

Human visual system

Dr. Tushar Sandhan

Introduction

- Mantis shrimp



- Tarsier



Introduction

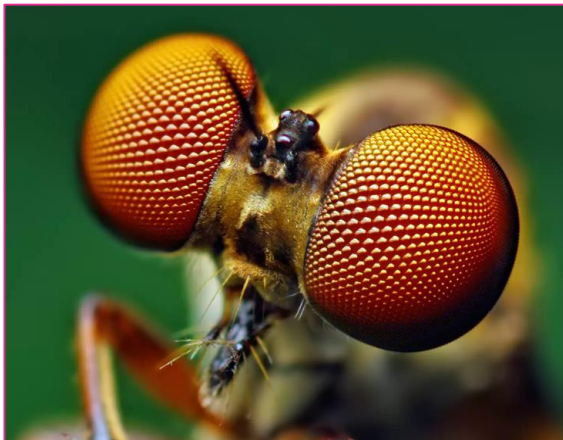
- Mantis shrimp



- Tarsier



- Robber fly



Introduction

- Mantis shrimp



- Tarsier



- Great ape species

Chimpanzee
(*Pan troglodytes*)



Bornean orangutan
(*Pongo pygmaeus*)



Mountain gorilla
(*Gorilla beringei*)



Sumatran orangutan
(*Pongo abelii*)



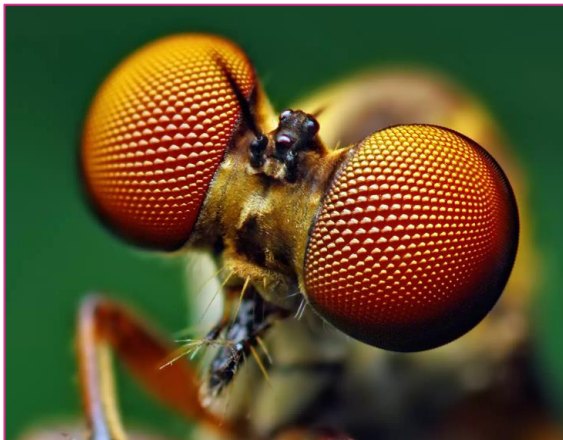
Lowland gorilla
(*Gorilla gorilla*)



Human
(*Homo sapiens*)



- Robber fly



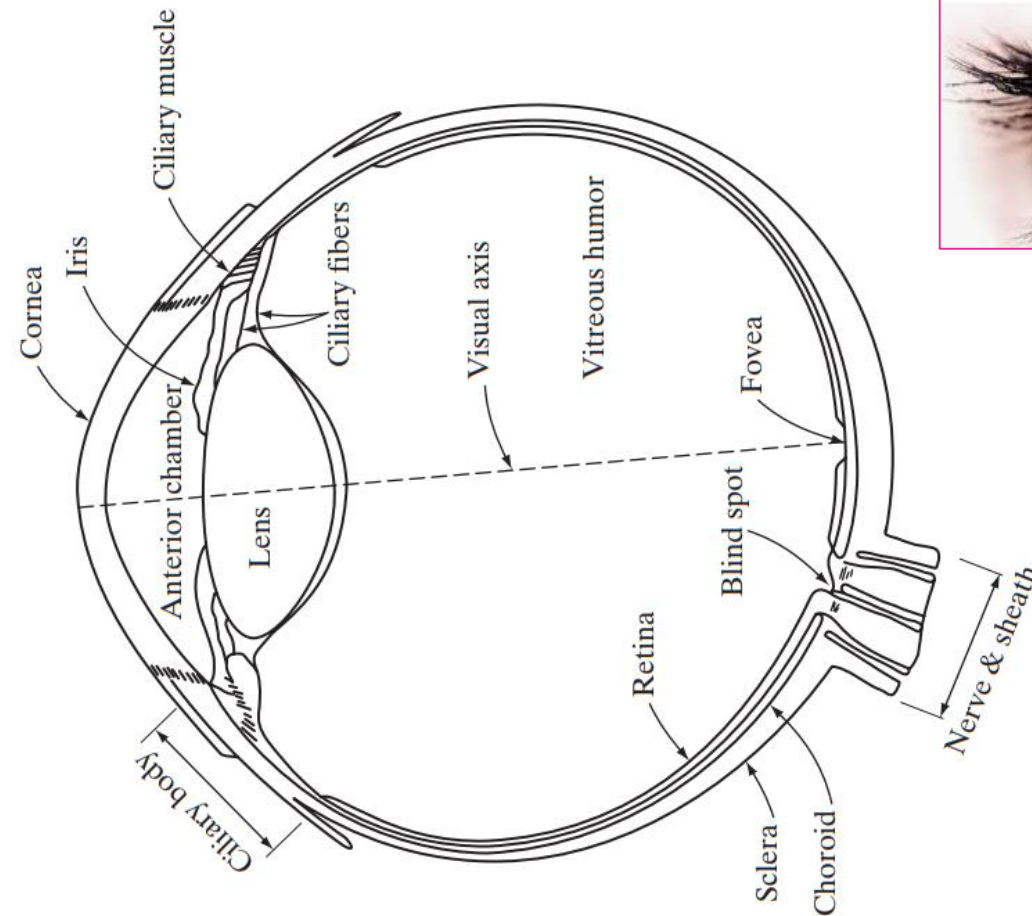
$$\text{Sclera Area Index} = \text{Sclera area} / \text{Eye-opening area}$$

credit: F. Kano et al.

Human visual system

■ EYE

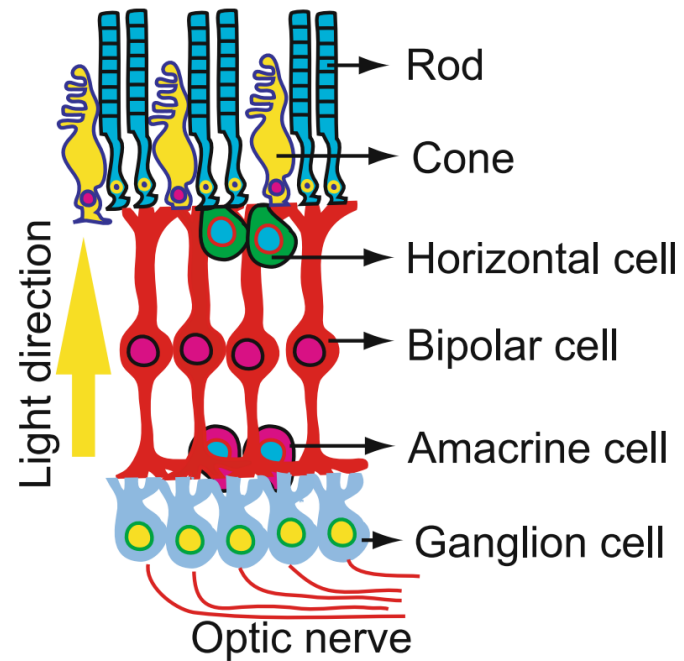
- Cornea
- Sclera
- Choroid (blood vessel network)
 - ciliary body
 - iris (light controller)
 - central opening – pupil
- Lens (concentric fibrous cells)
 - higher proteins – absorb UV, IR
 - cataract
 - F.L. = 14~17mm
- Retina
 - cones (photopic vision - bright light)
 - rods (scotopic vision - dim light)



Human visual system

- Distribution of Rods & Cones

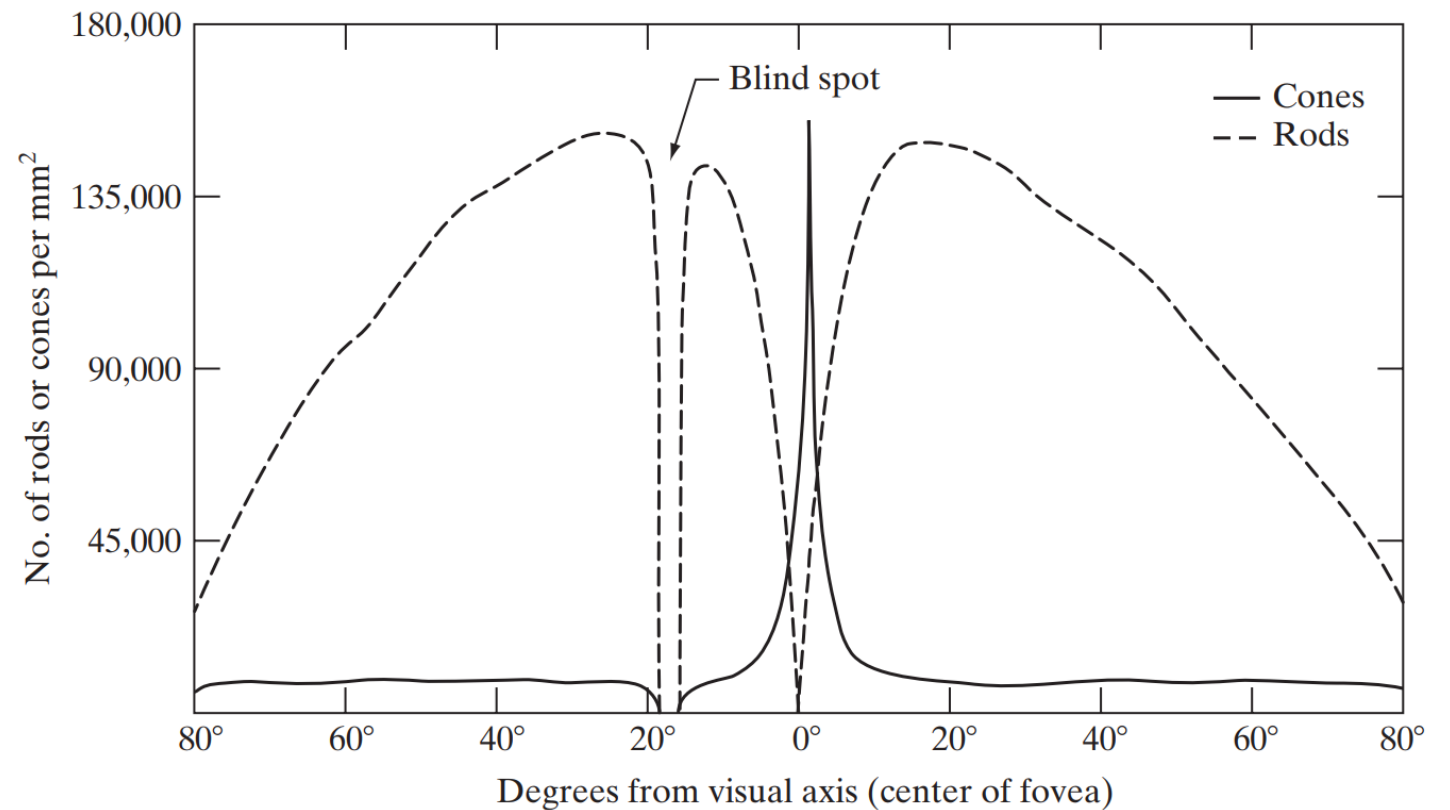
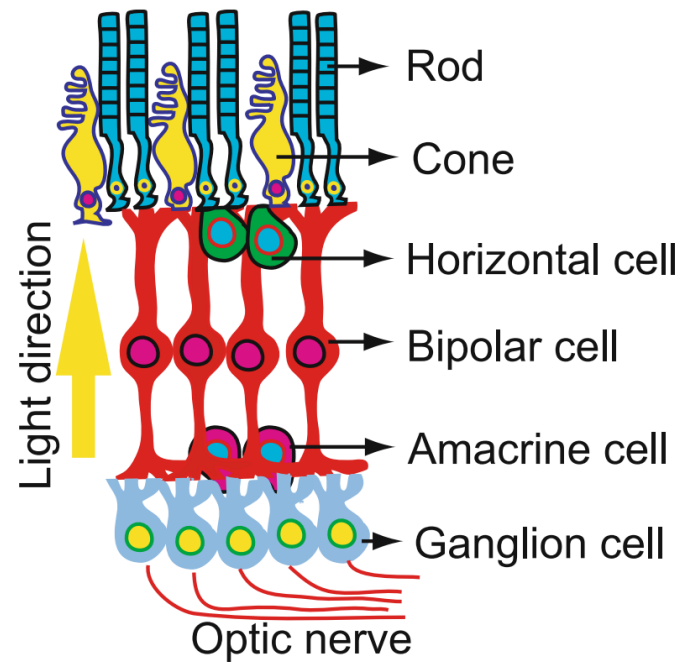
- blind spot



Human visual system

■ Distribution of Rods & Cones

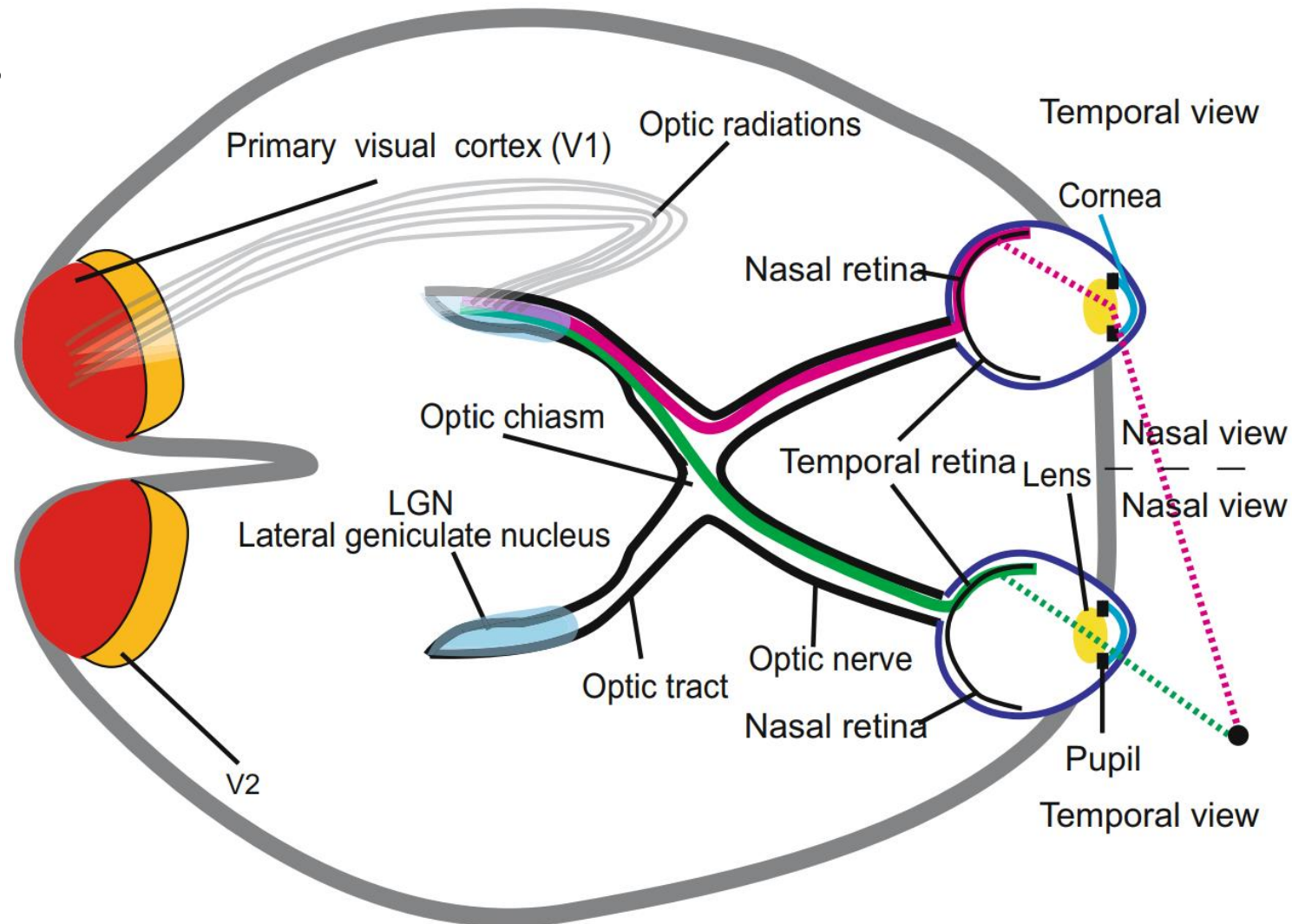
○ blind spot



Human visual systems

- Anatomic pathways

- visual signals

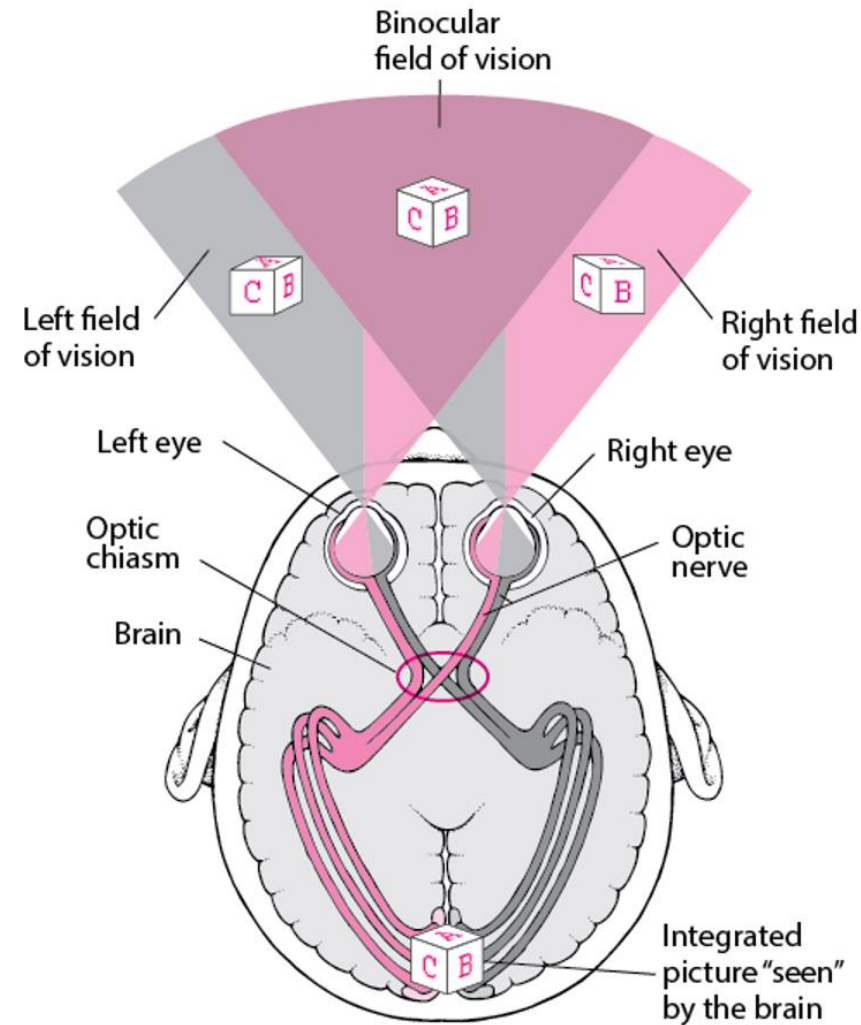


Human visual system

- Why two eyes?

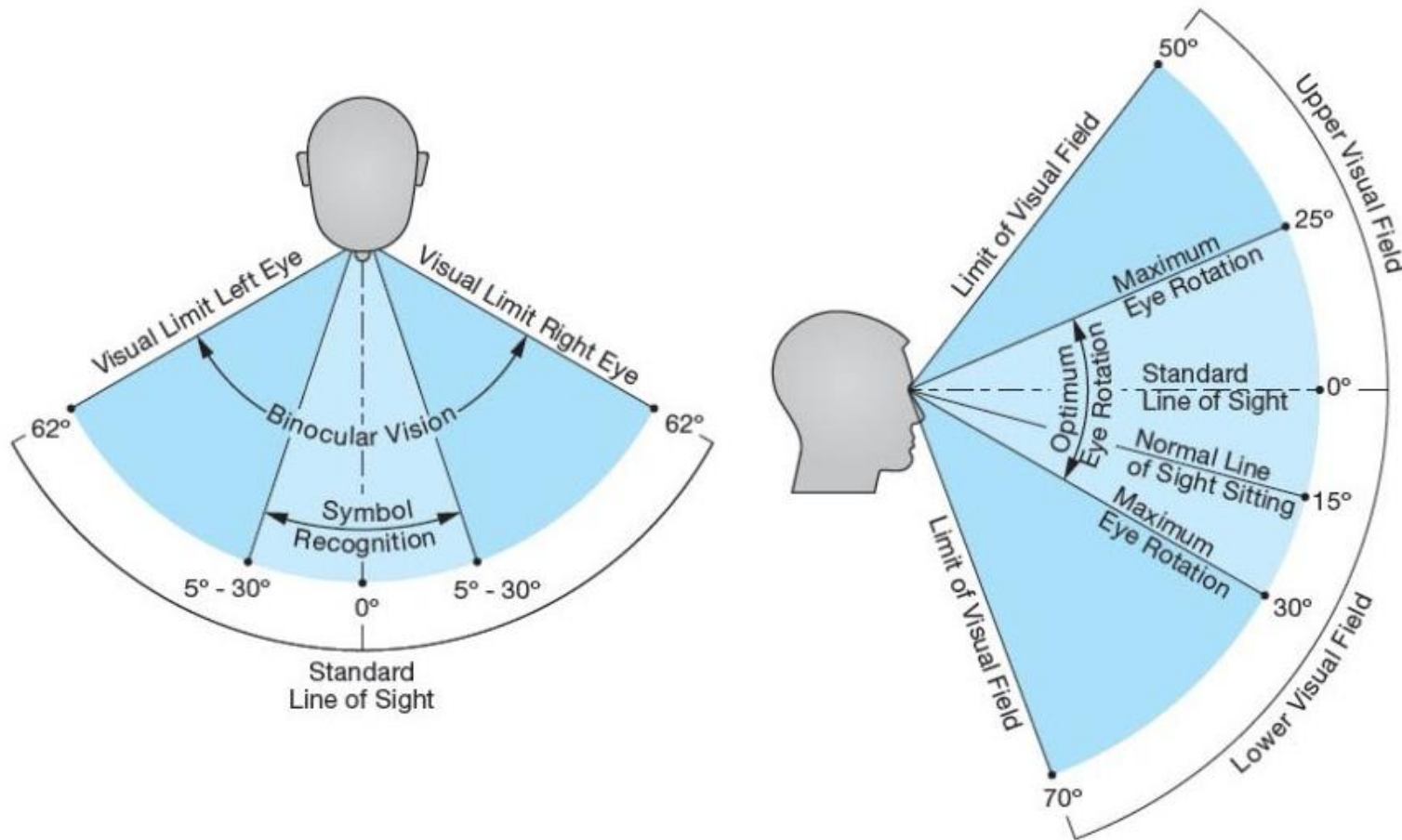
Human visual system

- Why two eyes?



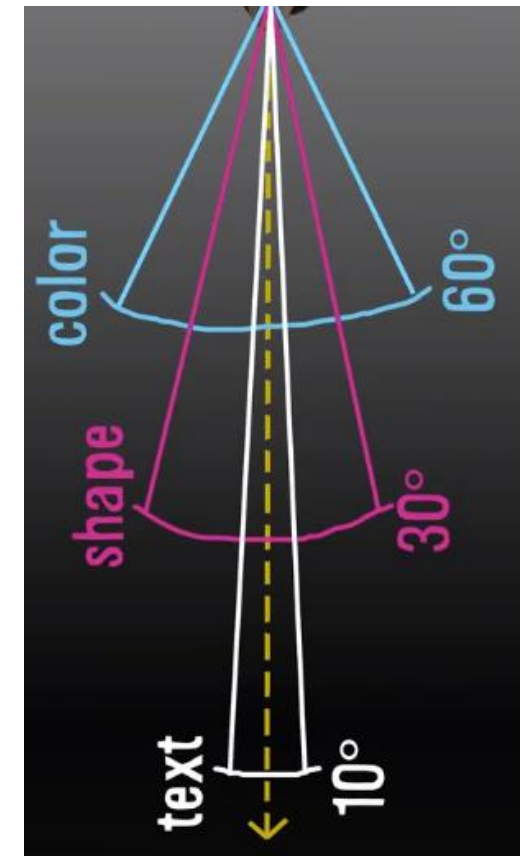
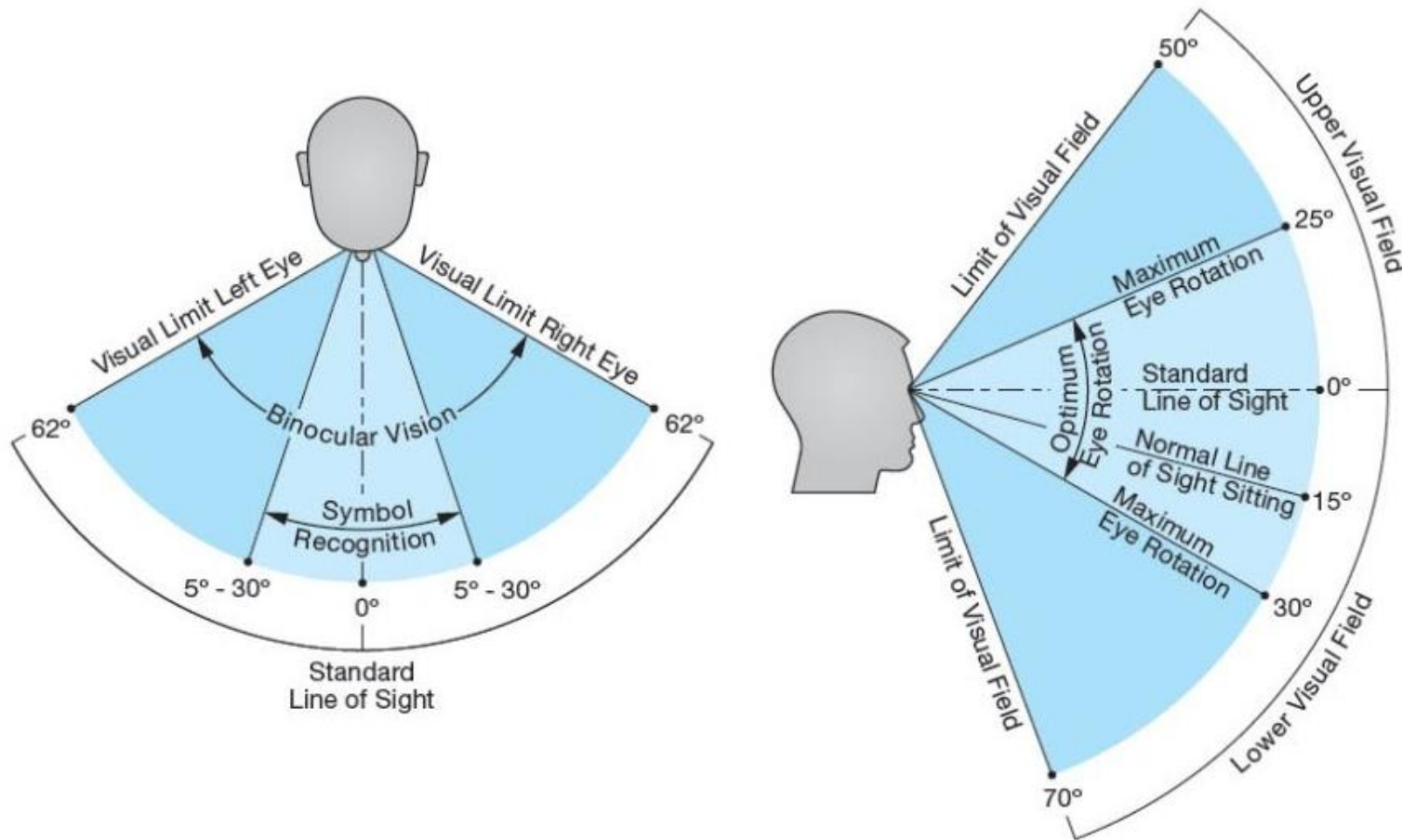
Human visual system

- Range



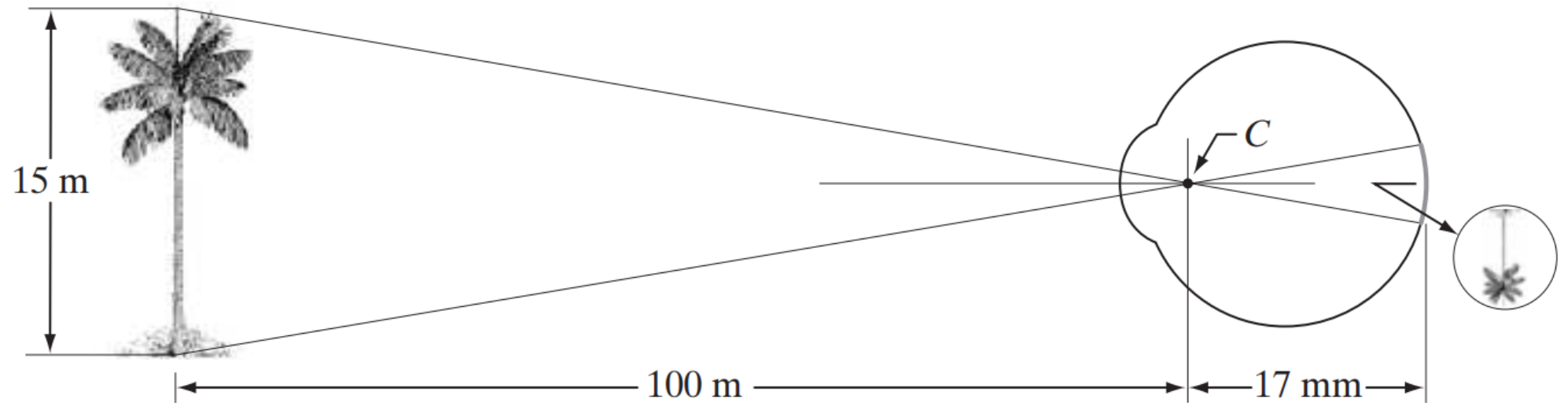
Human visual system

- Range



Human visual system

- Image formation
 - inverted over retina

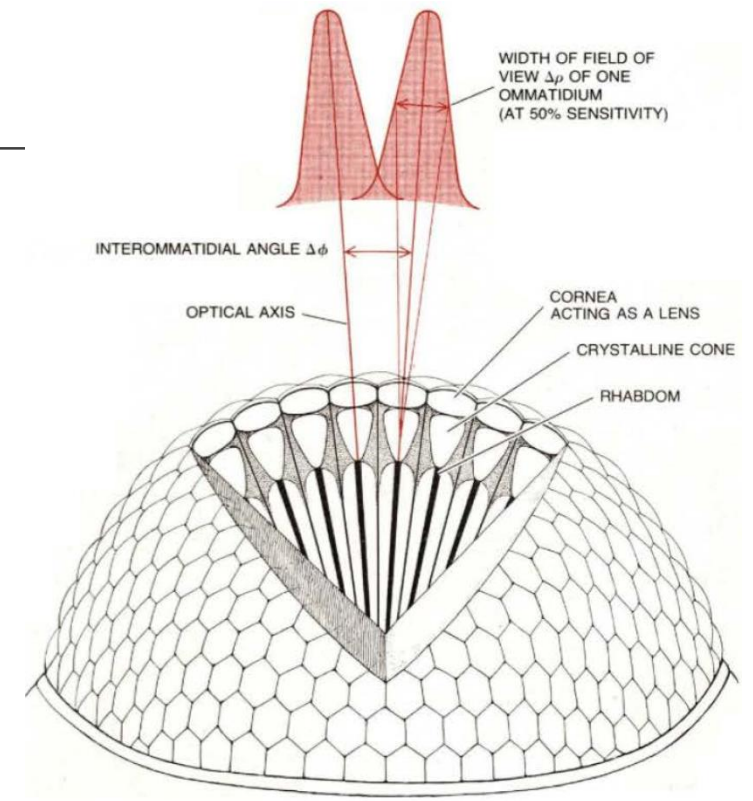
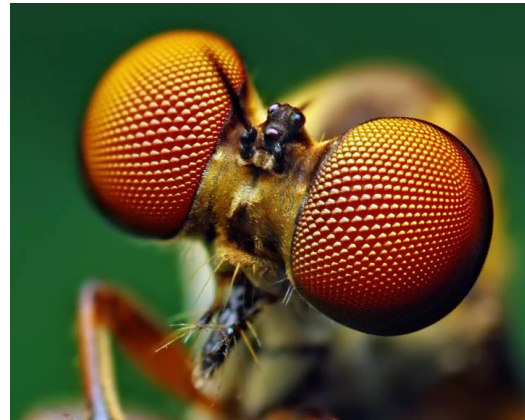


Fly's vision

■ Compound eyes

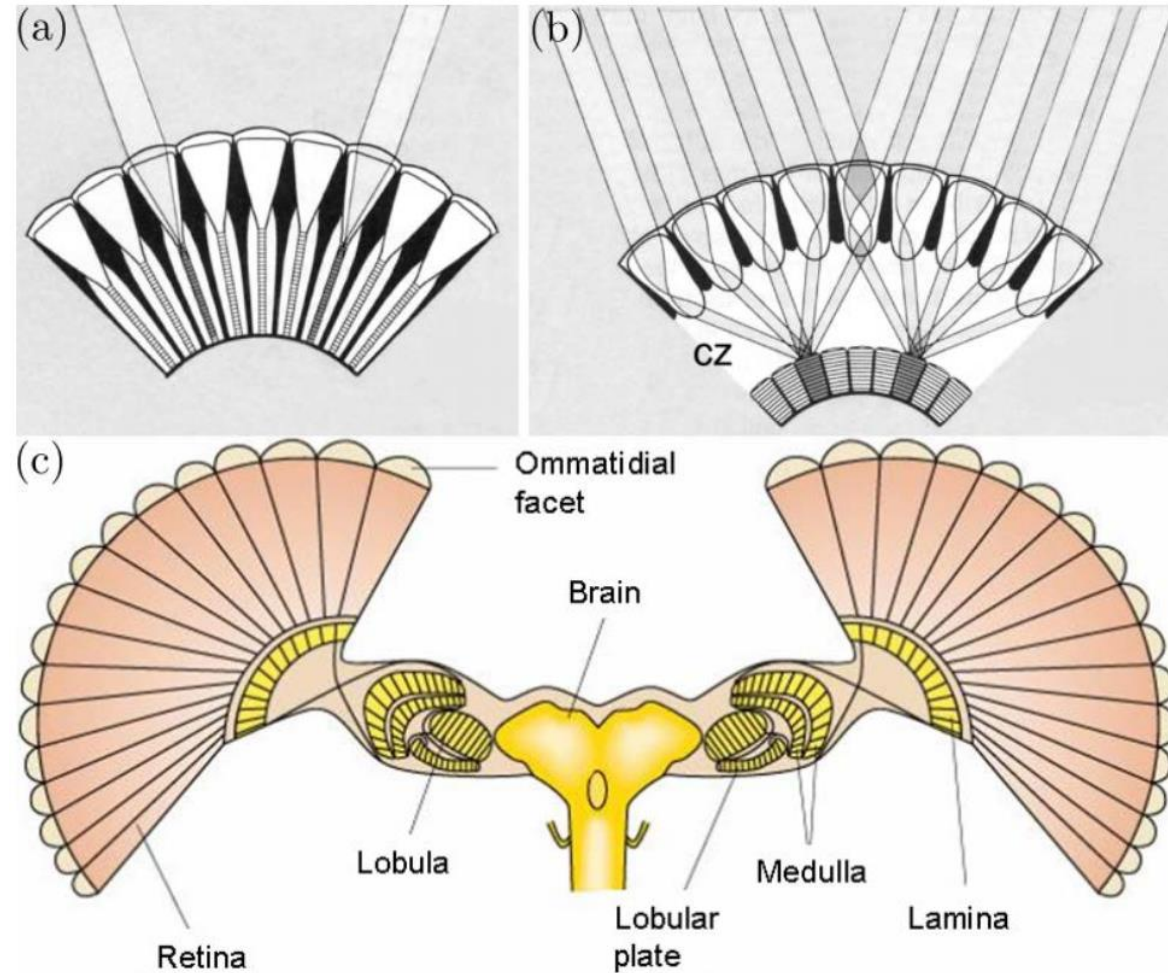
- different from HVS
- hexagonal lens
- 1 ommatidium \rightarrow 8 photoreceptors
- R7, R8 (inner) \rightarrow color
 - 4 spectral filters: Red to Yellow
- R1~R6 (outer) \rightarrow motion
- $\Delta\phi$ varies along eye
 - small – frontal regions – flowers, prey detection
 - lens diffraction – Gaussian angular sensitivity
 - spatial LPF – necessary for motion detection
 - $\Delta\phi \approx \Delta\rho$ ensuring no aliasing without oversampling the visual data

Robber fly



Fly's vision

- Compound eyes
 - Focal apposition
 - day
 - Refracting superposition
 - night
- Compactness
 - Visual processing immediate beneath ommatidia
 - HVS: wide gap between lens and retina



General visual systems

- Light adaption
 - night, cloudy ($\sim 10^{-2}$ Lux)
 - sunshine ($\sim 10^5$ Lux)
 - VS need to auto-adapt for maintaining good contrast sensitivity
 - Temporal contrast changes
 - Spatial contrast fluctuations

General visual systems

- Light adaption

- night, cloudy ($\sim 10^{-2}$ Lux)
- sunshine ($\sim 10^5$ Lux)
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- Michaelis-Menten eq

$$V = V_m \frac{I^n}{I^n + \sigma^n},$$

V – photoreceptor's response

V_m – max value

I – light intensity

n – order (0.7~1.0)

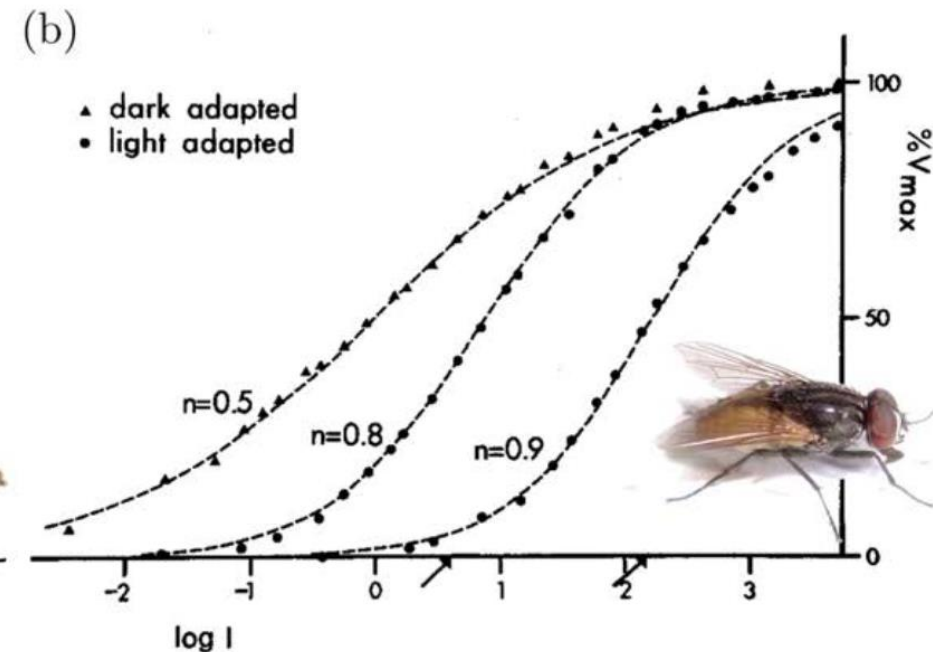
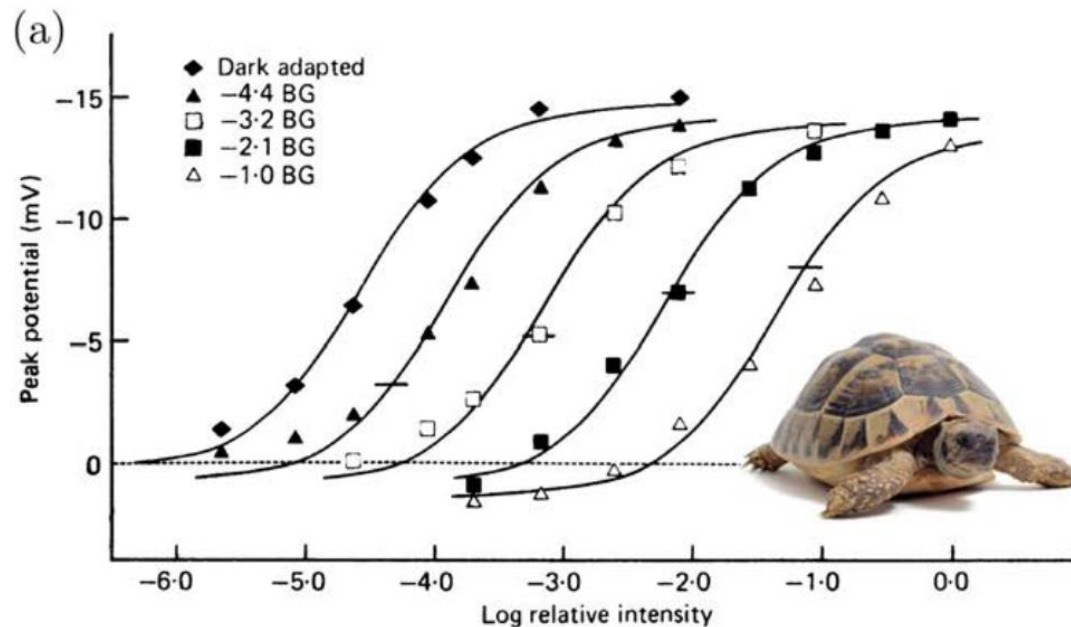
σ – adaptation parameter

General visual systems

■ Light adaption

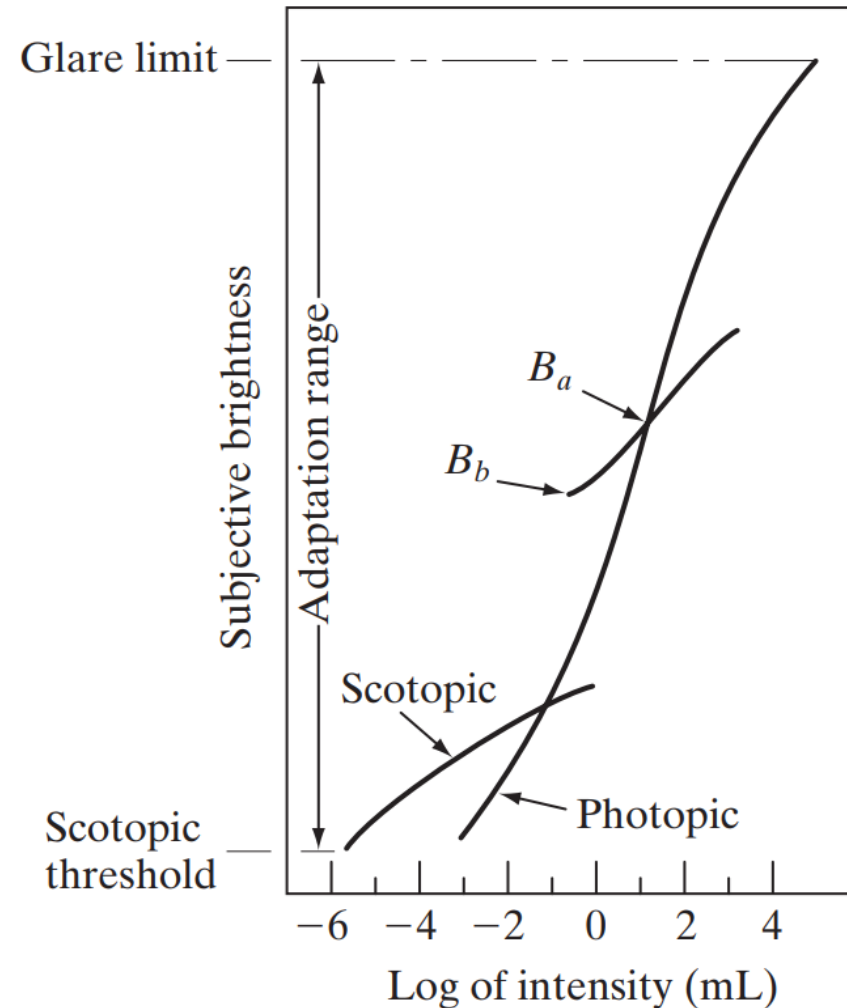
- BG lighting change cause entire 'S' curve to shift along light intensity
- i.e. change in sensitivity of photoreceptor
- slope at operating point: contrast sensitivity

$$V = V_m \frac{I^n}{I^n + \sigma^n},$$



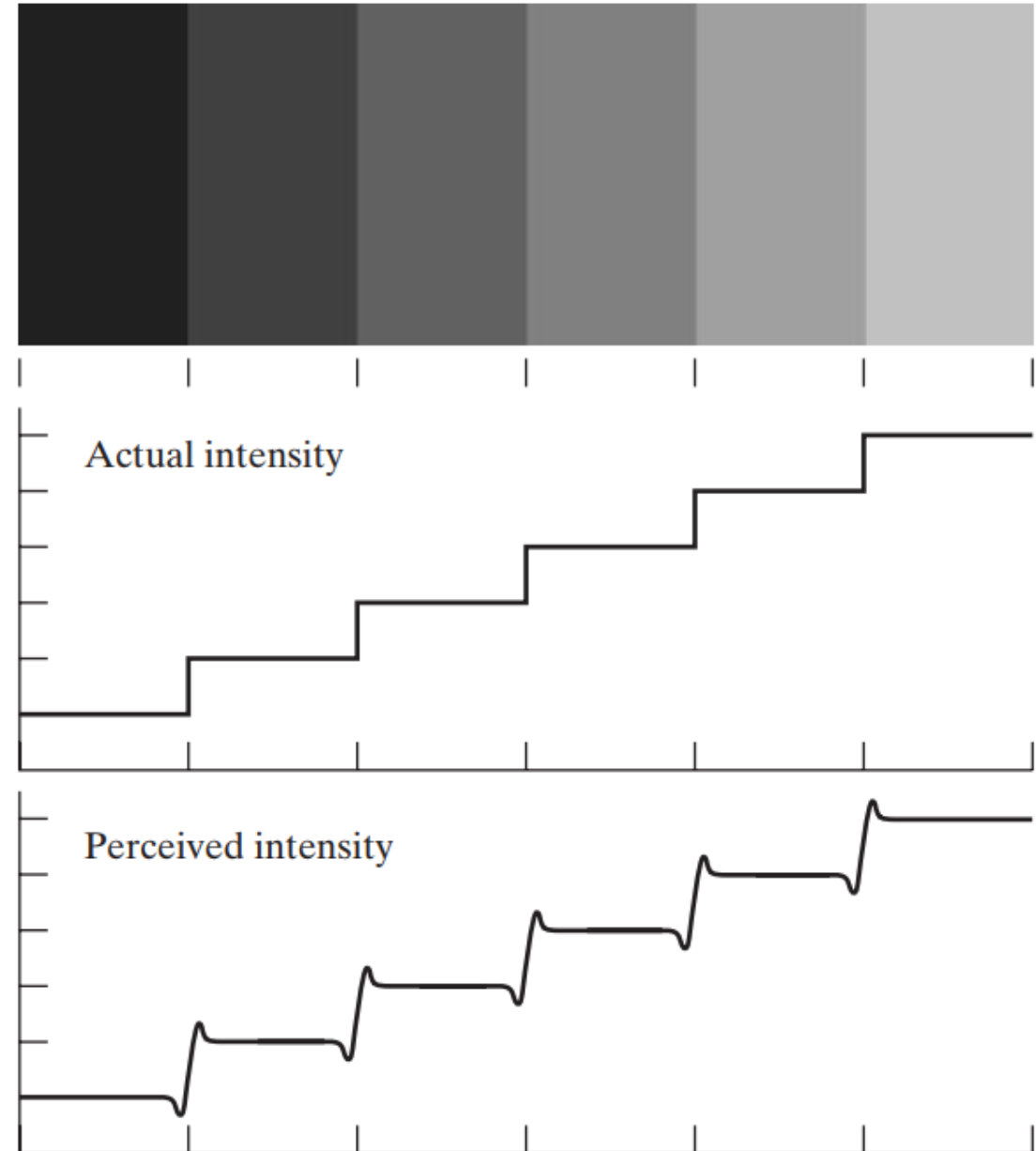
Human visual system

- Brightness adaption
 - system dynamics change
 - to achieve large dynamic range
 - by changing its overall sensitivity



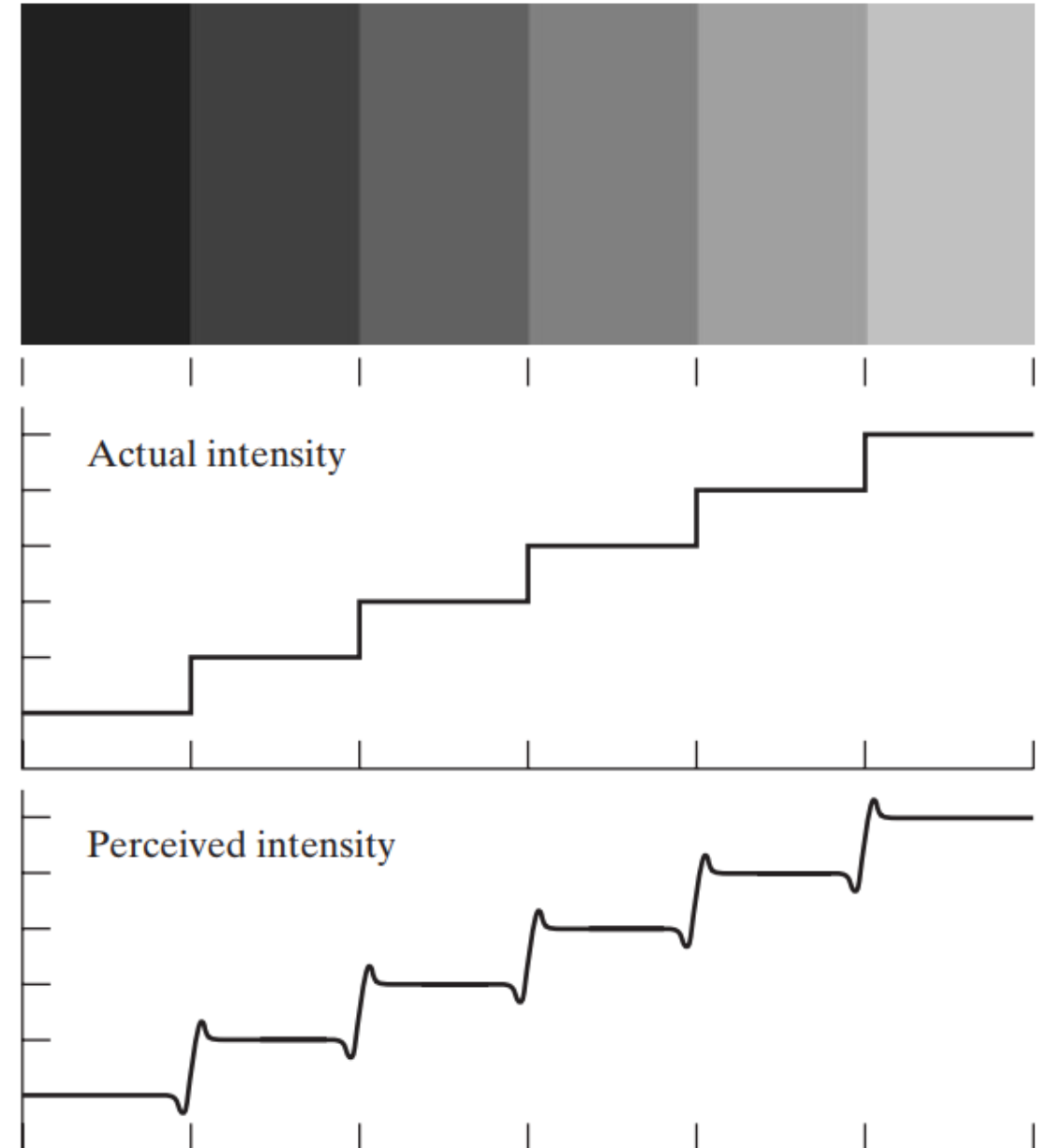
Mach band effect

- Human perception
 - Characteristics of HVS



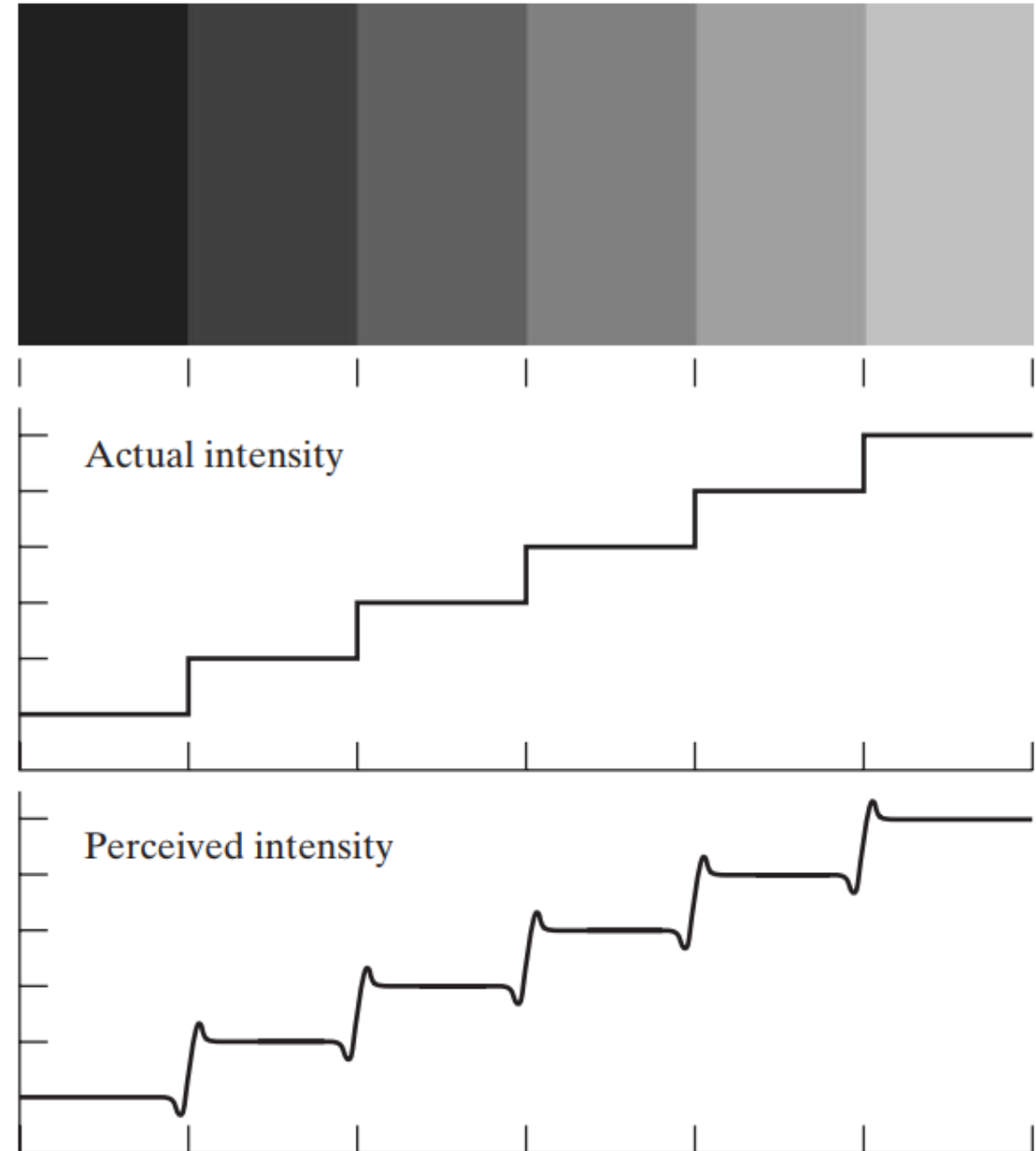
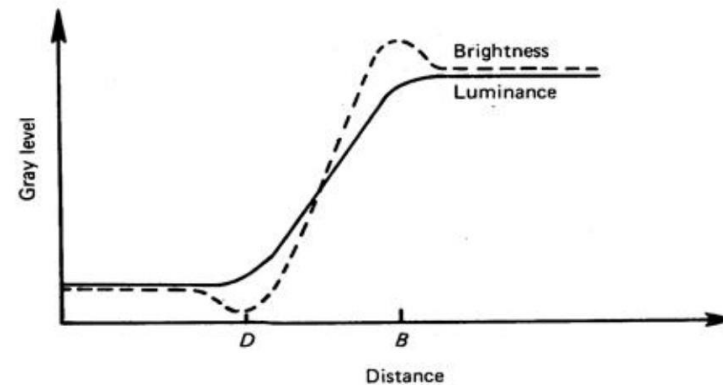
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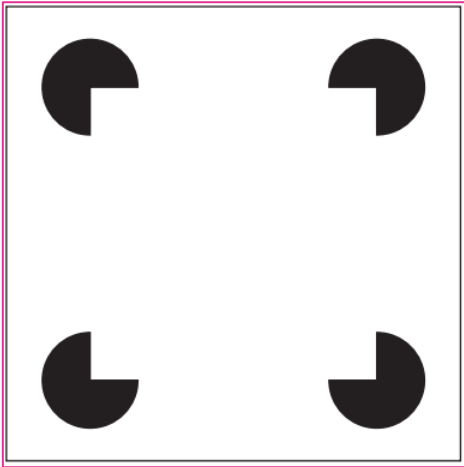
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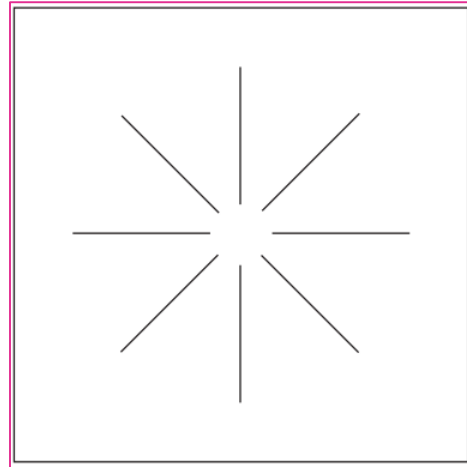
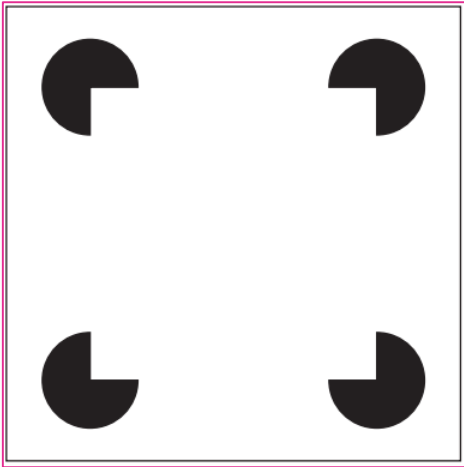
Optical illusions

- Human perception
 - Characteristics of HVS



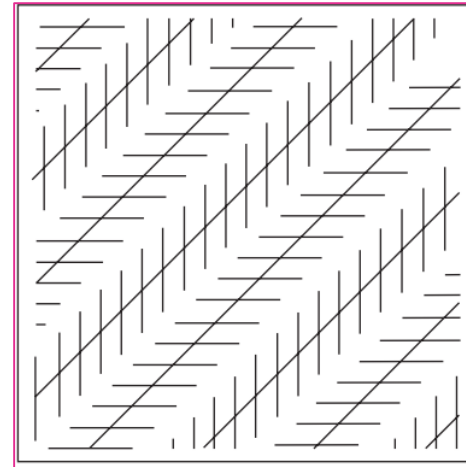
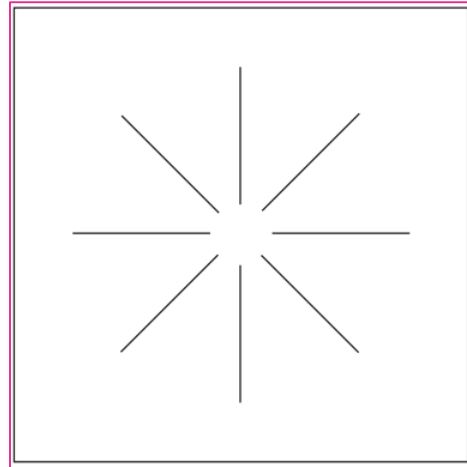
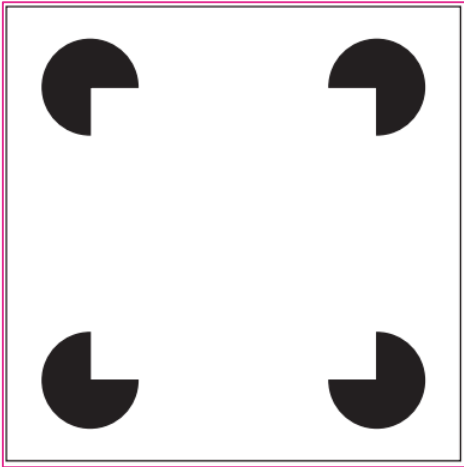
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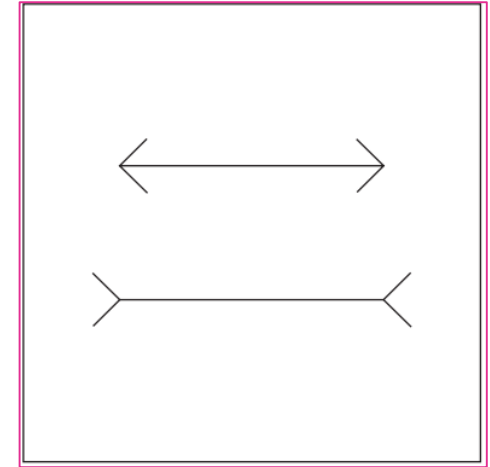
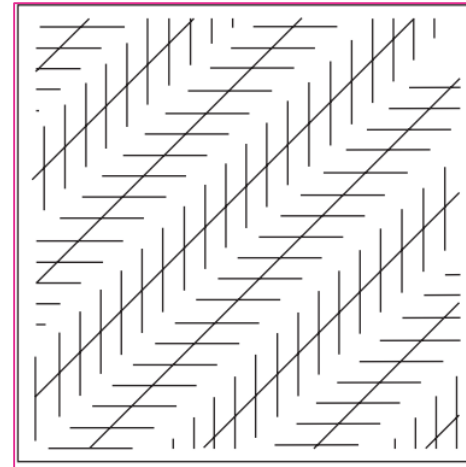
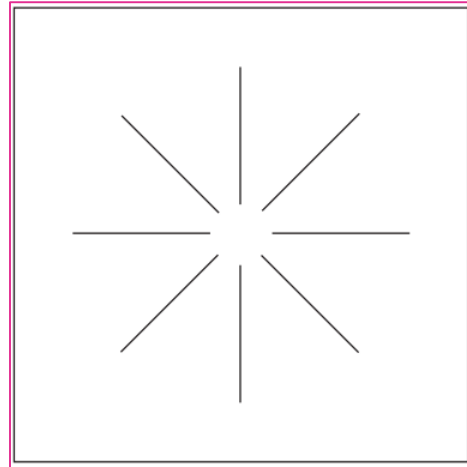
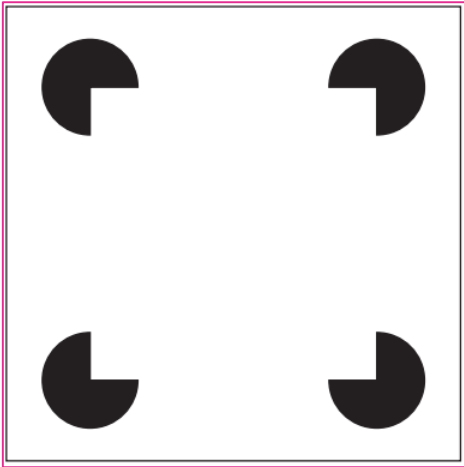
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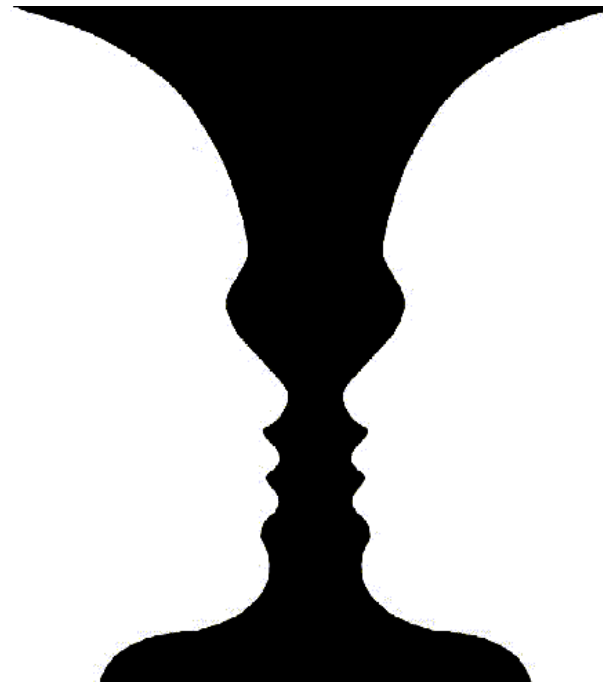
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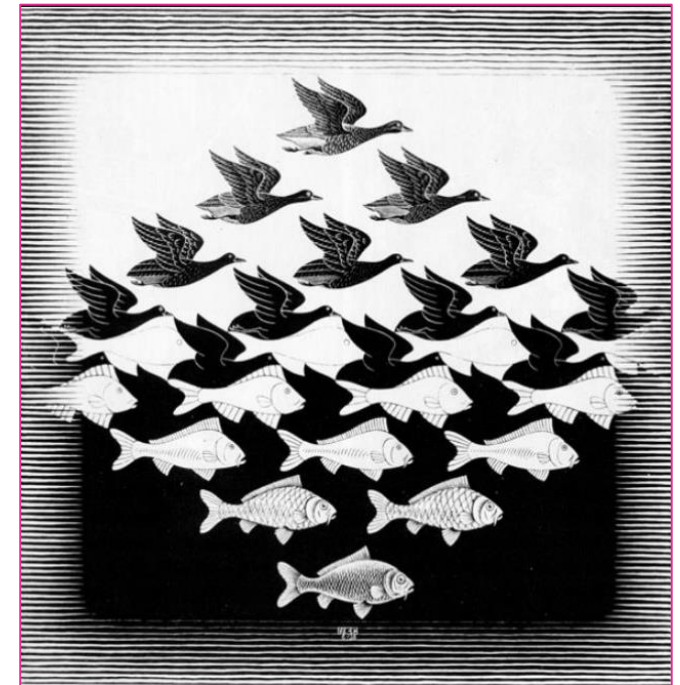
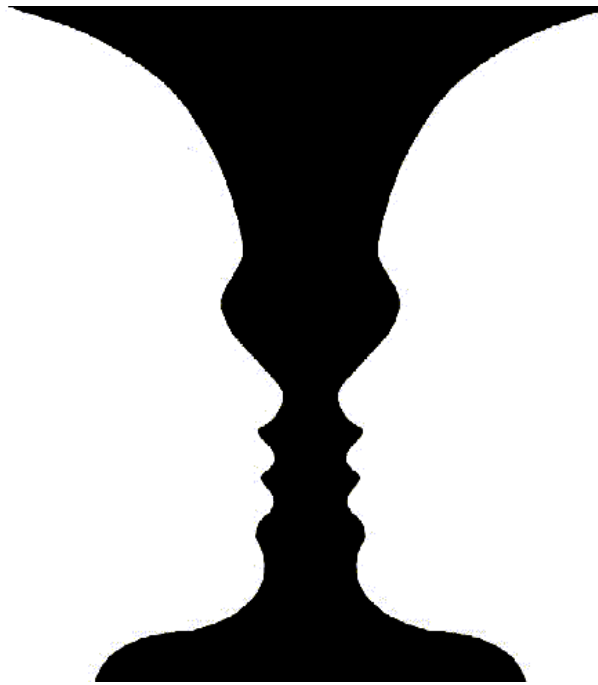
Optical illusions

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Optical illusions

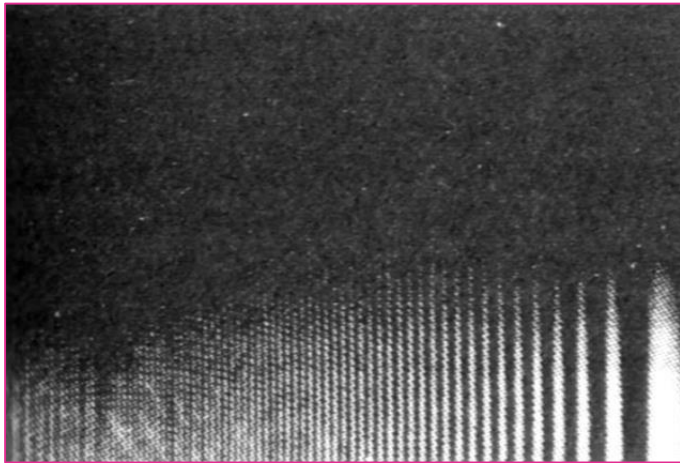
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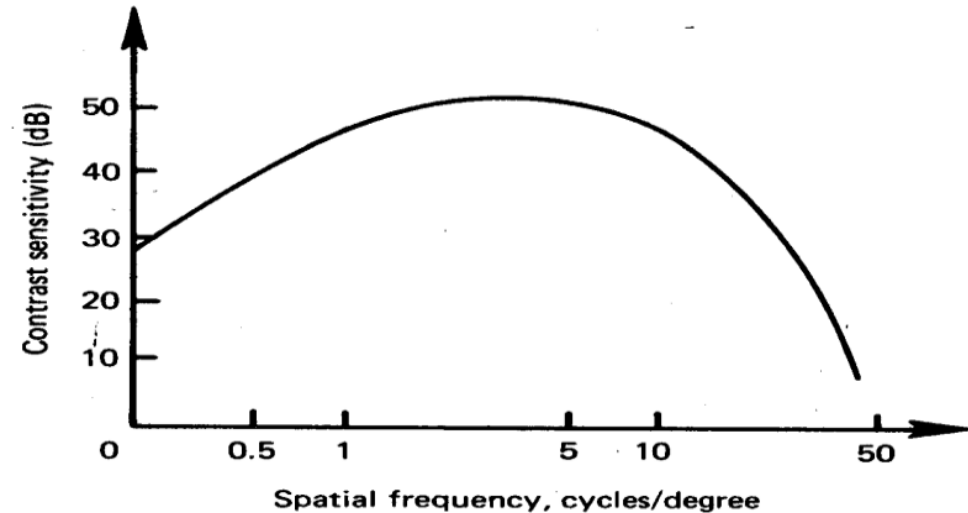
Spatial frequency response

- Human perception
 - characteristics of HVS
 - daily life application?

Contrast
variation



Frequency variation



Vision system

- HVS vs other vision systems
 - HVS: 3 modality of cones (red, green, blue)
 - Sensing
 - Interpretation
- } Perception

Vision system

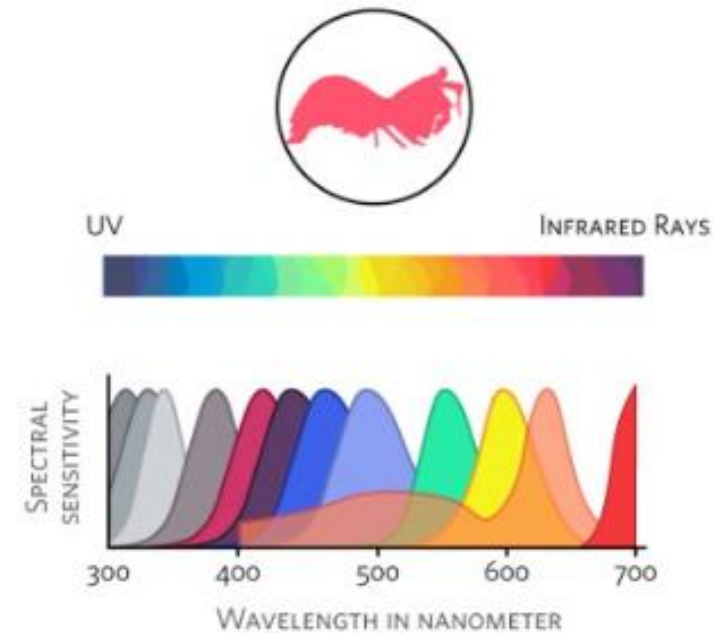
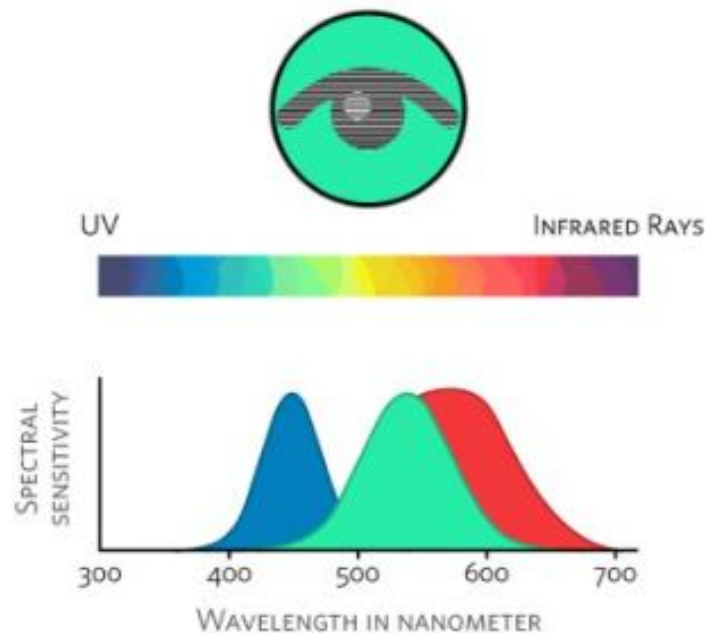
- HVS vs other vision systems

- HVS: 3 modality of cones (red, green, blue)

- Sensing

- Interpretation

} Perception



Conclusion

- General visual systems
- Human visual system

Conclusion

- General visual systems
- Human visual system

- ❑ Visual system comprised of
 - Sensors (specialized cells: rods, cones)
 - Light controllers (lens, supporting muscles and fluids)
 - Interpreters (brain)
- ❑ Visual system
 - Perception
- ❑ Compound lens
- ❑ HVS components