Visual Perception Process

Depend on visual limitation of observer & their mental process

Low radiation exposure → low S/N

Low response of eye & brain

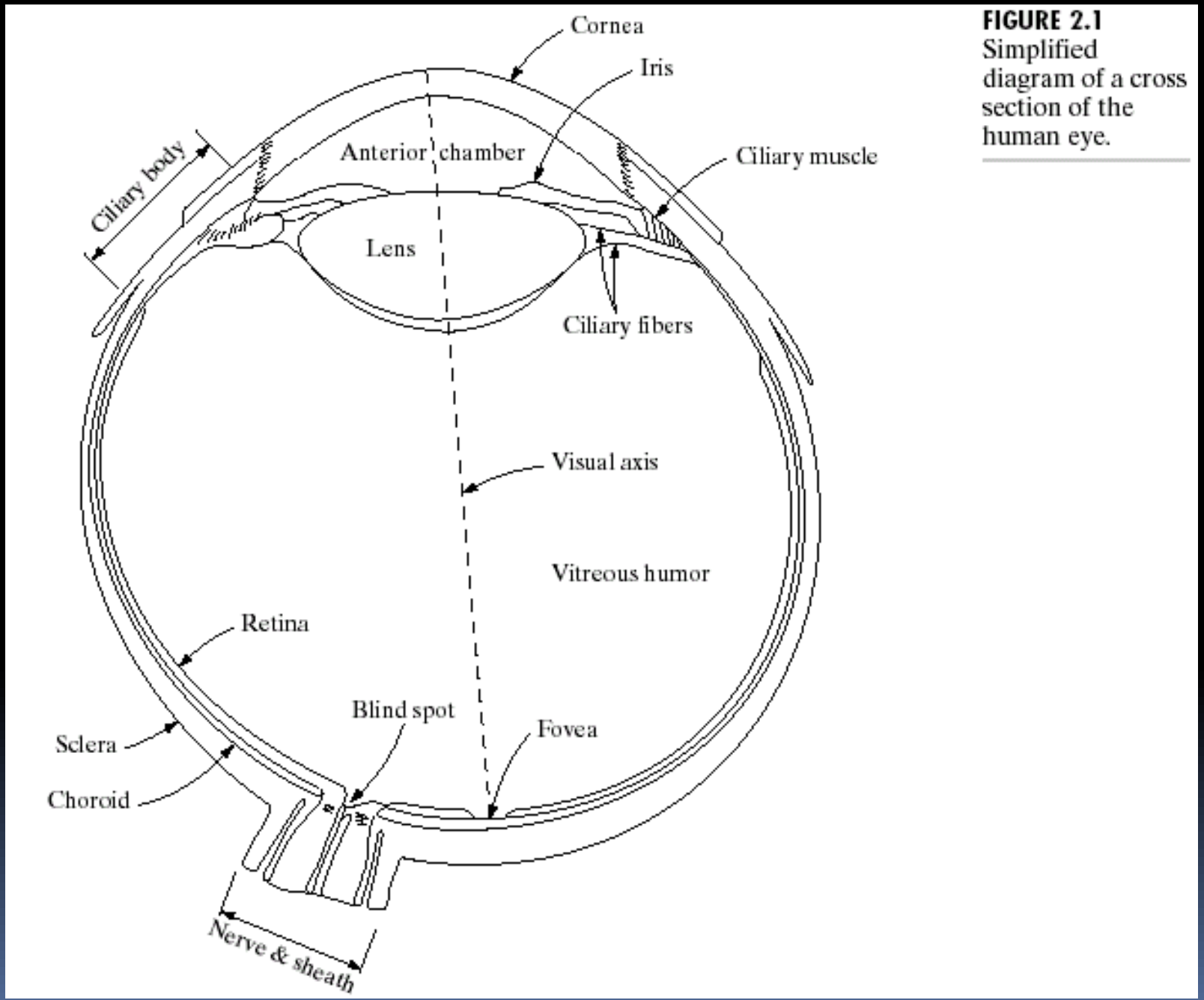
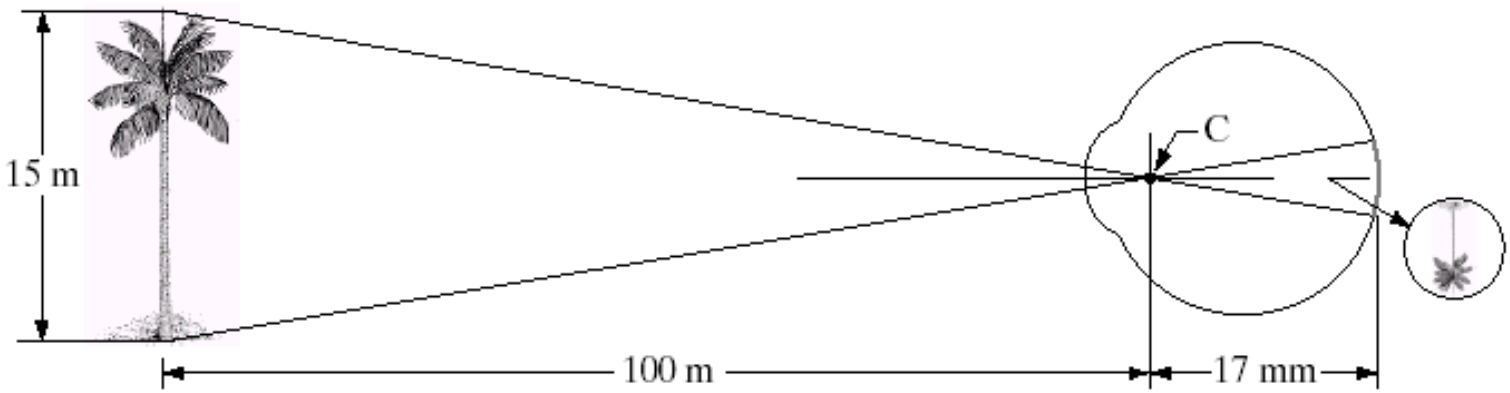


FIGURE 2.1
Simplified diagram of a cross section of the human eye.

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



Sensitivity & Contrast Characteristic of vision

Are related to structure of human retina:

Cone receptors	rod receptors
6-7 millions	75-150 millions
Centered in fovea	over the retina
Sensitive color & light	sensitive to low light
Each connected to 1 nerve	several connected to 1 nerve
Resolve fine details	show overall picture of field

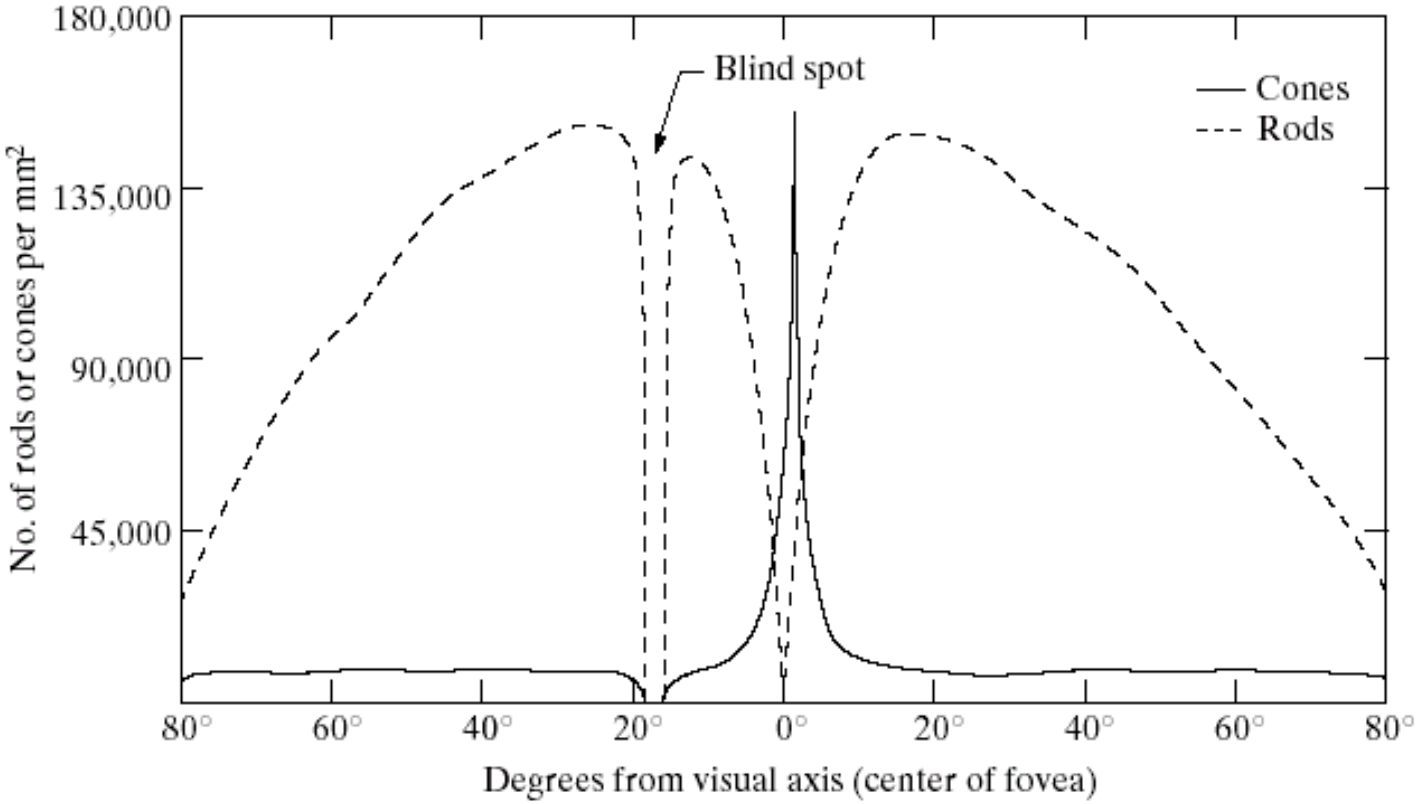
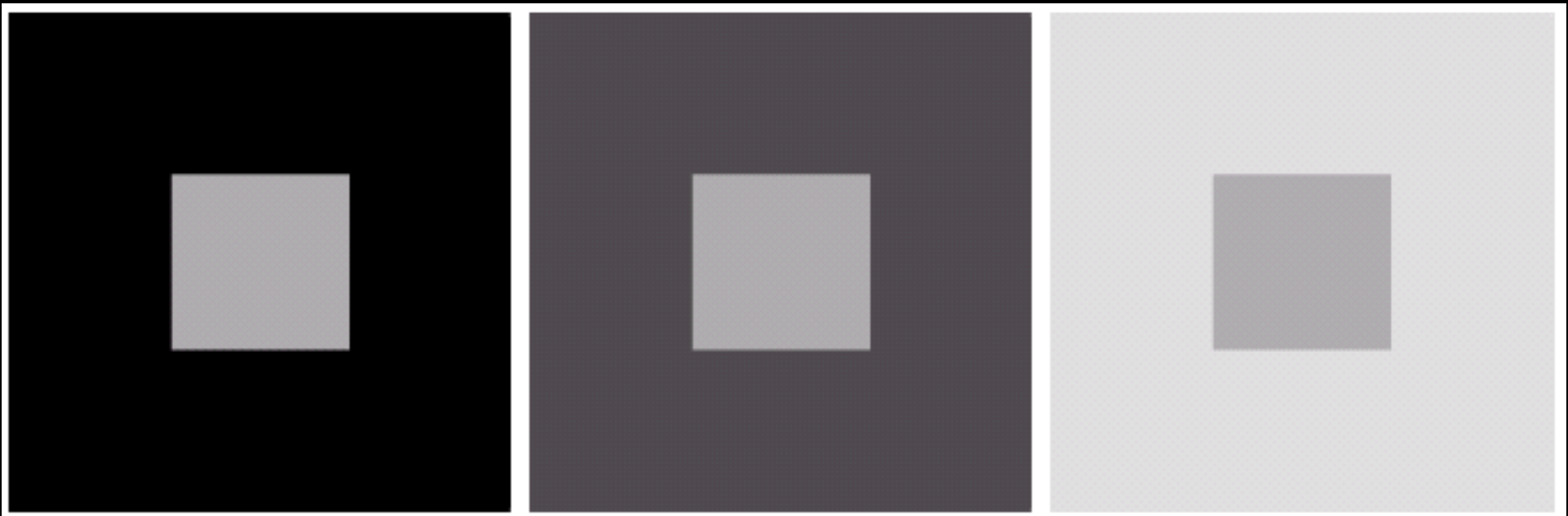
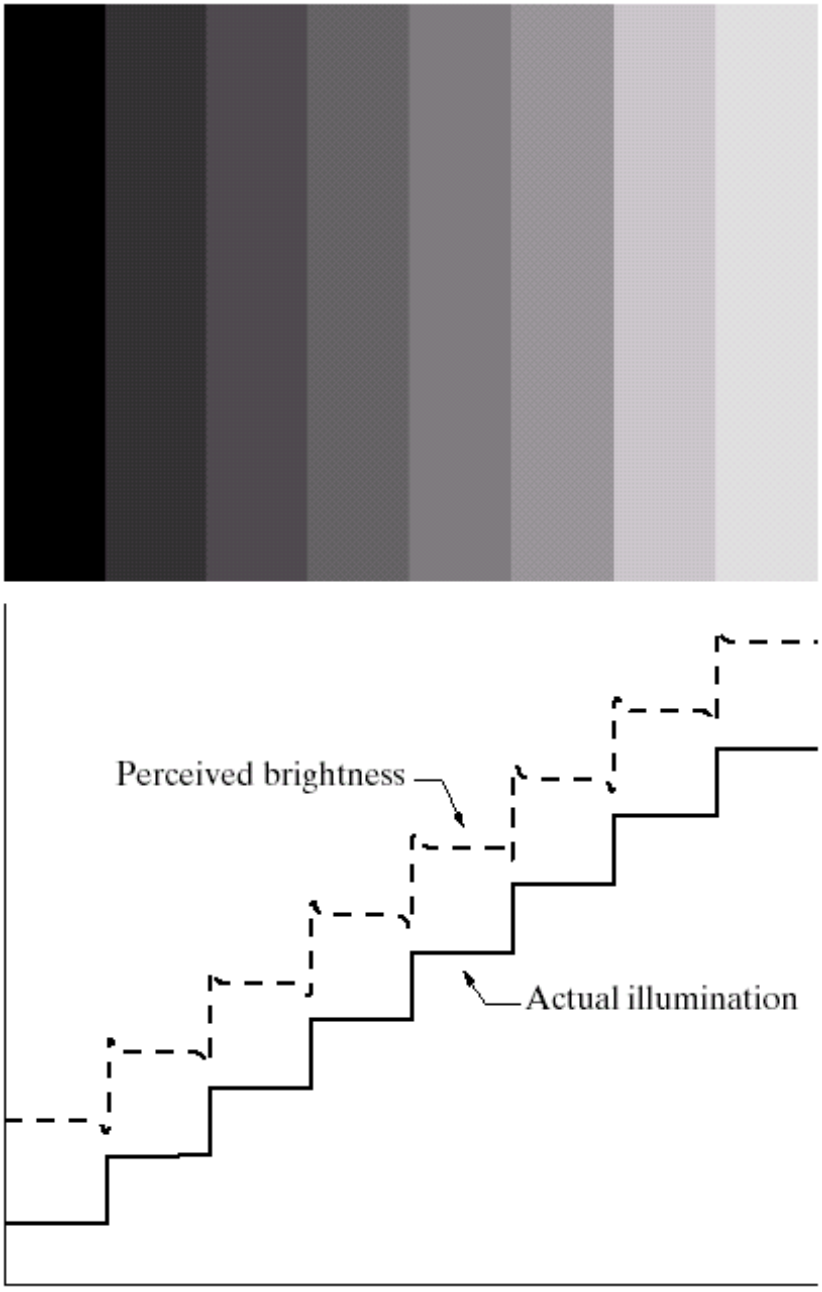


FIGURE 2.2
Distribution of rods and cones in the retina.



a b c

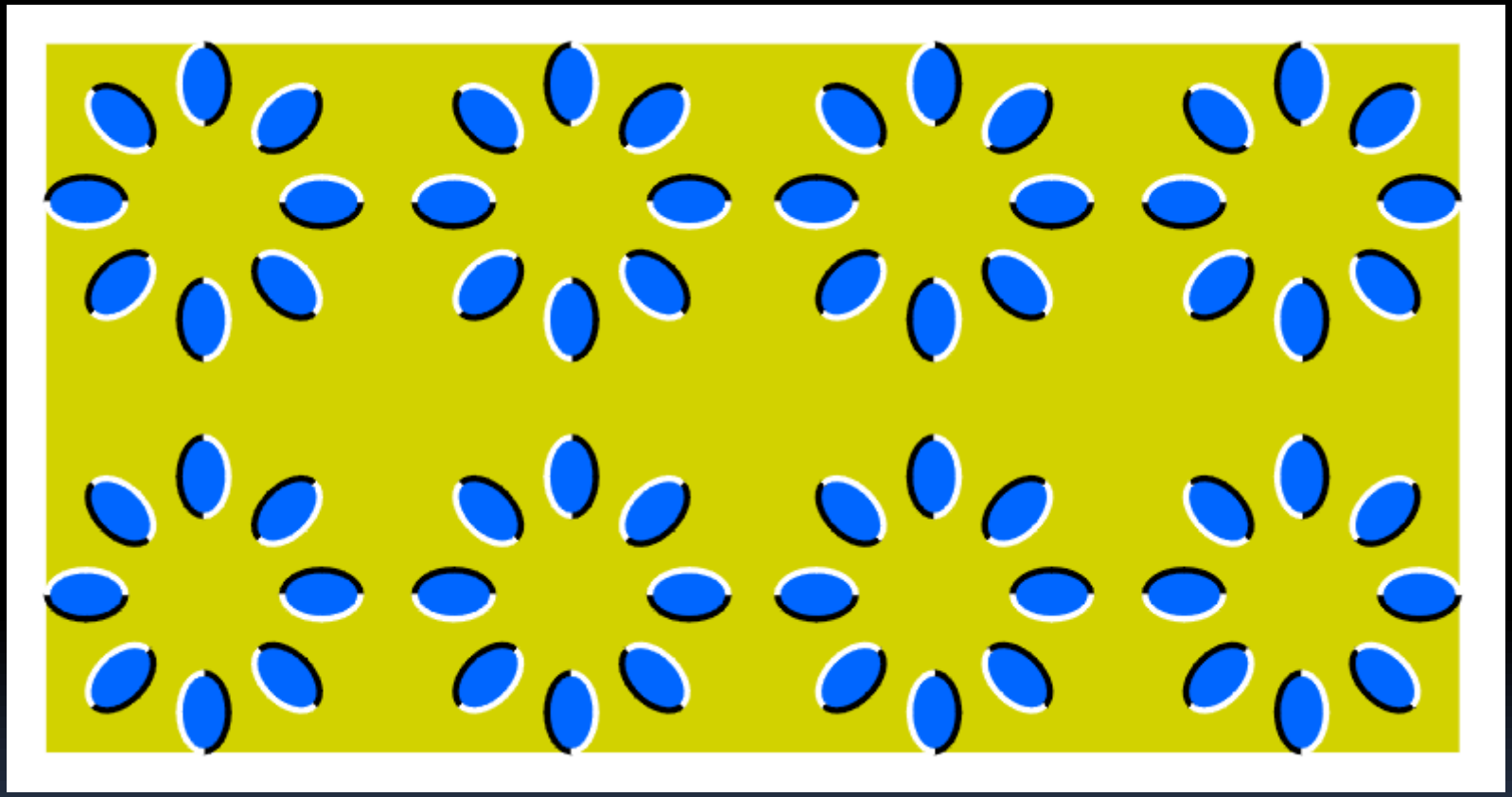
FIGURE 2.8 Examples of simultaneous contrast. All the inner squares have the same intensity, but they appear progressively darker as the background becomes lighter.



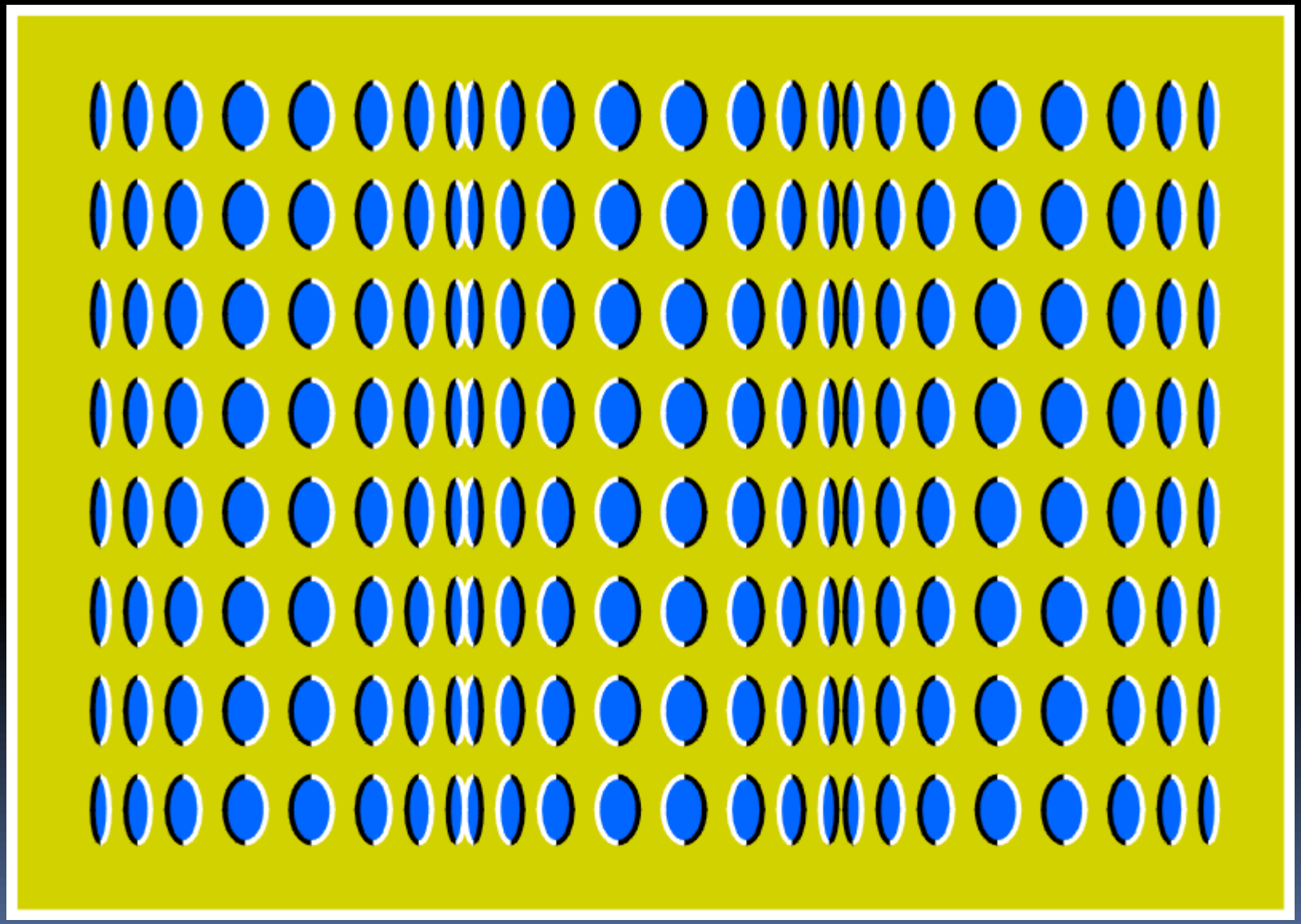
a
b

FIGURE 2.7
(a) An example showing that perceived brightness is not a simple function of intensity. The relative vertical positions between the two profiles in (b) have no special significance; they were chosen for clarity.

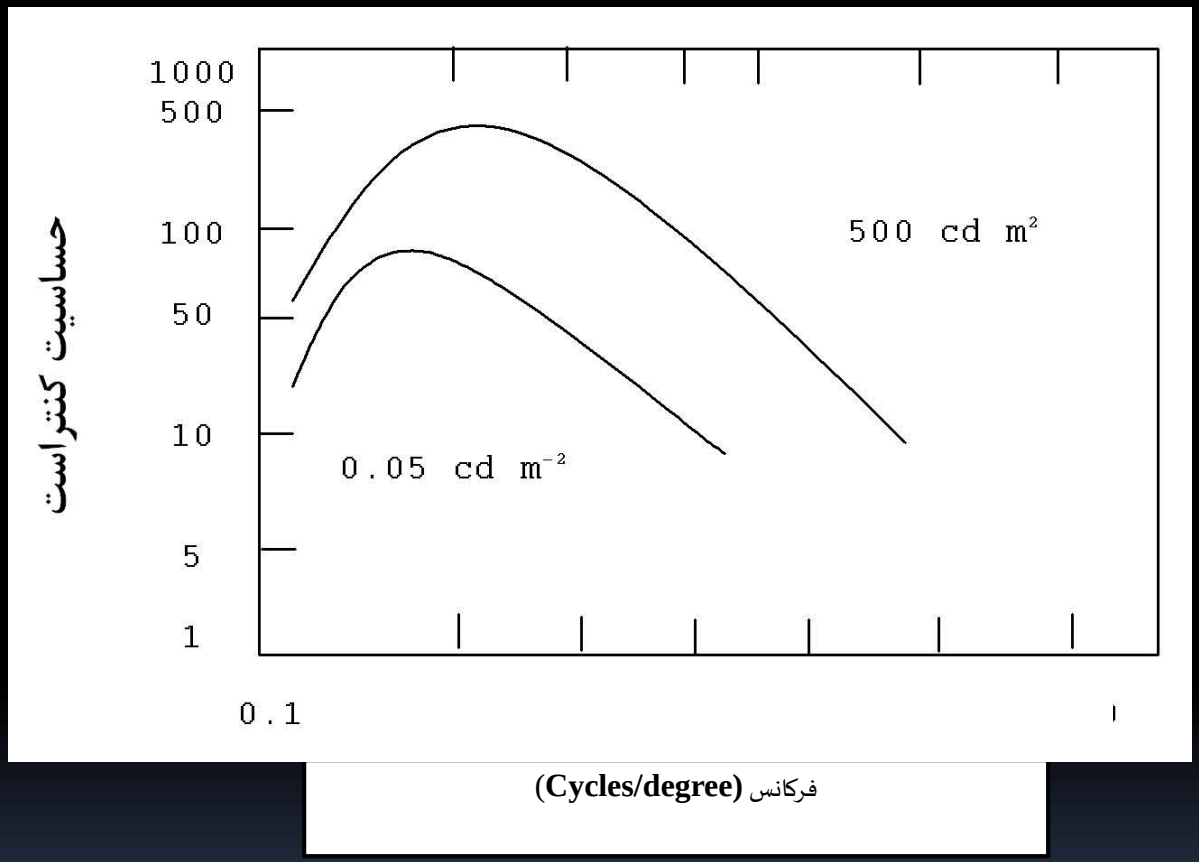
Illusion Examples



Illusion Example



Contrast Sensitivity of Eye



Typical contrast sensitivity of eye for a sine-wave gratings for two luminance levels

Contrast Sensitivity of Eye

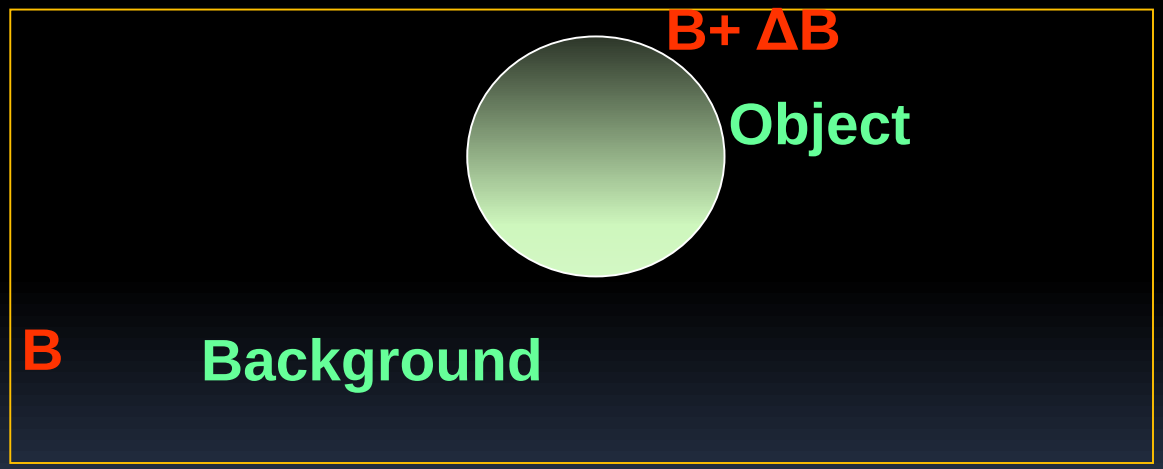
Remarkable facts from the curve:

1) Human eye-brain is adapted for the perception of sharp boundaries at peaks
2) There is a limit to the degree of fine detail that can be perceived
3) Very gradual boundaries (diffusely infiltrating border of a tumor maybe missed unless be enhanced by processing.

4) Optimum illumination should be set:
   For particular resolution of object
   For optimum perception of image details
   For suppression of noise & artifact

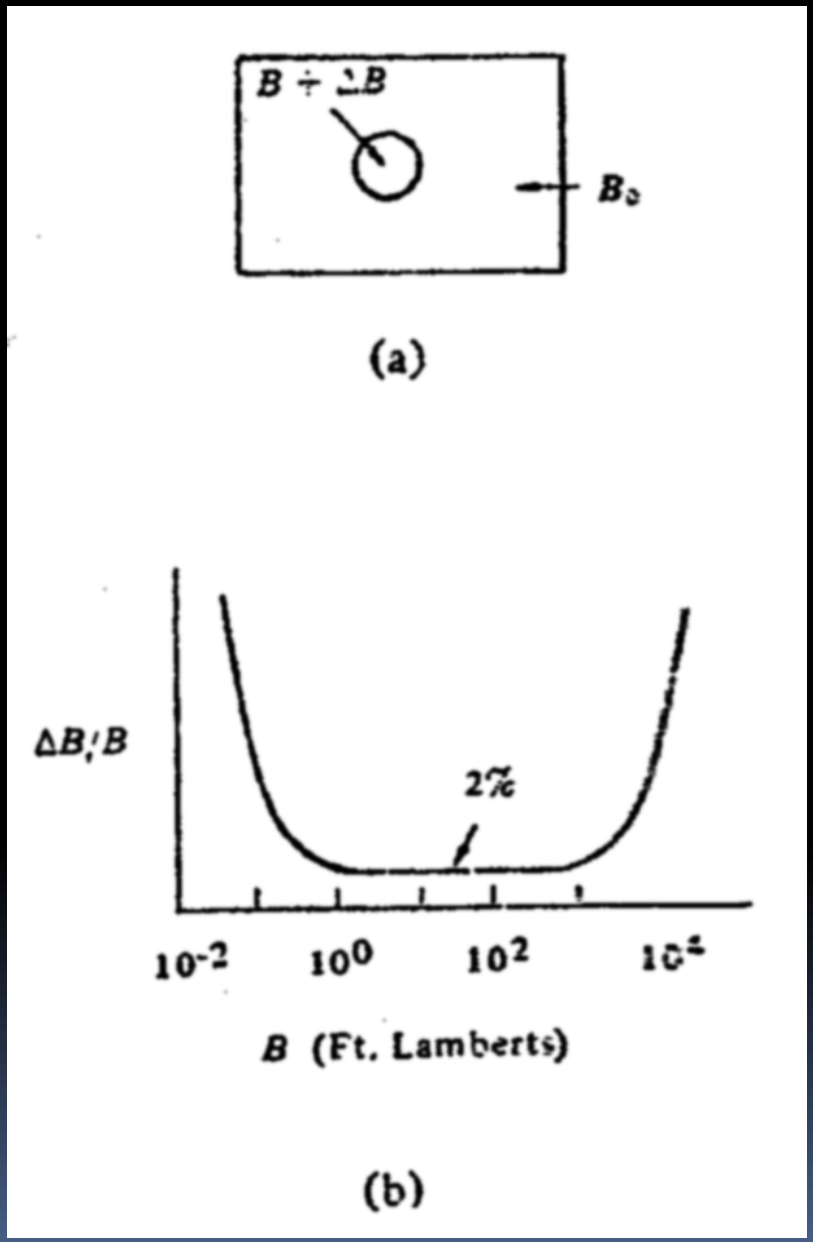
Contrast resolution

- The ability to discriminate regions of different image brightness.
- Under ideal condition (bright illuminate, sharp boundary, size, low nose) eye is capable of <u>contrast resolution of 1%.</u>



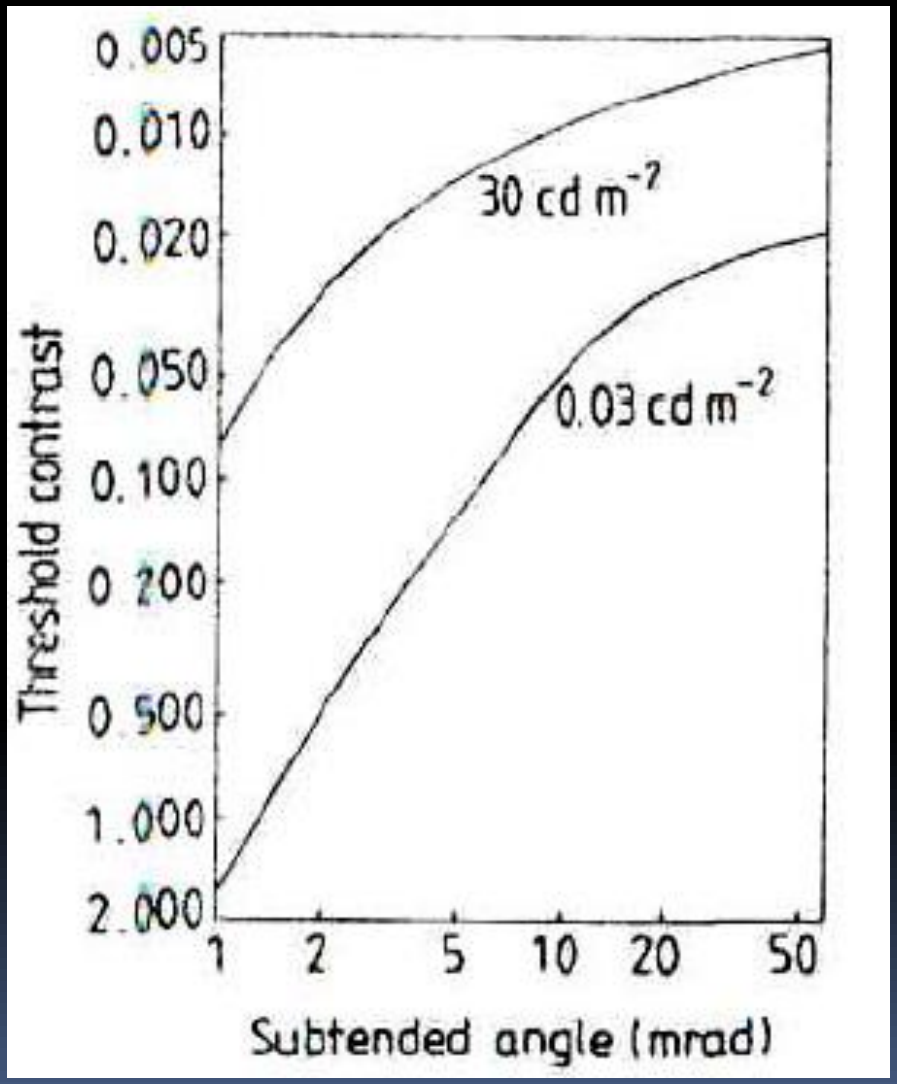
Weber ratio (threshold contrast resolution) ΔB/B

حساسیت چشم به کنتراست در شرایط کنتراست ثابت



Threshold Contrast resolution

Weber Ratio Depends on the size of object (eg. observed circular disc object.



Detection of an Object

Three stage of perception in optical imaging:

1) Detection (whether some abnormality is present)

2) Recognition (features, e.g: size & shape is quantified)

3) Identification (which disease pattern correspond to)

Object Detection is Size dependent

The size of object is **detectable if it is equal or bigger than $1/\nu$**

(ν is the highest detectable spatial frequency; Cy/degree)

Object size for Recognition and Identification should be 4 and 6.5 times of detection, respectively.

Contrast resolution
Depends on Spatial - frequency (details of object):

Effect of spatial resolution is investigated by: measuring the degree of modulation that is necessary for visual detectability as function of spatial frequency (in various noise conditions)

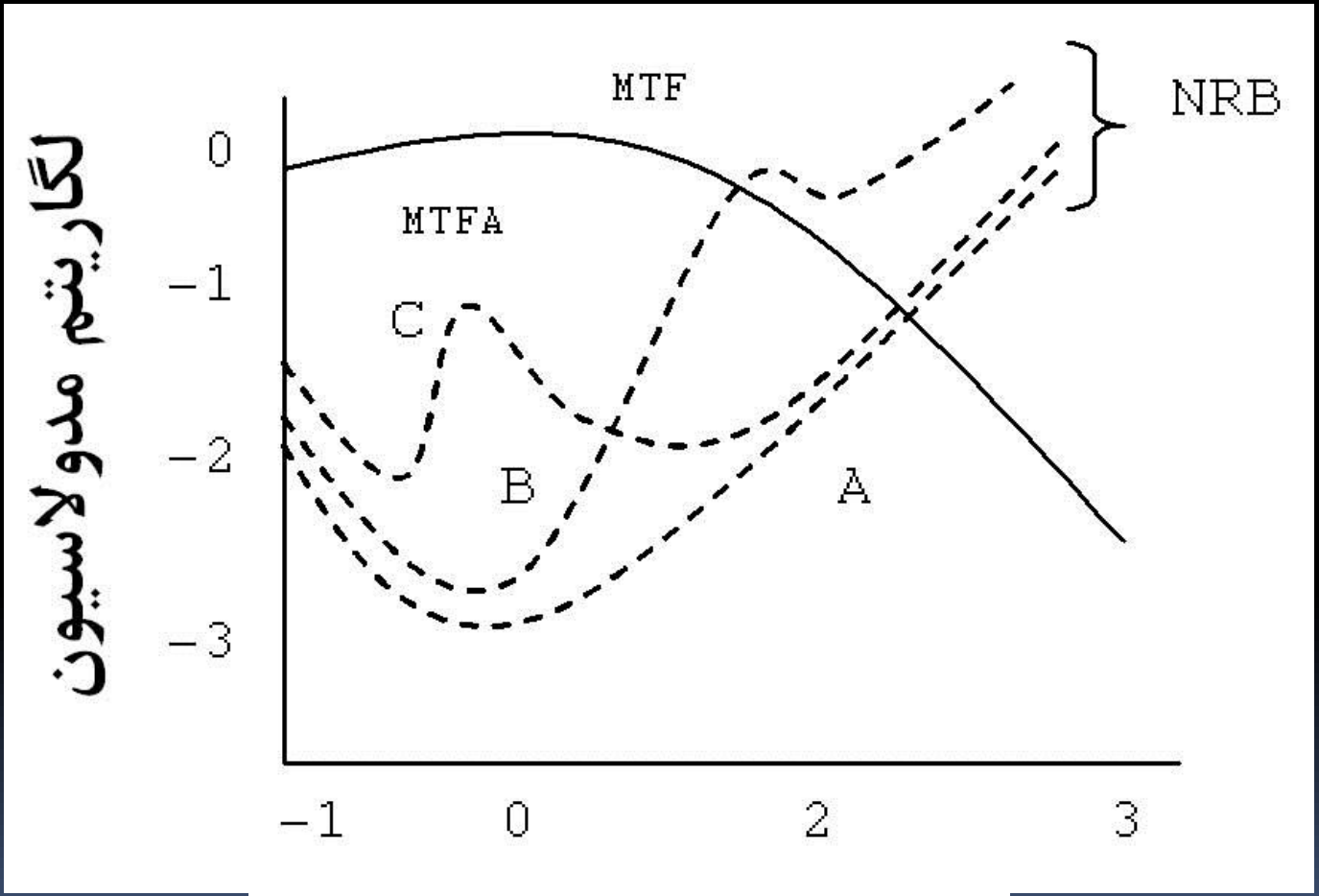
This is called:

Noise Related Modulation or NRM

Demand Modulation Function DMF

MTFمورد نیاز تشخیص

Demand Modulation Function (Noise required modulation)



Contrast-detail analysis

Rose model is measure of contrast-detail analysis.

Rose model provides a simple mathematical equation for the relationship between SNR (k), object size (A), and contrast (C):

$$k^2 = C^2 N = C^2 \Phi A$$

Where:

k = SNR needed to just see an object in an image

C = contrast of the object with respect to surrounding background

N = number of photons used to image the object of area A

A = area of the object

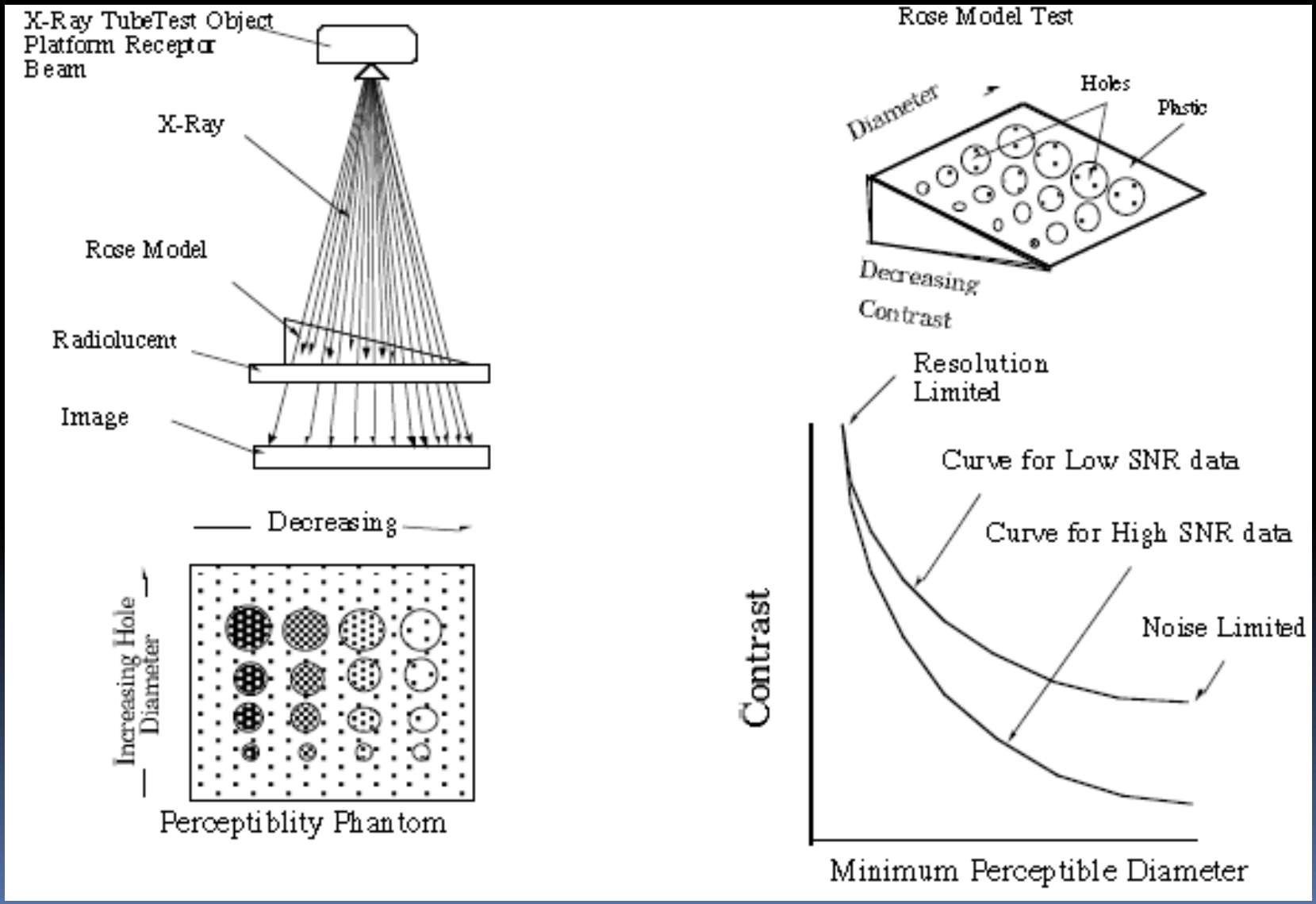
Φ = photon fluence (N/A) used to form the image

With a fixed value of k (SNR=5-7) we can estimate the size of the smallest object (A) we might be able to see at contrast level (C) with photon fluence (Φ) using Rose model.

Smaller objects must have higher contrast to be seen in the image.

The Rose model is a key element in estimation of the observability of low contrast objects in a noisy image (conditions often found in radiology).

"contrast detail" curve in which the size (i.e. detail) of smallest observable objects are plotted against their contrast for a given noise level.



Receiver operating characteristic (ROC) analysis

Which is the performance of the observer, with the aim of evaluating an imaging system.

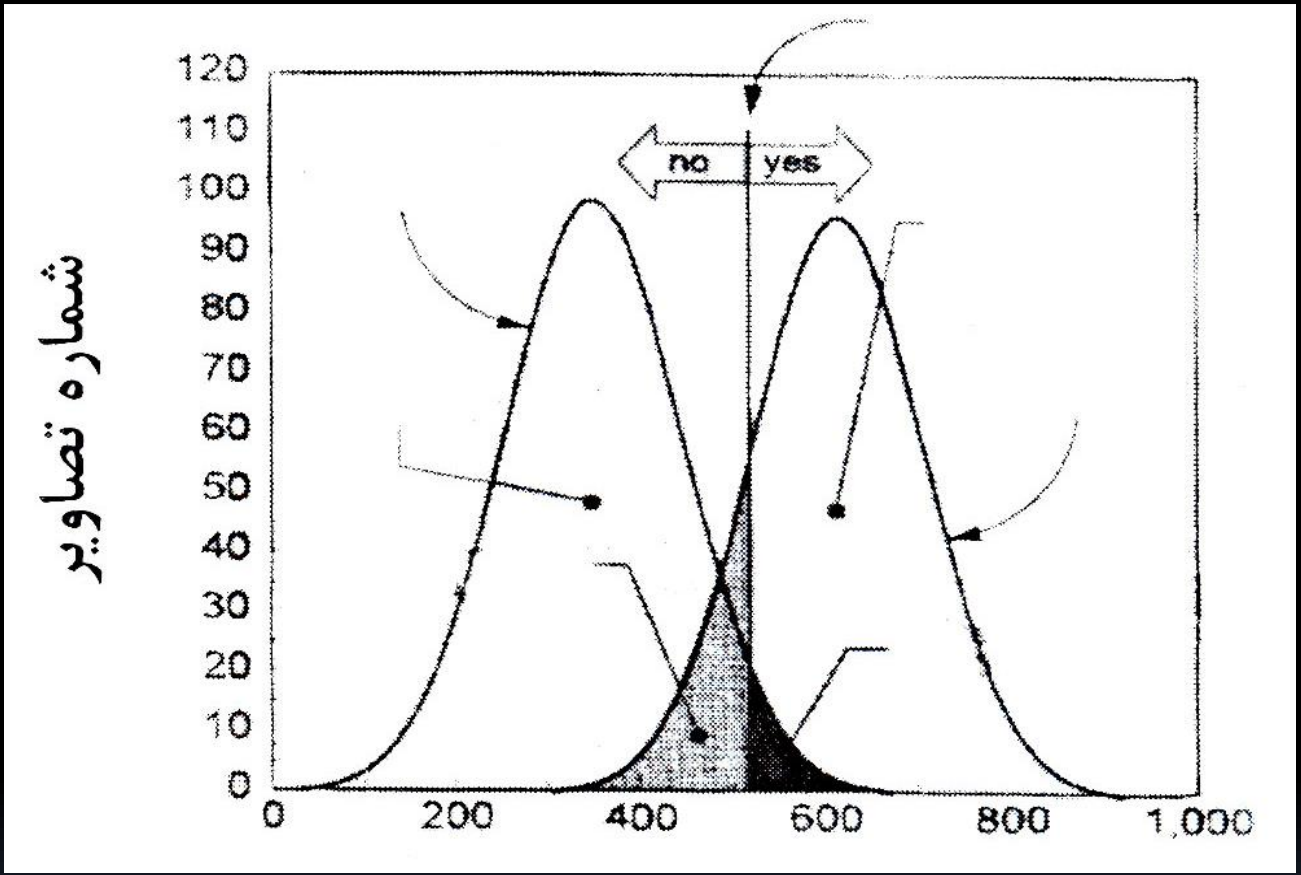
وجود ضایعه واقعی

قضاوت تشخیص دهنده	YES	NO
YES	TP	FP
NO	FN	TN

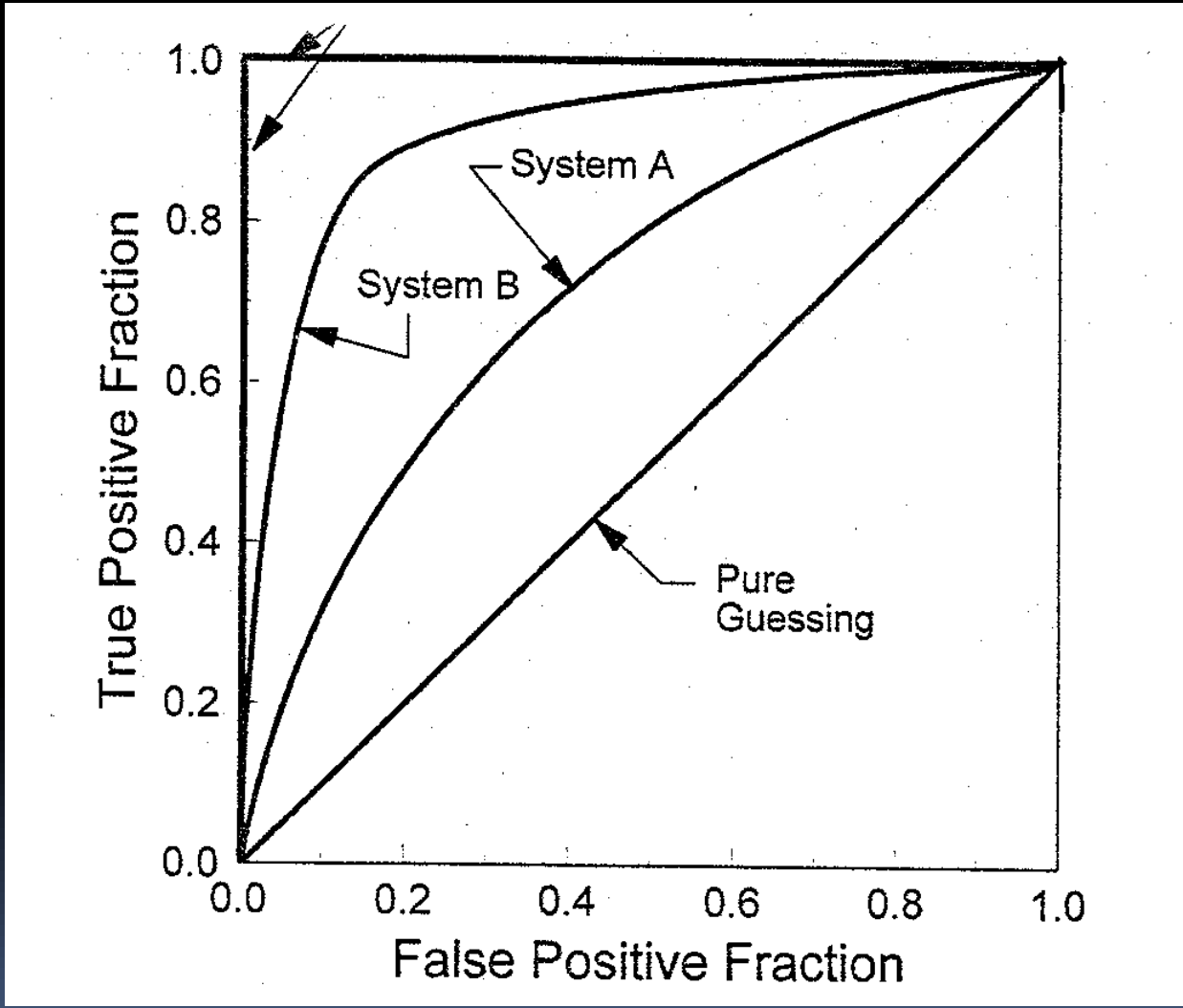
$$Sensitivity = \frac{N_{TP}}{N_{TP} + N_{FN}}$$

$$Specificity = \frac{N_{TN}}{N_{TN} + N_{FP}}$$

$$Accuracy = \frac{N_{TP} + N_{TN}}{N_{Total}}$$


شماره تصاویر
120
110
100
90
80
70
60
50
40
30
20
10
0
no
yes
0
200
400
600
800
1,000

ROC Curve


1.0
0.8
0.6
0.4
0.2
0.0
True Positive Fraction
System A
System B
Pure
Guessing
0.0
0.2
0.4
0.6
0.8
1.0
False Positive Fraction