Clinical Visual Optics (OPTO 223)

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Week IV : Visual acuity

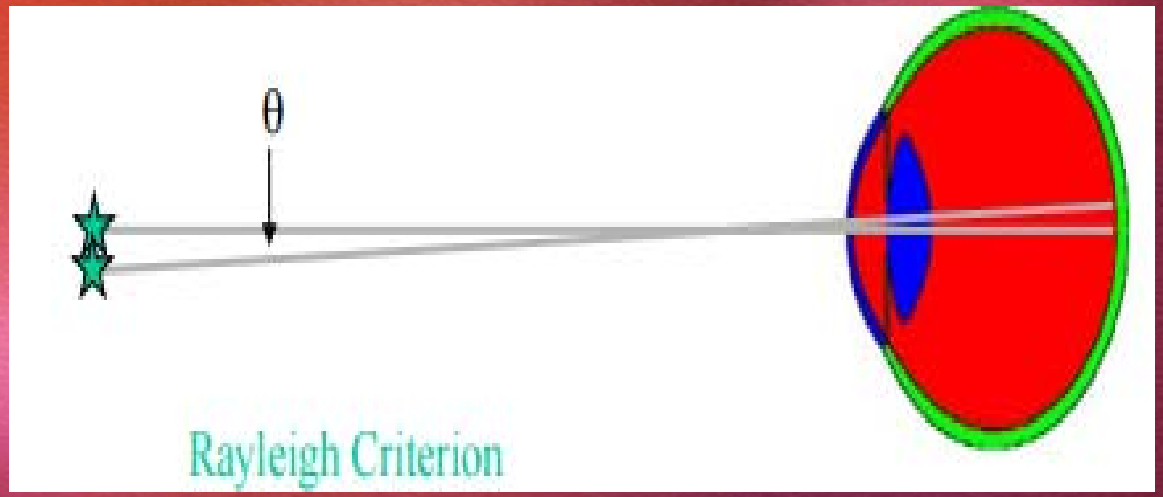
Week IV outline

- Revision of week III
- Visual acuity calculations
- Factors affecting visual acuity

To wrap up week III

- Eye Resolution: The ability of the eye to distinguish two neighboring objects.
- Rayleigh Criterion: Estimates the angle (hence the resolution) by the relation:

$$\theta = 1.22 \frac{\lambda}{D}$$



To wrap up week III

- Visual Acuity: A measure of the smallest detail that can be resolved by the visual system. There are different types of acuity measures.
- Types of VA:

1- Point Acuity

2- Vernier Acuity

3- Grating Acuity

4- Letter Acuity

More on letter acuity

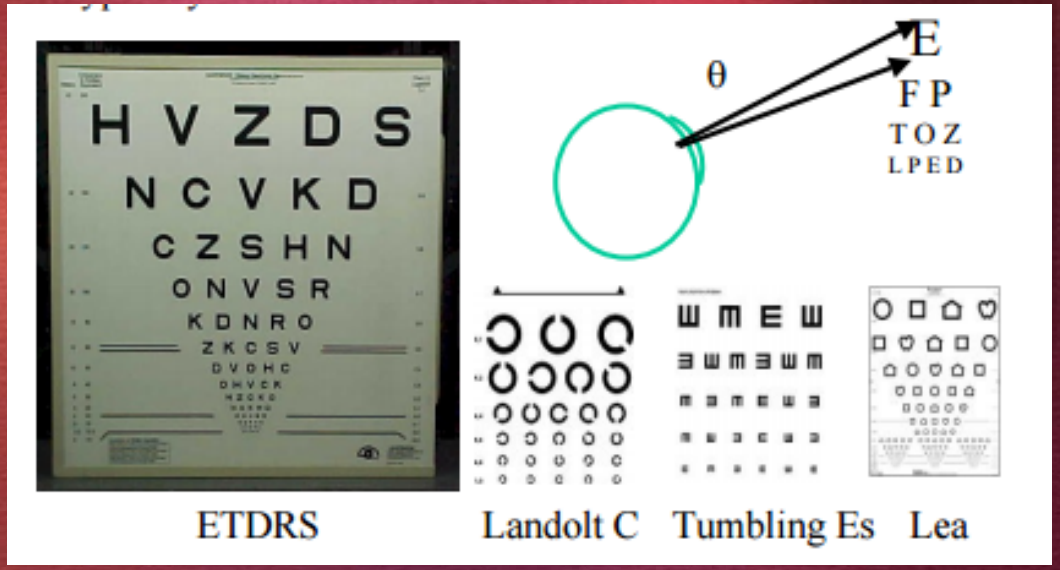
- There are several types of letter acuity tests, including:

1- Tumbling E's method

2-ETDRS method

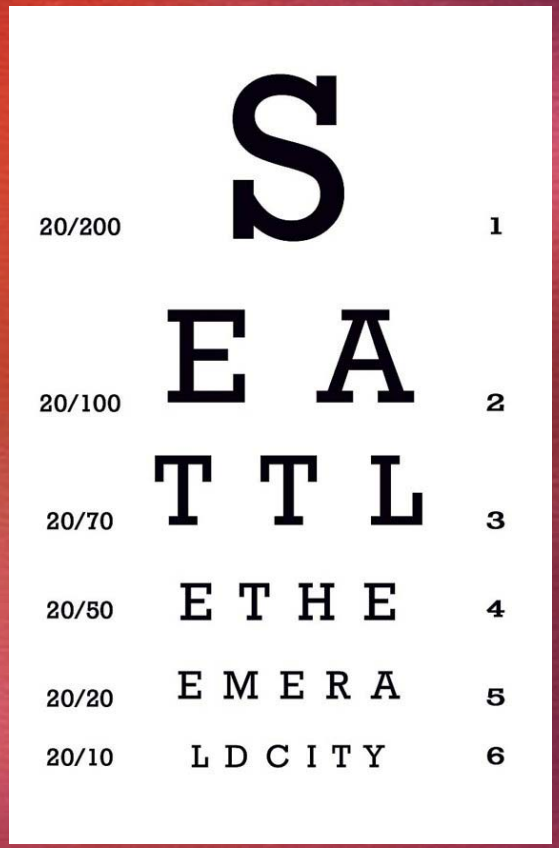
3-Landolt C

4- Lea method



Visual acuity charts/measures

- Visual Acuity Charts are designed so the 20/20 line subtends 5 arcmin, viz $\theta = \frac{5}{60}^{o}$

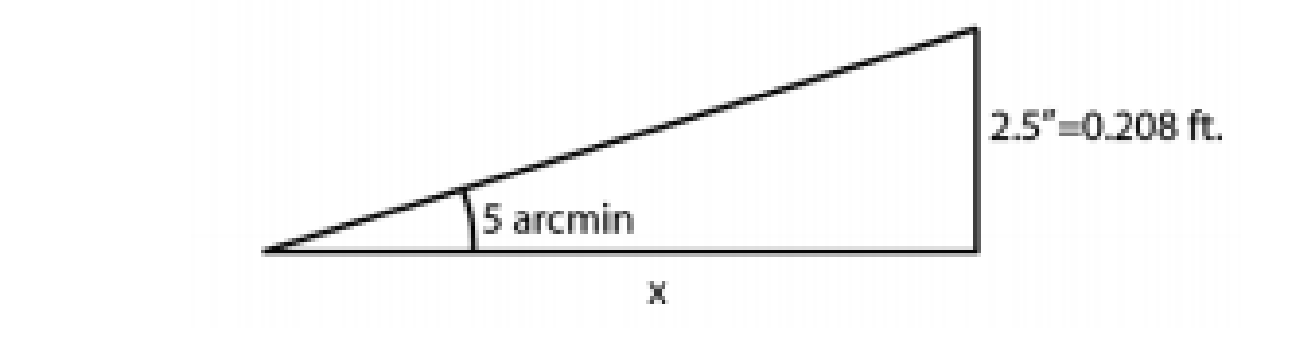


Example

- A car gets away from you, and you have 20/20 vision on the E test. How far from the car can you be in order to read the license plate ?

Example 1 : Solution

- A character on a license plate is 2.5”= 6.35 cm tall. From the geometry of the system



- $x = 6.35 \dfrac{cm}{\tan 1/12}$= 43.6 m

Factors affecting Visual acuity

- First,Refractive Error:

Refractive error is one of the important factors that affect visual acuity. Refractive error affects visual acuity depending on the correction, either Hypermetropic or Myopic or an Emmetropic eye. Visual acuity is affected depending if it causes a defocus at the retina.

Hypermetropic Myopic and Emmetropic

- In a Hypermetropic eye(long-sigtness), the eye is too strong so the image is focused in front of the retina causing a defocus hence affecting visual acuity. The reverse occurs with a myopic eye(short sigthness), as the eye is too weak, the image is focused in front of the retina therefore again causing a defocus hence affecting visual acuity.

- On the other hand to obtain a perfect image, image should be focused sharply on the retina. This is the case in an emmetropic eye (well-proportioned 20/20); no defocus hence no visual acuity problem due to refractive error.

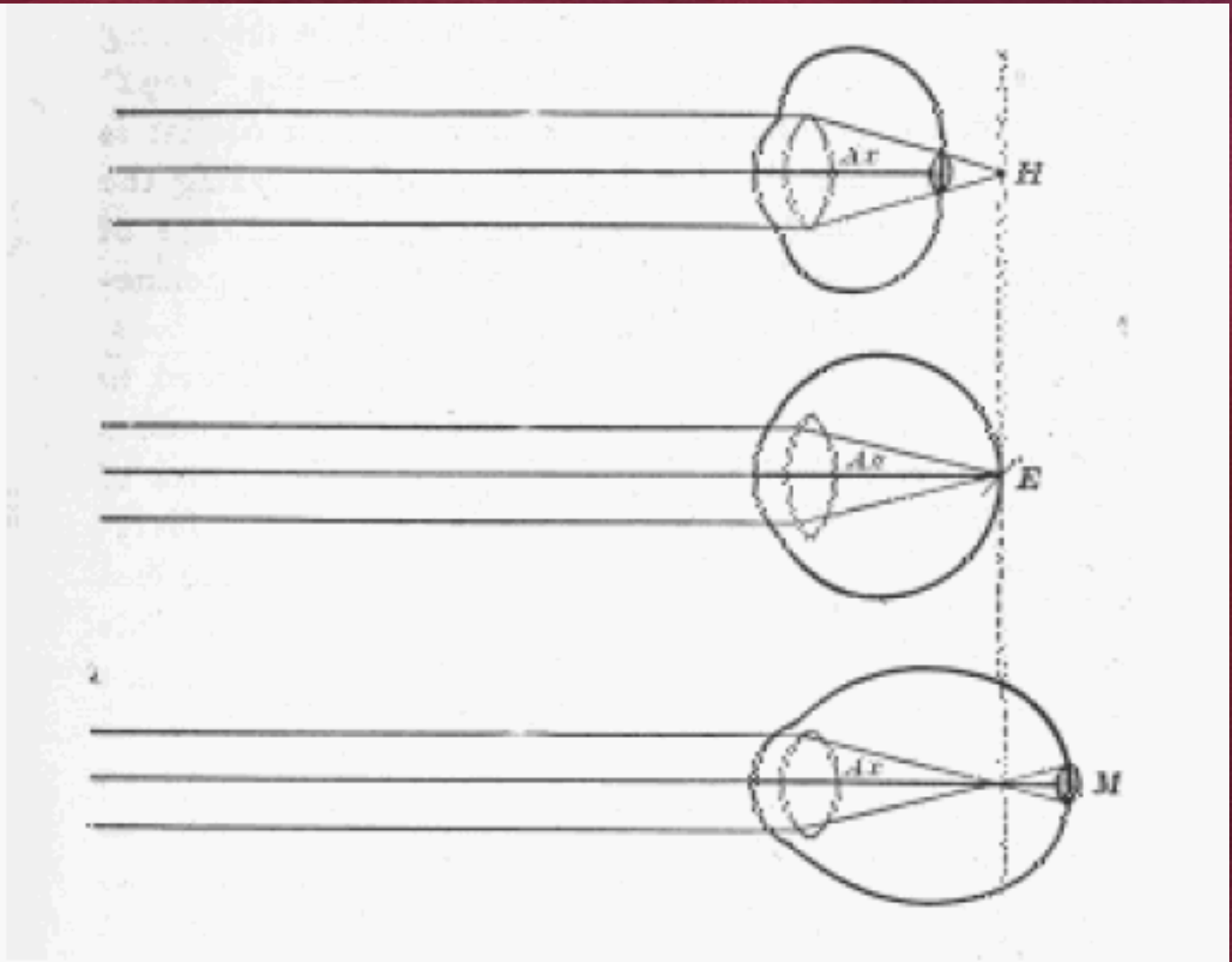


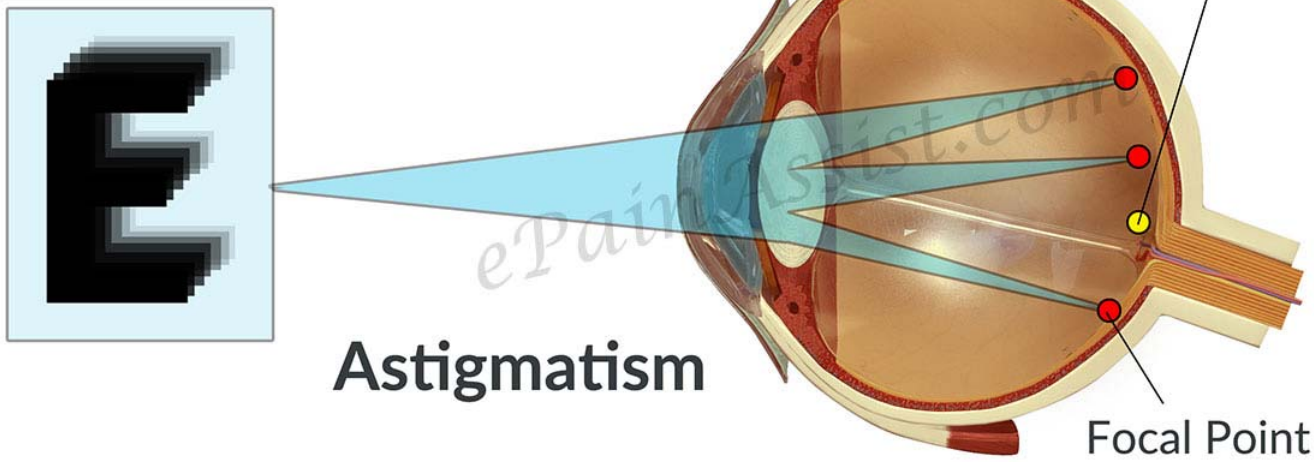
Fig. 4. Diagram of the Hypermetropic, Emmetropic and Myopic Eyeballs

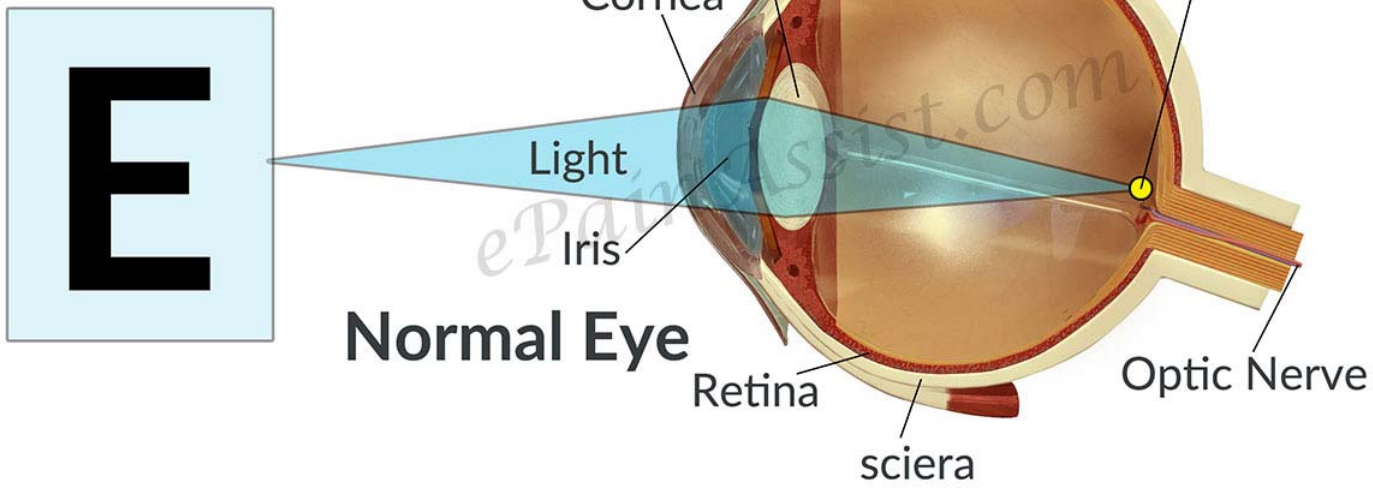
H, hypermetropia; E, emmetropia; M, myopia; Ax, optic axis. Note that in hypermetropia and myopia the rays, instead of coming to a focus, form a round spot upon the retina.

Astigmatism

- Having astigmatism also affects visual acuity. A phenomenon called the oblique effect states that oblique lines are seen less accurately, meaning that visual acuity is greater when lines are orientated horizontally or vertically. This is still the case even after a perfect correction of refractive error and astigmatism.

Astigmatism



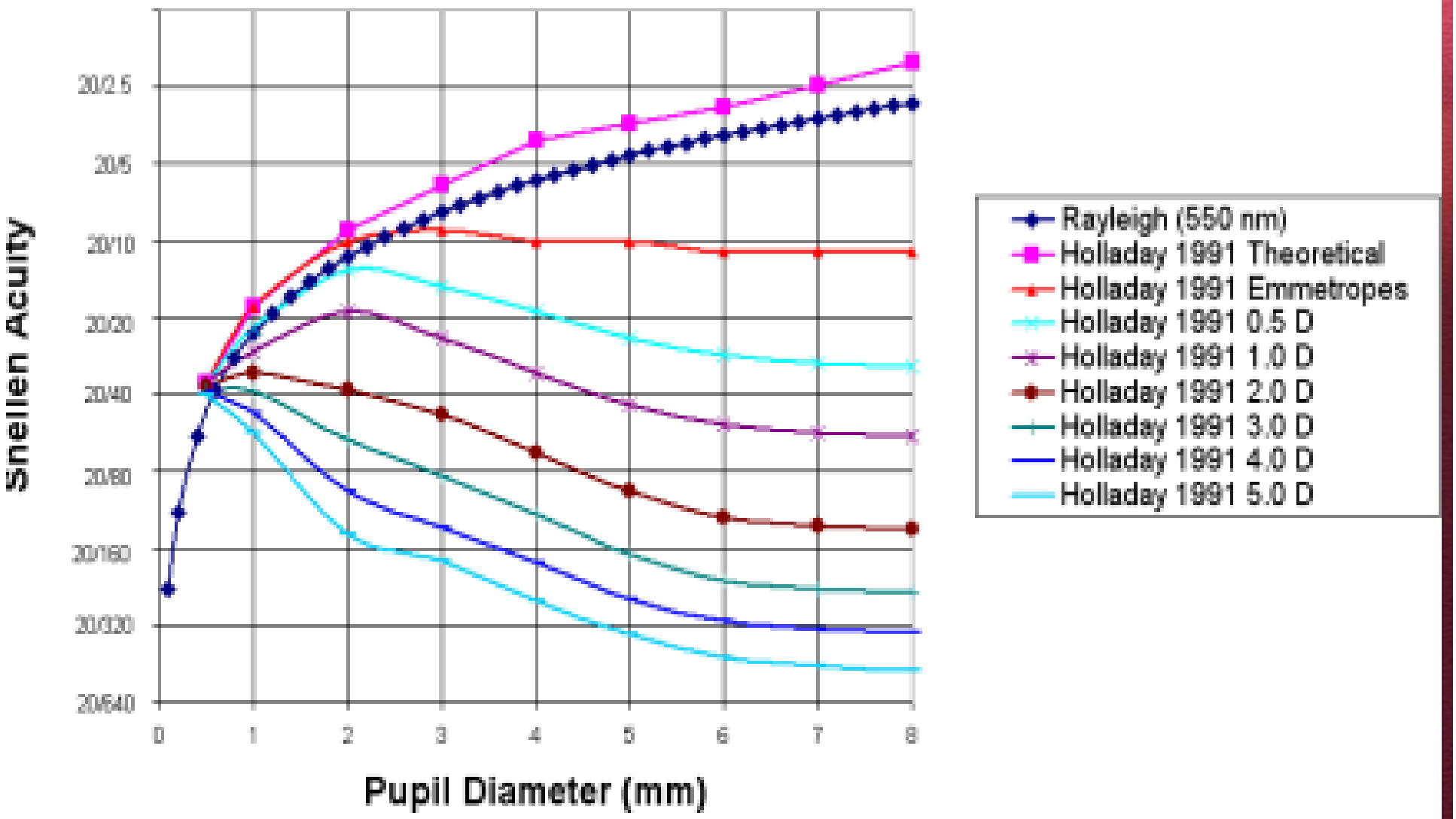


Factors affecting Visual acuity

- Second, Size of Pupil:

Eye takes time to see things. The nerve signals take a limited amount of time to travel along the optic nerve and instigate visual awareness. Therefore the size of pupil can determine how quickly or slow a signal can be stimulated thus determining how much visual acuity is affected. Large pupils let more light pass through into the eye so stimulating the retina more. However this does have a disadvantage; it affects resolution due to the aberrations that increase in the eye due to an increase in light.

- Small pupils reduce optical aberrations due to less light passing through into the eye however resolutions are diffraction limited. Therefore for good visual acuity a mid size pupil of approximately 3mm to 5mm is optimal as this is a compromise between the diffraction and aberration limits. Visual acuity also decreases with age due to decrease in pupil size, so a higher level of illumination is needed in older people to improve visual acuity.

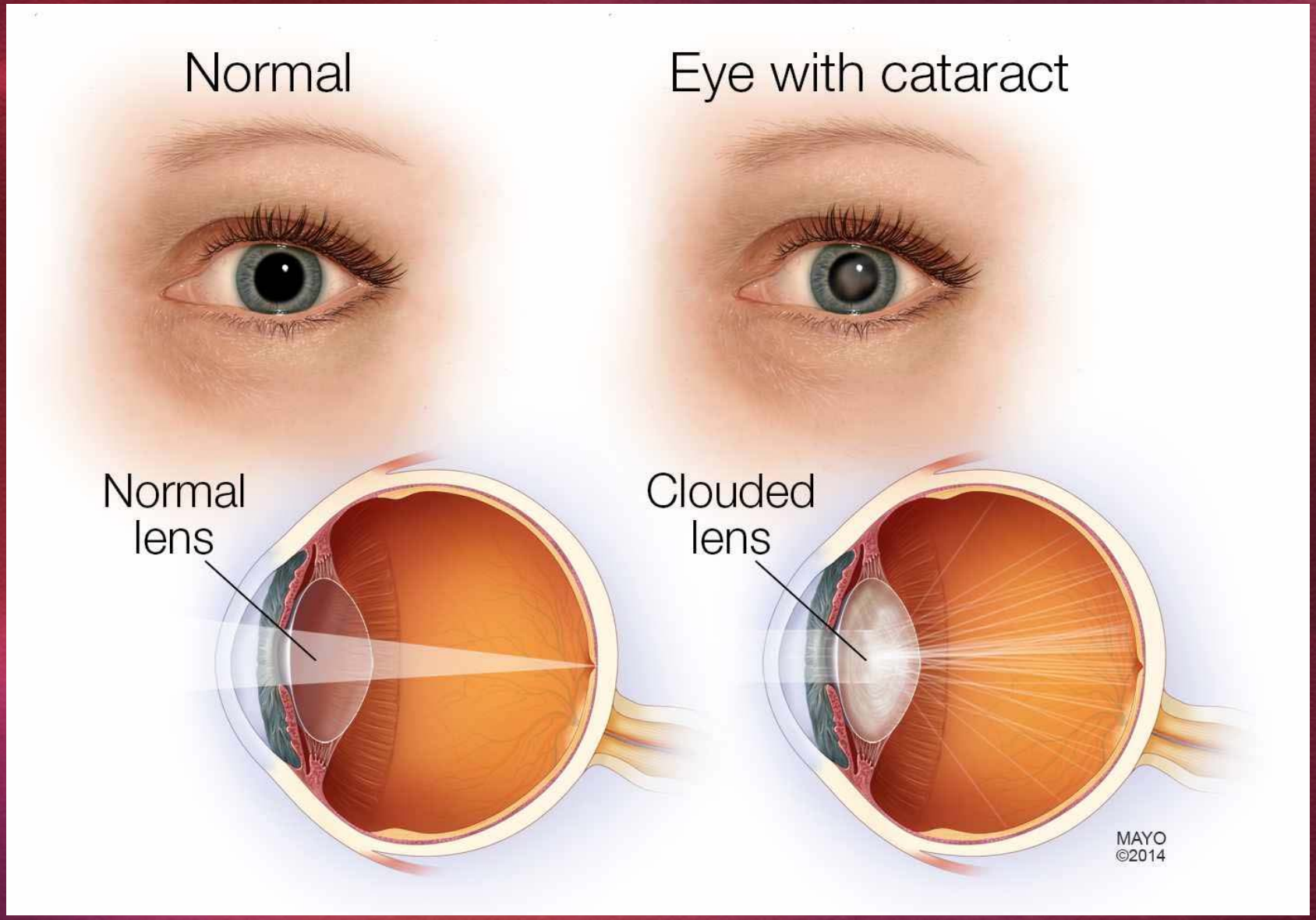

Snellen Acuity
20/2.5
20/5
20/10
20/20
20/40
20/80
20/160
20/320
20/640
0
1
2
3
4
5
6
7
8
Pupil Diameter (mm)
Rayleigh (550 nm)
Holladay 1991 Theoretical
Holladay 1991 Emmetropes
Holladay 1991 0.5 D
Holladay 1991 1.0 D
Holladay 1991 2.0 D
Holladay 1991 3.0 D
Holladay 1991 4.0 D
Holladay 1991 5.0 D

Factors affecting Visual acuity

- Third, illumination :
  For recognition tasks, visual acuity increases with illumination. However at very high illumination levels, acuity may decrease because of loss of contrast between object and its background, or reflections on the surface of the object decreasing the contrast between the background and object. Higher the contrast between the object and the background the greater the acuity is.

- When contrast is reduced, it becomes more difficult to read it against a darker background therefore the text need to be made larger in order for the illumination levels to be correct for good visual acuity.
- Illumination levels greatly affect the older generation due to many people having **cataracts**. The cataract becomes a source of veiling glare within the eye therefore visual acuity decreases.

Cataracts


Normal
Eye with cataract
Normal lens
Clouded lens
MAYO ©2014

Factors affecting Visual acuity

- Fourth, Time Exposure of the Target

To detect a small bright spot, detection is greatly dependent on the quantity of light rather than the exposure time. However to detect a line, the acuity is proportional to the exposure time. There is no simple acuity-exposure time relationship for the resolution of the target.

Factors affecting Visual acuity

- Fifth, Area of the Retina Stimulated

Visual acuity is greatest at the centre of fixation, which in this case is at the fovea. Fovea has the greatest visual acuity due to the densely packed cones, so once the image is moved away from the centre of fixation visual acuity is affected

At a distance of 5 minutes of arc from the centre of fixation, there is a loss in visual acuity.

- At approximately 10 minutes of arc from fixation there is about 25% visual acuity loss. This shows that our vision is most accurate at the fovea and acuity falls rapidly as we move towards the peripheral retina. Therefore in order to achieve best visual acuity we must scan our visual field to place the fovea on the area of interest and to achieve this we must have excellent oculo-motor co-ordination.

Factors affecting Visual acuity

- Sixth, State of Adaptation of the Eye:
-

  Highest level of acuity is achieved if the eye is tailored to the equivalent level as the test luminance of $34cd/m^2$ to $34{,}000cd/m^2$. Test luminance less than $34cd/m^2$ will achieve to some extent, better acuity. Under photopic conditions, the high density of cones at the fovea is accountable for the high levels of acuity. Under scotopic conditions it is a little altered, due to the Aii Amacrine cells appearing to limit resolution. Maximum scotopic acuity occurs at 5-15 degrees eccentricity which is corresponding to the cell density, while peak rod density occurs at about 15-20 degrees.

Factors affecting Visual acuity

- Seventh, Eye Movements:

In steady eye fixation, the eyes are in constant motion; therefore moving objects are more difficult to see than stationary objects thus affecting visual acuity. Visual acuity will be greater when point of interest is constant or little movement however visual acuity will be at a great loss when object is in constant movement.
Conclusion: Dynamic visual acuity is lower than Static visual acuity.

Conclusion

- Visual acuity is measured in a number of different procedures however it is dependant on many factors. Visual acuity cannot just be taken as a figure without considering all the factors that affect it. Such as the refractive error, size of pupil, illumination, area of retina stimulated, adaptation of the eye, eye movements and time exposure of the target. Therefore without an understanding of this visual acuity cannot be taken accurately.

End of lecture IV

- Further reading for this week include

Contrast sensitivity, Lenses and their role in refract error correction and more on the methods of estimating visual acuity.

Homework II is due to next week

Have a nice week !!