Human visual system

Dr. Tushar Sandhan

Introduction

- Mantis shrimp
- Tarsier

Introduction

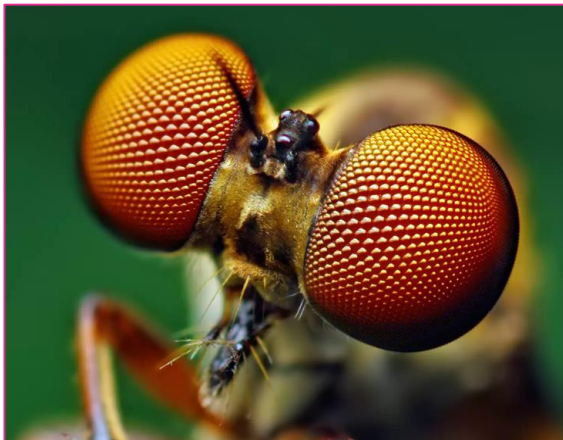○ Mantis shrimp

○ Tarsier

○ Rober fly

Introduction

- Mantis shrimp

- Tarsier
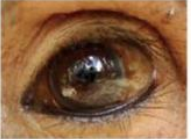
- Great ape species

Chimpanzee	Bornean orangutan
(*Pan troglodytes*)	(*Pongo pigmaeus*)
Mountain gorilla	Sumatran orangutan
(*Gorilla beringei*)	(*Pongo abelii*)
Lowland gorilla	Human
(*Gorilla gorilla*)	(*Homo sapiens*)

- Rober fly

Eye-opening area   Sclera area

Longest width
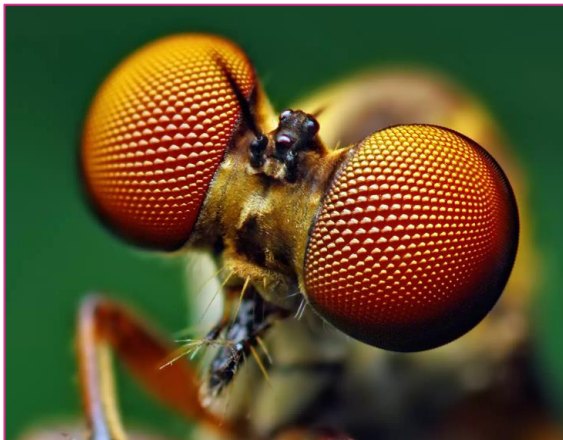
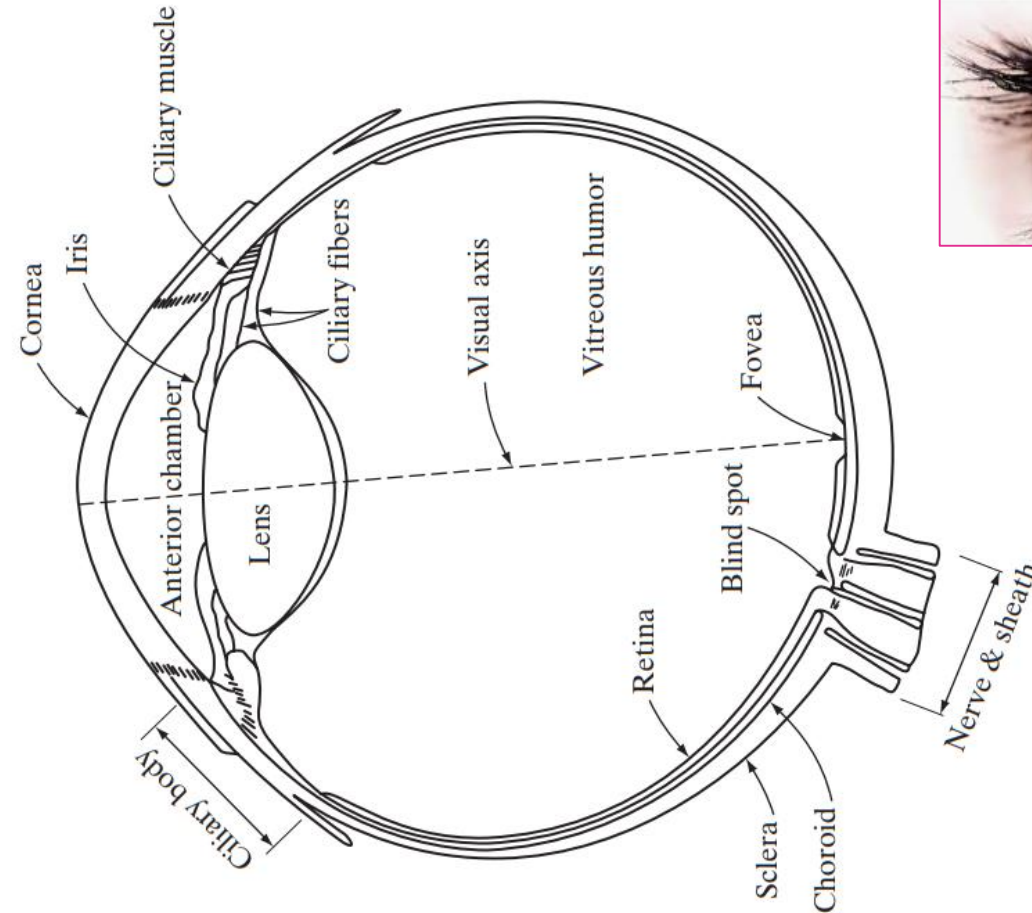Sclera Area Index = Sclera area / Eye-opening area

credit: F. Kano et al.
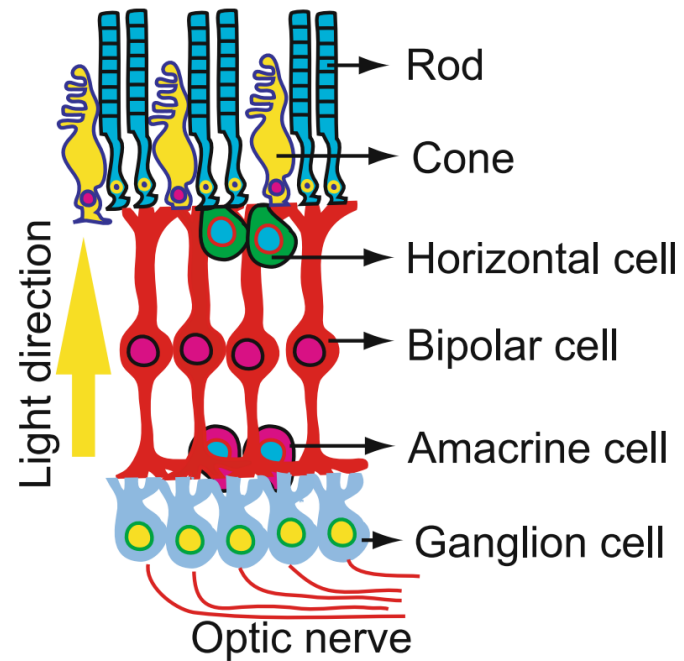
Human visual system

- 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)

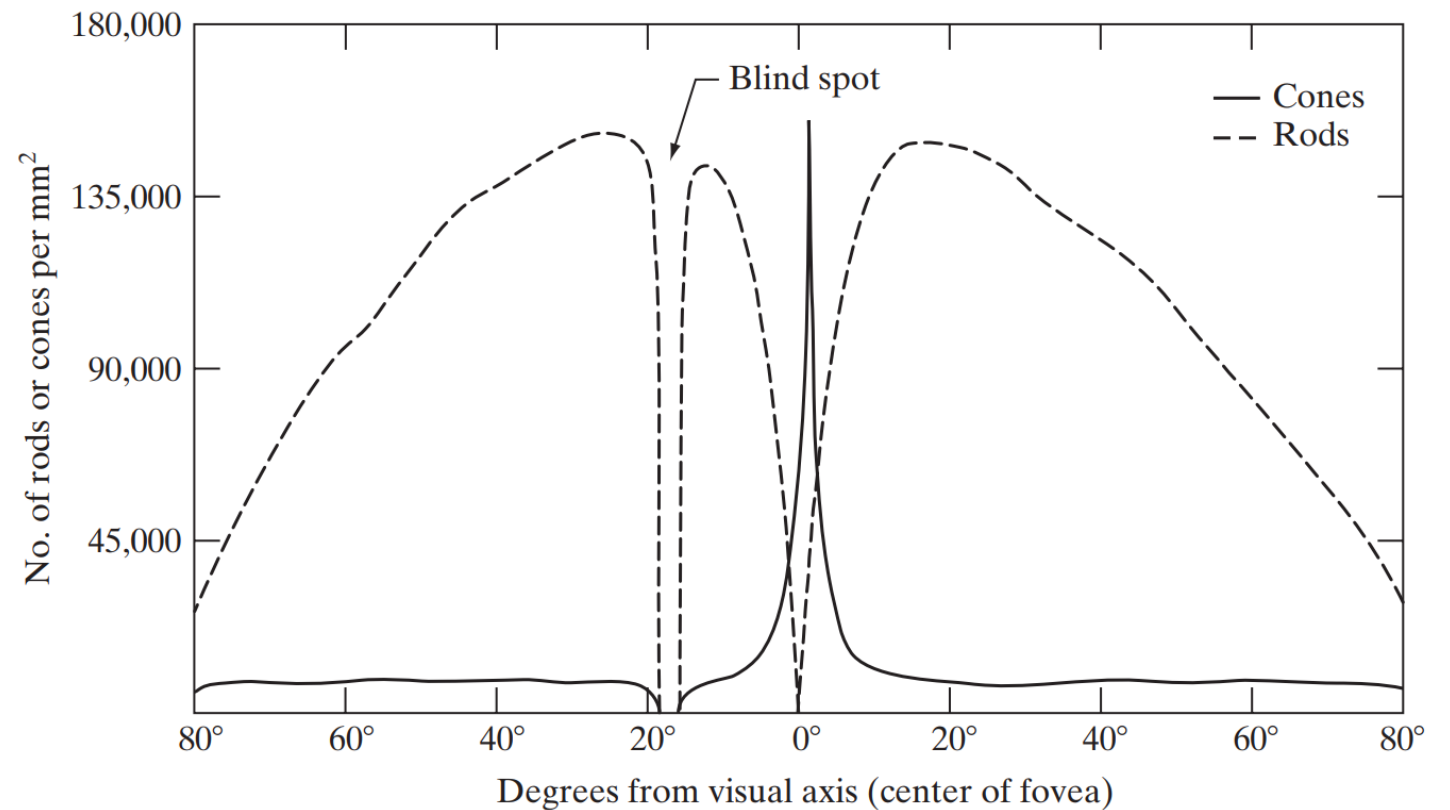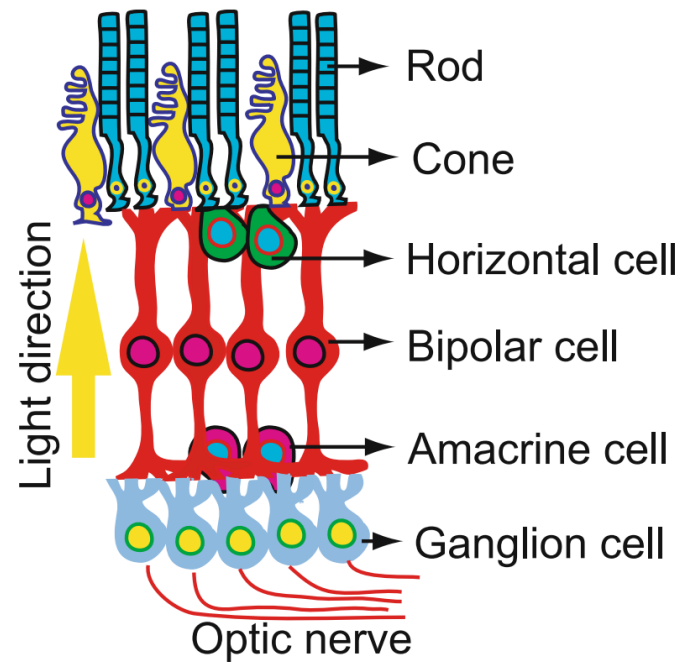# Human visual system

- Distribution of Rods & Cones
  - blind spot
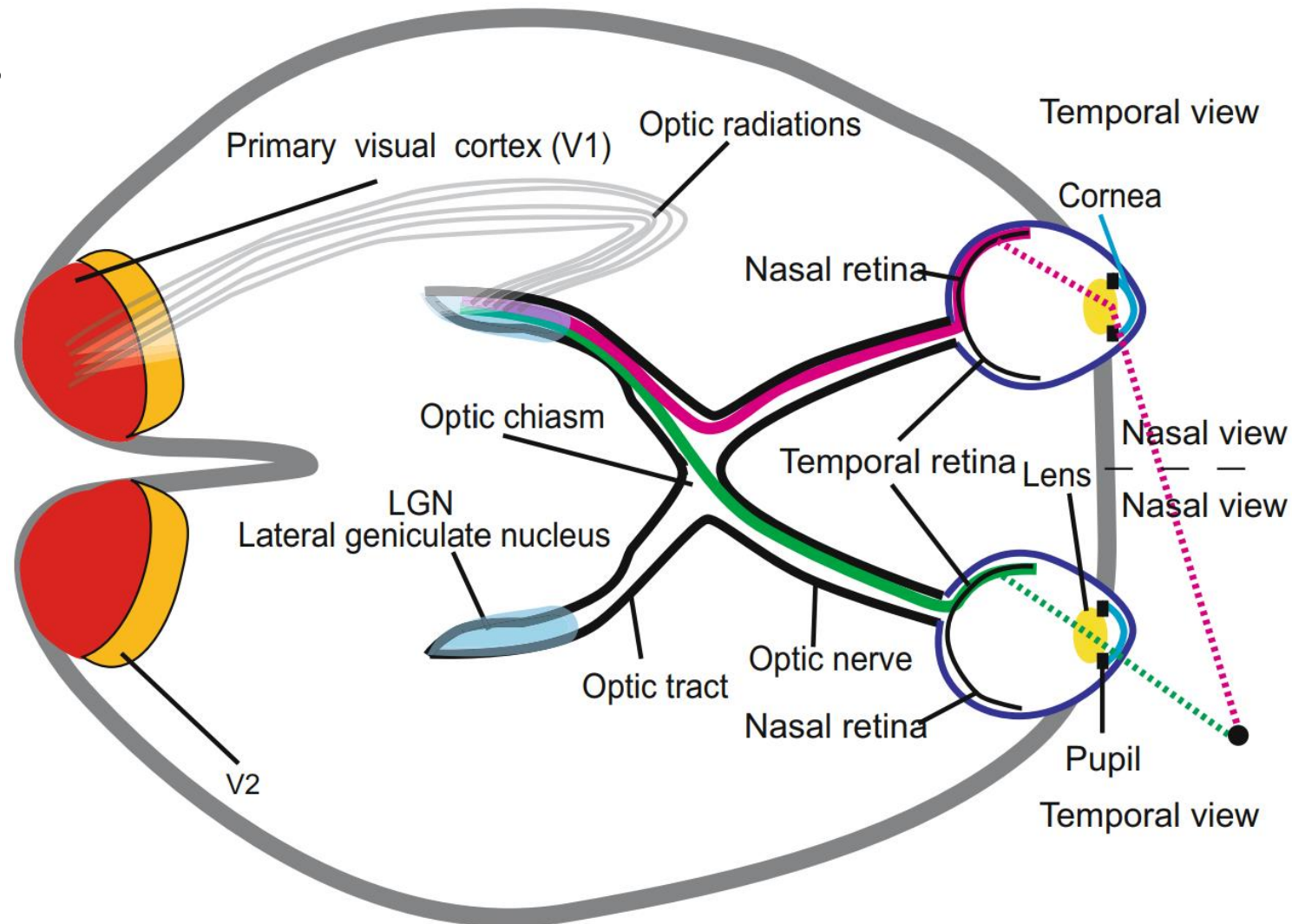
Human visual system

- Distribution of Rods & Cones
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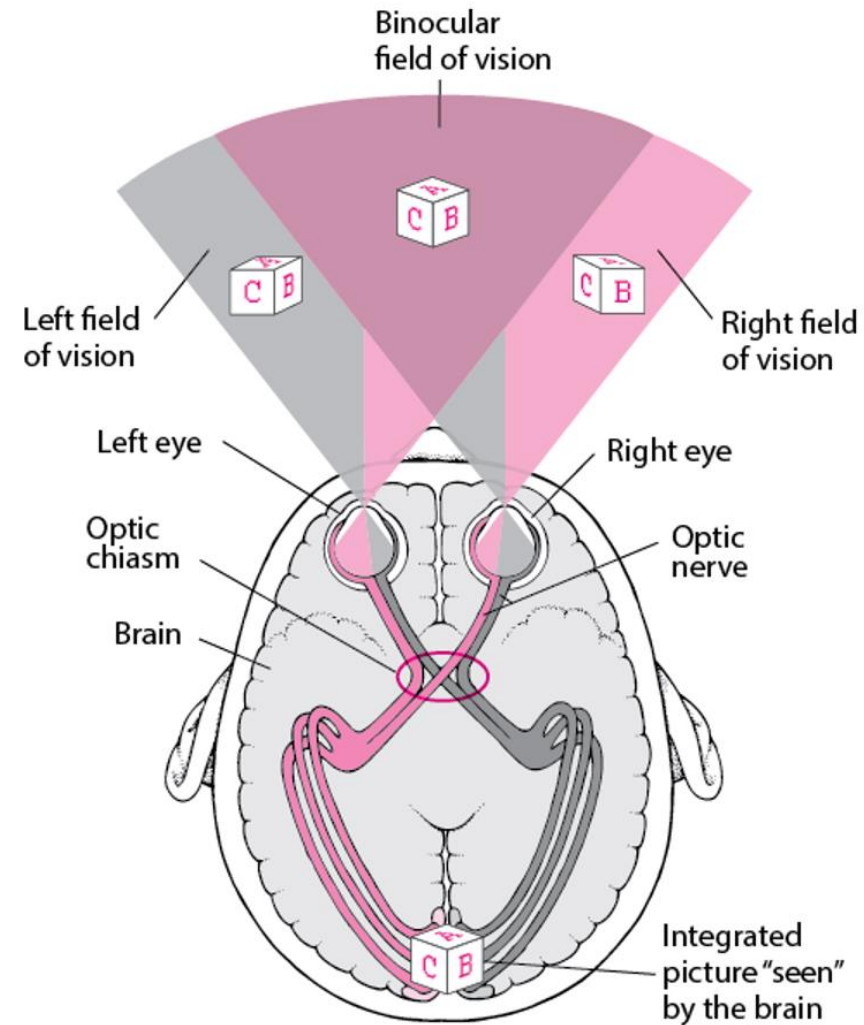# Human visual systems

- Anatomic pathways
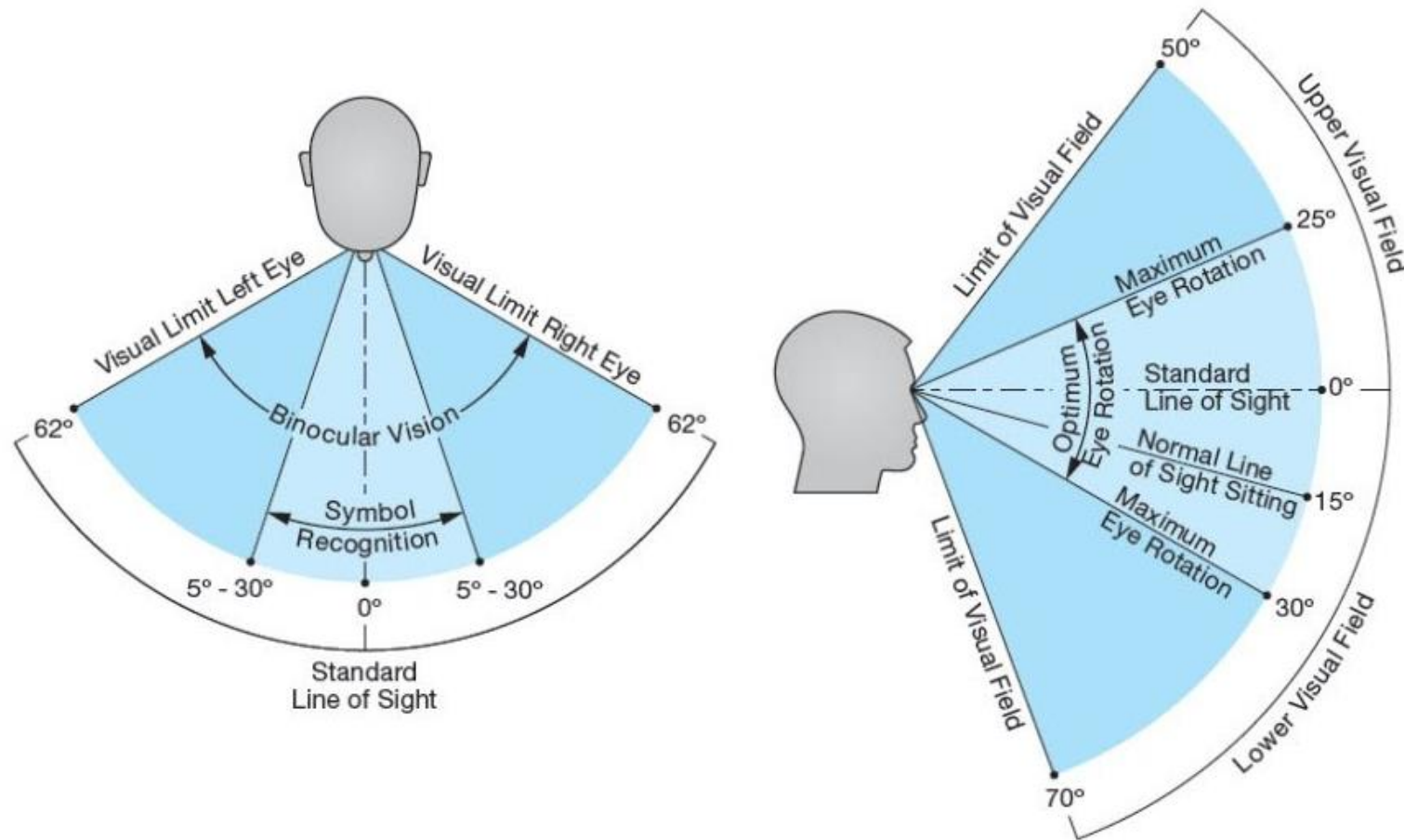 - visual signals

Human visual system

- Why two eyes?

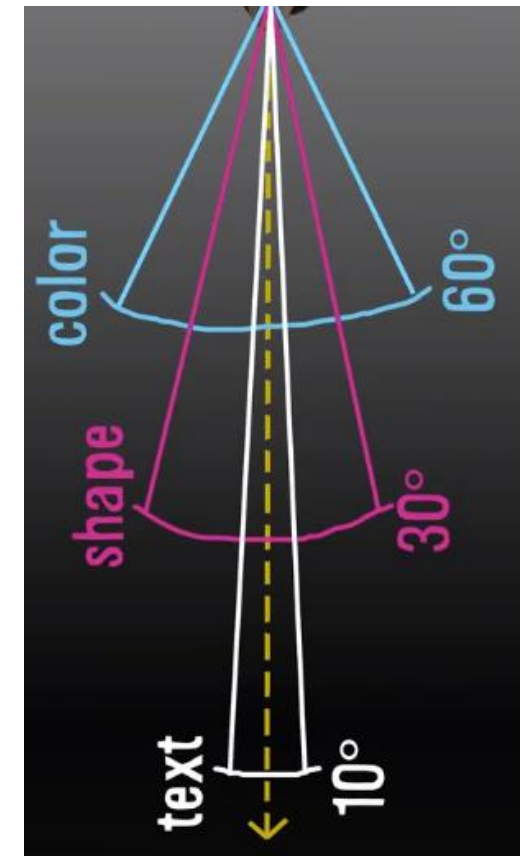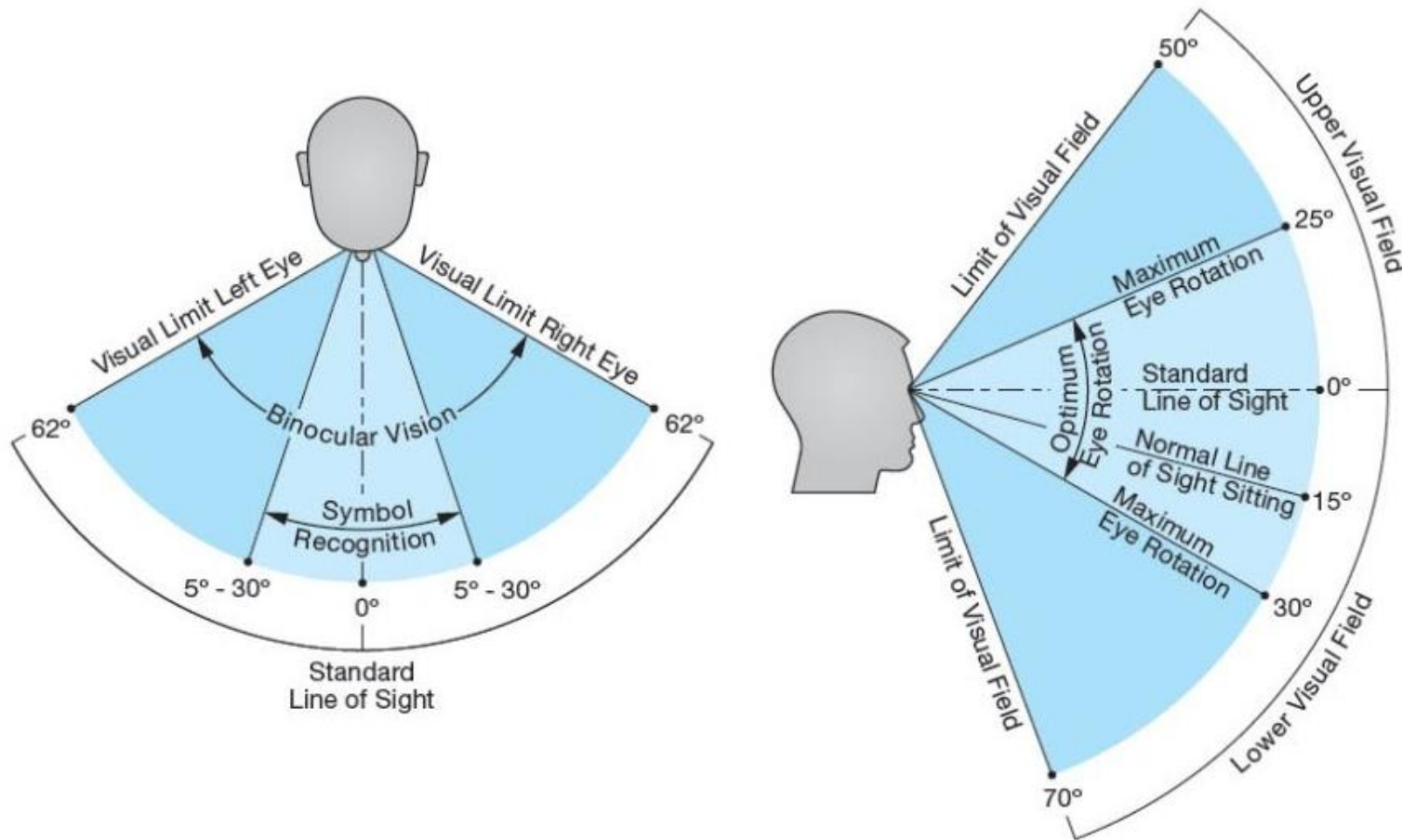# Human visual system

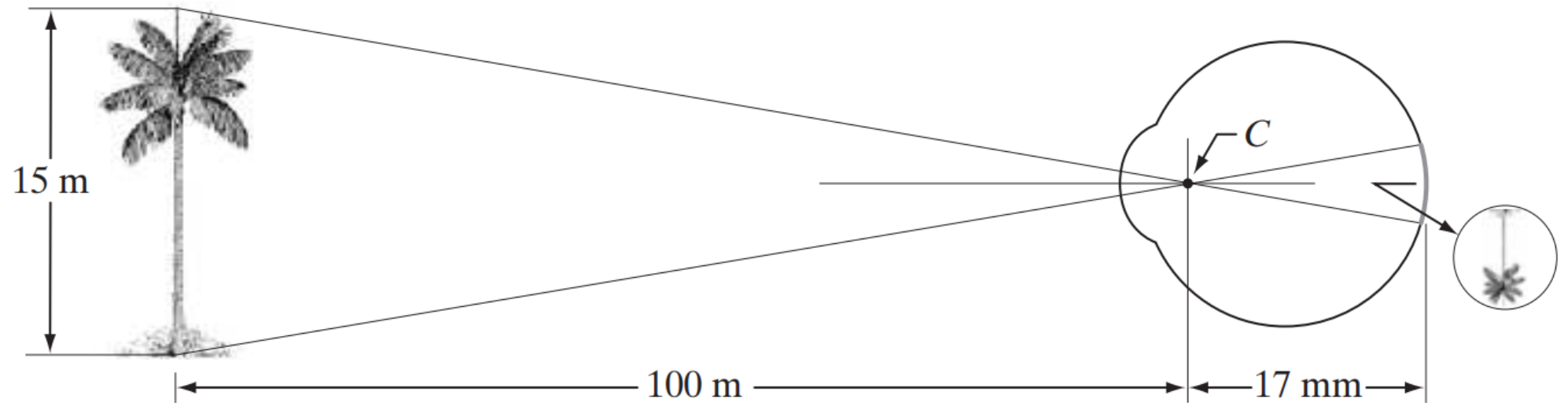- Why two eyes?

Human visual system

- Range

Human visual system

- Range

Human visual system

- Image formation
  - inverted over retina

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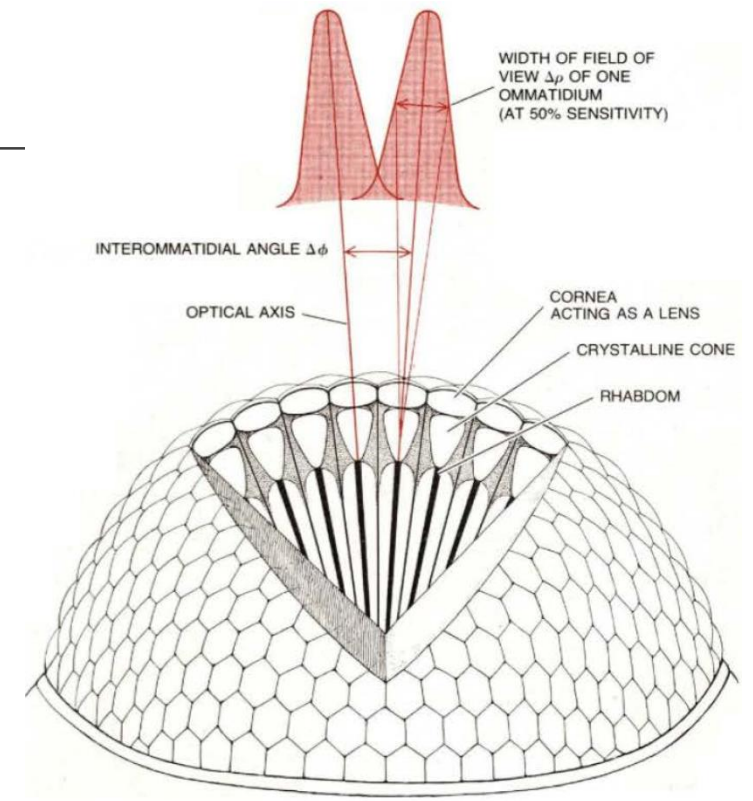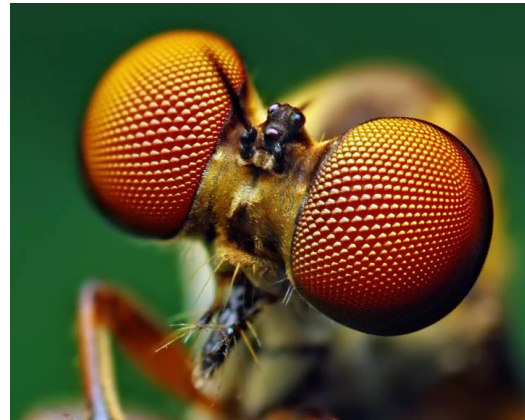
- Compound eyes
  - different from HVS
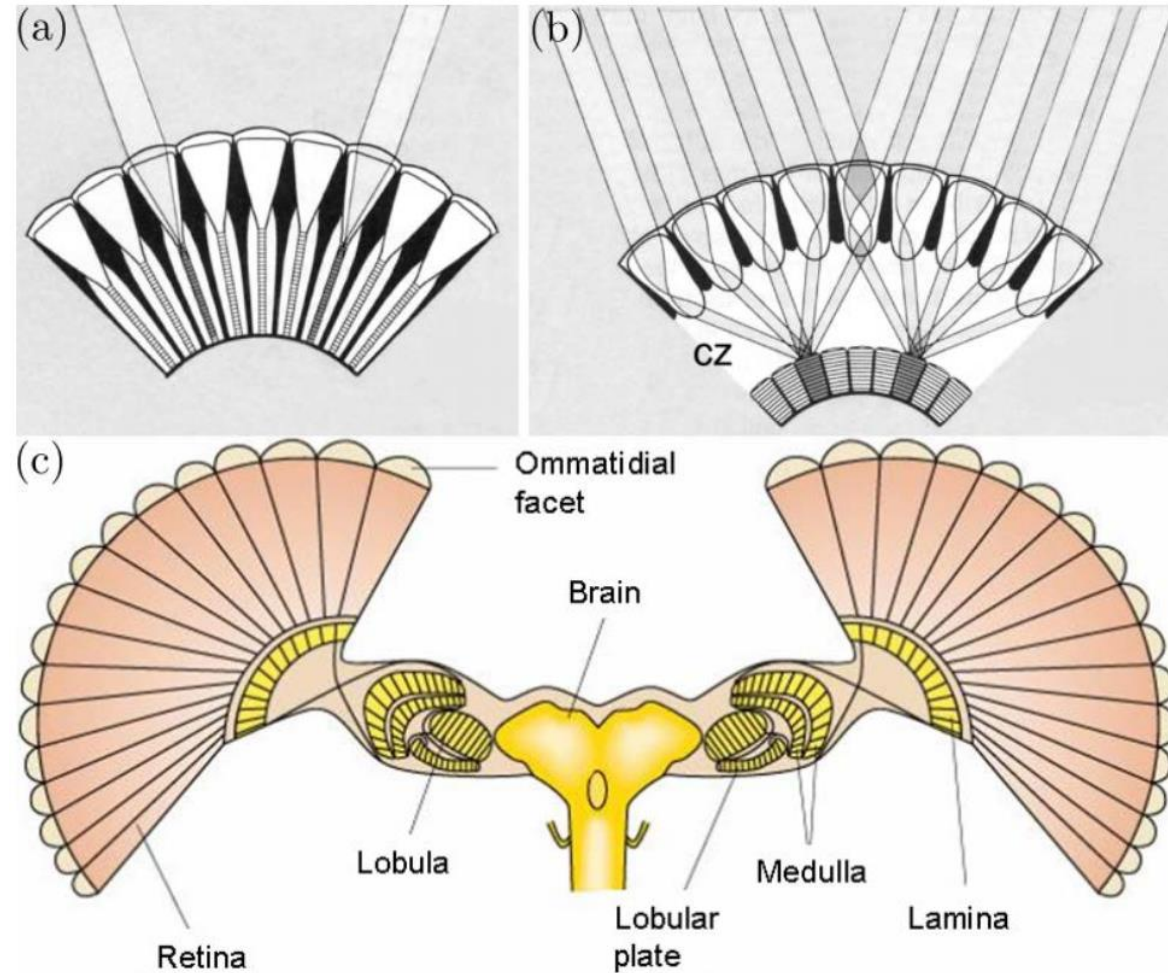 - hexagonal lens
  - 1 ommatidium → 8 photoreceptors
  - R7, R8 (inner) → color
    - 4 spectral filters: Red to Yellow
  - R1~R6 (outer) → motion
  - $\Delta\phi$ varies along eye
    - small – frontal regions – flowers, prey detection
    - lens diffraction – Gaussian angular sensitivity
    - spatial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

Robber fly

WIDTH OF FIELD OF VIEW $\Delta\rho$ OF ONE OMMATIDIUM (AT 50% SENSITIVITY)

INTEROMMATIDIAL ANGLE $\Delta\phi$

OPTICAL AXIS

CORNEA ACTING AS A LENS

CRYSTALLINE CONE

RHABDOM

Fly's vision

- Compound eyes
  - Focal apposition
    - day
  - Refracting superposition
    - night

  - Compactness
    - Visual processing immediate beneath ommatidia

    - HVS: wide gap between lens and retina

(a)

(b)

CZ

(c) Ommatidial facet

Brain

Lobula

Retina

Lobular plate

Medulla

Lamina

General visual systems

- Light adaption
  - night, cloudy (~10^{-2} Lux)
  - sunshine (~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 (~10^{-2} Lux)
  - sunshine (~10^5 Lux)
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    - Spatial contrast fluctuations

- Michaelis-Menten eq

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

V $-$ photoreceptor's response
V_m $-$ max value
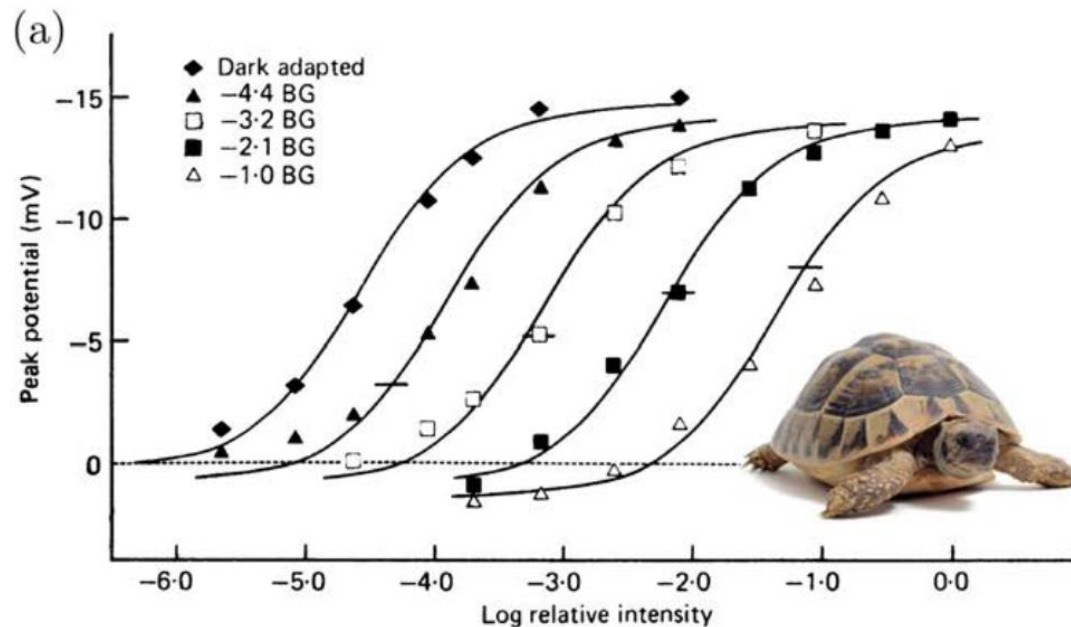I $-$ light intensity
n $-$ order (0.7~1.0)
σ $-$ adaptation parameter

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

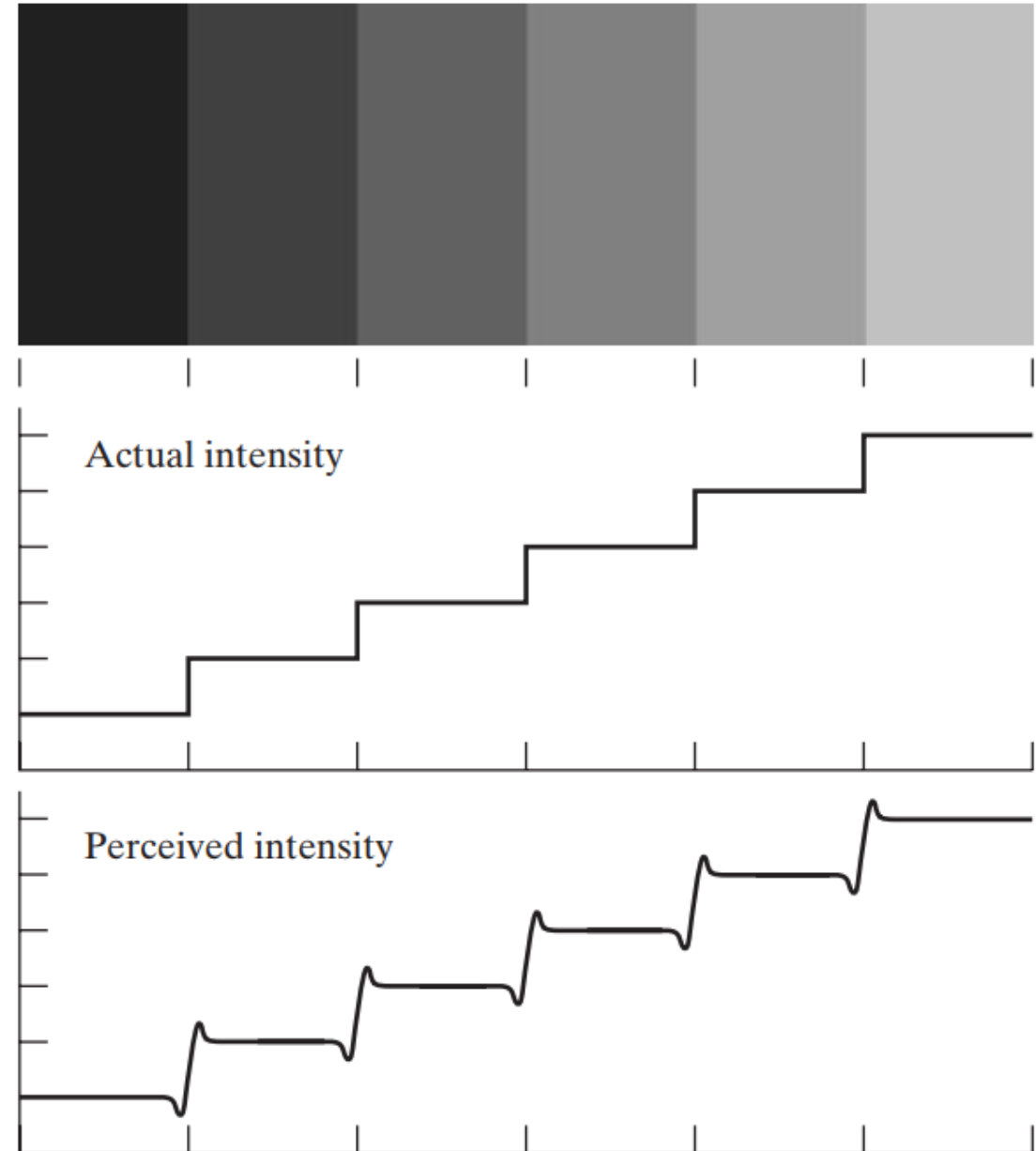$$V = V_m \frac{I^n}{I^n + \sigma^n},$$
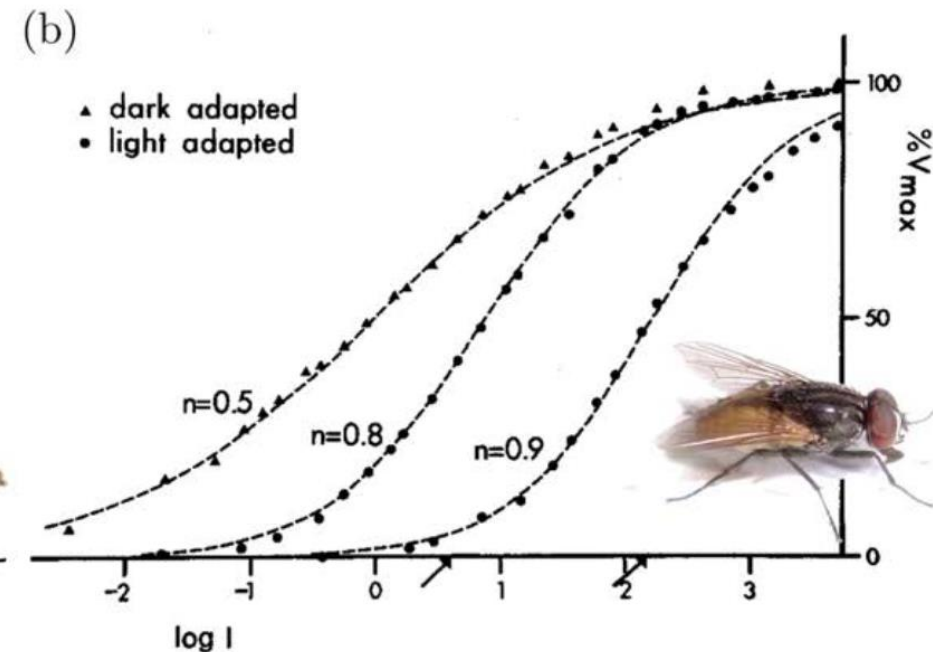
Human visual system

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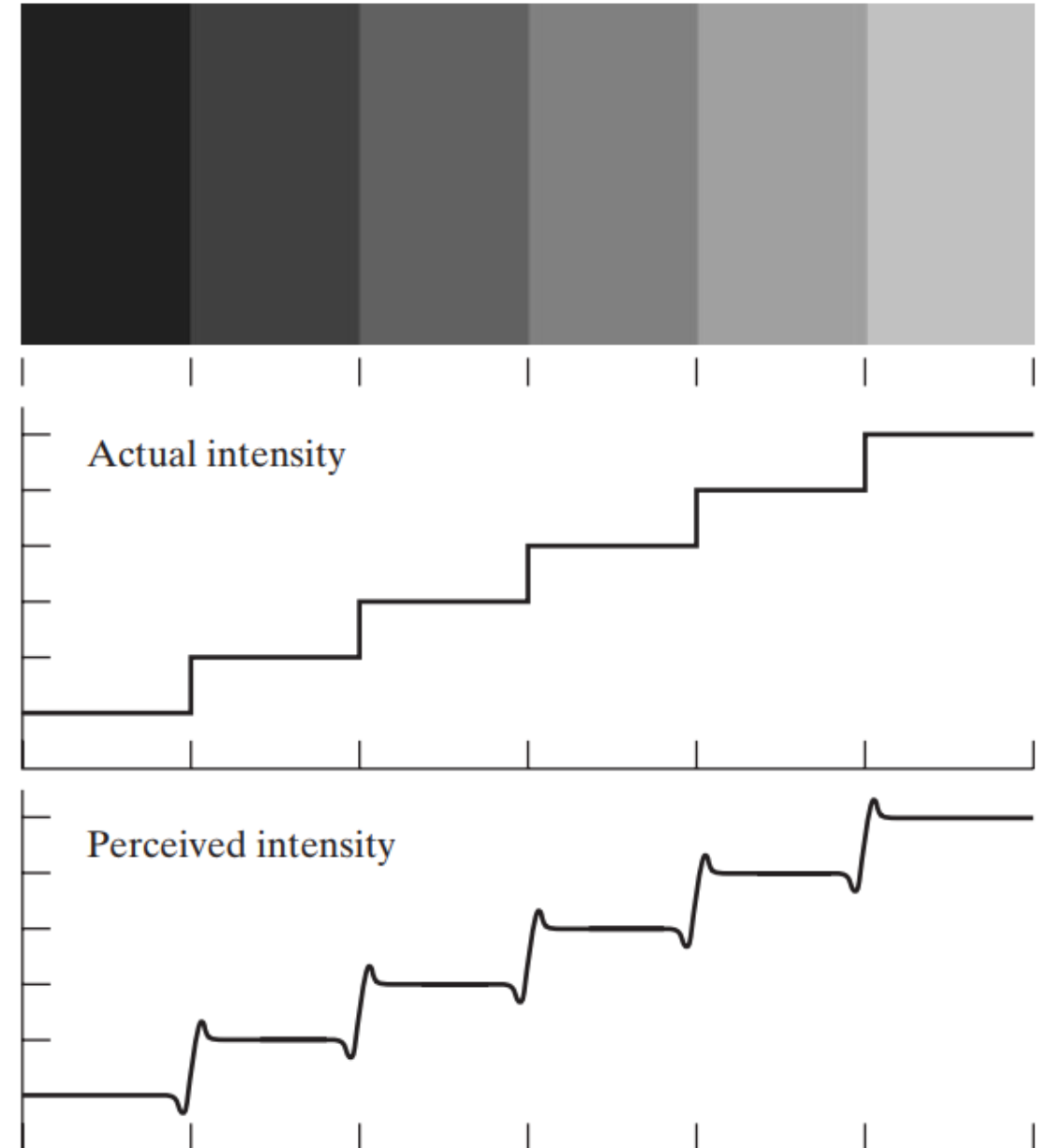 - by changing its overall sensitivity

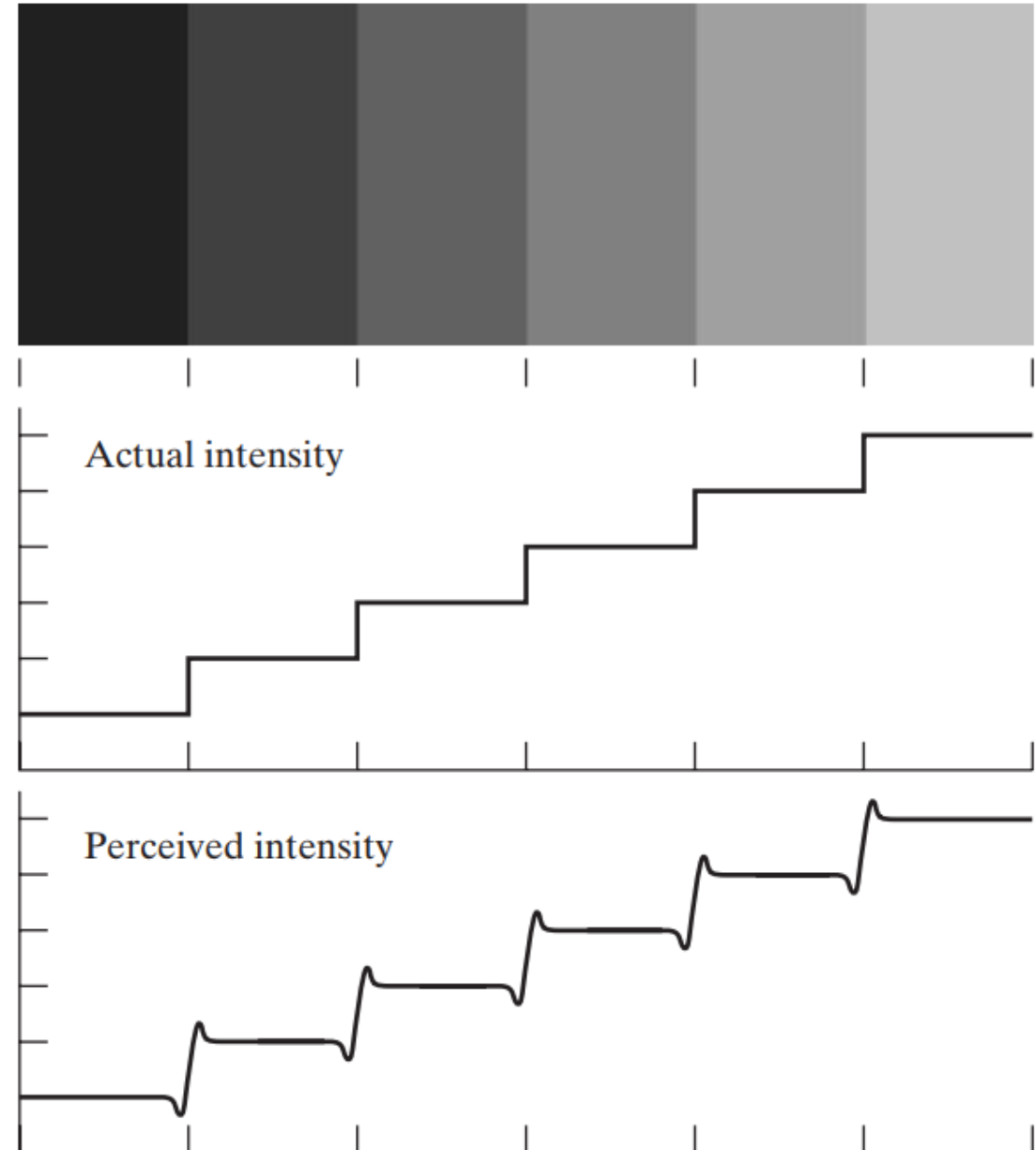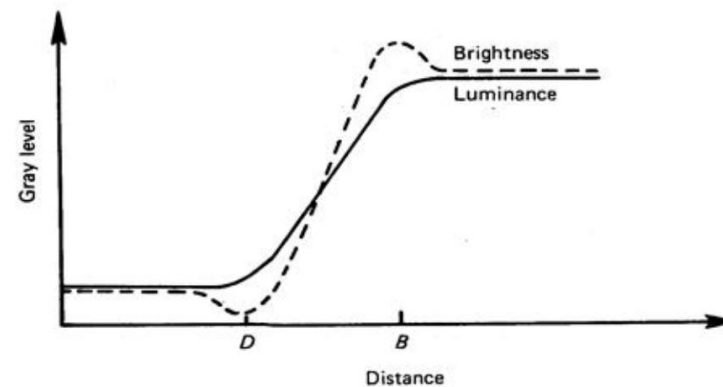# Mach band effect

- Human perception
  - Characteristics of HVS

Actual intensity

Perceived intensity
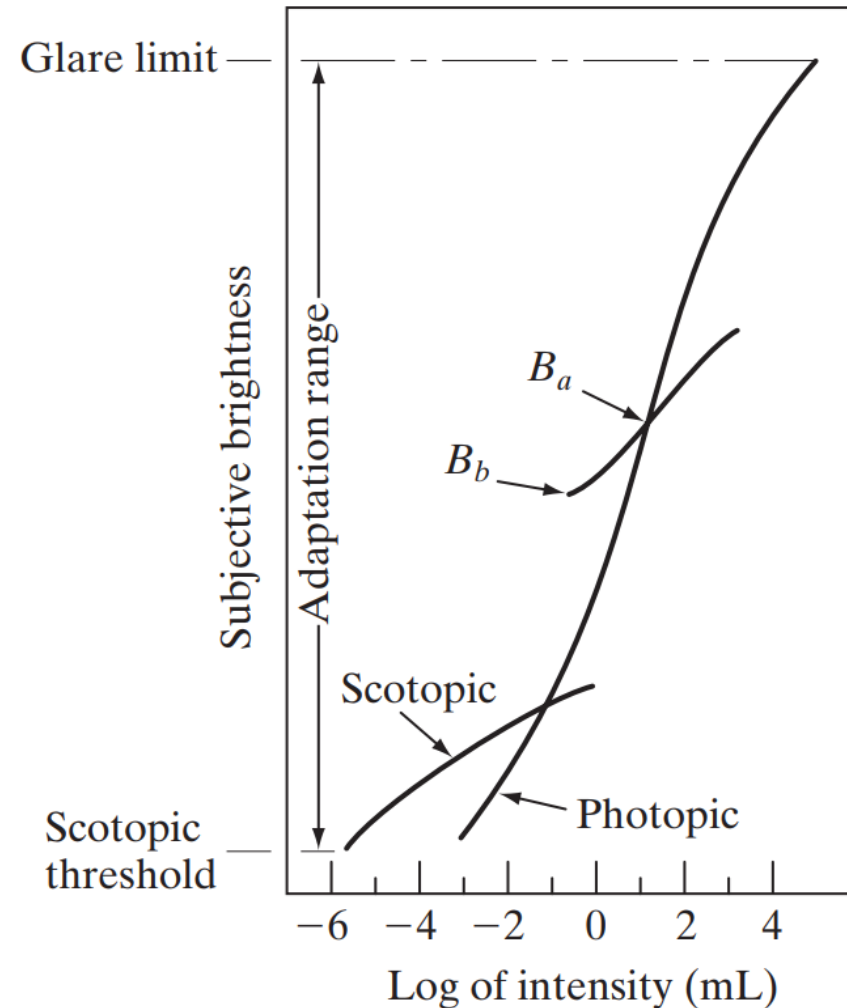
Mach band effect

- Human perception
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Mach band effect
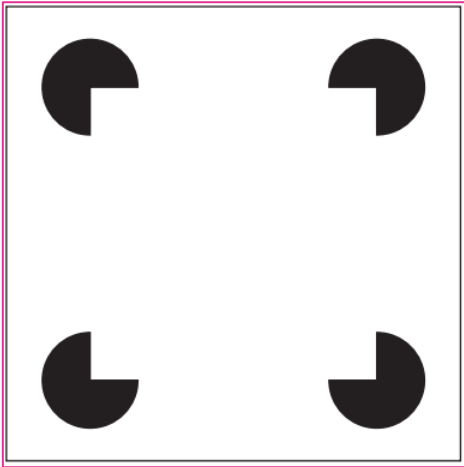
- Human perception
  - Characteristics of HVS

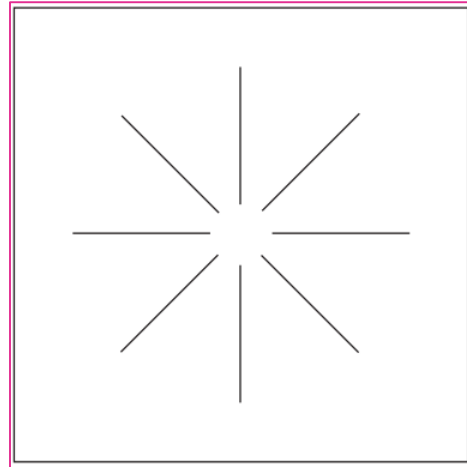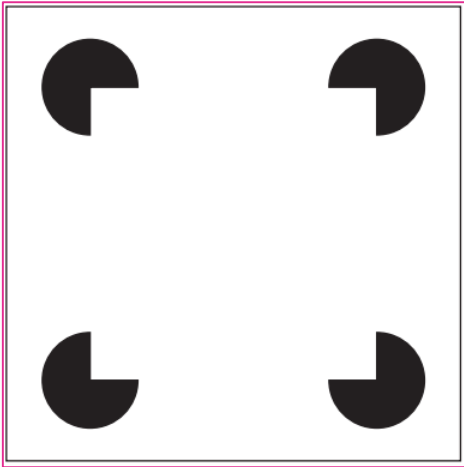# Optical illusions

- Human perception
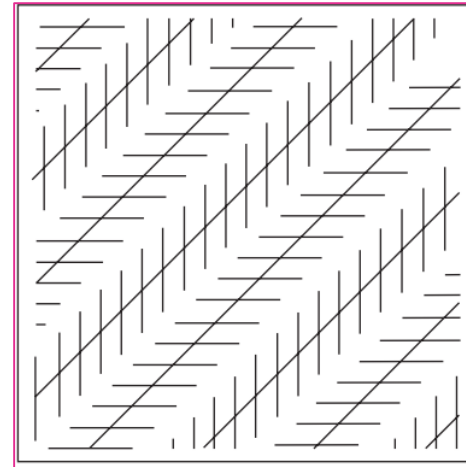 - Characteristics of HVS

Optical illusions

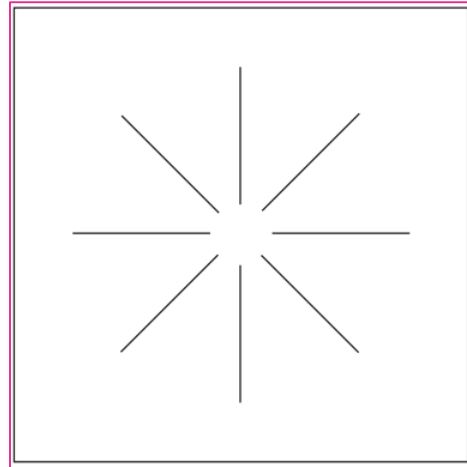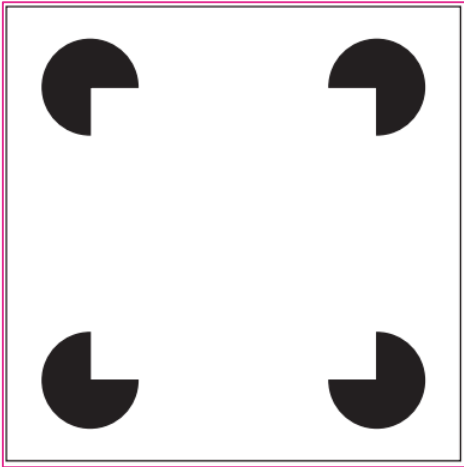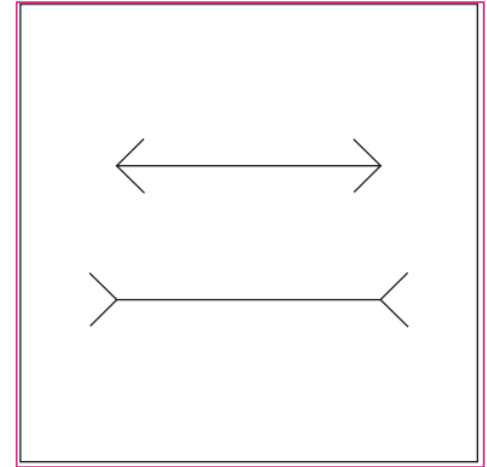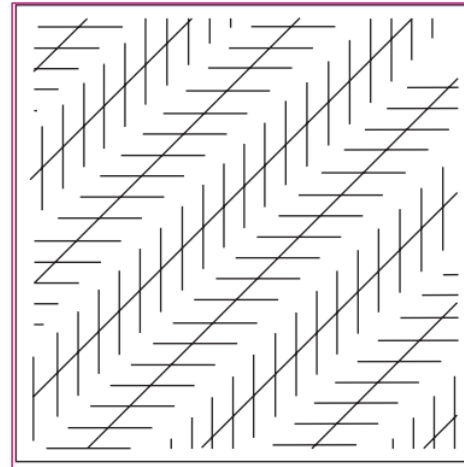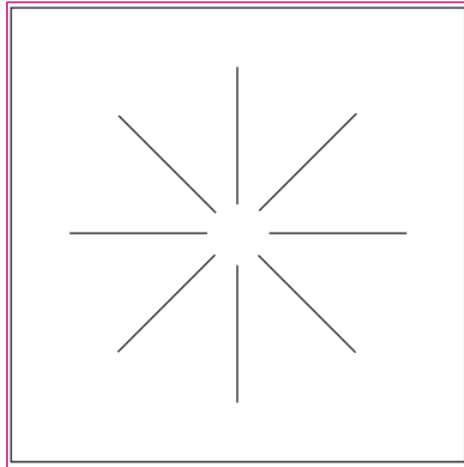- Human perception
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Optical illusions

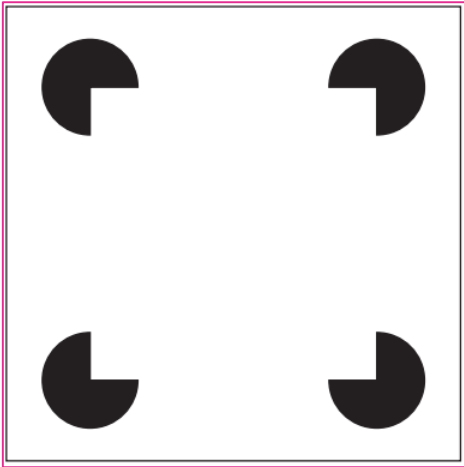- Human perception
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Optical illusions

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Optical illusions

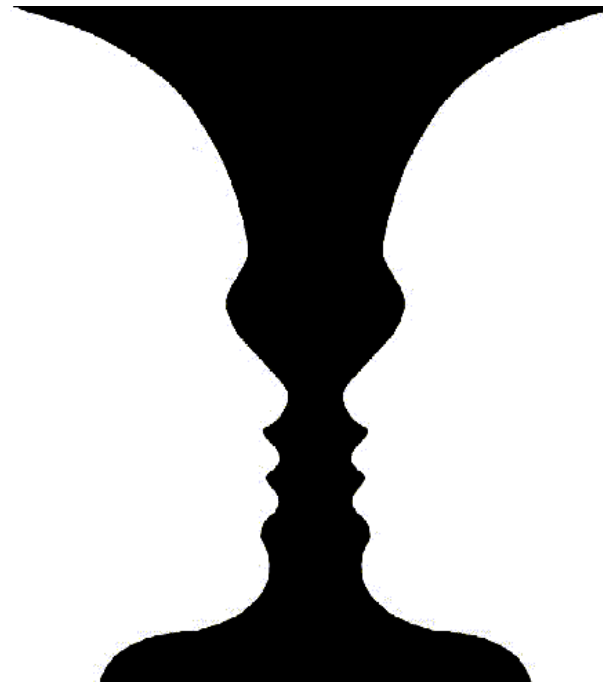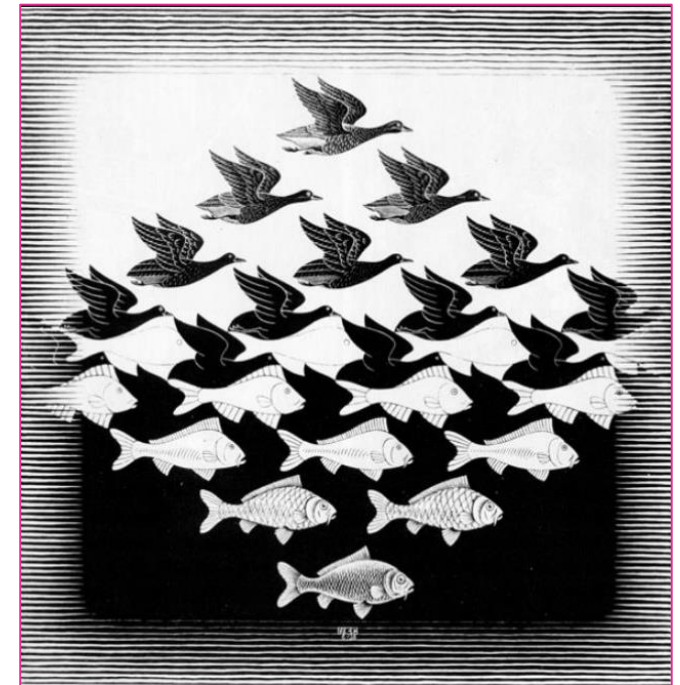- Human perception
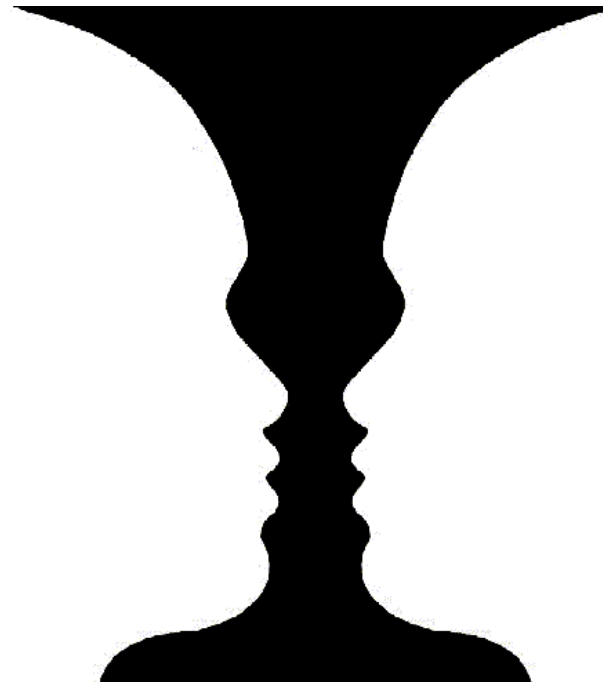 - Characteristics of HVS

Optical illusions

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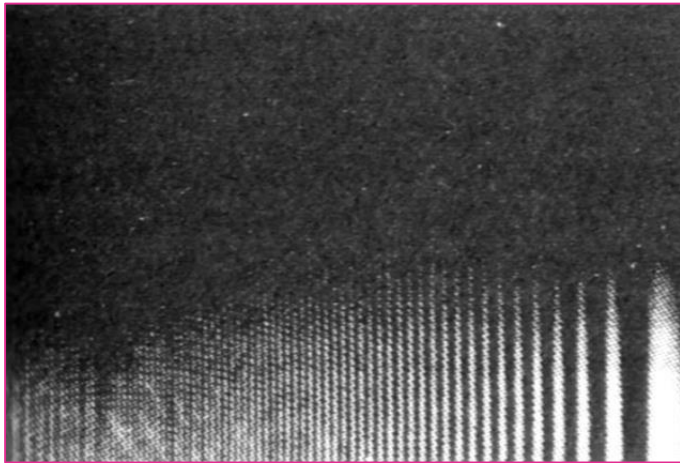
Optical illusions

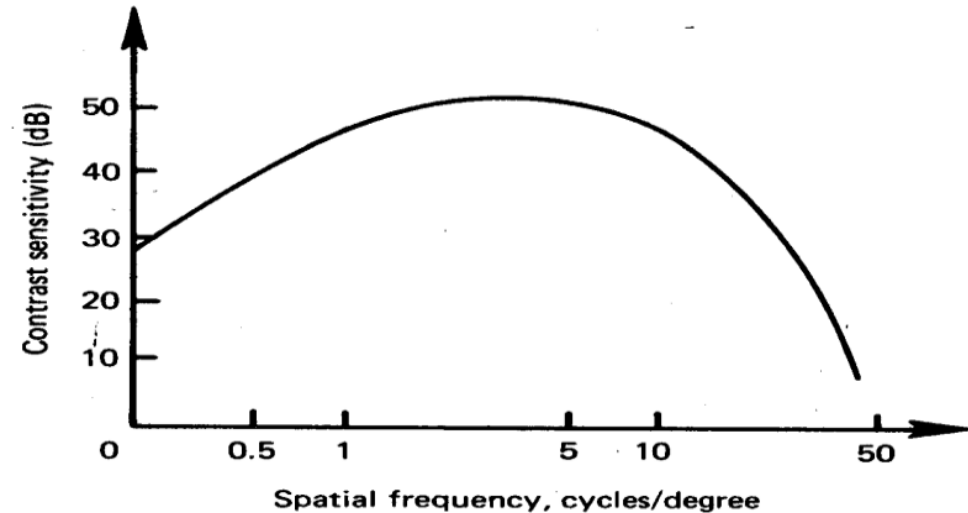- Human perception
  - Characteristics of HVS

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
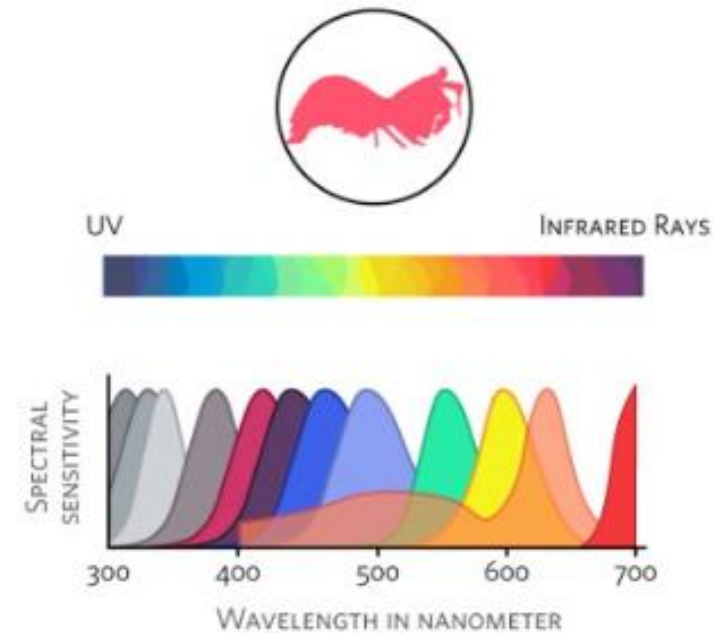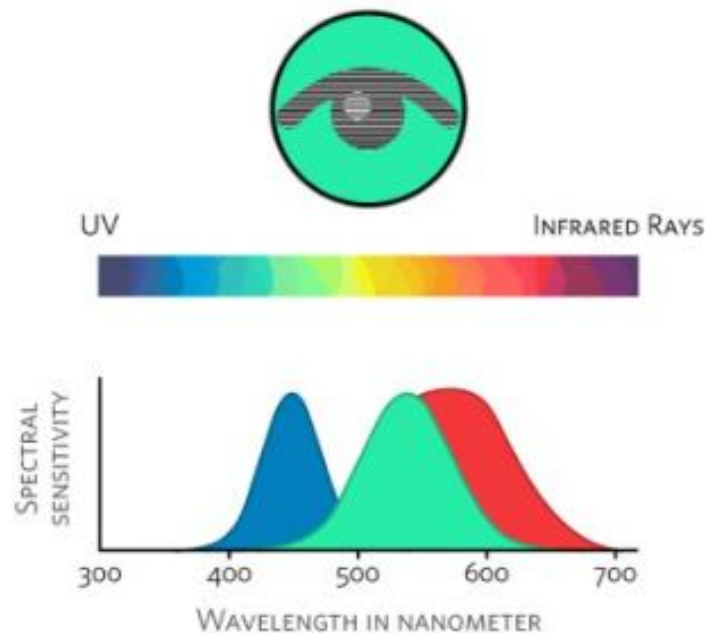 - Interpretation ⎤ Perception

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