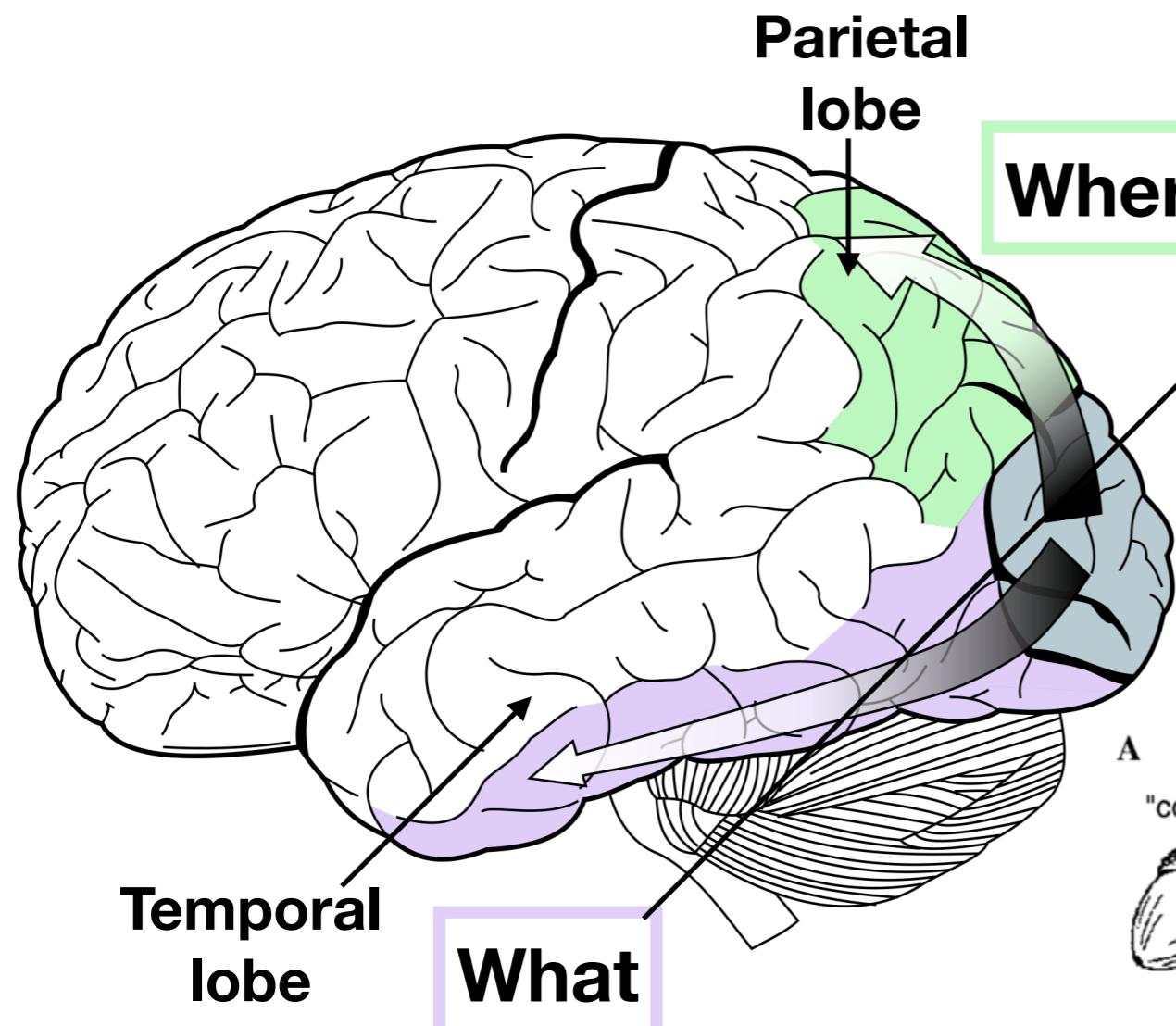
Abnormal patterns:



Note: colors do not correspond to visual tracts slide!

McGee, Mental Status exam, 2012

Visual Field Processing

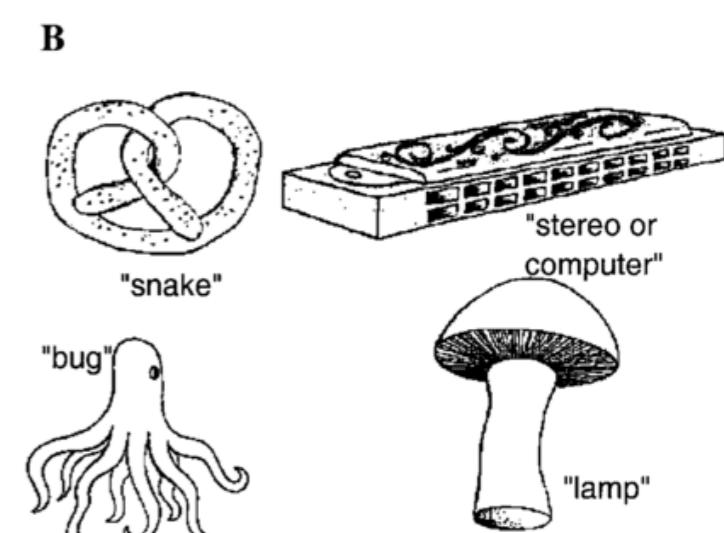
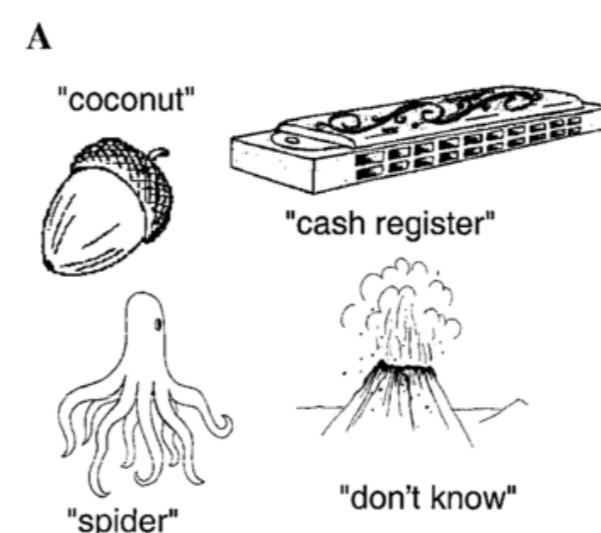


What system

Object recognition
Detailed but slow
Color recognition
Fovea (local)

Breaks

“visual agnosias”



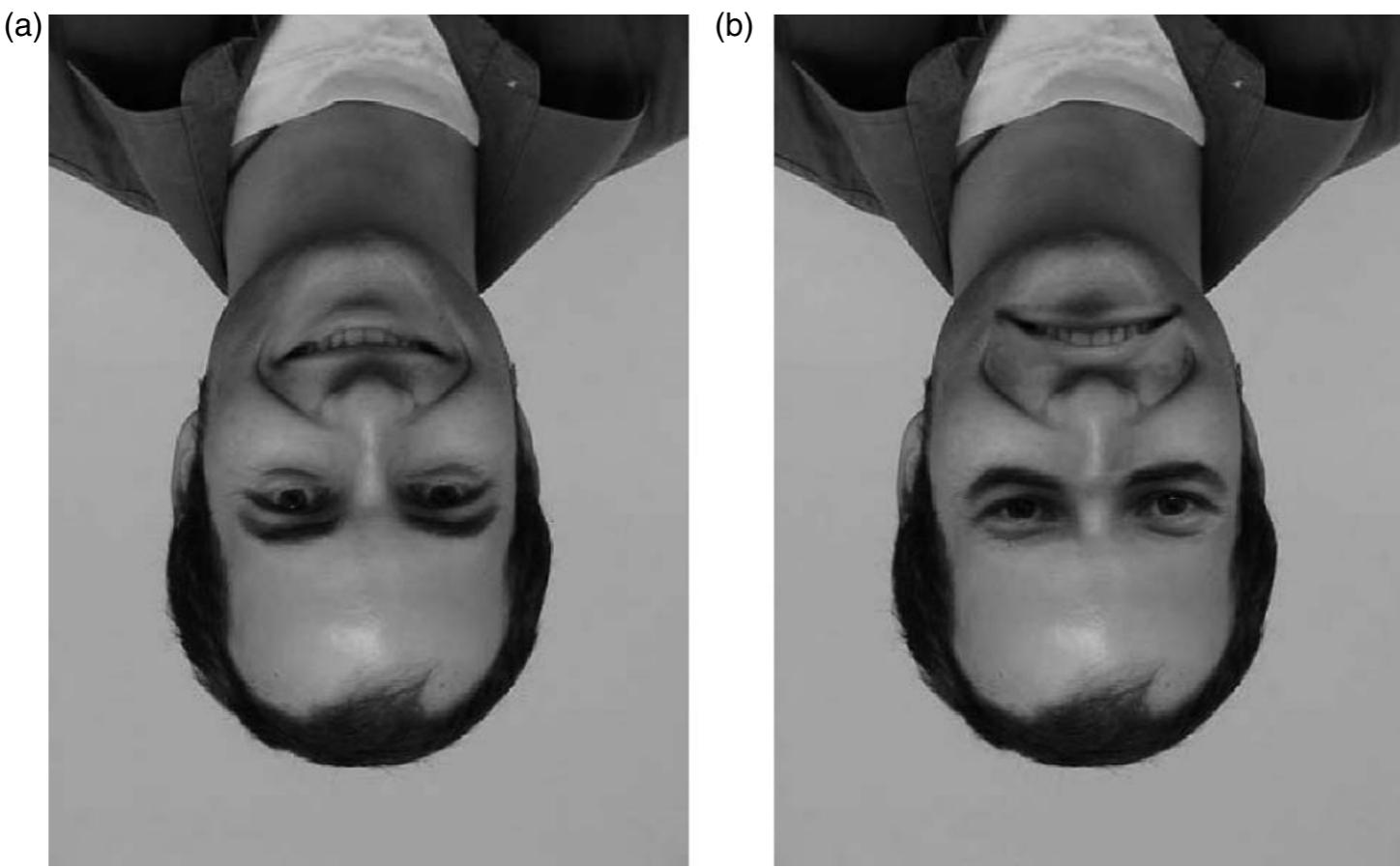
Responses of “S.M.” and “R.N.”, Behrmann 2003

Note: colors do not correspond to visual tracts slide!

Face blindness

**Object
Recognition
is local**

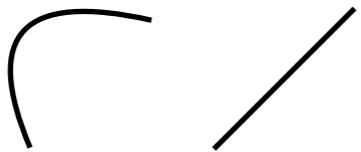
**Face
Recognition
is special!**



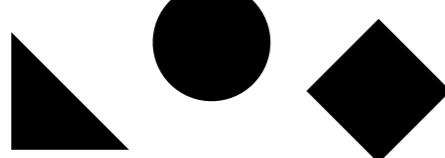
Putting Neuroscience into Practice: Designing Visualizations

- Specific examples of **fast processing differences**:

- curved/straight



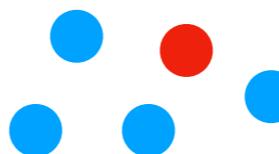
- shape



- hue intensity



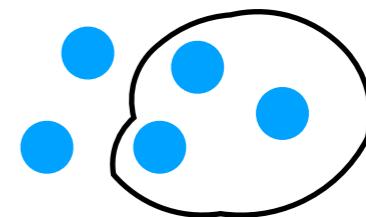
- color



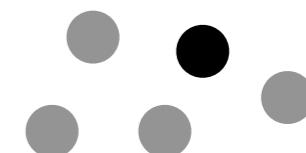
- blur



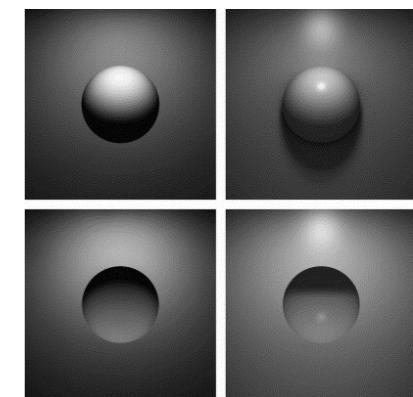
- enclosure



- light/dark



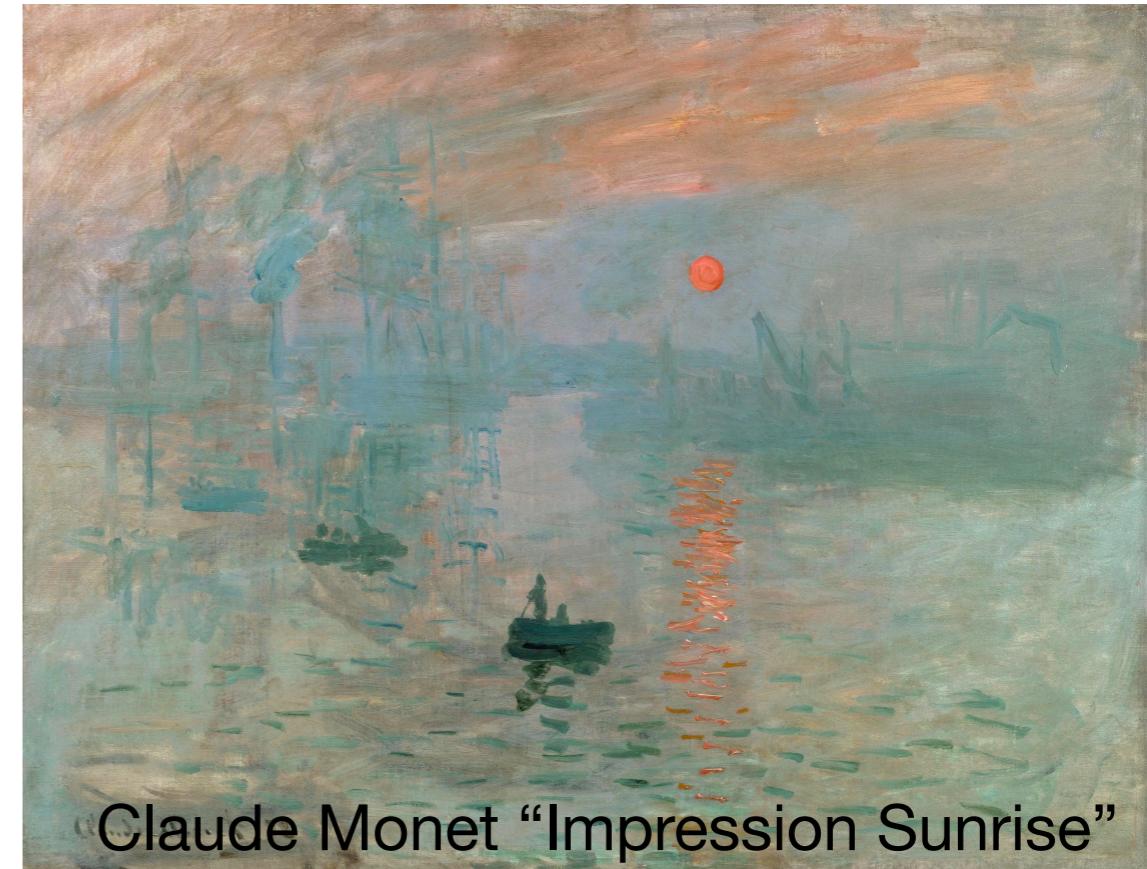
- convex/concave



USE THESE

What happens when the systems get confused...

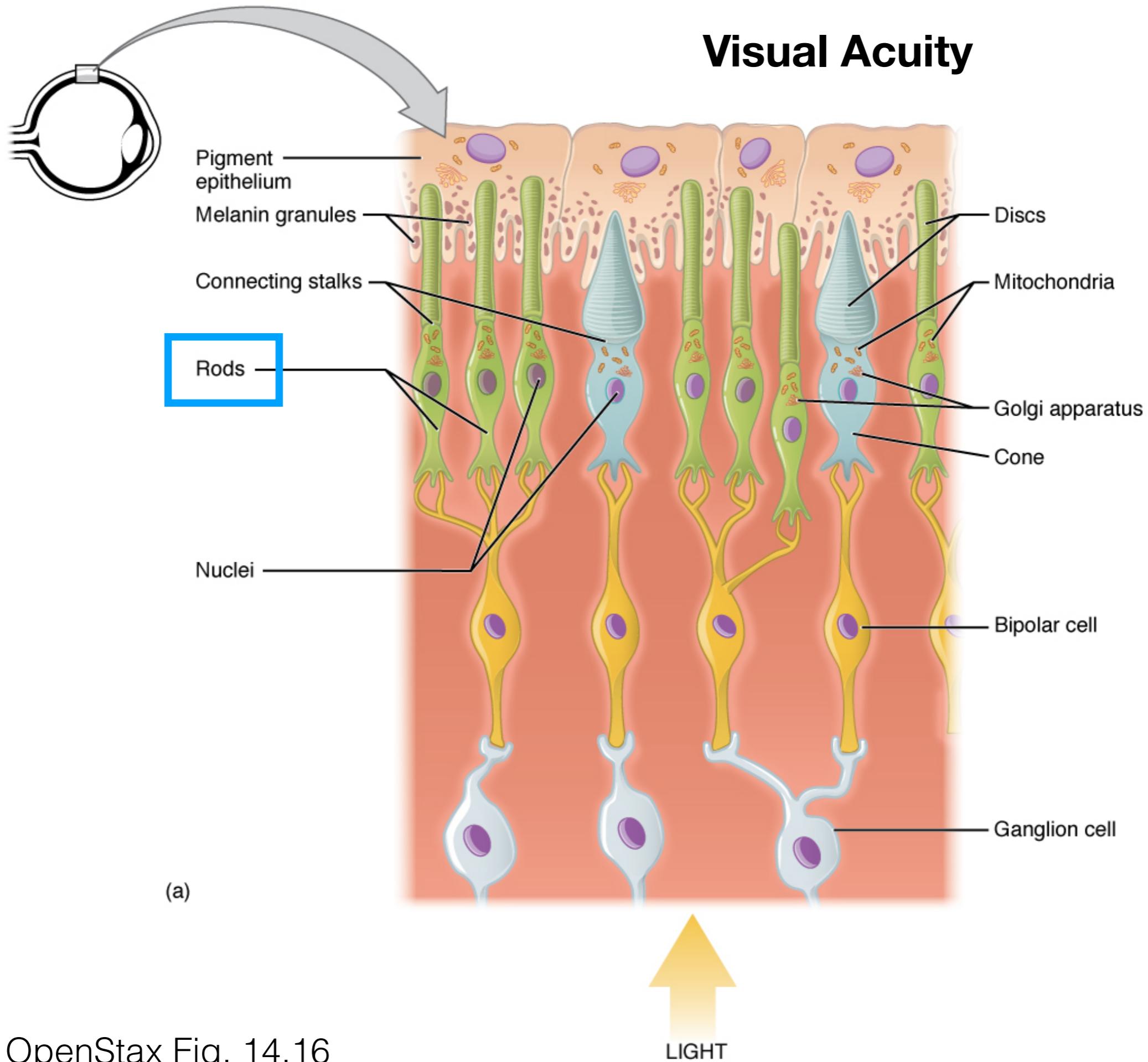
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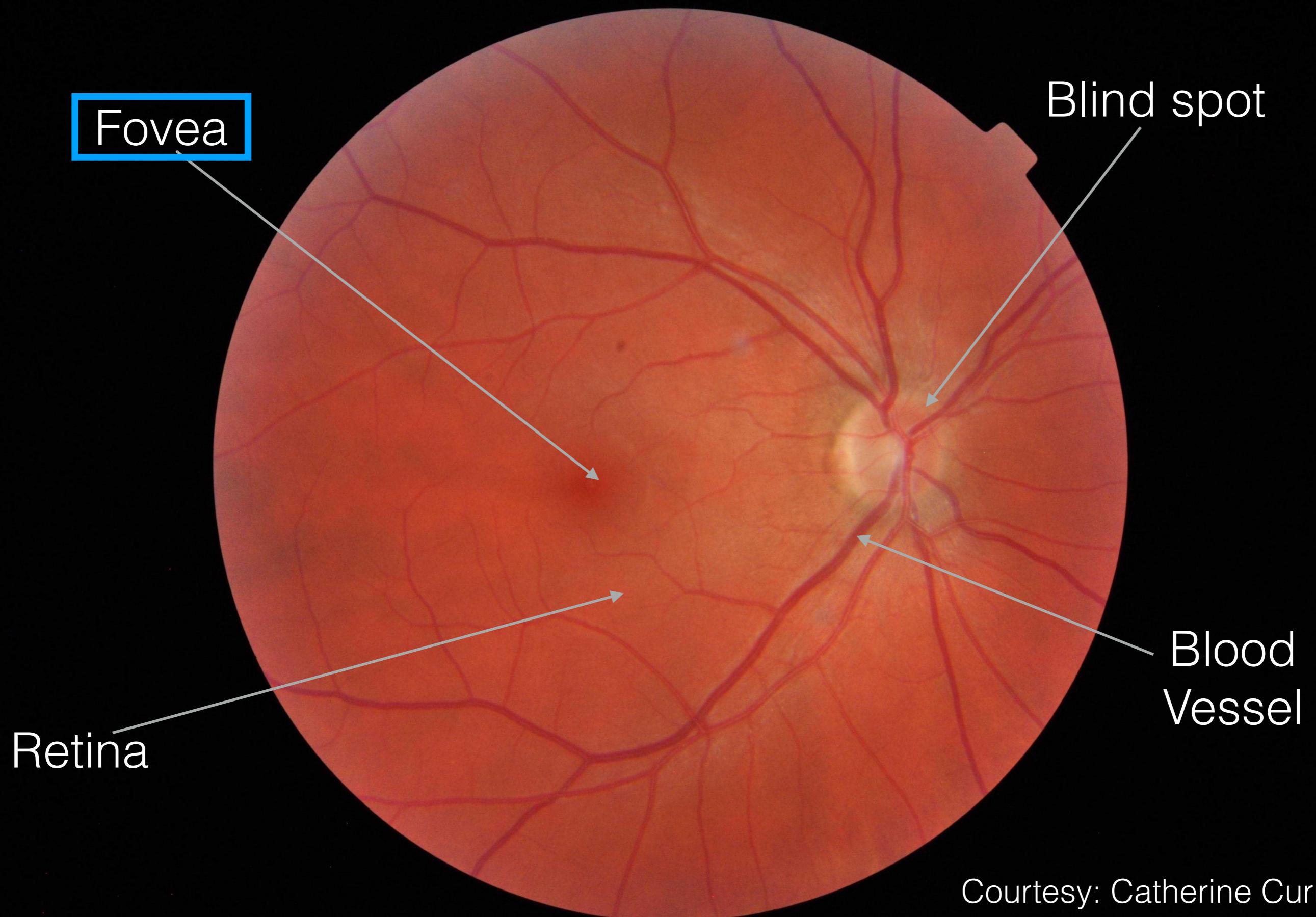


Visual Acuity



OpenStax Fig. 14.16

My Eyeball!

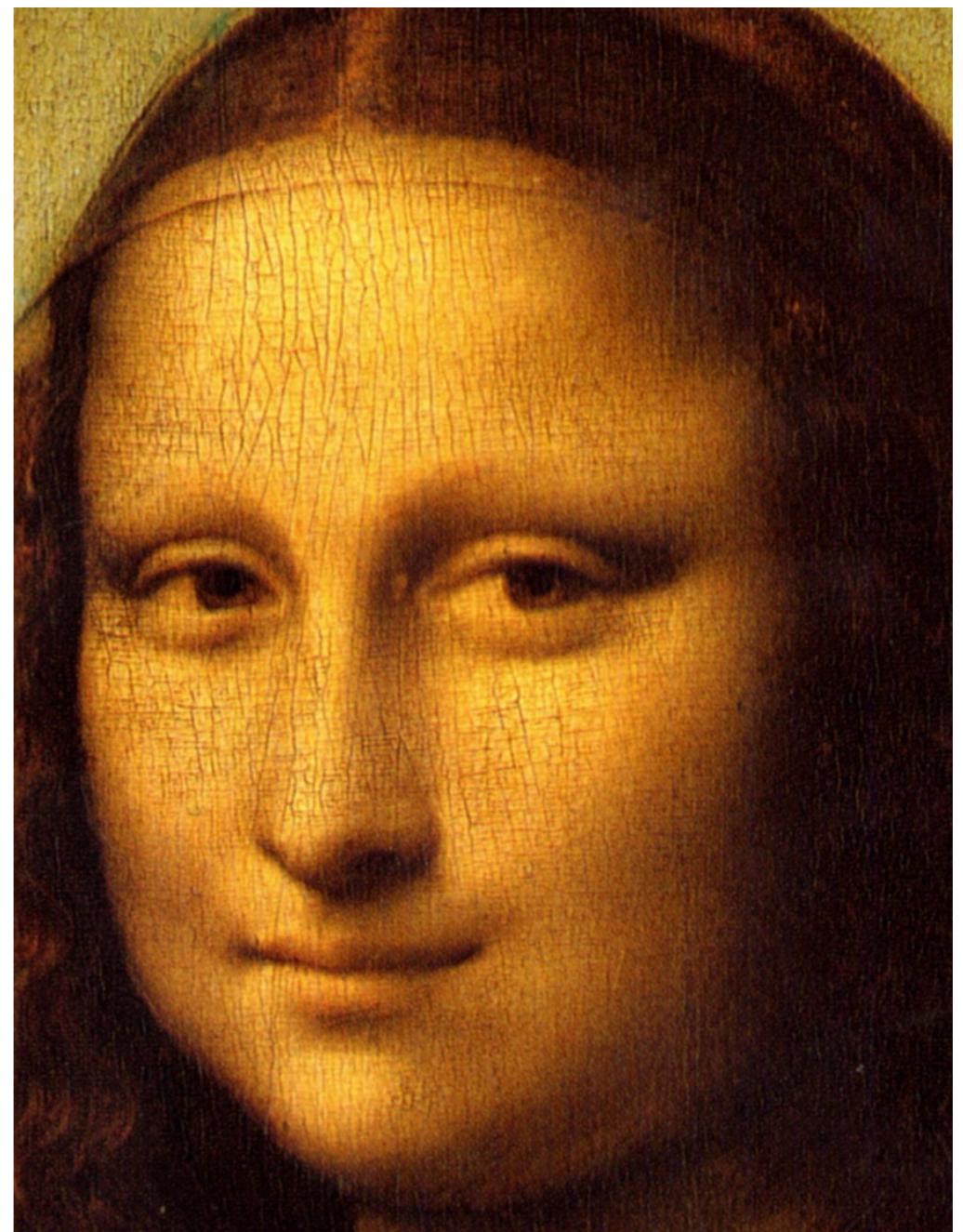
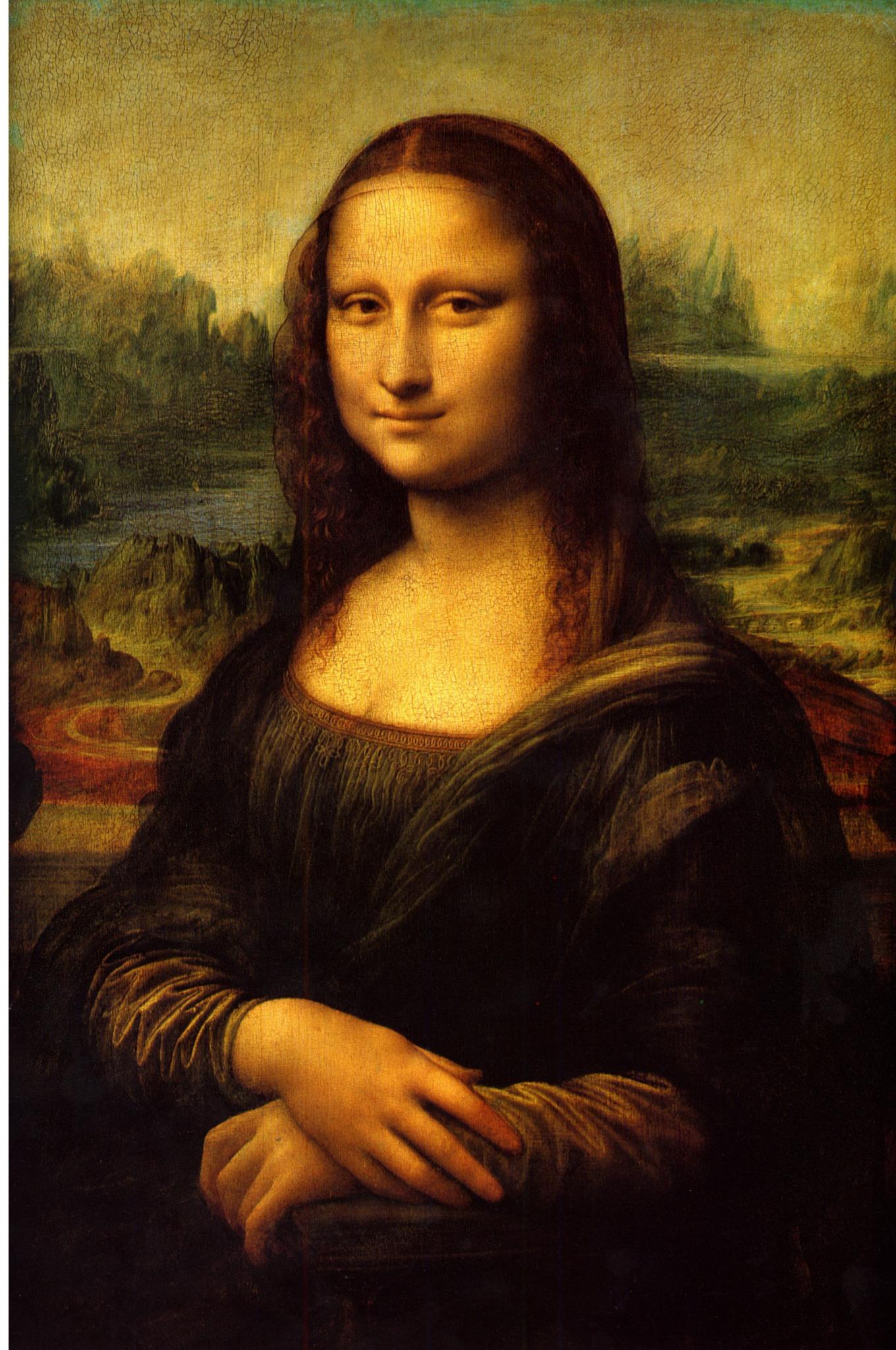


Acuity is high centrally and drops off peripherally.





Pointillism: Georges Seurat
“El Sena y la Grande Jatte en primavera” 1888



“Mona Lisa”
Leonardo da Vinci

Visual Processing Matters!

- Sight is not based on image transmission, but visual processing
 - Your brain makes stuff up all the time, so be weary of it.
 - Use features with fast-processing differences to encode your data.
 - Avoid equal-luminance elements, they jitter and are unpleasant!
 - Be mindful of the limits of visual acuity! Don't spread too much detail out.

Conclusions:

- 1. Our visual systems are built primarily on contrast.**
- 2. We see based on visual processing, not image transmission.**



Seeing is *not* believing

More resources:

Oliver Sacks *The Man Who Mistook His Wife for a Hat*

Oliver Sacks *An Anthropologist on Mars*

Margaret Livingstone “What Can Art Tell Us about the Human Brain?”

<https://www.youtube.com/watch?v=fwPqSxR-Z5E>

References:

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- Kuffler SW. 1953. Discharge patterns and functional organization of mammalian retina. *J Neurophysiol* 16: 37-68.
- Livingstone M. 2014. “What Can Art Tell Us about the Human Brain?” UC Irvine Lecture, Youtube: <https://www.youtube.com/watch?v=fwPqSxR-Z5E>
- McGee S. 2012. *Evidence-Based Physical Diagnosis*. 3rd ed. Elsevier Saunders Publishing.
- Muir D. 2012. H. Keffer Hartline and lateral inhibition: a brief biography of an influential idea. 30th Oct. dylan-muir.com.
- Wyttenbach RA. 2012. Exploring sensory neuroscience through experience and experiment. *J Under Neuro Ed* 11(1): A126-A131.