511-perception

CODE

Rick Gilmore

2021-10-19 08:06:37

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            - Photoreceptor physiology
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        - Retina
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        - *Opponent processing*
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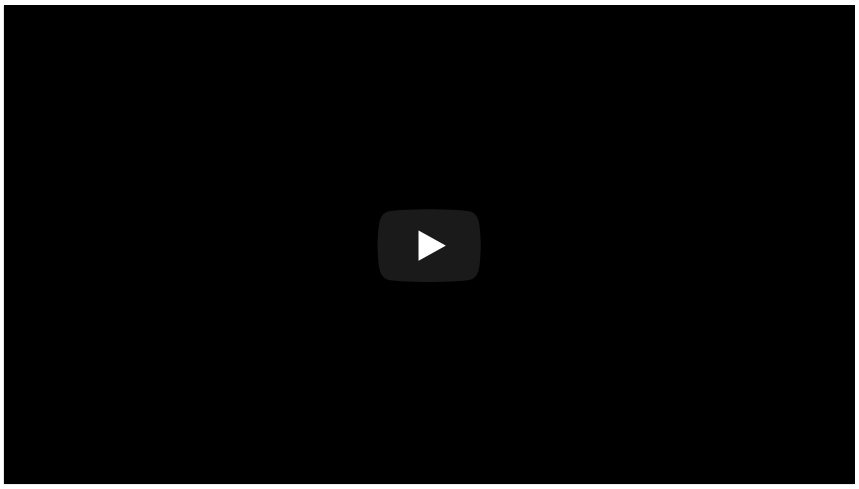
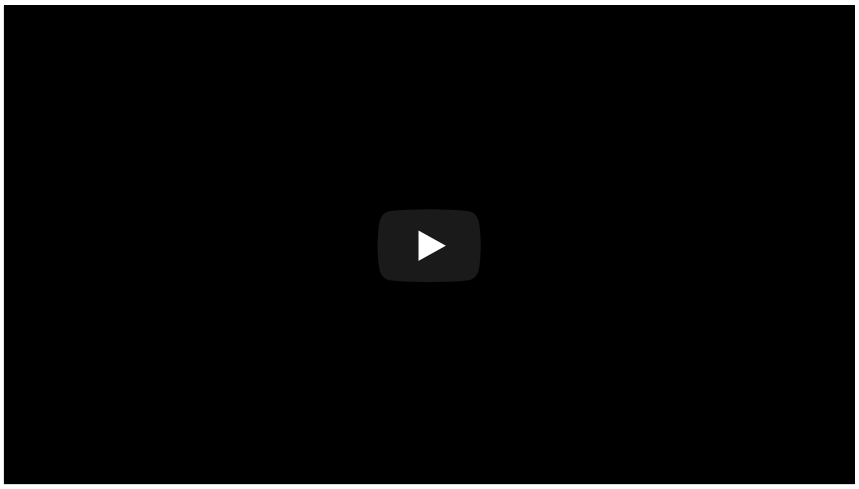
        - LGN
        - From LGN to V1
        - Human V1
            - Laminar, columnar organization
            - From center-surround receptive fields to line detection
        - Ocular dominance columns
        - Beyond V1
    - What is vision for?
- References

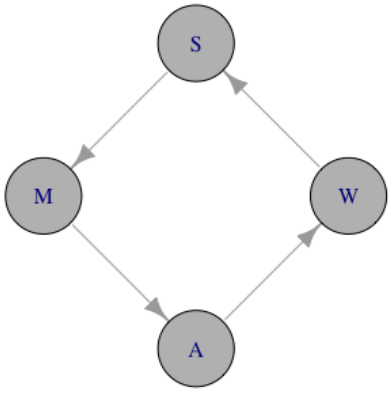
Fun

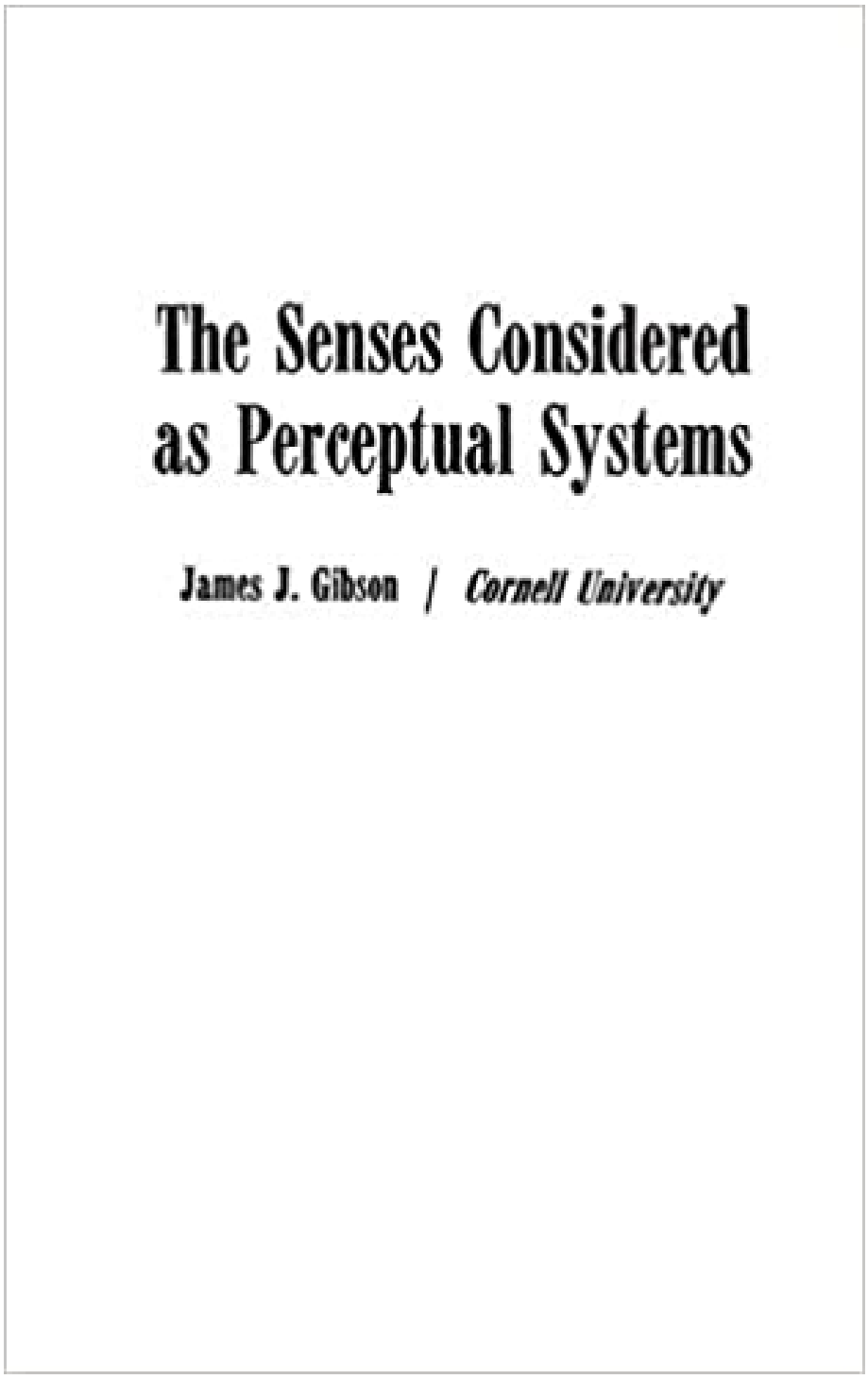




Principles of sensation & perception

Senses as (perception/action) systems





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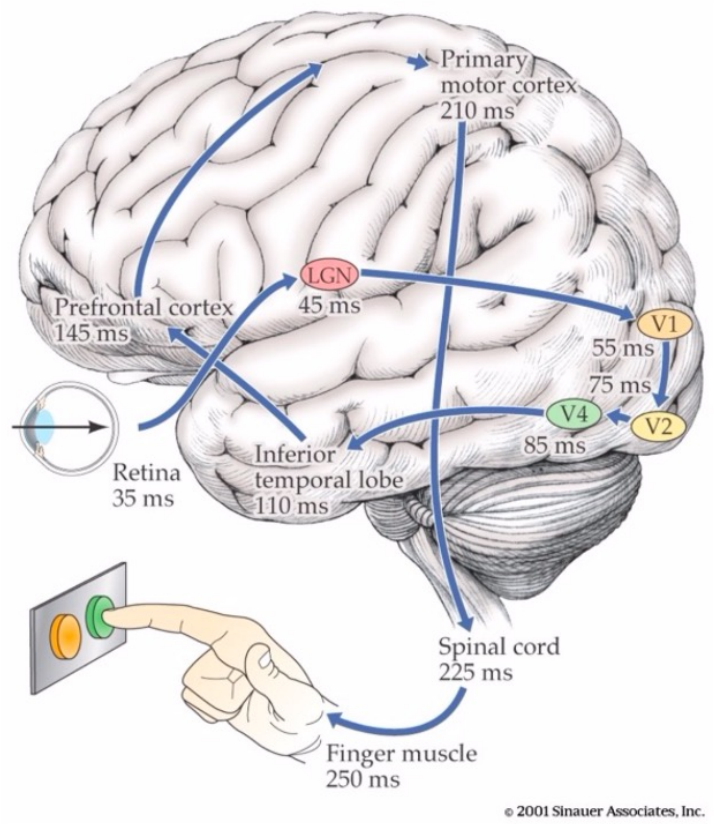


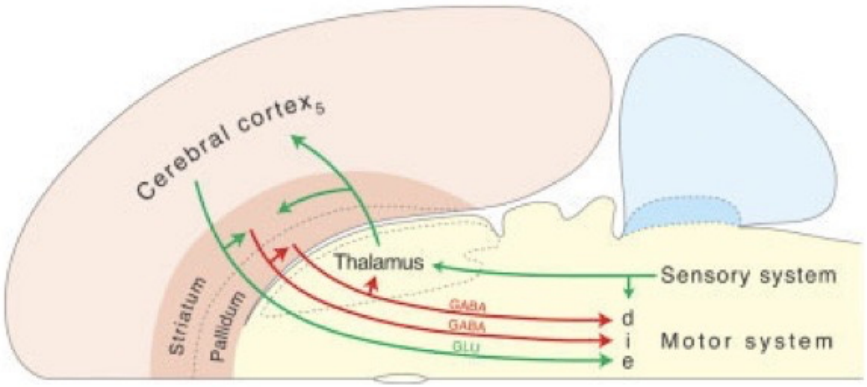


Fig. 2. A model of the elementary or minimal circuit element characteristic of almost all parts of the cerebral hemispheres (pink). It consists of a triple descending projection to the motor system of the brainstem and spinal cord (see Fig. 1B), with feedback to cerebral hemisphere via thalamus. The model predicts that the cerebral hemisphere provides a direct excitatory input (e) to motor system via glutamatergic (GLU), layer 5 (for isocortex), cortical pyramidal neurons that generate a collateral in the striatum (lateral cerebral nuclei), which sends an inhibitory input (i) to motor system via GABAergic (GABA) medium spiny stellate neurons providing a collateral to pallidum (medial cerebral nuclei). The latter then sends a disinhibitory (d), GABAergic projection to motor system, with collaterals to dorsal thalamus, which then projects back to cortex via glutamatergic neurons (and of course receives various classes of sensory input). Many thalamic nuclei also project to striatum (Smith et al., 2004). This minimal circuit element is topographically organized and differentially elaborated regionally.

Source: Swanson

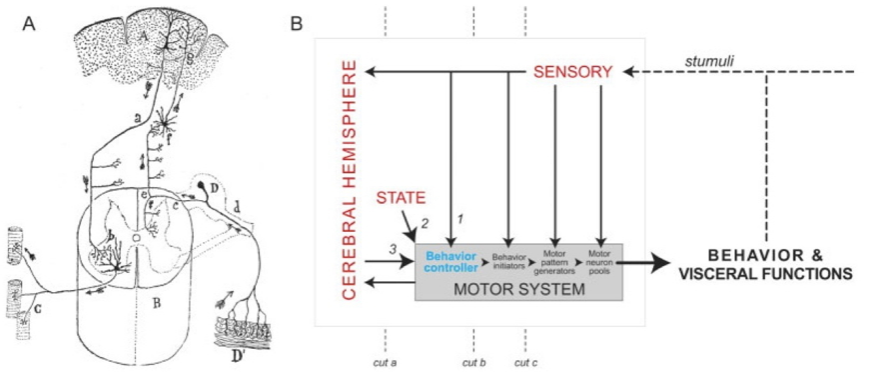


Fig. 1. **A:** Perhaps the first diagram illustrating the cellular organization of a vertebrate spinal reflex, based on the neuron doctrine and law of functional polarity, published by Cajal in 1890 (see Cajal, 1894). Note that he emphasized two interconnected sources of motor neuron (b) control: dorsal root ganglion cells (D) and cerebral cortical pyramidal (or psychomotor) neurons (A). For clarity, he showed sensory input to the right side of the spinal cord, and motor output from the left side. **B:** A modern version of the basic plan of nervous system organization, adding behavioral state inputs (2) to sensory or voluntary (1) and cerebral hemisphere/cognitive or voluntary (3) inputs to the motor system hierarchy; see text for details (adapted from Swanson, 2000a).

Source: Swanson, 2005

Smartphone as metaphor

- Accelerometer
- Gyroscope
- Magnetometer
- Proximity sensor
- Ambient light sensor
- Barometer
- Thermometer
- Mic
- Camera
- Radios (Bluetooth, wifi, cellular, GPS)

http://www.phonearena.com/news/Did-you-know-how-many-different-kinds-of-sensors-go-inside-a-smartphone_id57885 (http://www.phonearena.com/news/Did-you-know-how-many-different-kinds-of-sensors-go-inside-a-smartphone_id57885)

Perception/action system dimensions

- Interoceptive
  - Body position, movement, posture
  - Internal status: hunger, thirst, arousal, discomfort/pain, etc.
- Exteroceptive
  - Layout of environment, contents

Questions for interoception

- Tired or rested?
- Well or ill?

- Hungry or thirsty or sated?
- Stressed vs. coping?
- Emotional state?

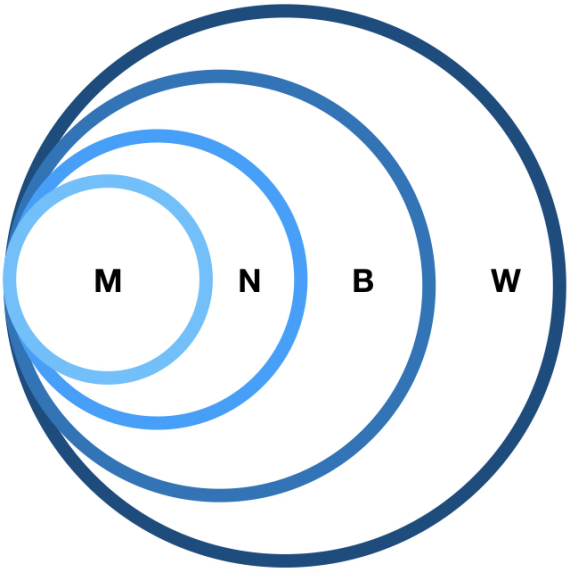
Questions for exteroception

- Who/What is out there?
- Animate/inanimate?
    - Conspecific (same species)/non?
    - Threat/non?
    - Familiar/un?
    - Mate/non? or Friend/not?
    - Food source/non
- Where is it?
    - Distance
        - Proximal
        - Distal
    - Elevation, azimuth
    - Coordinate frames
        - Self/ego (left of me)
        - Object (top of object)
        - Allo/world (North of College)
- Where moving?

Questions for action

- What kind of response?
    - External
        - Move body
            - Approach/avoid/freeze
            - Signal/remain silent
            - Manipulate
    - Internal
        - Change physiological state
- Speed, quality, direction of response

From world to brain



Realm	Domain
W	The world
B	The body
N	The nervous system
M	The mind

Properties of the world

- Behaviorally relevant conditions, events, and entities…
- Generate patterns…
  - Chemical
  - Photic/electromagnetic
  - Mechanical/acoustic
- That specialized sensors detect
- Neural circuitry processes

More than 5 sensory channels

TABLE 8.1 *Classification of Sensory Systems*

Type of sensory system	Modality	Adequate stimuli
Mechanical	Touch	Contact with or deformation of body surface
	Hearing	Sound vibrations in air or water
	Vestibular	Head movement and orientation
	Joint	Position and movement
	Muscle	Tension
Photic	Seeing	Visible radiant energy
Thermal	Cold	Decrement of skin temperature
	Warmth	Increment of skin temperature
Chemical	Smell	Odorous substances dissolved in air or water in the nasal cavity
	Taste	Substances in contact with the tongue or other taste receptor
	Common chemical	Changes in CO_2, pH, osmotic pressure
	Vomeronasal	Pheromones in air or water
Electrical	Electroreception	Differences in density of electrical currents

BIOLOGICAL PSYCHOLOGY, Fourth Edition, Table 8.1 © Sinauer Associates, Inc.

- What is the energy/chemical channel?
- Different energy/chemical channels carry different types of information
  - What is out there
  - Where it's located
- Different energy/chemical channels convey information at different rates
- Information about behaviorally relevant dimensions often signaled by multiple sources

Vision

- Source: Electromagnetic radiation
  - Reflected from surfaces
- What is it?
  - Shape, size, surface properties (color, texture, reflectance, etc.)
  - Wavelength/frequency, intensity
- Where is it?
  - Position: Left/right; up/down on retina
  - Near/far: retinal disparity, interposition, height above horizon…
  - Orientation, motion

Audition

- Source: Mechanical vibrations in air or water
- What is it?
  - Pattern of frequencies, amplitudes, durations
- Where is it?

    - Left/right or up/down: Interaural time/phase, intensity differences, pinnae filtering
    - Motion: Frequency shifts via Doppler effect

Chemosensation

- Source: Chemicals in mouth, nasal cavity
- What is it?
    - Mixtures of chemicals
- Where is it?
    - Left/right; up/down; near/far via intensity gradients

Somatosensation

- Source: Thermal or mechanical stimulation (vibration/pressure) of skin
- What is it?
    - Shape, size, smoothness, mass, temperature, deformability: Pattern of stimulation
- Where it it?
    - Pattern of cutaneous receptors on skin

Interoception

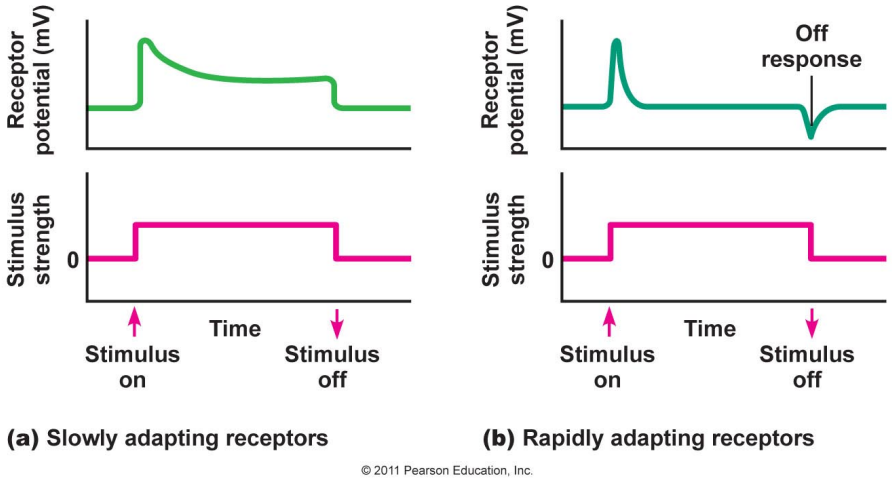
- Hunger/thirst
    - Receptors for nutrient, fluid levels
- Energy levels
    - Receptors for hormones, NTs
    - ANS responses
- Temperature
    - Receptors in skin, viscera
- Mating interest
    - Receptors for hormones, NTs
    - ANS responses
- Body position & movement (proprioception)
    - Receptors in muscles, joints, skin

Features of sensory signals

Change across time

- Tonic (sustained) vs. phasic (transient) responses
- Adaptation

- Decline in sensitivity with sustained stimulation
- Most sensory systems attuned to change



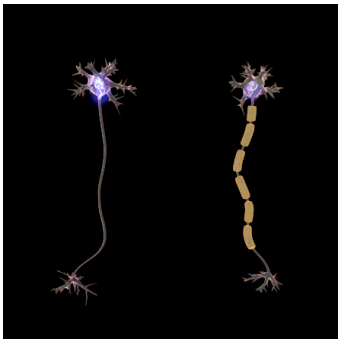
- Information propagates at different speeds
  - Bigger diameter: Faster
  - Denser myelin: Faster

WIKIPEDIA

Nerve conduction velocity

Nerve conduction velocity (**CV**) is an important aspect of nerve conduction studies. It is the speed at which an electrochemical impulse propagates down a neural pathway. Conduction velocities are affected by a wide array of factors, which include; age, sex, and various medical conditions. Studies allow for better diagnoses of various neuropathies, especially demyelinating diseases as these conditions result in reduced or non-existent conduction velocities.

Contents



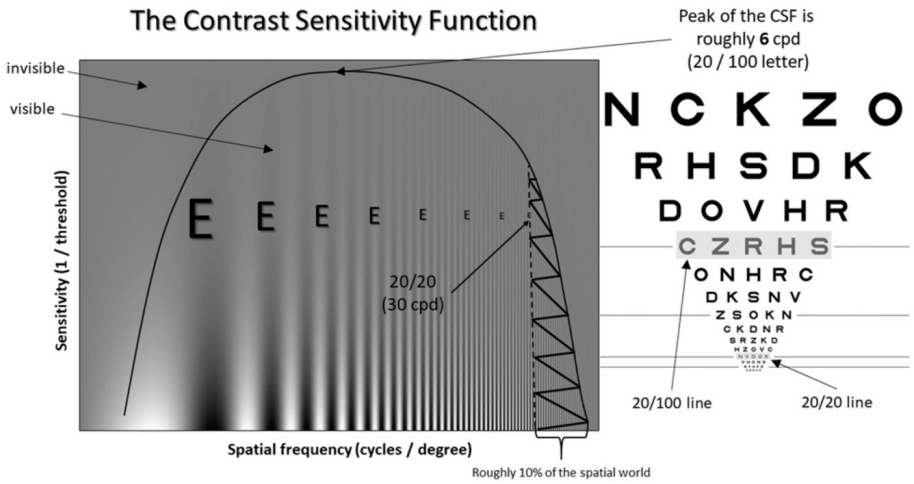
Saltatory conduction

Normal conduction velocities

Detect repeating signals

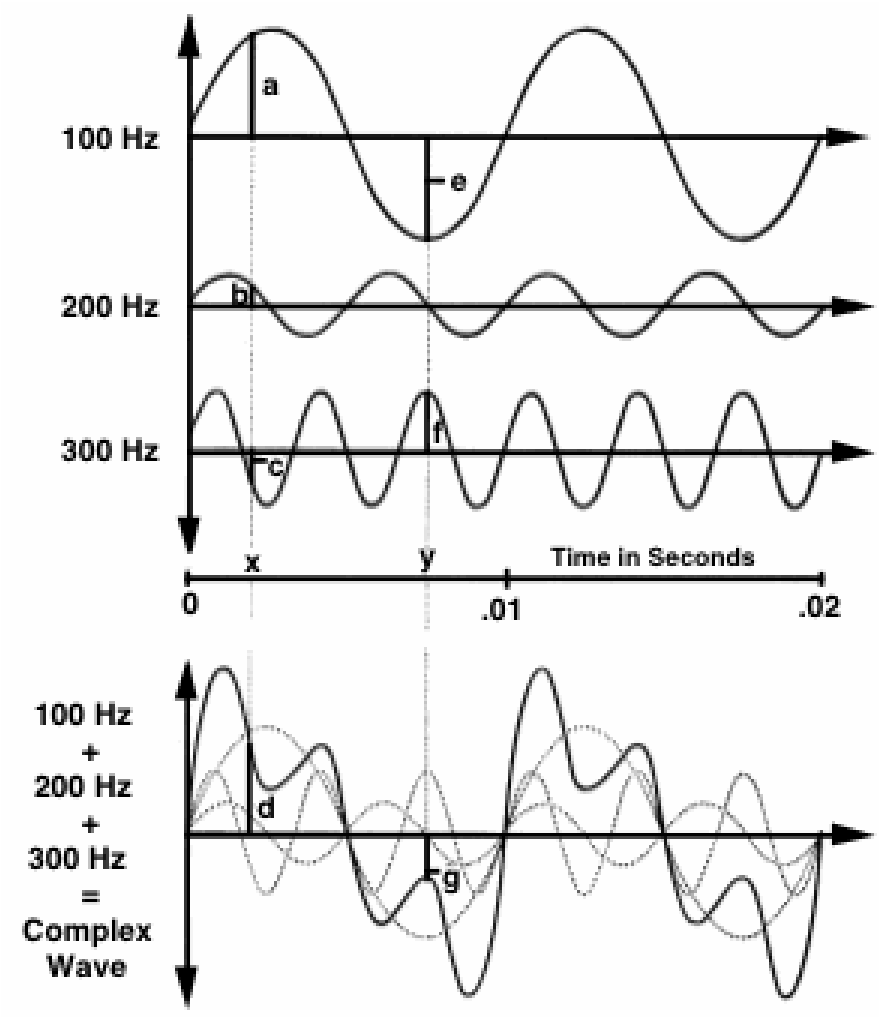
- In space (textures)
- In time

Vision: Spatial frequency/contrast sensitivity



(Roark & Stringham, 2019) (http://dx.doi.org/10.1002/mnfr.201801053)

Audition: Frequencies in sound



Compare (>1) sensors located in different parts of the body

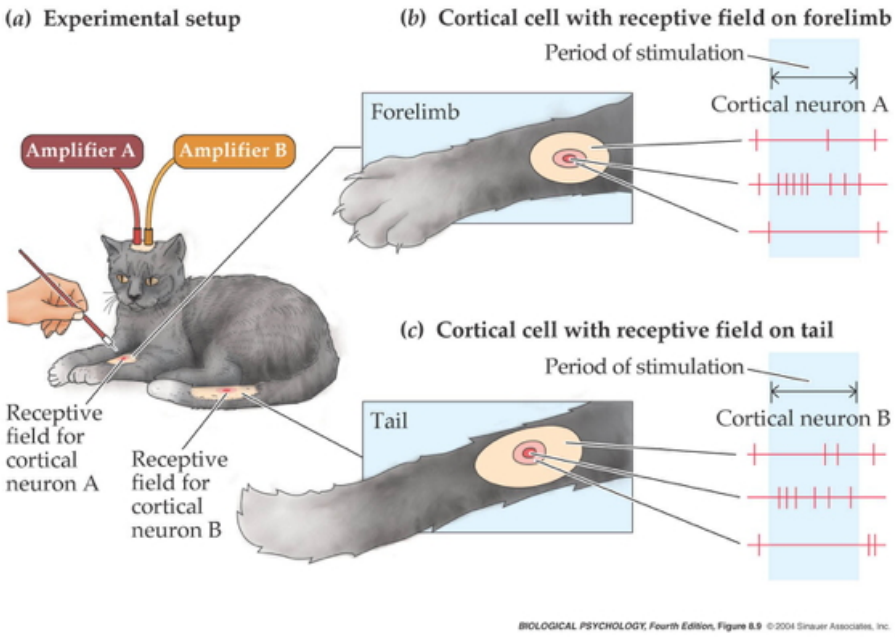
- Eyes
- Ears
- Skin surface

- Nostrils
- Tongue

“Receptive fields” (https://en.wikipedia.org/wiki/Receptive_field)

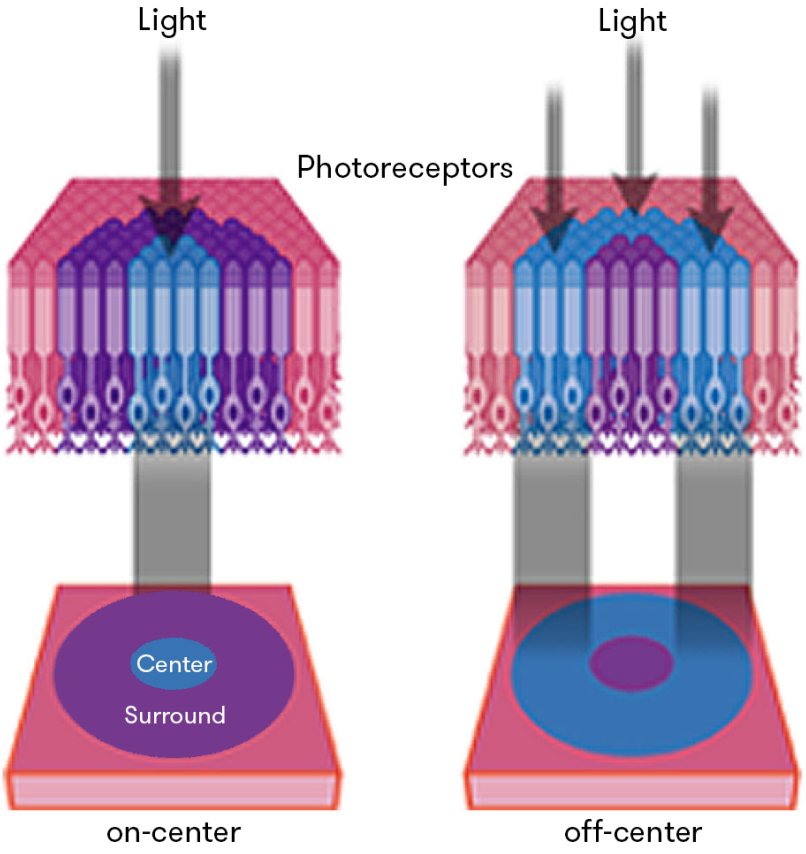
- Area on sensory surface (e.g., retina, skin) that when stimulated changes neuron’s firing

Tactile

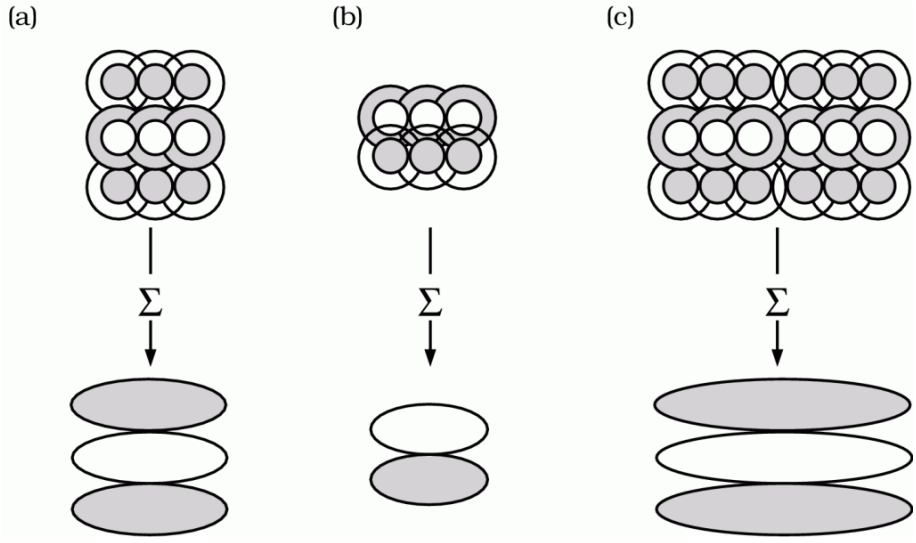


Visual

Figure 1



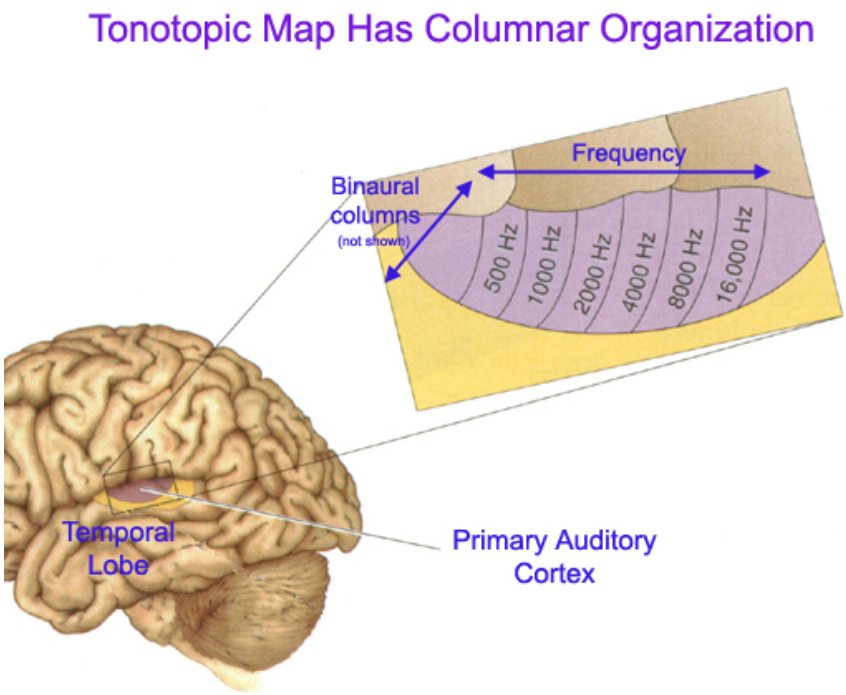
https://brainconnection.brainhq.com/2004/03/06/overview-of-receptive-fields/ (https://brainconnection.brainhq.com/2004/03/06/overview-of-receptive-fields/)



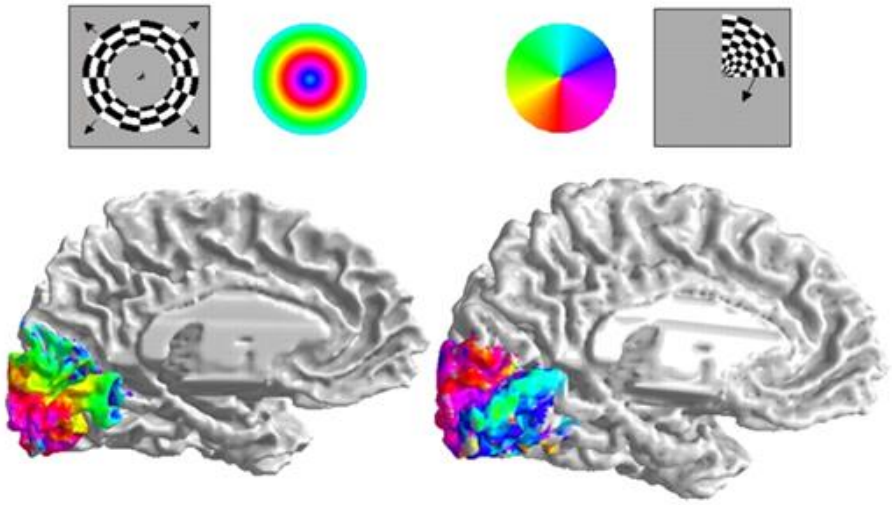
https://foundationsofvision.stanford.edu/chapter-6-the-cortical-representation/ (https://foundationsofvision.stanford.edu/chapter-6-the-cortical-representation/)

Topographic maps

Auditory: Tonotopic maps

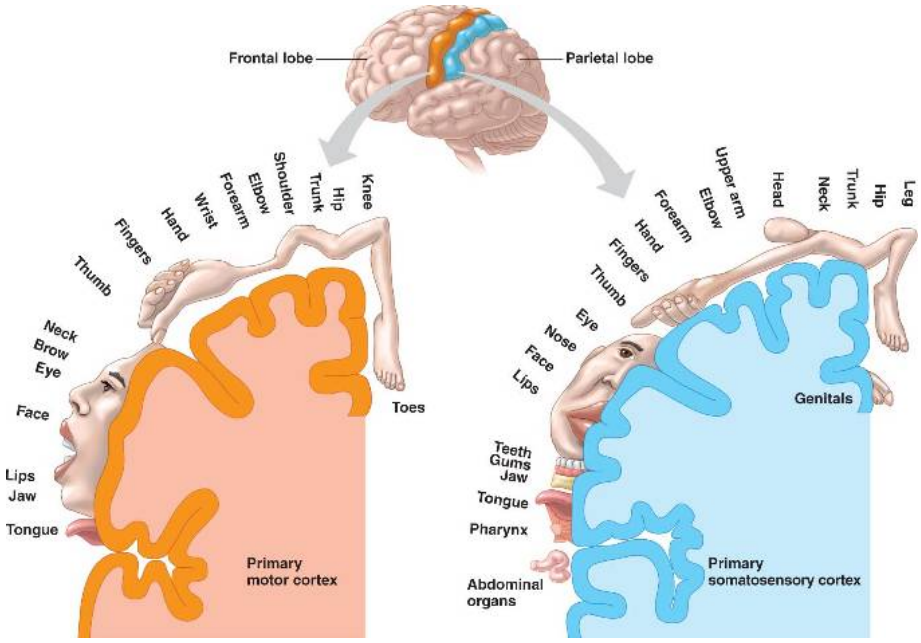


Visual: Retinotopic maps



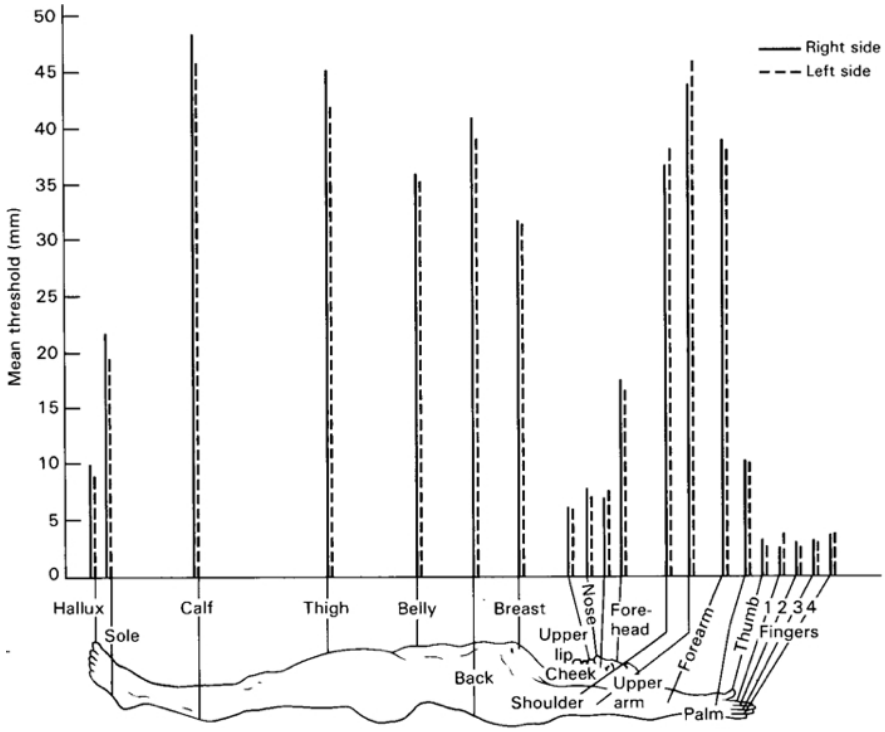
(Dougherty et al., 2003) (https://doi.org/10.1167/3.10.1)

Somatosensory: Somatotopic maps in S1 & M1



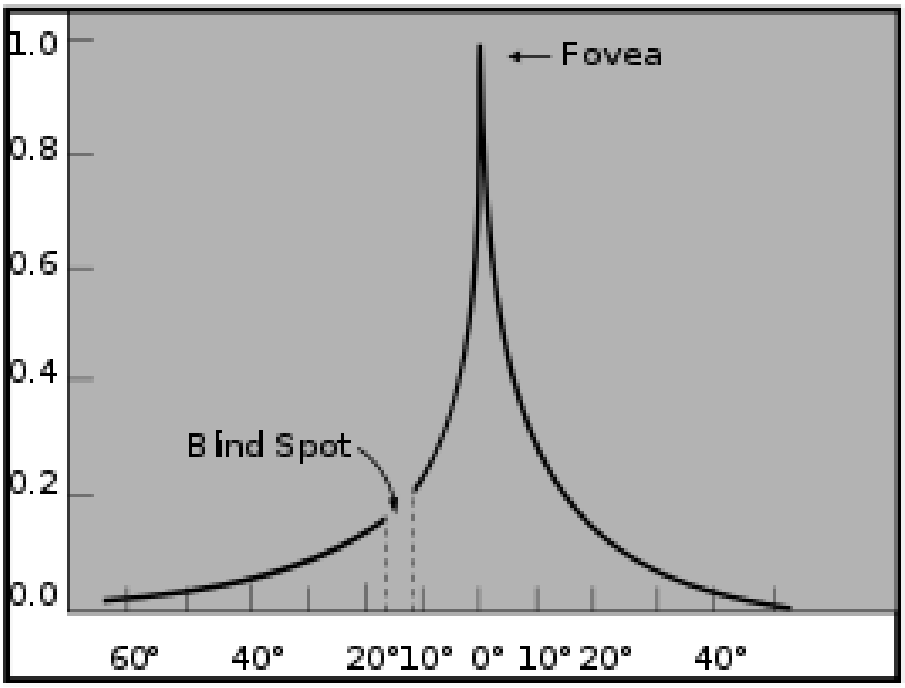
Sensivity non-uniform

Two-point touch thresholds



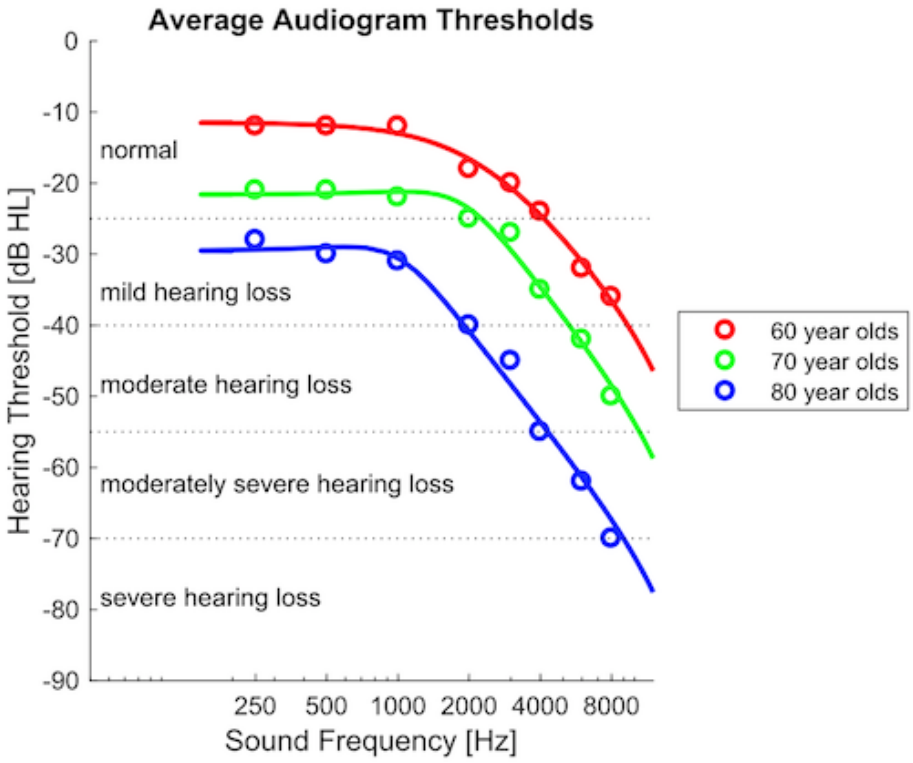
Somatosensory homunculus

Visual acuity non-uniform



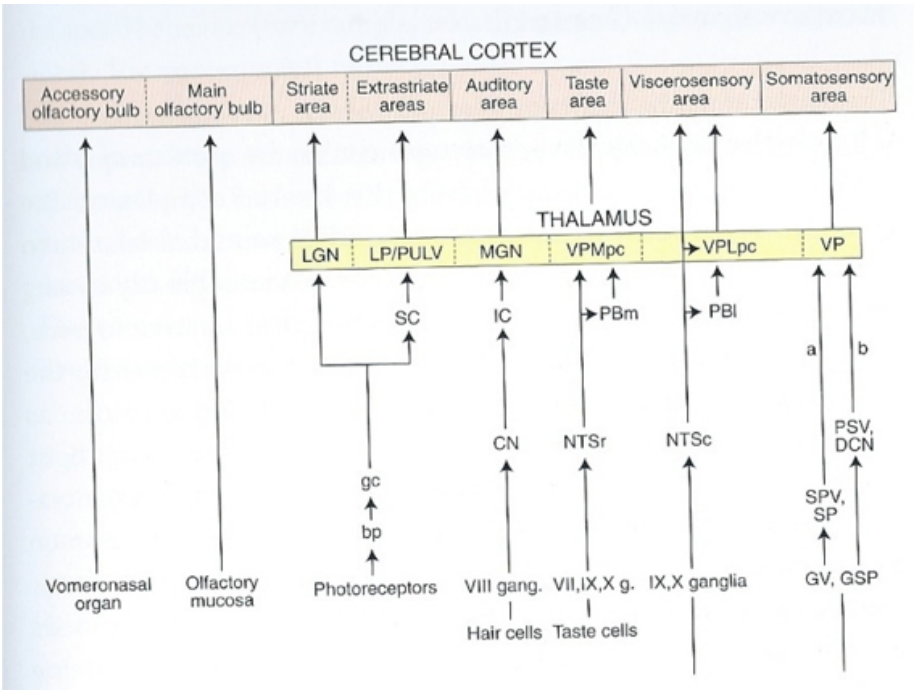
https://upload.wikimedia.org/wikipedia/commons/thumb/2/27/AcuityHumanEye.svg/270px-AcuityHumanEye.svg.png (https://upload.wikimedia.org/wikipedia/commons/thumb/2/27/AcuityHumanEye.svg/270px-AcuityHumanEye.svg.png)

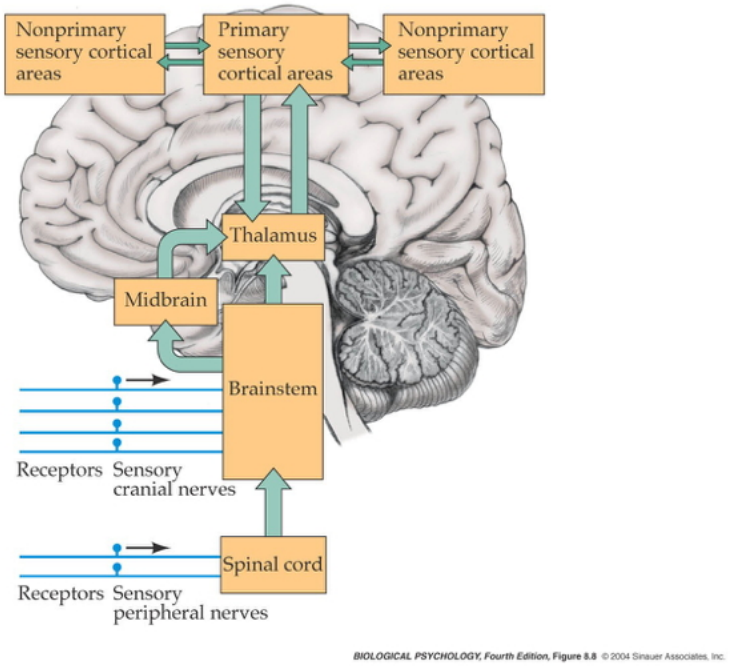
Hearing thresholds non-uniform



http://auditoryneuroscience.com/ (http://auditoryneuroscience.com/)

Processing hierarchical/sequential AND parallel





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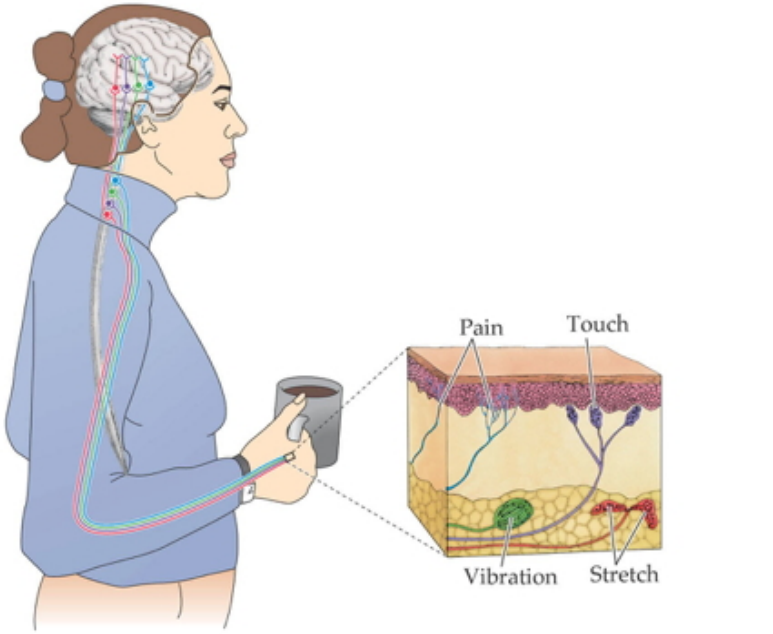

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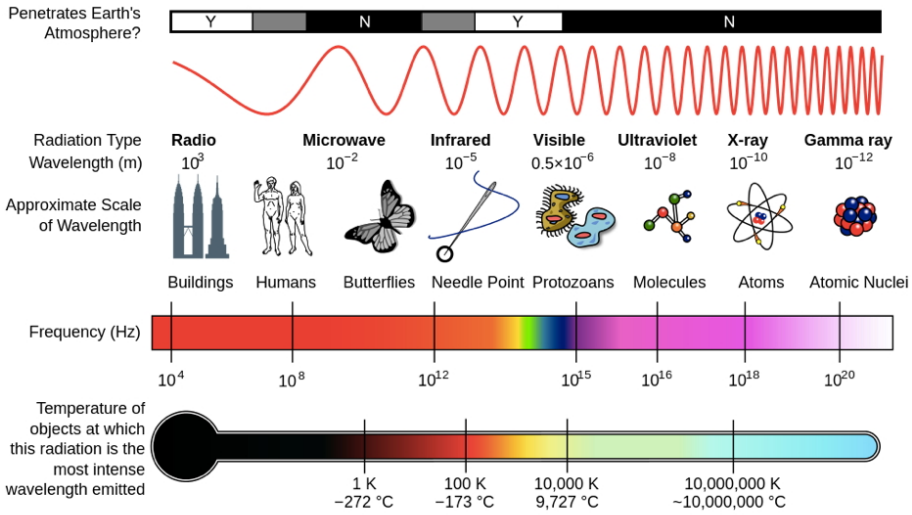
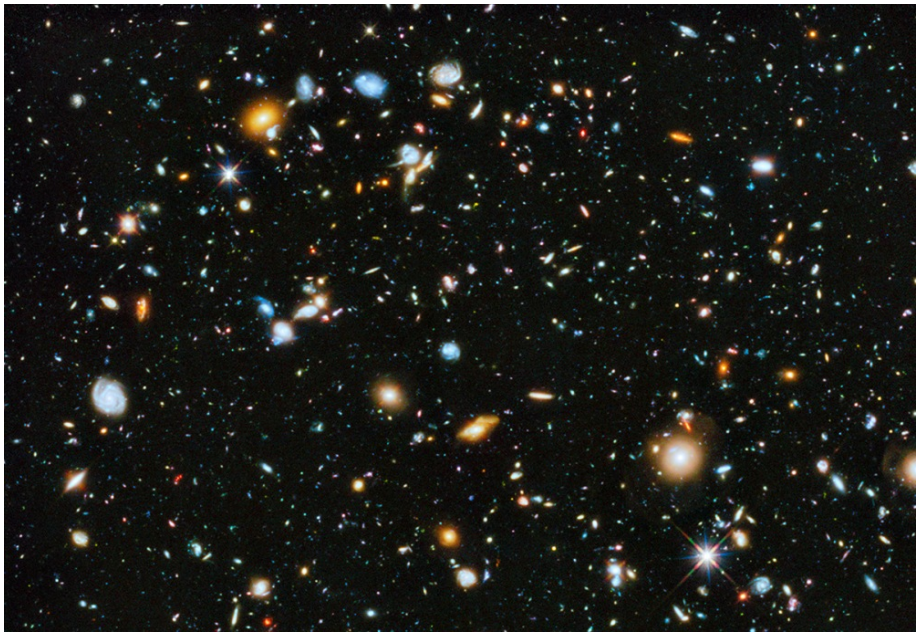
Case study: Vision

Properties of Electromagnetic (EM) radiation



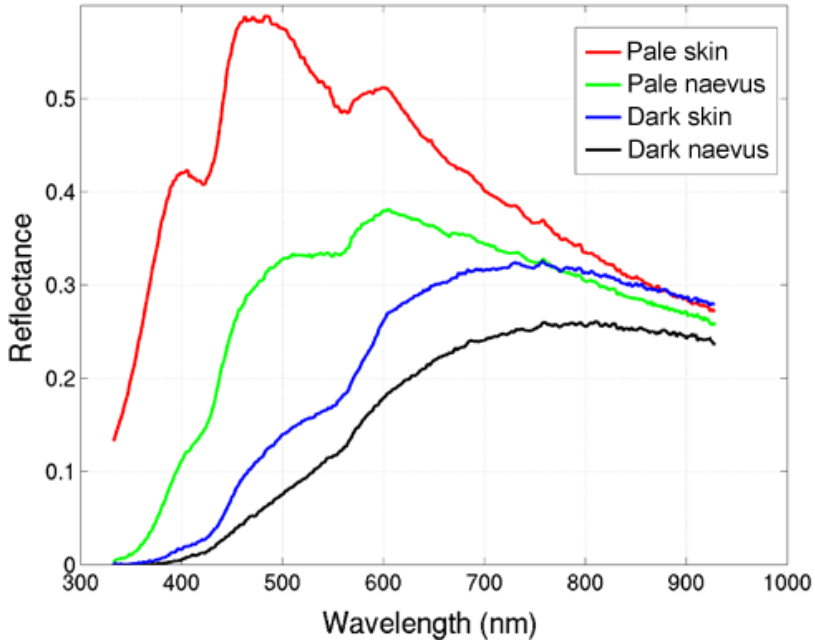
http://en.wikipedia.org/wiki/File:EM_Spectrum_Properties_edit.svg (http://en.wikipedia.org/wiki/File:EM_Spectrum_Properties_edit.svg)

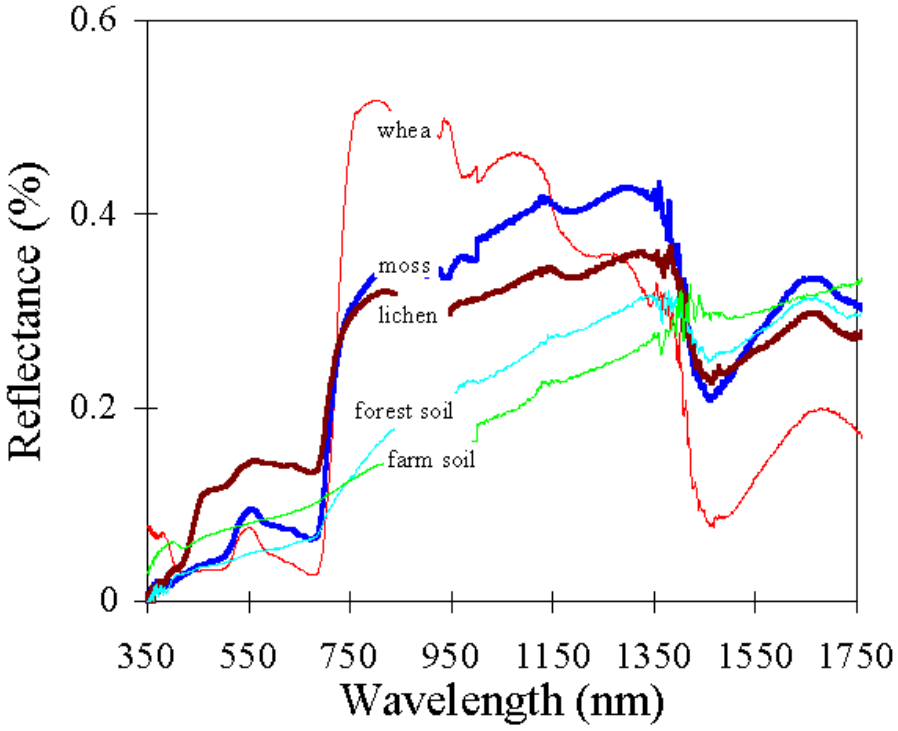
- Wavelength/frequency
- Intensity
- Location/position of source
- Reflects off some materials
- Refracted (bent) moving through other materials
- Information across space (and time)



http://apod.nasa.gov/apod/ap140605.html (http://apod.nasa.gov/apod/ap140605.html)

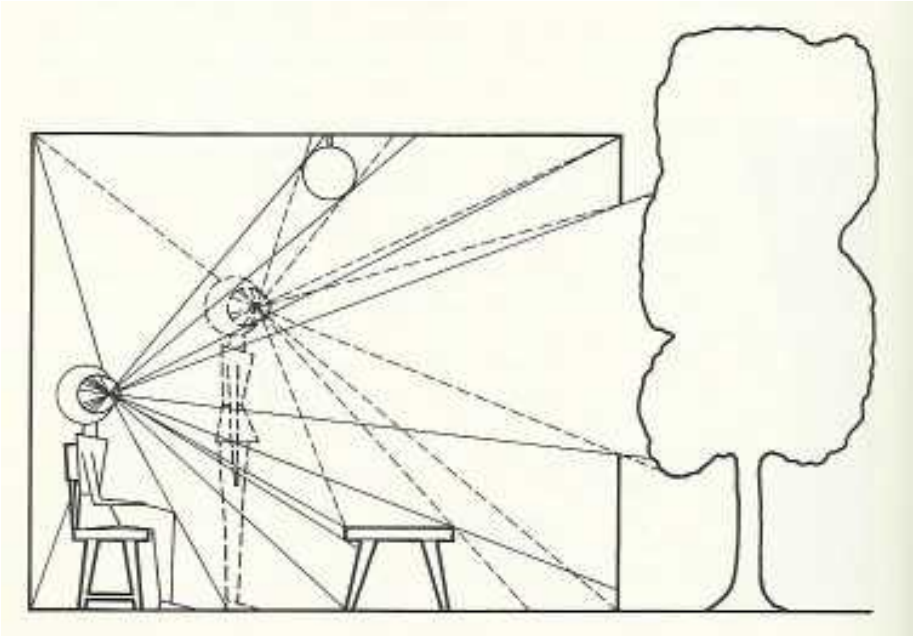
Reflectance spectra differ by surface





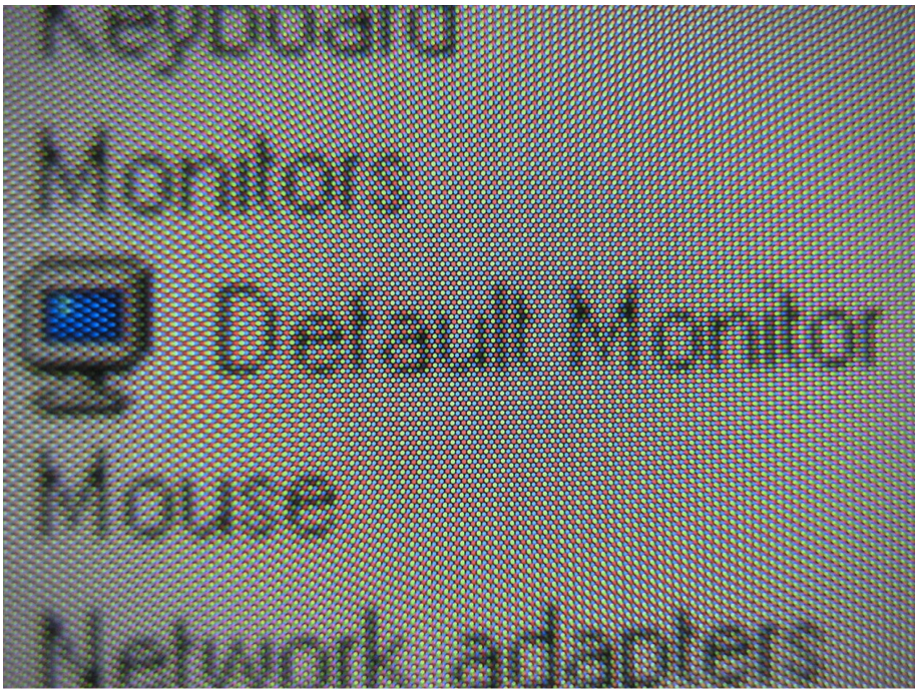
http://http://www.vgt.vito.be/userguide/book_1/4/42/ie42bd.gif
(http://http://www.vgt.vito.be/userguide/book_1/4/42/ie42bd.gif)

Optic array (https://en.wikipedia.org/wiki/Ambient_optic_array) specifies geometry of environment

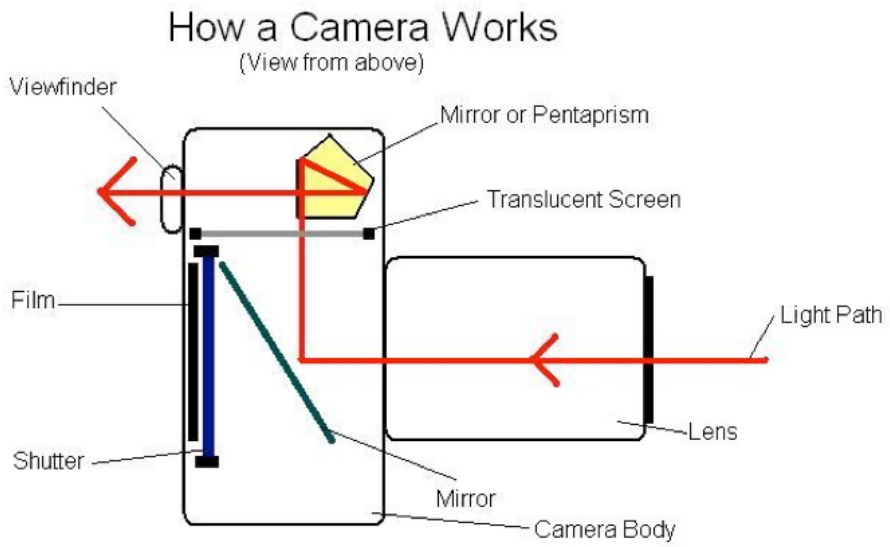


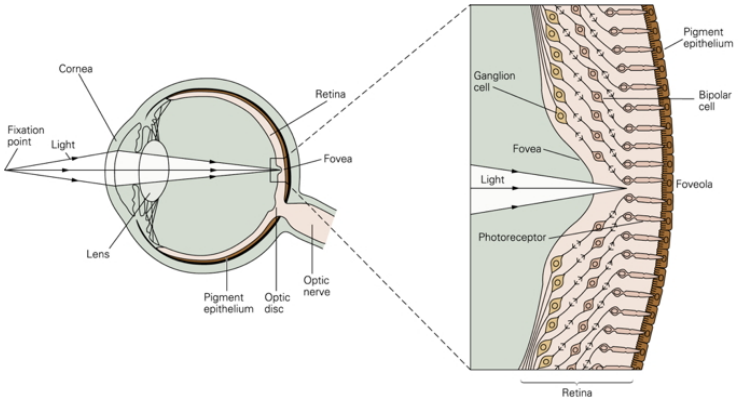
Categories of wavelength specify perception of color

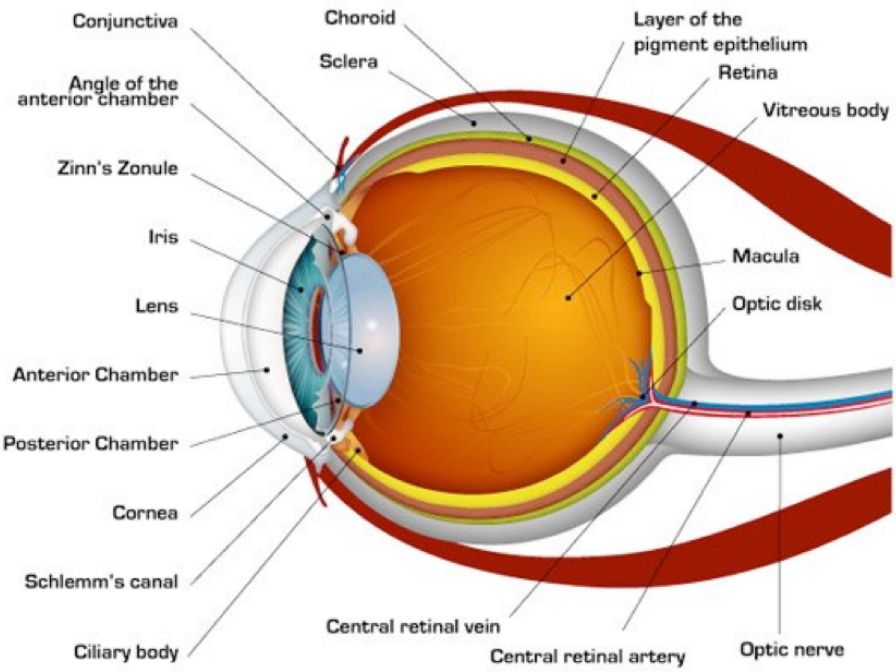
- Eyes categorize wavelength into relative intensities within wavelength bands
- RGB ~ **R**ed, **G**reen, **B**lue
    - Long, medium, short wavelengths
- *Color is a neural/psychological construct*



The biological camera







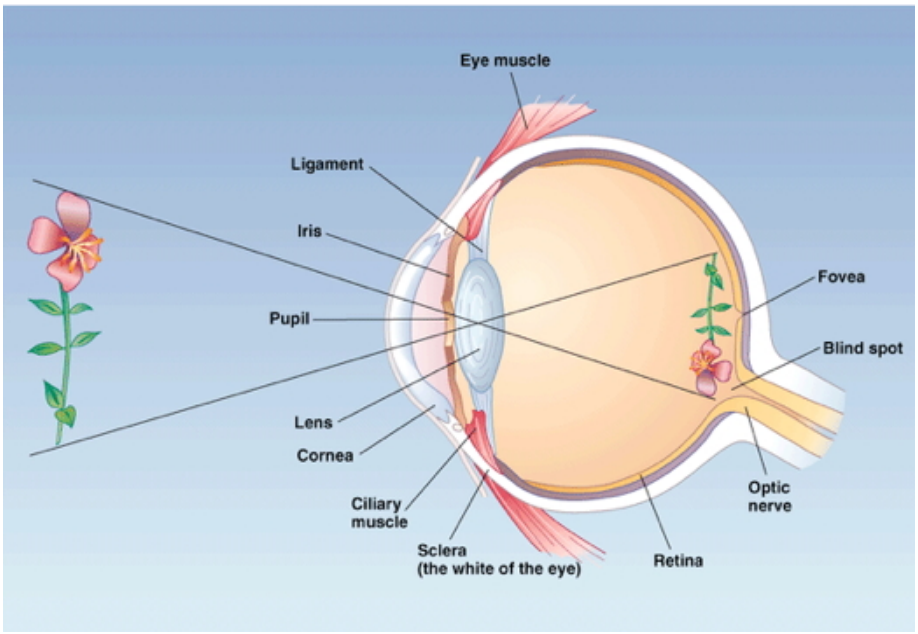
Parts of the eye

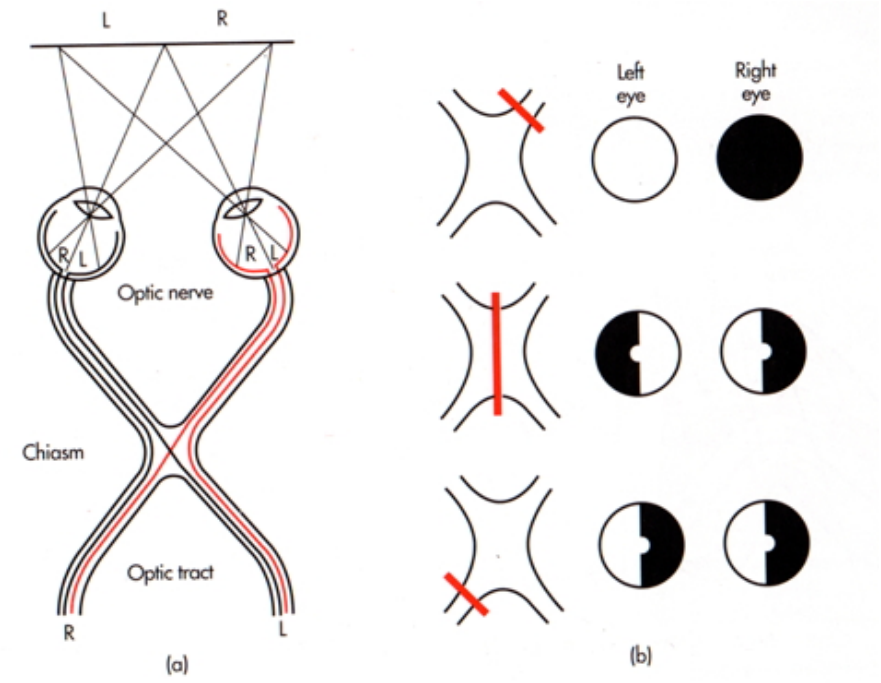
- *Cornea* - refraction (2/3 of total)

- *Pupil* - light intensity; diameter regulated by Iris.
- *Lens* - refraction (remaining 1/3; focus)
- *Retina* - light detection
    - ~ skin or organ of Corti in inner ear
- *Pigment epithelium* - regenerate photopigment
- *Muscles* - move eye, reshape lens, change pupil diameter

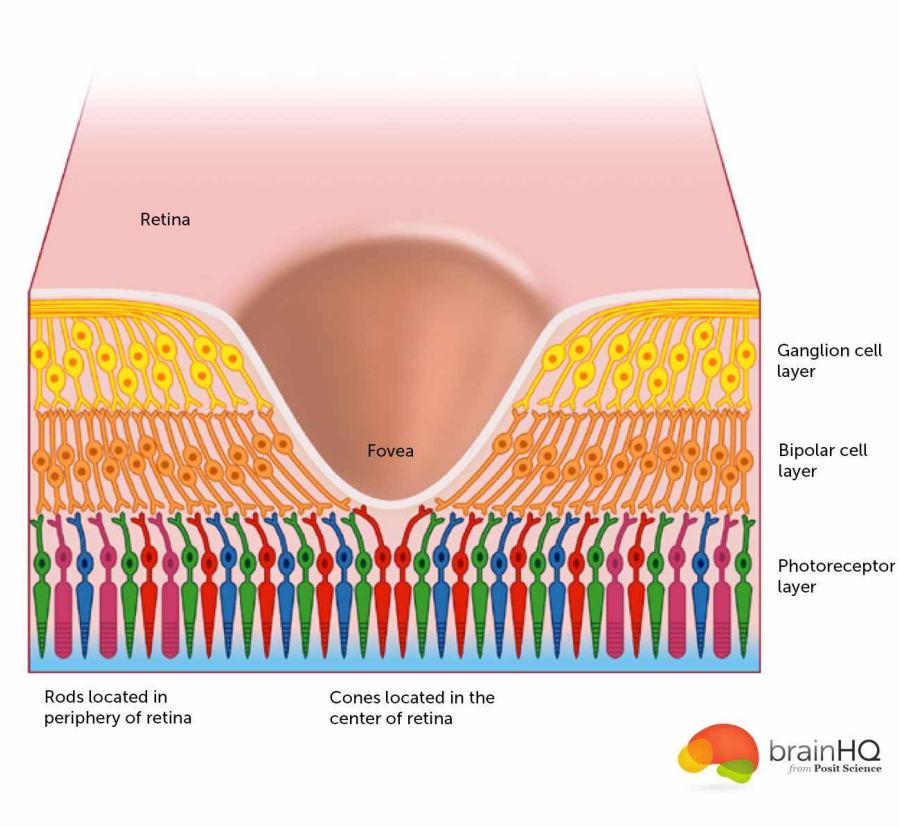
Geometry of retinal image

- Image inverted (up/down)
- Image reversed (left/right)
- Point-to-point map (*retinotopic*)
- Binocular and monocular zones





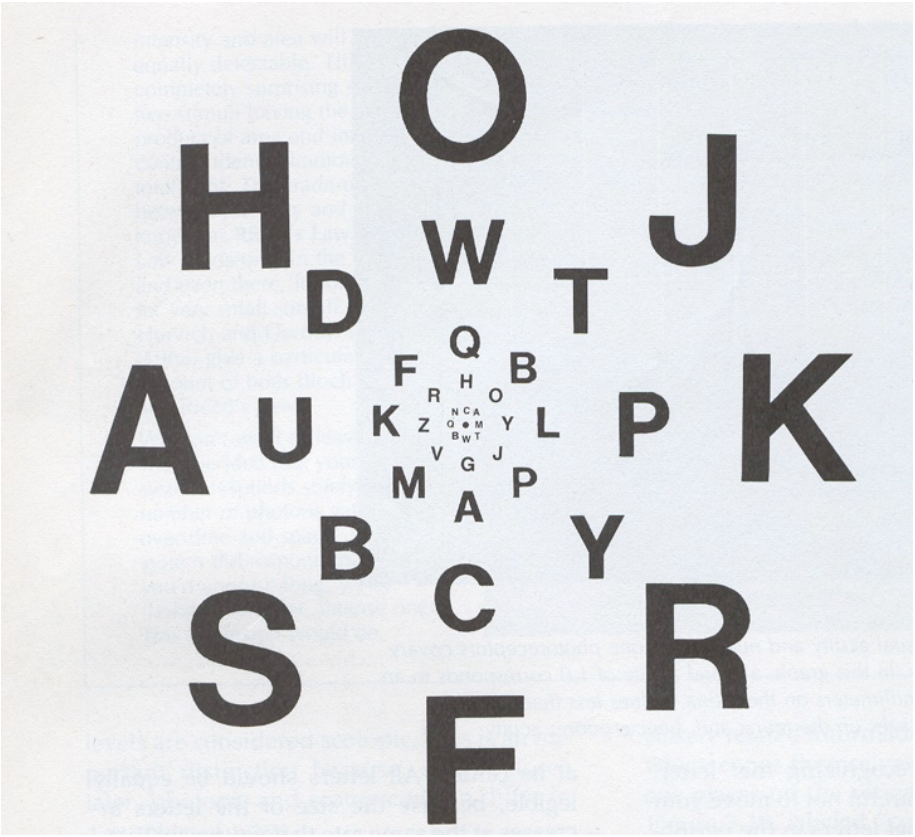
The *fovea*

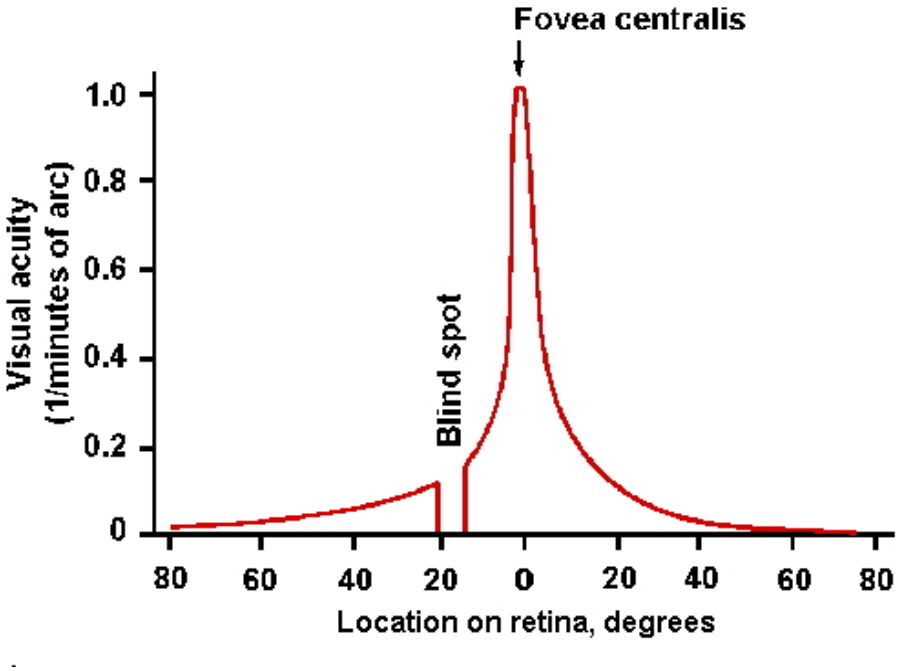


http://www.brainhq.com/sites/default/files/fovea.jpg (http://www.brainhq.com/sites/default/files/fovea.jpg)

- Central 1-2 deg of visual field
- Aligned with visual axis
- *Retinal ganglion cells* pushed aside

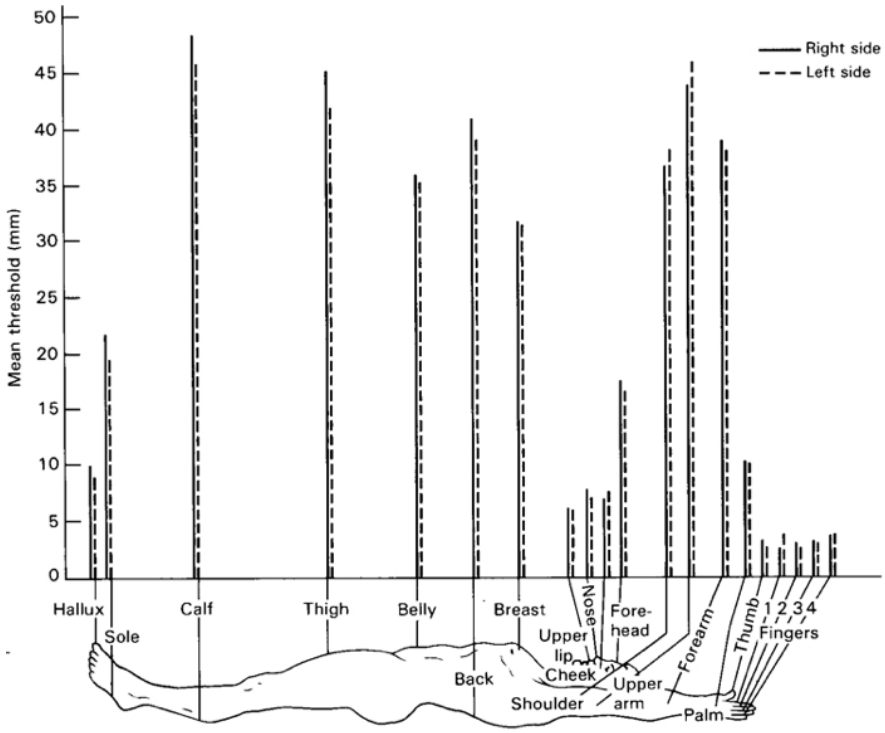
- Highest *acuity* vision == best for details
- Acuity varies from center to periphery



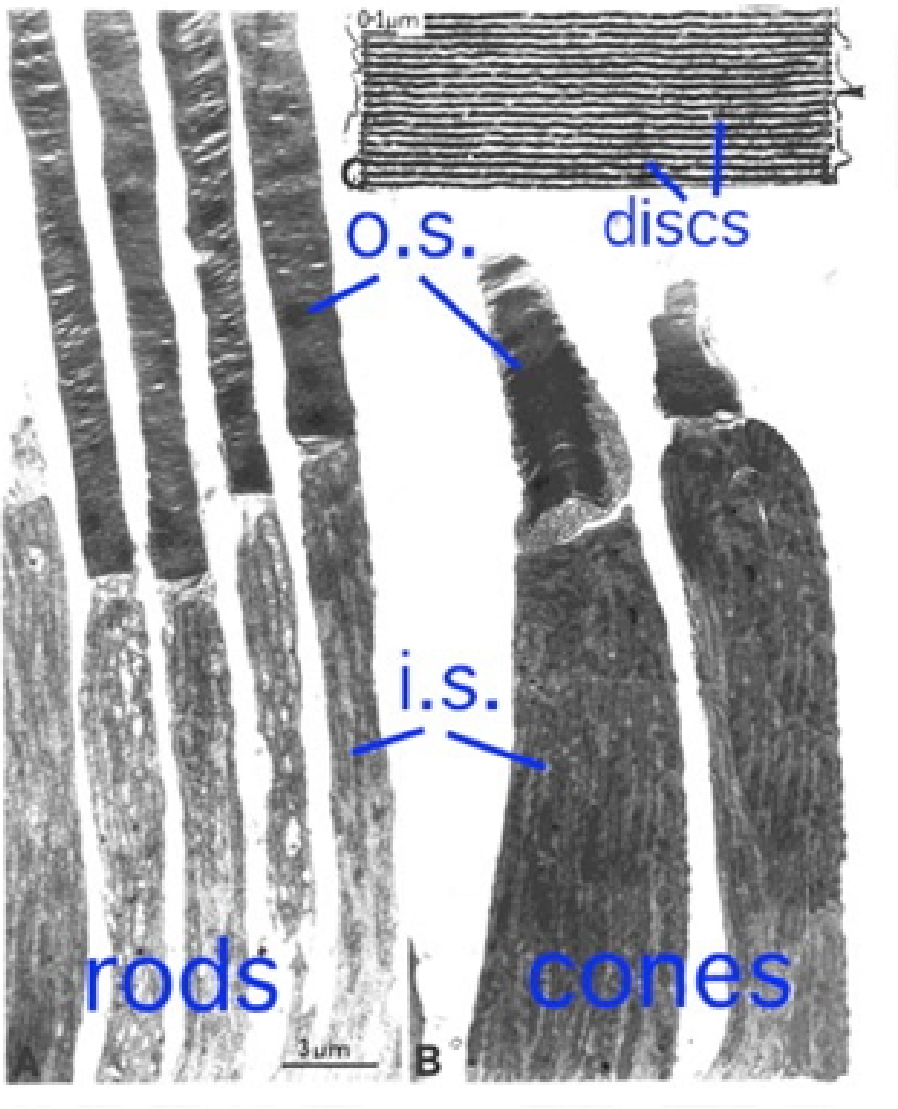


http://michaeldmann.net/pix_7/blndspot.gif
(http://michaeldmann.net/pix_7/blndspot.gif)

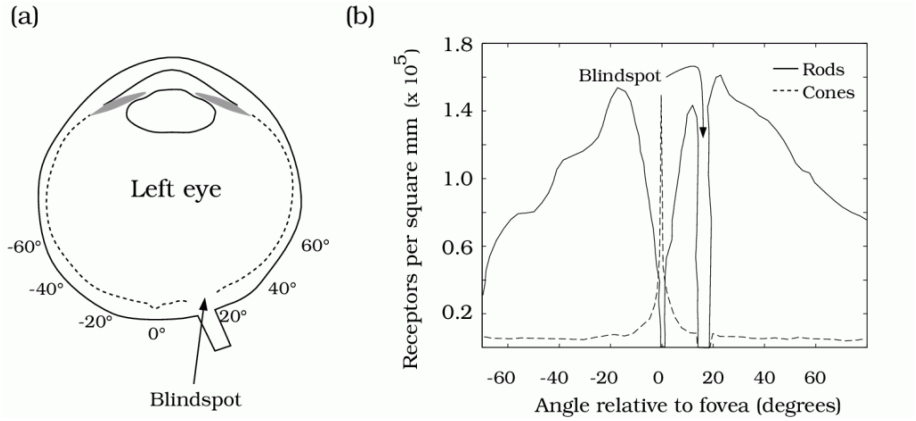
What part of the skin is like the fovea?



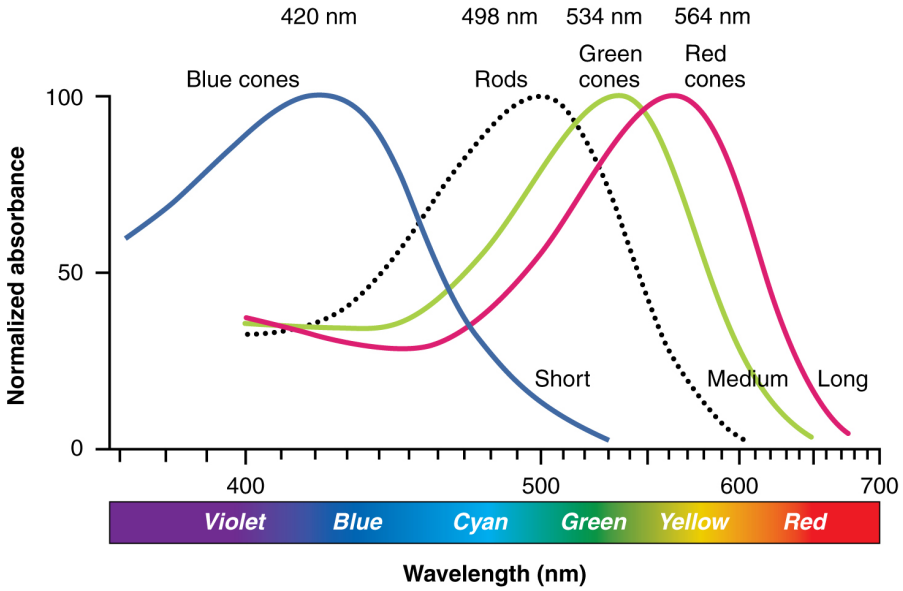
Photoreceptors in retina detect light



- *Rods*
  - ~120 M/eye
  - Mostly in periphery
  - Active in low light conditions
  - One wavelength range
- *Cones*
  - ~5 M/eye
  - Mostly in center
  - 3 wavelength ranges



https://foundationsofvision.stanford.edu/ (https://foundationsofvision.stanford.edu/)



http://cnx.org/content/col11496/1.6/ (http://cnx.org/content/col11496/1.6/)

Photoreceptor physiology

- Outer segment
  - Membrane disks
  - *Photopigments*
    - Sense light, trigger chemical cascade
- Inner segment
  - Synaptic terminal
- Light *hyperpolarizes* photoreceptor!
  - The *dark current*

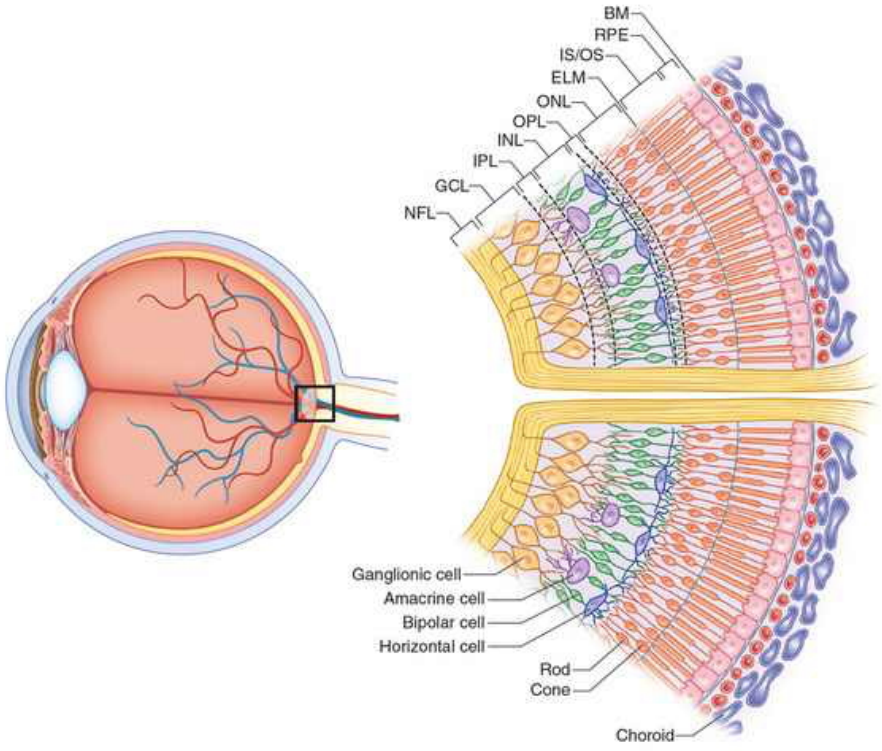
Retina

- Physiologically *backwards*
  - How?
- Anatomically *inside-out*

- How?

Retina

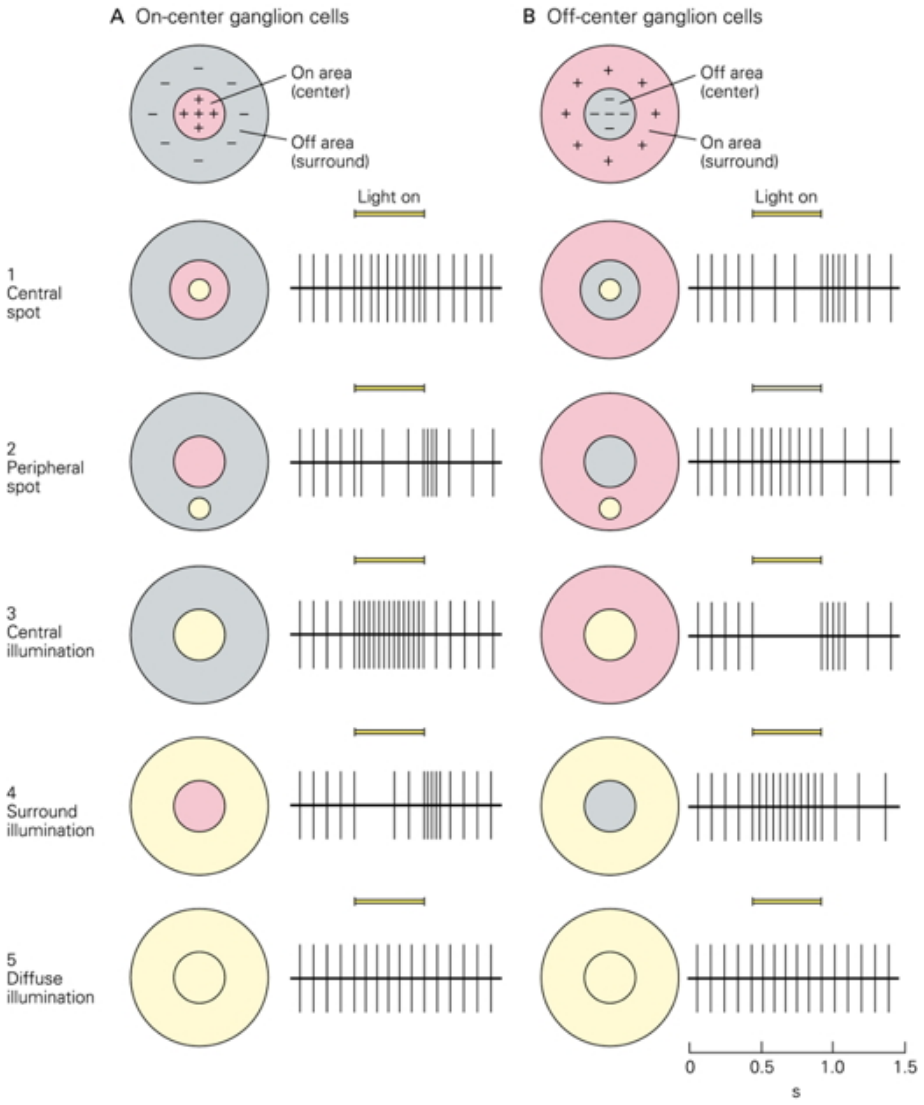
- Physiologically *backwards*
  - Dark current
- Anatomically *inside-out*
  - Photoreceptors at back of eye



http://www.retinareference.com/anatomy/ (http://www.retinareference.com/anatomy/)

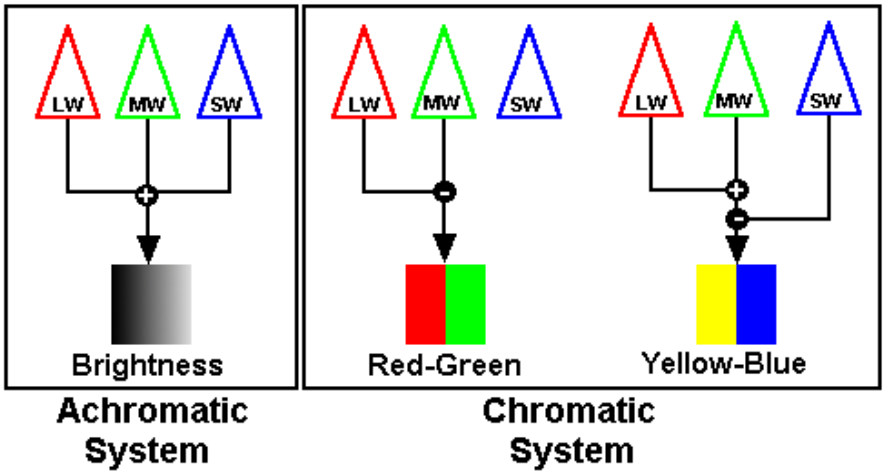
- Information flows…
  - From photoreceptors…
  - To *Bipolar cells*
    - <-> and *Horizontal cells*
  - To *Retinal ganglion cells*
    - <-> and *Amacrine cells*
  - To cerebral cortex

Center-surround receptive fields



- Center region
  - Excites (or inhibits)
- Surround region
  - Does the opposite
- Bipolar cells & Retinal Ganglion cells ->
- Most activated by “donuts” of light/dark
  - Local contrast (light/dark differences)

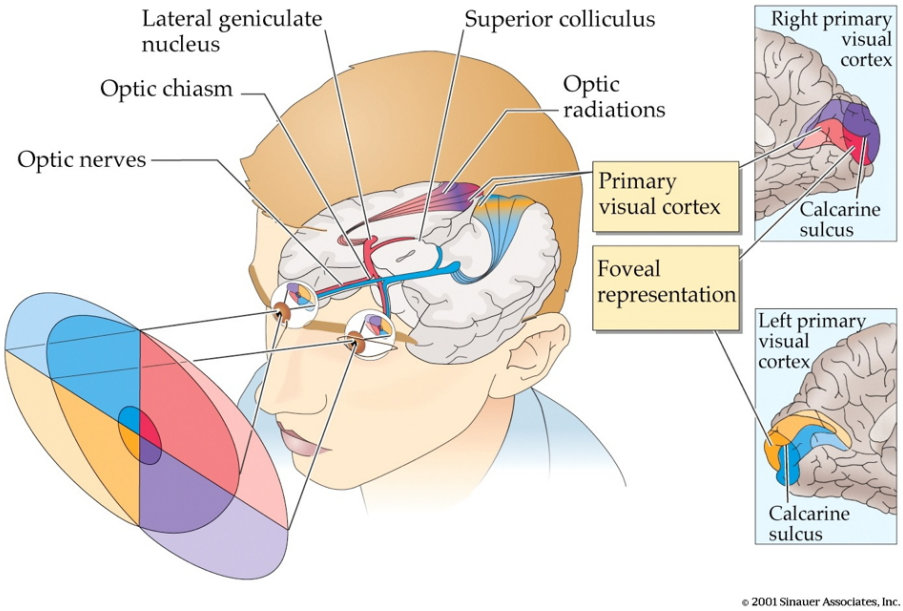
Opponent processing



http://www.visualexpert.com/sbfaqimages/RGBOpponent.gif
(http://www.visualexpert.com/sbfaqimages/RGBOpponent.gif)

- Black vs. white (achromatic)
- Long (red) vs. Medium (green) wavelength cones
- (Long + Medium) vs. Short cones
- Can't really see reddish-green or bluish-yellow
  - "Oppose" one another at cellular/circuit level

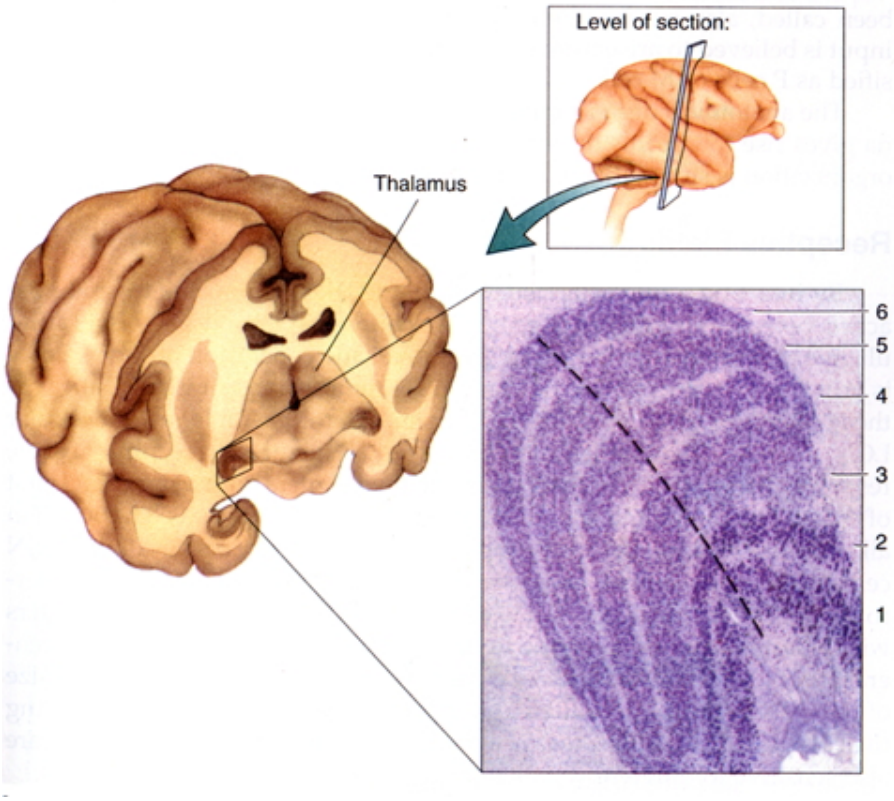
From eye to brain



- Retinal ganglion cells
- 2nd/II cranial (optic) nerve
  - Optic chiasm (χ - asm): Partial crossing of fibers
  - Nasal hemiretina (lateral/peripheral visual field) cross
  - Left visual field (from L & R retinae) -> right hemisphere & vice versa
- *Lateral Geniculate Nucleus (LGN)* of thalamus (receives 90% of retinal projections)

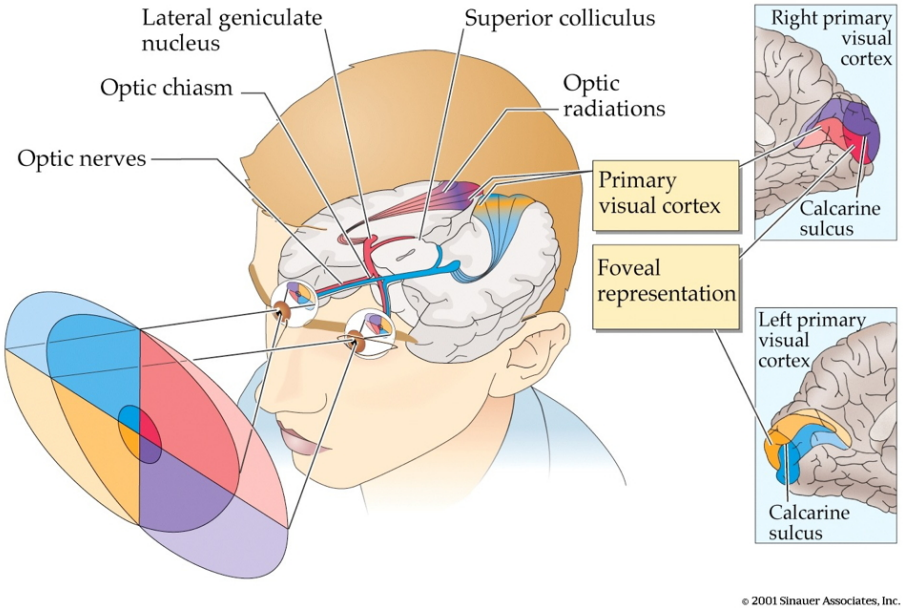
- Hypothalamus
  - *Suprachiasmatic nucleus* (superior to the optic chiasm): Synchronizes day/night cycle with circadian rhythms
- Superior colliculus & brainstem

LGN



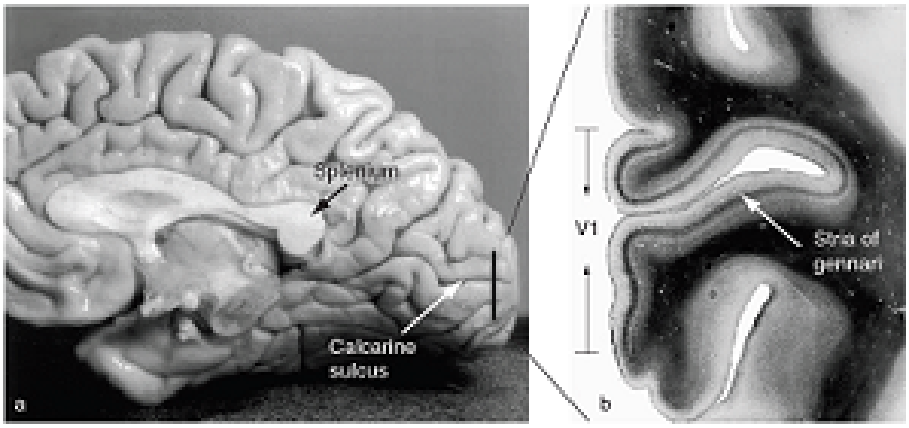
- 6 layers + intralaminar zone
  - Parvocellular (small cells): chromatic
  - Magnocellular (big cells): achromatic
  - Koniocellular (chromatic - short wavelength?)
- Retinotopic map of opposite visual field

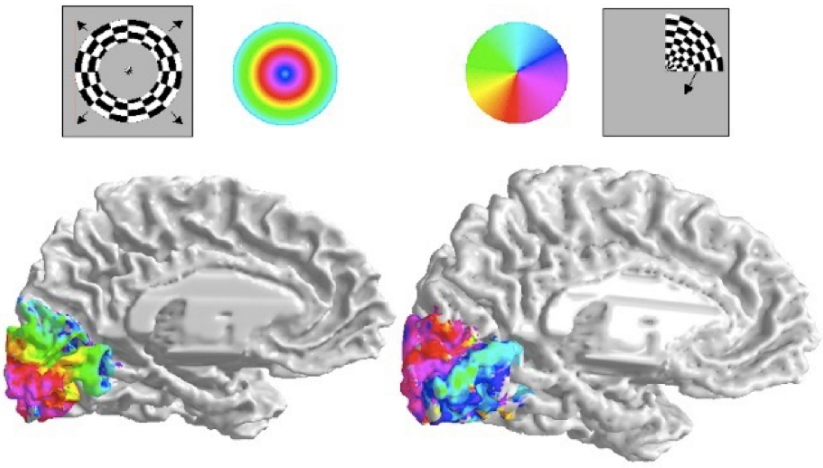
From LGN to V1



- Via *optic radiations*
- *Primary visual cortex (V1) (http://www.scholarpedia.org/article/Area_V1)* in occipital lobe
- Create “stria of Gennari” (visible stripe in layer 4)
- Calcarine fissure (medial occiptal lobe) divides lower/upper visual field

Human V1

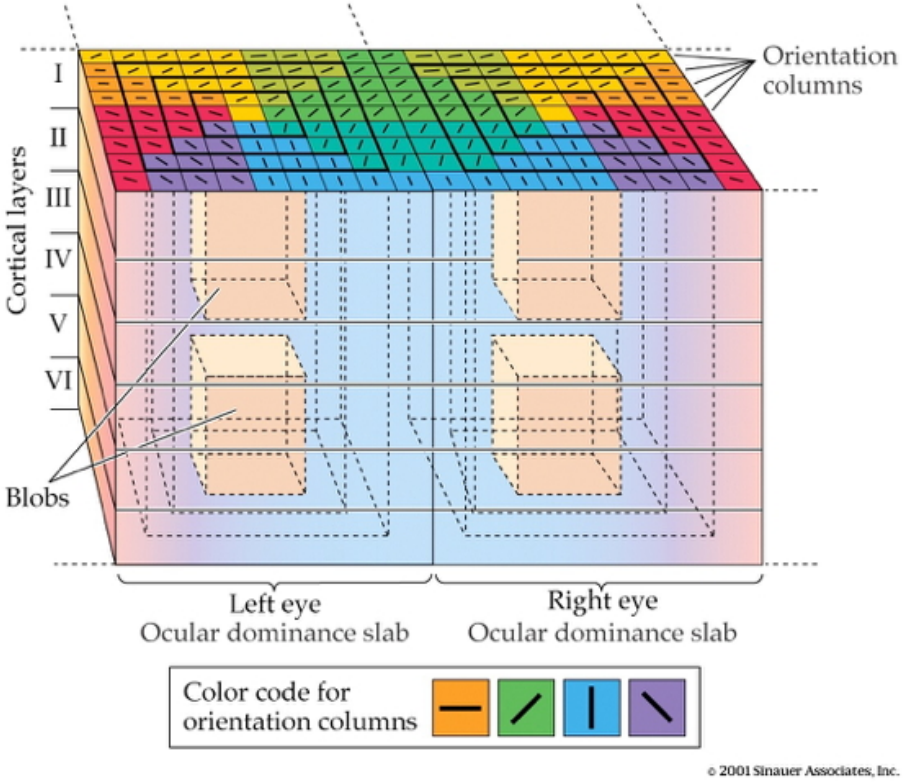




(Dougherty et al., 2003) (http://dx.doi.org/10.1167/3.10.1)

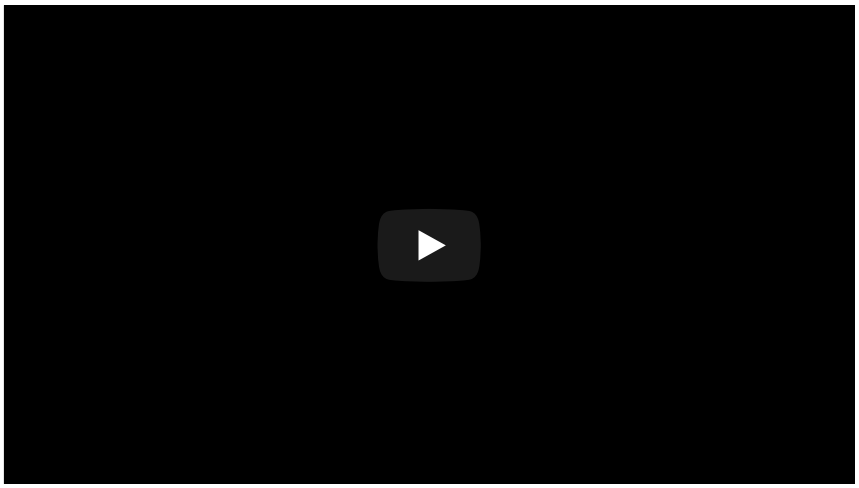
- Fovea overrepresented
  - Analogous to somatosensation
  - High acuity in fovea vs. lower outside it
- Upper visual field/lower (ventral) V1 and *vice versa*

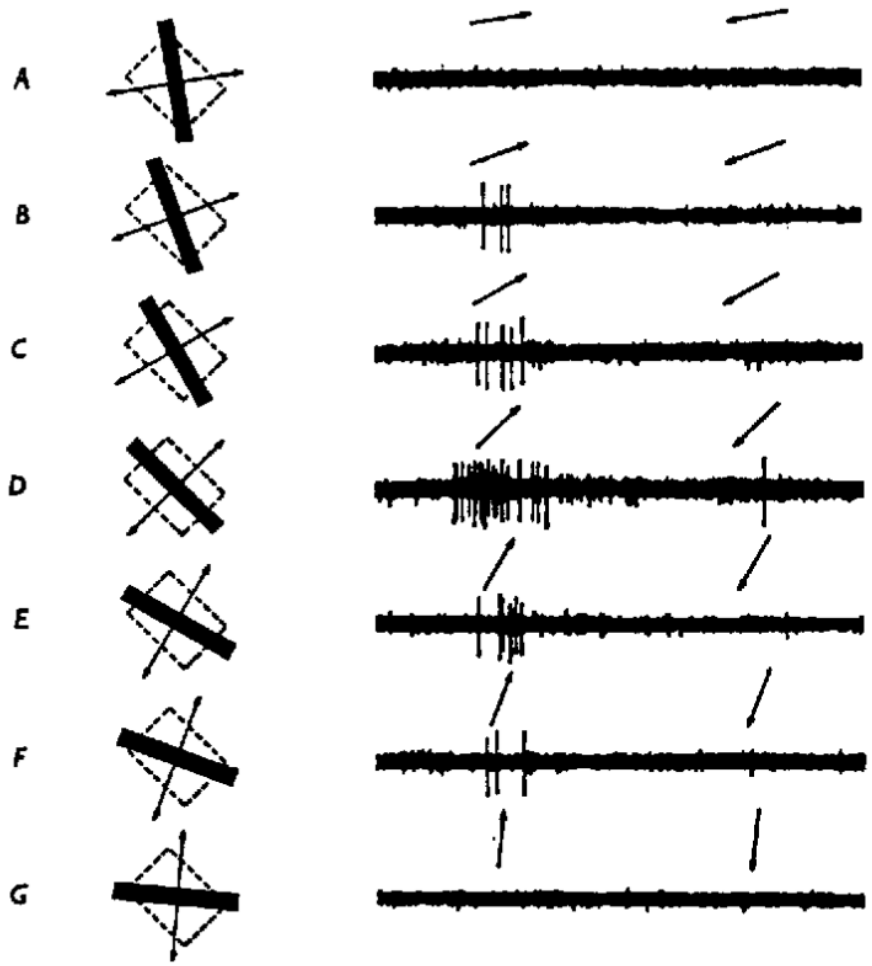
Laminar, columnar organization



- 6 laminae (layers)
  - Input: Layer 4 (remember stria of Gennari?)
  - Output: Layers 2-3 (to cortex), 5 (to brainstem), 6 (to LGN)
- Columns

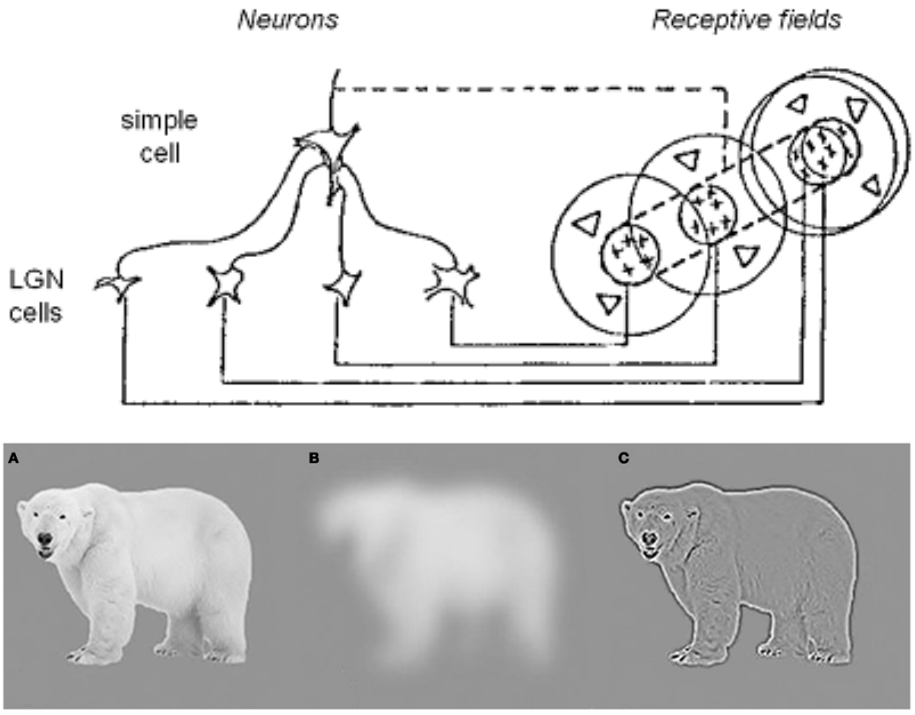
- Orientation/angle
- Spatial frequency
- Color/wavelength
- Eye of origin, *ocular dominance*





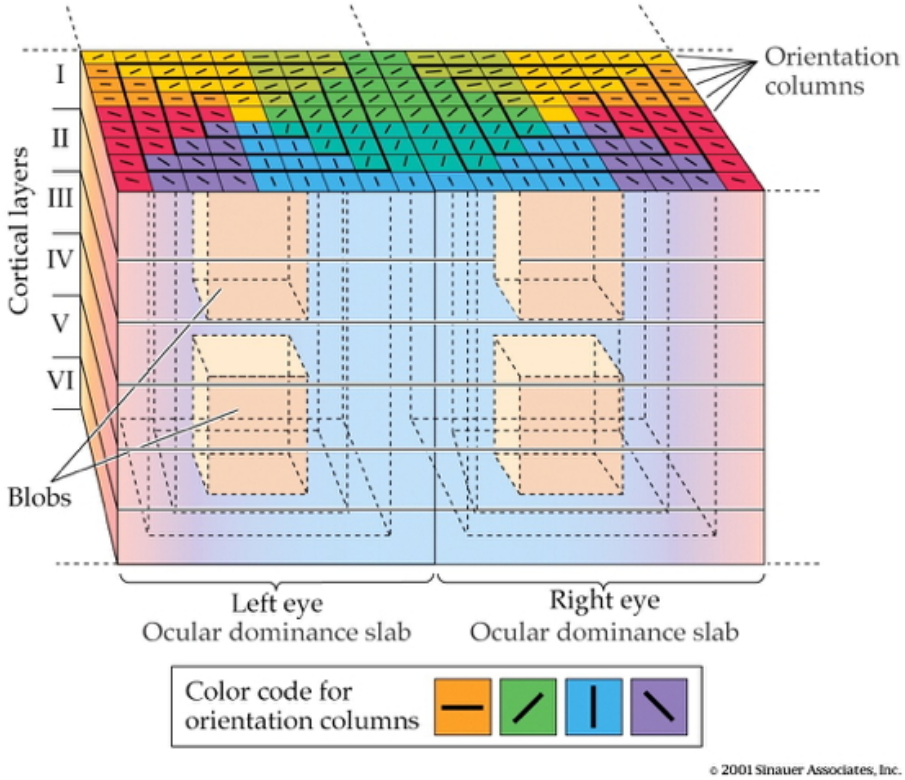
https://foundationsofvision.stanford.edu/wp-content/uploads/2012/02/dir.selective.png (https://foundationsofvision.stanford.edu/wp-content/uploads/2012/02/dir.selective.png)

From center-surround receptive fields to line detection

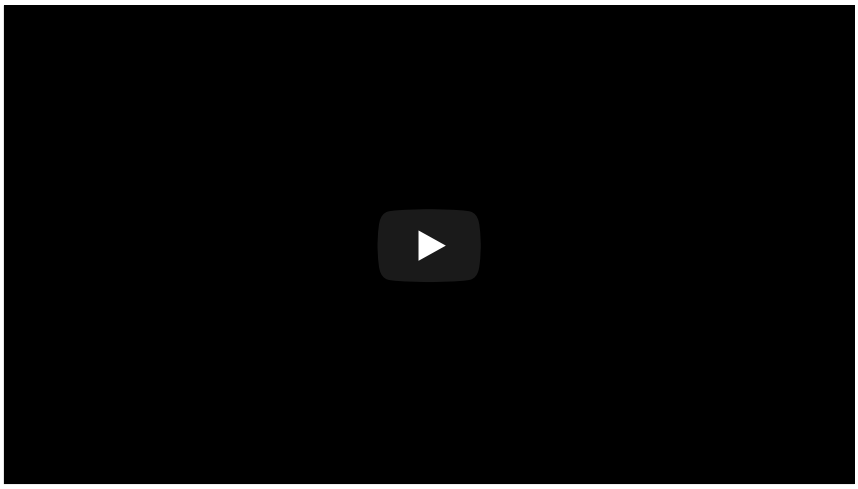


(Panichello, Cheung, & Bar, 2013) (http://dx.doi.org/10.3389/fpsyg.2012.00620)

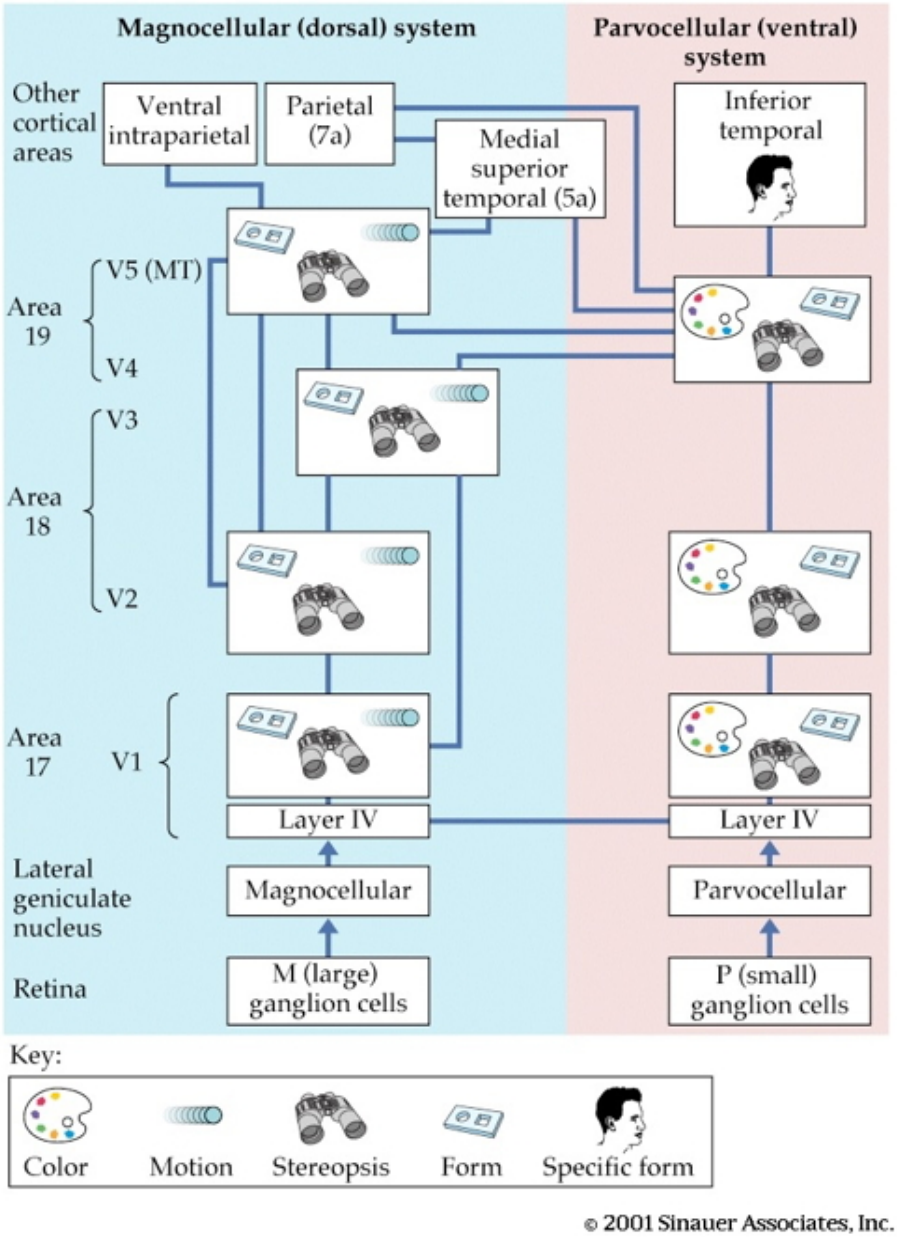
Ocular dominance columns



http://www.scholarpedia.org/w/images/9/99/11-Hubel-Wiesel-model.png (http://www.scholarpedia.org/w/images/9/99/11-Hubel-Wiesel-model.png)



Beyond V1



- Larger, more complex receptive fields

- *Dorsal stream* (where/how)
  - Toward parietal lobe
- *Ventral stream* (what)

What is vision for?

- What is it? (form perception)
- Where is it? (space perception)
- How do I get from here to there (action control)
- What time (or time of year) is it?

References

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Panichello, M. F., Cheung, O. S., & Bar, M. (2013). Predictive feedback and conscious visual experience. *Perception Science*, *3*, 620. https://doi.org/10.3389/fpsyg.2012.00620 (https://doi.org/10.3389/fpsyg.2012.00620)

Roark, M. W., & Stringham, J. M. (2019). Visual performance in the “real world”: Contrast sensitivity, visual acuity, and effects of macular carotenoids. *Molecular Nutrition & Food Research*, *63*(15), e1801053. https://doi.org/10.1002/mnfr.201801053 (https://doi.org/10.1002/mnfr.201801053)