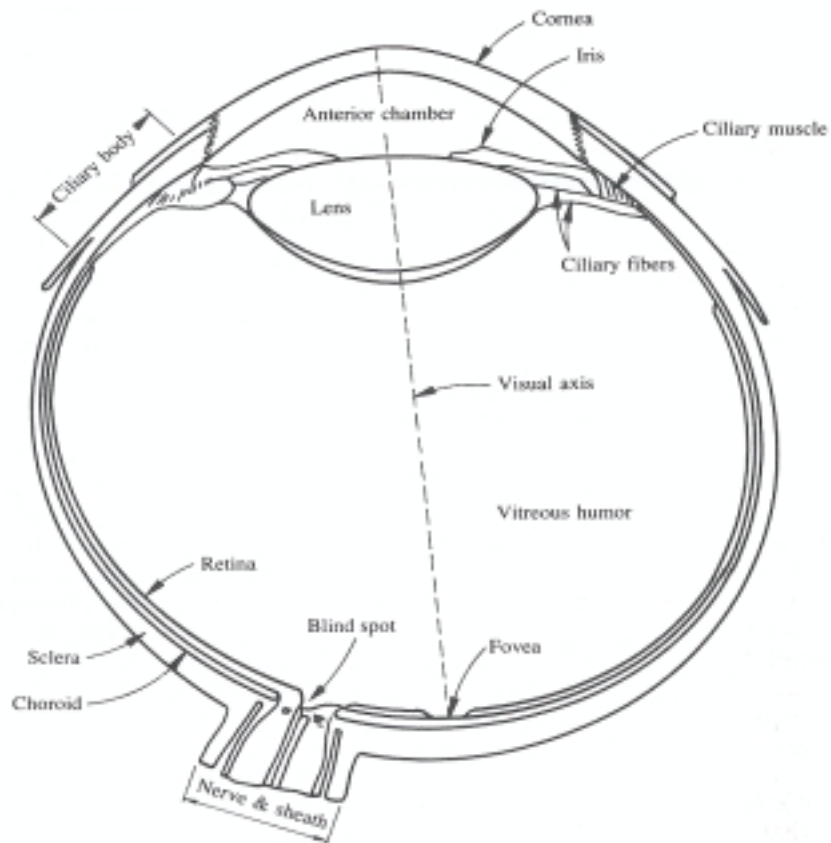


## Chapter 2. Digital Image Fundamentals

- mechanics of human visual system
- image model based on illumination-reflection phenomena
- image sampling and quantization
- basic relationship between pixels
- imaging geometry

### 2.1 Elements of Visual Perception

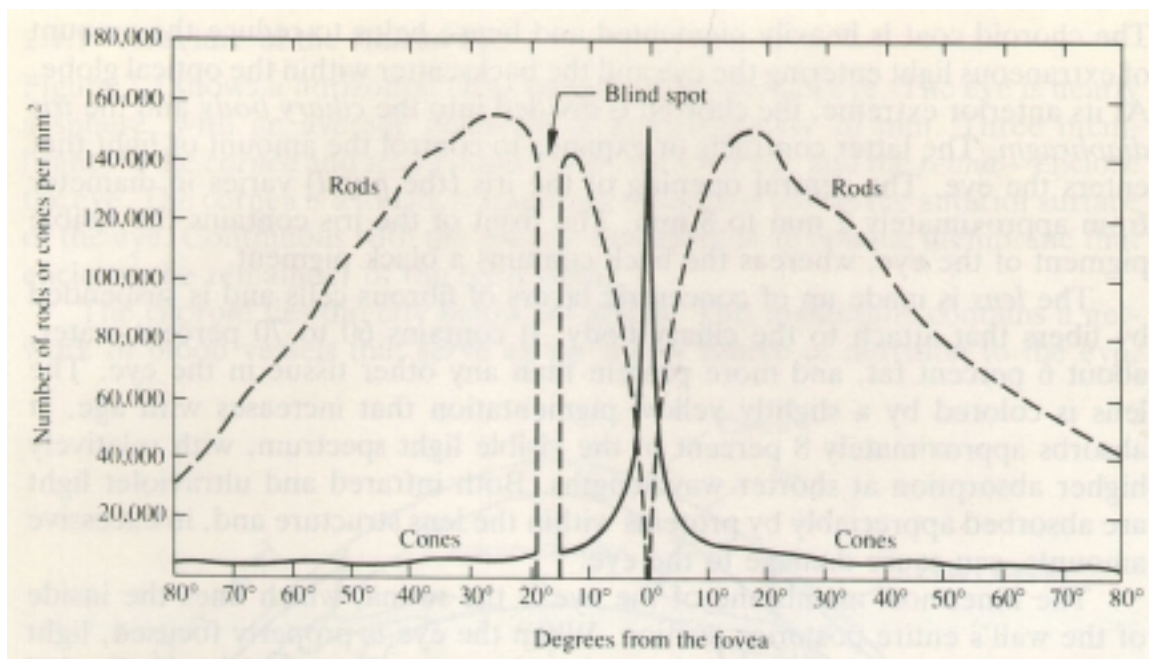
#### 2.1.1 Structure of the Human Eye



- Shape of eye

- nearly a sphere : diameter of approximately 20mm
- three membranes
  - ✓ cornea and sclera outer cover
  - ✓ choroid
  - ✓ retina

- Cornea
  - : tough, transparent, tissue that cover the anterior surface
  
- Sclera
  - : opaque membrane that encloses the remainder of the optic globe
  
- Choroid
  - ✓ lie directly below the sclera
  - ✓ contain a network of blood vessels
  - ✓ reduce the amount of extraneous light entering the eye
  - ✓ divided into the ciliary body and the iris diaphragm
  - ✓ iris diaphragm: contract of expand to control the amount of light (diameter : 2~8mm)
  
- Lens
  - suspended by fibers attached to the ciliary body
  - 60~70% : water, 6% : fat
  - colored by a slightly yellow pigmentation that increase with age
  
- Retina
  - the innermost membrane
  - light : imaged on retina
  - two classes of receptors : cones, rods
  
  - **Cones** (Photopic or bright light vision)
    - ✓ 6~7million
    - ✓ located primarily in the central portion of the retina, called the fovea
    - ✓ highly sensitive to color
    - ✓ related to chromatic vision
    - ✓ resolve fine detail
  
  - **Rods** (Scotopic or dim light vision)
    - 75~150million
    - distributed over the retinal surface
    - give a general, overall picture of the field of views
    - sensitive to low levels of illumination
    - not involved in color vision
  
- Blind spot
  - absent area of receptor

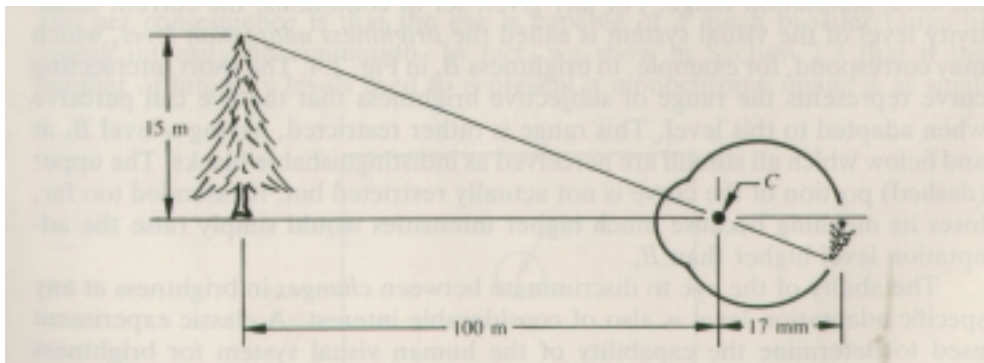


- Distribution of receptor (symmetric about the fovea)
- Cones are most dense in the center of retina(fovea)

## 2.1.2 Image Formation in the eye

- Lens of eye
  - flexible
  - radius of anterior surface is greater than radius of posterior surface
  - shape : controlled by tension in the fibers of the ciliary body
    - to focus distant objects → lens : flattened
    - near objects → thicker lens
  - distance between the focal point of lens and the retina : varies from appr. 17mm to 14mm.
  - object farther away than about 3m : the lowest refractive power
  - nearby object : most strongly refractive
  - size of retinal image

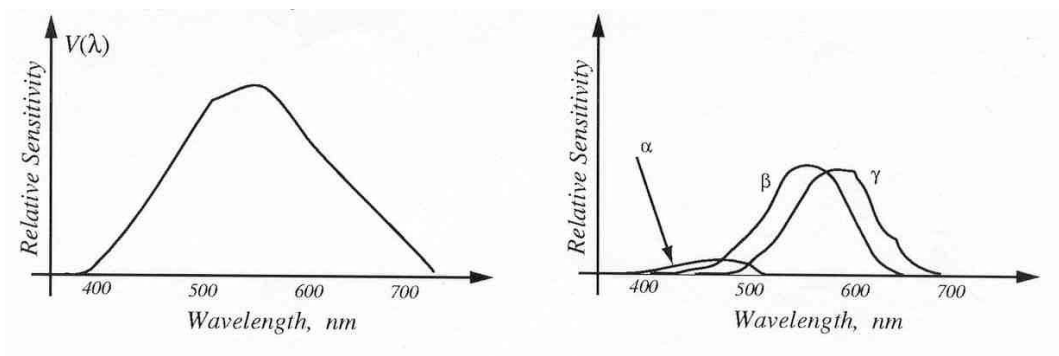
$$\frac{15}{100} = \frac{x}{17} \rightarrow x = 2.55\text{mm}$$



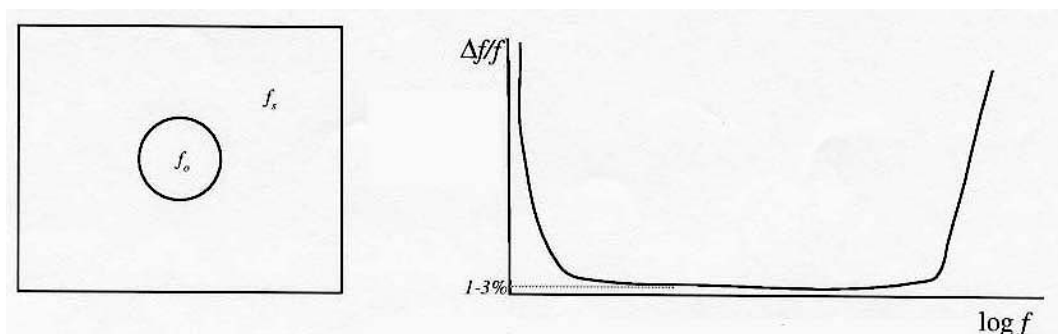
- retinal image is reflected primarily in the area of forvea
- perception then takes place by relative excitation of light receptors
  - transform radiant energy into electrical impulses that are ultimately decoded by the brain

### 2.1.3 Image Perception

- Perceived information in an image may be represented by attributes such as brightness, color and edges
- Light, Luminance and Brightness
  - **Light**: is an EM radiation that stimulates our visual response
  - **Luminance**: (intensity) of a spatially distributed object

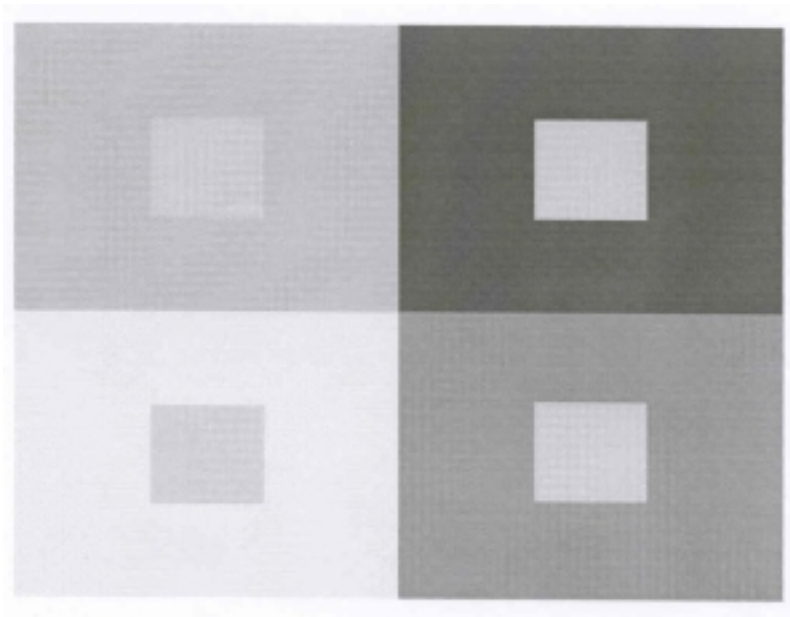


- Luminance of an object is independent of the luminances of surrounding objects
- **Brightness**: of an object is the perceived luminance
  - Brightness depends on luminance of surrounding objects
  - Two objects with different surrounding could have identical luminances but different brightness
- **Contrast Sensitivity**
  - HVS is sensitive to luminance contrast rather than the absolute luminance values themselves
  - **Weber's Law**:  
slight changes in intensity in dark regions are more perceptible



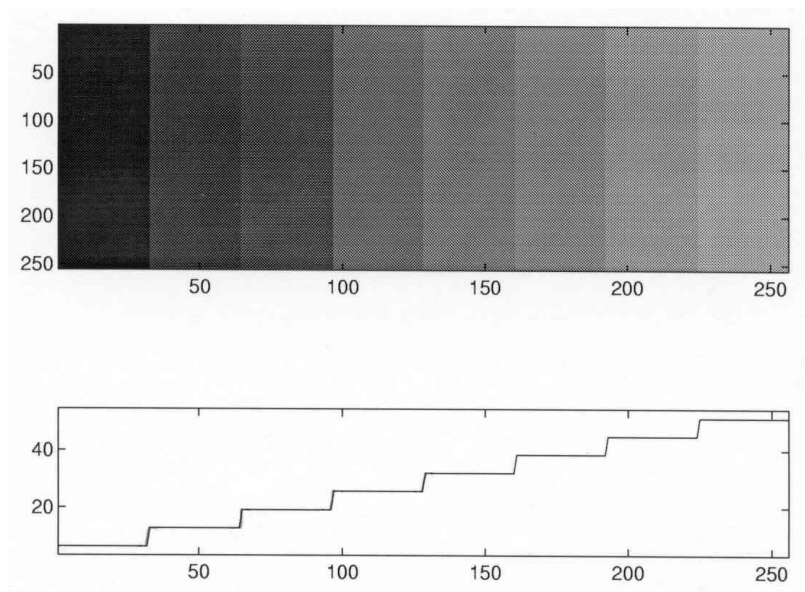
- **Simultaneous Contrast:**

- Even though the small squares all have the same luminance, they appear to have different brightness. This is due to the different background intensities.



- **Mach Band Effect:**

- results from spatial interaction of luminances from an object and its surroundings
- brightness(perceived luminance) is not a monotonic function of luminance





- typical values of  $i(x, y)$ , and  $r(x, y)$

- 1)  $i(x, y)$  ;

- a clear day : 9,000 foot-candles (표준 양초가 1feet 에서 비추는 밝기)
- a cloudy day : 1,000 foot-candles
- a full moon : 0.01 foot-candles
- a commercial office : 100 foot-candles

- 2)  $r(x, y)$  ;

- black velvet : 0.01
- stainless steel : 0.65
- flat-white wall paint : 0.9
- silver-plated metal : 0.93

- gray level ;

- intensity of monochrome image  $f$  at coor.  $(x, y)$

$$L_{\min} \leq l \leq L_{\max}$$

positive finite

$$L_{\min} = i_{\min} r_{\min} \approx 0.005$$

$$L_{\max} = i_{\max} r_{\max} \approx 100$$

for indoor image processing applications.

- interval  $[L_{\min}, L_{\max}]$  : gray scale  
: practically, interval  $[0, L]$   
black white



## 2.3 Sampling and Quantization

### 2.3.1 uniform sampling and quantization

- image sampling of a continuous image  $f(x, y)$

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

:  $N \times M$  array

- mathematical representation

- $N = 2^n$ ,  $M = 2^k$ ,  $G = 2^m$  ( $m$  : no. of bits) : integer power of two
- no. of bits required to store a digitized image (table 2.1 and table 2.2 참조)

$b = N \times M \times m$  : 총 데이터 용량

if  $N = M$

$b = N^2 m$

ex.  $M = N = 128$   $G = 64$  ( $m=6$ )

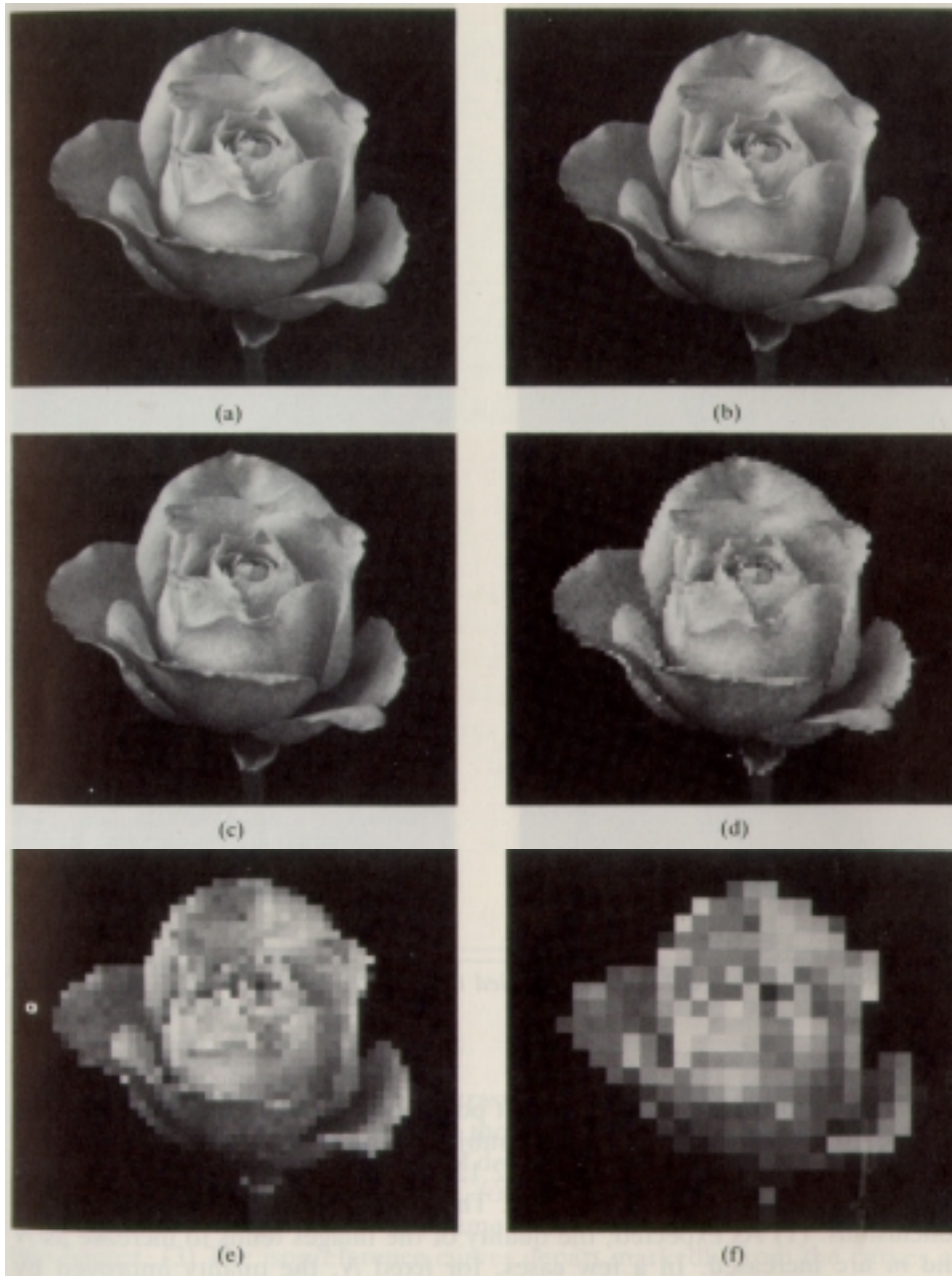
$b = 98,304$

- Resolution

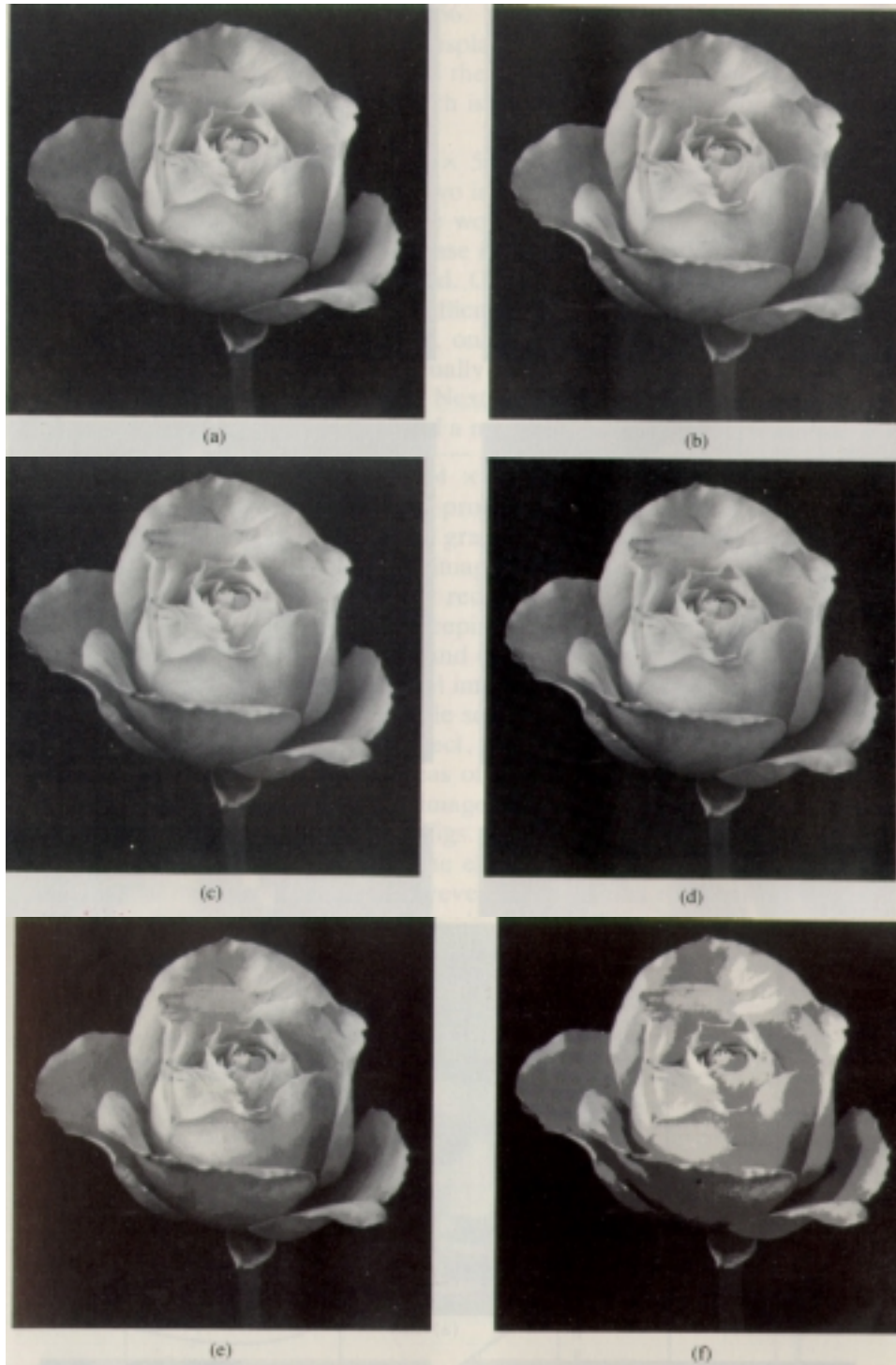
- degree of discernible detail
- how many samples and gray levels
- strongly dependent on the applications
- highly subjective

Effect of reducing spatial resolution

- pixel : replicated



- Effect of reducing no. of bits  
: false contouring



- relationship between parameters  $N$ ,  $m$



- (a) little detail
- (b) intermediate detail
- (c) large detail

- nonuniform sampling and quantization:
  - fine sampling; sharp gray level transitions
  - coarse sampling; relatively smooth regions
  - quantization levels 도 마찬가지로
  - “tapered quantization”