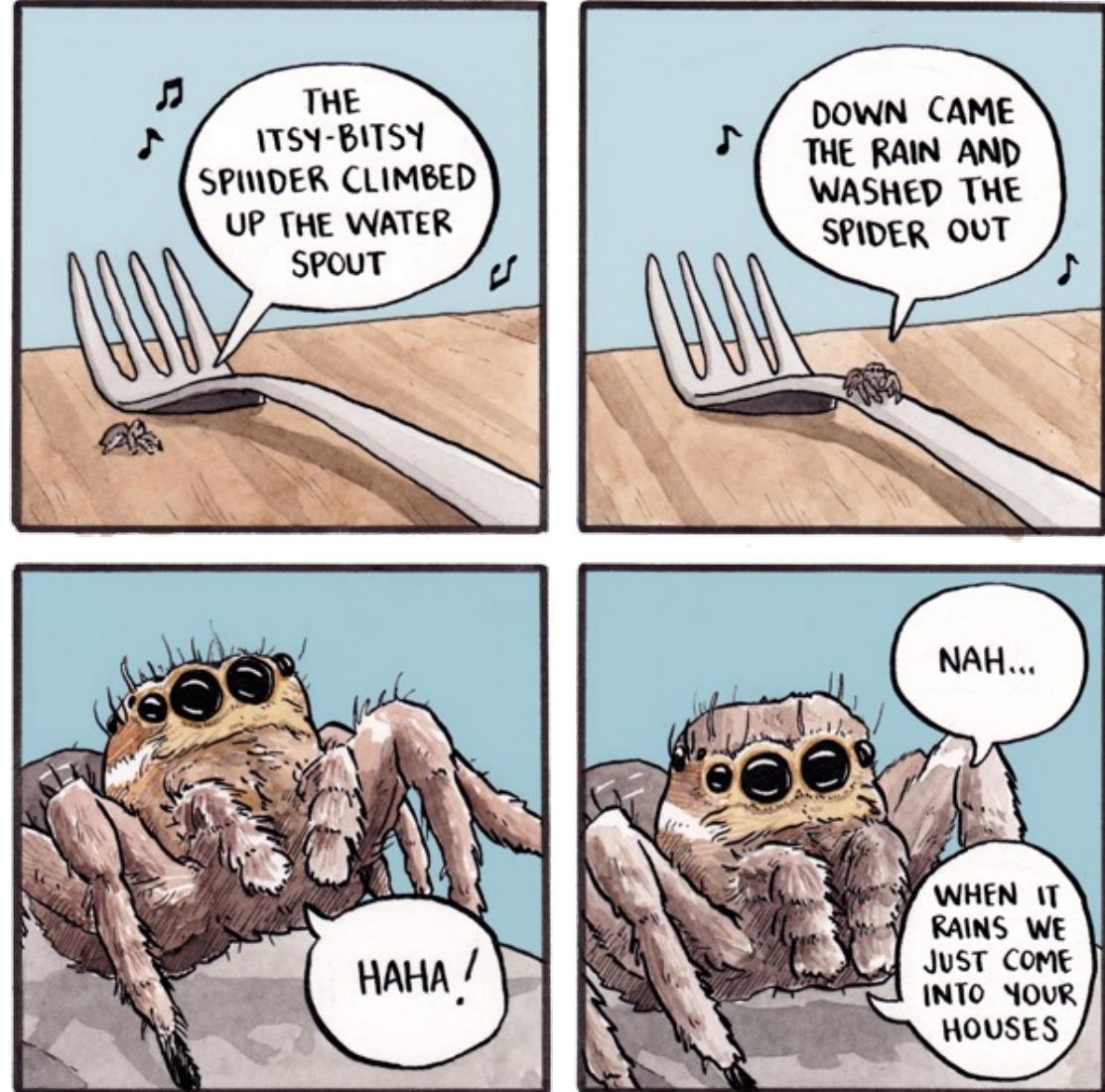


# PSYC304

## Vision

Jay Hosking, PhD

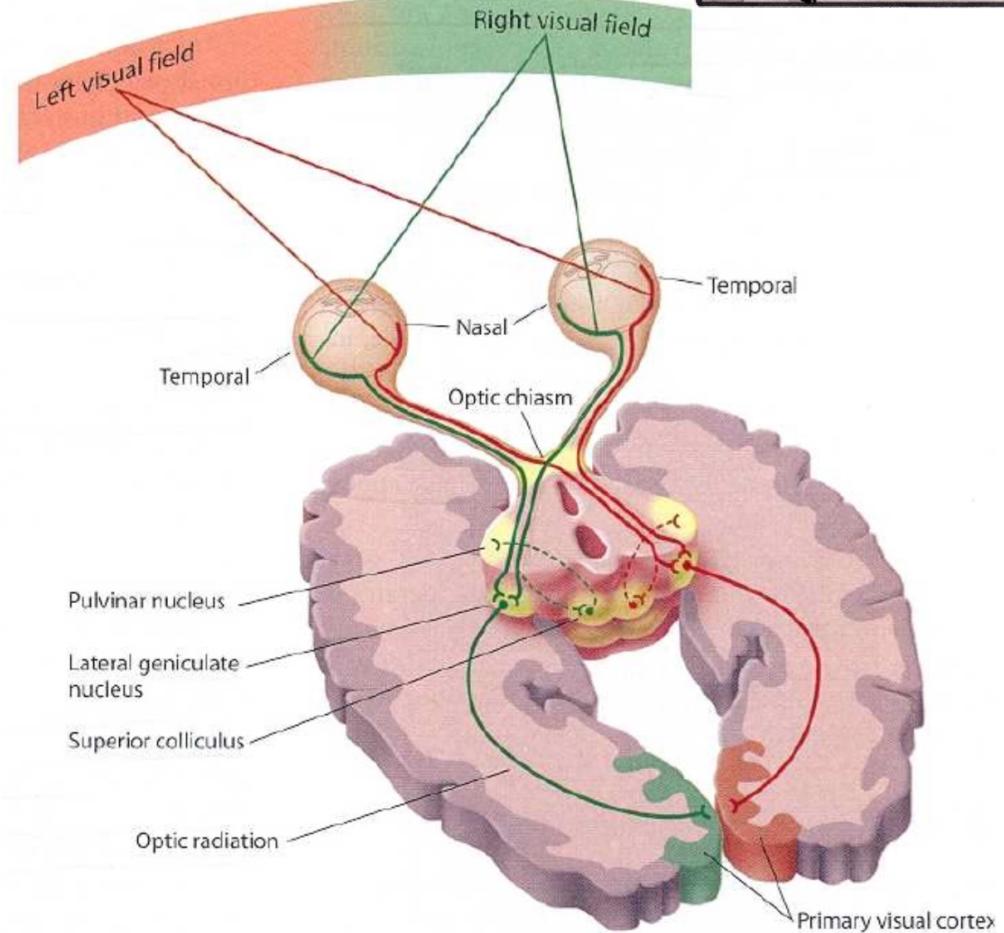


# Visual system: great model for the CNS



- Introduction to vision
- The retina
- Receptive fields
- Pathways to the cortex
- Visual cortex
- Other visual processing

Overview



# Learning objectives

1. What does it mean to say, “The brain is not a hard drive, and the eye is not a camera”? i.e. What does it mean to say that perception is *active*?
2. Describe numerous examples of active perceptual processing, both in this lecture and the previous.
3. Describe parallel processing and its relation to the visual system.
4. Describe separate systems for processing visual information in the retina.
5. Describe a receptive field, and how it varies across the visual system.
6. Describe separate pathways for visual information from retina to thalamus to cortex.
7. What two theories describe colour vision? Are they mutually exclusive or complementary? Do they completely describe colour perception? Describe the putative neural mechanisms for each theory, and what else might account for our perception of colour.
8. How does the visual cortex turn basic light stimulus into perceptions?
9. Describe separate pathways for processing information in the cortex. What do these suggest about discrete damage to visual areas?



# DARPA Grand Challenge 2004



Intro

# Where are we today?

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The  
Guardian

Cities Global development Football Tech Business Environment Obituaries

## Self-driving Uber kills Arizona woman in first fatal crash involving pedestrian

Tempe police said car was in autonomous mode at the time of the crash and that the vehicle hit a woman who later died at a hospital



### most viewed



Self-driving Uber kills Arizona woman in first fatal crash involving pedestrian



Cambridge Analytica boasts of dirty tricks to swing elections



Fran Lebowitz: 'You do not know anyone as stupid as Donald Trump'



'I made Steve Bannon's psychological warfare tool': meet the data war whistleblower



Trump calls for death penalties for drug dealers as focus of opioids plan

# A selective, active process



Intro

# A selective, active process



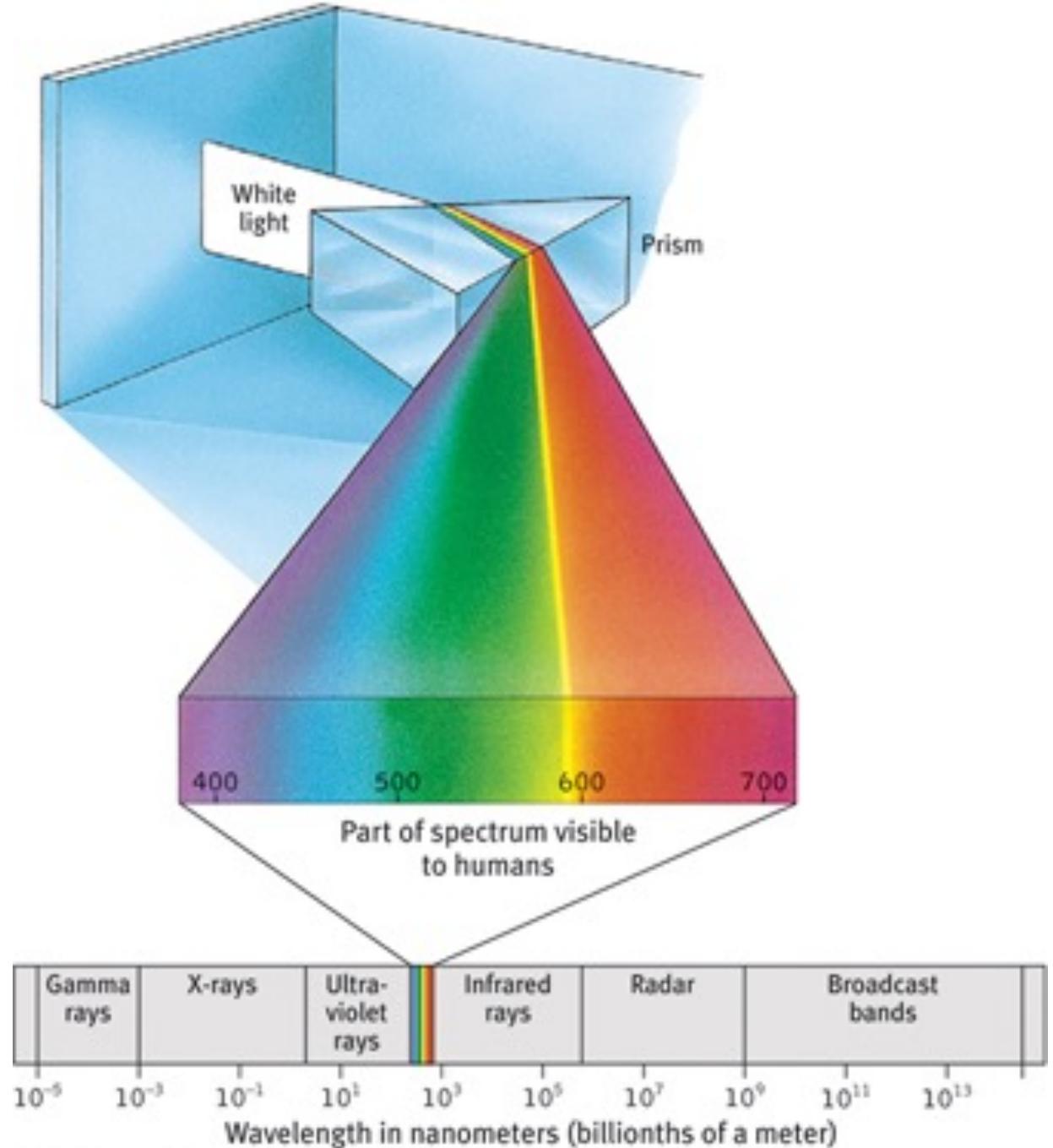
Intro

Reminder: vision has a restricted range

Based on evolutionary usefulness

Varies by species

As ever, has a biological basis



Intro

# Adaptation

- A consequence of constant stimulation
- Influences how the world is perceived in a personally useful way
- Explains why we (usually) don't see the blood vessels in our eyes
- Thus, we need constant eye movement (**saccades**) to prevent the world from fading

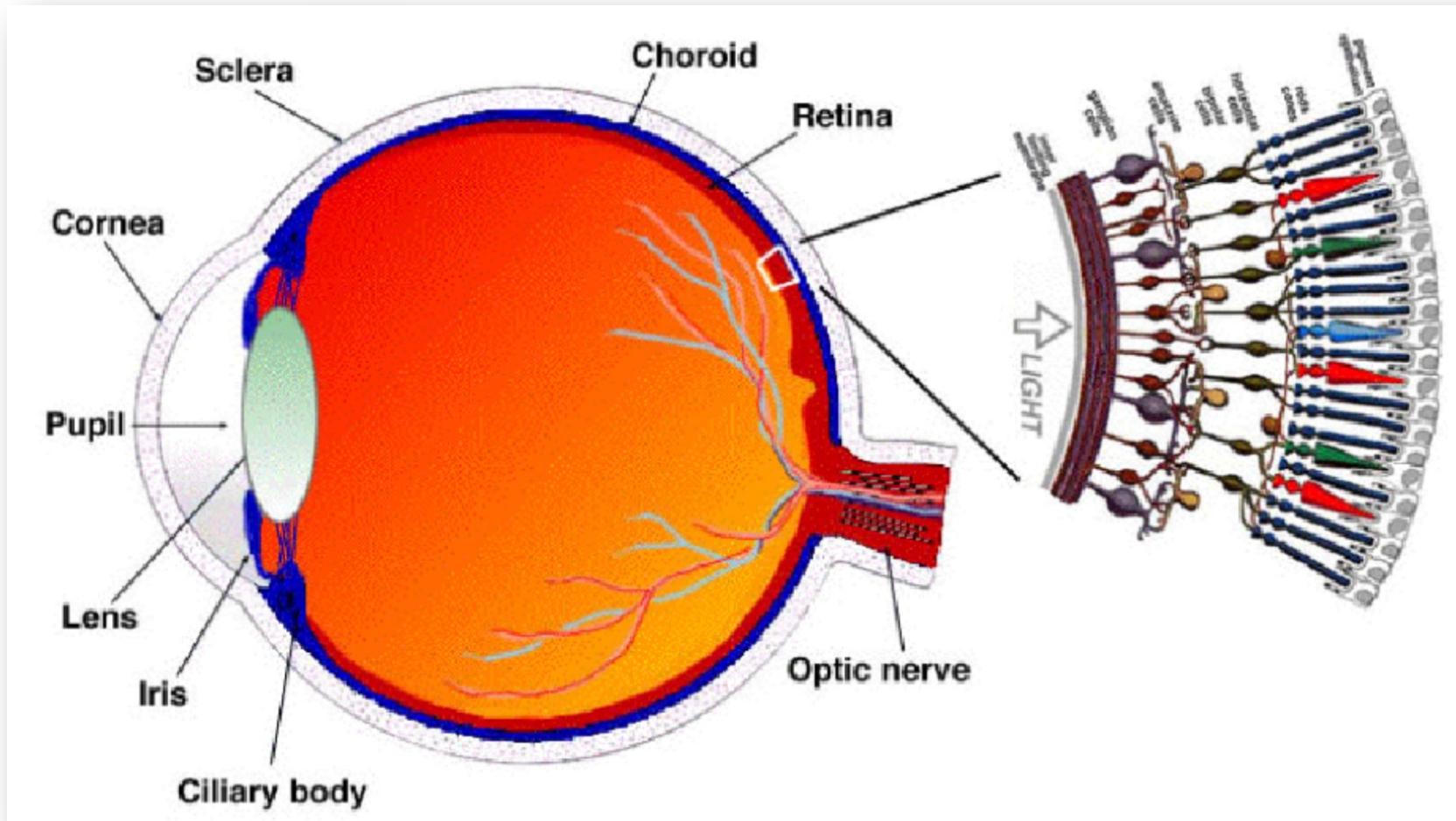


△  $\angle$  — / ^

H B H B 3 4

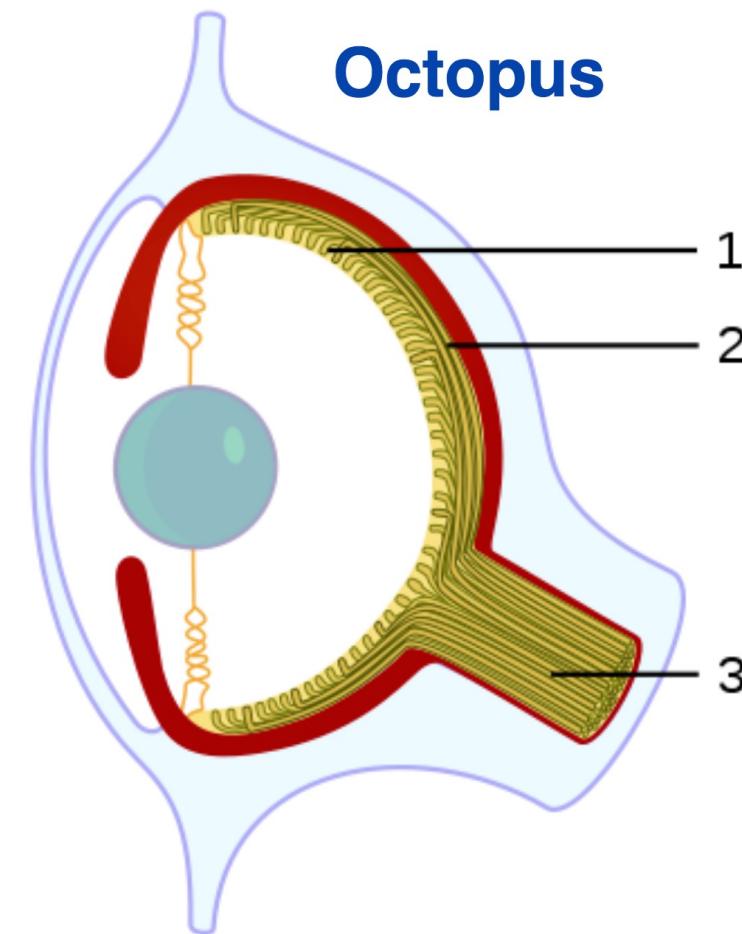
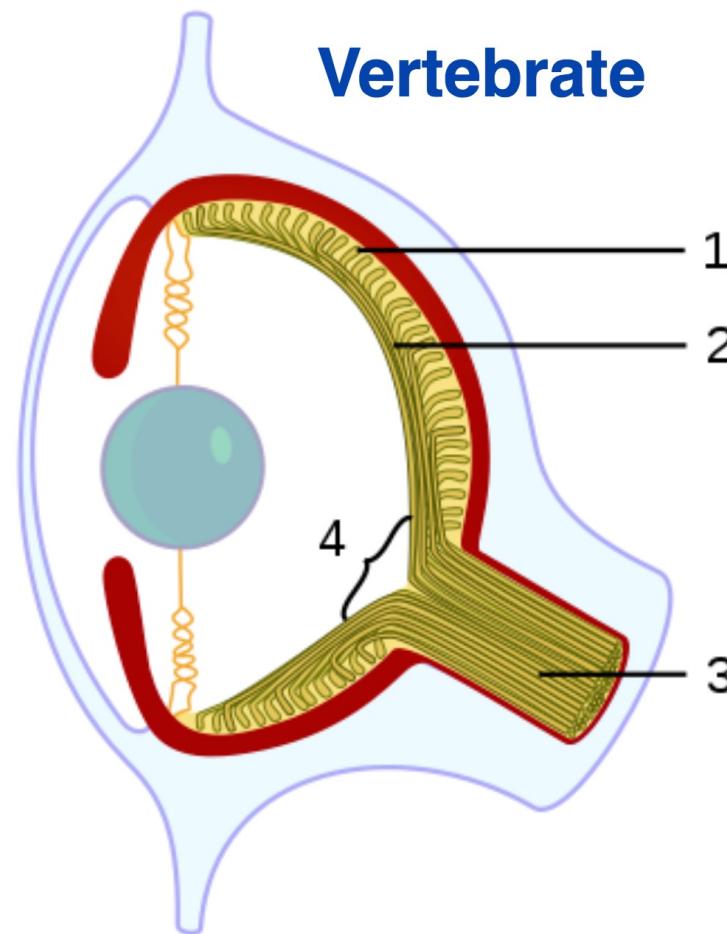
BEER PEER PEEP BEE BE 9

# A messy path to travel



The retina

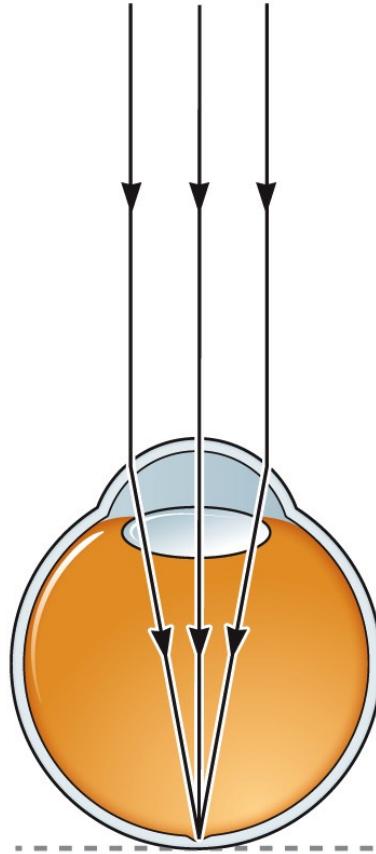
# Reminder: a less messy path to travel



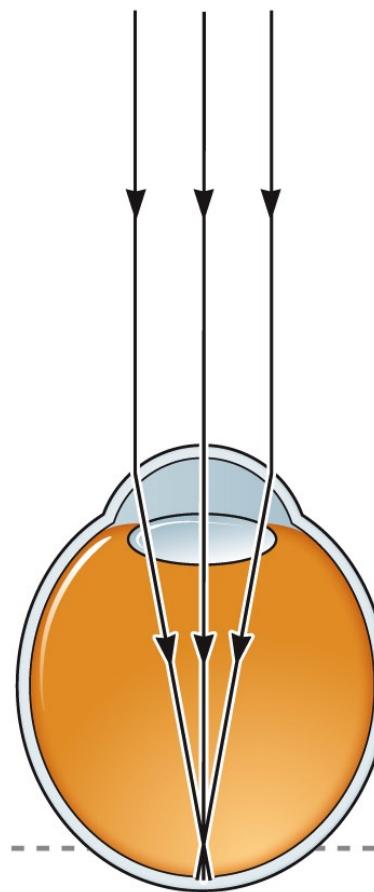
The retina

# The cornea and lens focus images on retina

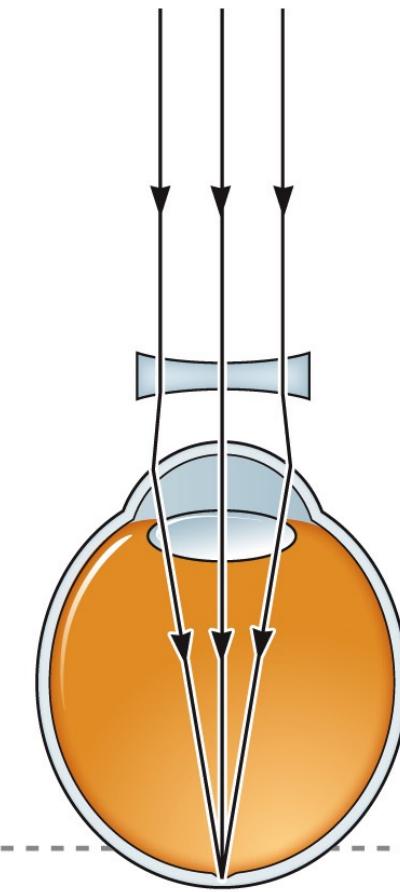
(A) Normal vision



(B) Myopia



(C) Myopia with correction



The retina

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# A well organized structure

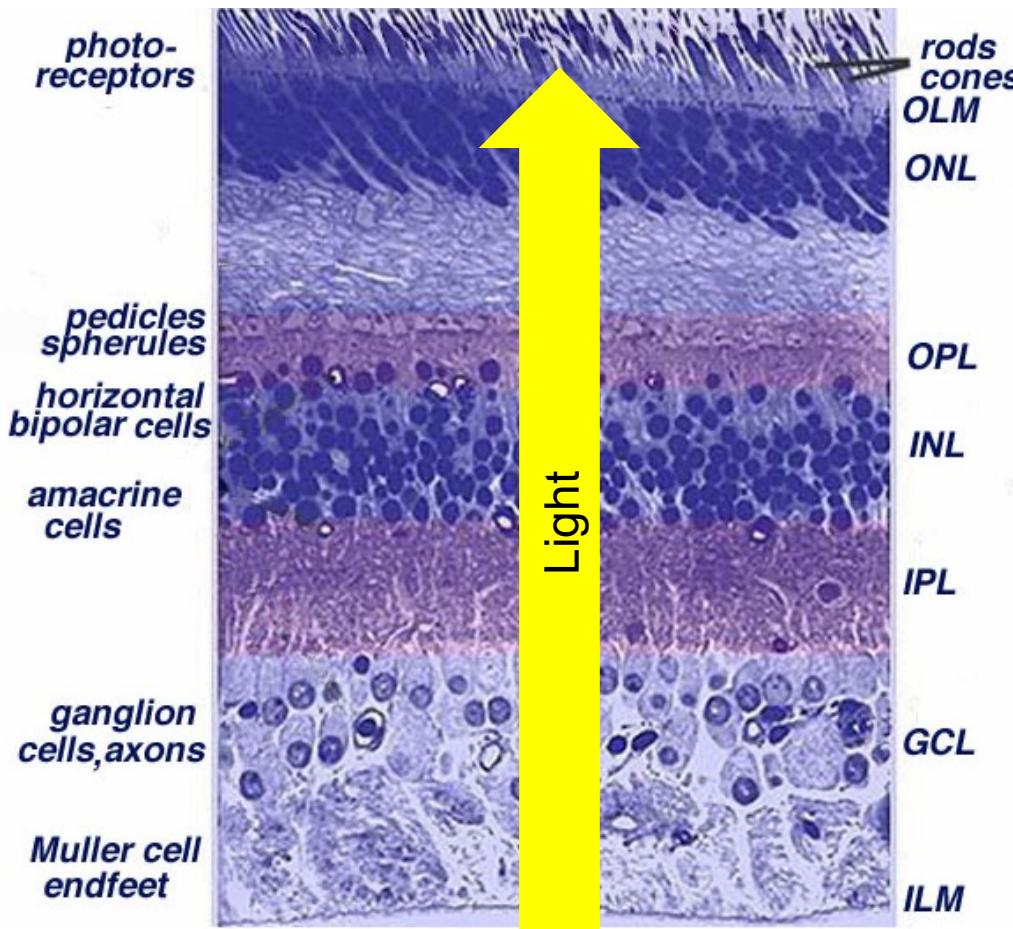
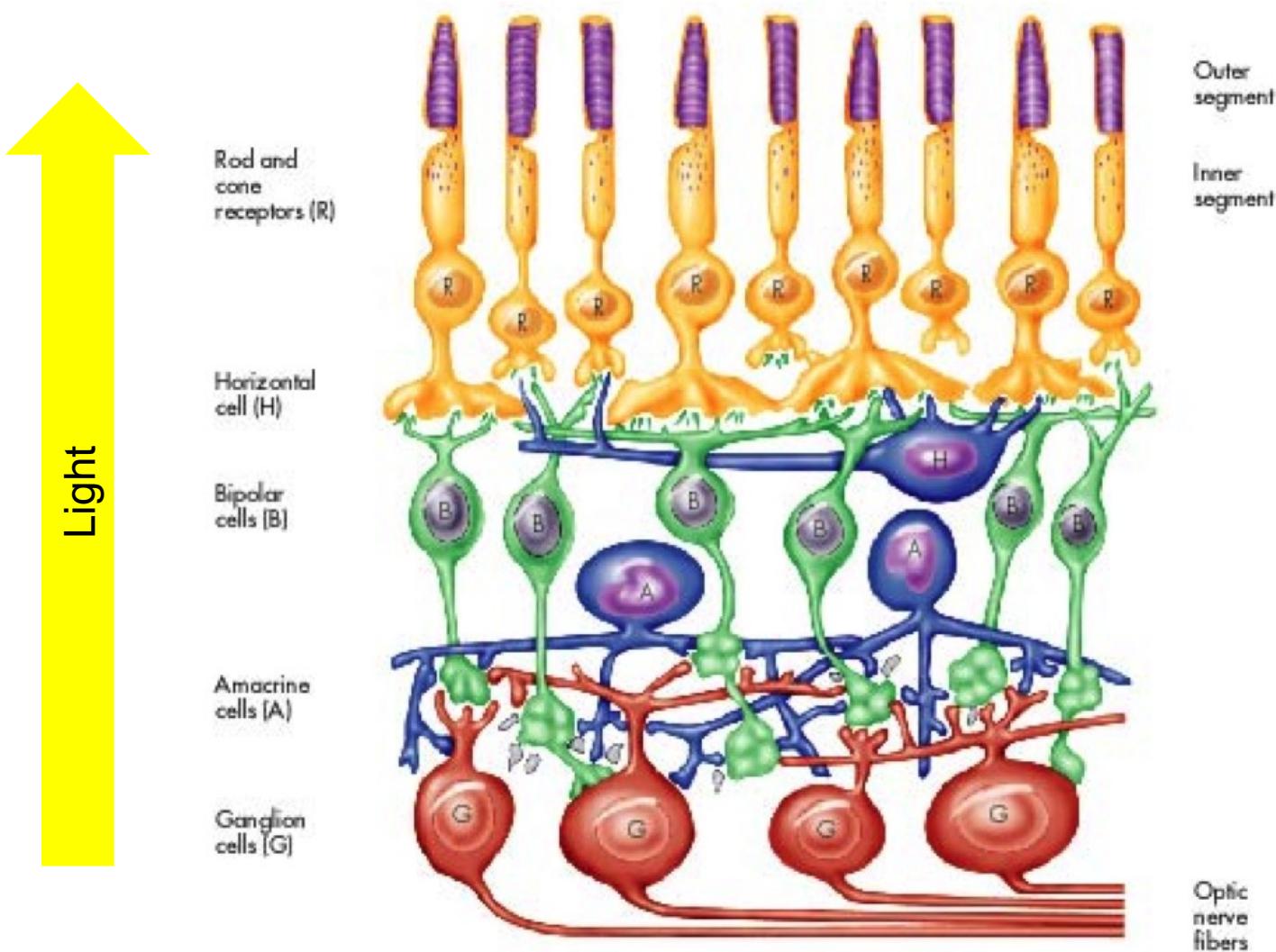


Fig. 3. Light micrograph of a vertical section through central human retina.

- Many translucent layers
- ~130 million photoreceptors
- Photoreceptors convert light into neural activity

The retina

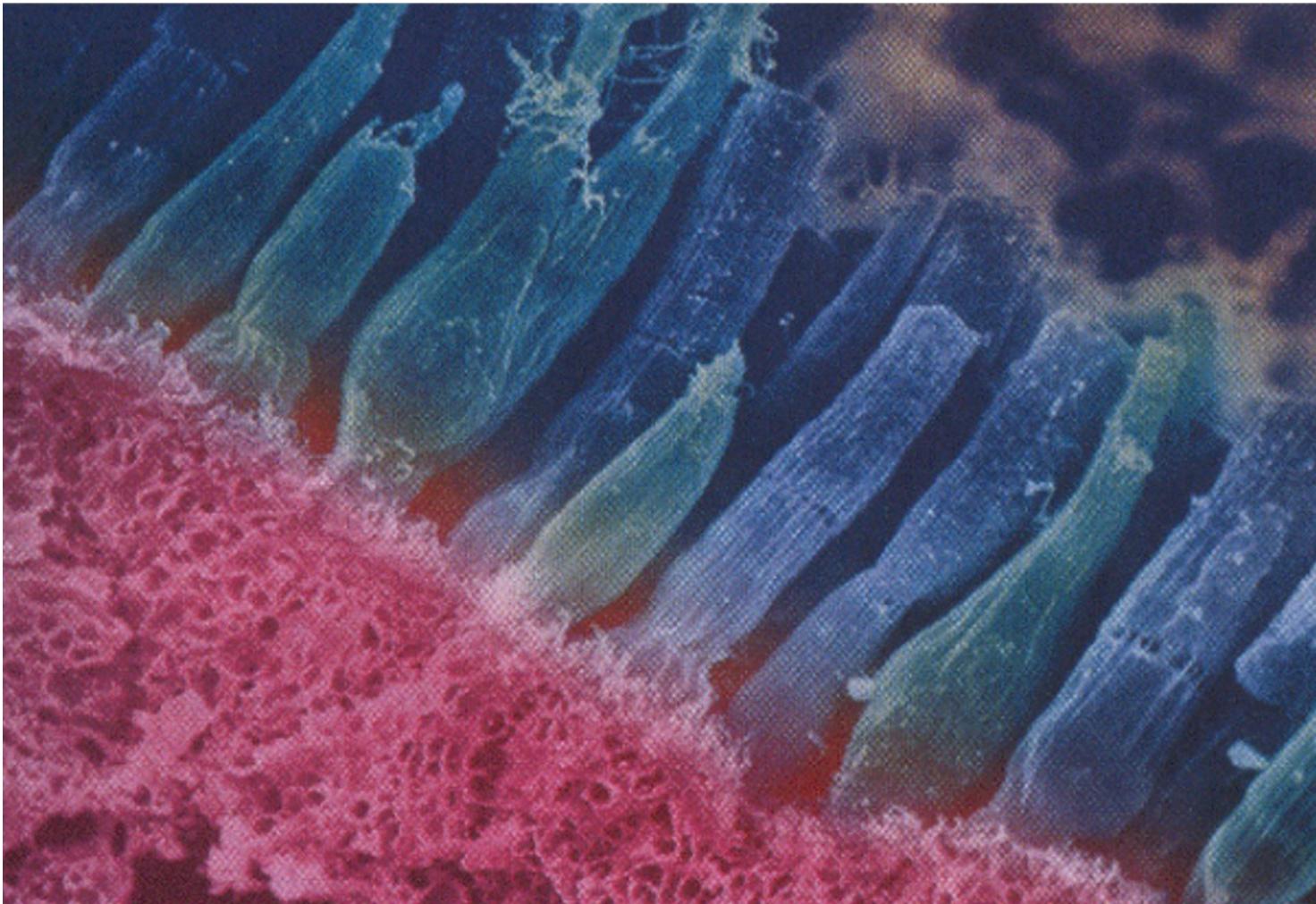
# A well organized structure



The retina

Note 1: graded potentials

# Specialized function



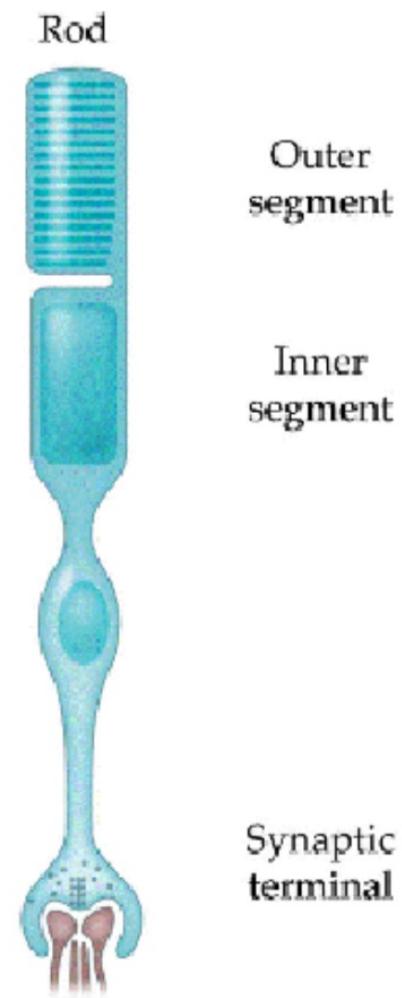
The retina

# Specialized function

## Rods

(scotopic)

- Long, thin, cylindrical
- Highly sensitive to light



## Cones

(photopic)

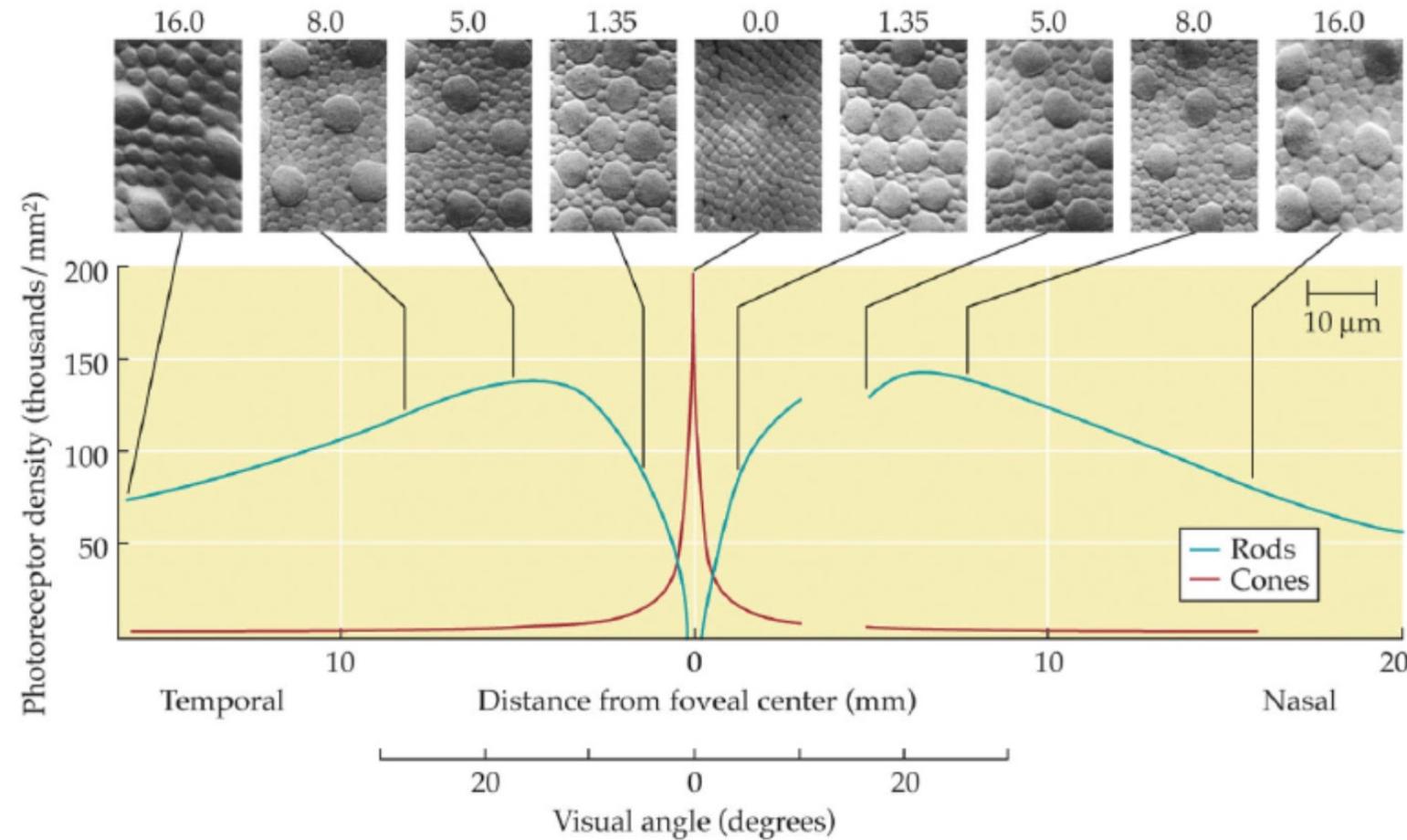
- Short, thick, tapered
- Less sensitive to light



The retina

Note 2: signal causes  
hyperpolarization via GPCRs

# Function influences localization



The retina

# Rods



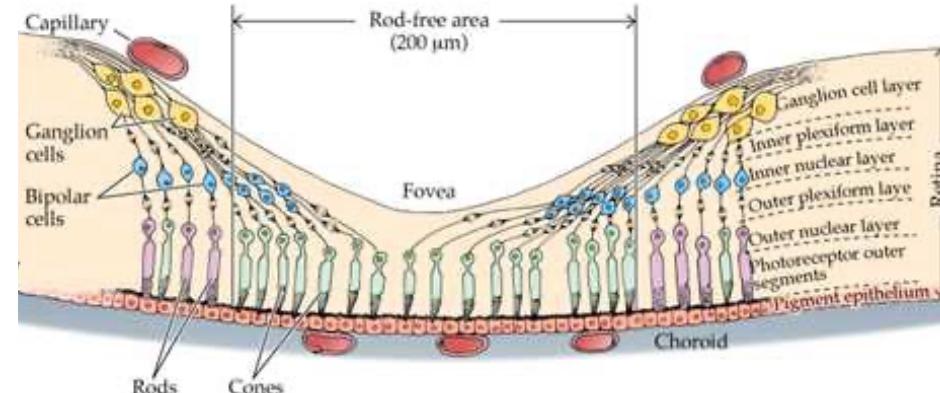
- ~120 million cells
- Very sensitive to light
- Not sensitive to wavelength of light
- Located everywhere except fovea
- Critical for vision at night (convergence)
  - Explains why colour vision is poor in low light
- Easily “bleached” during the day
- Important for perceiving movement

The retina

# Cones

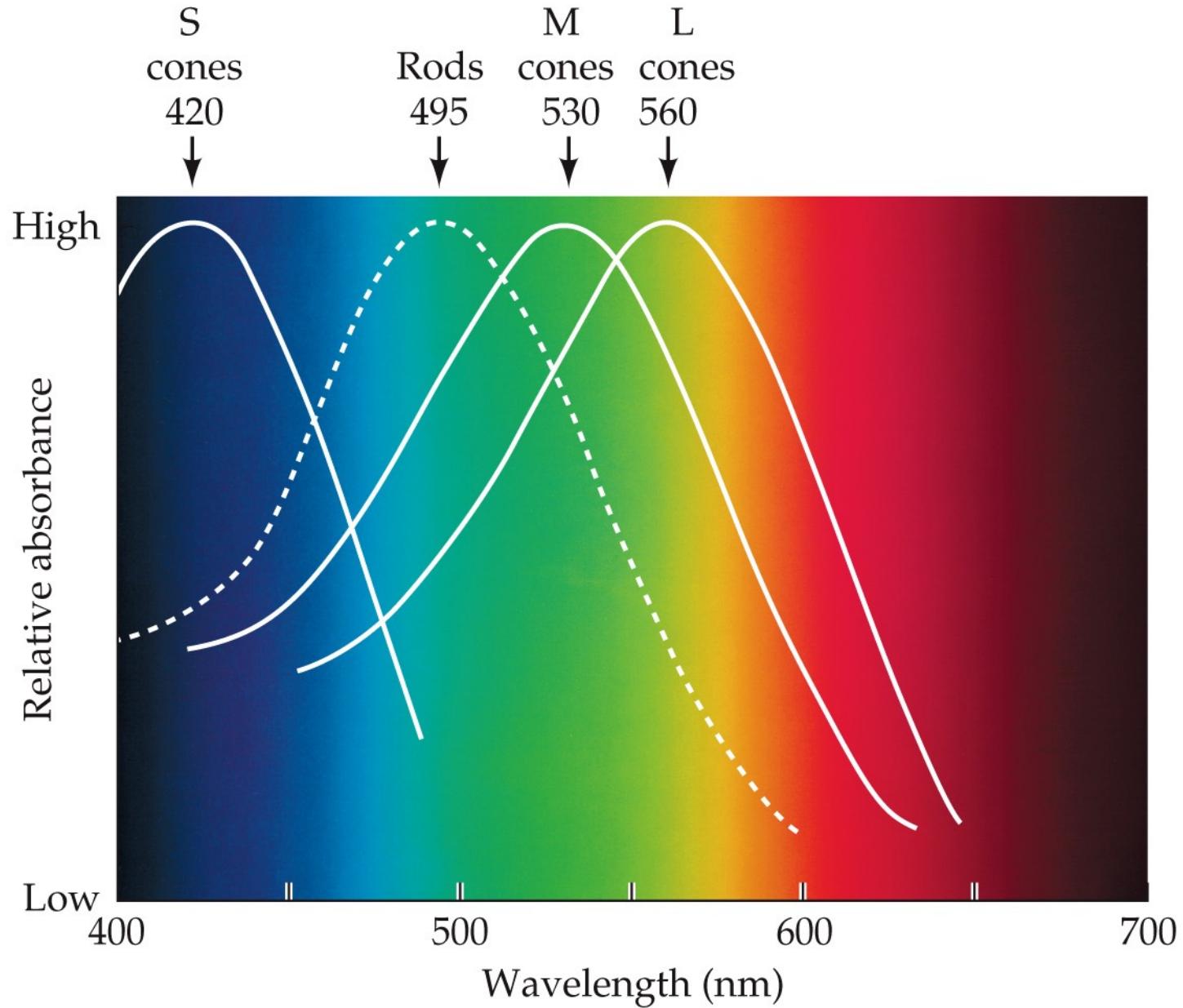


- ~7 million cells
- Less sensitive to light, *but*
- Sensitive to wavelength of light
  - Three types of cones
- Located mostly in the fovea (explains why fovea less useful at night)
- Critical for perceiving colour
- Important for acuity (not cones *per se...*)



The retina

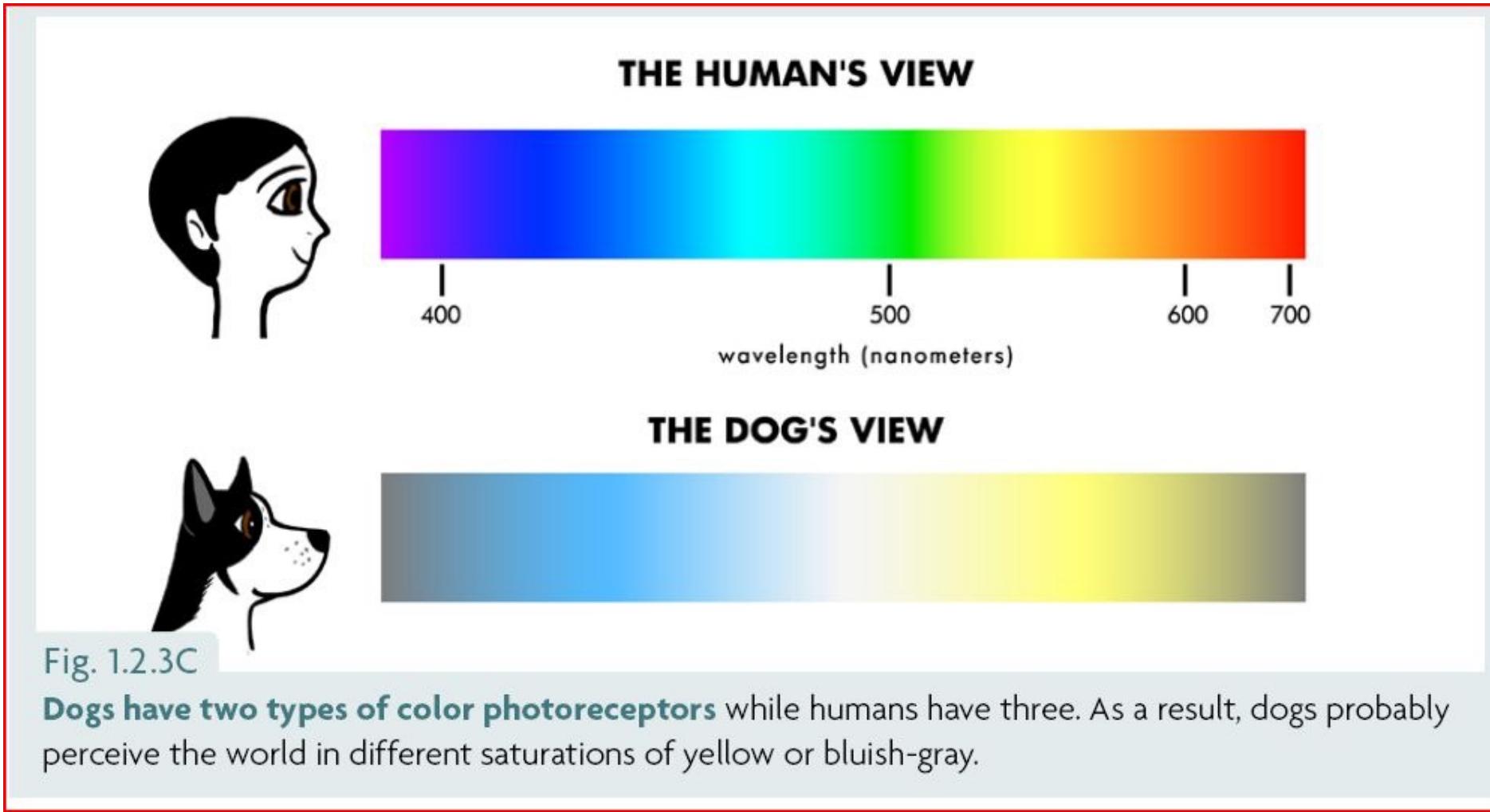
# Rods and cones have different sensitivities of wavelength



The retina

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# Most mammals have dichromatic colour vision



# Colour blindness in humans

Trichromatic colour vision



Protanopia



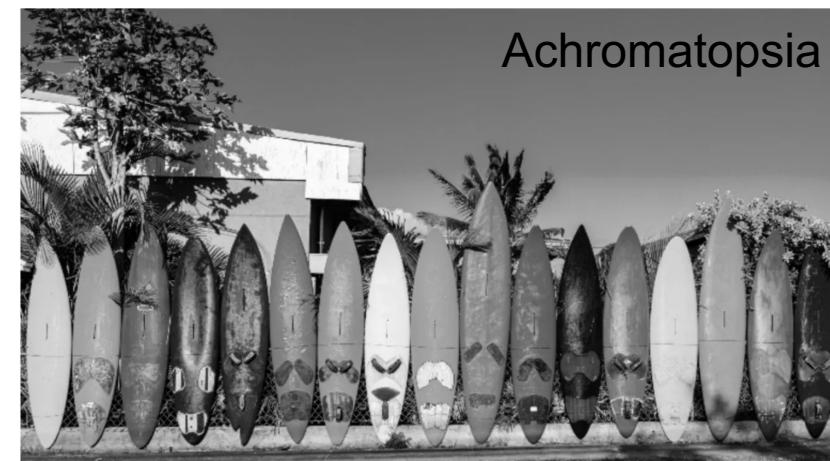
Deutanopia



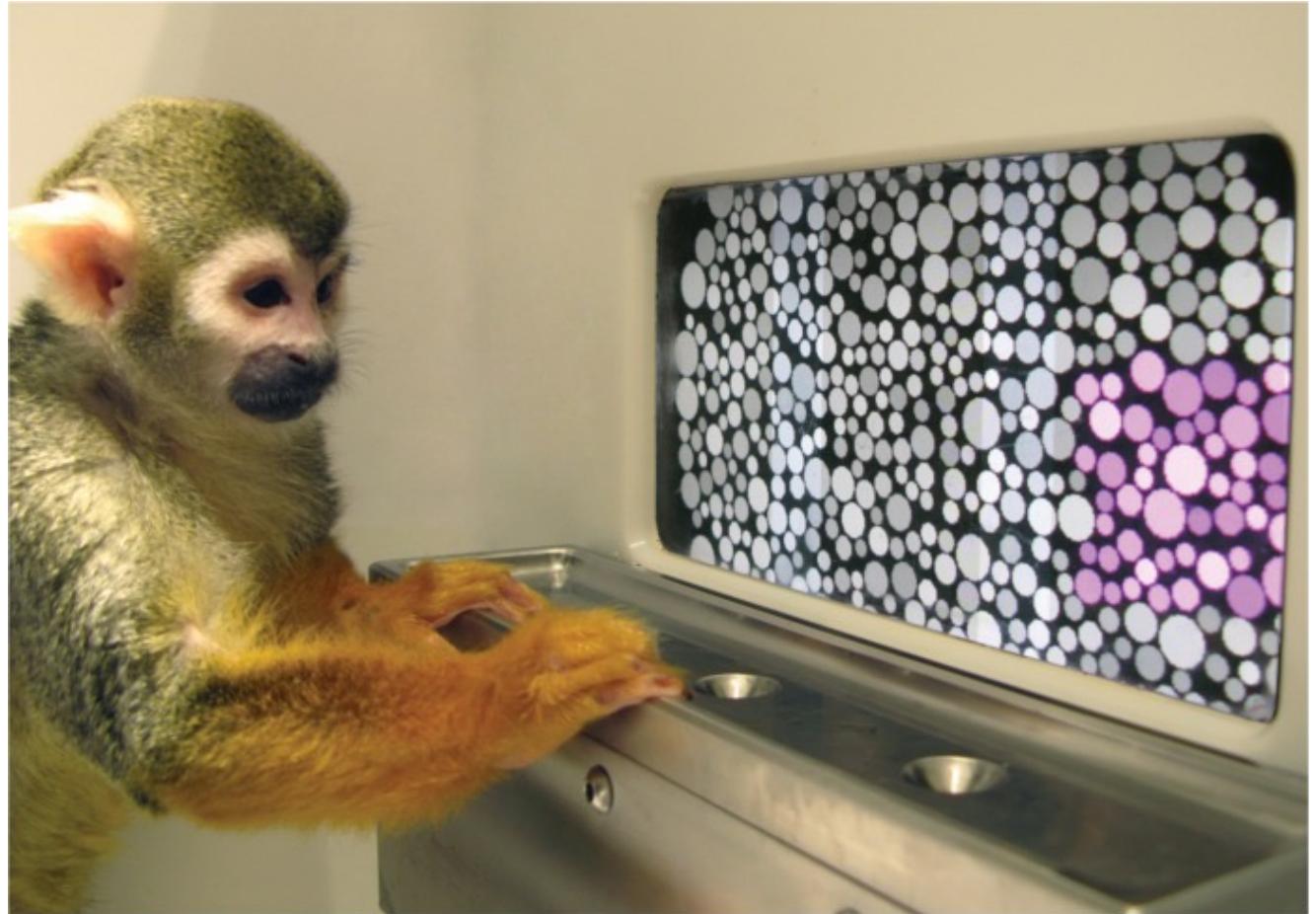
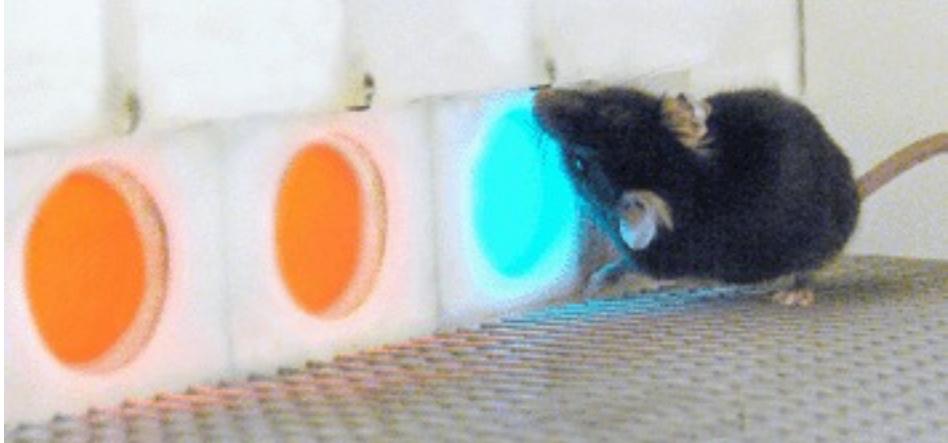
Tritanopia



Achromatopsia



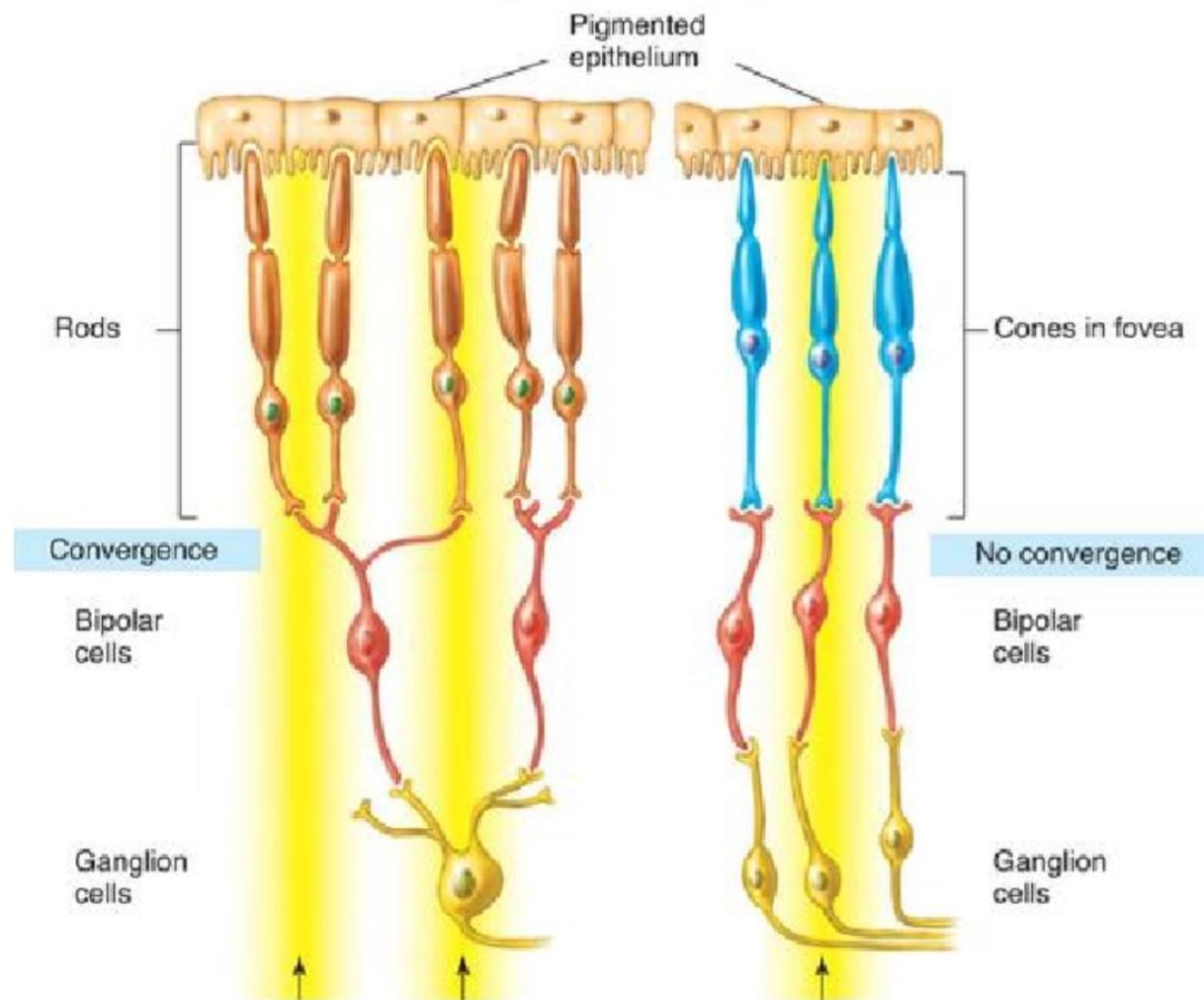
# Acquired trichromacy



- Brain can make sense of new information
- Therapeutic (and science fiction!) implications

The retina

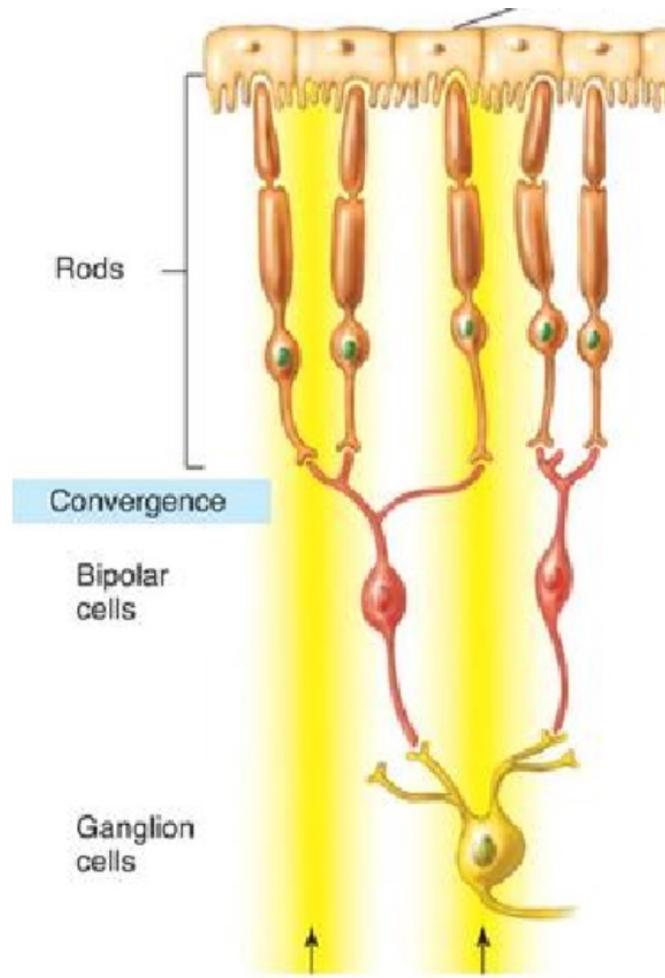
# Parallel processing, convergence



The retina

# Pro's and con's

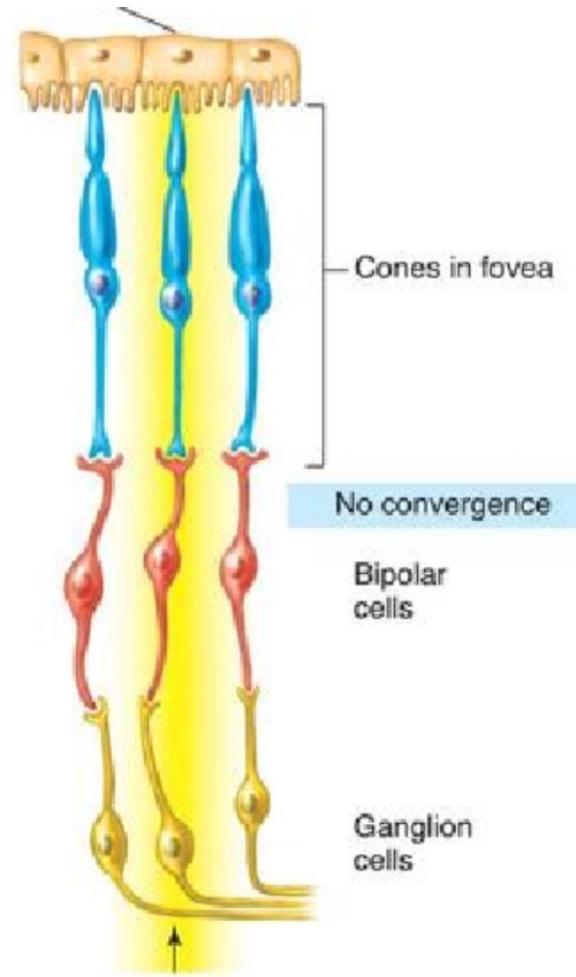
- + High sensitivity
- Low acuity



The retina

# Pro's and con's

- + High acuity
- Low sensitivity



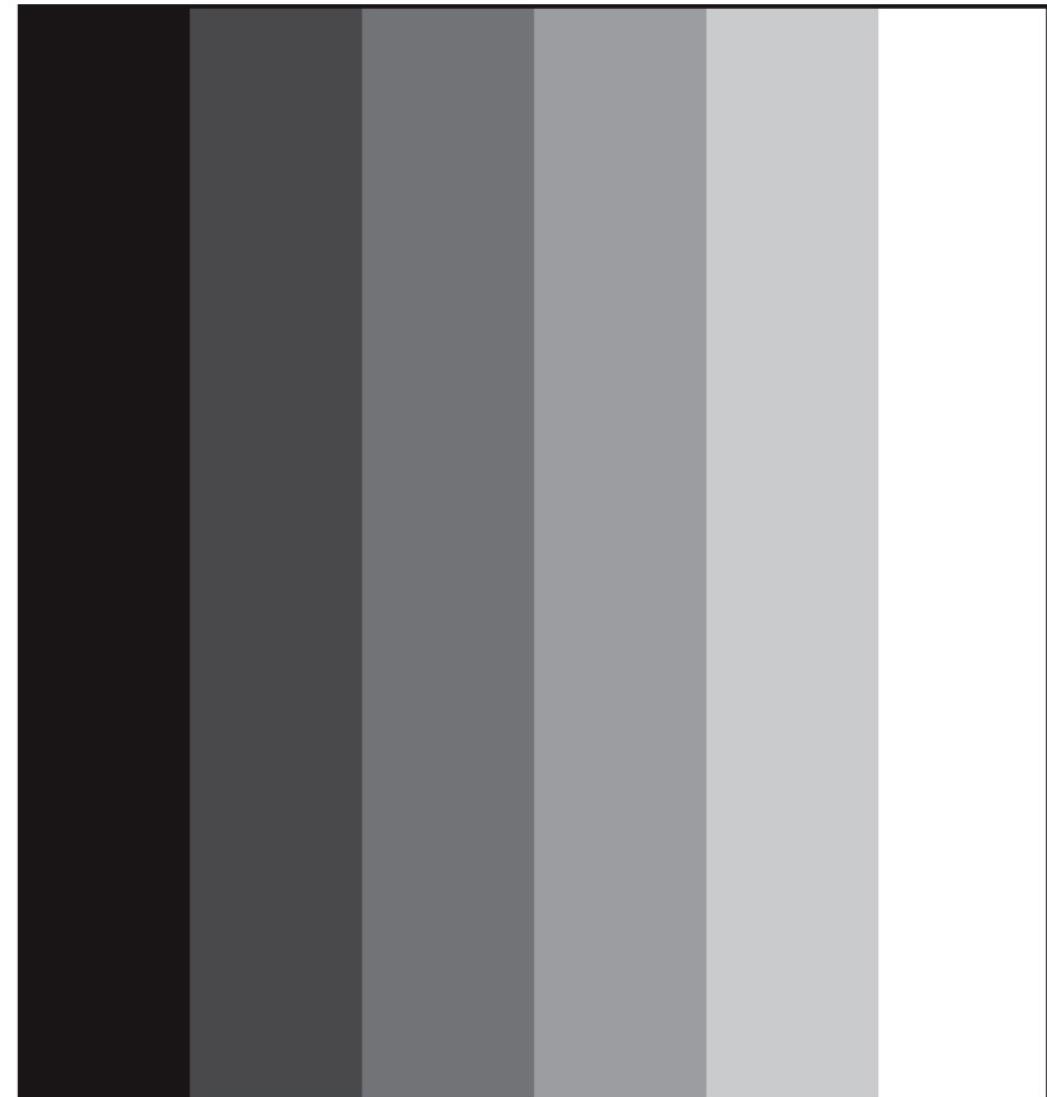
The retina

**WHY HAVE BOTH?**

# Lateral inhibition and Mach bands

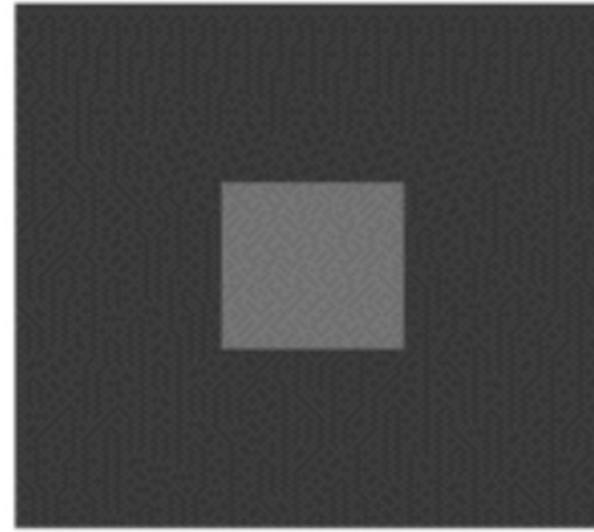
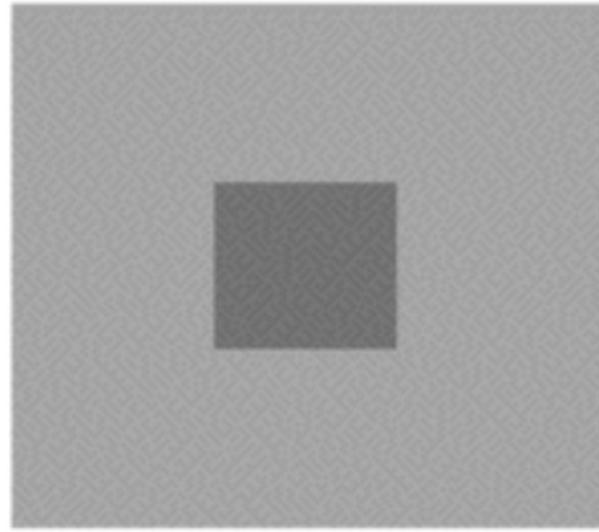
We are built to detect contrast,  
not to sense absolute values

(A)



Receptive fields

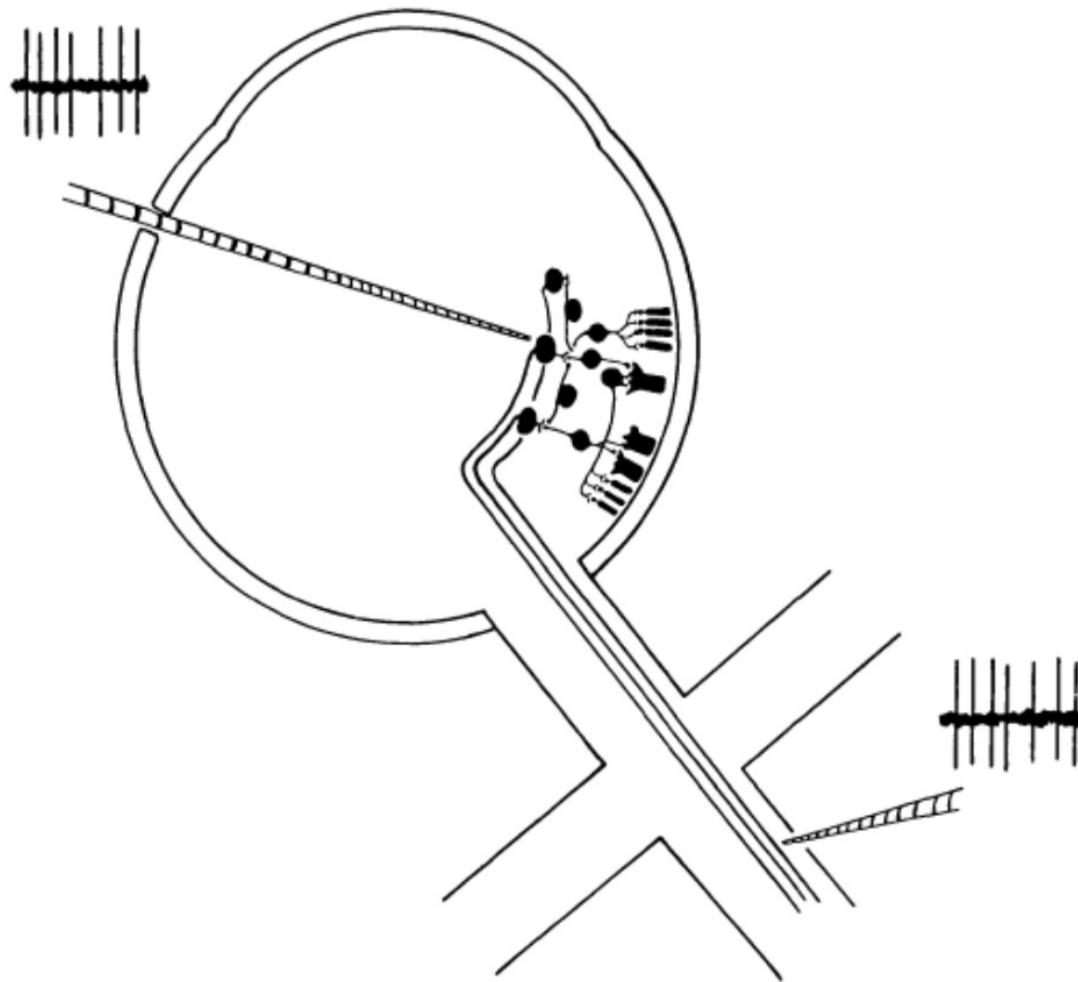
# Relative, not absolute values



- Centre-surround organization
- Contrast enhancement

Receptive fields

# How to measure receptive fields



Receptive fields

# ON and OFF channels

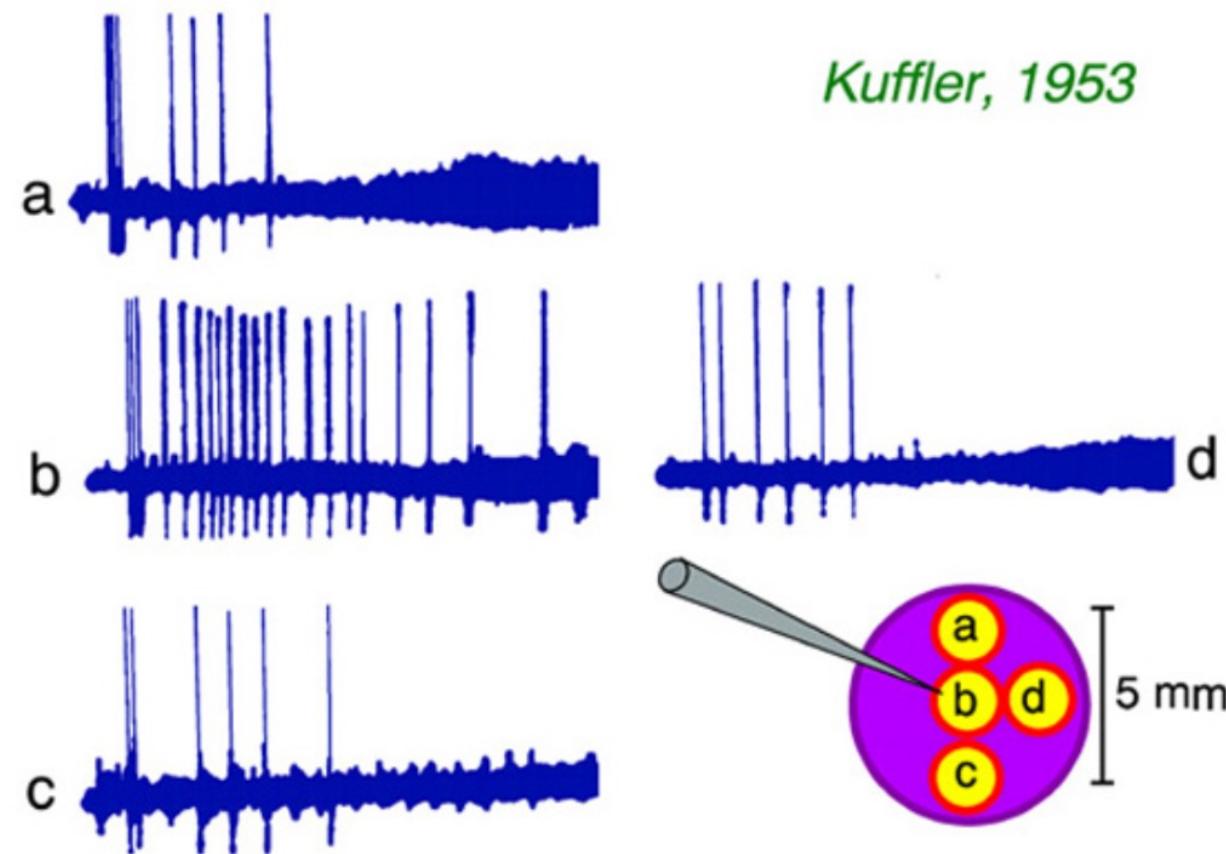
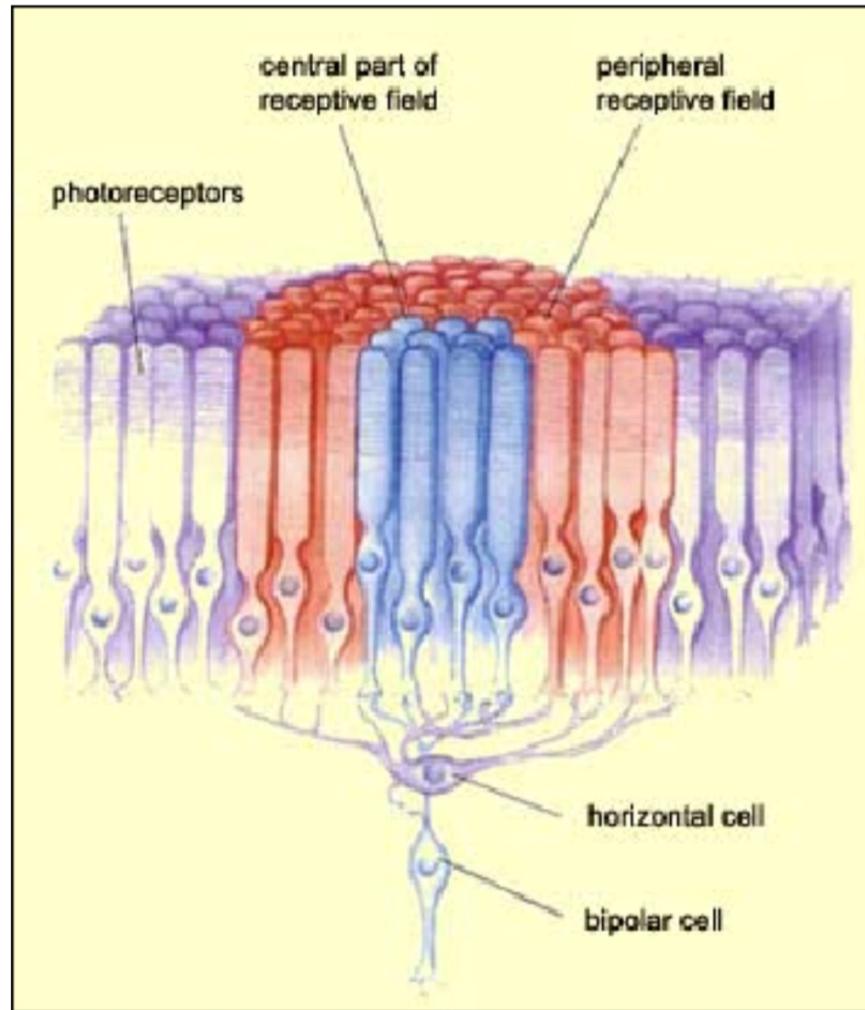


Fig. 5. Spot mapping of cat retinal ganglion cell receptive-field center (Kuffler, 1953).

Receptive fields

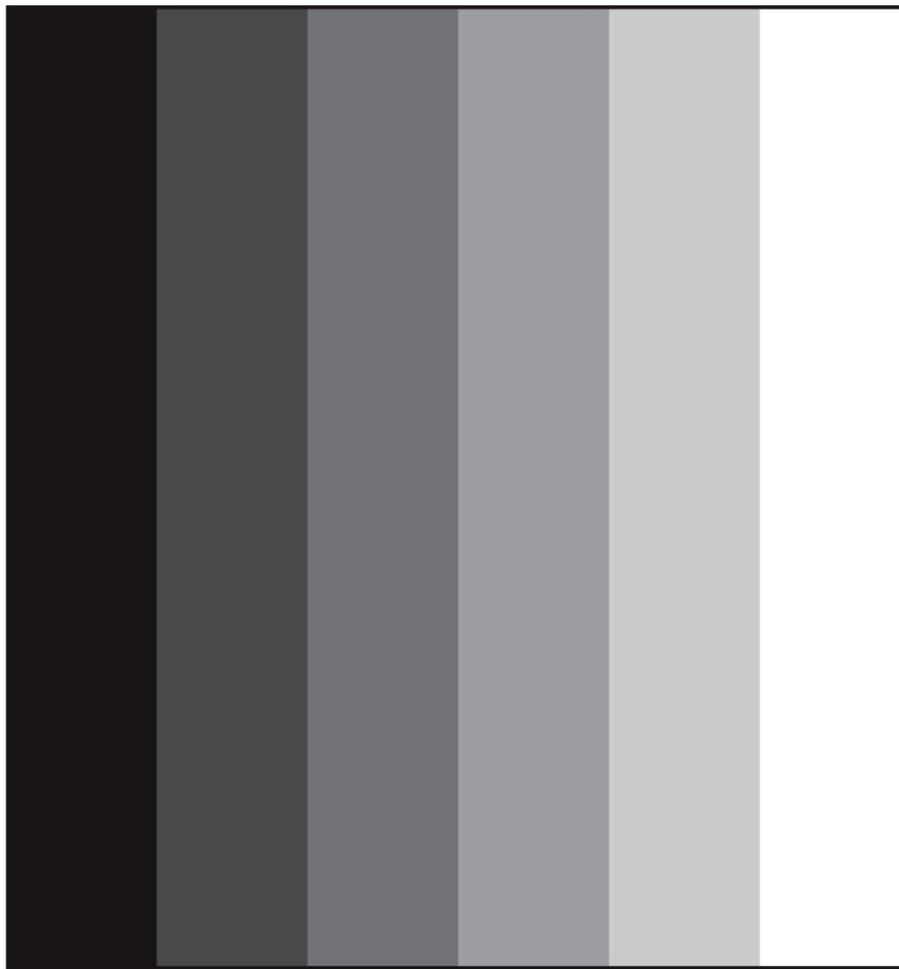
# ON and OFF channels via lateral inhibition



Receptive fields

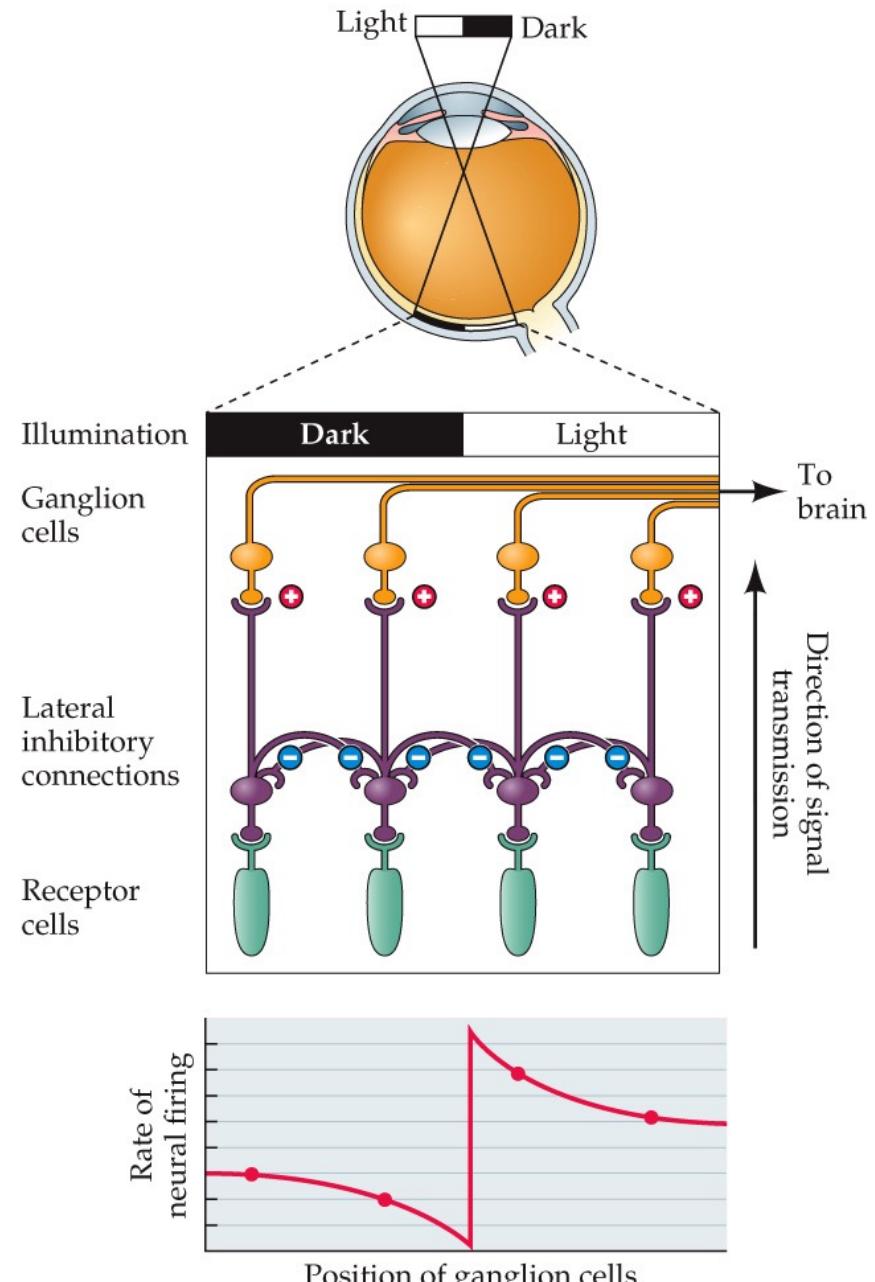
# Lateral Inhibition in the Retina

(A)



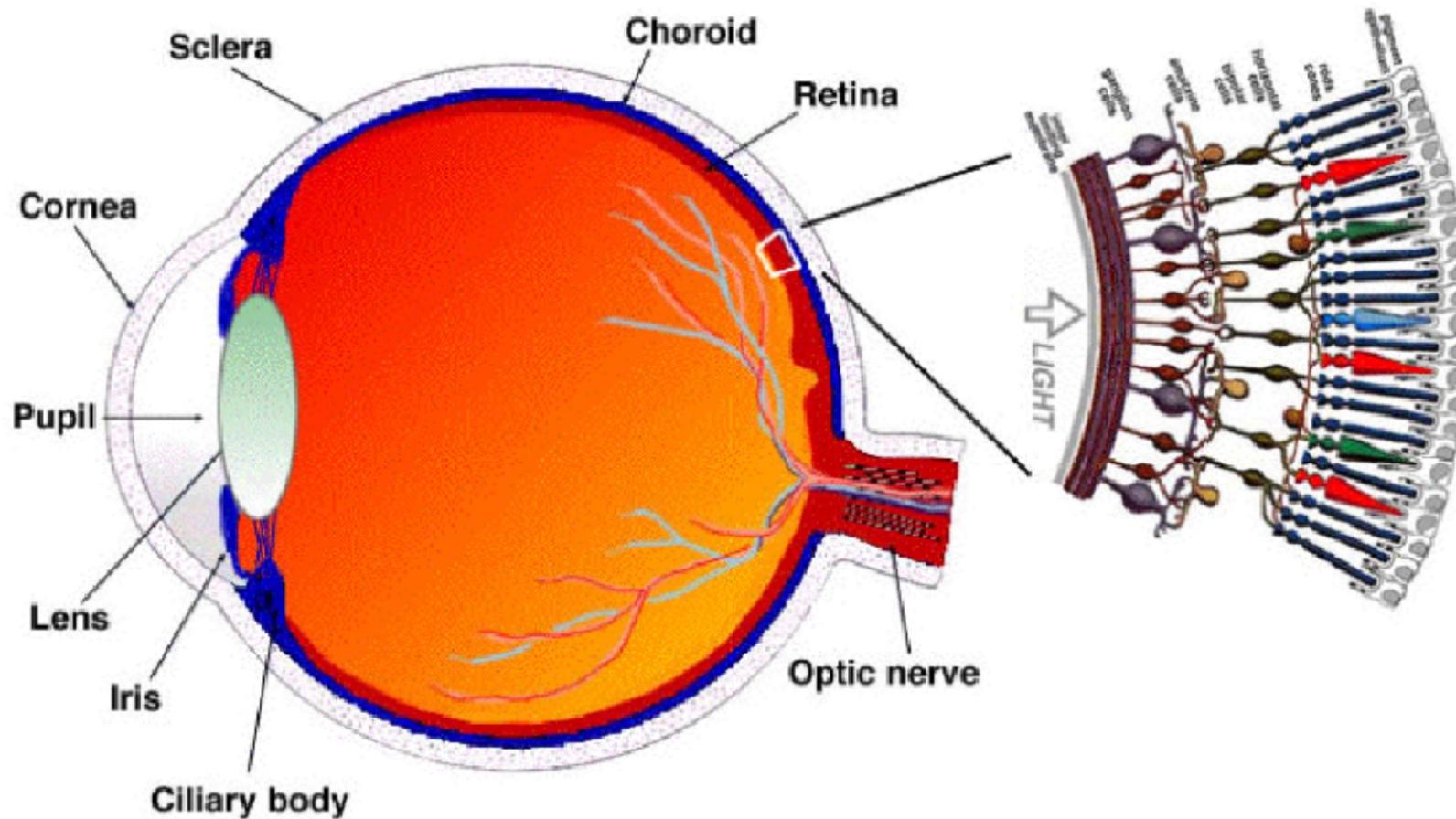
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## Receptive fields



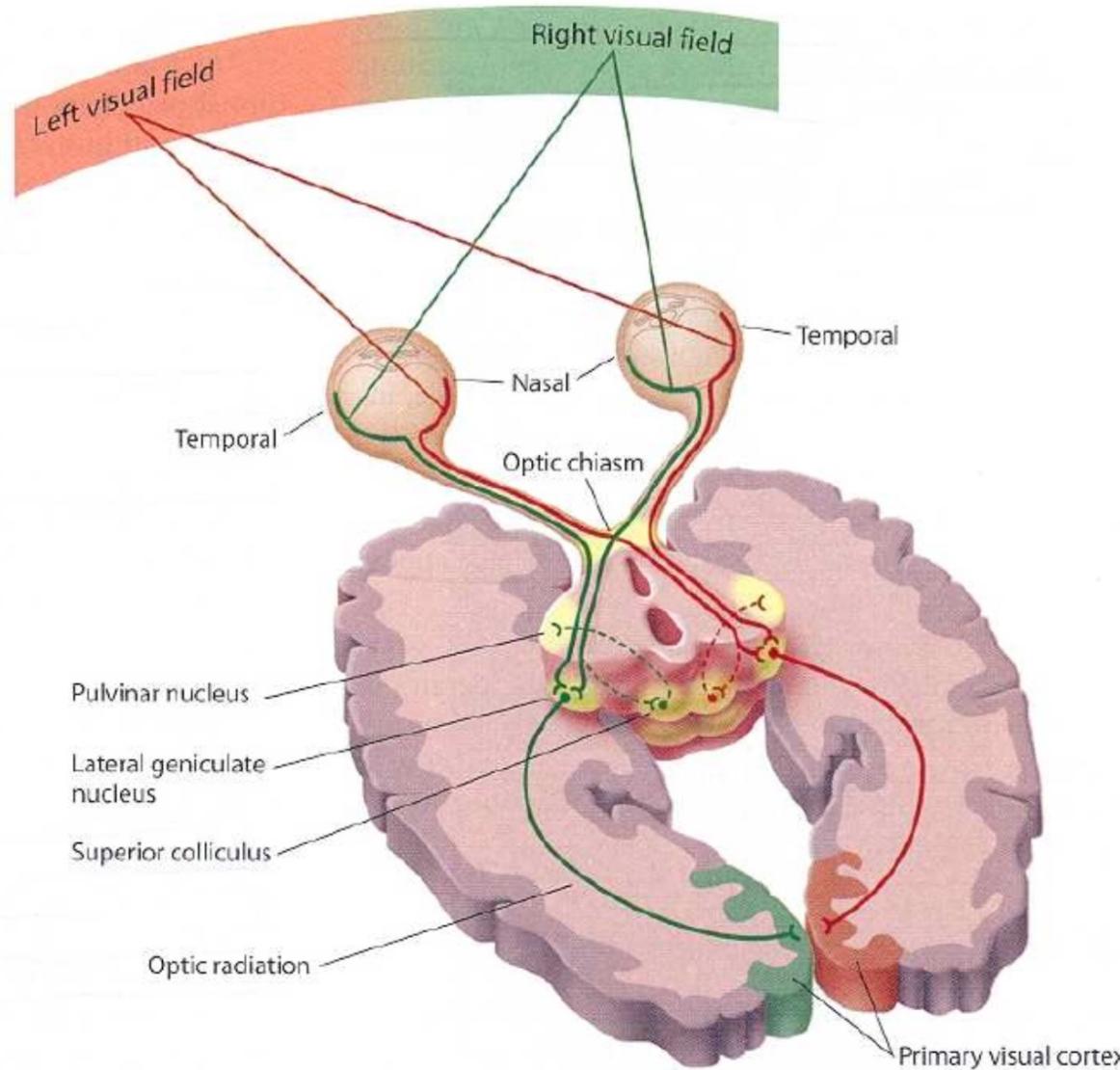
BEHAVIORAL NEUROSCIENCE 8e, Figure 10.8  
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# A messy path to travel 2: the revenge



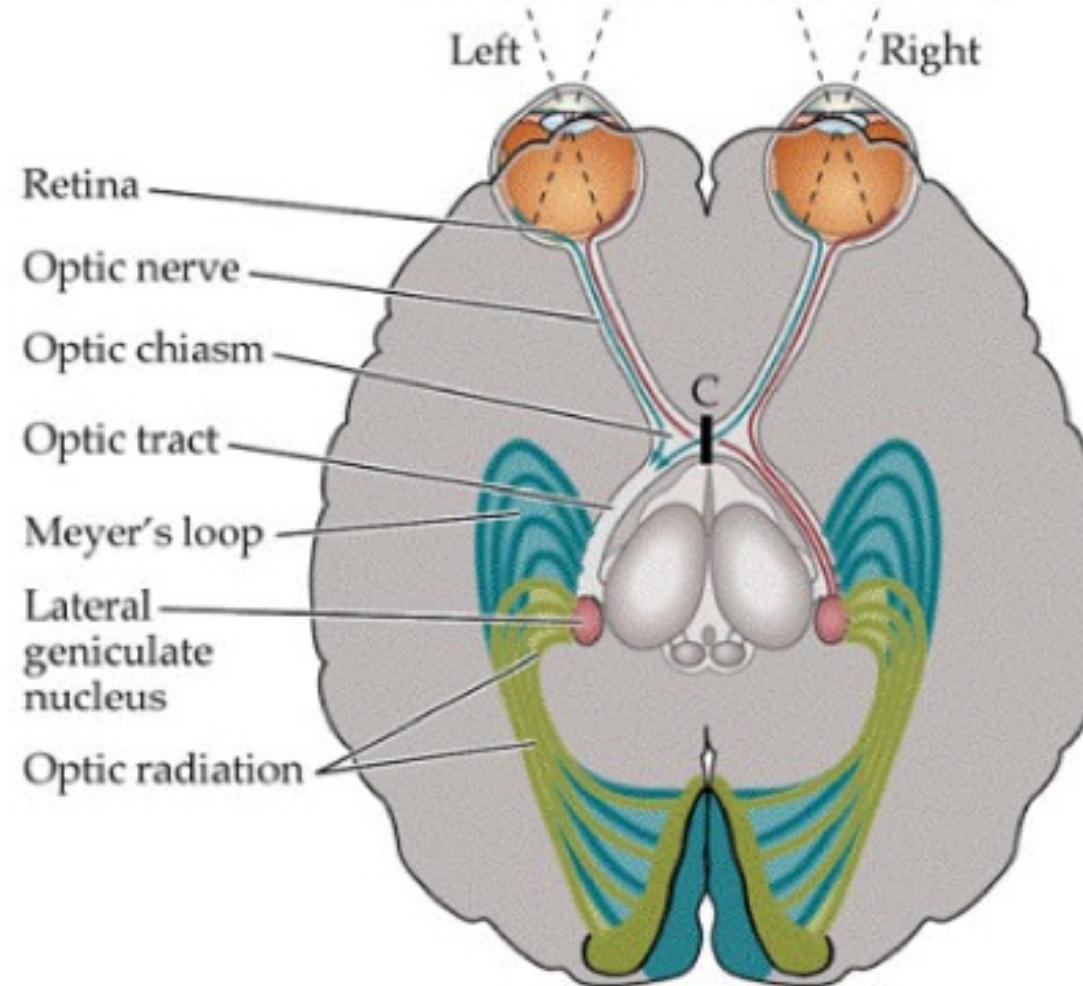
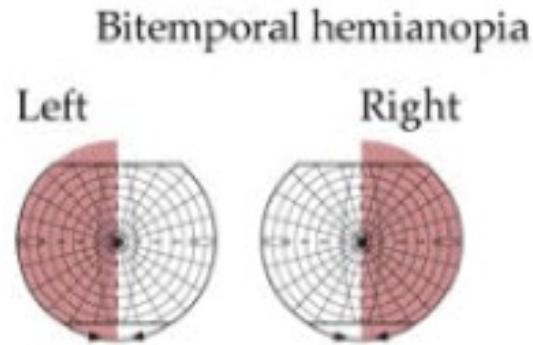
Pathways

# Optic nerve, chiasm, tract

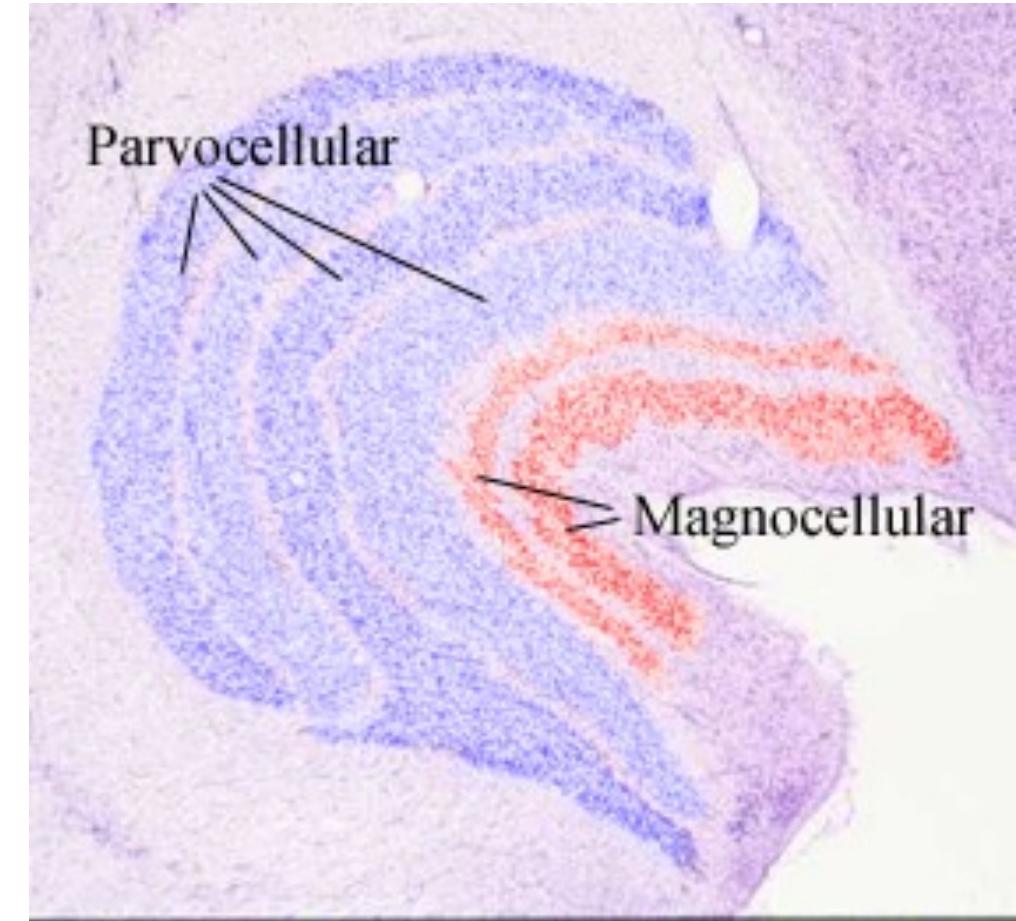
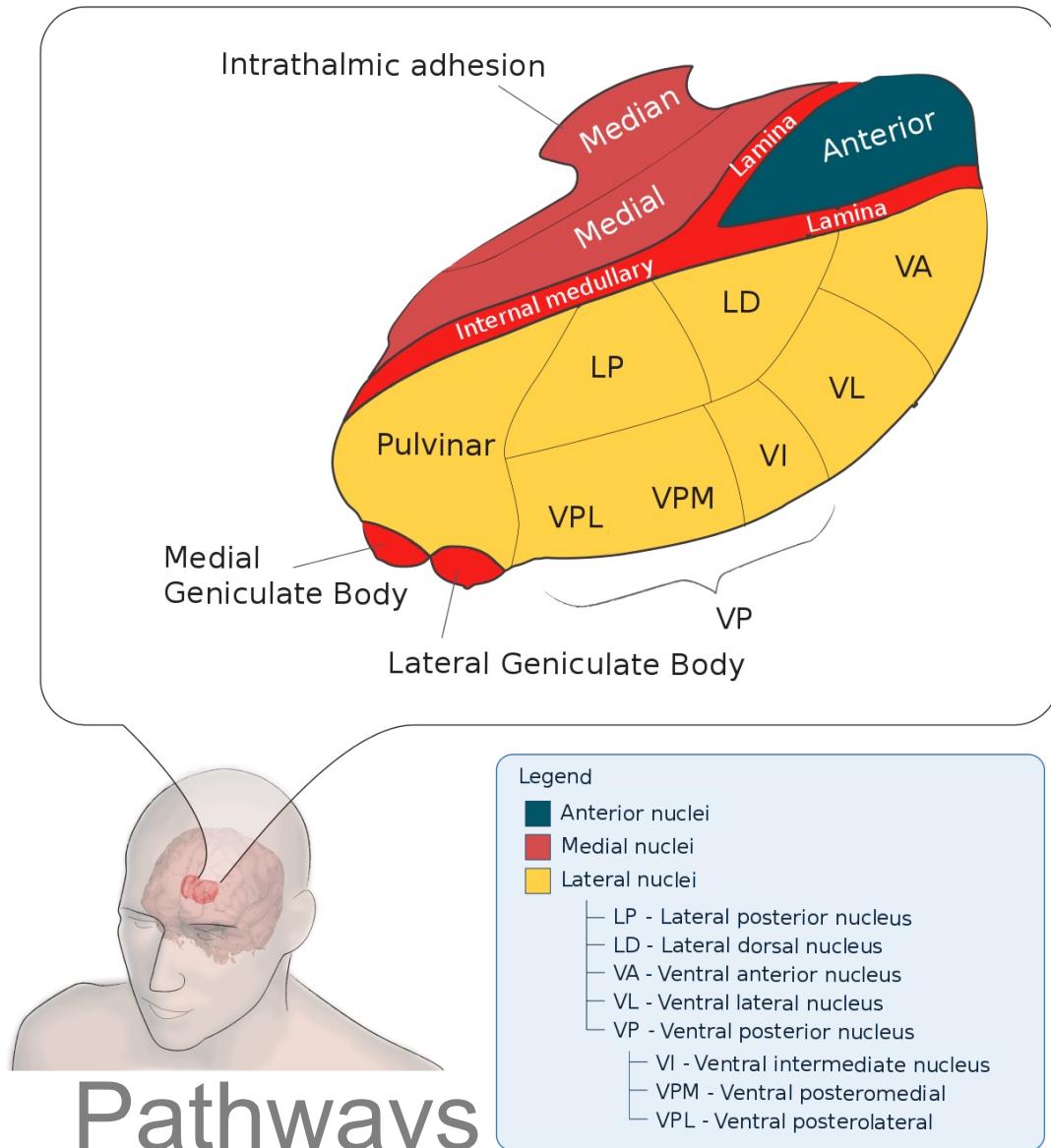


Pathways

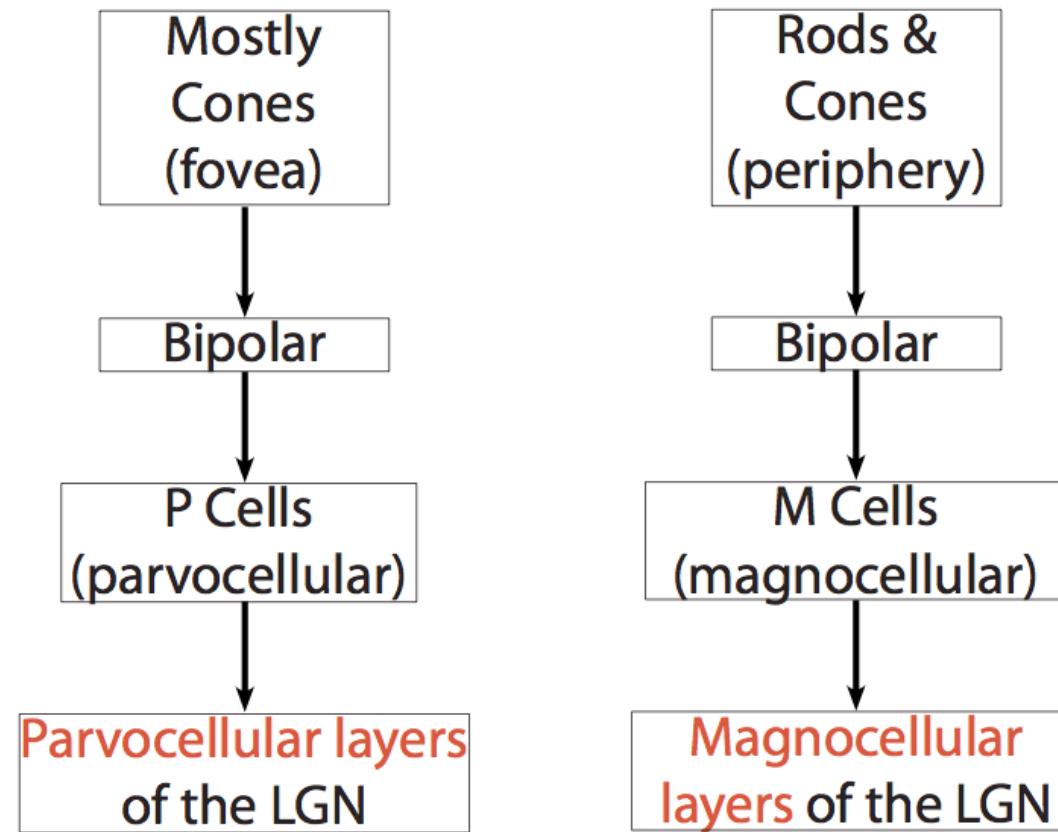
# Cutting the optic chiasm



# The lateral geniculate nucleus (LGN)



# Specialized processing



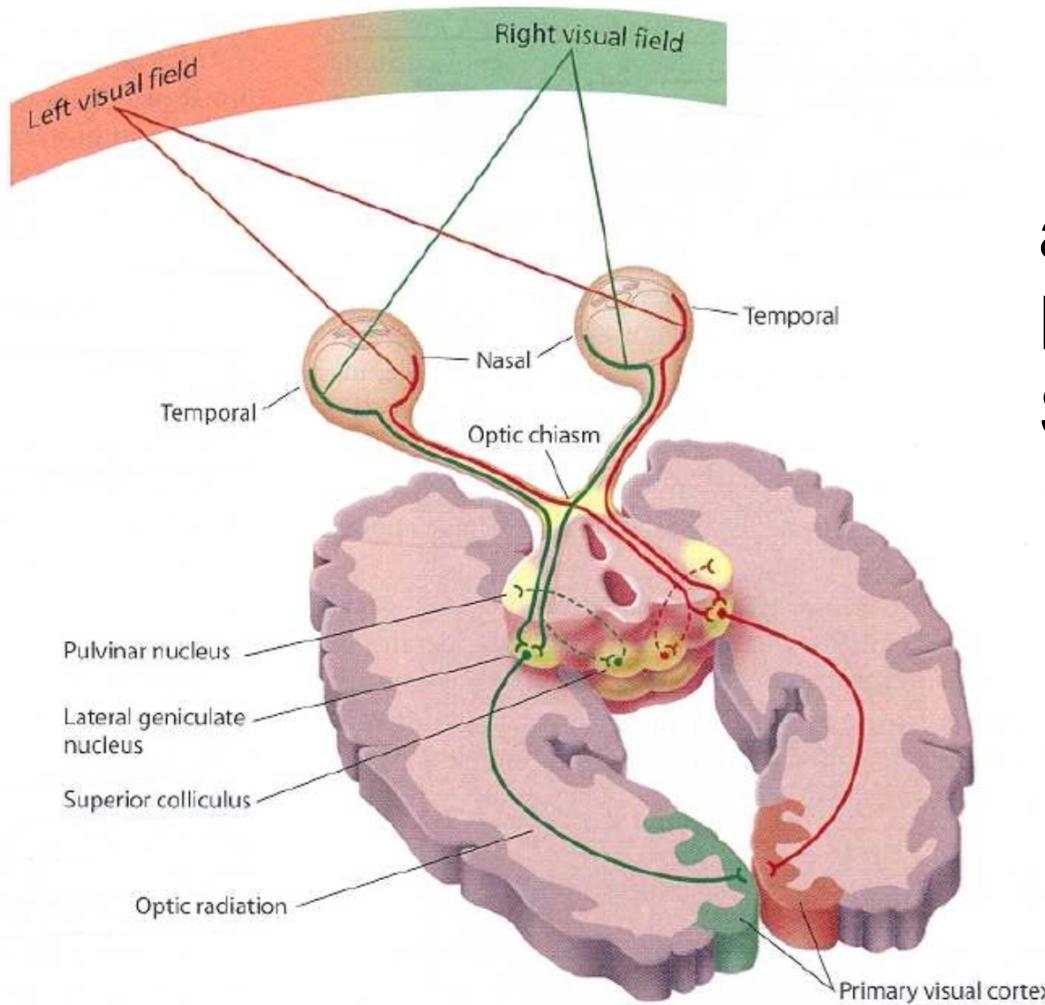
Handy mnemonic:

**P is for perception**

**M is for motion**

Pathways

# Welcome to V1, the primary visual cortex

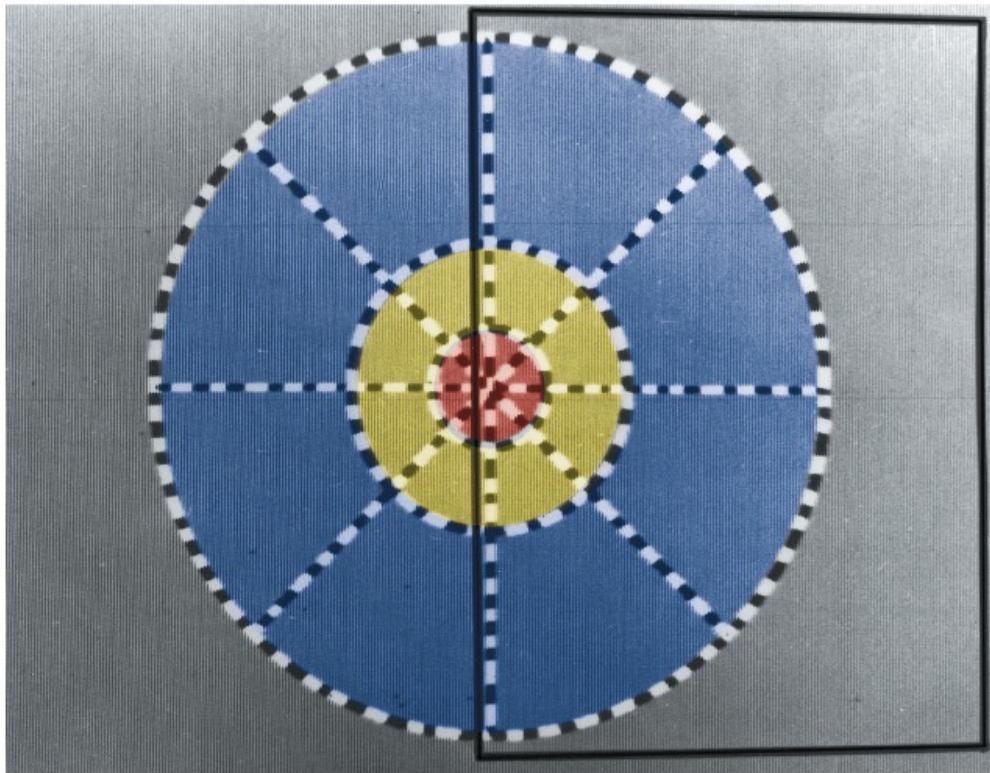


aka  
Brodmann Area 17  
Striate cortex

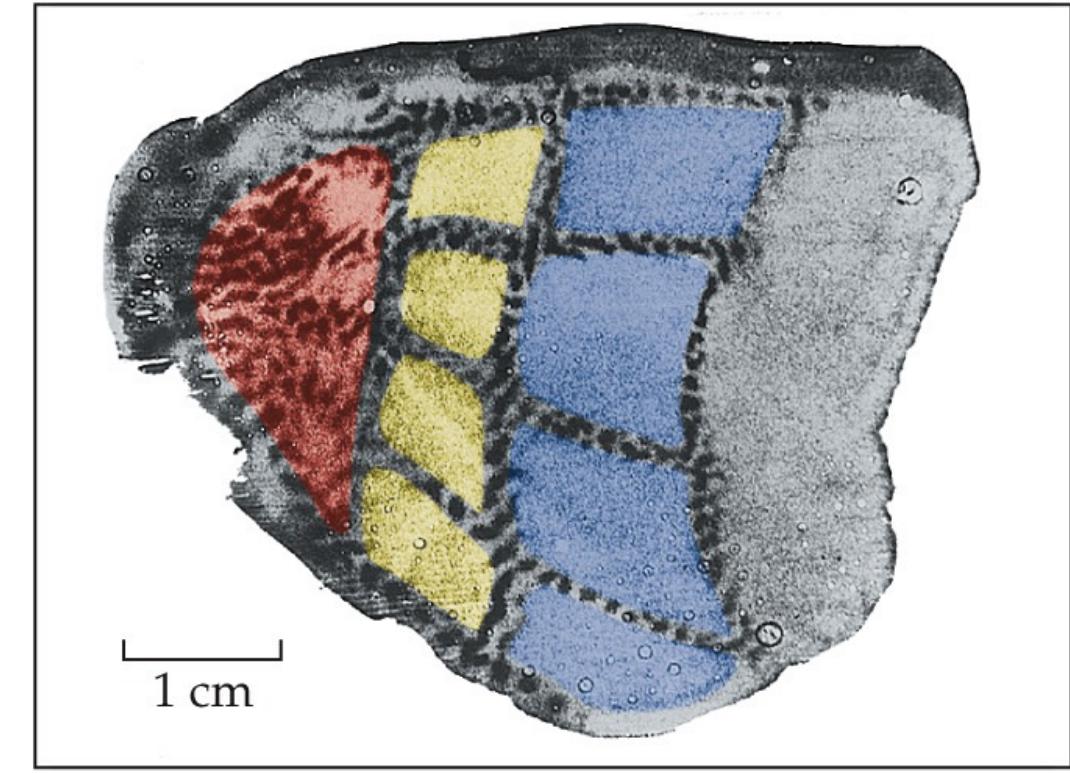
Visual Cortex

# Retinotopic map

(A) Monkey



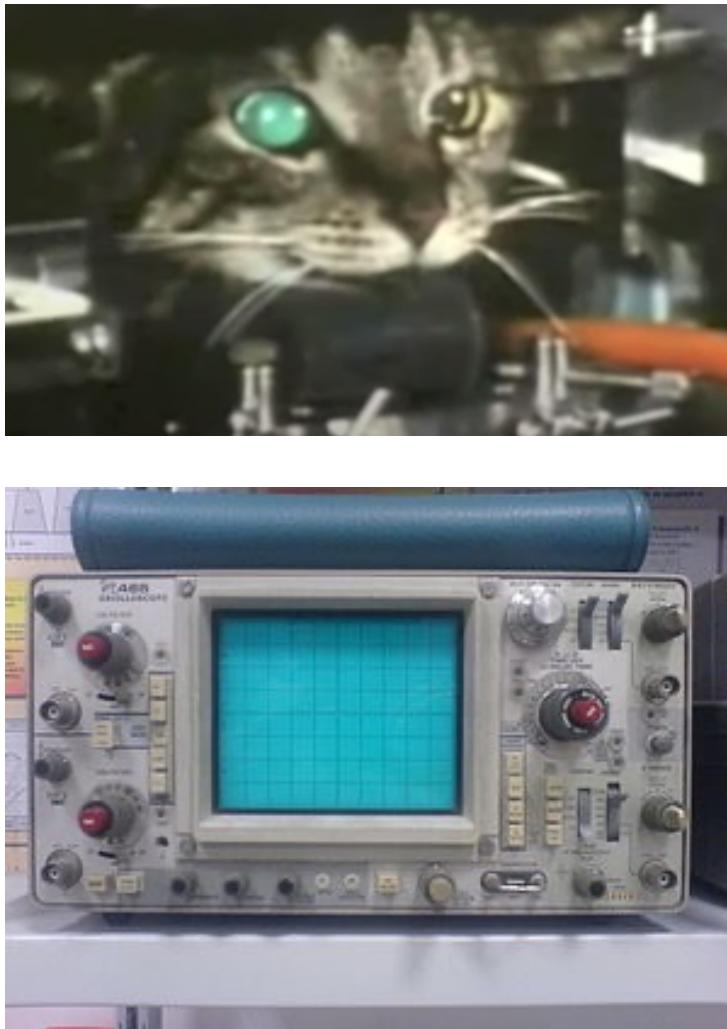
*BEHAVIORAL NEUROSCIENCE 8e, Figure 10.11 (Part 1)*  
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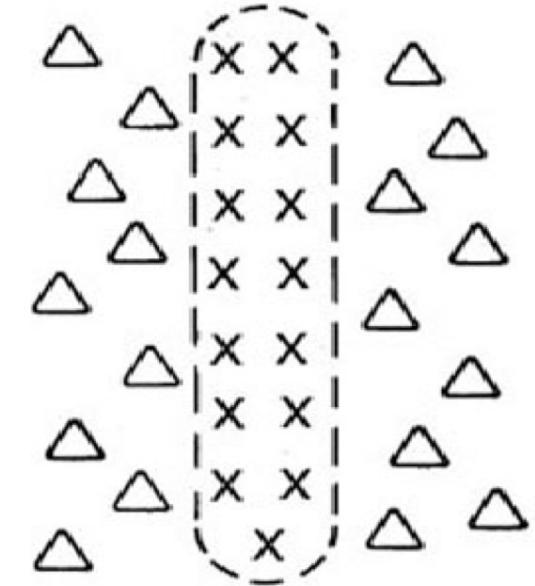
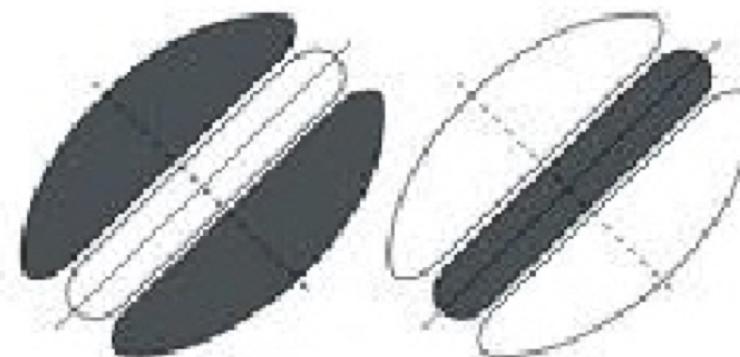
Cortical magnification, again

Visual Cortex

# Simple cells



Visual Cortex

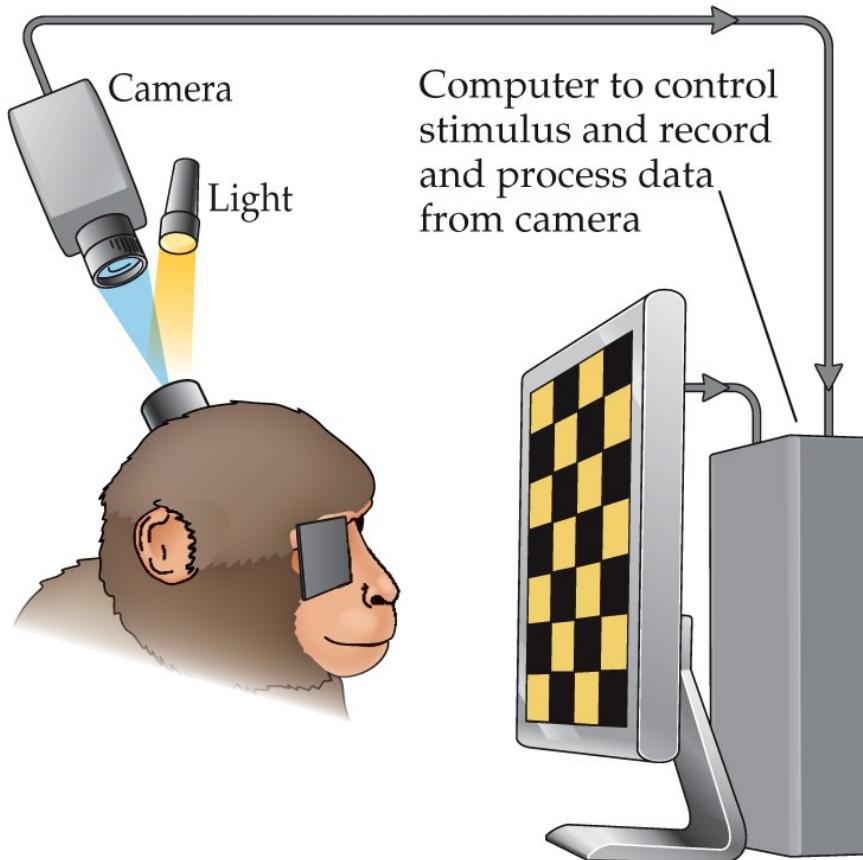


**x** = Excitatory area  
**△** = Inhibitory area

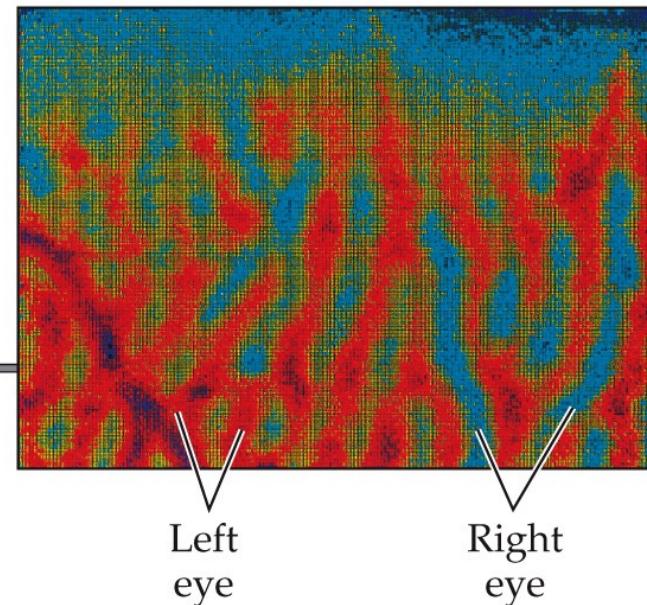
<https://www.youtube.com/watch?v=IOHayh06LJ4>  
<https://www.youtube.com/watch?v=8VdFf3egwfg>

# Ocular Dominance Columns

(A) Method for visualization of  
ocular dominance slabs



(B)

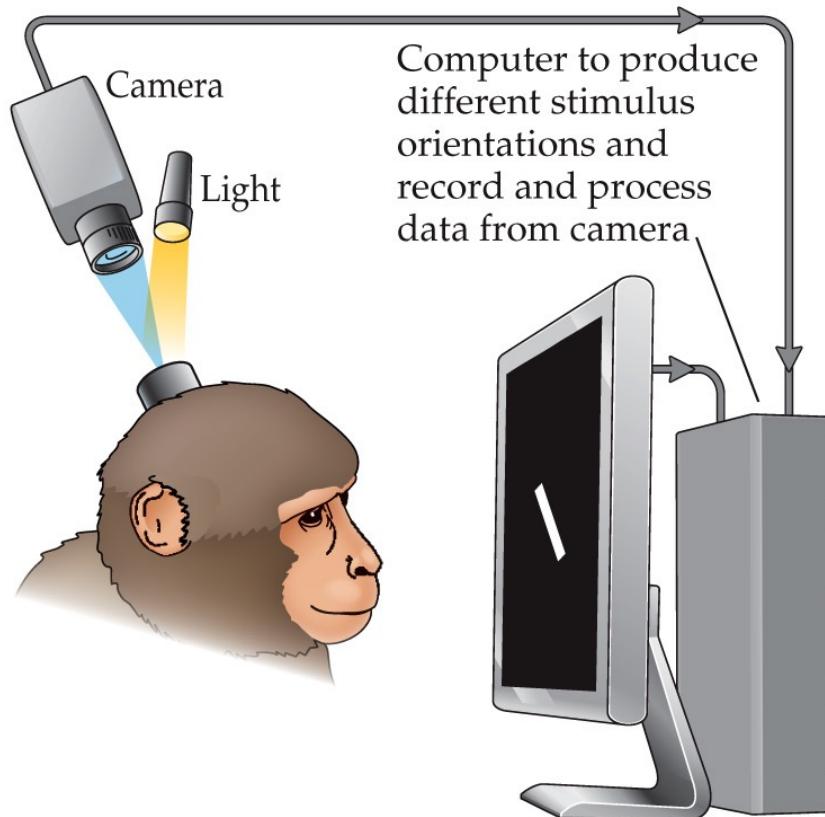


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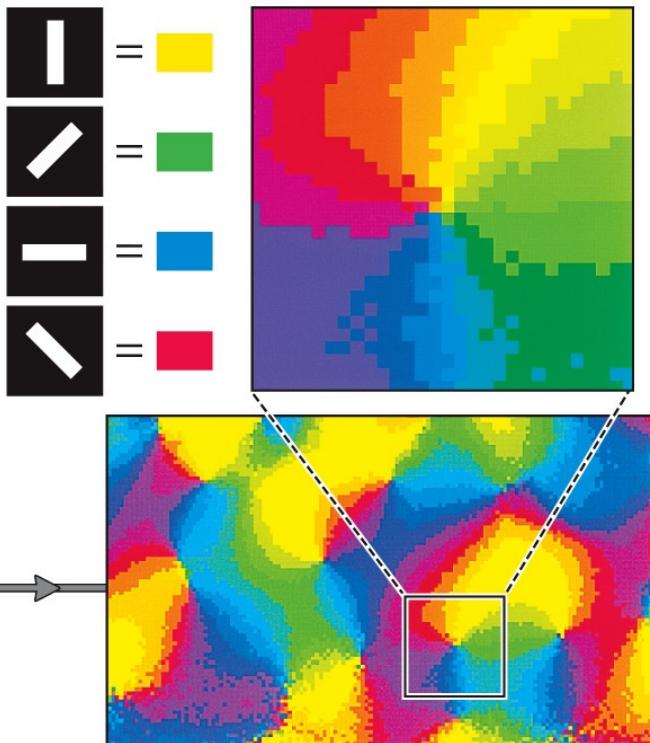
Visual Cortex

# Orientation Columns

(C) Method for visualization  
of orientation columns



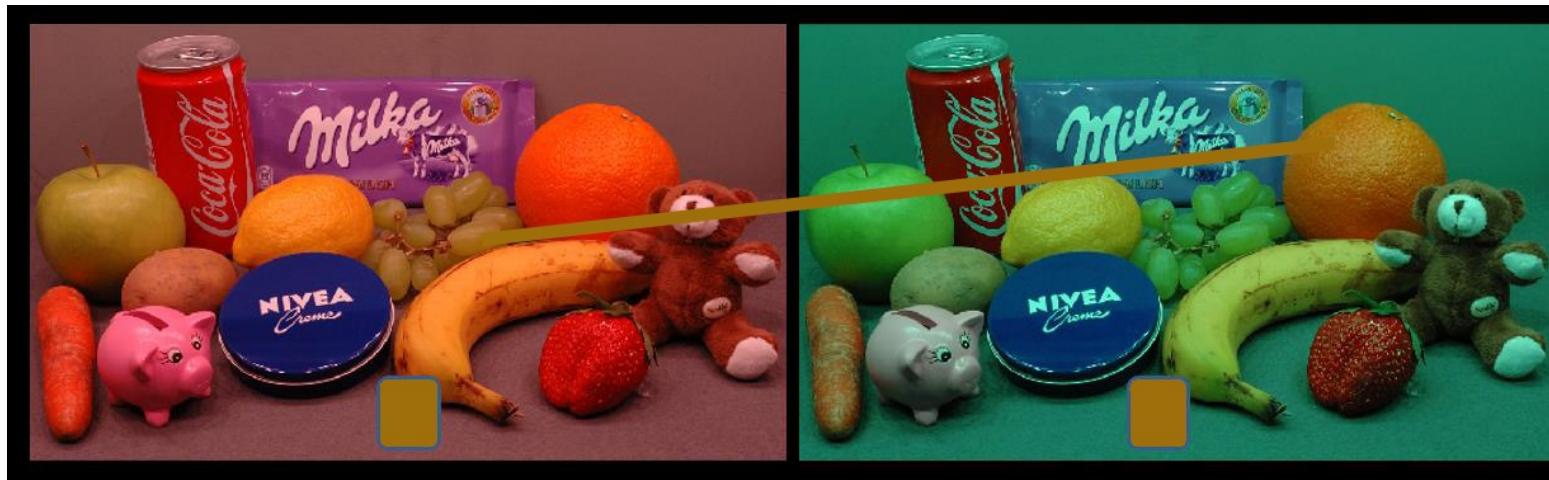
(D)



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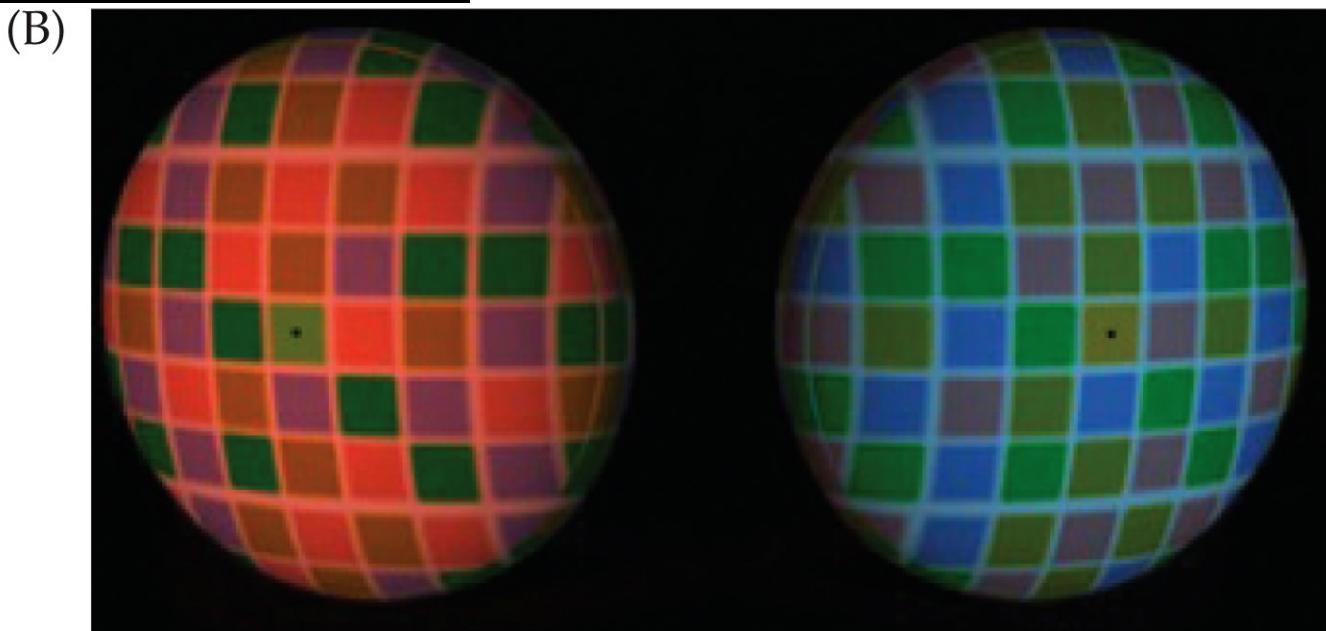
## Visual Cortex

# Colour perception: not simply wavelength



(B)

Colour constancy  
Visual Cortex



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# Theories of colour

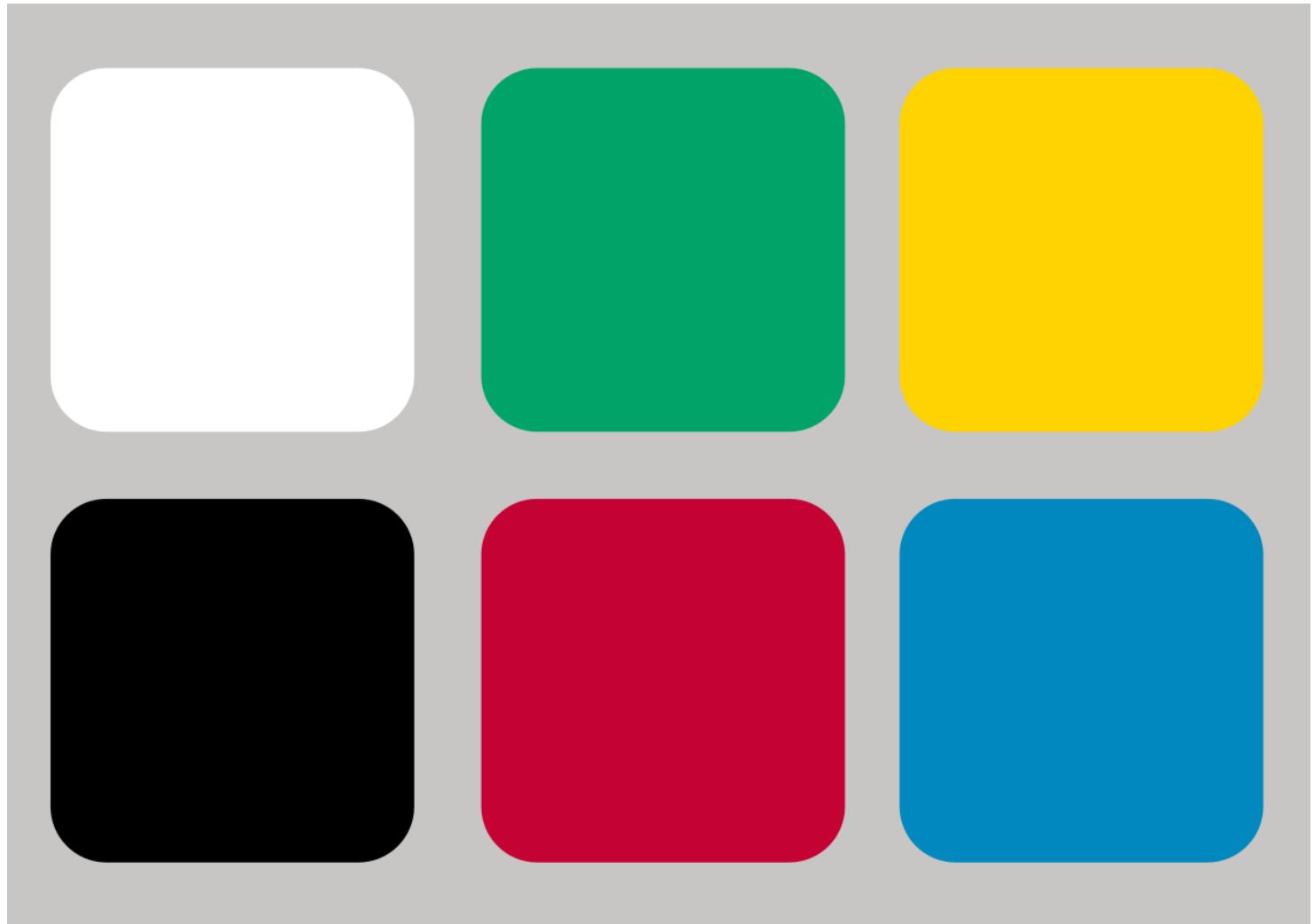
- Colour processing occurs in two stages.
  - 1. Young-Helmholtz trichromatic theory



Visual Cortex (well, this one is in the retina)

# Theories of colour

- Colour processing occurs in two stages.
  - 2. Hering's opponent process theory



Visual Cortex (this one's really cortex)

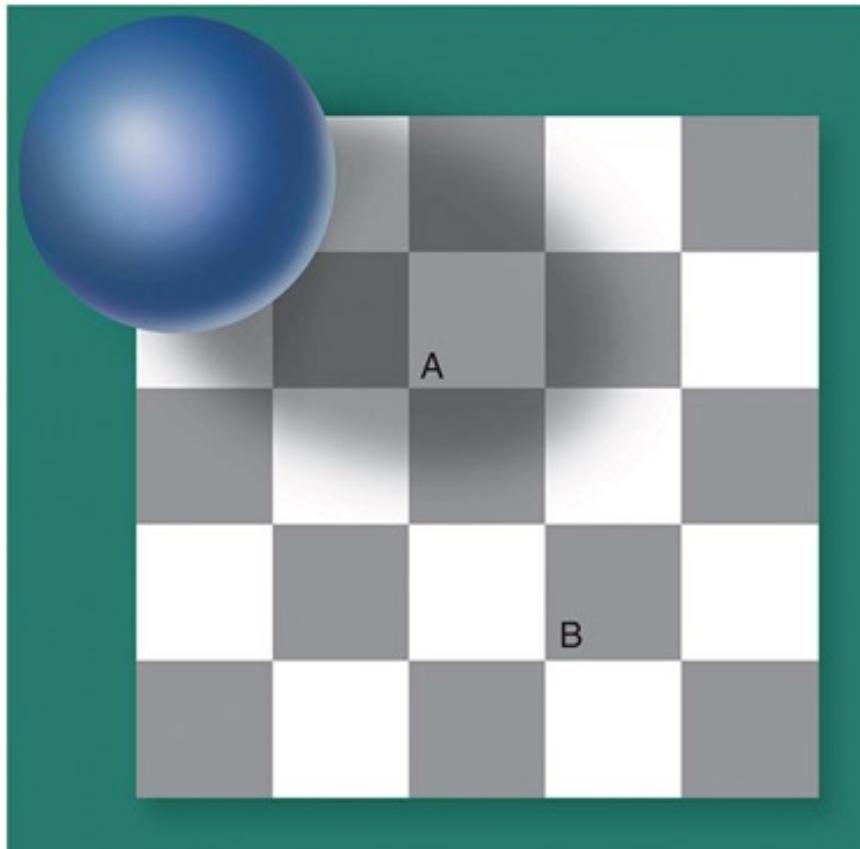
# Theories of colour

- Colour processing occurs in two stages.
  - 2. Hering's opponent process theory

These two theories alone are still insufficient  
(i.e. a lot of colour perception is top-down)

Visual Cortex (this one's really cortex)

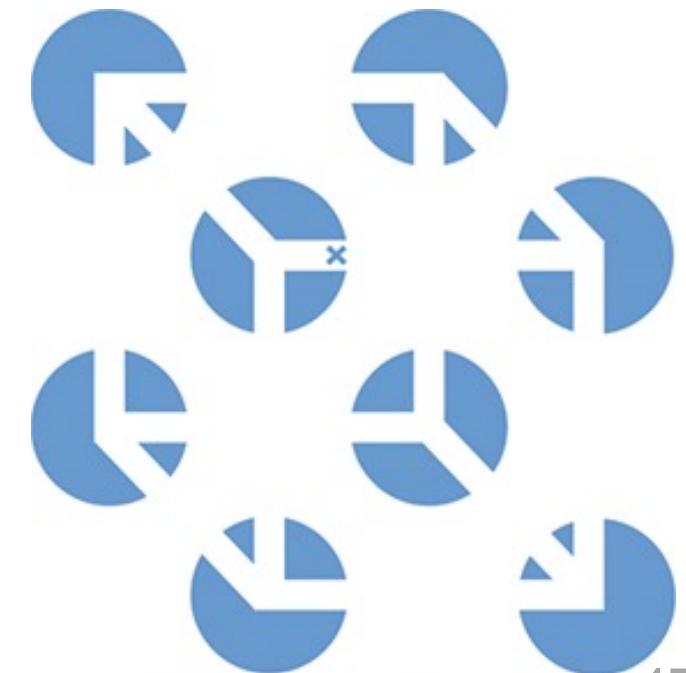
# Reminder: Perception is heavily influenced by top-down processes



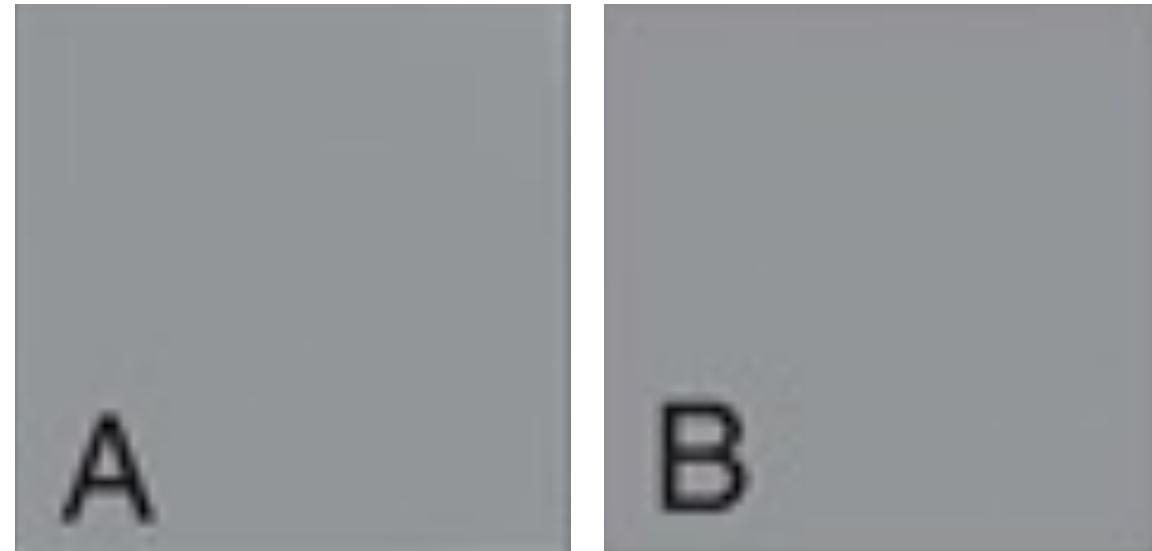
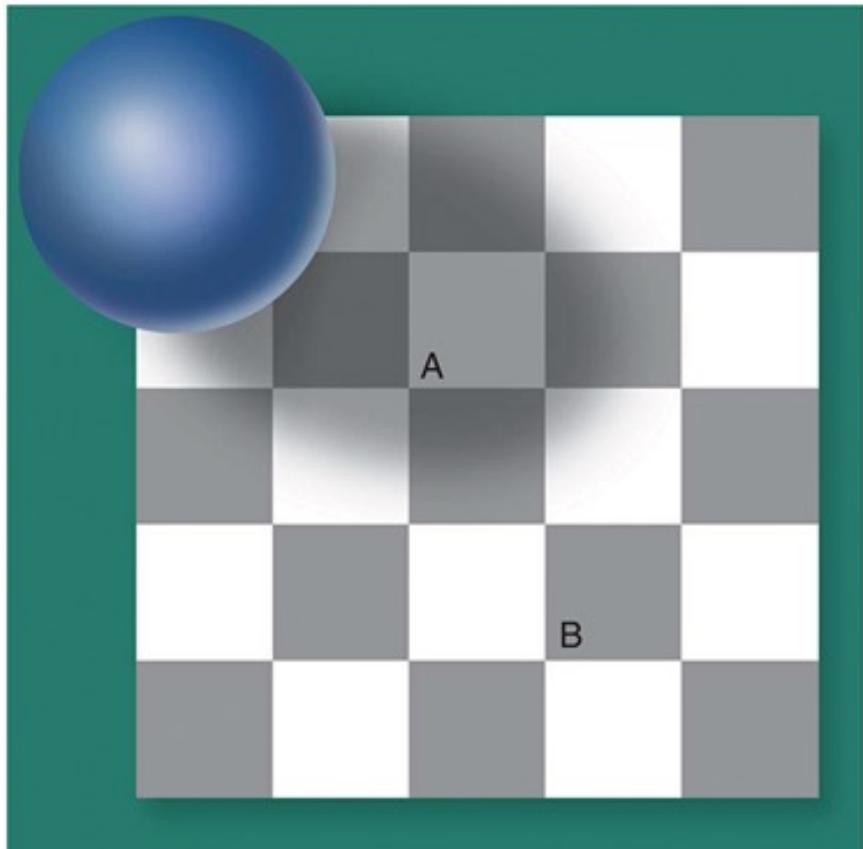
Visual Cortex



Perceptual constancy

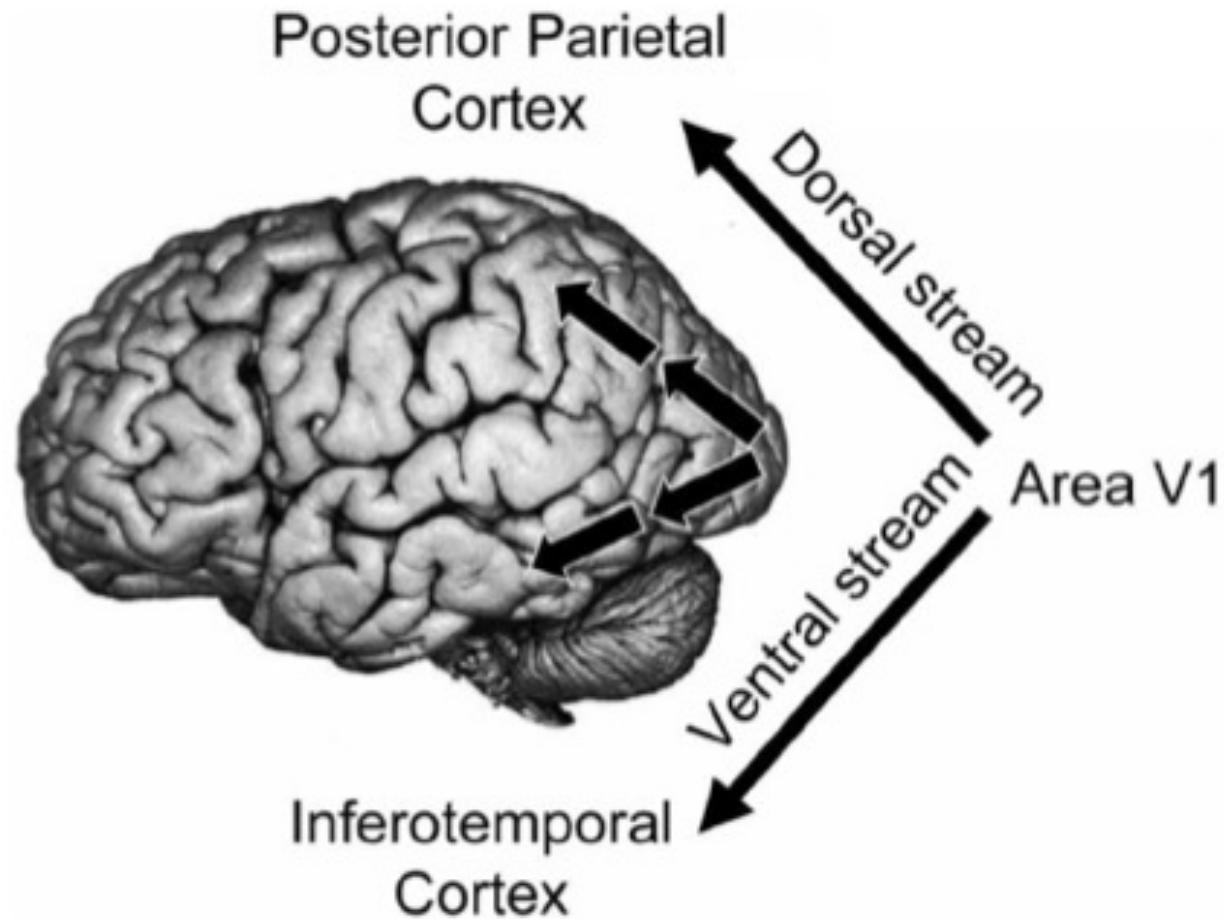


# Reminder: Perception is heavily influenced by top-down processes



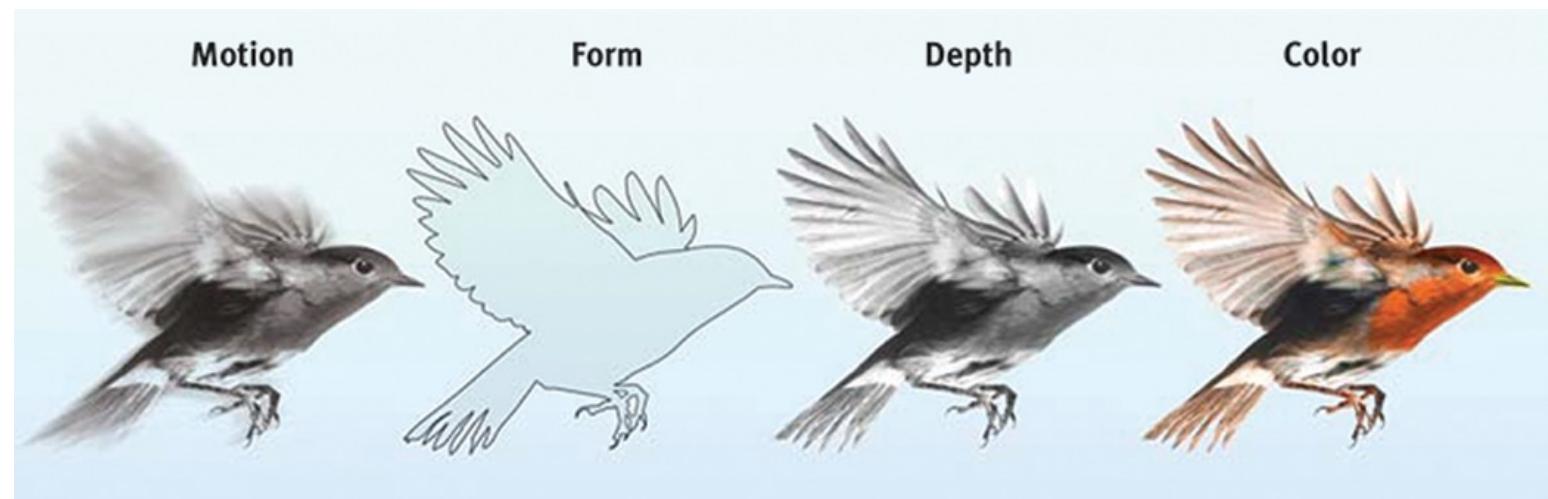
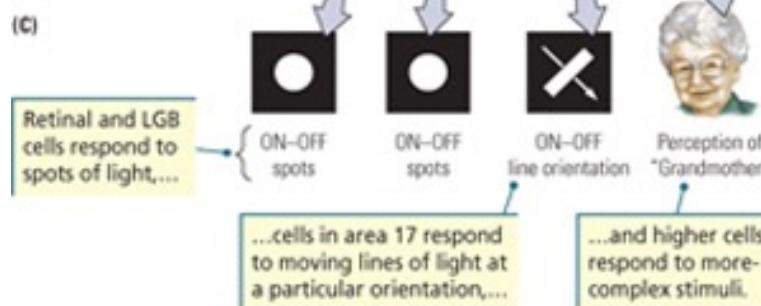
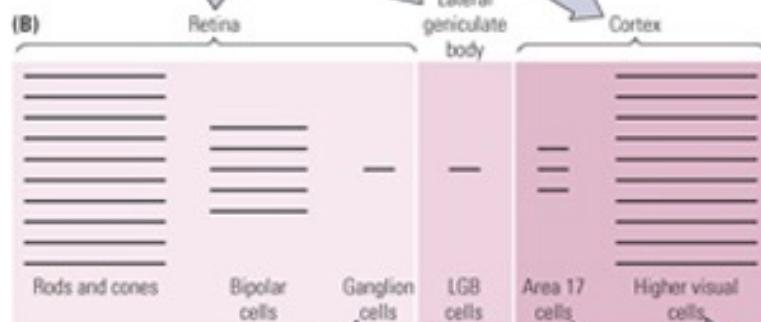
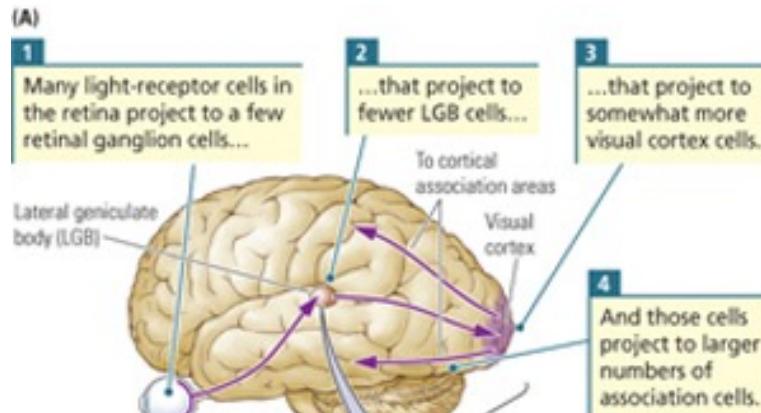
Visual Cortex

# Specialized processing continues!



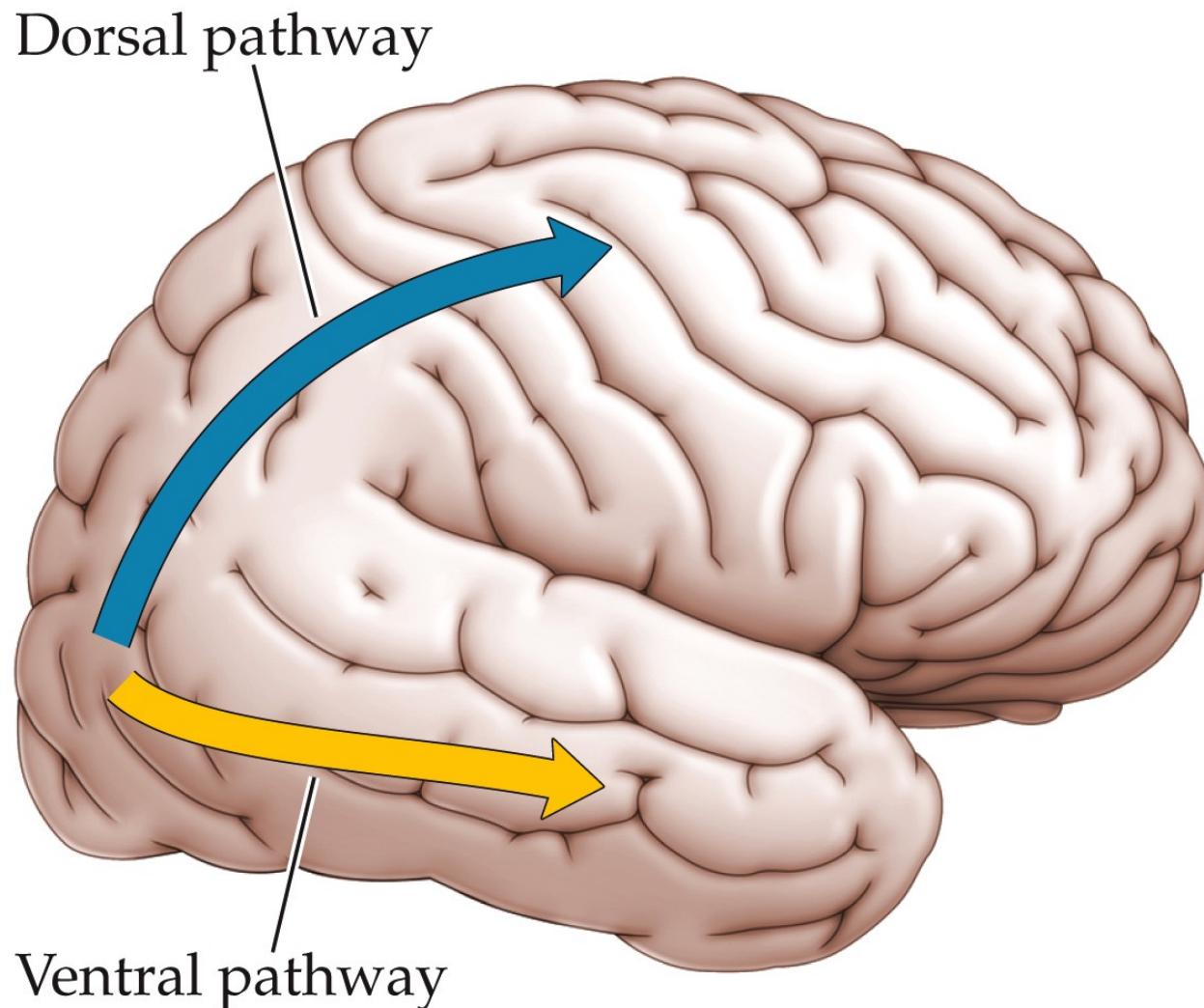
Visual Cortex

# Parallel processing



Visual Cortex  
50

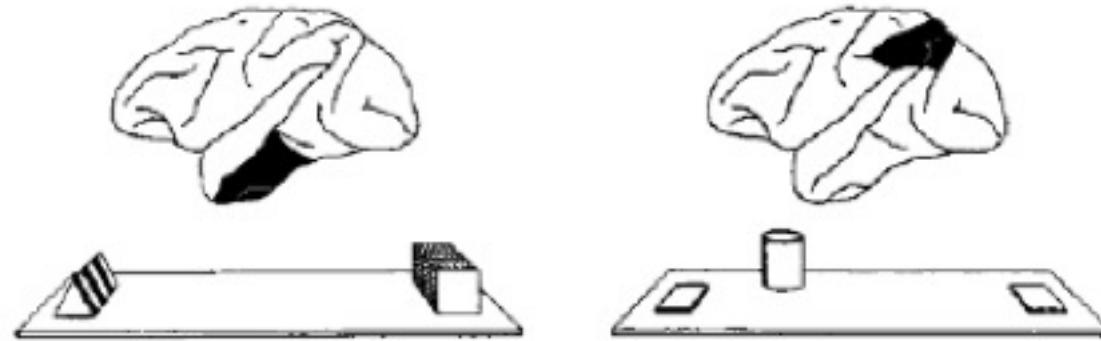
# Specialized processing continues!



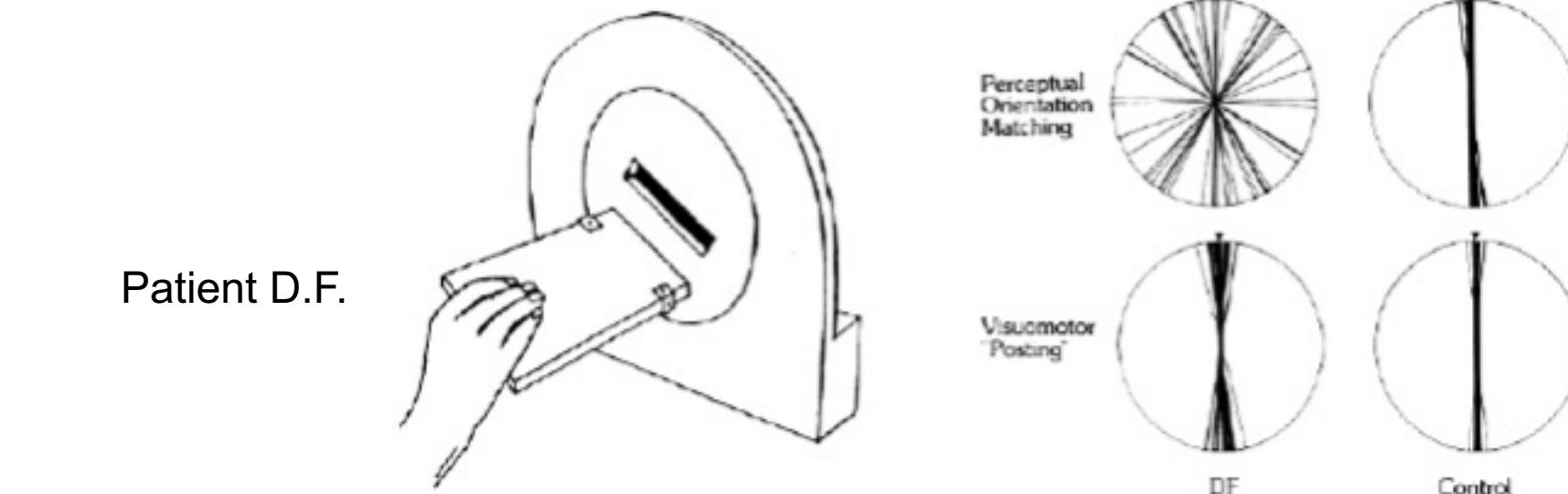
Visual Cortex

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# Cortical damage may not affect all vision

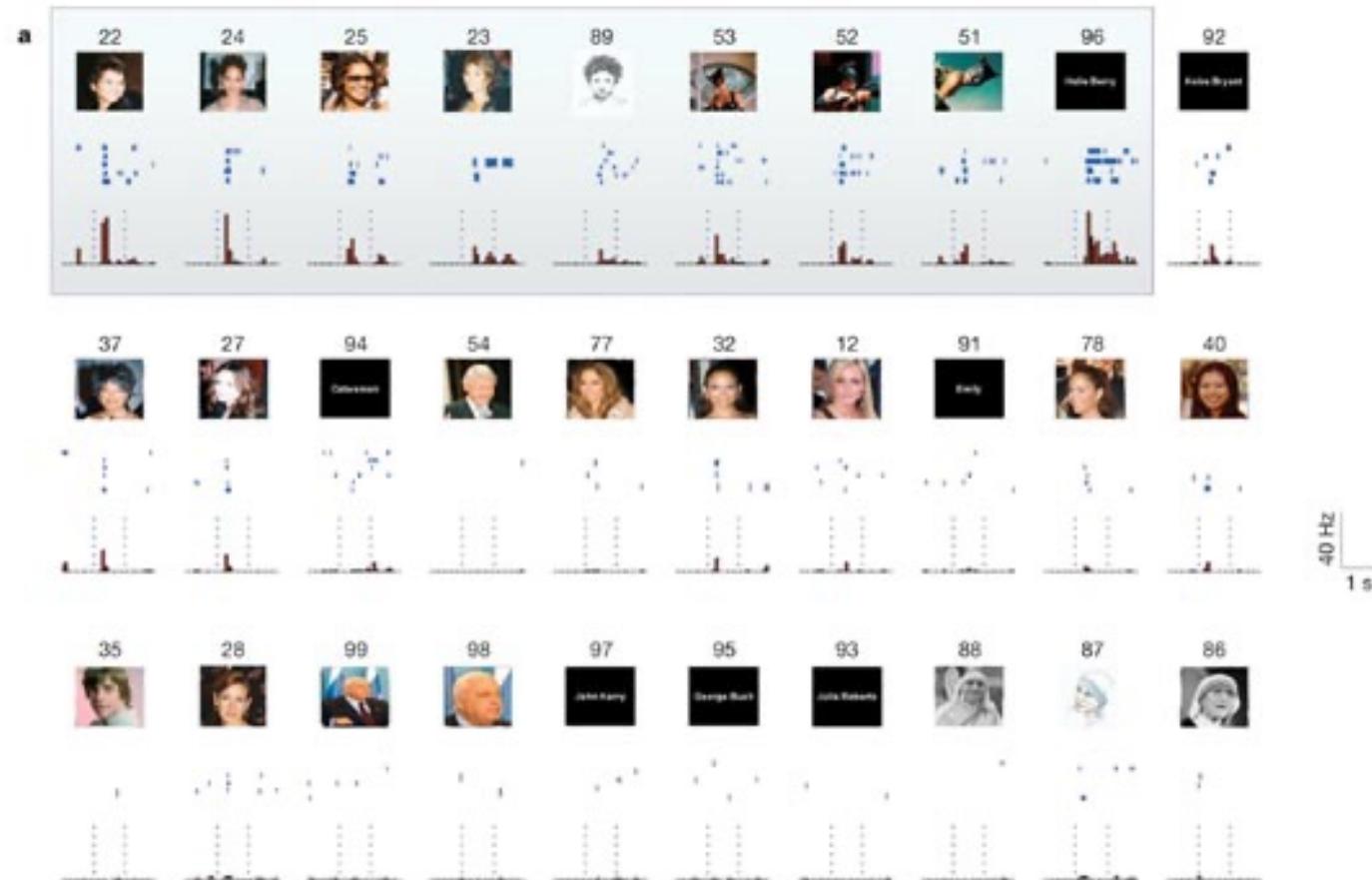


Monkeys



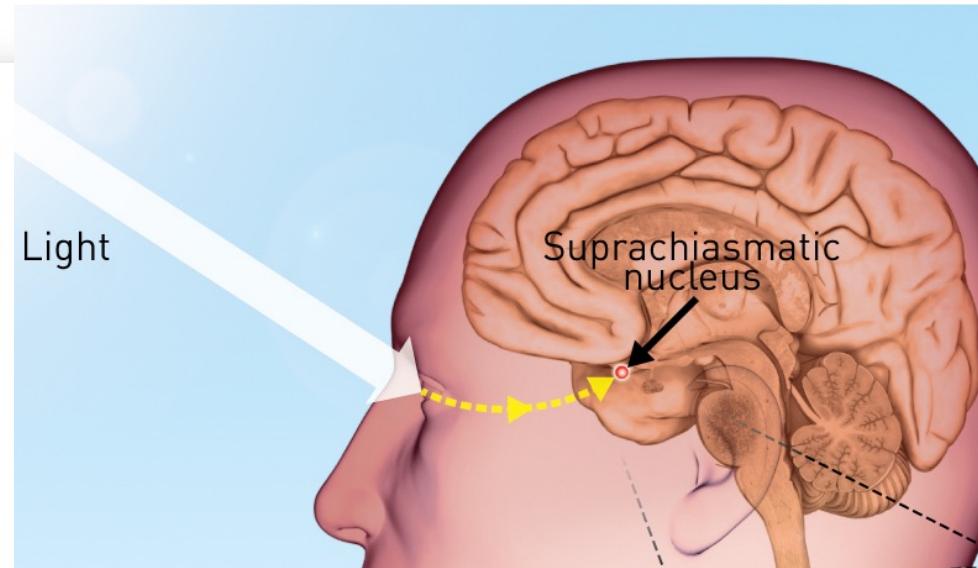
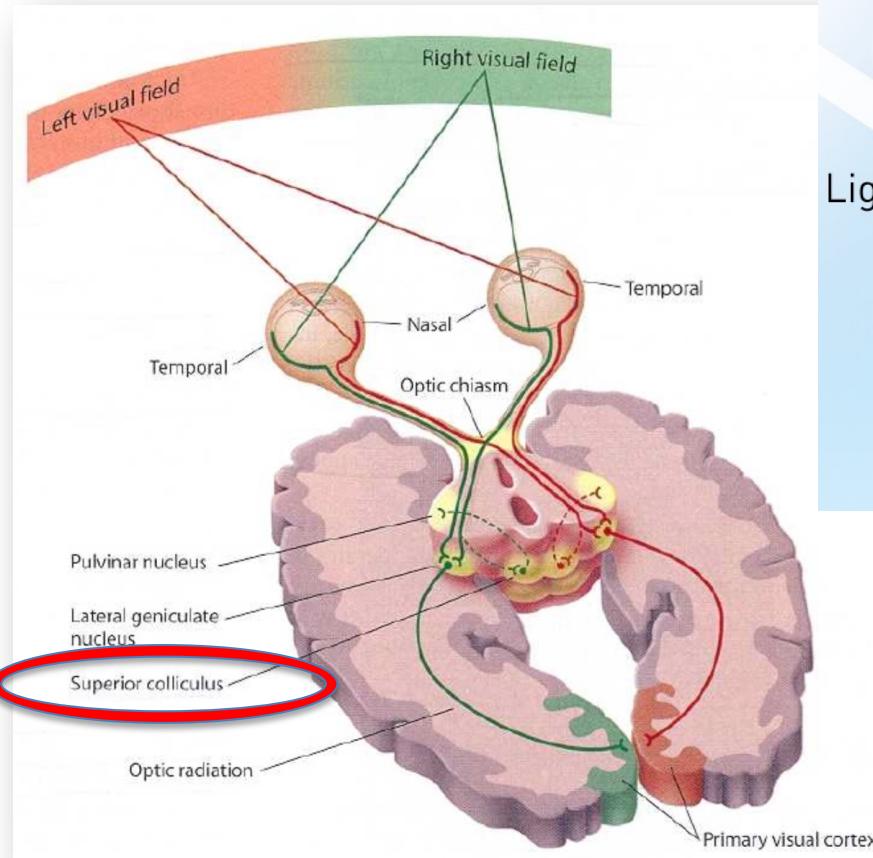
Visual Cortex

# Is the Halle Berry neuron a visual neuron?



Other visual processing

# Non-conscious vision?



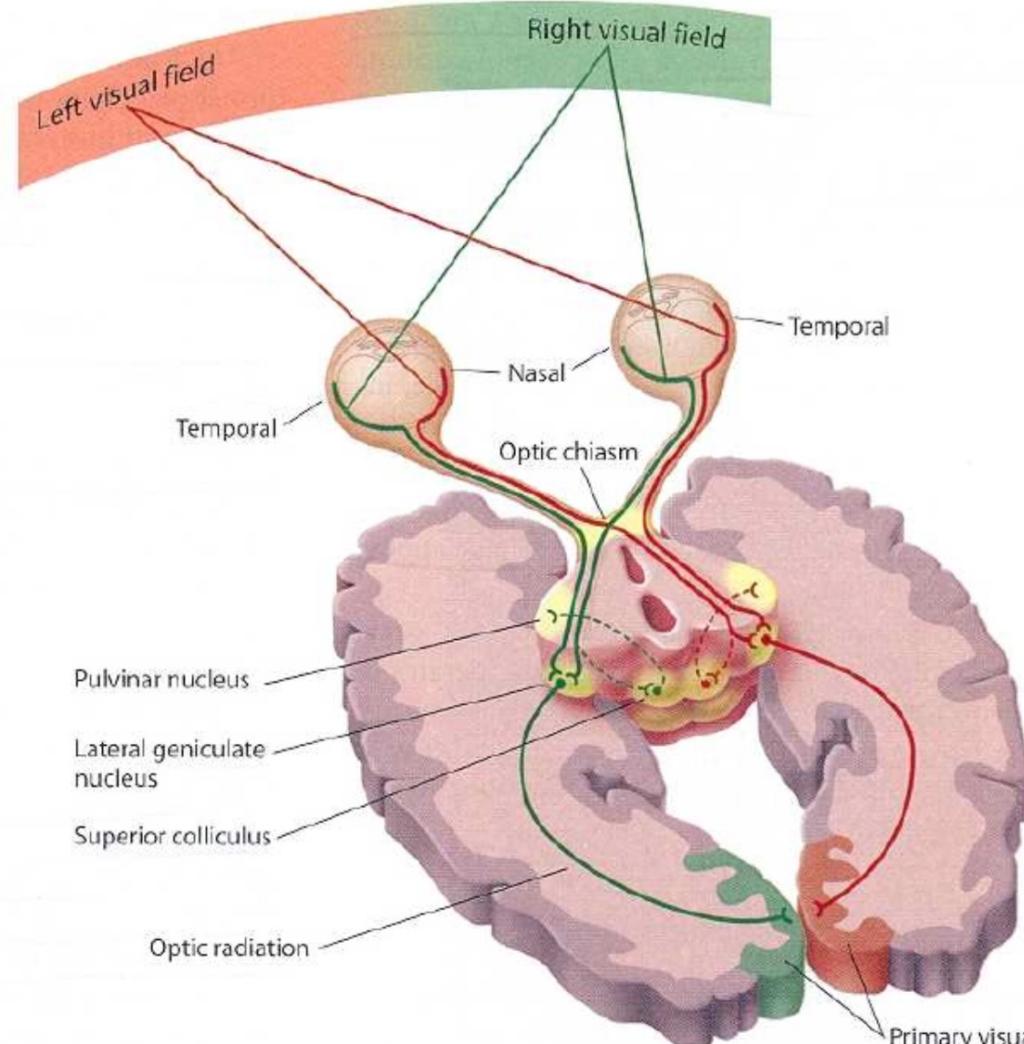
Loss of vision ≠ loss of circadian rhythm

Can't consciously see (V1 damage) but can guess stimuli with higher-than-chance accuracy and navigate a room full of obstacles — “**Blindsight**”

Other visual processing

# Visual system: great model for the CNS

- Active, not passive
- Relative, not absolute
- Parallel processing
- Convergence and divergence
- Contralateral, -topic organization



Summary