COGS 17 section A02

vision

section resources repo

reminders

- homework 5 due wednesday 11:59 PM!

rods and cones

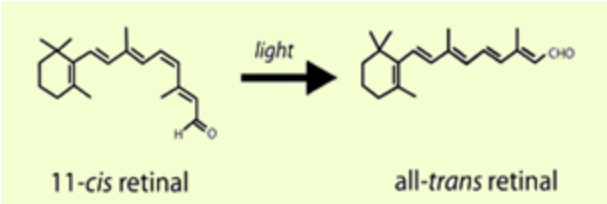
specialized photoreceptors in the retina

contain photopigments that react to light and alter NT release

- isomerization: conversion of light into neural signals

photopigment mechanism

- in outer segment of receptors; made of
  - opsin: long protein chain
  - retinal: short lipid
- process:
  - 11-cis retinal→ all-trans retinal (shape change)
  - detaches from opsin → opsin gets “bleached”
  - triggers second messenger signal cascade: ion (Na+ and Ca++) gates close, altering *graded* NT release



photopigment regeneration

after a photon isomerizes a photopigment, photopigment needs to regenerate to its original form to respond to next photon

- regeneration = retinal + opsin recombine
  - all trans retinal → 11-cis retinal to re-bind with opsin
  - via enzymes in pigment epithelium
- takes time (explains light/dark adaptation)
  - light adapted
    - following bright light exposure, most photopigments are bleached
    - vision temporarily desensitized
  - dark adapted
    - vision gradually improves in low light as rhodopsin (in rods) regnerates
- opsin quantities
  - rods: ~10 million rhodopsin /cell
  - cones: fewer and more variable (sensitive to different wavelengths)

the eye

retina

- light sensitive
- converts light (environment) into electric signals

fovea

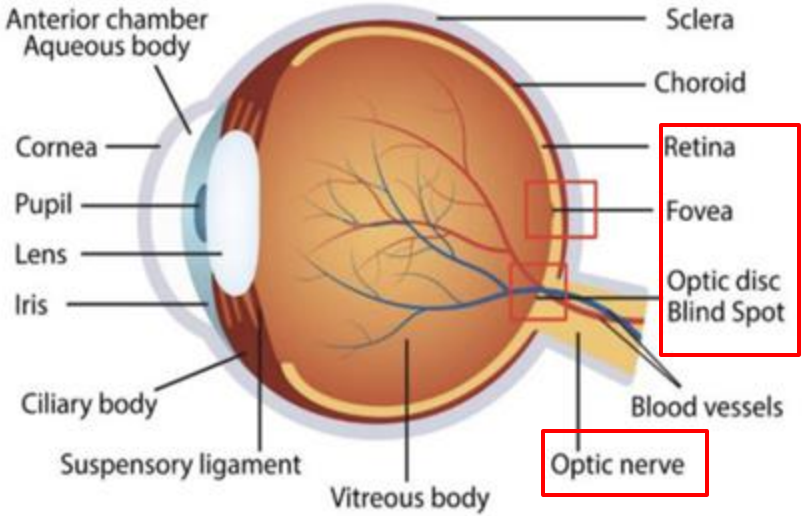
- center of retina
- highest visual acuity

optic nerve

- bundle of nerve fibers
- carries electrical signals from retina to brain

optic disc (blind spot)

- where optic nerve leaves the eye



cells in the retina

photoreceptors (**graded** potentials)

- rods
  - high sensitivity
  - function in scotopic (low light) vision
  - located in periphery
  - no color info
- cones
  - low sensitivity
  - high spatial and temporal resolution
  - highly concentrated in fovea
  - color vision and fine detail

bipolar cells (**graded excitatory**)

- postsynaptic to rods and cones
- spontaneous firing (by amount of NT received from photoreceptors)
- release excitatory NT to ganglion cells

ganglion cells (**action** potentials)

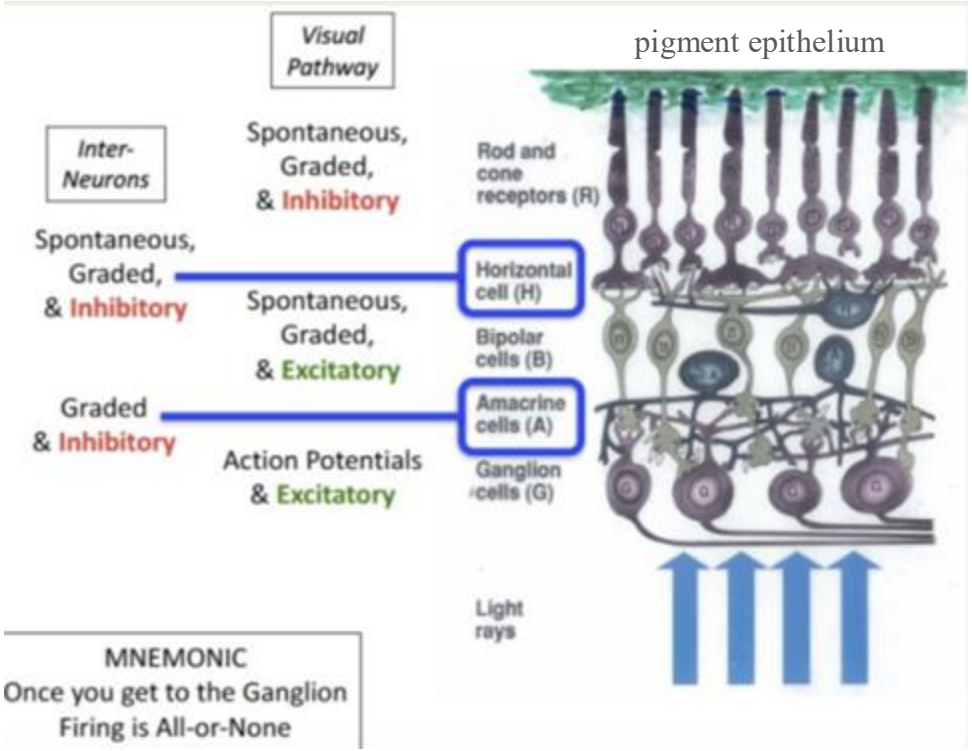
- final output of retina
- axons form optic nerve
  - exit eye via optic disk (blind spot)

interneurons (**graded inhibitory**)

- horizontal cells
  - photoreceptors ⟷ bipolar
  - **graded** inhibitory
- amacrine cells
  - bipolar ⟷ ganglions
  - diverse

pigment epithelium

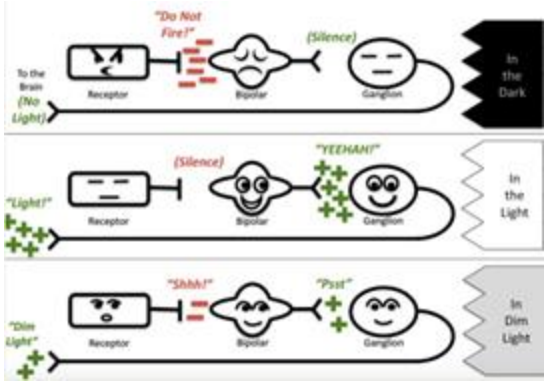
- non-neuronal cells that feed and recycle from receptors
- helps reflect/maximize light

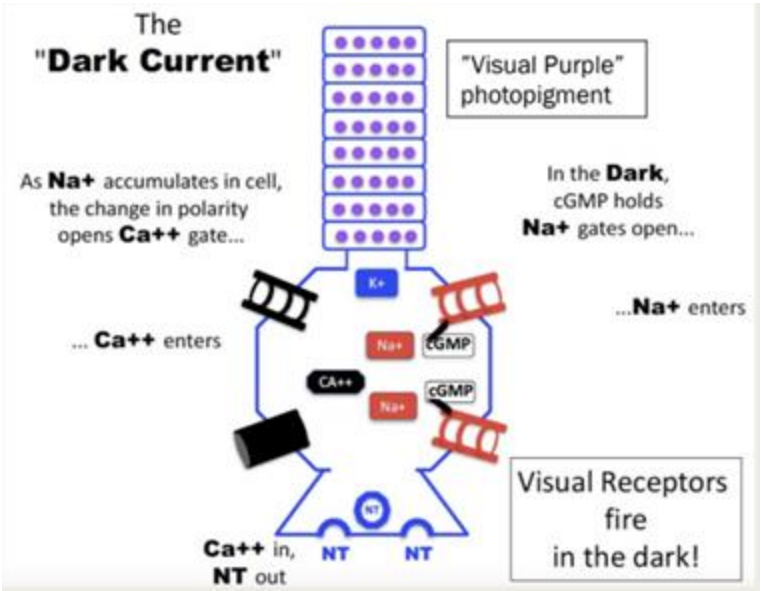

Visual Pathway
pigment epithelium
Inter-Neurons
Spontaneous, Graded, & Inhibitory
Rod and cone receptors (R)
Spontaneous, Graded, & Inhibitory
Horizontal cell (H)
Spontaneous, Graded, & Excitatory
Bipolar cells (B)
Graded & Inhibitory
Amacrine cells (A)
Action Potentials & Excitatory
Ganglion cells (G)
Light rays
MNEMONIC
Once you get to the Ganglion
Firing is All-or-None

paradox of visual transduction: light ***inhibits*** photoreceptors!

in the dark (absence of stimulation):

- ion channels on photoreceptors remain open
- constant influx of Na^+ = dark current
- Ca^{2+} influx triggers continuous release of inhibitory NT
    - bipolar cells inhibited → ganglion cells do not fire



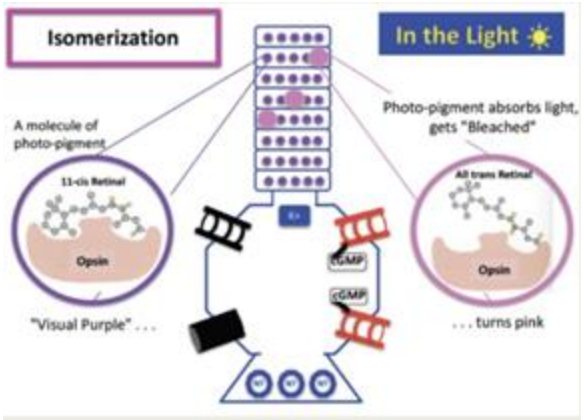


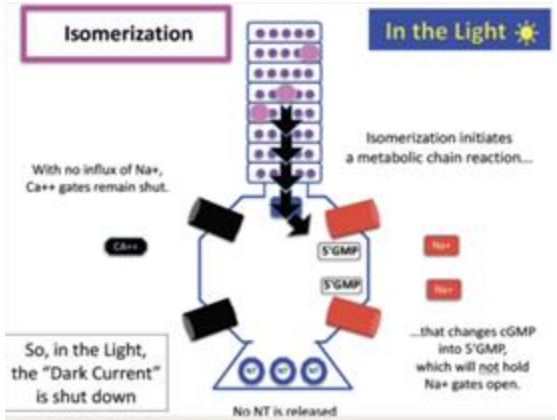
! **photoreceptors** fire in the dark and release **inhibitory** NT
! more light → less NT → more bipolar disinhibition

paradox of visual transduction: light ***inhibits*** photoreceptors!

in the light: dark current is shut down

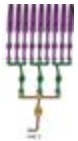
- isomerization closes Na^+ and Ca^{2+} ion channels preventing them from entering cell
- cell is hyperpolarized → decreases NT release
    - bipolar cells *disinhibited*, spontaneously release **excitatory** NT → enough to pass threshold ganglion cell fires (rmb ganglion cells fire action potential)

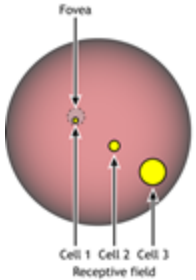




connectivity patterns

convergence: number of photoreceptors whose signals funnel through **bipolar cells** to ultimately influence a single **ganglion cell**

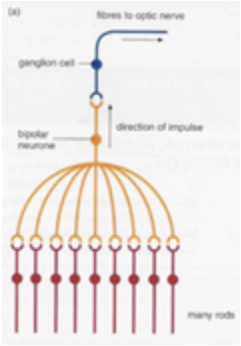
photoreceptor	convergence ratio
rods	high; many (~120 rods) : 1 (ganglion) 
cones	low; few (~6 cones) : 1 (ganglion) 
cones in fovea	very low; 1 cone : 1 ganglion



<u>functional consequences</u>

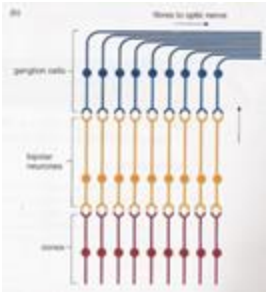
high convergence (rods)

- high sensitivity (detect weak stimuli)
- low acuity



low convergence (cones)

- low sensitivity
- high acuity (preserve detail)



connectivity patterns: low light sensitivity

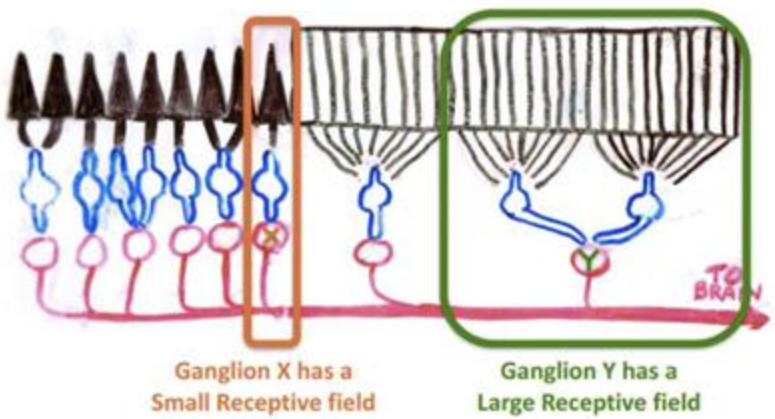
rods dominate in dim light

- cones
  - individual cones react weakly
  - not enough activity to stimulate each bipolar → ganglion cells can't cross threshold to fire
- rods
  - summation of weak signals across many receptors
  - small hyperpolarizations *collectively* stimulate bipolar → ganglion threshold reached

connectivity patterns: receptive fields

receptive field: set of receptors whose activity influences activity of a “target” cell

- size and shape determined by
  - degree of convergence
  - lateral inhibition

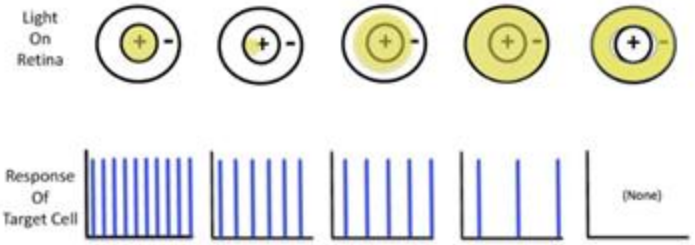


photoreceptor-ganglion interaction	receptive field size	functional outcome
rod – ganglion	large	high visual acuity: more nerve fibers dedicated to particular detail
cones – ganglion	small	low visual acuity: less nerve fibers dedicated to particular detail

rods vs cones

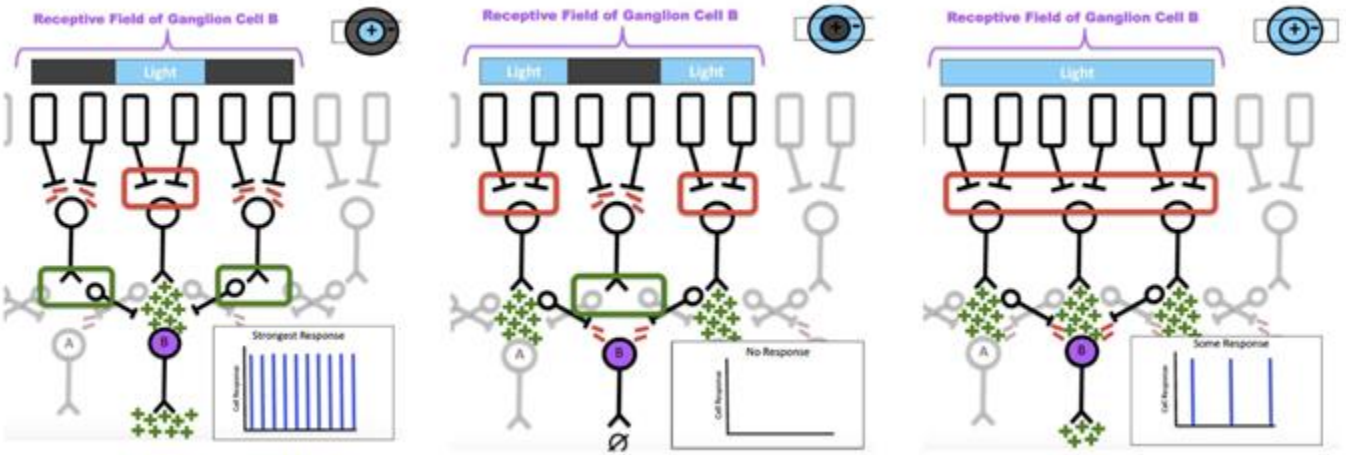
	RODS	CONES
Shape	Outer Segment rod-like	Outer Segment cone-like
Size	Larger (more photopigment)	Smaller (less photopigment)
#	~ 120 million/eye	~ 6 million/eye
Distribution	None in Fovea, highly conc'd in periphery	High concentration in Fovea, dispersed in periphery
Re: Ganglion Cells	High Convergence	Low Convergence
Potential	Graded potentials	Graded potentials
NT	Spontaneously release Inhibitory NT	Spontaneously release Inhibitory NT
Photopigment	1 kind (Rhodopsin)	3 kinds (sensitive to Long, Medium, Short λs)
Code Color	No (dark/light only)	Yes (Long, Medium, Short λs)
Motion Detection	Excellent	Poor
Acuity	Low	High (esp in Fovea)
Sensitivity	High (can operate in dim light)	Not as good (require brighter light)
Pathway	Magnocellular/Dorsal Stream	Mostly Parvocellular/Ventral Stream

connectivity patterns: receptive fields



center-surround receptive fields

- center and periphery (surround) respond oppositely to light
- excitatory (+) center - inhibitory (-) surround
  - light on center → excites ganglion via excitatory bipolar cells connected
  - light in surround → amacrine and horizontal cells send inhibition to ganglion



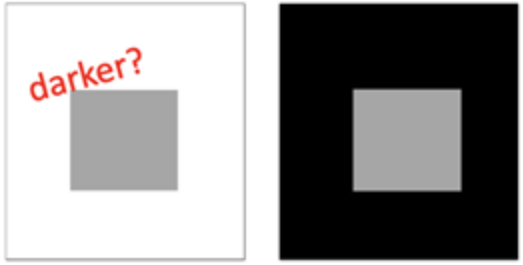
connectivity patterns: lateral inhibition

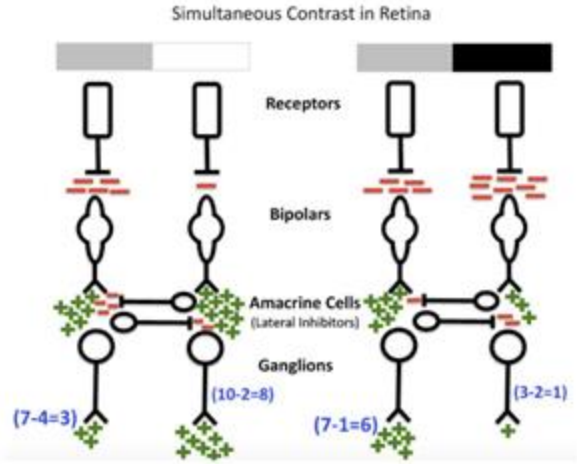
to exaggerate contrast (between dark/light for edge detection)

- lateral activity modulation from nearby circuits
  - bipolar cell strongly activated → amacrine excited → inhibits neighboring ganglions

simultaneous contrast illusion

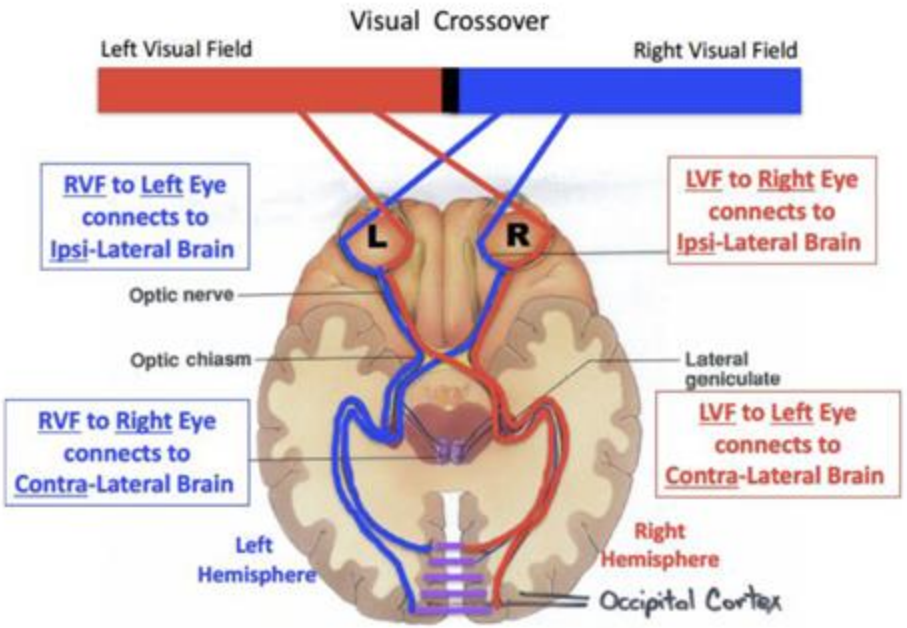
- identical grey patches appear different based on surrounding luminance
  - because of lateral inhibition, ganglions “lie” to brain about grey in the lighter square appearing darker
  - more excited bipolar (from bright surround) → more lateral inhibition → central area appears darker





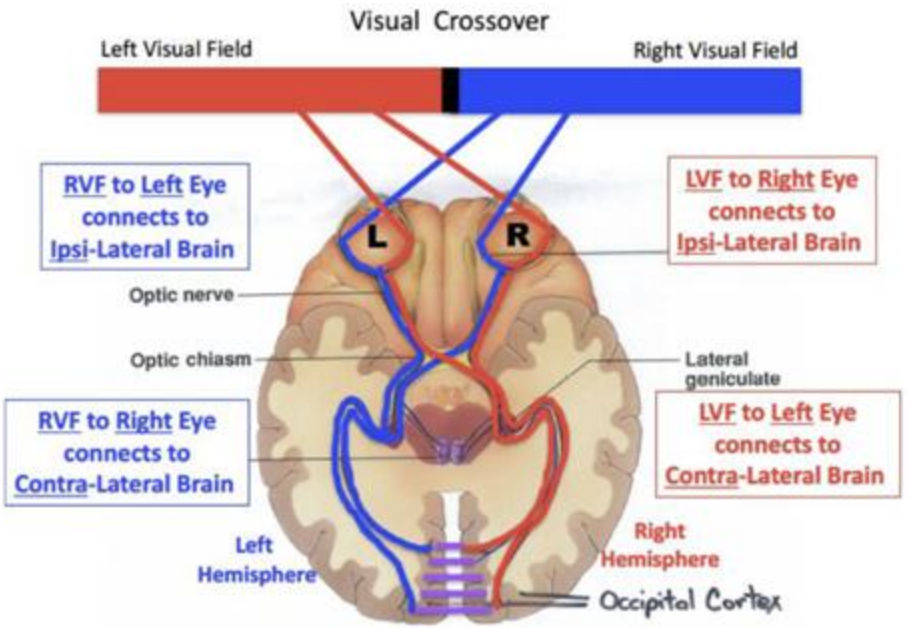
visual crossover

- *right visual* field → left half (hemiretina) of EACH eye → *left hemisphere*
- *left visual* field → right half of EACH eye → *right hemisphere*
- optic nerve contains axons from both hemiretinas of one eye
    - **optic chiasm**: where axons cross
        - inner hemiretina cross to contralateral brain
        - outer hemiretina do not cross



visual crossover

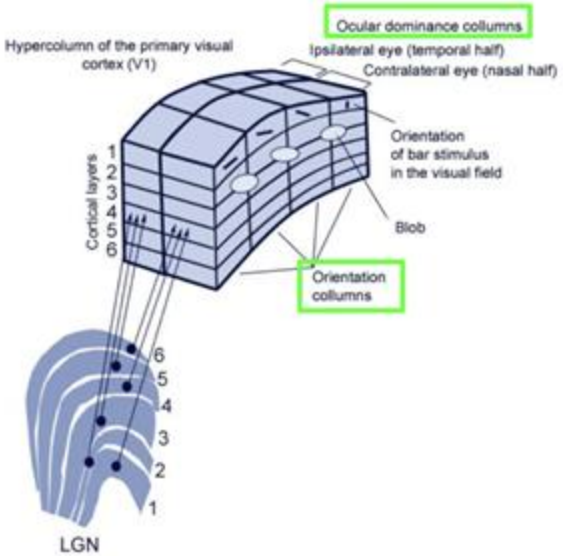
- axon then goes to **lateral geniculate nucleus** (LGN) of thalamus → striate cortex (V1 / primary visual cortex)
- integration of left and right visual fields at corpus callosum → binocular vision



primary visual cortex (V1) in occipital lobe

organization

- 6 layers of cells; layer 4 receives LGN input
- cortical columns
    - neurons in each column respond best to same preferred stimulus
        - line orientation by “simple cells”
    - hypercolumn = set of columns
        - neurons share same receptive field (retinal location)
        - full set of orientations
        - color processing blobs



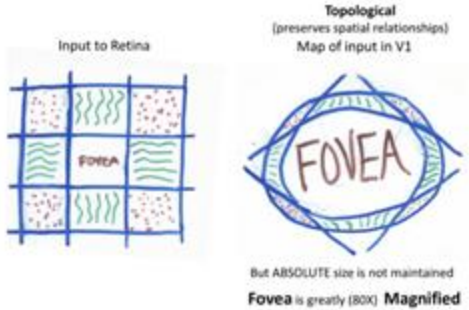
retinotopic map

- adjacent cells correspond to adjacent points in retina
- preserves topological (spatial) relationships from retina to cortex
    - not necessarily absolute distances!

primary visual cortex (V1) in occipital lobe

magnification factor

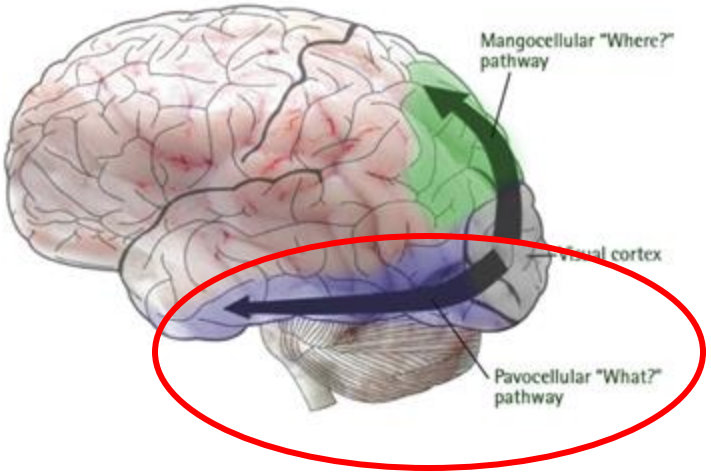
- cortical regions with small receptive fields have disproportionately large area of cortex dedicated to processing its information
- fovea (0.01% of retina) is greatly overrepresented in cortex (8% of V1)
    - high density of photoreceptors and fine visual detail processing



mental imagery

- activates many areas of cortex the same way even without visual input
- shared neural substrates for perception and imagination

information pathways: ventral stream



ventral stream | **who/what** | **parvocellular** pathway

- <u>stimuli identification</u> – shape, color, texture, fine detail
  - integrates with language centers for object naming
- info from cones in or near fovea
- **X ganglions**
  - *small* receptive fields, sustained response
  - (top 4 layers) LGN → V1 →V2→V3→V4→inferior temporal cortex (IT)

ventral stream: detail

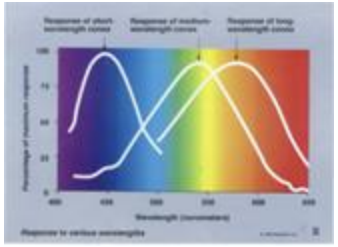
V1: simple cells; respond best to lines of specific orientation
V2: complex cells; respond best to moving lines of preferred orientation
V3: more complex combinations
IT: final target of ventral stream; interprets complex visual stimuli

- **fusiform gyrus**
  - face recognition
  - objects of expertise (car brands, dog breeds)

spatial frequency: # light-dark transitions (change in contrast) in a given visual space

- high: fine detail
- low: gross shapes/outlines

ventral stream: color



visible light: wavelengths ~350 nm to ~700 nm

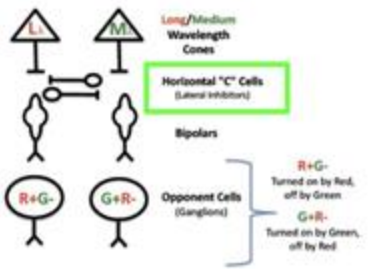
trichromatic theory (young-helmholtz)

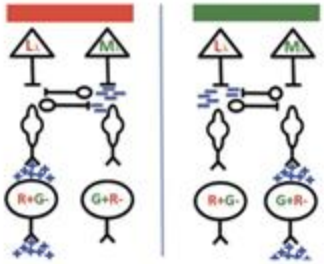
- 3 cone types (short (blue), medium (green), long (red))
- code color via ratio of cone responses (across-fiber coding)

opponent process theory

- trichromatic input re-encoded to opponent pairs
  - red/green, blue/yellow, black/white

- arise via *lateral inhibition* by horizontal cells
- double opponent ganglion cells: eg. R+G- center and G+R- surround
- explains afterimage (adapt red see green afterimage) and color blindness

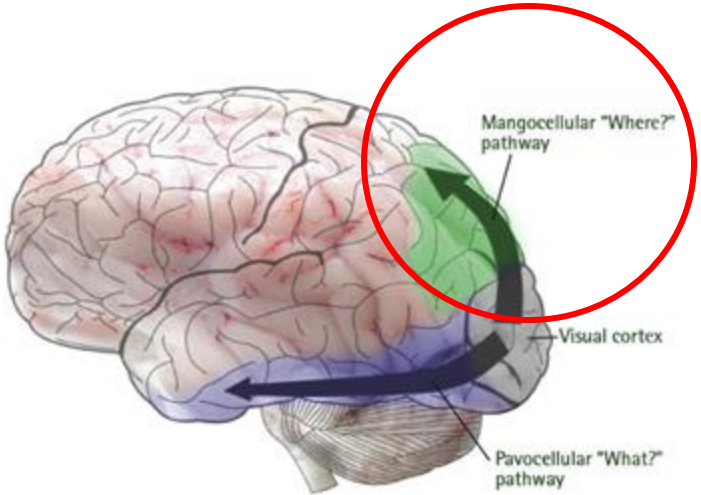




color constancy

- perceive consistent colors despite lighting change
- **retinex theory**: V4 compares colors across scene and filters out overall tint

information pathways: dorsal stream



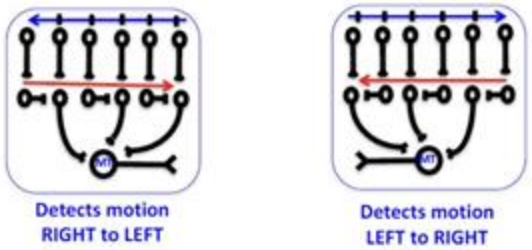
dorsal stream | **where/how** | **magnocellular** pathway

- visuo-spatial mapping: motion, location, overall form
  - integrates somatosensory (parietal) and motor (frontal)
- info from rods and peripheral cones
- **Y ganglions**
  - *large* receptive fields, transient response
  - some go to superior colliculus (blindsight)
  - most: (bottom 2 layers) LGN → V1 →V2→medial temporal (MT)→medial superior temporal (MST)→posterior parietal cortex

dorsal stream: motion

direction sensitivity

- direction-sensitive motion detectors in **medial temporal** (MT)
  - respond selectively to motion in particular direction
    - uni-directional lateral inhibition
- MT feeds to MST (**medial superior temporal**)
  - *optic flow* detectors: respond to global motion patterns



red: inhibited direction

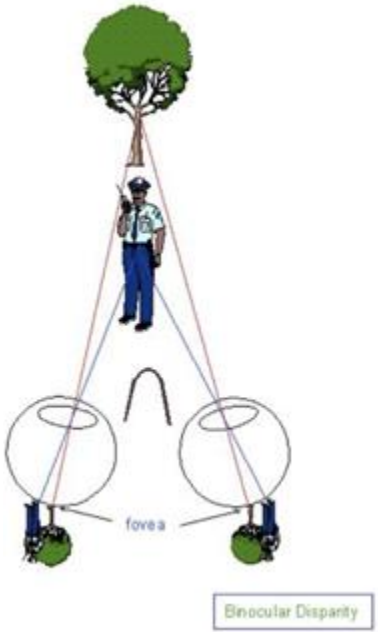
biological motion (lateral temporal lobe) – walking, head movements, facial expressions

- superior temporal sulcus (STS)

dorsal stream: depth

binocular disparity: difference in image location of an object seen by both eyes

- if both eyes focus on a point, other points fall onto retina based on their distance from the focal point
  - close/farther = greater disparity
- disparity detectors
  - V2: specific disparities within defined receptive field
  - MT: disparity anywhere in visual field



higher parietal cortex: visuomotor integration

integrates visual + somatosensory info

- connects to motor cortex for action planning

anterior intraparietal (AIP)

- **canonical cells** for object affordances
    - graspability: signal to premotor cortex to change hand shape in reaching

mirror cell system

- responds to seeing self or other performing an action

kahoot

https://play.kahoot.it/v2/?quizId=7fb395af-2d50-4e7e-9dc4-d2c26e5c8bf4&hostId=0889db3c-c5d4-454b-b692-99e48772950b