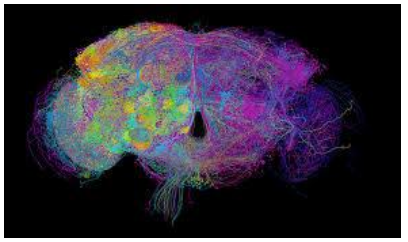
First 57 for quiz 2

Caenorhabditis elegans

302 neurons and 7,000 connections



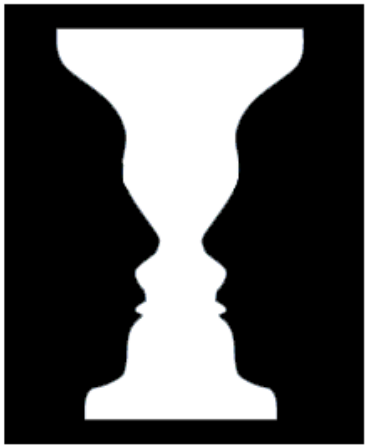
Drosophila melanogaster

roughly 135,000 *neurons*in the brain

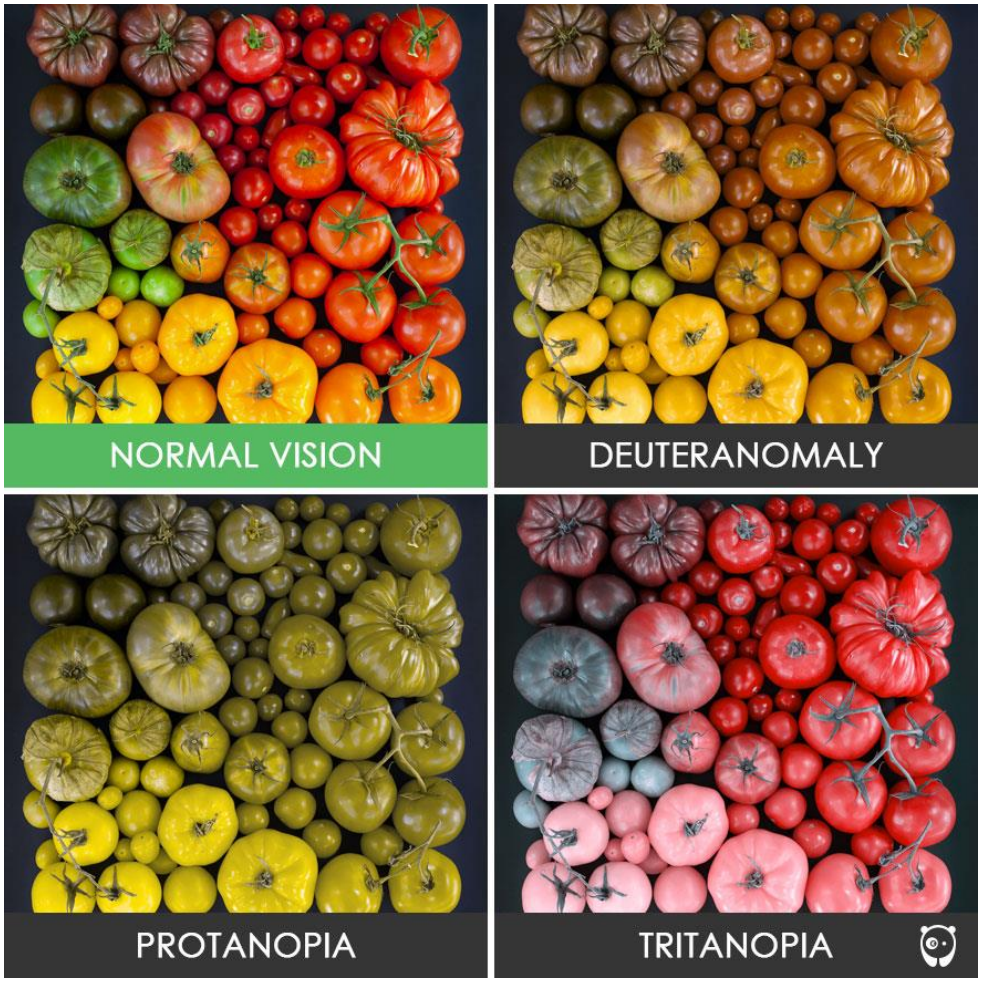
86 billion neurons in our brains

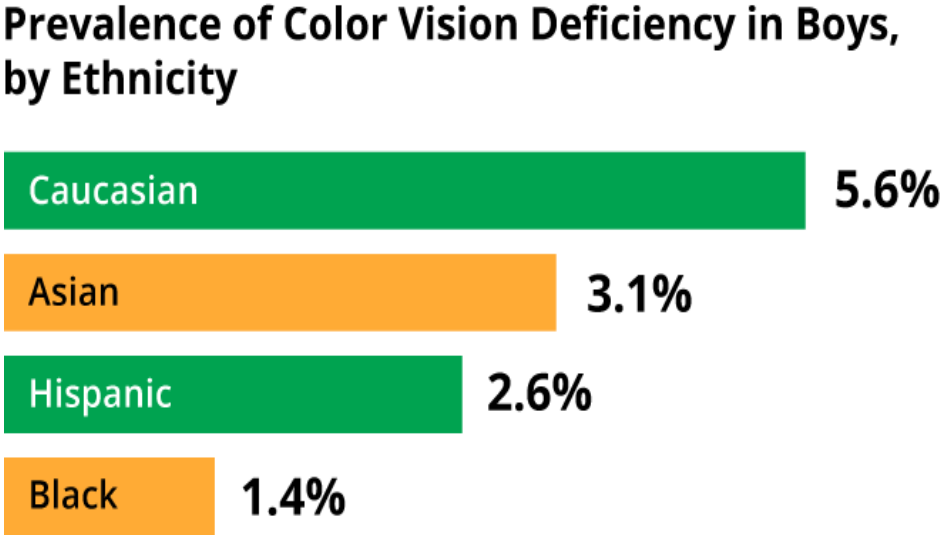
Visual System

Kavita Vemuri



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 rare.

prosopagnosia

- **Case report Annie**

 - faces

- Navigation

- attention

Object & face recognition deficiency

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

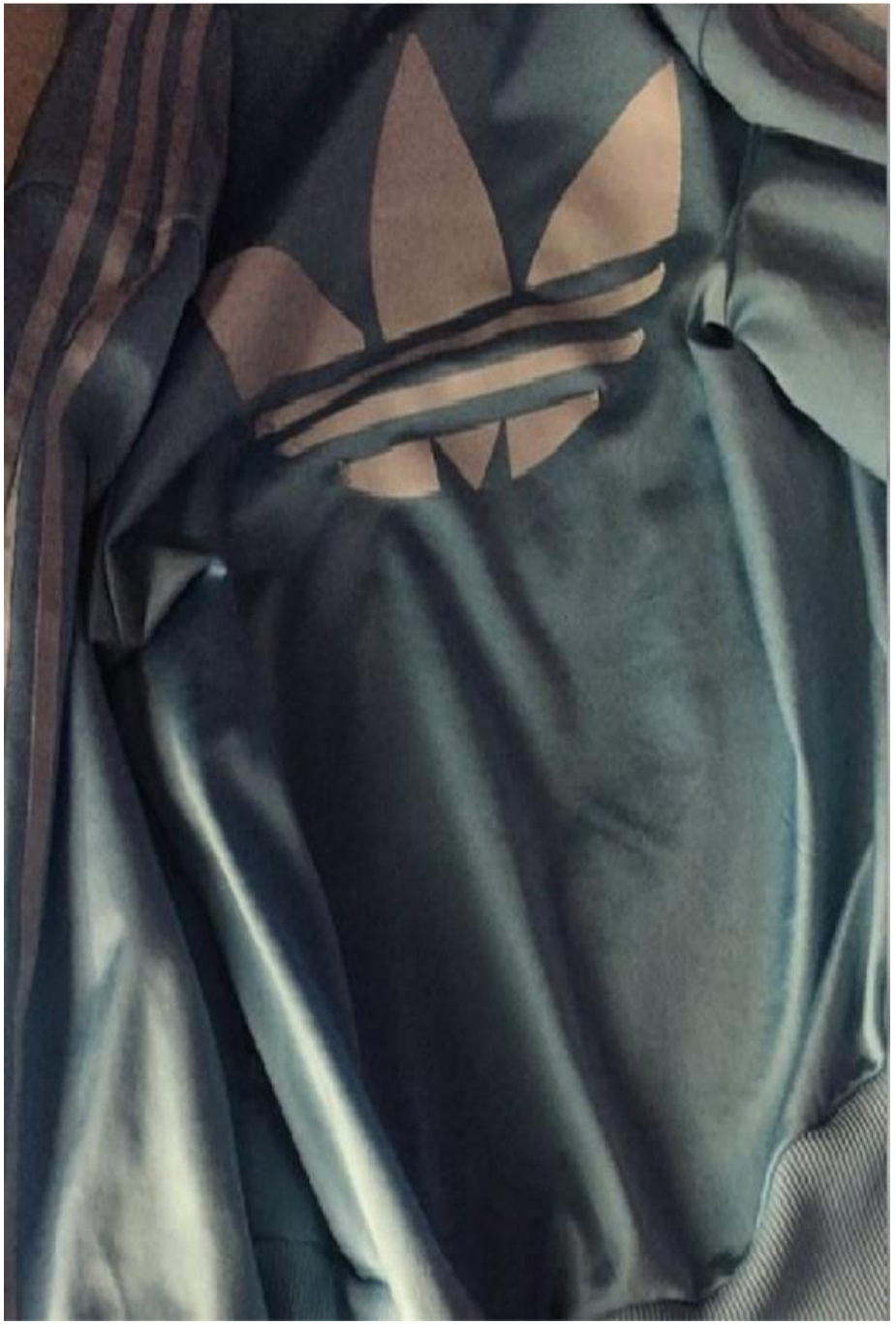
Face recognition – prosopagnosia.

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

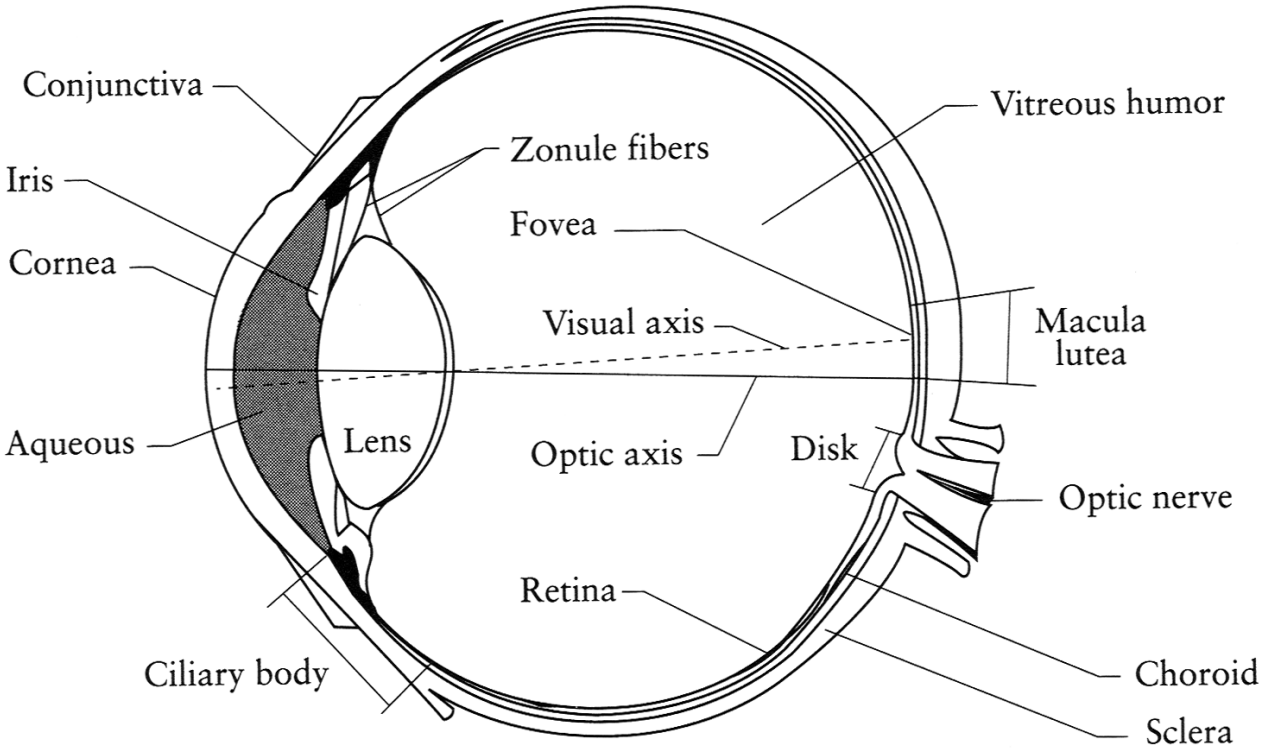
Recent study:Long covid might have lead to prosopagnosia
https://www.sciencedirect.com/science/article/pii/S0010945223000448



The visual system

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

The Eye is a camera?

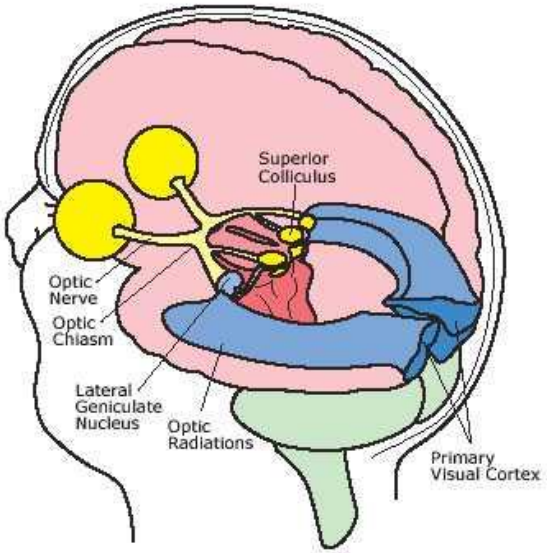


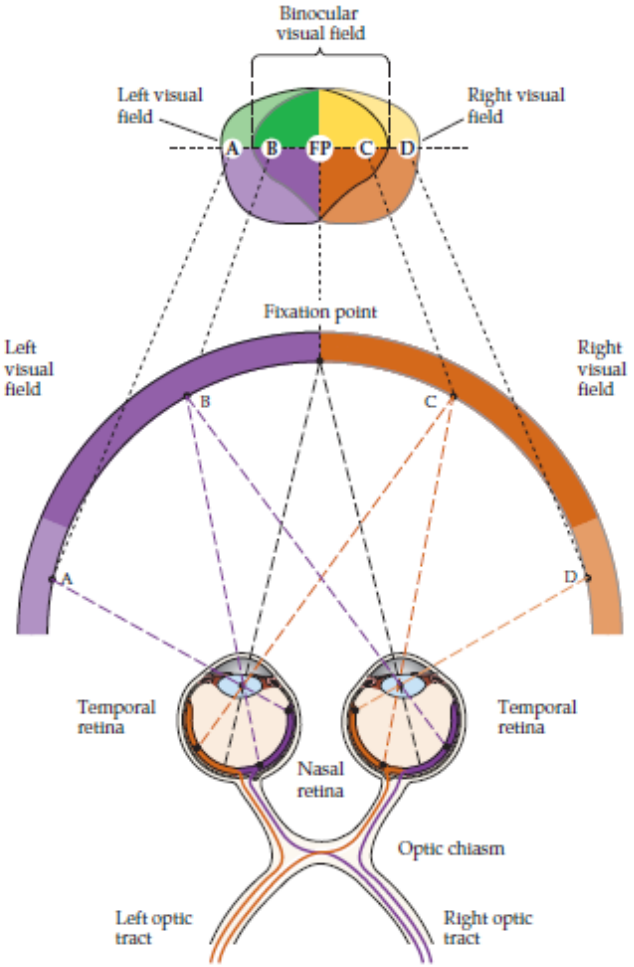
The camera is designed as the eye!

- **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**

The Visual System

Both eye and brain are required for functional vision

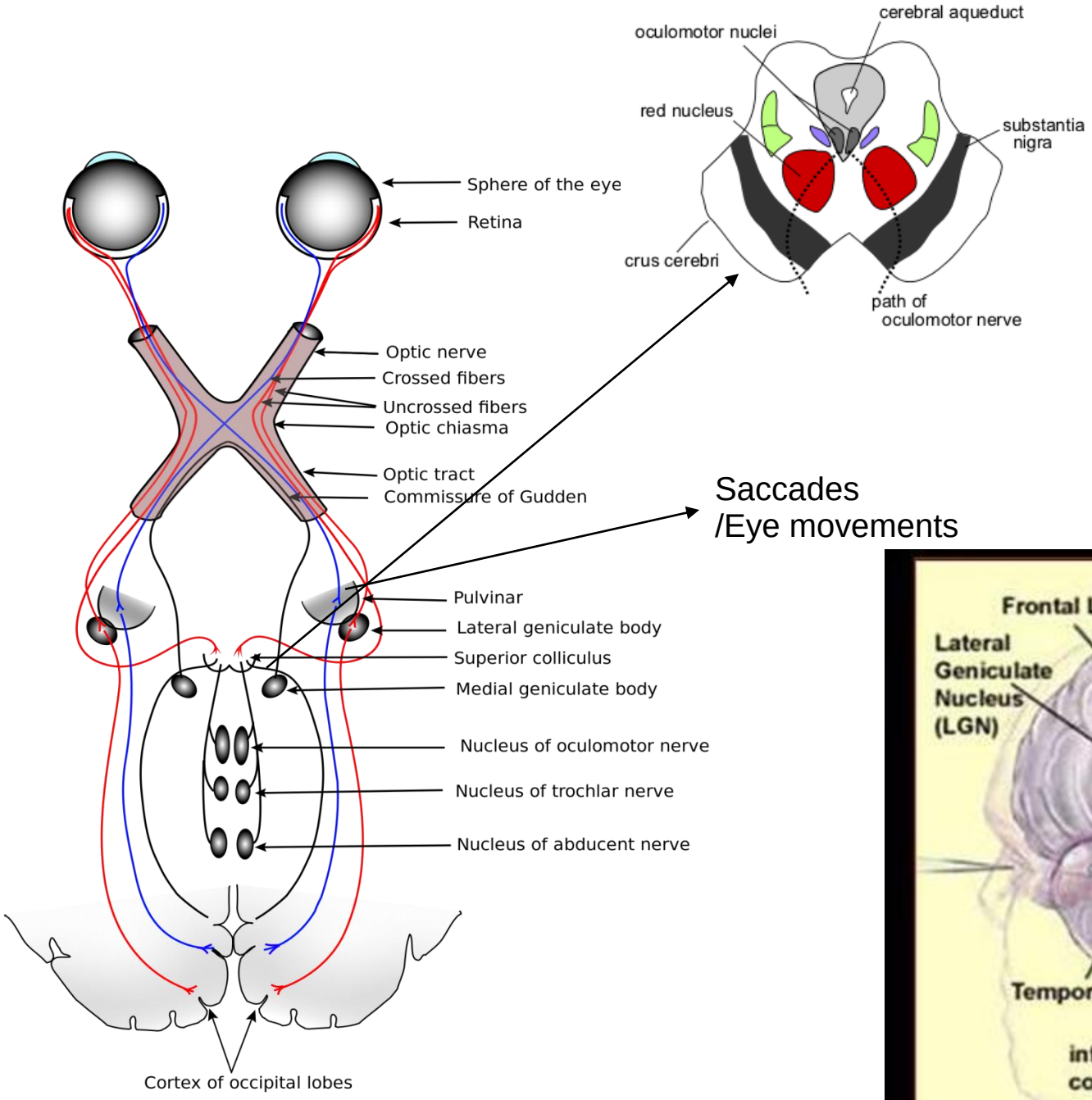




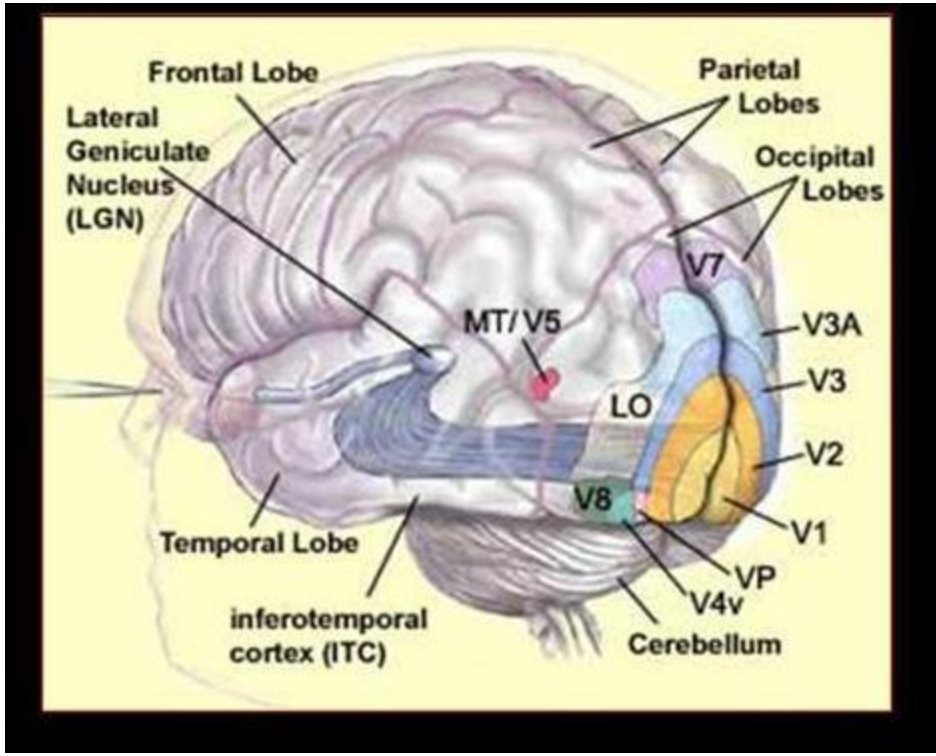
Two kinds of blindness:

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

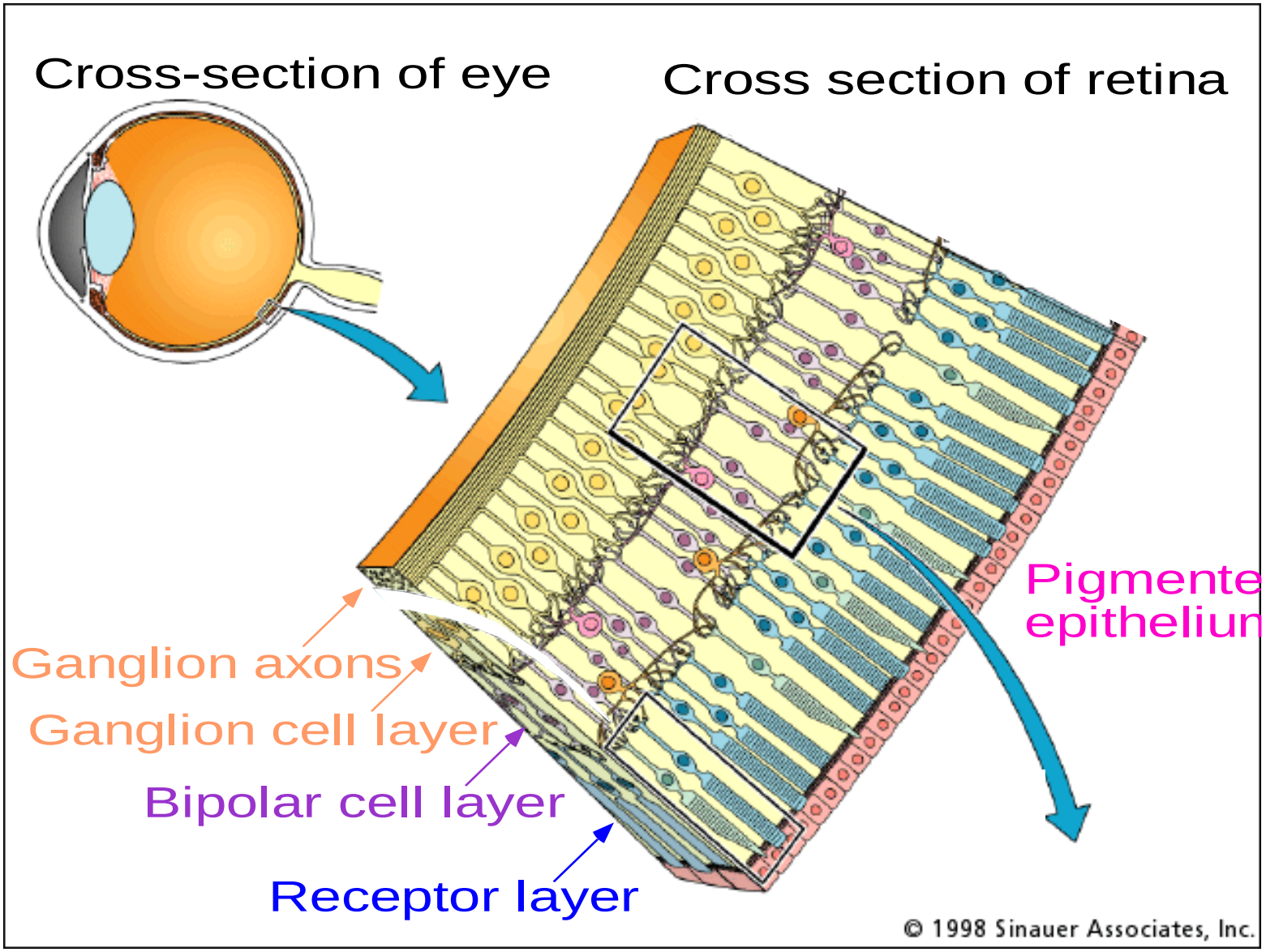
Pathway to Visual Cortex



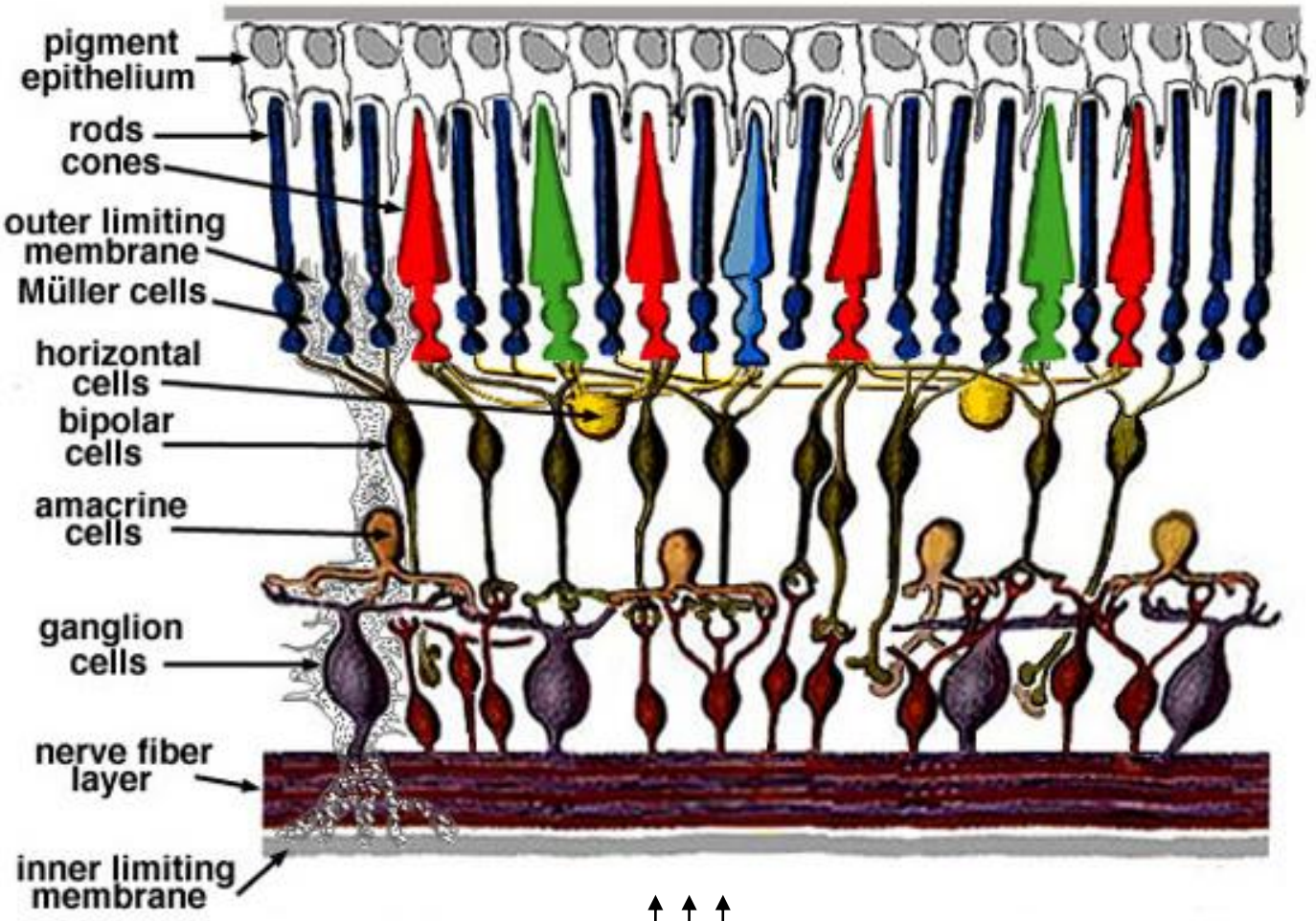
Saccades
/Eye movements



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

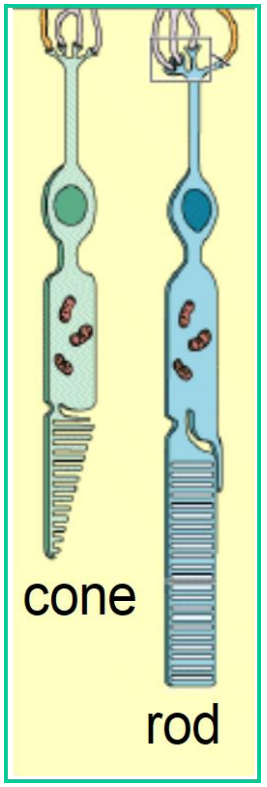
Two types of light-sensitive receptors

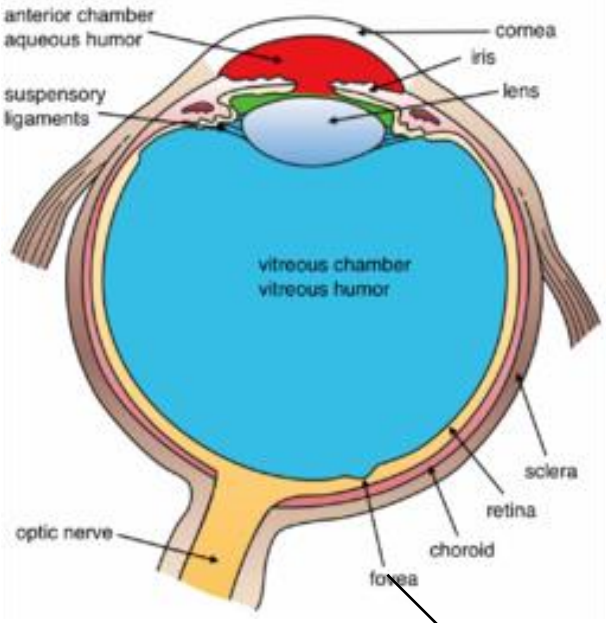
Cones

- cone-shaped
- less sensitive
- operate in high light
- color vision
  - Discern fine detail

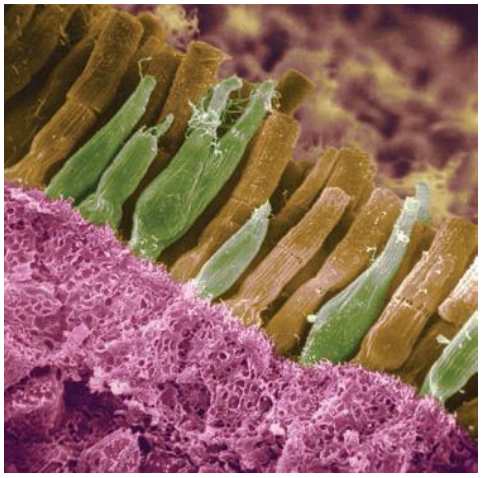
Rods

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





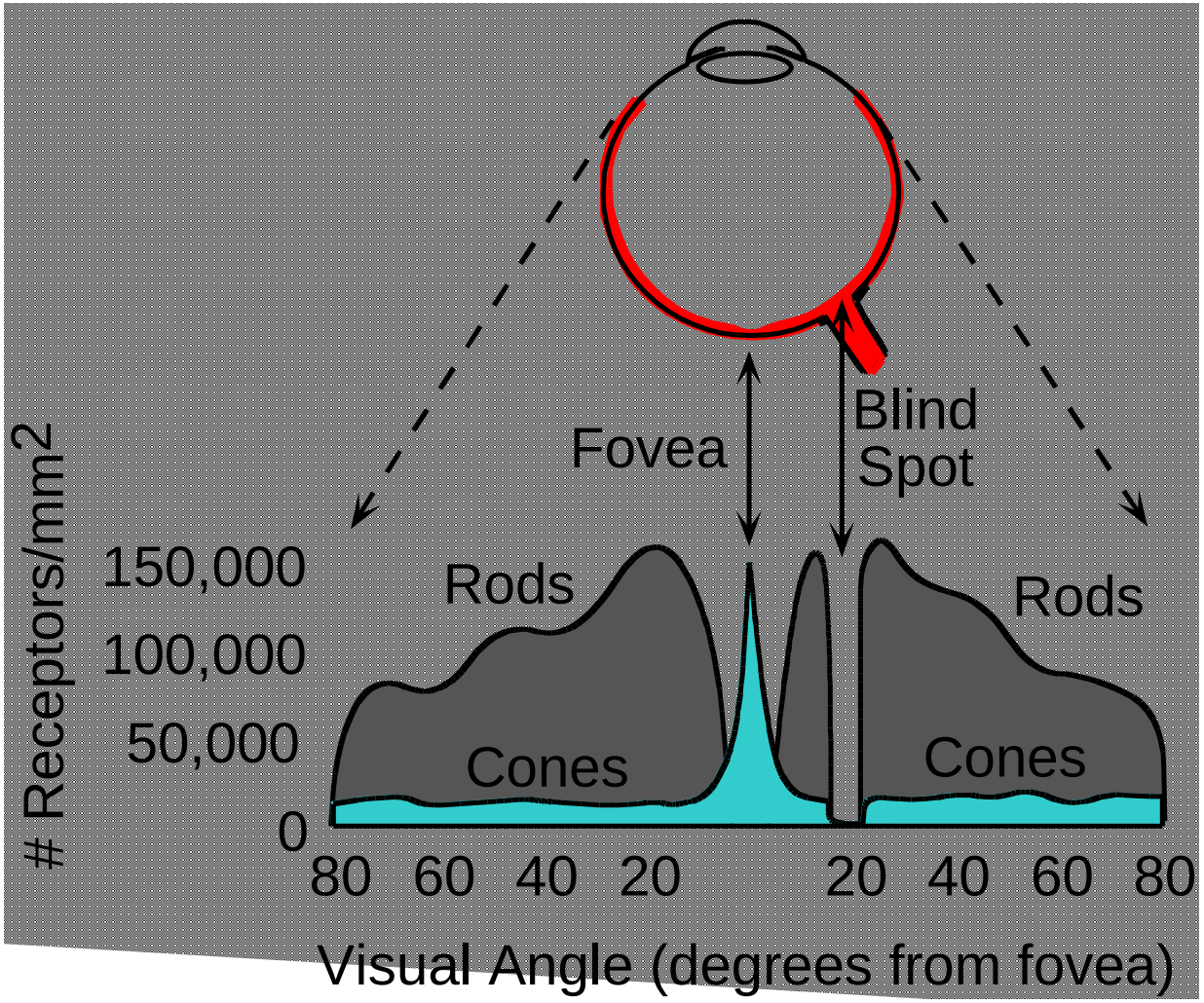
0.3 mm diameter rod-free area



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

Source: Daniel Reisberg's book

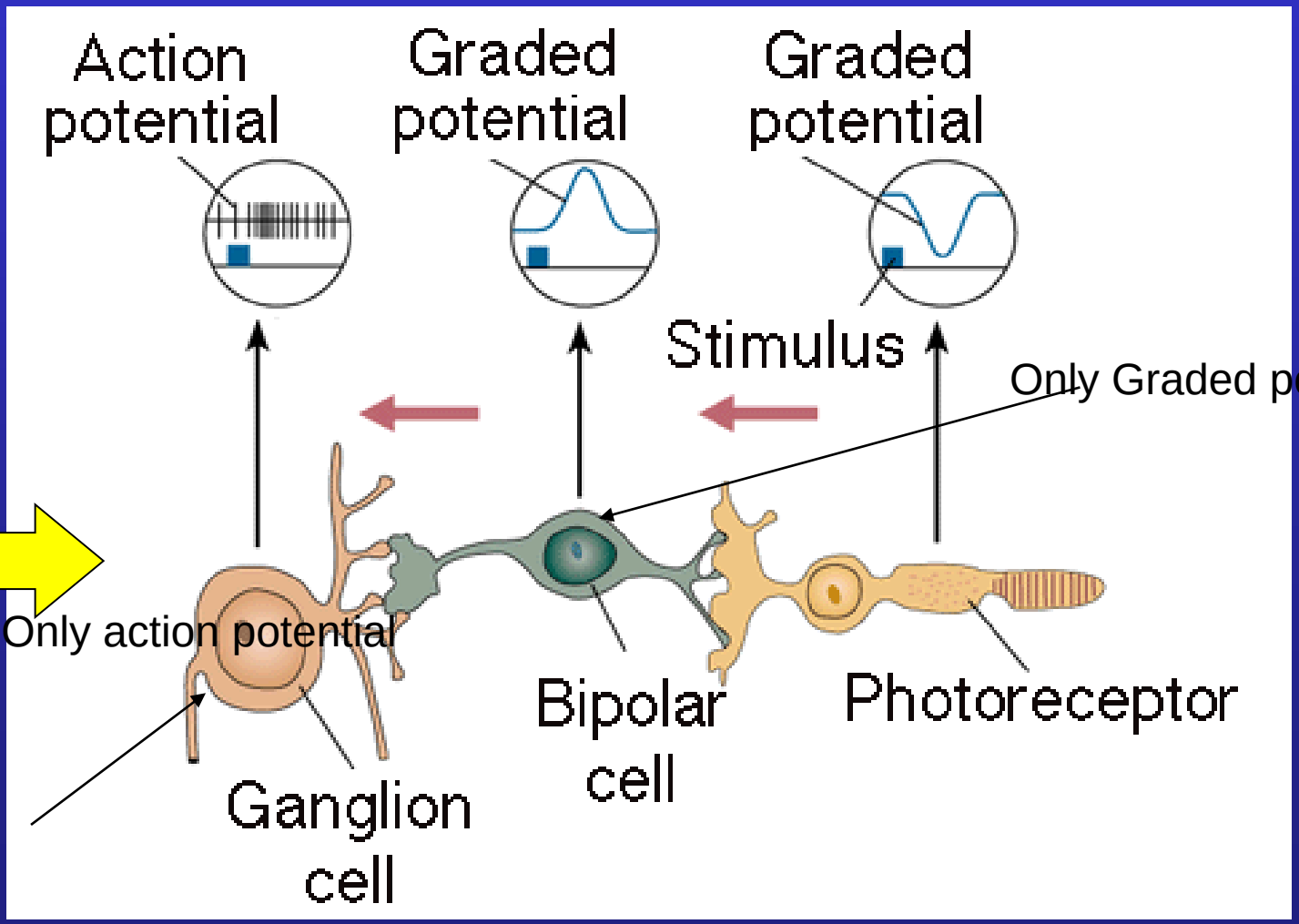
Distribution of Rods and Cones



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

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.

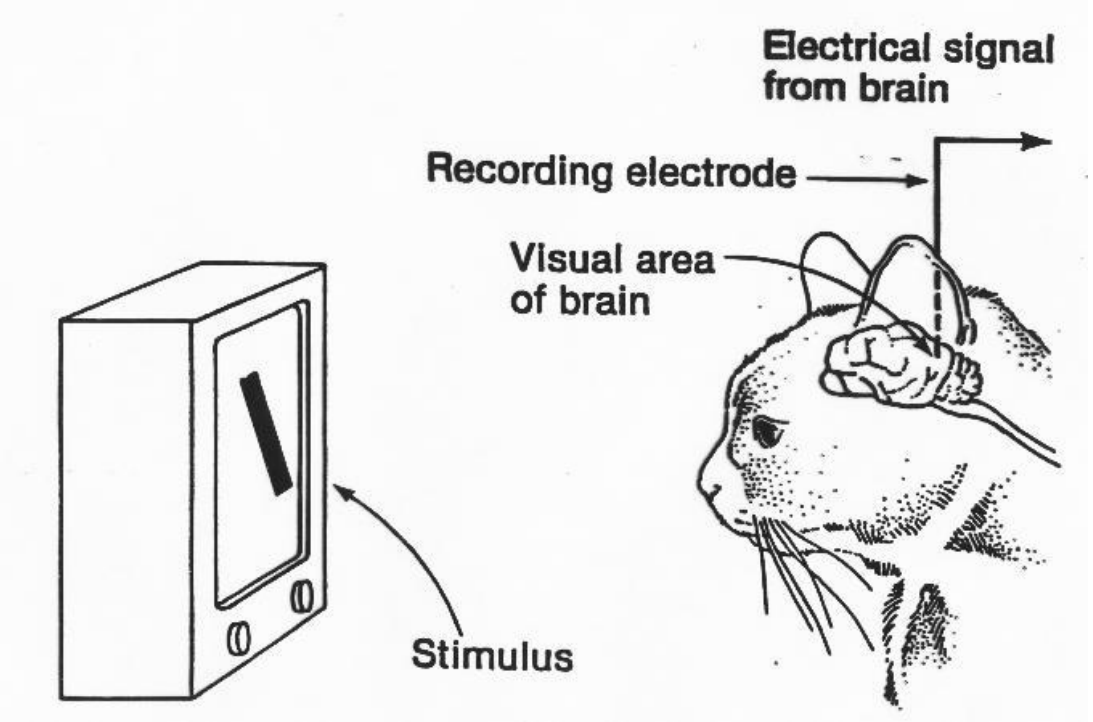
http://www.cns.nyu.edu/~david/courses/perception/lecturenotes/ganglion/ganglion.html

Cortical Receptive Fields

Single-cell recording from visual cortex

David Hubel & Thorston Wiesel

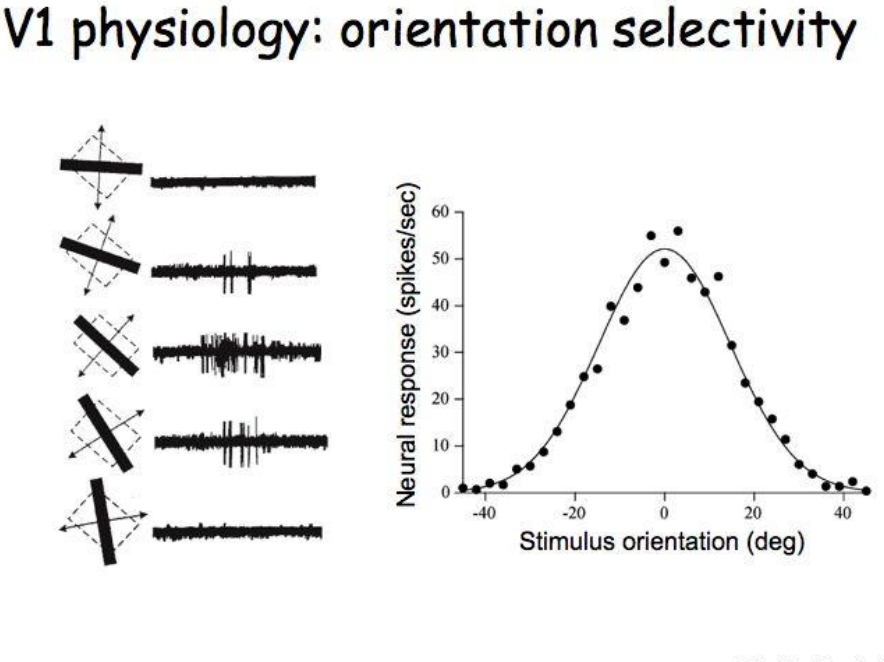
Hubel and Wiesel



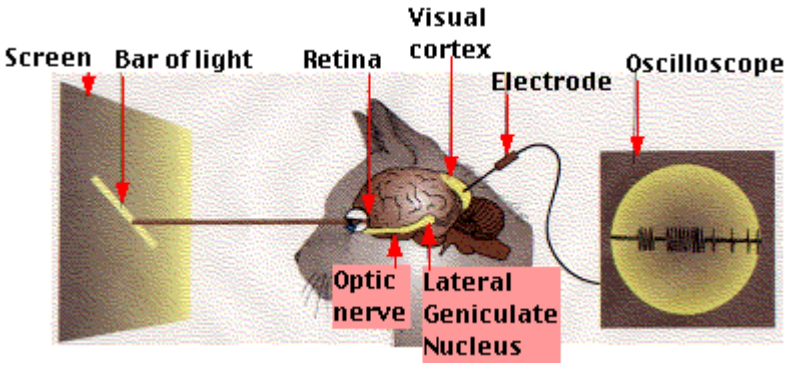
http://www.cns.nyu.edu/~david/courses/perception/lecturenotes/V1/LGN-V1-slides/hw-2-cortical-rfs-640x480.mov

Function of the V1

- David Hubel and Torsten Wiesel discovered the functional organizatior 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*.

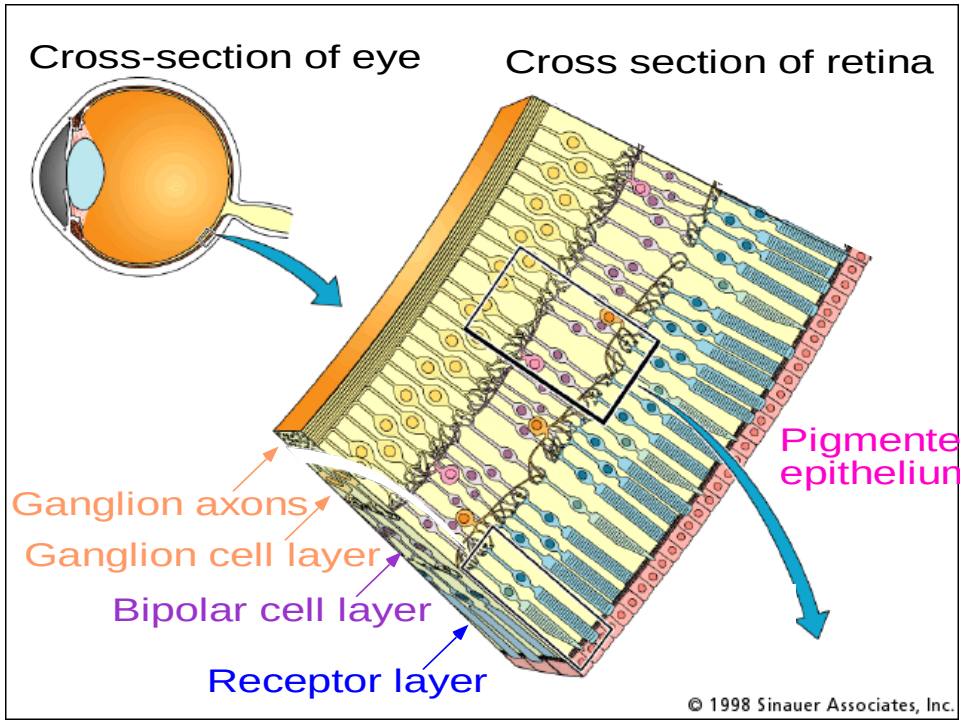


Hubel & Wiesel, 1968

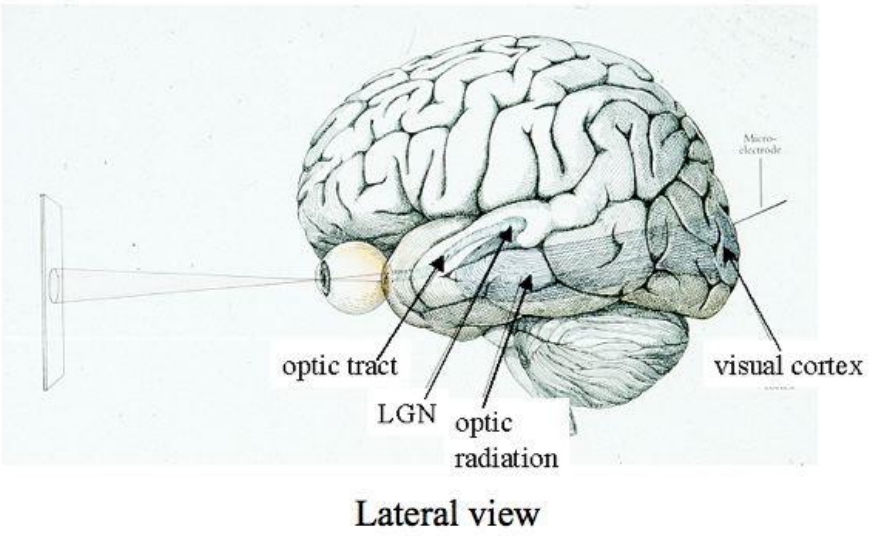


The Eye and Light

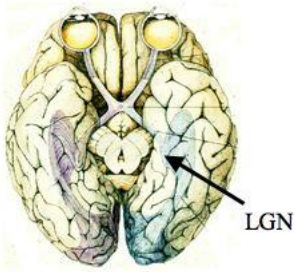
Theories on:
how color is perceived?
How objects are recognized?
How do we pattern recognize?
How motion is perceived?



Retinogeniculate visual pathway



Lateral Geniculate Nucleus (LGN)



- 6 layers.
- Cells have monocular input.
- Layers alternate inputs from each of the two eyes.
- The top four are parvocellular layers, two layers from each eye. Parvo (small) LGN cells receive inputs from (small) midget ganglion cells.
- The bottom two are magnocellular layers, one layer from each eye. Magno (large) LGN cells receive inputs from (large) parasol ganglion cells.

lateral geniculate nucleus

- Research is not conclusive, as yet, on the exact role of the LGN, as no extra processing post retina seems to take place, but two compelling hypothesis are:
- The LGN brings retinotopic maps from both eyes into register to make it easy for cortex to combine inputs from the two eyes.
- Only 10% of inputs to LGN come from the retina. 90% are modulatory inputs from cortex and the brainstem. The brainstem modulates the information flow from the eye to the visual cortex. Cortical (feedback) inputs to LGN are not well understood but might have to do with attention. The LGN is a convenient bottleneck for these modulatory inputs from the brainstem and cortex. If you tried to send these projections from brainstem and cortex all the way back to the retina then you'd end up with a blind spot that was 10 times larger.

Visual Cortex

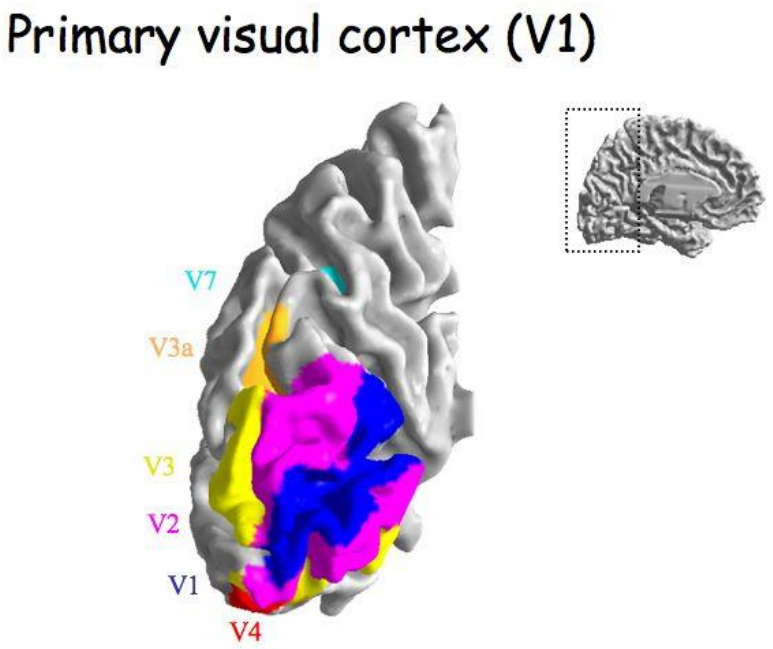
V1 (in blue).

V1 processes the information coming from the LGN and then passes its output to the other visual cortical areas which are (creatively) named V2, V3, V4, etc.

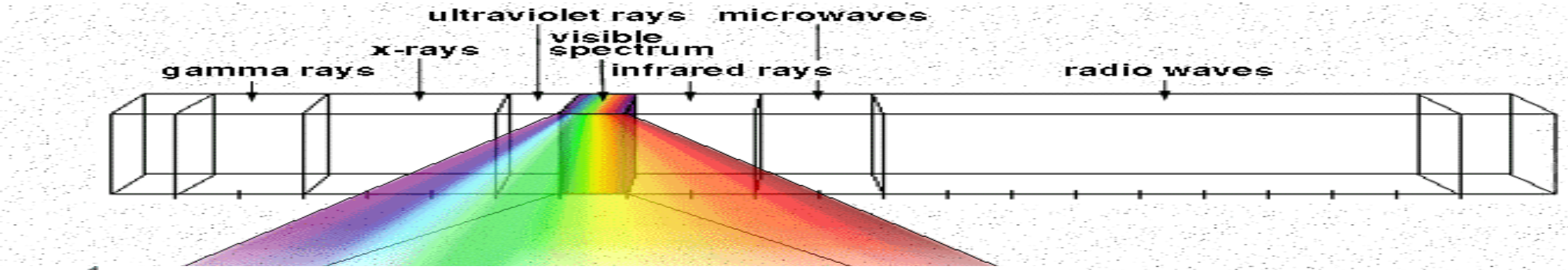
A large area of the visual cortex is mapped to some portion of the retina

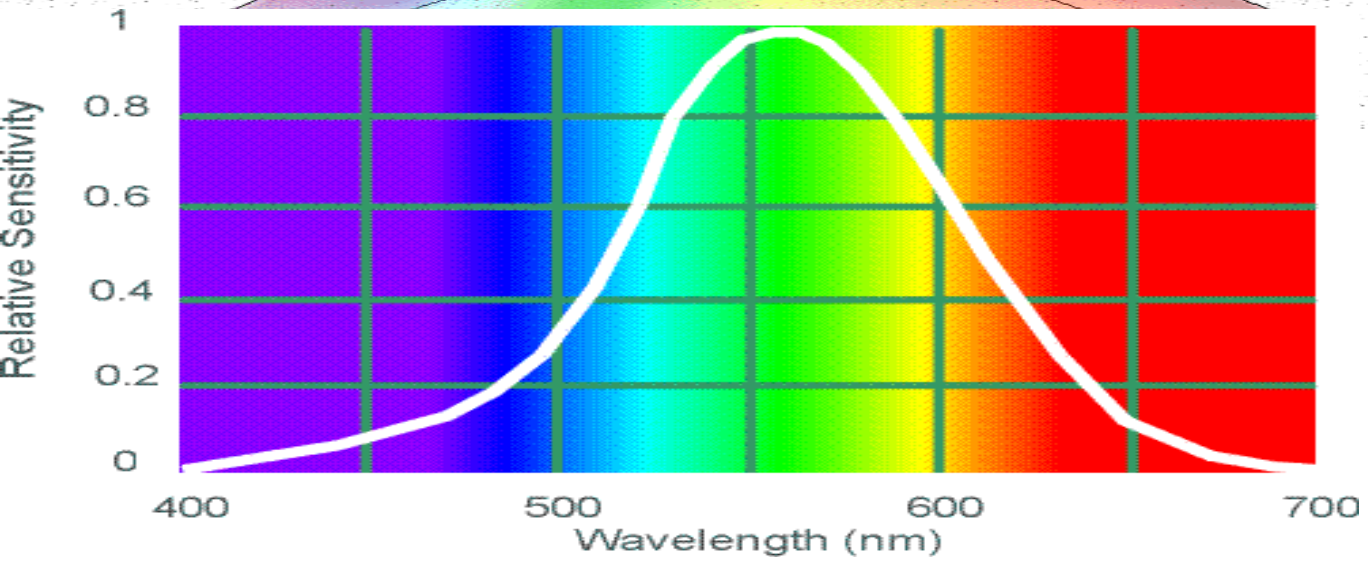
Contains 6 layers and the layers are distinguished by the cells.

In humans, it contains about 140 million neurons per hemisphere (Wandell, 1995), i.e. about 40 V1 neurons per LGN neuron



Electromagnetic Spectrum

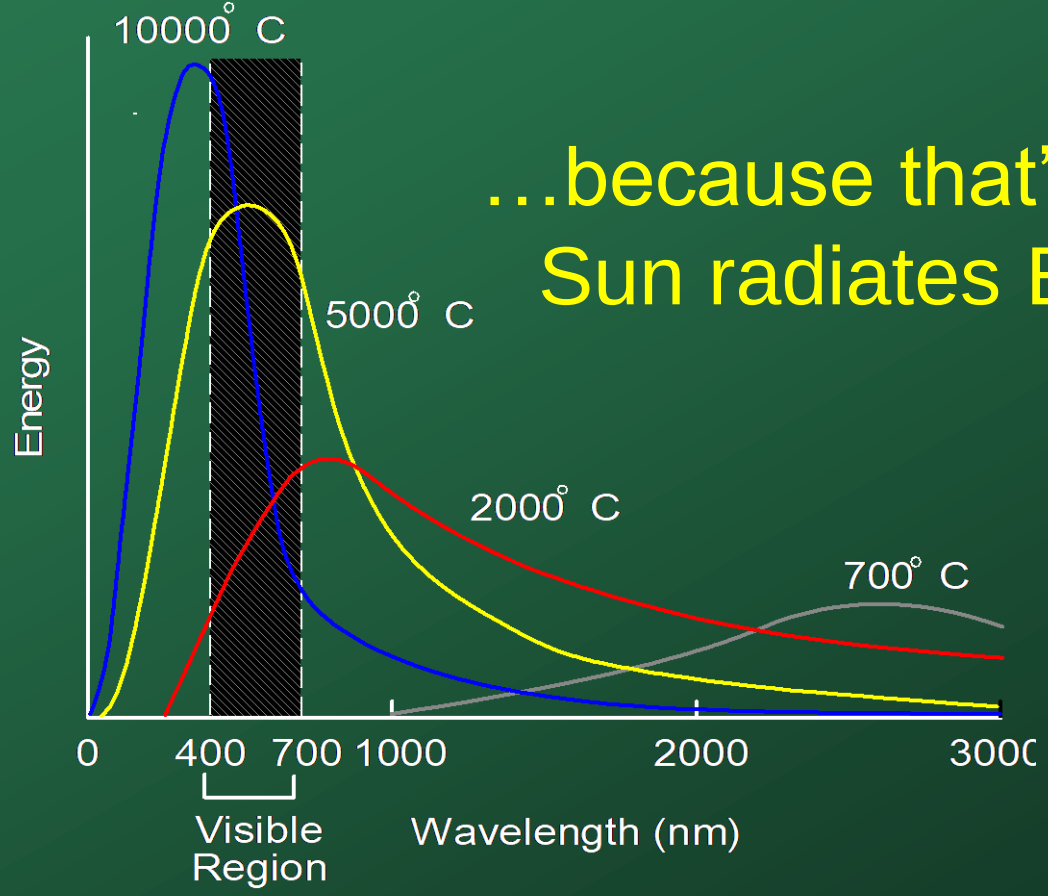




Human Luminance Sensitivity Function

Visible Light

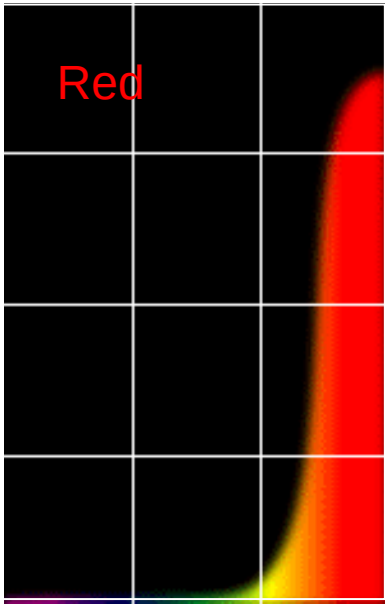
Why do we see light of these wavelengths?

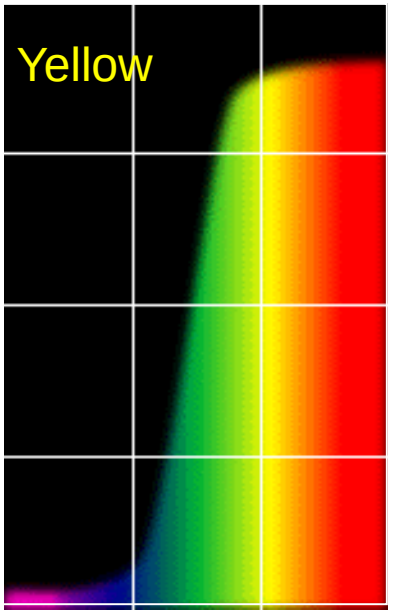


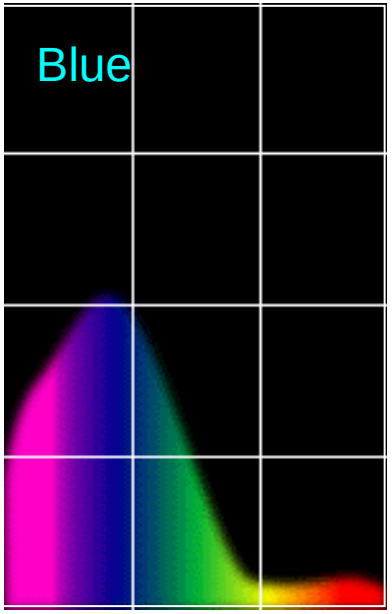
…because that's where the Sun radiates EM energy

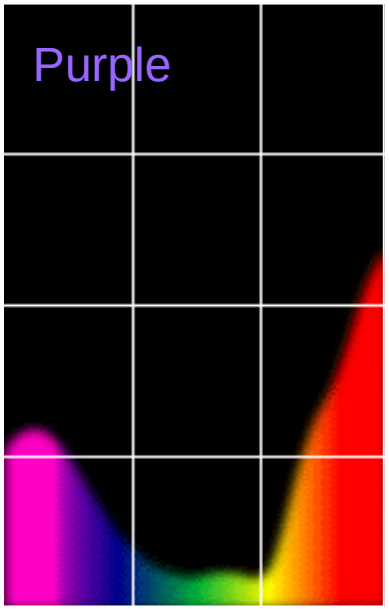
The Physics of Light

Some examples of the reflectance spectra of surfaces



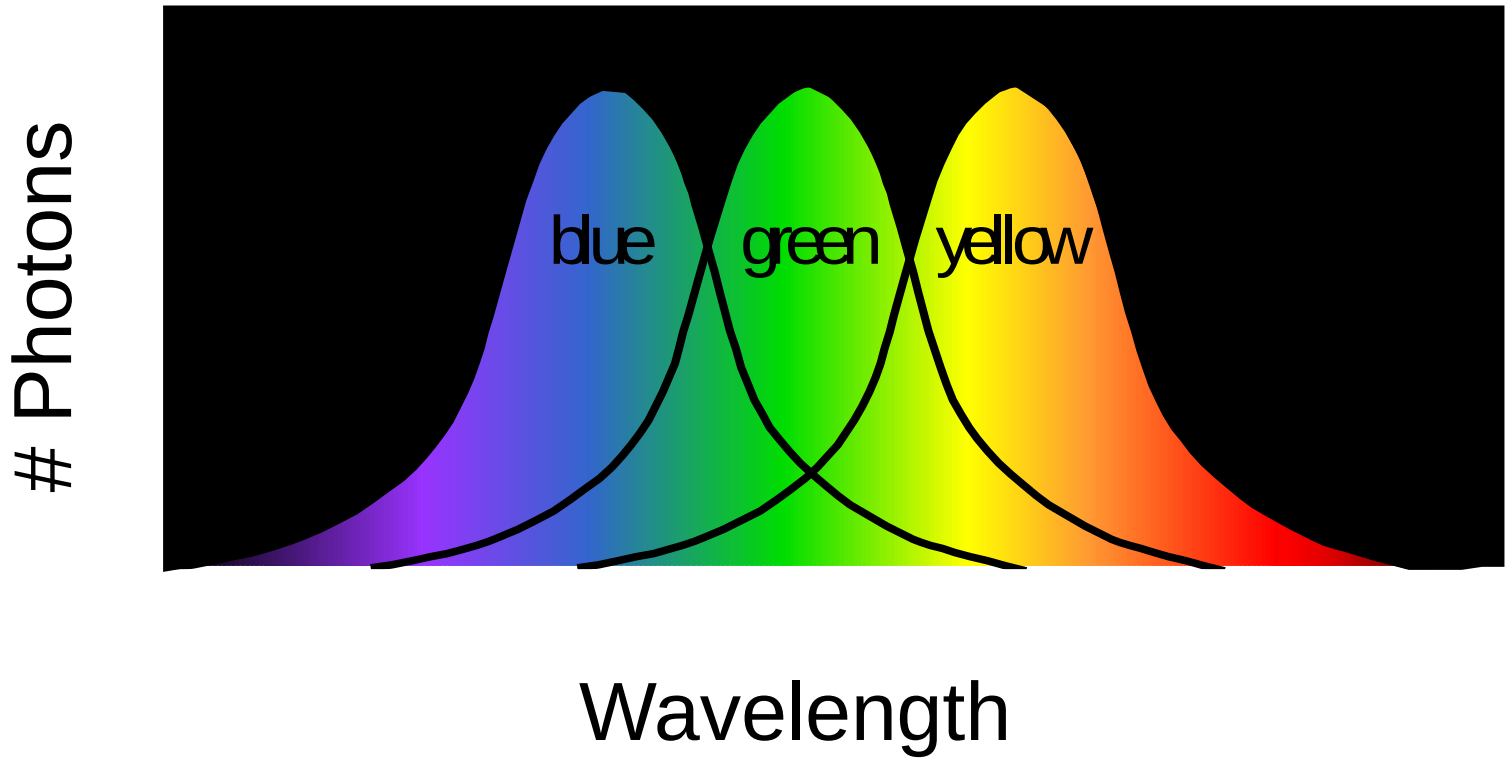






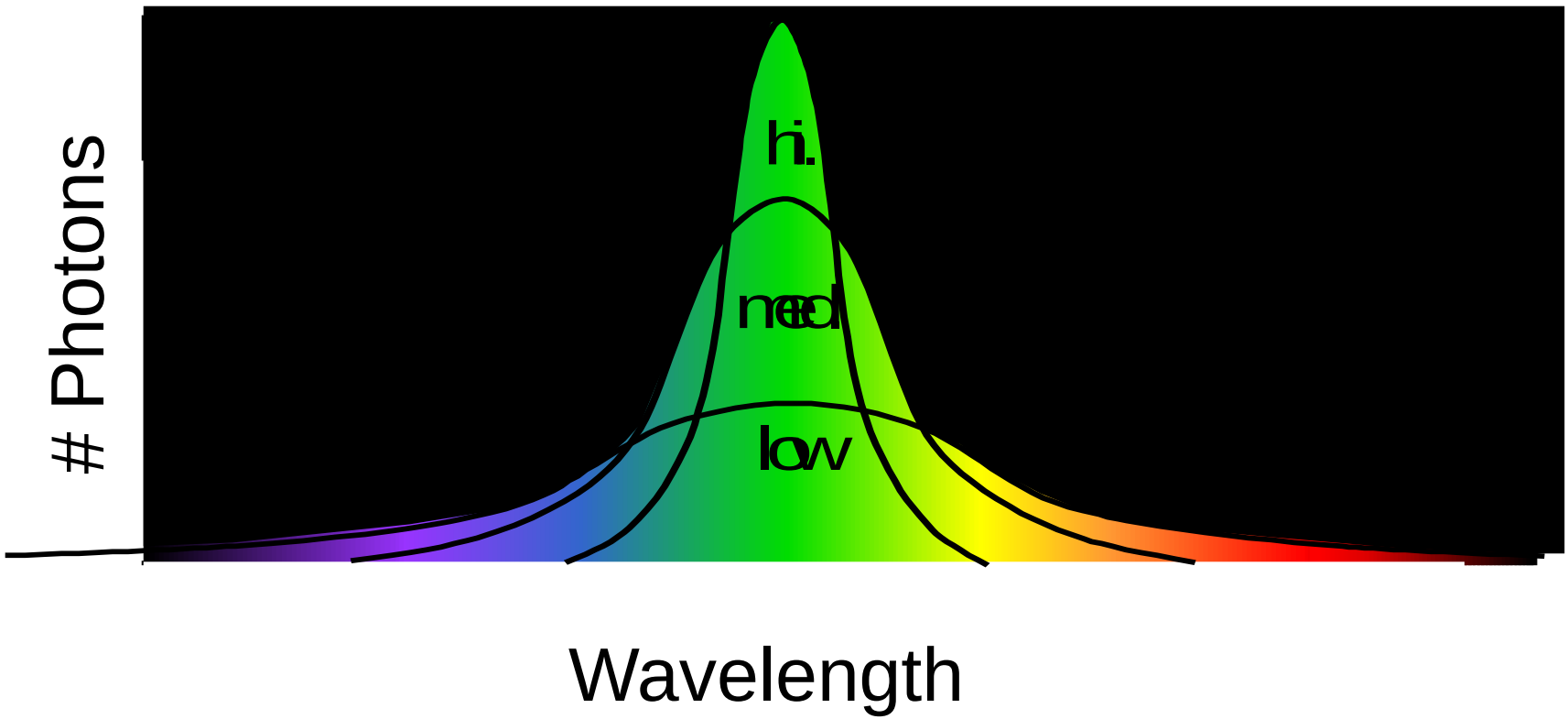
The Psychophysical Correspondence

Mean ⟷ **Hue**



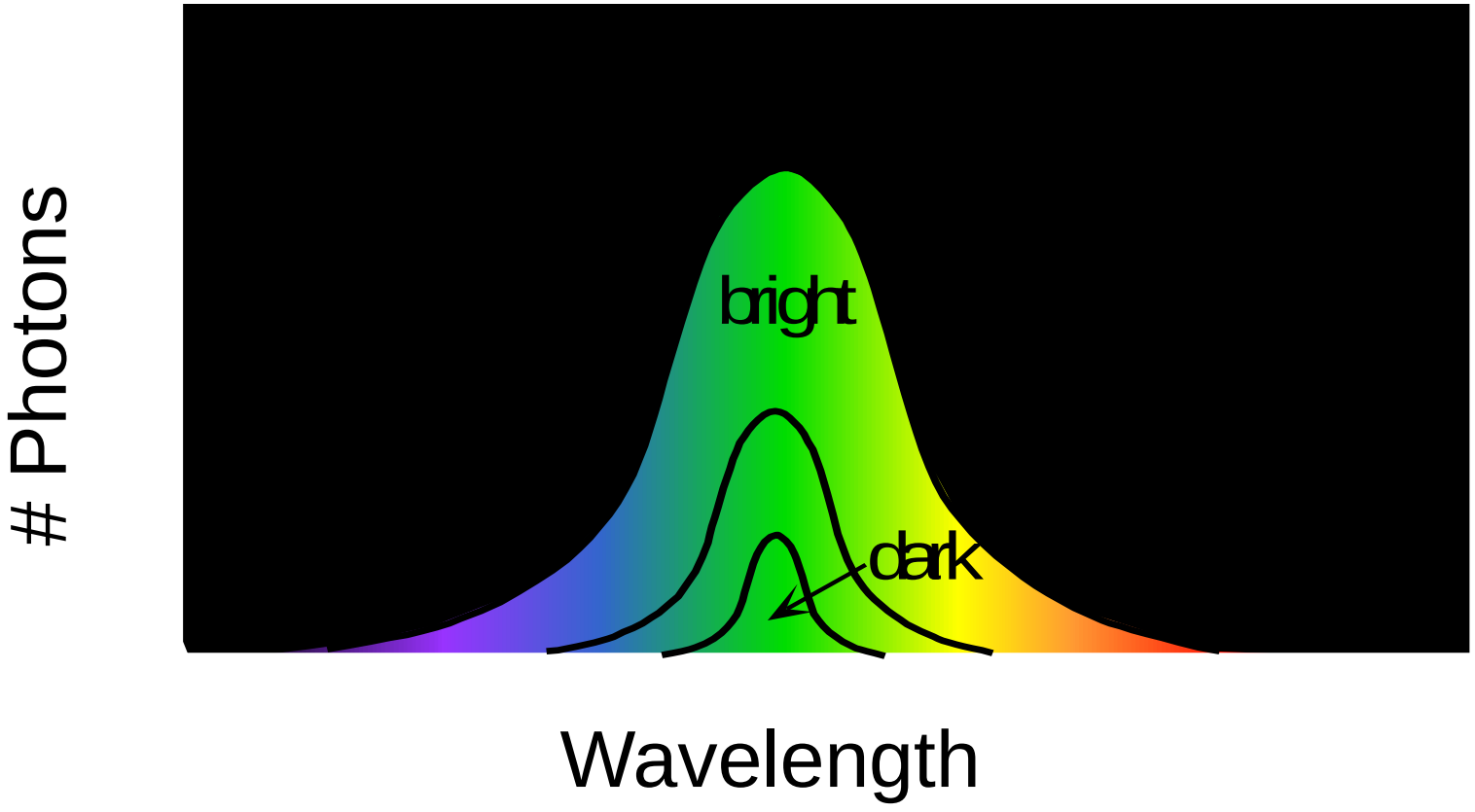
The Psychophysical Correspondence

Variance ⟷ Saturation



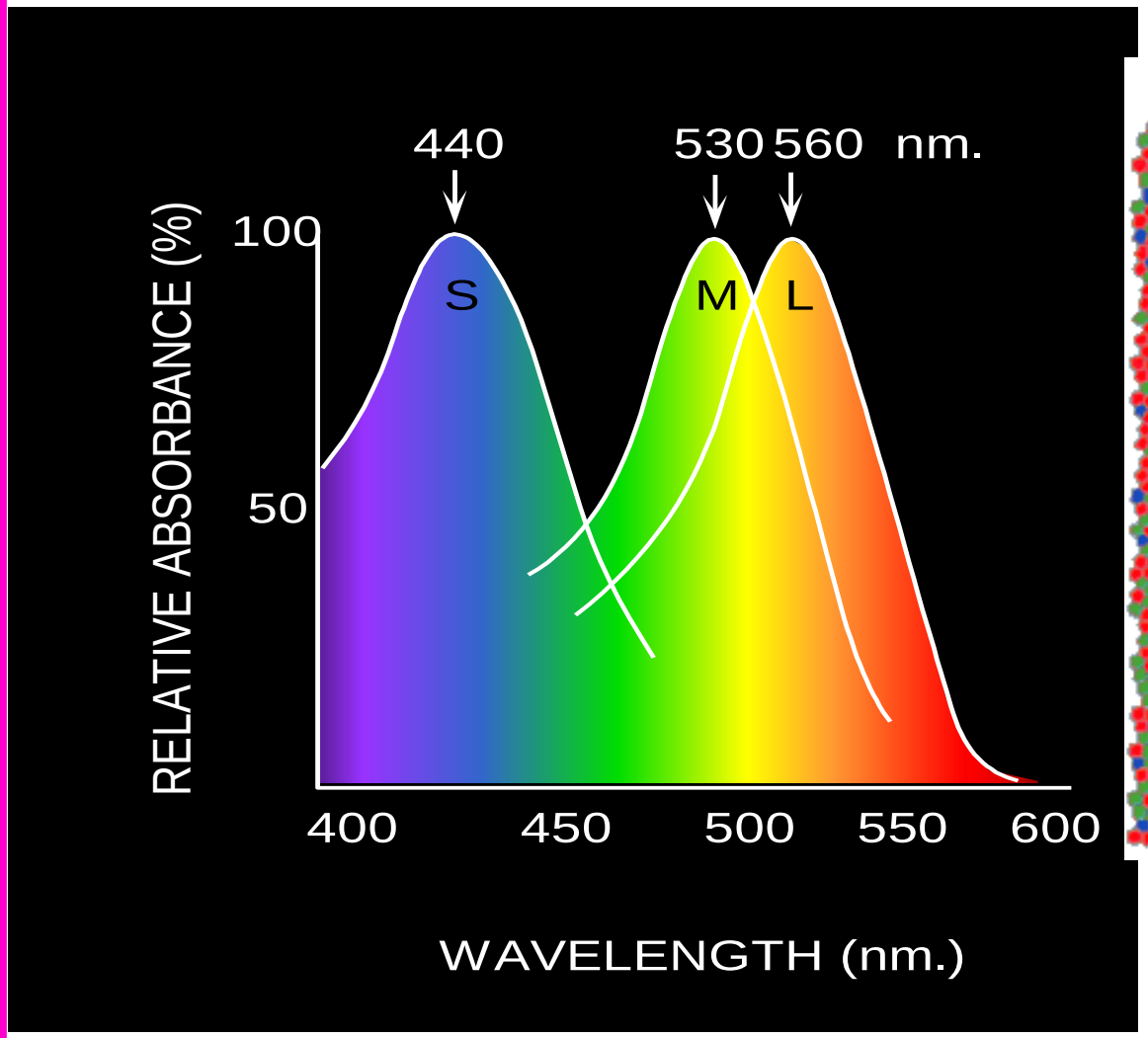
The Psychophysical Correspondence

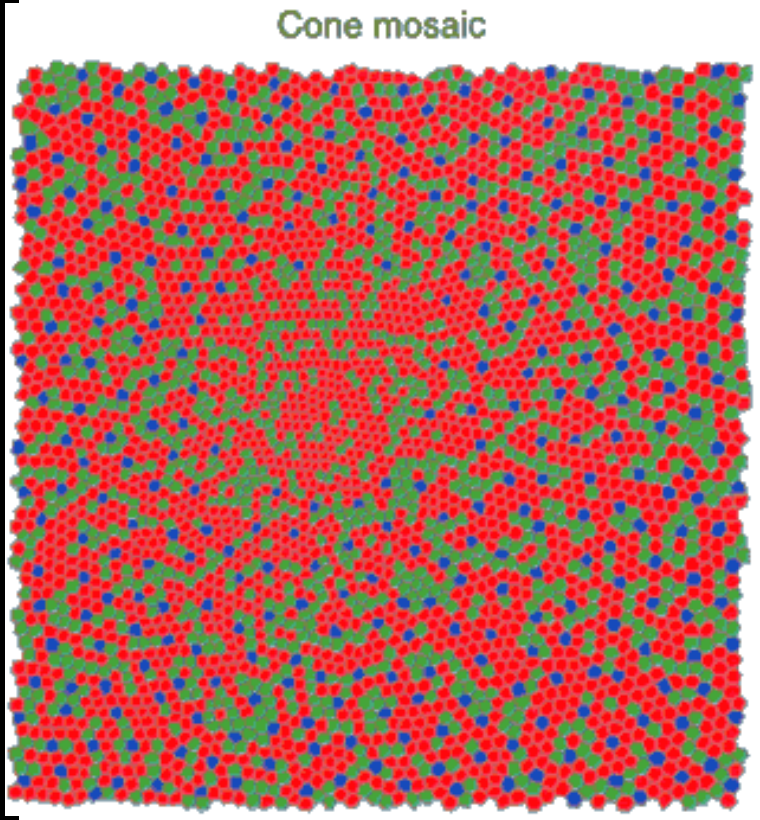
Area ⟷ Brightness



Physiology of Color Vision

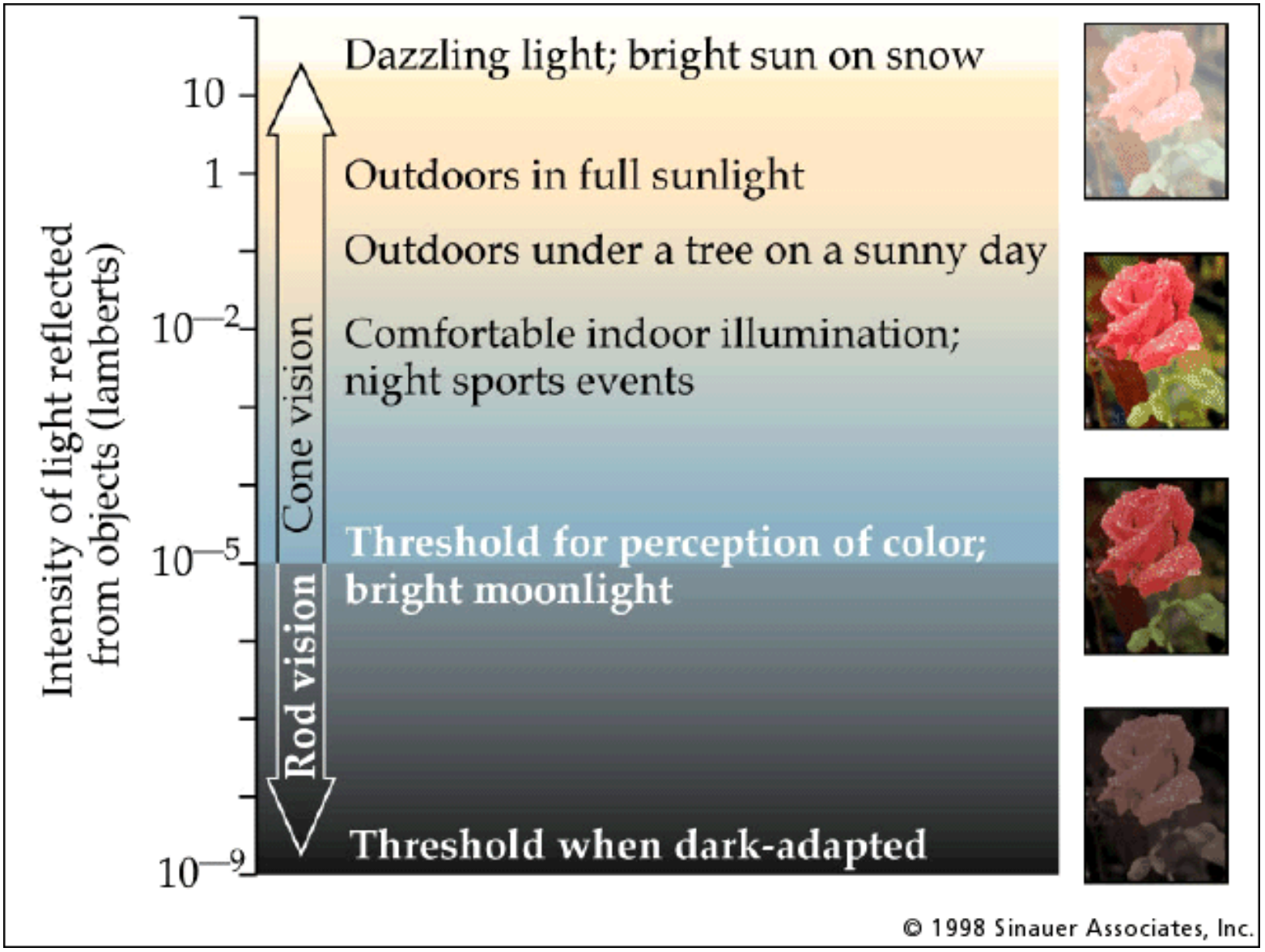
Three kinds of cones:



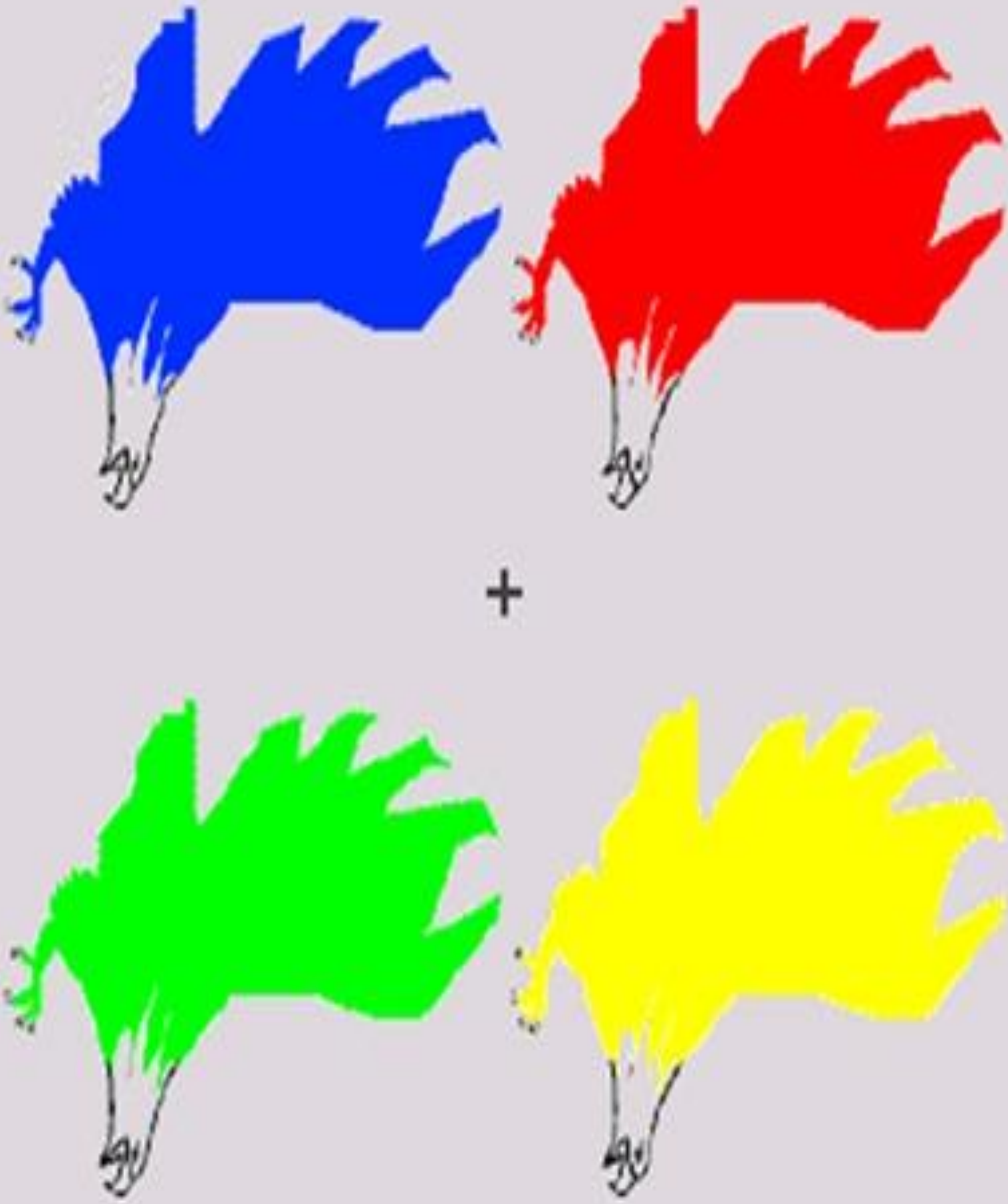


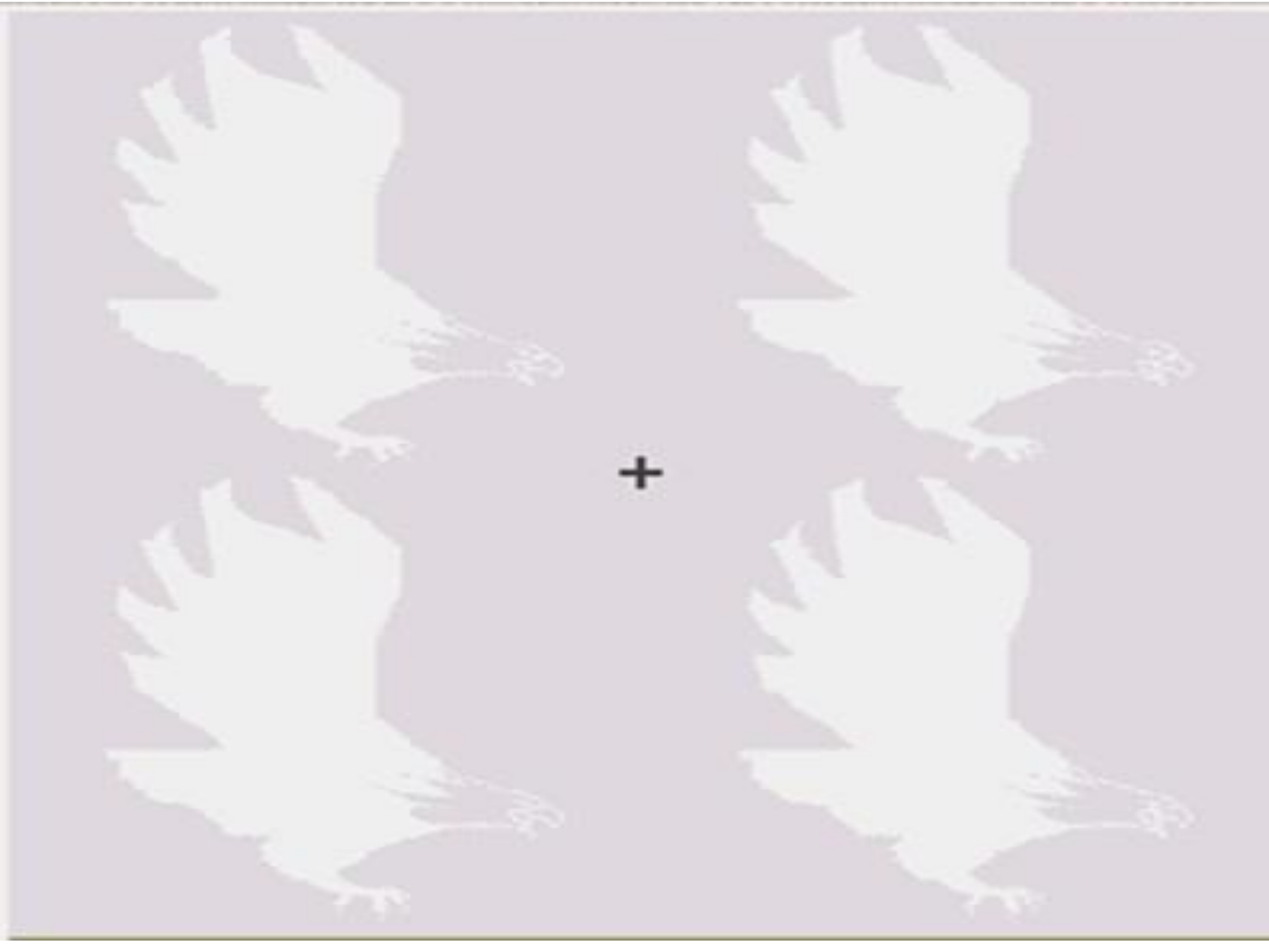
?

Rod / Cone sensitivity

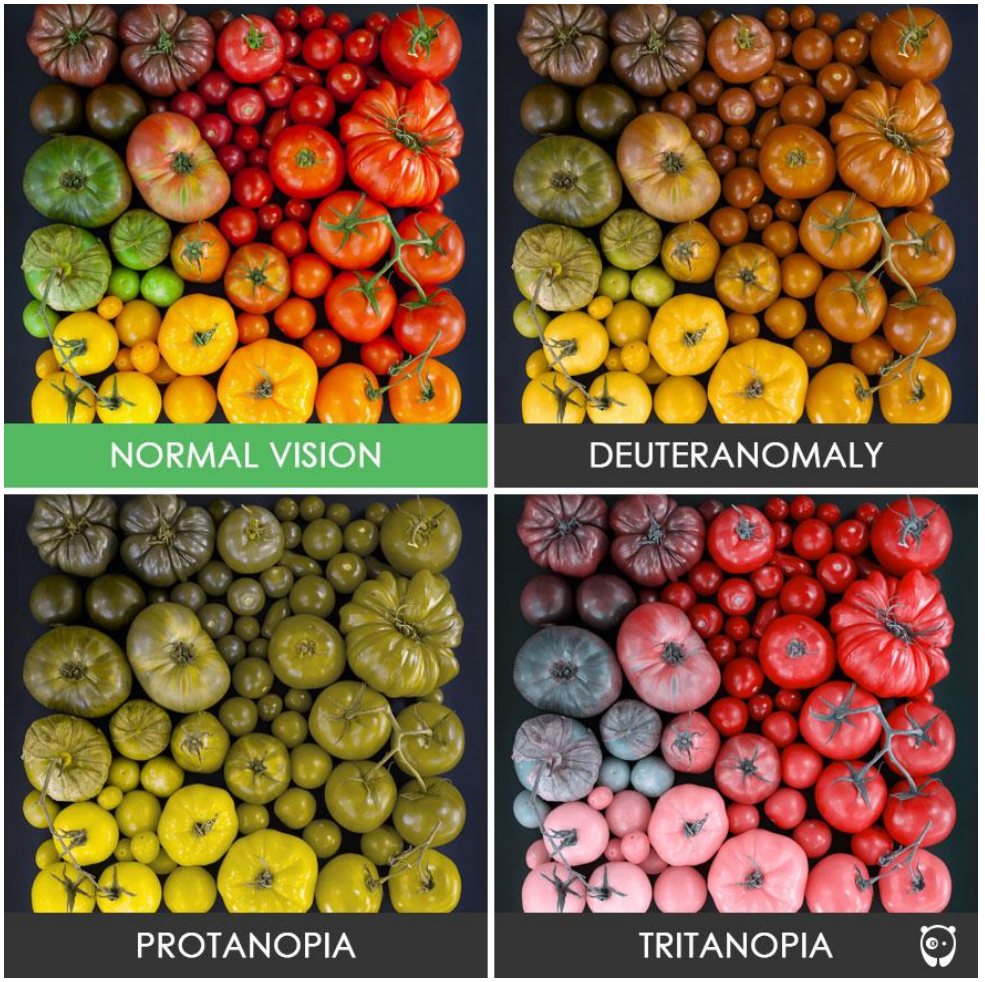


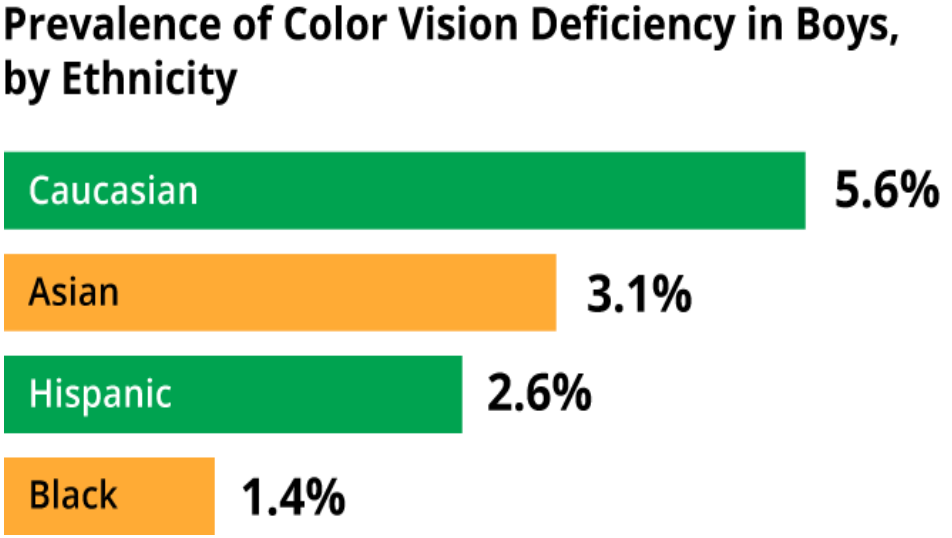
The famous sock-matching problem…





Color deficiency





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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 rare.

Opponent-process theory

- While we see greenish-blue or blueish-reds, we do not see reddish-green or yellowish-blue.
- Opponent-process theory suggests that color perception is controlled by the activity of two opponent systems; a blue-yellow mechanism and a red-green mechanism.

The perception of colour

Young-Helmholtz theory or trichromatic theory : retina might consist of three different types of colour-detecting cells, each sensitive to red, blue or green wavelengths of light. They further speculated that different rates of firing of these cells gives rise to the perception of different colours.

Shortcomings of this theory: Colour blindness, Negative after-effects

Opponent-process theory by Ewald Hering : three types of cells in the retina respond to pairs of opposite colours: red/green, blue/ yellow and light/dark. According to the opponent-process theory, these cells can only detect the presence of one color at a time because the two colors oppose one another. For example: You do not see greenish-red because the opponent cells can only detect one of these colors at a time.

Negative after effects can be explained by assuming that cells become fatigued by prolonged stimulation of the same colour and that they will work in the opposite way as they recover.

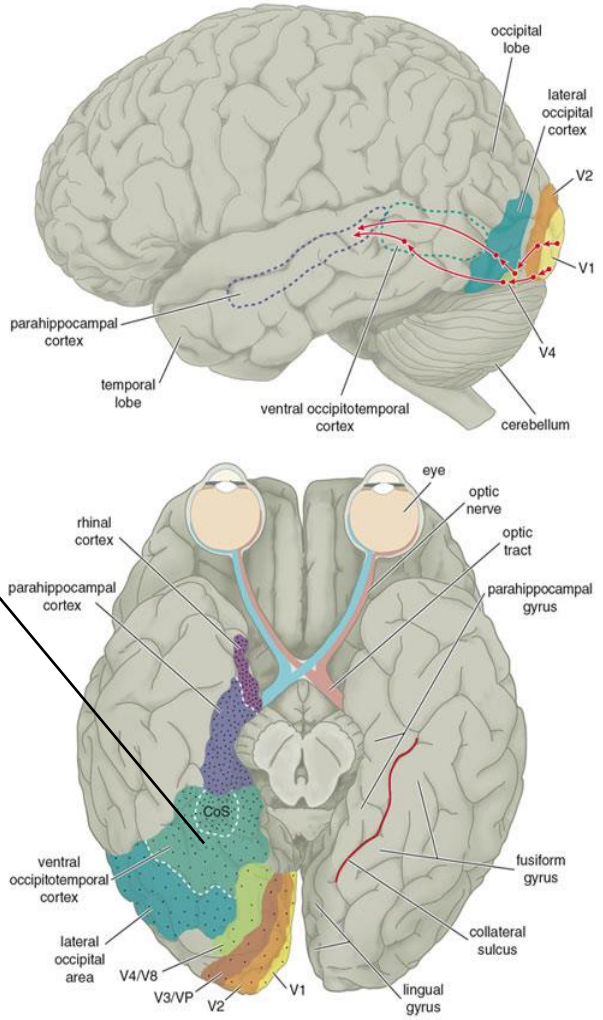
The evidence to support the above theories: De Valois, Abramov and Jacobs (1966) – found bipolar cells in the second layer of the retina and in the thalamus (supporting the later theory) .

MacNichol (1986) found three different types of cells in the retina that respond maximally to one of the three different wavelengths of light (supporting the former theory).

Neural correlates of Color perception issues

Cerebral achromatopsia: ventral occipitotemporal cortex

Acquired color blindness are from chronic illness like: Alzheimer's disease, diabetes mellitus, glaucoma, leukaemia, liver disease, chronic alcoholism etc., .Certain medications can also cause color blindness



Some color illusions

- http://www.michaelbach.de/ot/col-context/index.html
- http://researchweb.iiit.ac.in/~saksham.agrawal/honors/blue_eyes.
- http://www.michaelbach.de/ot/col-lilacChaser/index.html

So which theory is correct?

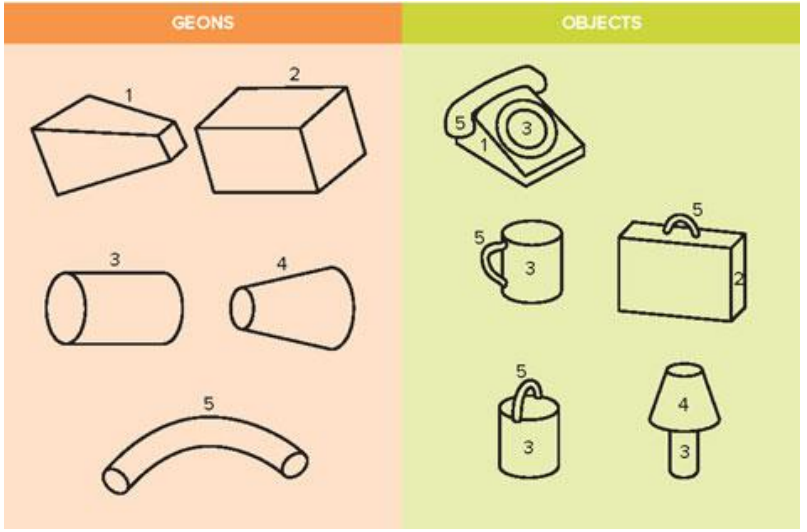
- Trichromatic/Young-Helmholtz theory or opponent process theory?

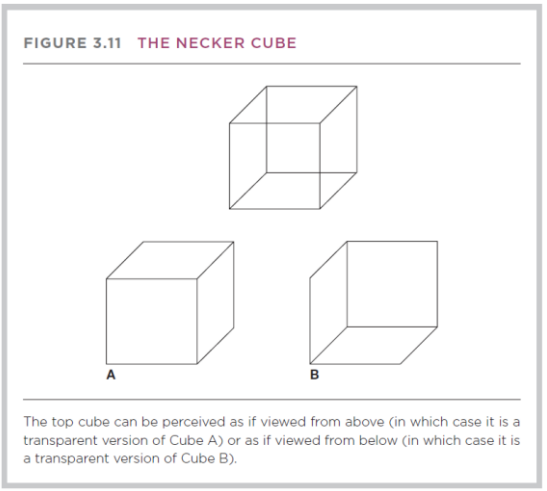
It turns out that both theories are needed to account for the complexity of color vision. The trichromatic theory explains how the three types of cones detect different light wavelengths while opponent process theory how the cones connect to the ganglion cells. These ganglion cells are where the opposing elements inhibit each other to determine how color is perceived.

Form/Object recognition

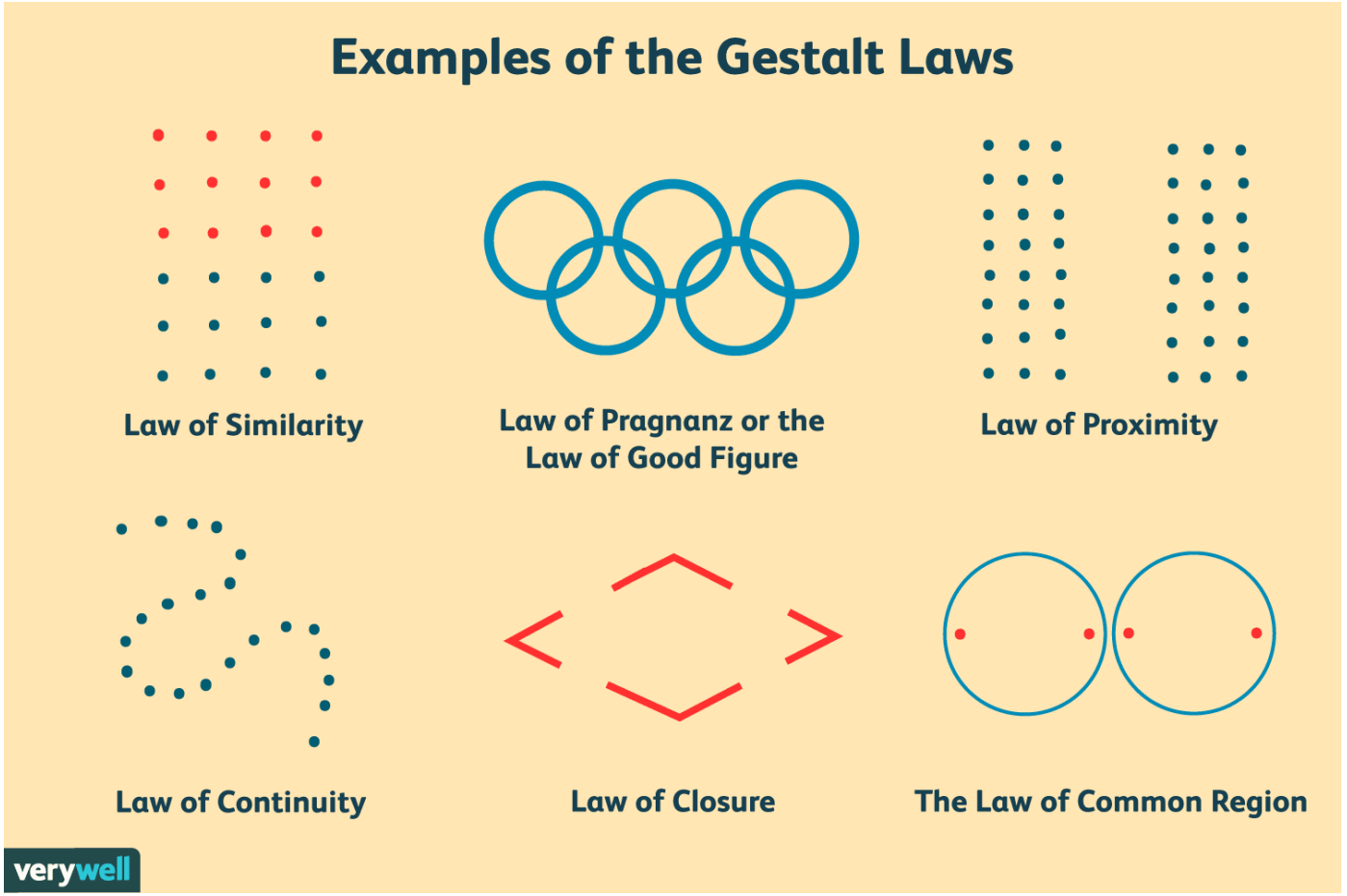
Gestalt principles of perceptual organization

- 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.



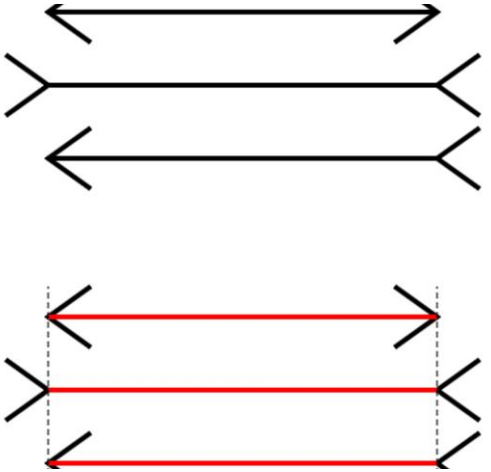


Gestalt principles



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)

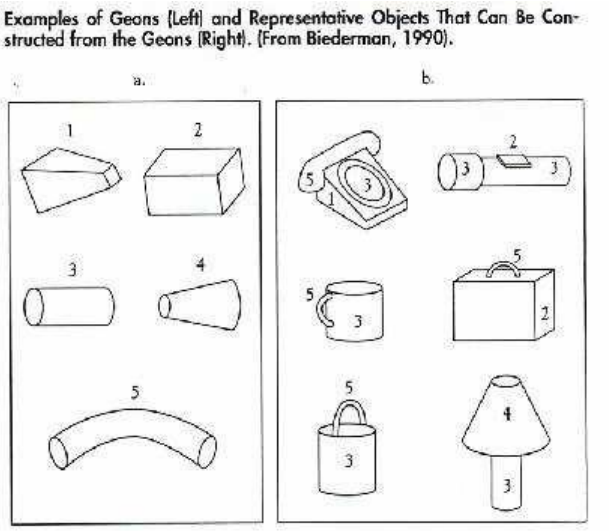


Figure 5.35 (a) It is difficult to identify the object behind the mask because its geons have been obscured.
(b) Now that it is possible to identify geons, the object can be identified as a flashlight.

Recognition by Components

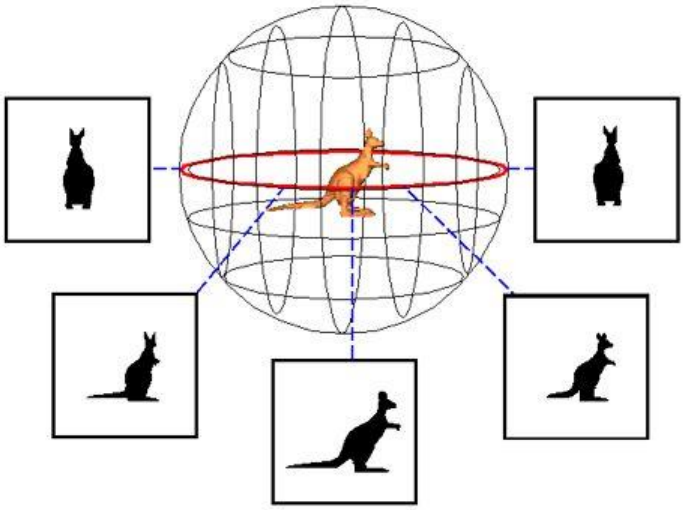
Strengths

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

Weaknesses

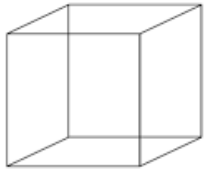
- – Complexity of representation
- – Doesn’t easily represent subtle metric differences (e.g.,distance between eyes)
- – Recognition is at the level of categories (chair vs. table) rather than individuals (my office chair vs. my kitchen chair)

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

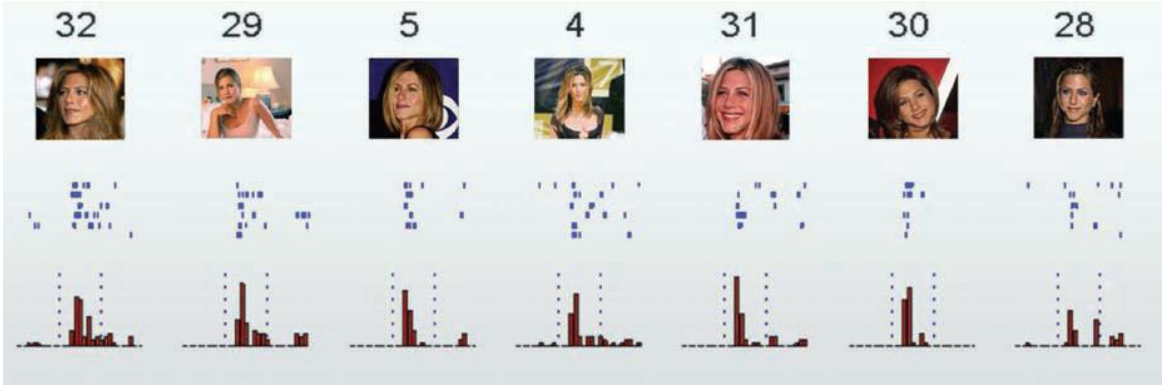
Object recognition

- 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

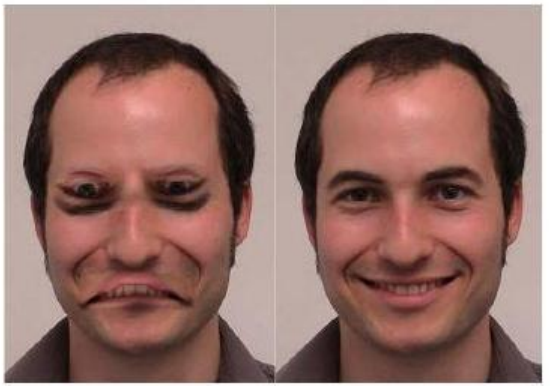
Face,Speech/music,text, art
Theories of pattern recognition:

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



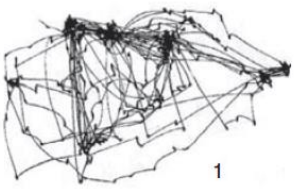
Attention

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

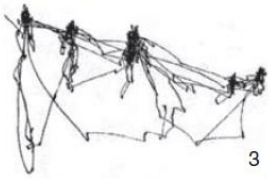


1

Free examination.

2

Estimate material circumstances of the family.

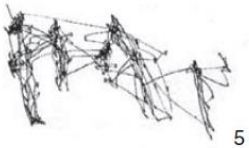


3

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

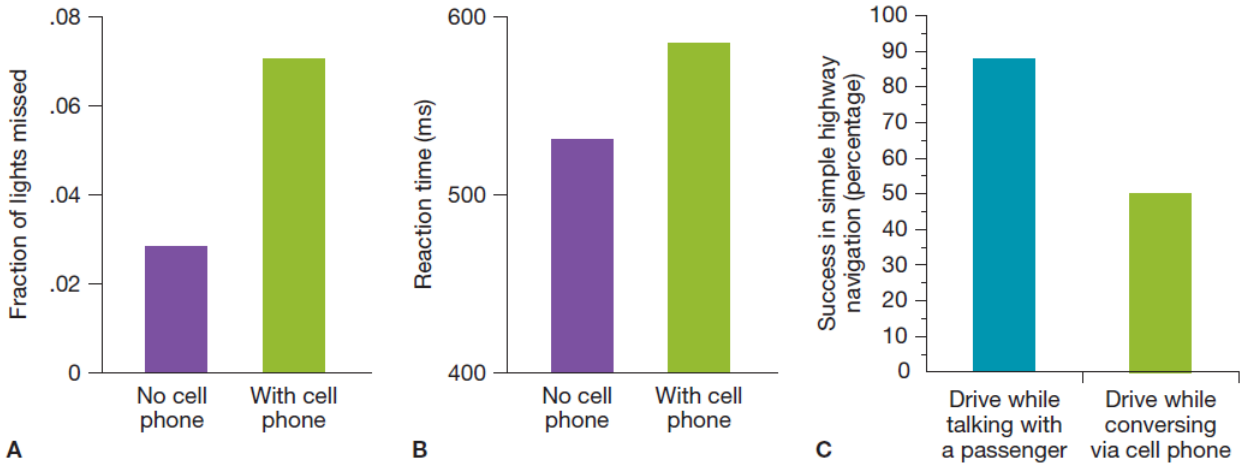
Remember positions of people and objects in the room.

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)

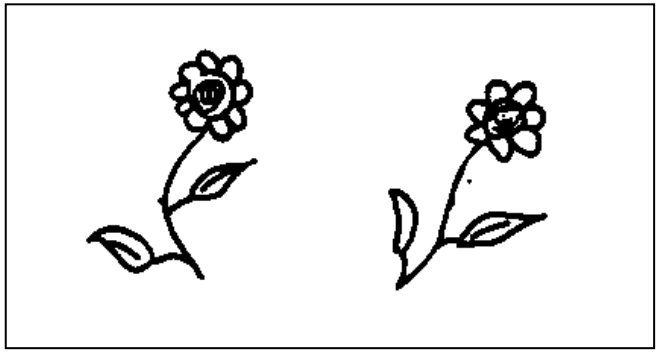
FIGURE 5.21 STROOP INTERFERENCE

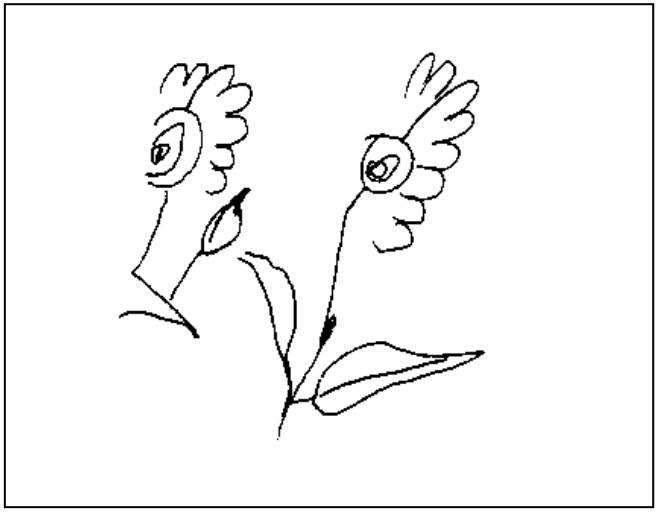
As rapidly as you can, name out loud the colors of the *ink* in Column A. (You'll say, "black, green" and so on.) Next, do the same for Column B—again, naming out loud the colors of the ink. You'll probably find it much easier to do this for Column A, because in Column B you experience interference from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

Alan Burgess

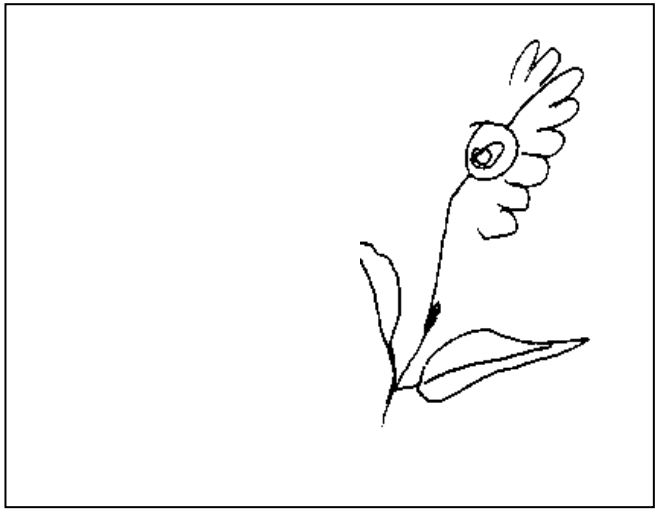
- hemispatial neglect – an inability to pay attention to sensory stimuli on his left side .
- Stroke damaged the parietal lobe on the right side of his brain, the part that deals with the higher processing of attention. The damage causes him to ignore people, sounds, and objects on his left.
- research 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

The pathways

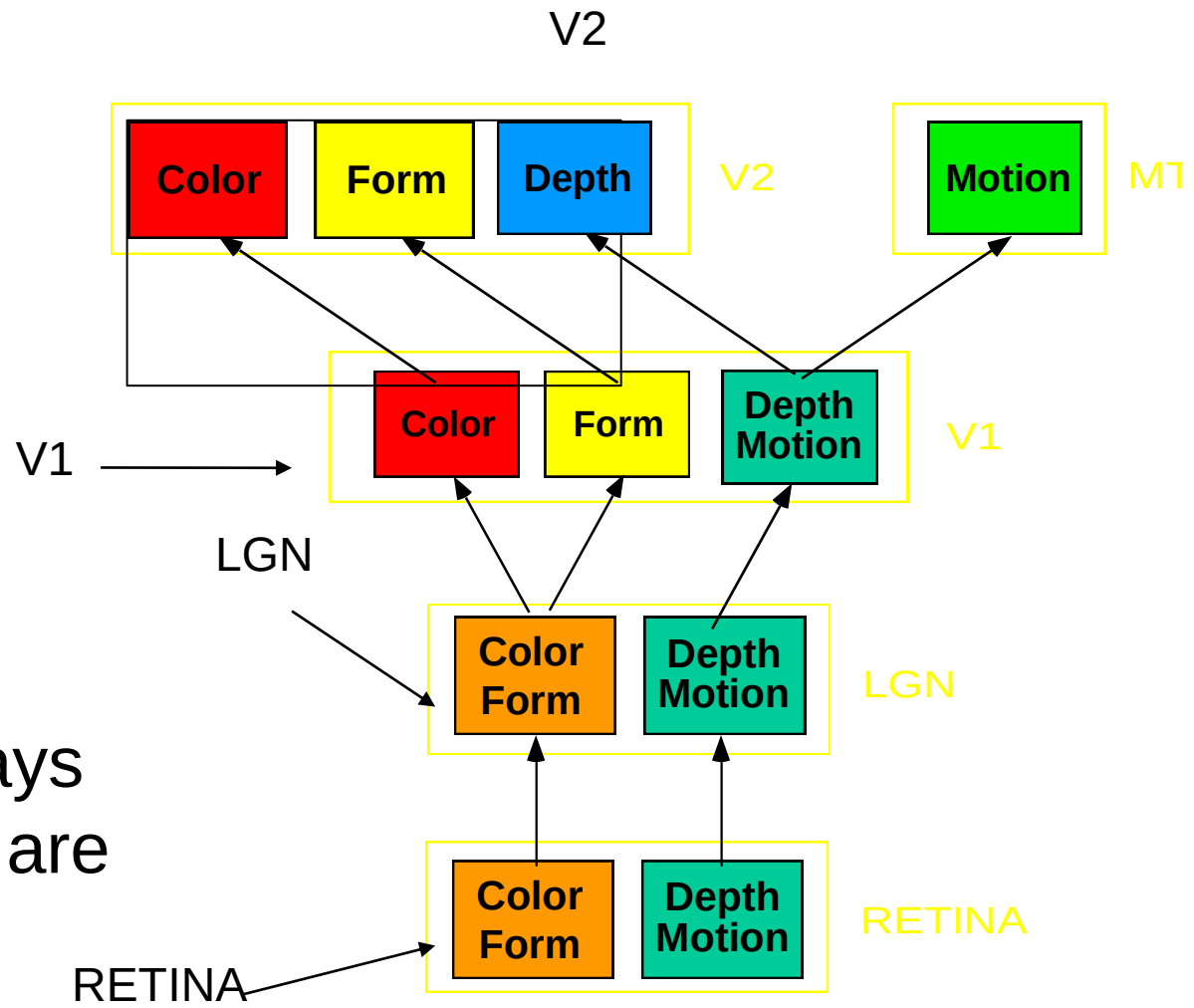
Feature-based Pathways Hypothesis

Visual Features

Color
Shape
Depth
Motion

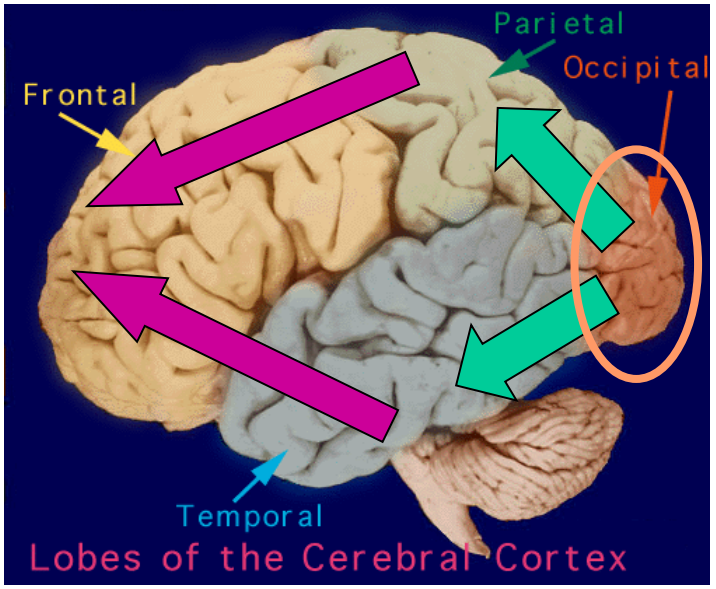
Featural Pathways

Separate neural pathways in which different features are processed.



The pathways in the brain

Eyes register optical information

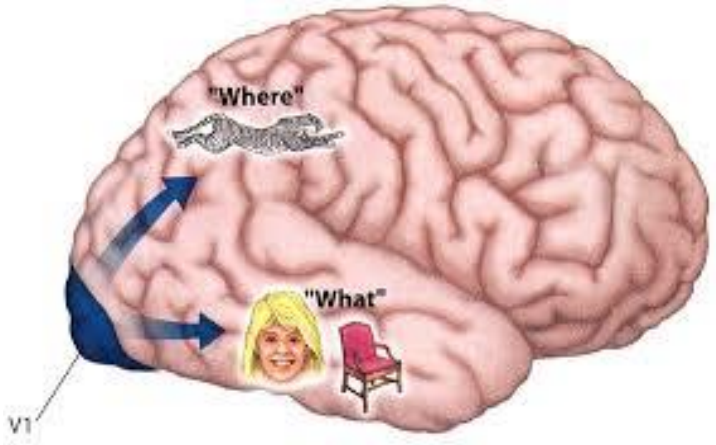


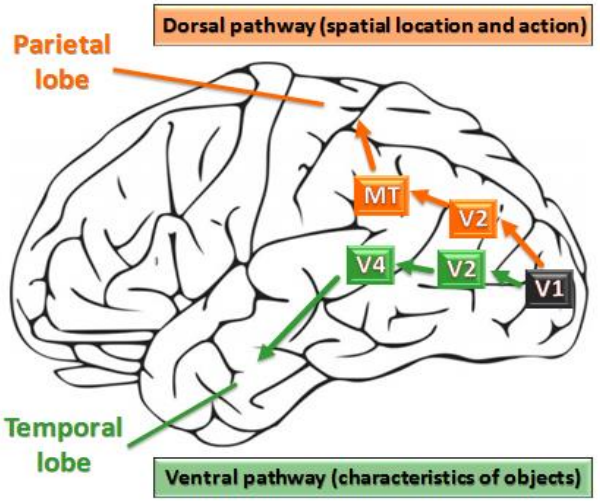
Two pathways from V1

"What" pathway to temporal cortex

"Where" pathway to parietal cortex

Convergence on frontal cortex





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

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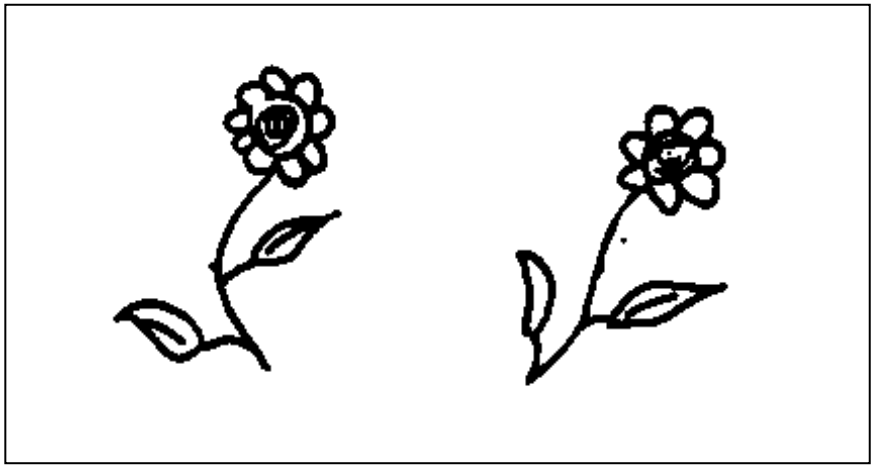
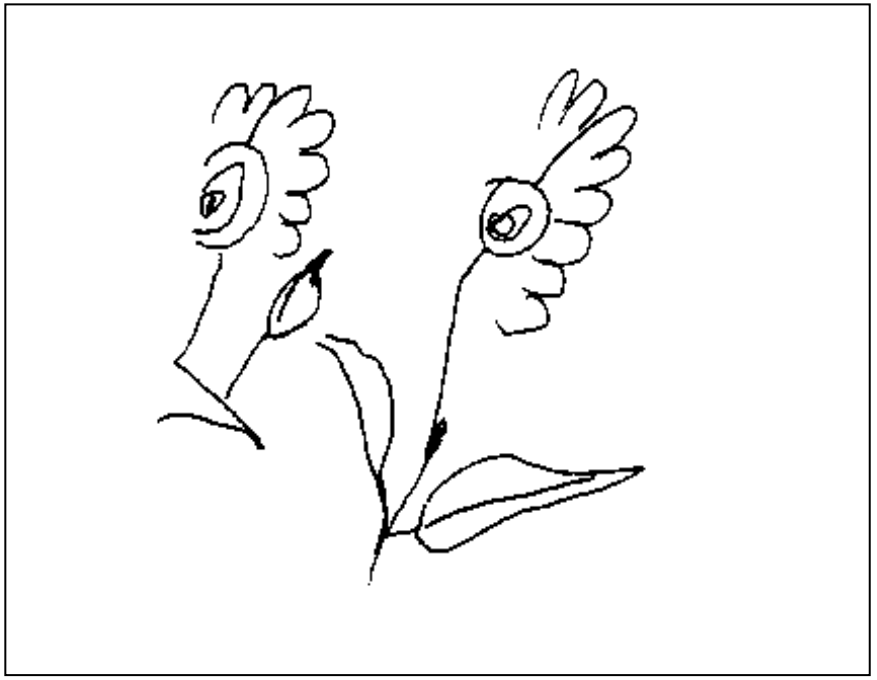
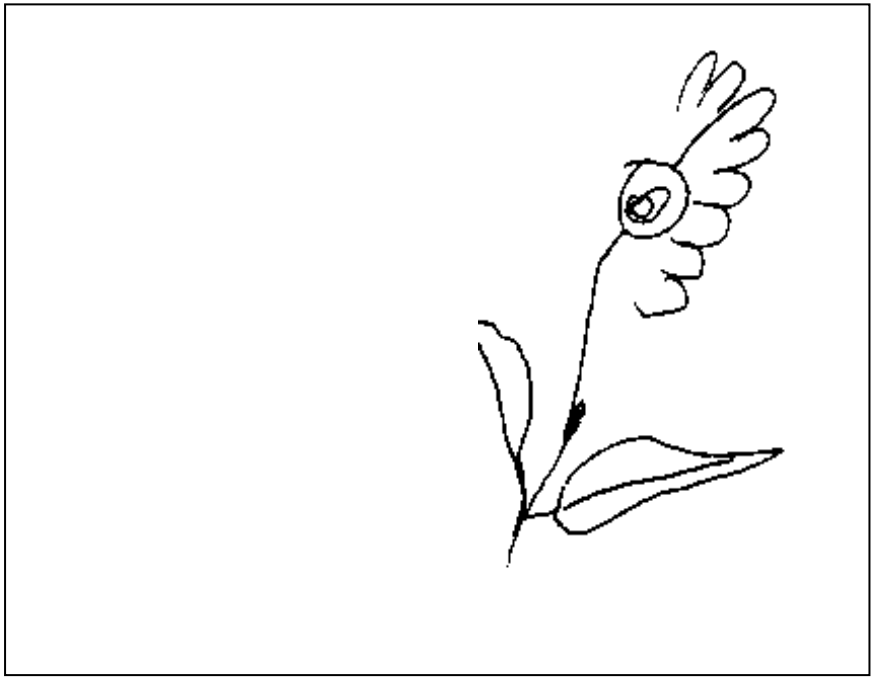




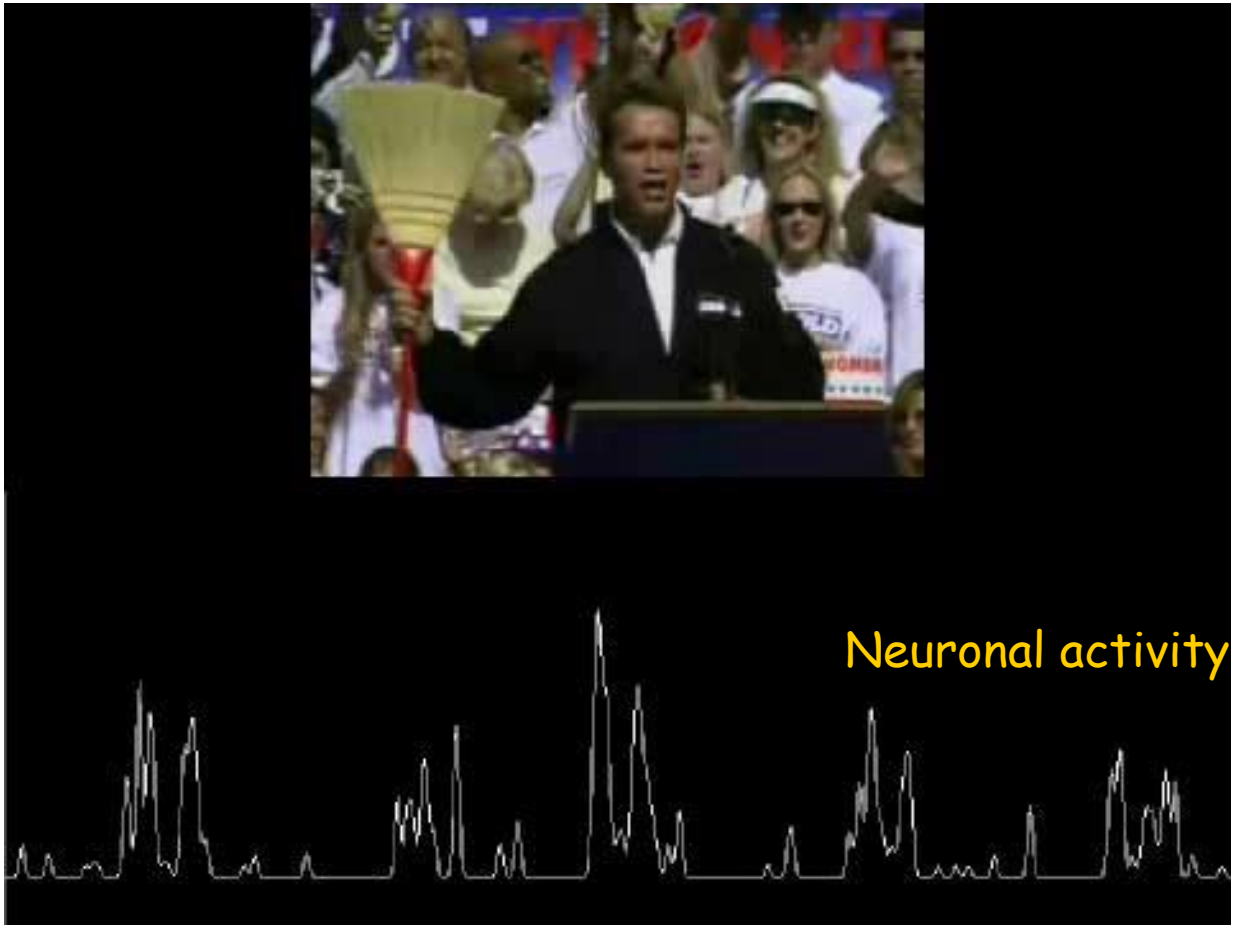
Object-centred Neglect



Object and Location-based Neglect

Visual responses

What the patient saw

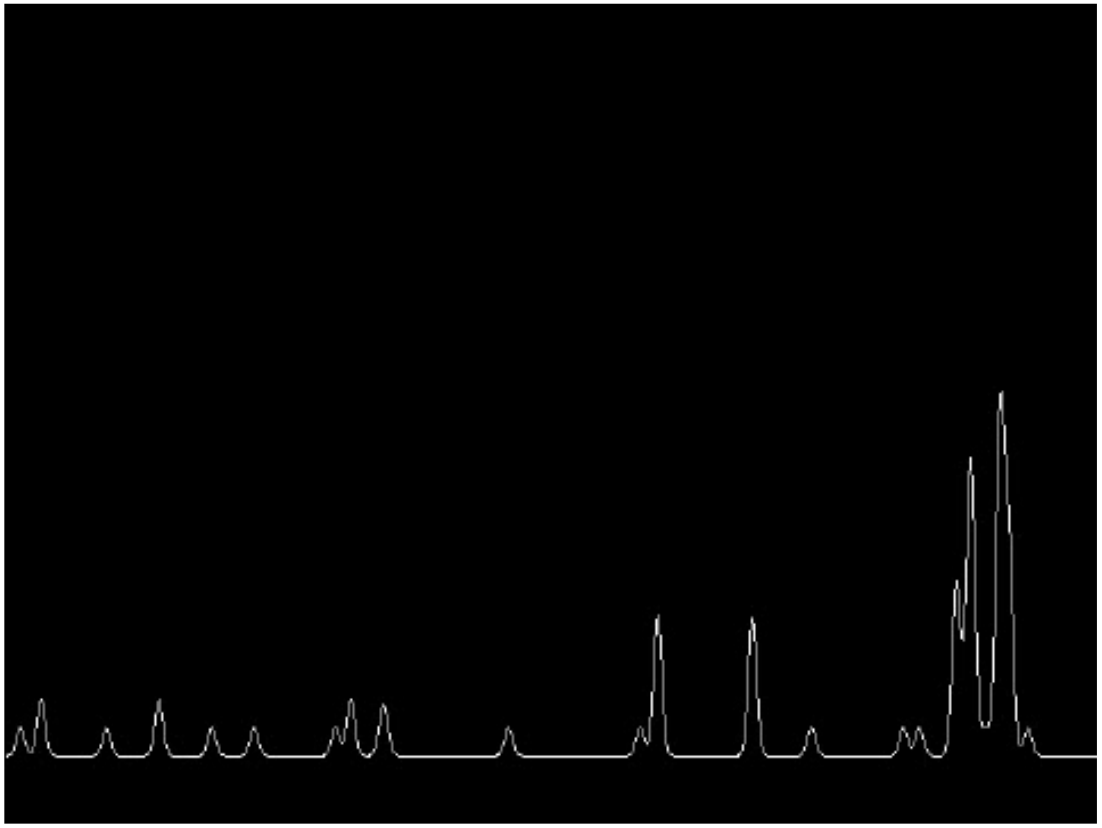


beeps are spikes of a single human neuron

entorhinal cortex

Recollection in the absence of visual stimulation

What the patient said



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)

Assignment

- Agnosia
- The mystery of Van Gogh’s ‘yellow’