# Human Visual System and Image Acquisition Systems

**Pengolahan Citra**

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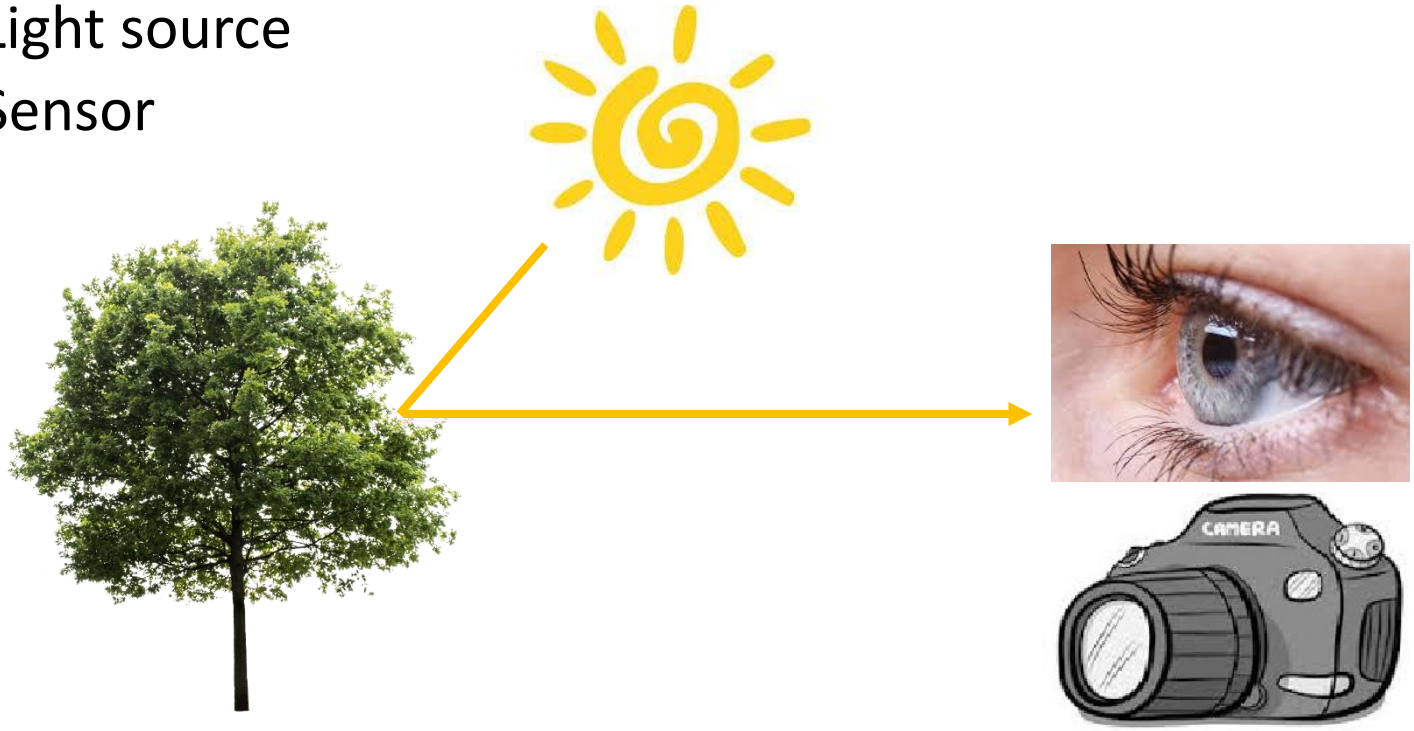
# Image Acquisition

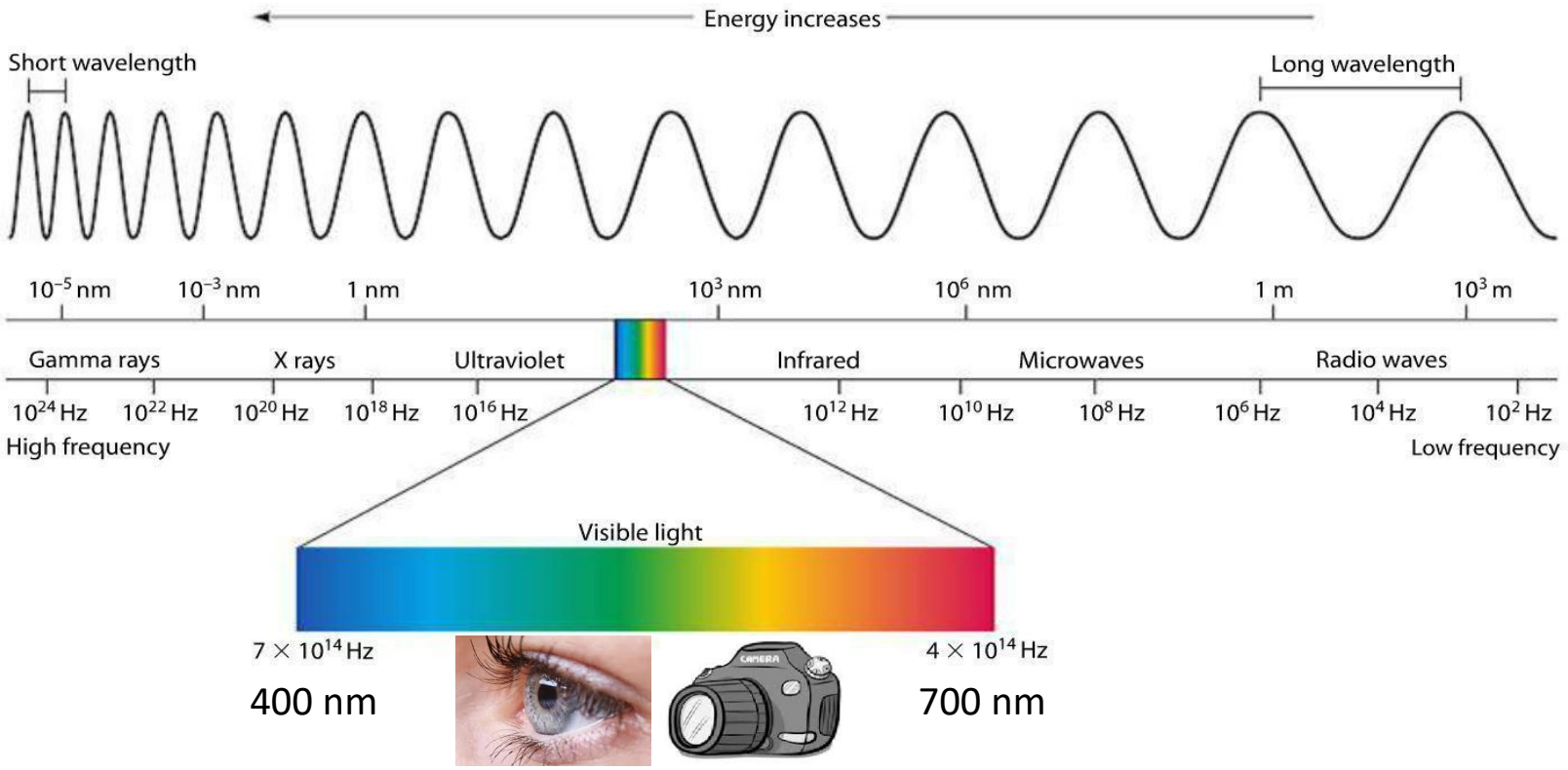
- Proses akuisisi citra membutuhkan 3 komponen:
  - *Scene*
  - Light source
  - Sensor



# Light and the Electromagnetic Spectrum

Ohta, Noboru & R. Robertson, Alan. (2006). Colorimetry: Fundamentals and Applications. Wiley.

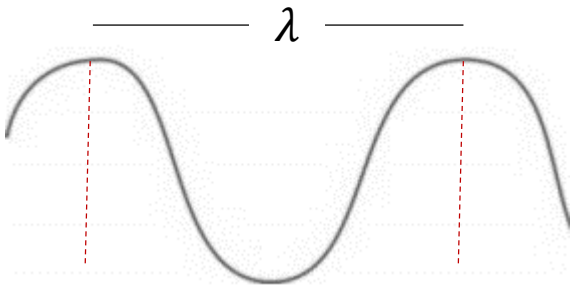
# The Electromagnetic Spectrum




Wavelength = c / Frequency, dimana c = speed of light (2.998 x 108 m/s)

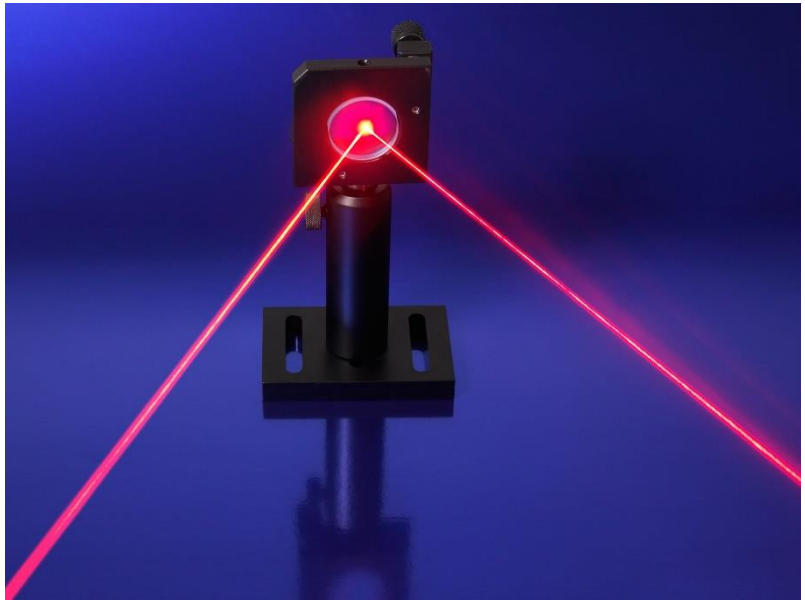
# Cahaya sebagai Gelombang Elektromagnetik

- Cahaya adalah gelombang
  - Panjang gelombang / *wavelength* (λ / lambda)
  - Frekuensi gelombang $f$
  - $\lambda = \frac{c}{f}$, where c = speed of light (2.998 x 108 m/s)



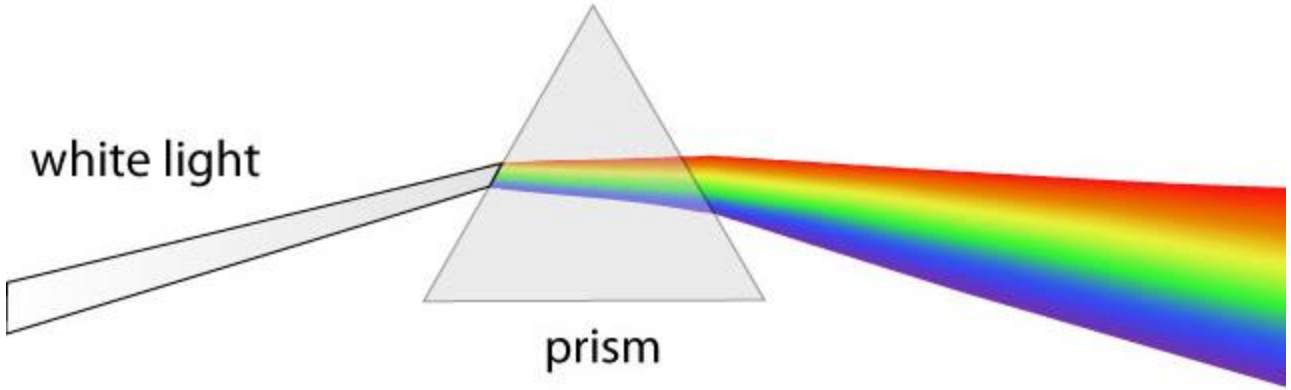
# Light / Light sources / Illuminants

- Monochromatic light
  - At one wavelength only, from coherent light sources



# Light / Light sources / Illuminants

- Chromatic light
  - Or visible light
  - Spans the visible spectrum (λ 400-700 nm)
  - We can measure:
    - Radiance: amount of energy from the light source (watt/W)
    - Luminance: amount of energy an observer perceives (lumens/lm)
  - Brightness? → a subjective measure, cannot be measured



# Common Illuminants

***Tungsten***

***LED***

***Xenon***

***Fluorescent***

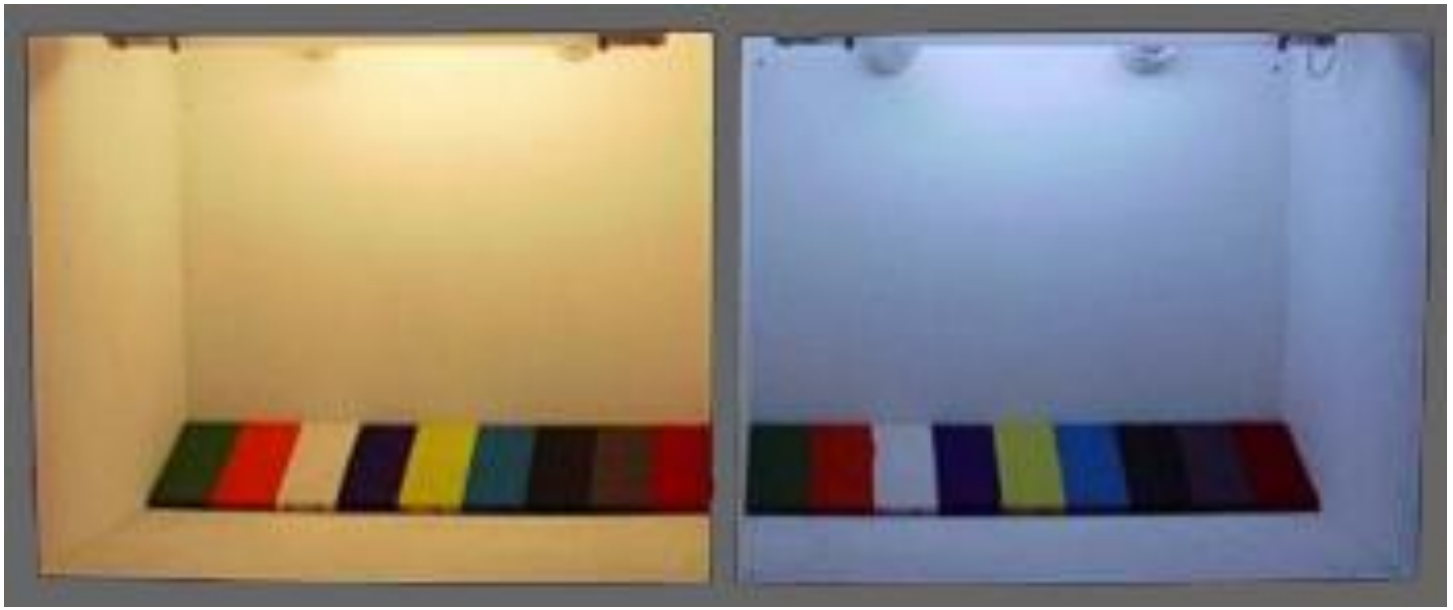
***Compact Fluorescent***

# Brainstorming

- Why are the illuminants important?

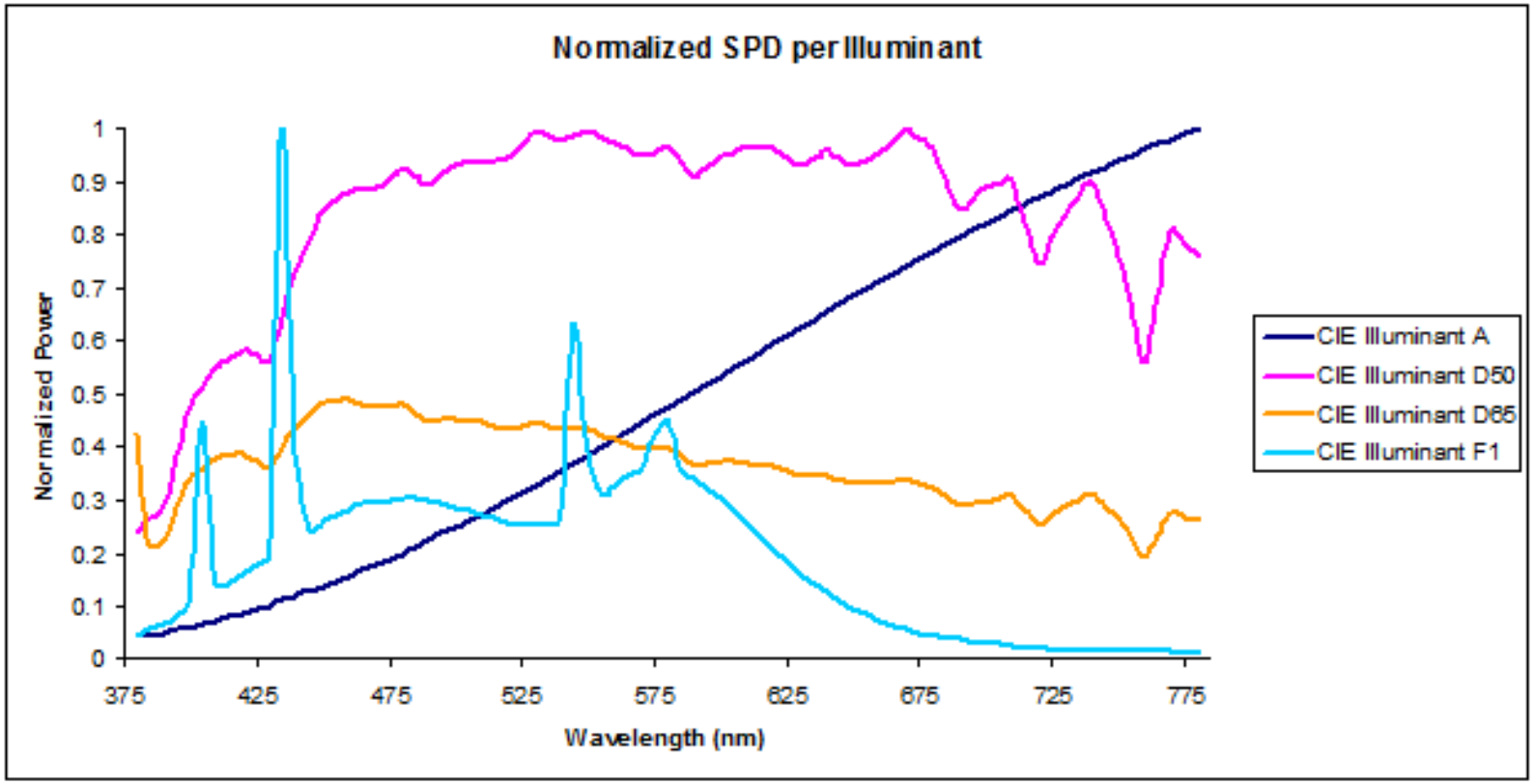
# Brainstorming

- Why are the illuminants important?



- But why?

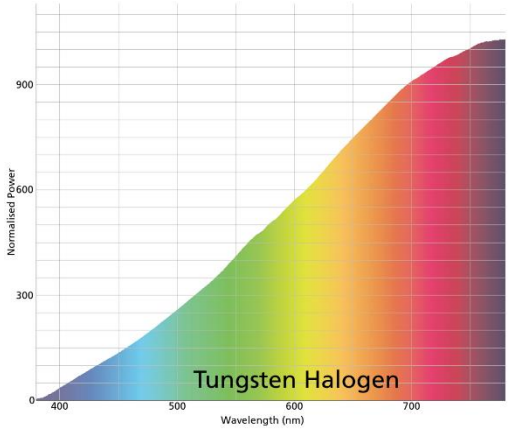
# Spectral Power Distribution

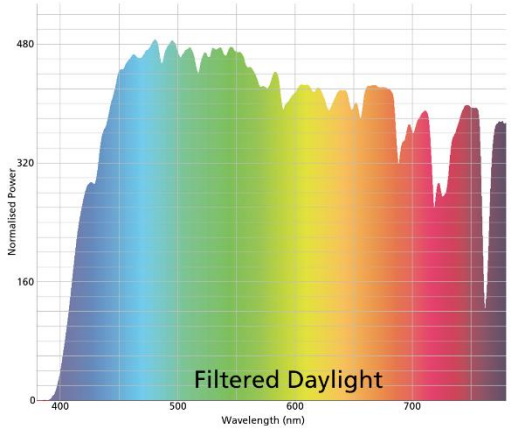


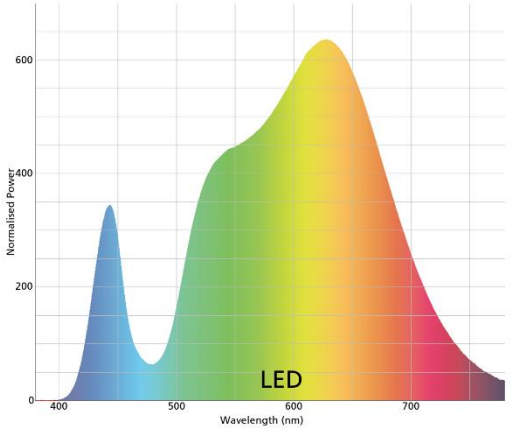

**CIE**: Commission internationale de l'éclairage (International Commission on Illumination) is the international authority on light, illumination, colour, and colour spaces.

# Spectral Power Distribution

- Different lights appear differently



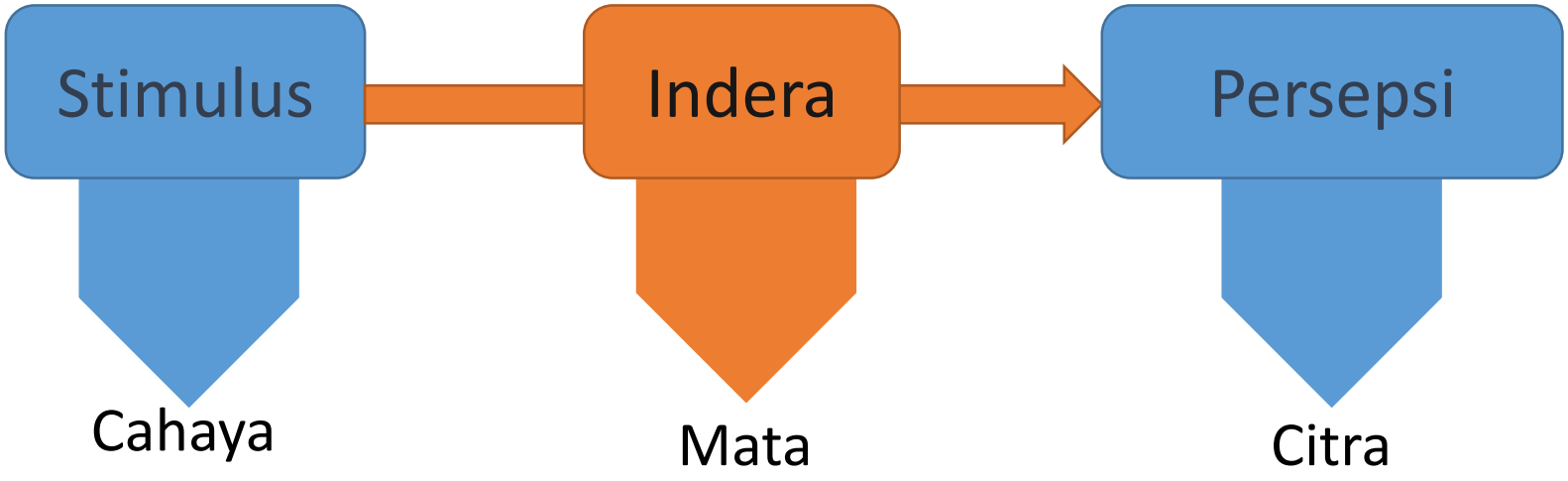
# Human Visual System

Additional References:

Sensation and Perception. E. Bruce Goldstein, Wadsworth Publishing, 2007.
Introduction to Visual Optics. Alan H. Tunnacliffe. Association of British Dispensing Opticians, 1993.

# Citra pada Mata Manusia

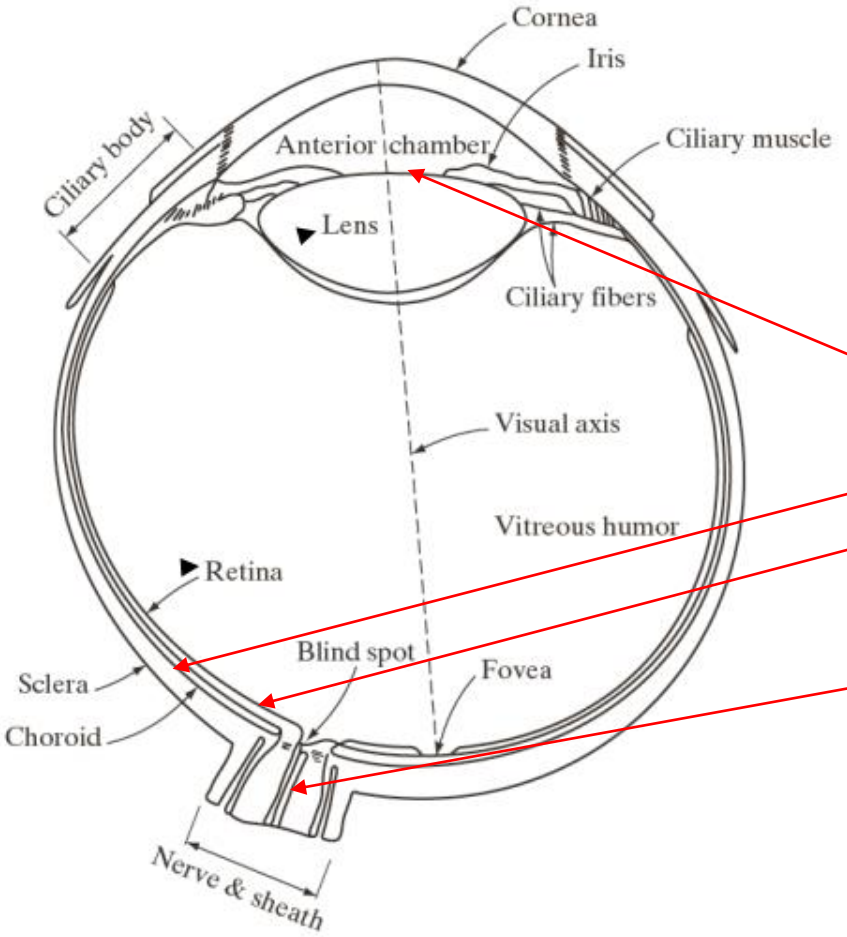
- Citra yang terbentuk bukan citra fisik, tetapi persepsi



# Persepsi Penglihatan Manusia

1. Cahaya memasuki mata
2. Citra terbentuk pada retina
3. Citra diterjemahkan menjadi sinyal biologis
4. Transmisi sinyal ke otak
5. Pemrosesan di dalam otak
6. Persepsi Visual

# A cross section of the human eye
(Gonzalez & Woods, 1992)

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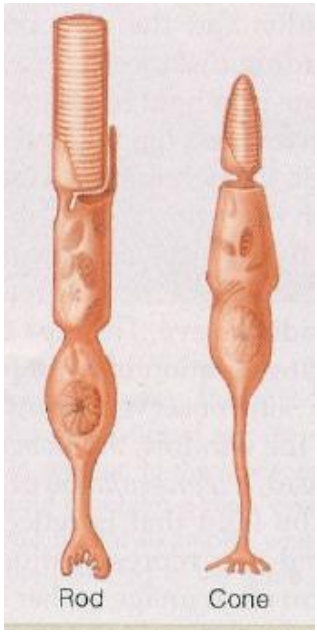
6. Persepsi visual

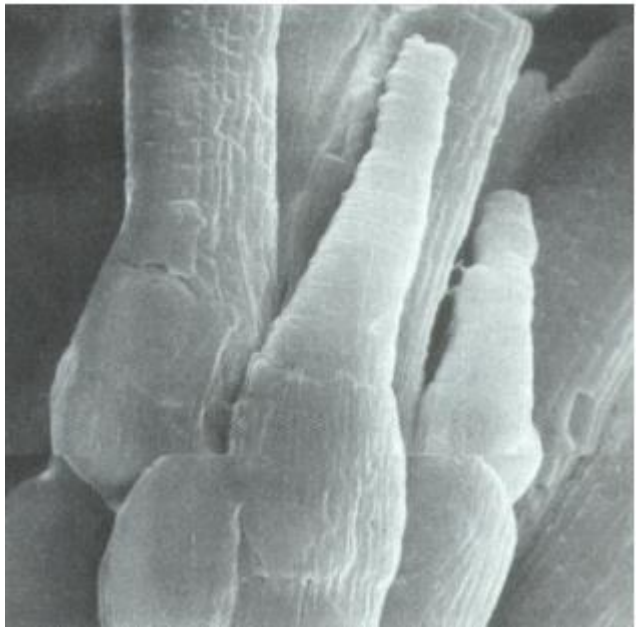
?

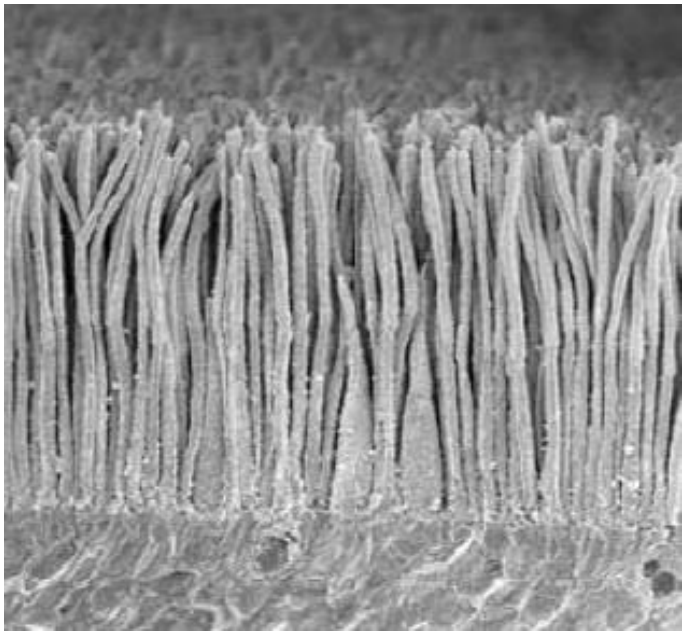
# Visual Perception in The Brain

# Pembentukan Citra pada Retina

- Retina terdiri sensor-sensor optik:
  - *Cones* (6-7 juta sensor)
  - *Rods* (75-150 juta sensor)

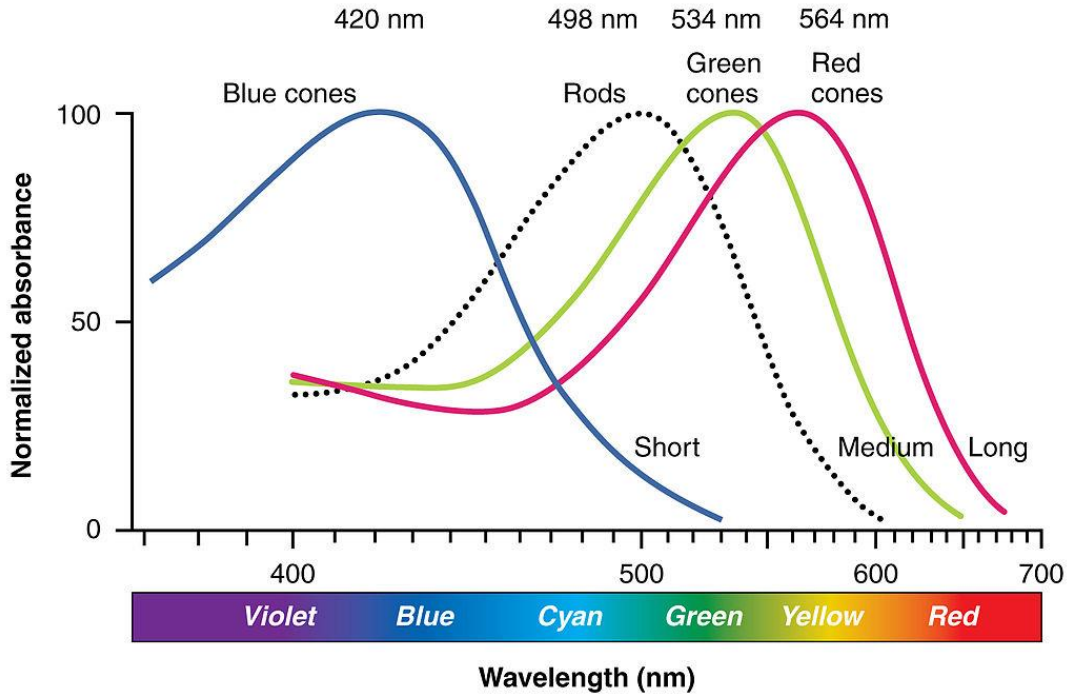




# Cones and Rods

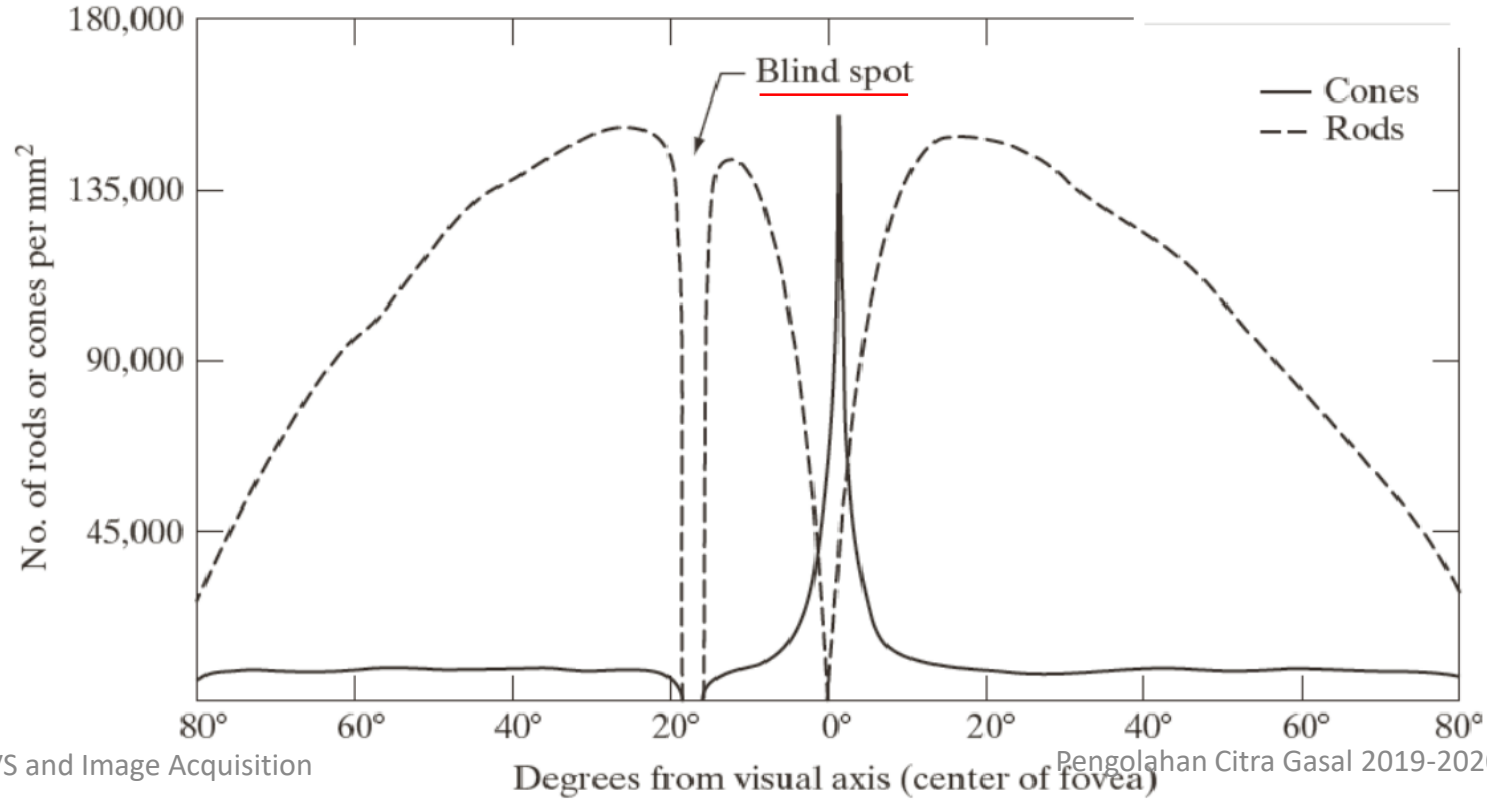
- *Cones* sangat sensitif terhadap warna →Photopic Vision
- *Rods* lebih tersebar sepanjang retina, dan berfungsi membuat persepsi yang lebih umum →Scotopic Vision



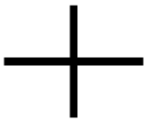

Bowmaker J.K. & Dartnall H.J.A. (1980). "Visual pigments of rods and cones in a human retina". J. Physiol.

# Cones and Rods (2)

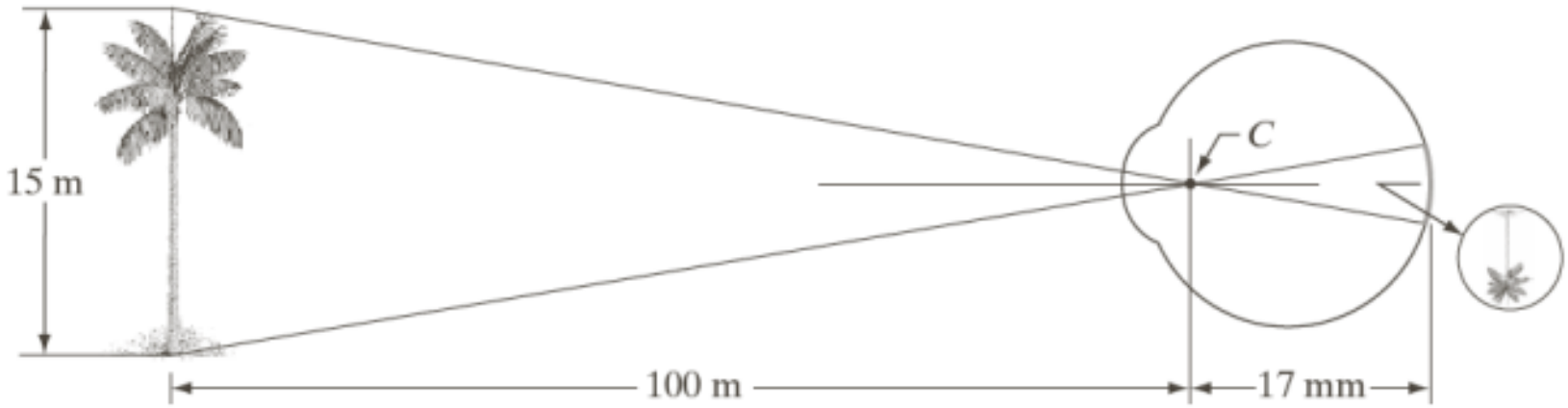
- Lokasi *cones* terpusat pada *fovea*
- Lokasi *rods* lebih tersebar sepanjang retina



# Blind Spot



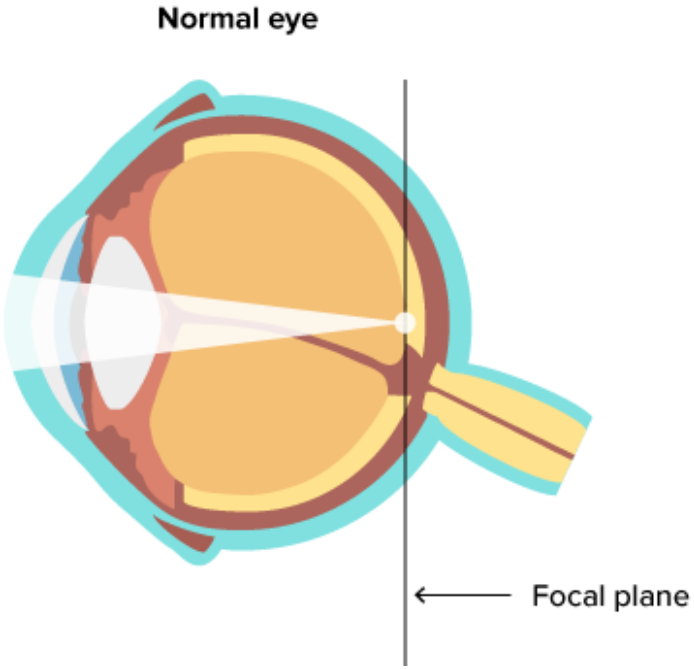
# Image Formation in the Eye

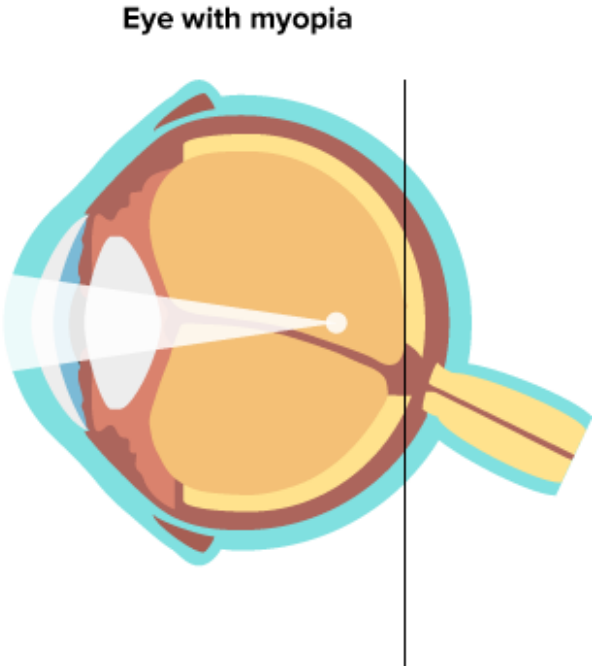



- Photo camera: lens has fixed focal length. Focusing at various distances by varying distance between lens and imaging plane (location of film or chip)
- Human eye: Distance lens-imaging region (retina) is fixed. Focal length for proper focus obtained by varying the shape of the lens.

# What could go wrong?

- Myopia
  - Near-sightedness
  - Rabun jauh
- Why?
  - Mata melonjong
  - Lensa terlalu kuat/fokus

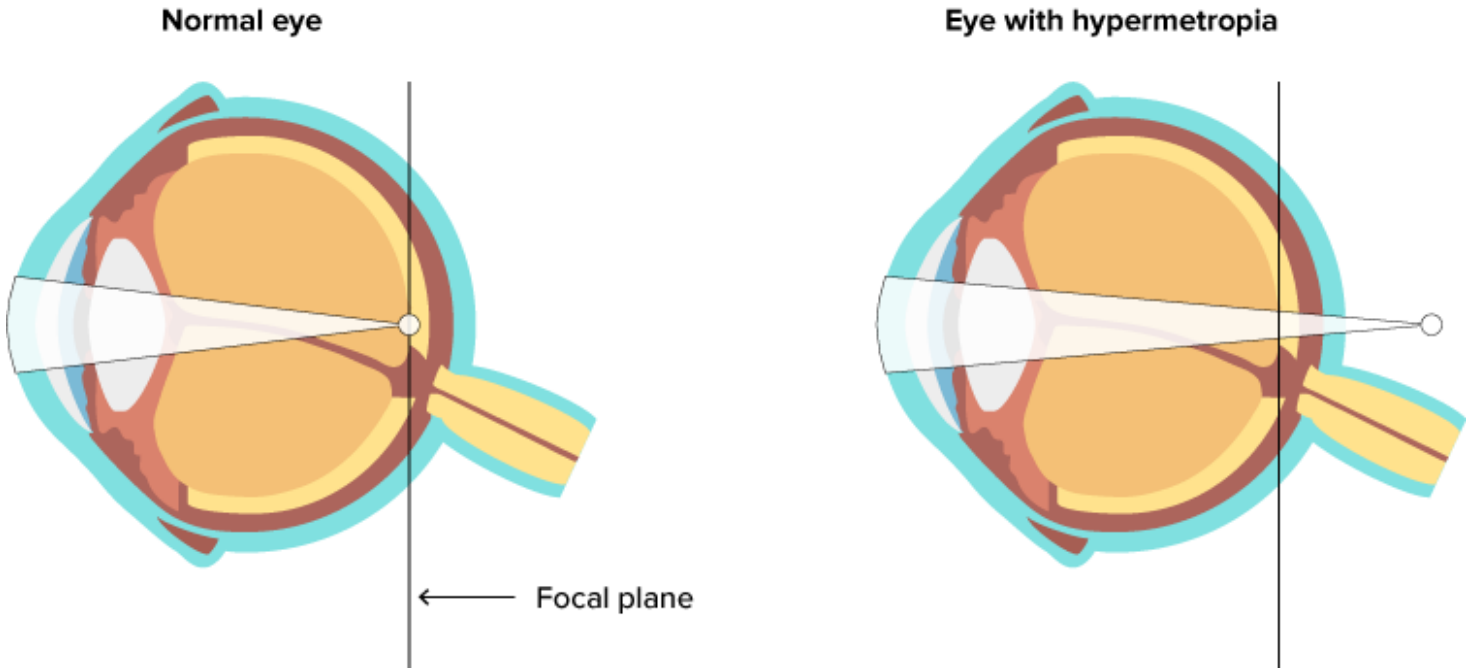



A Family Optician , 2017.

# What else could go wrong?

- Hypermetropia
  - Far-sightedness
  - Rabun dekat
- Why?
  - Mata memendek
  - Lensa tidak cukup kuat



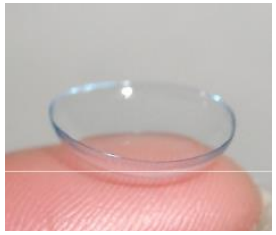

A Family Optician , 2017.

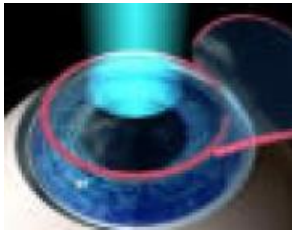
# What else could go wrong?

- Presbyopia
  - Due to old age
- Astigmatism
  - Stigmatic optical system: one object point produces one point image.
  - Astigmatism: the opposite.

Refractive errors

- These days, we have many optical correctors



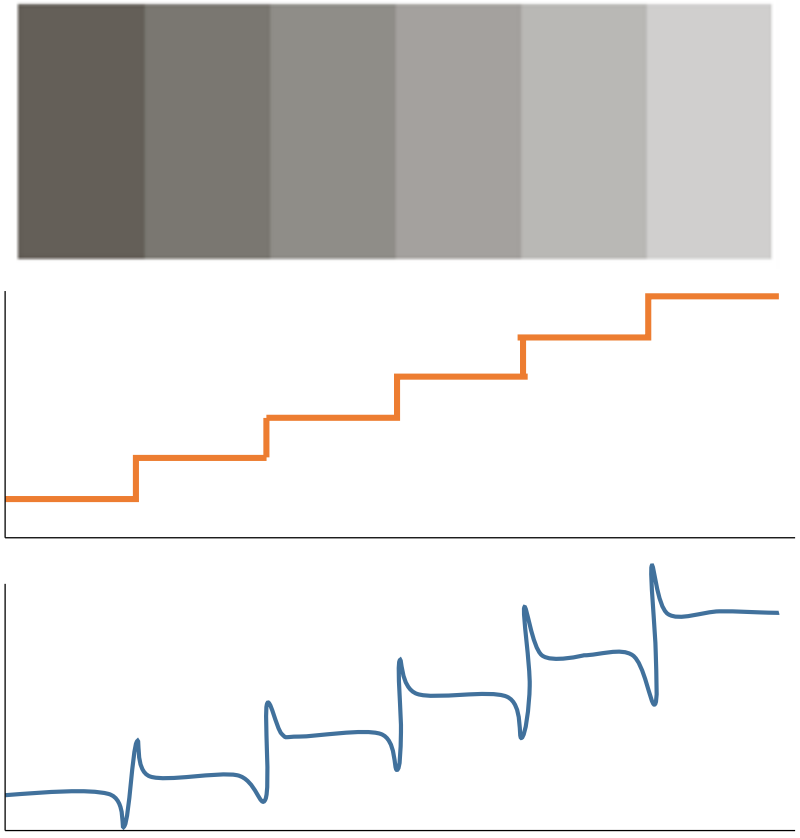


# The Human Eye

- Tapi pembentukan citra pada mata manusia tidak sesimpel itu!

# Brightness Adaptation

- Mach Bands: Perceived intensity is not a simple function of actual intensity

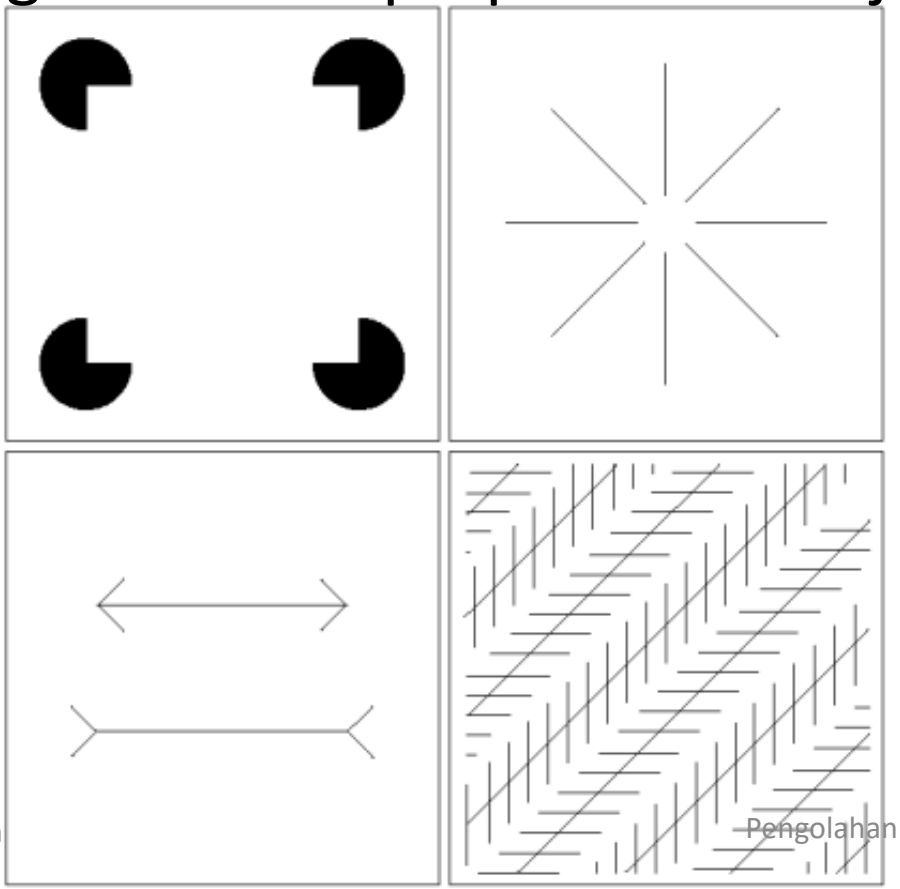


# Brightness Adaptation

- Simultaneous Contrast: a region's perceived brightness does not depend simply on its intensity.

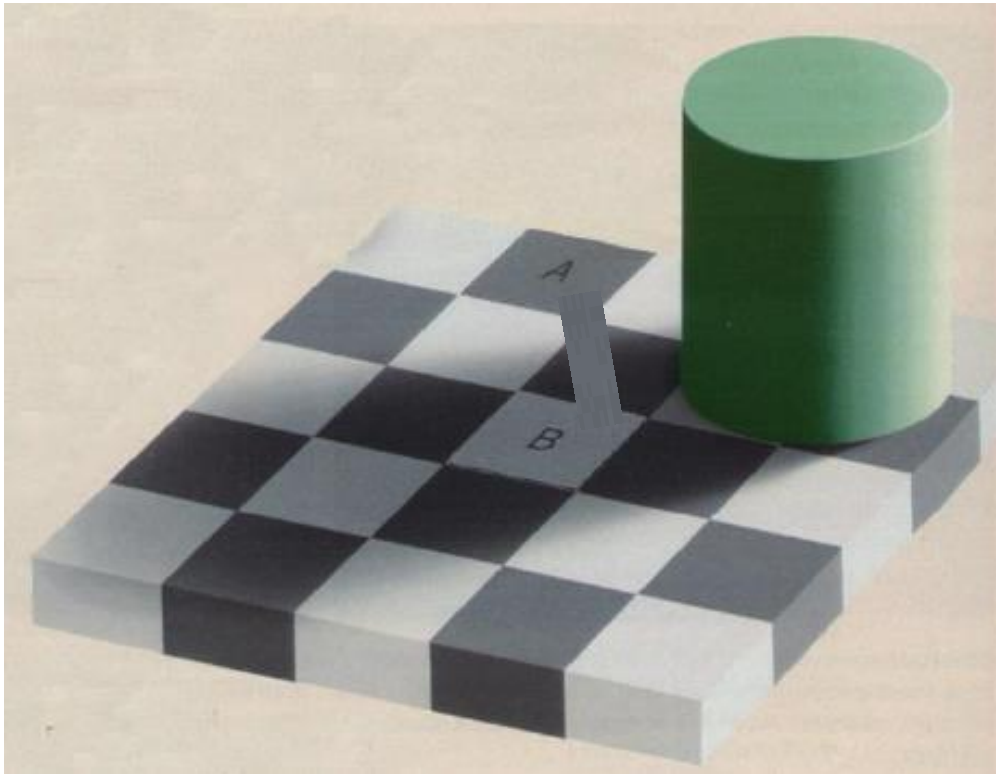
# Other Curious Things about the Human Eye

- The eye fills in non-existing info or wrongly perceives geometrical properties of objects



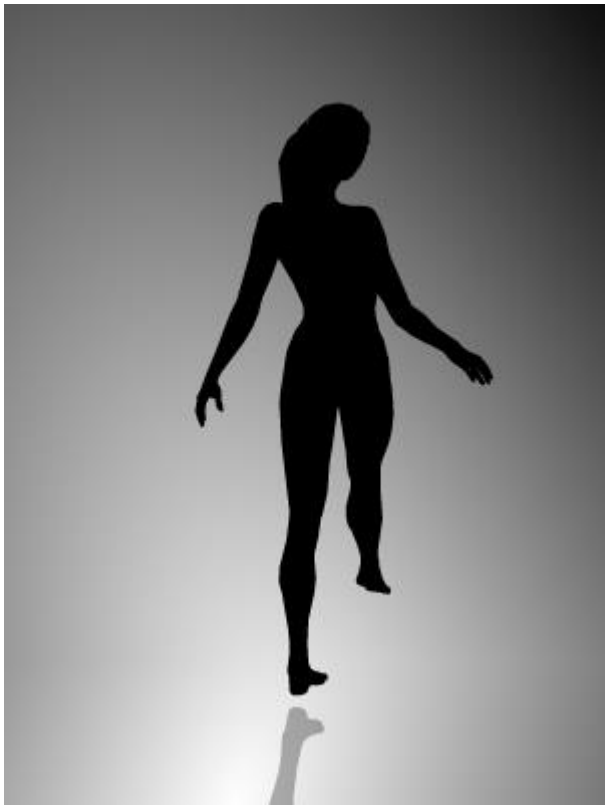
# It gets weirder with color

- Is A and B the same color?




Color Constancy

# And Weirder with Motion



# The Human Eye

- What can we replicate in digital images?
- What information can we recover from digital images with computer vision?

There are simply some things that image processing/computer vision can not do.

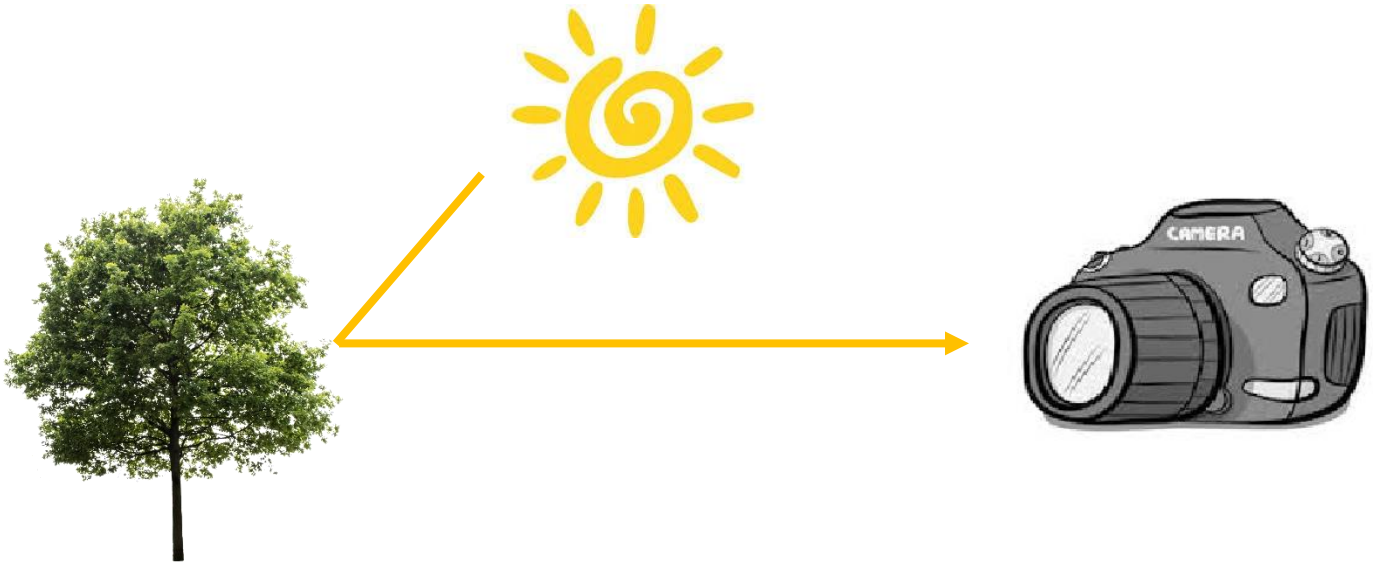
# Digital Images

Additional References:

Ohno, Y., “Photometry and Radiometry”, Ch. 14, Vol. III, OSA Handbook of Optics, 2nd Ed. McGraw-Hill, New York (2001).

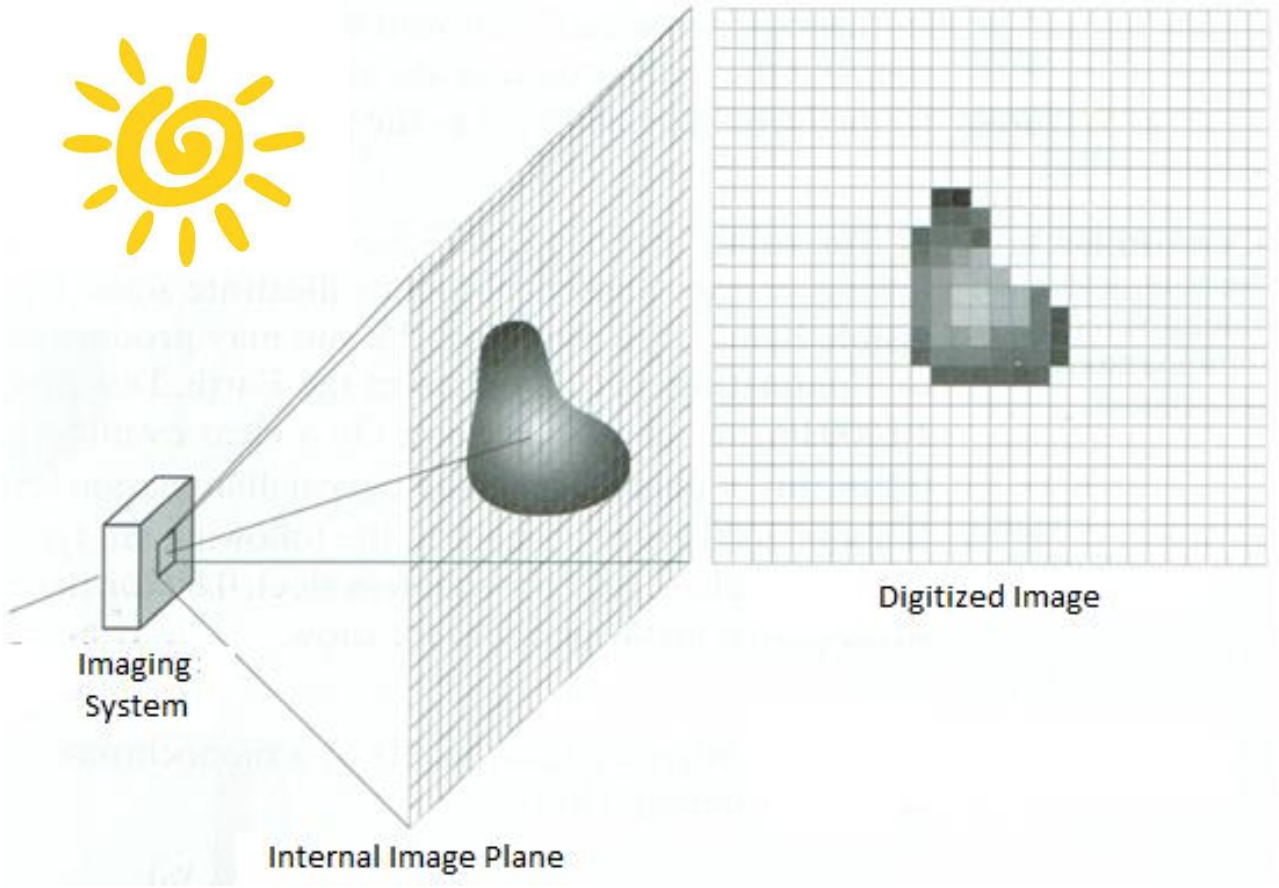
Sato, J. Computer Vision – Visual Geometry. Corona Publishing, Tokyo (1999)

# Digital Image Acquisition



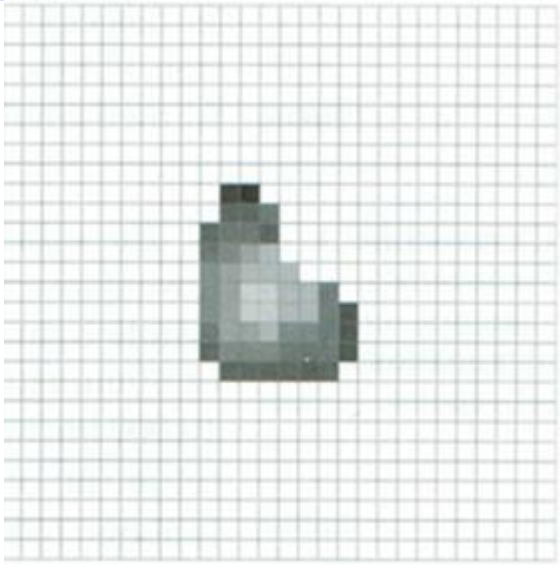

- Lets look a little closer into the camera

# Digital Images



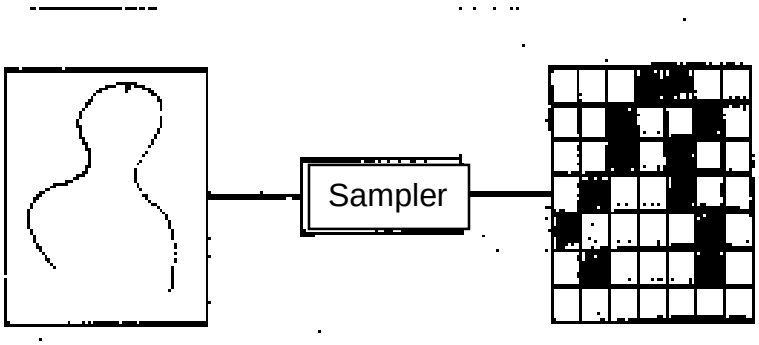
# Definisi Citra Dijital

- **Suatu matriks** di mana elemen matriksnya (yang disebut sebagai elemen gambar / piksel / pixel / **picture element**) menyatakan tingkat keabuan pada titik tersebut.
- **Fungsi intensitas cahaya $f(x, y)$ :** $x$ dan $y$ merupakan koordinat spasial dan nilai fungsi $f(x, y)$ merupakan tingkat intensitas citra pada titik tersebut;
- **Fungsi intensitas cahaya $f(x, y)$** didapatkan melalui:
  - diskritisasi koordinat spasial (**sampling**)
  - diskritisasi tingkat intensitas/keabuan (**kuantisasi**);



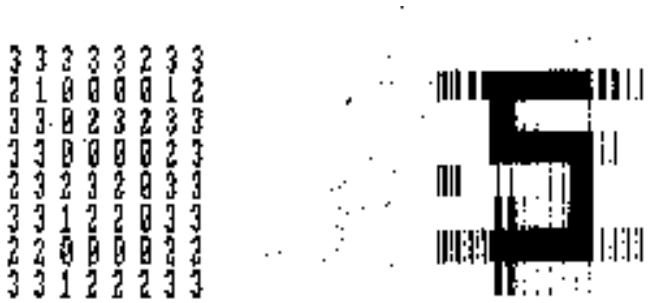
Digitized Image

# Citra Dijital

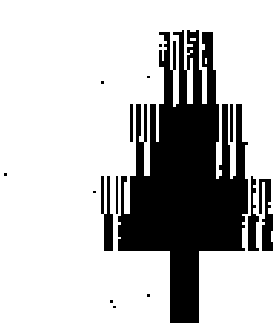



Citra kontinue

Citra dijital



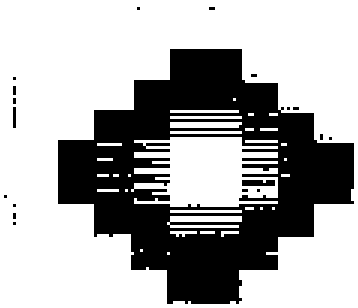
Matriks citra dengan obyek angka 5

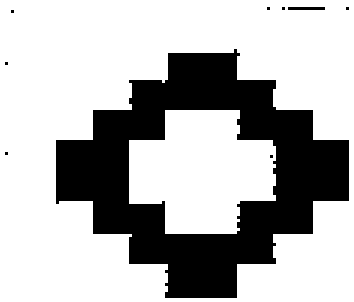


**Resolusi spasial** :

Tinggi (16 x 16)

Rendah (8 x 8)





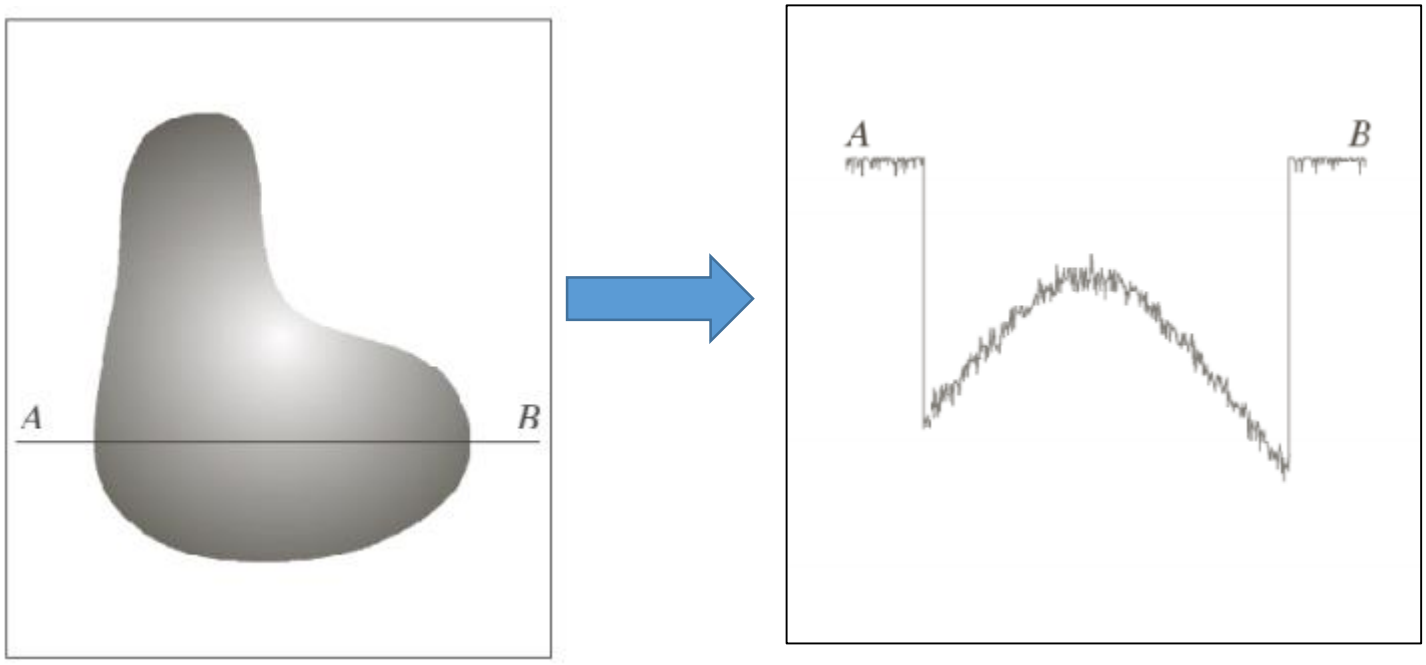
**Resolusi intensitas** :

Tinggi (4)

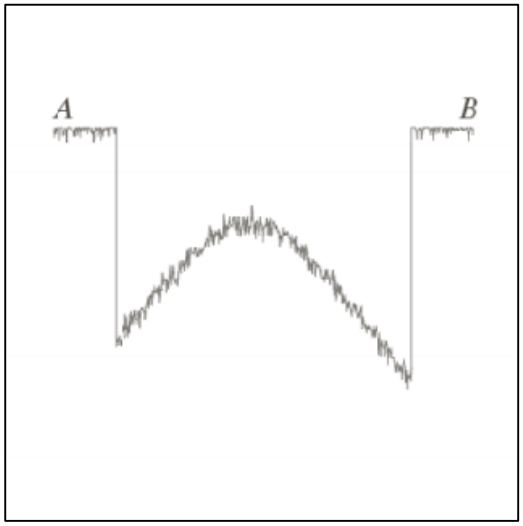
Rendah (2)

# Sampling and Quantization

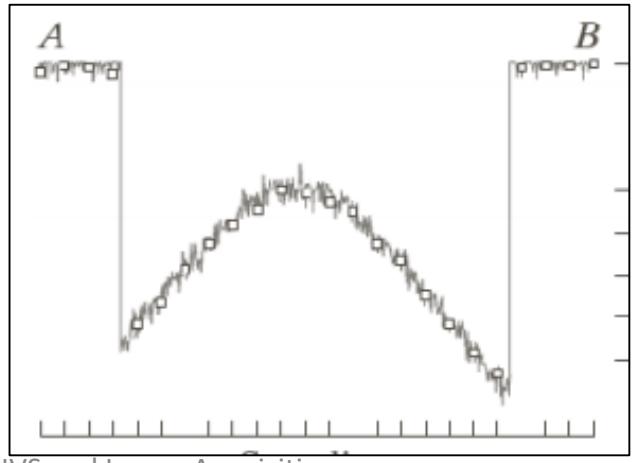
- Scan the object along line AB



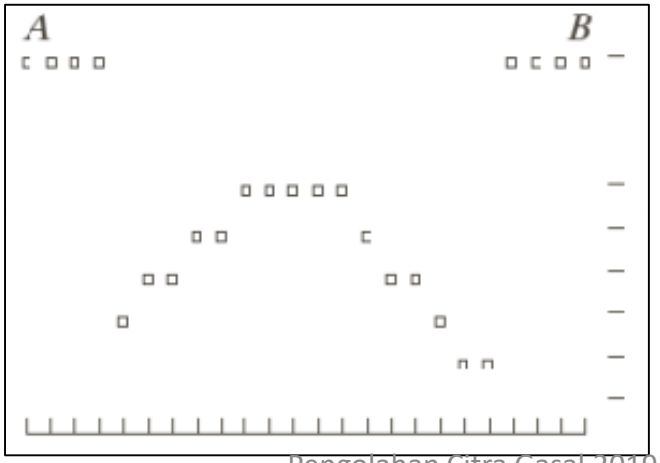
# Sampling and Quantization (2)




Sampling

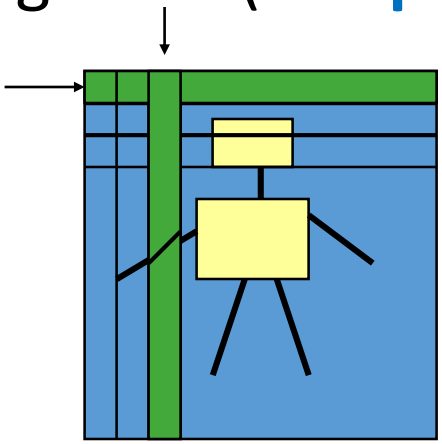



Quantization



# Resolusi Spasial Citra

- Resolusi spasial: halus / kasarnya pembagian *grid* baris dan kolom. Transformasi citra kontinu ke citra digital disebut digitisasi (**sampling**).

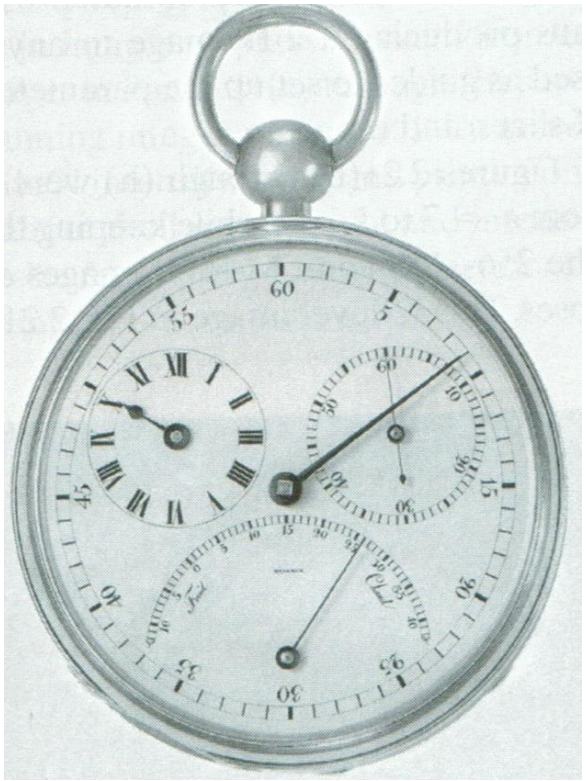


Picture

# Diskusi

- Apa pengaruh resolusi spasial dengan proses-proses pengolahan citra?

# Resolusi Spasial

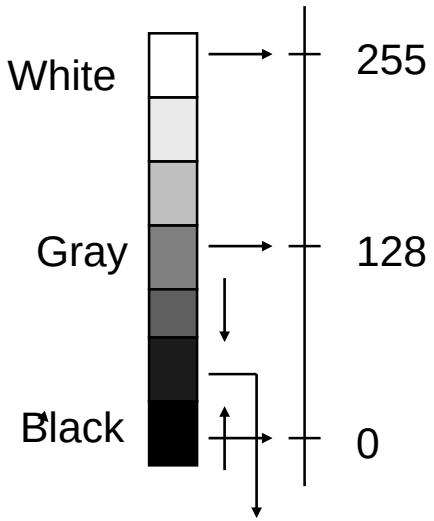


Resolusi Spatial = 300 dpi (dot per inch) 72 dpi (dot per inch)

(Sumber: Gonzalez & Woods, 2008)

# Resolusi Instensitas Citra

- Resolusi intensitas / *brightness*: halus / kasarnya pembagian level intensitas. Transformasi data analog yang bersifat kontinu ke daerah intensitas diskrit disebut kuantisasi.



# Digitization of Intensity

- Assume we have a MxN matrix of captured image intensities
- We can encode L discrete intensity levels.
- For digital images, $L = 2^k$
- The intensity values can be encoded as [0,…L-1].
- The range of values are often referred to as *dynamic range.*
- More accurately, the *dynamic range* of the image can be defined as the ratio of maximum measurable intensity to the minimum detectable intensity level.
- The number of bits needed to store the image is thus

$$M \times N \times k$$

# Resolusi Intensitas

Resolusi Intensitas = 16

Resolusi Intensitas = 4

(Sumber: Gonzalez & Woods, 2008)

# Diskusi

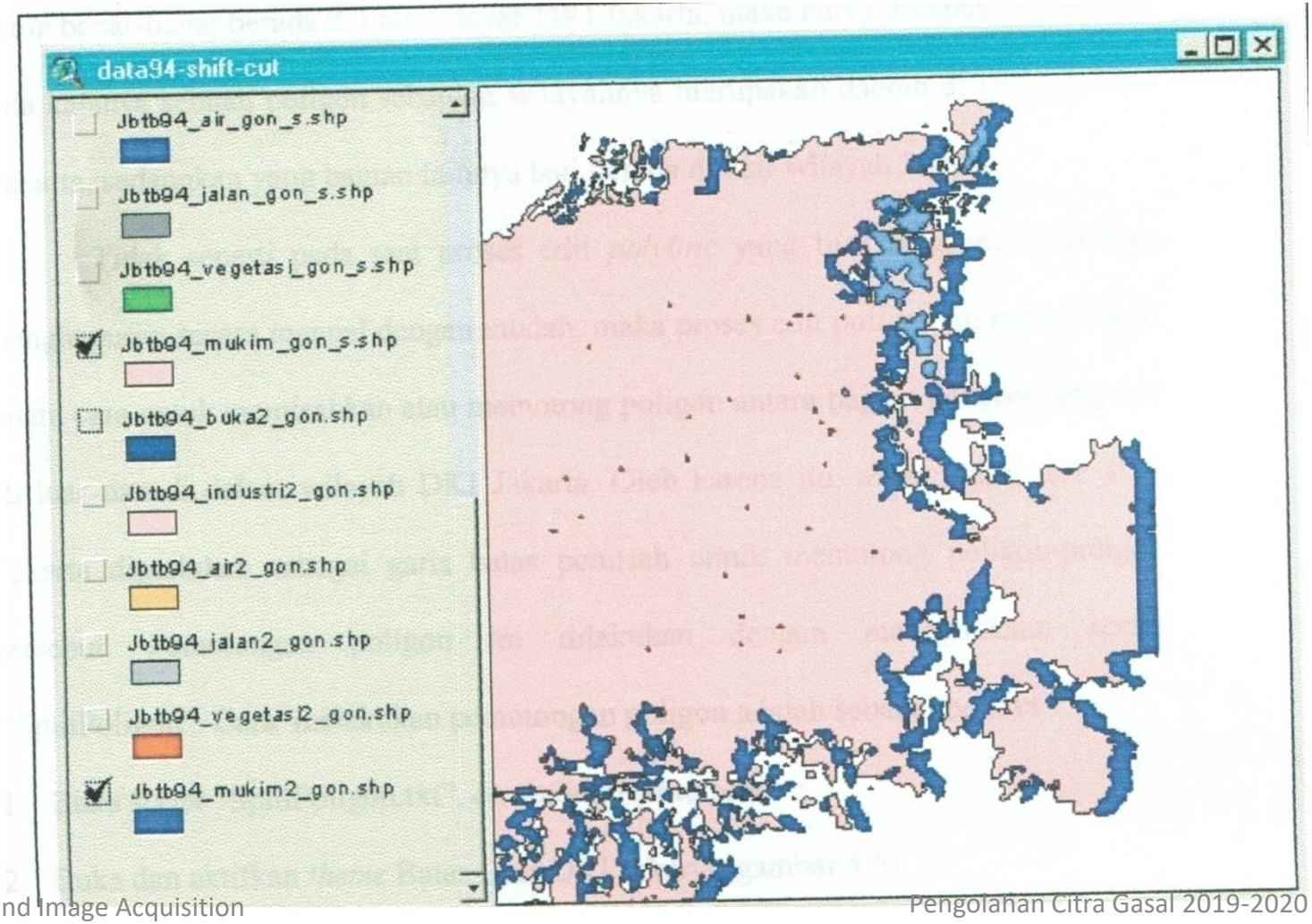
- Dengan MATLAB, kita bisa menyimpan data intensitas s/d berapa bit?
- Bagaimana dengan Python?
- Apa pengaruh resolusi intensitas dengan proses-proses pengolahan citra?

# Distorsi pada Citra Dijital

- Distorsi Geometrik
  - Merupakan distorsi spatial
  - Penyebabnya antara lain adalah letak dan arah serta adanya gerakan perekam citra atau dari objek yang direkam
  - Juga bisa dari internal sensor

# Distorsi Geometrik

(Source: Ira Hastitu *et. al,* 2002)

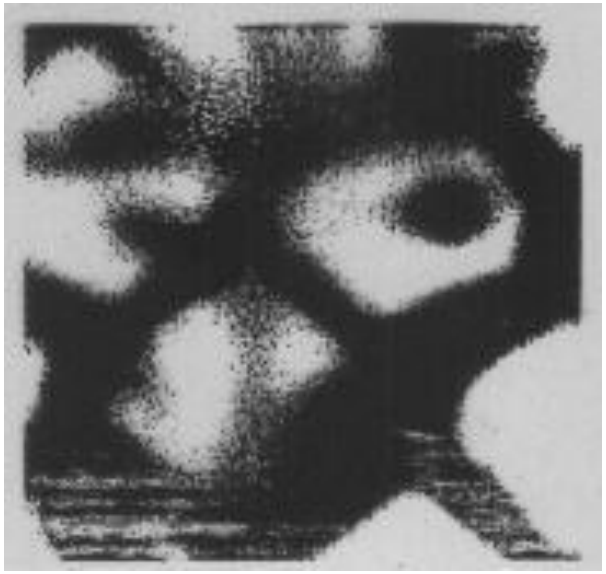


# Distorsi pada Citra Dijital

- Distorsi Radiometrik
  - Merupakan distorsi pada distribusi intensitas yang tidak tepat
  - Penyebabnya antara lain adalah keadaan atmosfer yang berbeda (ada kabut), sehingga objek yang sama memberikan respon gray level yang berbeda
  - Juga bisa dari internal sensor (shading)

# Distorsi Radiometrik

- Koreksi dilakukan dengan teknik filtering
- Distorsi bisa dalam bentuk distorsi low frequency
- Distorsi juga bisa dalam bentuk distorsi high frequency



Citra foto tangkai daun (MSU, 1990): distorsi radiometrik *blurring* – filtering dengan high pass filter

# Other Digital Distortions

- Camera noise
  - Sensor noise
  - Foreign object noise
  - Dead pixels, etc
- Quantization errors

# Camera Image Acquisition

# Brainstorming

- Berdasarkan komponen penglihatan yang sudah kita pelajari, bisakah anda menemukan komponen yang equivalen pada sebuah kamera digital?

# Brainstorming

- Faktor-faktor apakah yang perlu dipertimbangkan ketika melakukan pengambilan citra dengan camera digital?