

# 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.**

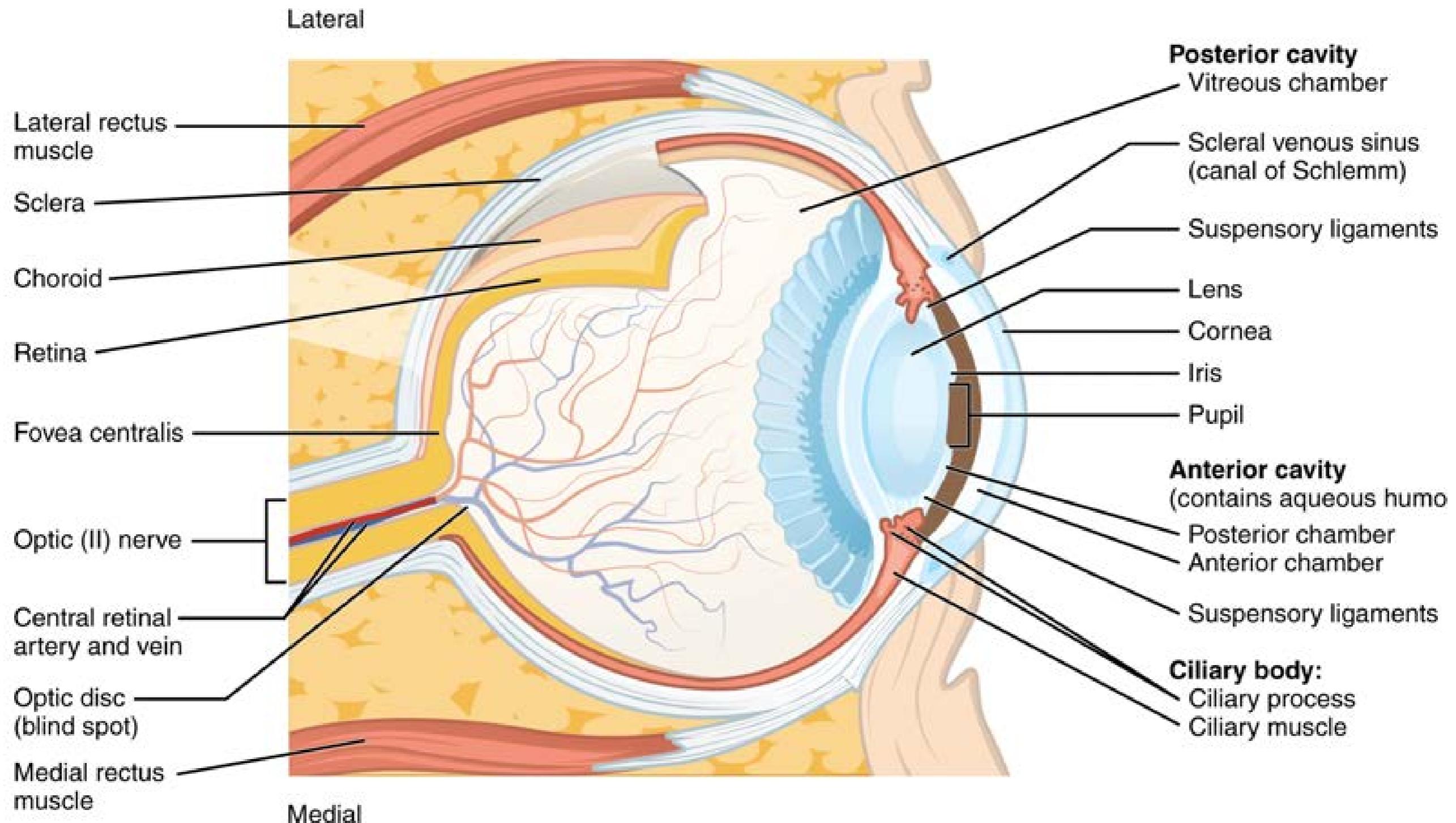
**Monologue from *The X-Files*  
“Jose Chung’s From Outer Space”**



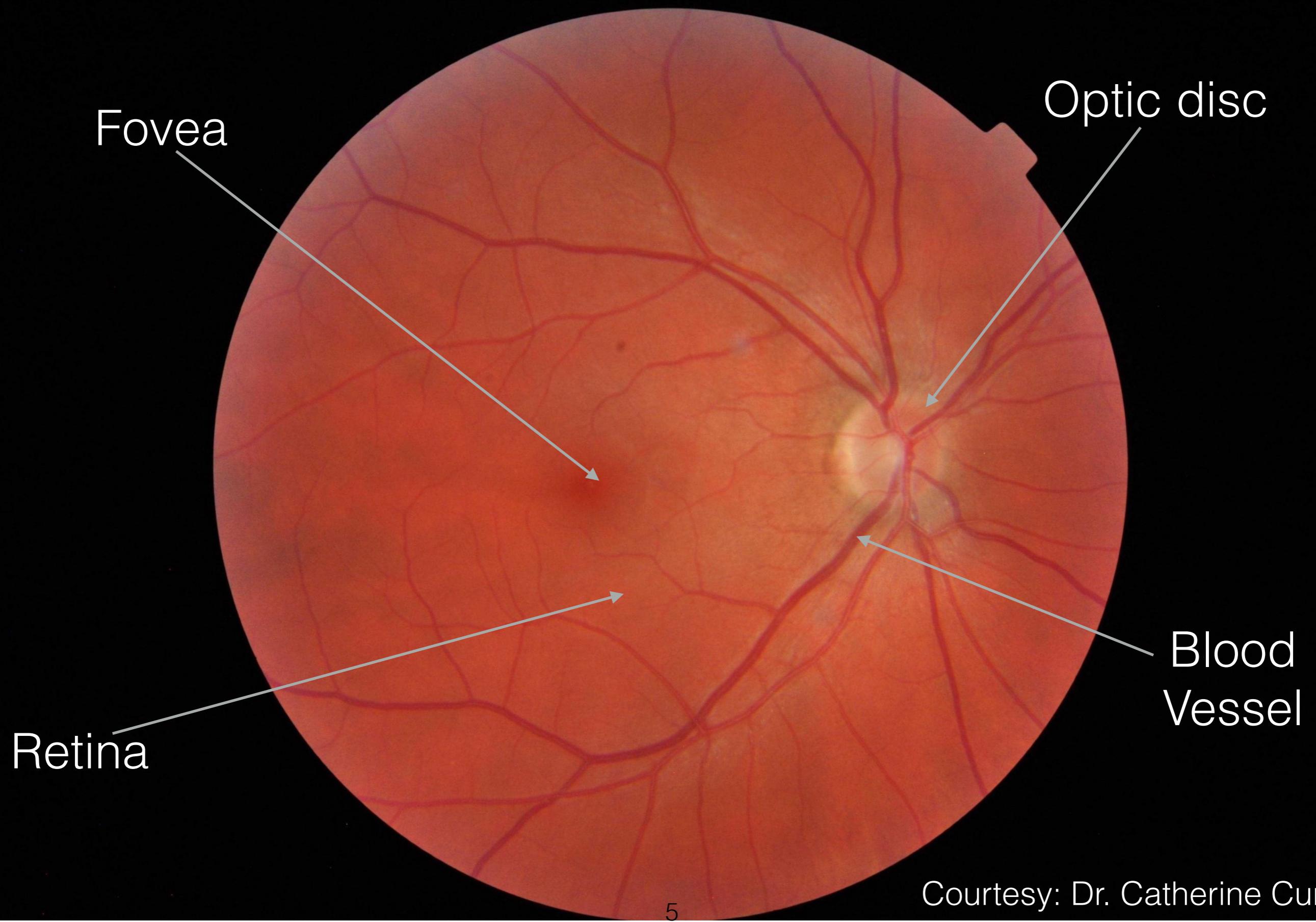
# How We See

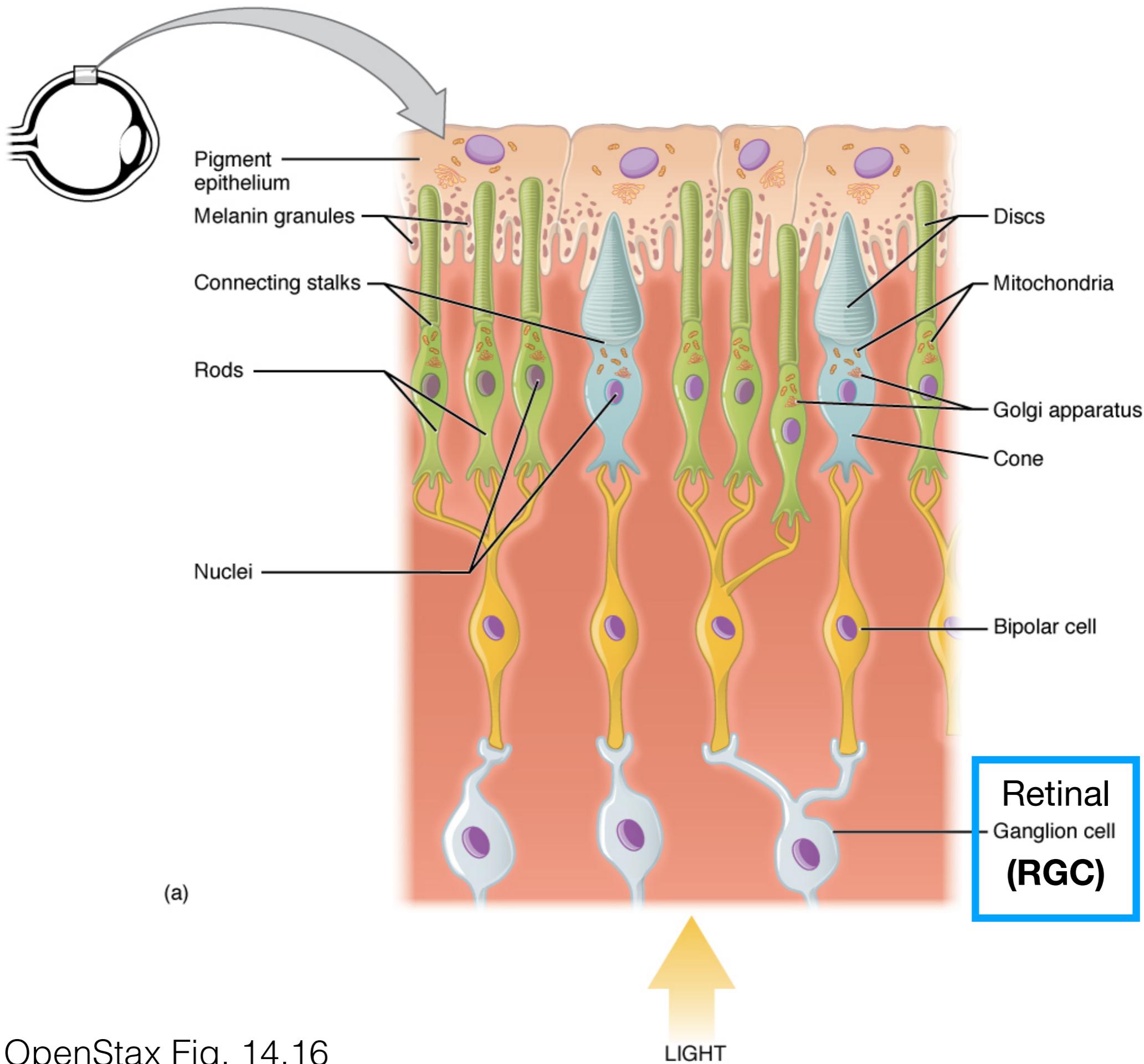
- 1. Our visual systems are built primarily on contrast  
(not just sensing light).**
  
- 2. We see based on visual processing  
(not image transmission).**

# Anatomy of the Eye



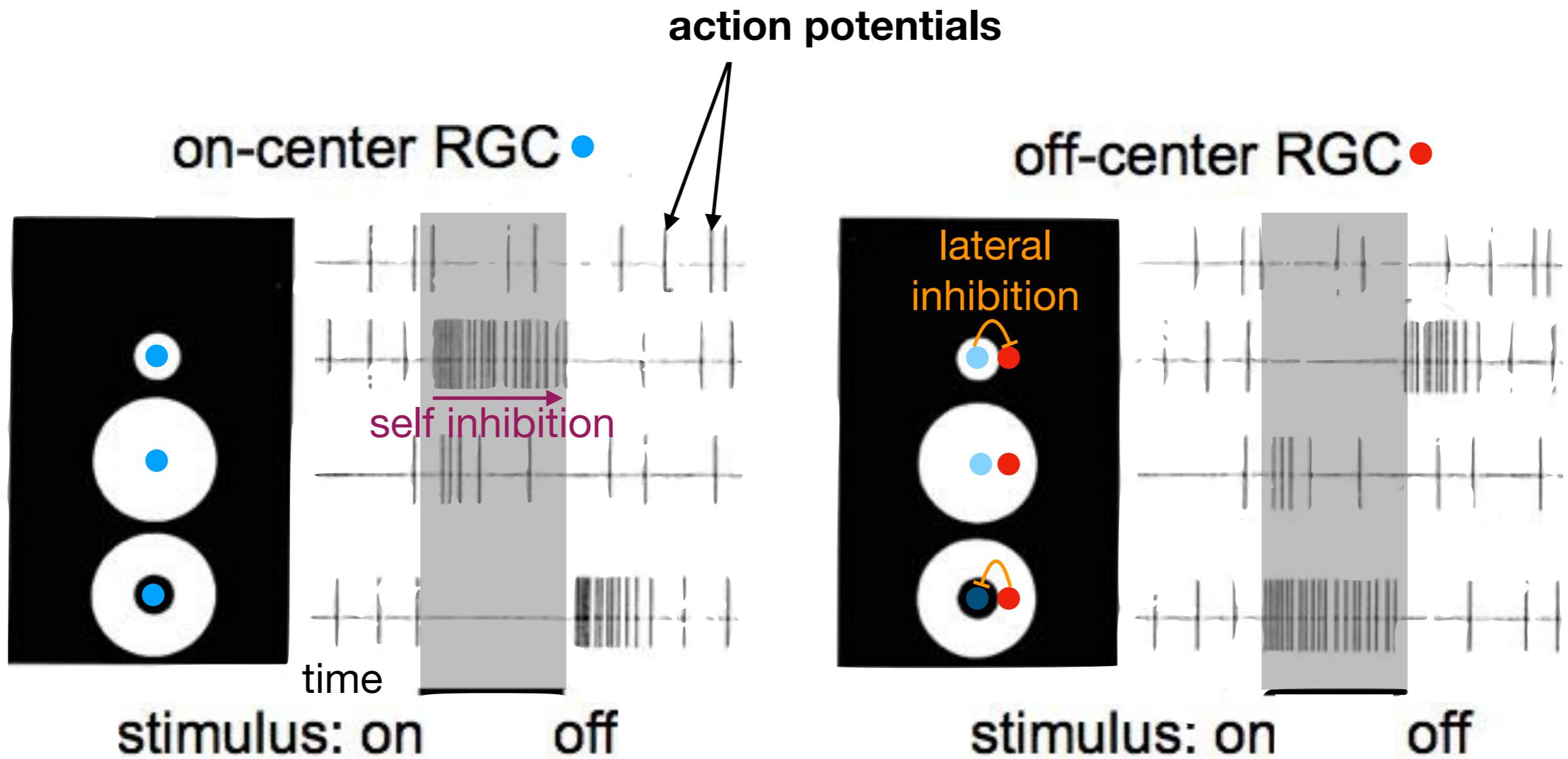
# My Eyeball!





OpenStax Fig. 14.16

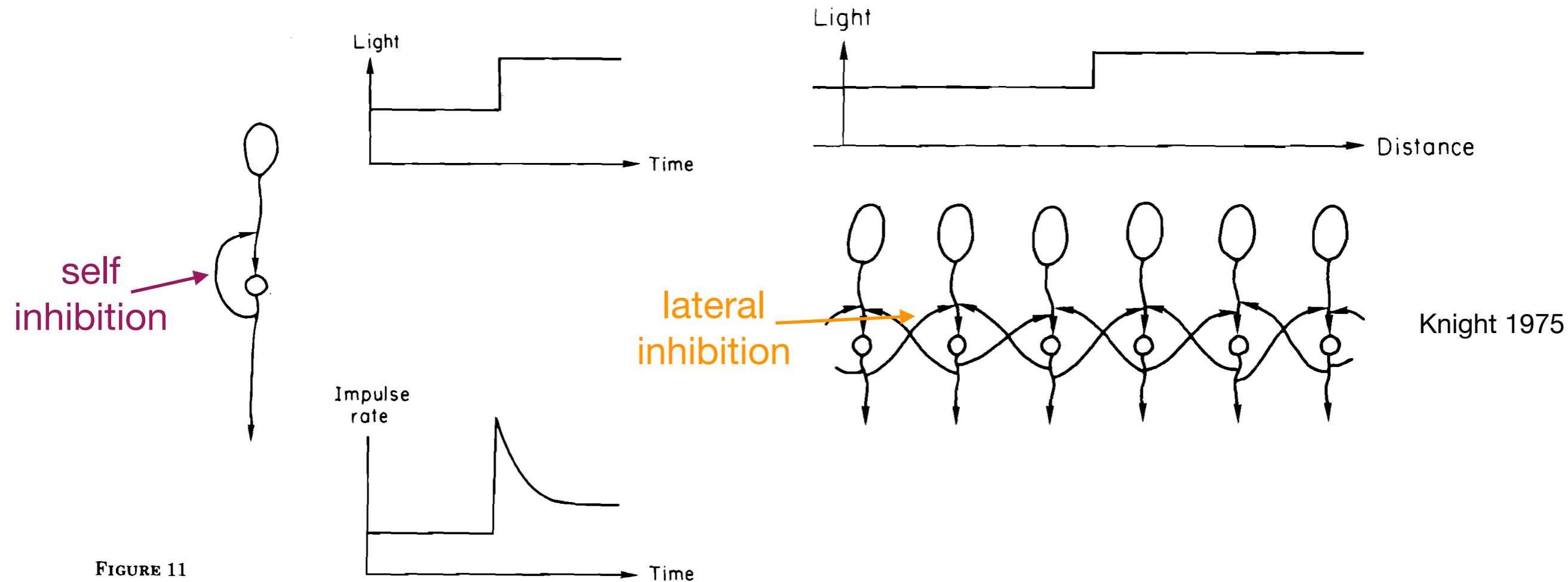
# How Contrast Works



- 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)

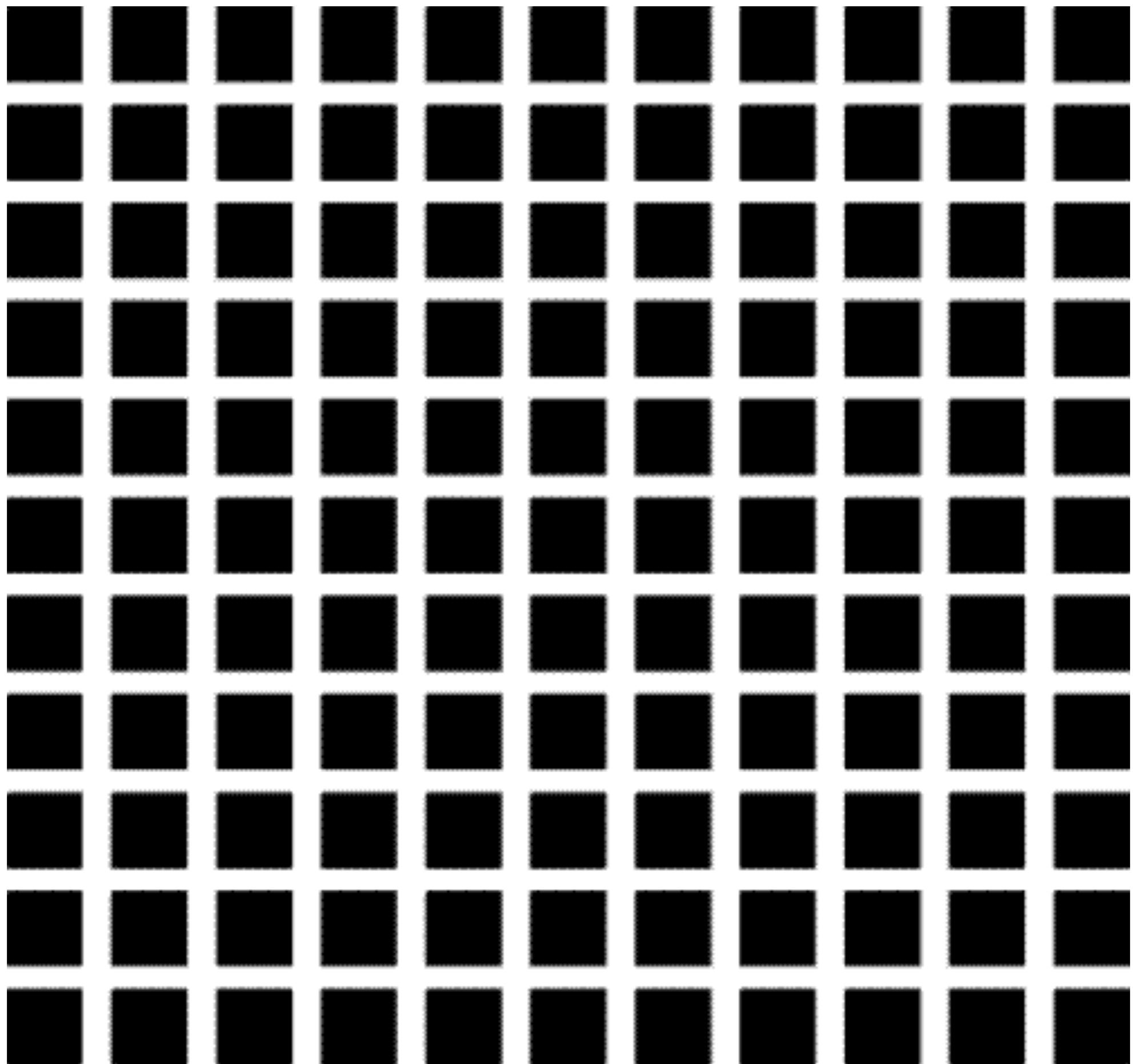
# How Contrast Works

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



**Chevreul Illusion or  
“Mach banding”**





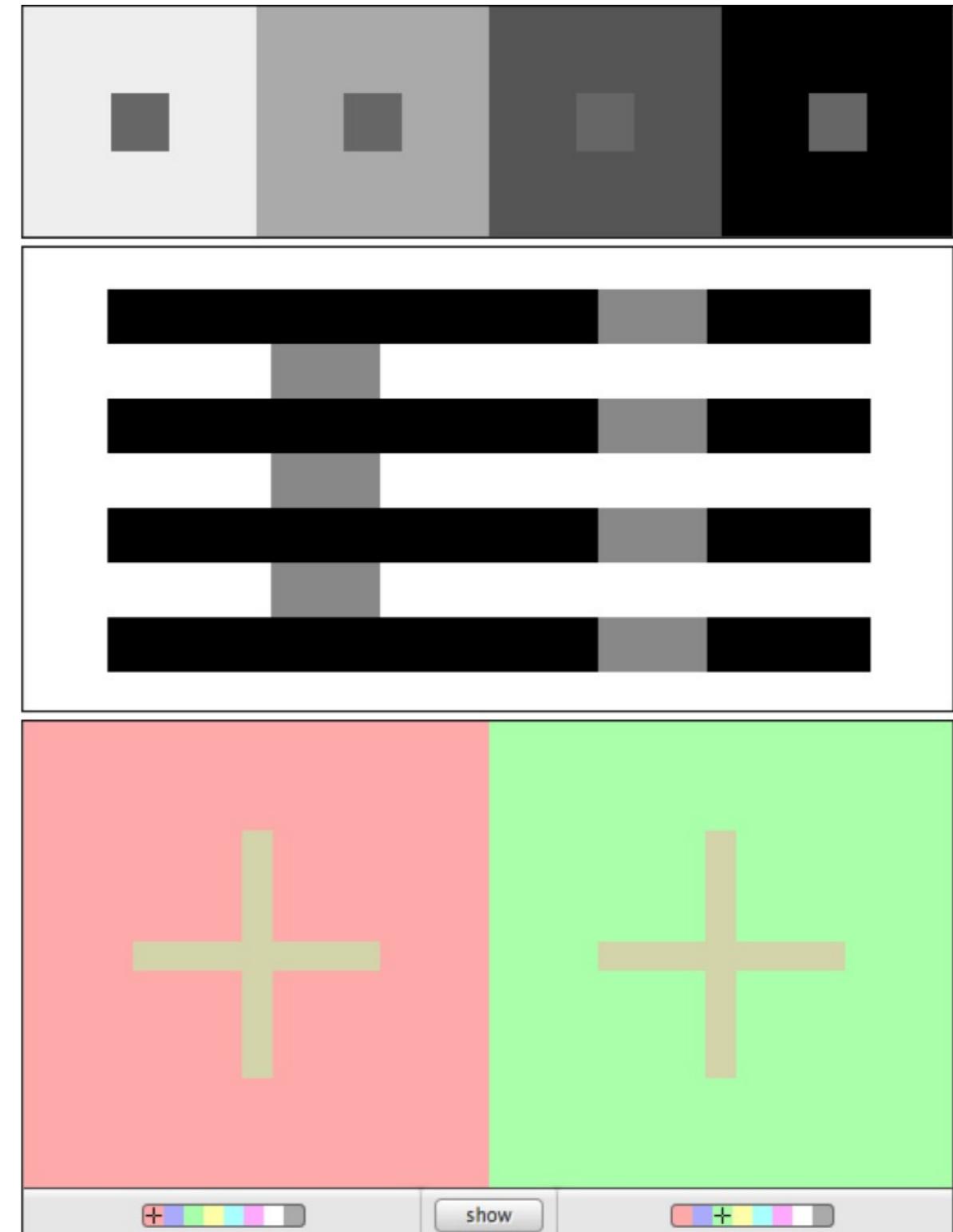
# We only see contrast: everything is relative



This is white



This is also white



# Contrast can improve understanding or be misleading

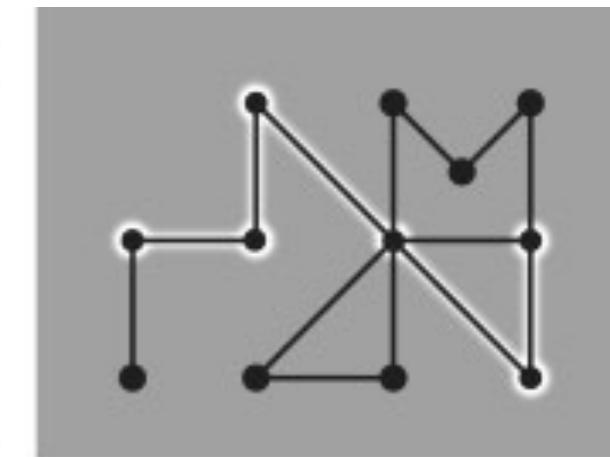
Cornsweet contours help identify shapes



Improving background contrast improves readability



(a)



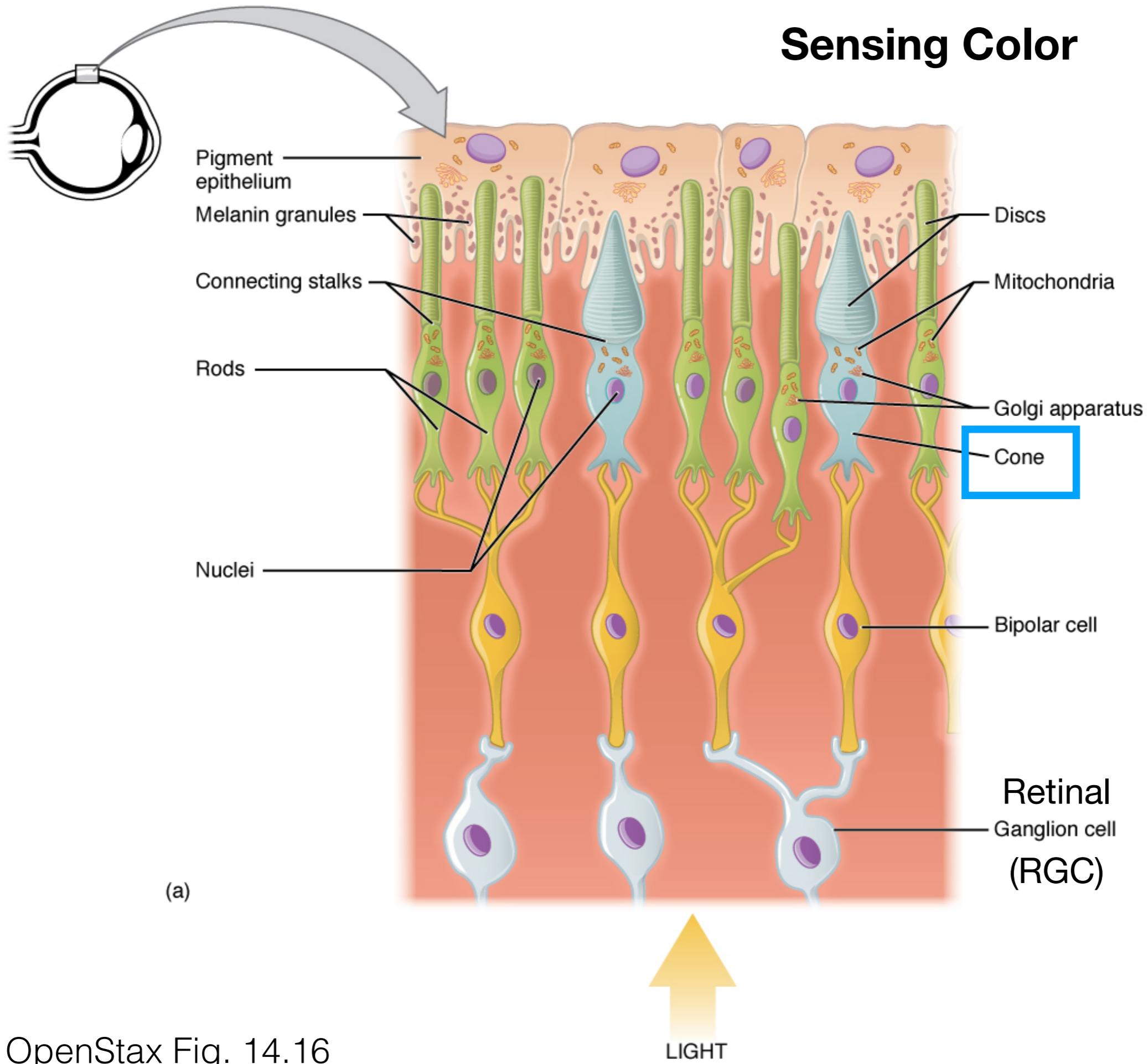
(b)

Chevreul Illusion or “Mach banding”



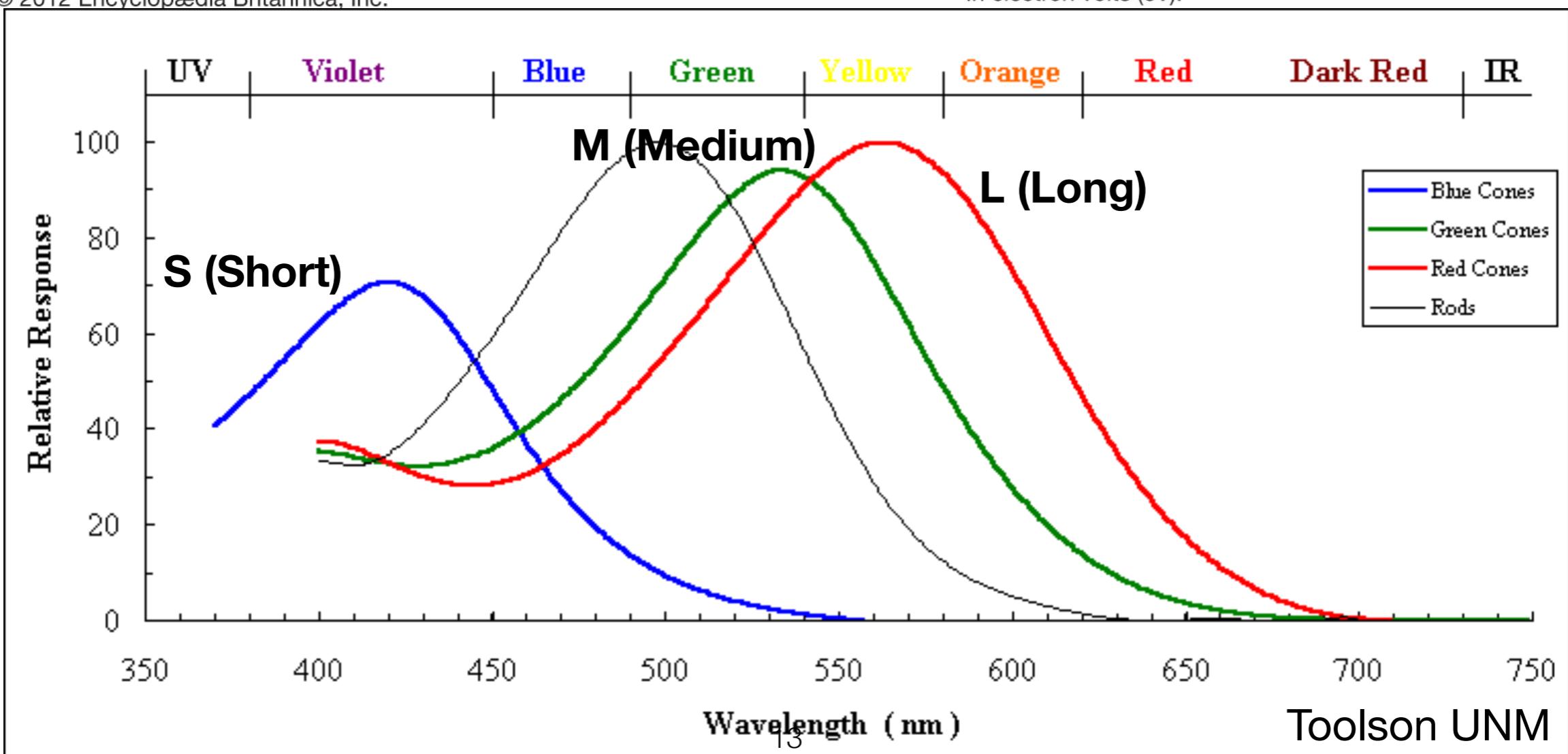
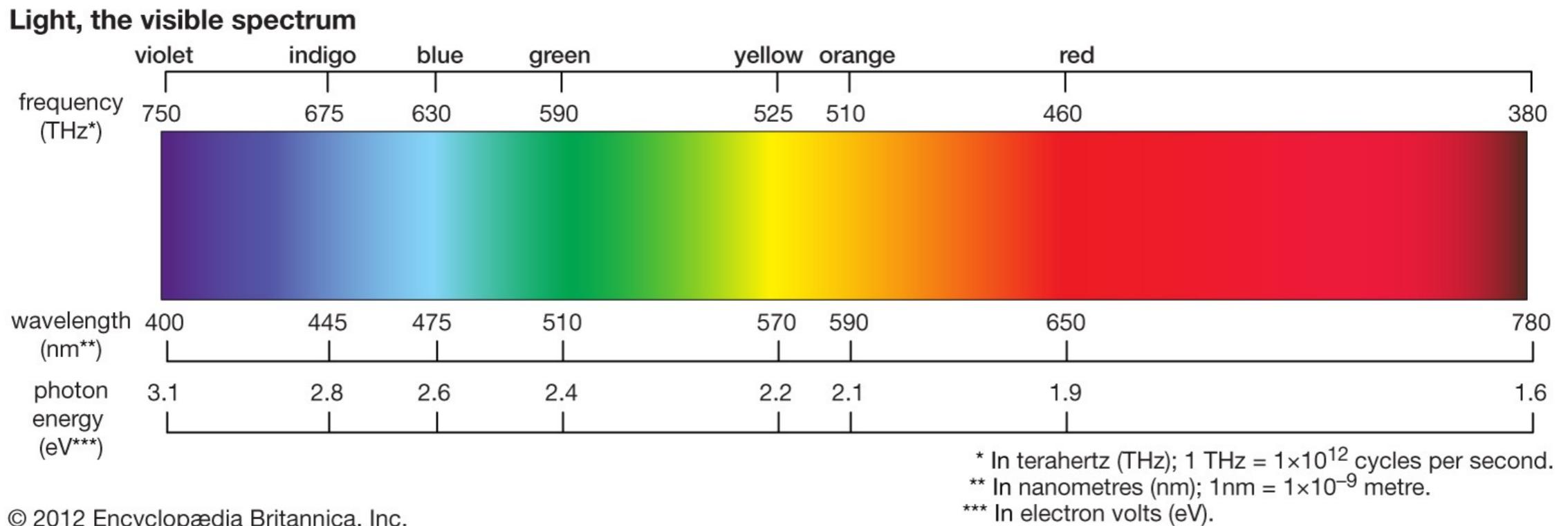
Can mislead viewers of color scales!

# Sensing Color

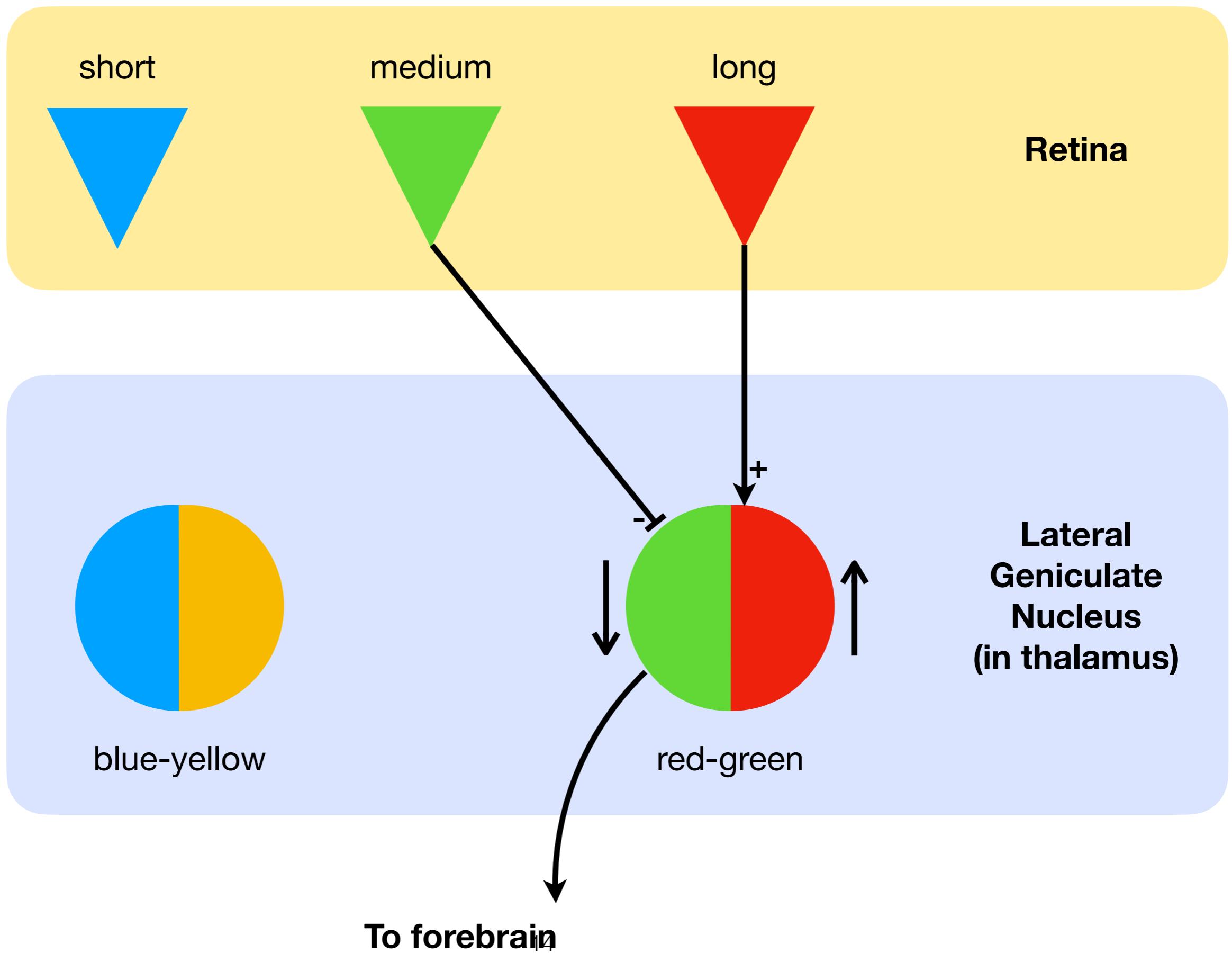


OpenStax Fig. 14.16

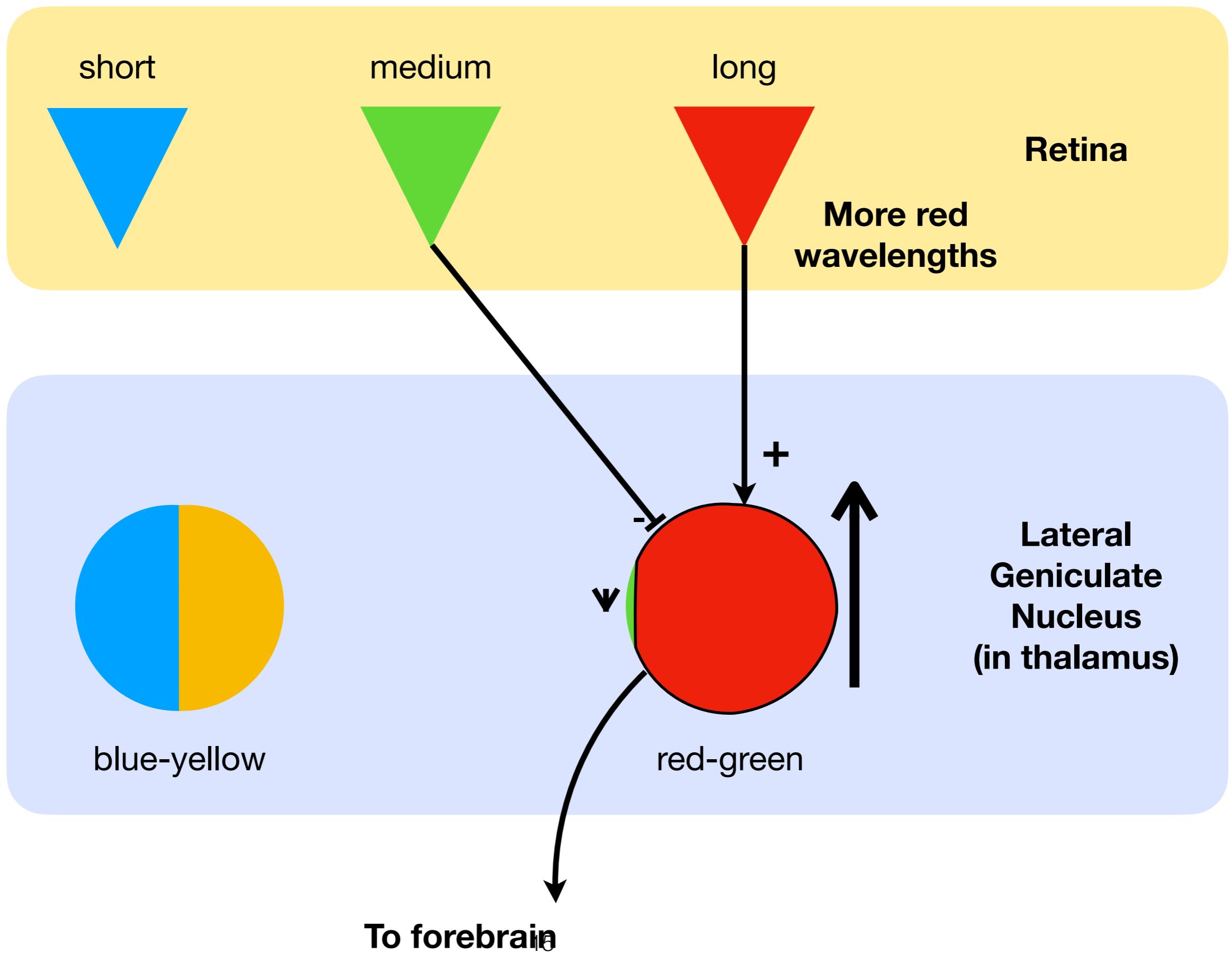
# Cone types



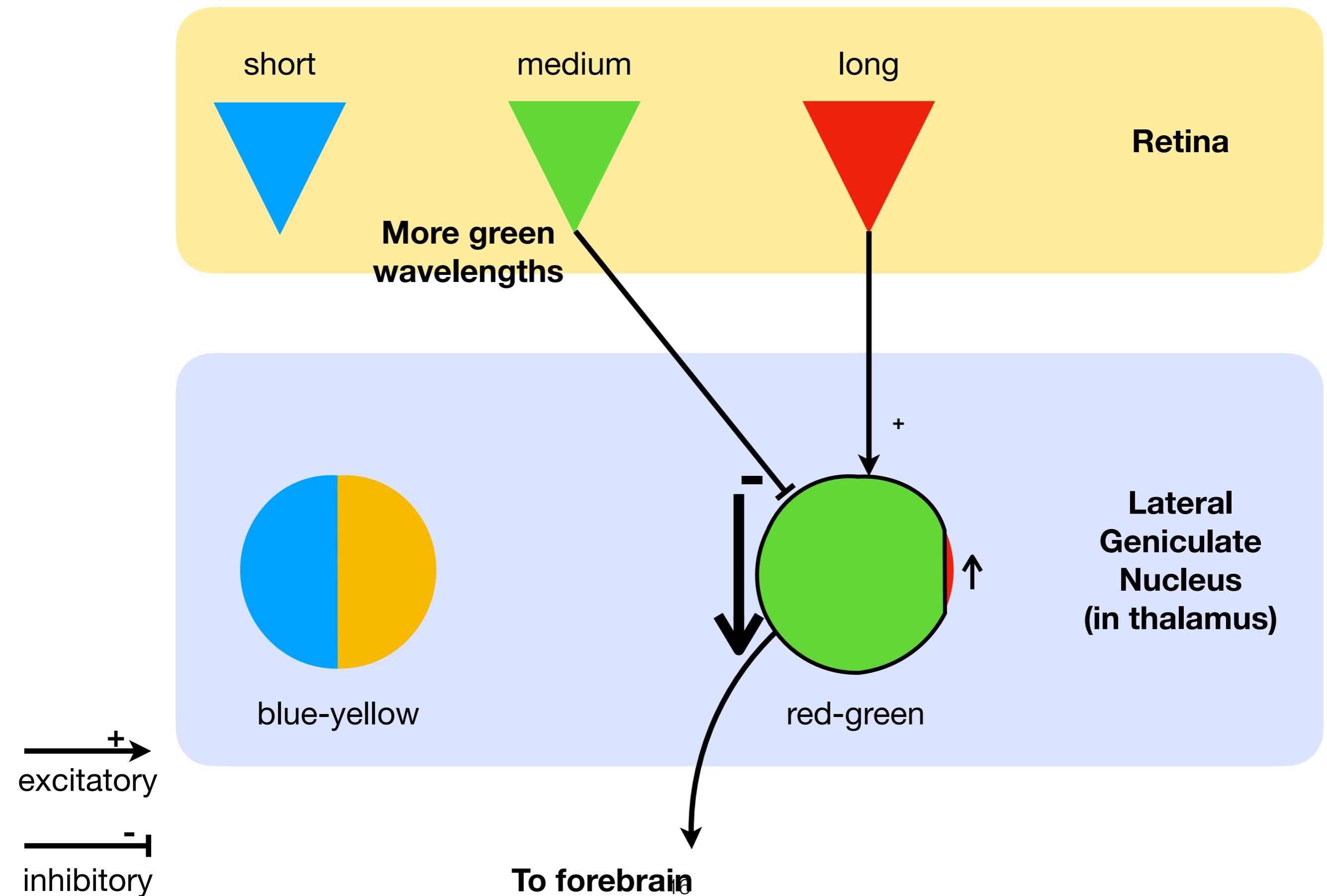
# Opponent-Process Theory of Color (Chromatic)



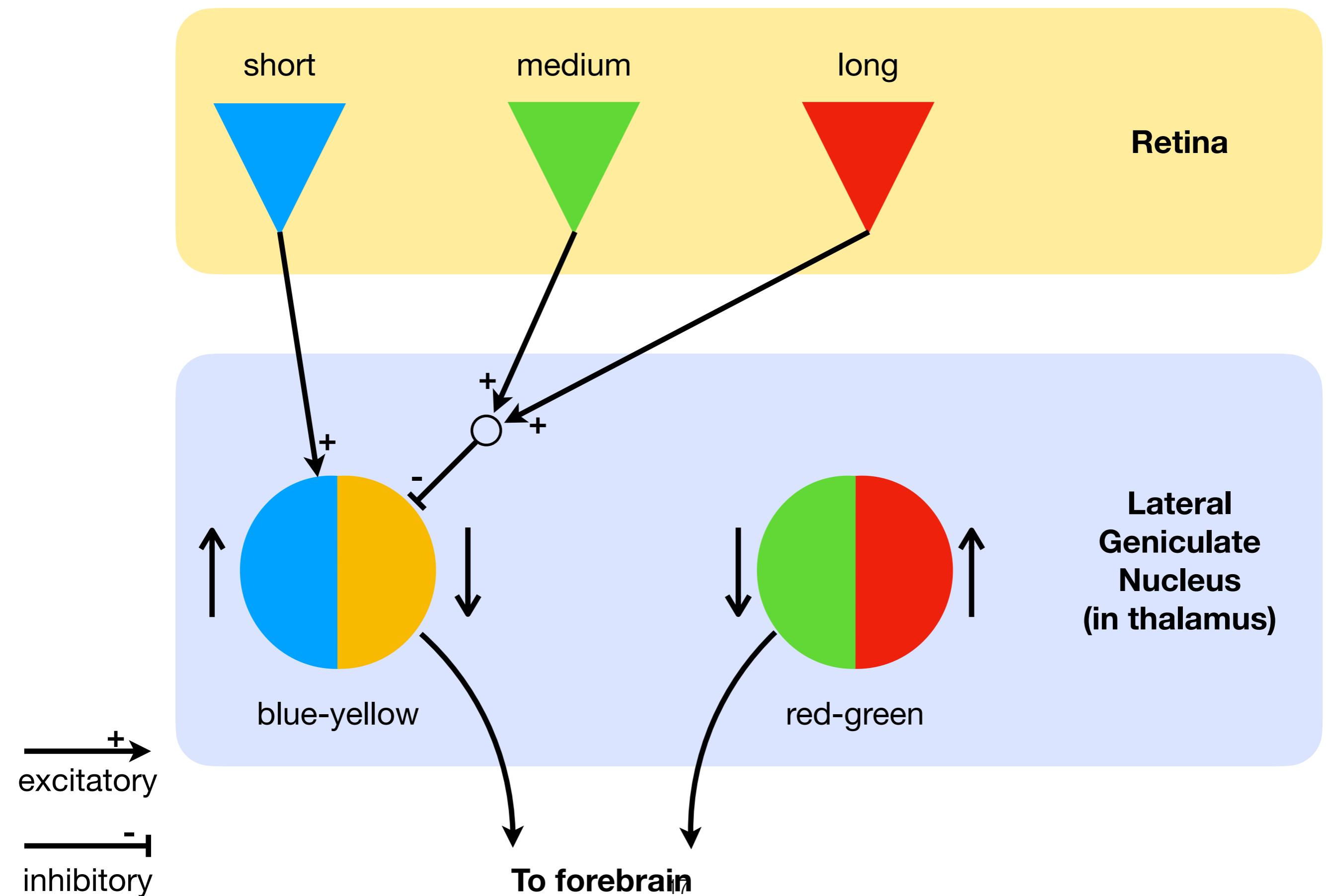
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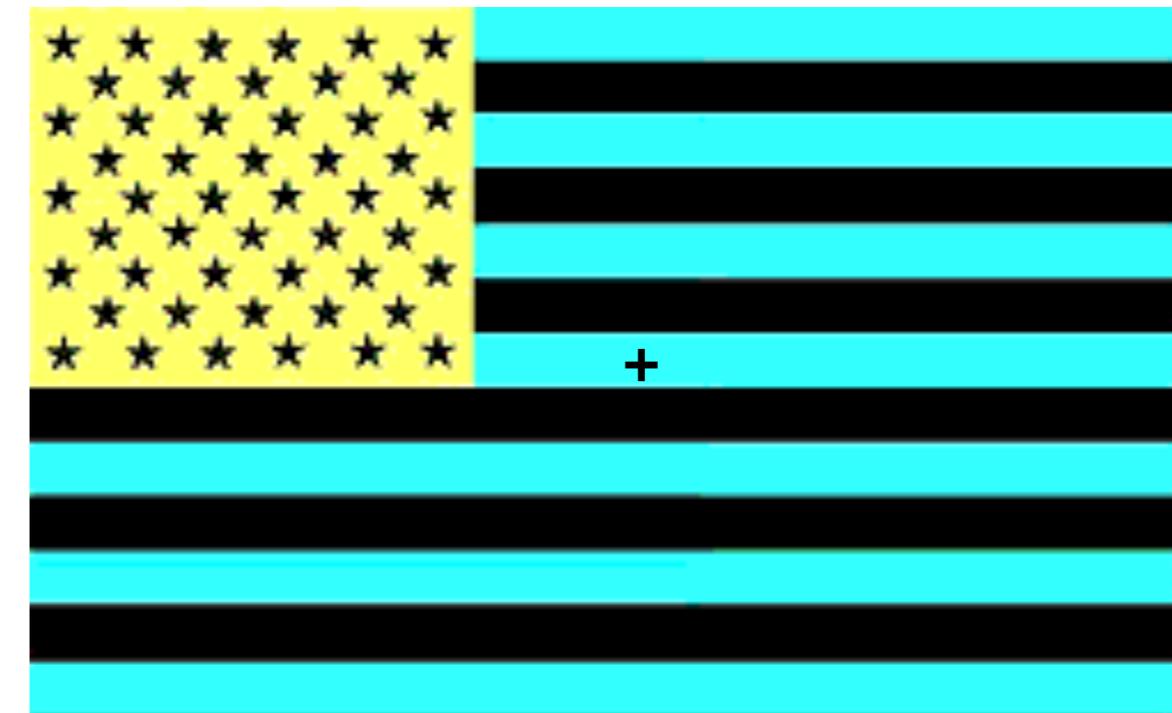
# Opponent-Process Theory of Color (Chromatic)



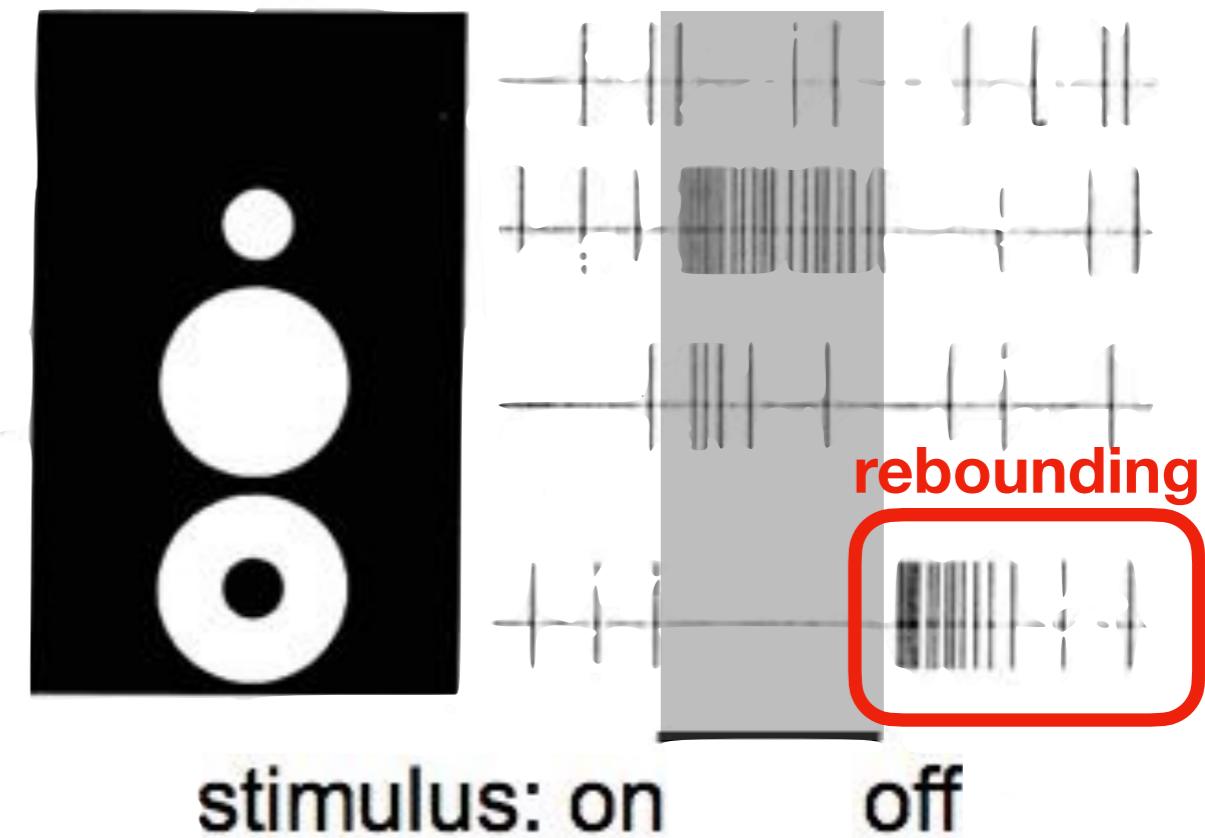
# Complementary Color illusions

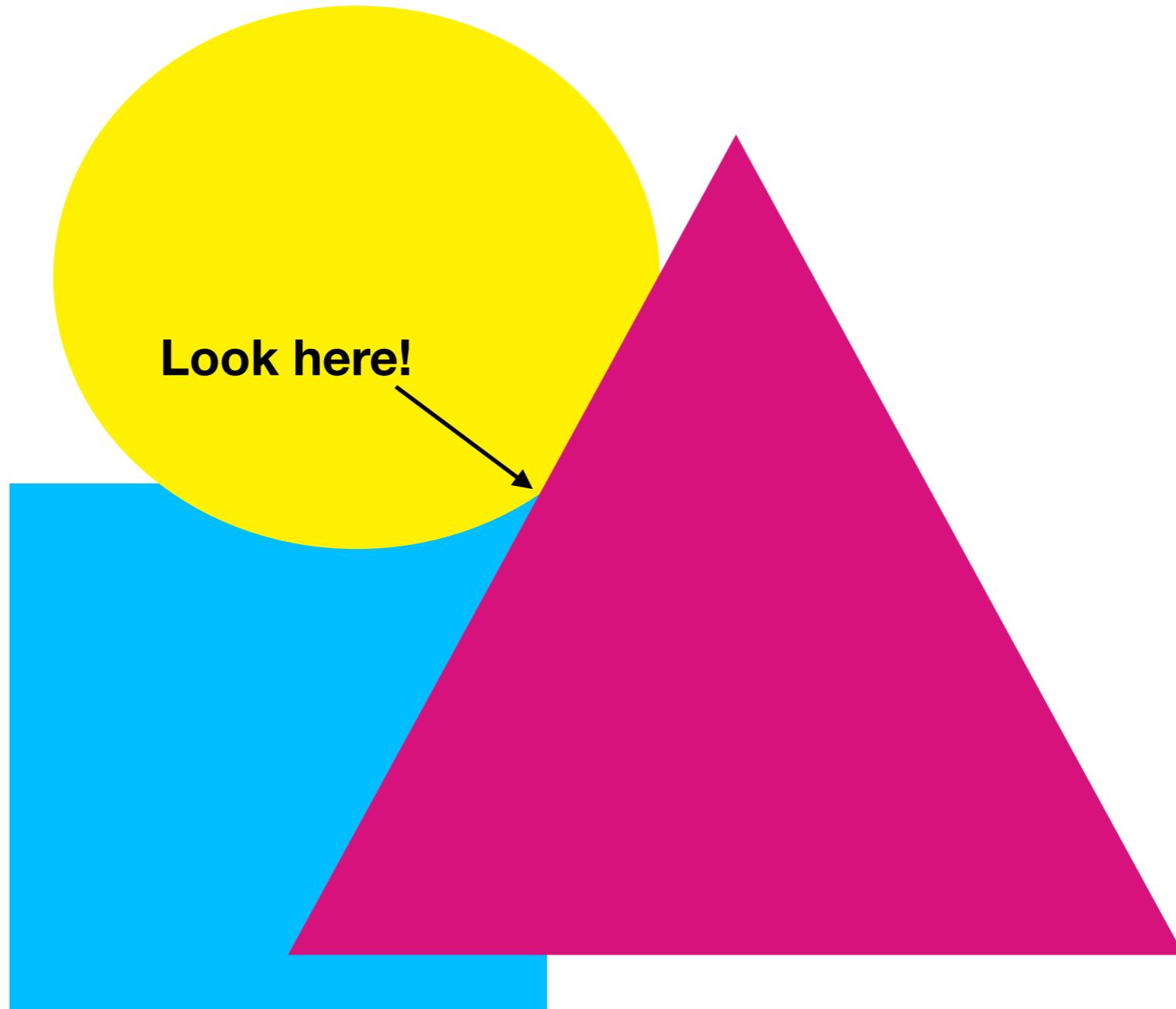
# “Lilac Chaser”

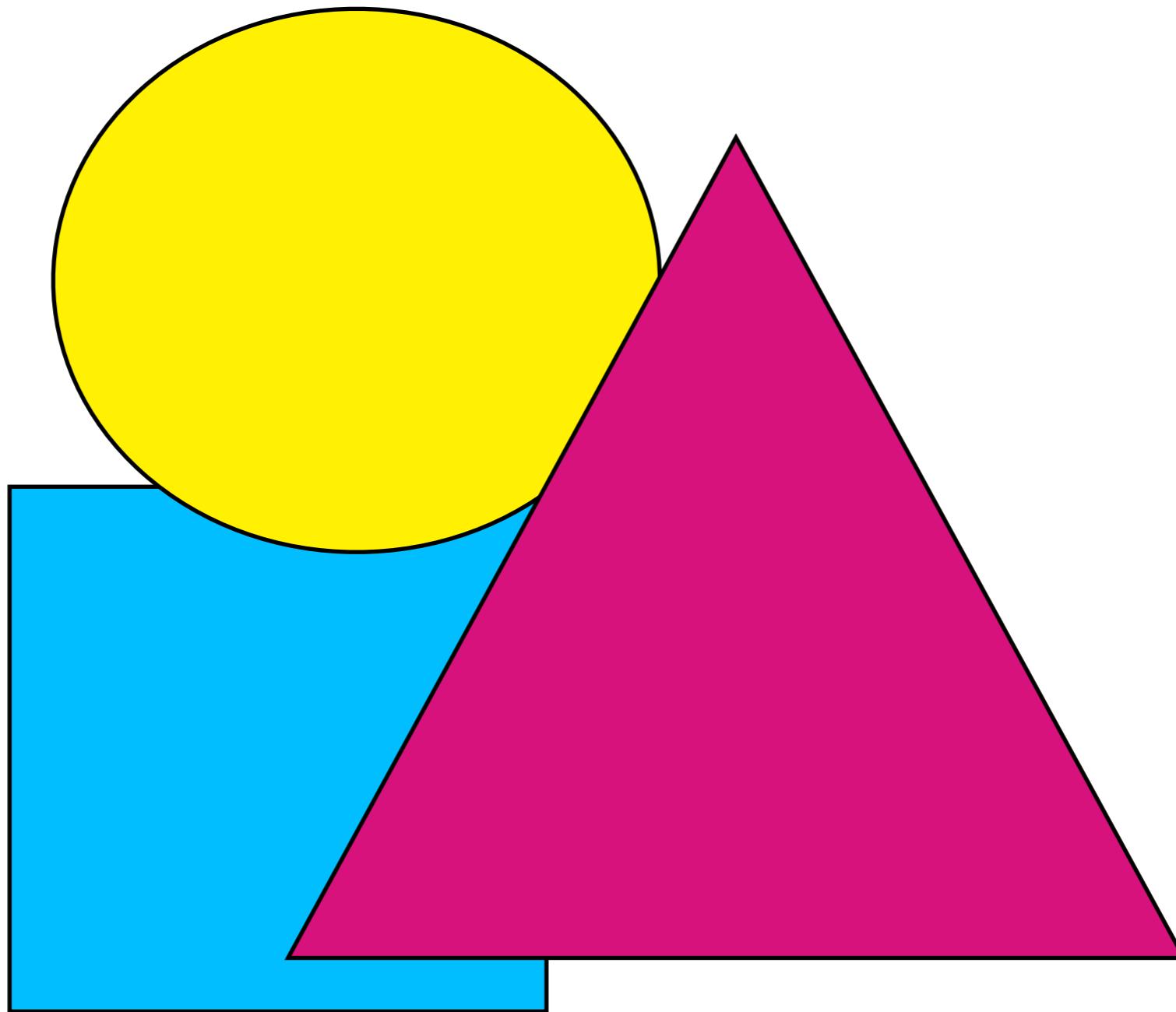
[https://en.wikipedia.org/wiki/  
Visual adaptation](https://en.wikipedia.org/wiki/Visual_adaptation)



### on-center RGC





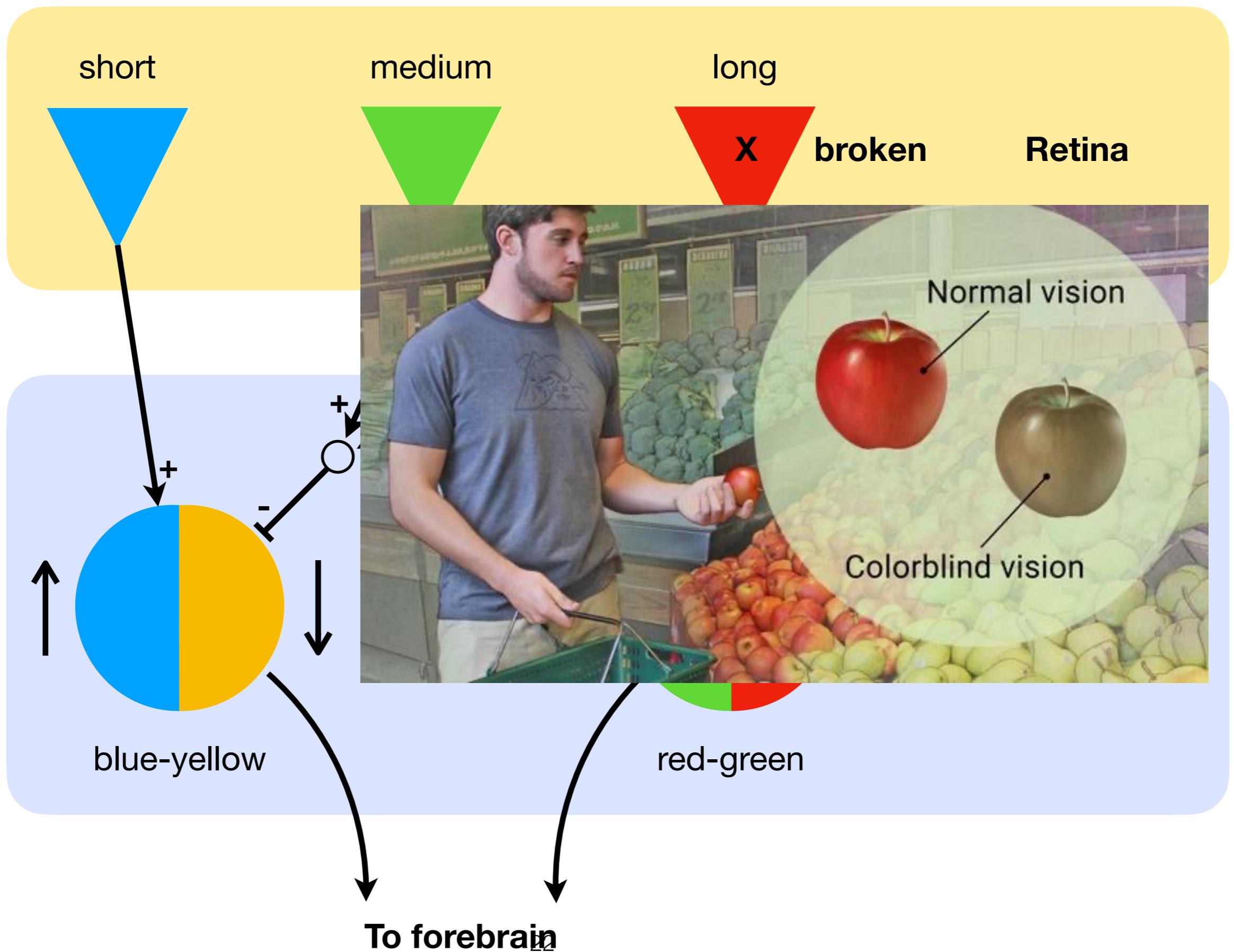


# We only see contrast

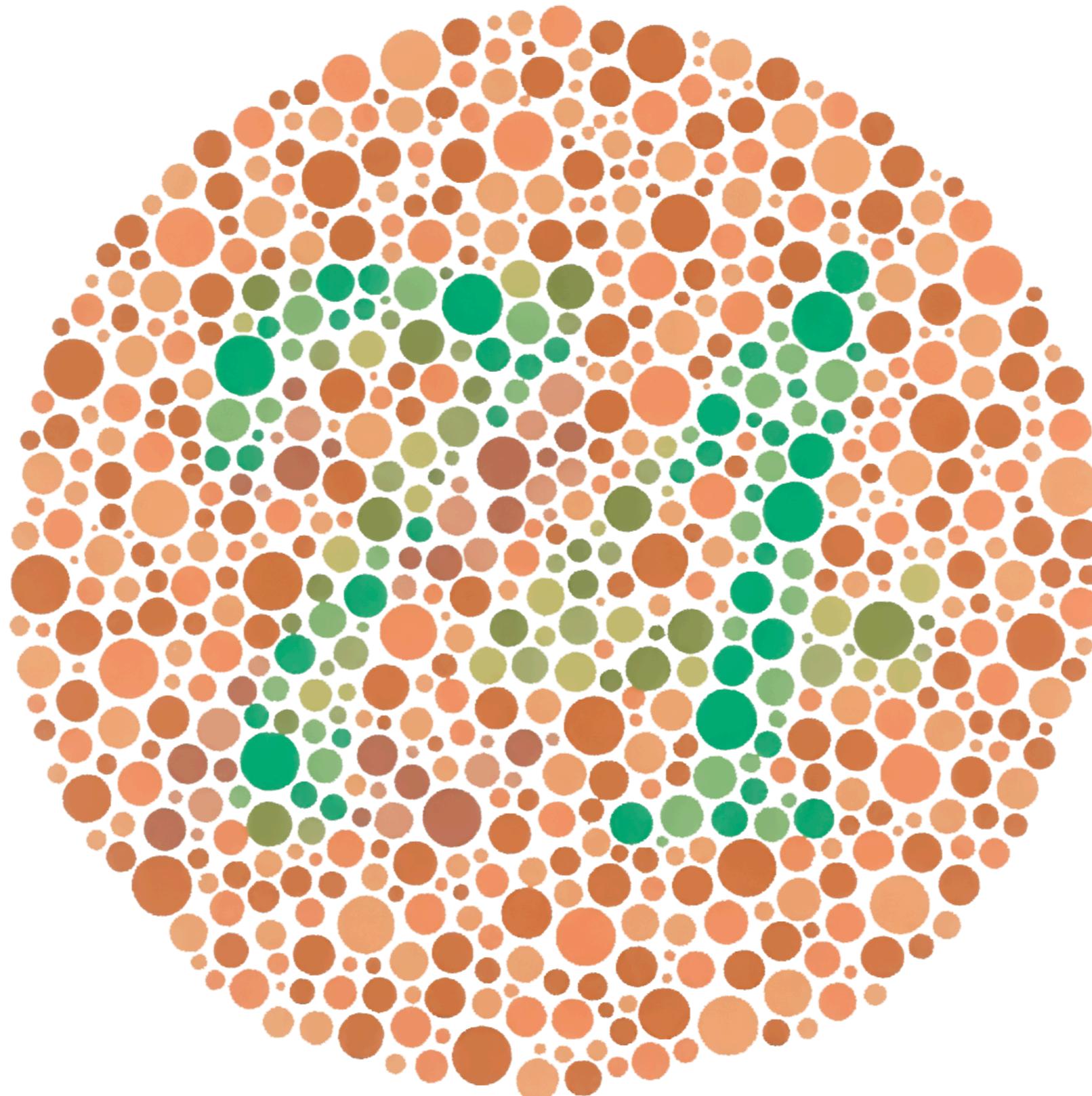
“The Dress”



# 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!

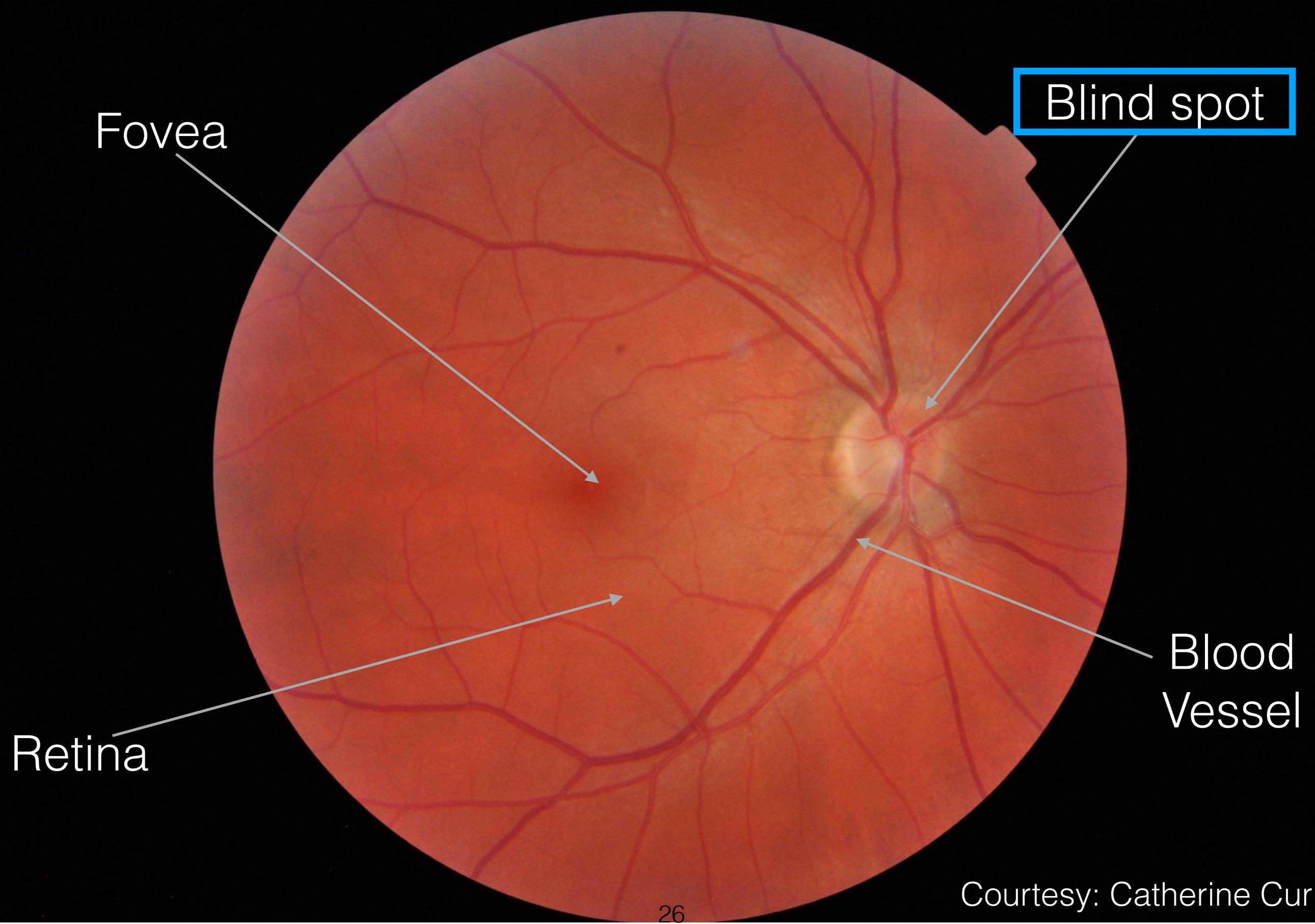
**Text, lines, and other design elements should not be of equal or close luminance (grayscale) to the background. Near-equal luminance objects are very hard to pick out, and near-equal luminance text is very difficult to read. Use luminance contrast that is sufficiently different to avoid problems.**

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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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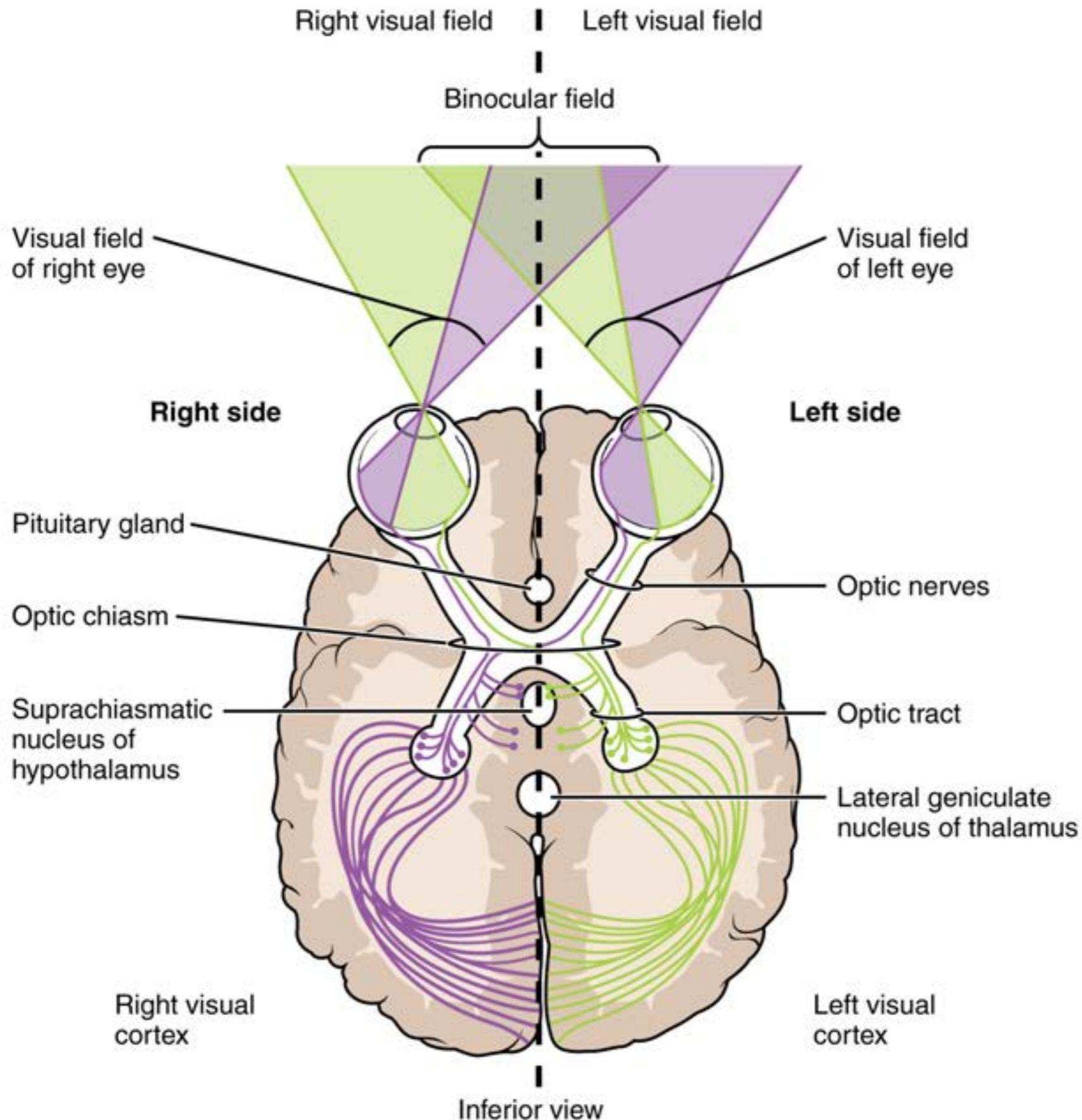
3,367

9,482

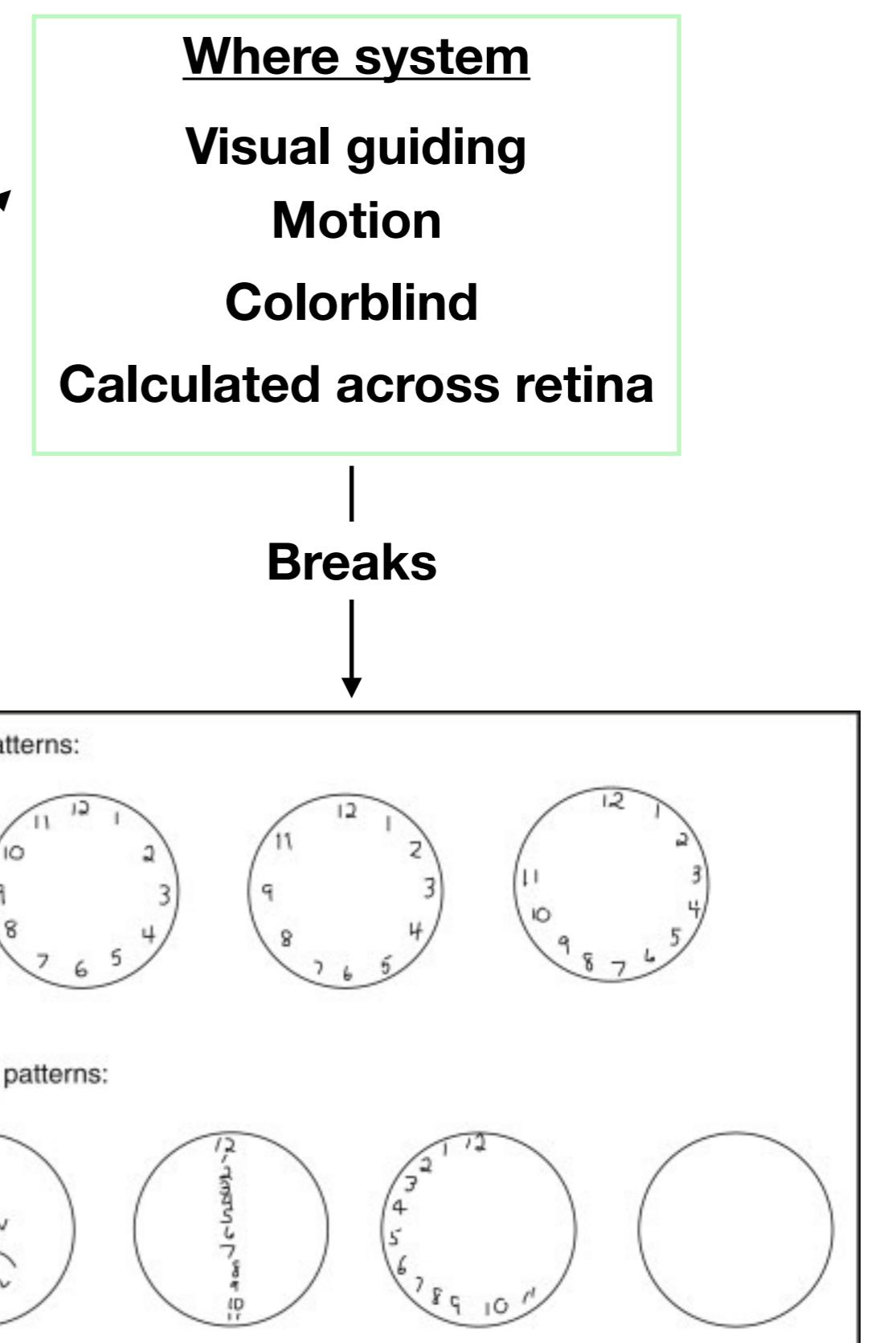
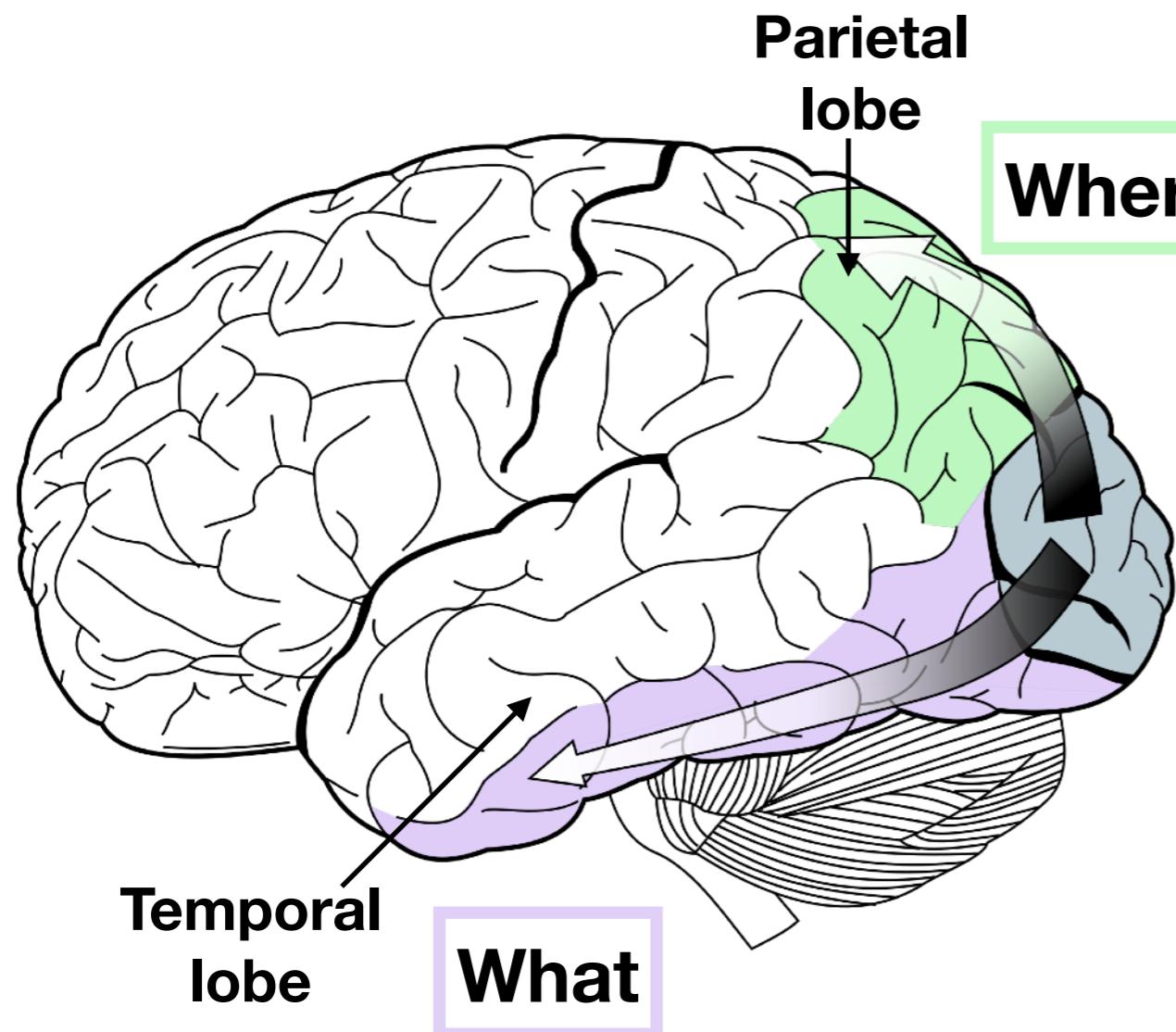


We see based on visual processing, not image transmission.

# Visual Field Tracts

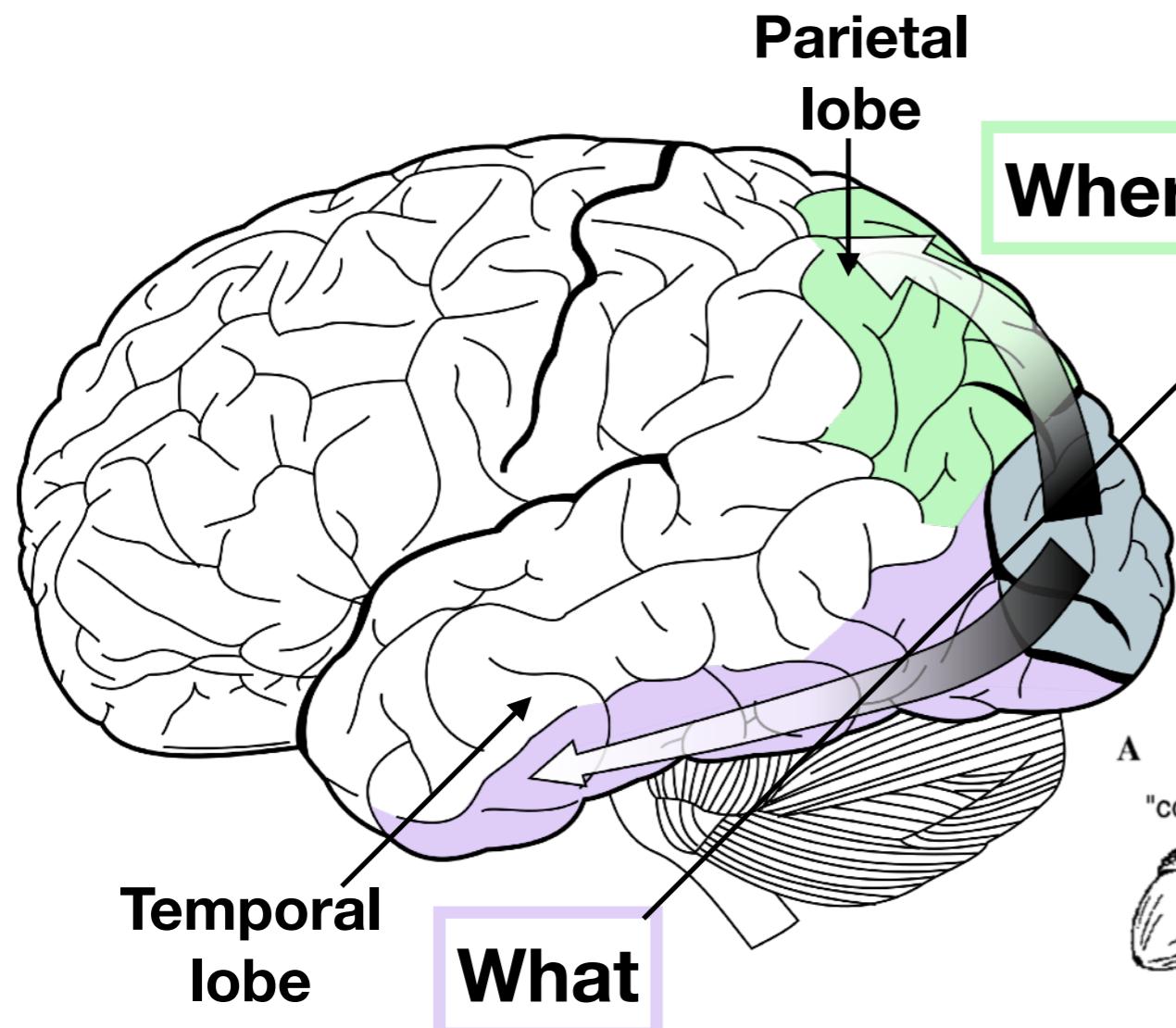


# Visual Field Processing



Note: colors do not correspond to visual tracts slide!

# Visual Field Processing

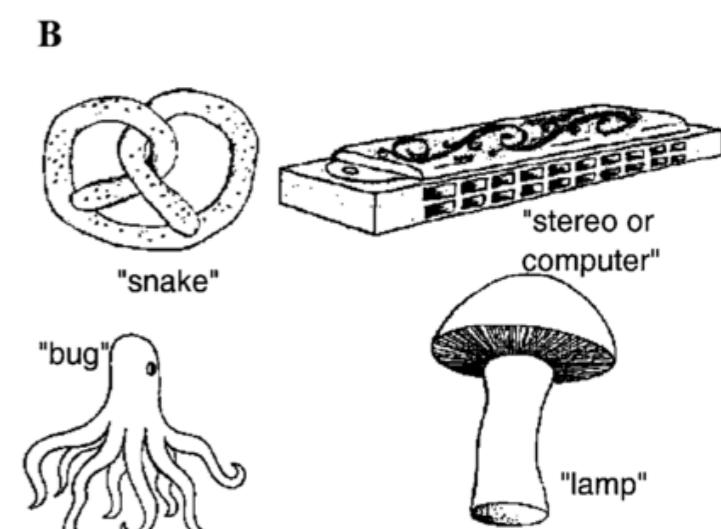
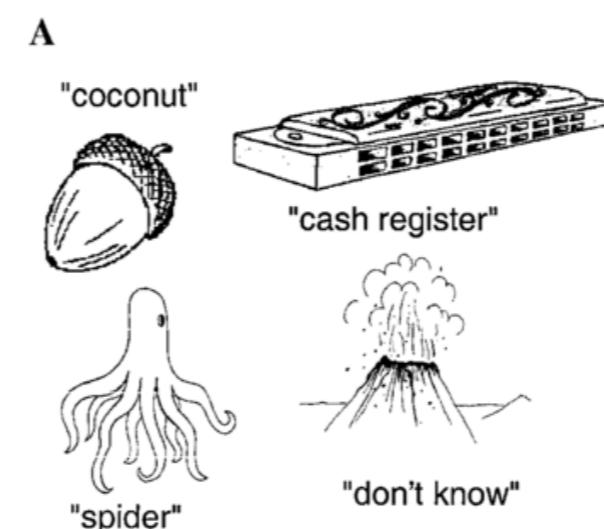


## What system

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**

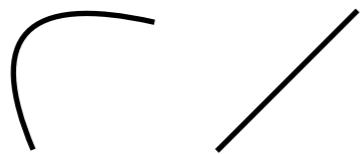
**Face  
Recognition  
is special!**



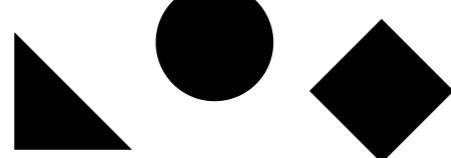
# Putting Neuroscience into Practice: Designing Visualizations

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

- curved/straight



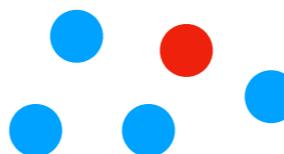
- shape



- hue intensity



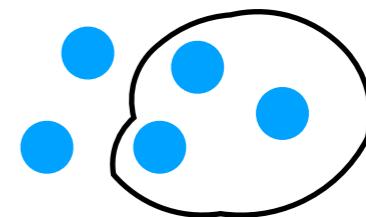
- color



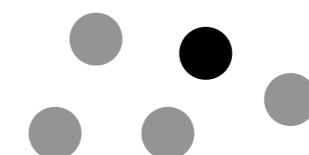
- blur



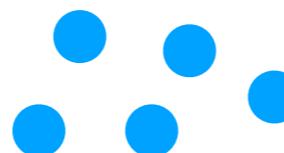
- enclosure



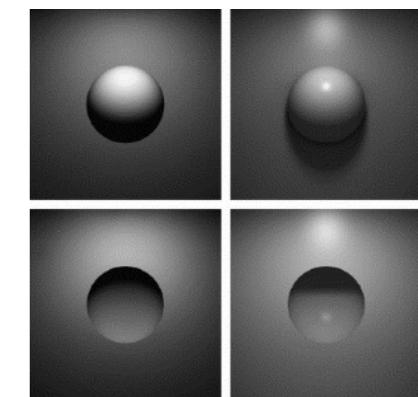
- light/dark



- motion



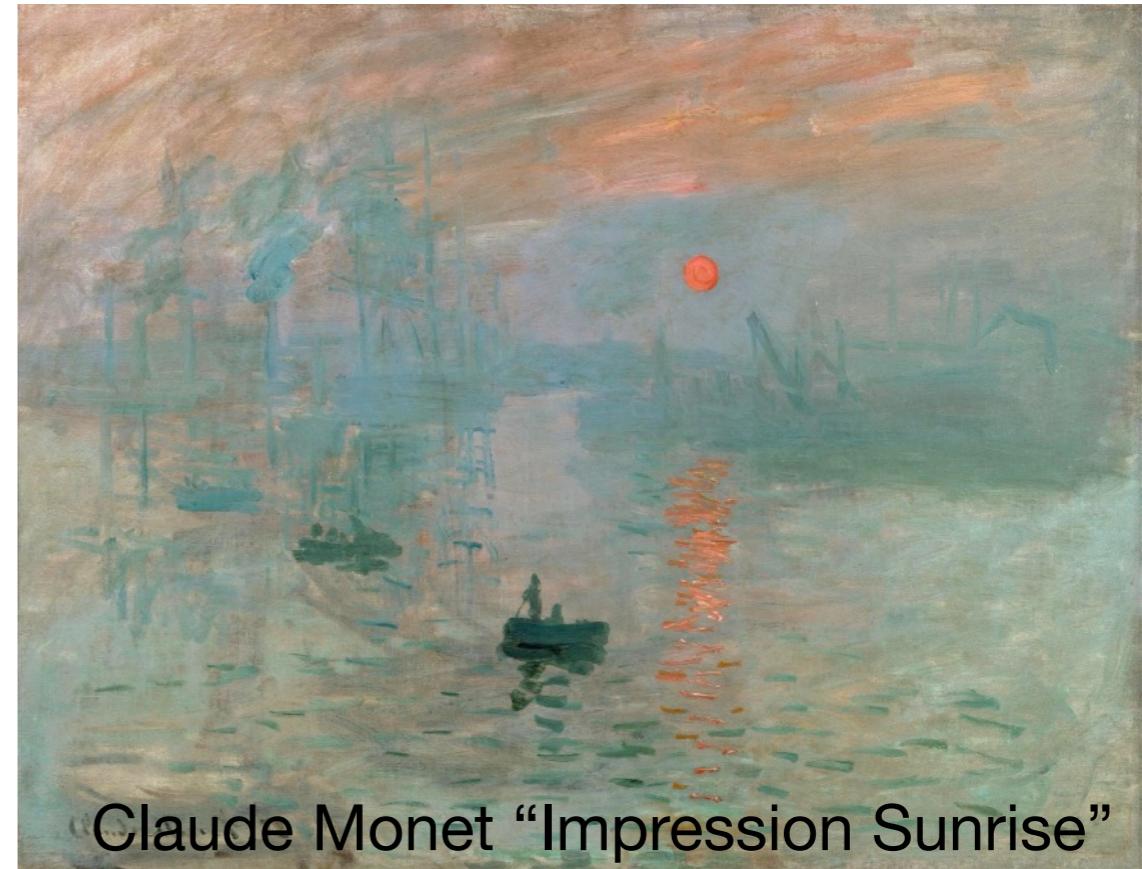
- convex/concave



**USE THESE**

# What happens when the systems get confused...

Text, lines, and other design elements should not be of equal or close luminance 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.

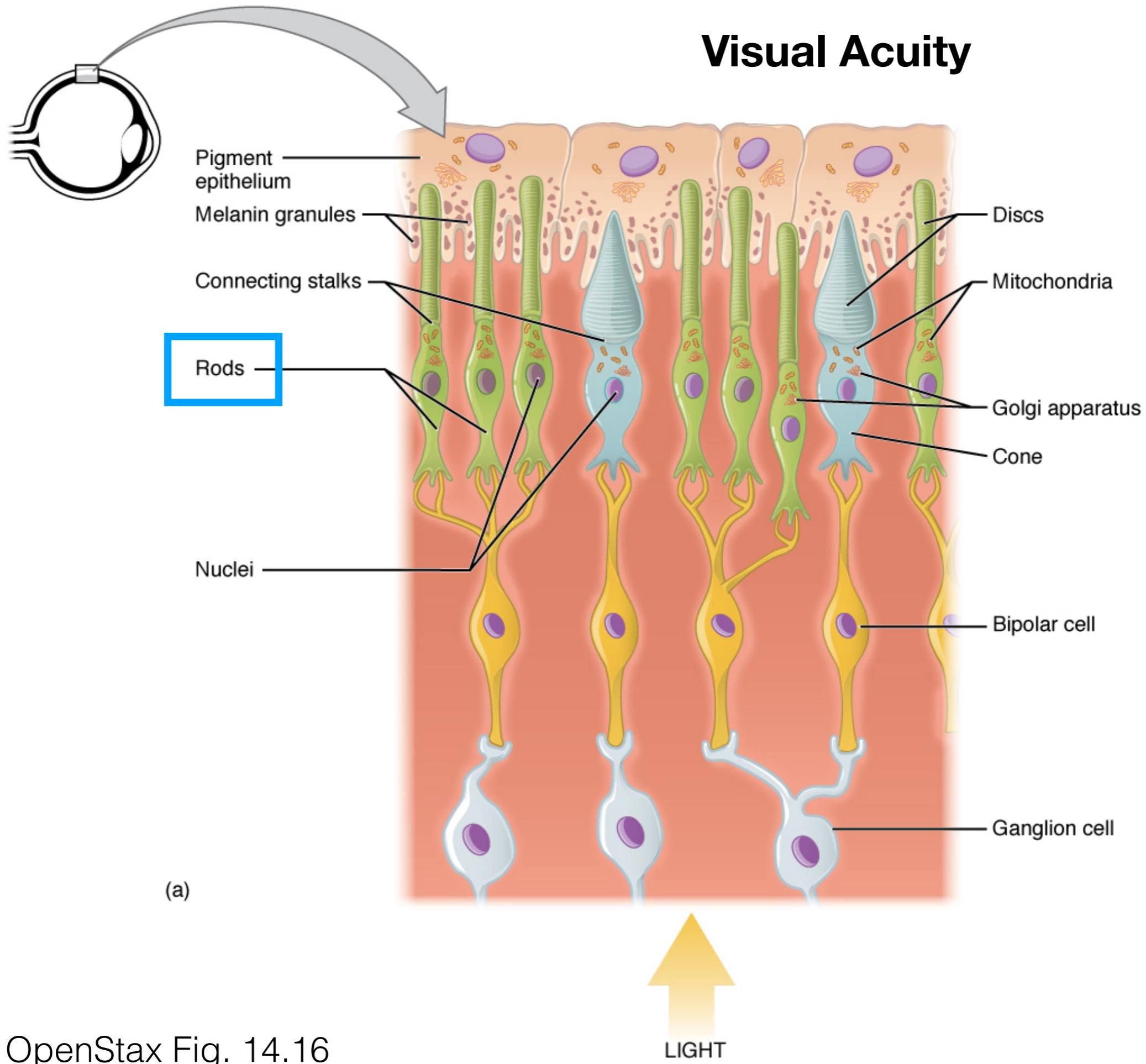


Claude Monet “Impression Sunrise”

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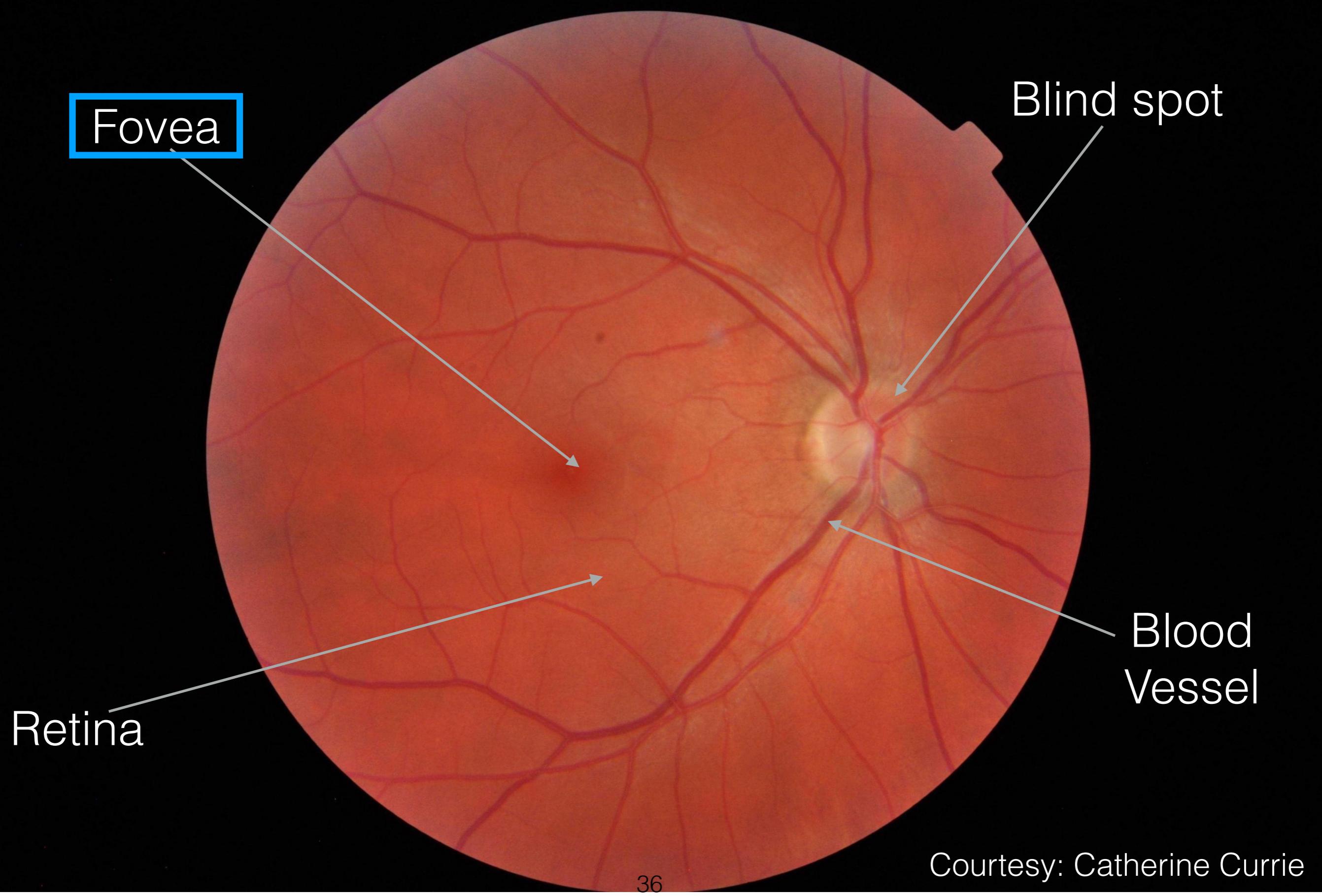


# Visual Acuity



OpenStax Fig. 14.16

# My Eyeball!

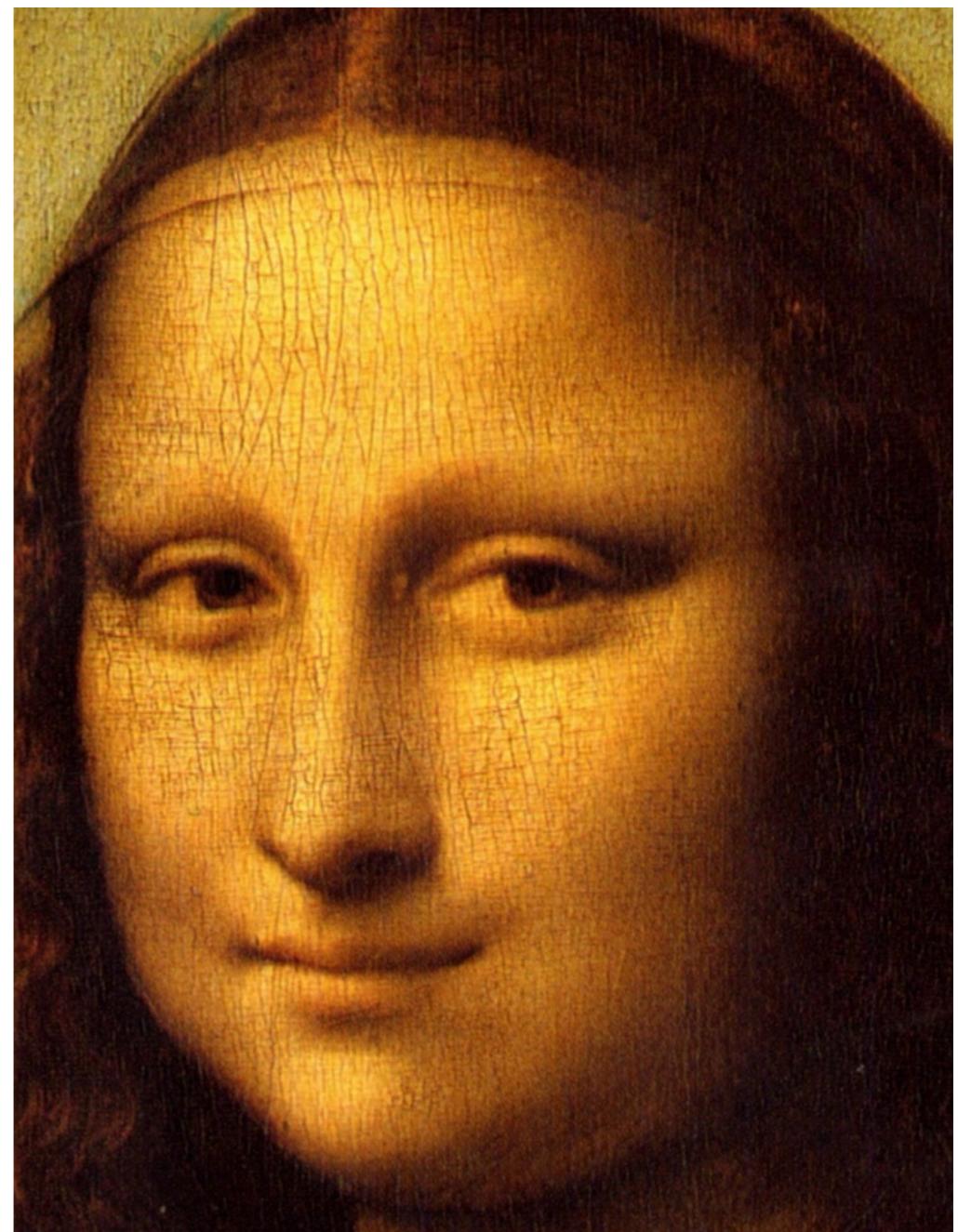
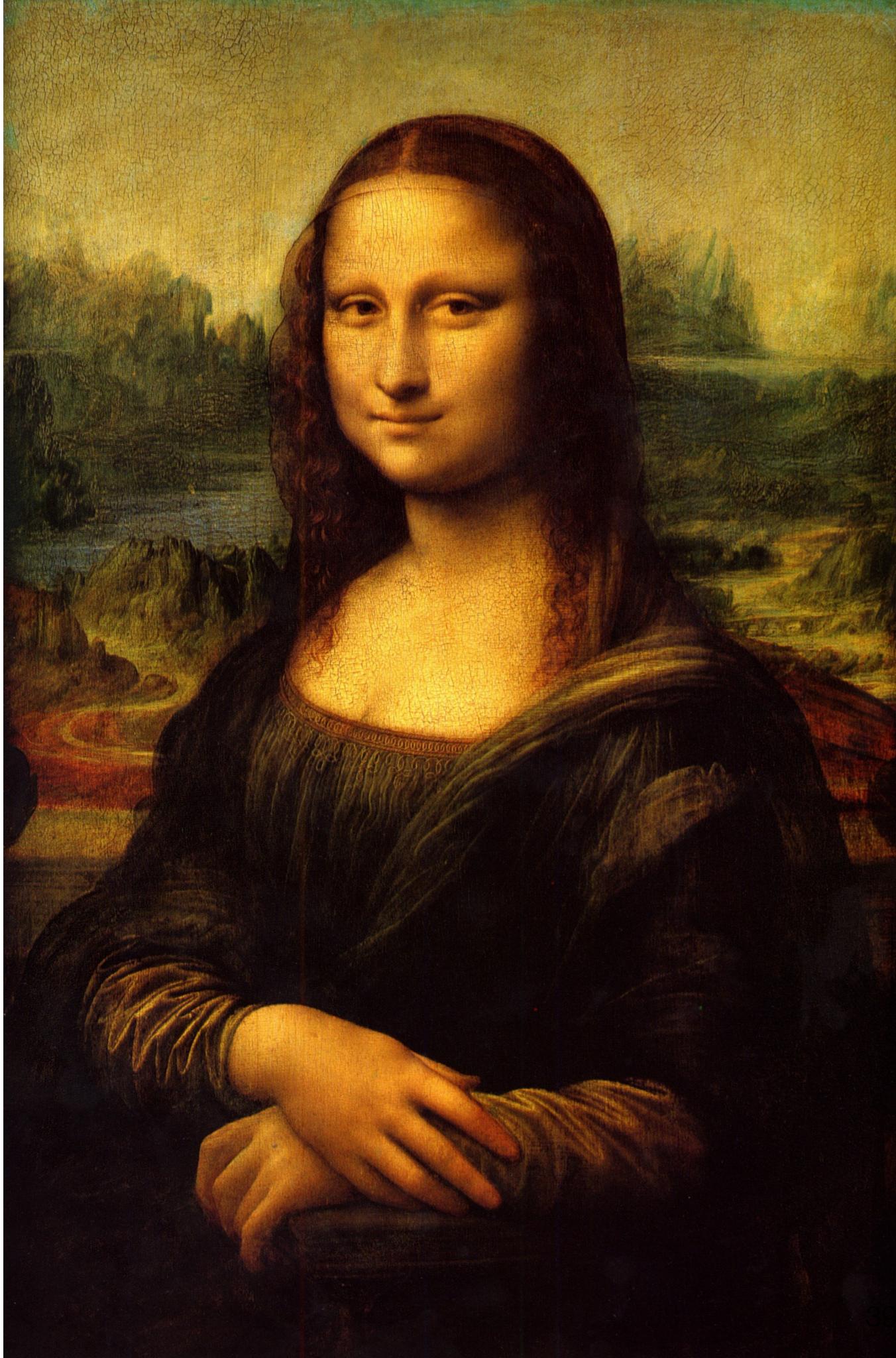


**Acuity is high centrally and drops off peripherally.**





Pointillism: Georges Seurat  
“El Sena y la Grande Jatte en primavera” 1888<sup>38</sup>



**“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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- Muir D. 2012. H. Keffer Hartline and lateral inhibition: a brief biography of an influential idea. 30th Oct. [dylan-muir.com](http://dylan-muir.com).
- Wyttenbach RA. 2012. Exploring sensory neuroscience through experience and experiment. *J Under Neuro Ed* 11(1): A126-A131.