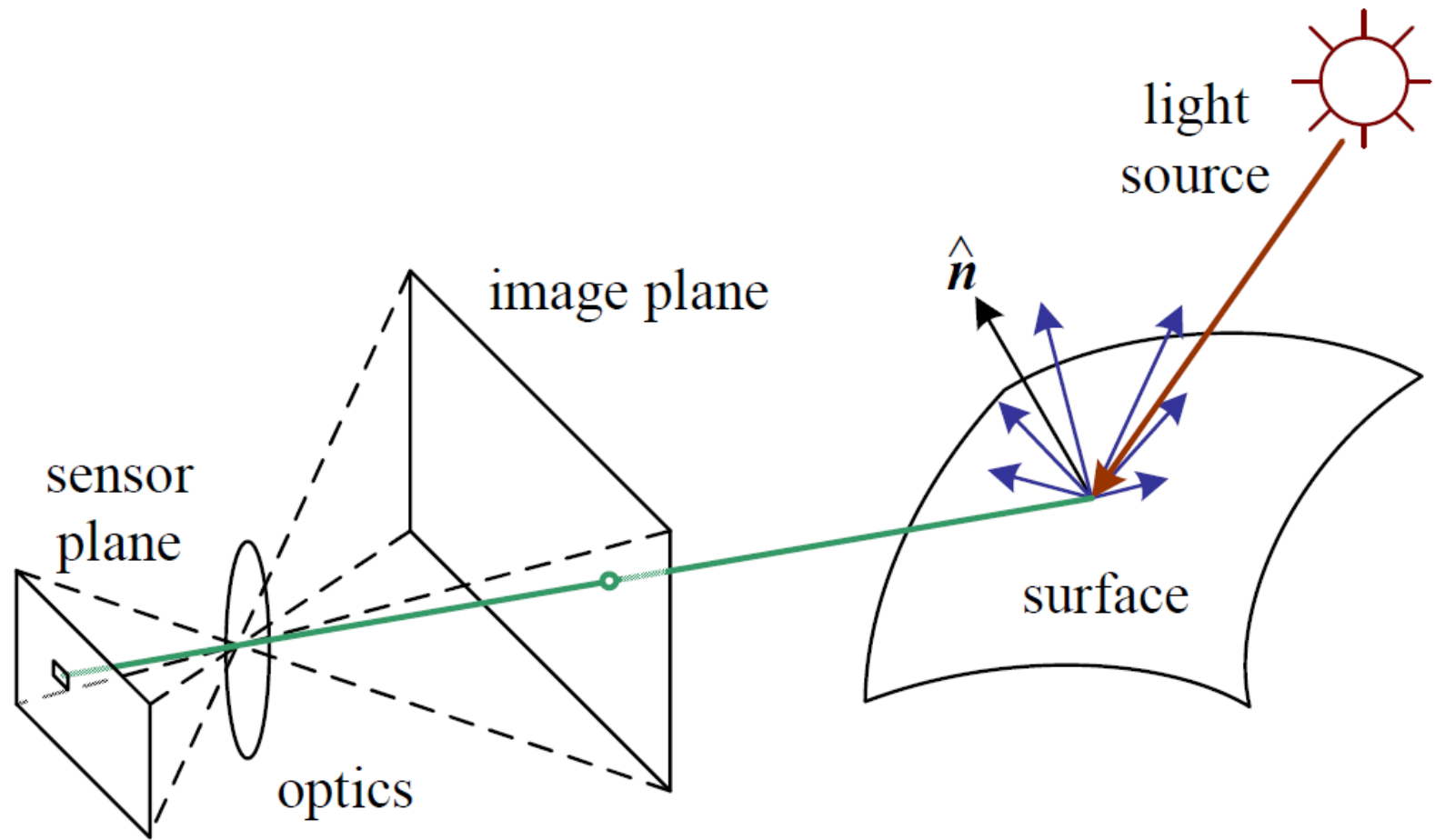


Lecture 1

Cheng-Ming Huang

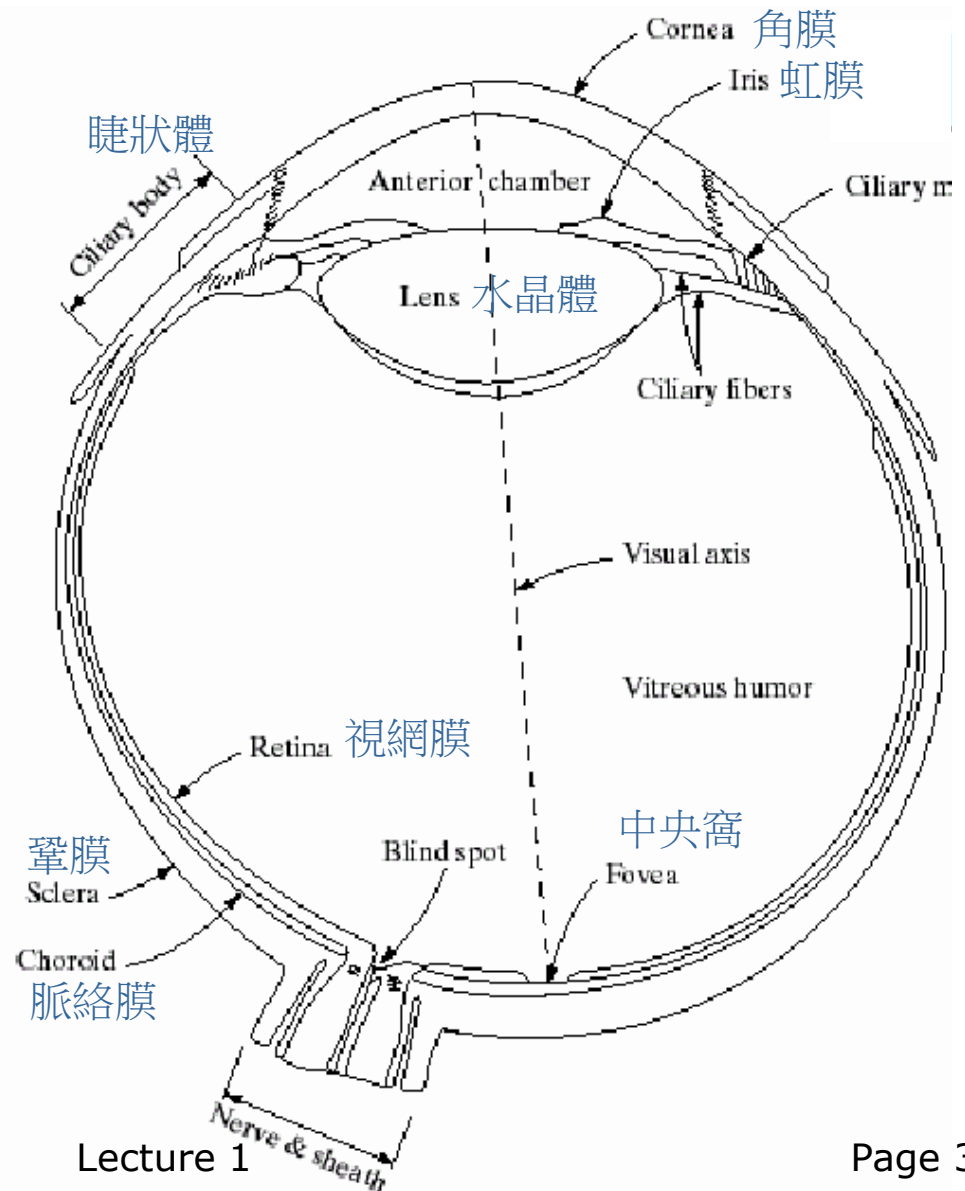
EE, NTUT

Photometric Image Formation



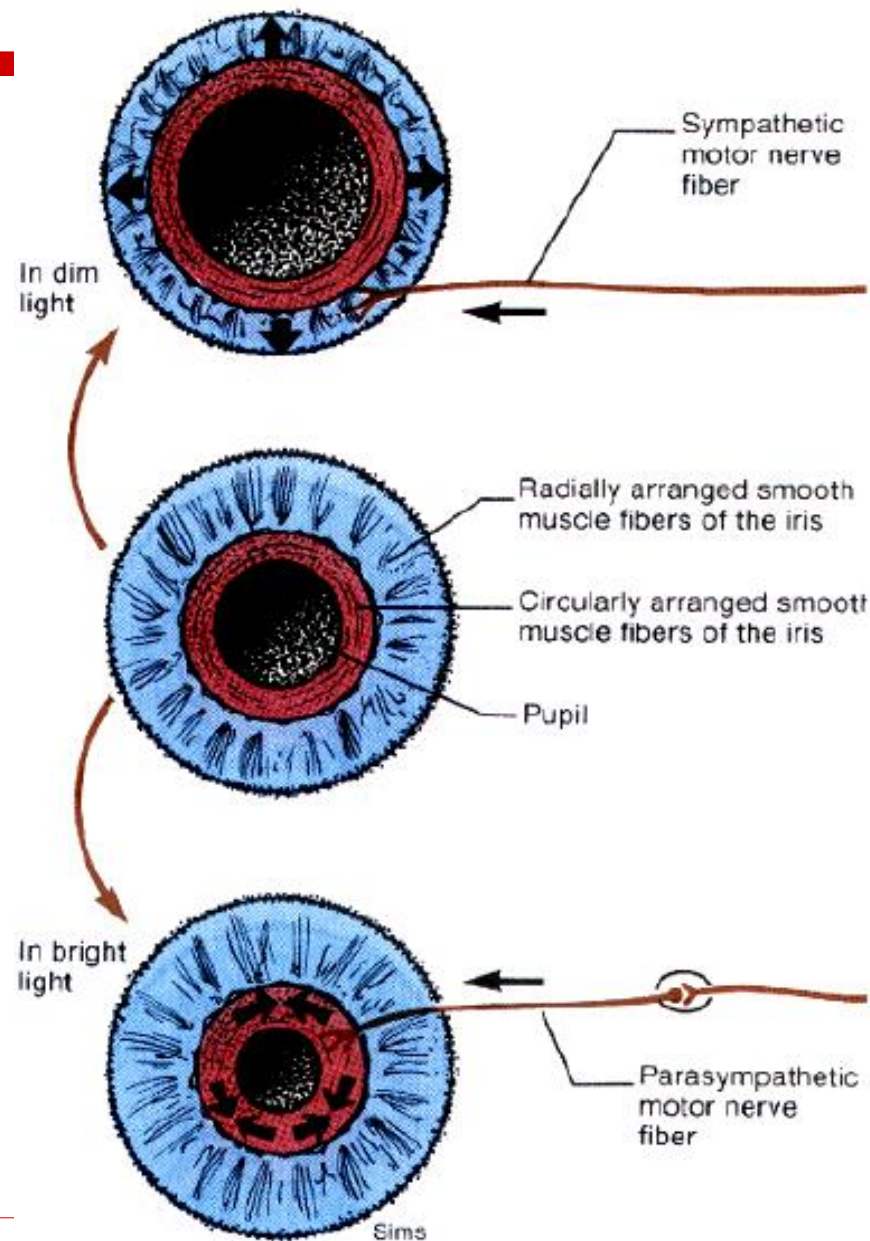
Human Eye

- 外覆薄膜
 - 眼角膜與鞏膜外覆 (Cornea and Sclera outer cover)
 - 脈絡膜(Choroid)
 - 網膜(Retina)
- 瞳孔(Pupil) - 虹彩膜 (Iris Diaphragm)
- 水晶體(Lens) - 60-70%水,約6%脂質, 高蛋白



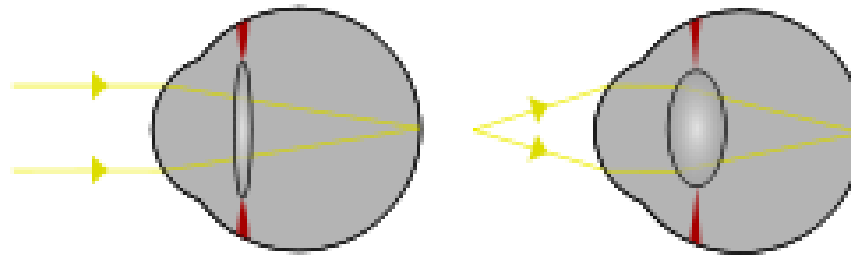
Human Eye – Iris

- ❑ 瞳孔大小的調節機制是根據環境的光亮強度
- ❑ 瞳孔放大：放射狀纖維（縱走肌）收縮、環狀纖維（環狀肌）舒張，使得中間的孔徑放大
- ❑ 瞳孔縮小：放射狀纖維舒張、環狀纖維向內收縮



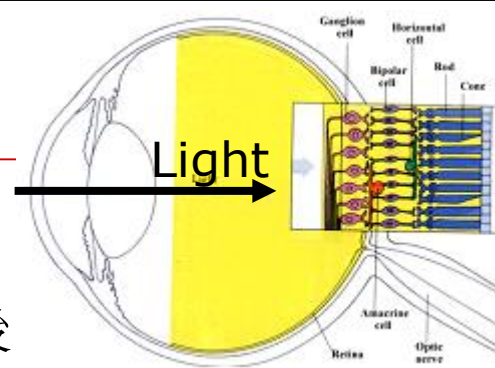
Human Eye – Lens

- ❑ 水晶體為一雙凸面透明組織，是眼球屈光系統的重要組成部分，也是唯一具有調節能力的屈光間質。



物體距離	遠	近
睫狀肌	鬆弛	收縮
睫狀體圓環直徑	大	小
懸韌帶張力	大	小
晶狀體厚度	小	大
晶狀體曲率	小	大
折射程度	低	高

Human Eye – Light Receptor



- 神經細胞
光線的路徑是由上往下，但訊號卻是在最底層接收後
- 神經節細胞：將光線訊號實際轉成脈衝訊號（較不易有雜訊）

無軸突細胞：運動訊號的初級處理

雙極細胞：強化影像的邊緣

水平細胞：把數個錐狀或

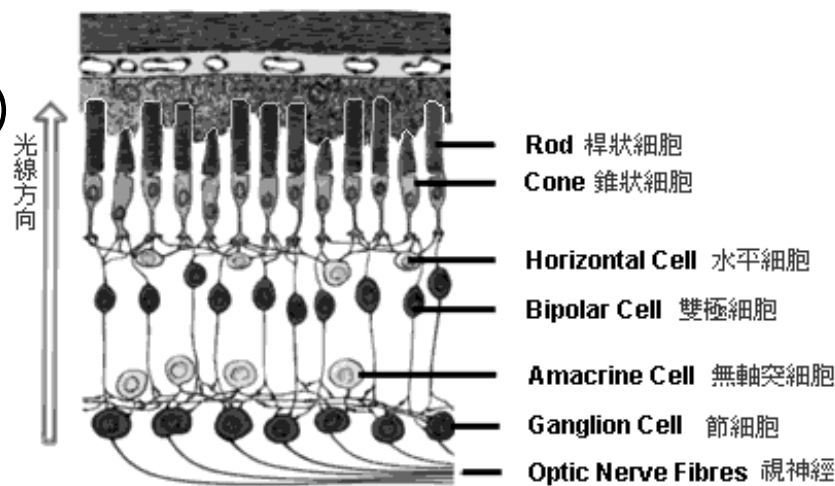
桿狀細胞的訊號平均（模糊化）

桿狀細胞：感受明暗

（對400~600nm光線敏感）

錐狀細胞：對紅藍綠三種光線敏感

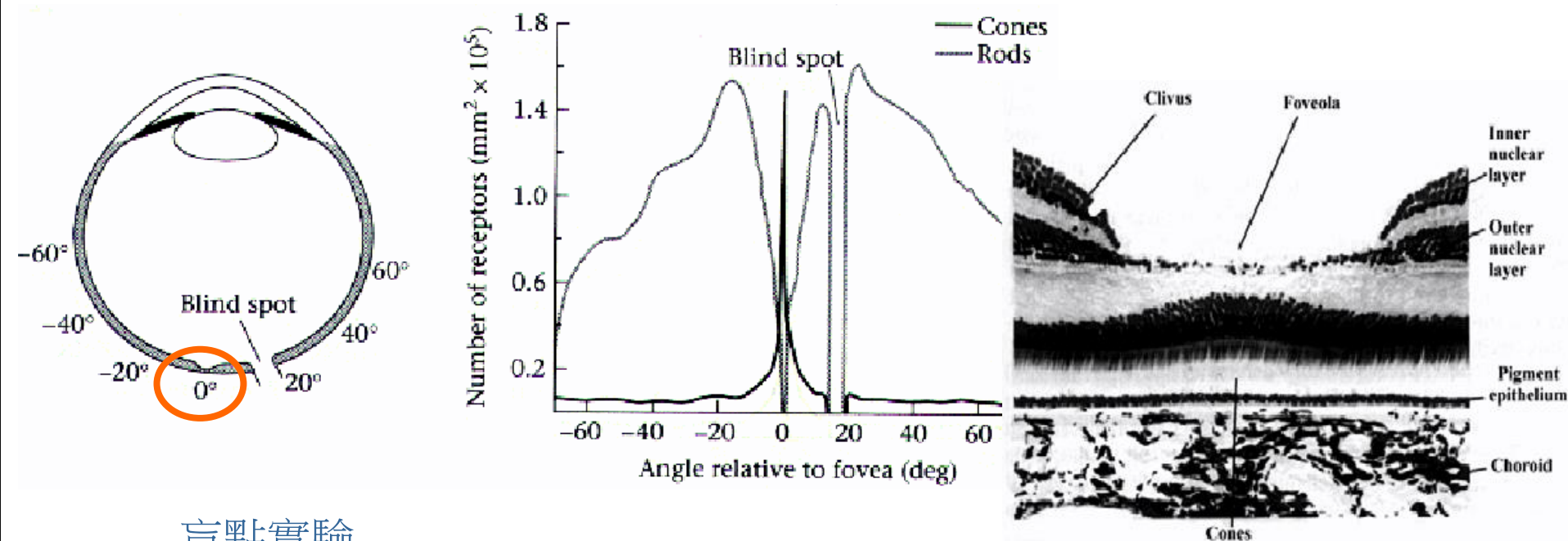
色素上皮細胞



Human Eye – Light Receptor

□ 中央窩地區

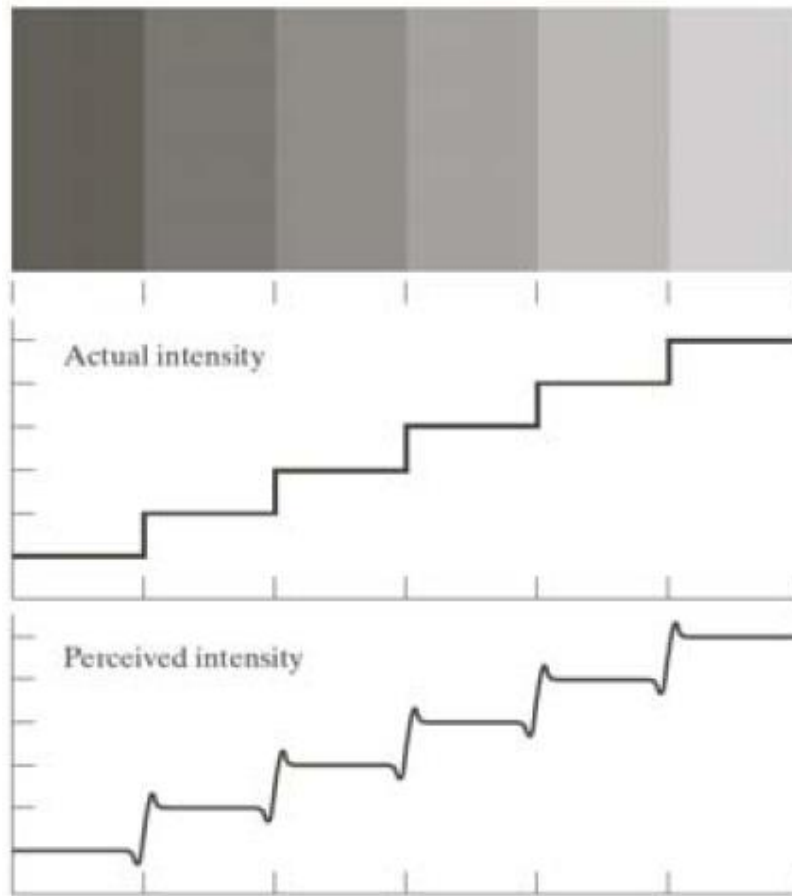
神經層較薄，沒有阻礙光線的血管層



盲點實驗

在眼前約30公分的地方，伸出兩隻手比個‘讚’的手勢。
右眼閉上，左眼盯著右手拇指，接著左手漸漸向右手靠近。
大約在不到10公分的距離時，左手拇指不見了～

Human Vision Phenomenon



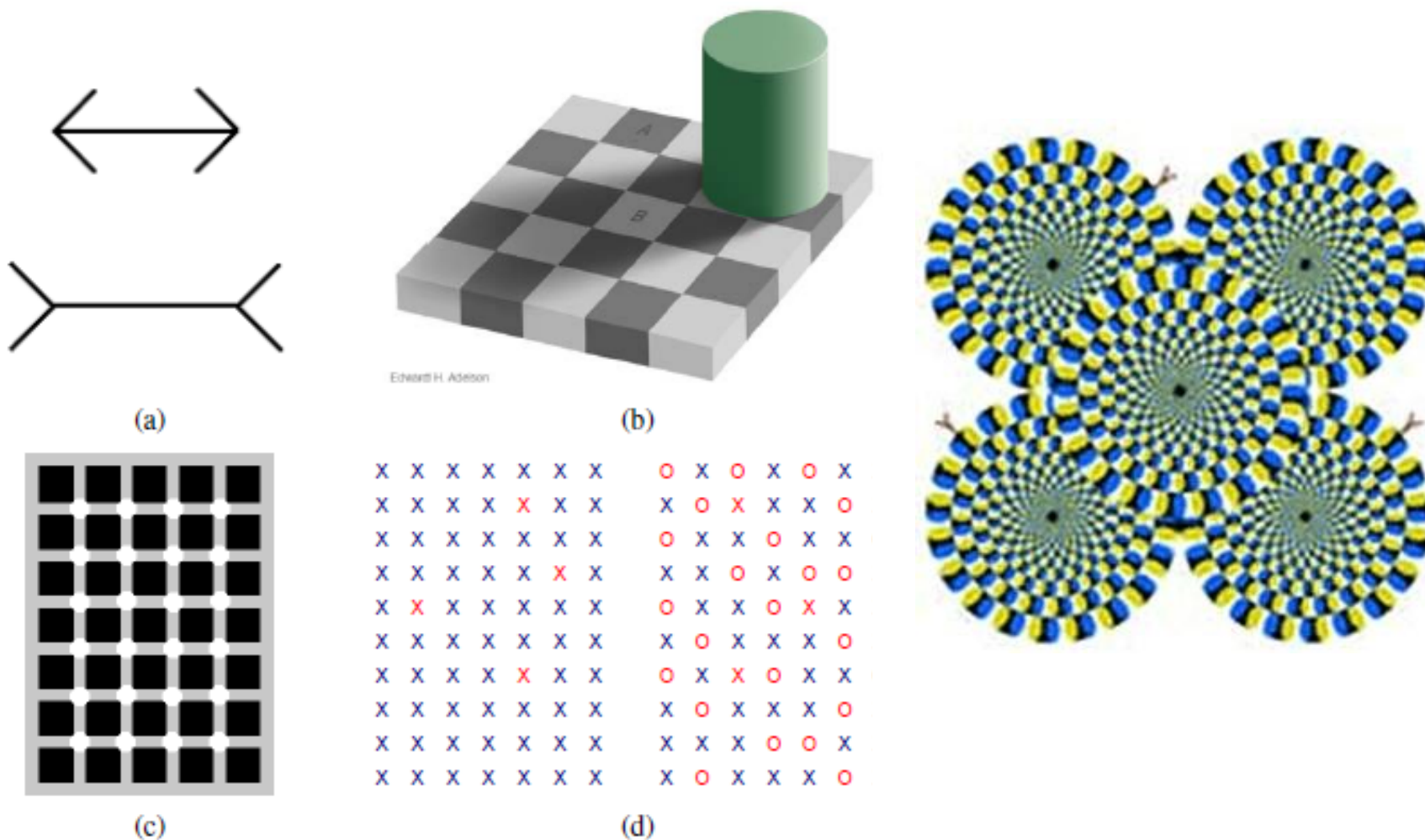
Mach Band



Simultaneous Contrast

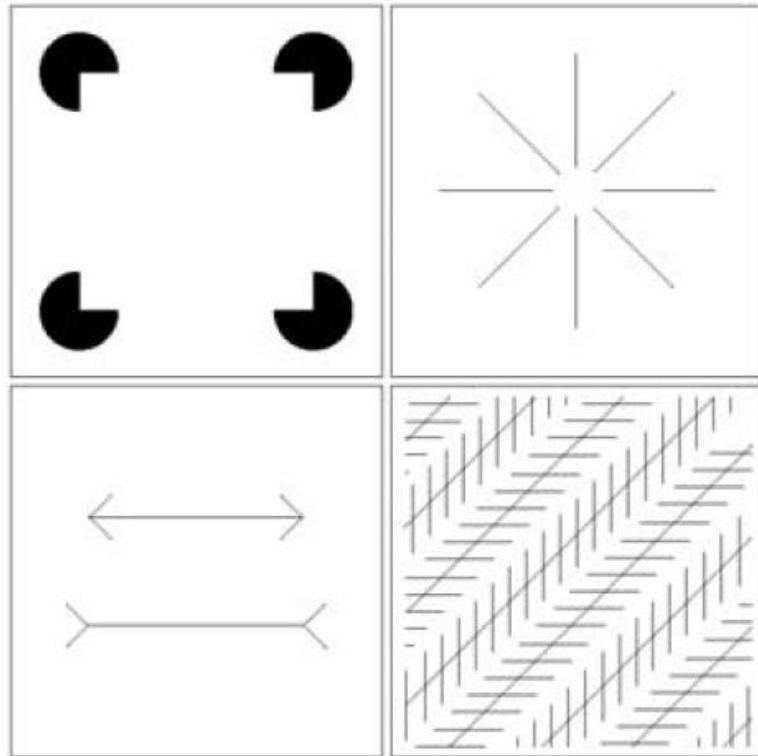
Human Vision Phenomenon

Visual(optical) illusion 視覺錯覺



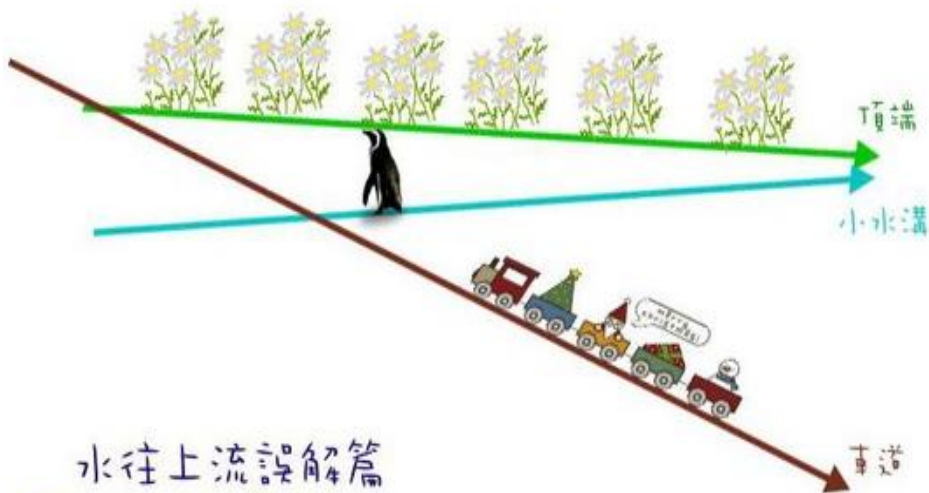
Human Vision Phenomenon

□ Visual(optical) illusion

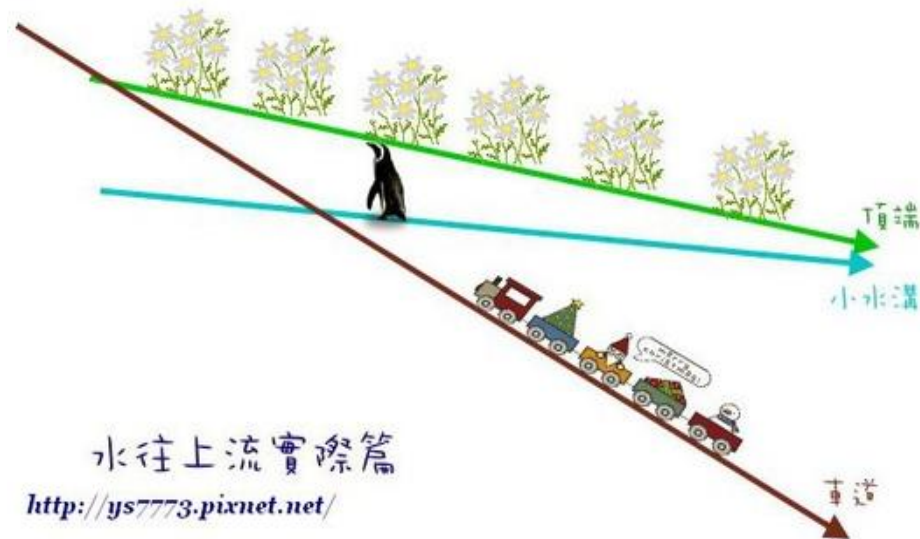


Human Vision Phenomenon

□ 台東 水往上流

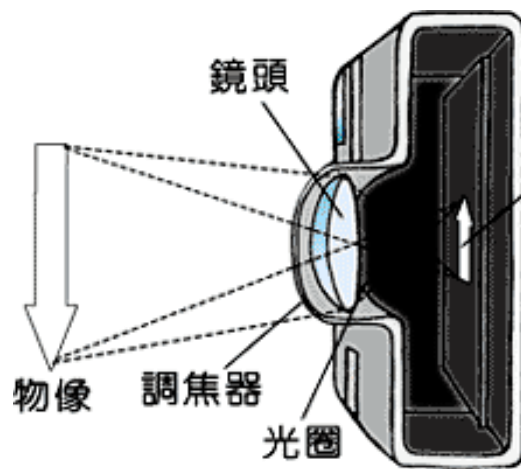
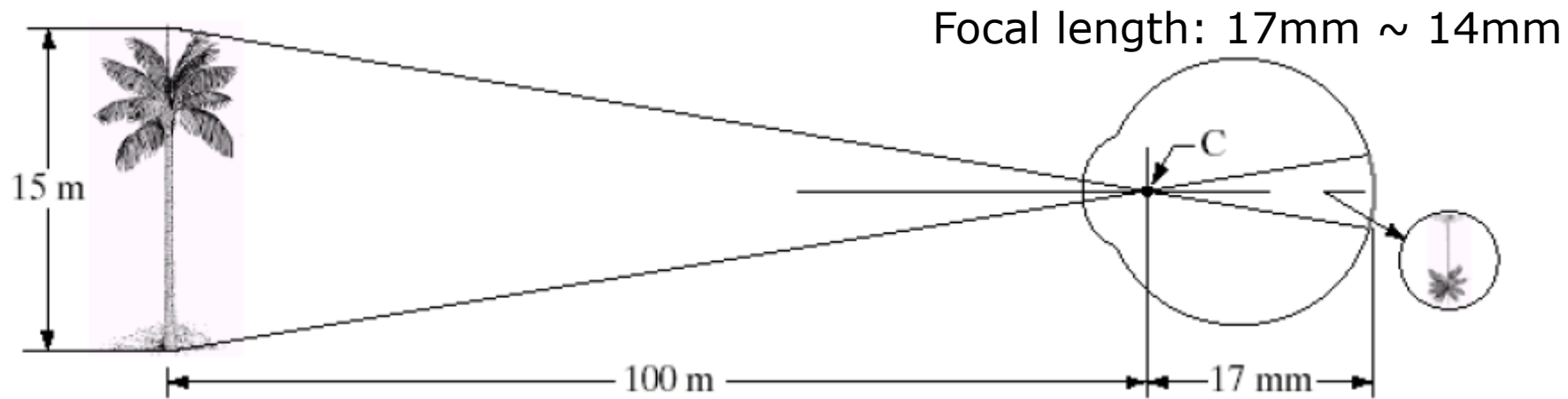


<http://ys7773.pixnet.net/>

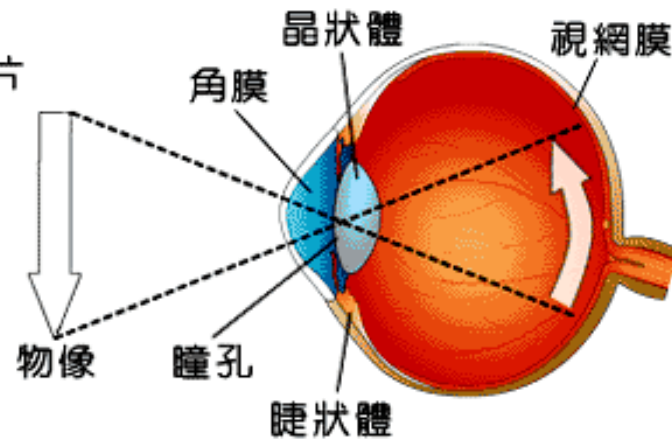


<http://ys7773.pixnet.net/>

Image Formation



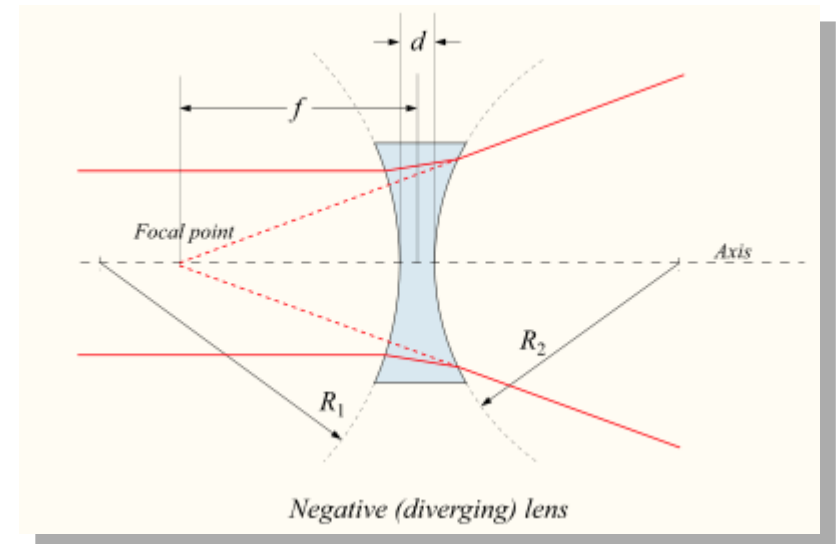
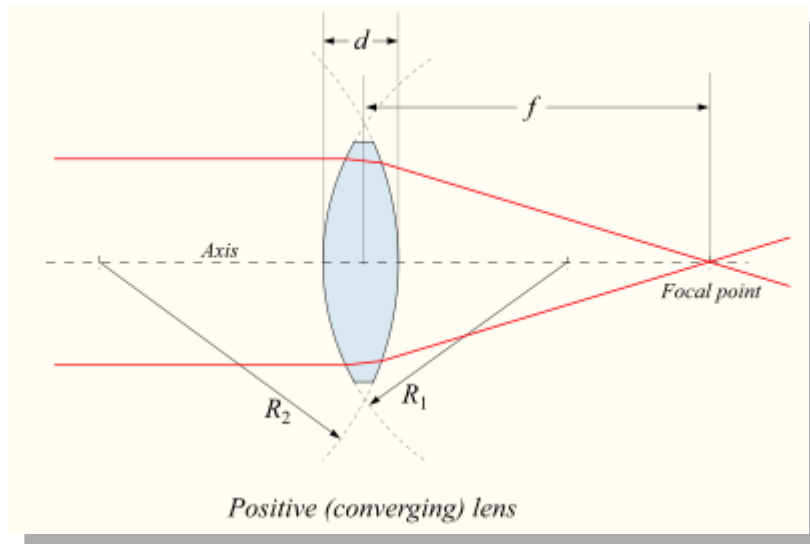
照相機橫切面



眼球橫切面

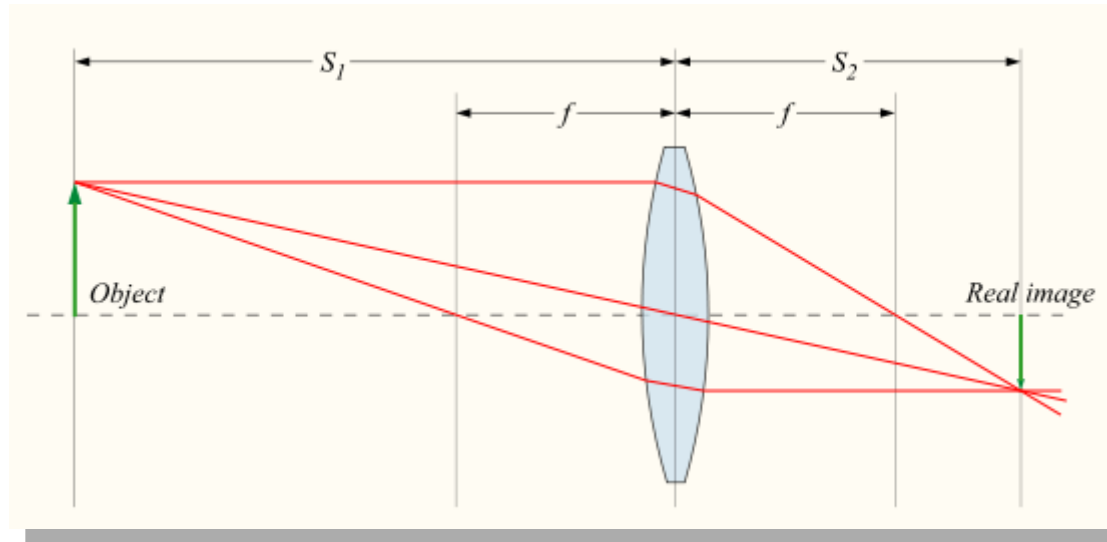
Perspective Projection

□ Lens



Perspective Projection

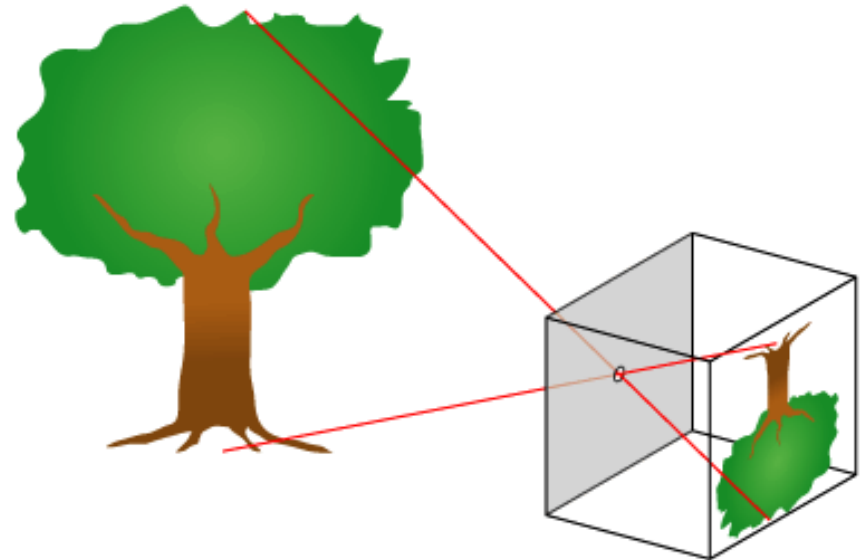
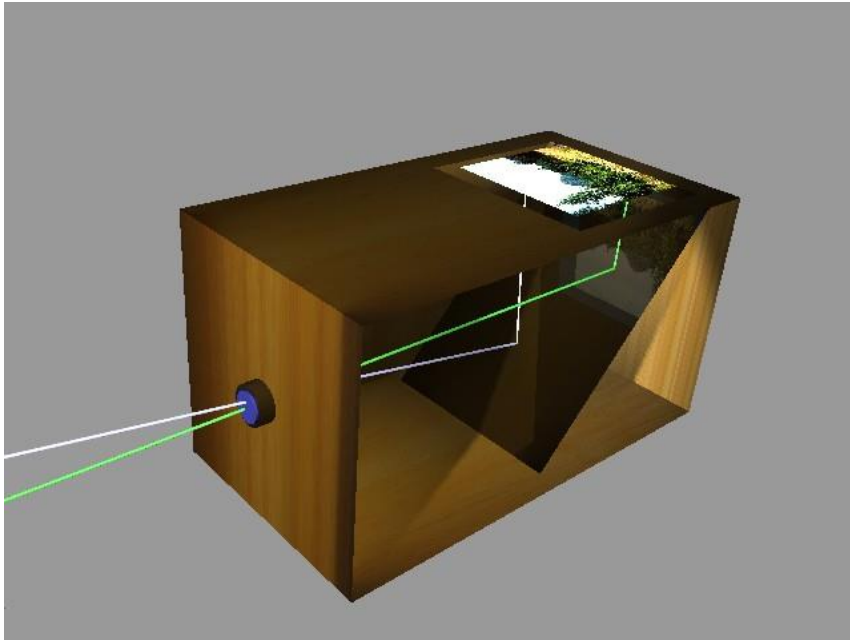
□ Thin lens formula



$$\frac{1}{S_1} + \frac{1}{S_2} = \frac{1}{f}$$

Perspective Projection

□ Pin-hole camera model

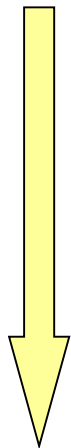


Perspective Projection

□ Pin-hole camera model

■ Camera frame

$$(x_c, y_c, z_c)$$



projection

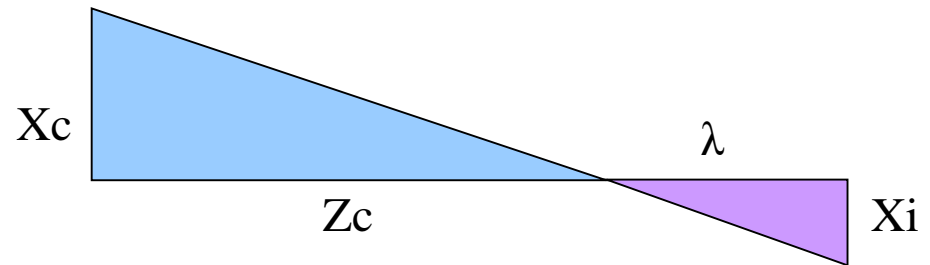
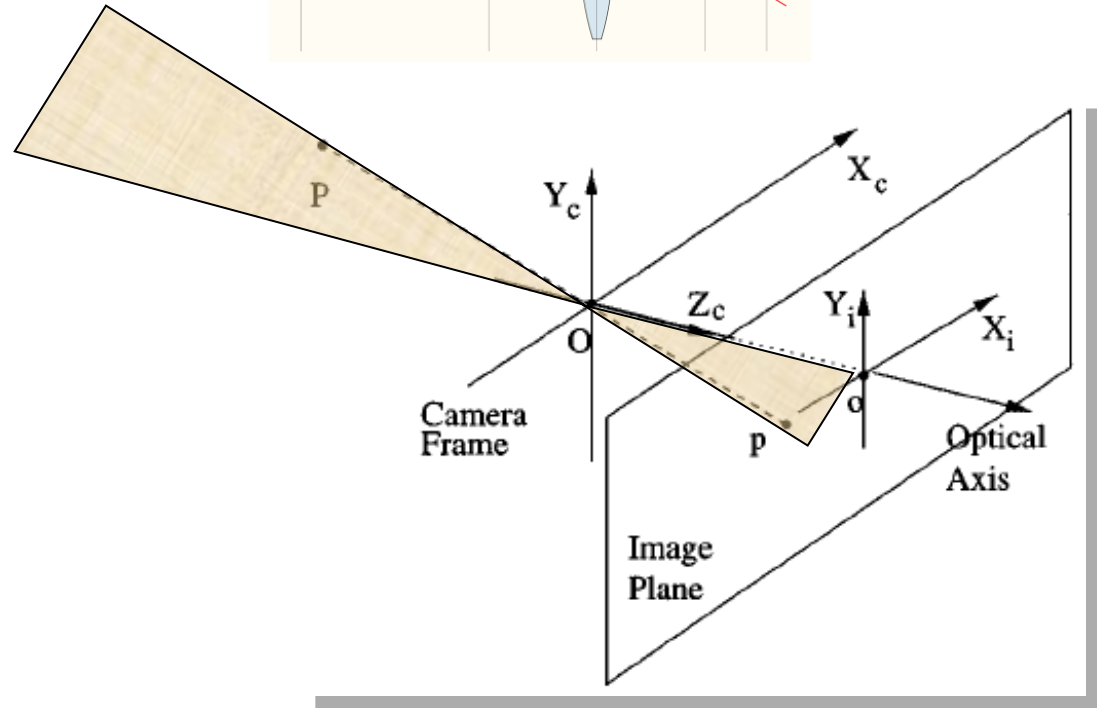
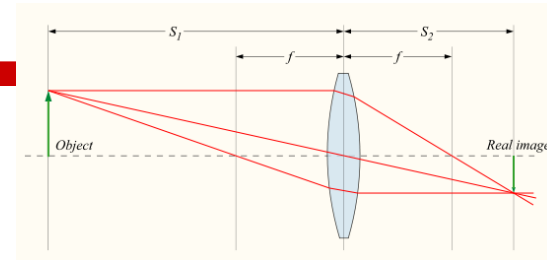
$$\begin{cases} x_i = \lambda \frac{x_c}{z_c} \\ y_i = \lambda \frac{y_c}{z_c} \end{cases}$$



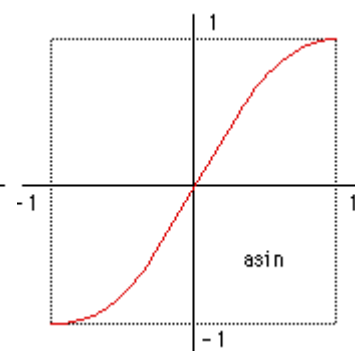
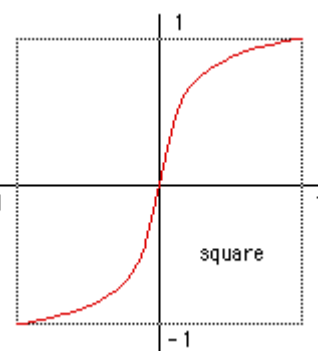
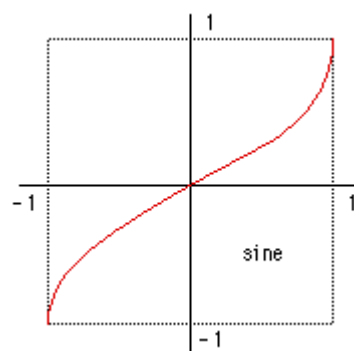
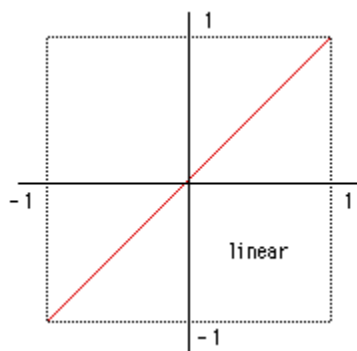
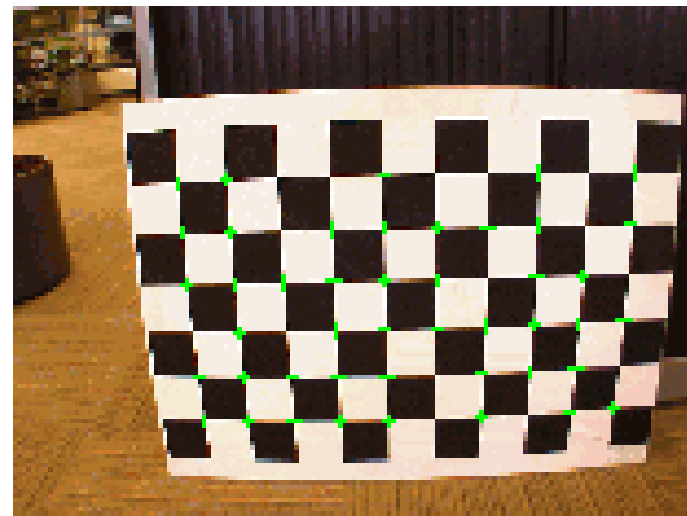
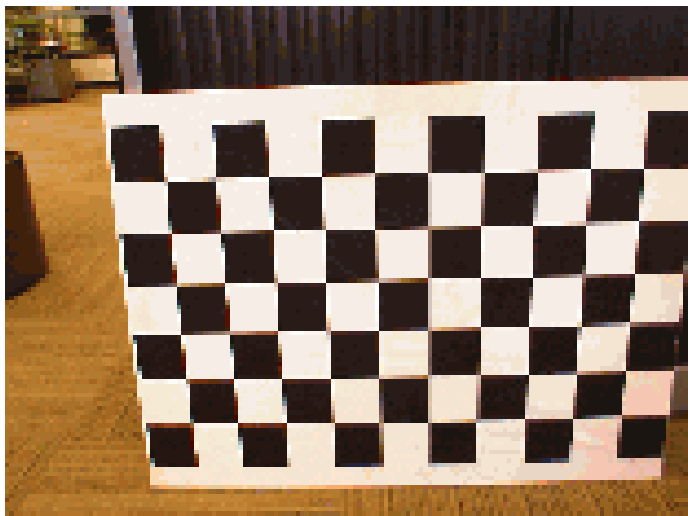
■ Image plane

$$(x_i, y_i, \lambda)$$

■ Depth?

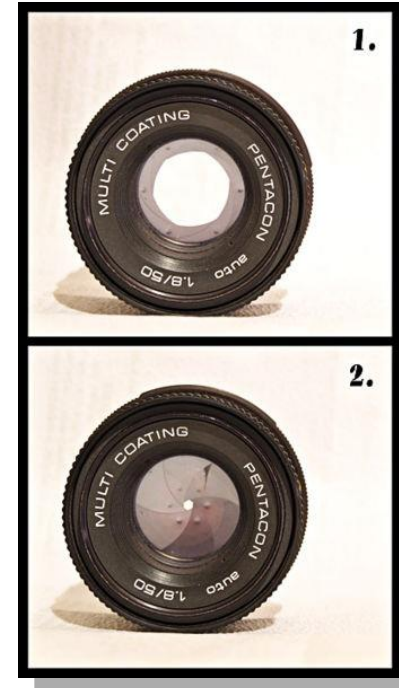


Lens-Distortion



Traditional Camera

□ 快門、光圈



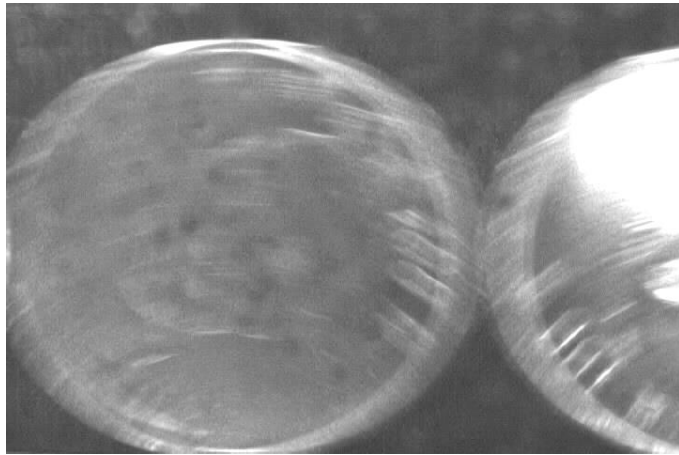
□ 底片

- 鹵化銀塗抹在聚乙酸酯片基上
- 當有光線照射到鹵化銀上時，

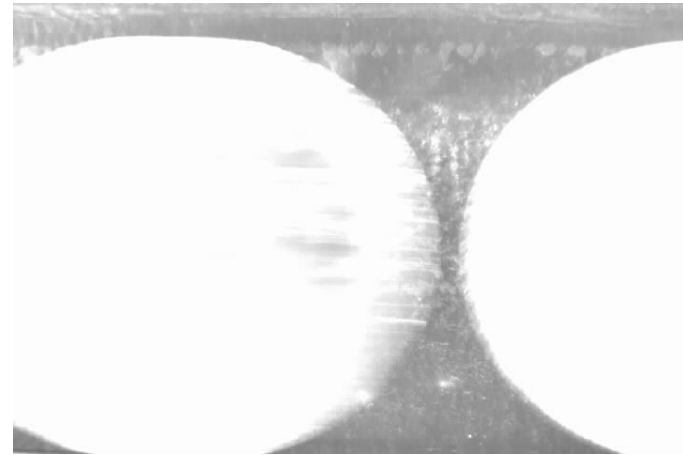


Shutter & Aperture

快門慢光圈小



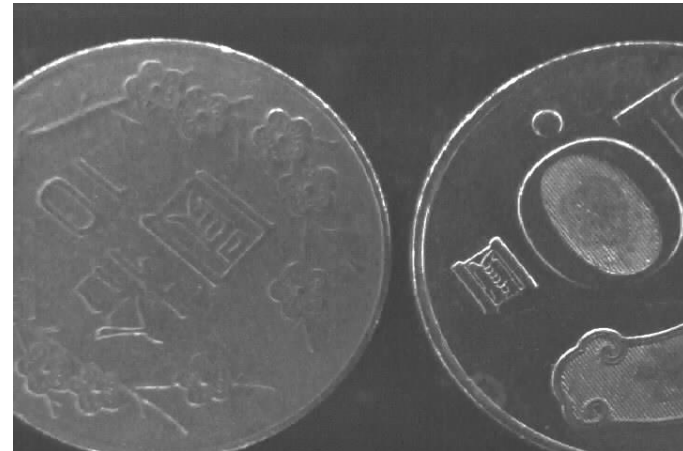
快門慢光圈大



快門快光圈小

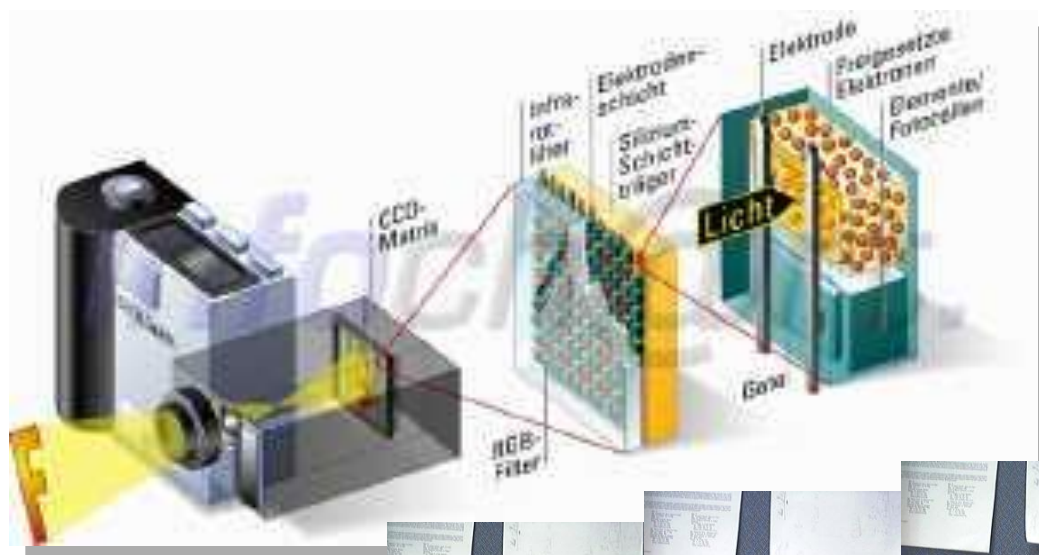


快門快光圈大



Digital Camera 攝影機/相機

- ❑ 鏡頭光學圖像聚焦
- ❑ Charge Coupled Device (CCD) 轉換為隨時間變化視頻訊號
- ❑ 攝影機內部線路處理CCD轉換視頻訊號，經由同軸或光纜或其它傳輸途徑將訊號傳送至監視器上顯現



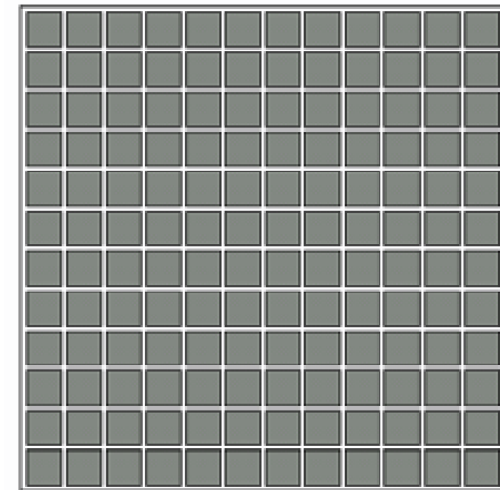
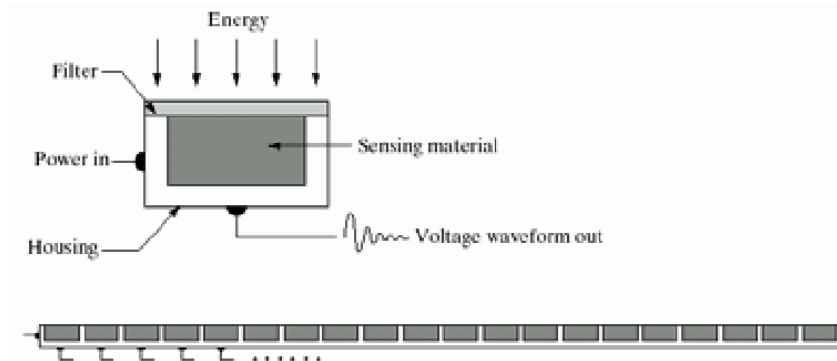
→ B/W (EIA / CCIR)
→ Color (NTSC / PAL)



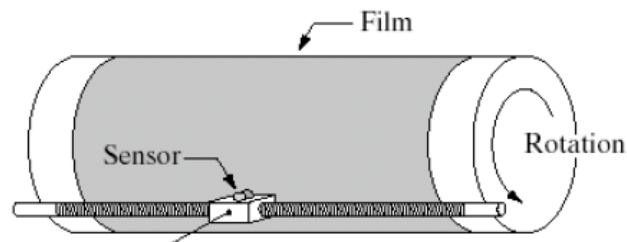
Monitor,
Image grabber (frame)



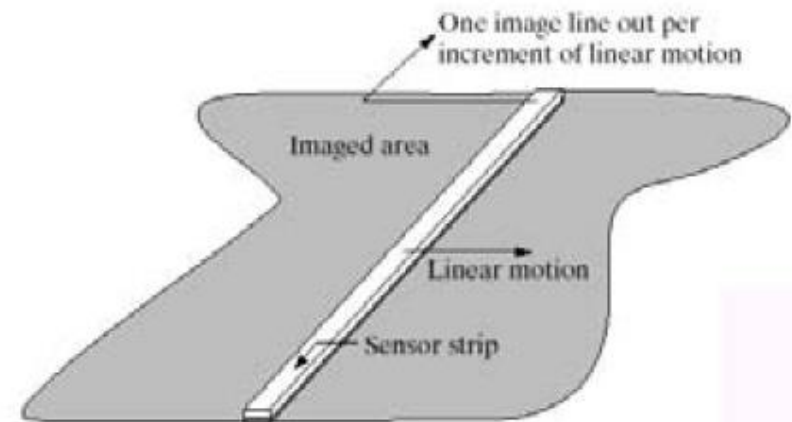
Image Acquisition



Sensor arrays

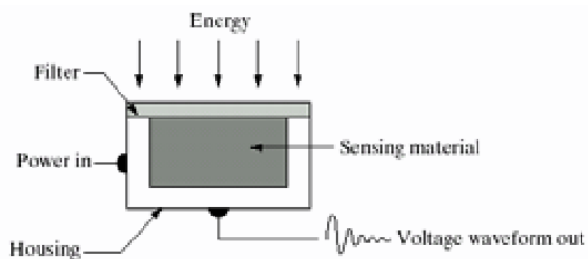


Single sensor

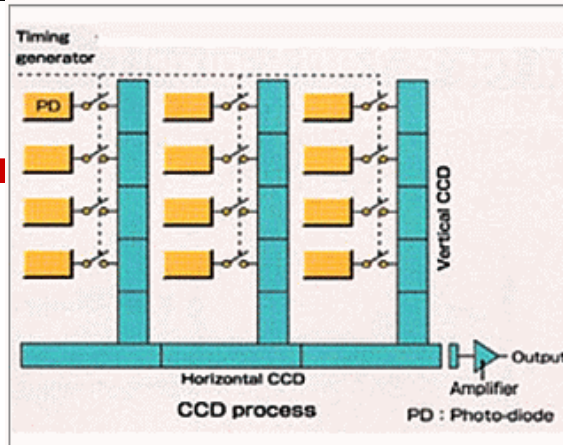


Sensor strips

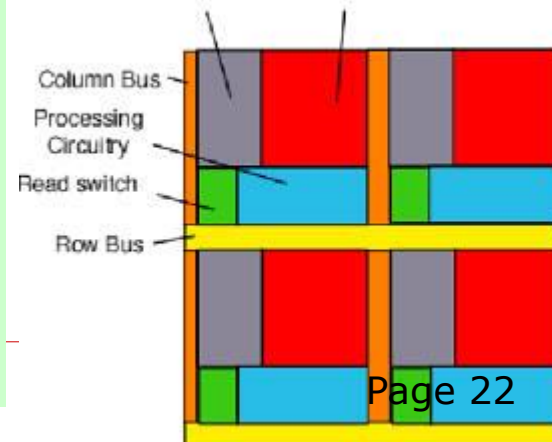
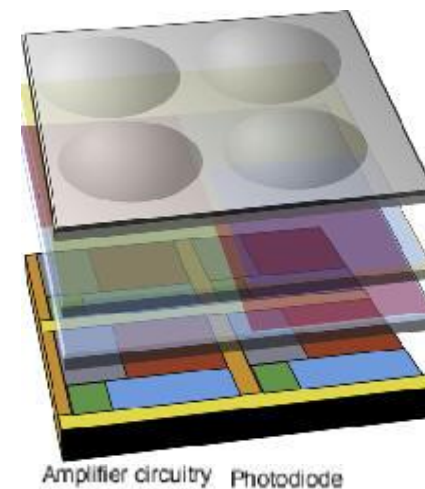
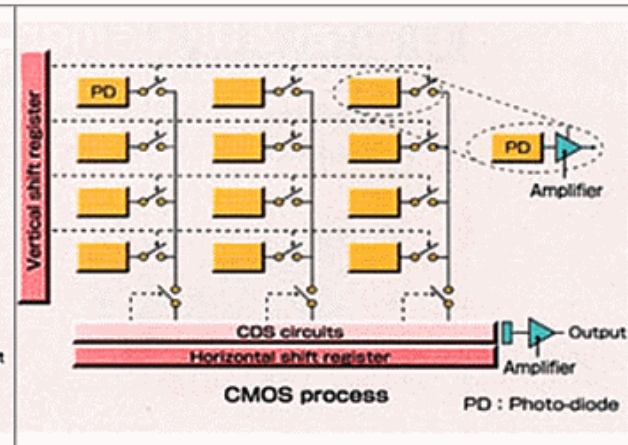
CCD v.s. CMOS



CCD



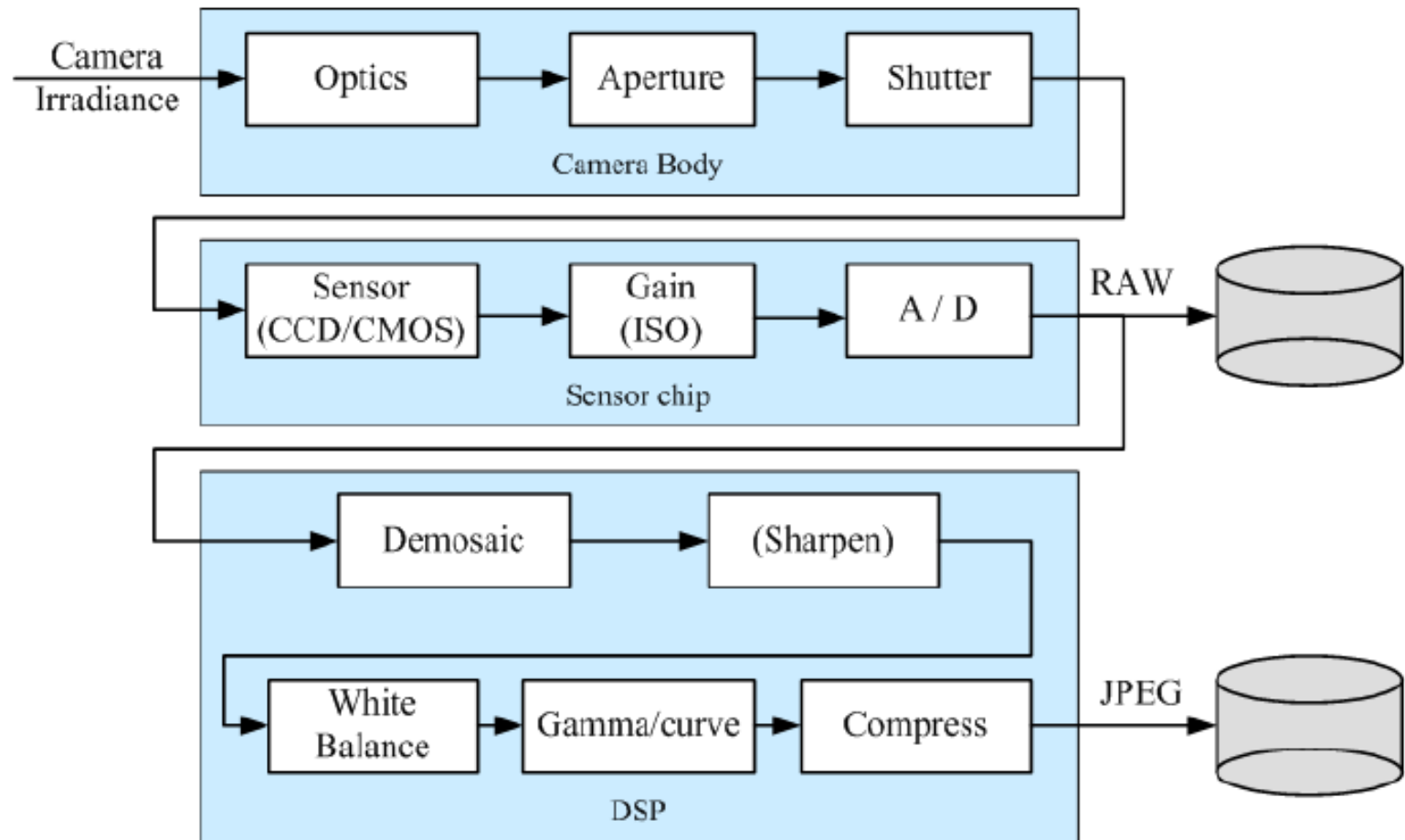
CMOS



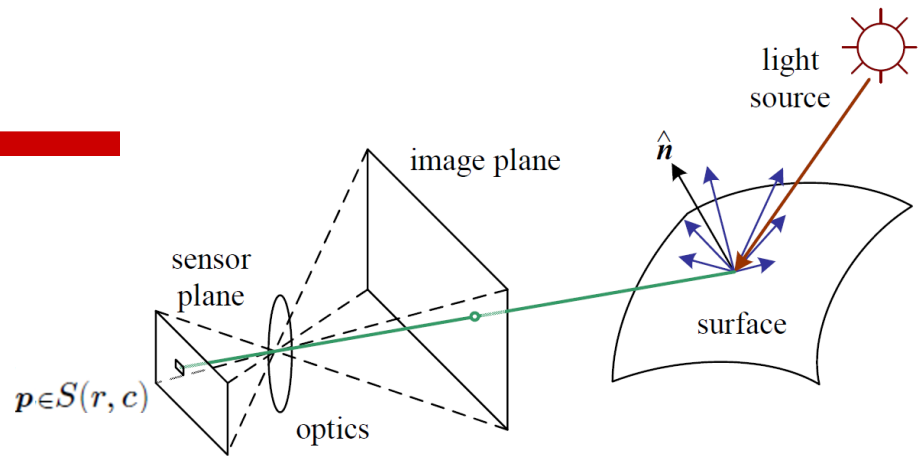
設計	單一感光器	感光器連結放大器
靈敏度	同樣面積下較高	感光開口小低 (Fill Factor 因感光開口大，較高)
成本	線路品質影響良率 高	整合製程 低
解析度	結構複雜度低 高	傳統技術較低 新技術擺脫面積限制，可達全片幅
雜訊比	單一放大器主控 低	多元放大器，誤差大 高
耗能比	需外加電壓導出電荷 高	畫素直接放大 低
反應速度	慢	快
製造機具	特殊訂製機台	可以使用記憶體或處理器製造機

Digital Camera

□ Image sensing pipeline



Sensor Model



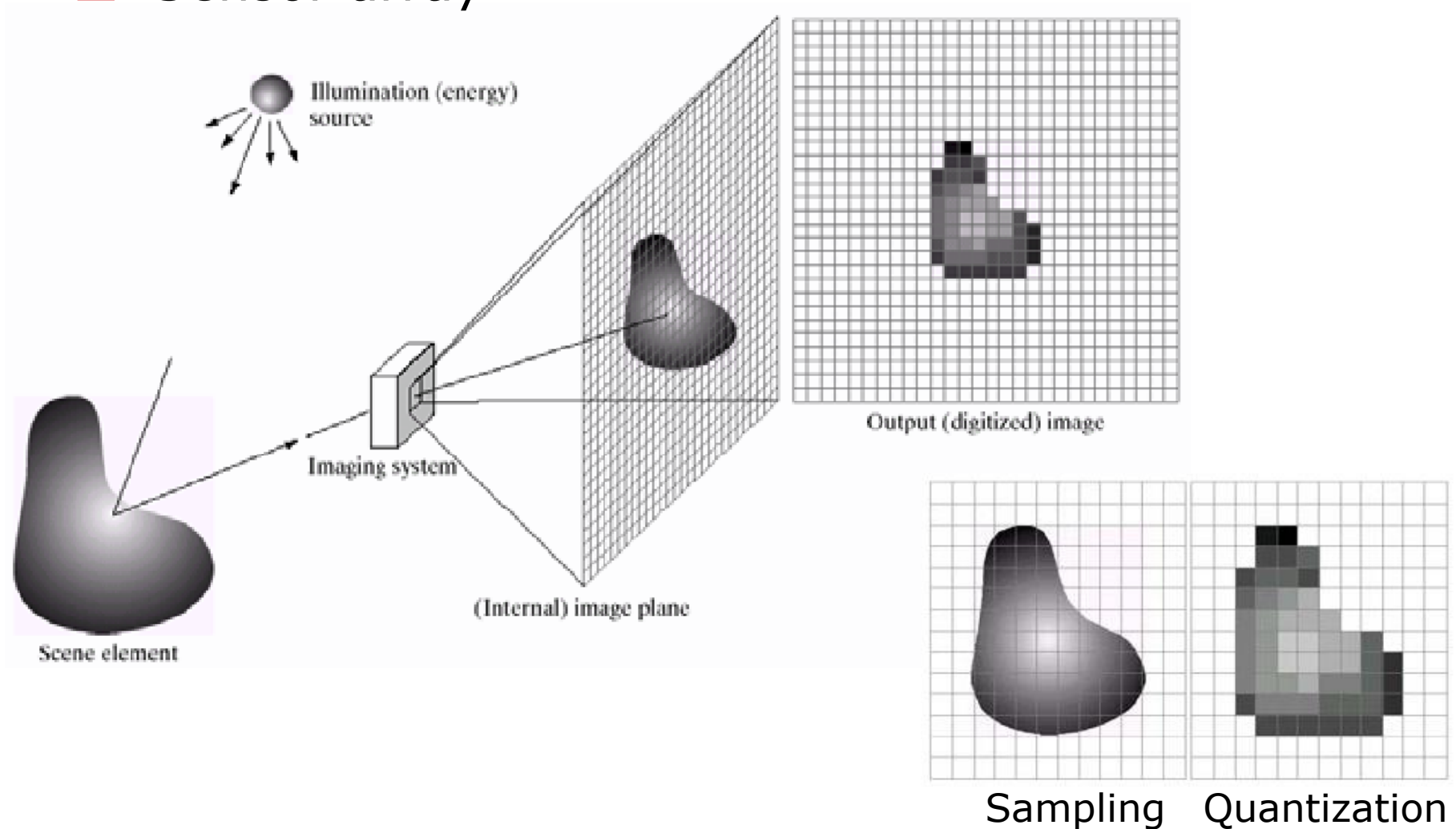
The number I of electrons recorded at the cell located at row r and column c of a CCD array can be modelled as

$$I(r, c) = T \int_{\lambda} \int_{\mathbf{p} \in S(r, c)} E(\mathbf{p}, \lambda) R(\mathbf{p}) q(\lambda) d\mathbf{p} d\lambda,$$

where T is the electron-collection time and the integral is calculated over the spatial domain $S(r, c)$ of the cell and the range of wavelengths to which the CCD has a non-zero response. In this integral, E is the irradiance, R is the spatial response of the site, and q is the *quantum efficiency* of the device, i.e., the number of electrons generated per unit of incident light energy. In general, both E and q depend on the light wavelength λ , and E and R depend on the point location \mathbf{p} within $S(r, c)$.

Image Acquisition

□ Sensor array



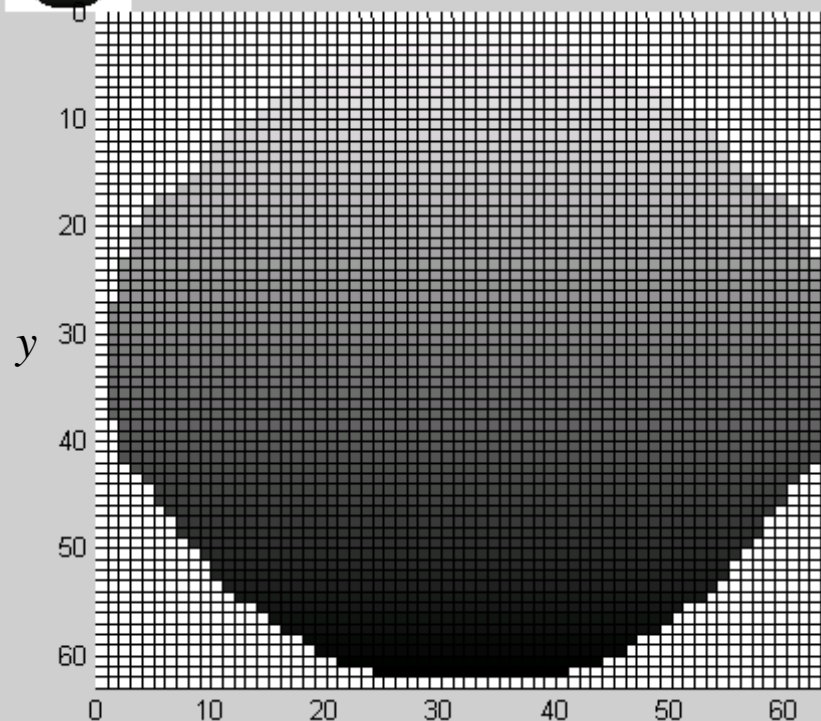
(Gray-level) Image Domain

□ 2D matrix

- Pixel
- Width, height
- Image size, resolution

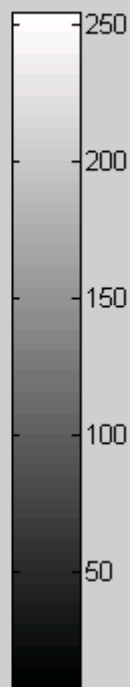
$$f(x, y) = \begin{bmatrix} f(0,0) & f(0,1) & \dots & f(0,N-1) \\ f(1,0) & f(1,1) & \dots & f(1,N-1) \\ \vdots & \vdots & \ddots & \vdots \\ f(M-1,0) & f(M-1,1) & \dots & f(M-1,N-1) \end{bmatrix}$$

$$f(x, y) \in [0, 2^k - 1]$$

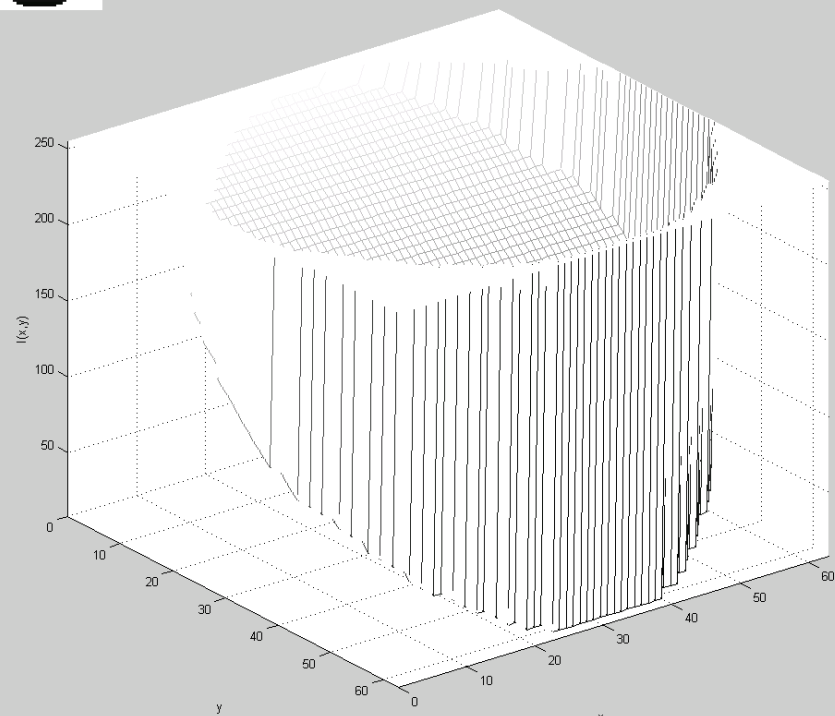


ACV

x

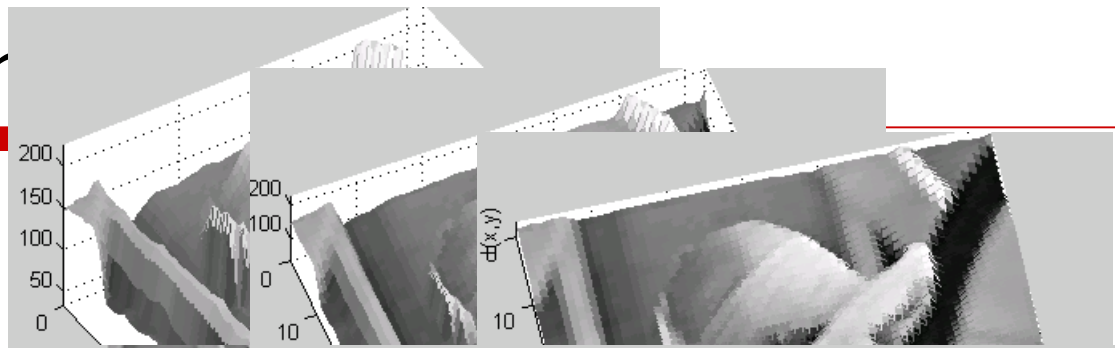


Color index

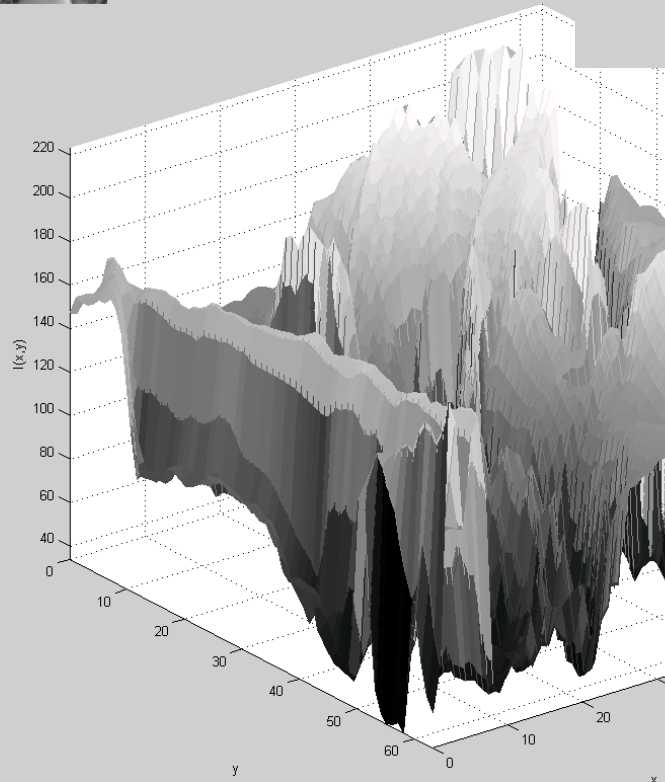
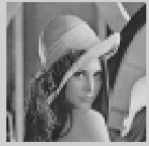


2D discrete function

Image domain



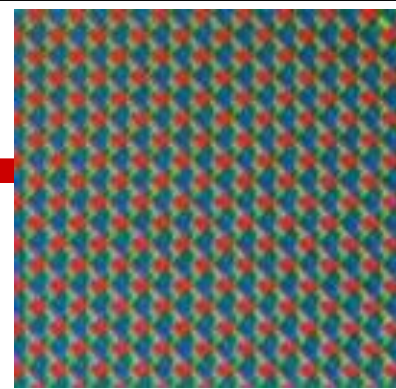
2D discrete function



Color image

□ Three channels

- R channel
- G channel
- B channel



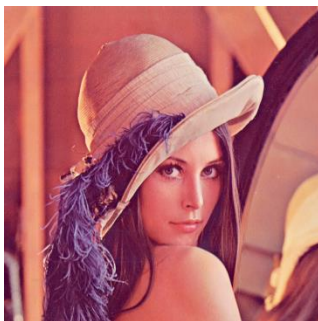
A micrograph of photosensor array



Additive colors

□ Three 2D matrices

- Three gray-level Images



red



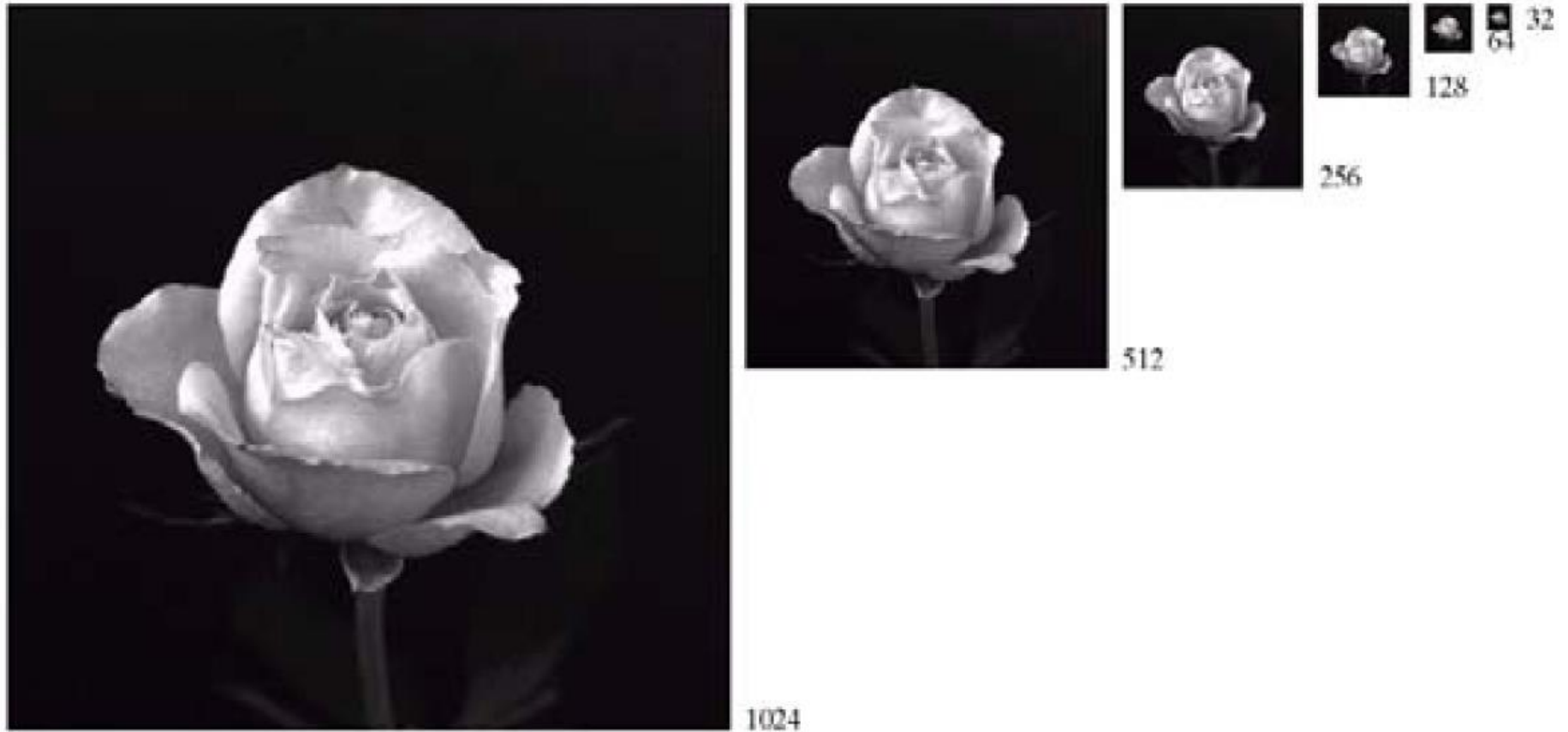
green



blue

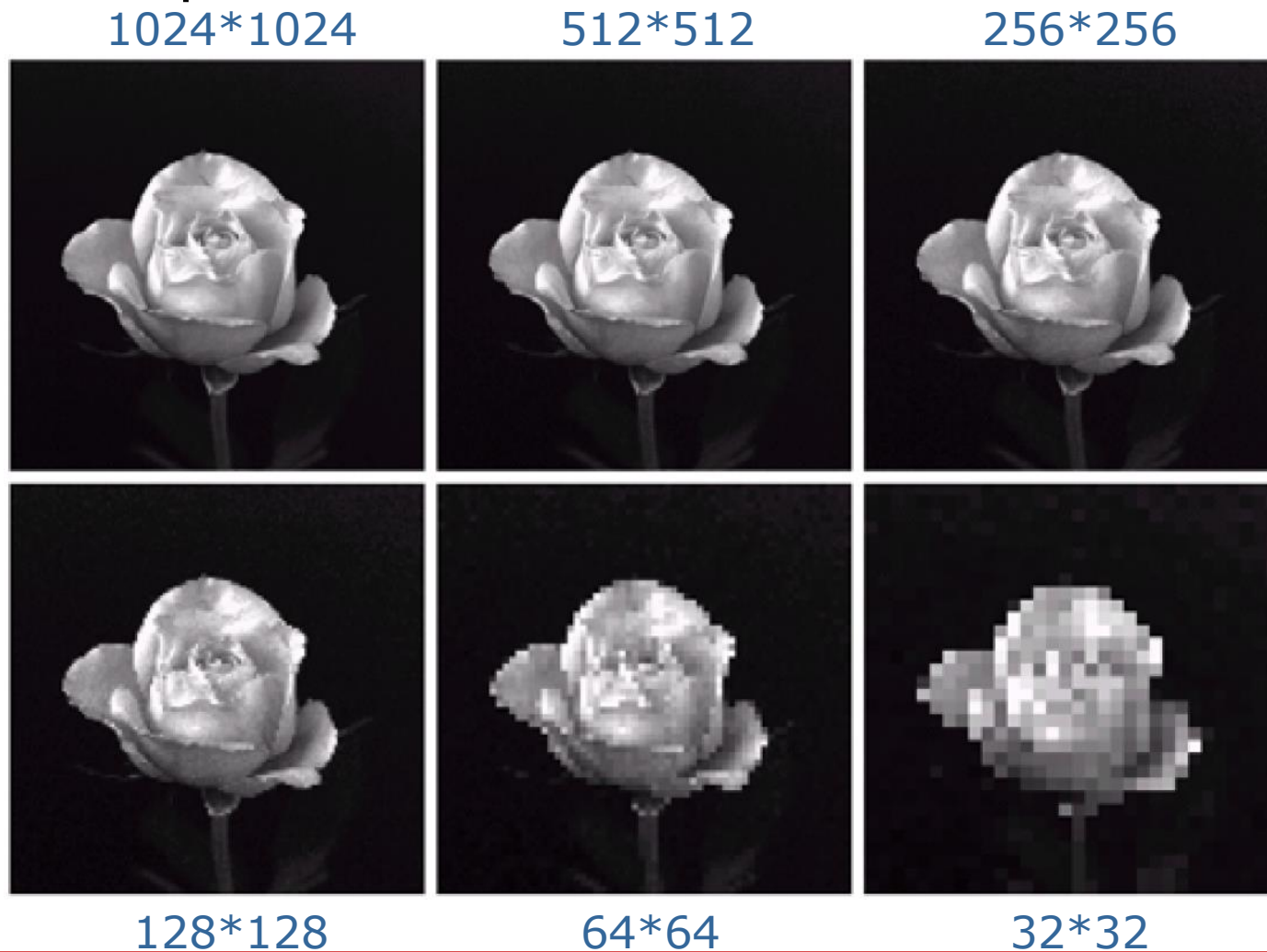
Resolution

□ Sampling

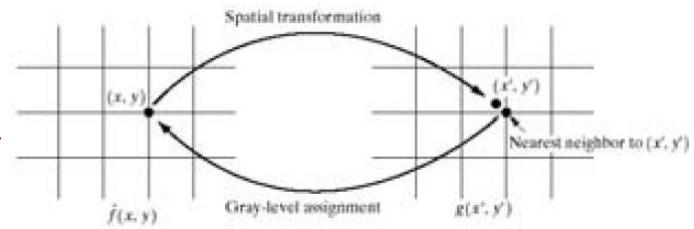


Resampling

□ Resampled to 1024×1024



Up-sampling



□ Nearest neighbor interpolation

128*128



64*64



32*32



1024*1024



為什麼買了新的Full HD電視，畫質反而變差？

- 「空有HD電視卻沒有HD內容，HD電視等於沒有用」



<http://www.mobile01.com/topicdetail.php?f=350&t=530906>

Quantization

- ❑ Lossless compression (沒有損失資料)
- ❑ Lossy compression

256色



128色



16色



8色



64色



32色



4色



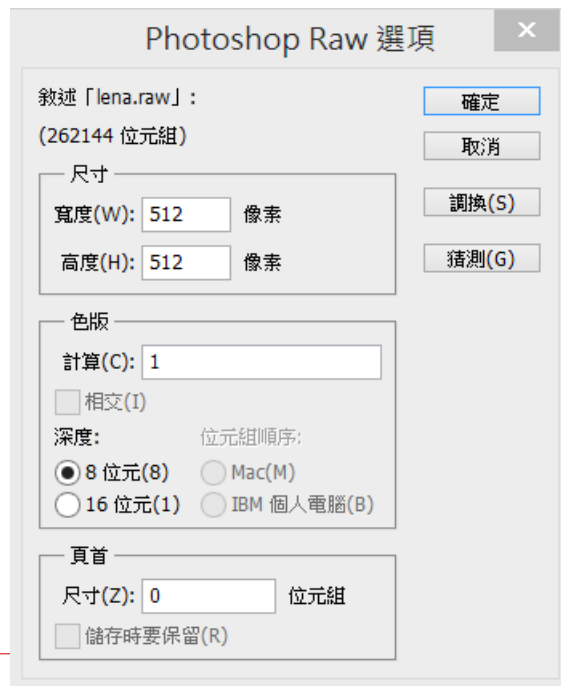
2色

Raw Data

□ .raw

- 僅影像matrix
- 需要知道正確的影像資訊
- 1個pixel使用1bytes
- File size (gray level)

$512 * 512 = 262144$ bytes



BMP Formation

□ BMP (Bitmap)

是 **Windows** 所使用的標準圖檔格式，未經過壓縮，資料結構為單純的像素資料，檔案容量較大，但讀取過程較容易且迅速。

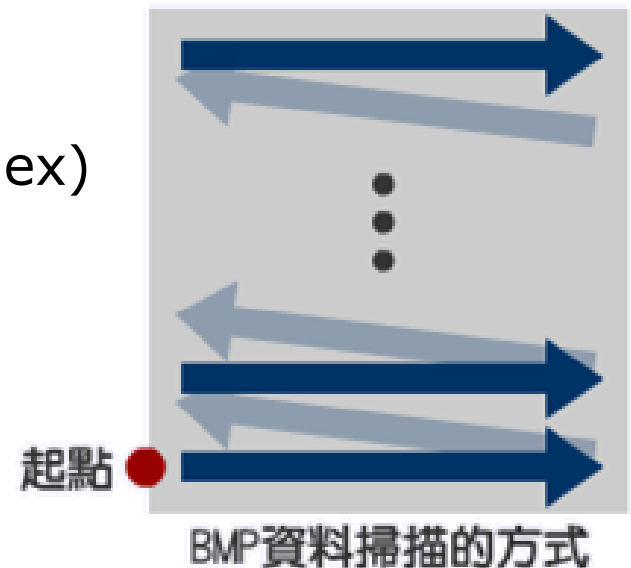
- 檔頭部分

- 尺寸

- 顏色表 (不一定有)

- 影像資訊

- 每一個 pix的資料 (raw data: index)



BMP Formation

□ 512*512 24bit(color) bmp file

■ File size

$512 * 512 * 3$ (image data) + 54 (header) = 786486 bytes



red



green



blue

