



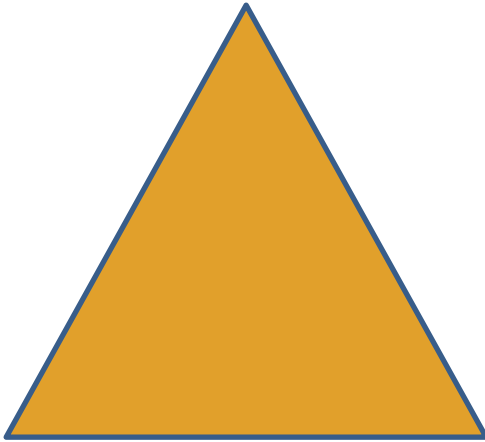
IMAGE PROCESSING

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Human visual system



- What is the shape?
- What color is it?
- Do you like it?

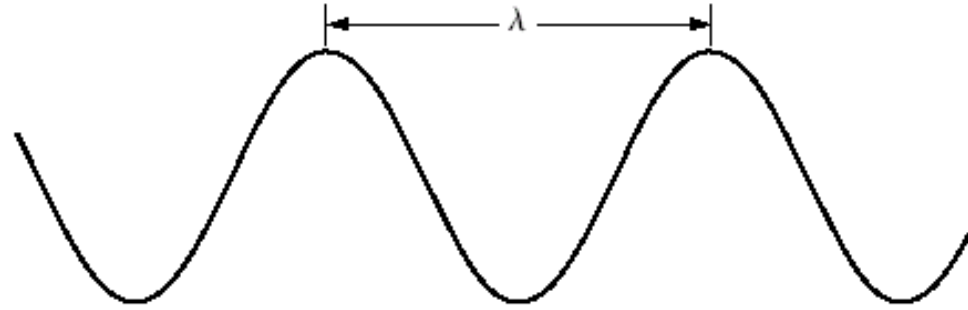
Content

2. Fundamental of Digital Images

- Electromagnetic Spectrum of Light & Image Formation in human eyes.
- Human Visual Perception
- Spatial Frequency Resolution
- Temporal Frequency Resolution

Light

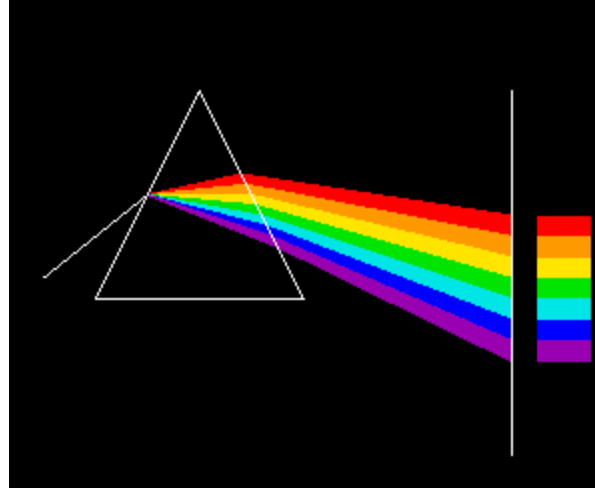
FIGURE 2.11
Graphical
representation of
one wavelength.



$$\lambda = \frac{c}{f}$$

- λ : wavelength
- c : speed of light ($2.998 \times 10^8 \text{ m/s}$)
- f : frequency

Isaac Newton prism



- Sunlight consists of continuous spectrum of colors ranging from violet to red

Light and Electromagnetic Spectrum

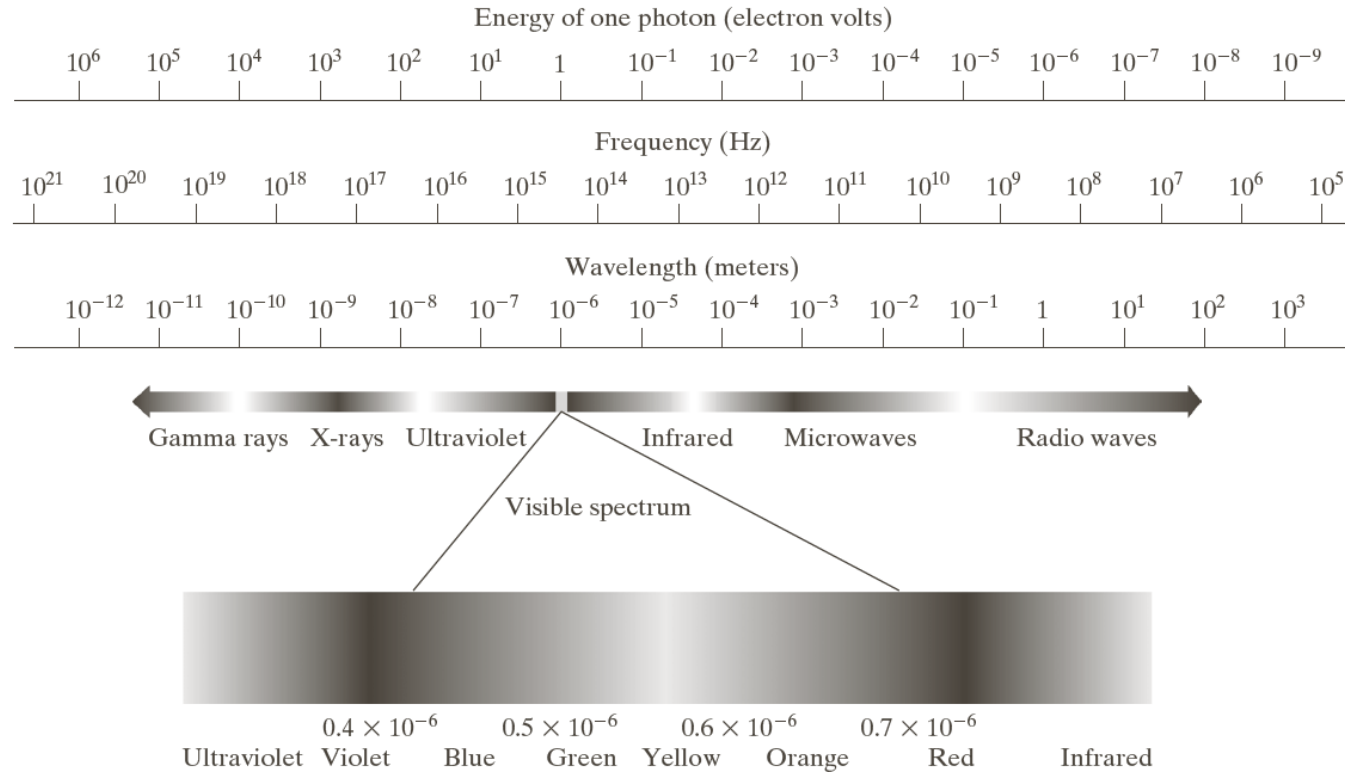


FIGURE 2.10 The electromagnetic spectrum. The visible spectrum is shown zoomed to facilitate explanation, but note that the visible spectrum is a rather narrow portion of the EM spectrum.

Light properties

- Light is a particular type of EM radiation:
 - Can be presented by frequency or wavelength
 - Natural white light (include all frequencies) comes from the sun (S. I. Newton's glass prism)
 - When an object is radiated by white light:
 - Object absorbs some ranges of light's frequency and reflects the others
 - Human eyes perceive the reflected light and assume it as the object's color.
 - Eg: green objects reflect light with wavelengths primarily in [500,570] nm range and absorb most of the energy at other wavelengths.

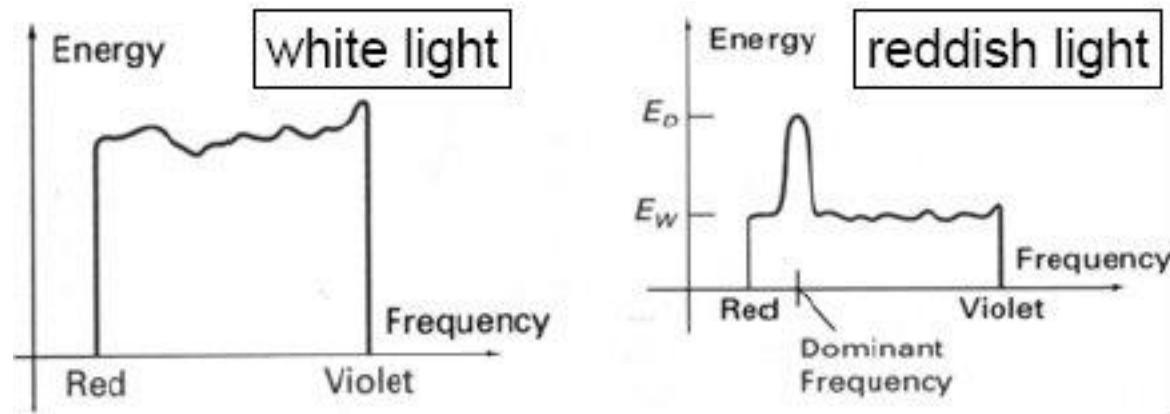
Why we still perceive scene around even though there is no sun?

Light properties

- Light that is devoid of color is called monochromatic light (ML).
 - Intensity of ML varies from black to gray, and white → gray level, or just intensity.
- Color light:
 - Luminance: amount of energy perceived.
 - Chrominance:
 - Frequencies of wavelight
 - Hue
 - Purity

Light properties

- Frequency (hue, color)
- Luminance (sum of area under the freq. curve)
- Purity: $(E_D - E_W) / E_D$



Human Visual Perception

- Human perception encompasses both the physiological and psychological aspects.
- We will focus more on physiological aspects, which are more easily quantifiable and hence, analyzed.

Human Visual Perception

- Why study visual perception?
 - Image processing algorithms are designed based on how our visual system works.
 - In image compression, we need to know what information is not perceptually important and can be ignored.
 - In image enhancement, we need to know what types of operations that are likely to improve an image visually.

The Human Visual System

- The human visual system consists of two primary components
 - the eye and the brain, which are connected by the optic nerve.
 - Eye – receiving sensor (camera, scanner).
 - Brain – information processing unit (computer system).
 - Optic nerve – connection cable (physical wire).

How eye looks

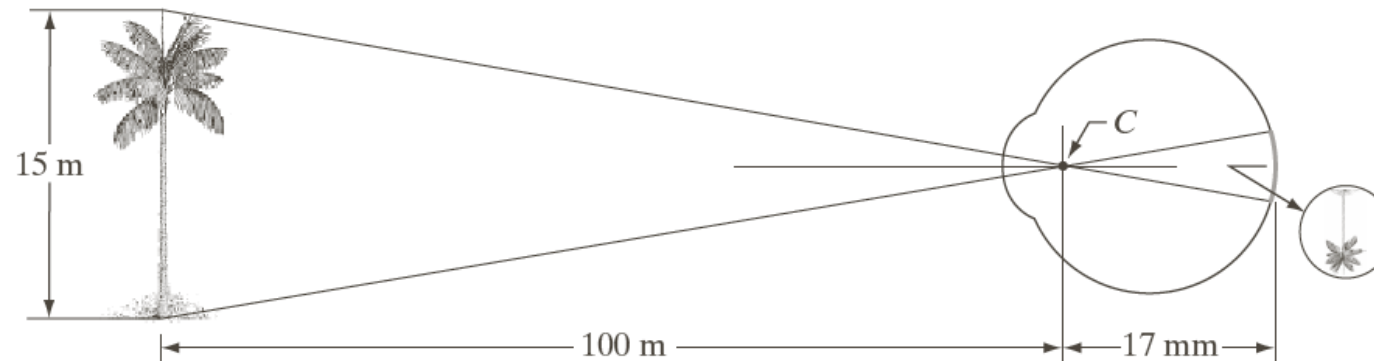
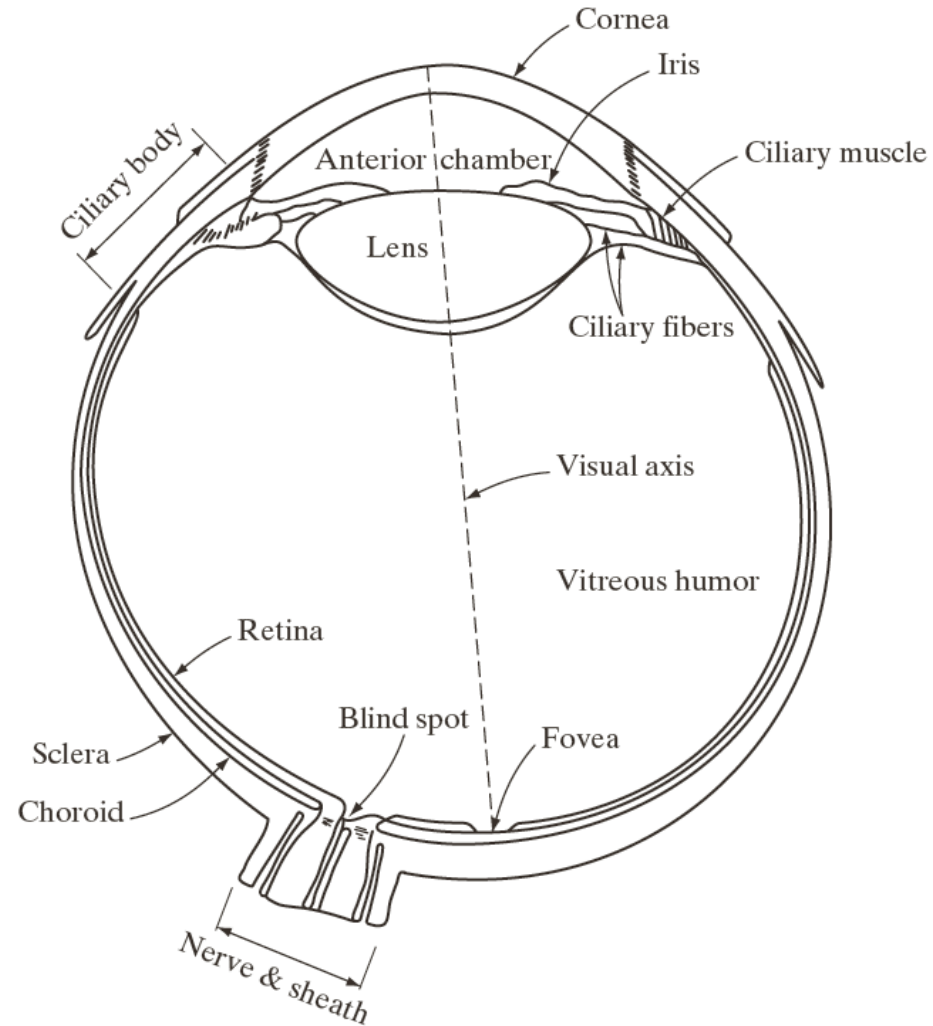


FIGURE 2.3
Graphical representation of the eye looking at a palm tree. Point *C* is the optical center of the lens.

Thu Human Visual System



The Human Visual System

- This is how human visual system works:
 - Light energy is focused by the lens of the eye into sensors and retina.
 - The sensors respond to the light by an electrochemical reaction that sends an electrical signal to the brain (through the optic nerve).
 - The brain uses the signals to create neurological patterns that we perceive as images.

The Human Visual System

- The visible light is an electromagnetic wave with wavelength range of about 380 to 825 nanometers.
 - However, response above 700 nanometers is minimal.
- We cannot “see” many parts of the electromagnetic spectrum.

The Human Visual System

- The visible spectrum can be divided into three bands:
 - Blue (400 to 500 nm).
 - Green (500 to 600 nm).
 - Red (600 to 700 nm).
- The sensors are distributed across retina.

The Human Visual System

- There are two types of sensors: rods and cones.
- Rods:
 - For night vision.
 - See only brightness (gray level) and not color.
 - Distributed across retina.
 - Medium and low level resolution.

The Human Visual System

- Cones:
 - For daylight vision.
 - Sensitive to color.
 - Concentrated in the central region of eye.
 - High resolution capability (differentiate small changes).

The Human Visual System

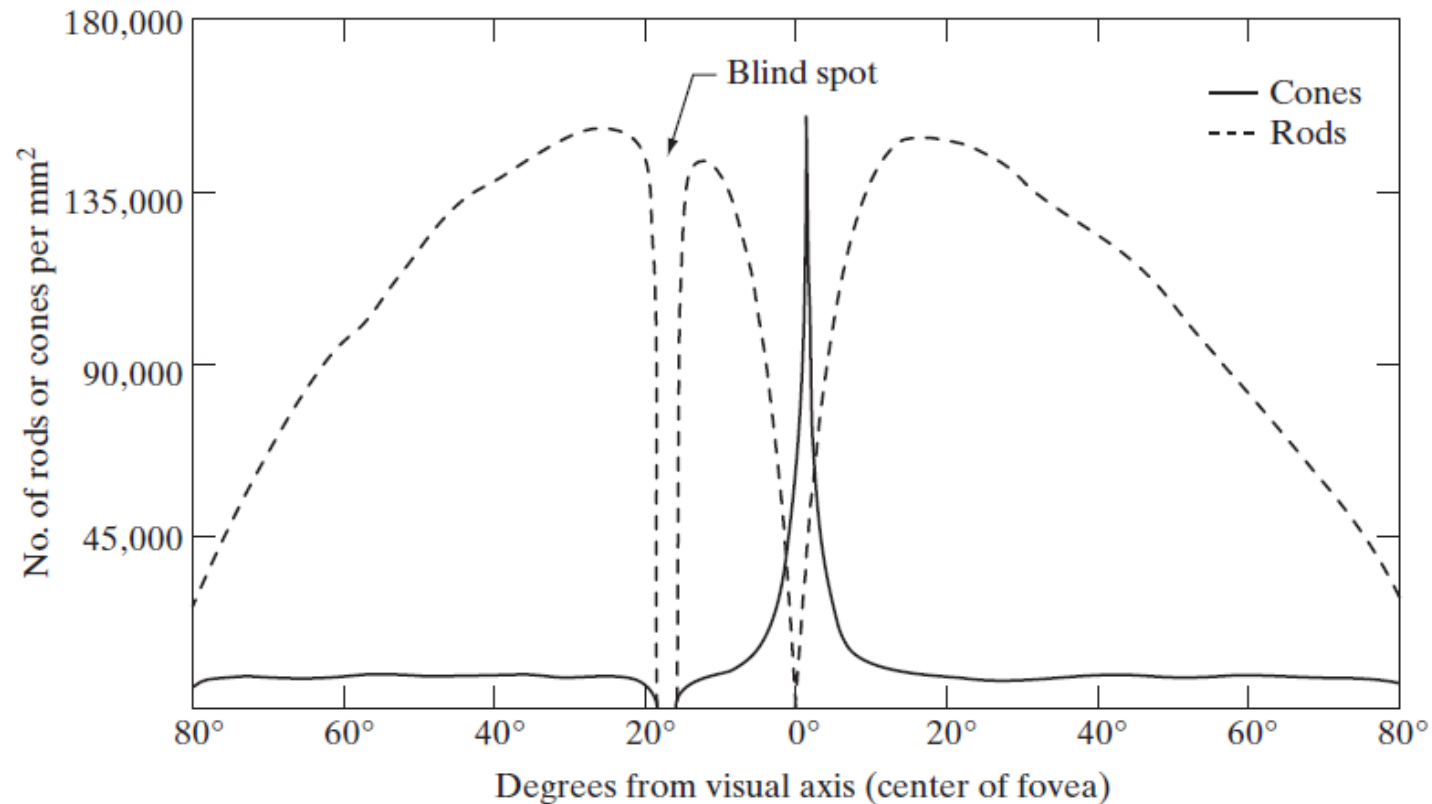


FIGURE 2.2
Distribution of
rods and cones in
the retina.

The Human Visual System

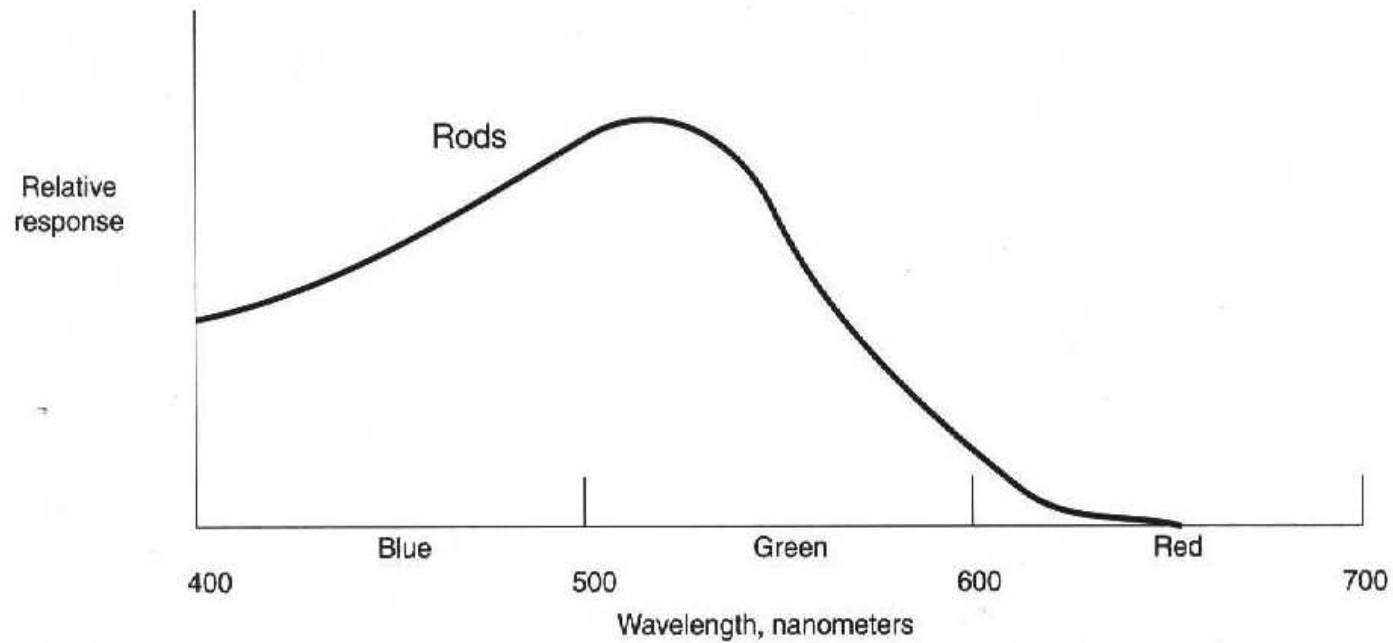
- Blind spot:
 - No sensors.
 - Place for optic nerve.
 - We do not perceive it as a blind spot because the brain fills in the missing visual information.
- Why does an object should be in center field of vision in order to perceive it in fine detail?
 - This is where the cones are concentrated.

The Human Visual System

- Cones have higher resolution than rods because they have individual nerves tied to each sensor.
- Rods have multiple sensors tied to each nerve.
- Rods react even in low light but see only a single spectral band. They cannot distinguish color.

The Human Visual System

Figure 1.6-4 Relative Responses of Rods and Cones

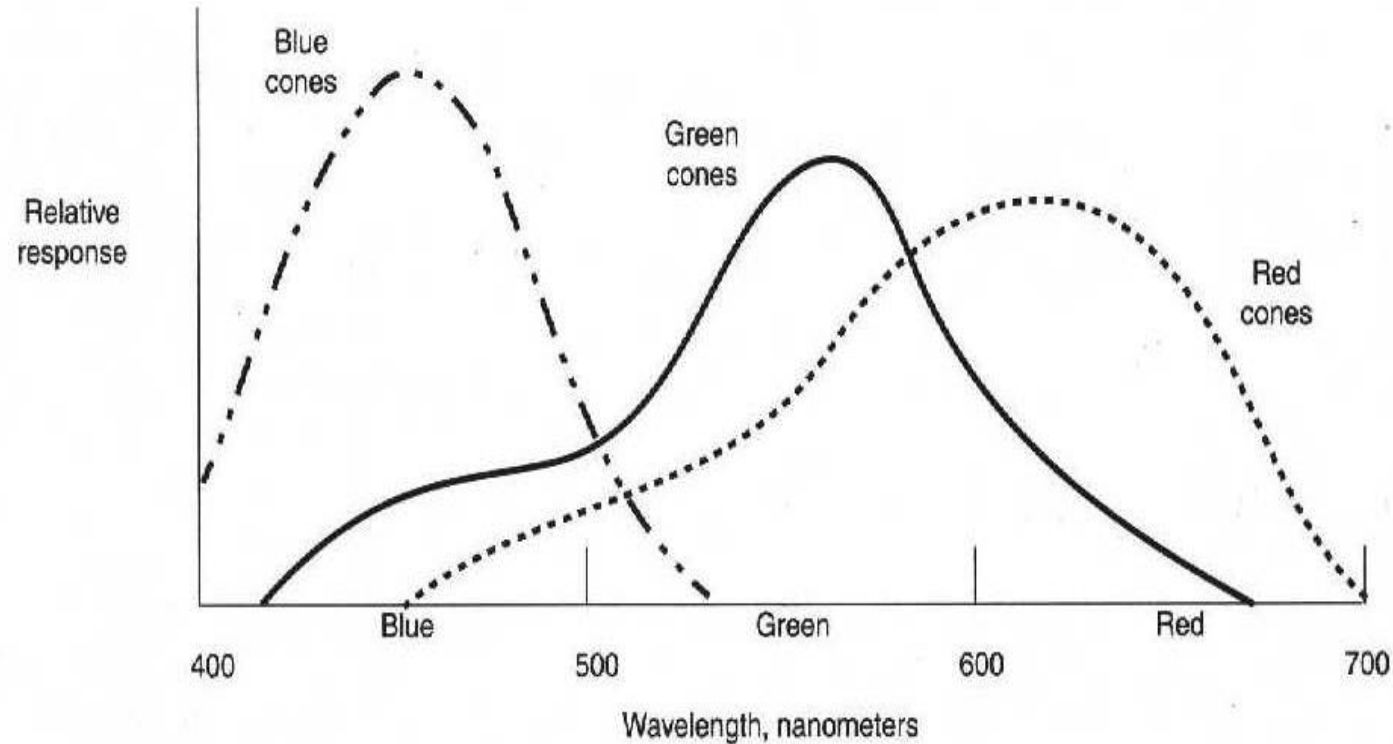


a. Rods react even in low light levels but see only a single spectral band; they cannot distinguish colors.

The Human Visual System

- There are three types of cones. Each responding to different wavelengths of light energy.
- The colors that we perceive are the combined result of the response of the three cones.

The Human Visual System



b. Cones react only to high light intensities; the three types enable us to see colors.

Other species' Visual Systems

- Eagle: Best resolution (6 times than human)
- Owl: Largest visual field (360°)
- Ants: Ultraviolet sensing
- Rattle snake: Infra red sensing
- Dogs: Color blind

Số hóa (Thu nhận hình ảnh)

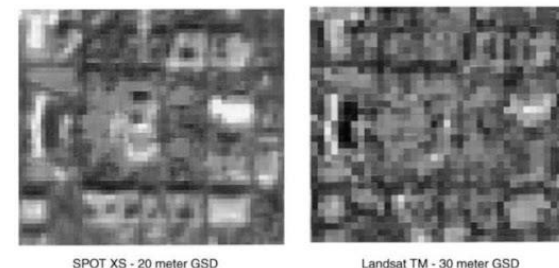
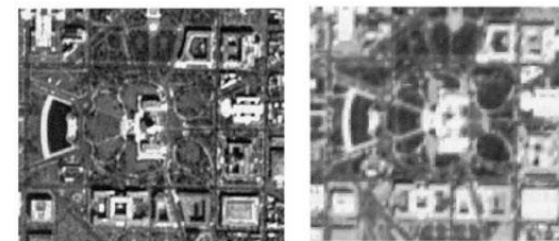
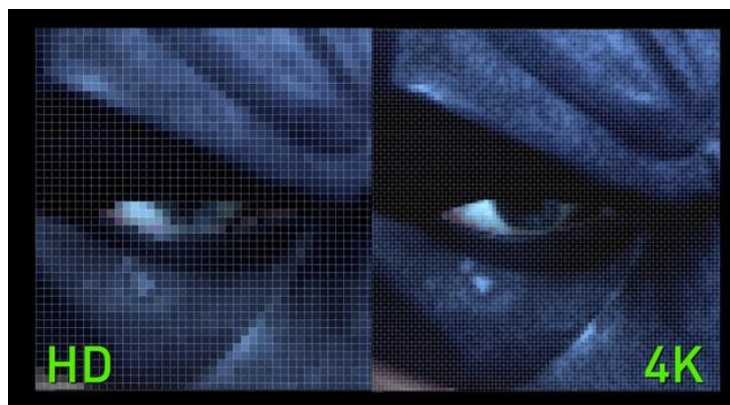
- Thu nhận hình ảnh bằng thiết bị số bản chất là số hóa năng lượng ánh sáng theo các trục:
 - Không gian
 - Thời gian
 - Cường độ
 - Phổ ánh sáng

Độ phân giải

- Độ phân giải không gian
- Độ phân giải thời gian
- Độ phân giải bức xạ
- Độ phân giải phổ

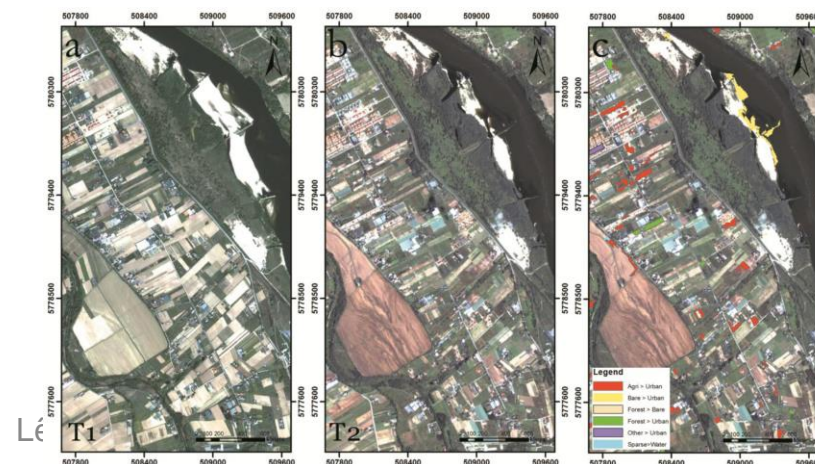
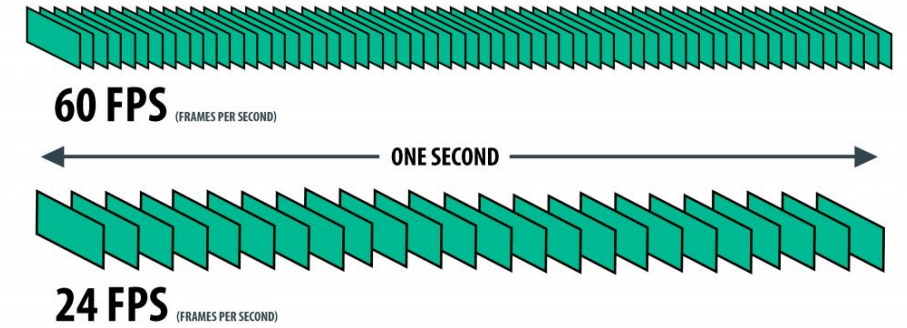
Độ phân giải không gian

- Kích thước ảnh (VGA, Half-HD, HD, 2K, 4K, ...)
- Mega pixels (2M Pixels, 12M Pixels, ...)
- Kích thước thực tế mà một điểm ảnh có thể biểu diễn (1m, 10m, 500m, 1km, 10km, ...)



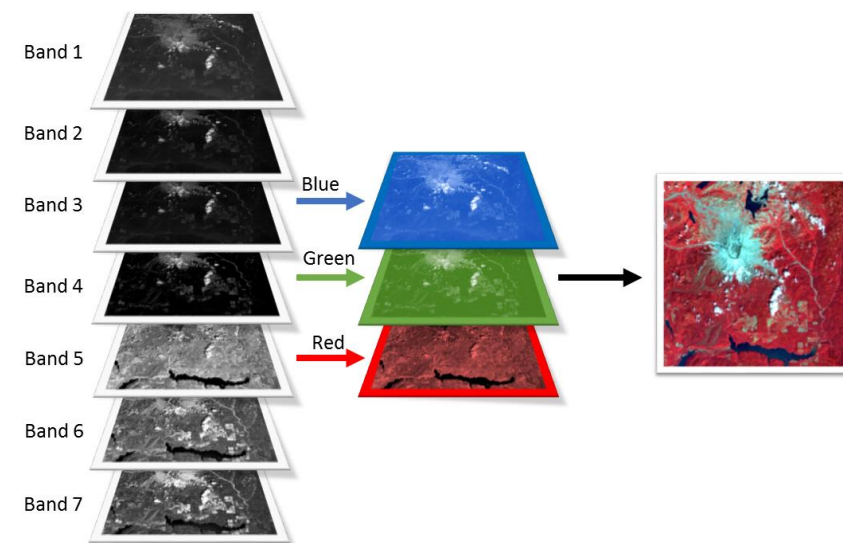
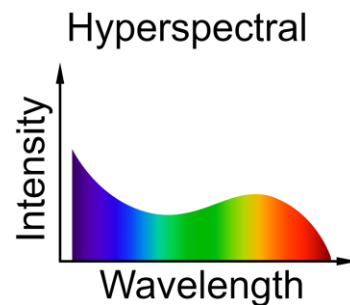
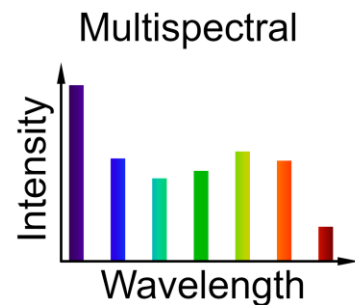
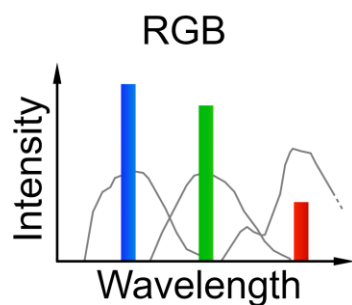
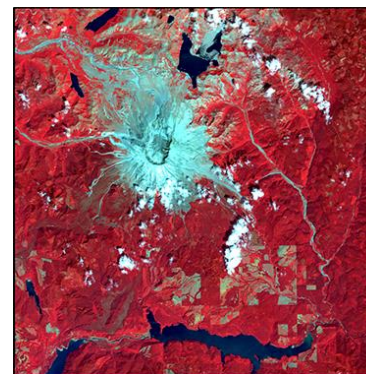
Độ phân giải thời gian

- Số frame trong một giây (fps): 15fps, 24fps, 30fps, 60fps, ...
- Khoảng thời gian chụp giữa 2 ảnh (1 ngày, 2 ngày, 16 ngày, ...)



Độ phân giải phổ

- Ảnh đen trắng
- Ảnh màu
- Ảnh đa phổ
- Ảnh siêu phổ



Độ phân giải bức xạ

- Ảnh nhị phân
- Ảnh 8 bit
- Ảnh 10 bit
- Ảnh 24 bit
- Số bit được sử dụng để biểu diễn 1 điểm ảnh.

