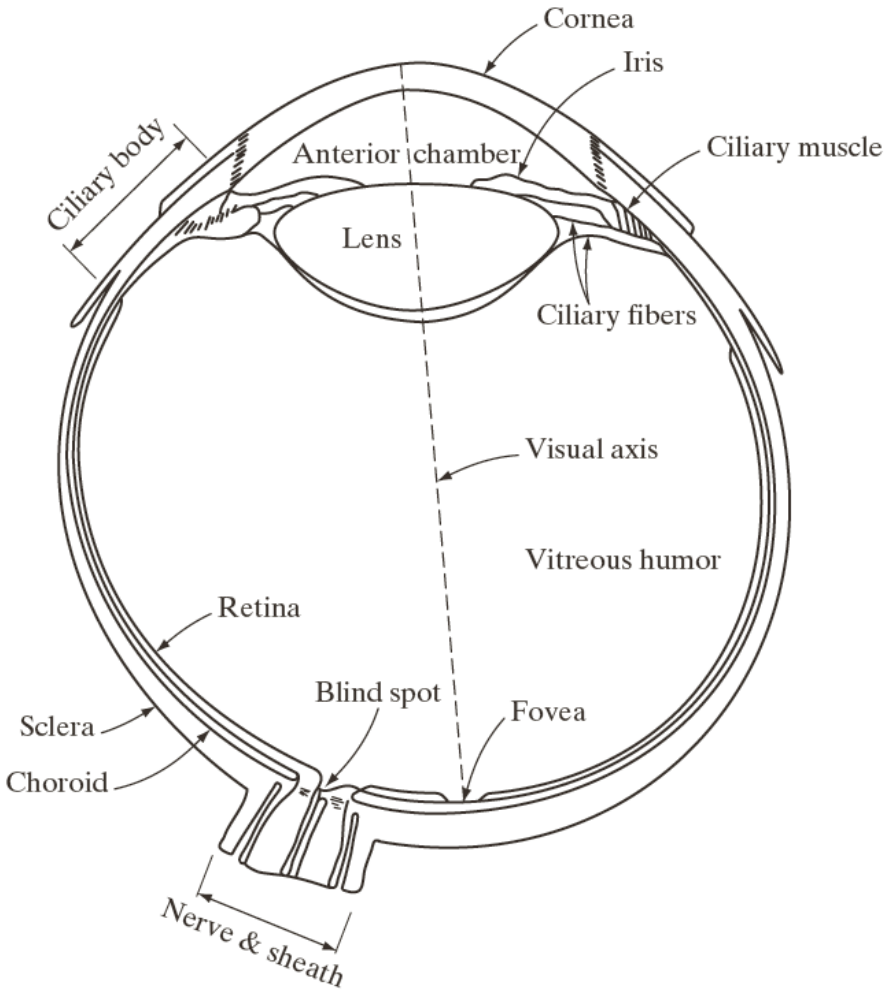
SYDE 575: Introduction to Image Processing

Pyschovisual Model

Human Eye

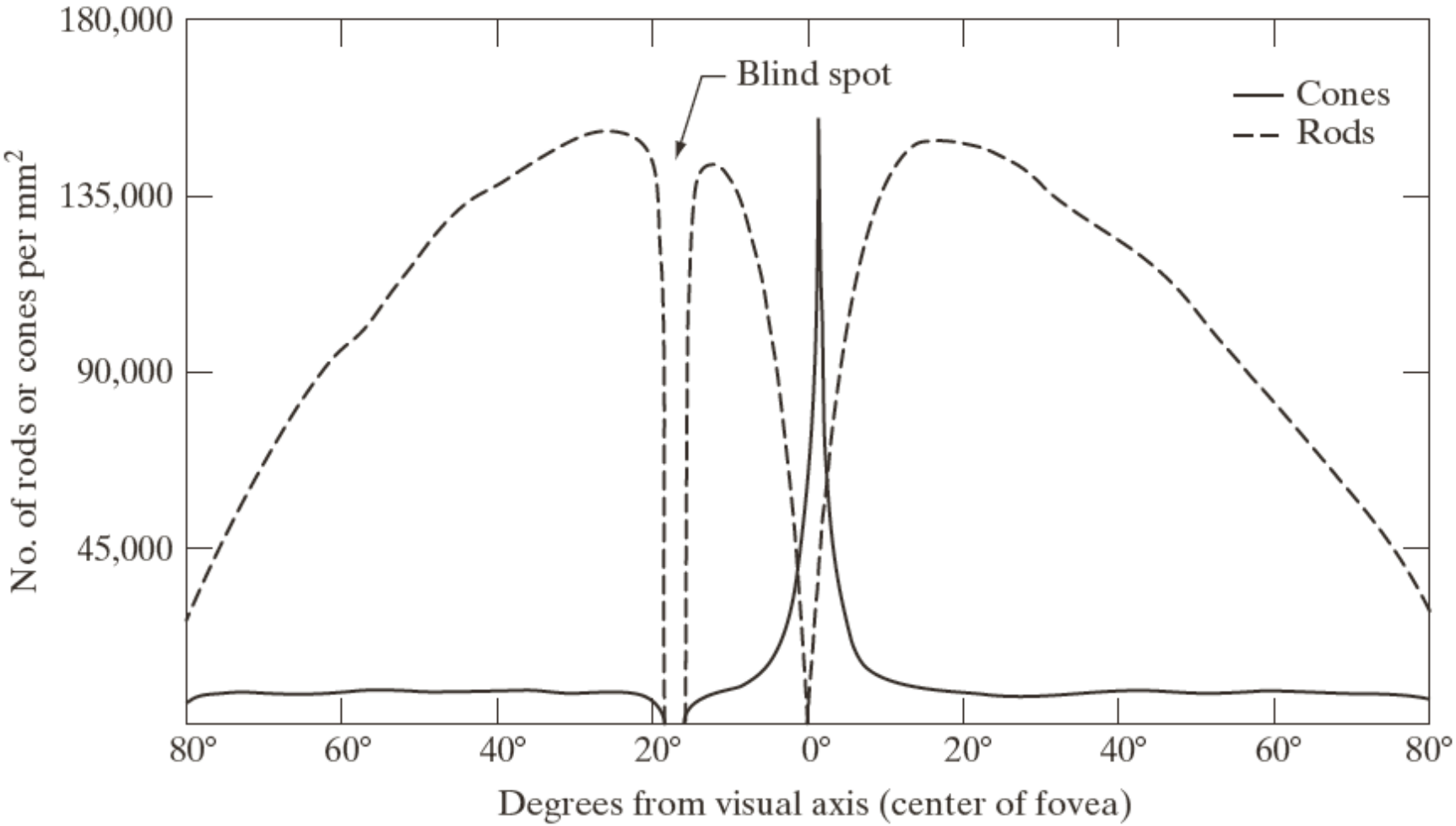


Source: Gonzalez and Woods

Rods and Cones

- Rods
  - 75 to 150 million
  - High light sensitivity
  - Dim-light vision (scotopic)
  - Monochrome vision
  - Low visual resolution (shares nerve ends)
- Cones
  - 6 to 7 million
  - Low light sensitivity
  - Bright-light / day-time vision (photopic)
  - High visual resolution (has own nerve end)
  - Color vision

Distribution of Rods and Cones

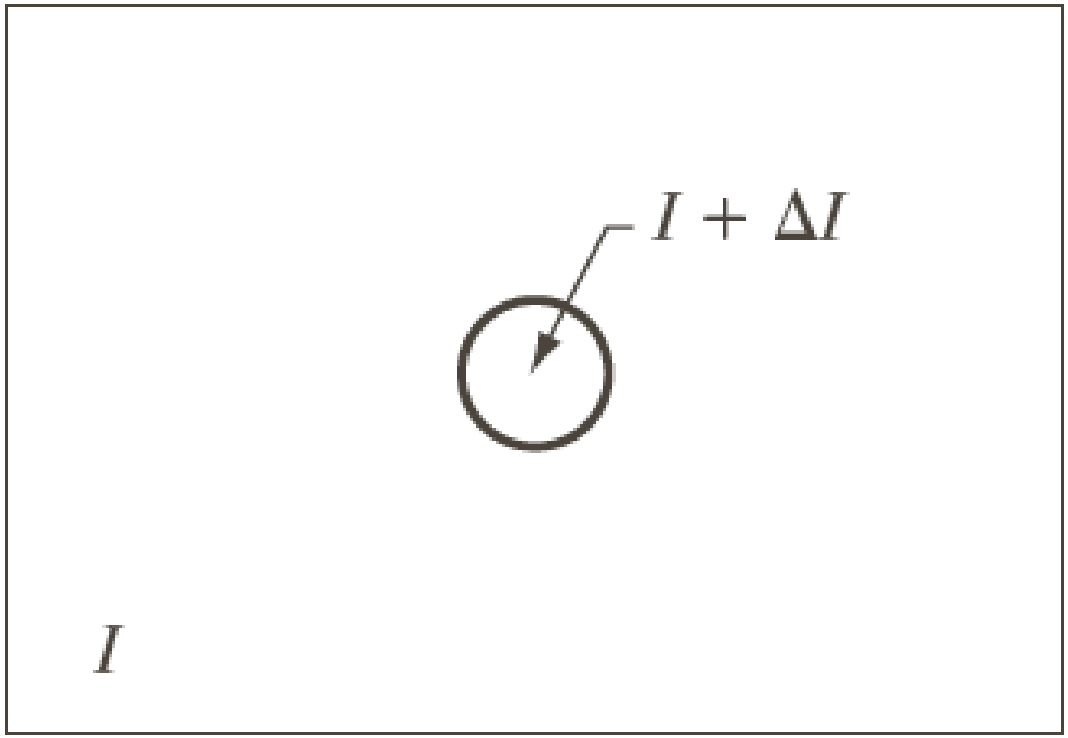


Source: Gonzalez and Woods

Blind Spot

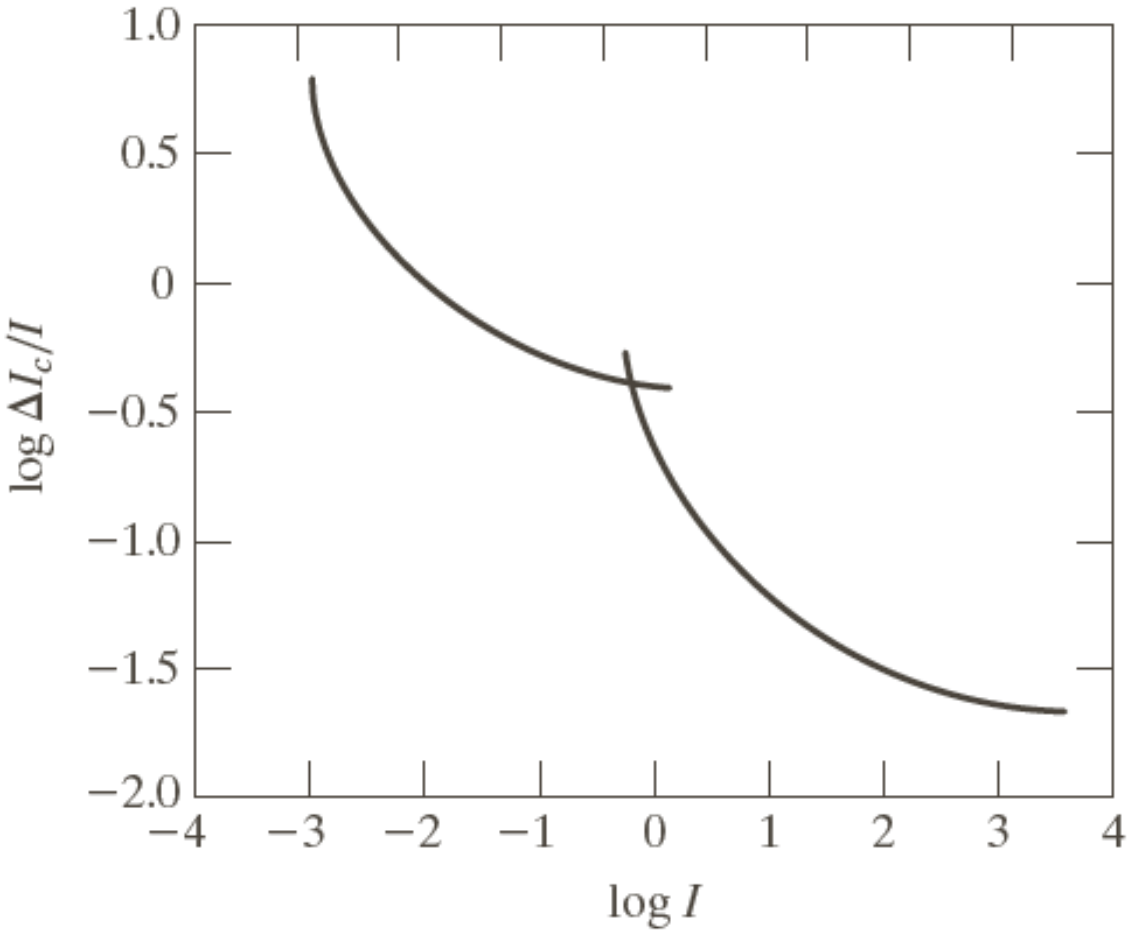
- Close left eye and stare at cross with right eye
- Move farther and closer from screen until dot

Brightness Adaptation



Source: Gonzalez and Woods

Weber Ratio



Source: Gonzalez and Woods

What does it mean?

- Brightness discrimination poor (large Weber ratio) at low levels of illumination
- Brightness discrimination improves (small Weber ratio) at high levels of illumination
- Reflects fact that dim-light vision carried out by rods, while bright-light vision carried out by cones.

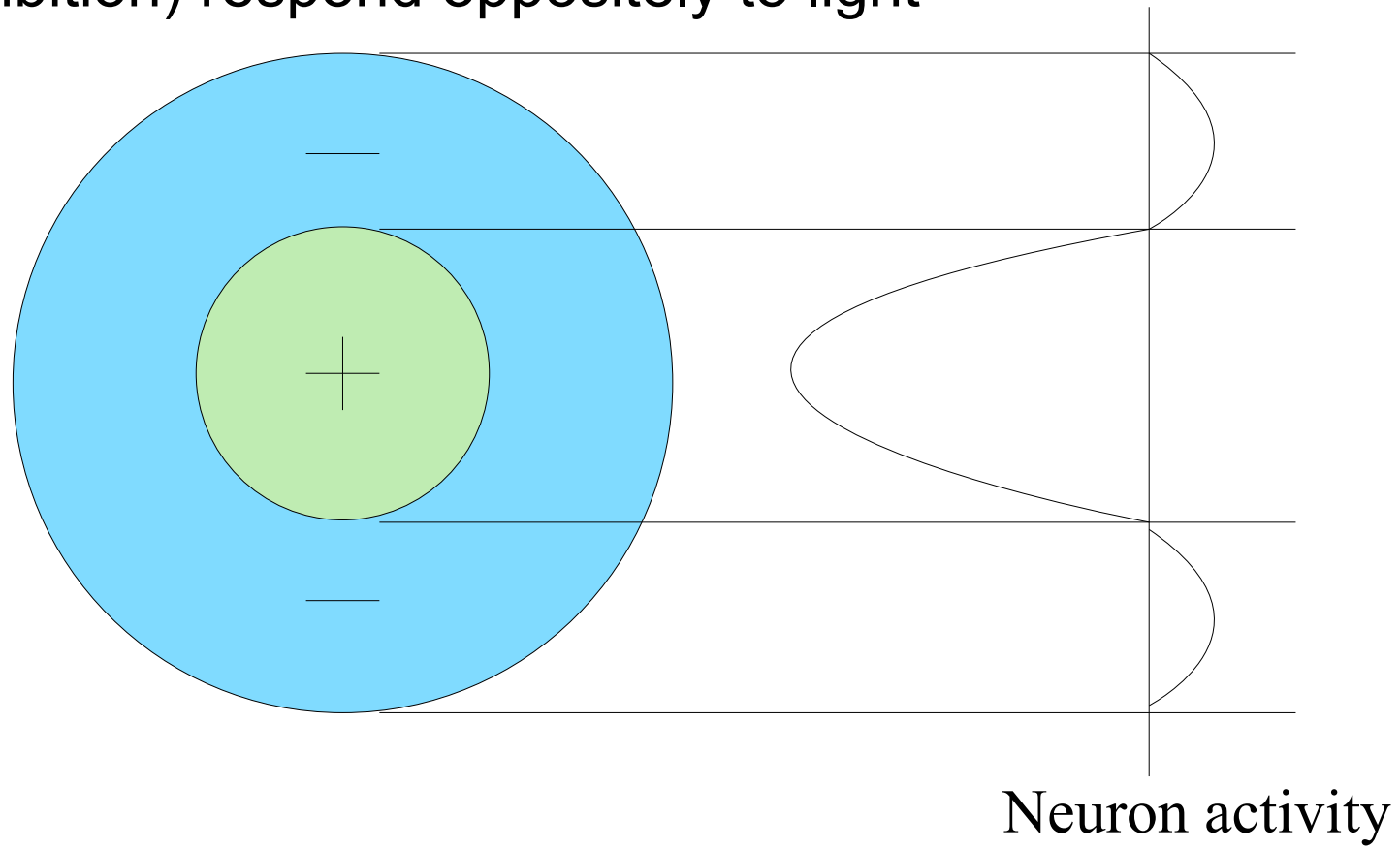
Color vs. Luminance Sensitivity

- Human vision system is less sensitive to changes in chrominance (color) than luminance (brightness)

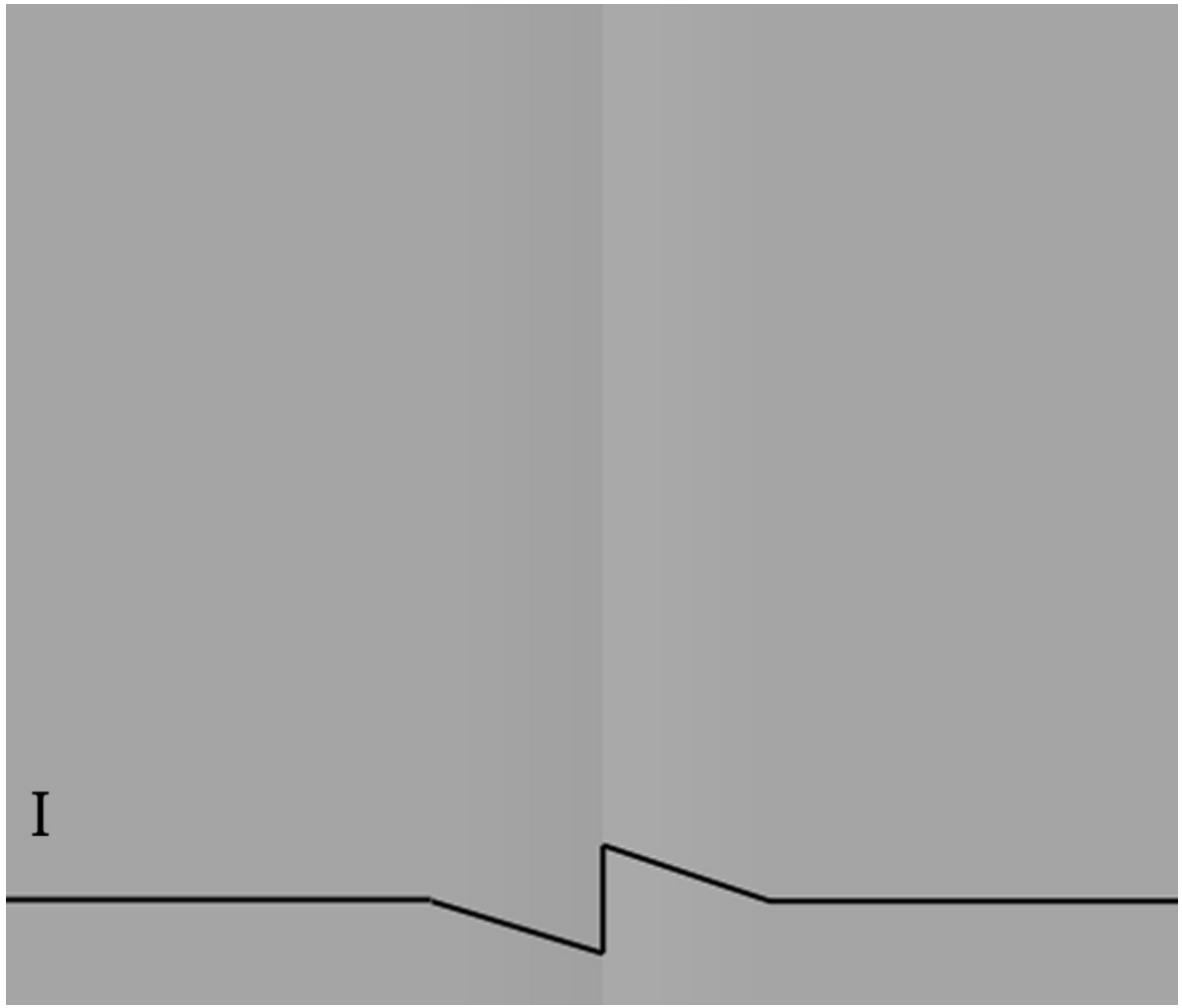
¼ color information

Retinal Ganglion Cells

- Receptive field of ganglion cell organized for contrast detection (discontinuities in distribution of light)
- Centre (lateral excitation) and surround regions (lateral inhibition) respond oppositely to light



Effect of Lateral Inhibition and Excitation (Cornsweet Effect)



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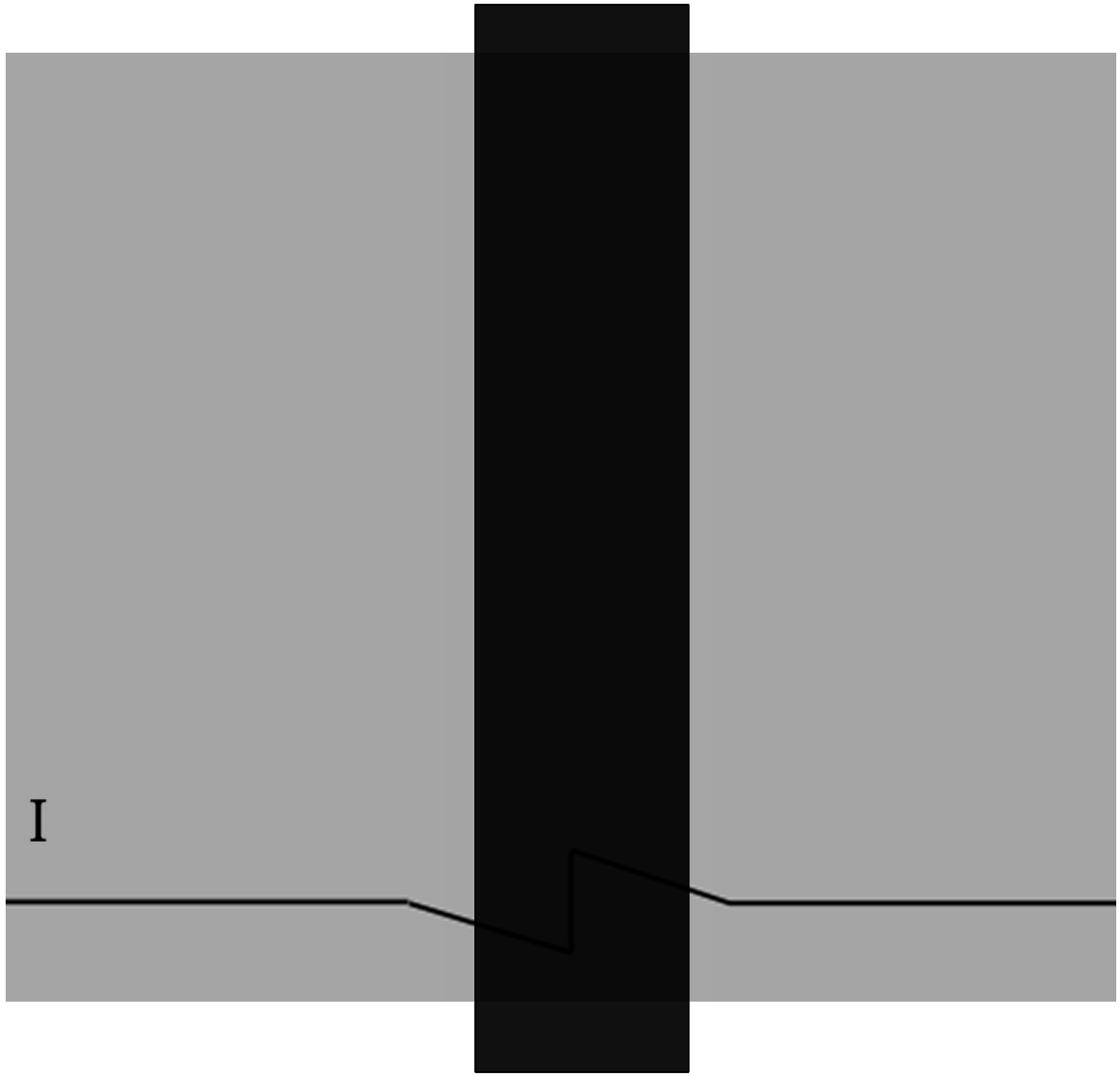

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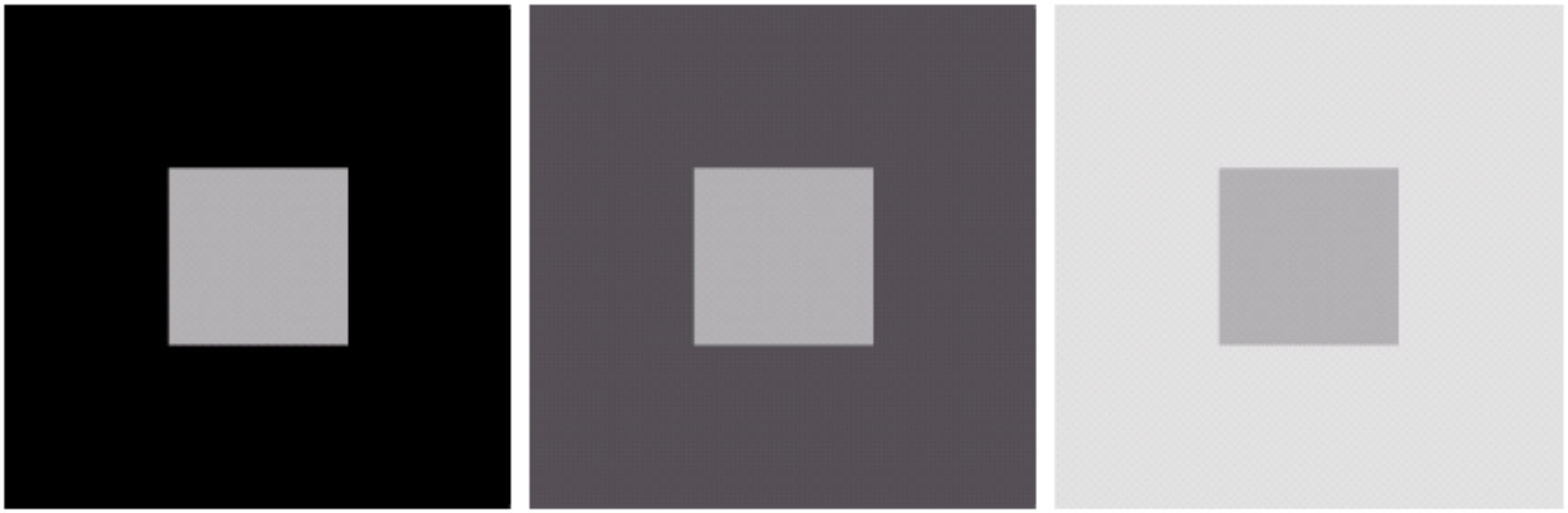


a b c

FIGURE 2.8 Examples of simultaneous contrast. All the inner squares have the same intensity, but they appear progressively darker as the background becomes lighter.

Source: Gonzalez and Woods

Why?

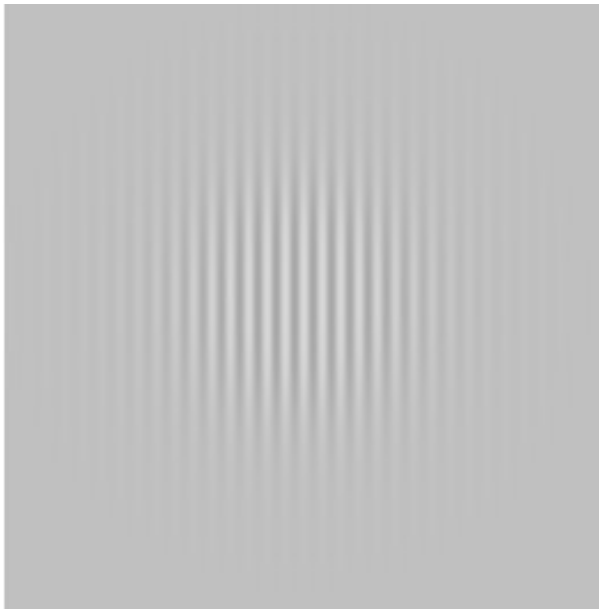
- Cells near edge of grey square on right say decreasing intensity as you move into square
- Cells near edge of grey square on left say increasing intensity as you move into square
- Relative intensity has significant impact on perception

Spatial Contrast Sensitivity

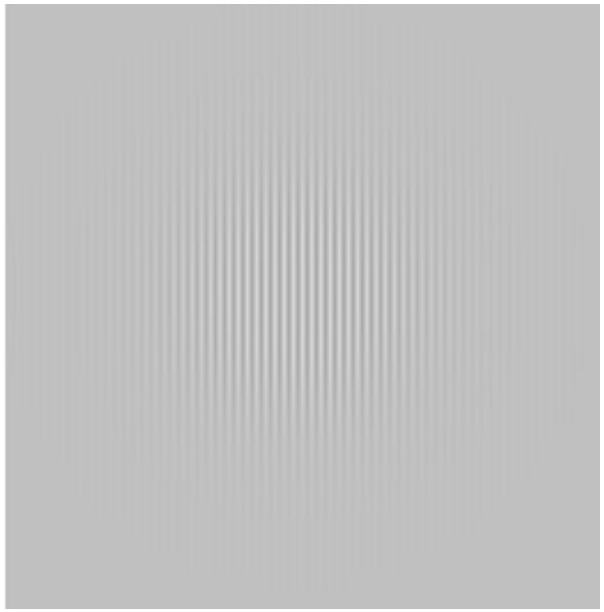
- Size of retinal ganglion cells' receptive field controls spatial frequency sensitivity
- Small receptive fields
  - Sensitive to high spatial frequencies
  - Responsible for fine detail
- Large receptive fields
  - Sensitive to low spatial frequencies
  - Responsible for coarse detail

Sine Wave Grating

8 cycles/ deg



32 cycles/ deg



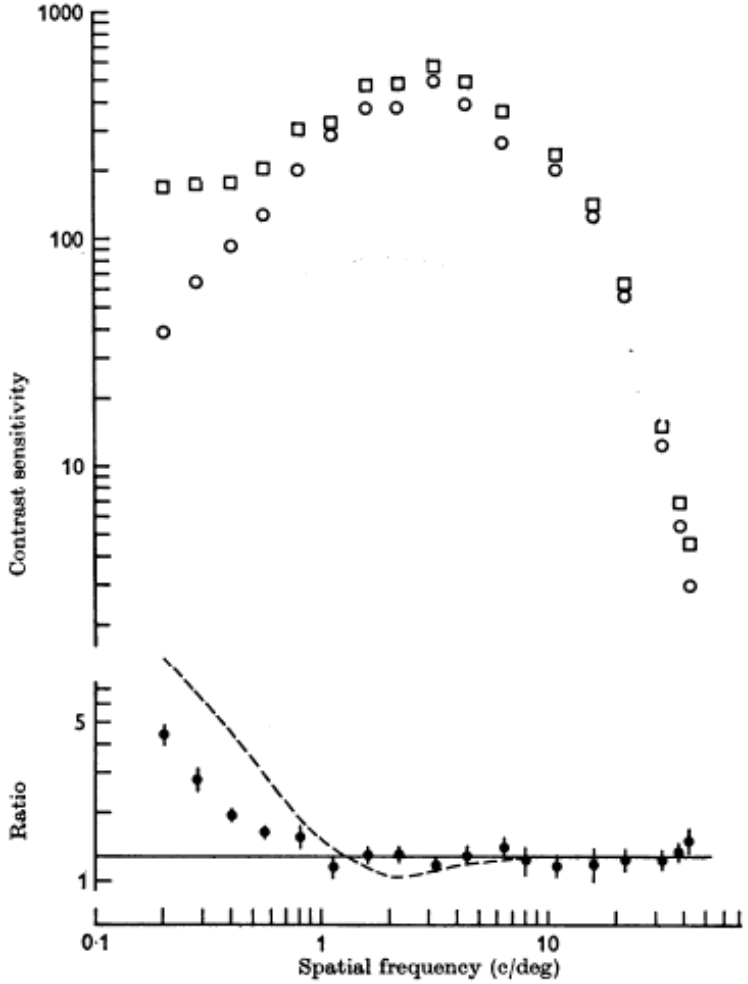
64 cycles/ deg

Source: Schieber, 1992

Spatial Contrast Sensitivity

- Lateral inhibition results in bandpass nature of spatial contrast sensitivity of human vision system
- For coarse gratings (low frequencies), bands fall on both centre and surround region
- This results in lateral inhibition and low frequency drop-off in contrast sensitivity
- High resolution drop-off due to optical limitations (e.g., packing density of photoreceptor cells)

Contrast Sensitivity Function



Source: Campbell et al., 1968

Effects of Spatial Contrast Sensitivity

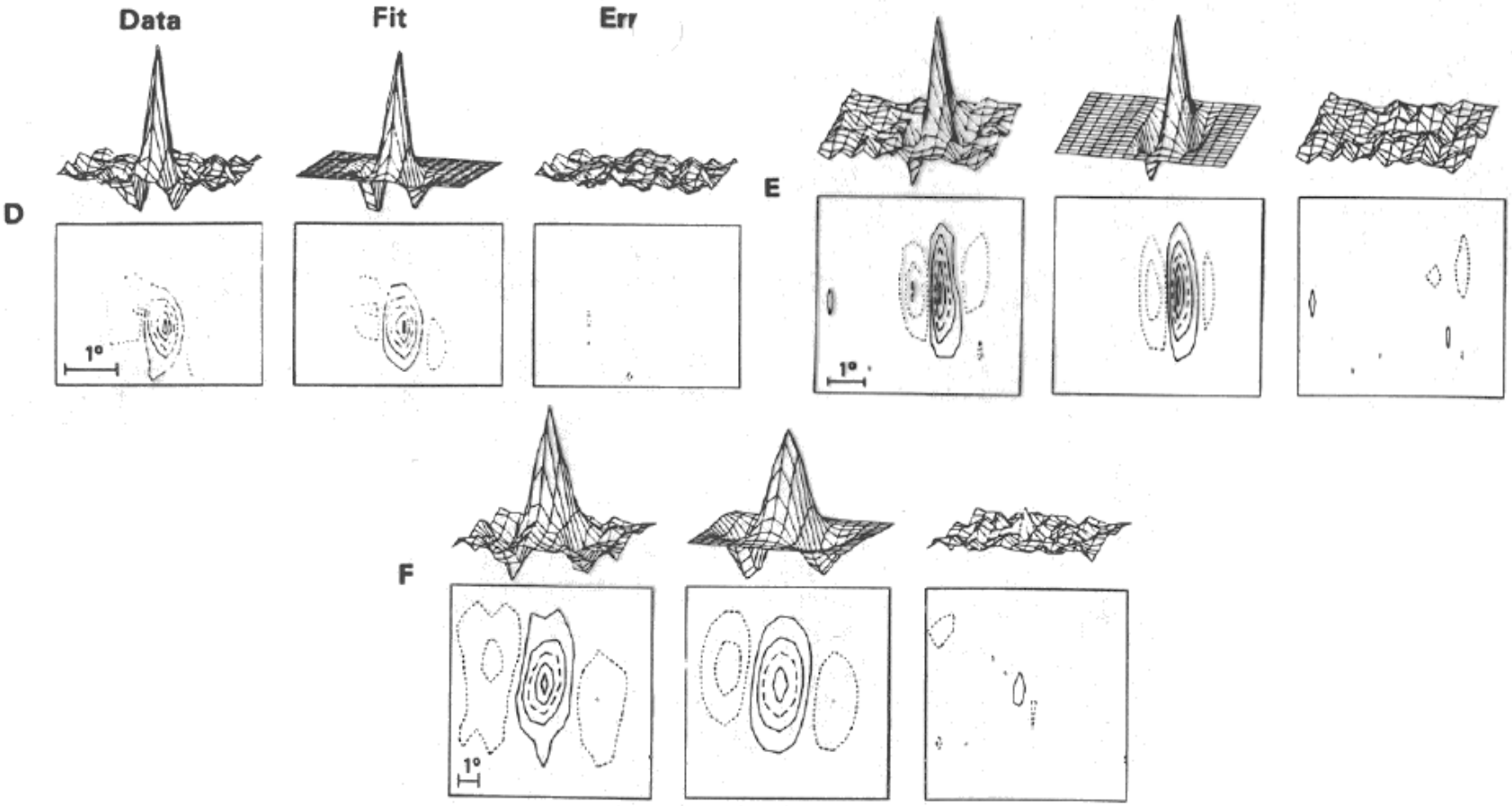
- Human vision good at spotting small brightness differences in low to medium frequencies
- Human vision poor at judging brightness differences in regions with high frequency information
- Human vision more sensitive to noise in low to medium frequency regions than high frequency regions

Source: Schieber, 1992

Primary Visual Cortex (V1)

- Earliest and largest cortical visual area
- Majority of all visual information enter cortex through V1
- V1 neurons considered simplest of all neurons in visual cortext
- Early V1 neurons tuned to low-level visual characteristics such as orientations and spatial frequencies
- Often modeled using Gabor wavelets

Response of V1 neurons



Source: Jones et al., 1987

Why care about all of this?

- Image quality is highly subjective and greatly dependent on the way our vision system works
- By taking into account the pyschovisual characteristics of the human vision systems, we can:
  - Design image processing algorithms that make images looks better perceptually
  - Design image compression algorithms that look almost as good as the original while storing much less information
  - Design information extraction algorithms that provides good representation of the image content