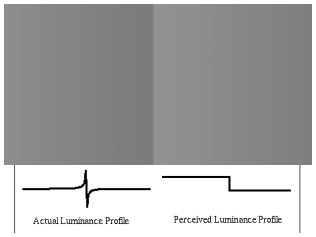
Announcements

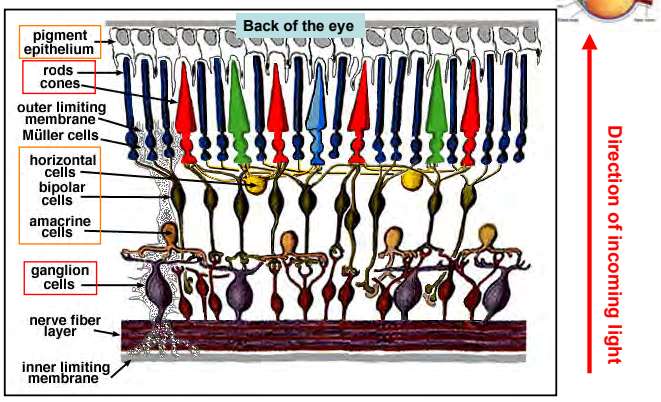
- Exam:
  - Multiple choice (about 22), short answer and short essay
    - don't list everything you know for the essay questions
  - Book vs. lectures
    - know **bold** terms for things that were not covered in class
    - if something was covered in class (in some detail), know all information in the textbook
    - skip: Cranial Nerves
    - skip: Light transduction details (Chromophore, rhodopsin, photoactivation, hyperpolarization, graded potentials)
  - Powerpoint files are on Blackboard only. PDFs are both on BB & on the class page



Early visual processing: retina & LGN

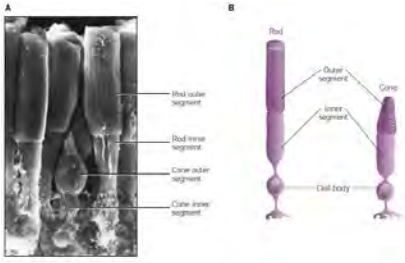
- Retina
  - **rods and cones**
  - **spatial layout**
- Receptive fields
  - **center-surround organization**
  - **perceptual consequences of center surround organization**
- Beginning of parallel pathways in vision
  - **M and P cells**

Retina



Pigment Epithelium: Black, Nourishes Receptors, Non reflective in humans, Absorbs stray light

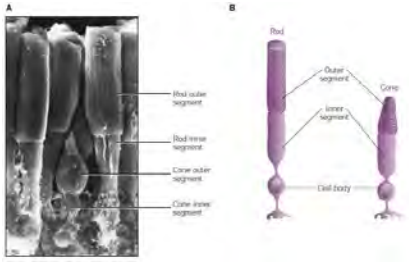
Visual Photoreptors: rods and cones



Light hits the outer segment of rods and cones which contain photosensitive chemicals (photopigments).

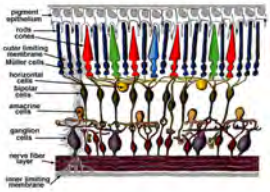
The light changes the molecular properties of the photopigments, which in turn changes the electrical state of these cells – this is called transduction.

Visual Photoreptors: rods and cones



- 5 million cones vs. 120 million rods
- Rods = precursors to motion perception & sensitivity
- Cones = precursors to color vision & resolution

Convergence



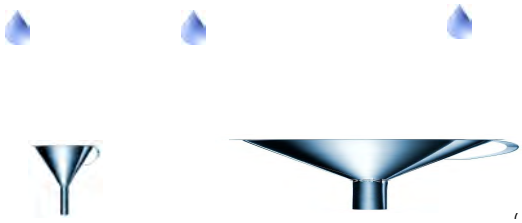
- There are:
  - 5 million cones and 120 million rods
  - Only 2 million ganglion cells
- Therefore, many receptors must send signals to each ganglion cell. This is called **convergence**.
- The **extent of convergence** on different parts of the retina determines a **tradeoff** between:
  - **sensitivity** to low light levels
  - **resolution** of fine spatial detail.

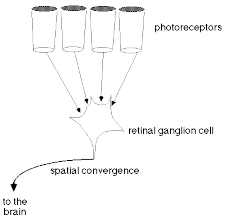
Perception…**involves competing demands**

sensitivity vs resolution

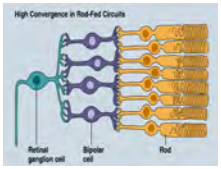
Sensitivity - being able to detect "faint" signals

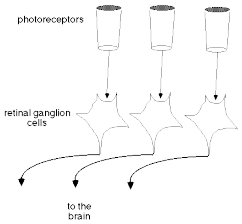
Resolution - being able to distinguish among multiple signals (e.g., their location)



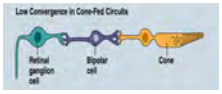


- Many-to-one convergence
- Found in: Visual periphery & Rods
- Promotes sensitivity

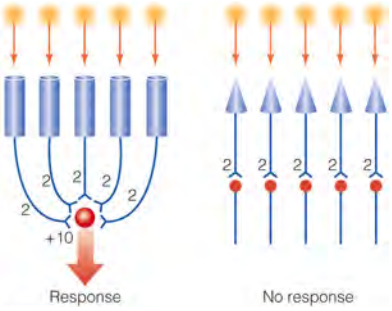




- One-to-one convergence
- Found in: Fovea & Cones
- Promotes spatial resolution



Rod vision is more sensitive to light than cone vision



- Greater convergence of rods than cones onto ganglion cells
- Thus, greater summation of rod signals
- Thus, less stimulation per rod is required.

…thus rods are specialized for low light vision…

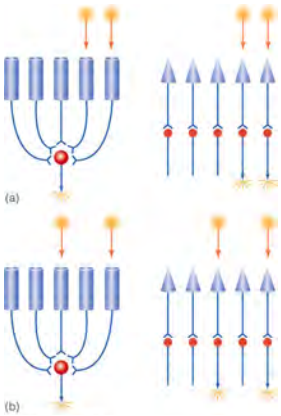
CONES

RODS

Luminance Values for Typical Visual Stimuli

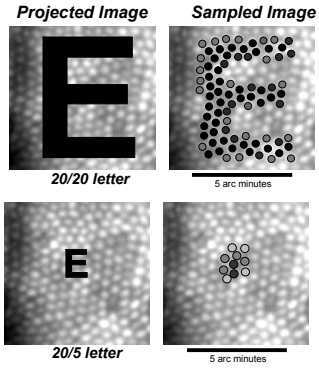
	Scale of Luminance (millilamberts)	
Sun's surface at noon	10^{10}	
	10^{9} Damaging	
	10^{8}	
	10^{7}	
Tungsten filament	10^{6}	
	10^{5}	
White paper in sunlight	10^{4}	Photopic (color vision)
	10^{3}	
	10^{2}	
Comfortable reading	10	
	1	
	10^{-1}	
White paper in moonlight	10^{-2}	
	10^{-3}	Scotopic (colorless vision)
White paper in starlight	10^{-4}	
	10^{-5}	
Absolute threshold	10^{-6}	

Cone vision can see finer details than rod vision



Greater convergence of rods than cones onto ganglion cells limits rod spatial resolution.

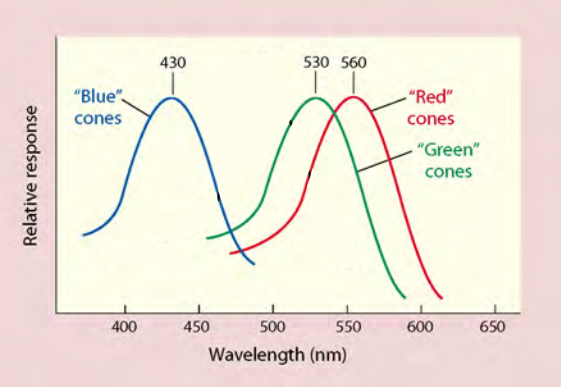
…and cones are specialized for high resolution vision



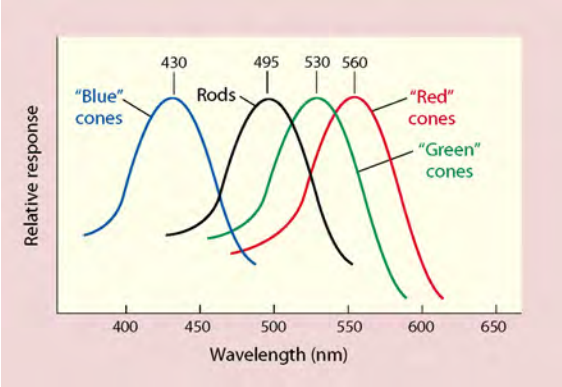
Cones and color vision

- Humans have 3 different cone types, each with a different photopigment.
- Photopigments are maximally sensitive to specific wavelengths.
  - Short wavelength sensitive
  - Mid-wavelength sensitive
  - Long wavelength sensitive

Cones and color vision

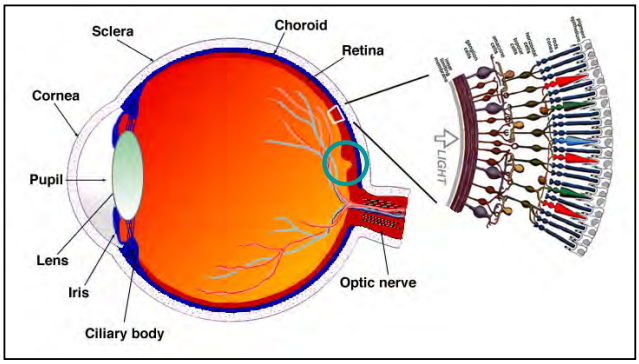


Cones and color vision



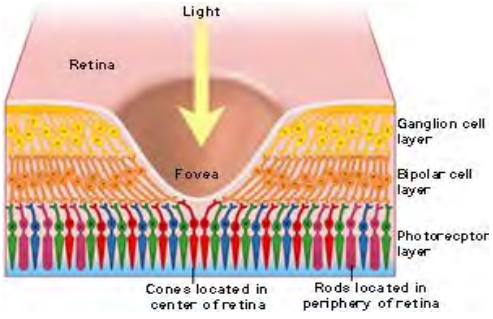
Early visual processing: retina & LGN

- Retina
  - **rods and cones**
  - **spatial layout**
- Receptive fields
  - **center-surround organization**
  - **perceptual consequences of center surround organization**
- Beginning of parallel pathways in vision
  - **M and P cells**

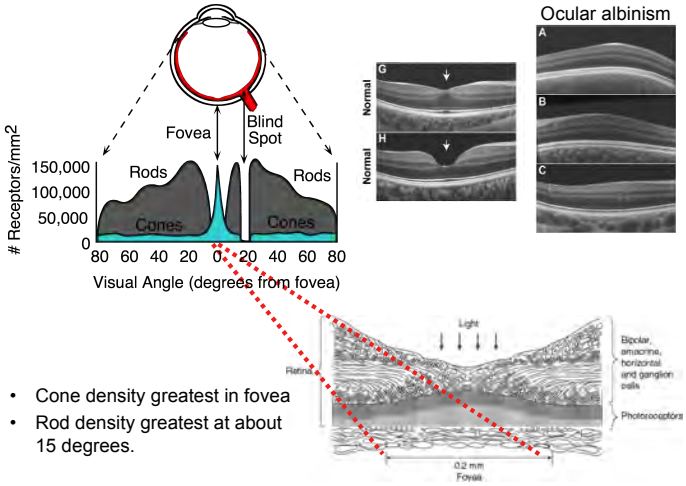


Pupil The opening through which light enters the eye
Iris The colored aperture that controls the amount of light entering the eye
Cornea Accounts for 2/3 of eye's refraction (light-focusing)
Lens Adjustable light refraction on the retina.
Retina The lining of the back of the eye containing photoreceptors and neurons.
Optic nerve Connects retina to the brain
Fovea a 1mm "pit" in the retina responsible for high resolution vision

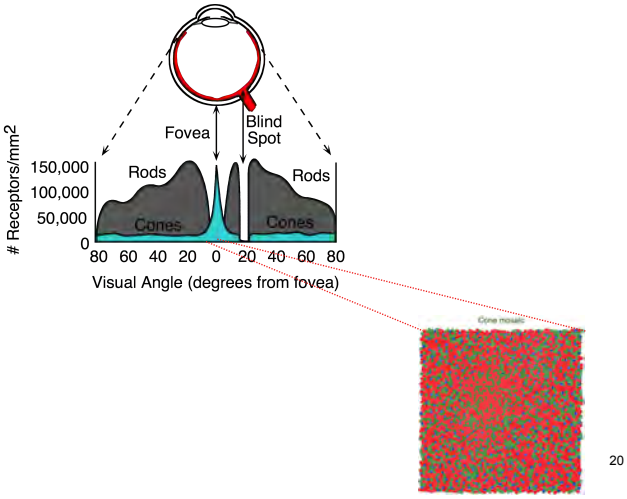
Fovea



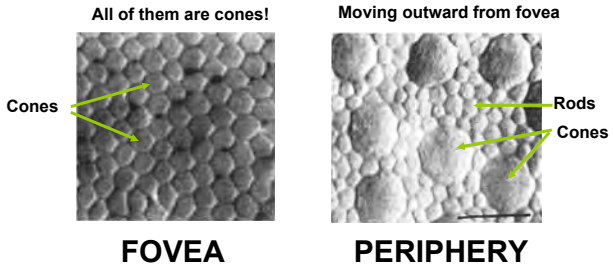
- 1 mm pit at the center of the retina, high acuity
- Reduced light distortion
- It cortical representation is magnified



- Cone density greatest in fovea
- Rod density greatest at about 15 degrees.

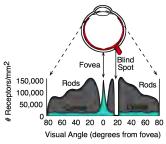


rods and cones



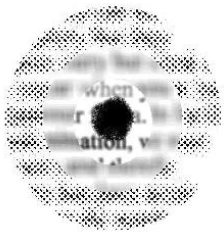
What retina sees……

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

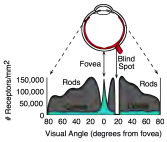


Day: cone vision

Night: rod vision



Blind spot



+

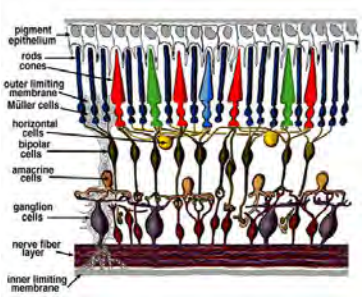
☺

+ ——————— —

Early visual processing: retina & LGN

- Retina
  - **rods and cones**
  - **spatial layout**
- Receptive fields
  - **center-surround organization**
  - **perceptual consequences of center surround organization**
- Beginning of parallel pathways in vision
  - **M and P cells**

The Retina



•Rods and cones connect with horizontal and bipolar cells (collector cells).

•**Lateral interaction** takes place at horizontal cells.

•Amacrine cells connect adjacent bipolar cells (lateral interactions again).

•Bipolar cells are connected to retinal **ganglion cells**.

Retinal Ganglion Cells

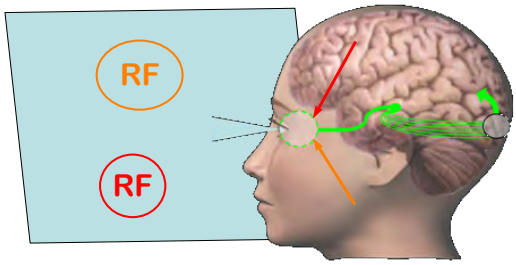
•Retinal ganglion cells possess **receptive fields** that are responsive to light stimulation.

•**Receptive field**

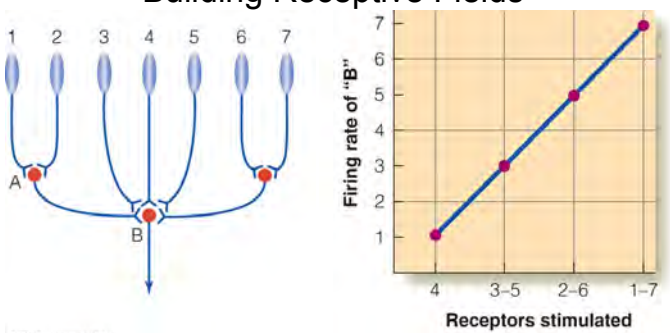
–STRICT definition: that area of the **retina** over which a ganglion cell is sensitive to light stimulation. I.e., an area of the **retina** that the cell monitors.

–PRACTICAL definition: that area of the **world** over which a ganglion cell is sensitive to light stimulation. I.e., an area of the **world** that the cell monitors.

Receptive field

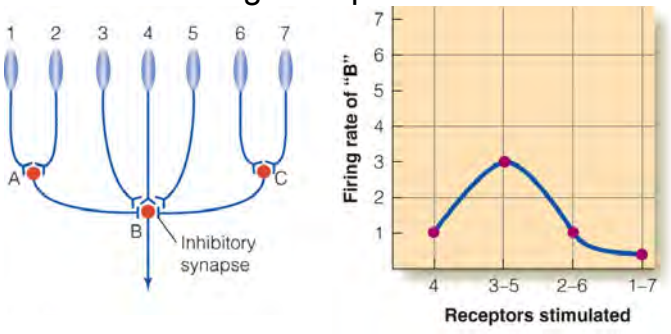


Photoreceptors to Ganglion Cells: Building Receptive Fields



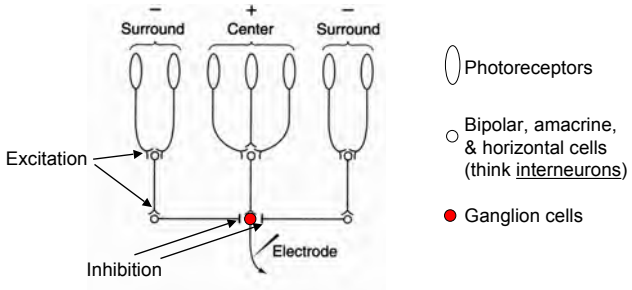
Neural circuit with convergence. Neuron B now receives inputs form all of the receptors, so increasing the size of the stimulus increases the size of neuron B's response.

Photoreceptors to Ganglion Cells: Building Receptive Fields



Neural circuit with convergence and inhibition. Because stimulation of the receptors on the side (1, 2, 6, and 7) sends inhibition to neuron B, neuron B responds best when just the center (3 - 5) are stimulated.

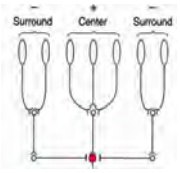
Photoreceptors to Ganglion Cells: Building Receptive Fields



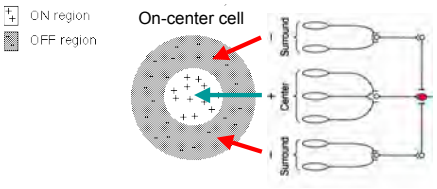
The response properties of retinal ganglion cells can be explained by the neural circuit depicted above. Commonly called **lateral inhibition**

Note that the neuron being recorded receives excitatory inputs from one group of receptors and inhibitory inputs from receptors in surrounding regions

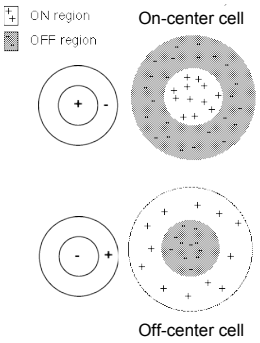
Photoreceptors to Ganglion Cells: Building Receptive Fields



Photoreceptors to Ganglion Cells: Building Receptive Fields

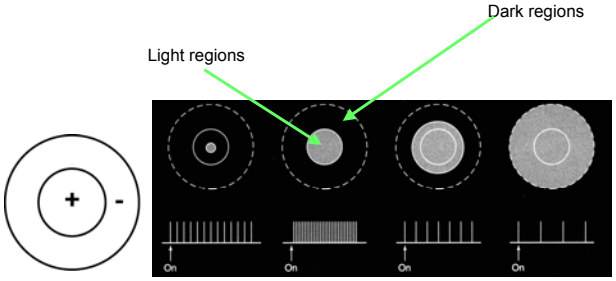


Photoreceptors to Ganglion Cells: Building Receptive Fields



- On-center (off-surround) cell:
  - Light stimulation of the ***center*** of the receptive field produces an **increase** in the firing rate of the ganglion cell.
  - Stimulation of the ***surround*** produces **decrease** in the firing rate of the cell
- Off-center (on-surround) cell = OPPOSITE

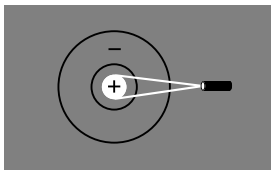
Photoreceptors to Ganglion Cells: Building Receptive Fields



For an **on-centered** ganglion cell, the response rate is greatest when the stimulus just fills the excitatory central region. When the stimulus covers the entire receptive field, the cell will fire at its background rate.

Photoreceptors to Ganglion Cells: Building Receptive Fields

On-center Off-surround

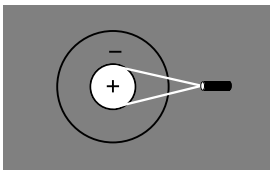


Stimulus condition

Electrical response

Photoreceptors to Ganglion Cells: Building Receptive Fields

On-center Off-surround

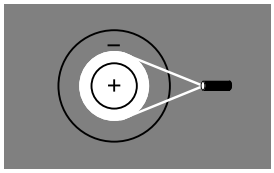


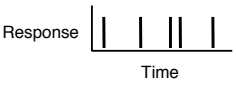
Stimulus condition

Electrical response

Photoreceptors to Ganglion Cells: Building Receptive Fields

On-center Off-surround



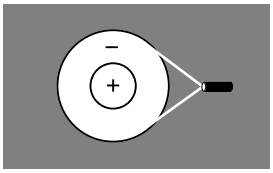


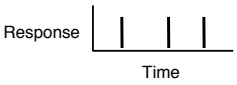
Stimulus condition

Electrical response

Photoreceptors to Ganglion Cells: Building Receptive Fields

On-center Off-surround



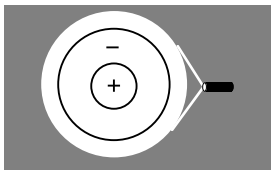


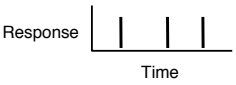
Stimulus condition

Electrical response

Photoreceptors to Ganglion Cells: Building Receptive Fields

On-center Off-surround



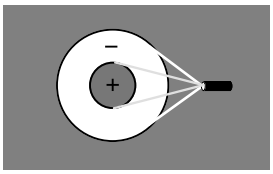


Stimulus condition

Electrical response

Photoreceptors to Ganglion Cells: Building Receptive Fields

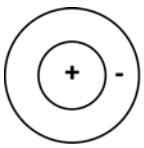
On-center Off-surround



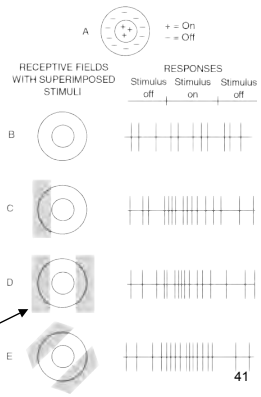
Stimulus condition

Electrical response

Photoreceptors to Ganglion Cells: Building Receptive Fields

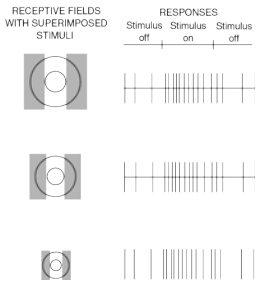


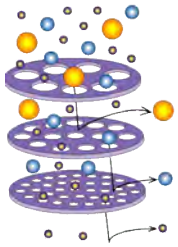
Works with bars too…



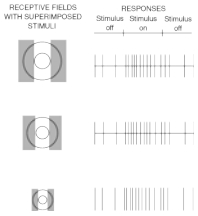
Dark bar

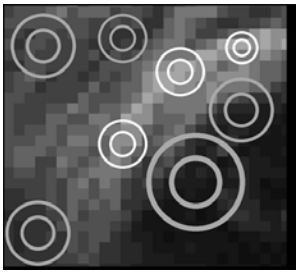
Photoreceptors to Ganglion Cells: Building Receptive Fields: **SIZE**



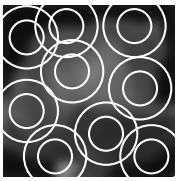


Photoreceptors to Ganglion Cells: Building Receptive Fields: **SIZE**



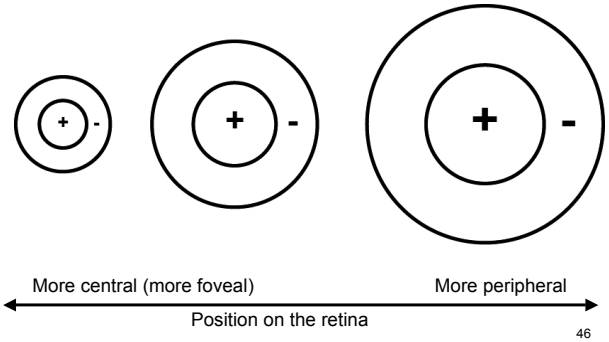


What Different Sized RFs "See"

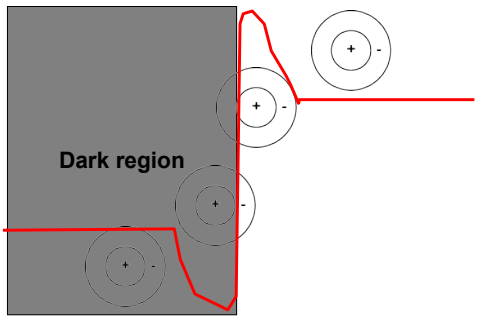


What Different Sized RFs "See"

On average, Ganglion cells that receive inputs from the fovea have smaller receptive fields than cells that receive inputs from more peripheral regions.

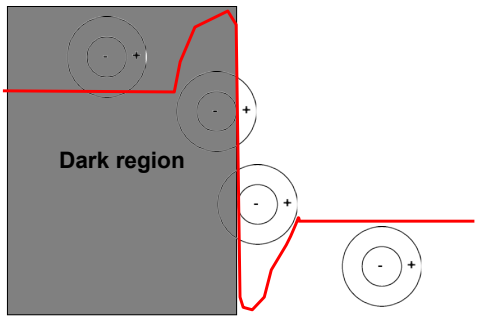


Receptive fields and border enhancement



- Borders are the main cue for objects.
- Responses of **ON-OFF** and OFF-ON receptive fields enhance borders

Receptive fields and border enhancement

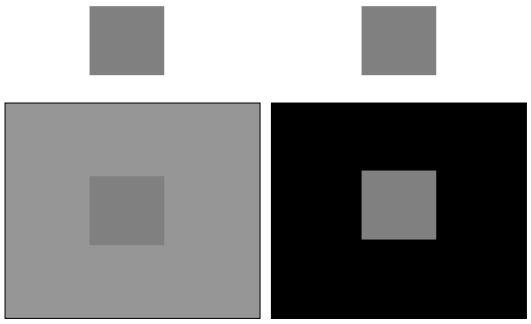


- Borders are the main cue for objects.
- Responses of ON-OFF and **OFF-ON** receptive fields enhance borders

Early visual processing: retina & LGN

- Retina
  - **rods and cones**
  - **spatial layout**
- Receptive fields
  - **center-surround organization**
  - **perceptual consequences of center surround organization**
- Beginning of parallel pathways in vision
  - **M and P cells**

Perceptual consequences of retinal receptive fields

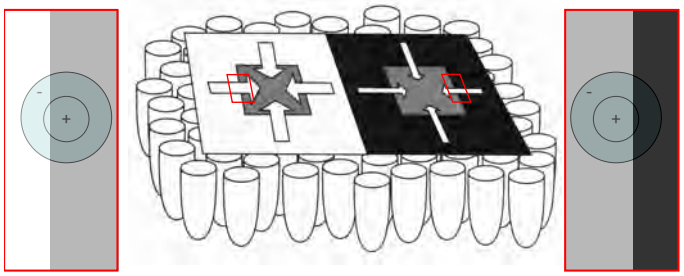


Simultaneous Lightness Contrast

Simultaneous Lightness Contrast

More surround inhibition
Less surround activation

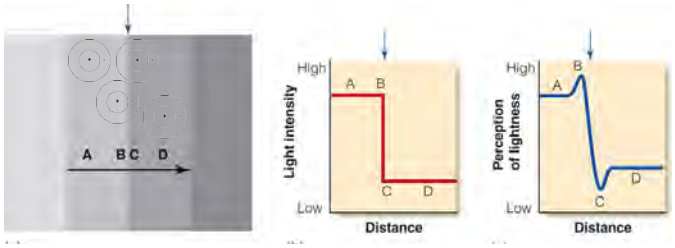
Less surround inhibition
More surround activation



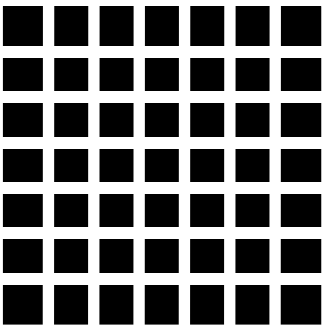
The right square appears lighter because cells with receptive fields near its border receive less inhibition from the surround.

Thus, what's happening at border matters!

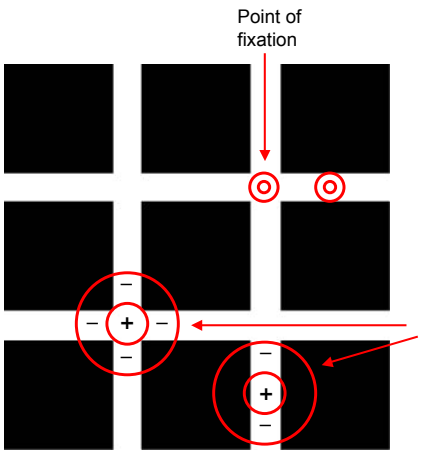
Mach bands



Perceptual consequences of retinal receptive fields: **Hermann Grid**



Why do spots appear at the junctions, and why do they disappear when a junction is fixated?

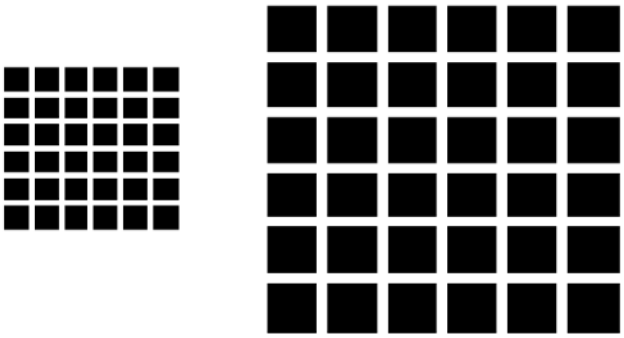


Spots do not appear at the fixated junctions because receptive fields in the fovea are smaller than in more peripheral regions.

Cells with receptive fields at the junction receive more inhibition, so that the junctions appear darker.

.. But!

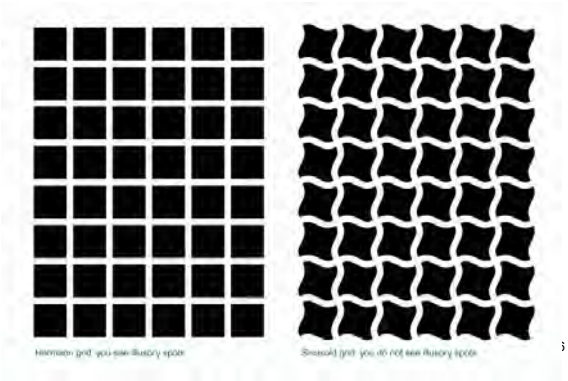
The effect is not size dependent



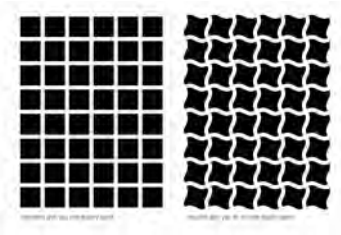
The illusion is effective over a large range of square sizes.
PROBLEM: Receptive field size of retinal ganglion cells is fixed

.. But!

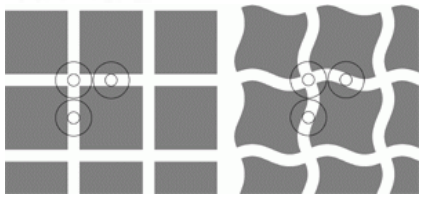
The effect can be negated without affecting the assumed relationship between the stimulus and the receptive fields



.. But!

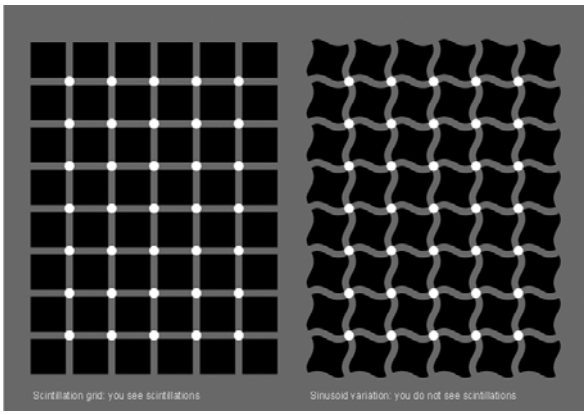


The effect can be negated without affecting the assumed relationship between the stimulus and the receptive fields



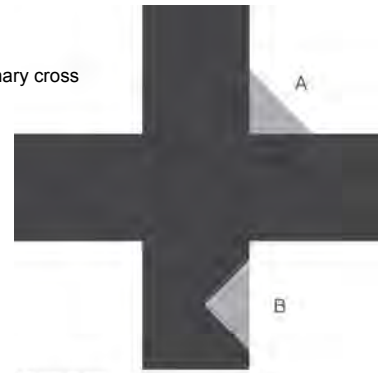
.. But!

The effect can be negated without affecting the assumed relationship between the stimulus and the receptive fields



Higher level factors also matter!

The Benary cross



People see differing brightness of triangles even though ON-OFF (and OFF-ON) receptive filed responses should be equal.

Higher level factors also matter!