Lecture 2.6 – 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.

3.6.4 Understand how acuity is focused centrally in vision and drops off as you move into the periphery.

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

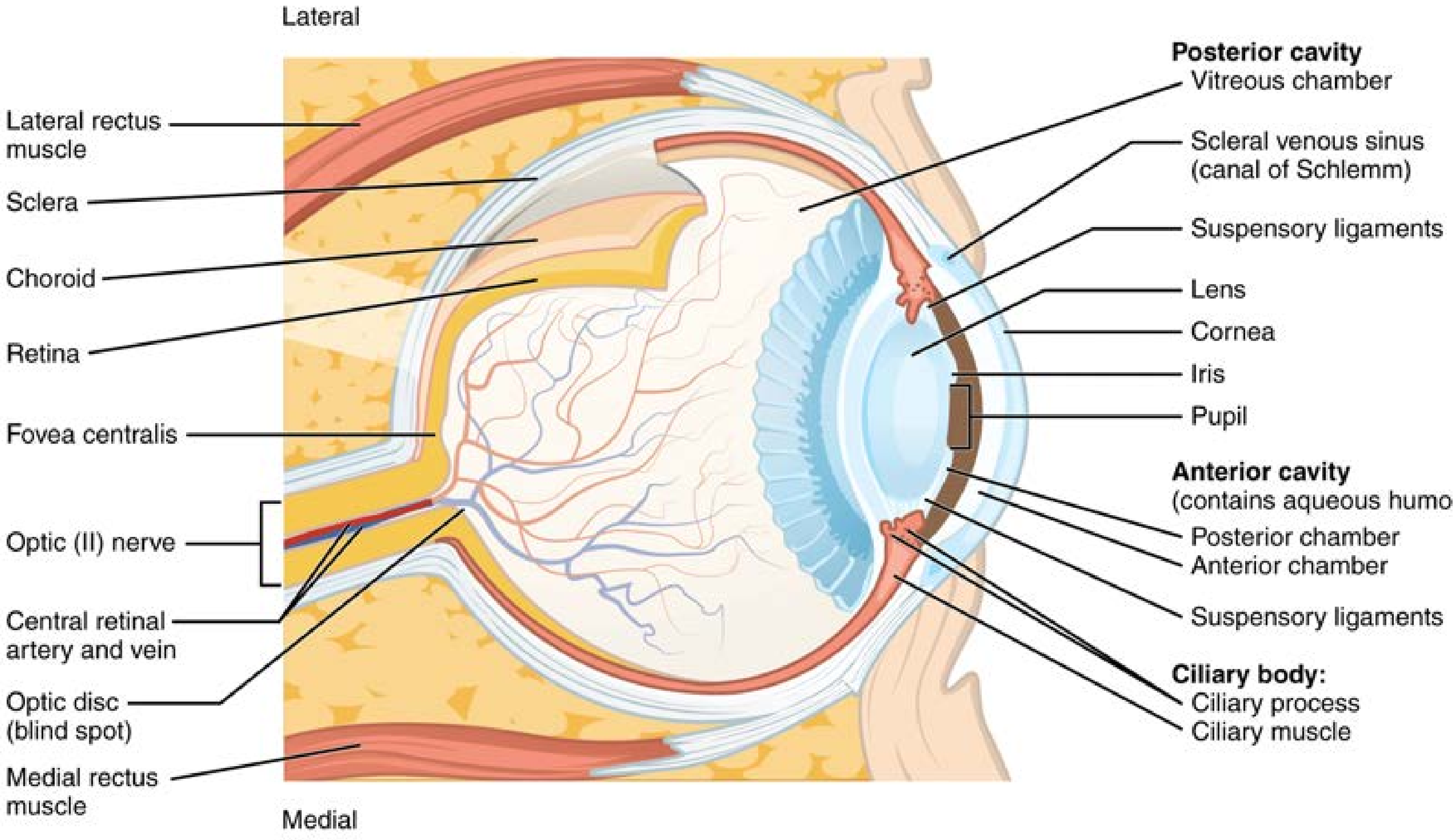
How We See

1. Our visual systems are built primarily on contrast.

2. We see based on visual processing, not image transmission.

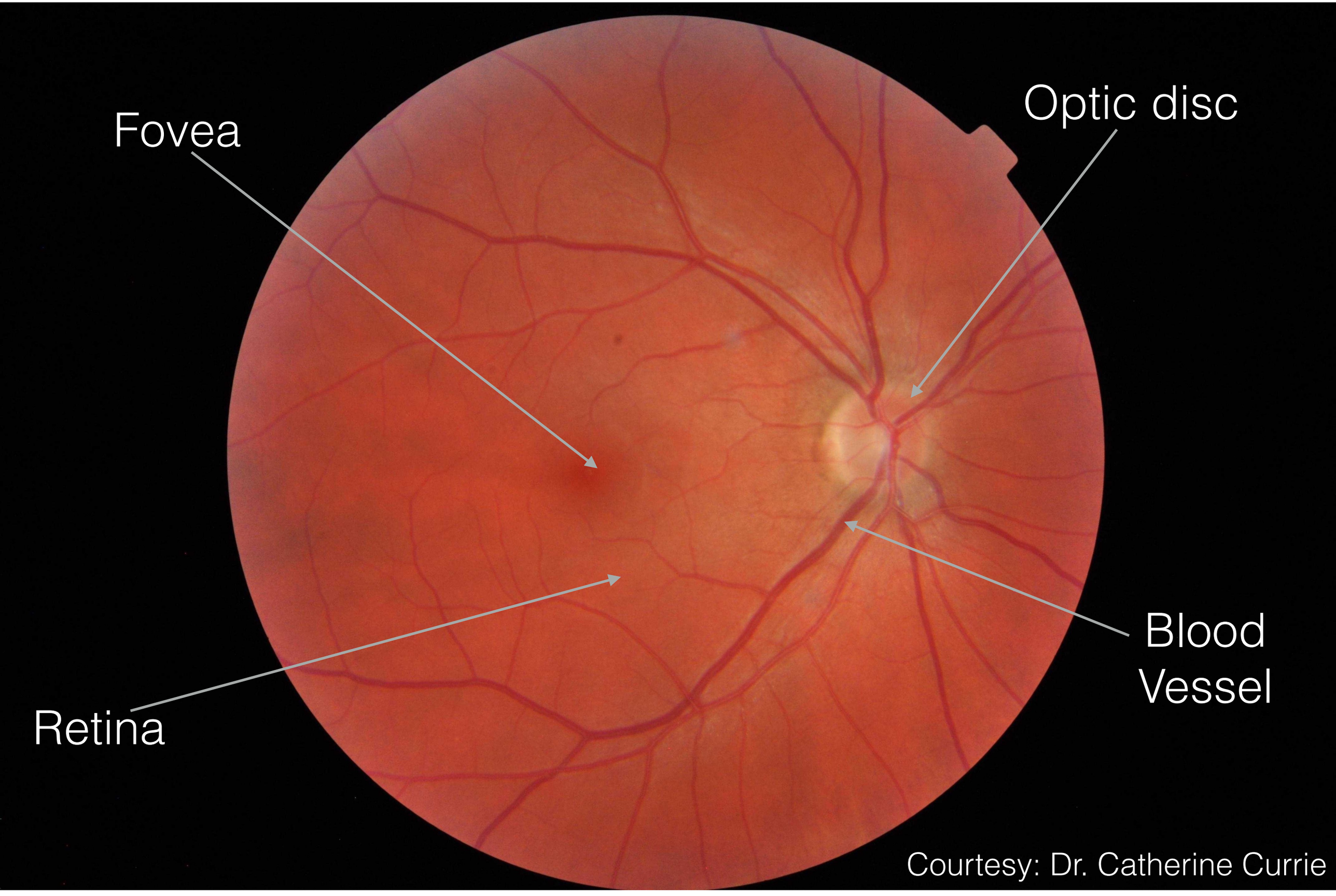
3. Acuity is high centrally and low peripherally.

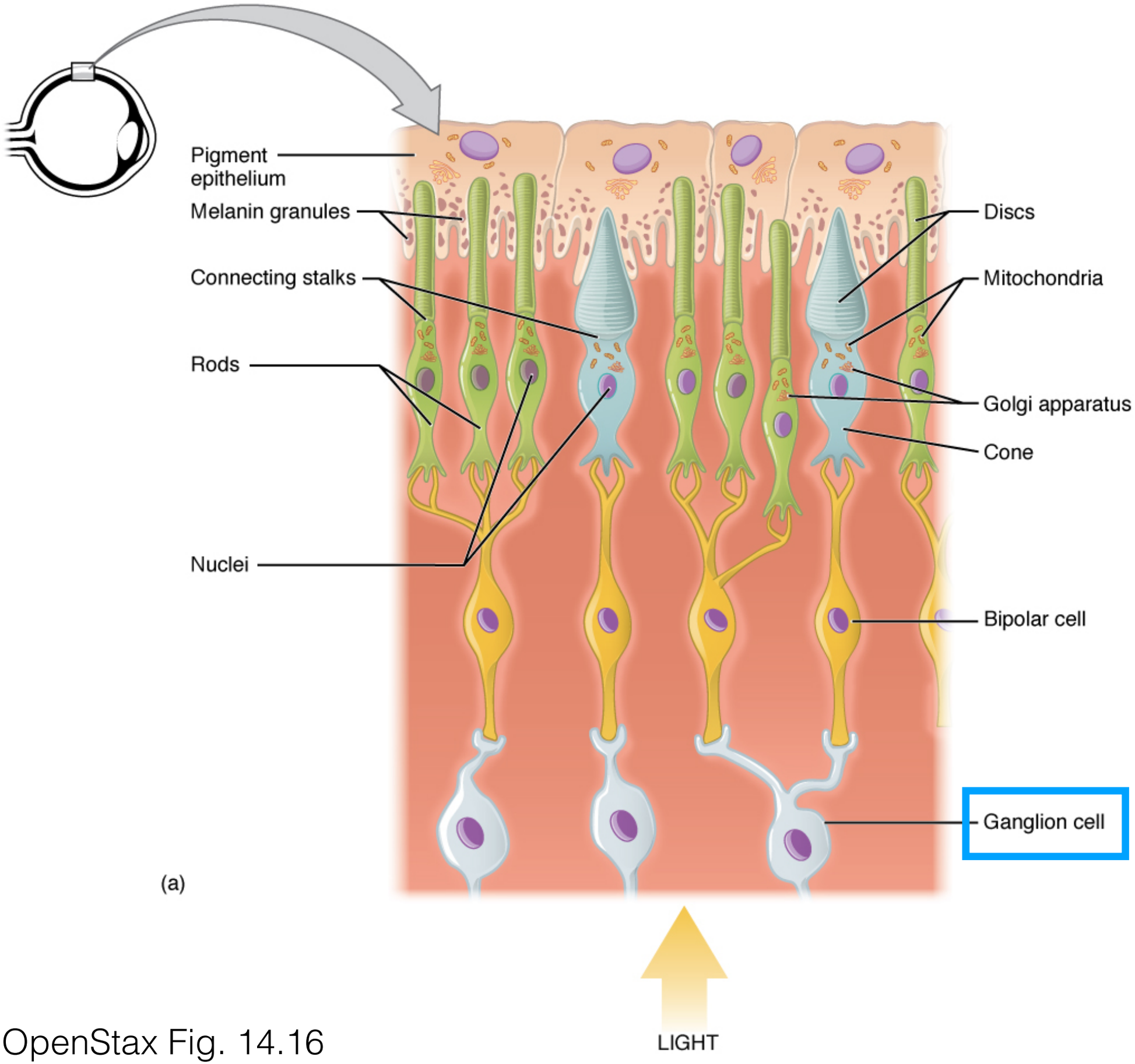
Anatomy of the Eye



OpenStax Fig. 14.13

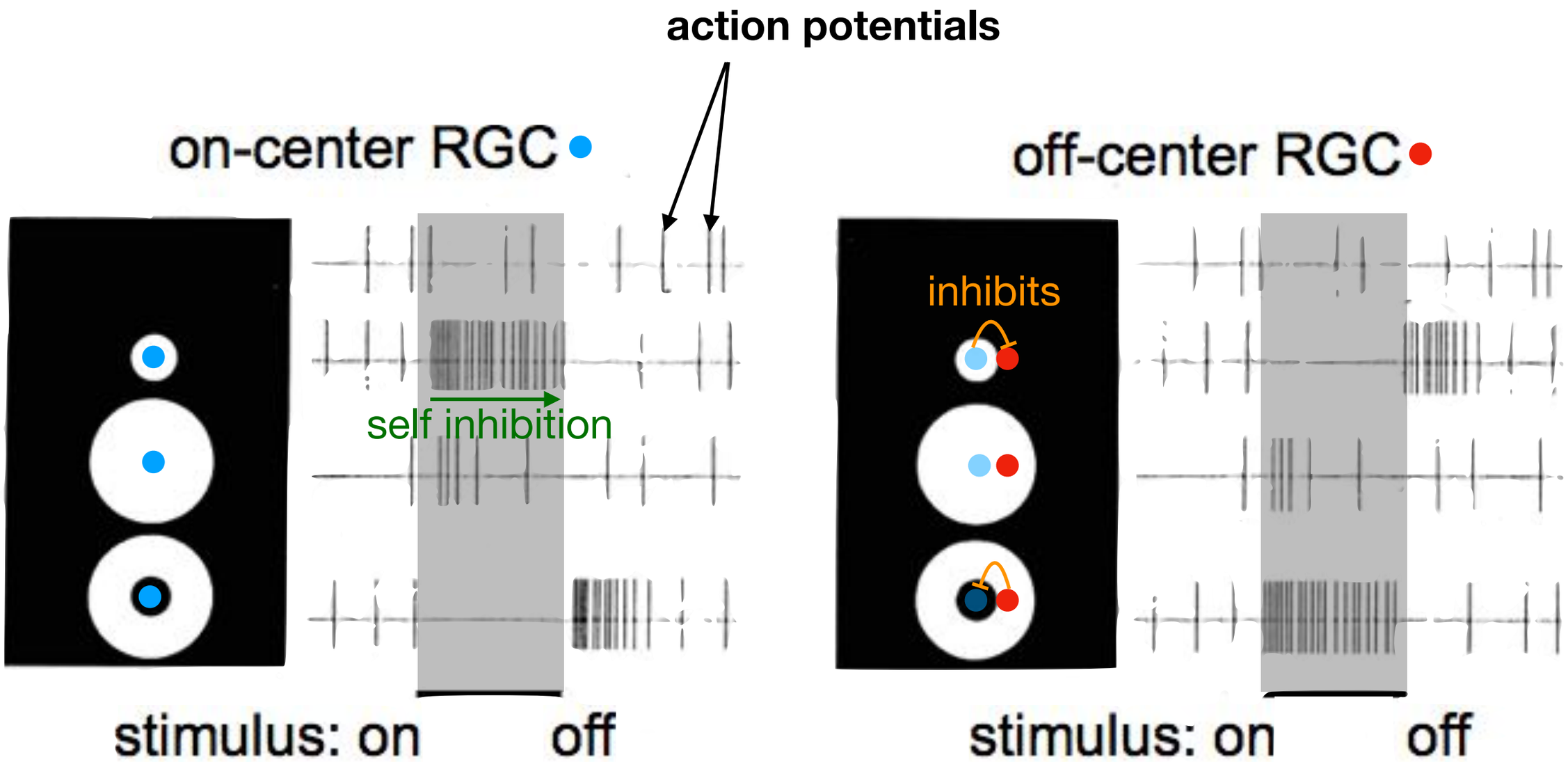
My Eyeball!


Fovea
Optic disc
Retina
Blood Vessel
Courtesy: Dr. Catherine Currie



OpenStax Fig. 14.16

How Contrast Works



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

Kuffler 1953

How Contrast Works

- Self-inhibition causes Mach banding

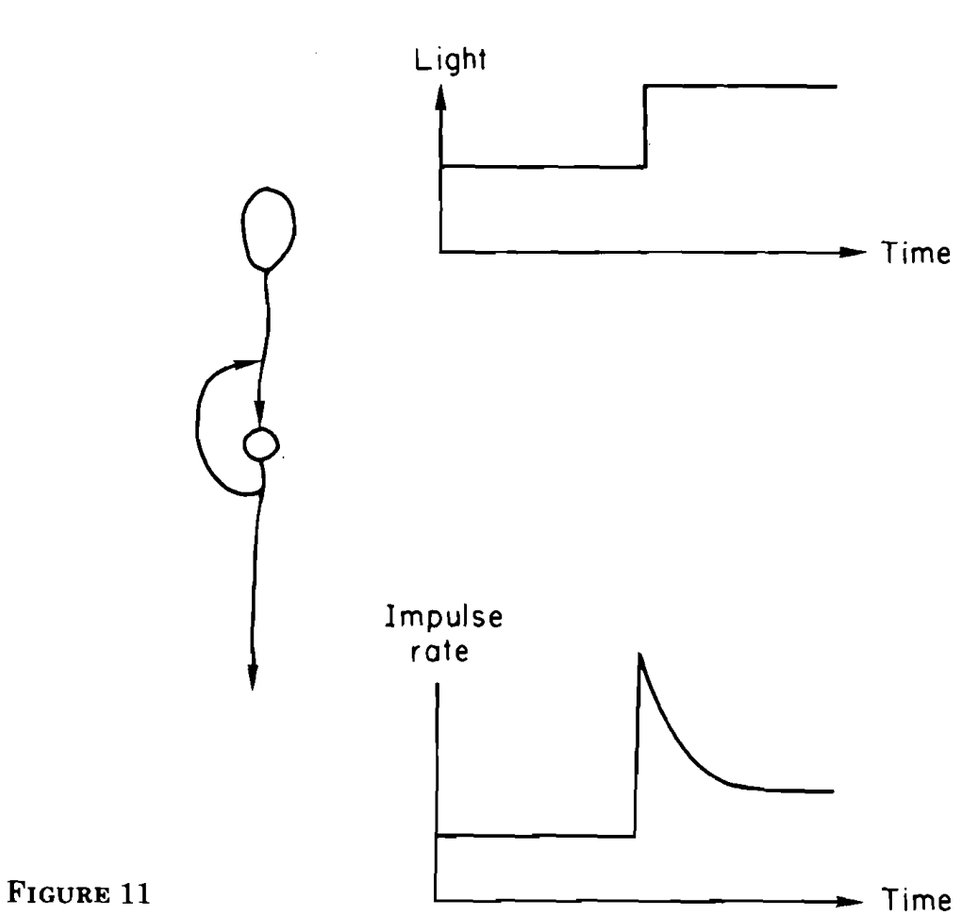
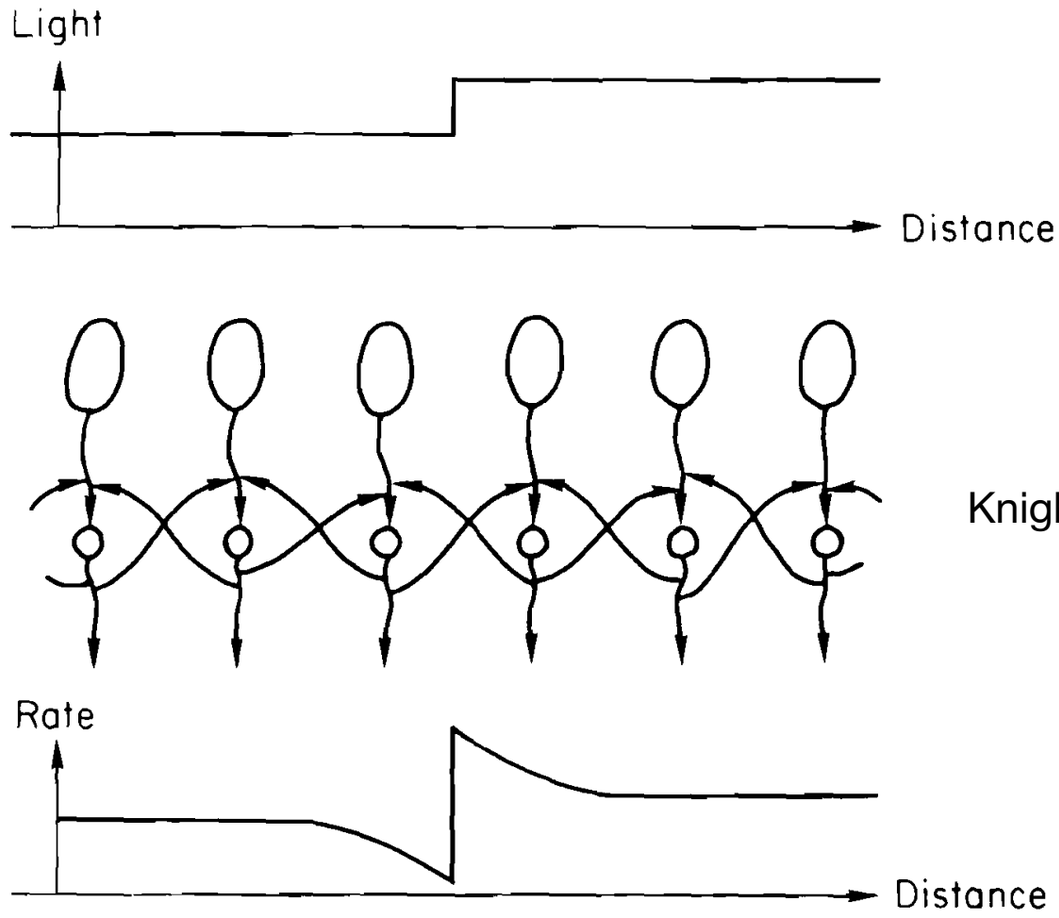
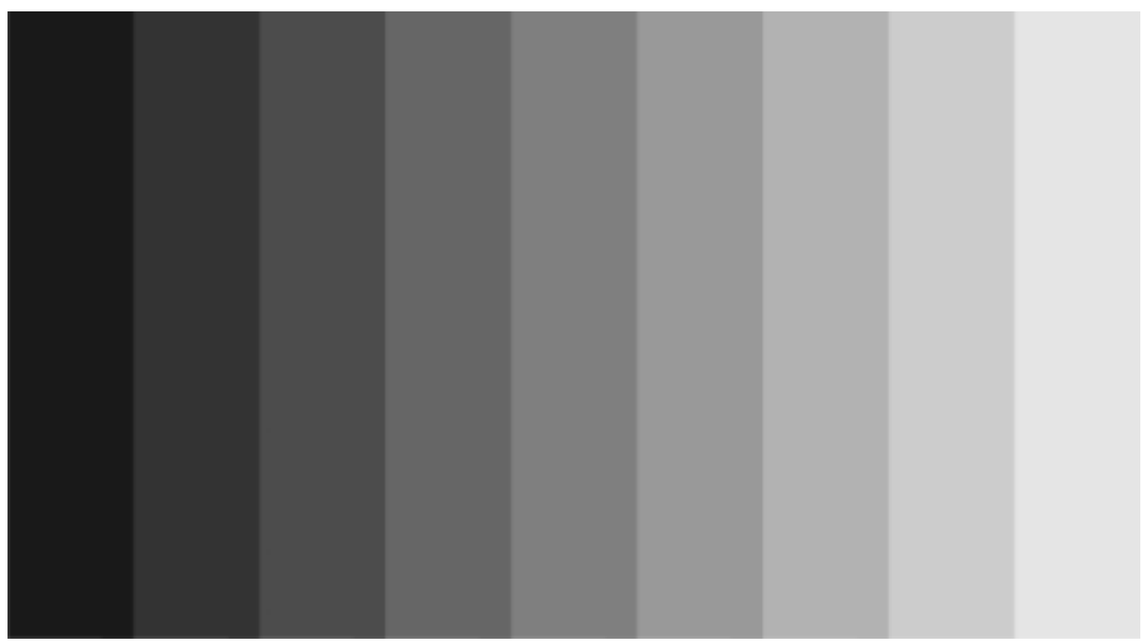


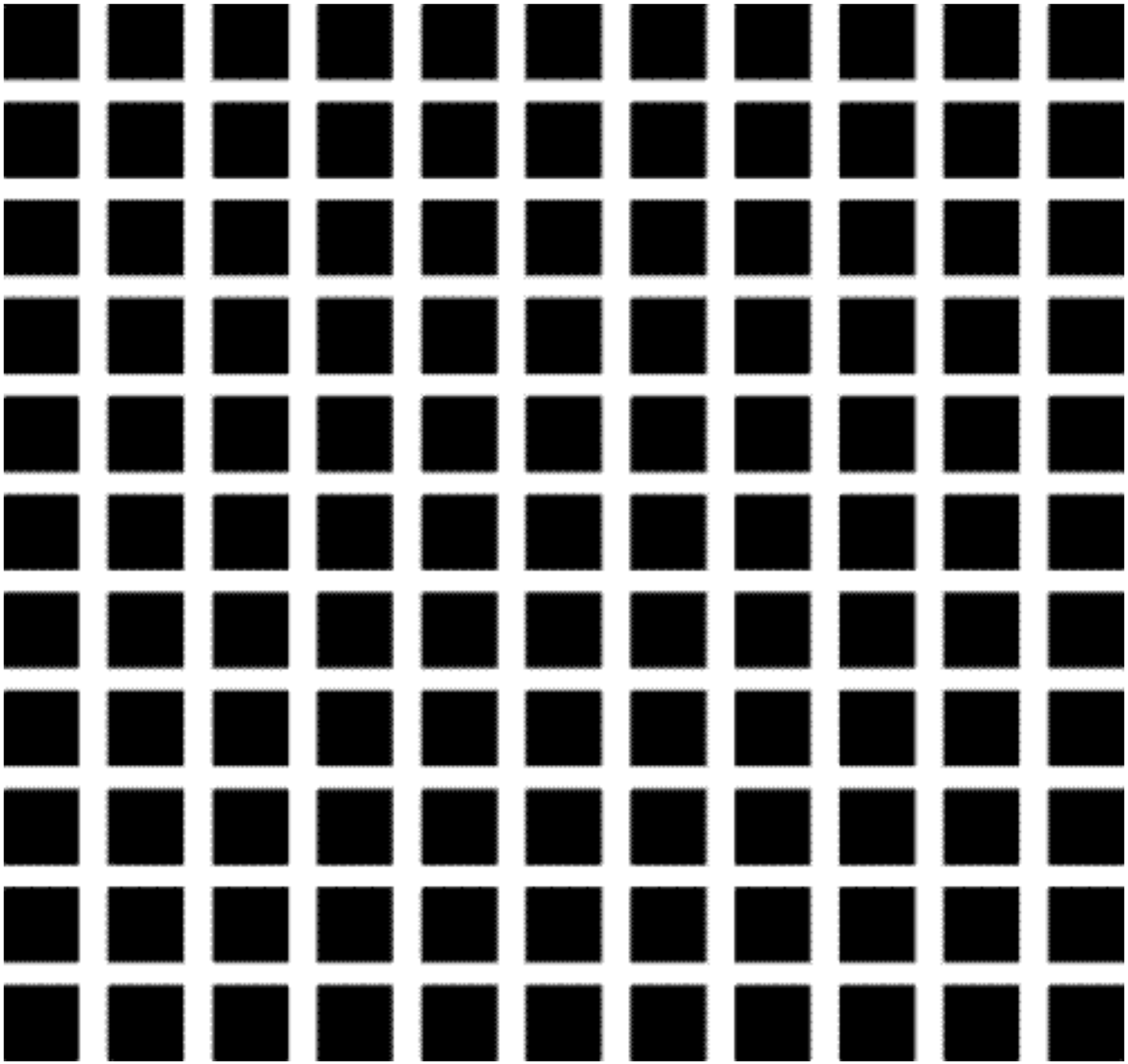
FIGURE 11



Knight 1975

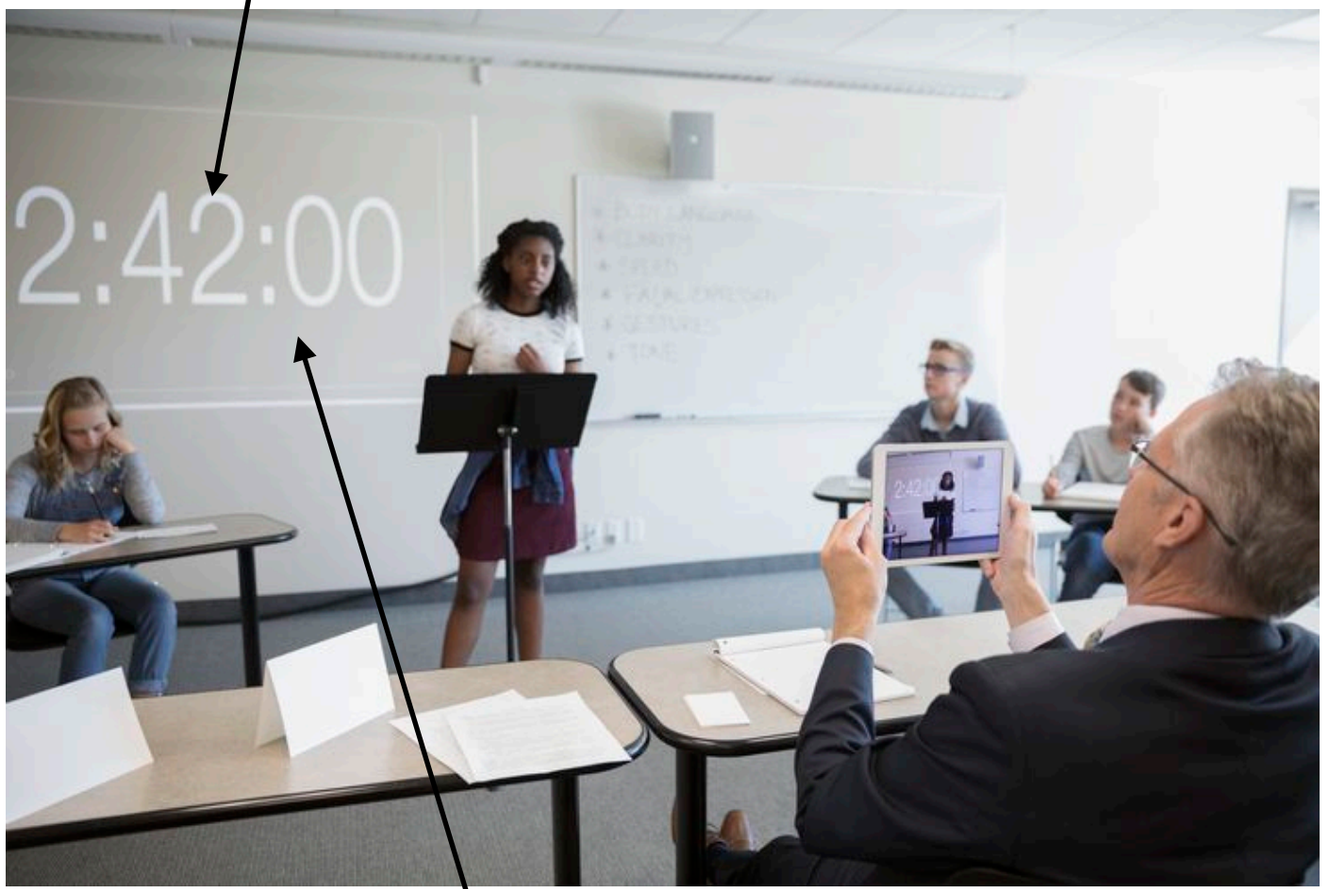
Chevreul Illusion or "Mach banding"



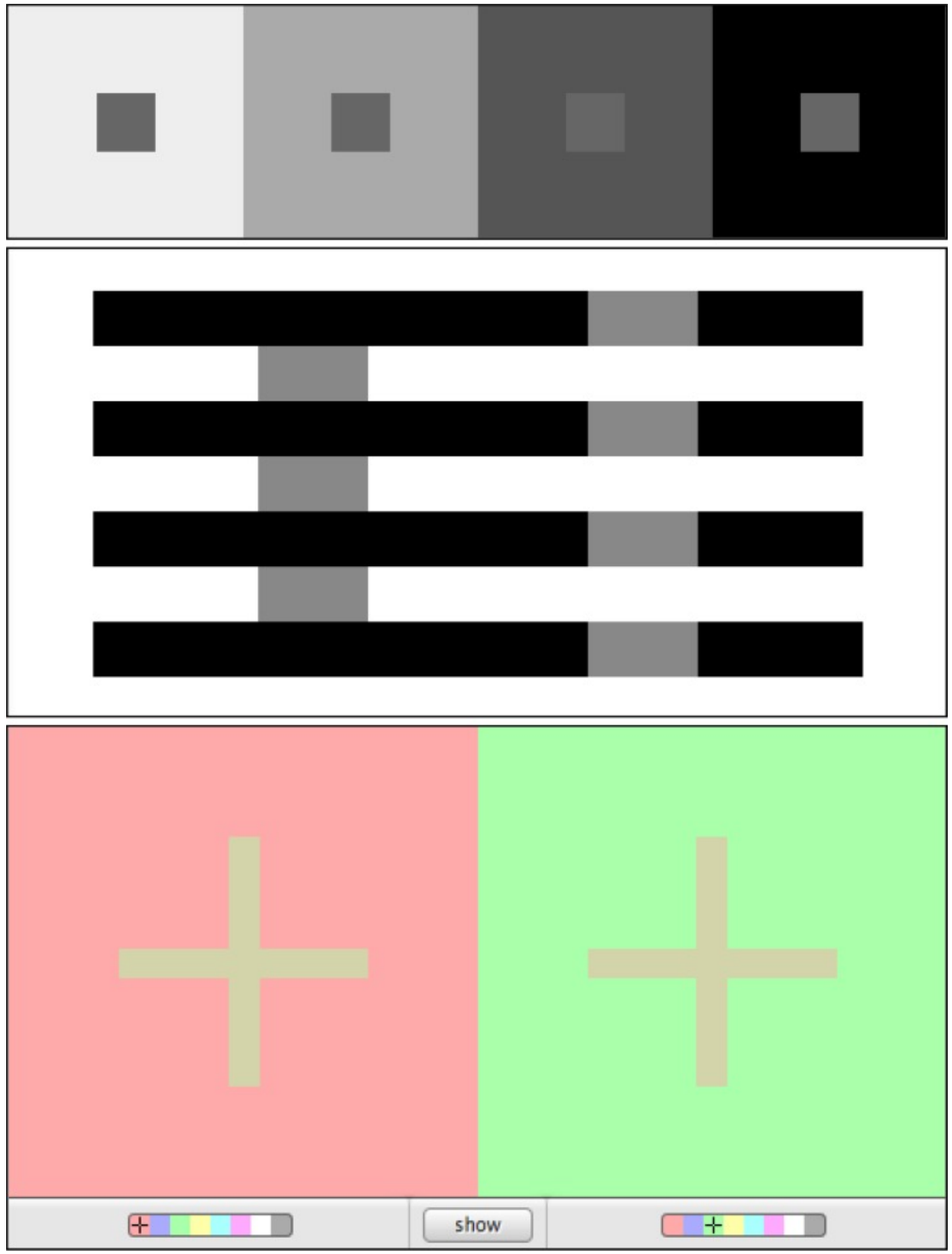


We only see contrast: everything is relative

This is white



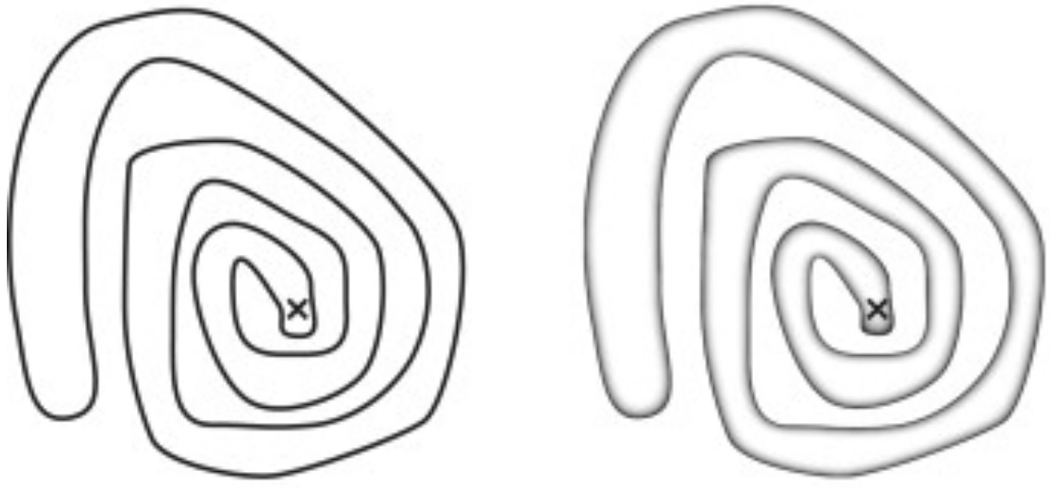
This is also white



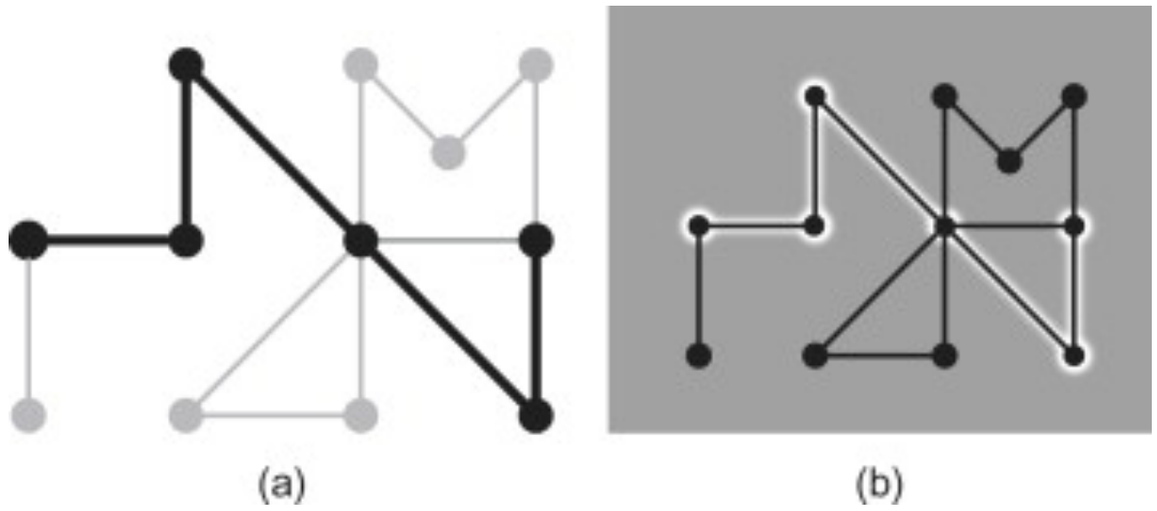
Wyttenbach 2012 J Under Neuro Ed

Contrast can improve understanding or be misleading

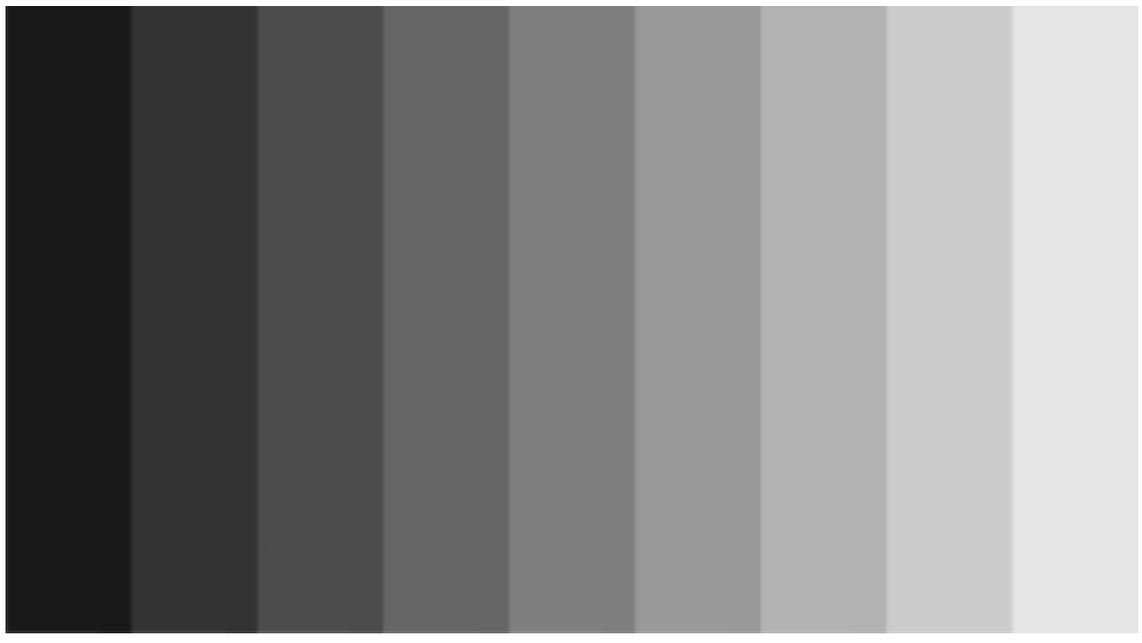
Cornsweet contours help identify shapes



Improving background contrast improves readability

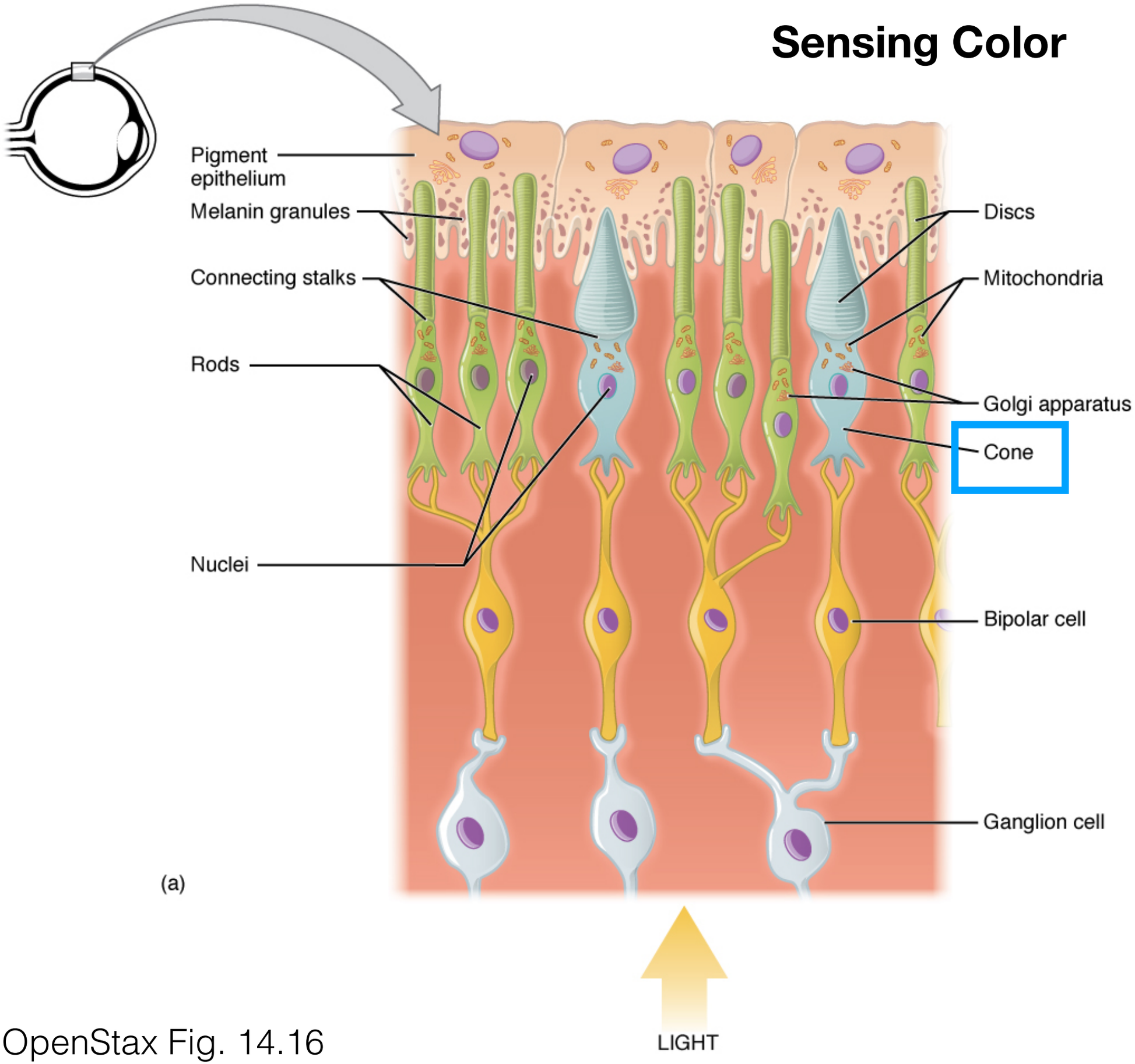


Chevreul Illusion or “Mach banding”



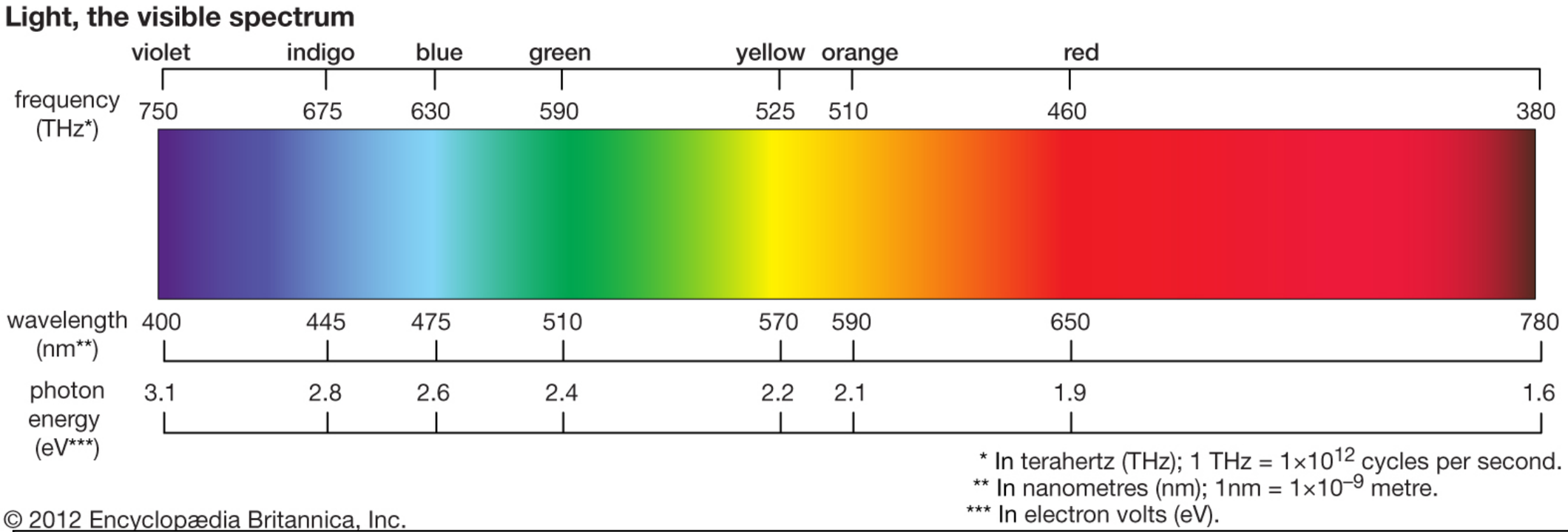
Can mislead viewers of color scales!

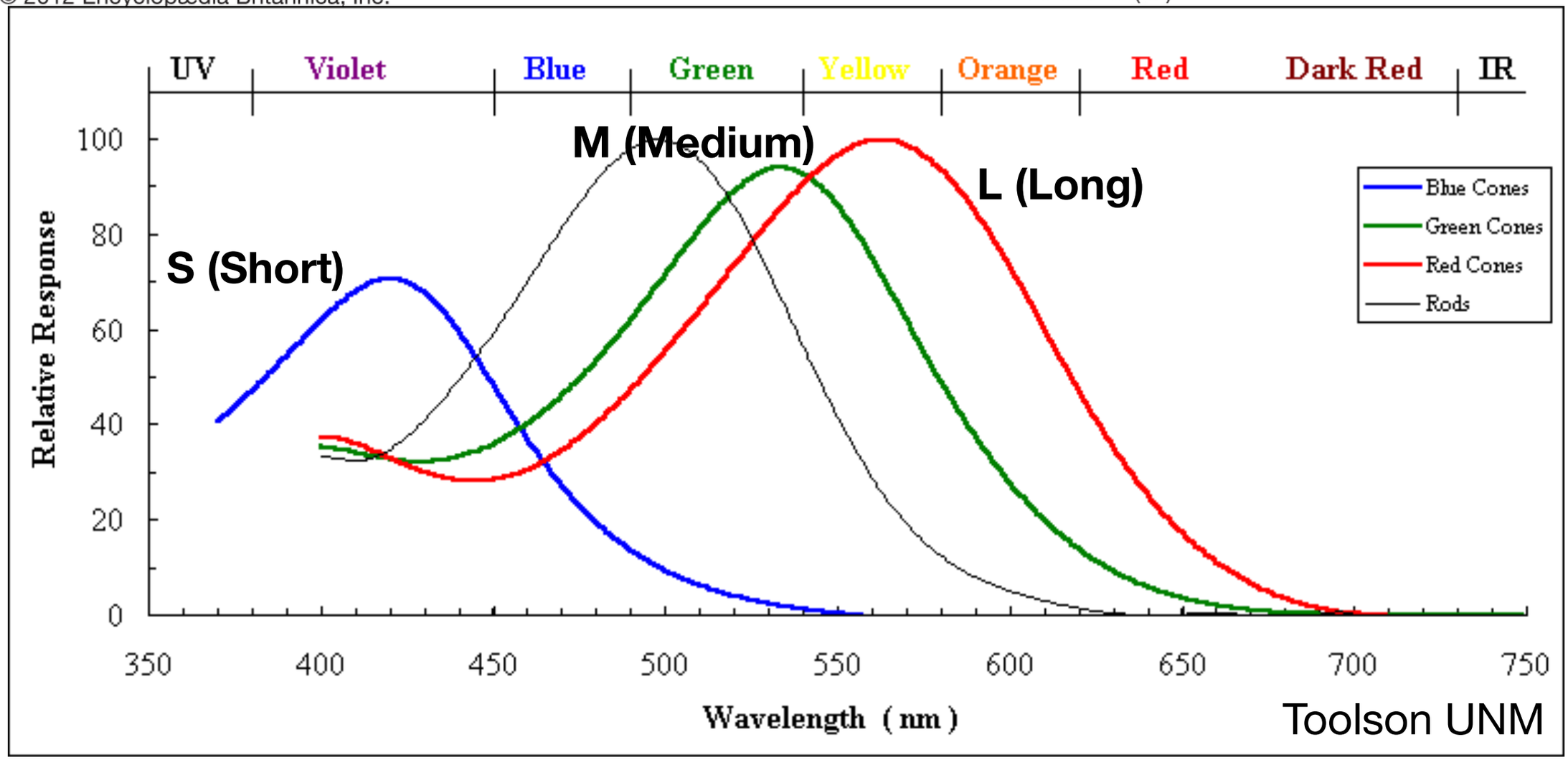
Sensing Color



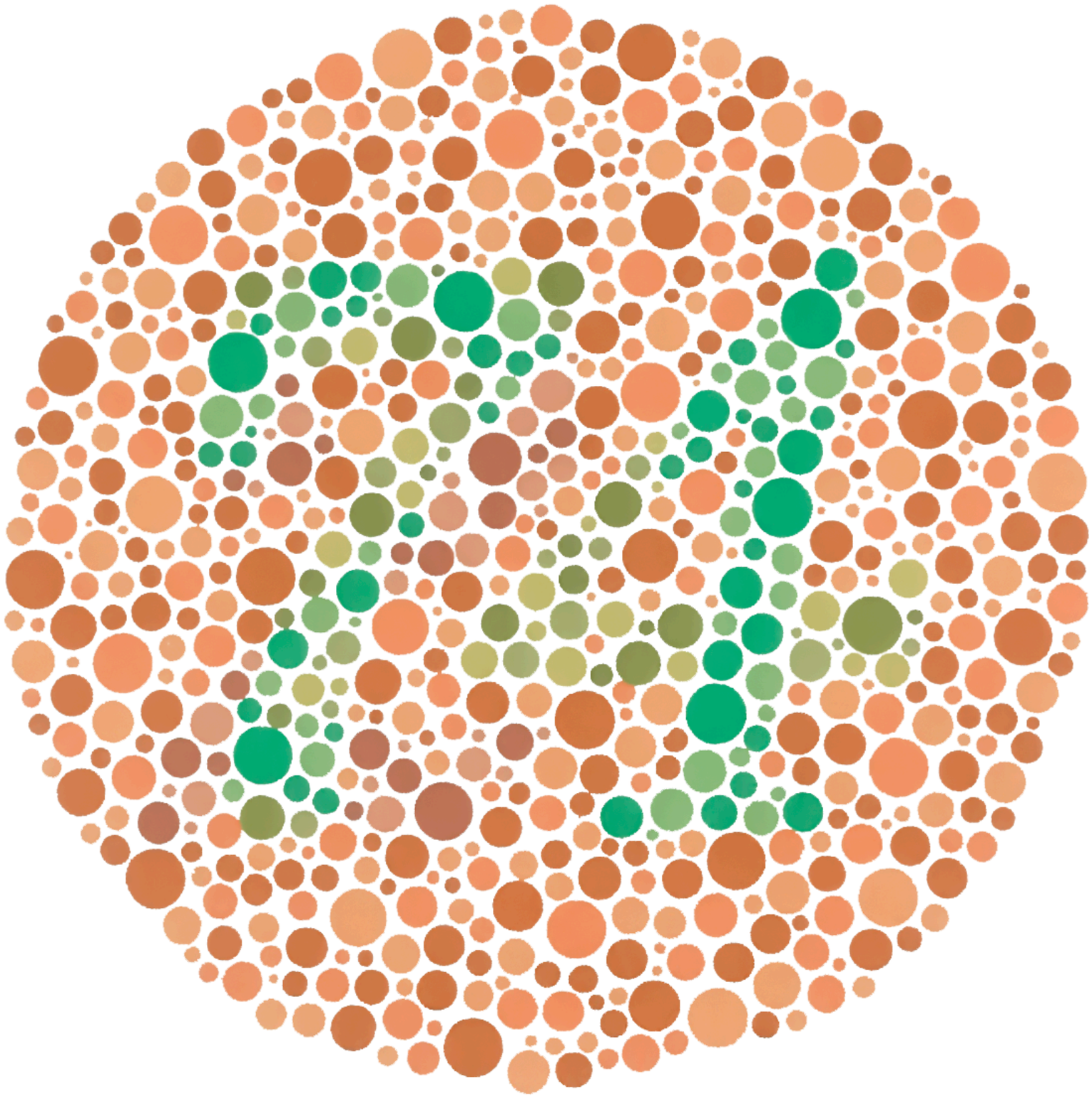
OpenStax Fig. 14.16

Cone types


Light, the visible spectrum
violet
indigo
blue
green
yellow
orange
red
frequency (THz*)
750
675
630
590
525
510
460
380
wavelength (nm**)
400
445
475
510
570
590
650
780
photon energy (eV***)
3.1
2.8
2.6
2.4
2.2
2.1
1.9
1.6
* In terahertz (THz); 1 THz = 1×10^12 cycles per second.
** In nanometres (nm); 1nm = 1×10^−9 metre.
*** In electron volts (eV).
© 2012 Encyclopædia Britannica, Inc.

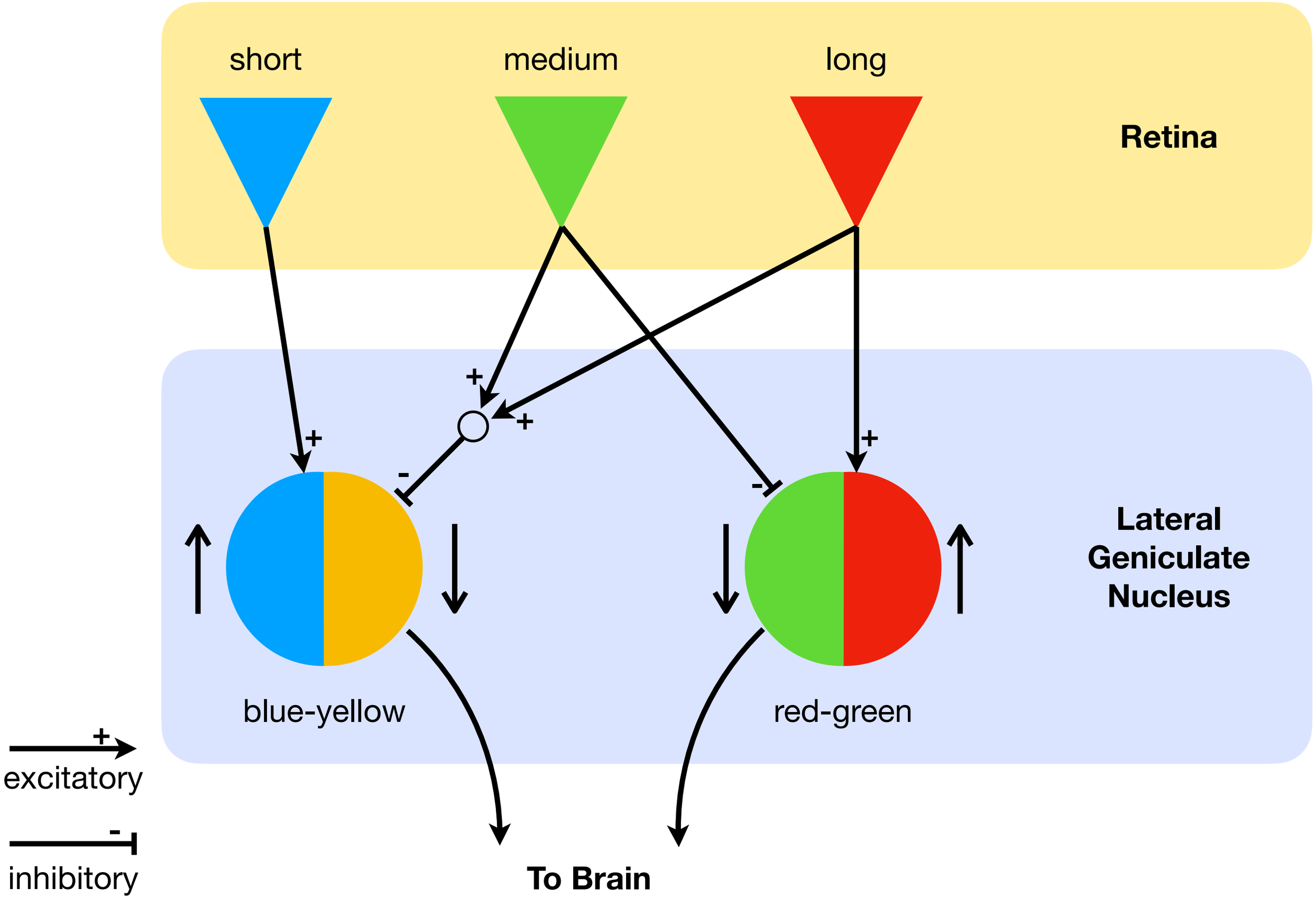

UV
Violet
Blue
Green
Yellow
Orange
Red
Dark Red
IR
M (Medium)
L (Long)
S (Short)
Blue Cones
Green Cones
Red Cones
Rods
Relative Response
100
80
60
40
20
0
350
400
450
500
550
600
650
700
750
Wavelength (nm)
Toolson UNM

Ishihara Plate 9 (Colorblindness Test)



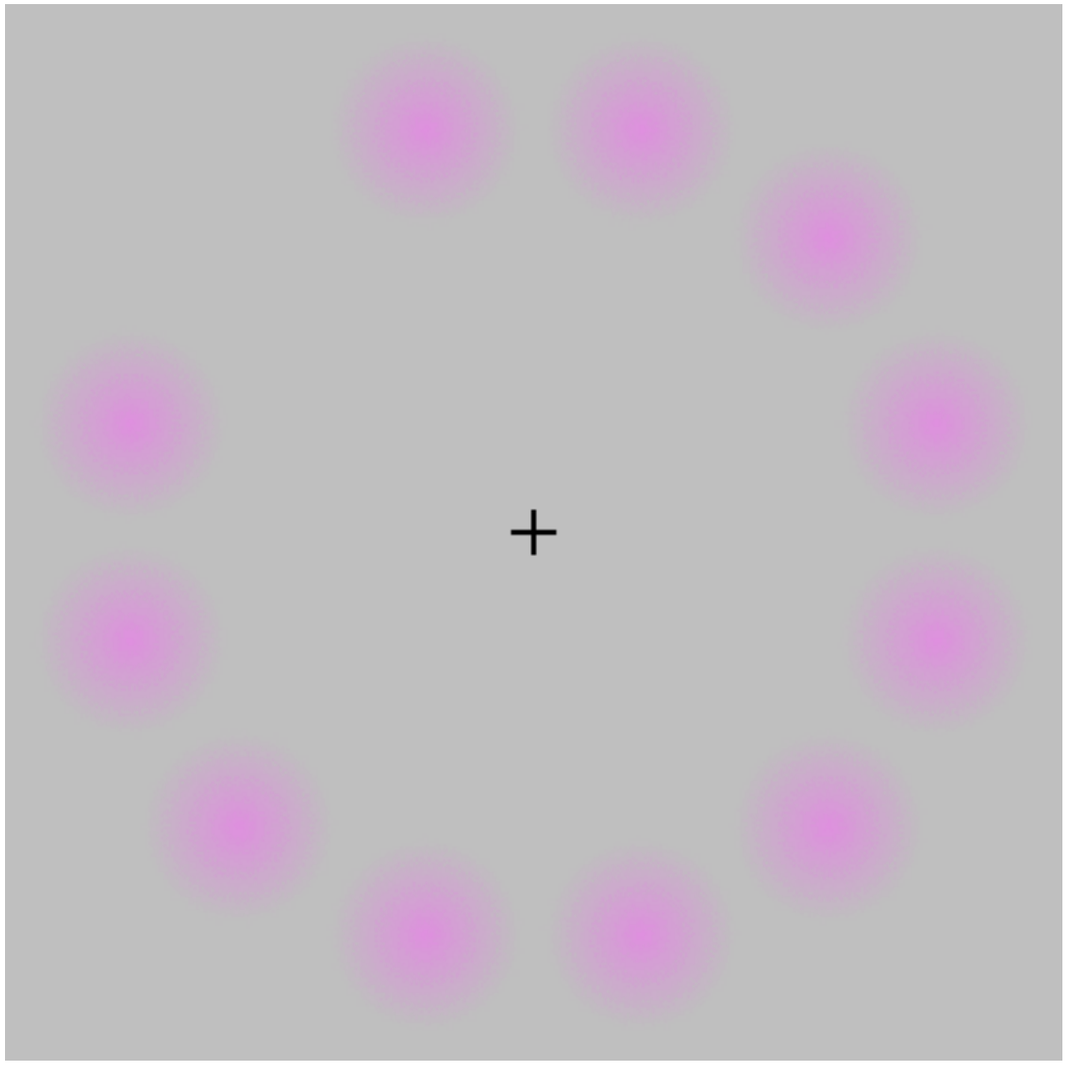
Colorblindness simulator: https://www.color-blindness.com/coblis-color-blindness-simulator/

Opponent-Process Theory of Color (Chromatic)

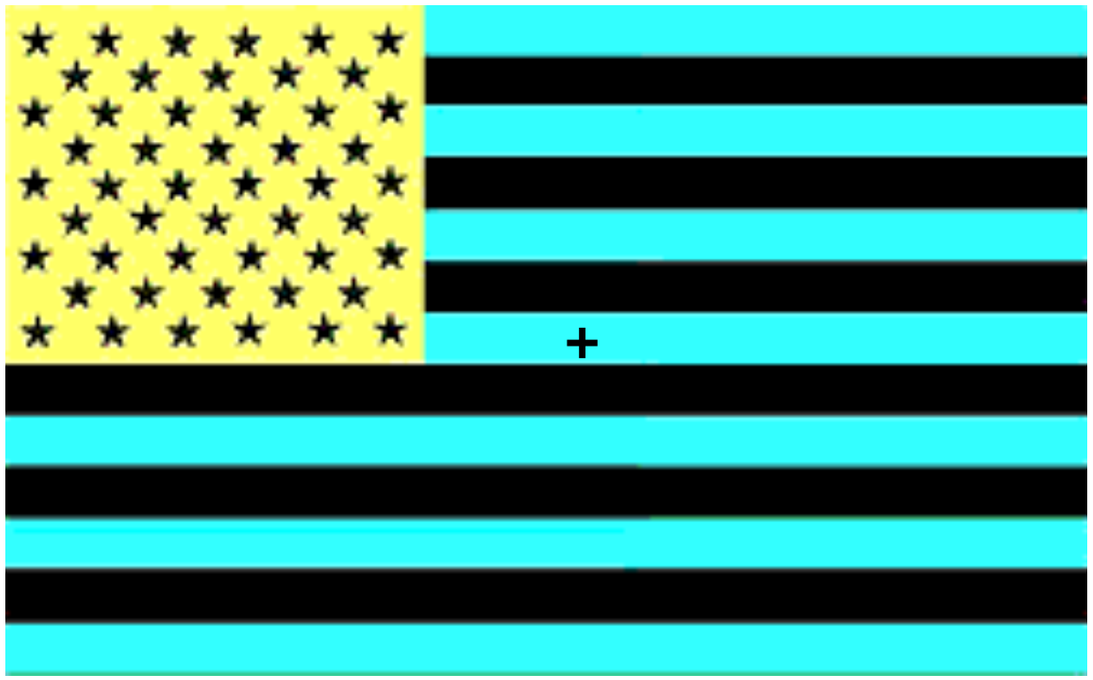


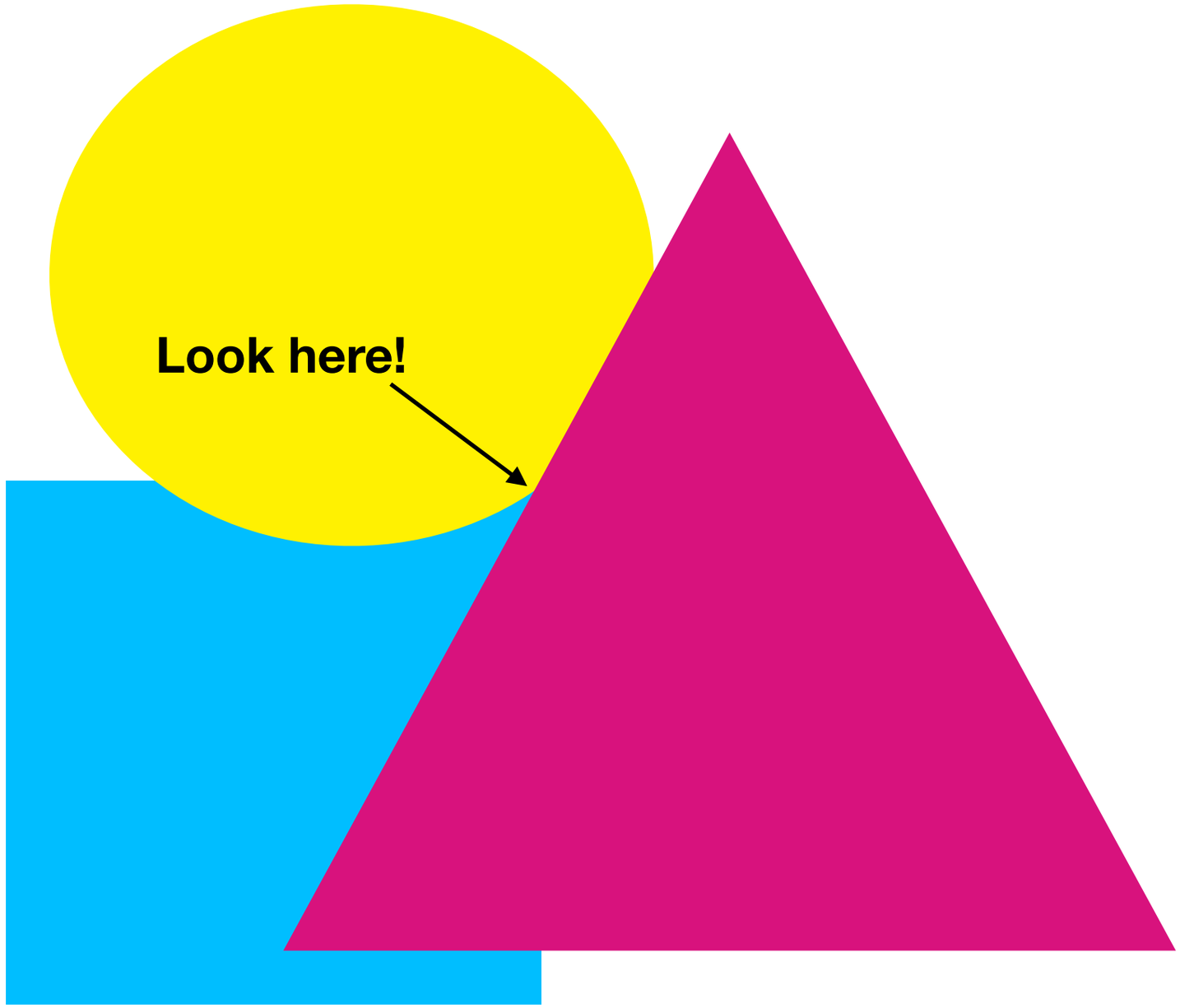
Complementary Color illusions

“Lilac Chaser”

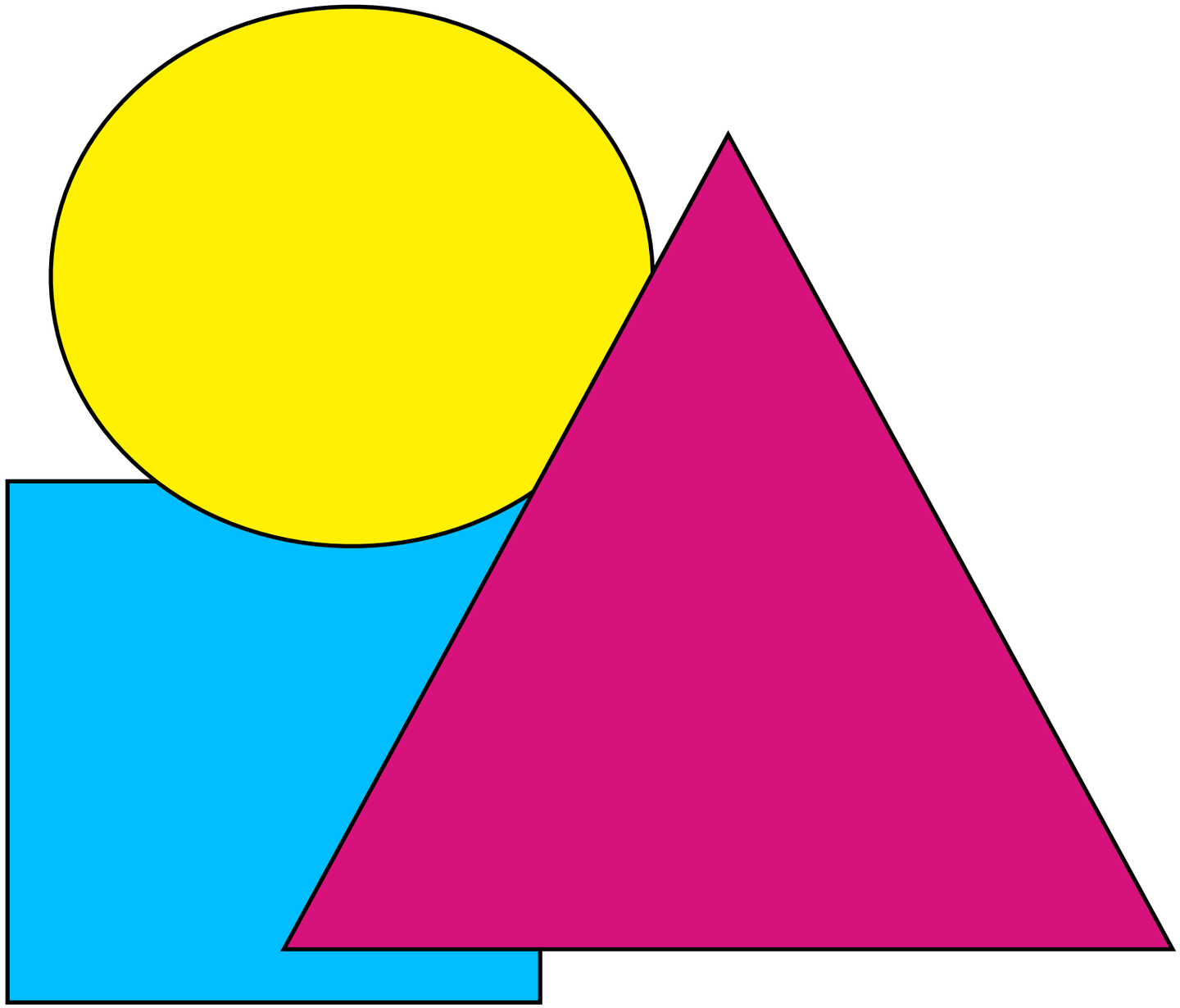


https://en.wikipedia.org/wiki/Visual_adaptation





Livingstone 2014 reproduction



Livingstone 2014 reproduction

We only see contrast

“The Dress”

Be careful of equal luminance in hues!

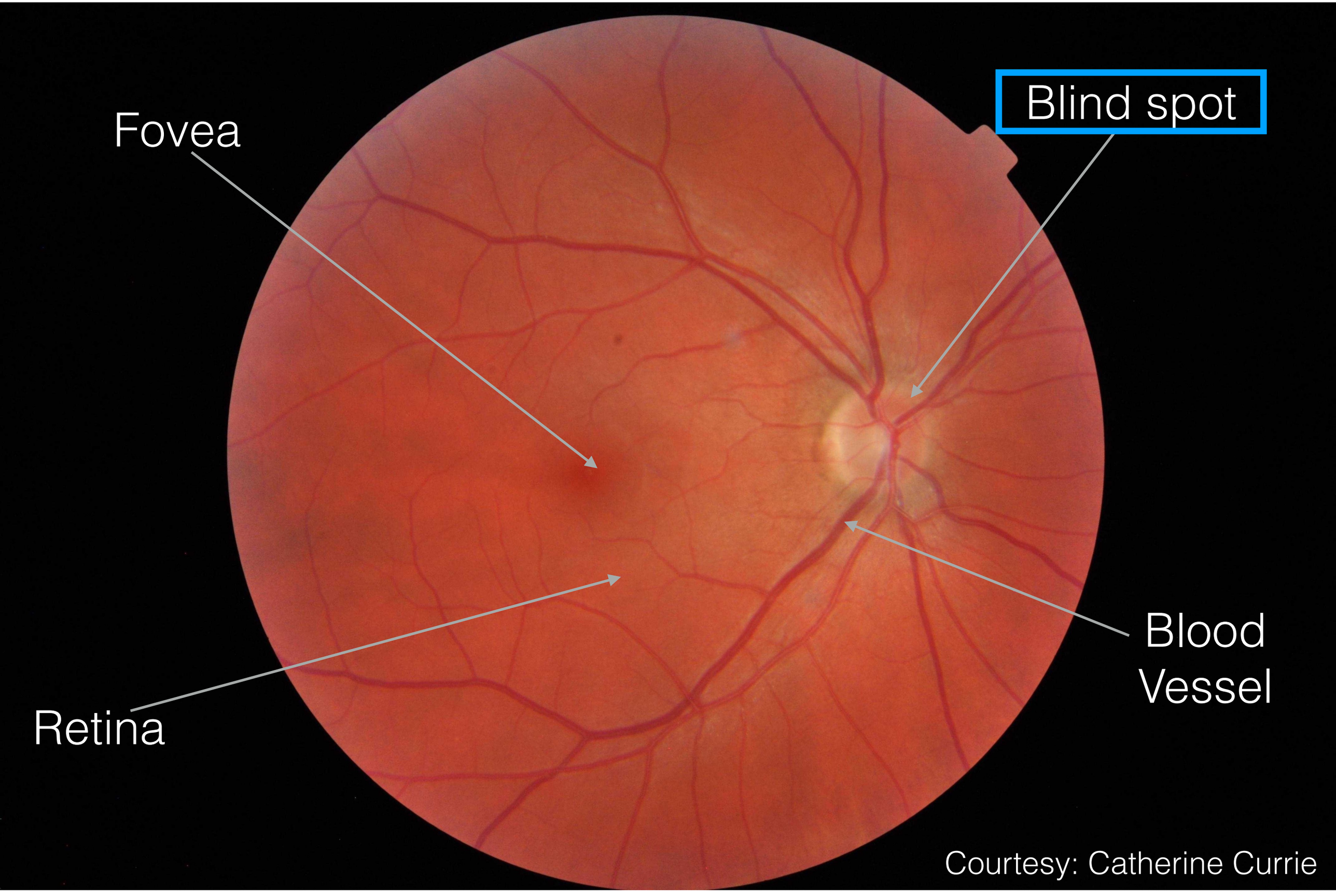
Text, lines, and other design elements should not be of equal or close luminance to the background. Near-equal luminance objects are very hard to pick out, and near-equal luminance text is very difficult to read. Use luminance contrast that is sufficiently different to avoid problems.

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.

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 contrast.

My Eyeball!


Fovea
Blind spot
Retina
Blood Vessel
Courtesy: Catherine Currie

Find Your Blind Spot

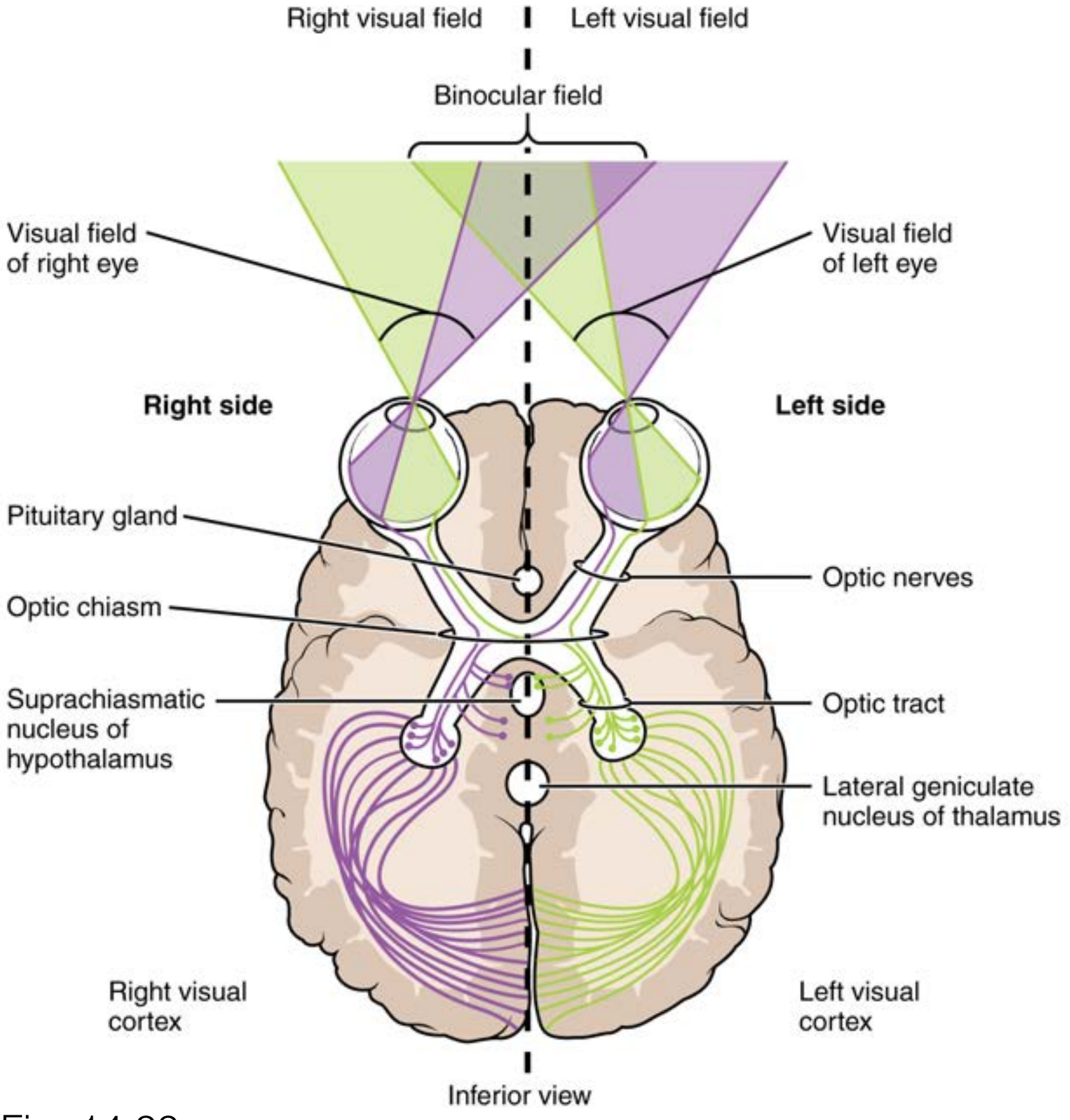
O

X

Your brain makes up stuff all the time 🤷‍♀️

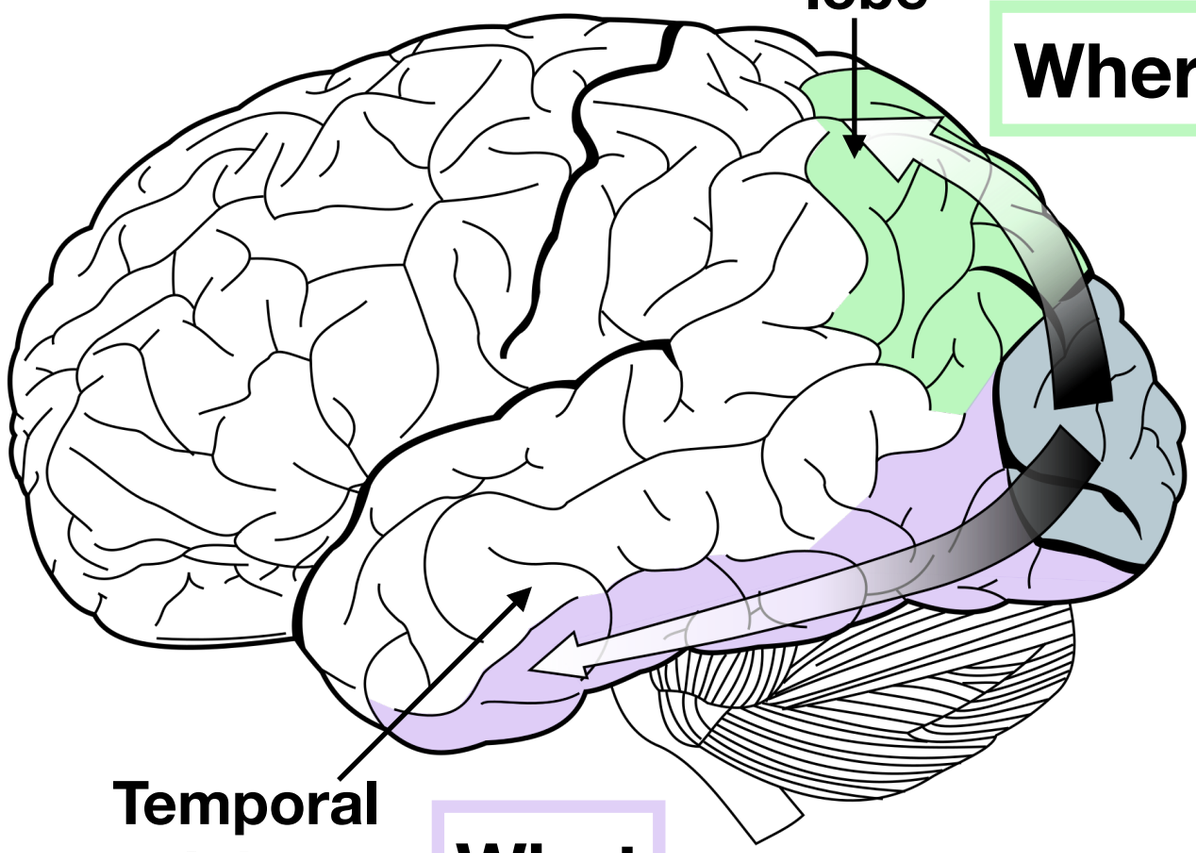
We see based on visual processing, not image transmission.

Visual Field Tracts



OpenStax Fig. 14.22

Visual Field Processing



Where system

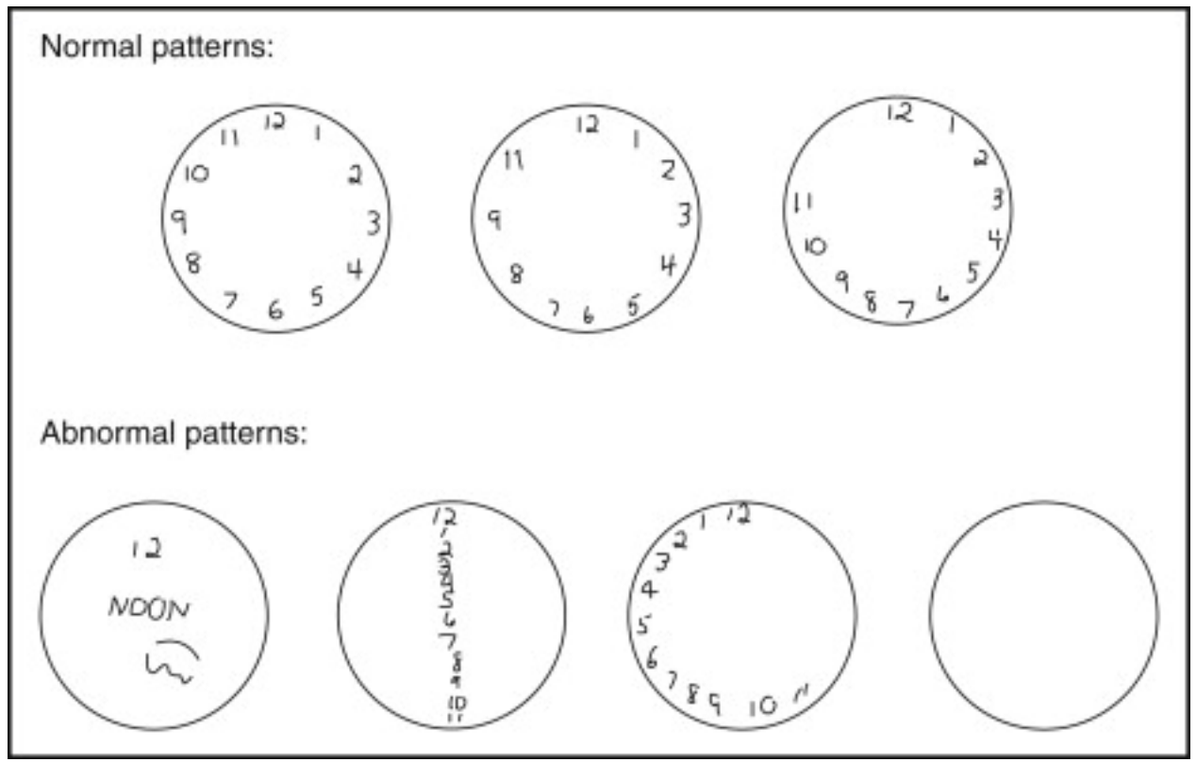
Visual guiding

Motion

Colorblind

Calculated across retina

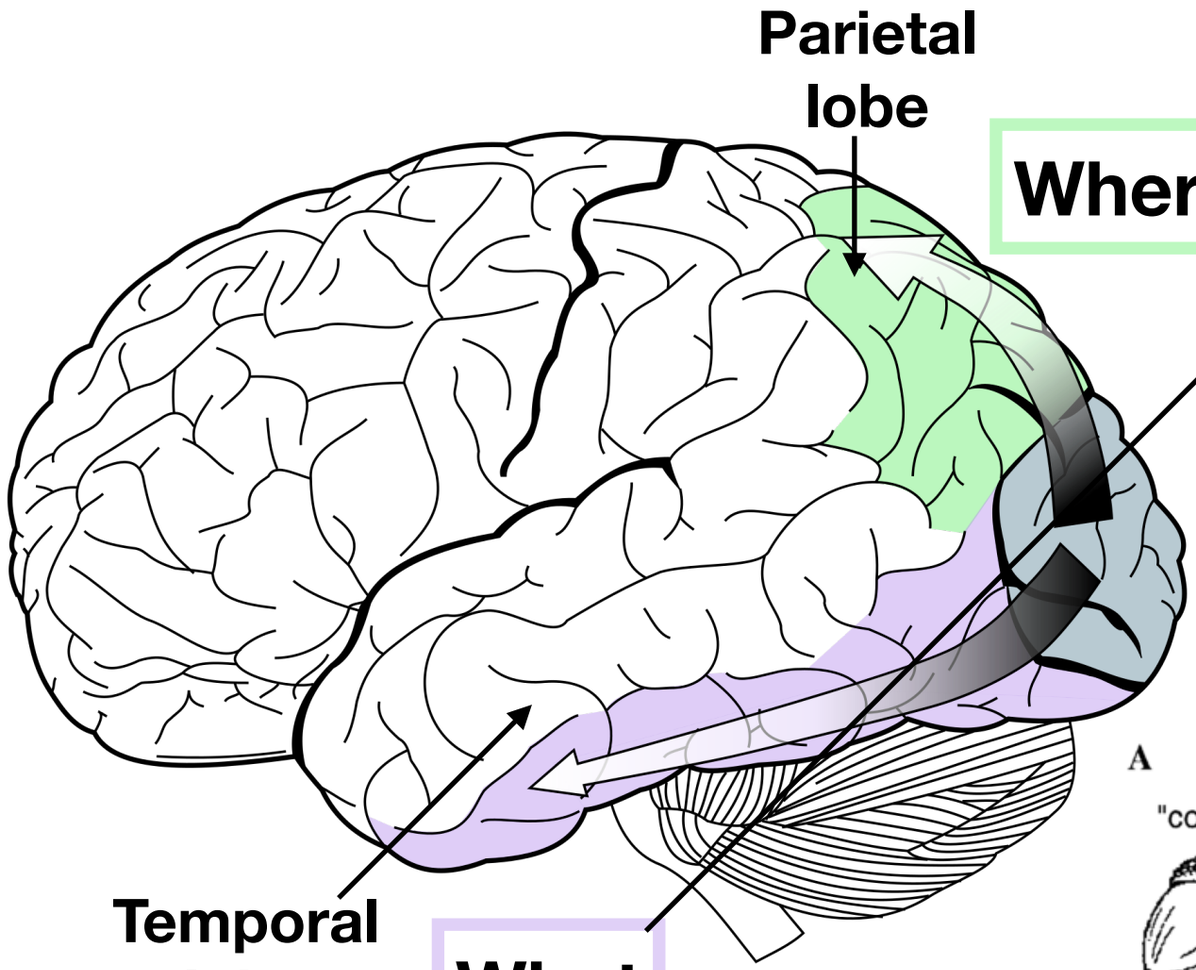
Breaks



McGee, Mental Status exam, 2012

Note: colors do not correspond to visual tracts slide!

Visual Field Processing



What system

Object recognition

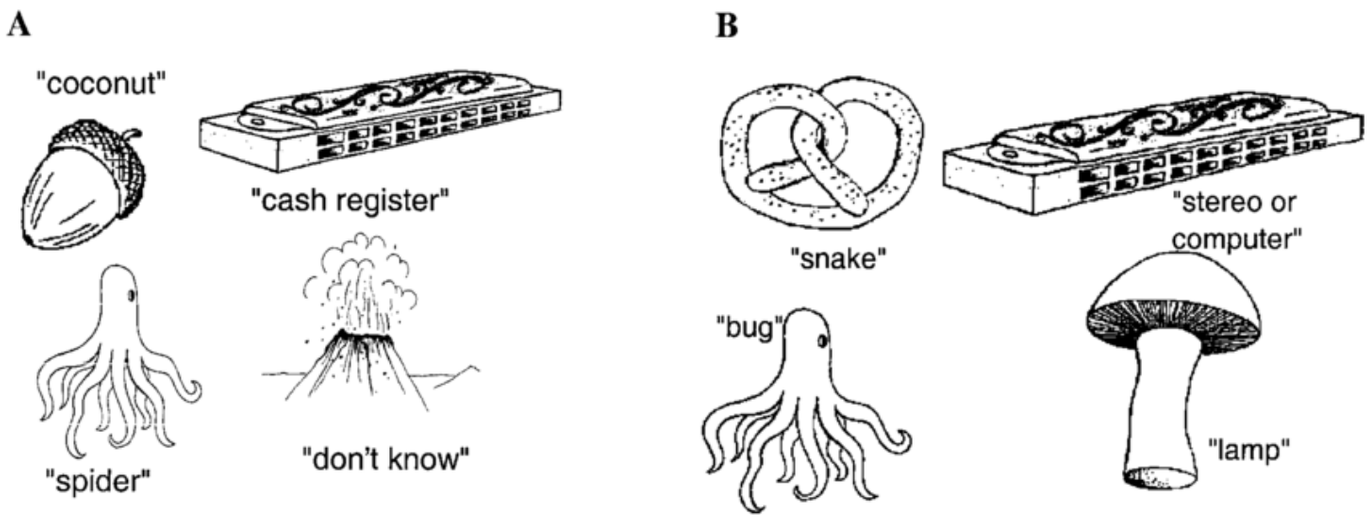
Detailed but slow

Color recognition

Fovea (local)

Breaks

“visual agnosias”



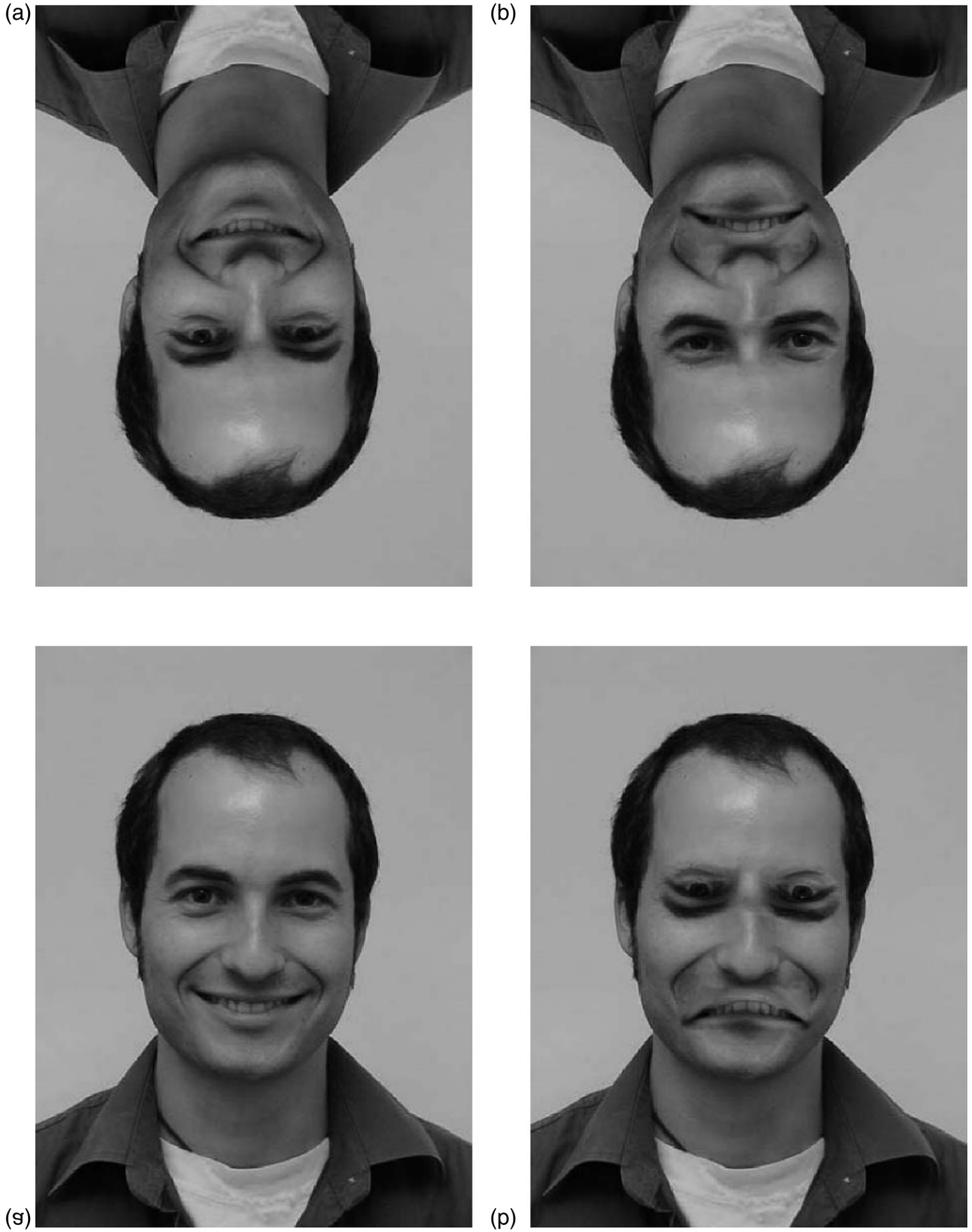
Responses of “S.M.” and “R.N.”, Behrmann 2003

Face blindness

Note: colors do not correspond to visual tracts slide!

Object Recognition is local

Face Recognition is special!

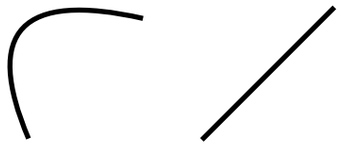


Grüter et al. 2008 *J Neuropsychology*

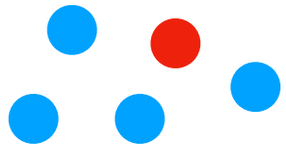
Putting Neuroscience into Practice: Designing Visualizations

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

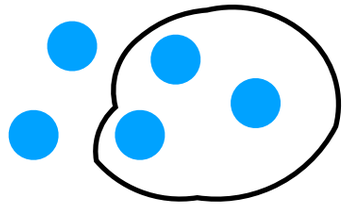
- **curved/straight**



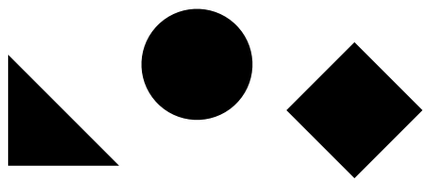
- **color**



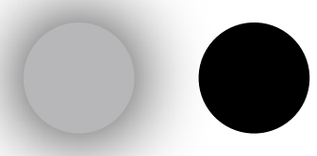
- **enclosure**



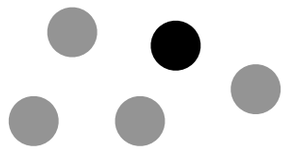
- **shape**



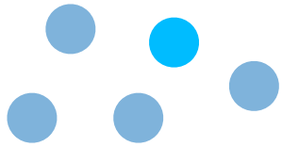
- **blur**



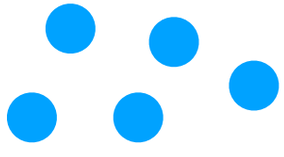
- **light/dark**



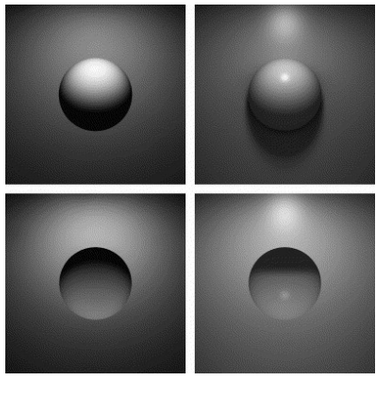
- **hue intensity**



- **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.

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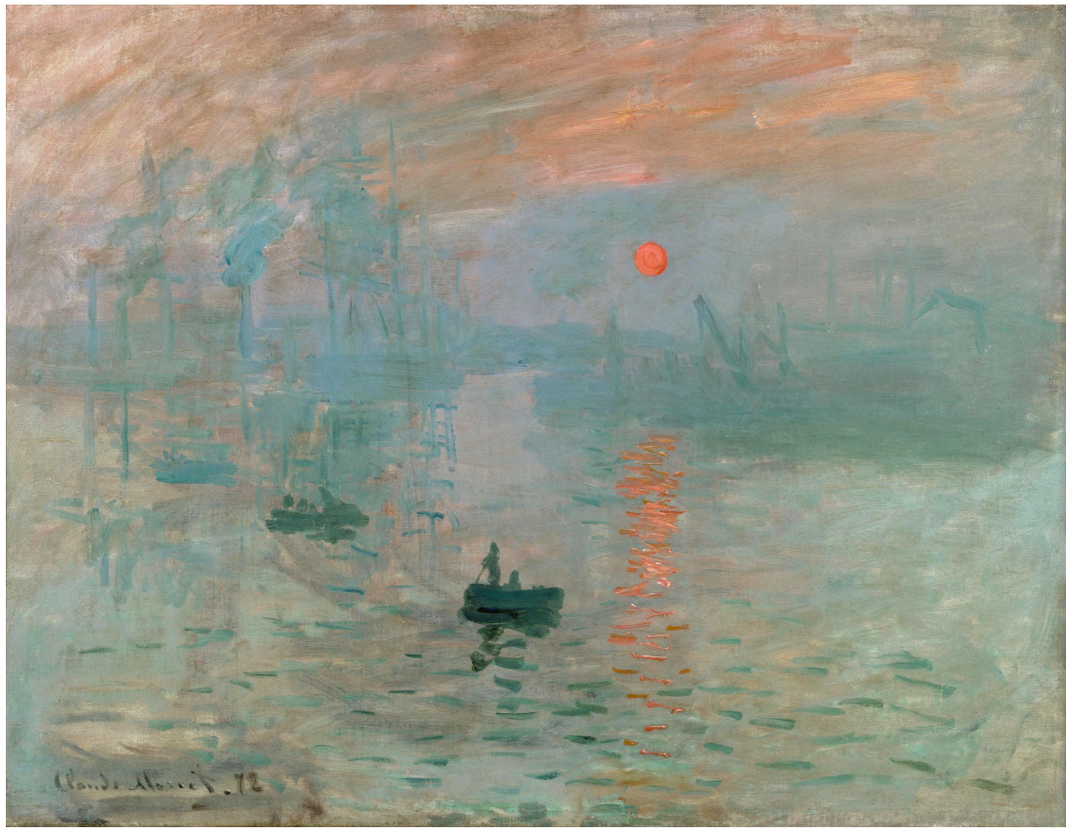
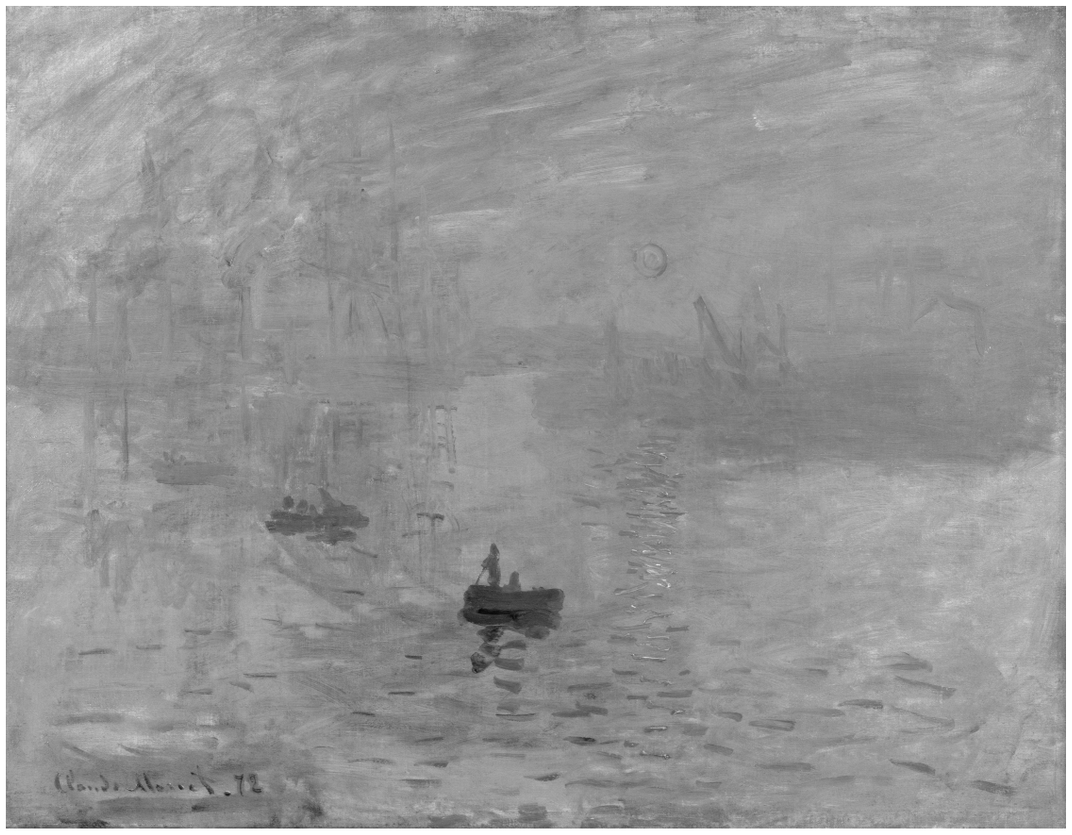
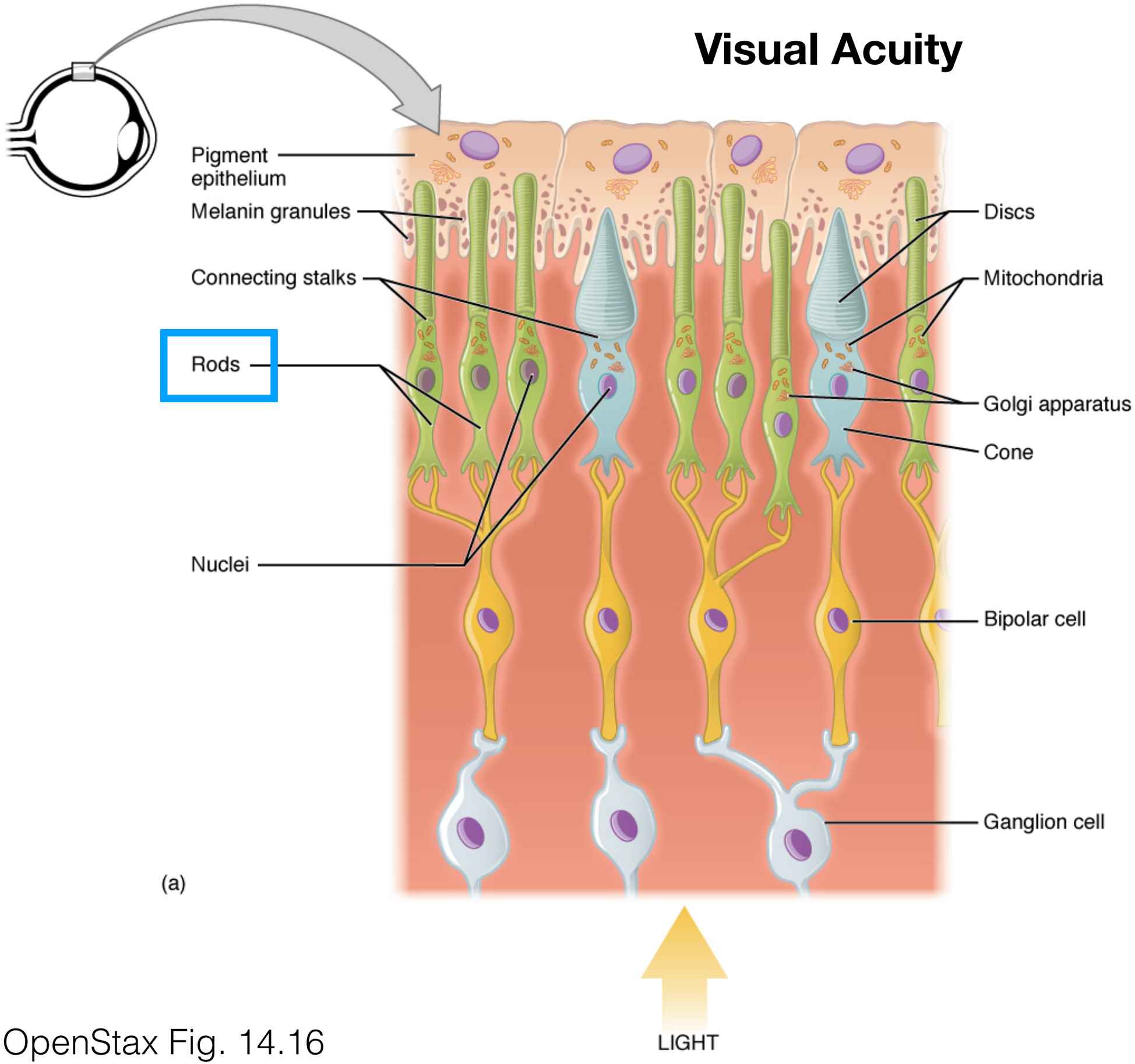




Visual Processing Matters!

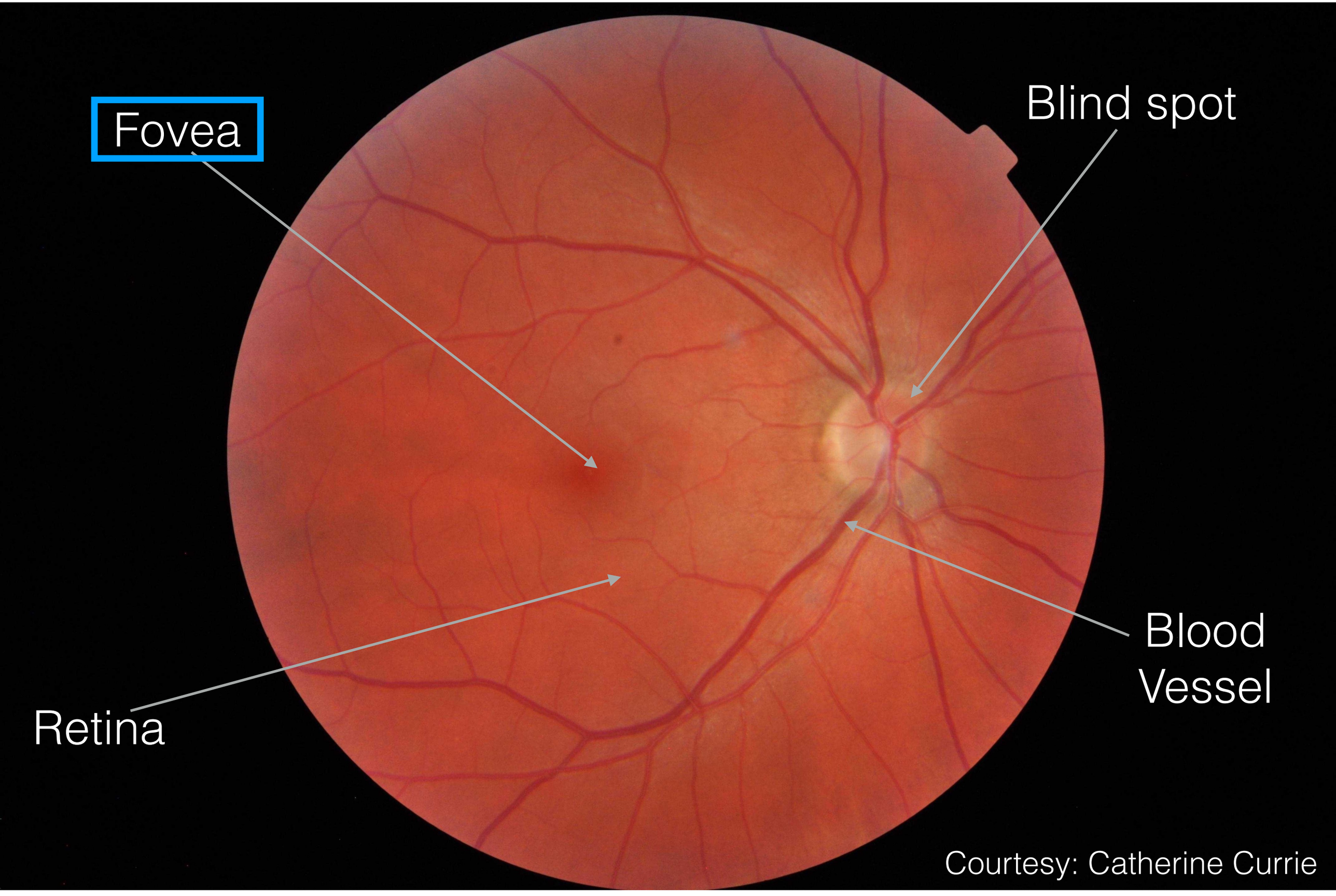
- Sight is not based on image transmission, but visual processing
    - Avoid equal-luminance elements, they jitter and are unpleasant!
    - Your brain makes stuff up all the time, so be weary of it.
    - Use features with fast-processing differences to encode your data.

Visual Acuity



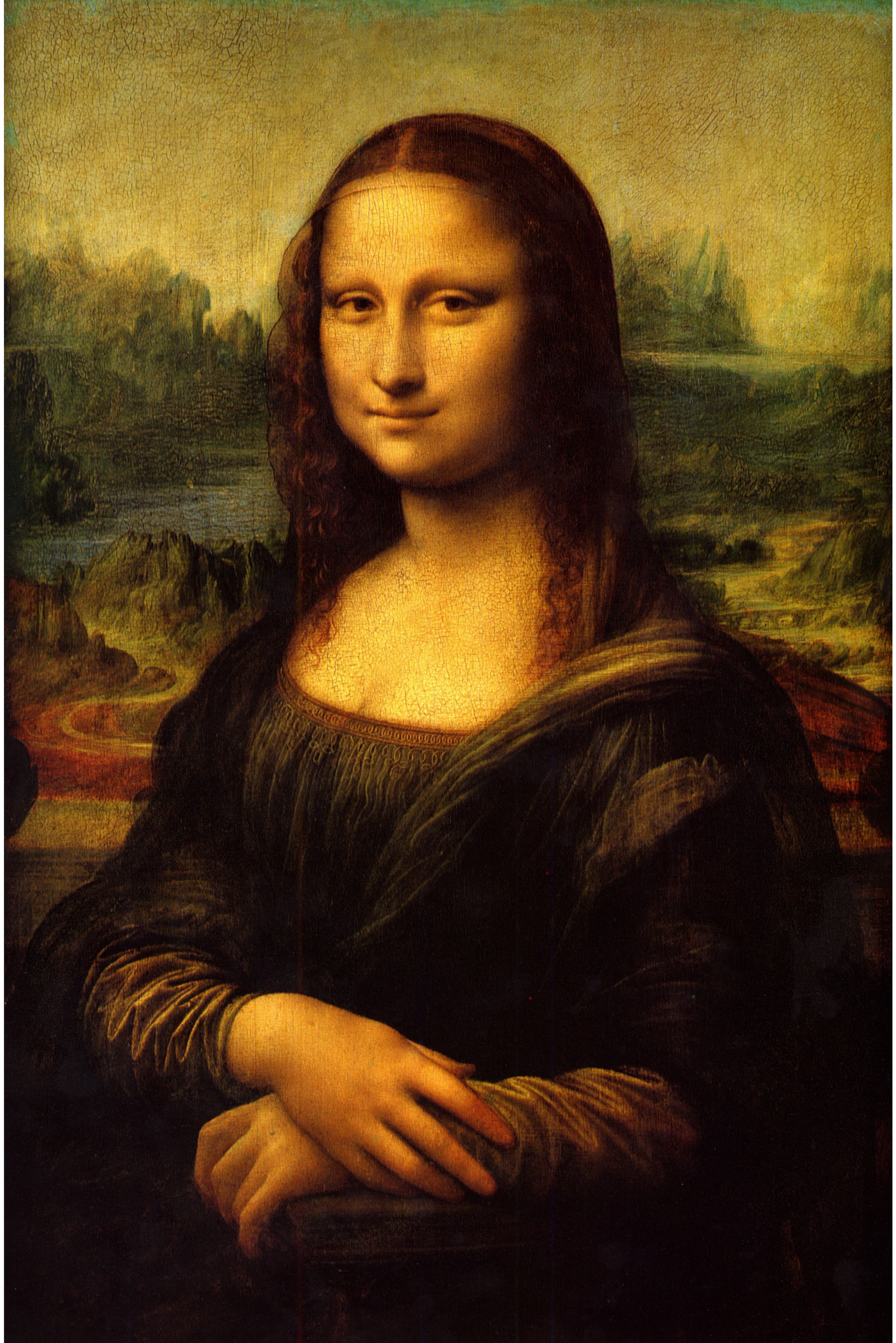
OpenStax Fig. 14.16

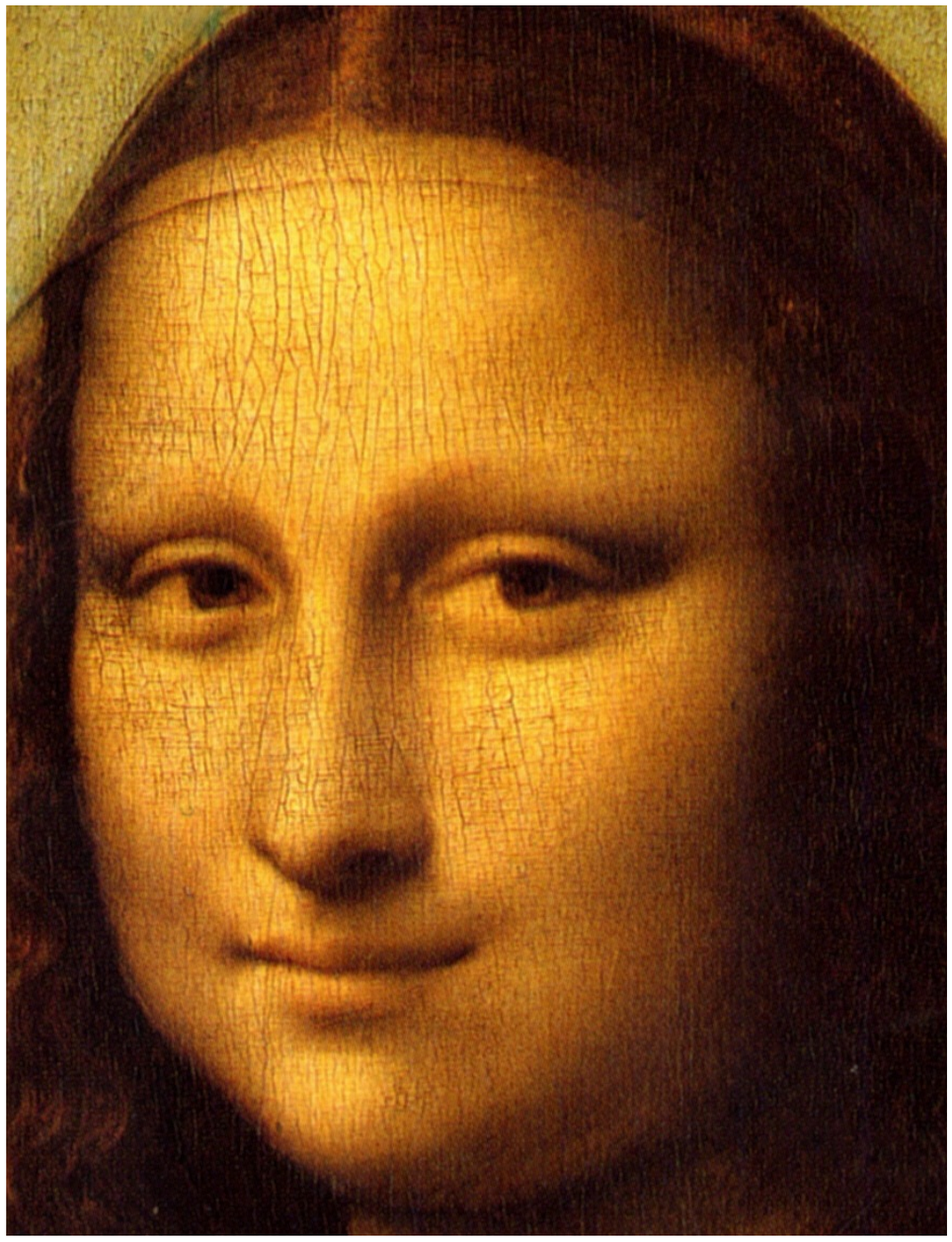
My Eyeball!


Fovea
Blind spot
Retina
Blood Vessel
Courtesy: Catherine Currie

Acuity is high centrally and drops of peripherally.

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





“Mona Lisa”
Leonardo da Vinci

Size Matters!

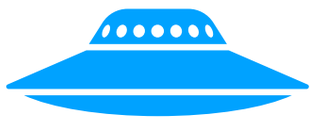
- Visual acuity is high centrally and quickly drops off in the periphery.
    - Design your graphics to fit within 1-3° of visual arc.
    - Any details on graphics should be large enough to scan and understand quickly. (Weird things happen if you need to look at two places to understand one concept.)
    - Guiding attention is key to understanding complicated, spread-out graphics!

Conclusions:

1. Our visual systems are built primarily on contrast.

2. We see based on visual processing, not image transmission.

3. Acuity is high centrally and low peripherally.



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

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