



EE 604

Digital Image Processing

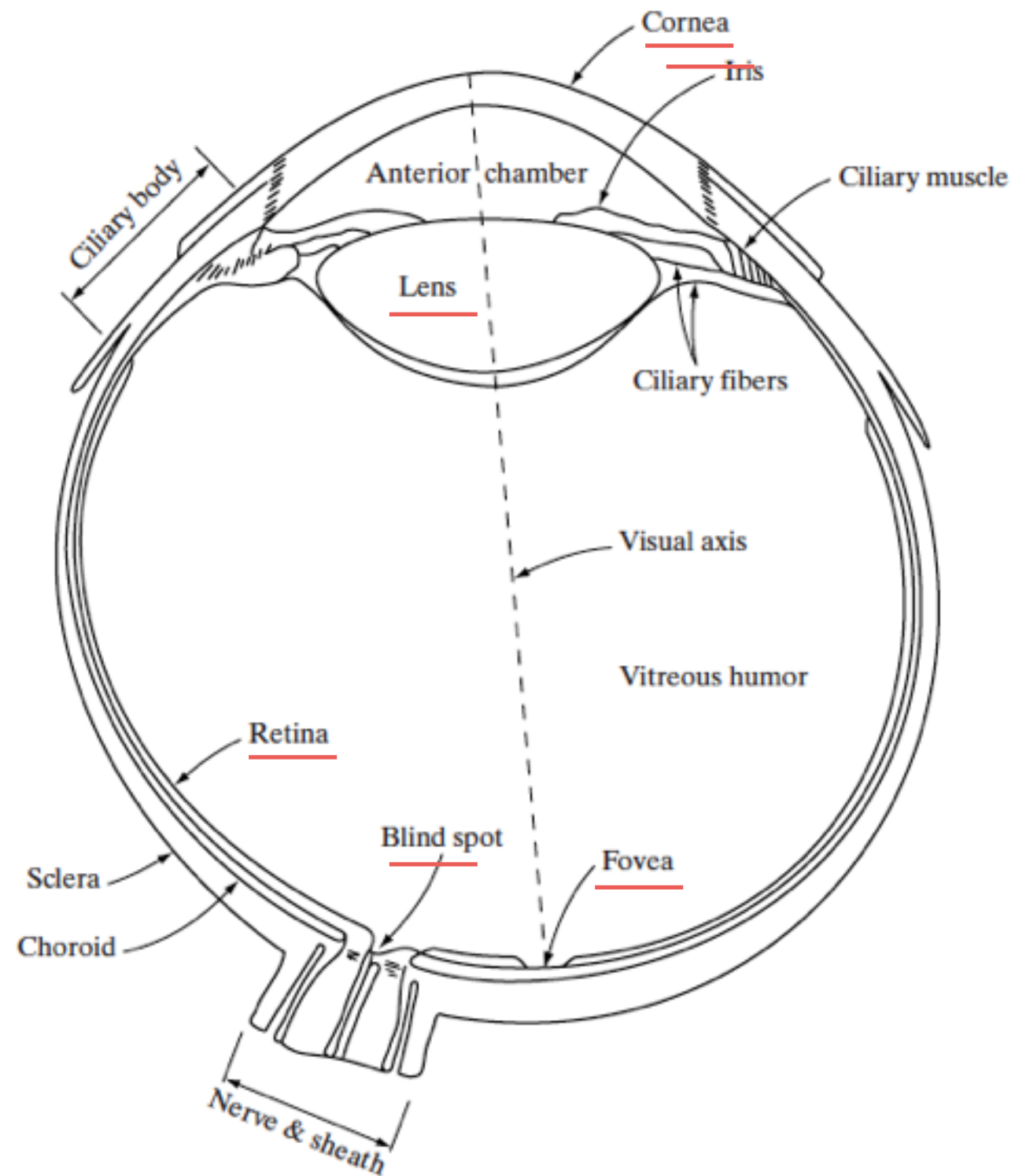
Announcements

- First quiz on Aug 23

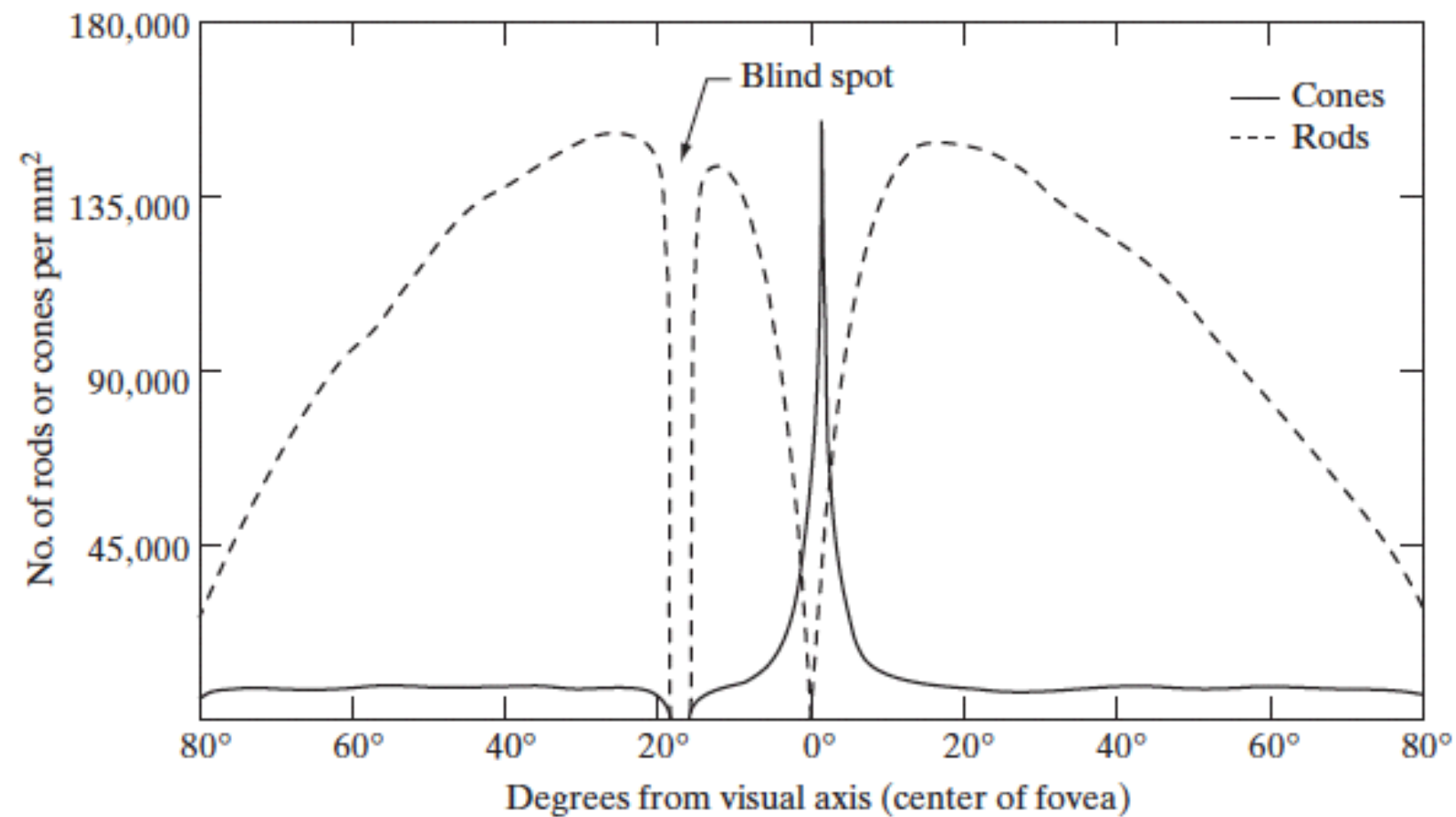
Lecture outline

- **Human visual system**
- Image sensing
- Image formation
- Image sampling

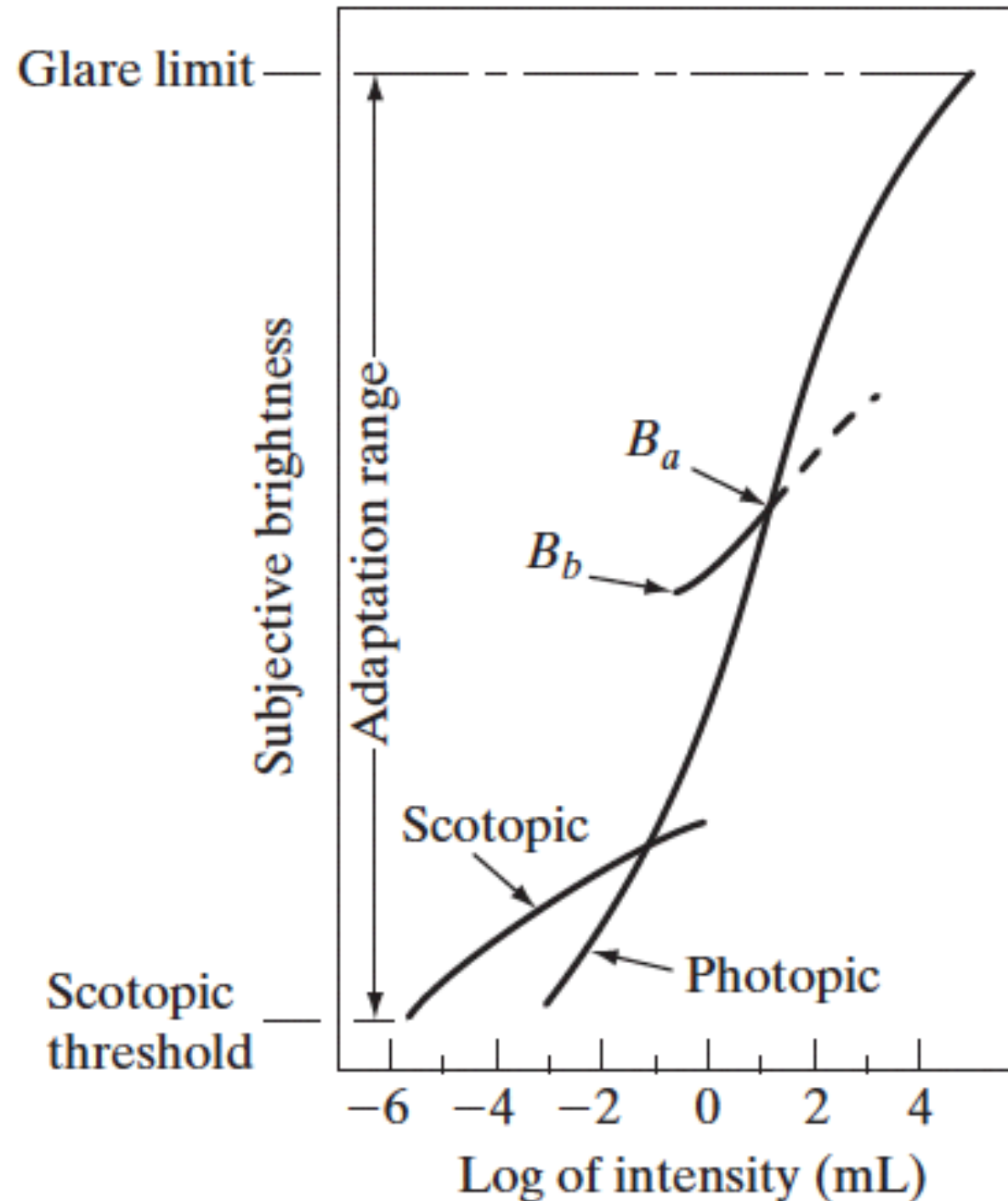
Human eye



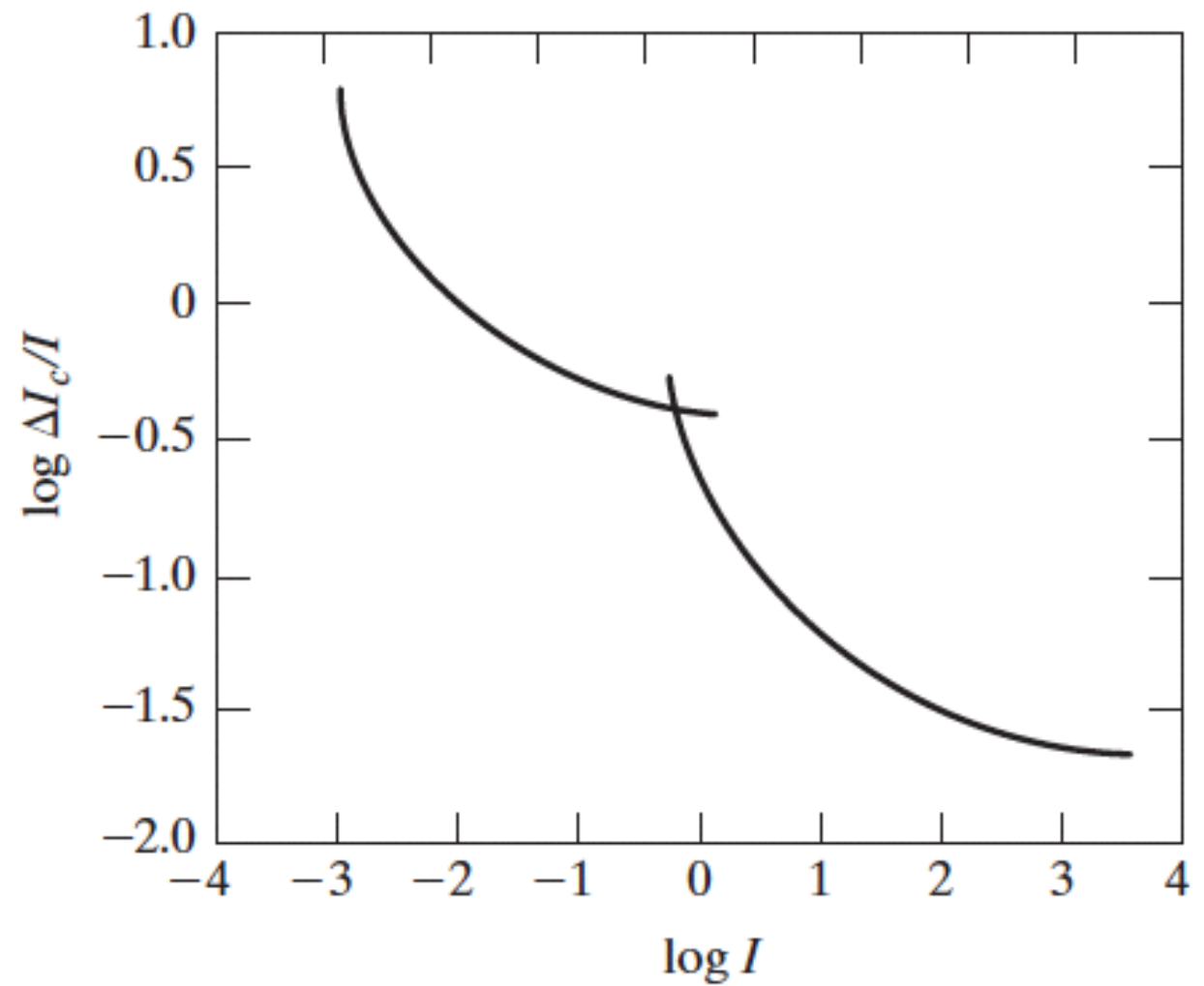
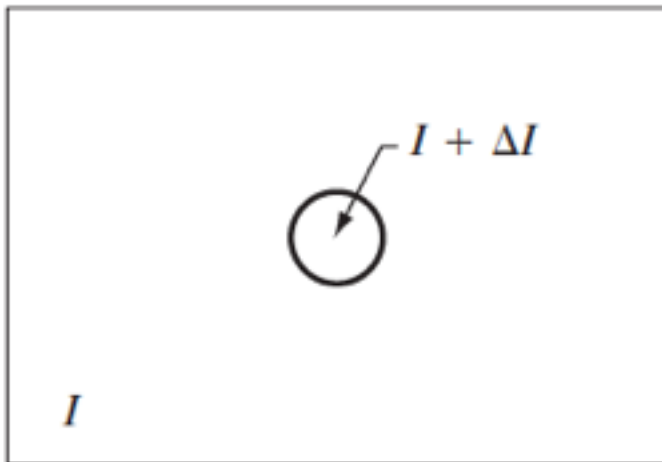
Photoreceptors



Brightness adaptation

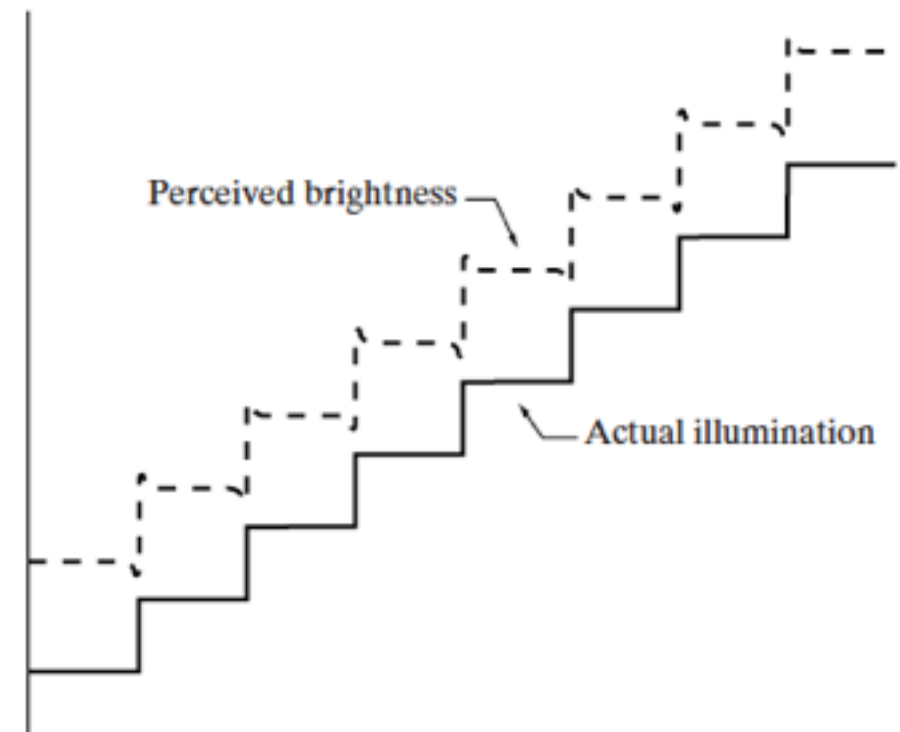


Brightness discrimination

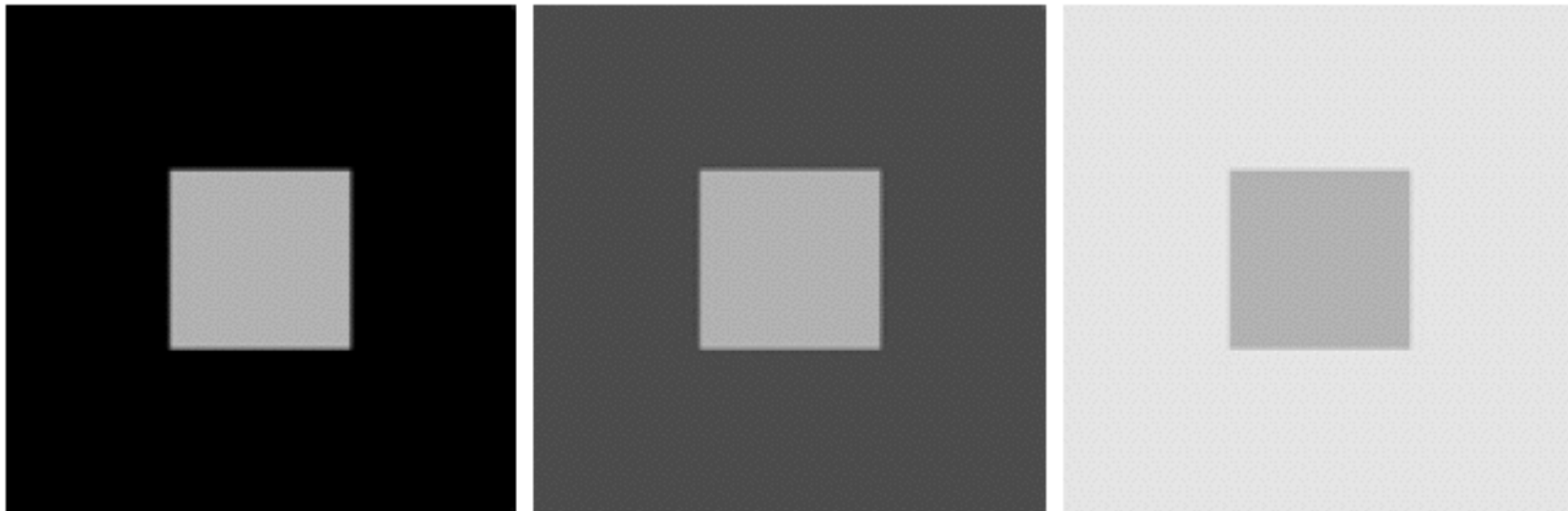


Mach band effect

Perceived brightness is NOT a monotonic function of intensity.

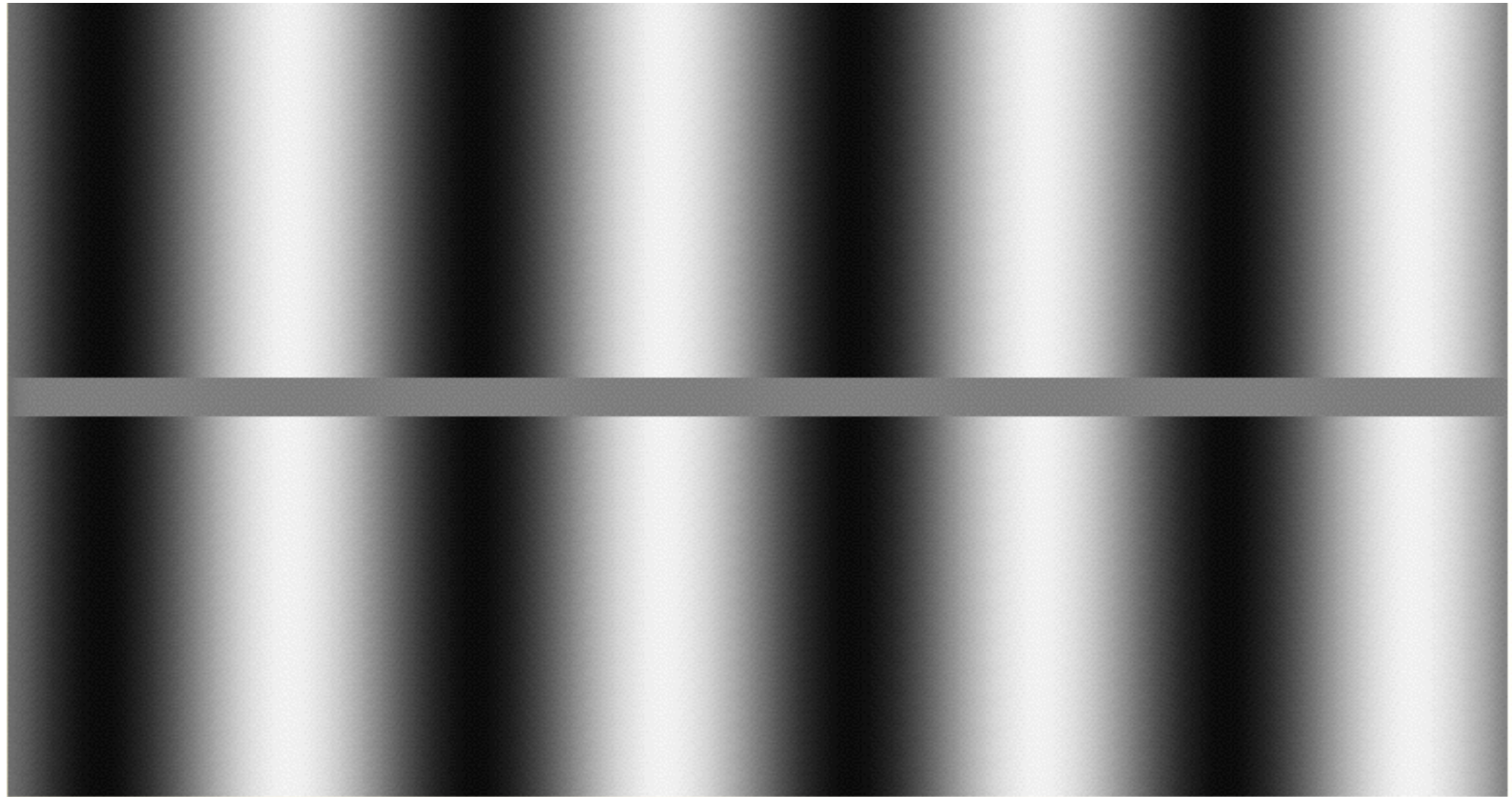


Simultaneous contrast



Perception depends on relative intensity (contrast) rather than absolute intensity level.

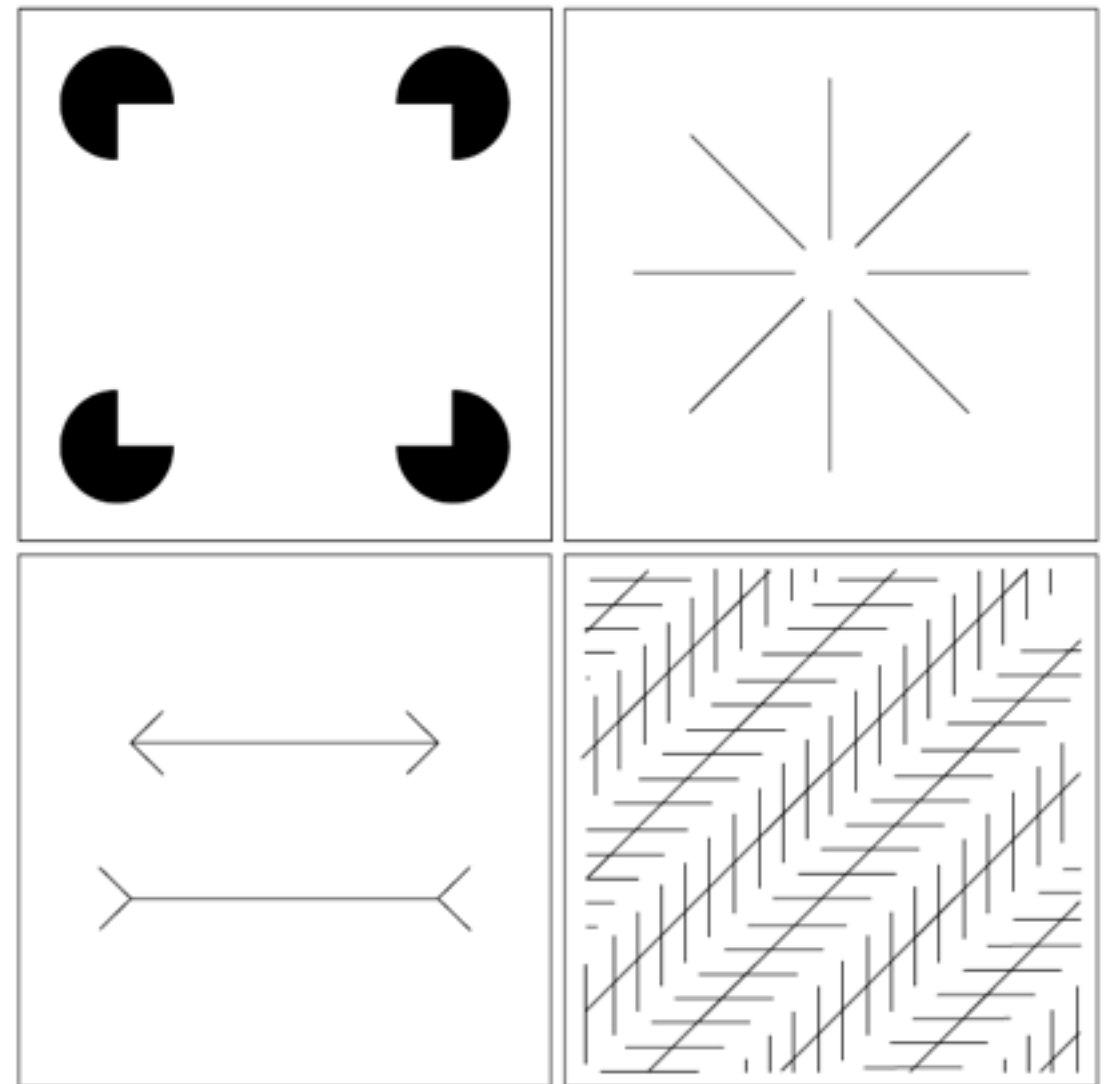
Simultaneous contrast



Optical illusions

More illusions:

<http://www.michaelbach.de/ot/>



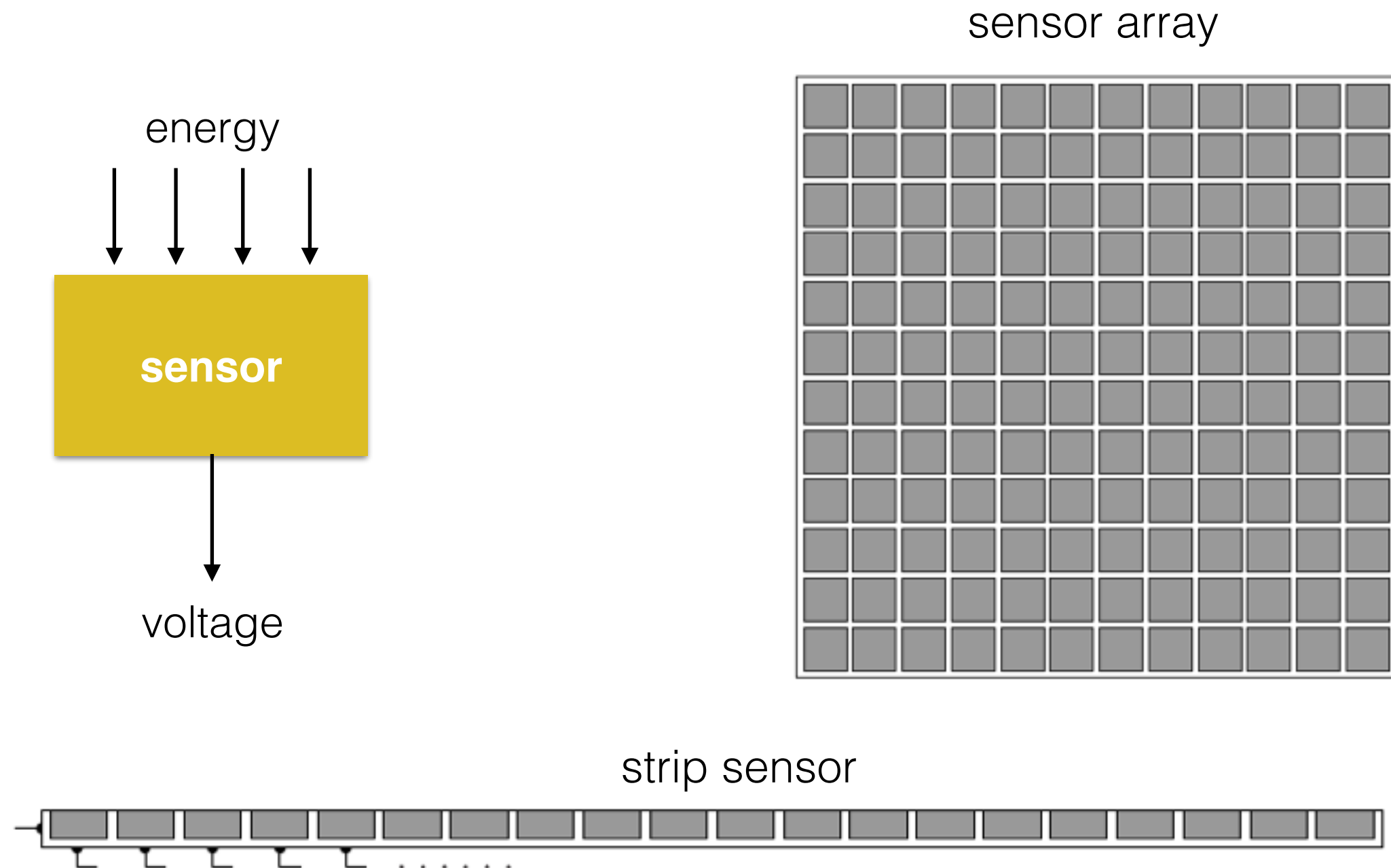
HVS Summary

- Light rays enter our eyes through **cornea**, while **iris** controls the amount of light that can enter. The indecent light rays get focused by the **lens** on to the **retina**. The retina has **photoreceptors** (rods and cones) which encode the scene information, and pass it on to the **visual cortex** in the brain through a pair of **optic nerves**.
- Humans can perceive a large range of light intensity, but not simultaneously.
- How well can we distinguish between different levels of intensity will depend on the background illumination.
- Perceived brightness is a complicated function of true intensity.

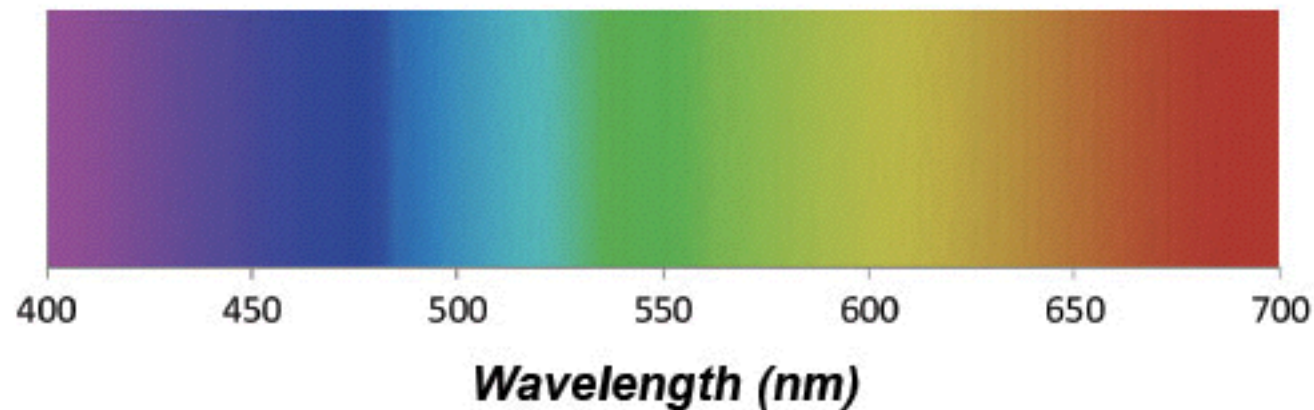
Lecture outline

- Human visual system
- **Image sensing**
- Image formation
- Image sampling

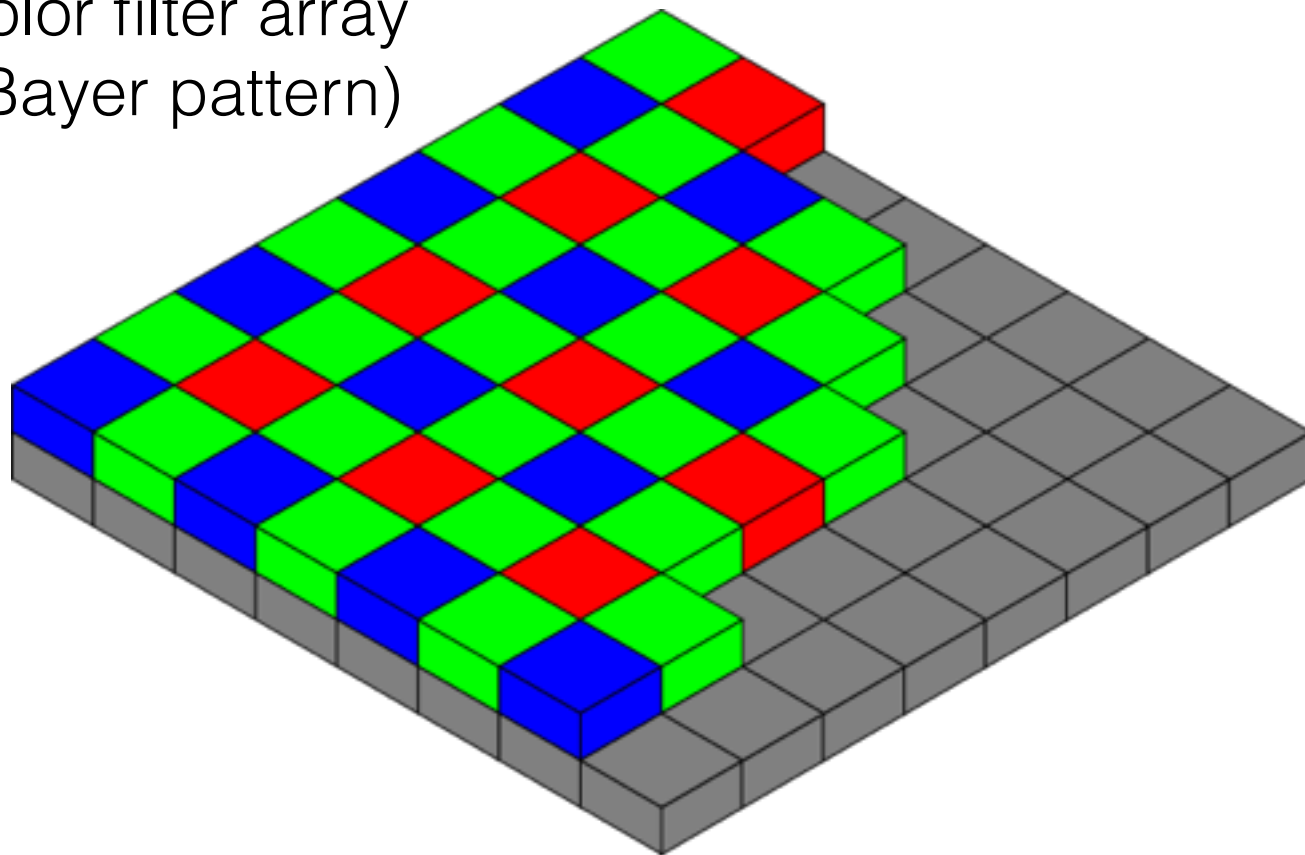
Image sensor



Color filter array



color filter array
(Bayer pattern)



Demosaicing is the process of recovering the complete RGB color channels from the Bayer pattern array. This is done by sophisticated interpolation algorithms (will be covered in later classes).

Lecture outline

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Image coordinates

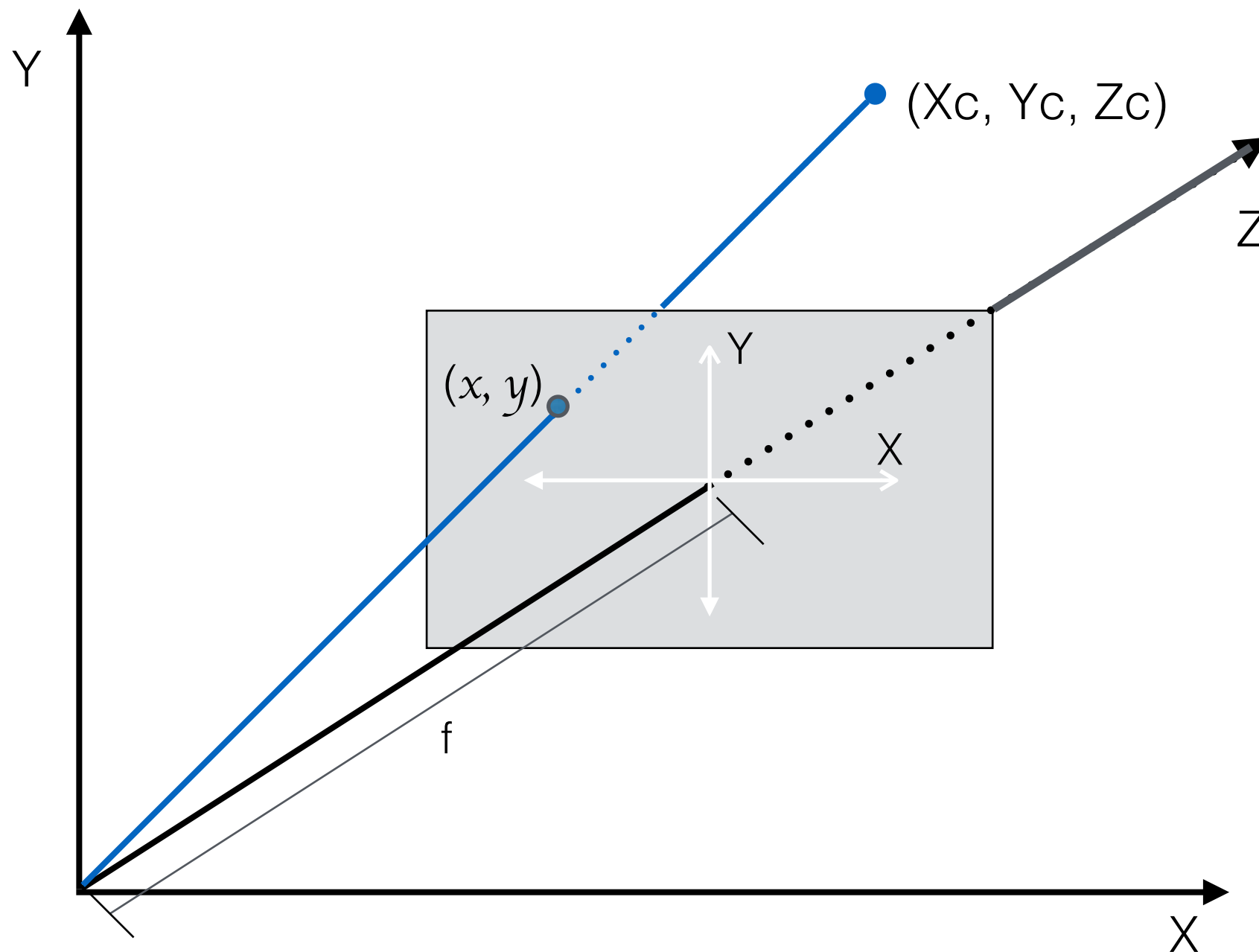
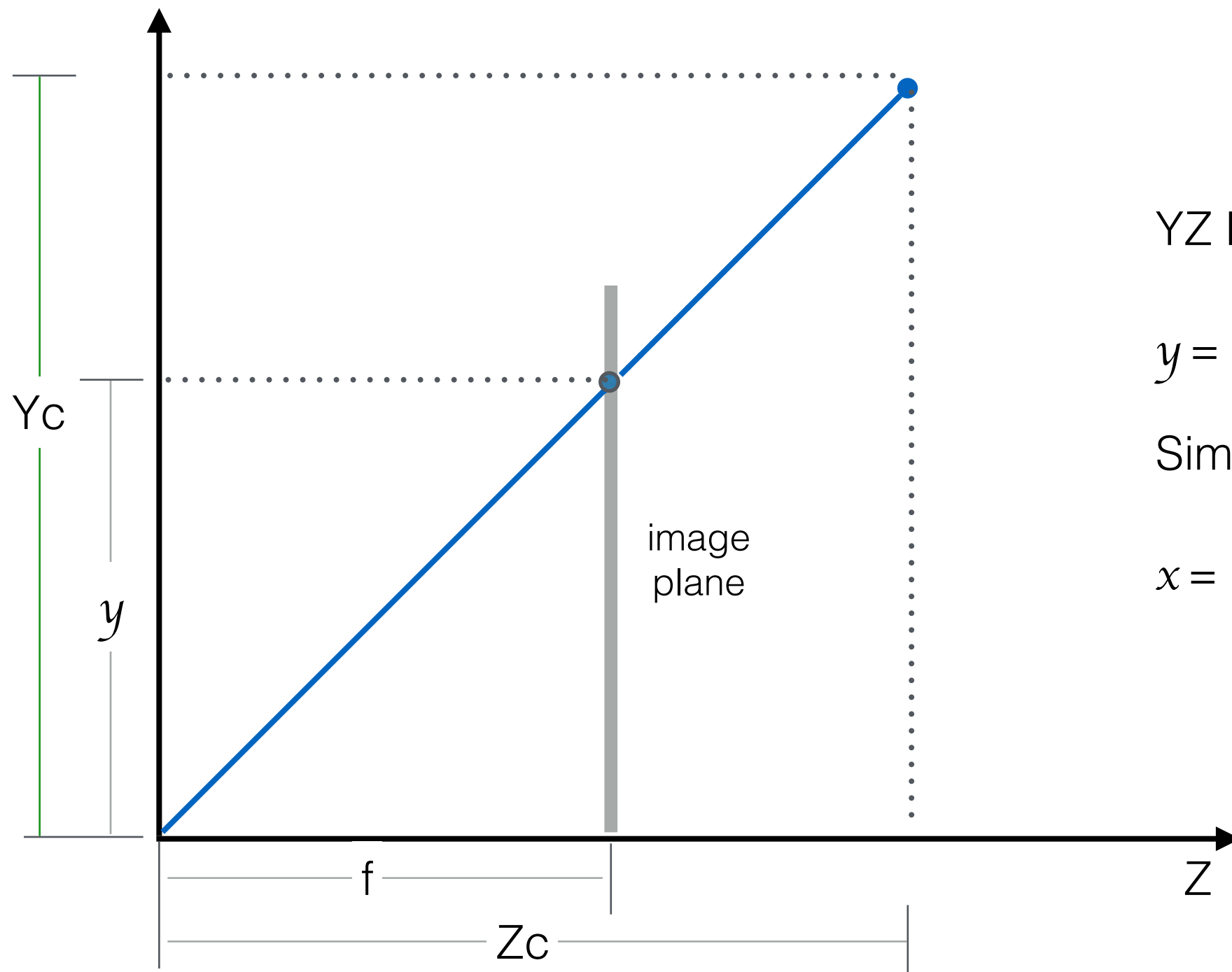


Image coordinates



YZ Plane (left)

$$y = f (Y_c / Z_c)$$

Similarly,

$$x = f (X_c / Z_c)$$

Image formation

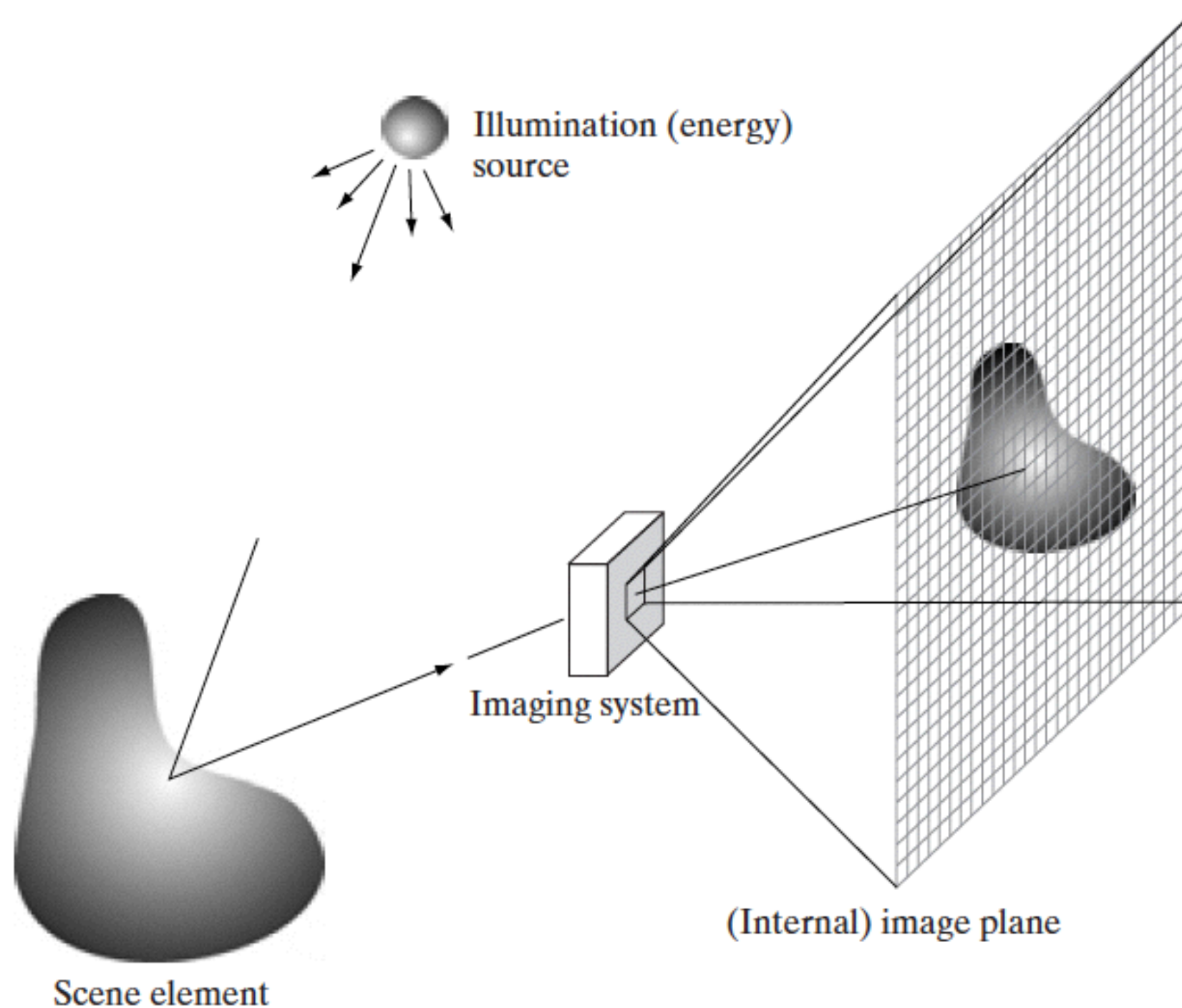


Image formation model

- Let the intensity value at (x,y) of an image be $f(x,y)$.
- $f(x,y) = i(x,y) r(x,y)$
where $i(x,y)$ is the amount of illumination the real-world scene received, and $r(x,y)$ is the reflectance.
- $i(x,y)$ is a positive, finite quantity.
- $r(x,y)$ varies from 0 to 1, where 0 means total absorption and 1 means total reflection.
- $f(x,y)$ thus is always a non-negative and finite quantity.

Lecture outline

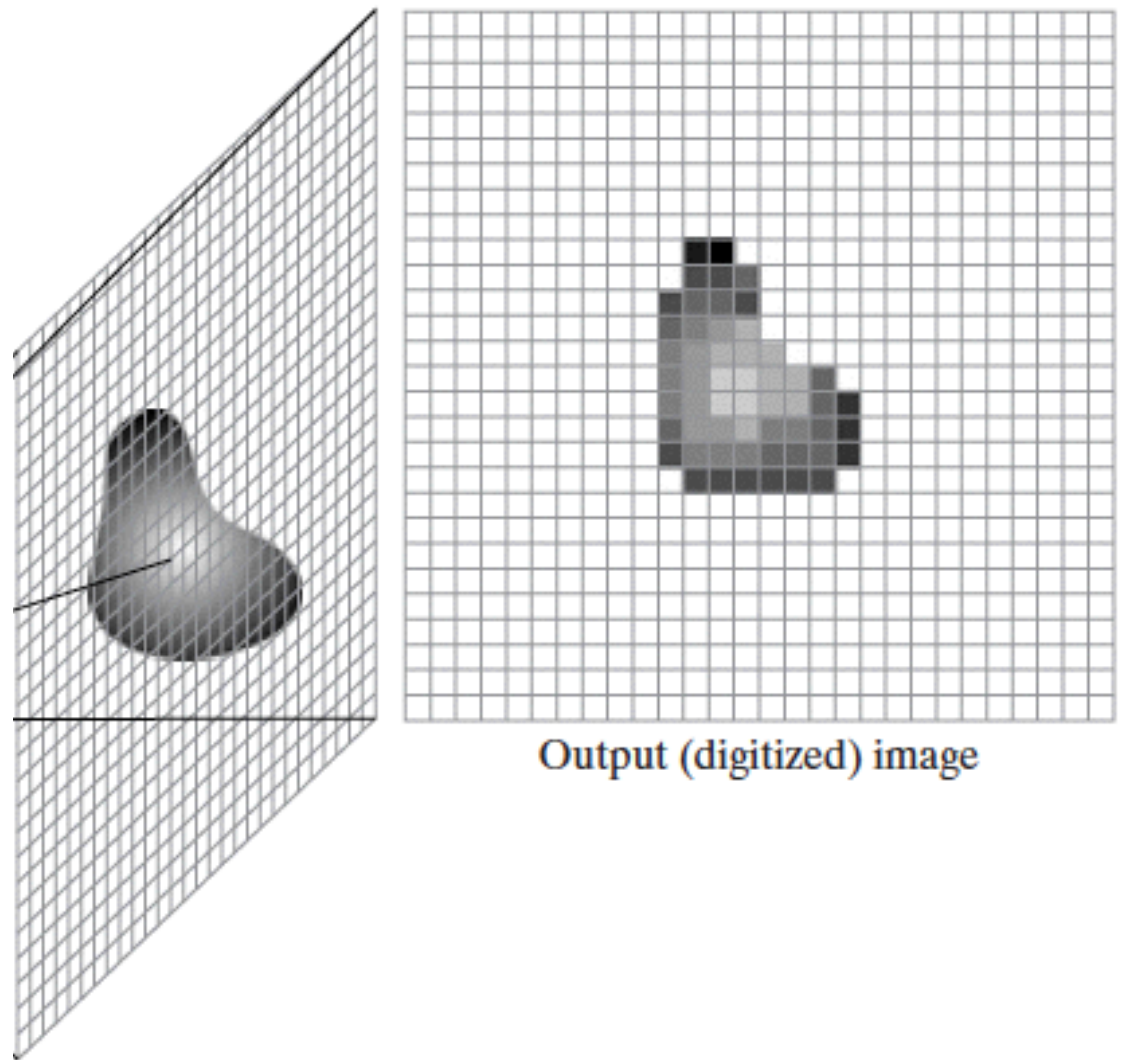
- Human visual system
- Image sensing
- Image formation
- **Image sampling**

Sampling

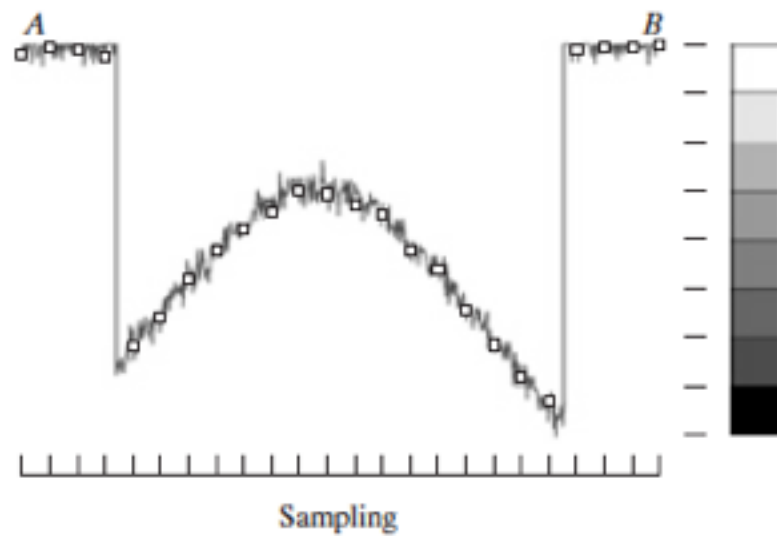
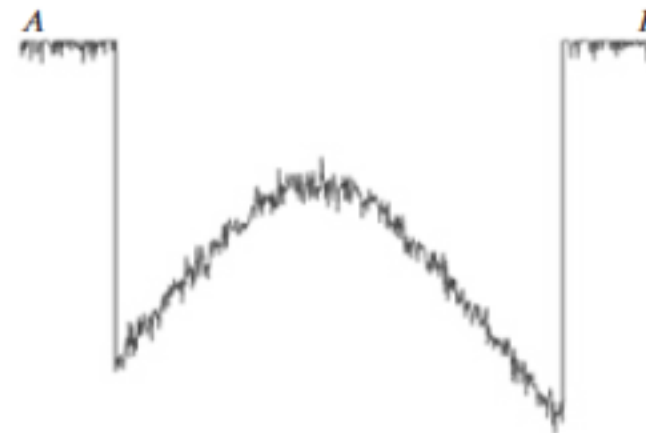
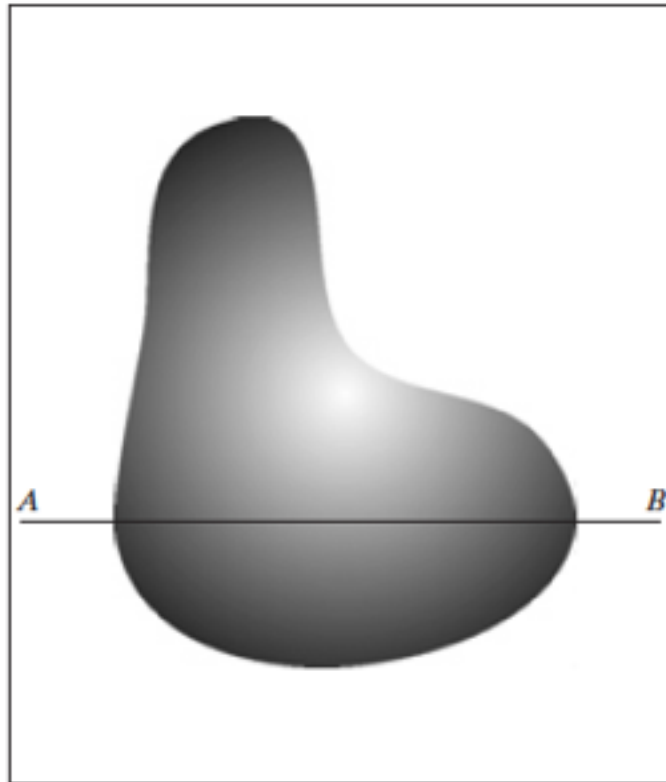
Sampling is the discretization of space.

The sampling rate is determined by the grid spacing size in the sensor array.

It determines the spatial resolution of an image.



Sampling



2D Sampling

$$f_s(x, y) = f(x, y) \text{comb}(x, y, \Delta x, \Delta y)$$

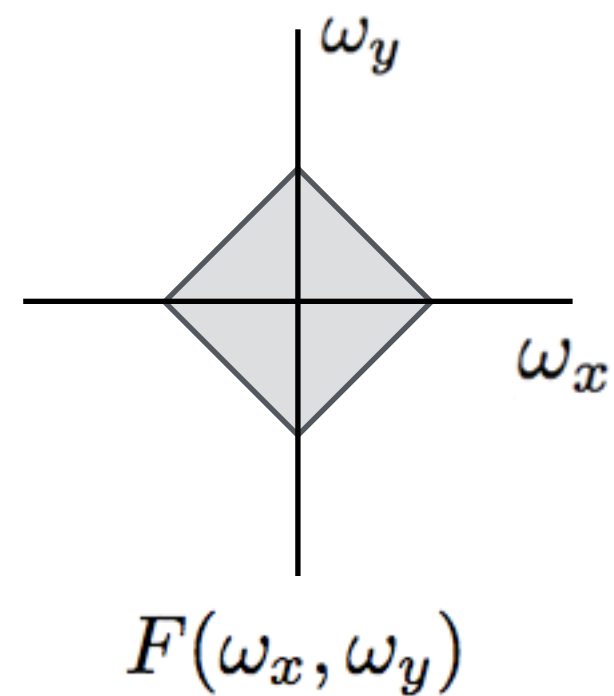
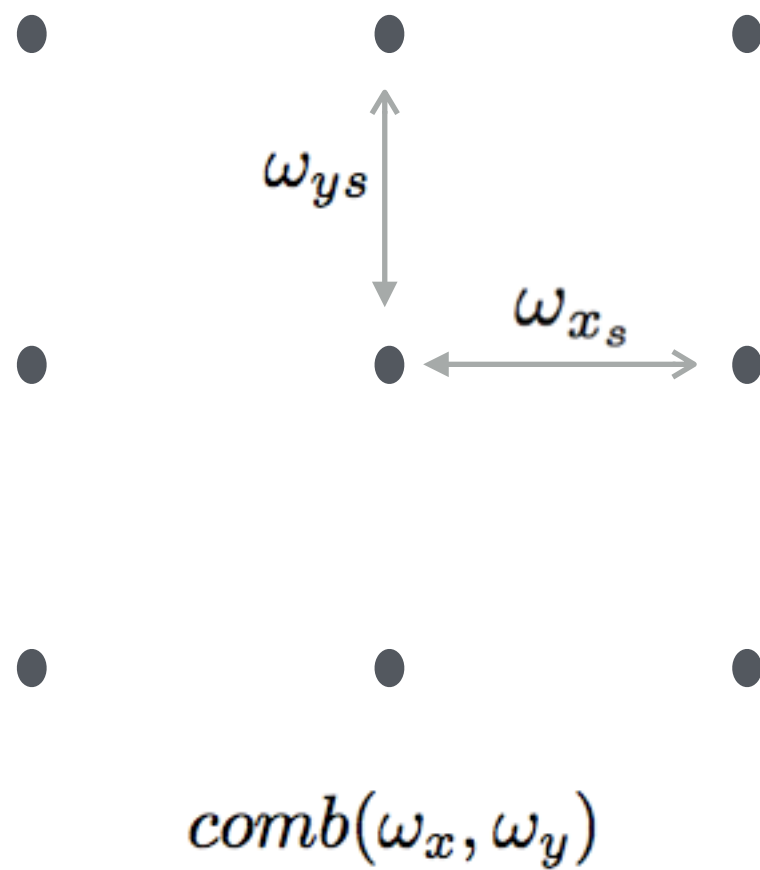
$$\text{comb}(x, y, \Delta x, \Delta y) = \sum_m \sum_n \delta(x - m\Delta x, y - n\Delta y)$$

In Fourier domain

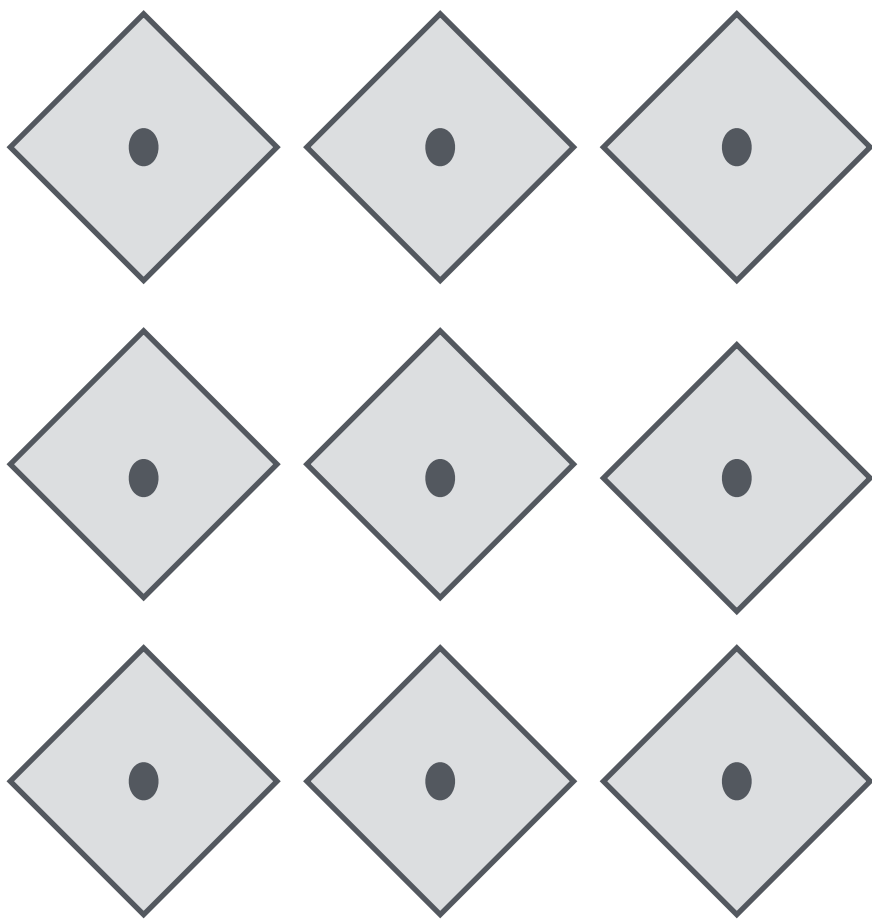
$$\begin{aligned} F_s(\omega_x, \omega_y) &= F(\omega_x, \omega_y) * \omega_{x_s} \omega_{y_s} \sum_p \sum_q \delta(\omega_x - p\omega_{x_s}, \omega_y - q\omega_{y_s}) \\ &= \omega_{x_s} \omega_{y_s} \sum_p \sum_q F(\omega_x - p\omega_{x_s}, \omega_y - q\omega_{y_s}) \end{aligned}$$

where $\omega_{x_s} = \frac{2\pi}{\Delta x}$, and $\omega_{y_s} = \frac{2\pi}{\Delta y}$

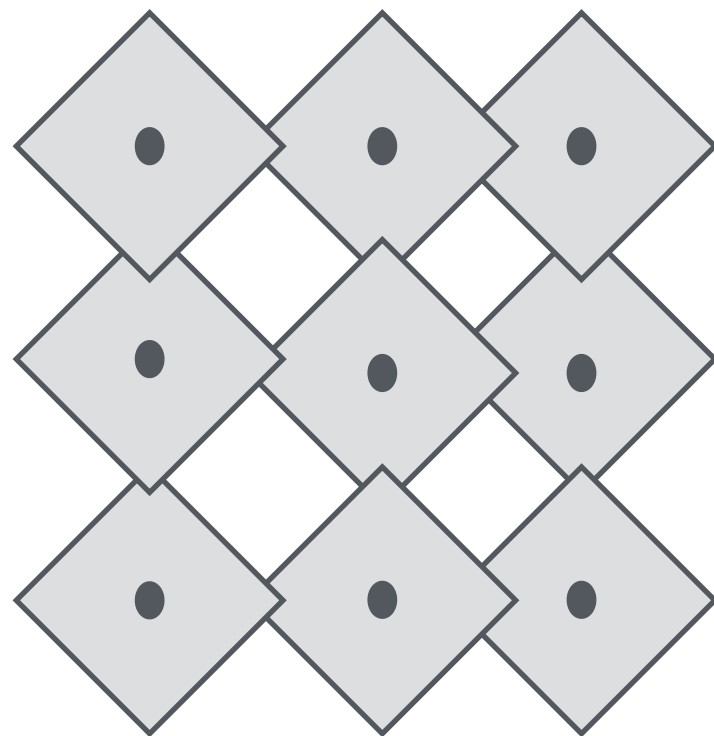
2D Sampling



2D Sampling



$$F_s(\omega_x, \omega_y)$$



$$F_s(\omega_x, \omega_y)$$

Aliasing