PHYSIOLOGY OF VISION
FUNCTIONAL ANATOMY
BASIC PRINCIPLES OF OPTICS
THE EYE AS AN OPTICAL INSTRUMENT

Rodolfo T. Rafael, M.D.
ANATOMY OF THE EYE
Anatomy

- spherical in shape
- 24mm in diameter
- orbital cavity
- loosely embedded in fatty tissue
- protected by the eyelids
Three Layers of the Eye
Layers

- Sclera
- Choroid
  - iris
  - ciliary body
- Retina

- External, fibrous tunic
- Intermediate, vascular tunic
- Internal tunic (retina)
Sclera

- Greater part of the external surface
- White of the eye
- Anteriorly
  - cornea
    - transparent
    - greater curvature than the rest of the eye.
Choroid

- Middle layer
- Vascular and pigmented
- Anteriorly, the choroids becomes modified into the:
  - Iris
  - Ciliary body
Retina

- The innermost layer
  - Pigmented Layer
  - Nervous Layer
- Macula lutea
- Fovea Centralis
- Optic nerve
  - Optic disc
    - area surrounding optic nerve
  - Optic cup
    - small depression at the center of the optic disc
Lens

- Transparent, colorless body
- Biconvex lens

IRIS

PUPIL
Humors

- The lens divide the eye cavity into an
  - **Anterior space**
  - **Posterior space**
<table>
<thead>
<tr>
<th>Eye Muscle</th>
<th>Nerve</th>
<th>Primary Function</th>
<th>Deficit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medial rectus</td>
<td>Oculomotor (CN3)</td>
<td>Moves eye nasally</td>
<td>Eye is down and out because of unopposed action of lateral rectus and superior oblique</td>
</tr>
<tr>
<td>Lateral rectus</td>
<td>Abducens (CN6)</td>
<td>Moves eye temporally</td>
<td>Eye cannot look temporally</td>
</tr>
<tr>
<td>Superior rectus</td>
<td>Oculomotor (CN3)</td>
<td>Moves eye up</td>
<td>Weakness of upward gaze</td>
</tr>
<tr>
<td>Inferior rectus</td>
<td>Oculomotor (CN3)</td>
<td>Moves eye down</td>
<td>Weakness of downward gaze</td>
</tr>
<tr>
<td>Superior oblique</td>
<td>Trochlear (CN4)</td>
<td>1) Moves eye down when eye is already looking nasally. 2) Rotates eye when eye is already looking temporally. 3) Moves eye down and out when eye is in straight ahead position.</td>
<td>Vertical diplopia Head tilt (compensation for imbalance of rotation).</td>
</tr>
<tr>
<td>Muscle Type</td>
<td>Motor Nerve</td>
<td>Action</td>
<td>Associated Signs</td>
</tr>
<tr>
<td>-----------------------------</td>
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<td>-------------------------------------------</td>
<td>-----------------------------------</td>
</tr>
<tr>
<td>Inferior oblique Oculomotor (CN3)</td>
<td>1) Moves eye up when eye is already looking nasally.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2) Rotates eye when eye is already looking temporally.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3) Moves eye up and out when eye is in straight ahead position.</td>
<td></td>
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<tr>
<td>Vertical diplopia Head tilt</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Levator palpebrae superioris Oculomotor (CN3)</td>
<td>Elevates upper lid</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Marked ptosis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Muller’s muscle (see Fig. 1) Cervical sympathetics</td>
<td>Elevates upper lid</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mild ptosis</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
OPTICS: FORMATION OF THE RETINAL IMAGE

1. Refraction of Light
2. Image Formation by a Convex Lens
3. Image Formation of the Eye
4. Accommodation of the Eye for Objects at Different Distances
5. Optic Defects and Abnormalities
6. Visual Acuity
Refraction of Light

- Light rays, on passing **obliquely** from one transparent medium to another of a different optical density, are deflected from their path
  - rarer to denser medium
  - denser to rarer medium
Figure 49–1. Wave fronts entering (top) a glass surface perpendicular to the light rays and (bottom) a glass surface angulated to the light rays. This figure demonstrates that the distance between waves after they enter the glass is shortened to about two thirds that in air. It also shows that light rays striking an angulated glass surface are bent.

Figure 49–3. Bending of light rays at each surface of a concave spherical lens, showing that parallel light rays are diverged by a concave lens.
The refractive index of a medium is the ratio of the sine of the angle of incidence and the sine of the angle of refraction. It is also the ratio of the velocities of light in air and in the medium.

\[ IOR = \frac{vel(air)}{vel(x)} = \frac{\sin e(i)}{\sin e(r)} \]
- Light waves travel 300,000 km/sec.
- The refractive index of air or a vacuum is arbitrarily considered to be 1.0.
- The refractive index of a transparent substance is inversely proportional to the speed at which light travels through the substance.

<table>
<thead>
<tr>
<th>Medium</th>
<th>Refractive Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td>1.003</td>
</tr>
<tr>
<td>Water</td>
<td>1.33</td>
</tr>
<tr>
<td>Linseed Oil</td>
<td>1.48</td>
</tr>
<tr>
<td>Diamond</td>
<td>2.42</td>
</tr>
</tbody>
</table>
ImageFormation by a Convex Lens

- Artificial lens
  - Converging lens
  - Diverging lens

- The principal axis of a lens with two spherical surfaces is a line passing through the centers of curvature.
Figure 49-2. Bending of light rays at each surface of a convex spherical lens, showing that parallel light rays are focused to a point focus.
- **Focal points**
  - Light from a point on the principal axis so distant that the rays are parallel when they strike the lens, will converge at a point.

- **Focal length**
  - which is a measure of the refractive power of “strength” of the lens.

- **Diopter**
  - The unit for the refractive power of a lens which is the reciprocal of the focal length expressed in meters.

- **Refractive power**
  - depends upon the curvature of the lens surface and the refractive index of the material the lens is made of.
Image Formation of the Eye

- Refracting media
- Reduced Eye
- IOR=1.333
- Optical center
  - 5 mm behind the cornea
  - the retina is 15 mm behind the optical center.
- Cornea to the retina is 20 mm
- The total refractive power is 59D.
A real, inverted image, smaller than the object

\[
\frac{\text{size}(\text{object})}{\text{size}(\text{image})} = \frac{\text{Distance from object to optical center}}{\text{Distance from image to optical center}}
\]
• The **visual angle** is formed at the optical center by the limiting rays from the object.

• This angle increases as the object is placed closer to the eye.
Retinal images are inverted they are perceived as “erect” (in the correct position) and “projected”.

The “righting” of the image
Accommodation of the Eye for Objects at Different Distances

- Accommodation for near Vision
- Near Points and Far Points of Distinct Vision
- Refractive Power and Amplitude of Accommodation
Figure 49-12. Parallel light rays focus on the retina in emmetropia, behind the retina in hyperopia, and in front of the retina in myopia.
Accommodation for Near Vision Involves

- Increase curvature of the lens of the eye
- Constriction of the pupils
- Convergence of the eyeball
Increase curvature of the lens of the eye

- The lens is suspended by the zonula
- Ciliary muscle is relaxed → zonule is under tension and pulls on the equator of the lens so that the lens is flattened.
  - Refractive power of the lens is decreased.
- Ciliary muscle contracts → pulls the ciliary body towards the lens, relaxing the zonula.
  - The tension which held the lens in its flattened shape having been reduced or abolished
  - Refractive power of the lens is increased.

![Diagram of the eye](image1.png)

Figure 49–10. Mechanism of accommodation (focusing).
Figure 49-10. Mechanism of accommodation (focusing).
Pupil constricts as circular muscles of iris contract (parasympathetic)

Pupil

Pupil dilates as radial muscles of iris contract (sympathetic)

Bright light

Normal light

Dim light

Anterior views

16.07
Constriction of the Pupils

- By constricting, the iris
  1. Excludes the periphery of the lens
  2. Increases the depths of focus
  3. Diminishes the quantity of light entering the eye.
Convergence of the Eyeball

Visual axis are so directed that the images will be formed on the corresponding points of the retina
Near Points and Far Points of Distinct Vision

- **Near Point**
  - the nearest point at which an object can be distinctly seen, with full accommodation.

- **The distance increases with age**
  - slowly in early life
  - most rapidly in the early 40’s
  - very slowly after 50.
    - progressive loss of the plasticity of the lens.

- **Presbyopia**
In the normal eye, parallel rays are brought to focus on the retina from infinity.

Object at distances greater than 20 ft. are seen distinctly without accommodation, that is, with the eye at rest.

Distance of 6 meters or 20 ft. is the Far Point of the normal eye.
Refractive Power and Amplitude of Accommodation

- The refractive power of a lens is usually expressed in terms of its principal focal distance or focal length.
- A lens with a focal distance of 1 meter is taken as a unit and is designated as having a refractive power of 1 diopter (D).
- The refractive power of the lens is expressed in terms of the reciprocal of their focal distances measured in meters.
  - lens with a principal focal distance of 0.10 meter is a lens of 10D, and one with a focal distance of 0.2 meters is a lens of 5D.
Figure 49–8. Effect of lens strength on the focal distance.
The reduced eye- If all the refractive surfaces of the eye are algebraically added together and then considered to be one single lens
  - Refractive power of 59D
  - Focal distance of 0.017 meter

The cornea contributes about twice as much to this power as does the lens
The amplitude of accommodation is expressed by the number of diopters added to the refractive power of the eye by the action of the ciliary muscles.

This is about 12D in children and 10D in young adults.

- 5.4D at 40 years
- 1.9D at 50 years
- 1.0D at 70 years.
Optic Defects and Abnormalities
Optic Defects of the Emmetropic (Normal Eye)

- Spherical Aberration
- Chromatic Aberration
- Blind Spot
Spherical Aberration

- In the optical lens, the marginal rays are focused in front of the focus of the central rays: thus blurring the image.

- Corrected:
  - Constriction of the iris
  - Greater optical density of the nucleus of the lens with respect to the cortex.
Chromatic Aberration

- This is due to
  - different dispersion of the light rays by the lens, according to their wavelength.

- Chromatic aberration is most marked to wavelengths at the end of the spectrum.
BlindSpot

- Optic nerve enters the eye has no cones and no rods.
- This produces a blind spot in the visual field.
- The blind spot is 15 degrees to the temporal side of the visual field.
Transverse plane

Scleral venous sinus (canal of Schlemm)

Ciliary body:
Ciliary muscle
Ciliary process

Anterior cavity (contains aqueous humor):

Anterior chamber
Posterior chamber

Light
Visual axis

Cornea
Pupil
Iris
Lens
Zonular fibers of lens

Bulbar conjunctiva

Ora serrata
Retina

Choroid
Sclera

Medial rectus muscle

Hyaloid canal

Medial rectus muscle

Vitreous chamber (contains vitreous body)

Central retinal artery and vein

Optic nerve (cranial nerve II)
Optic disc (blind spot)
Central fovea

(a) Superior view of transverse section of right eyeball
Optical Defects in the Ametropic Eye

- Emmetropia
- Ametropia.
Optical Defects in the Ametropic Eye

- Myopia
- Hyperopia or Hypermetropia
- Presbyopia: or “Old-Sightedness”
- Astigmatism
Myopia

- Without accommodation come to a focus in front of the retina due
  - the eyeball is too long
  - the lens is too thick.
- The far point is nearer than infinity
- All distant objects appear blurred.
- Its near point is nearer than that of an emmetropic eye with equal amplitude of accommodation. Thus the term “nearsightedness”
- For distant vision, the remedy is the use of concave lenses.
Figure 49-12. Parallel light rays focus on the retina in emmetropia, behind the retina in hyperopia, and in front of the retina in myopia.
Figure 49-13. Correction of myopia with a concave lens and correction of hyperopia with a convex lens.
Hyperopia or Hypermetropia

- Parallel rays of light without accommodation are focused behind the retina, that is, the retina is reached by the rays before they come to focus.
- The uncorrected hyperope may see distant objects clearly only by the use of his accommodation.
- The near point is greater than 10cm.
- The term “far-sightedness” refers mainly to the excessive distance of the near point.
- Correction is by the use of convex lenses.
Figure 49-12. Parallel light rays focus on the retina in emmetropia, behind the retina in hyperopia, and in front of the retina in myopia.
Figure 49–13. Correction of myopia with a concave lens and correction of hyperopia with a convex lens.
Presbyopia: or “Old-Sightedness”

- A decrease in the amplitude of accommodation as a consequence of aging.
- The near point of distinct vision recedes farther and farther from the eye until near is difficult or impossible.
- All properly corrected eyes will become presbyopic at about the same time, at an age approximately 45.
Astigmatism

- An error of refraction due to the uneven curvature of the cornea.
- The corneal surface is not spherical, so there is a meridian of least curvature and meridian of greatest curvature at right angle to the first.
- Rays falling on the greatest curvature are focused earlier than those falling on the least curvature.
- Correction is by the use of cylindrical lenses.
Figure 49-14. Astigmatism, demonstrating that light rays focus at one focal distance in one focal plane and at another focal distance in the plane at right angles.
Visual Acuity
Visual Acuity

- is the sharpness with which details and contours of objects are perceived and constitutes the basis for form or object vision.

- The zone immediately surrounding the fovea possesses the next greater capacity for detailed vision.

- Visual acuity diminishes further towards the periphery.

- The fovea is specialized for detailed vision in four ways:
  - 1. the cones are more slender and densely packed
  - 2. it is rod free
  - 3. blood vessels and nerves detour around it, and the cellular layers are deflected to the side, removing the scattering of light
  - 4. each cone is connected to one ganglion cell.
Measurement of Visual Acuity

- Visual acuity is usually expressed in terms of minimum separable, the smallest distance by which two lines may be separated without appearing as a single line.
- The angle that these two lines subtend at the eye is called the visual angle, which is one minute for the normal eye.

- Visual acuity can also be expressed in terms of minimum visible, the narrowest line or the finest thread that can be discriminated from a homogenous background.
Factors Modifying Visual Acuity

- **Dependent upon Stimulus**
  - Brightness of object in contrast with dark background.
  - Intensity of illumination
  - Size of object
- **Dioptric Factors**
  - Spherical aberration
  - Chromatic aberration
  - Error of refraction
  - Composition of light (monochromatic light improves visual acuity by decreasing chromatic aberration).
- **Retinal Factors.** The fovea centralis is adapted for acutest vision.
Clinical Tests for Visual Acuity

- Snellen’s Test Chart:
  - Consists of 9 lines of letters in which the letters in each line are smaller than those in the previous line.
  - The chart is viewed at a distance of 20 ft., or 6m.
  - If at 20 ft. the individual reads the letters of the line marked 20, visual acuity is 20/20 which is considered normal.
  - If the individual can read only the line marked 100 (which a normal individual can read at 100 ft), his visual acuity is 20/100.

\[
\text{Visual Acuity} = \frac{\text{distance of subject from the chart}}{\text{distance at which letter can be read by the normal eye}}
\]

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Fig. 3.5 Jaeger’s charts.
ThankYou ForNot Listening