جامعة المستقبل
كلية التقنيات الصحية والطبية
قسم تقنيات البصريات

Second Stage 2024-2025

REFRACTIVE ERRORS 1

Lecture Title
Human Eye

Lecture Number: 3 / course 1

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Human Eye

Anatomy of the Eye

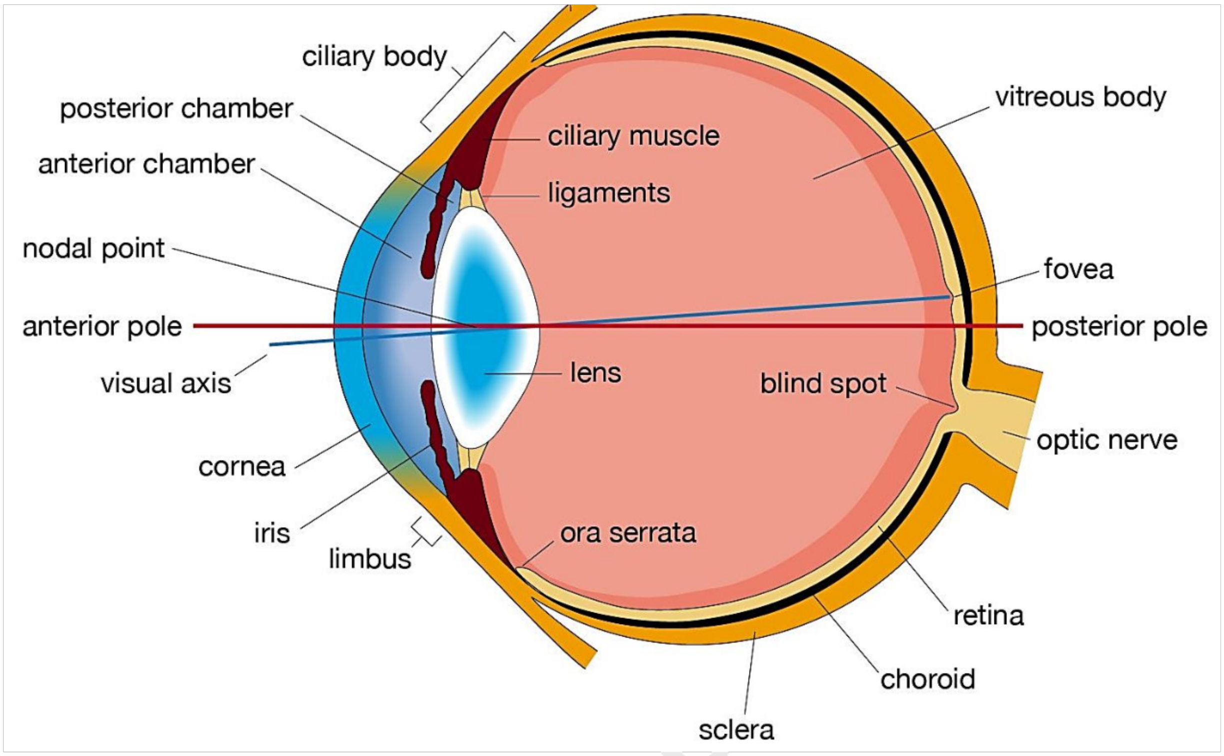

Figure1: Human eye

- **Cornea: The transparent front surface of the eye that refracts light entering the eye.**
  - ✓ **The cornea has a refractive index of approximately 1.376.**
  - ✓ **The corneal power is approximately +43 diopters (D) in range (+40 to +45D)**
- **Lens: A flexible, transparent structure that further focuses light onto the retina. The lens can change shape to adjust focus, a process known as accommodation.**
  - ✓ **The central part (nucleus) has a refractive index of approximately 1.406.**
  - ✓ **The outer part (cortex) has a refractive index of approximately 1.386.**
  - ✓ **The lens typically has a refractive power of around +18 to +20 diopters (D) in its relaxed state.**

- **Iris and Pupil**: The iris controls the size of the pupil, which regulates the amount of light entering the eye.
- **Aqueous humor**: is a clear, watery fluid found in the anterior segment of the eye. It fills the space between the cornea and the lens, including the anterior chamber (between the cornea and iris) and the posterior chamber (between the iris and lens). The aqueous humor has a refractive index of approximately 1.336.
- **Vitreous humor**: is a clear, gel-like substance that fills the large vitreous chamber, which occupies the space between the lens and the retina. The aqueous humor has a refractive index of approximately 1.336
- **Retina**: The light-sensitive layer at the back of the eye, where light is focused and converted into electrical signals sent to the brain.
- **Optic Nerve**: Transmits visual information from the retina to the brain.

Basic Optical Principles

- **Refraction**: The bending of light as it passes through different media (air, cornea, lens) in the eye. This bending is crucial for focusing light on the retina.
- **Focal Point**: Light rays entering the eye are refracted and brought to a focal point on the retina. A sharp image is formed when light rays converge precisely on the retina.
- **Accommodation**: The eye's ability to focus on objects at varying distances by changing the shape of the lens. For near objects, the lens becomes thicker to increase its refractive power, while for distant objects, it flattens out.
- **Field of Vision**: The range of vision seen without moving the eyes. Peripheral vision is less sharp than central vision due to the distribution of photoreceptors on the retina.

Refractive Errors

- **Myopia (Nearsightedness)**: Occurs when light rays focus in front of the retina, usually due to an elongated eyeball or overly curved cornea. Distant objects appear blurry.
- **Hyperopia (Farsightedness)**: This happens when light rays focus behind the retina, often due to a shorter eyeball or flatter cornea. Close objects are blurry.
- **Astigmatism**: Caused by an irregularly shaped cornea or lens, leading to multiple focal points. Vision can be blurry or distorted at all distances.
- **Presbyopia**: Age-related loss of accommodation, making it difficult to focus on near objects as the lens loses flexibility.

Image Formation

- **Inverted Image**: The image formed on the retina is inverted (upside-down). The brain processes this image and flips it so we perceive it correctly.
- **Resolution**: The sharpness of vision, depends on the density of photoreceptor cells in the retina, particularly in the macula (the central part of the retina).

Photoreception

- **Rods and Cones**: The retina contains photoreceptor cells—rods (for low-light vision) and cones (for color and detail). Cones are concentrated in the fovea, a small pit in the macula, providing sharp central vision.
- **Visual Pathway**: Once light is converted into electrical signals by photoreceptors, these signals travel through the optic nerve to the brain's visual cortex, where they are processed into images.

Visual Perception

- **Binocular Vision**: The overlap of the visual fields of both eyes provides depth perception and a 3D view of the world.
- **Stereopsis**: The brain compares slightly different images from each eye to perceive depth, a phenomenon known as stereopsis.

Schematic Eyes

Gullstrand's Schematic Eye

Gullstrand's Schematic Eye is a more detailed and anatomically accurate model of the human eye, developed by the Swedish ophthalmologist Allvar Gullstrand.

- **It includes multiple refracting surfaces and has six refracting surfaces.**

Refractive Components:

- **Anterior cornea**
- **Posterior cornea**
- **Anterior lens**
- **Posterior lens**
- **Aqueous and vitreous humors**

- **The accommodation exerted in the accommodative state is 10.6D.**
- **The power of the cornea is +37.7D and the power of the lens is +19.11 D.**
- **Total Refractive Power: +58.64 D, so it has a refractive error of +1.00 D (hypermetropic)**

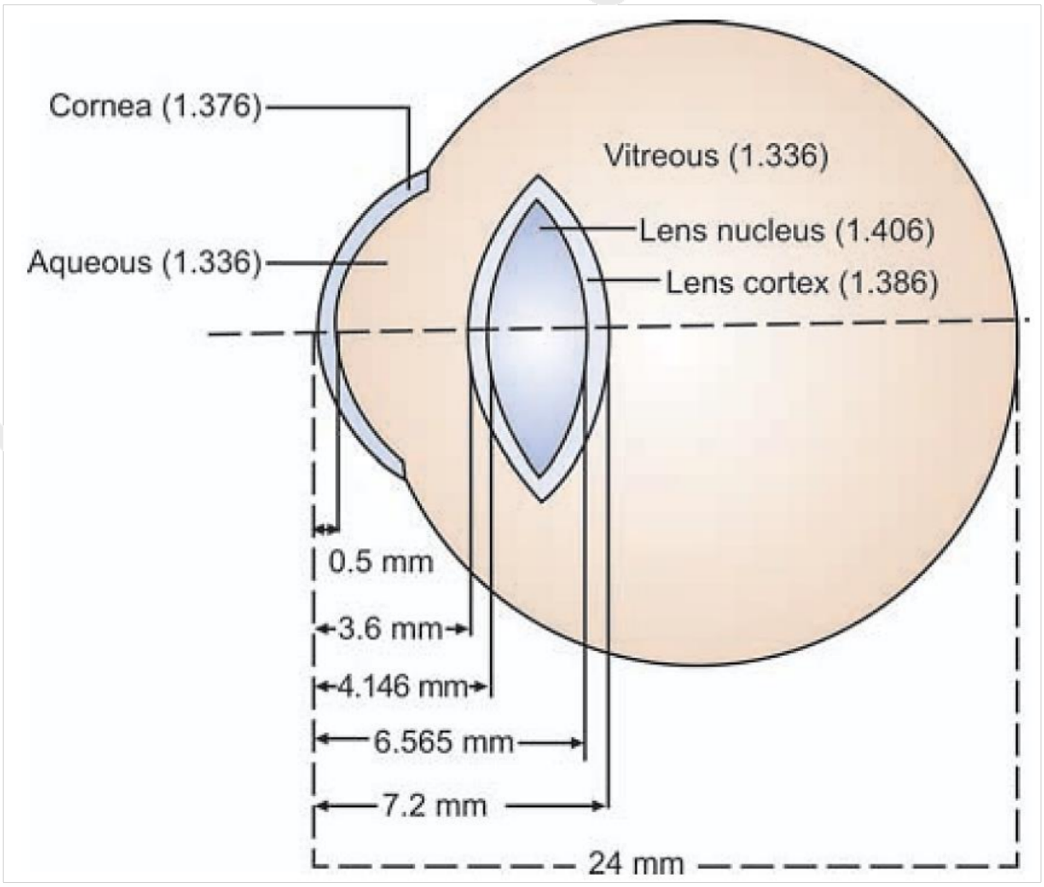

Figure 2: Gullstrand's Schematic Eyes

Gullstrand–Emsley schematic eye

Harold Emsley was a British optician and optical scientist known for his contributions to the field of physiological optics, particularly in the study and modeling of the human eye. His work is highly regarded in the field of vision science and optical design.

"Emsley developed this schematic eye with modifications of Gullstrand's schematic eye"

- **The lens is made optically homogeneous, i.e. the central nuclear area having a different refractive index is abolished.**
- **The posterior corneal surface is also removed.**
- **It has three refracting surfaces.**
- **The refractive index of aqueous humour and vitreous humour is 1.333.**
- **Total Refractive Power: +60.00 D, so is emmetropic**
- **First focal point (f_1) = – 16.67 mm in front of the cornea**
- **Second focal point (f_2) = + 22.22 mm behind the cornea**
- **The axial length of this reduced eye = +22.22 mm**
- **The radius of curvature of the cornea = 5.55 mm.**

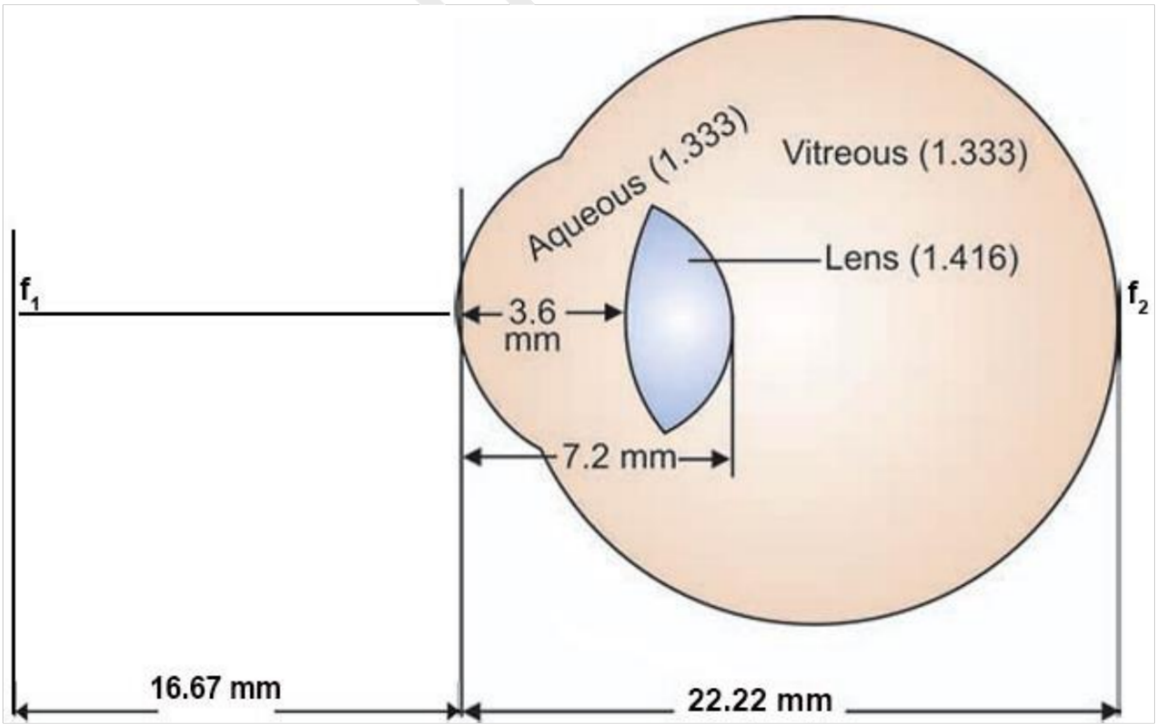

Figure 3: Gullstrand–Emsley schematic eye

Donder's Reduced Eye

is a simplified model of the human eye, introduced by the Dutch ophthalmologist Franciscus Cornelis Donders in the 19th century. This model is used to help understand the basic optical principles of the eye more straightforwardly.

- **It has only one refracting surface, i.e. the cornea with the elimination of the lens.**
- **It's total dioptric strength is +58.6D and its refractive index is 1.336.**
- **It is emmetropic with a second focal length, i.e. axial length of 24.13 mm which second focal point is on the retina. The first focal point is 15.7 mm in front of the cornea.**
- **The radius of curvature of the cornea is 5.73 mm, as opposed to 7.7 mm in a schematic eye.**
- **Since there is only one refracting surface, the first and second principal planes, points and nodal points merge to form only one principal plane, principal point and nodal point.**
- **The principal point is 1.35 mm behind the anterior corneal surface and the nodal point is 7.08 mm behind the anterior corneal surface.**

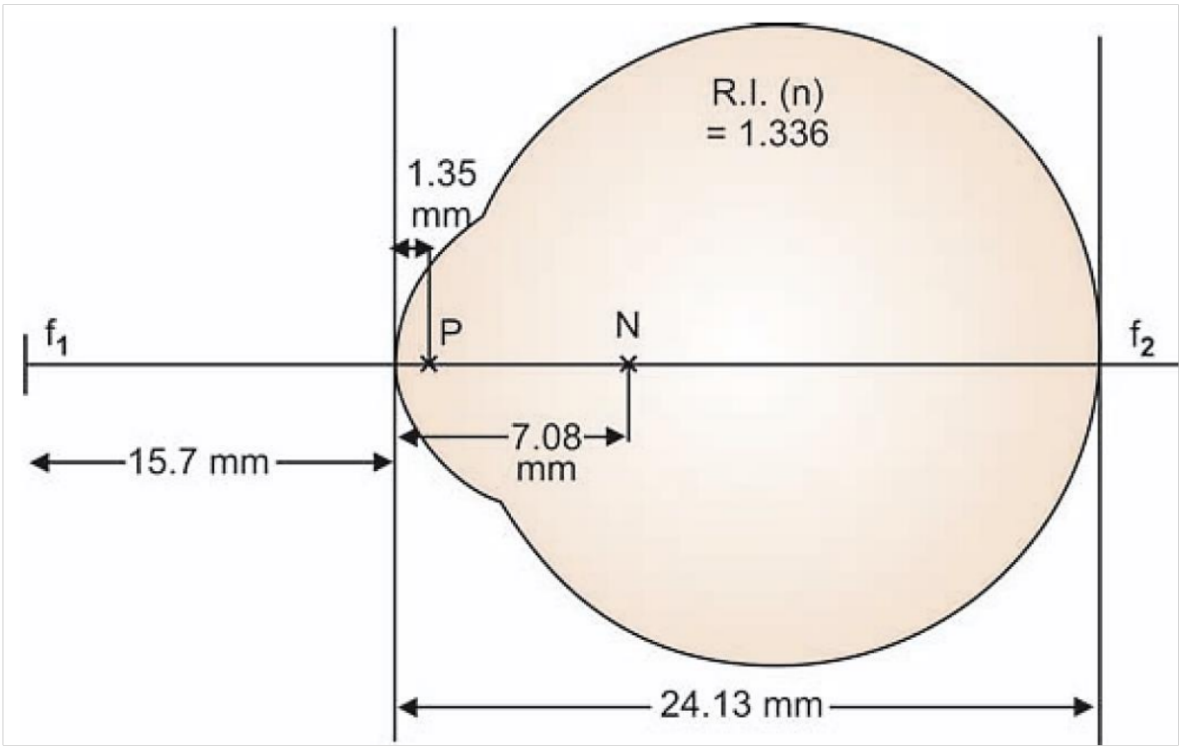

Figure 4: Donder's reduced eye. P = Principal point; N = Nodal point; f_1 = First focal point; f_2 = Second focal point

Axes of The Eye

Visual Axis: is the line that connects the object of regard (the point you're looking at), the center of the entrance pupil, and the fovea (the part of the retina responsible for sharp central vision) (F).

Optical Axis: is the line that passes through the centers of curvature of the cornea and lens. It represents the geometric center of the eye's optical system.

Pupillary Axis: is the straight line which passes through the center of the pupil (E).

Fixation Axis: is the line joining the fixation point with the center of rotation of the eyeball (C).

Angles of The Eye

Angle Alpha (α): is the angle between the optical axis and the visual axis.

Angle Kappa (κ): is the angle between the pupillary axis and the visual axis. This angle is particularly relevant in clinical assessments, such as in the measurement of strabismus. A large Angle Kappa can result in pseudo-strabismus, where the eyes appear misaligned due to the displacement of the visual axis.

Angle Lambda (λ): is often used interchangeably with Angle Kappa, though some distinctions are made in certain contexts. It refers to the angle between the pupillary axis and the line of sight. Angle Lambda is crucial in aligning optical devices, such as during laser eye surgery, to ensure the correction is centered on the visual axis.

Angle Gamma (γ): is the angle between the optical axis and the fixation axis.

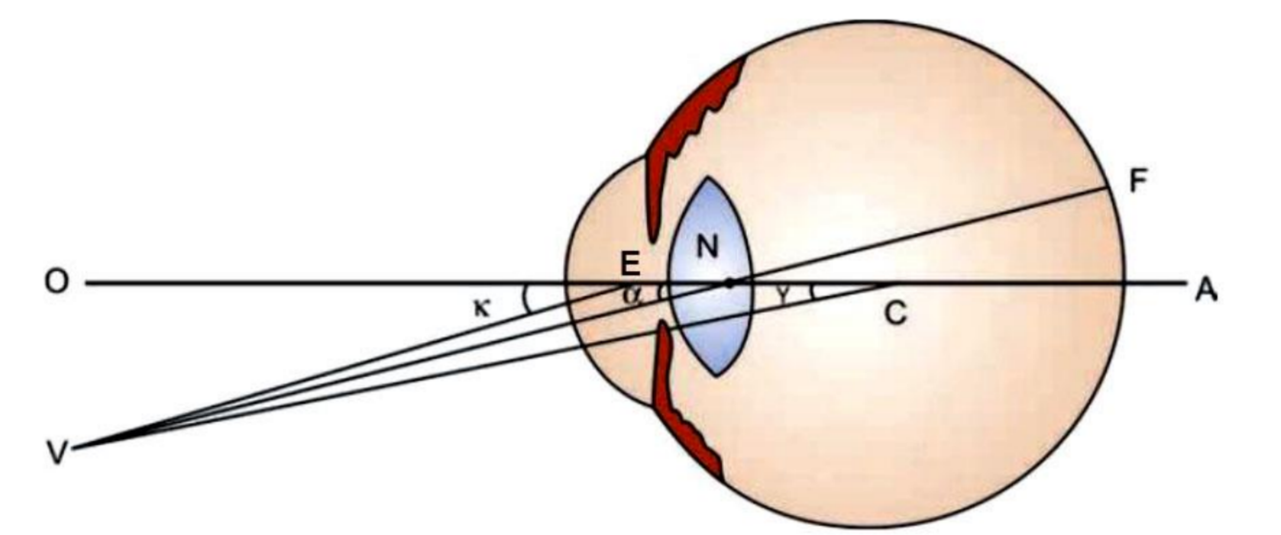

Figure 5: Axes and angles of the eye. OA = Optical axis; VF = Visual axis ; VC = Fixation axis ; VE = Pupillary Axis ; α = VNO ; κ = VEO ; γ = VCO and N = Nodal point

HOME WORK

1. **A patient has an elongated eyeball and experiences difficulty seeing distant objects. Identify the refractive error and suggest a possible correction method.**
2. **Calculate the total refractive power of an eye with the following refractive components: Anterior cornea (+43D), Posterior cornea (+6D), Anterior lens (+14D), and Posterior lens (+5D).**
3. **Compare Gullstrand's Schematic Eye with Donder's Reduced Eye. Discuss the differences in the refracting surfaces and total refractive power.**
4. **Draw and label the axes of the eye, including the Visual Axis, Optical Axis, Pupillary Axis, and Fixation Axis. Explain the significance of Angle Kappa in clinical assessments.**
5. **If the axial length of an eye is 24.5 mm, calculate the refractive error using Donder's Reduced Eye model.**
6. **If the power of the cornea increases by 2D in a patient, how would this affect the total refractive power of the eye? (Use the Gullstrand-Emsley model for reference).**