[1] Rafael C. Gonzalez, Richard E. Woods, Digital Image Processing 3rd edition）.
House of Electronics Industry, 2017, Chap2.1, Chap2.2, Chap6.1, Chap6.2.
[2] W.Pratt, Digital Image Processing, Third Edition, 2001, Chap2, Chap3.

DIGITAL IMAGE PROCESSING

VISION AND VISION PROPERTIES

CHANG SHU

2022-9-16

psychophysical properties

conceptual models

a stream of massless particles

VISION - LOW LEVEL

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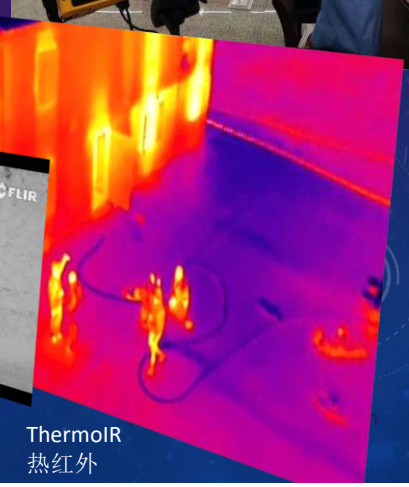
- ElectroMagnetic Spectrum
- Visual band 350 nm ~ 780 nm

Photon
光子

Ultraviolet
紫外

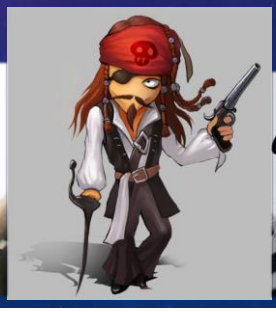
NearIR
近红外



ThermoIR
热红外

VISION - LOW LEVEL

- Why are the traffic lights red, green, yellow(amber) ?
- Why do pirates always wear eye patches?



VISION AND VISION PROPERTIES

visual phenomenon
视觉现象

Vision perception

- Low-level
- High-level

Vision Properties

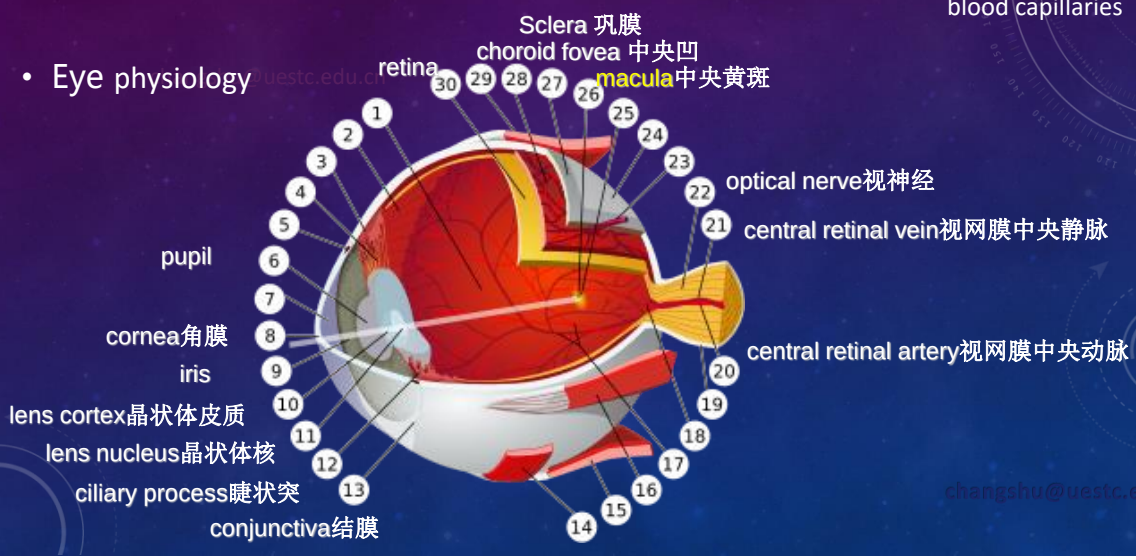
- Intensity property
- Frequency properties
  - Space
  - Wavelength
- Temporal property
- Color response

VISION - LOW LEVEL

- Eye

VISION - LOW LEVEL

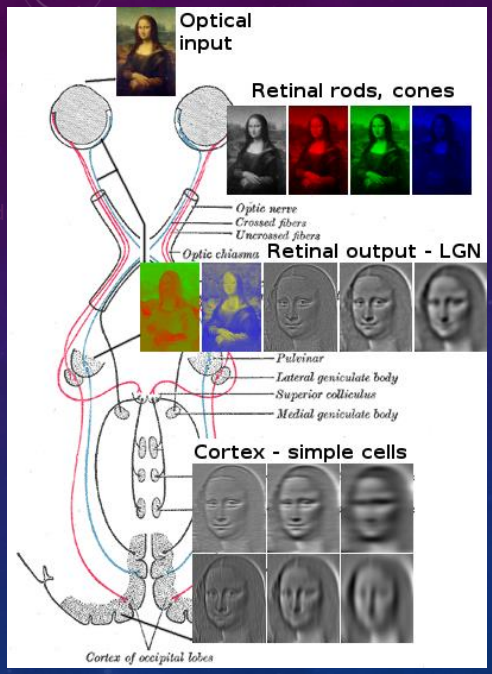
- Eye physiology



Lateral Geniculate Nucleus
外侧膝状体

cortical cell皮质细胞

thalamus丘脑

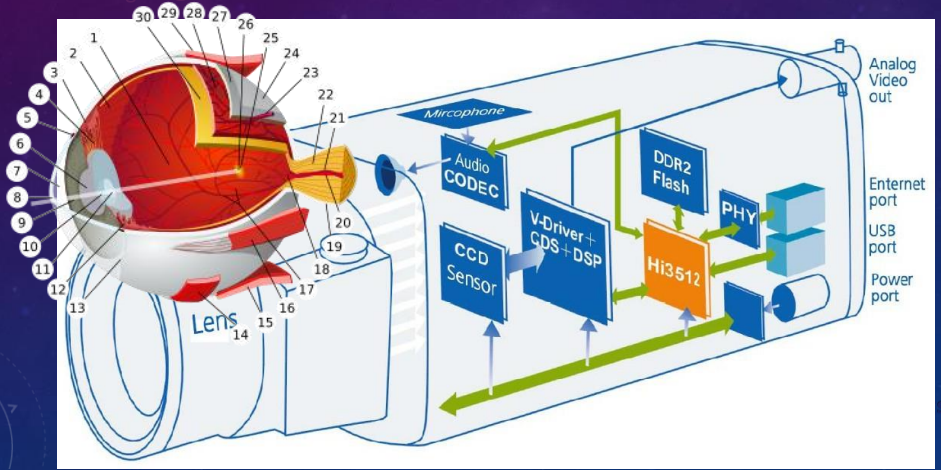


VISION - LOW LEVEL

out of focus

aperture

- Digital Camera vs Eye



VISION - LOW LEVEL

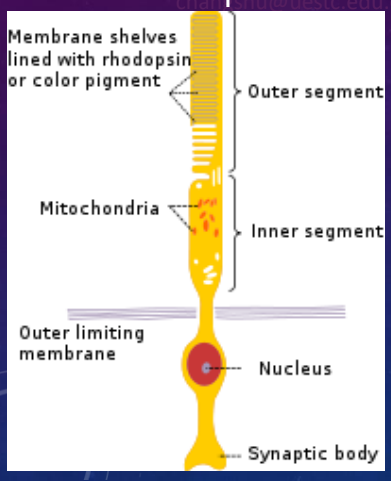
Photoelectrochemical reaction
光电化学反应

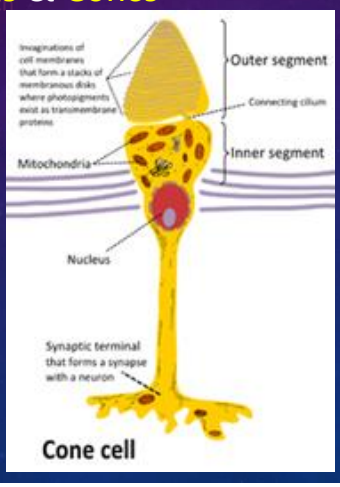
- Retina translates 2D image into impulses
- Optical nerve sends those impulses into the brain to create visual perception
- Two receptors – Rods & Cones
  - Rods：thin and long，~120 million， Scotopic Vision ， high sensitivity，achromatic，low acuity（spatial acuity）
  - Cones：thick and short，6~7 million， Photopic Vision，lower absolute sensitivity ， chromatic ， high acuity

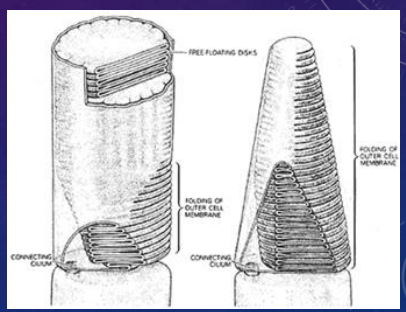
VISION - LOW LEVEL

pigment色素
Rhodopsin视紫红质
membrane细胞膜

- Two receptors – Rods & Cones







protein
chain-reactions

VISION - LOW LEVEL

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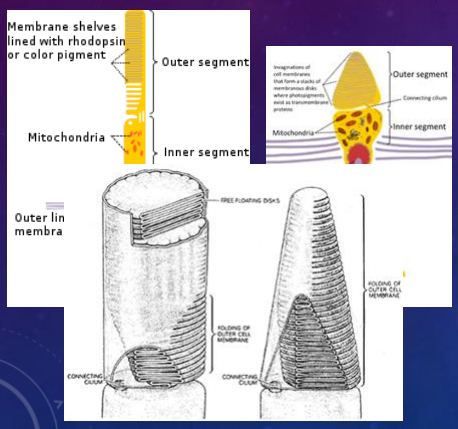
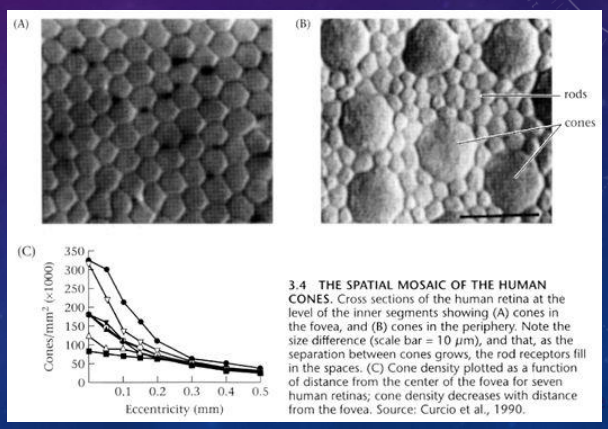
VISION - LOW LEVEL

- Two receptors – Rods & Cones



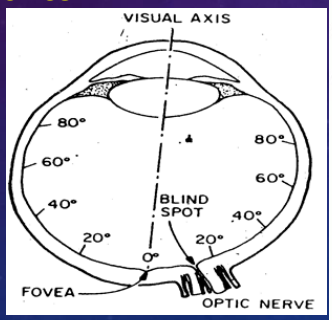
fovea periphery



3.4 THE SPATIAL MOSAIC OF THE HUMAN CONES. Cross sections of the human retina at the level of the inner segments showing (A) cones in the fovea, and (B) cones in the periphery. Note the size difference (scale bar = 10 μm), and that, as the separation between cones grows, the rod receptors fill in the spaces. (C) Cone density plotted as a function of distance from the center of the fovea for seven human retinas; cone density decreases with distance from the fovea. Source: Curcio et al., 1990.

VISION - LOW LEVEL

- Two receptors – Rods & Cones



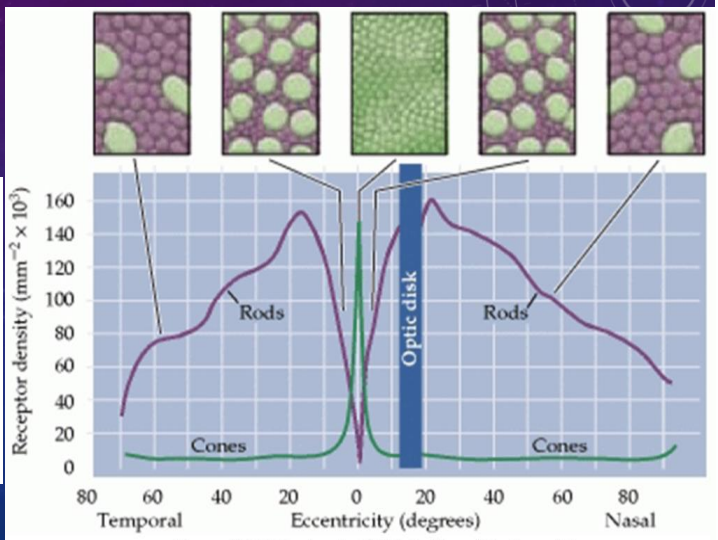
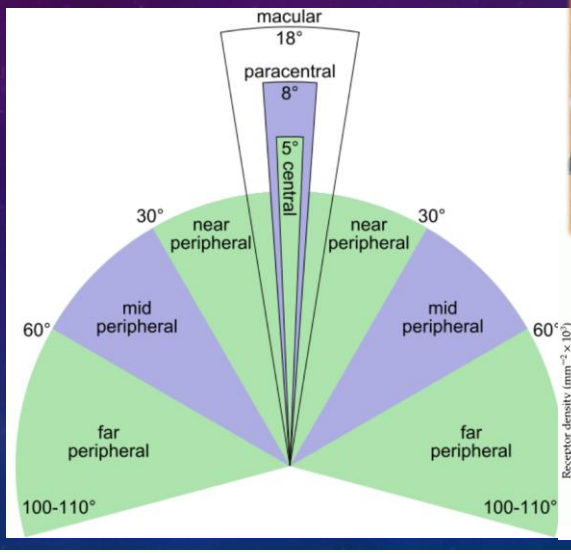


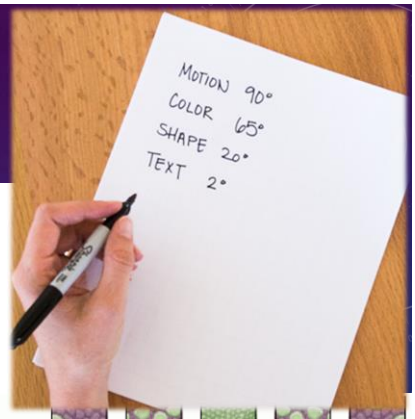
Figure 11.10 Anatomical Distribution of Rods and Cones

VISION - LOW LEVEL

Peripheral vision

Predator 捕食者





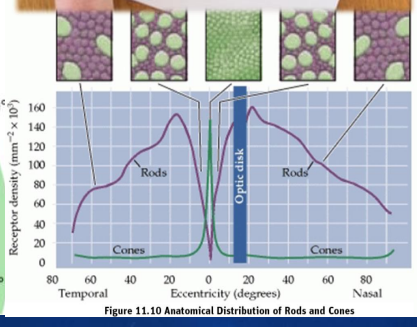


Figure 11.10 Anatomical Distribution of Rods and Cones

VISION - LOW LEVEL

iodopsins 视紫蓝质 (rhodopsin analogs)

protein-pigment complex

cyanolabe

chlorolabe

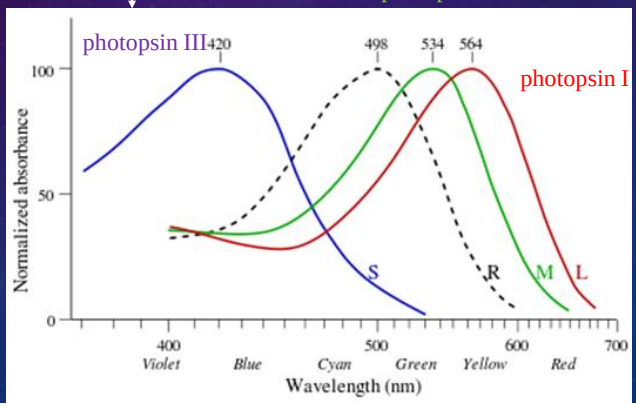
photopsin II

photopsin III

photopsin I

erythrolabe

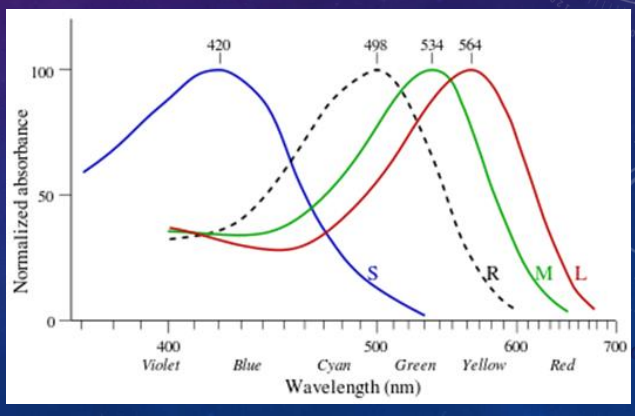
absorbance



VISION - LOW LEVEL

trichromatic theory
三原色理论

- **Two receptors – Rods & Cones**
  - Type：Rods(1) v.s. Cones(3)



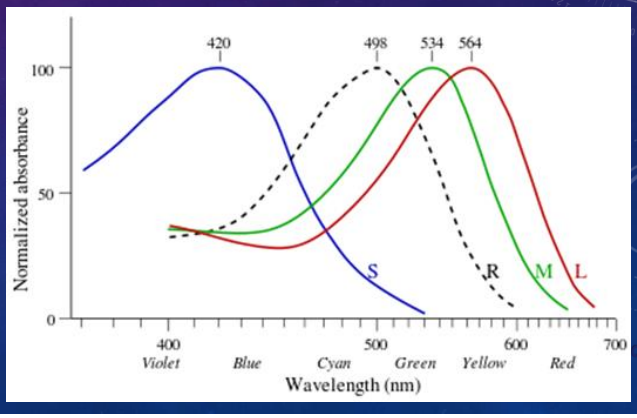
VISION - LOW LEVEL

Red rose at twilight

subdued green leaves

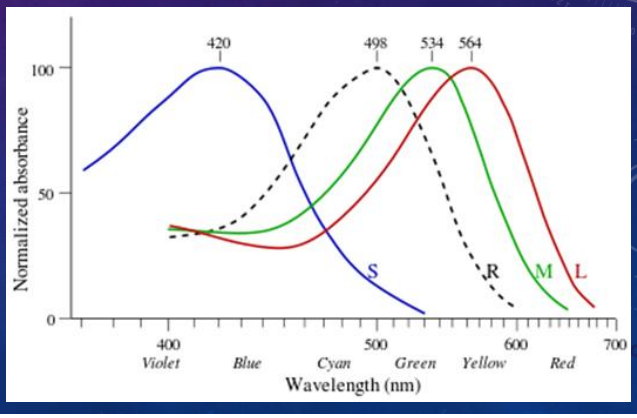
red petals

- **Two receptors – Rods & Cones**
  - Type：Rods(1) v.s. Cones(3)



VISION - LOW LEVEL

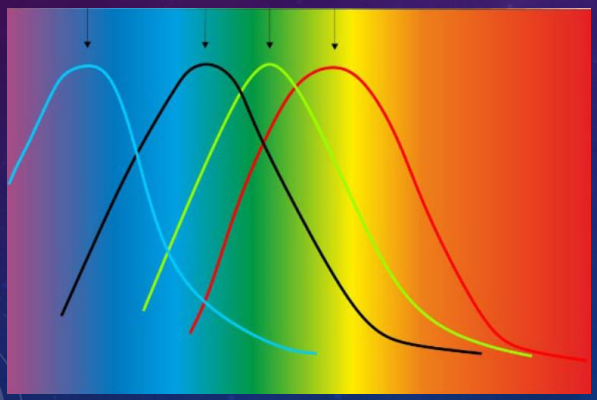
- **Two receptors – Rods & Cones**
  - Type：Rods(1) v.s. Cones(3)

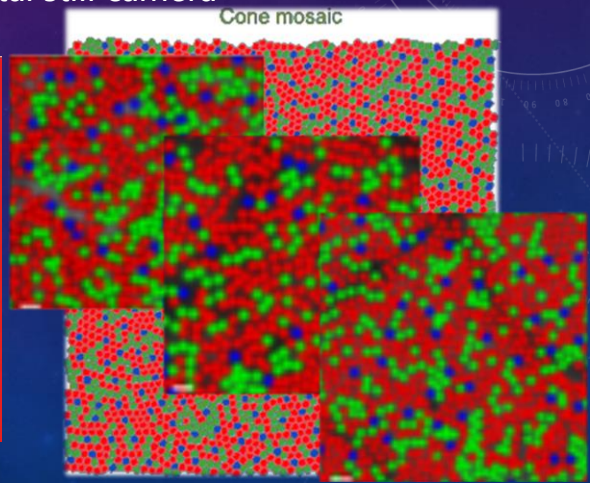


- Color Blindness
  - Monochromats
  - Dichromats

VISION - LOW LEVEL

- Image digitization process in CCD digital still camera

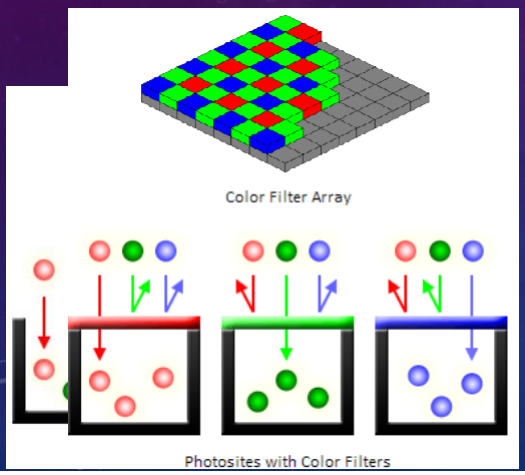


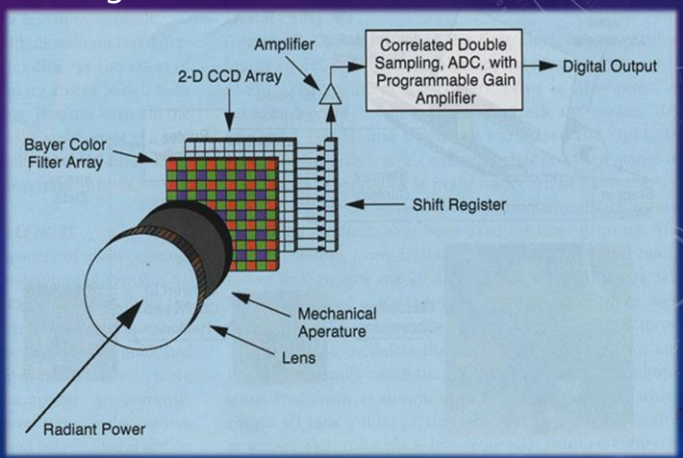


Photosites

VISION - LOW LEVEL

- Image digitization process in CCD digital still camera

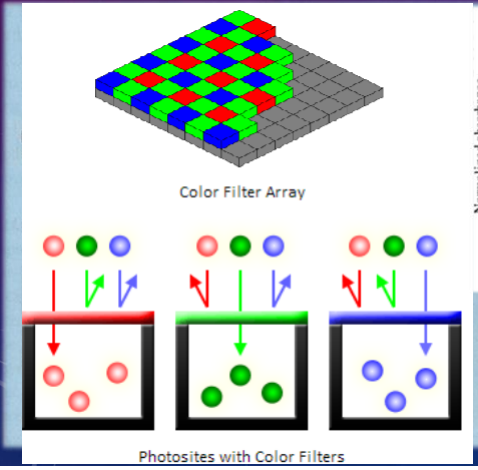


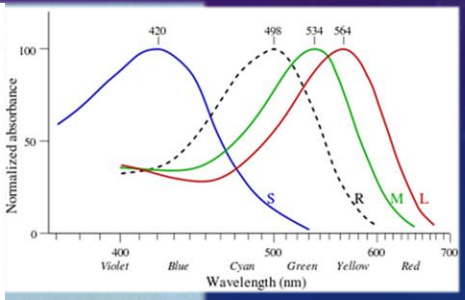


Bayer CFA

VISION - LOW LEVEL

- Image digitization process in CCD digital still camera





VISION - LOW LEVEL

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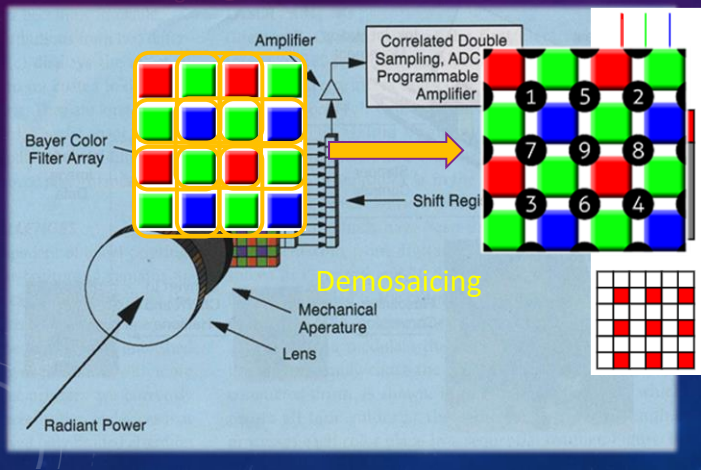

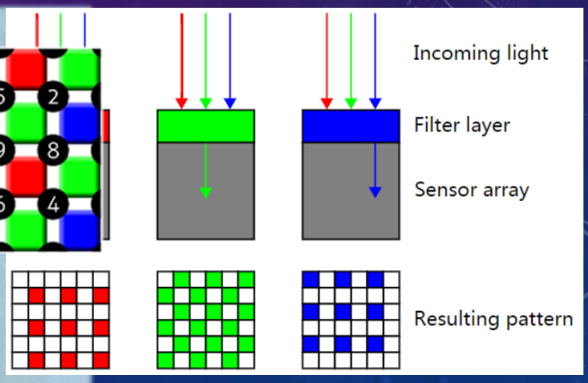

VISION - LOW LEVEL

- **Two receptors – Rods & Cones**
  - Rods：thin and long，~120 million， Scotopic Vision ， high sensitivity，achromatic，low acuity（spatial acuity）
  - Cones：thick and short，6~7 million， Photopic Vision，lower absolute sensitivity ，chromatic ， high acuity
  - They have different type (Rods 1 v.s. Cones 3), distribution and Connections to the brain:(Rods(group) v.s. Cones(single))

VISION - LOW LEVEL

Rods	Cones	Comment
• Achromatic • High sensitivity • High amplification • Slow response • Low acuity	• Chromatic • Low sensitivity • Less amplification • Fast response • High acuity	• 3 types of Cones • Single photon detection in rods • Temporal integration • spatial integration

VISION - HIGH LEVEL

- Some researchers believe that "Thinking is part of perception."
- Visual perception is also "visual thinking", not a simple copy action of stimulus, our past experience involves in our current visual perception

VISION - HIGH LEVEL

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- Visual perception is also "visual thinking", not a simple copy action of stimulus, our past experience involves in our current visual perception

pillar

VISION AND VISION PROPERTIES

Vision perception

- Low-level
- High-level

Vision Properties

- Intensity property
- Frequency properties
  - Space
  - Wavelength
- Temporal property
- Color response

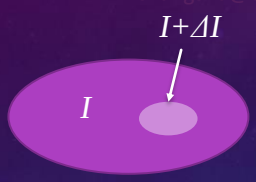
VISION PROPERTIES

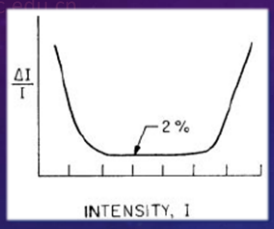
- Review: image
  - A mapping of the world

$$f(x, y, \lambda, t) \quad \text{-----> } \quad I(m, n)$$

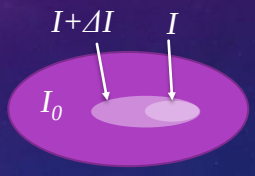
- Visual phenomena includes the visual responses to intensity, wavelength, color spectrum, and spacial frequency change such as the edges of an object, etc.

VISION PROPERTIES

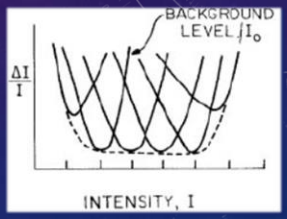




Weber fraction: ΔI/ I



$f(I, I_0)$



- Contrast sensitivity
  - The response of the eye to changes in the intensity of illumination is known to be nonlinear