Learning About the World around us
Visual System

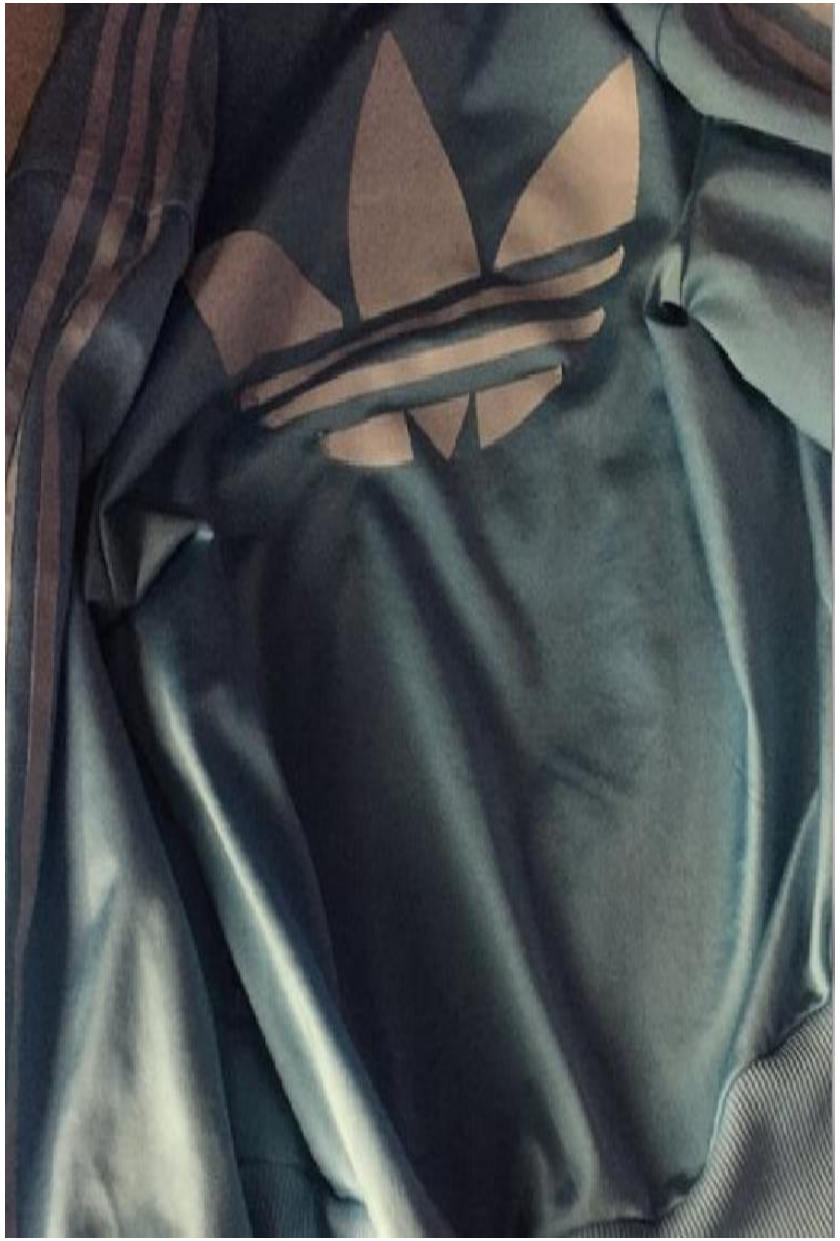
Part 2 of the book

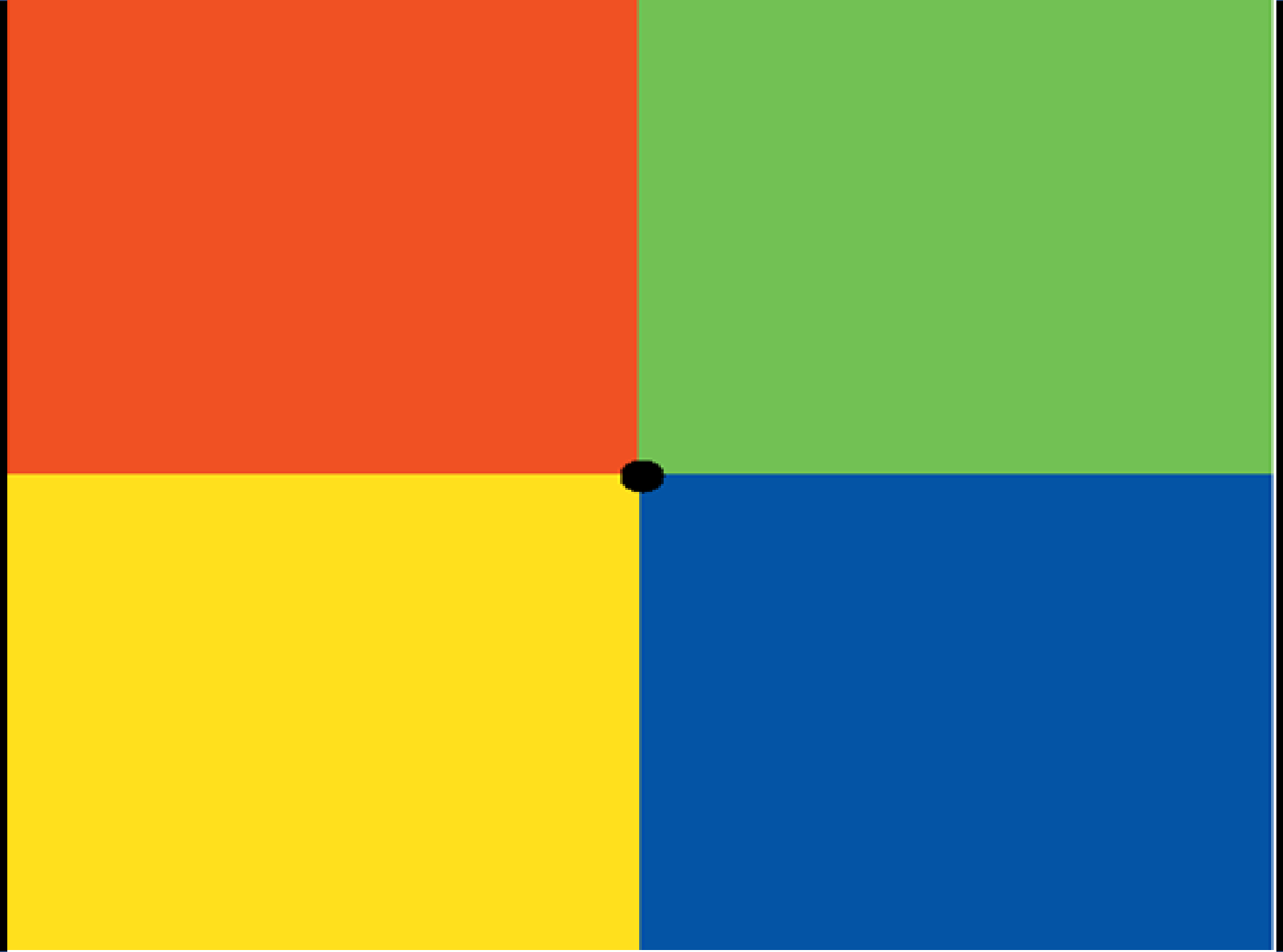
Kavita Vemuri

The Eye and Light

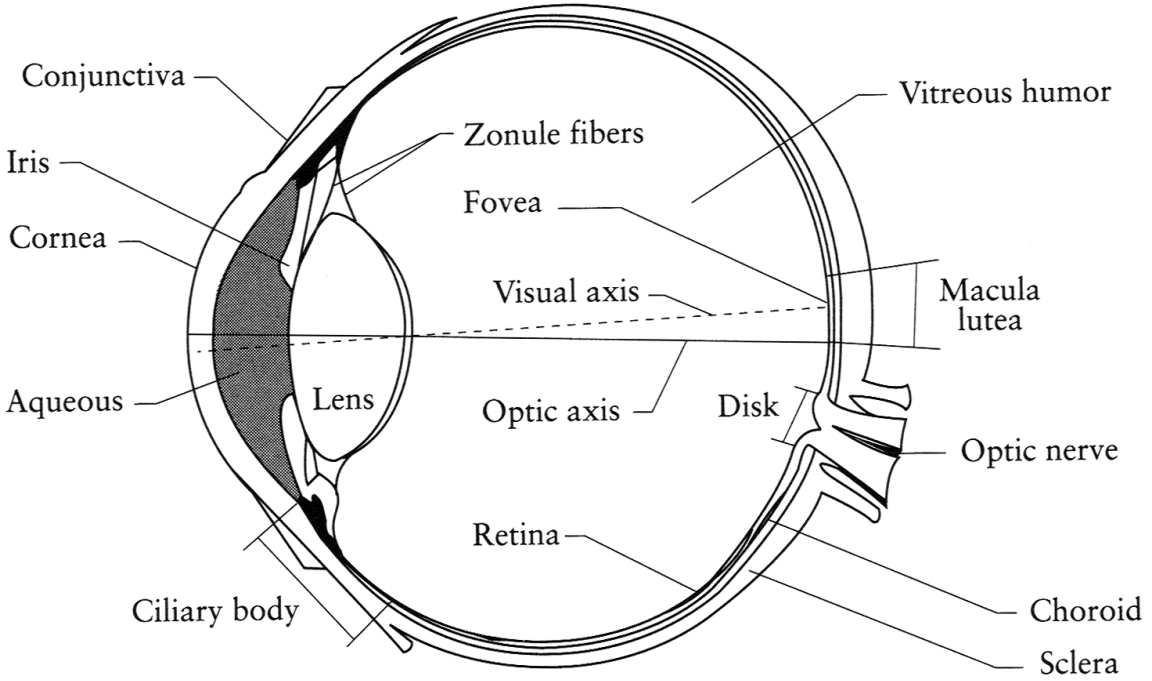
The visual system

- Color
- Shapes
- Depth
- Motion
- Texture
- ??





The Eye is a camera?

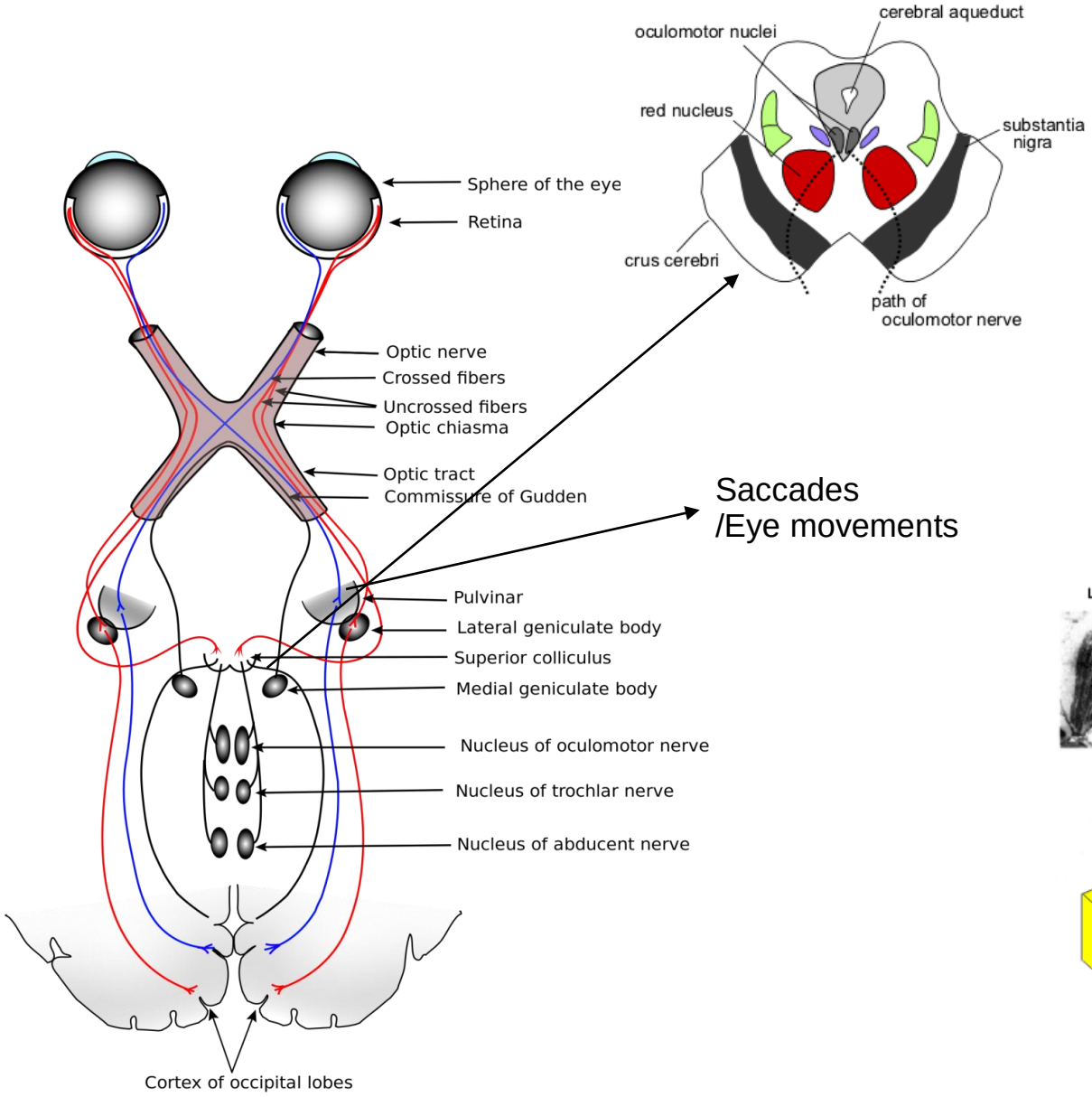


The camera is designed as the eye!

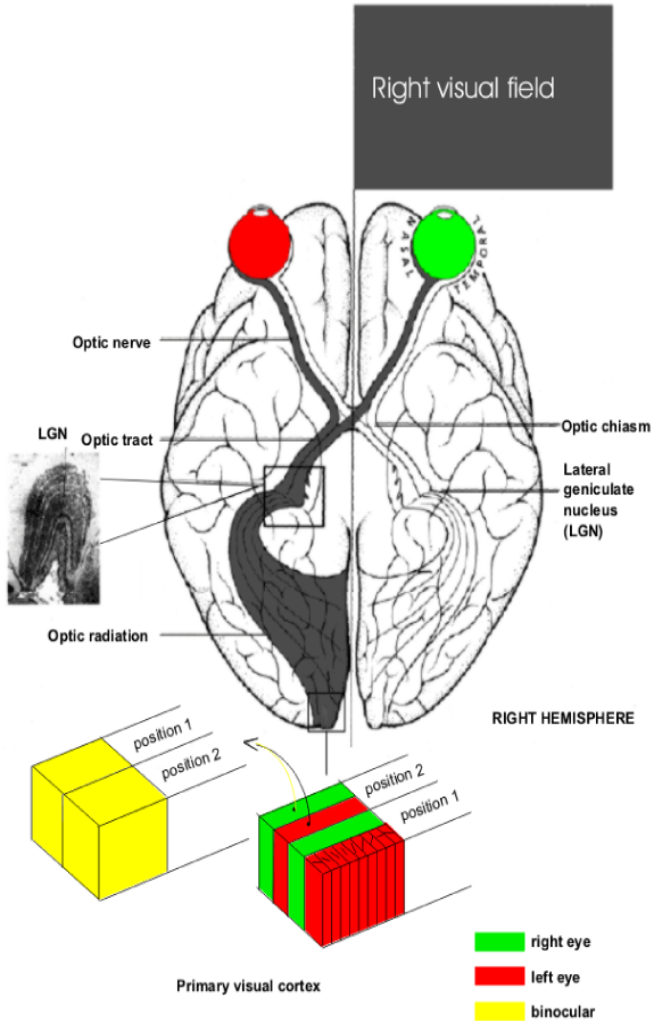
- **Iris** - colored annulus with radial muscles
- **Pupil** - the hole (aperture) whose size is controlled by the iris
- What's the "film"?

  –photoreceptor cells (rods and cones) in the **retina**

Pathway to Visual Cortex

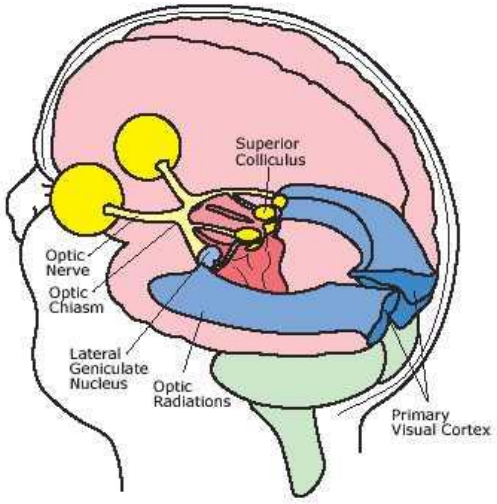


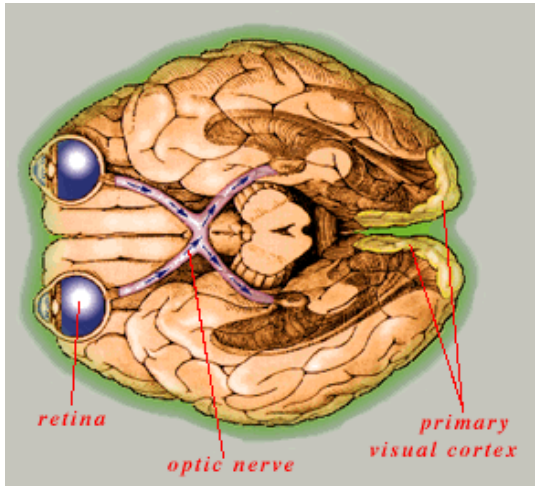
Saccades
/Eye movements



The Visual System

Both eye and brain are required for functional vision

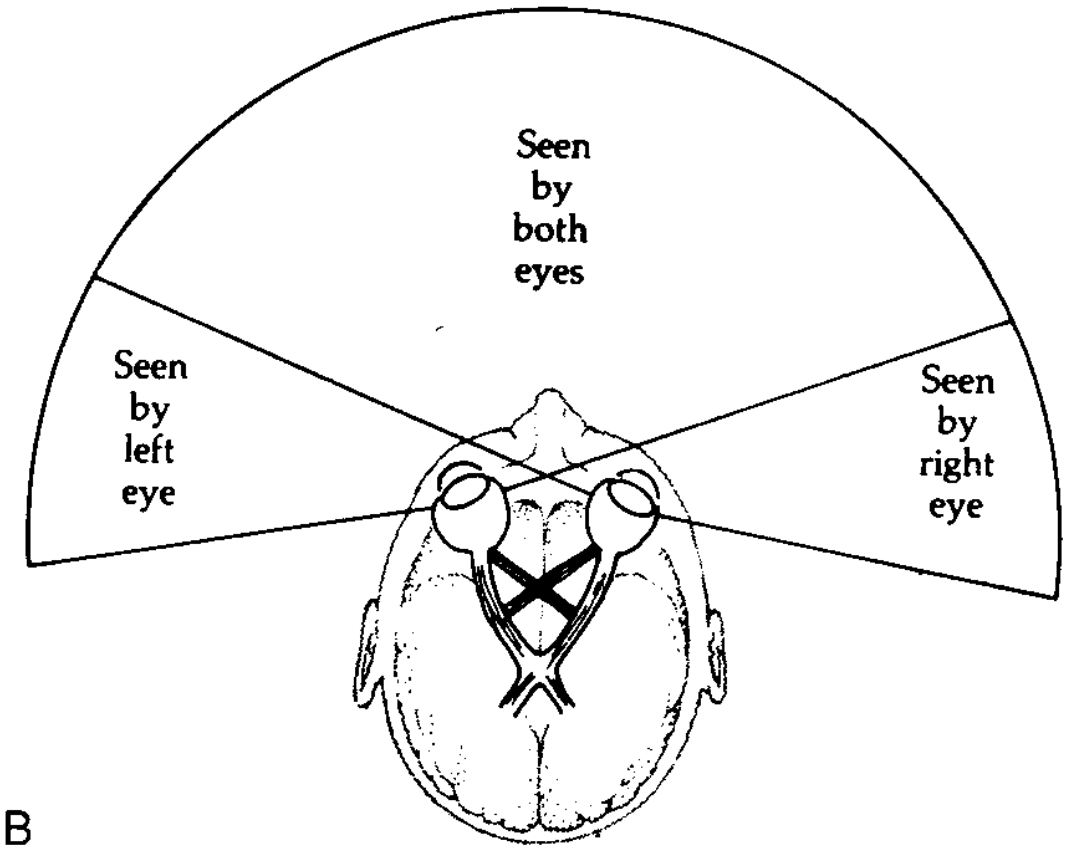




Two kinds of blindness:

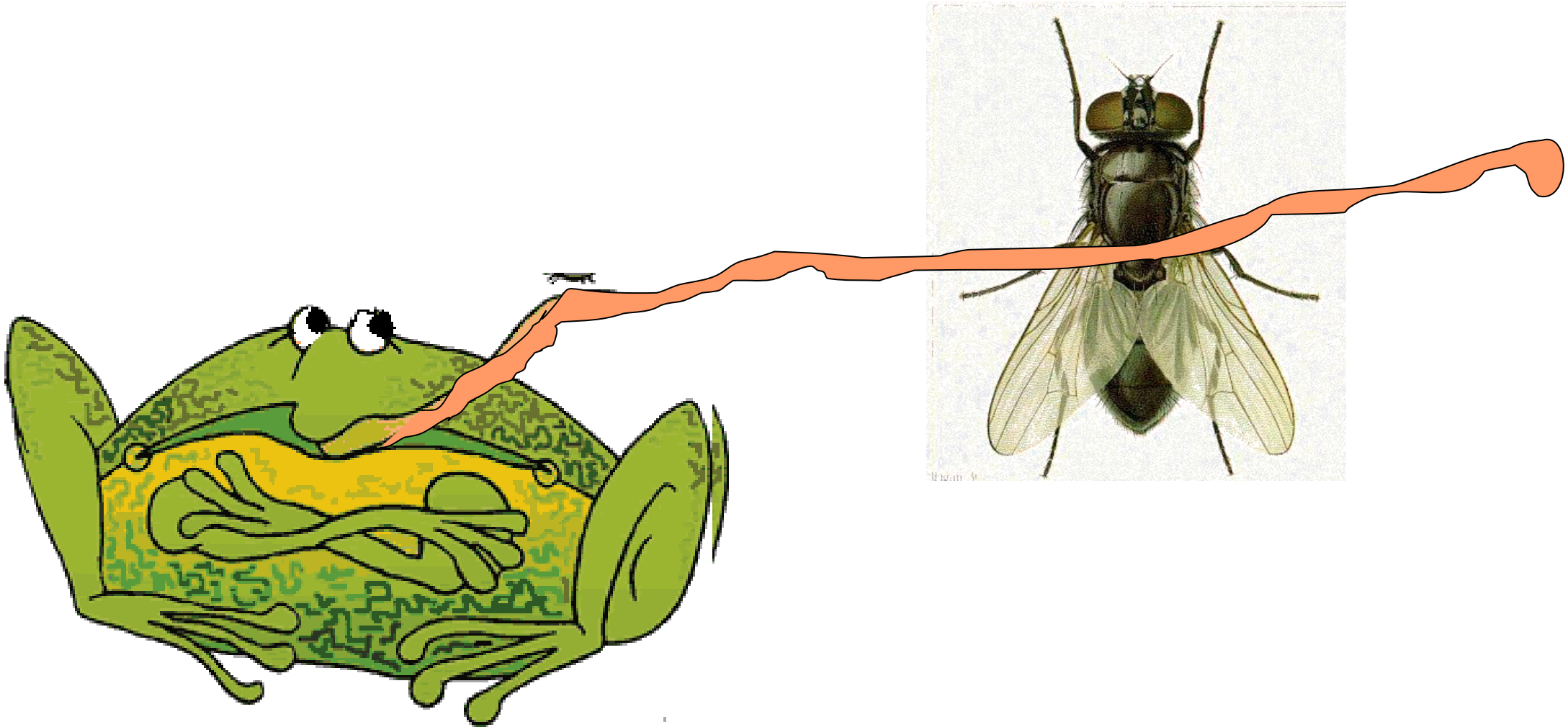
- Normal blindness (eye dysfunction)
- Cortical blindness (brain dysfunction)

Monocular Visual Field: 160 deg (w) X 135 deg (h)
Binocular Visual Field: 200 deg (w) X 135 deg (h)

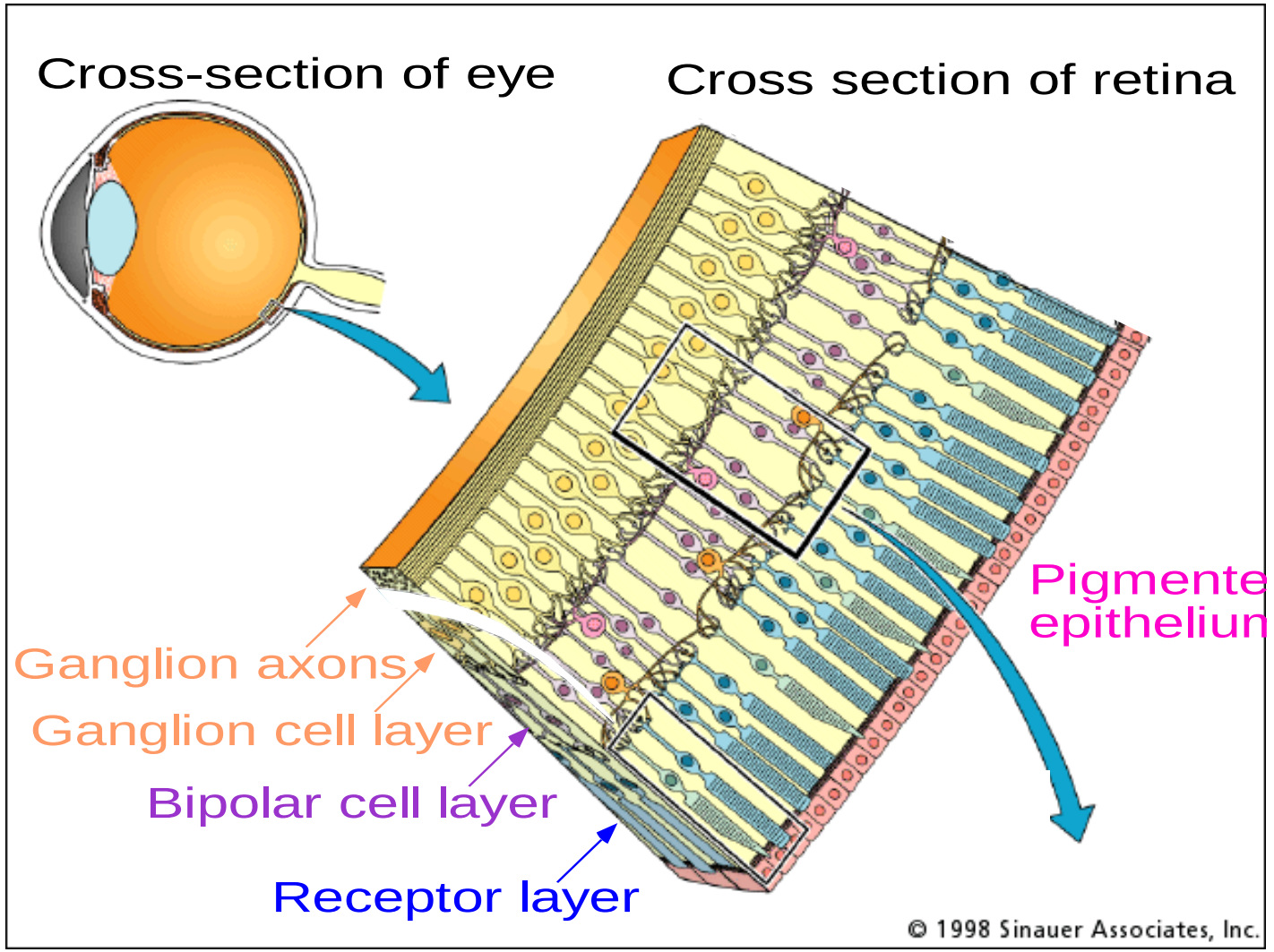


B

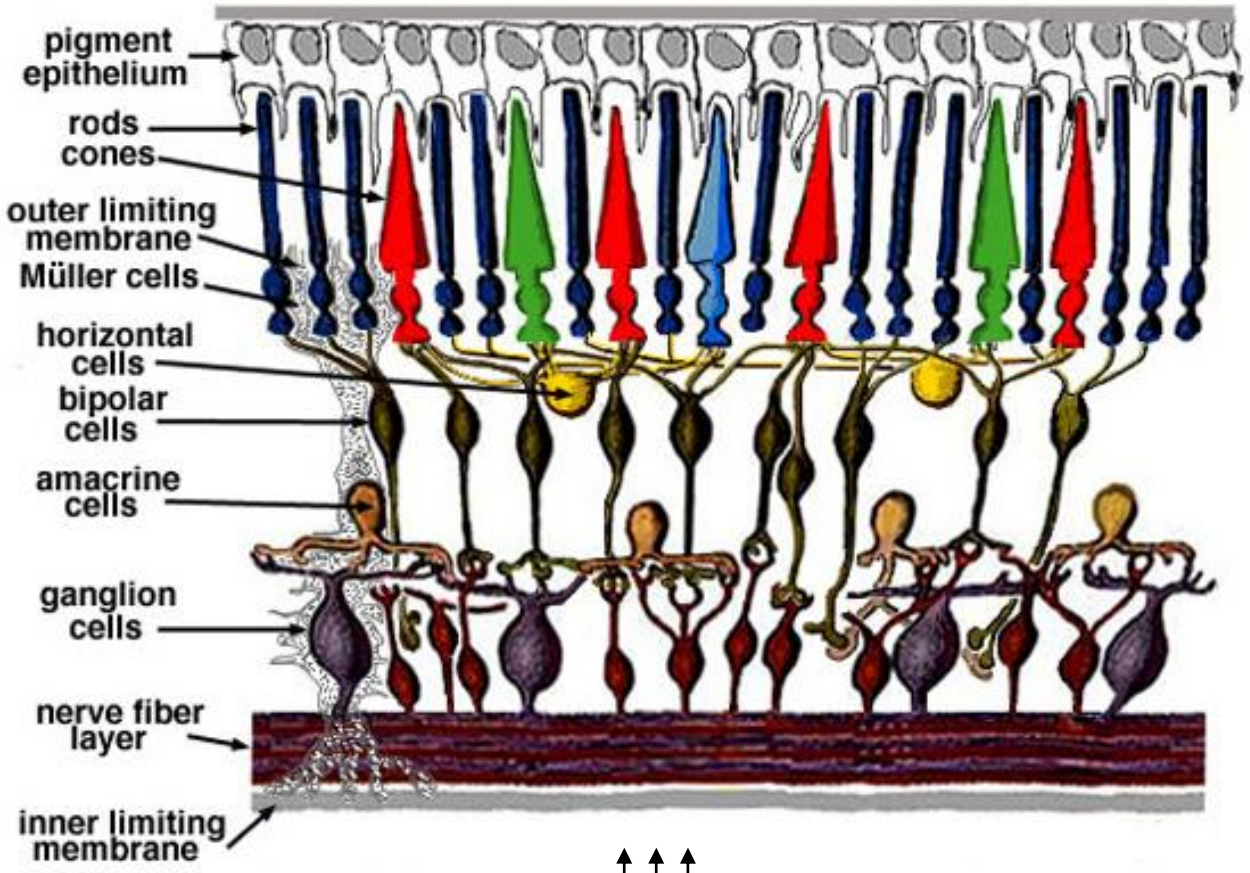
The Visual Grasp Reflex moves the eyes towards a suddenly appearing peripheral signal



The Retina


Cross-section of eye
Cross section of retina
Pigmente
epitheliun
Ganglion axons
Ganglion cell layer
Bipolar cell layer
Receptor layer
© 1998 Sinauer Associates, Inc.

Retina up-close



↑↑↑

Light

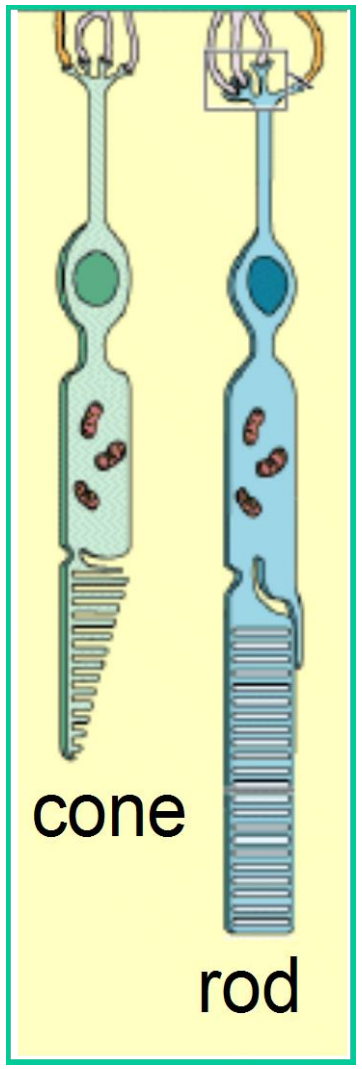
Two types of light-sensitive receptors

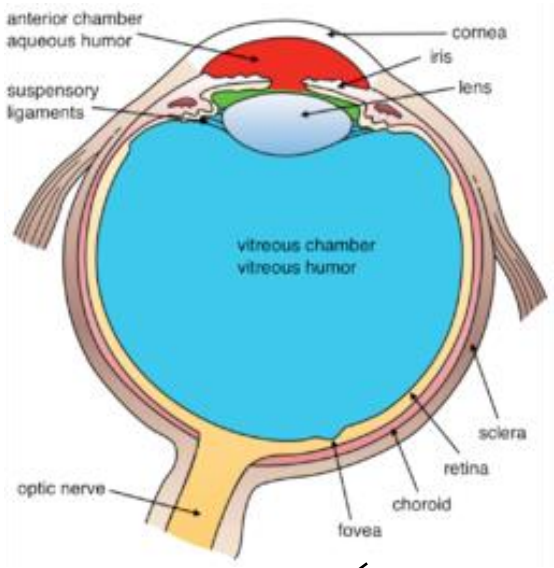
Cones

- cone-shaped
- less sensitive
- operate in high light
- color vision

Rods

- rod-shaped
- highly sensitive
- operate at night
- gray-scale vision



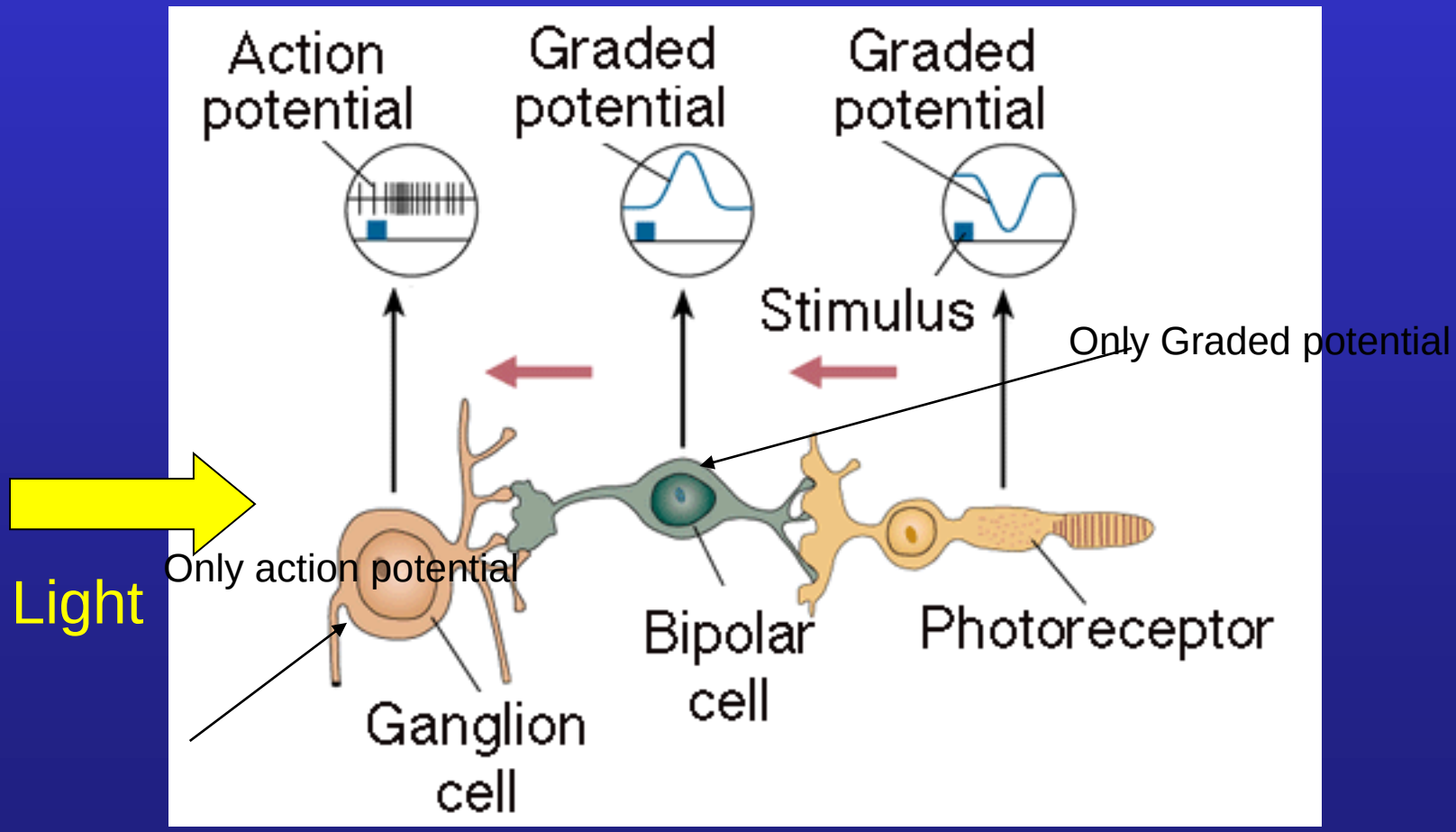


0.3 mm diameter rod-free area

Retina is organized into macula, optic disc, fovea and peripheral retina

Retinal Receptive Fields

Receptive field structure in bipolar cells



Transmission from the eye.

- Light or darkness cause changes in neurotransmitter release

in photoreceptors.

- Bipolar cells become either hyperpolarized or depolarized by light.

- Changes in glutamate release by the bipolar cells cause changes in the membrane potential of ganglion cells.

- If the ganglion cell is depolarized to threshold, it produces action potentials that are then conducted to the brain via axons that run in the optic nerve

Retinal ganglion cells respond to edges

Input image
(cornea)

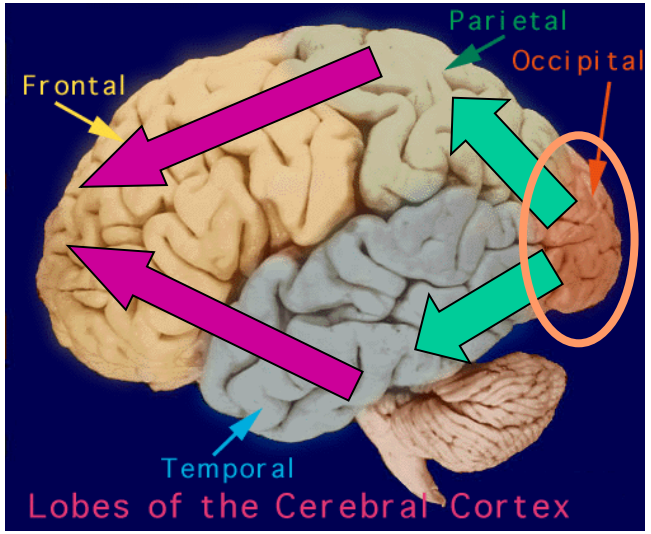
"Neural image"
(retinal ganglion cells)

Center-surround receptive fields: emphasize edges.

http://www.cns.nyu.edu/~david/courses/perception/lecturenotes/ganglion/ganglion.html

The pathways in the brain

Eyes register optical information

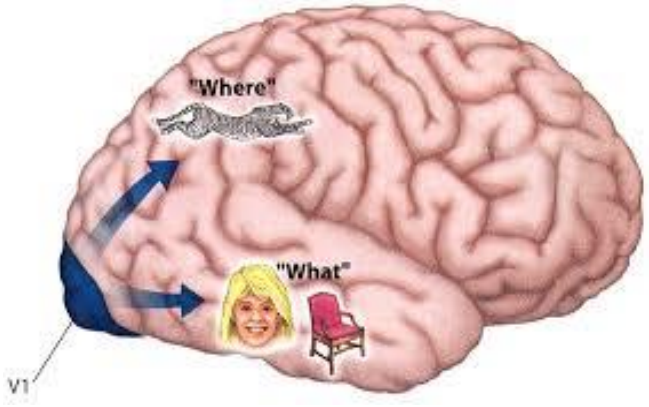


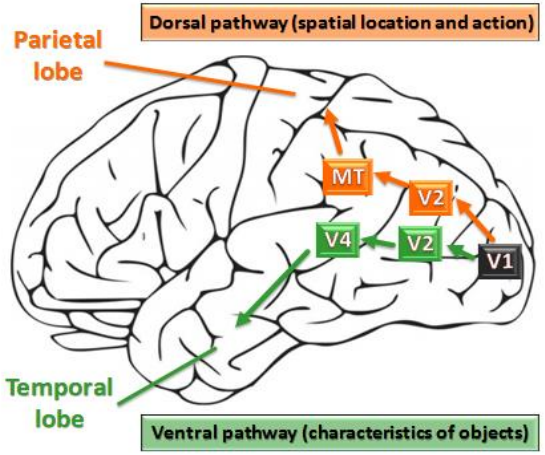
Two pathways from V1

"What" pathway to temporal cortex

"Where" pathway to parietal cortex

Convergence on frontal cortex





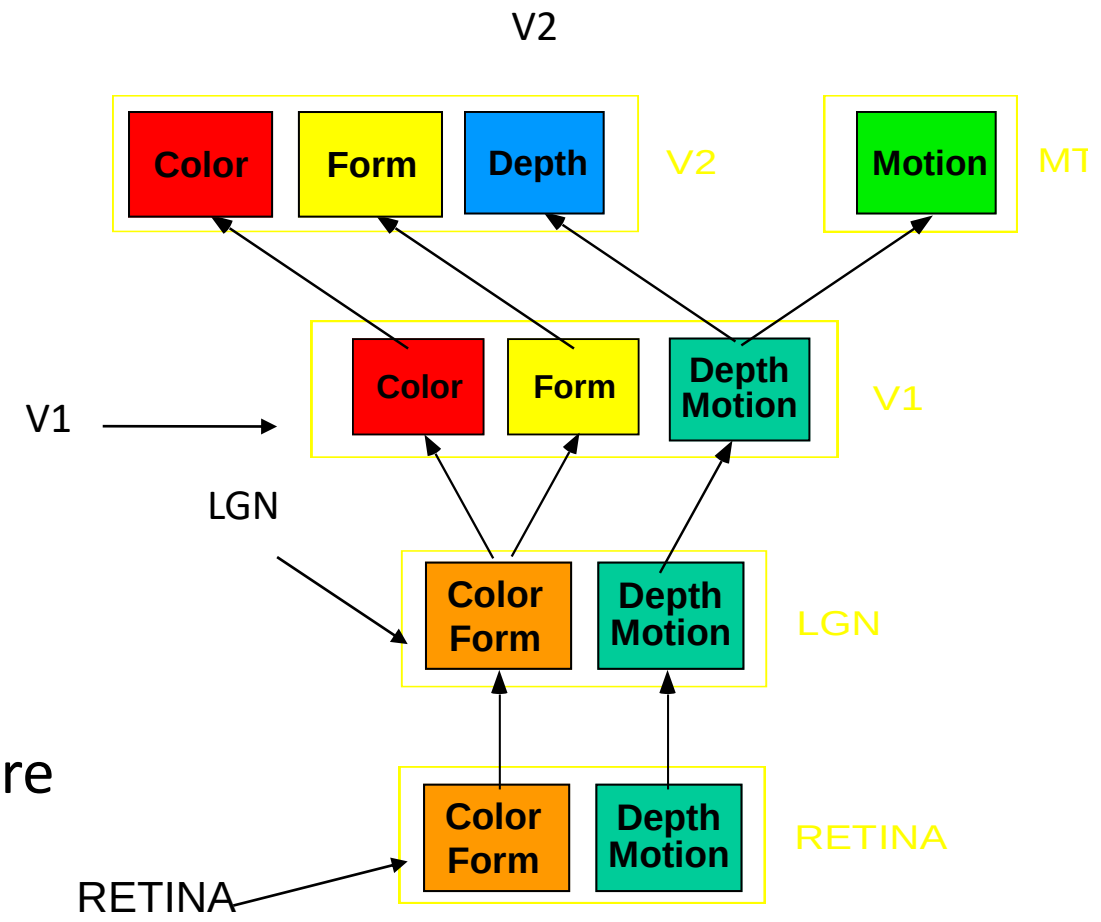
Feature-based Pathways Hypothesis

Visual Features

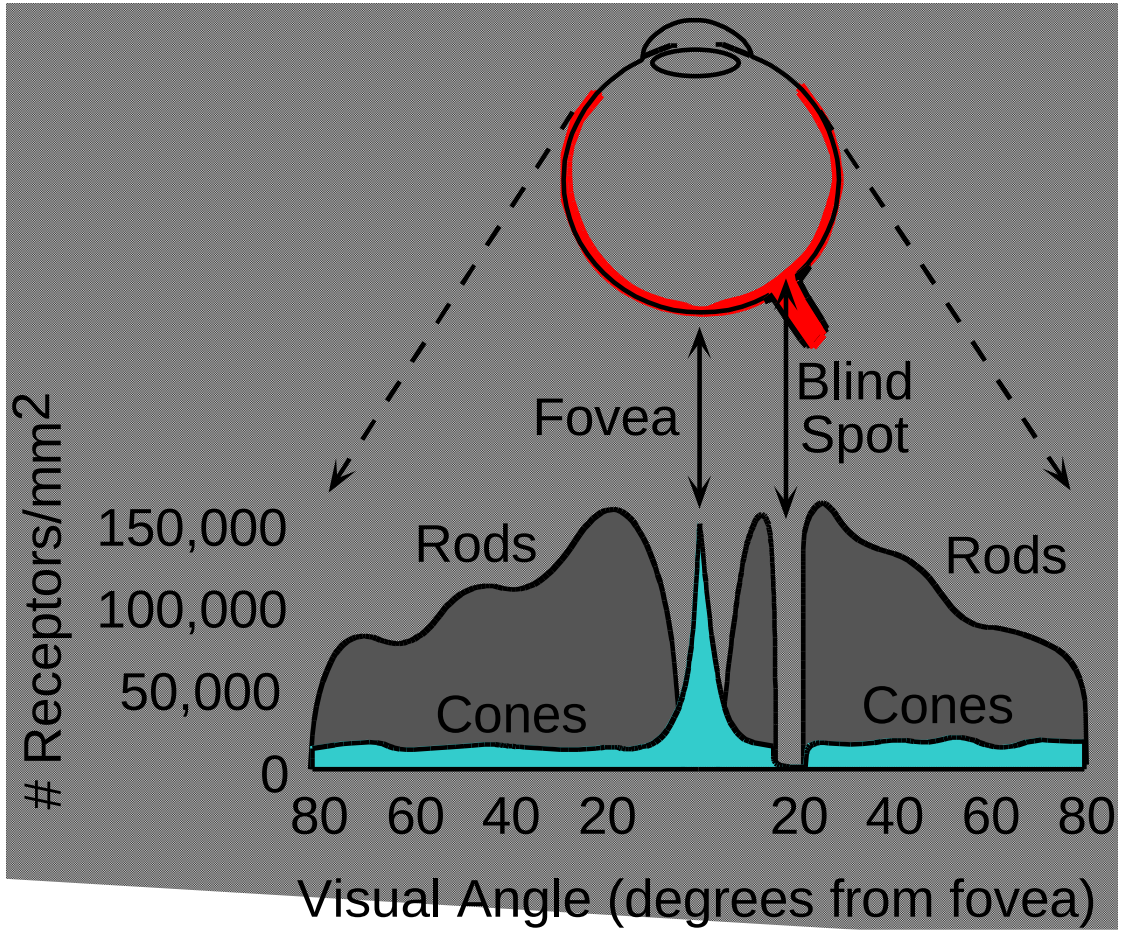
Color
Shape
Depth
Motion

Featural Pathways

Separate neural pathways in which different features are processed.



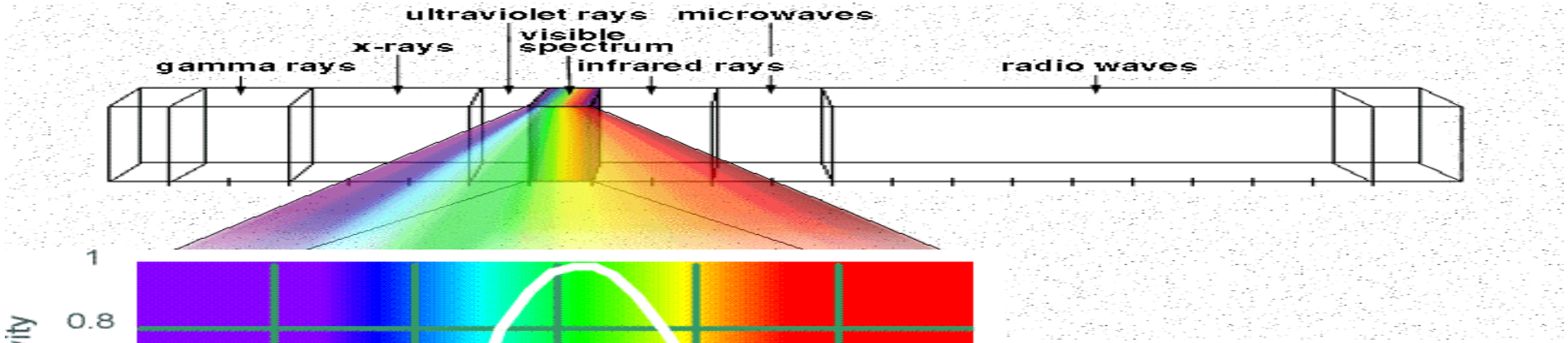
Distribution of Rods and Cones

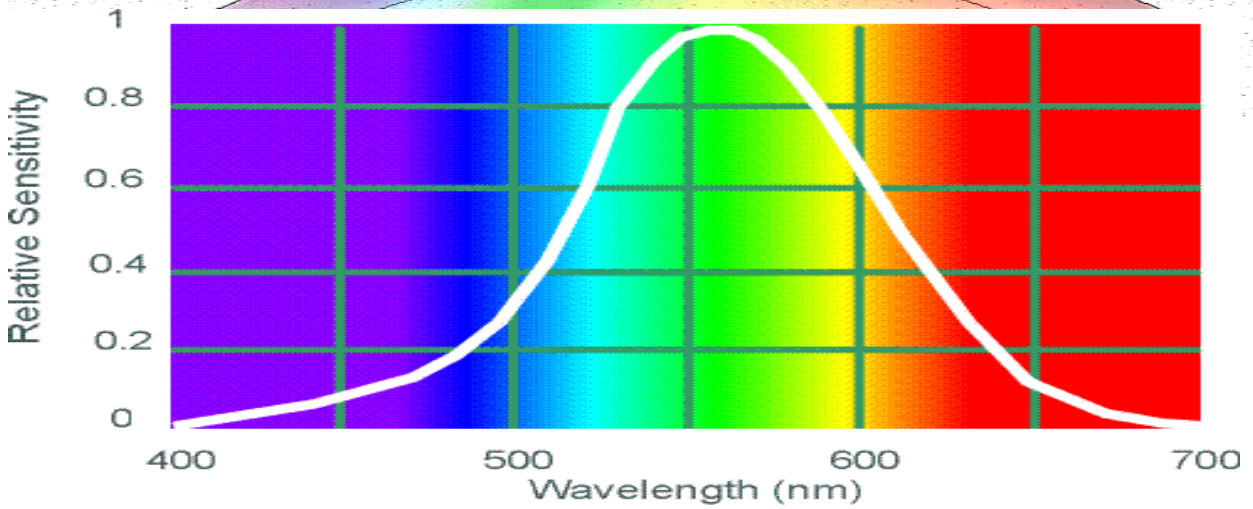


Night Sky: why are there more stars off-center?

Color Perception

Electromagnetic Spectrum

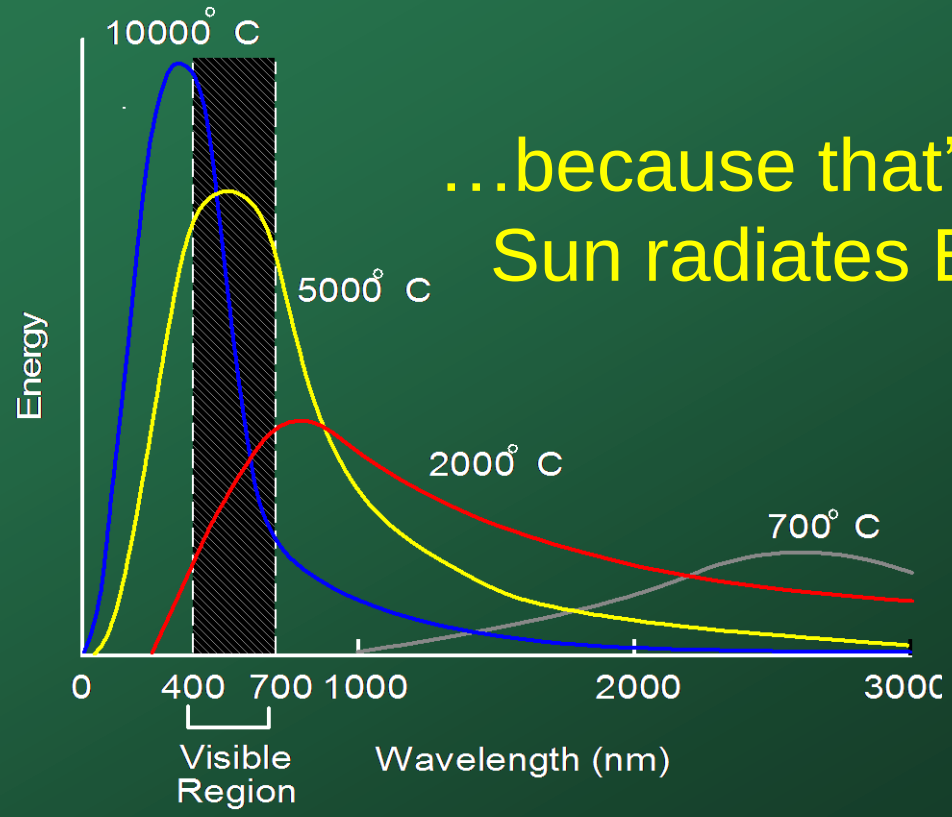




Human Luminance Sensitivity Function

Visible Light

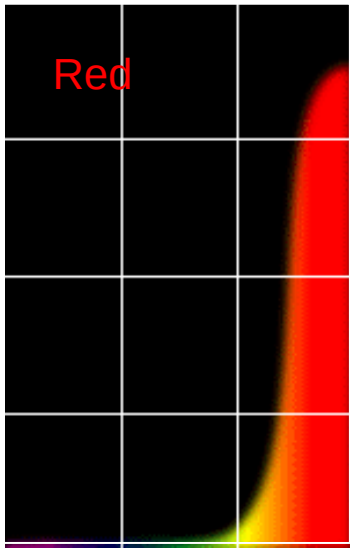
Why do we see light of these wavelengths?

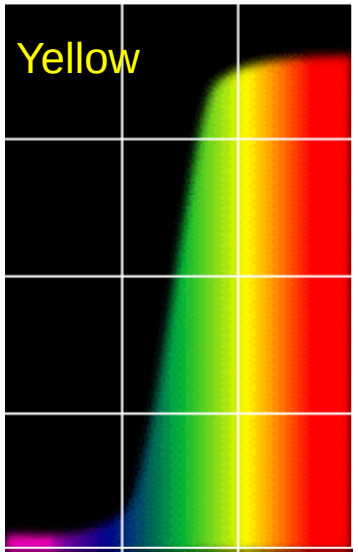


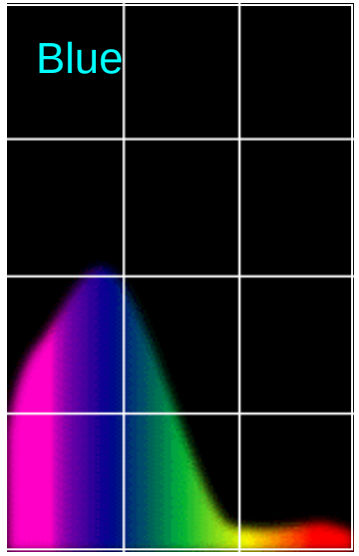
…because that's where the Sun radiates EM energy

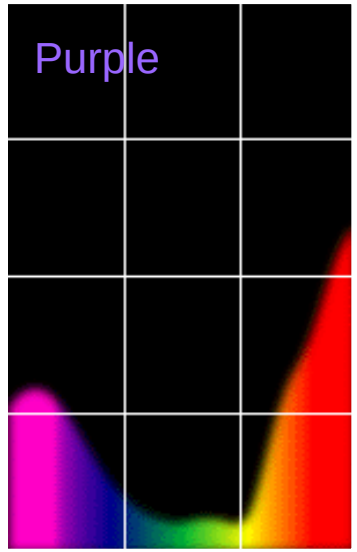
The Physics of Light

Some examples of the reflectance spectra of surfaces



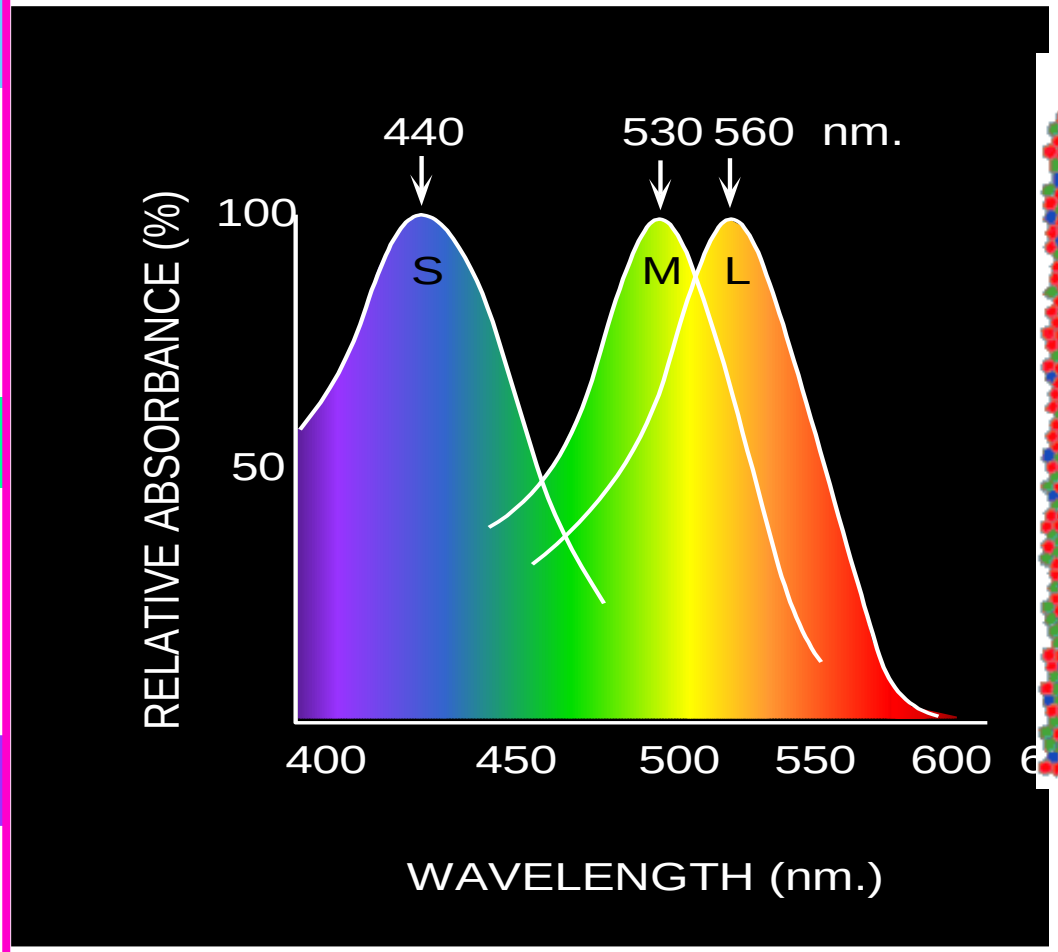


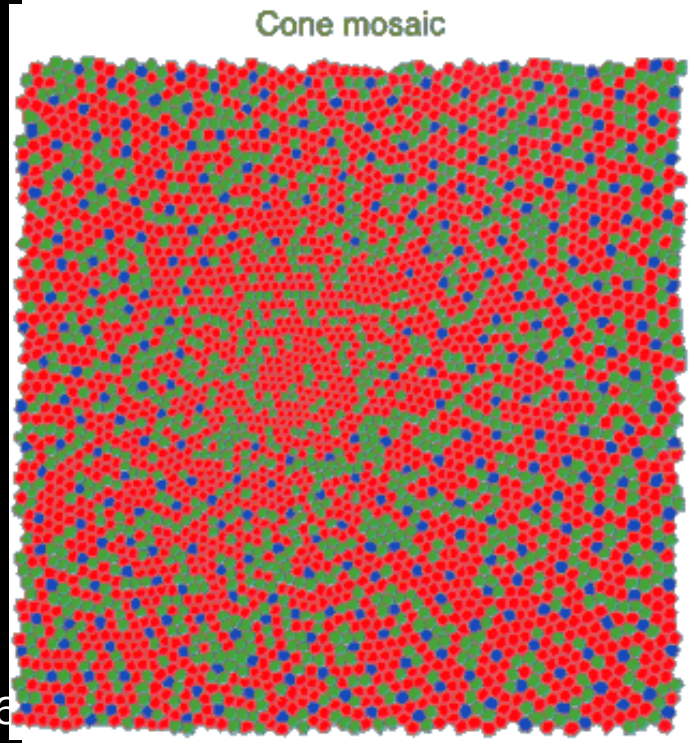




Physiology of Color Vision

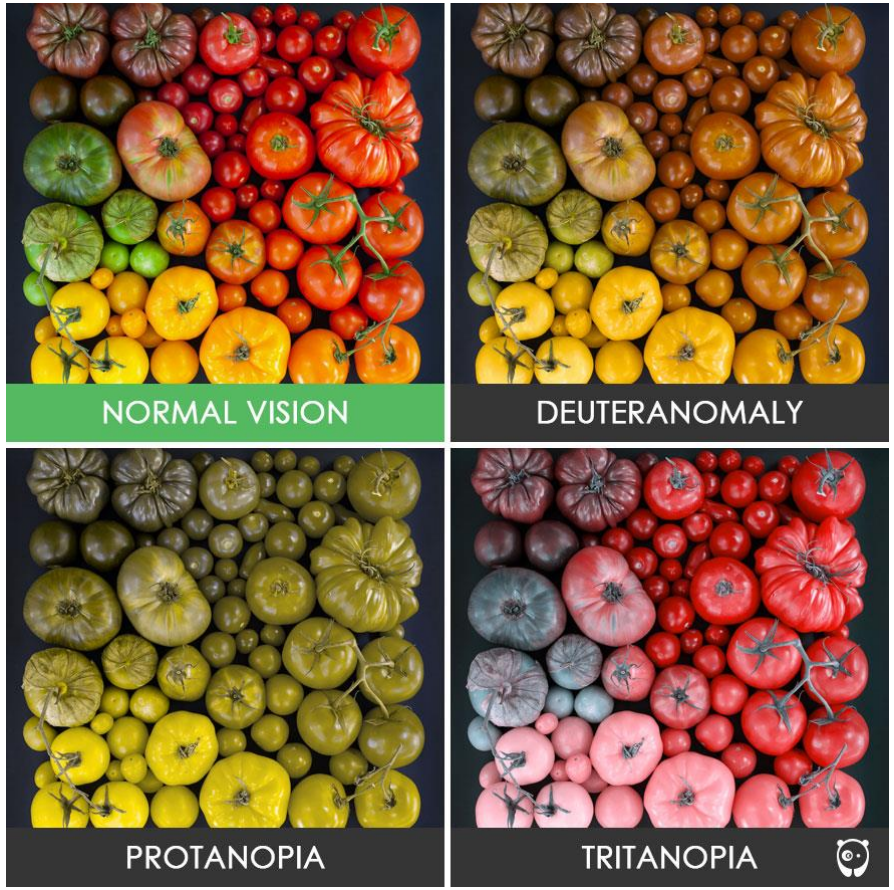
Three kinds of cones:

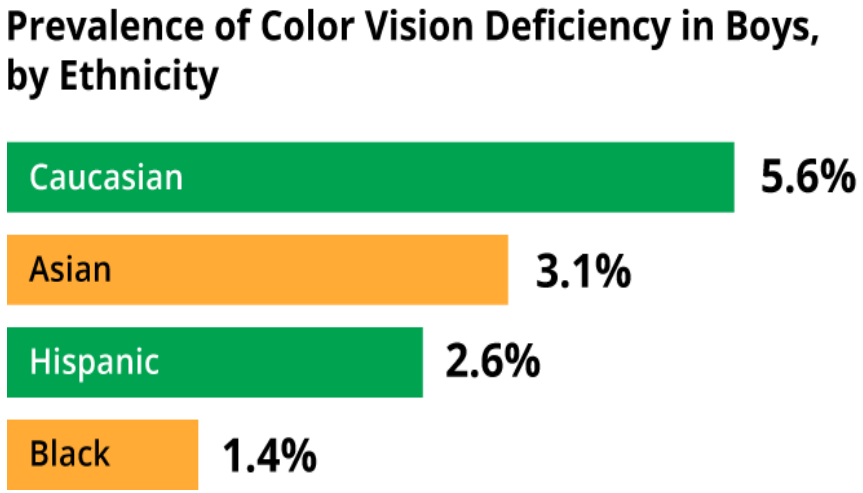




?

Color deficiency





4,005 California children ages 3 to 6 in Los Angeles and Riverside Counties

Xie et al.,
April 2014 in the journal *Ophthalmology*.

Deuteranomaly: reduced sensitivity to green light and is the most common form of colour blindness
Protanopia: reduced sensitivity to red light
Tritanopia: reduced sensitivity to blue light – extremely rae.

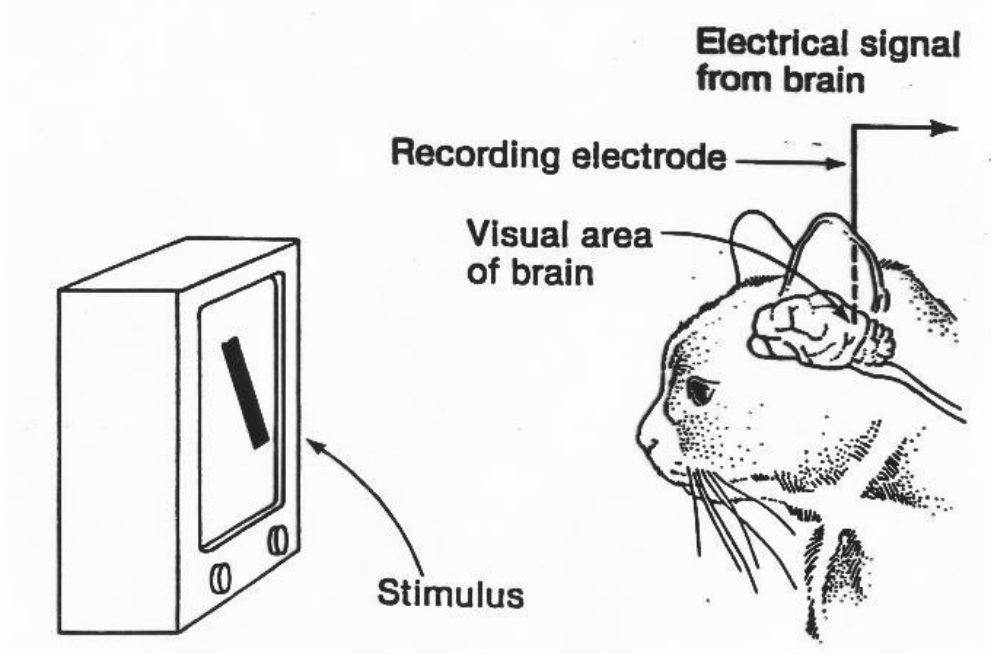
From rods and Cones to LGN and V1

Cortical Receptive Fields

Single-cell recording from visual cortex

David Hubel & Thorston Wiesel

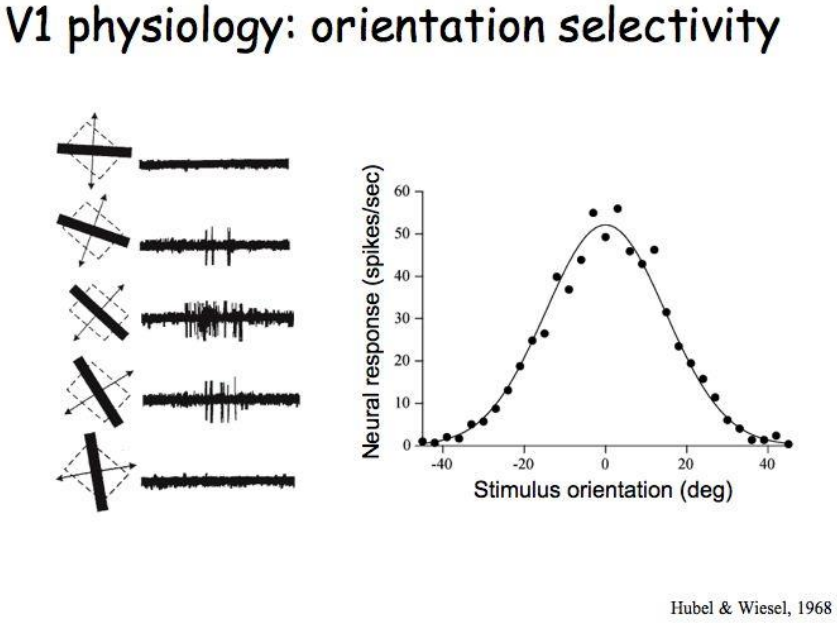
Hubel and Wiesel



http://www.cns.nyu.edu/~david/courses/perception/lecturenotes/V1/LGN-V1-slides/hw-2-cortical-rfs-640x480.mov

Function of the V1

- David Hubel and Torsten Wiesel discovered the functional organization and basic physiology of neurons in V1.
- They discovered three different types of neurons that can be distinguished based on how they respond to visual stimuli that they called: *simple cells*, *complex cells*, and *hypercomplex cells*.
- V1 neurons transform information (unlike LGN cells whose receptive fields look just like those of ganglion cells) so that they are *orientation selective* and *direction selective*.



summary

The visual system is composed of many interactive functional parts:

Eye (optics of image formation)

Retina (light transduction)

LGN (waystation?)

Area V1 (hypercolumns)

Higher cortical areas (features)

Cortical pathways (what/where)

Object recognition

Gestalt principles of perceptual organization

- The Gestaltists argued that the organization is contributed by the perceiver; this is why, they claimed, the perceptual whole is often different from the sum of its parts.

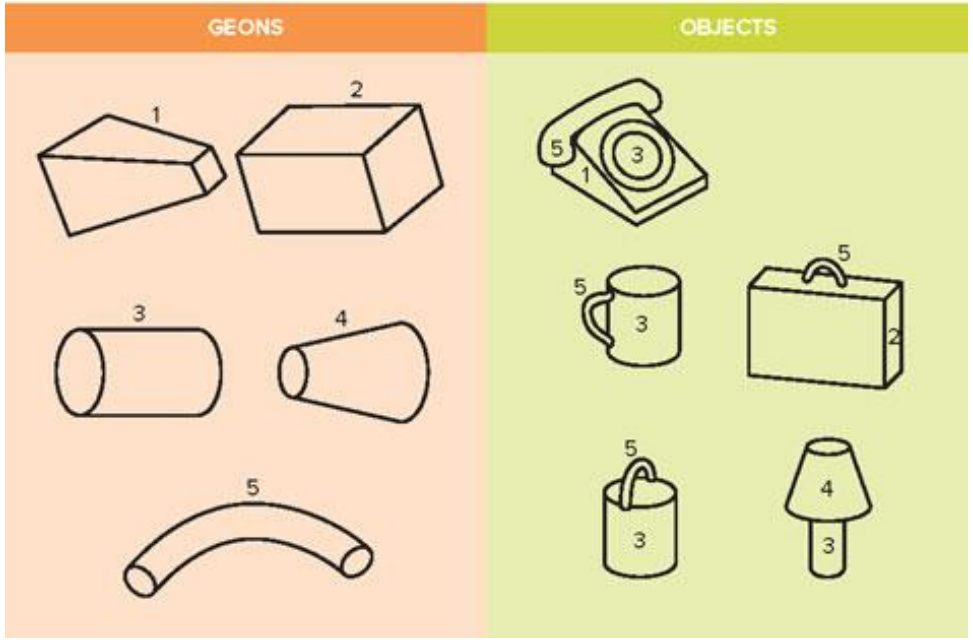
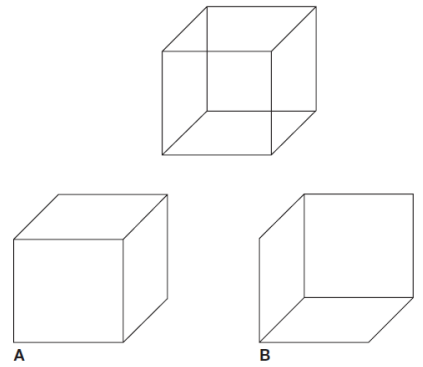
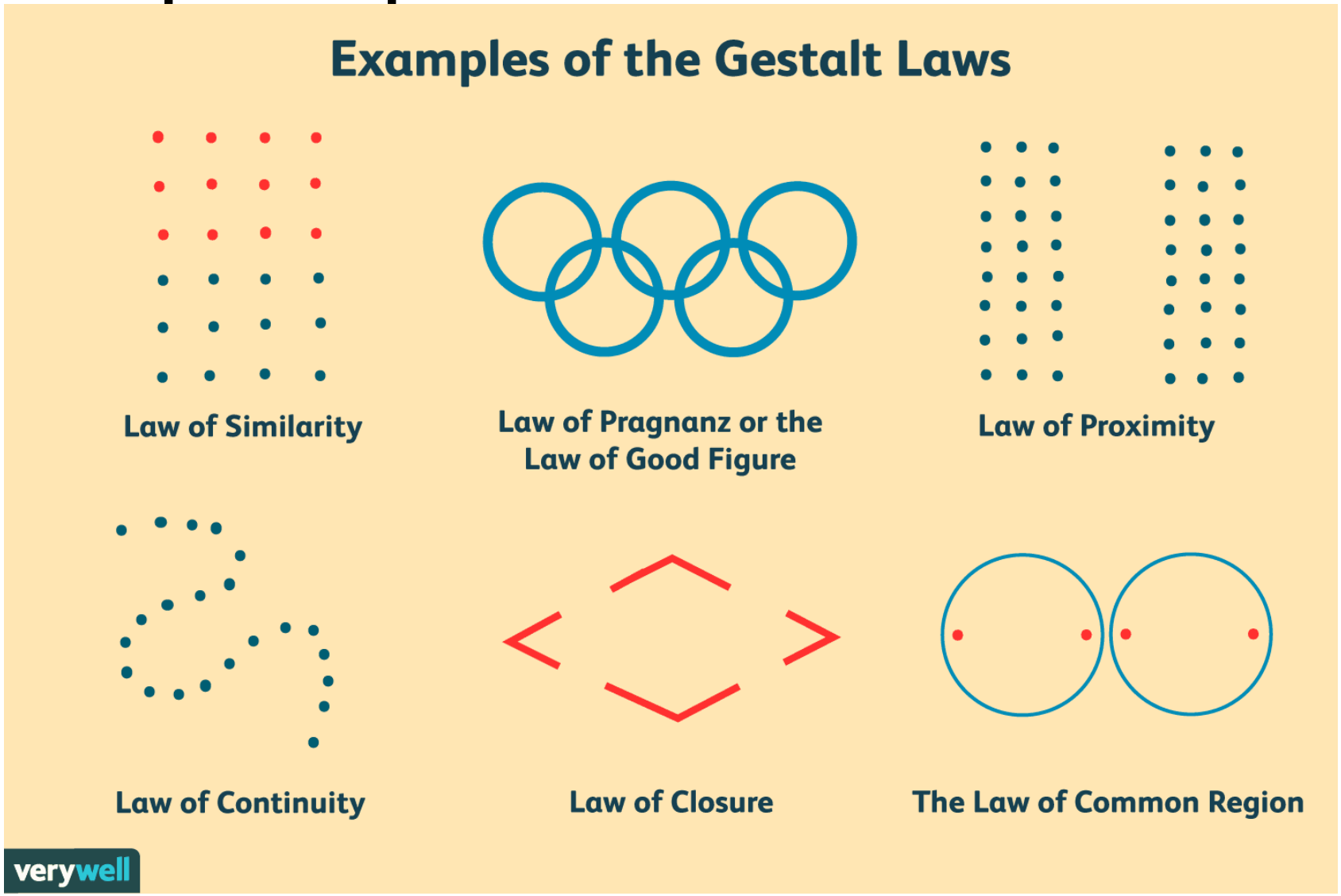


FIGURE 3.11 THE NECKER CUBE



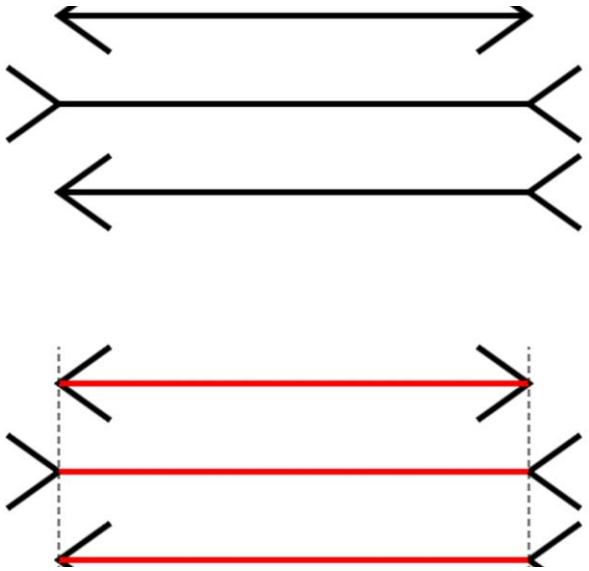
The top cube can be perceived as if viewed from above (in which case it is a transparent version of Cube A) or as if viewed from below (in which case it is a transparent version of Cube B).

Gestalt principles



Helmholtz’s theory of unconscious inference(1867)

- It states that some of our perceptions are a result of unconscious assumptions we make about the environment.
- Includes the **Likelihood principle** – we perceive an object that is most likely to have caused the pattern.



Object Recognition

How Humans Recognize Objects: Segmentation, Categorization and Individual Identification

Object agnosia (see only the faces)

How Do We Recognize Objects From Different Viewpoints?

- Two competing theories:

- Structural description models

- Image description models

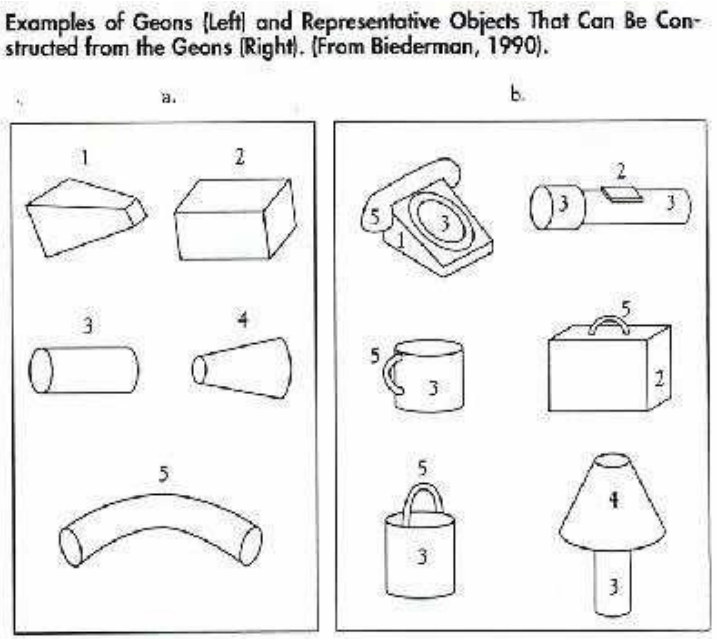
Structural-Description Models:

- Recognition by Components (RBC) {Biederman (1985)}
- Geons (“Geometric Ions”)
- Each geon is uniquely identifiable from most viewpoints *(viewpoint invariant).*
- Only 36 geons needed to make thousands of objects.
- Objects can be identified if the geons can be identified:
- which geons are present?
- what is the spatial relation among geons?

(a)

(b)

Figure 5.35 (a) It is difficult to identify the object behind the mask because its geons have been obscured.
(b) Now that it is possible to identify geons, the object can be identified as a flashlight.



Recognition by Components

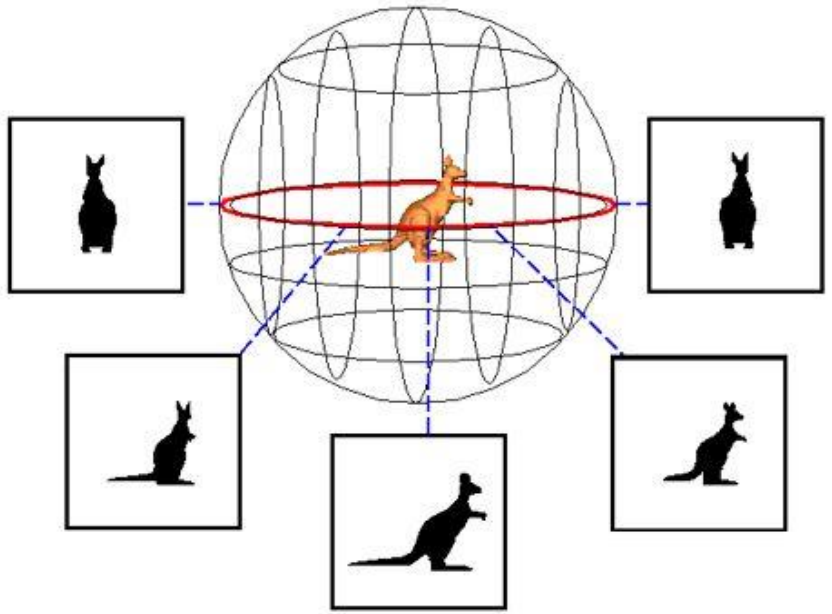
Strengths

- – Viewpoint invariant
- – Parts-based
- – May be able to deal with partial occlusion via feedback
- – Represent 3-D structure

Weaknesses

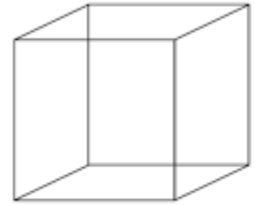
- – Complexity of representation
- – Doesn’t easily represent subtle metric differences (e.g.,distance between eyes)
- – Recognition is at the level of categories (chair vs. table) rather than individuals (my office chair vs. my kitchen chair)

Viewpoint-dependent theory of recognition



- This is an alternative theory. You store in your head a bunch of characteristic views (mental images) of objects. You recognize a new image by finding the closest match. That is, you don't use 3D shape to recognize objects. Only the 2D views of the objects

Image-Description Models



- Ability to identify 3-D objects comes from stored 2-D viewpoints from different perspectives
- – For a familiar object, view invariance occurs
- – For a novel object, view invariance does not occur

This shows that an observer needs to have the different viewpoints encoded before recognition can occur from all viewpoints

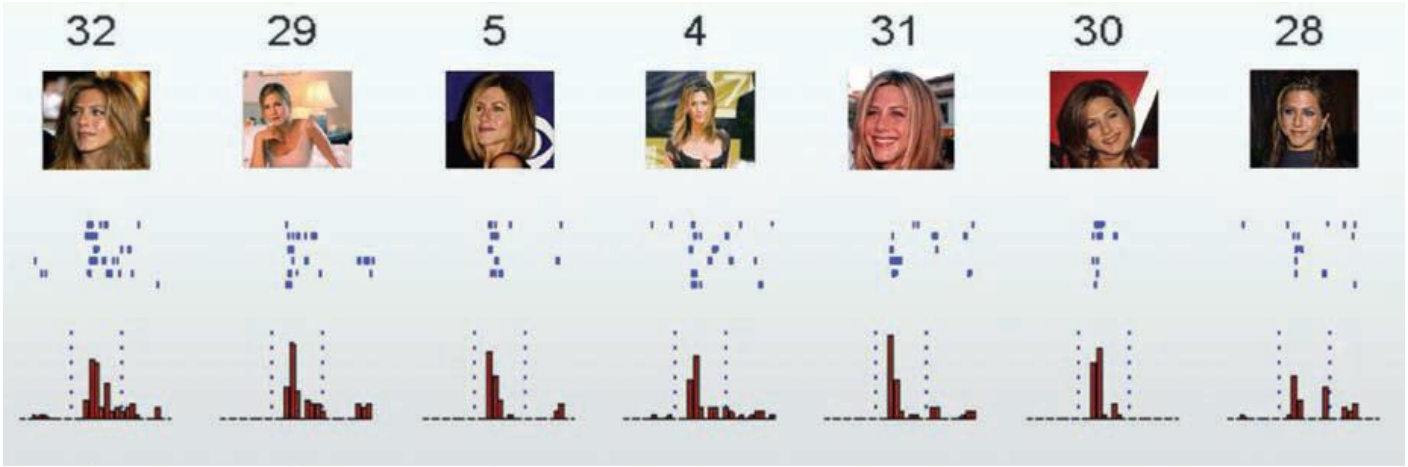
Object recognition

- Schneider's (1969) suggestion that two distinct pathways support visual orientation toward object features.
- Research stemming from this idea has inextricably linked object recognition to the experiences of space, time, and persistence over time, i.e., individual identity (Scholl, 2007; Fields, 2012).
- Without a spacetime "container" and individual, time-persistent objects, motion and causation cannot be defined; hence object recognition underlies these experiences as well.
- **Will object recognition be possible without memory?**

https://www.frontiersin.org/articles/10.3389/fpsyg.2016.00400/full

Object Recognition

- Researchers in one study were able to do single-cell recording within the brains of people who were undergoing surgical treatment for epilepsy. The researchers located cells that fired strongly whenever a picture of Jennifer
- Aniston was in view — whether the picture showed her close up (picture 32) or far away (picture 29), with long hair (picture 32) or shorter (picture 5). These cells are largely viewpoint-independent; other cells, though, are viewpoint-dependent.



Pattern Recognition

Face,Speech/music,text, art

Theories of pattern recognition:

1. Template-matching theory.
2. Feature detection theories
3. Prototype theories

Prototype theory is preferred, because (a) it appears to be amore flexible approach (since prototypes can be updated continuously with new experiences), and (b) fewer representations need to be stored.

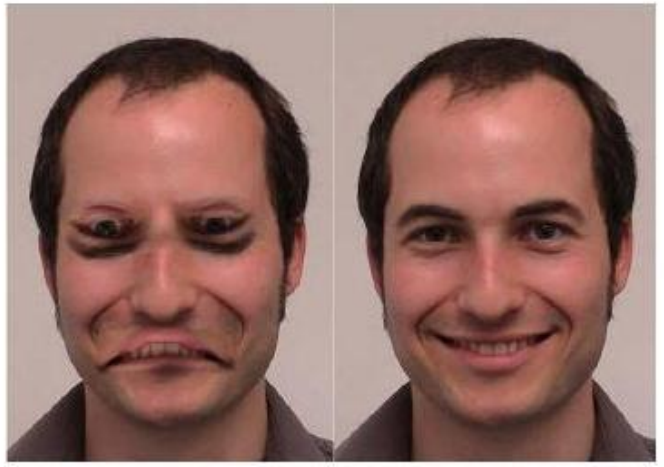
Extreme cases:

Apophenia (early stages of schizophrenia).

Pareidolia: ringing phone while taking a shower.

Gambler's fallacy: school oneself to see patterns

Pattern Invariance- Pattern recognition



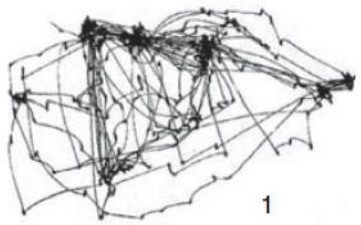
Attention

FIGURE 5.1 THE INVISIBLE GORILLA

In this procedure, participants are instructed to keep track of the ballplayers in the white shirts. Intent on their task, participants are oblivious to what the black-shirted players are doing, and—remarkably—they fail to see the person in the gorilla suit strolling through the scene. (FIGURE PROVIDED BY DANIEL J. SIMONS.)

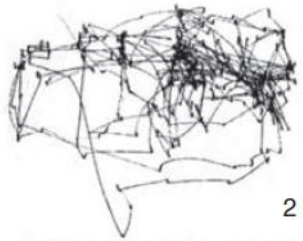
Change Blindness

Eye movements and vision



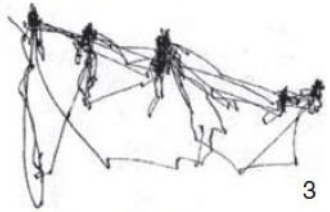
1

Free examination.



2

Estimate material circumstances of the family.

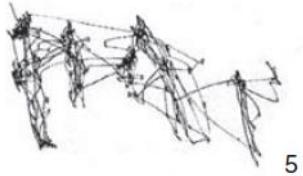


3

Give the ages of the people.

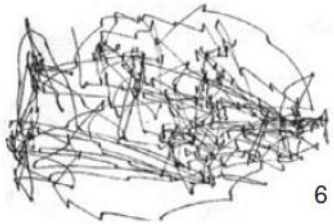
4

Surmise what the family had been doing before the arrival of the unexpected visitor.



5

Remember the clothes worn by the people.



6

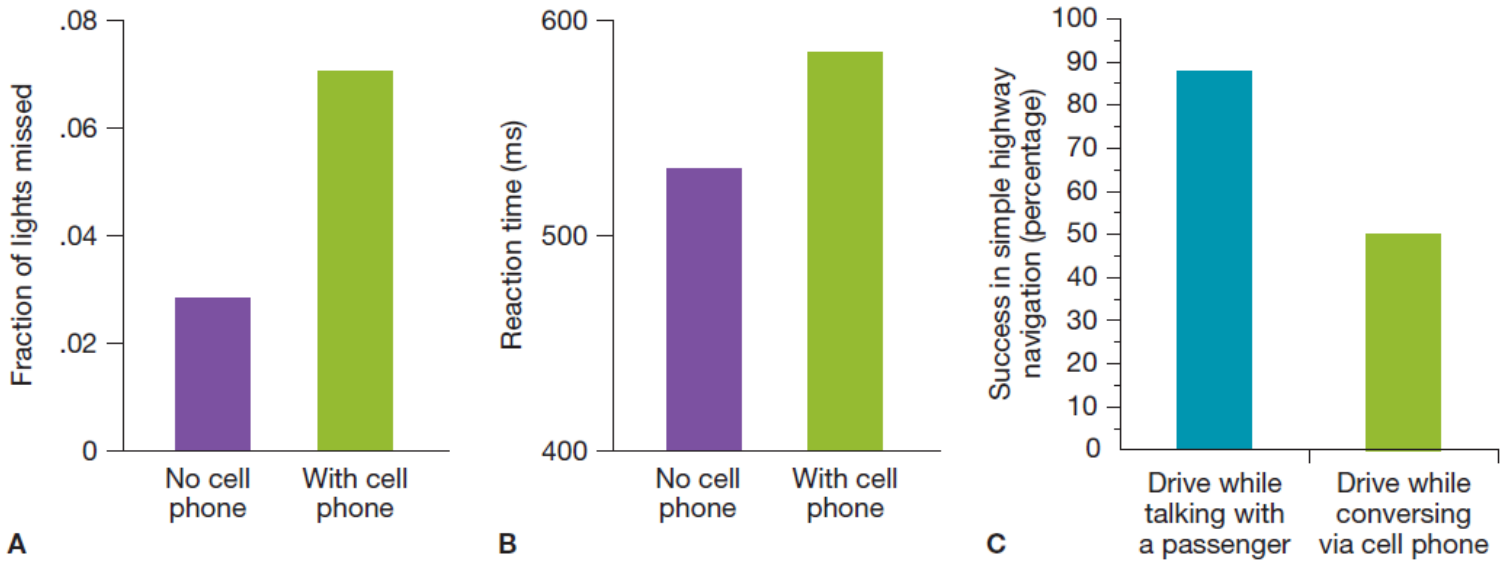
Remember positions of people and objects in the room.

7

Estimate how long the visitor had been away from the family.

Multitasking & Attention

FIGURE 5.19 CELL PHONE USE AND DRIVING



Many studies show that driving performance is impaired when the driver is on the phone (whether hand-held or hands-free). While on the phone, drivers are more likely to miss a red light (Panel A) and are slower in responding to a red light (Panel B). Disruption is not observed, however, if the driver is conversing with a passenger rather than on the phone (Panel C). That's because the passenger is likely to adjust her conversation to accommodate changes in driving—such as not speaking while the driver is navigating an obstruction.

(AFTER STRAYER & JOHNSTON, 2001)

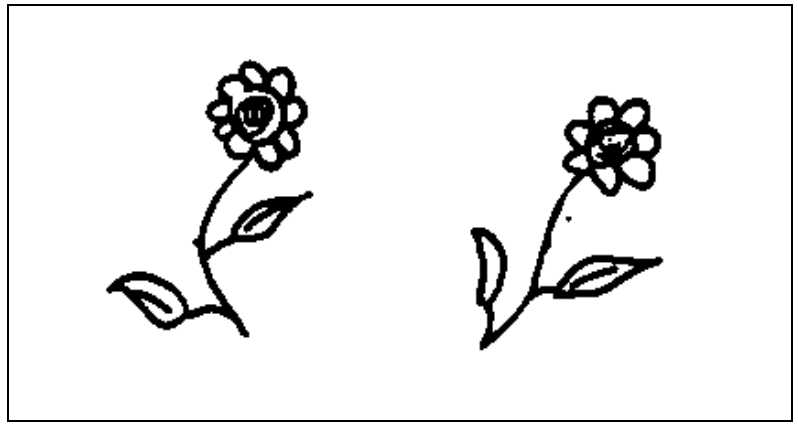
FIGURE 5.21 STROOP INTERFERENCE

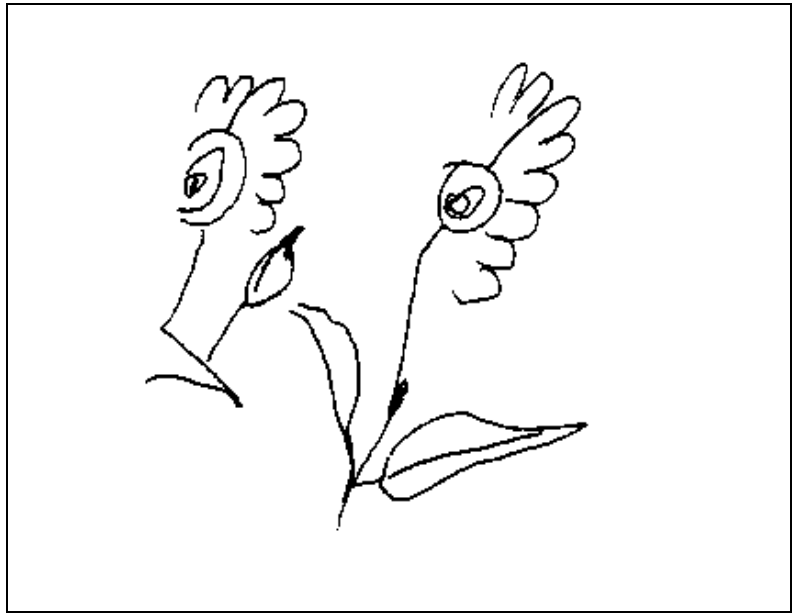
As rapidly as you can, name out loud the colors of the *ink* in Column A. (You'll say, "black, green" and so on.) Next, do the same for Column B — again, naming out loud the colors of the ink. You'll probably find it much easier to do this for Column A, because in Column B you experience interference from the automatic habit of reading the words.

Alan Burgess

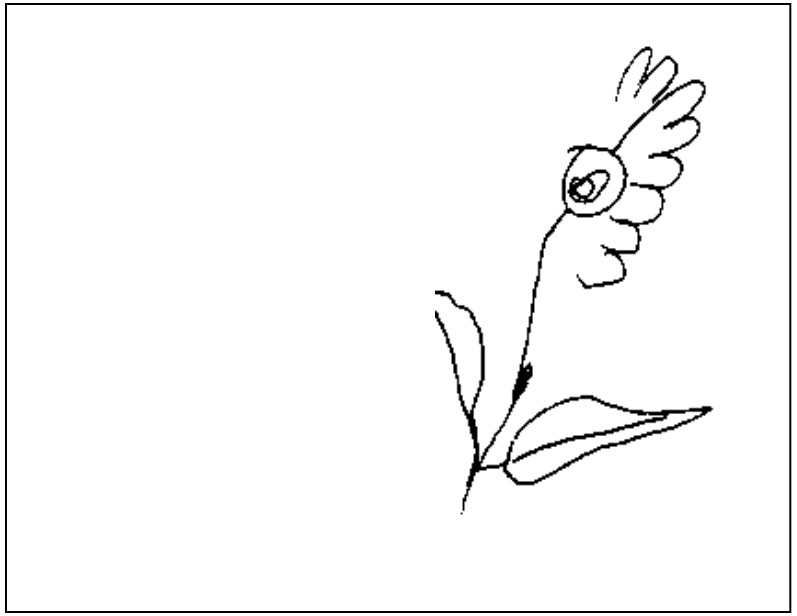
- hemispatial neglect – an inability to pay attention to sensory stimuli on his left side .
- Stroke damaged the parietal lobe on the right side of his brain, the part that deals with the higher processing of attention. The damage causes him to ignore people, sounds, and objects on his left.
- research suggests that people with normal vision perform better at visual attention tasks when they are rewarded for good performance and Dr Malhotra and his team have found the same thing in neglect patients.

Dr Paresh Malhotra, senior lecturer in neurology at Imperial College London



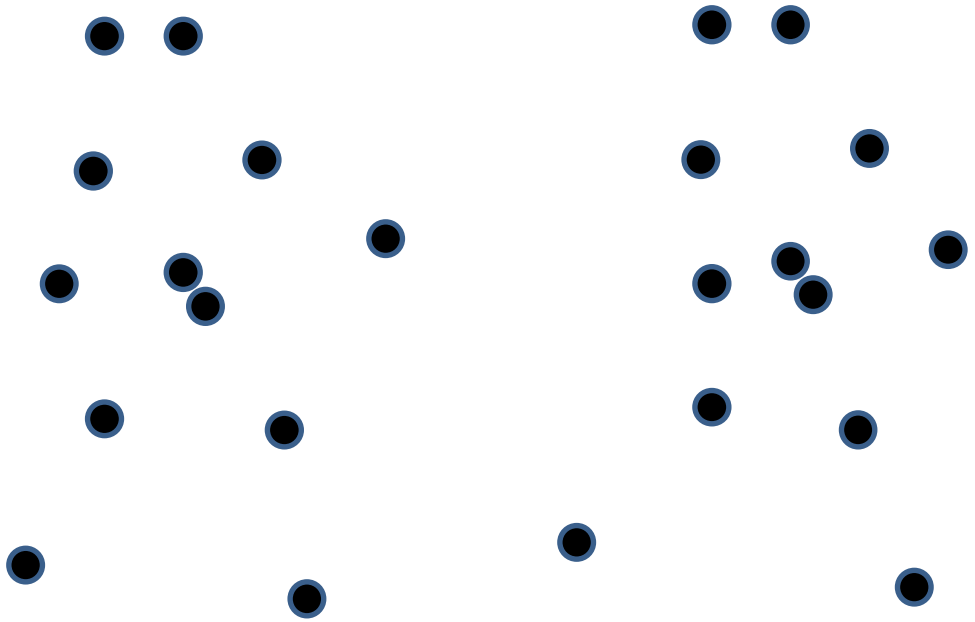


Object-centred Neglect



Object and Location-based Neglect

Reconstructing shape from movement



Johansson (1973)

https://www.youtube.com/watch?v=rEVB6kW9p6k

What/Where Pathways
Evidence from Neuropsychology

Visual agnosia: apperceptive agnosia (features) and associative agnosia (meaning).

Inability to identify objects and/or people

Caused by damage to inferior (lower) temporal lobe

Disruption of the "what" pathway

https://www.youtube.com/watch?v=ze8VVtBgK7A

Face recognition – prosopagnosia.

2006 study revealed that about one in 50 Americans is affected by Prosopagnosia.

https://www.youtube.com/watch?v=-vQGPcYfIAo

https://www.youtube.com/watch?v=vwCrxomPbtY