Neuroscience Approach (Cognitive Neuroscience)

Examine how brain is physical implementation of cognitive functions:

- Object Recognition
- Attention
- Memory
- Problem Solving

Can structure of brain illuminate function?

- Higher-level Function -> Not so much (yet)
- Low-level Perceptual Functions -> Yes
  - Edge detection
  - Color vision

Neuroscience Approach Methodology

- Imaging
  - Functional Magnetic Resonance Imaging
  - Electrical Encephalography (EEG)
- Brain Stimulation
- Neuropsychology
  - Damage to Brains -> Impaired functions
    - Humans: Wait for damage
    - Animals: Create damage

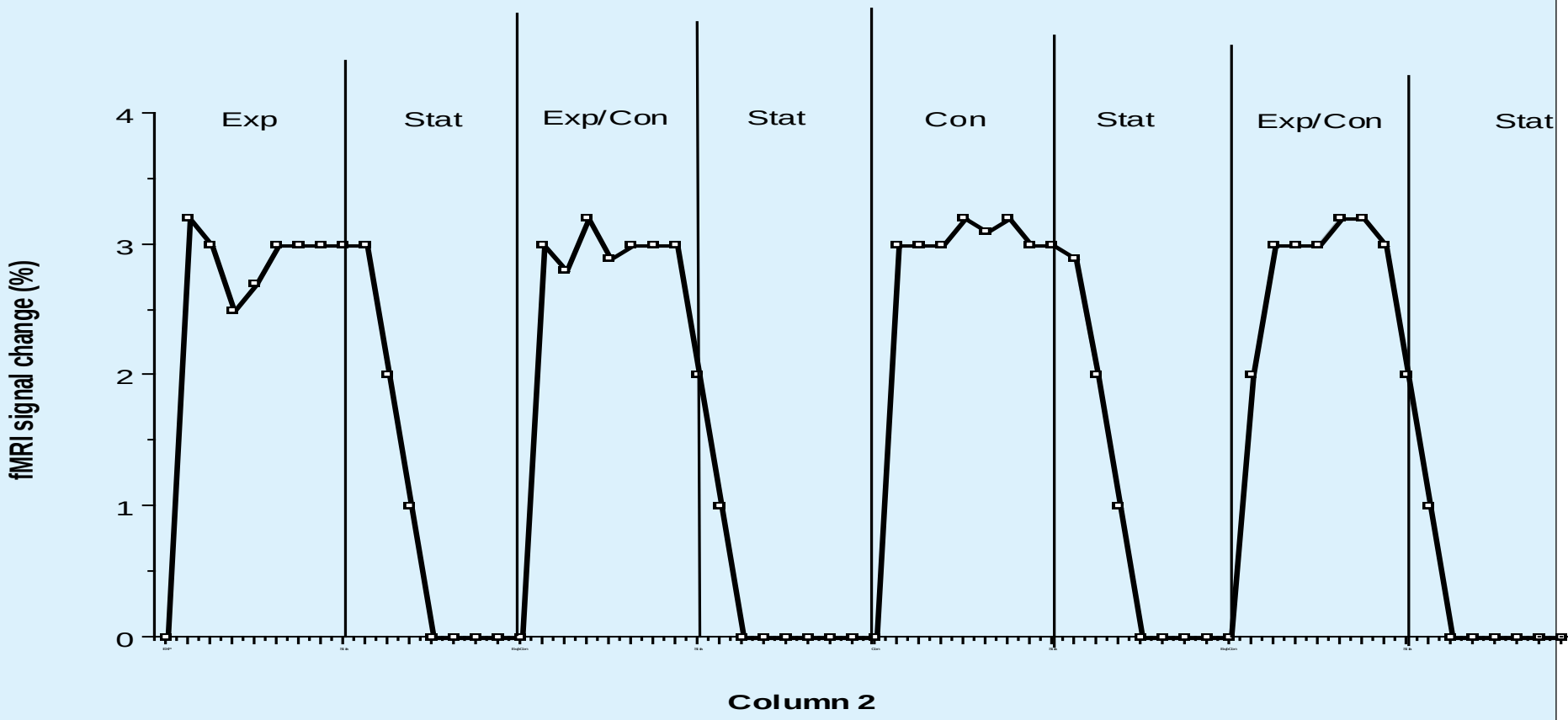
Functional Magnetic Resonance Imaging (fmri)

- Use to take a picture of your brain as it "thinks"
- MRI is a technique that takes one picture of your brain a to one time
- fMRI looks at multiple pictures over time while brain does a task

fMRI Example: Motion After-Effect in MT

- MT is cortical area that has been associated with motion processing (part of dorsal stream)
- Alternating blocks:
  - Had subjects look at the swirly motion thing (outward motion)
  - Look at stationary stimulus
- Same task was done outside the magnet to measure behavioral effects

Results of fMRI study:



Results of fMRI study:

- This pattern of activation was specific to MT
- For example, pattern of activation in V1 was not like this
- Percent signal change compared to looking at blank field

MRI: Subtraction Method

- Assumes that nothing is going on in control condition
- This may be incorrect sometimes
  - Looking at blank field - still a whole lot of thinking goin on.
  - E.g. Getting hippocampus activation might be tough because we are often using it even when we don't realize it
- Bottom line: subtraction method is OK, but we must be careful

MRI: Parametric studies

- Vary degree of activation in task and look at fMRI signal
- E.g. working memory task where you have to remember 2,4 or 6 digits
- Look at areas correlated with behavioral difficulty (I.e. areas that are twice as active in the 4 as in the 2, and 3 times as active in 6)
- These are great but sometimes it is difficult to parametrically vary the behavior

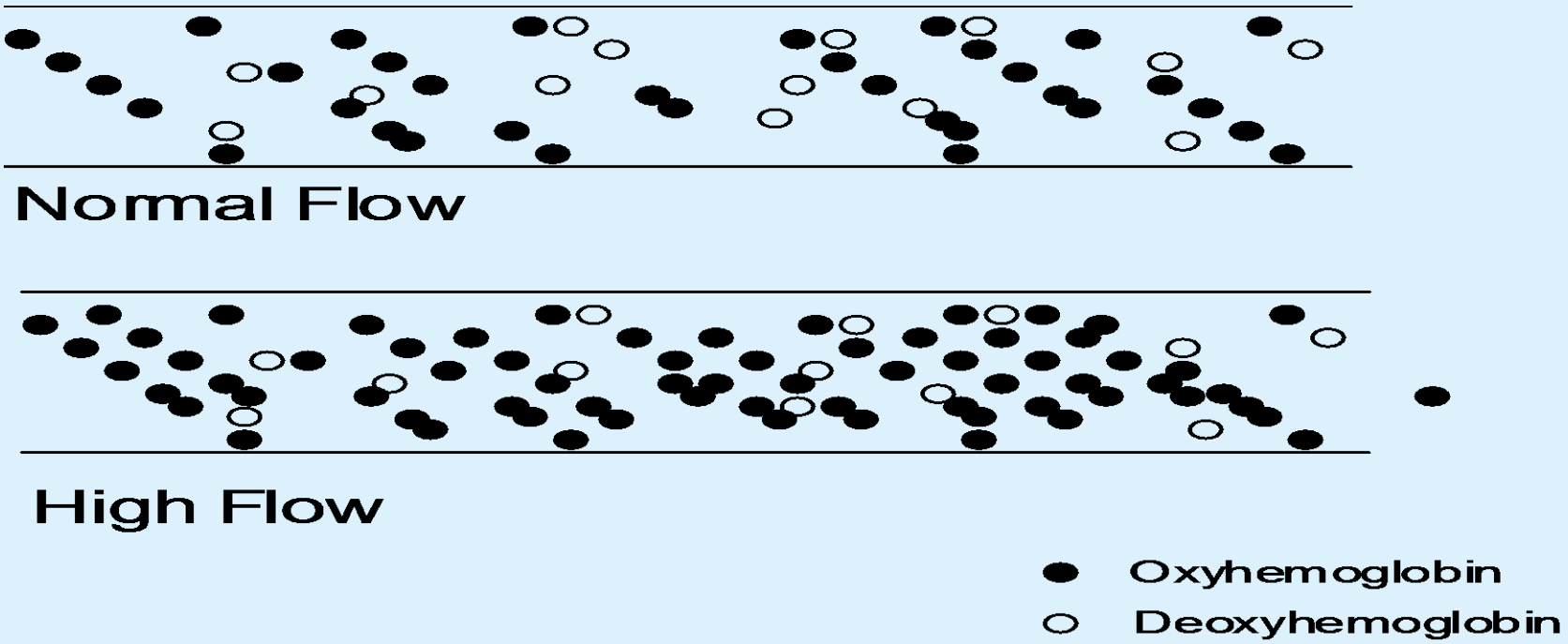
MRI: What's Measured

- MRI usually measures changes in blood flow
- More active parts of your brain get more blood for fuel
- Correspondence between blood flow and neural activity is OK, but not perfect
- Some analyses try to factor out some info based on our knowledge of the circulatory system

MRI: How Does it See Increase In Blood Flowing?

- When part of brain becomes more active, more blood flows
- Although blood flow increases a lot, oxygen uptake only increases marginally
- Net result is that the overall level of Oxygen becomes greater when flow increases

MRI Blood Flow: A picture



Getting Stuck on a Giant Refrigerator

- MRI machine magnetizes your whole head by placing you in a very powerful magnetic field
- Increased Oxygen has higher the magnetic signal (oxygen is more magnetic than other stuff)
- The magnetic signal of each part of the brain (voxel) is then measured
- The magnetic signals for each part of the brain become parts of a "picture" of the brain

MRI Strengths

- Great spatial resolution (a few millimeters)
- Non-obtrusive (no harmful effects)

MRI Weaknesses

- Temporal resolution is not great
  - Hemodynamic lag -- time between brain activation and blood flow increase about 2 seconds
- Very expensive
- Problems with indirect measure of blood flow
- Some behaviors can't be done inside a giant magnet

Positron Emission Tomography (PET)

- Uses radioactive isotopes (e.g. Oxygen-15) created by a cyclotron which emit a positron (that's a positive electron)
- When that positron hits an electron somewhere in the brain, it creates gamma rays that are measured by the detectors

PET strengths and weaknesses

- Strengths
  - Spatial resolution OK
  - Can radioactively "tag" other isotopes besides Oxygen (e.g. glucose)
- Weaknesses
  - Use of radioactive materials limits subject exposure
  - Need a cyclotron nearby to produce isotopes (they decay quickly)

Electroencephalogram (EEG)

- Attach electrodes to scalp (a few or as many as several hundred
- Measure electrical activity on scalp while a task is performed
- A single neuron does not generate enough activity for an EEG, but large assemblies of neurons firing together can
- Event-Related Potential is average of EEGs over hundreds of trials

EEG Strengths and Weaknesses

- Strengths
  - Great temporal resolution (on the order of milliseconds)
- Weaknesses
  - Crummy spatial resolution

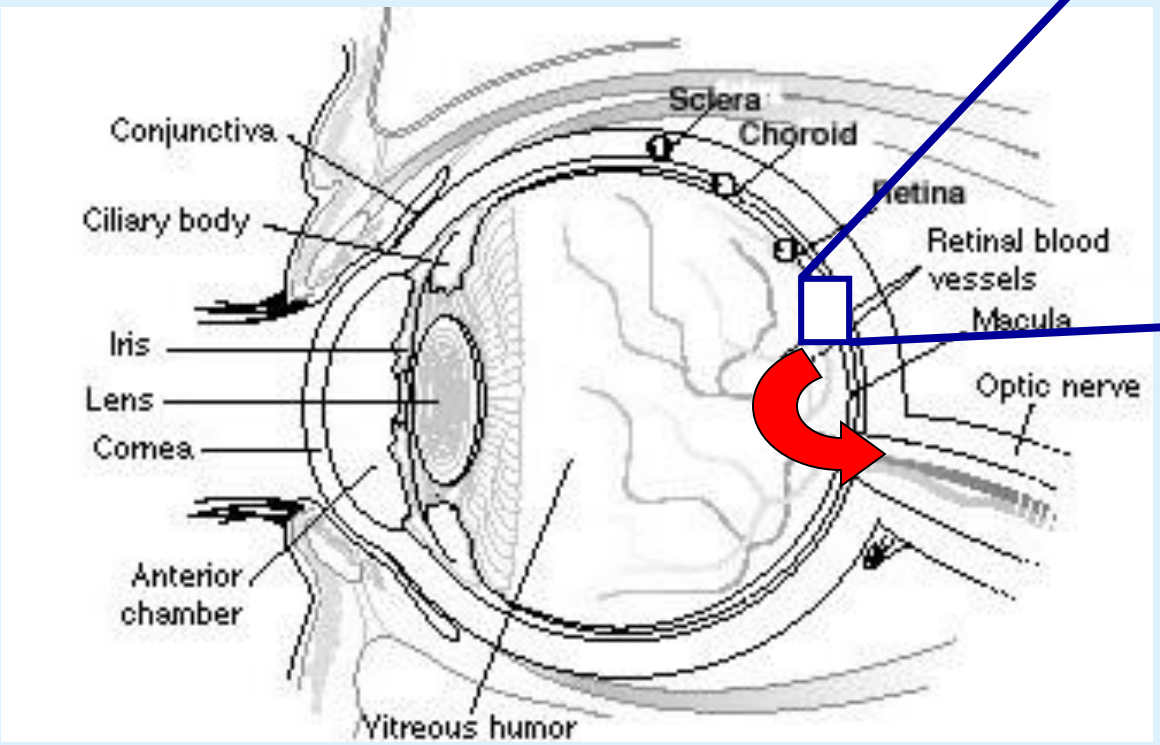
Problems with any imaging techniques

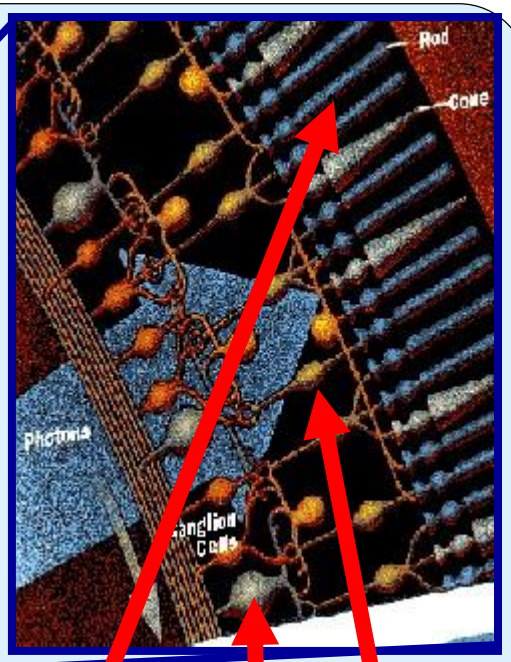
- See which areas are correlated with particular task
- But you don't know if these areas are necessary
- A silly analogy
  - Every day the sun rises and a rooster crows
  - Is the rooster necessary for a sunny day?

Brain Stimulation

- Electrode Stimulation
  - Activate a particular region
  - May overactivate neurons resulting in atypical behavior
- Transcranial Magnetic Stimulation
  - Strong magnetic field activates neurons under a coil
  - Over motor area causes body parts to move
  - Can be used repeatedly to treat depression
  - Inexact science
- Optogenetics
  - Opsins embedded in cell membranes make neurons light sensitive
  - Allows for very precise control of neurons in space and time
  - Fiver optics can deliver light to different parts of animals brains
  - Possible treatments for Parkinson's, autism and schizophrenia

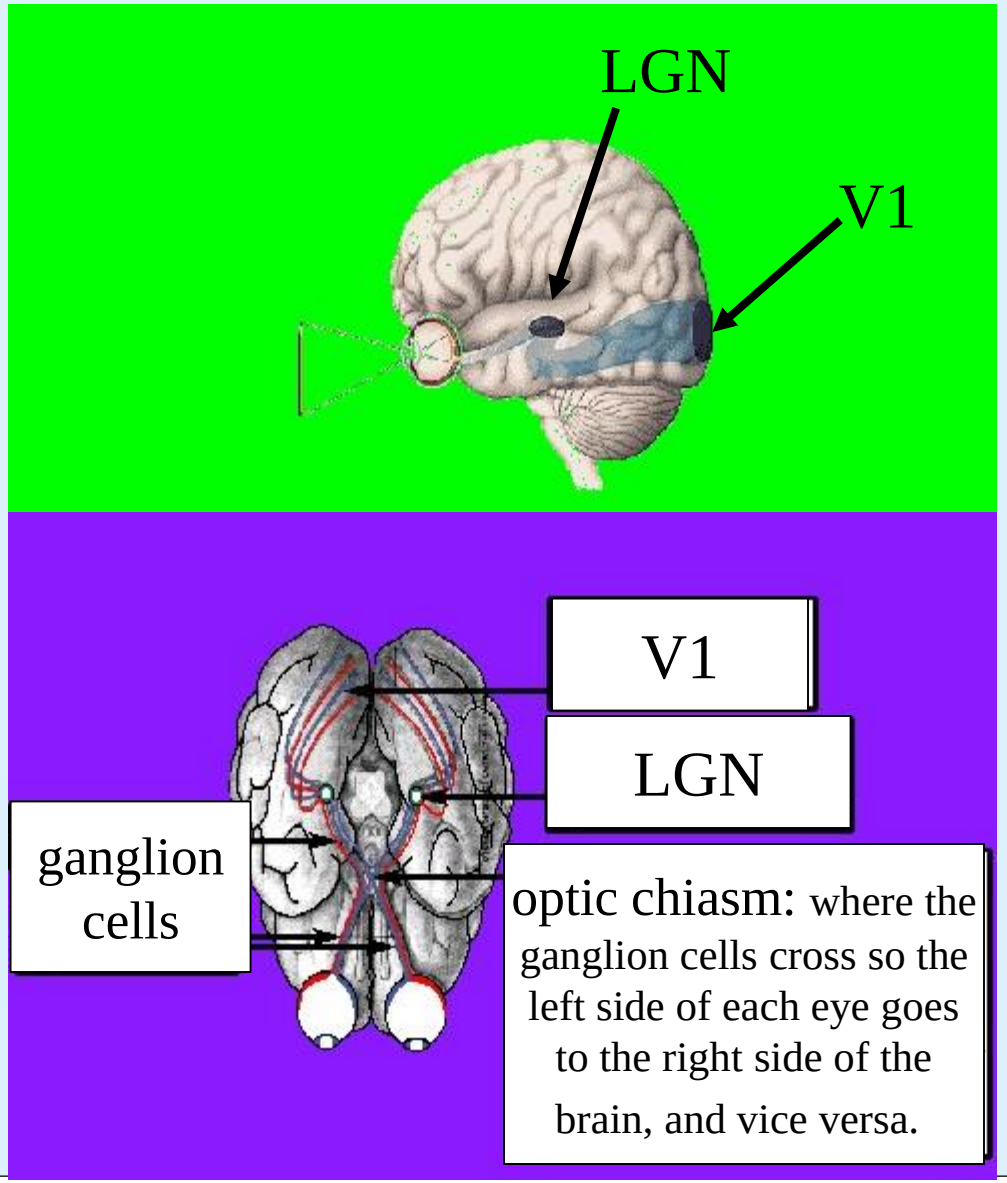
Vision



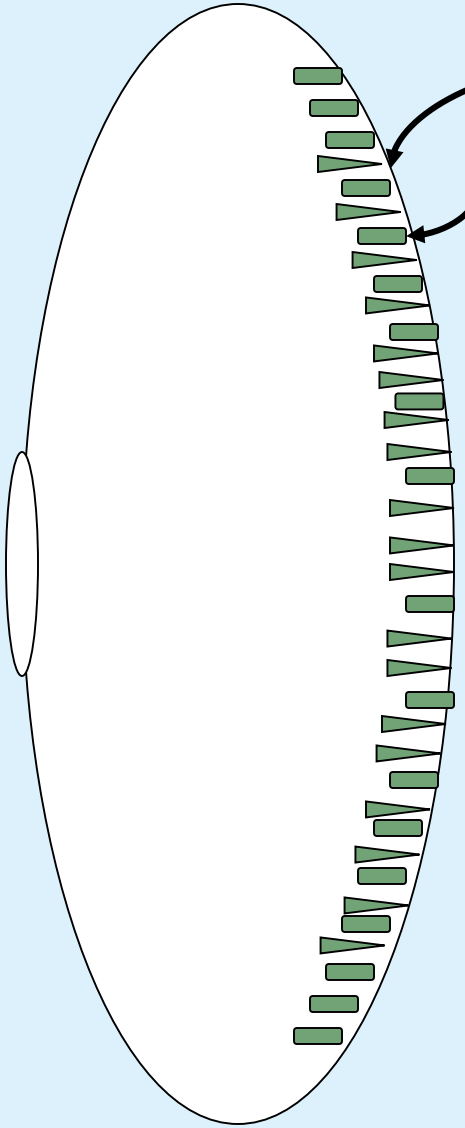


- **Photoreceptor cells**
  - Rod & Cone cells
- **Bipolar Cells**
  - Connect in between
- **Ganglion Cells**
  - Go to the brain

Vision


LGN
V1
V1
LGN
ganglion cells
optic chiasm: where the ganglion cells cross so the left side of each eye goes to the right side of the brain, and vice versa.

The Eye

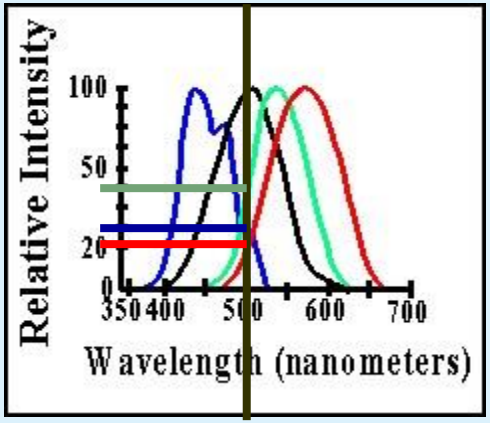


rod cells:

- periphery
- movement
- black and white

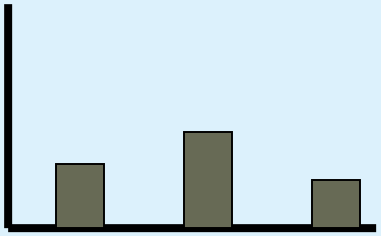
cone cells:

- fovea (center)
- detail
- color



(broad tuning)

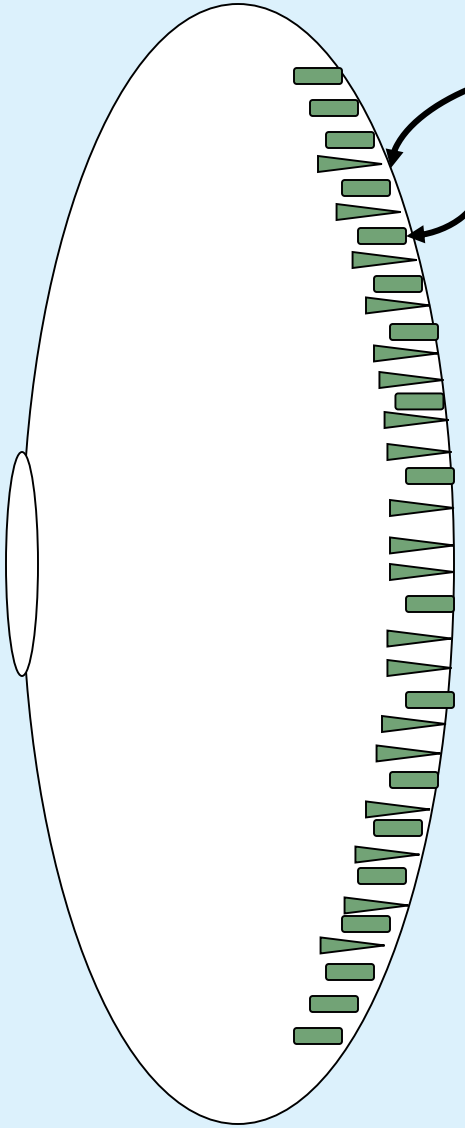
500 nm light



blue green red

cone firing

The Eye

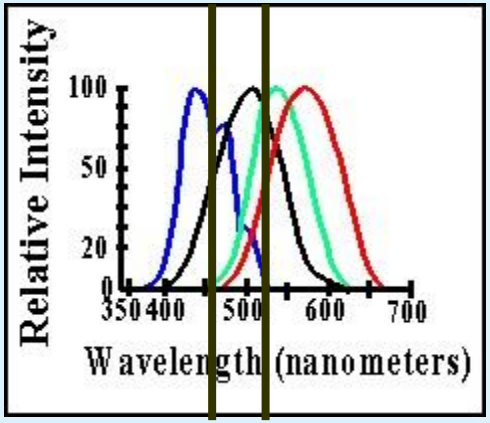


rod cells:

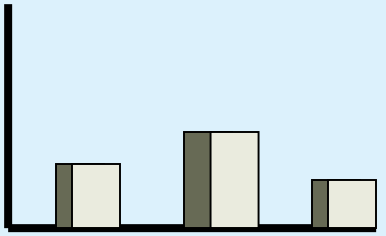
- periphery
- movement
- black and white

cone cells:

- fovea (center)
- detail
- color

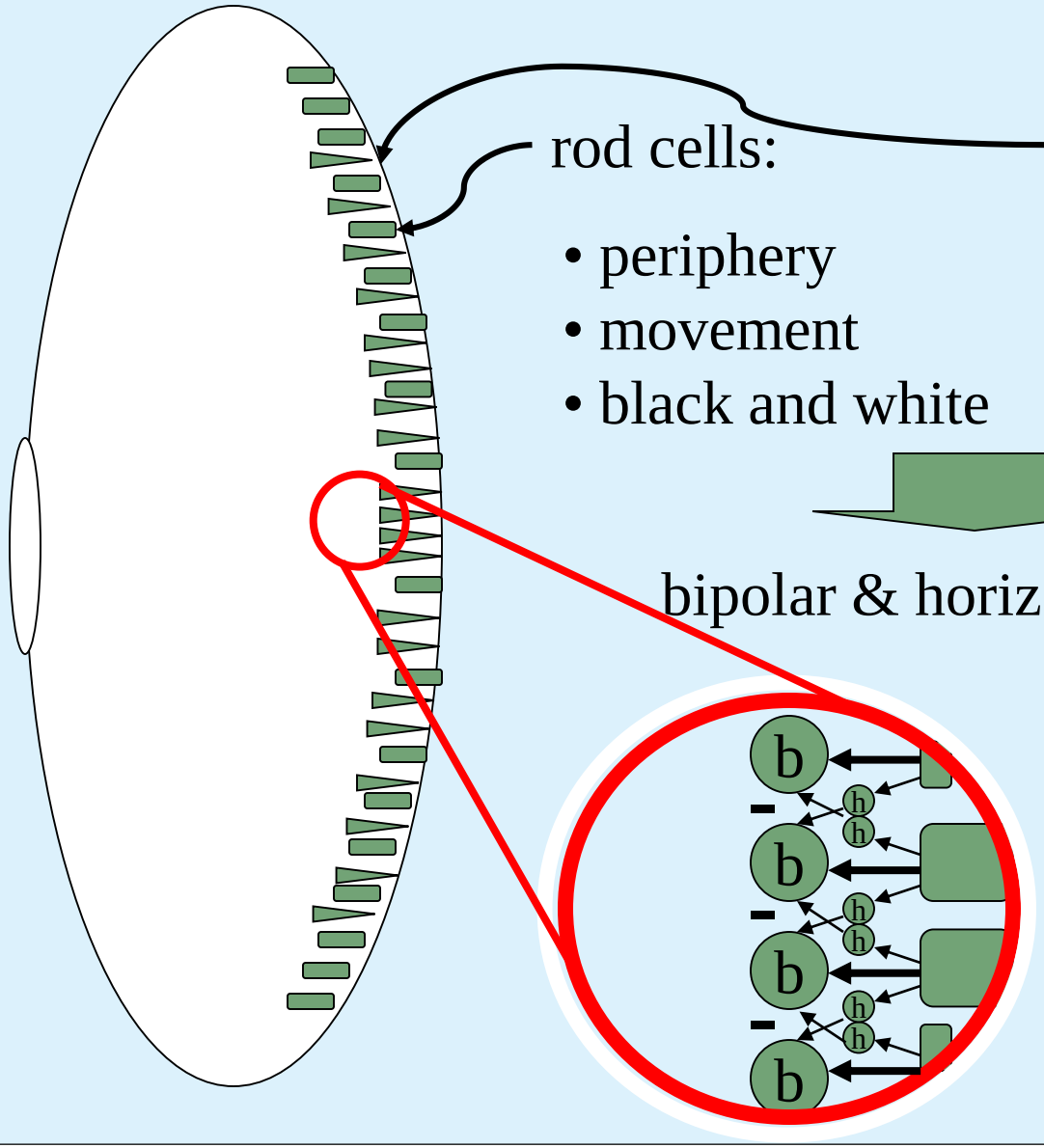


(broad tuning)



cone firing

The Eye



rod cells:

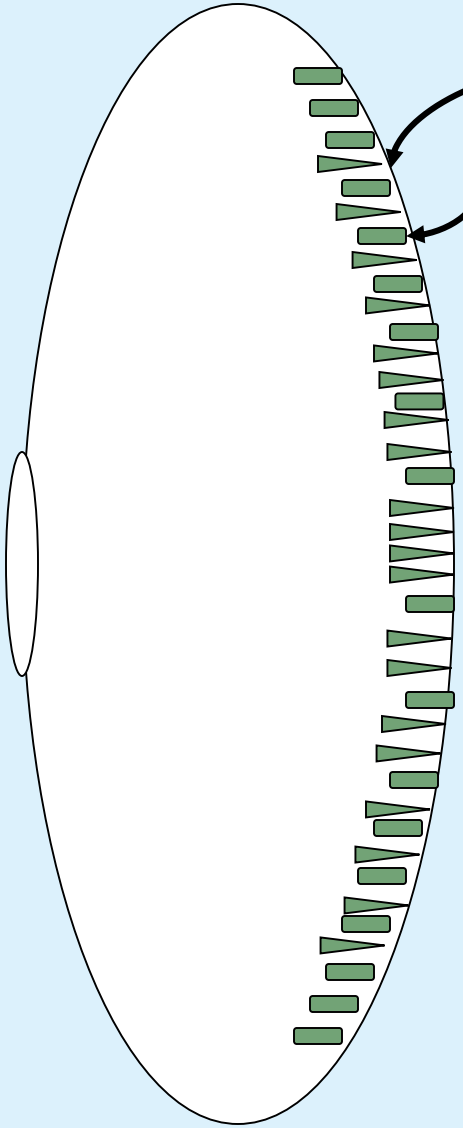
- periphery
- movement
- black and white

cone cells:

- fovea (center)
- detail
- color

bipolar & horizontal cells

The Eye



rod cells:

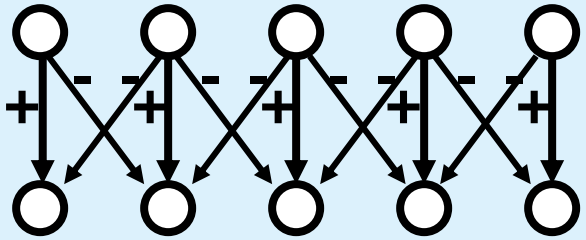
- periphery
- movement
- black and white

cone cells:

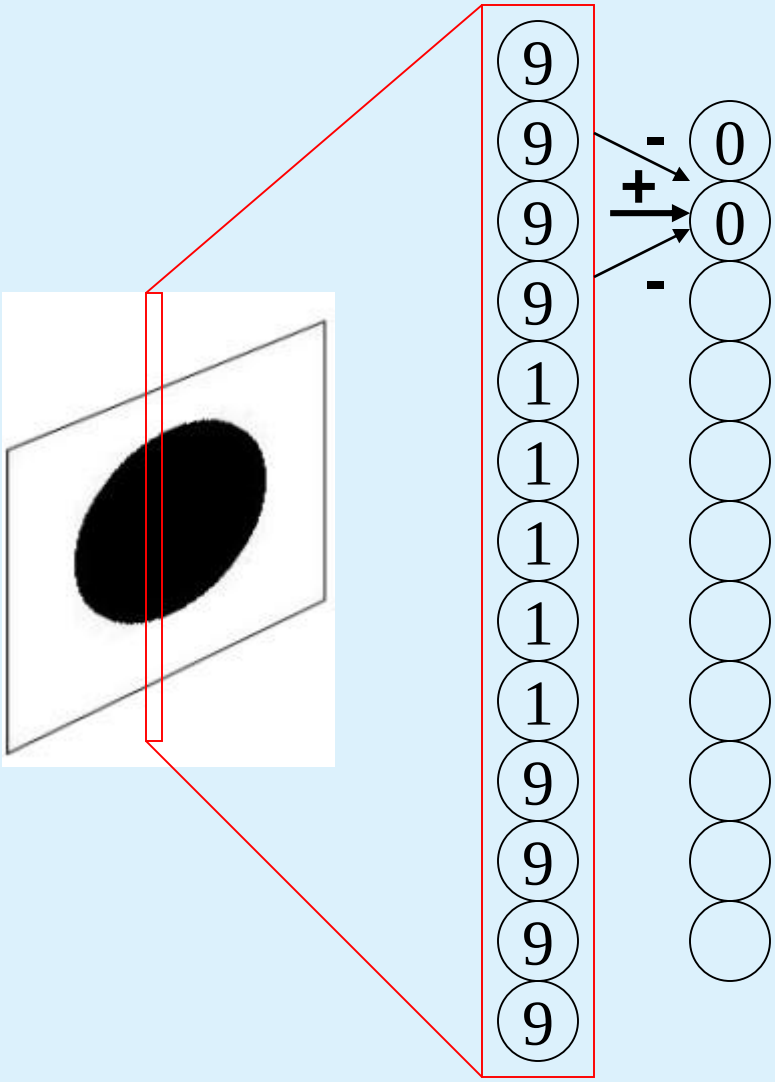
- fovea (center)
- detail
- color

bipolar & horizontal cells

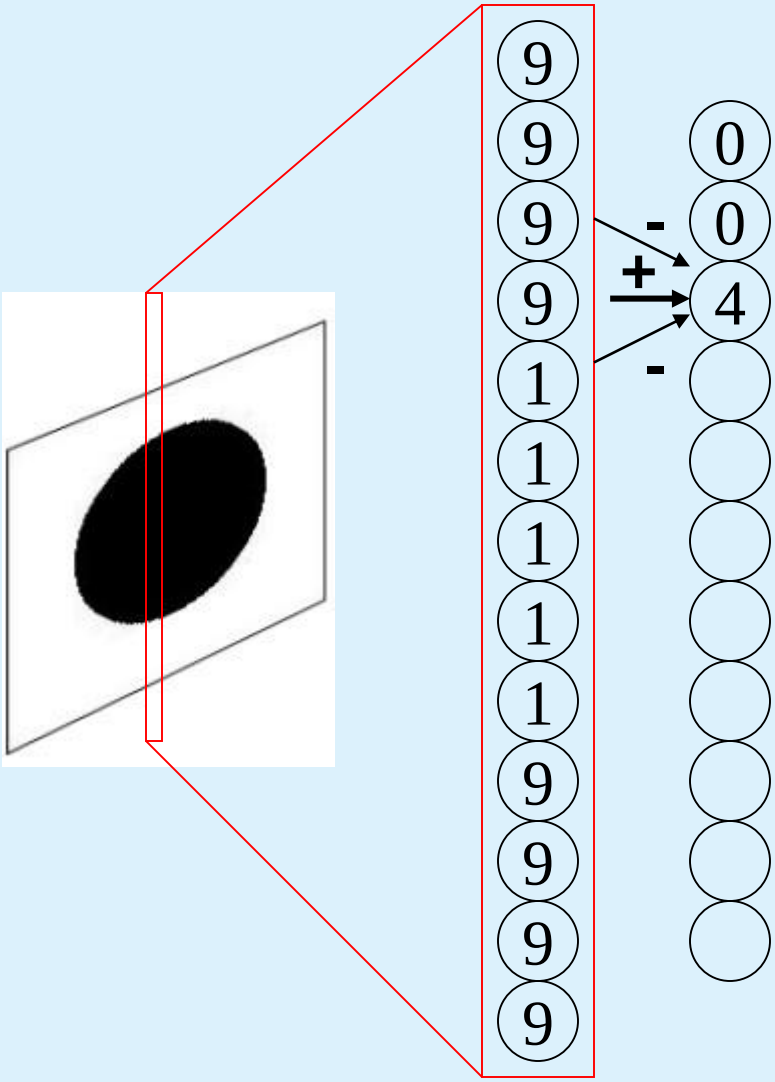
- lateral inhibition



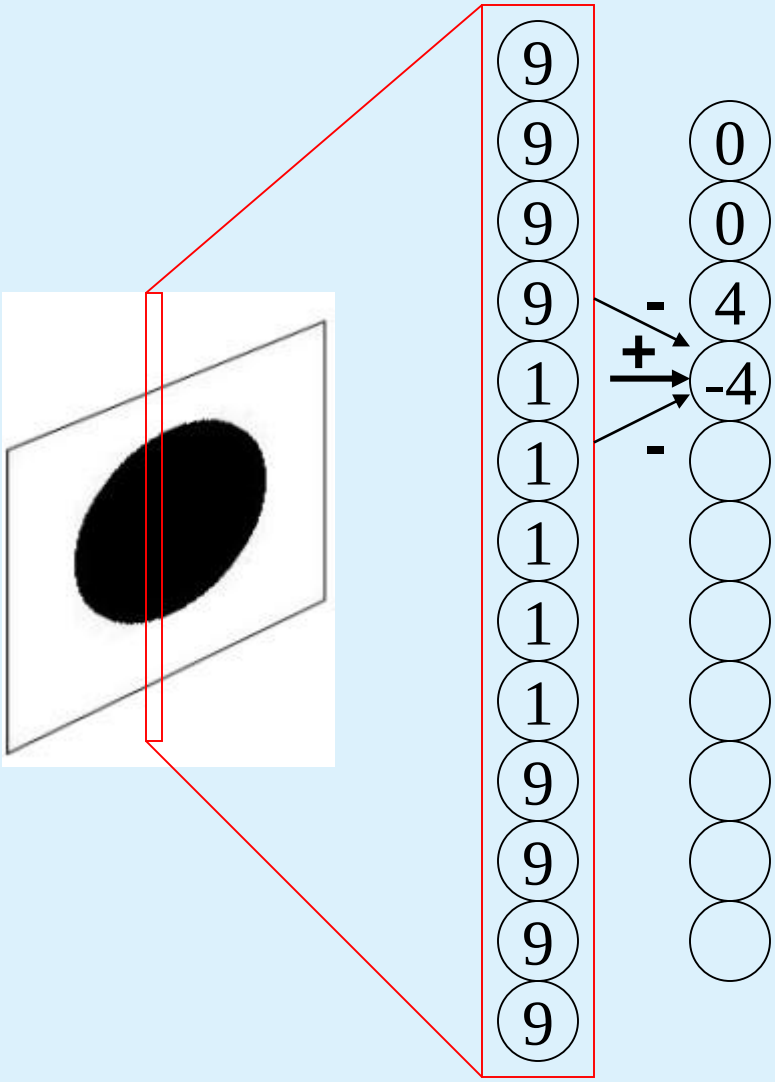
Lateral Inhibition



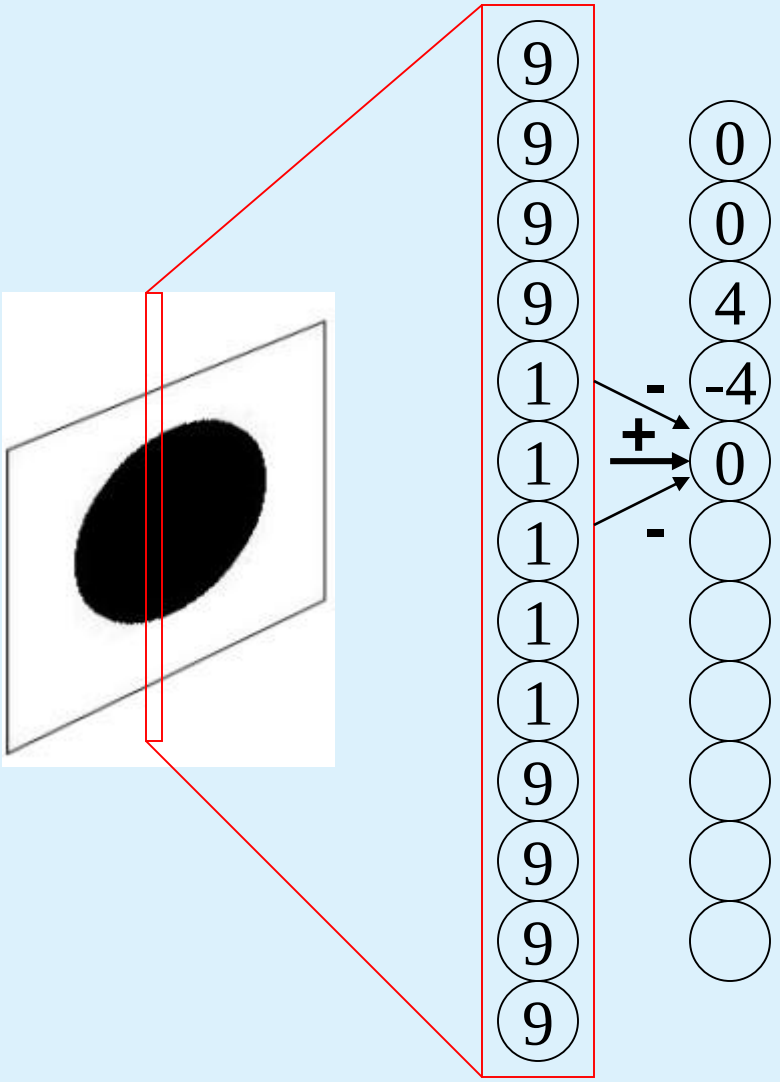
Lateral Inhibition



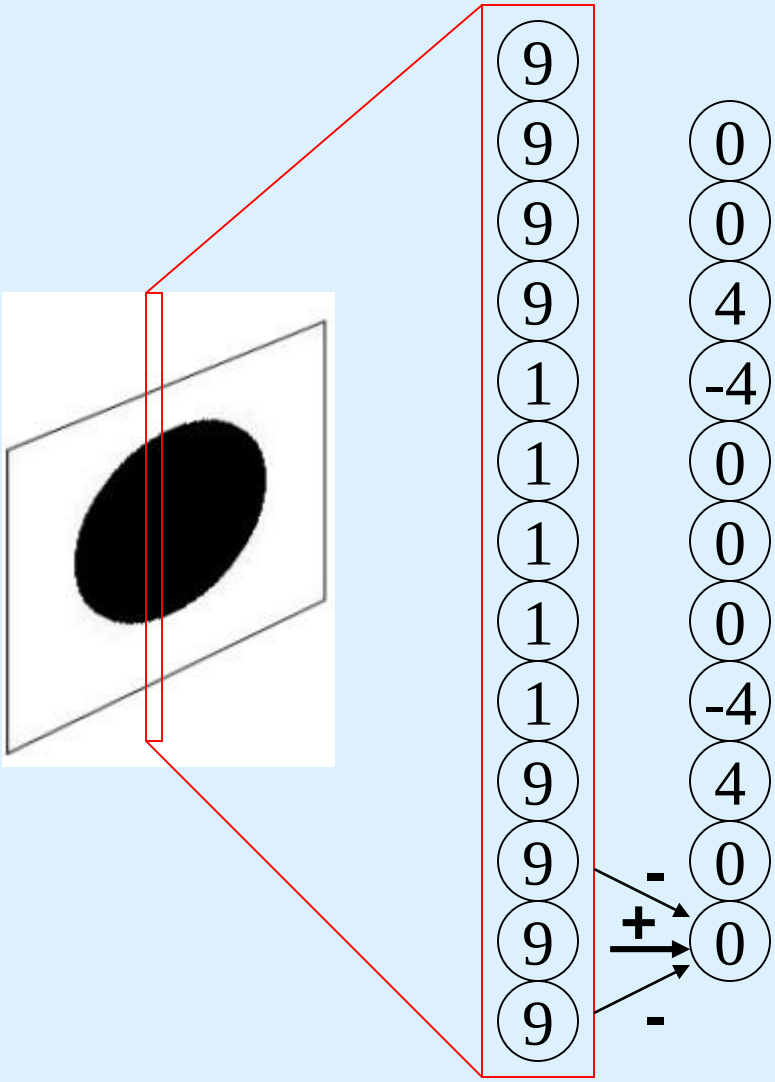
Lateral Inhibition



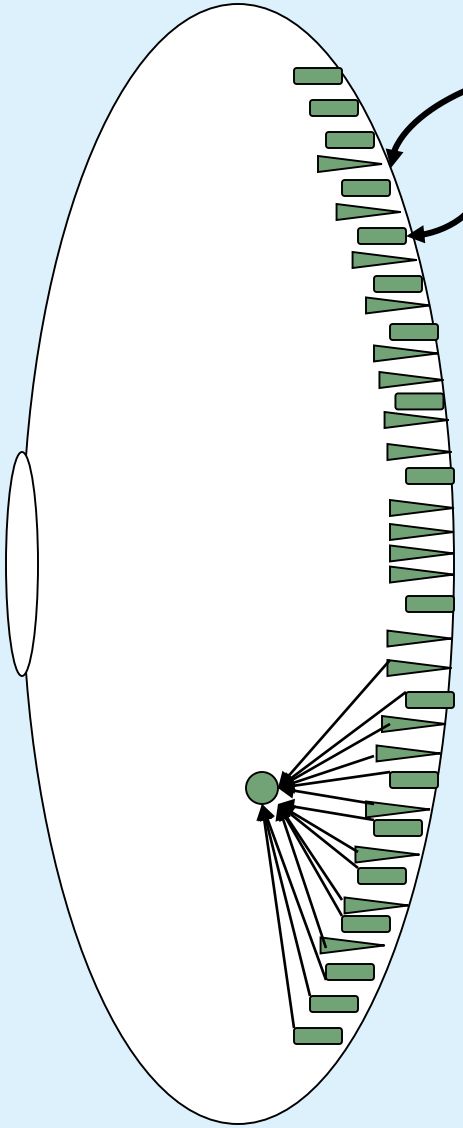
Lateral Inhibition



Lateral Inhibition



The Eye



rod cells:

- periphery
- movement
- black and white

cone cells:

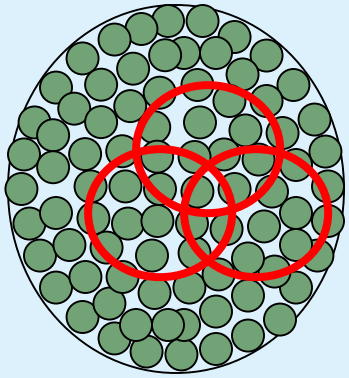
- fovea (center)
- detail
- color

bipolar & horizontal cells

- lateral inhibition
- edge detection

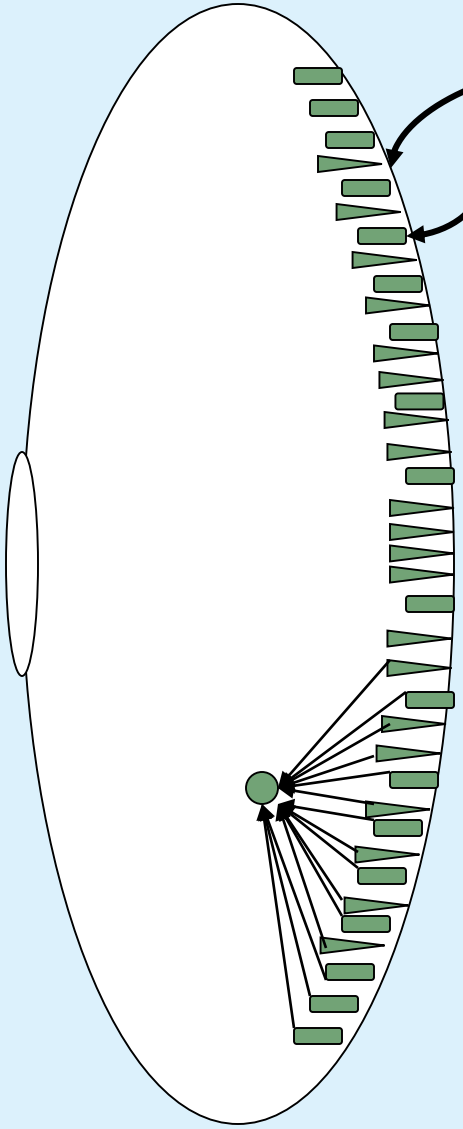
ganglion cells

front view



Bipolar cells

The Eye



rod cells:

- periphery
- movement
- black and white

cone cells:

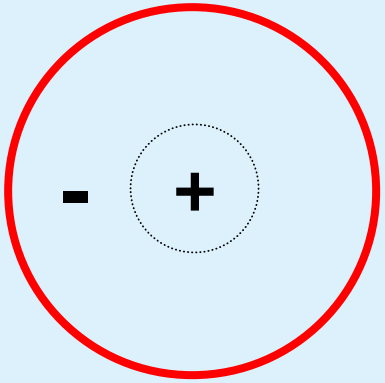
- fovea (center)
- detail
- color

bipolar & horizontal cells

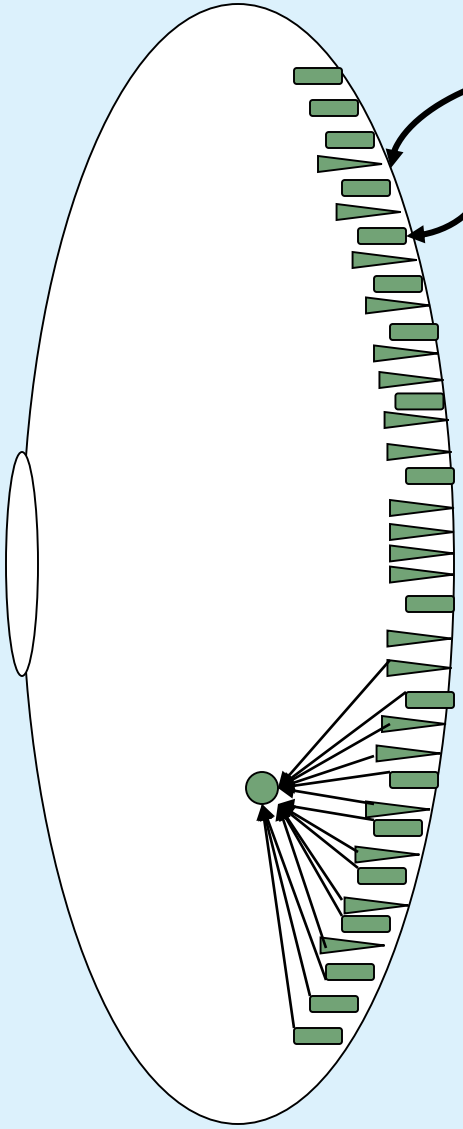
- lateral inhibition
- edge detection

ganglion cells

receptive field



The Eye



rod cells:

- periphery
- movement
- black and white

cone cells:

- fovea (center)
- detail
- color

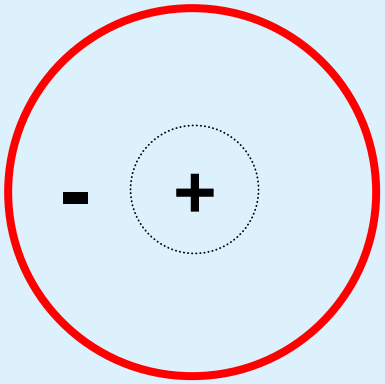
bipolar & horizontal cells

- lateral inhibition
- edge detection

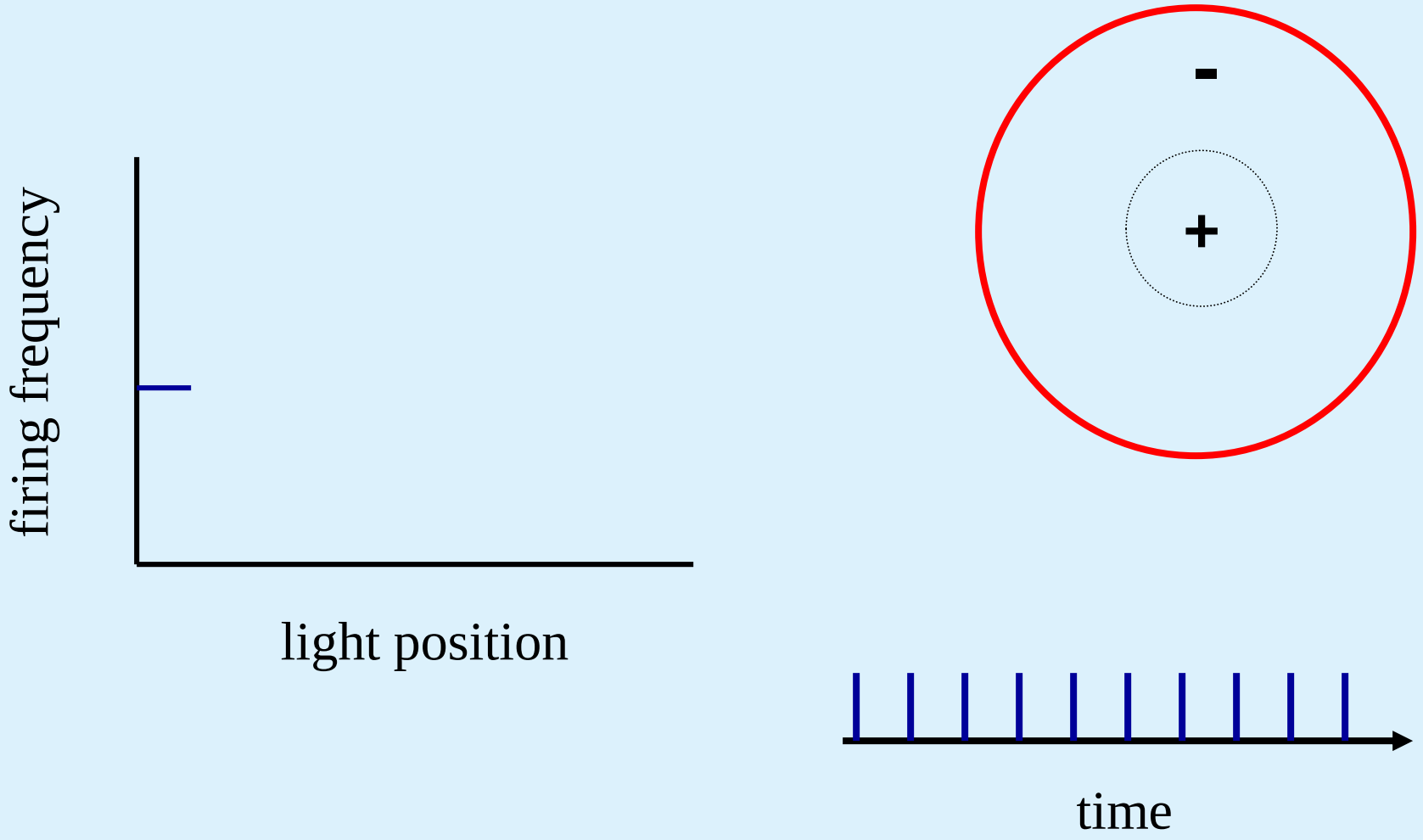
ganglion cells

- center/surround

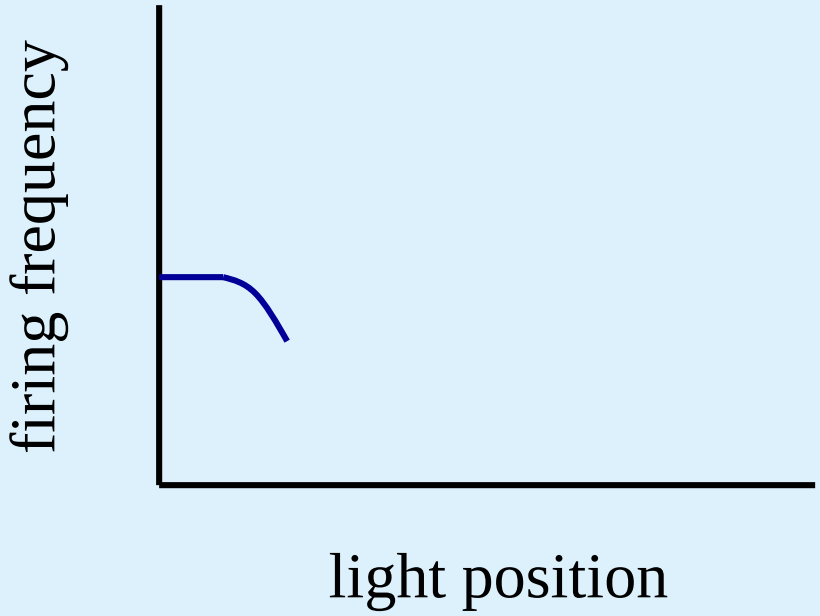
receptive field

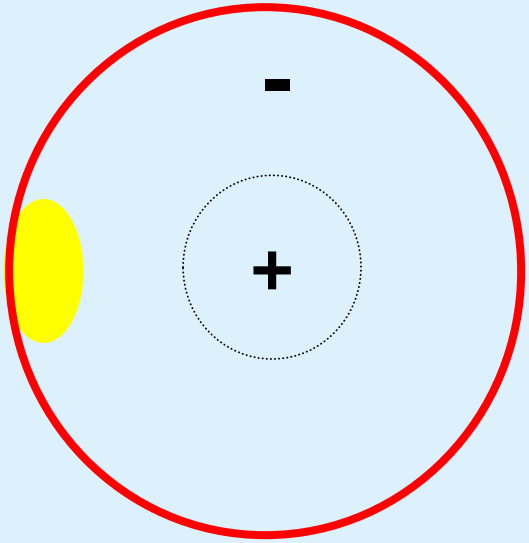


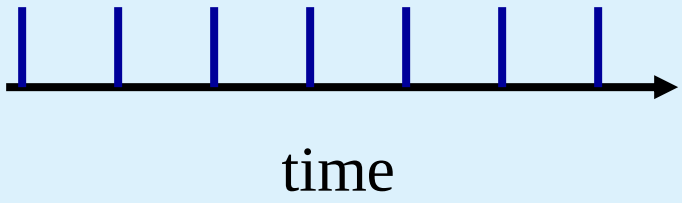
Center-Surround (Blob detector)



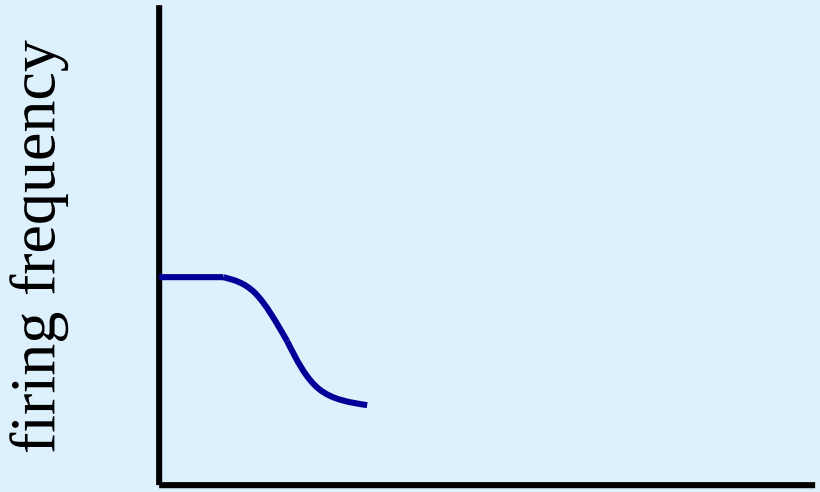
Center-Surround

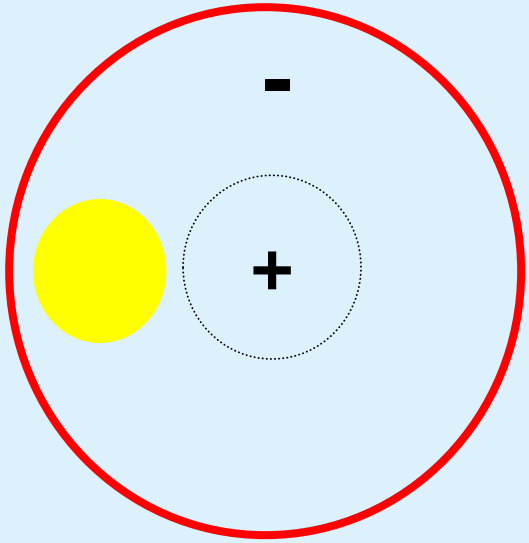


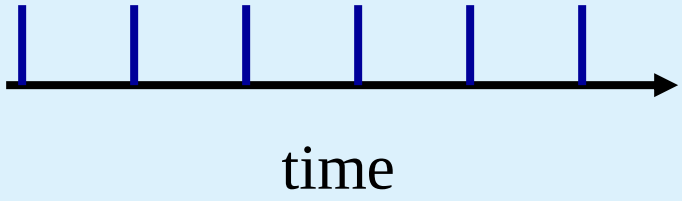




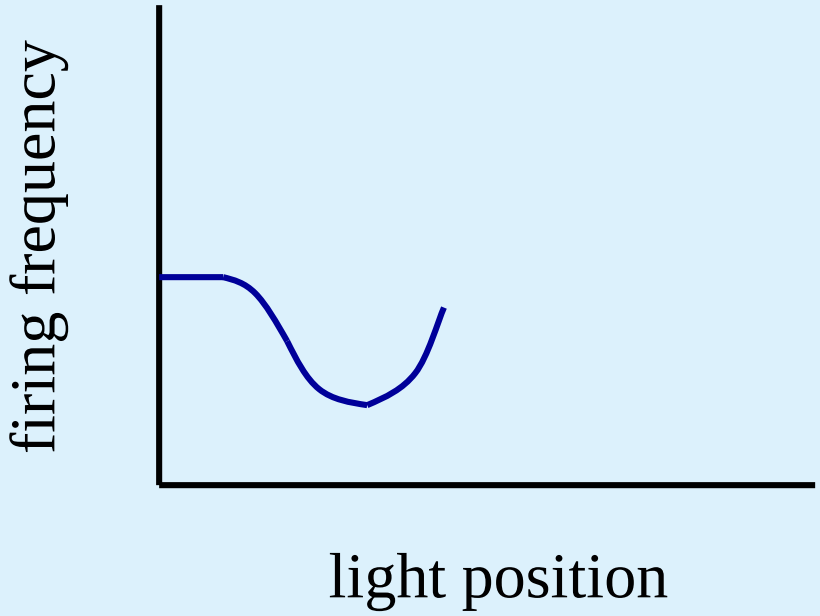
Center-Surround

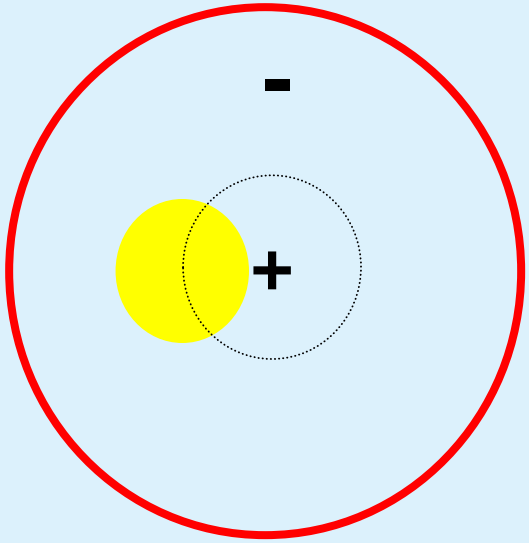


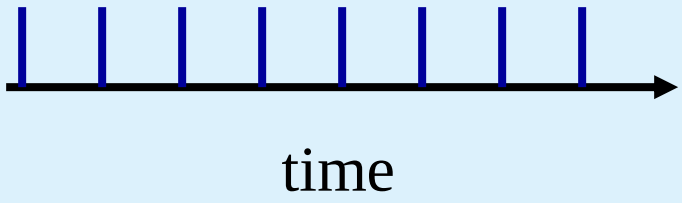




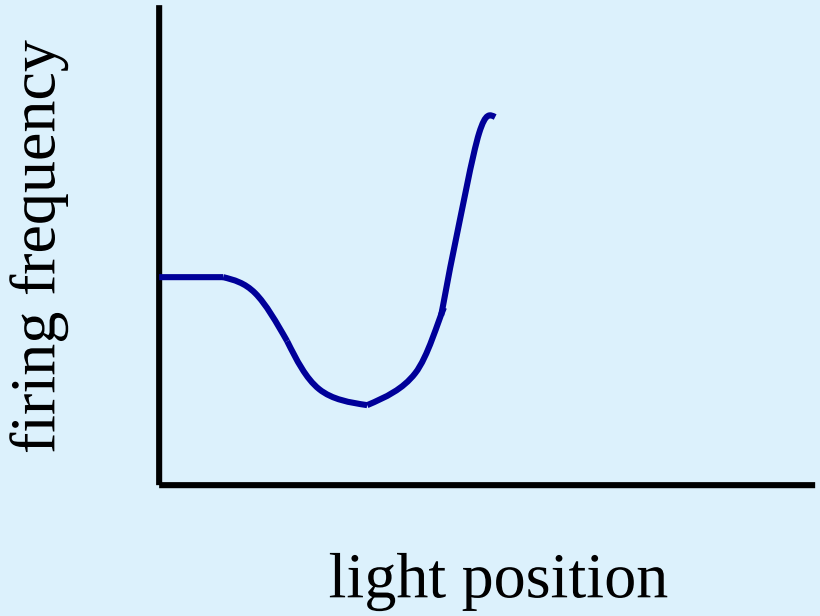
Center-Surround

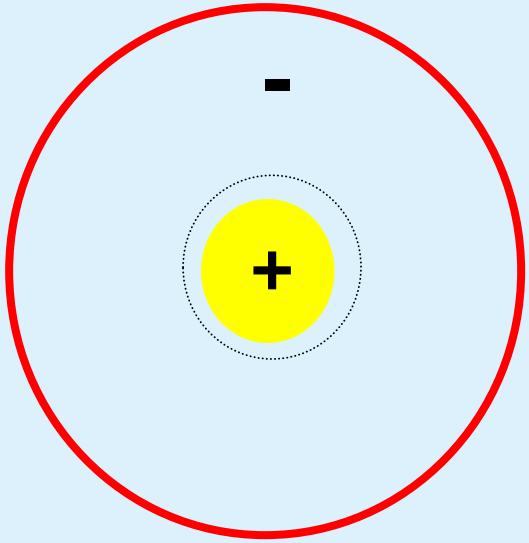


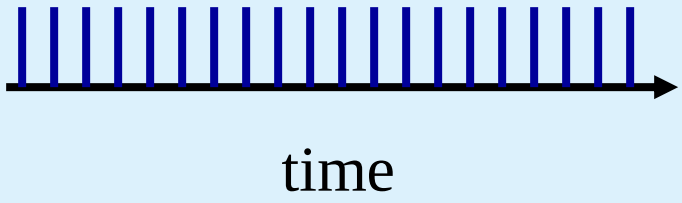




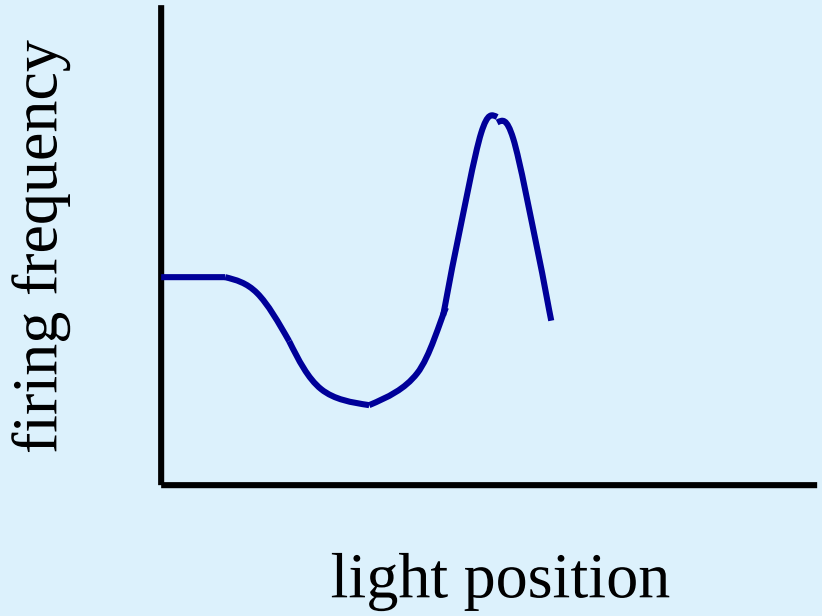
Center-Surround

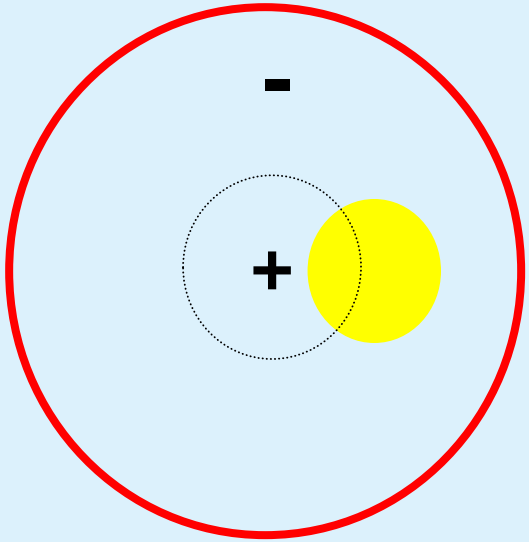


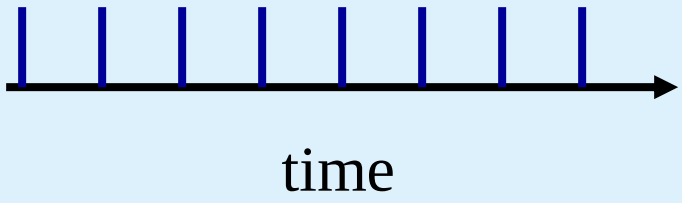




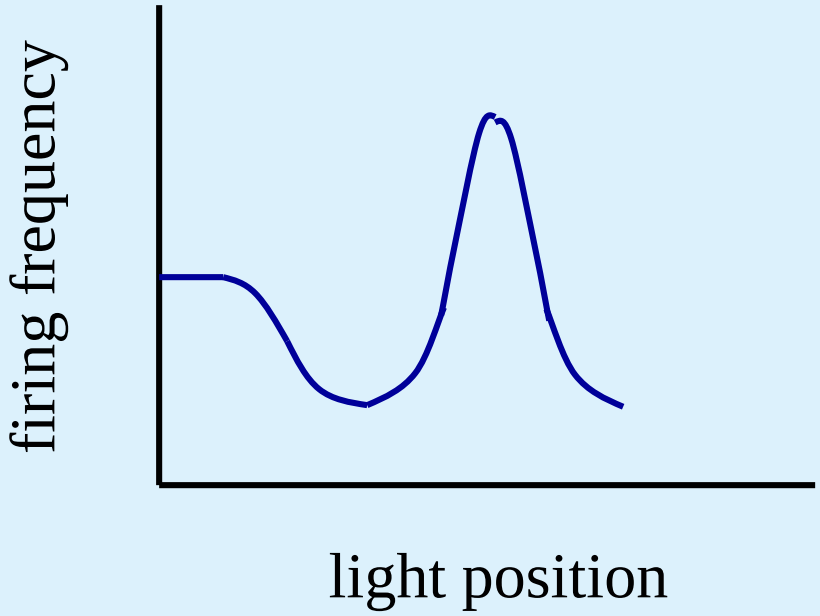
Center-Surround

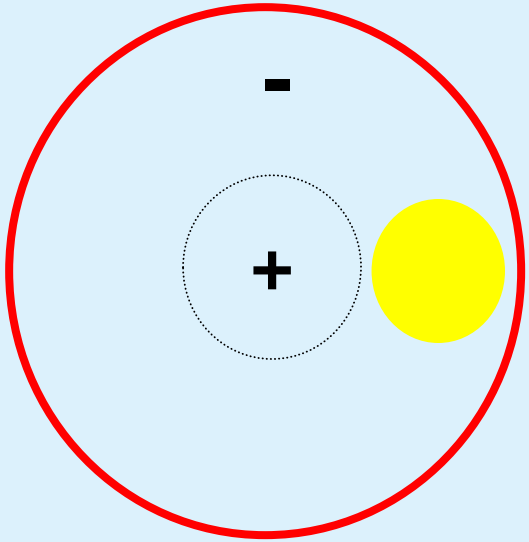


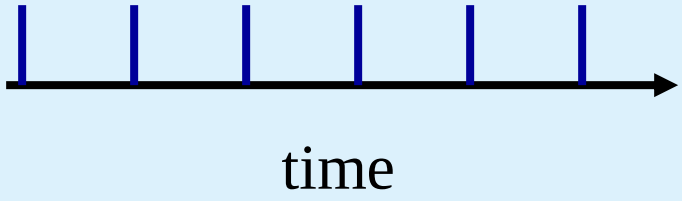




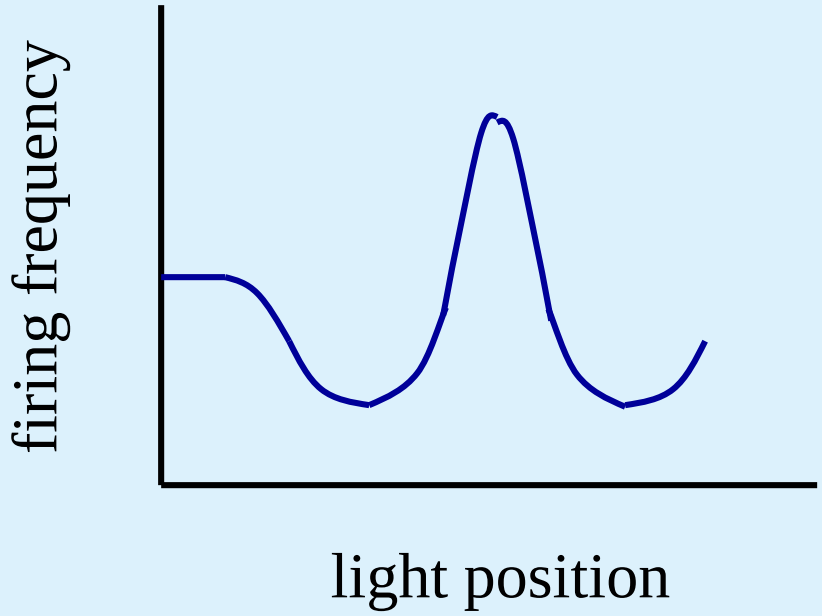
Center-Surround

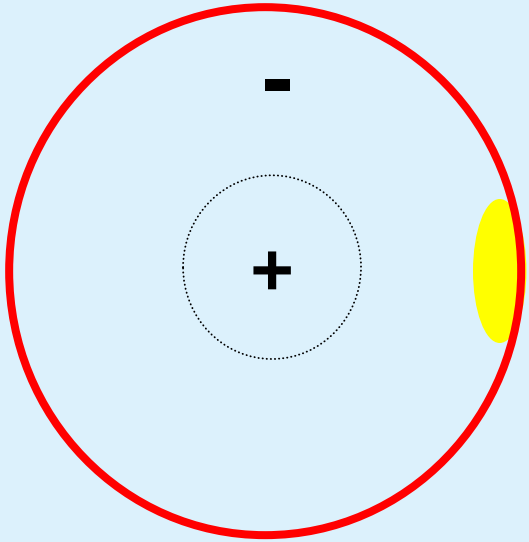


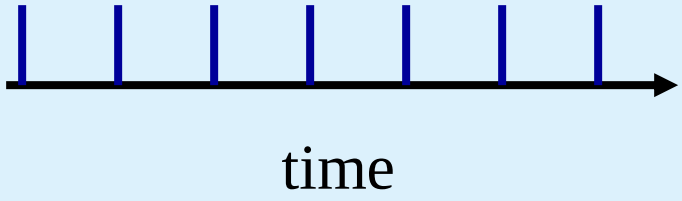




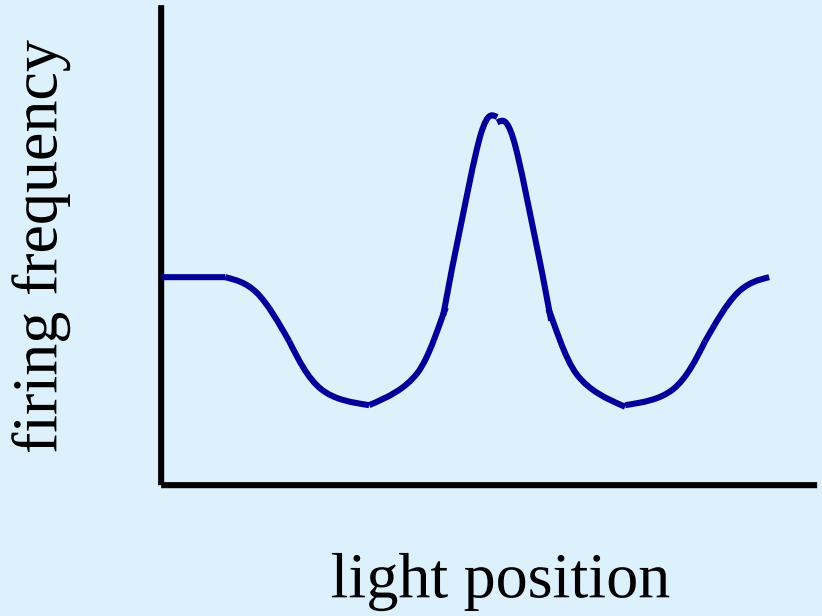
Center-Surround

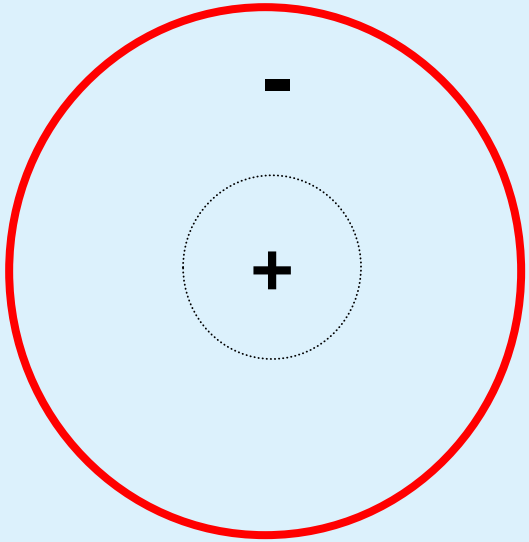


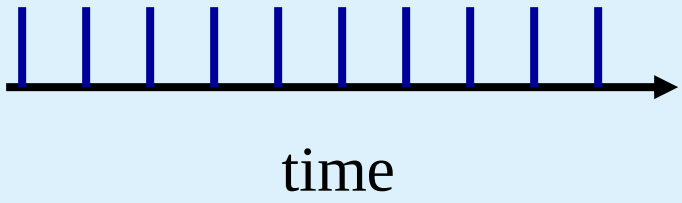




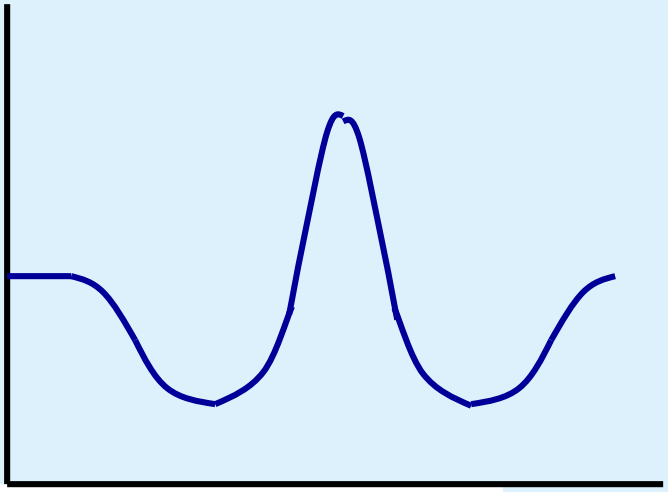
Center-Surround







Center-Surround How's it done?



Difference of Gaussians (Mexican hat)

light position