THE VISUAL SYSTEM

Visual Perception

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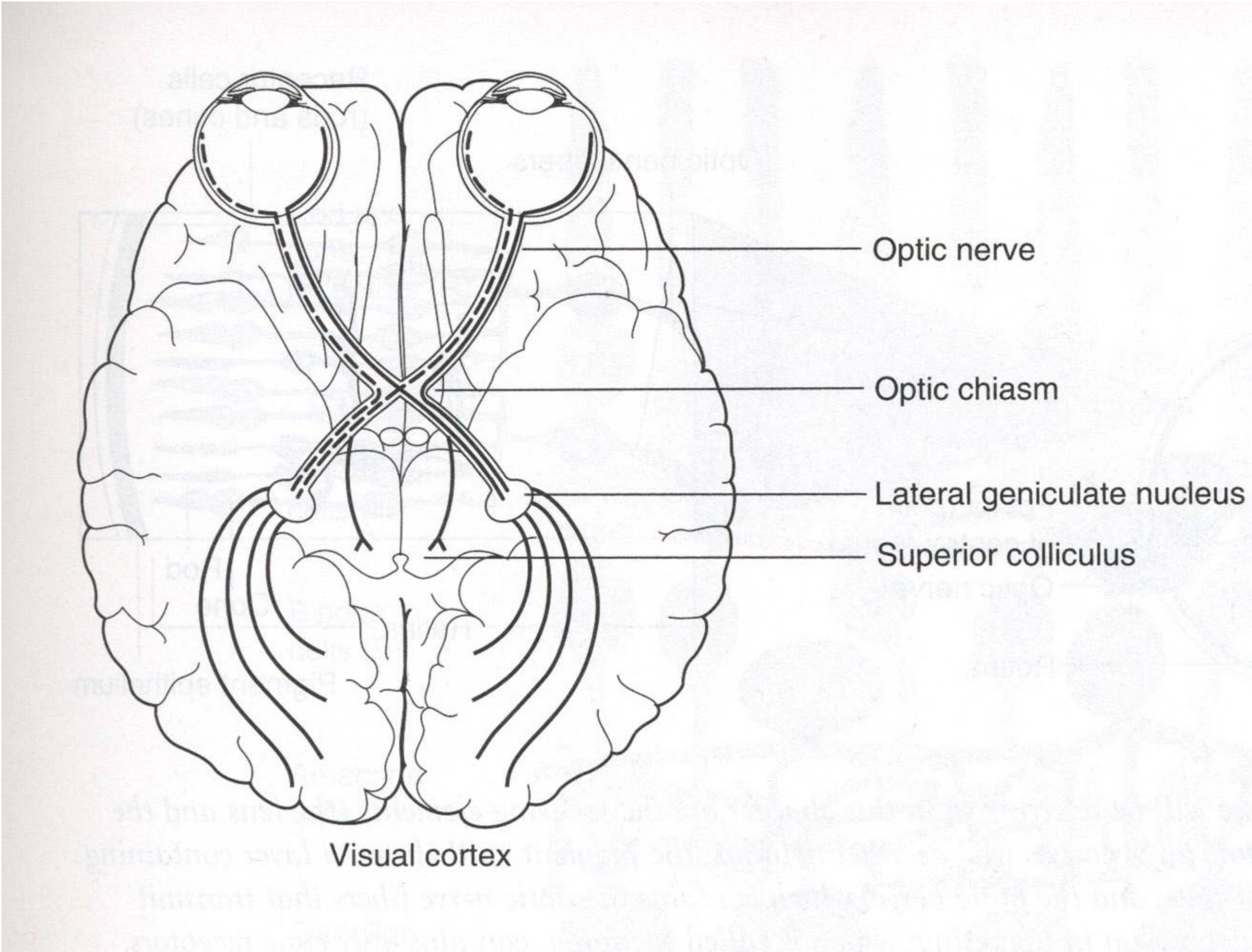
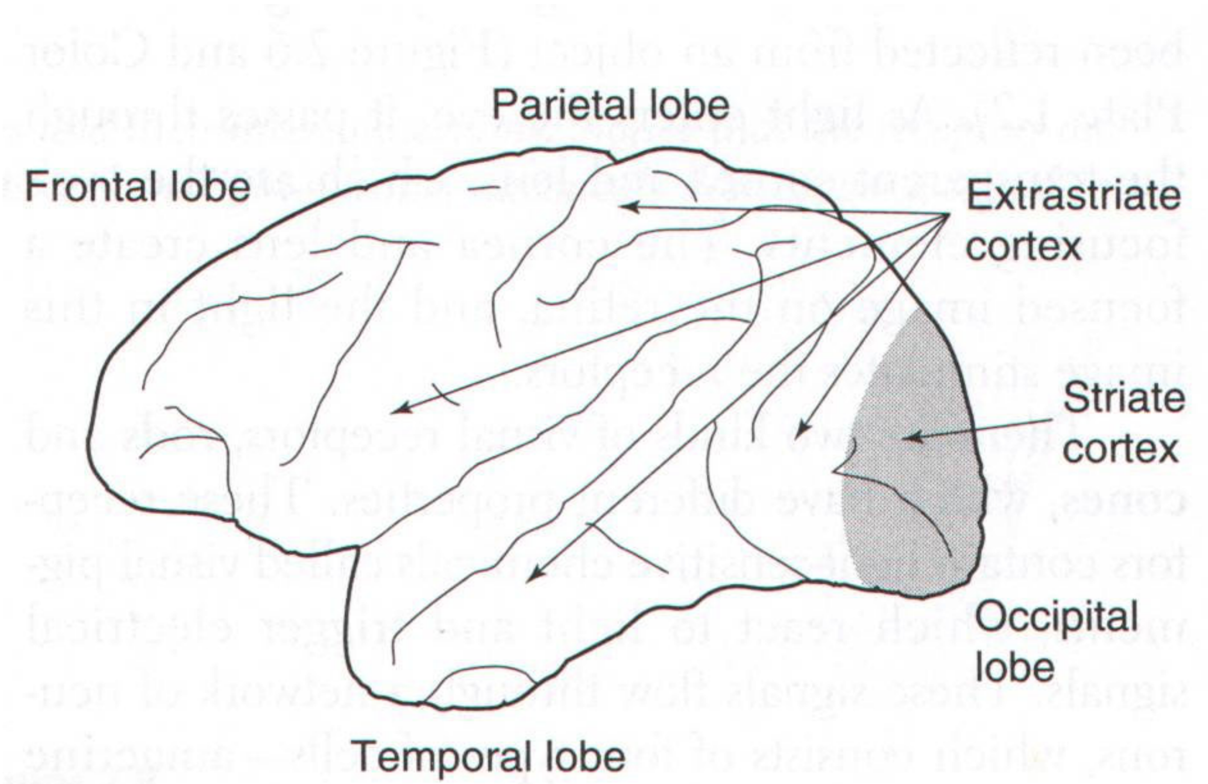
Visual System

- Eye - sensor
- Lateral geniculate nucleus
- Striate cortex
  - Striped Appearance
- Extra striate cortex

Visual System

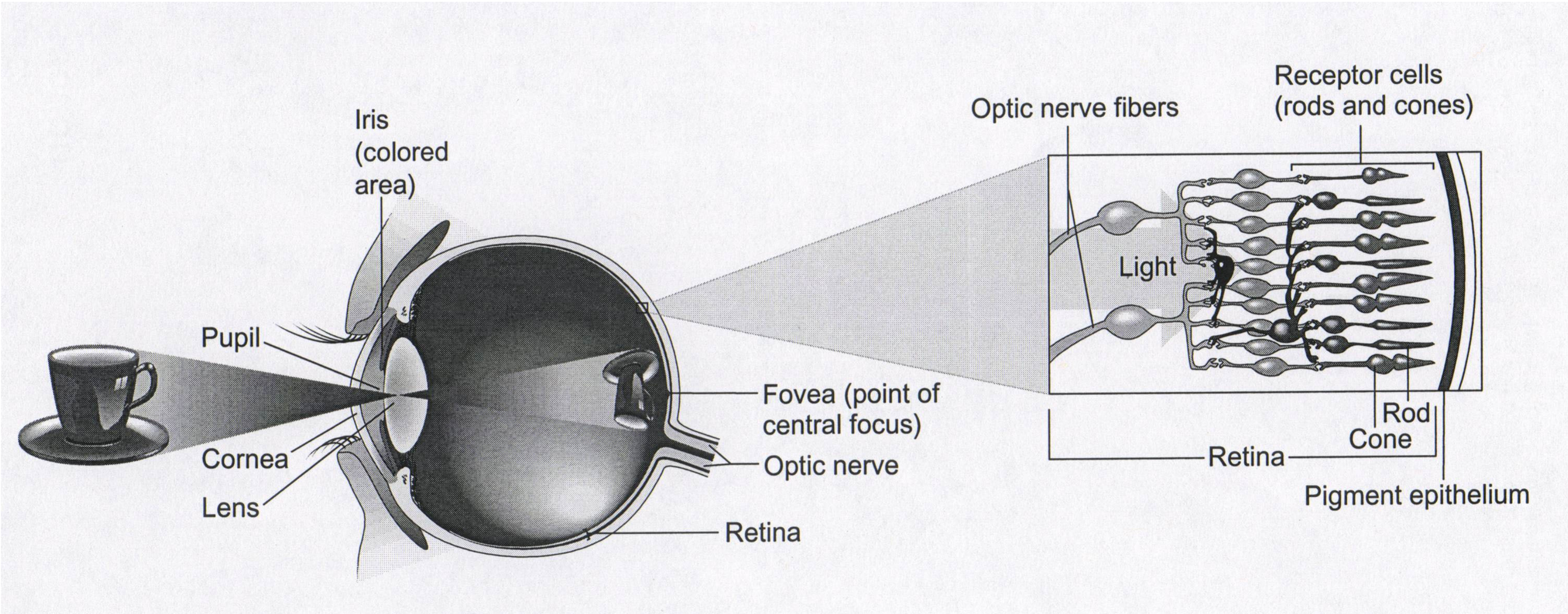


Visual System



Eye : The Sensor

Eye : Structure



Eye : Accommodation

- Accommodation : Flexible focusing ability
  - Cornea – 80% of focusing ability
  - Lens – 20% *adaptable* focusing ability
- Focus at one depth at a time
- Limitation
  - Depth of field
  - Near and far point

Effects

- Far and near point is different for different individuals
  - If near point is far: presbyopia
  - If far point is near: myopia

- Stiles-Crawford Effect
  - Lower response of photo-receptors for light entering at an angle when compared to equal intensity light entering directly
  - Different perceived color of monochromatic light when entering from an angle

- Strong acuity fall-off
  - Try reading text elsewhere while fixating on this, almost impossible

Iris

- Muscle controlling the pupil size
- Controls the illumination on the retina
- 3mm – 7mm
- Increase by 5 times
- Cannot explain the 10 orders of magnitude light sensitivity

Other

- Pigmented Epithelium
  - Behind the retina – dark
  - Absorbs light and avoid scattering
  - Allows high-contrast sharp retinal image
- Fovea
  - 2 degress of angle subtended
  - Most densely populated with photoreceptors
  - Image fixated on the retina

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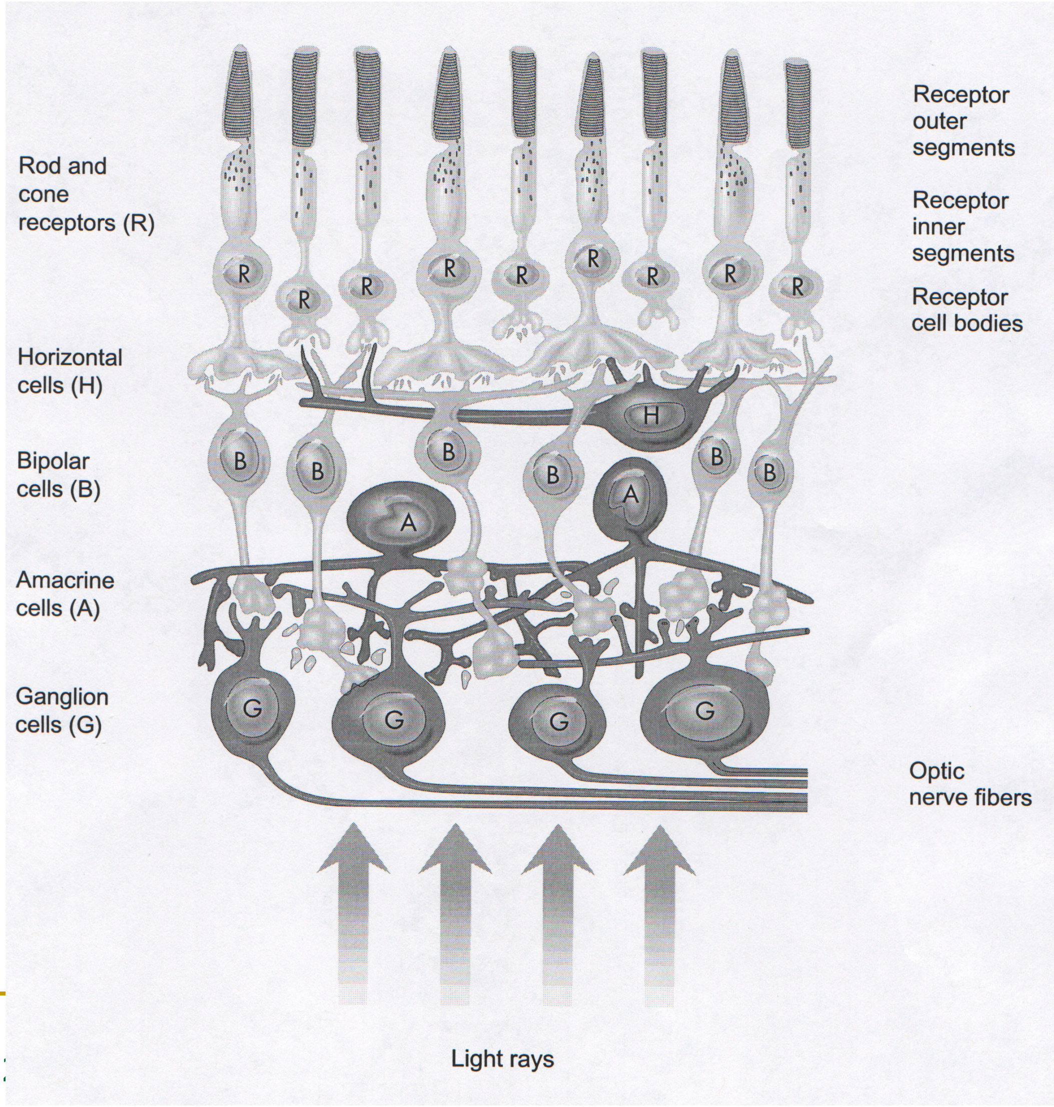
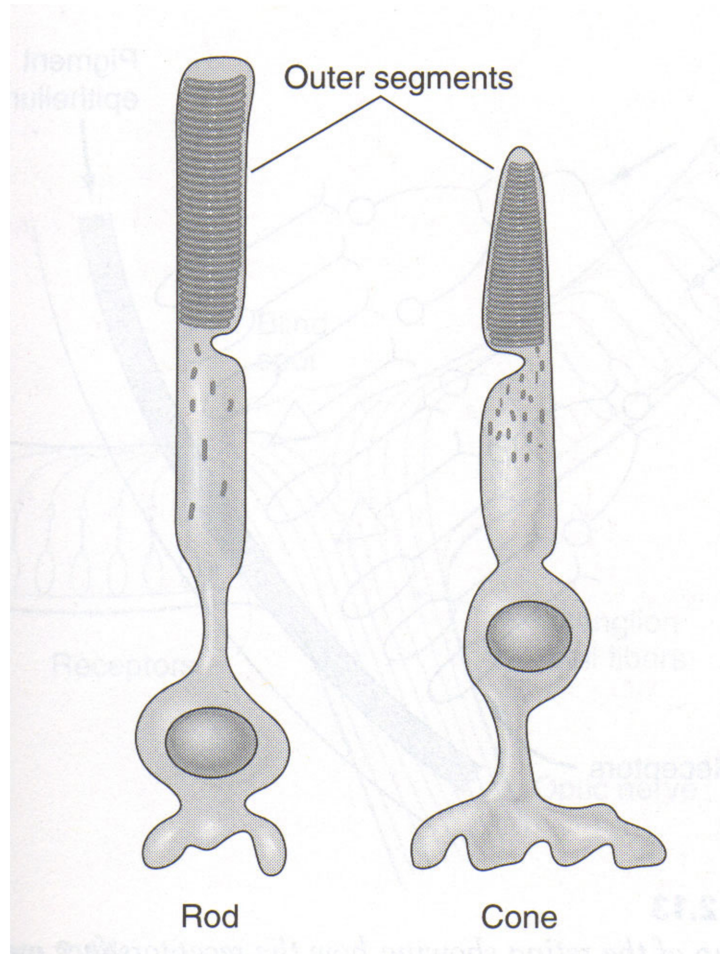
Receptors in Eye

Receptor Organization



Receptors

- Rods
  - 120 million
  - Only in periphery
- Cones
  - 6 million
  - 1% in fovea
  - Rest in periphery
- In periphery 20:1 ratio for rods and cones
- Blind Spot



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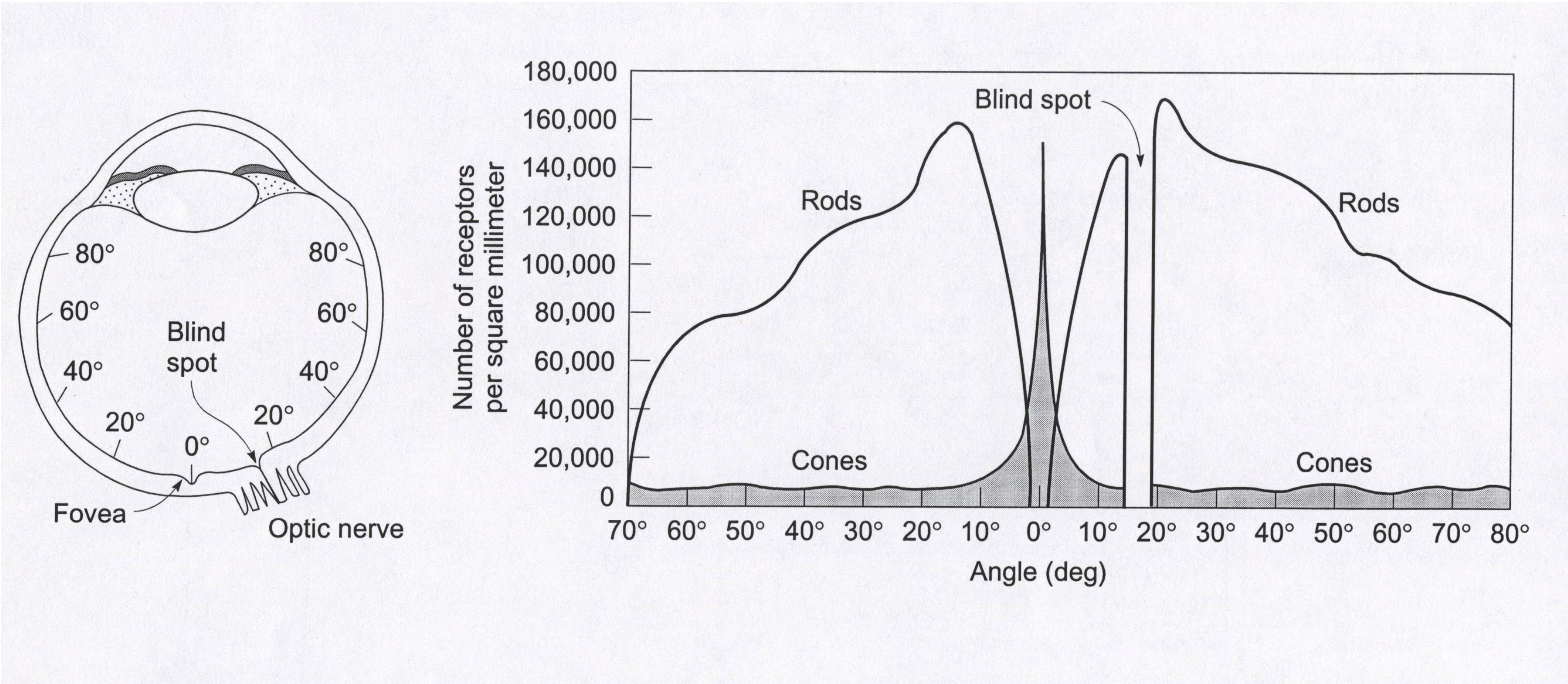
Receptor Distribution



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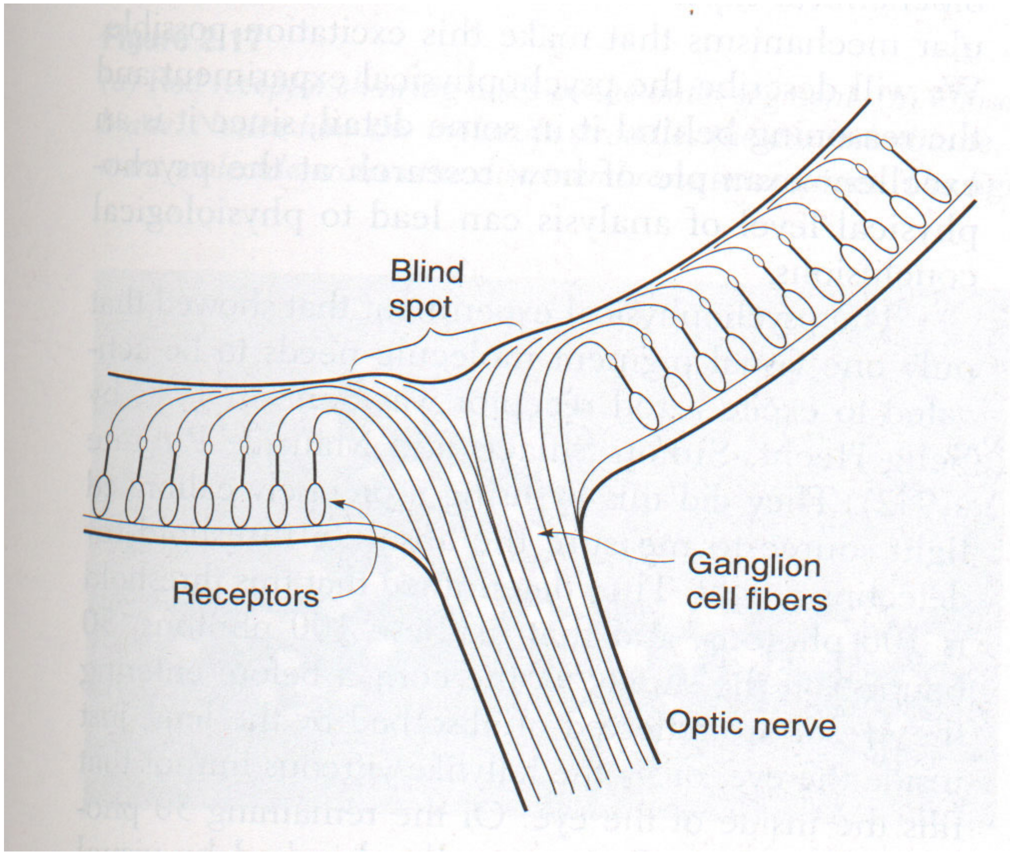
Receptor Distribution

- Turned away from light
- To get nutrition from opaque pigment epithelium
- The other cells are transparent not to block light reaching the retina
- Block the axons of the ganglion cells from leaving the eye

Blind Spot

- Ganglion nerve fibers fold and leave by crossing a part of retina
- This part does not have any receptors
- Filled out by the brain
- Experiment



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Receptor Functions

- Cones – for vision in photopic conditions
- Rods – for vision in scotopic conditions
  - Saturate at high light levels
- Both – for vision in mesopic conditions

Receptor Functions

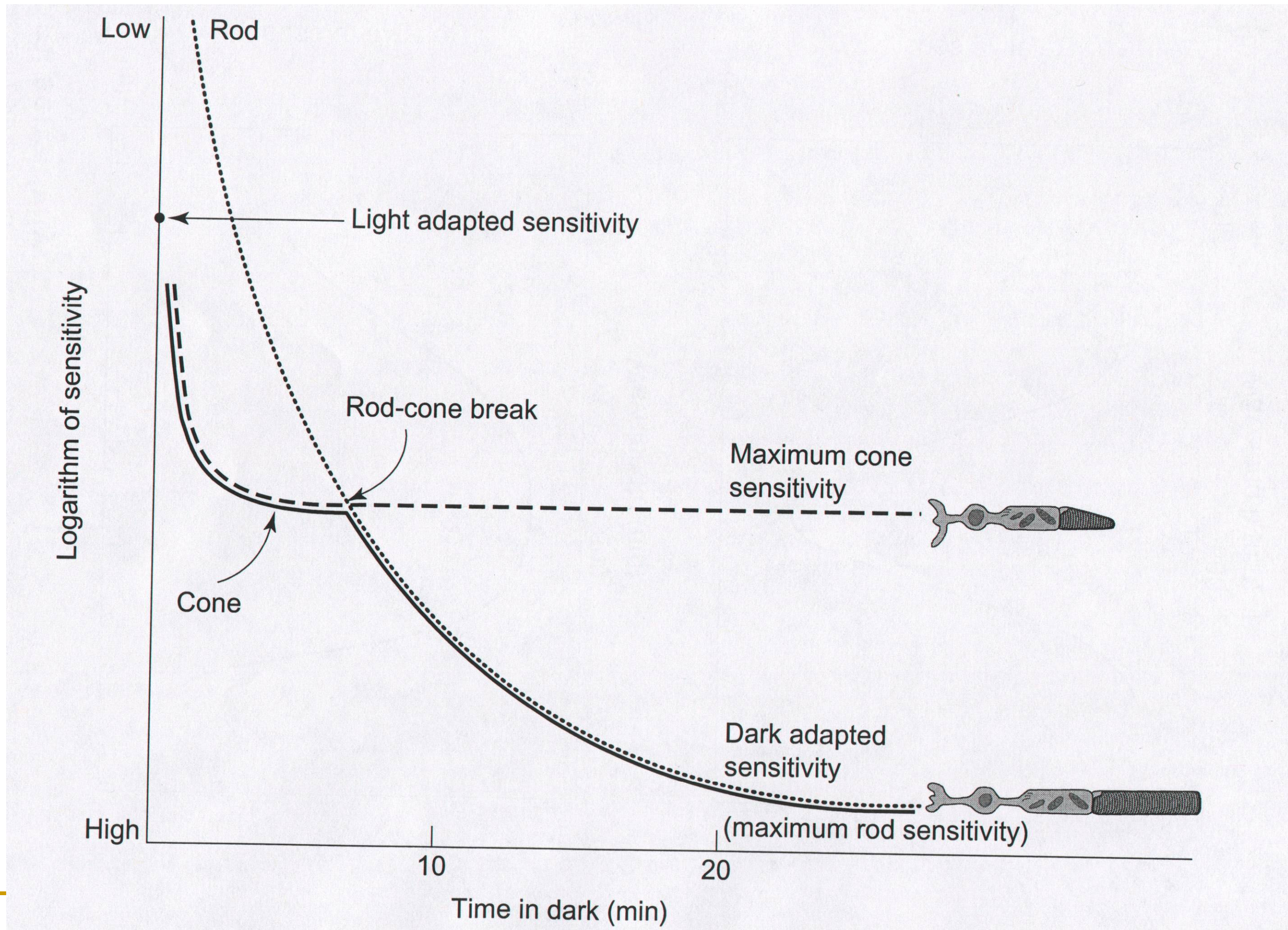
- Conversion of light to electrical energy
  - Light sensitive chemical pigment in the receptors
  - Absorbs photons and changes the shape to create a graded potential across the membrane of the outer segment
  - Logarithmic response supports Stevens Law
  - Potential is transmitted down the outer membrane to other cells

Receptor Functions

- Pigment Bleaching
- Pigment Regeneration
  - 30 minutes for rods and 6 minutes for cone

Effects of Visual Pigments on Perception

Dark Adaptation Curve



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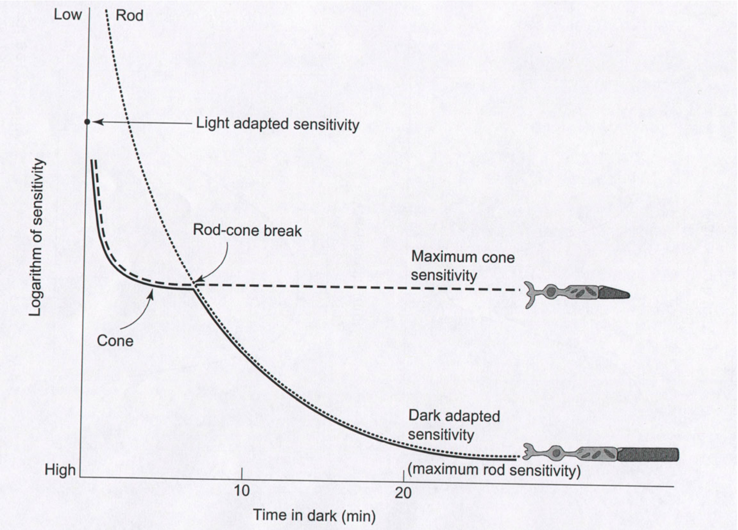
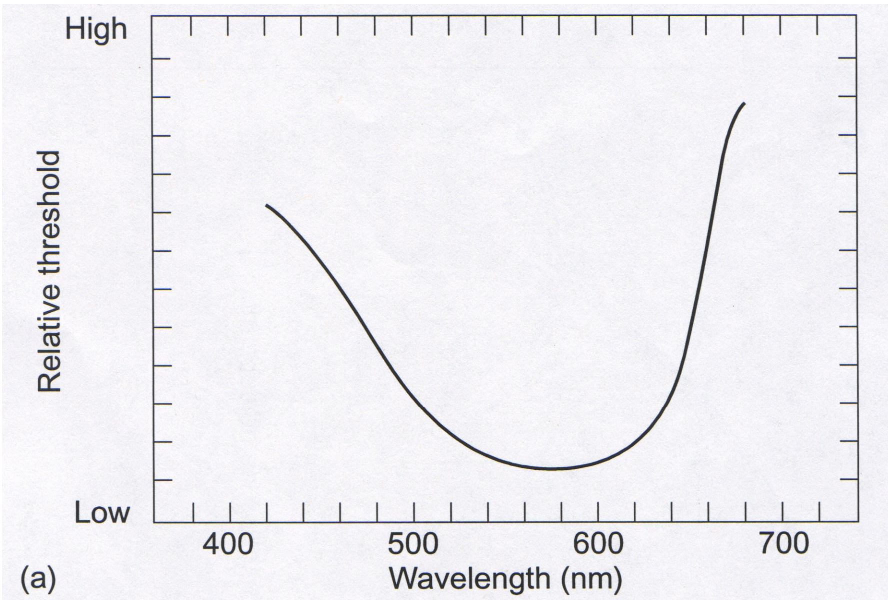
Dark Adaptation

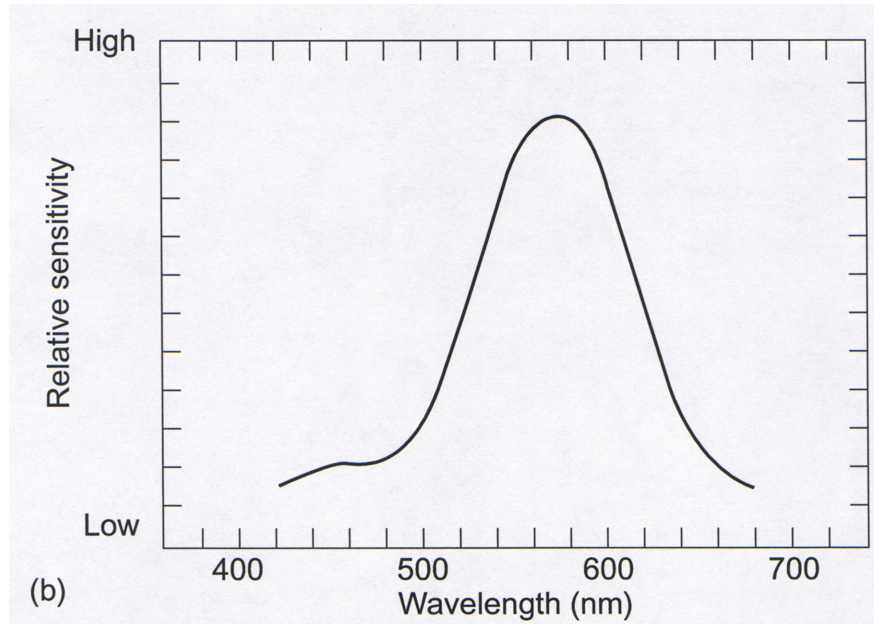
- Initial rapid increase
  - 6 minutes
- Slower further increase
  - 25-30 minutes
- Rods have higher sensitivity than cones
  - Rods responsible for dark vision
- Pigment Regeneration
  - 6 minutes for cones
  - 30 minutes for rods



Spectral Sensitivity



Threshold Curve

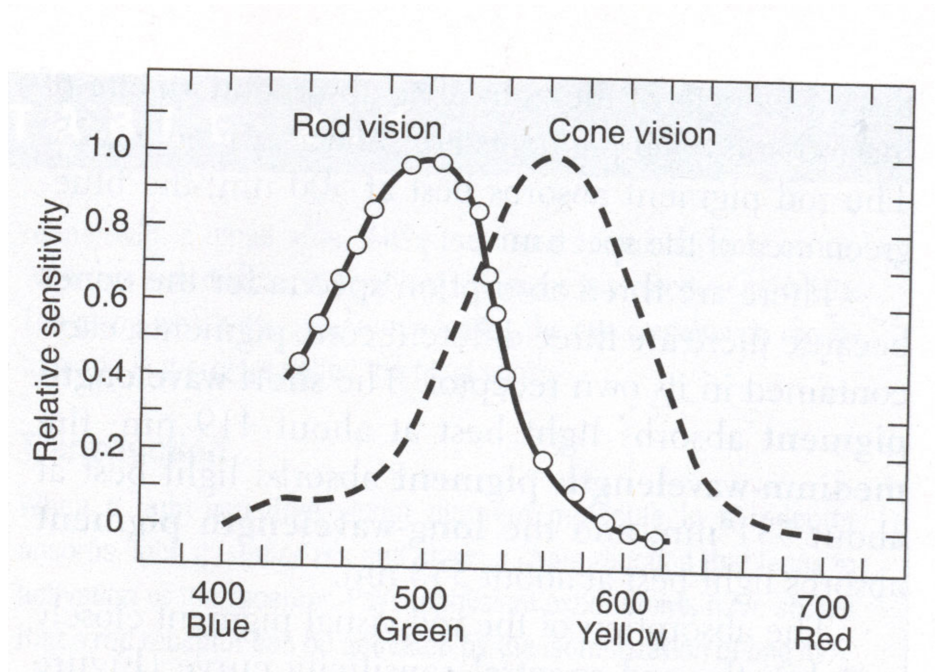


Sensitivity Curve

Relative threshold of light required to detect monochromatic light of each wavelength

Rod and Cone Sensitivity

- Rods have sensitivity to shorter wavelengths
- Peak near *500nm* being maximum sensitive to the blue-green region
- Shift of wavelengths in dark
  - Purkinje shift
  - Things appear bluish in dark
  - Green foliage seems to stand out in the dusk



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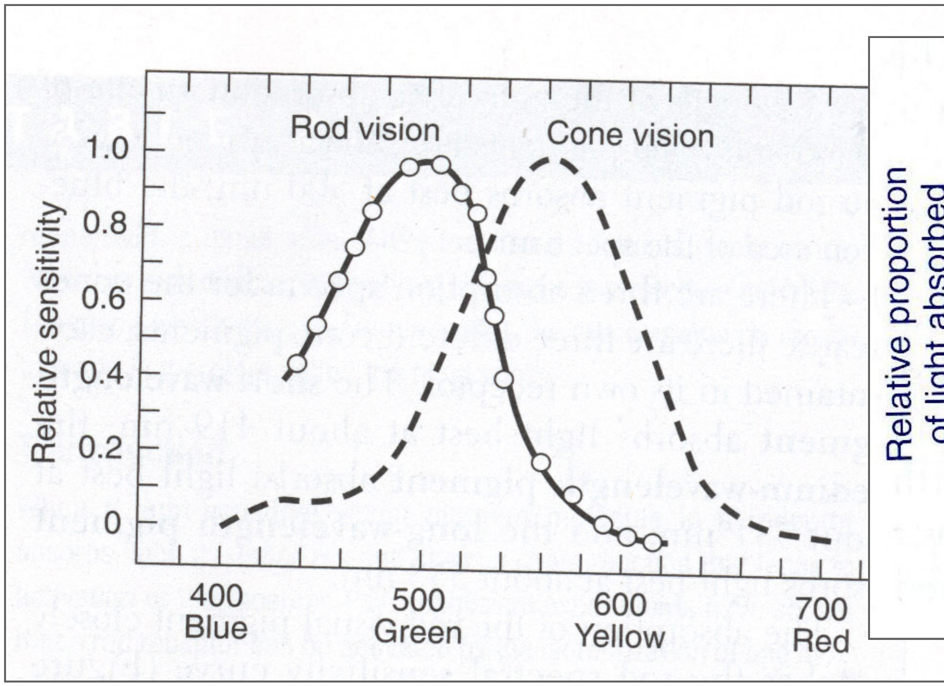
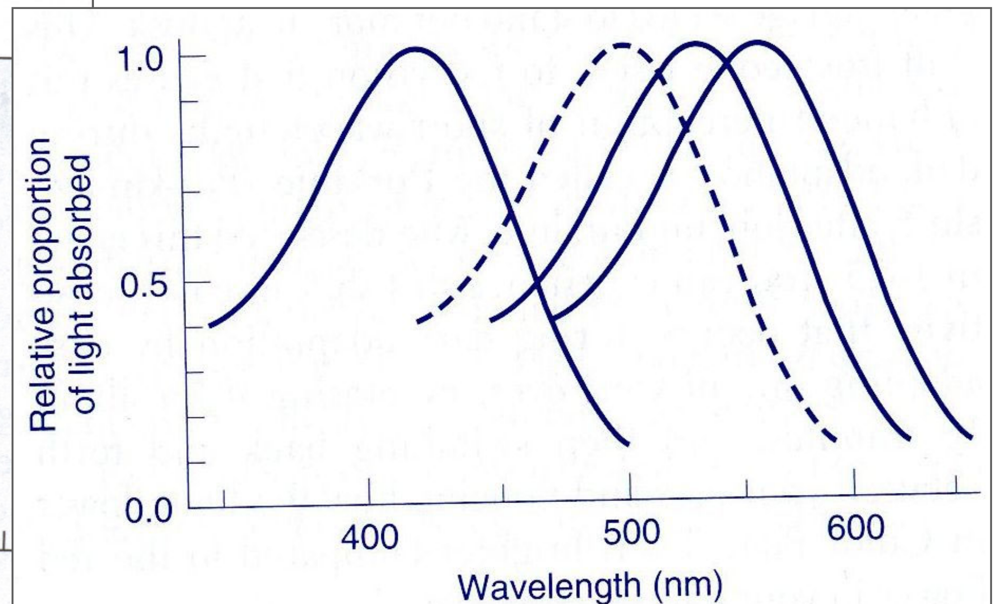
Cone Sensitivity

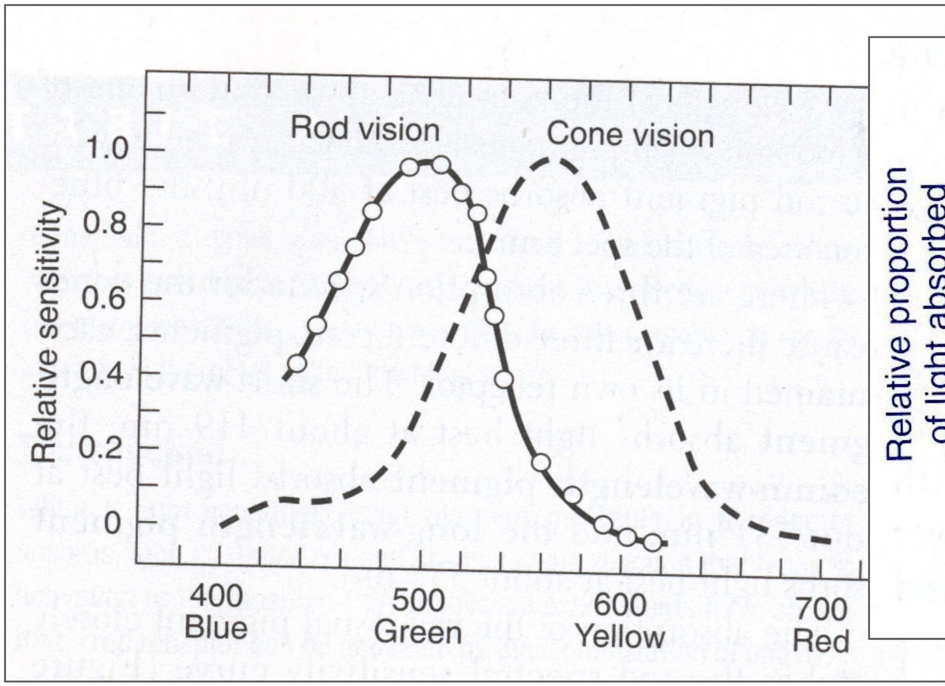


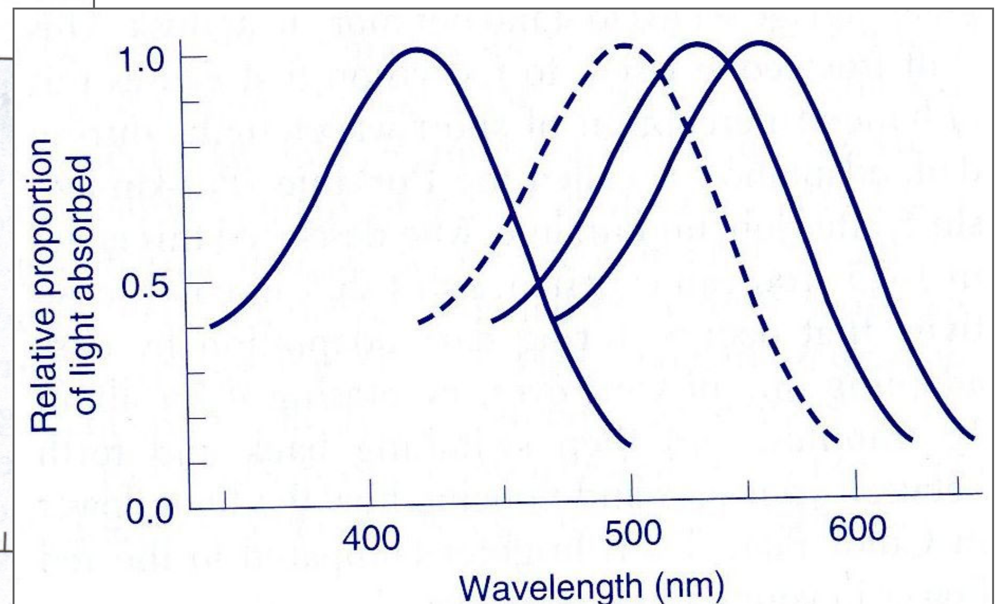


Cone curve is the combined sensitivity of three cones

- Short wavelength – S cones
- Medium wavelength – M cones
- Long wavelength – L cones

Cone Sensitivity





Inconsistent with parts? – NO

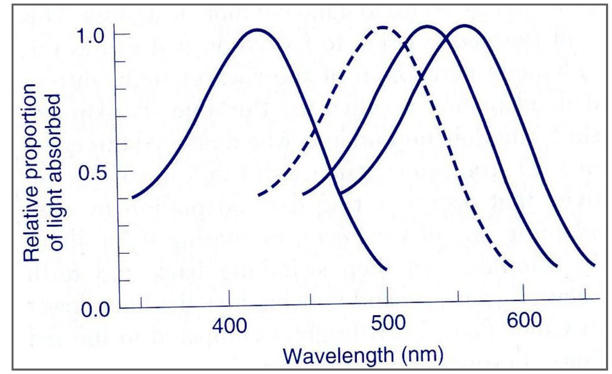
Relative proportions of the S,M and L cones are different

S:M:L = 1:6:12

Rods does not help in color vision. No color perception in dark

Why do we need three cones?

- What happens with one cone?
  - 10 photons of 500nm produce x reaction
  - 10 photons of 560nm produce 4x reaction
  - 40 photons of 500nm produce 4x reaction
- No way to tell between the wavelength



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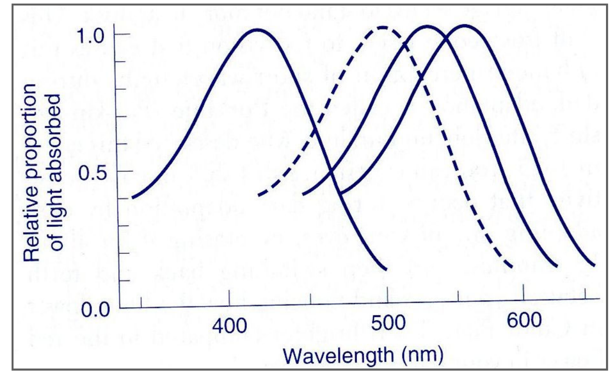
Why do we need three cones?

- What happens with one cone?
  - Two parameters: Which wavelength and what brightness?
  - Cannot measure both with one sensor

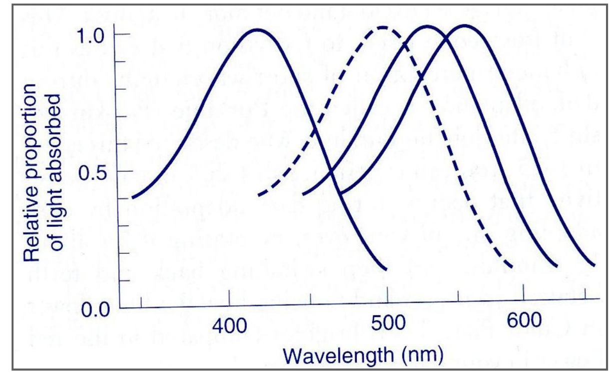
Why do we need three cones?

- What happens with two cones?
  - You can distinguish both intensity and wavelength
  - Need more wideband sensitivity to cover all colors
  - Miss out completely parts of the spectrum



Why do we need three cones?

- With three cones
  - We do not need more than three since they cover the visible spectrum



Why rods not considered as the fourth cone?

- Spatial distribution and nature of convergence are completely different
- They are activated usually in completely different light conditions

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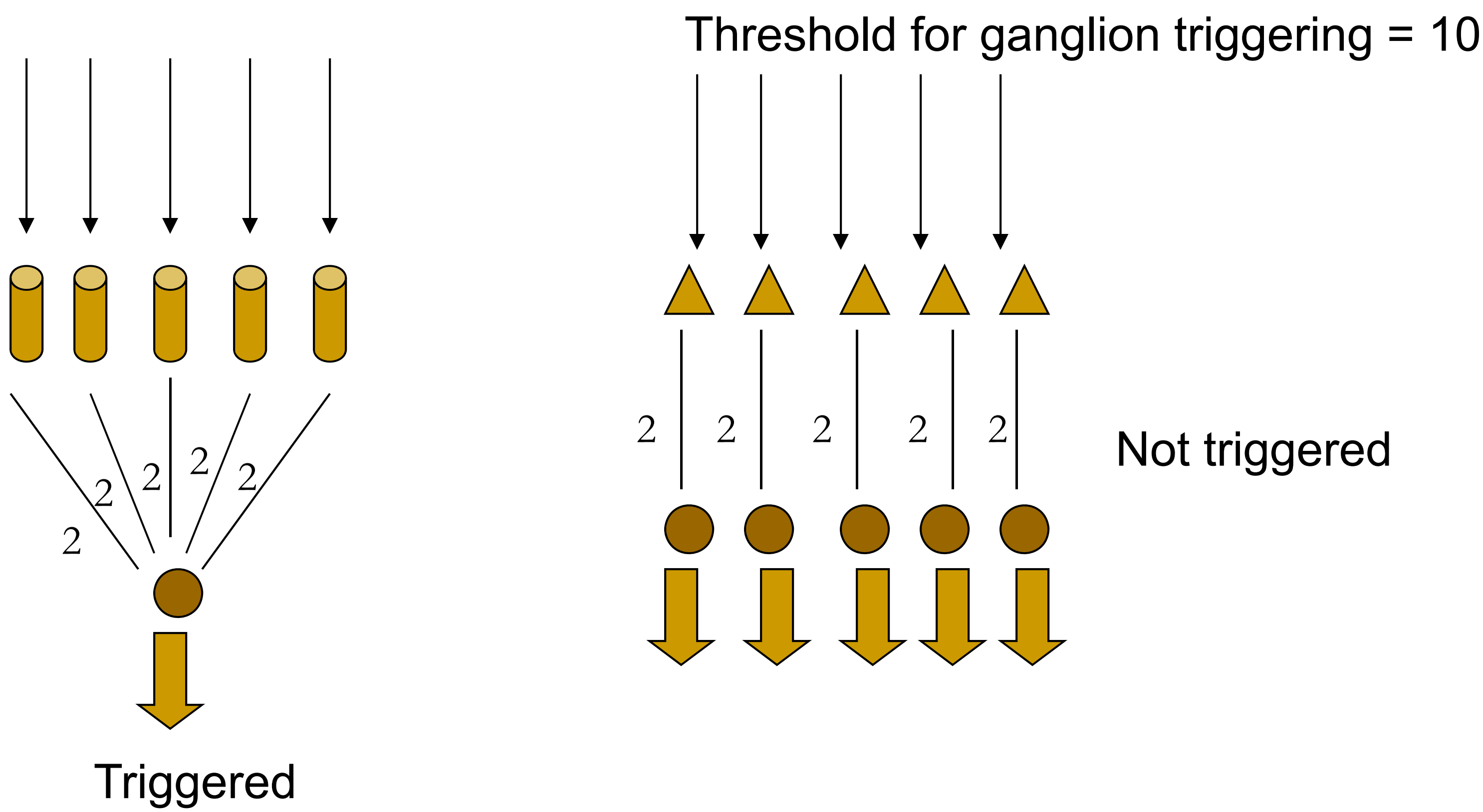
Effects of Neural Processing on Perception

Convergence

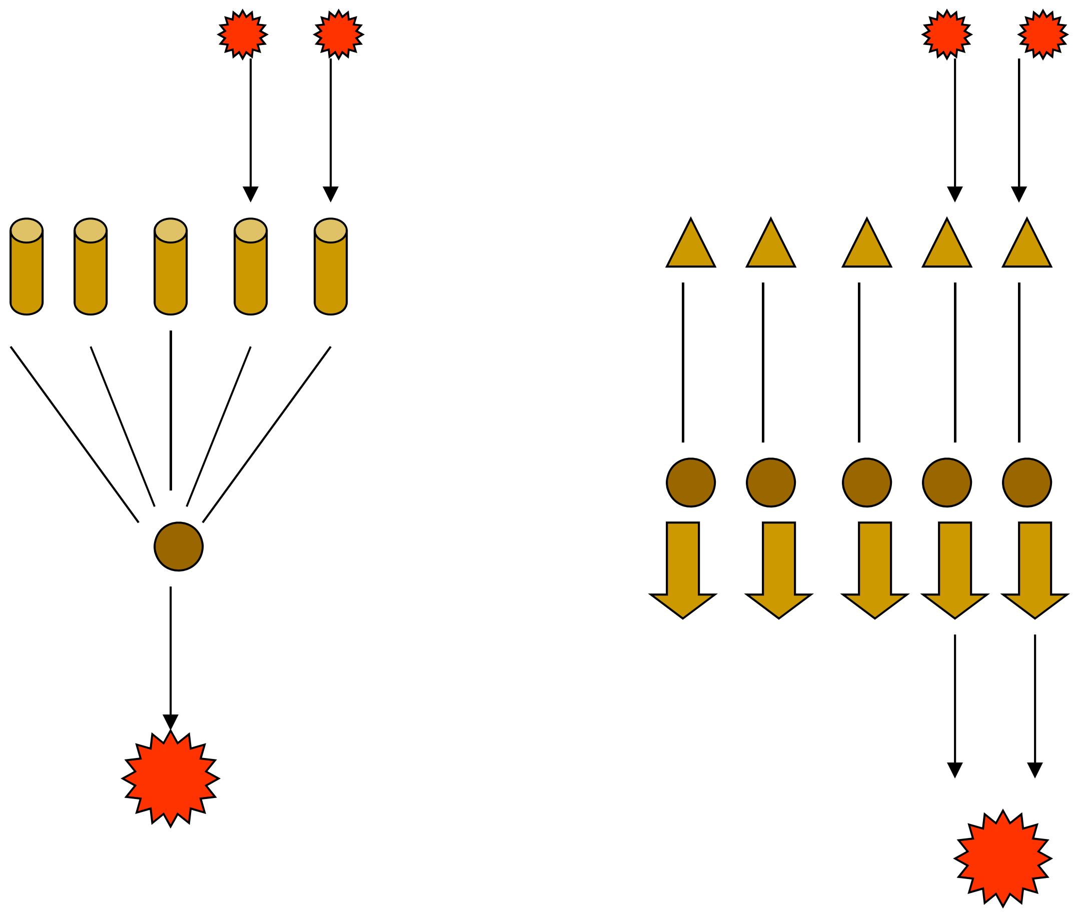
- Measured number of neuron synapse on another neuron
  - Eye : Number of receptor neuron synapses on a ganglion cell
- Each ganglion cell receives many synapses
  - Rods to cones convergence ratio is 20:1
  - 1 million ganglion cells, 120 million rods and 6 million cones
  - Rods have higher convergence than cones

Rods are more sensitive in dark

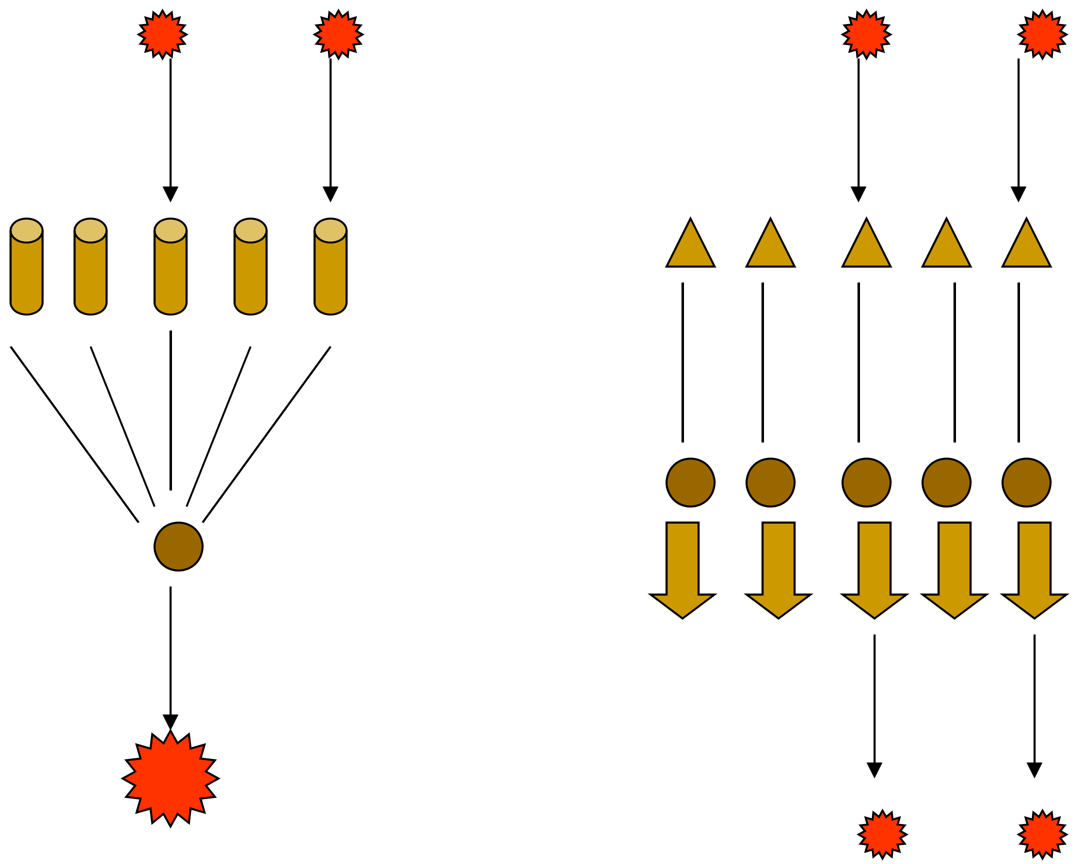


Rods have greater spatial summation than cones

Cones give visual acuity



Cones give visual acuity

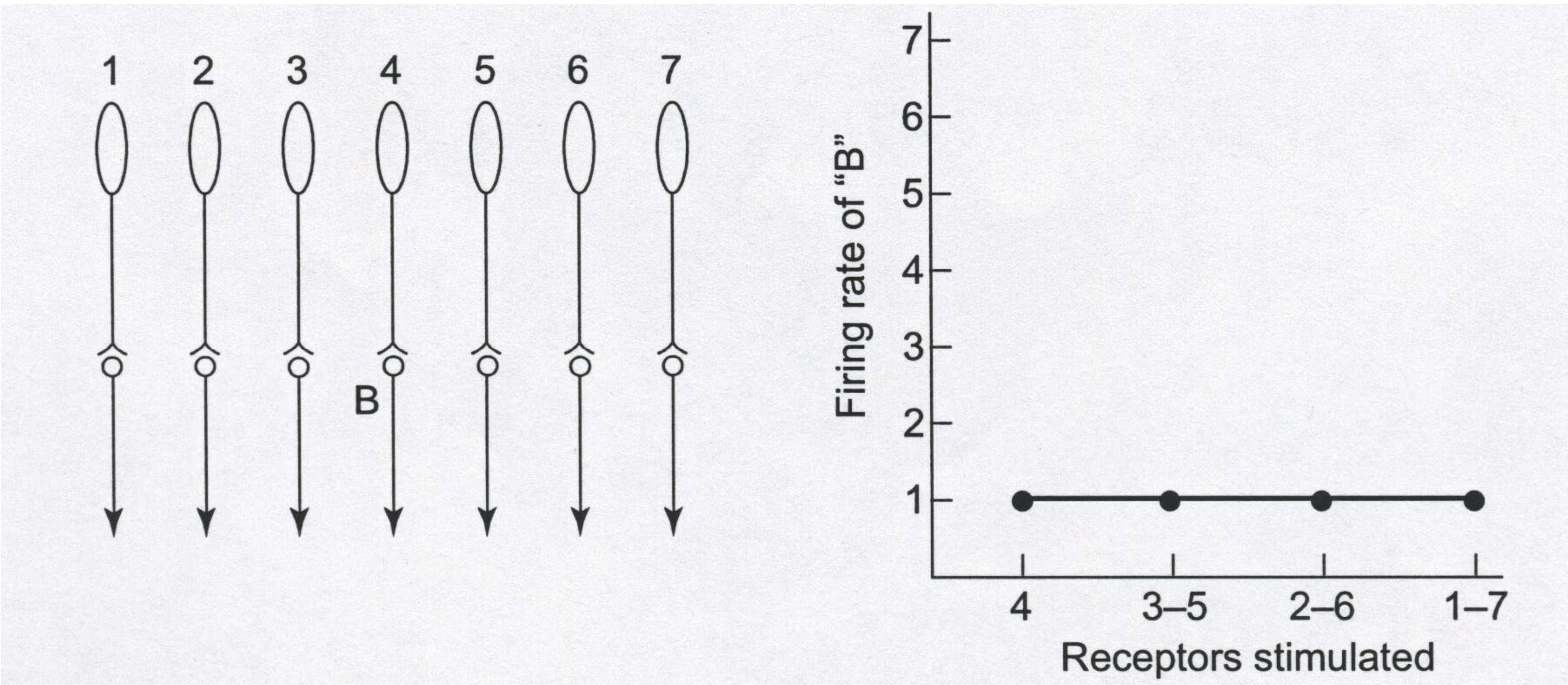


Neural Circuits and their Effects on Perception

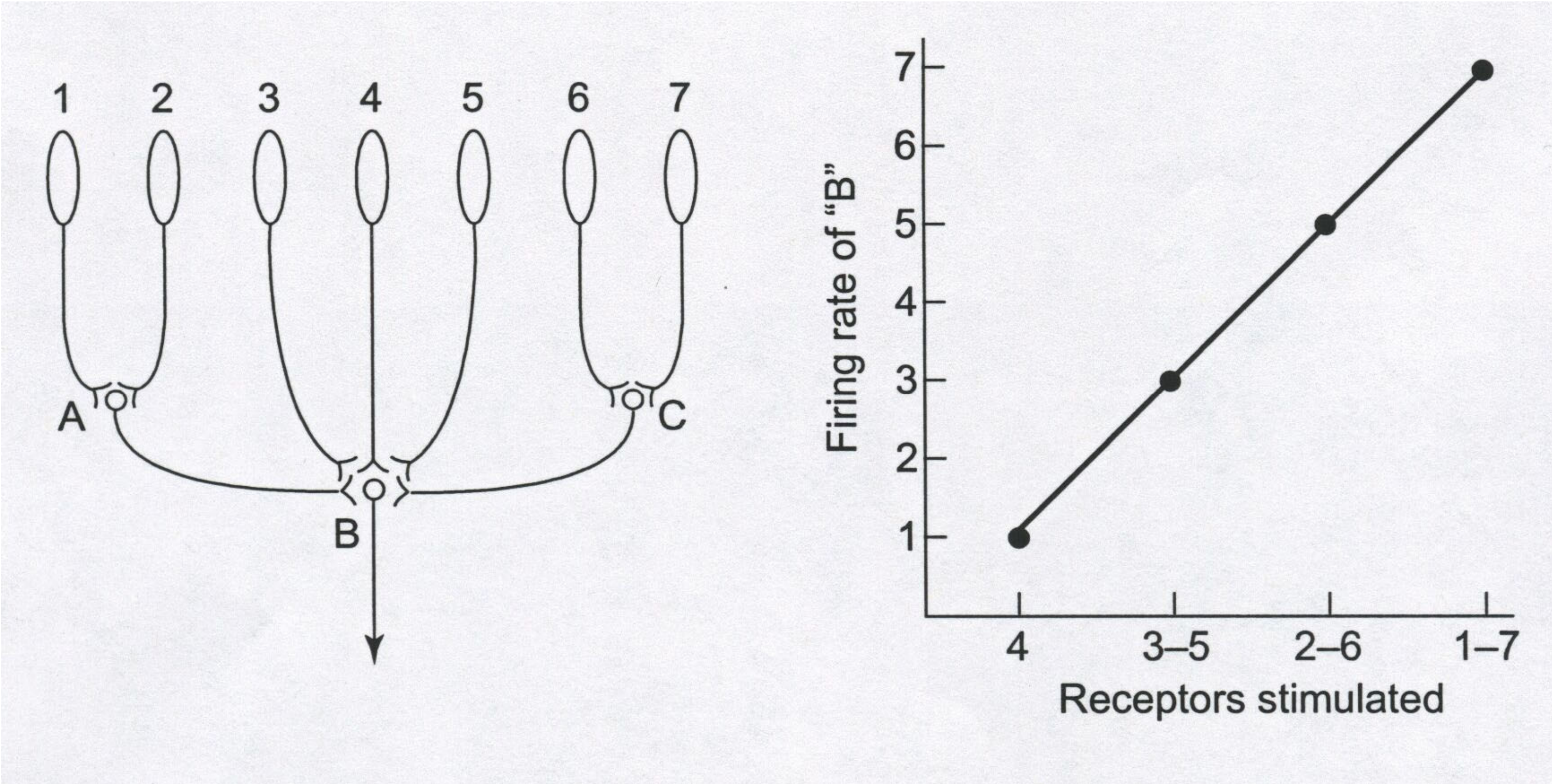
Neural Circuits

- Many neurons connected through convergence
  - Small – a few neurons
  - Large – a few hundred thousand neurons

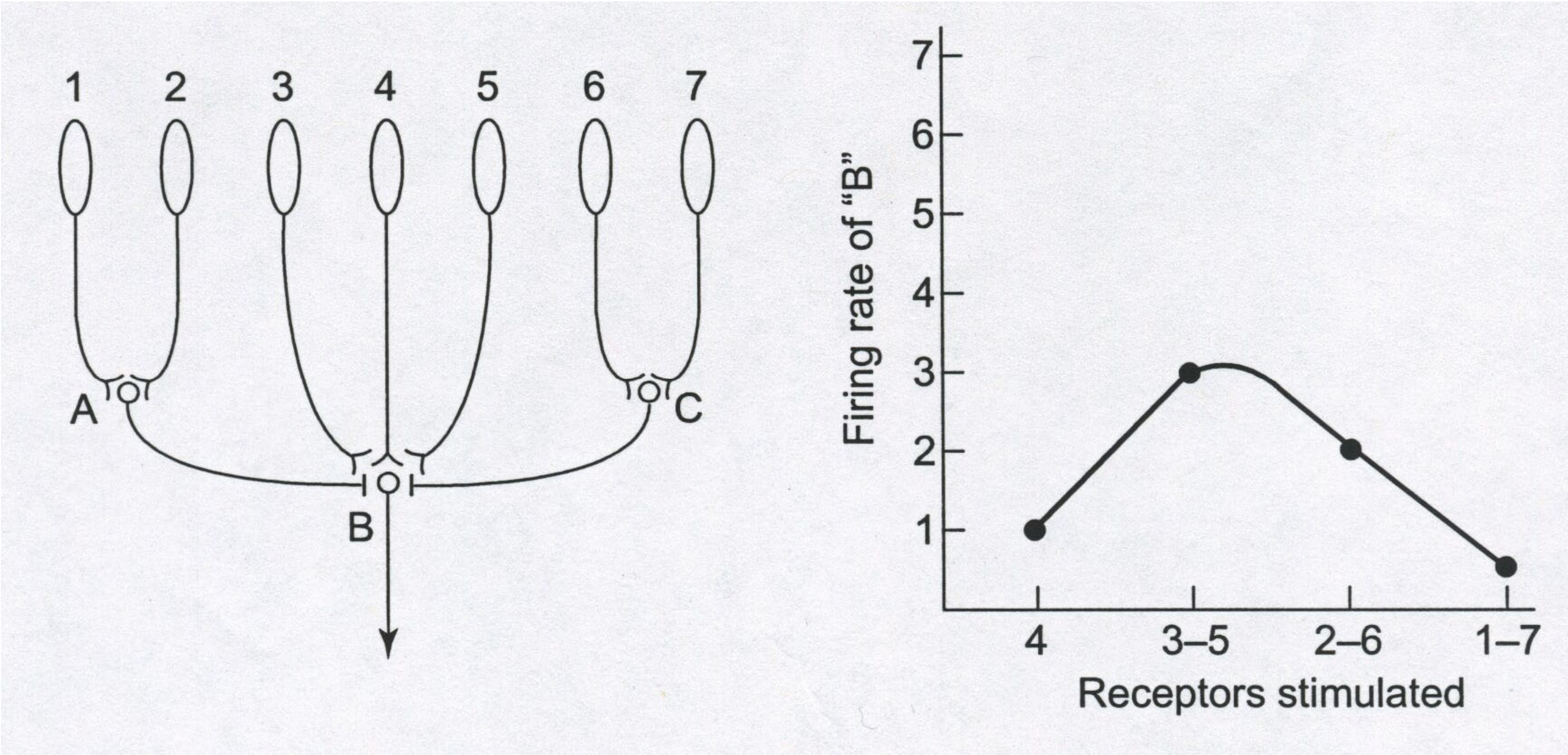
Neural Processing by Excitation and Inhibition



Neural Processing by Excitation and Inhibition

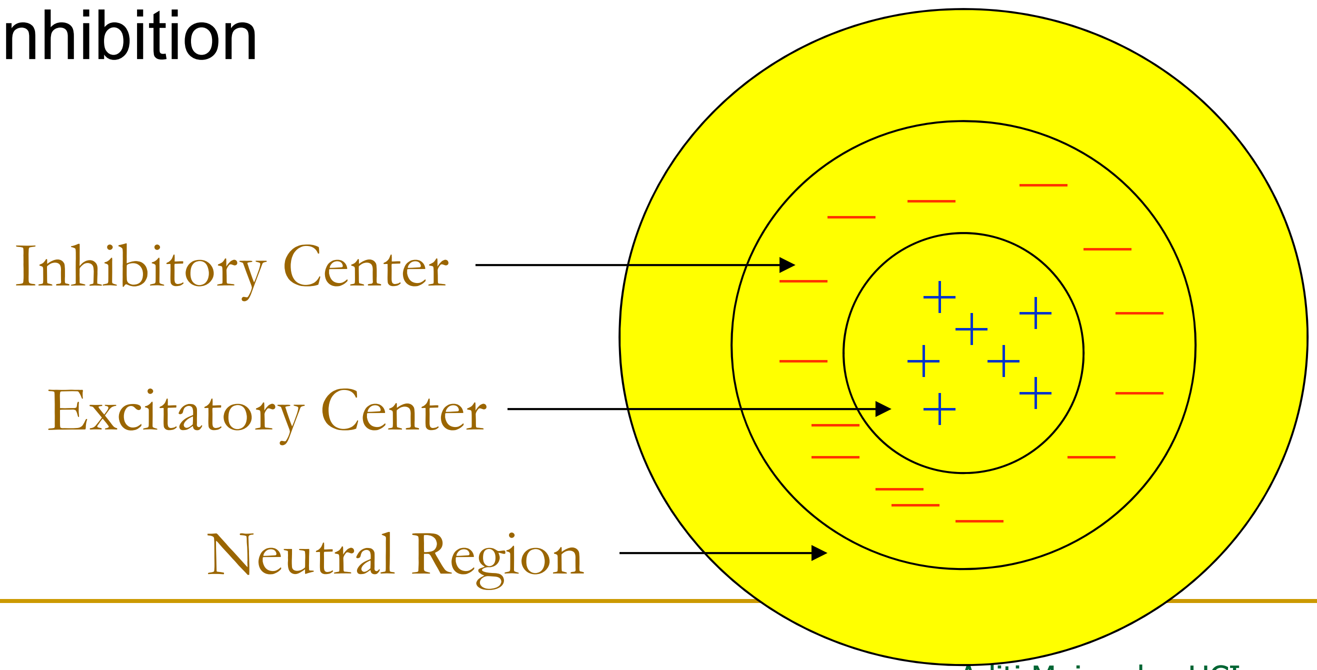


Neural Processing by Excitation and Inhibition

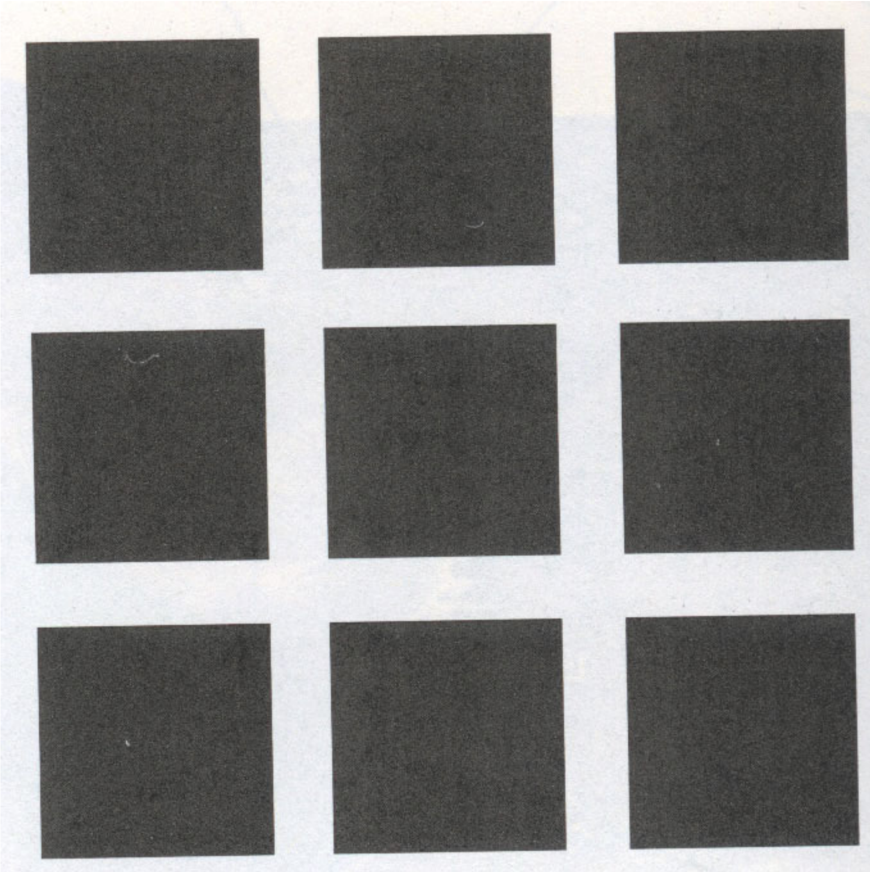


Receptive Fields

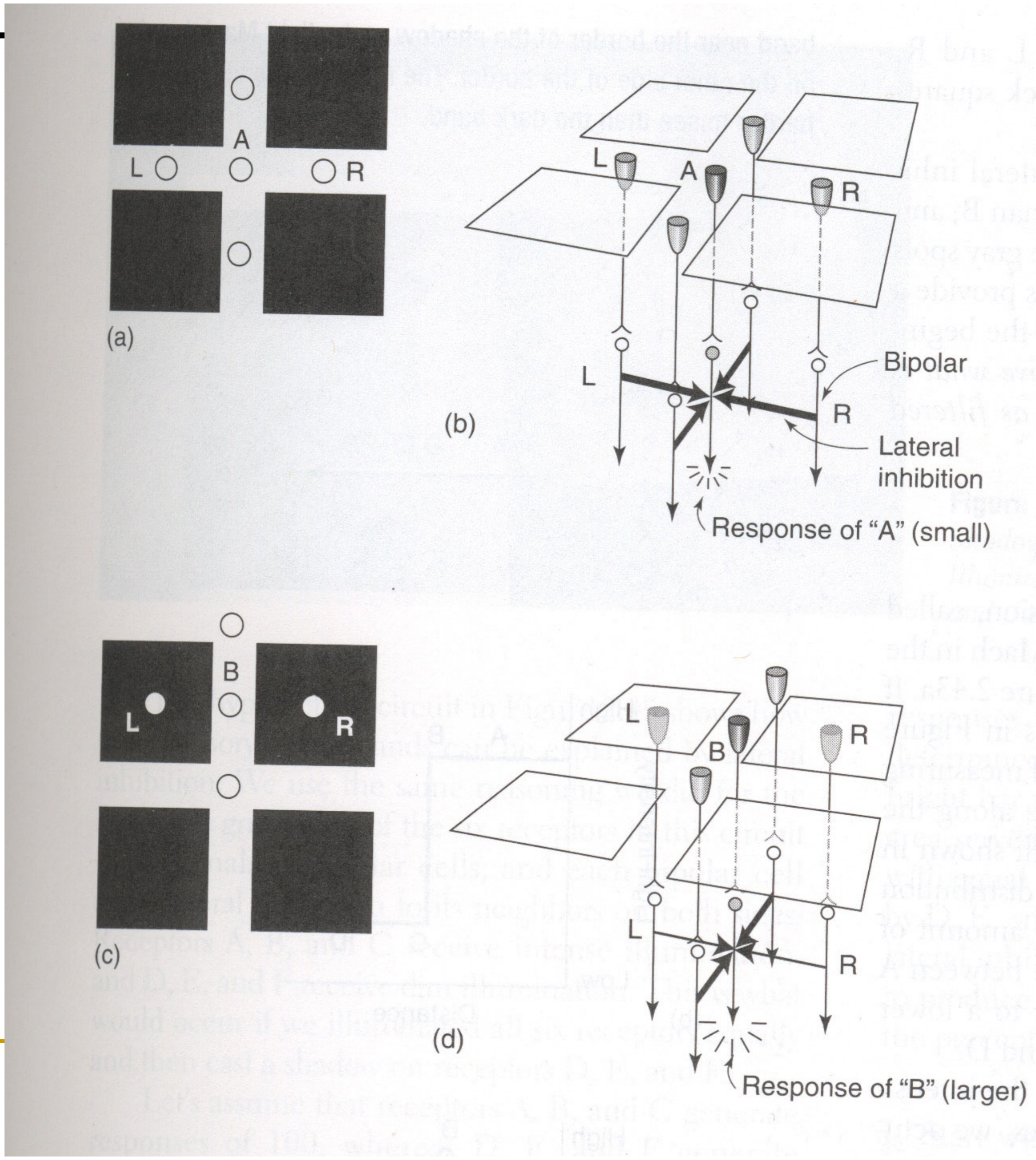
- The area of the retina that when stimulated influences the firing rate of the ganglion cells
- Excitatory center
- Inhibitory surround
- Lateral Inhibition



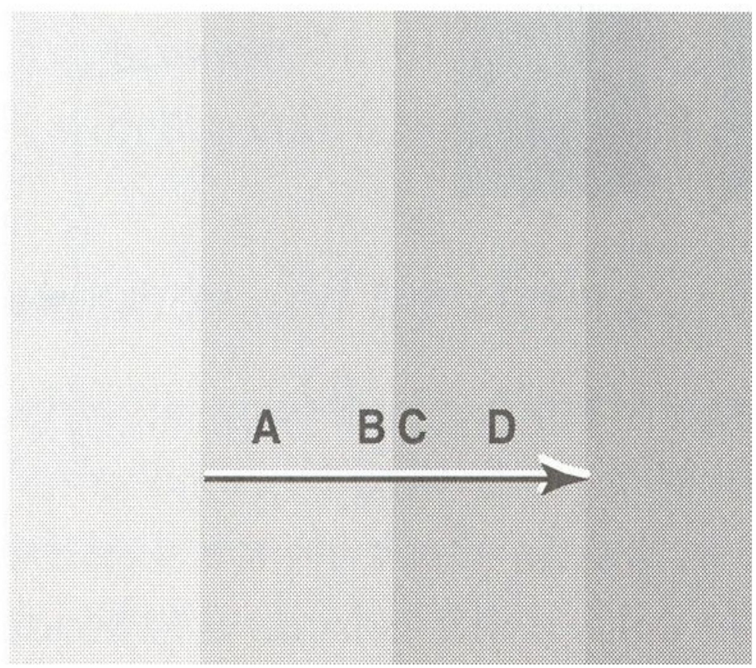
Hermann Grid

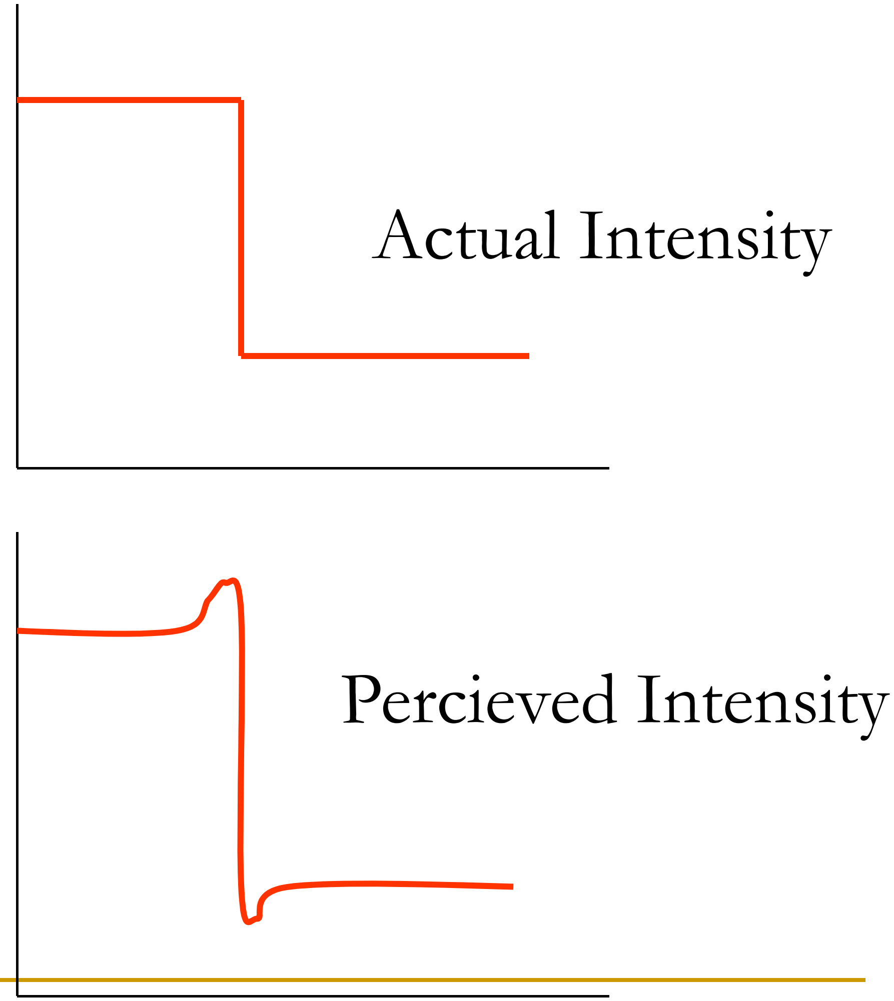


Explanation : Lateral Inhibition

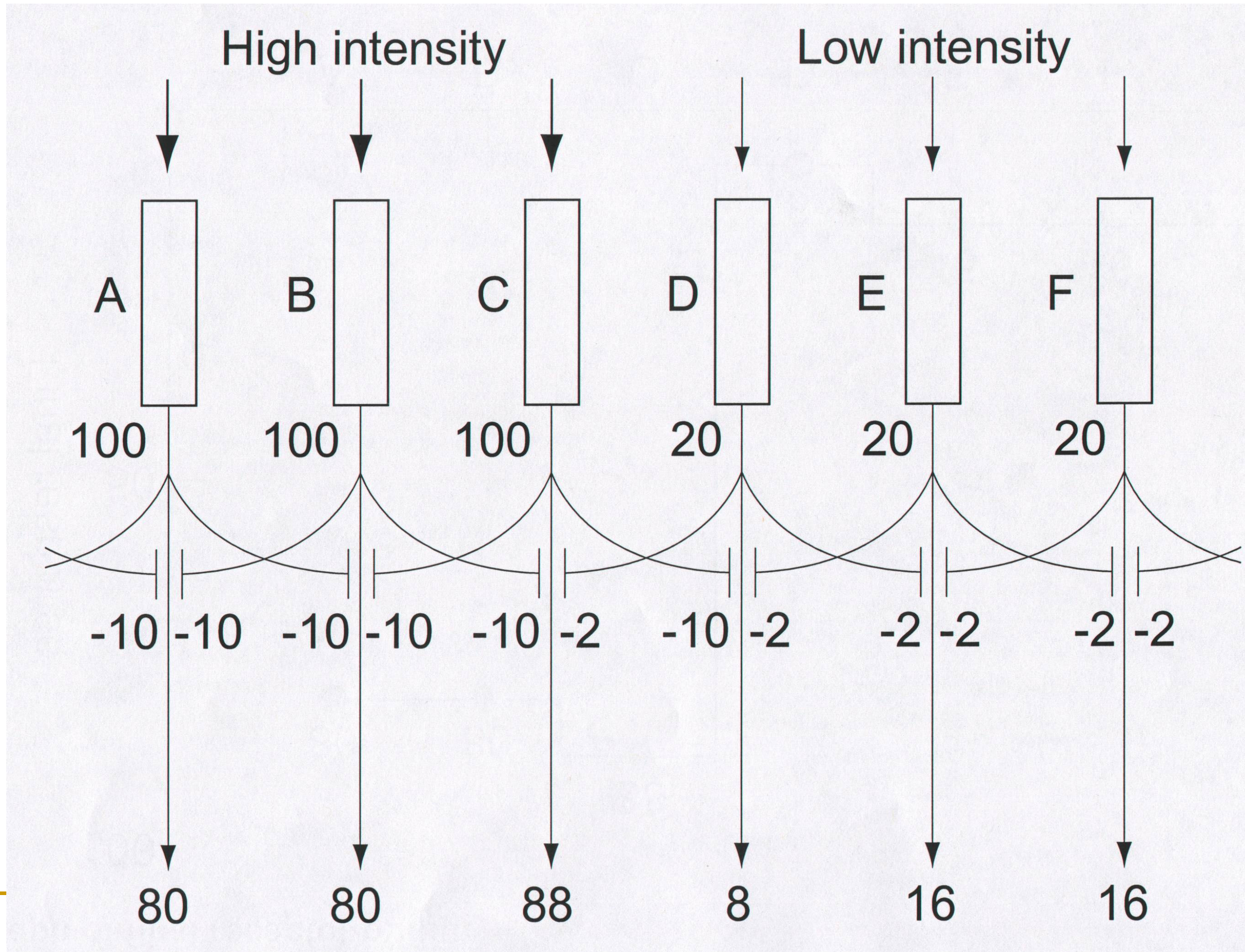


Mach Bands

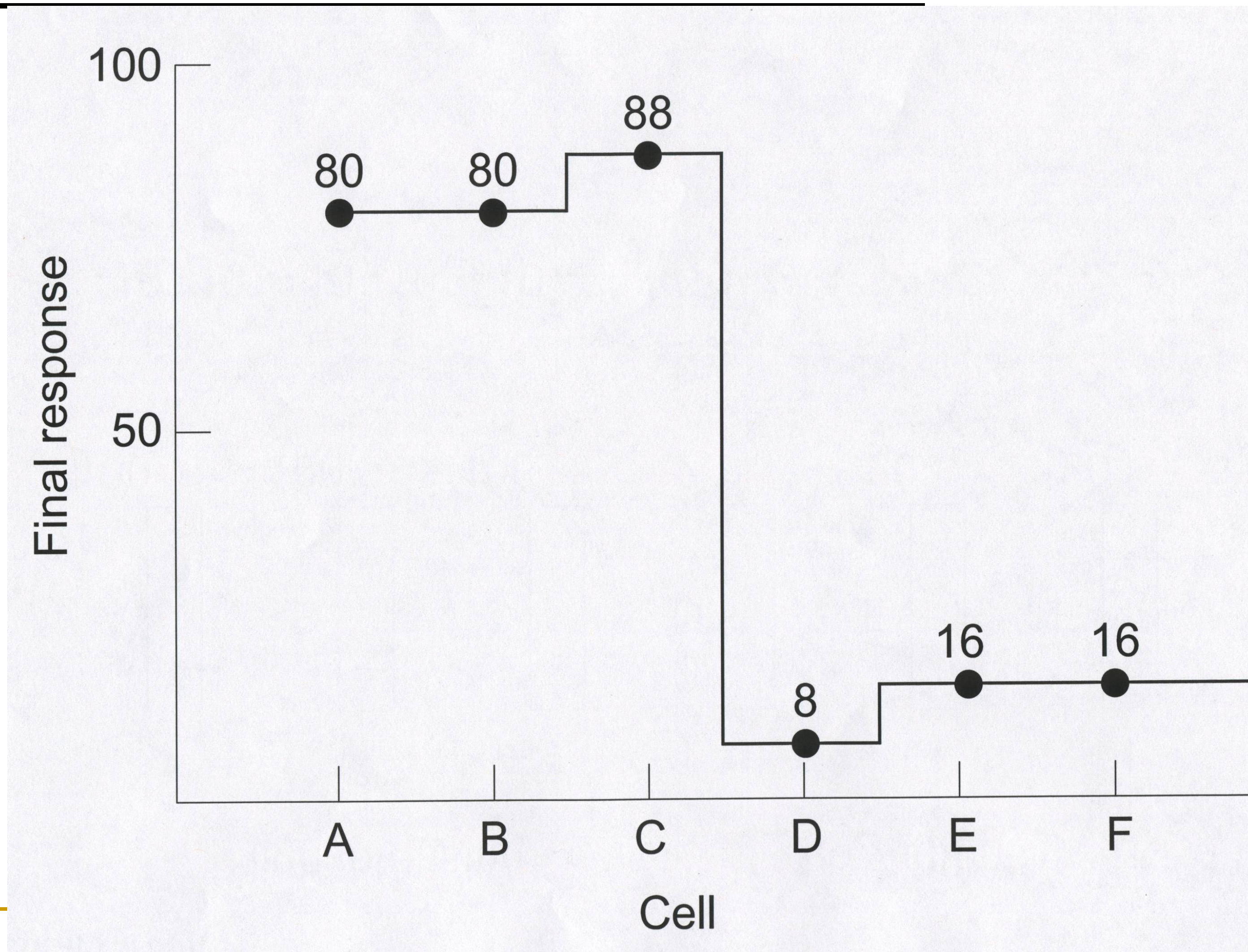




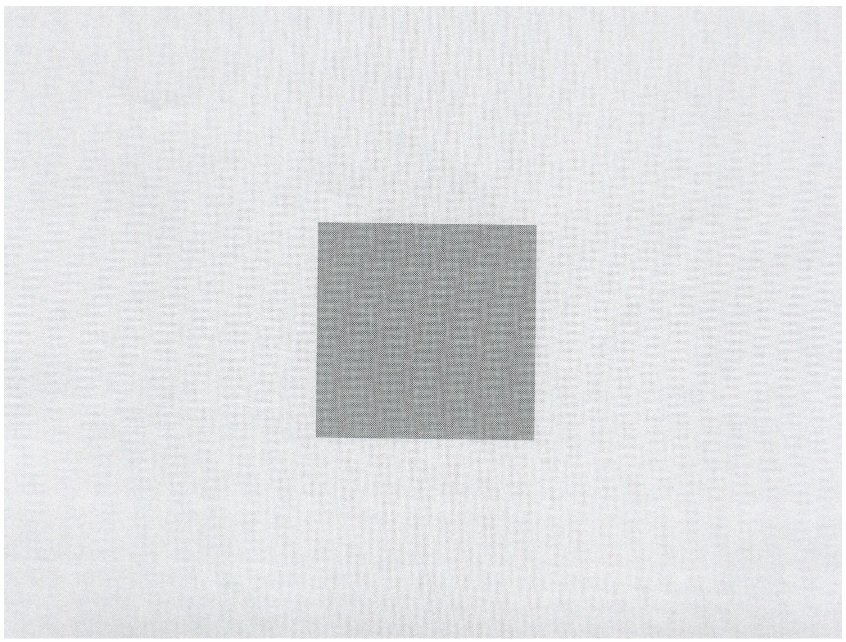
Explanation : Lateral Inhibition

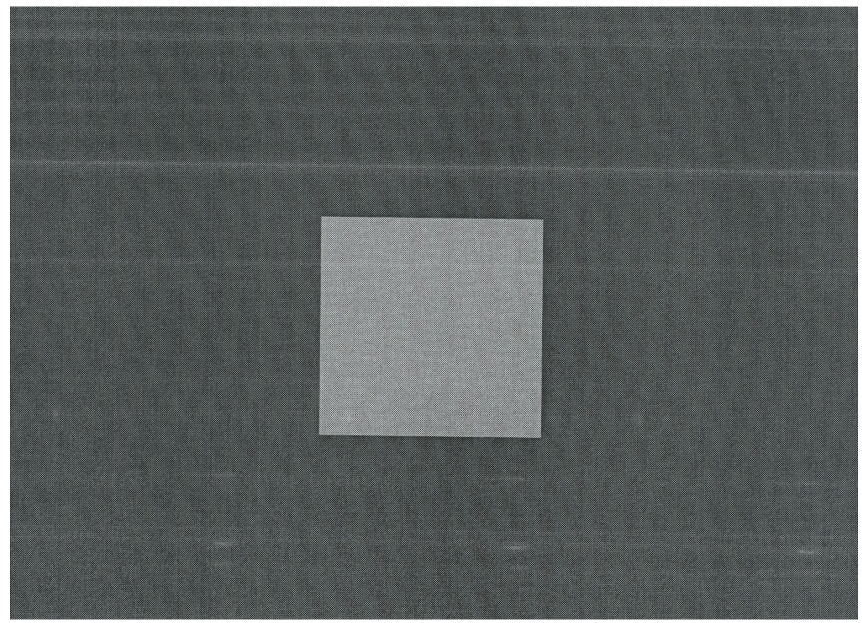


Explanation : Lateral Inhibition



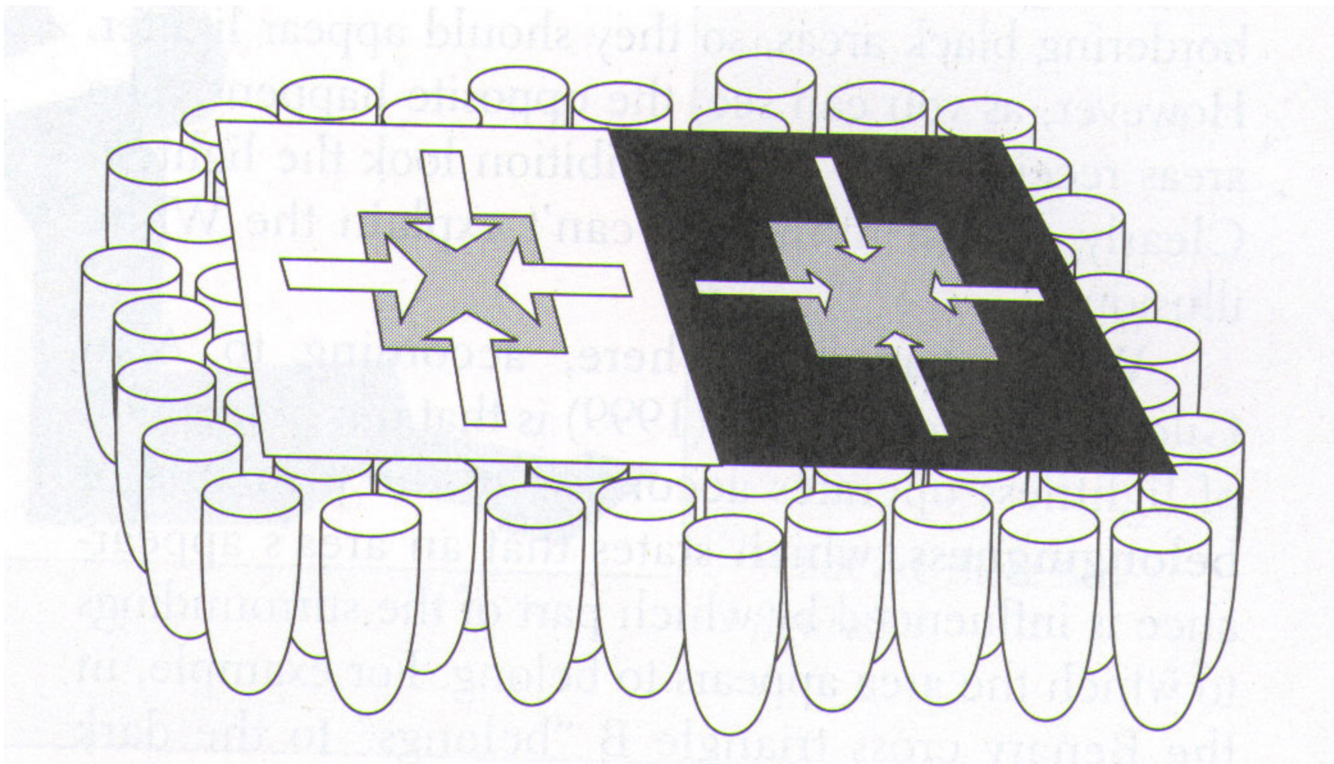
Simultaneous Contrast





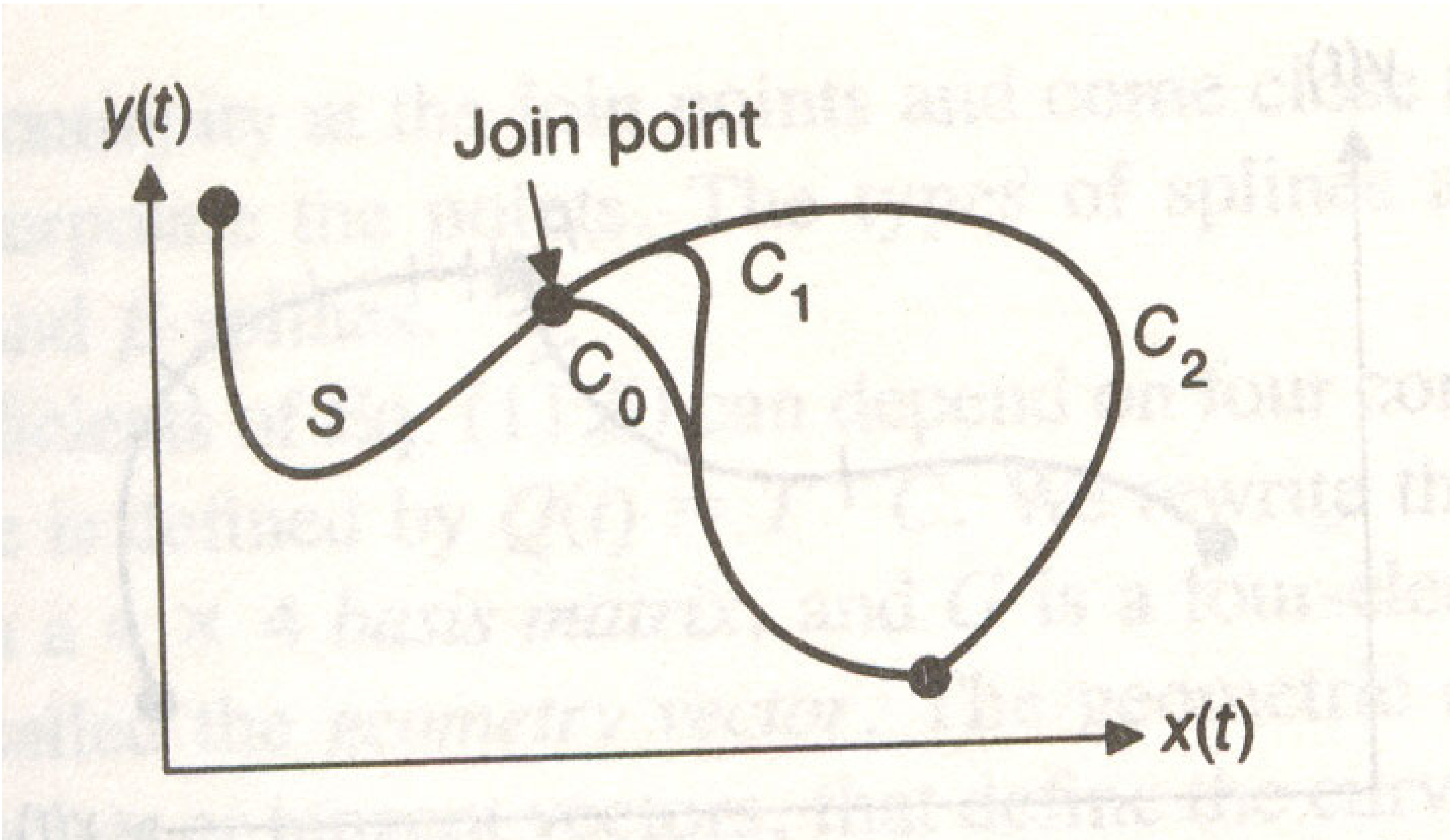
Simultaneous Contrast

Explanation : Lateral Inhibition

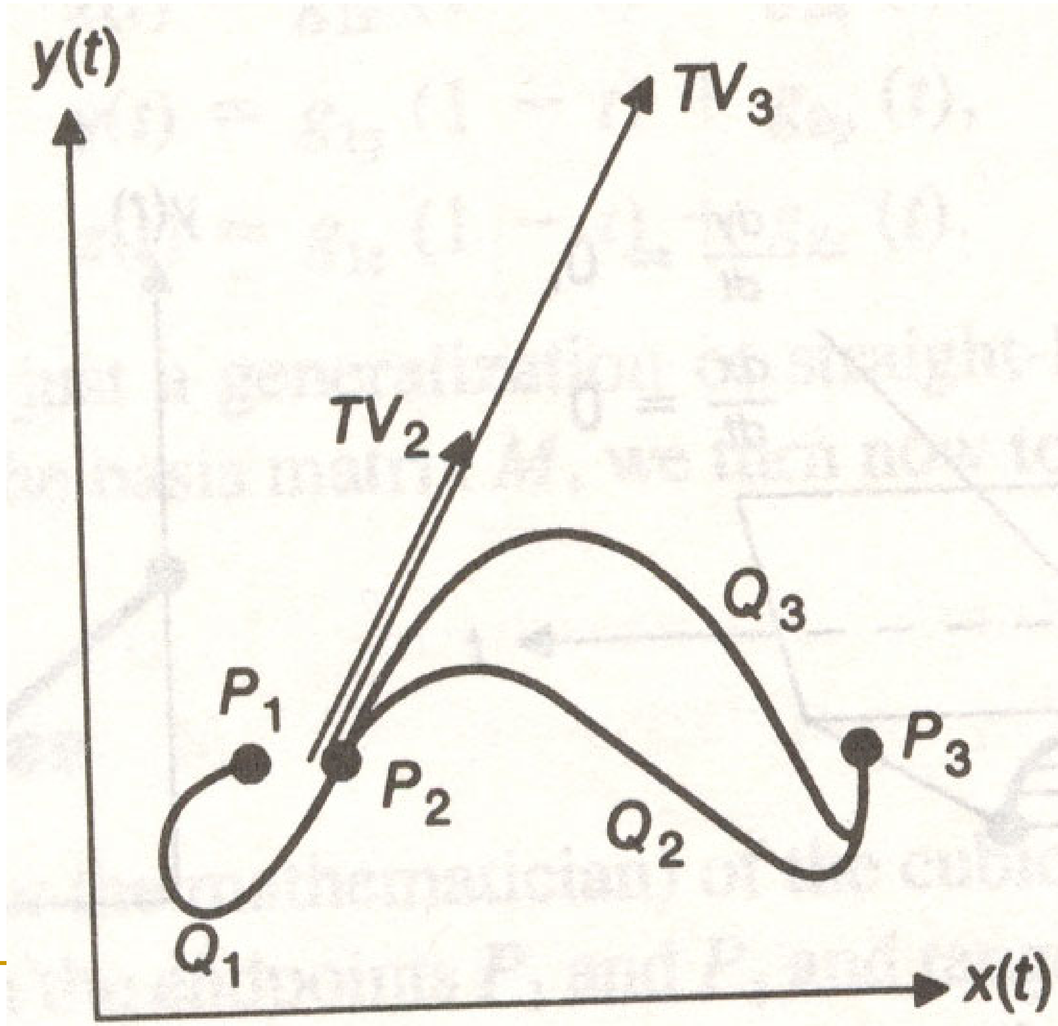


Applications

Theory of Continuity



Geometric Continuity

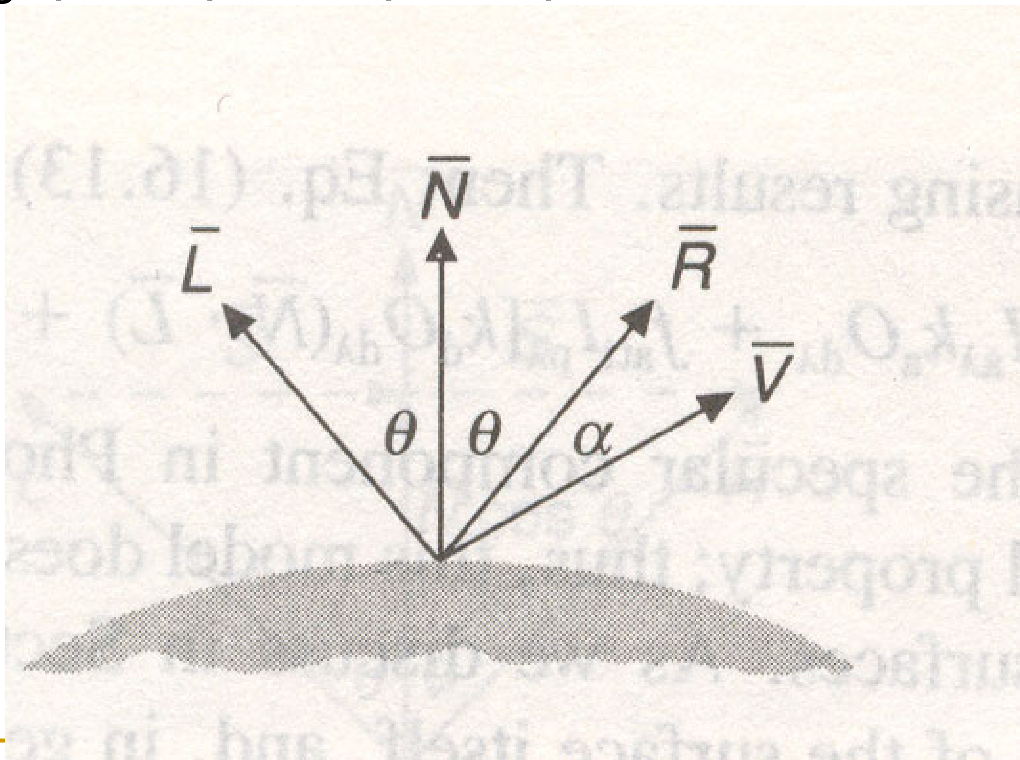


Mach Bands

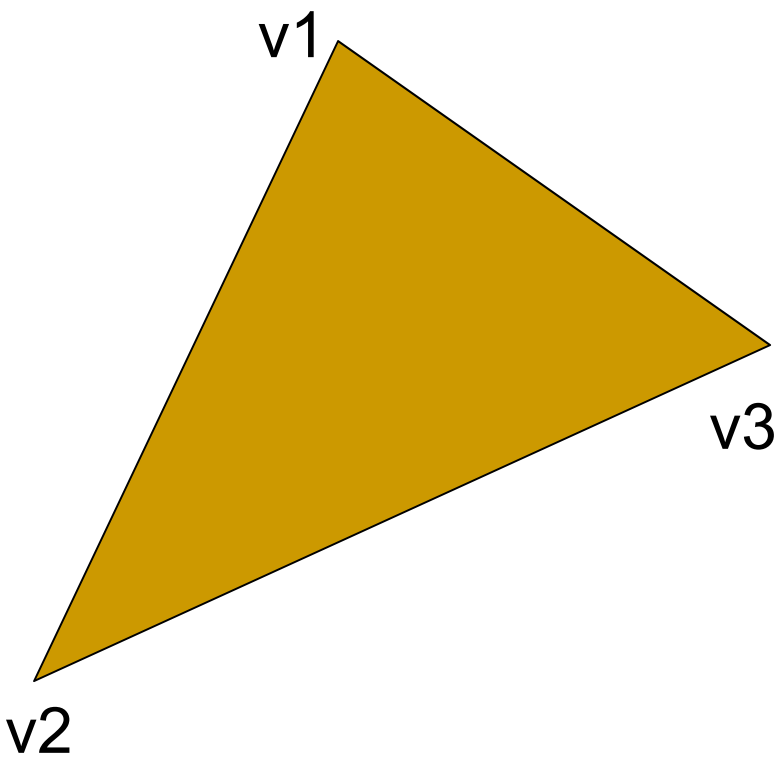
- Artifacts when any patch or curve does not show C^1 continuity
- They are always avoided
  - Shading
  - Blending
    - Image editing, contrast compressing, tone reduction
  - Geometric Modeling

Shading

- $I_d = k_d\,(L \,.\, N)$
- $I_s = k_s\,(2N\,(L \,.\, N) – L) \,.\, V$

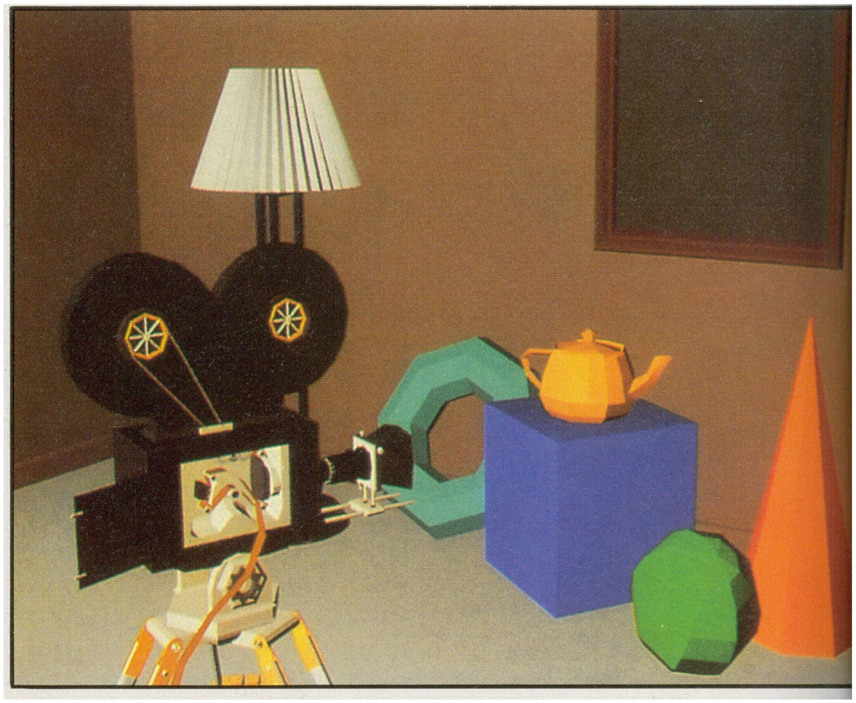


Shading

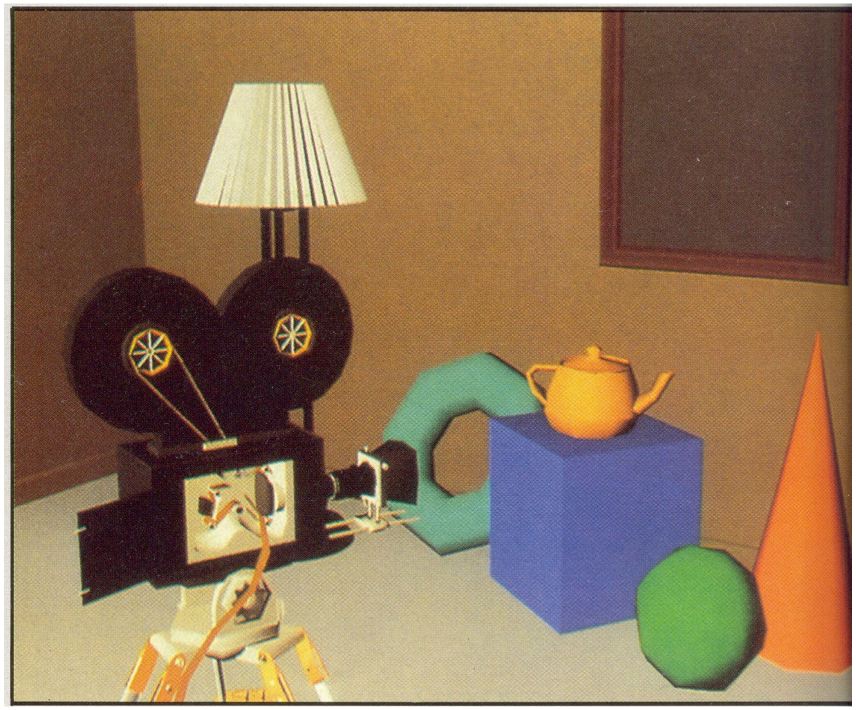


- Flat Shading
  - [I(v1)+I(v2)+I(v3)]/3
  - Is not C^0 continuous
- Interpolated Shading
  - Linear Interpolation of I(v1), I(v2) and I(v3)
  - Is C^0 continuous

Shading



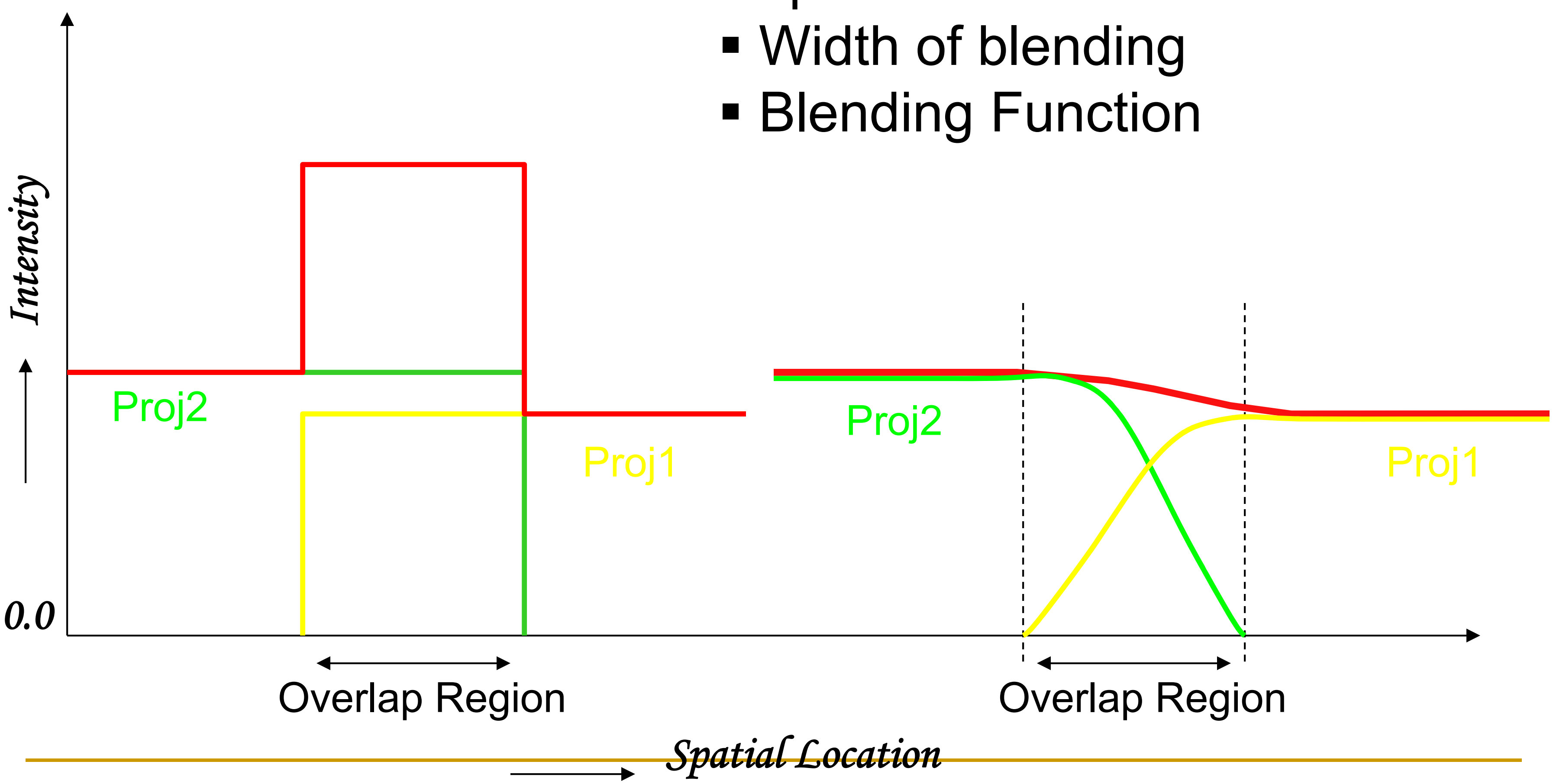
Flat Shading – Mach Bands



Interpolated Shading

Intensity Blending

Depends on
- Width of blending
- Blending Function



Intensity Blending

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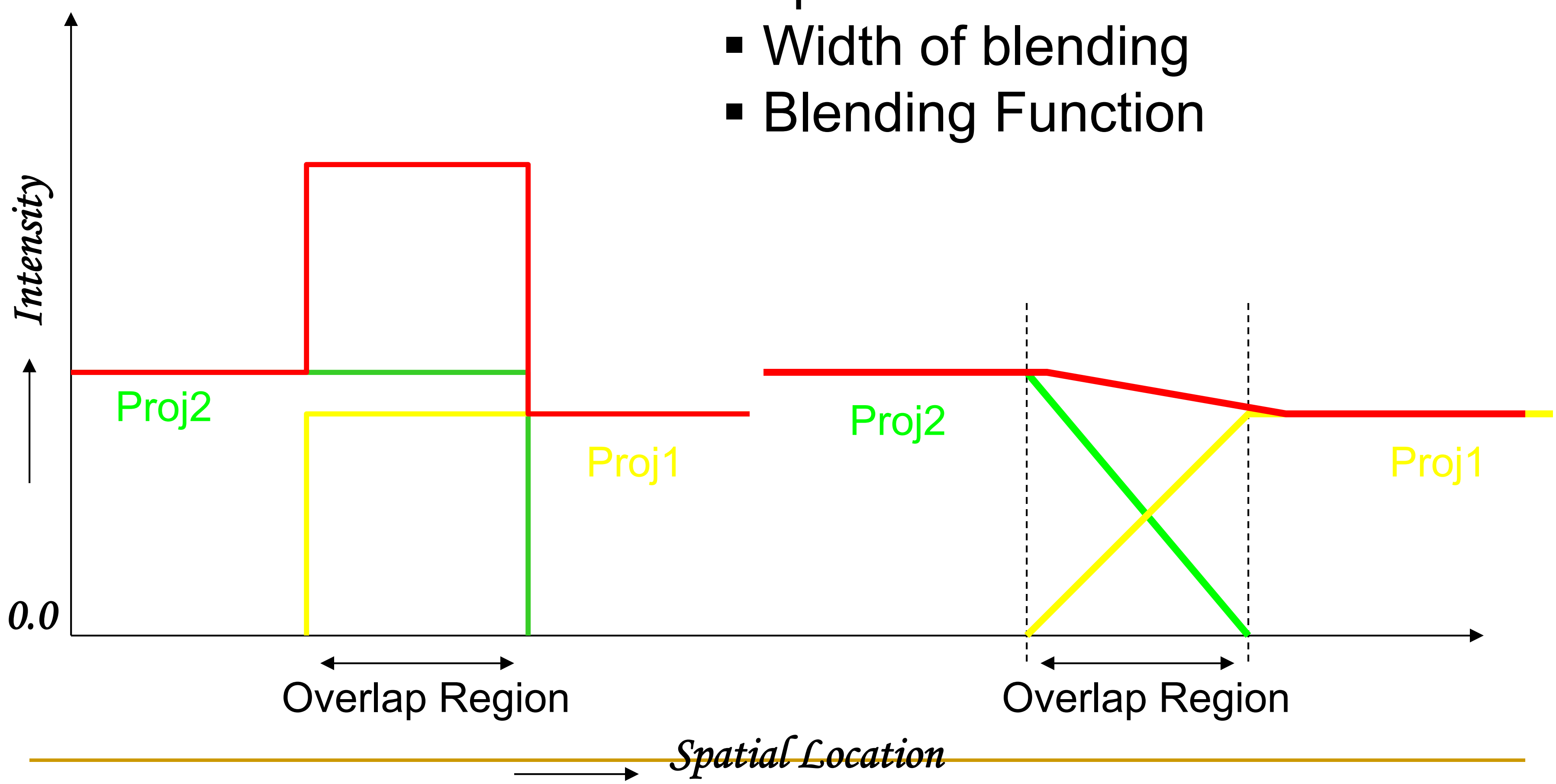

Intensity Blending

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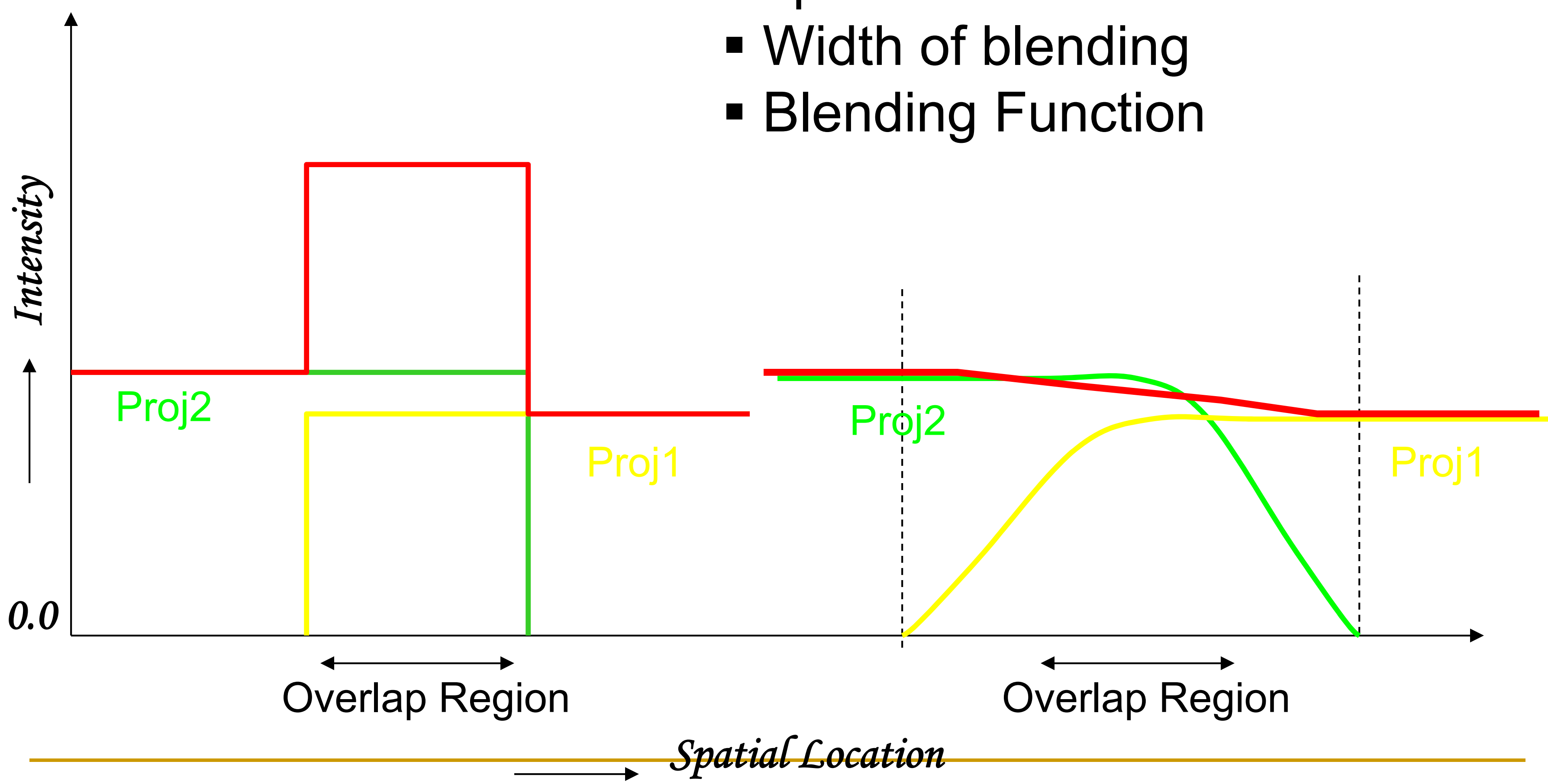
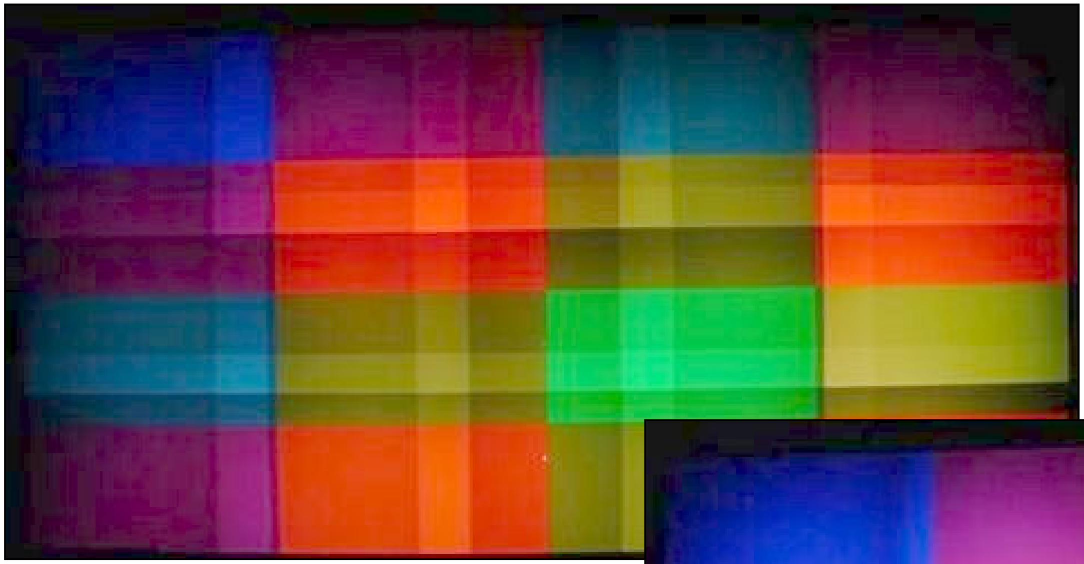
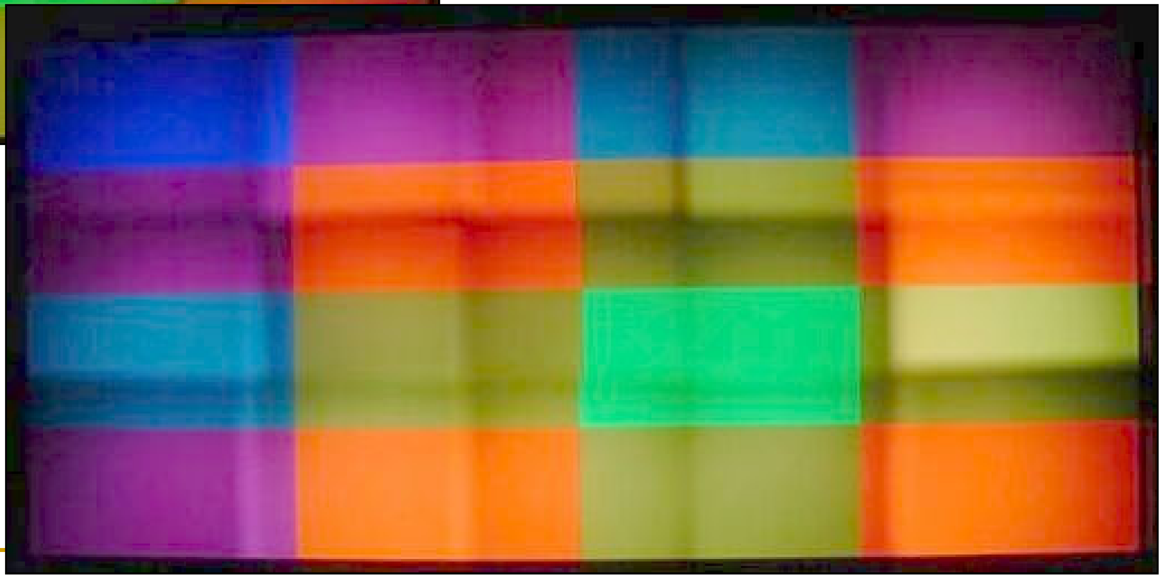
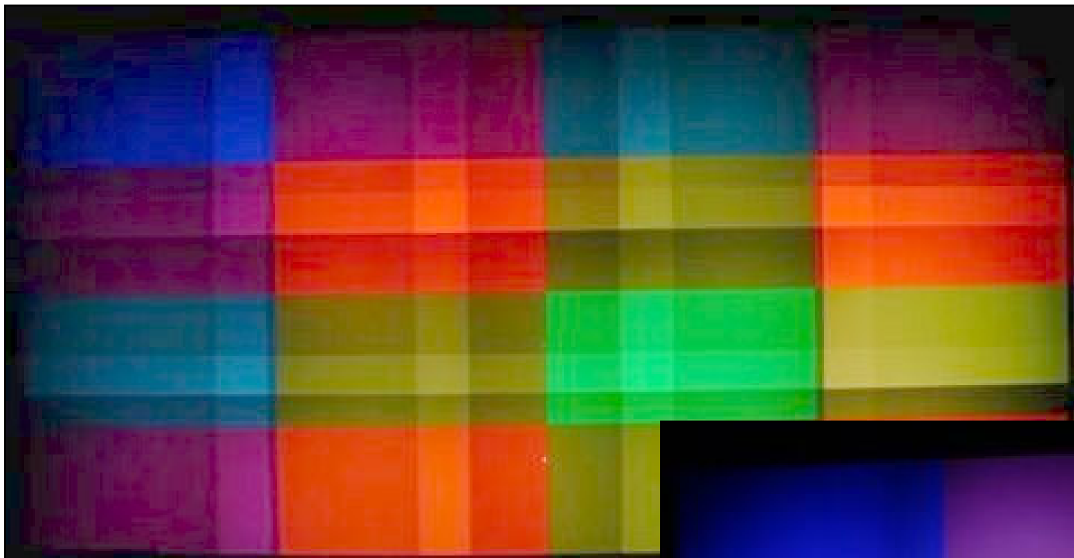


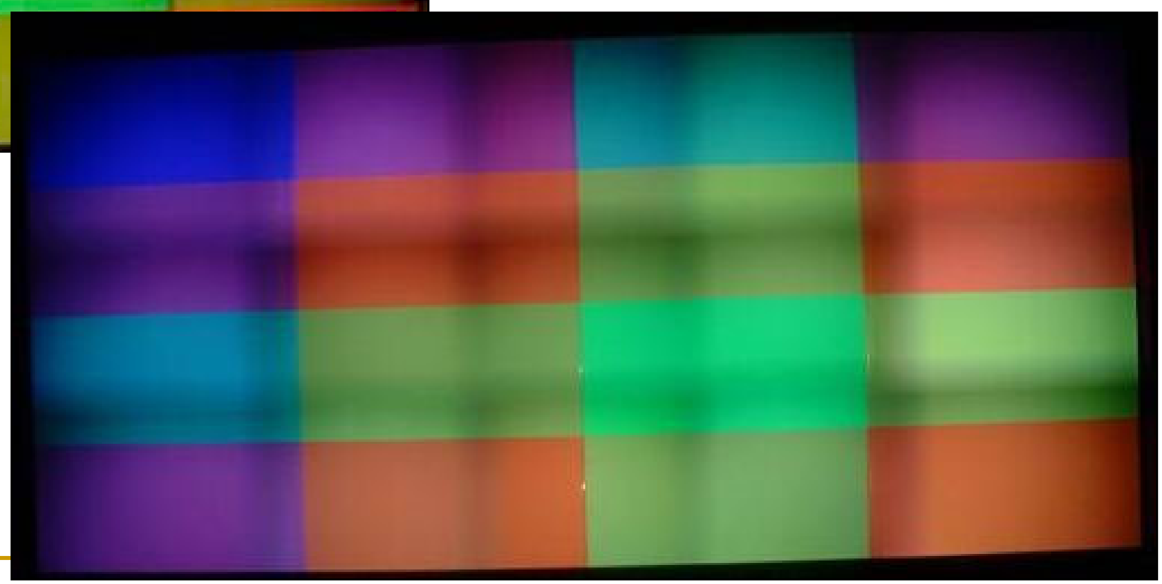
Intensity Blending





Intensity Blending





Applications

- Image Mosaics
- Multi-Projector Displays
- Image Editing

Geometric Modeling Primitives

- Three properties
  - Continuous
  - Continuous with transformations
  - Continuous with subdivisions

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