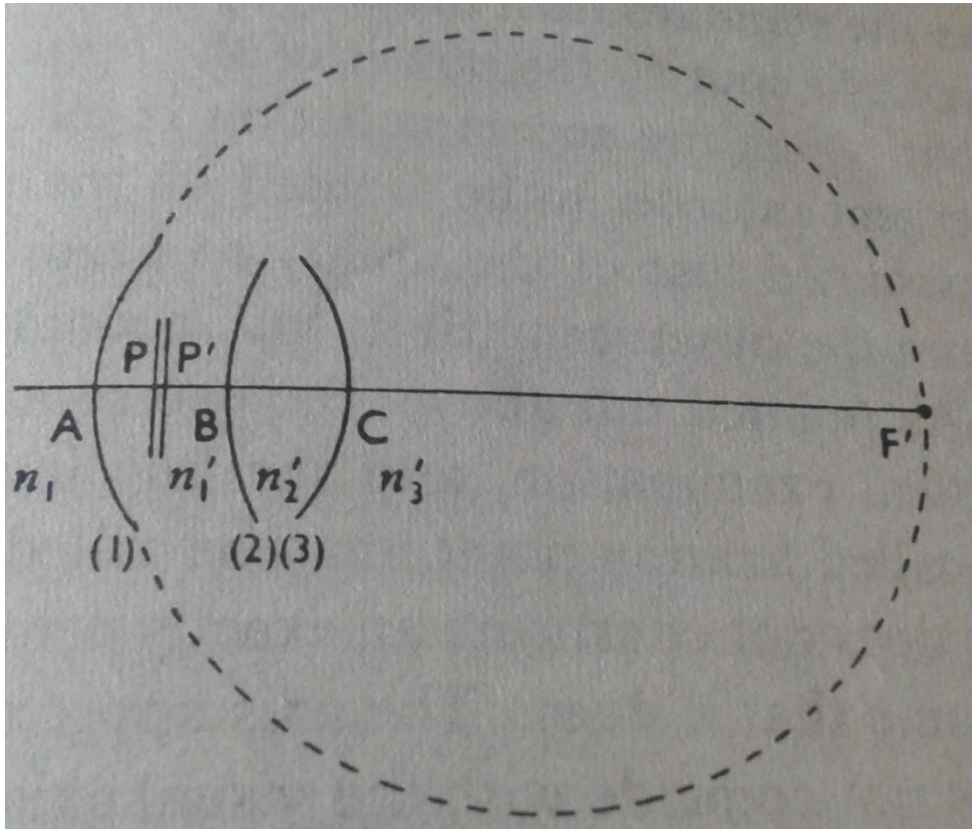
PH 301

ENGINEERING OPTICS

Lecture_Vision Optics_23

Ref.:
Geometrical and Physical Optics by R.S. Longhurst

- **Optical system of eye is complicated - non-homogeneous nature of crystalline lens.**



Optical system of eye

- **Gullstrand suggested a schematic eye which employed a lens of only two parts – an outer layer of index 1.386 & a core of index 1.406.**

- **Gullstrand suggested a simpler schematic eye in which cornea was replaced by a simple refracting surface separating air & aqueous humour.**

Specifications:

(n_1 = 1.000 – air)

(Cornea) r_1 = + 0.78 cm

d'_1 = 0.36 cm (n'_1 = 1.336 – aqueous humour)

(Lens) r_2 = + 1.00 cm

d'_2 = 0.36 cm (n'_2 = 1.413 – crystalline lens)

r_3 = - 0.60 cm

(n'_3 = 1.336 – vitreous humour)

- **Maximum change in power which eye can effect is called amplitude of accommodation.**

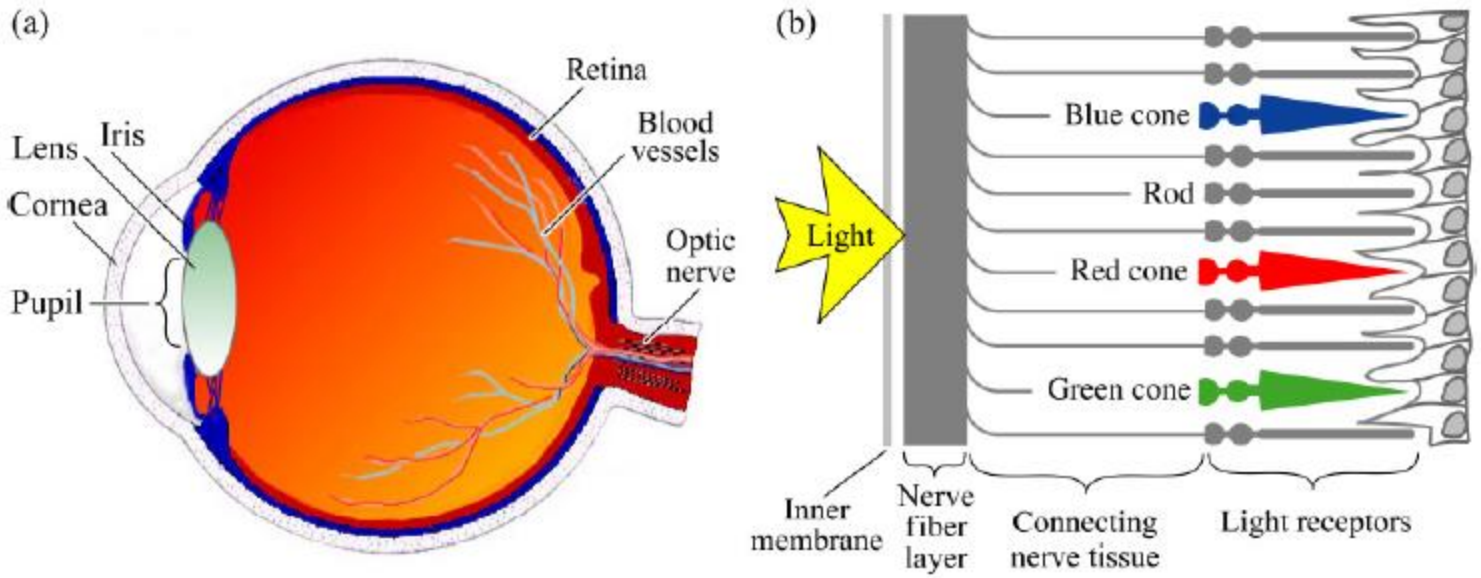
- **For "average person", amplitude of accommodation varies from about 14 diopters at the age of 10 years to about 4 diopters at the age of 40, falling almost to zero at age 75.**

Accommodation

- **Resolving power of a retina reaches a sharp maximum in the region of a small depression known as *fovea centralis*. When it 'looks at an object the eye is rotated until the image falls on the fovea.**
- **When a normal eye is at rest, optical system brings parallel rays to a focus on the retina, i.e., distant objects are clearly seen.**
- **In order to view nearer objects, power of optical system of eye is increased – a process known as *accommodation*.**
- **Although most of the power of optical system of eye is derived from refraction at cornea, changes in power during accommodation are effected by means of a change in the *shape of the crystalline lens*.**
- **Greatest observable change is in the curvature of the front surface of the lens & is controlled by *ciliary muscle*.**

- **Object point for which the image is in focus when the optical system has minimum power is called the *far point*, & *near point* is focused when eye has maximum power.**
- **For average observer, far point is at infinity until the age of about 50. thus, at age of 40, near point is 25 cm in front of eye & this is called *least distance of distinct vision*, Dv.**
- **Beyond the age of about 50, power of optical system of eye tends to decrease so that, when accommodation is relaxed, light entering eye must be convergent in order to be focused on retina; far point is then virtual. The associated loss of ability to accommodate causes near point to recede from observer until it, too, becomes virtual.**
- **Eye rotates to bring image on to the fovea for critical examination, & line joining fovea, the nodal point, & the so-called fixation point, may be called the visual axis.**
- **Centre of rotation of eyeball is about 14 mm from front surface of cornea.**

Spectral Sensitivity



Spectral sensitivity of eye

- **Sensitivity of eye varies with wavelength & equal amounts of energy of different wavelengths will, in general, produce different sensations of brightness.**

- **If a spectrum is viewed & energy received per second is same for all wavelengths, middle of visible region appears brighter than red & blue ends.**

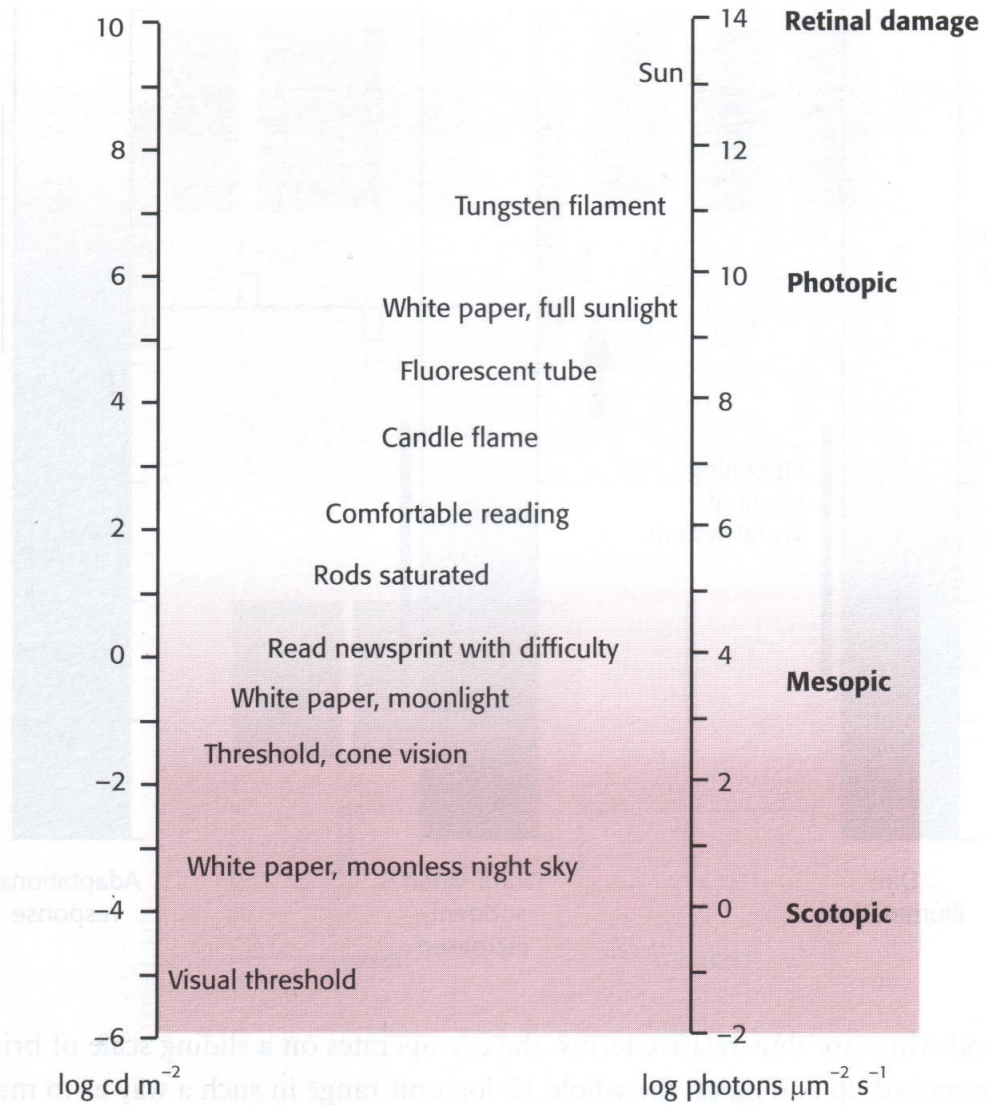
- **When intensity is high (i.e. for photopic vision) maximum brightness occurs at about $\lambda = 0.555$ μm.**

- **Under ordinary conditions of observation, brightness of a source of a given wavelength (due to light emitted, reflected, refracted, or scattered) depends upon the energy per second received per unit area of retina, & upon state of adaptation of eye.**

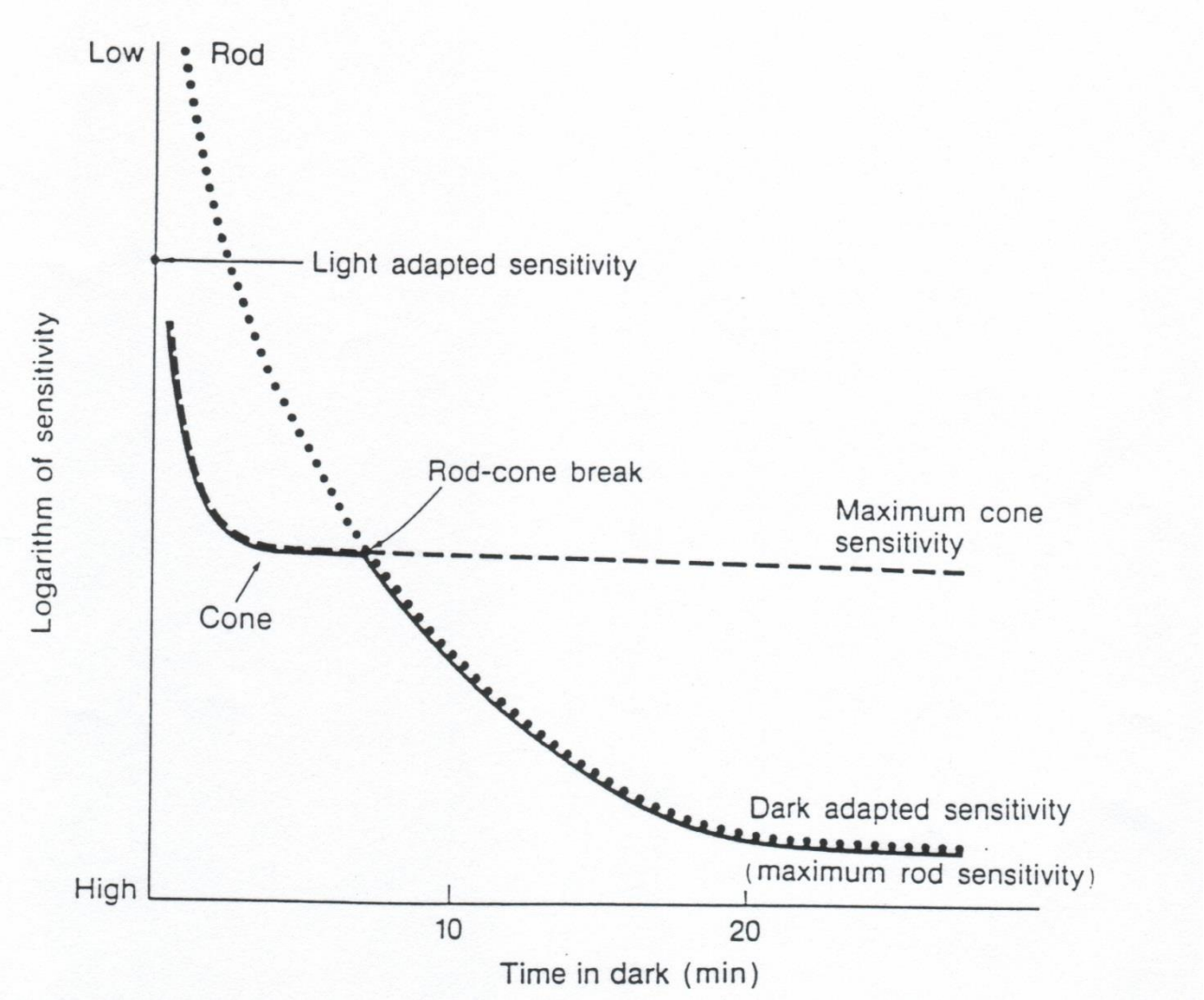
Adaptation

- Given stimulus does not always produce same visual response.
- Brightness level in a moderately well lit room appears very high if one enters from a dark room, but appears relatively dim if one enters from a considerably brighter room. After a time impression of excessive brightness or excessive dullness disappears – once eyes have become adapt to the level of illumination.
- Effect is particularly noticeable when one leaves a well lit house on a dark night. At first one can see almost nothing, but after a few minutes a few outlines can dimly be seen, & once vision continues to improve over a period of more than half an hour.
- Light & dark adaptation are referred to the two extremes, although there are an infinite number of states of adaptation. Changes in sensitivity of eye are to a small extend due to changes in size of pupil which is increased involuntarily by iris in dim light.

Dynamic Range of Light Intensity



Dark Adaptation

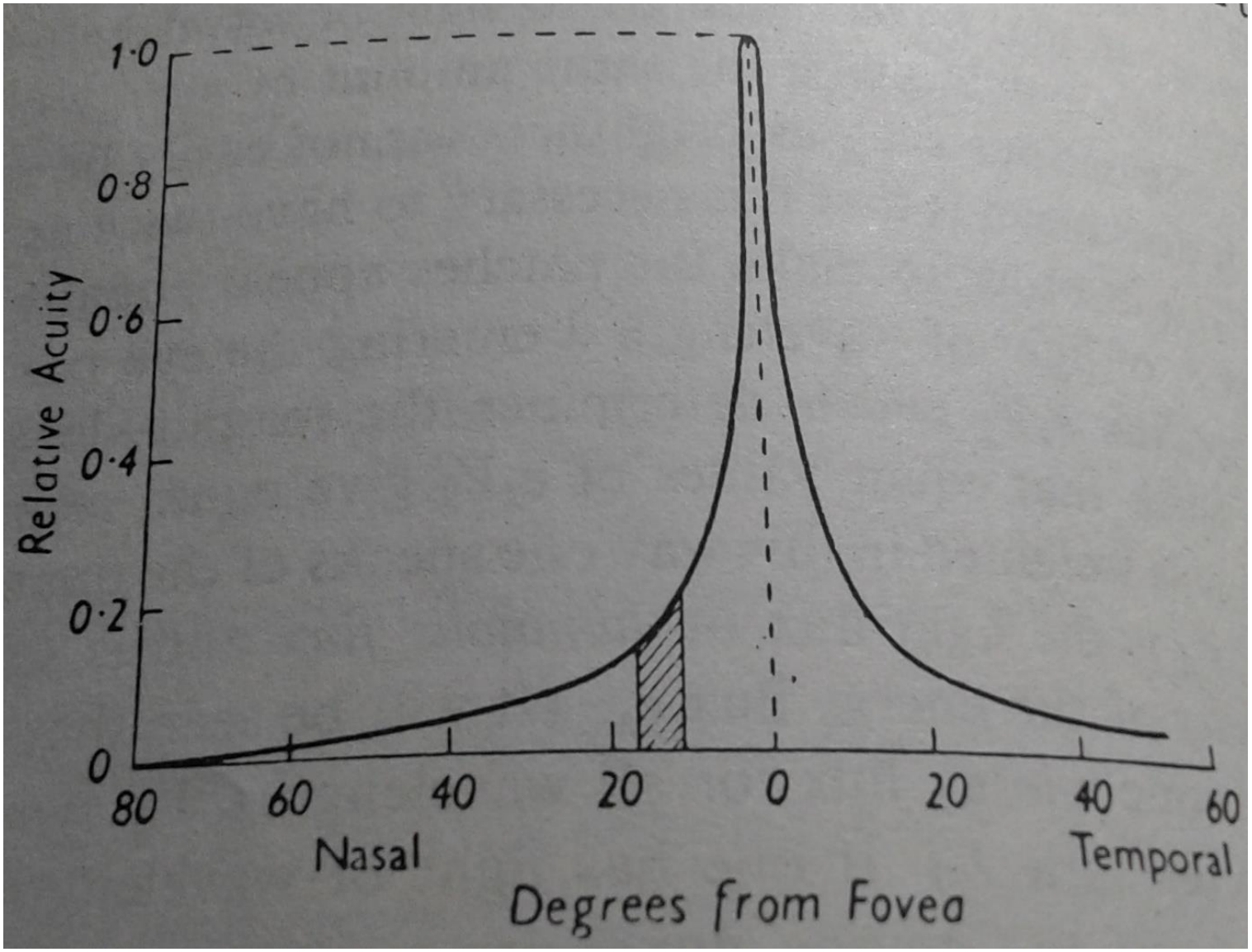


Visual Acuity

- Visual acuity - clarity of vision. It is dependent on optical & neural factors, i.e.,
  (i) sharpness of retinal focus within eye,
  (ii) health & functioning of retina, &
  (iii) sensitivity of interpretative faculty of brain.

- Assuming eye stationary, following conditions must be satisfied if two neighbouring independent point sources are to be resolved:
  (i) optical system of eye must give physically resolved images,
  Taking an average value of 4 mm for pupil diameter (assuming circular), one finds that angular limit of resolution of optical system is about half a minute.
  (ii) mosaic of retinal receptors must have a structure sufficiently fine to record resolved images.
  It is reasonable to assume that if eye is to resolve two neighbouring retinal images, there must be an unstimulated receptor between them.

- In the fovea it is estimated that a cone subtends an angle of about half a minute at nodal point, i.e., just has the order of magnitude necessary to take advantage of resolving power of optical system.



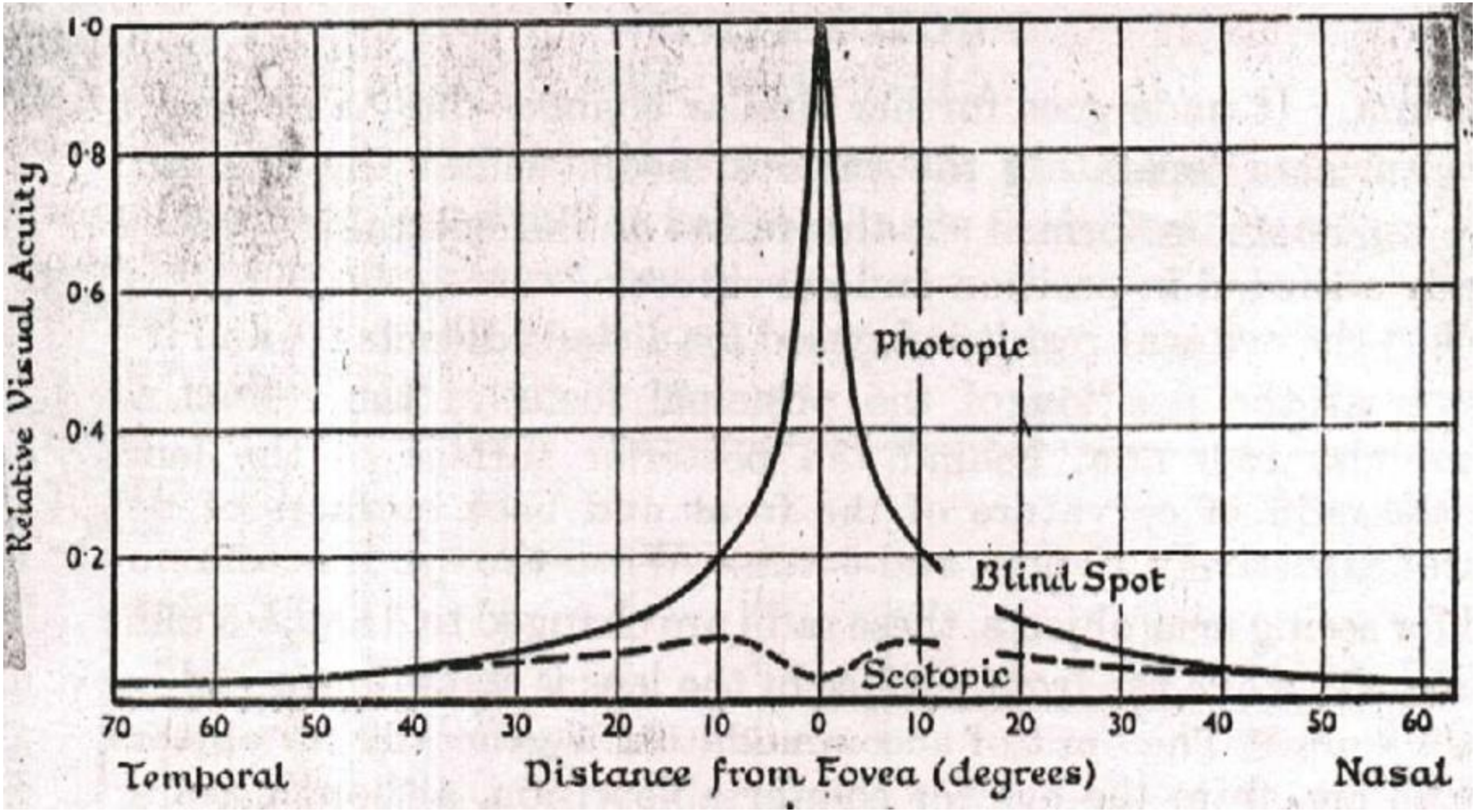
Variation of visual acuity across the retina

Visual Acuity

- Visual acuity describes how well you see detail with your central vision.
- Refers to the limit of visual discrimination.
- It is defined as the smallest visual angle under which the object can be clearly distinguished.
- Resolution in image depends on many factors: Diffraction, aberrations, scatter, absorption, …
- Mosaic of retinal receptors must have a structure sufficiently fine to record the resolved images.
- Cones in fovea subtend an angle of about 30sec at the nodal point.
- This is found to be nearly the resolution limit of optical system of eye (for 4mm dia)

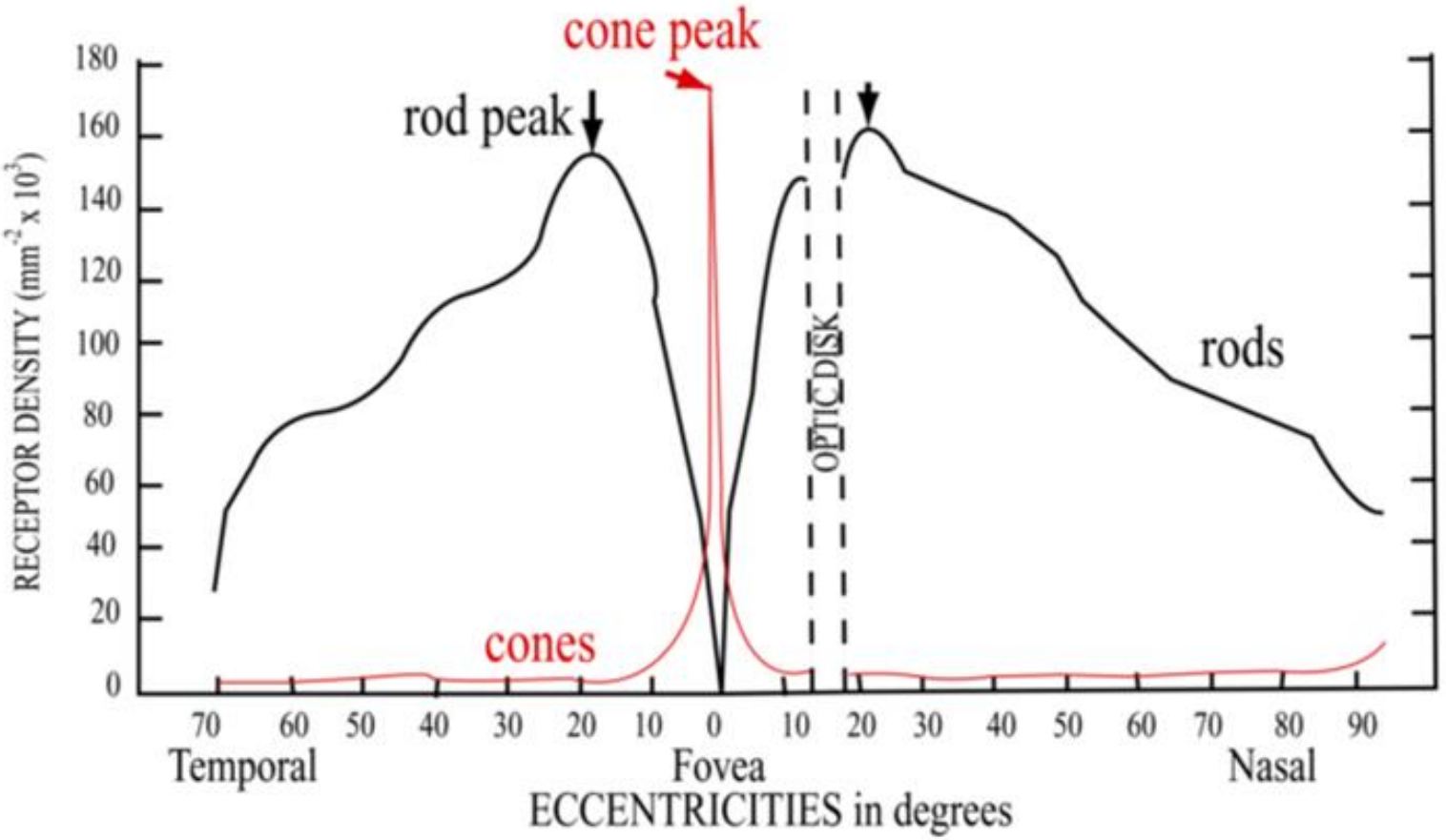
- For resolving two neighbouring retinal images, there must be an unstimulated receptor between them.
- Hence limit of visual resolution is 60sec of arc.
- This correspond to a linear distance of 1/10 mm at the near point (least distance of distinct vision, D_v = 25cm)
- This limit of visual resolution angle is Visual Acuity

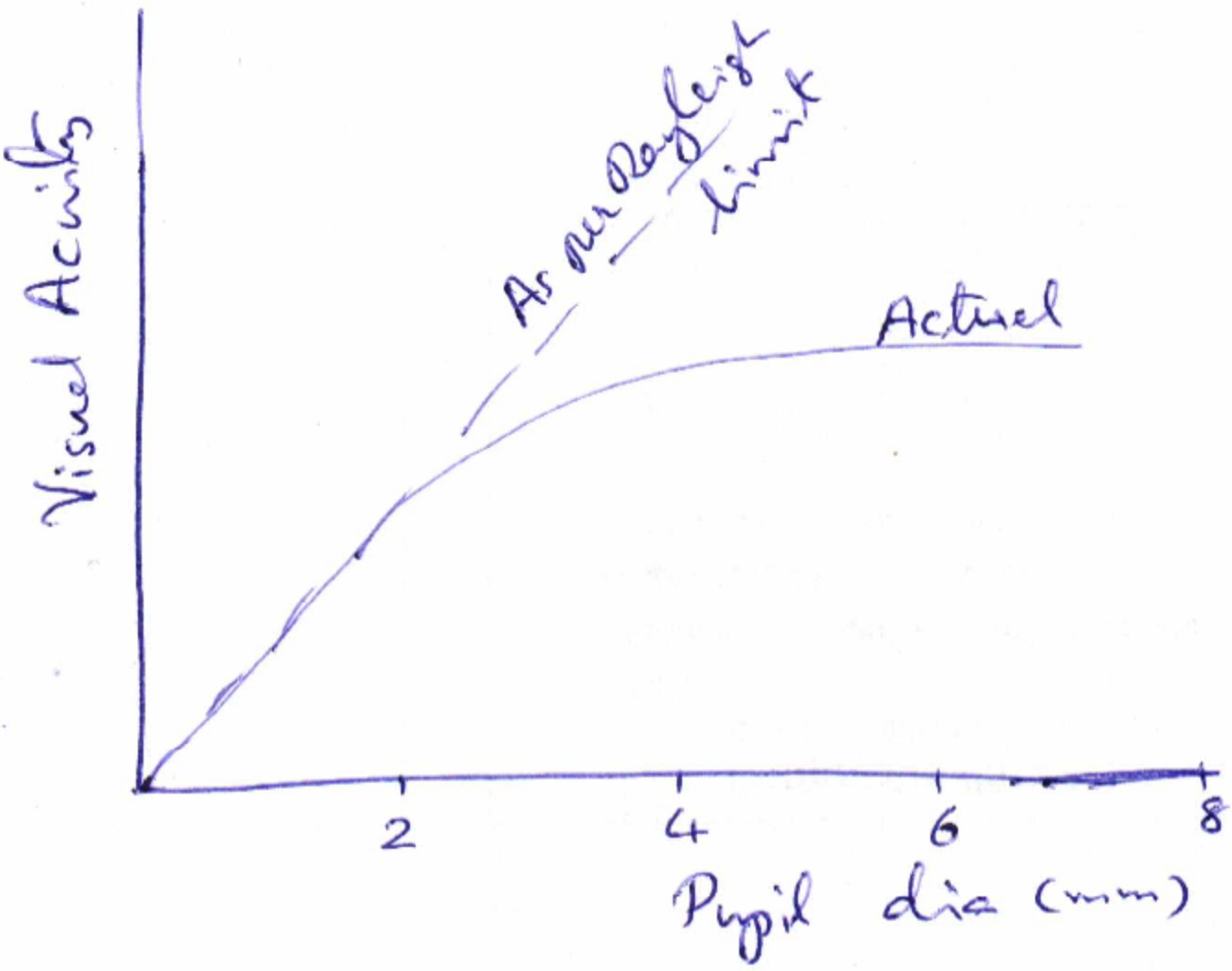
- In photopic vision, highest visual acuity is at fovea
  - (i) Cones are densely packed at fovea
  - (ii) Oblique aberrations
- In scotopic vision, fovea with cones is inactive & near zero acuity, region just beyond gives max acuity & also max sensitivity



Variation of visual acuity across retina

Rod & Cone distribution




Visual Acuity
As our Daylight limit
Actual
2
4
6
8
Pupil dia (mm)

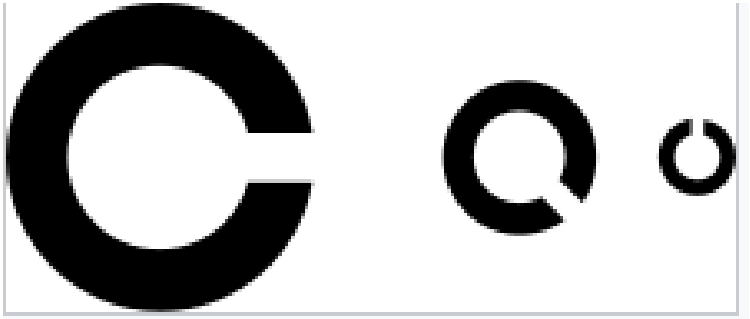
Measurement of Visual Acuity

1. Landolt's Ring or C
2. Snellen's Illiterate E
3. Jackson's hook

Edmund Landolt C

(Swiss-born Ophthalmologist)

A **Landolt C**, also known as a Japanese vision test, **Landolt ring** or **Landolt broken ring**, is an optotype, i.e. a standardized symbol used for testing vision.



Landolt C optotypes in various sizes & orientations

Landolt C consists of a ring that has a gap (looking similar to letter C).

Gap can be at various positions (usually left, right, bottom, top & 45° positions in between) & task of tested person is to decide on which side the gap is.

Size of C & its gap are reduced until subject makes a specified rate of errors (astigmatic). Minimum perceivable angle of gap is taken as measure of visual acuity.

Herman Snellen's Chart

(Dutch Ophthalmologist, 1862)

≡ 6/60
≡ 6/36
≡ 6/24
≡ 6/18
≡ 6/12
≡ 6/9
≡ 6/6

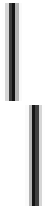
The Snellen Chart is used in most facilities for testing distance vision

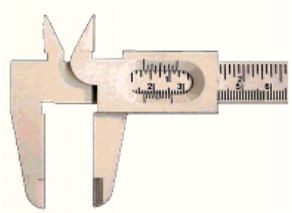
They are designed to be read at 6 metres or 3 metres (usually indicated on chart)

1	20/200
2	20/100
3	20/70
4	20/50
5	20/40
6	20/30
7	20/25
8	20/20
9	
10	
11	

If you can only read the big letter on the top line, that's recorded as 6/60 - you can see at 6m what can usually be seen from 60m with normal vision.

Vernier Acuity





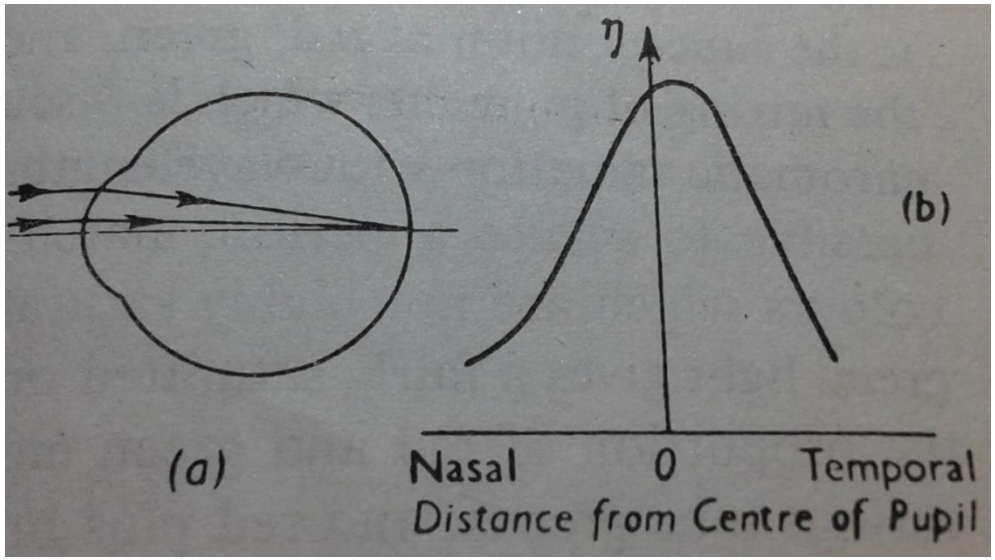
- Extraordinary ability of eye to lineup two straight lines
- Can be adjusted to be collinear to an accuracy to less than 10 sec (Visual Acuity was 60sec)
- Ceaseless scanning of object due to eye movement
- Also, eye has high sensitivity for flicker in periferal regions

Stiles-Crawford Effect

Directional sensitivity of retina (cone photoreceptors)

Light entering eye near centre of pupil is usually more effective in producing a visual response than that entering near periphery.

- **In scotopic vision the effect is found only with wavelengths greater than 0.58 µm, but under conditions of photopic vision the effect is found throughout the visible region & is same in foveal & extrafoveal regions.**



- **Suppose the eye receives a beam of light & that the energy is evenly distributed as the eye pupil. As far as the effective flux reaching the retina is concerned, an eye pupil of area *a* in the presence of Stiles-Crawford effect is equivalent to an area *Sa* with the effect absent.**

Eye pupil diameter	Stiles factor, *S*
2 mm	0.95
4 mm	0.82
6 mm	0.66