Al-Furat Al-Awsat Technical University
College of Health and Medical Technologies - Kufa
Department of Vision Screening Techniques

Third Stage 2025-2026

REFRACTIVE ERRORS 3

Lecture Title

HUMAN EYE

Lecture Number: 1 / course 1

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OPTOMETRIST

Human Eye

Anatomy of the Eye

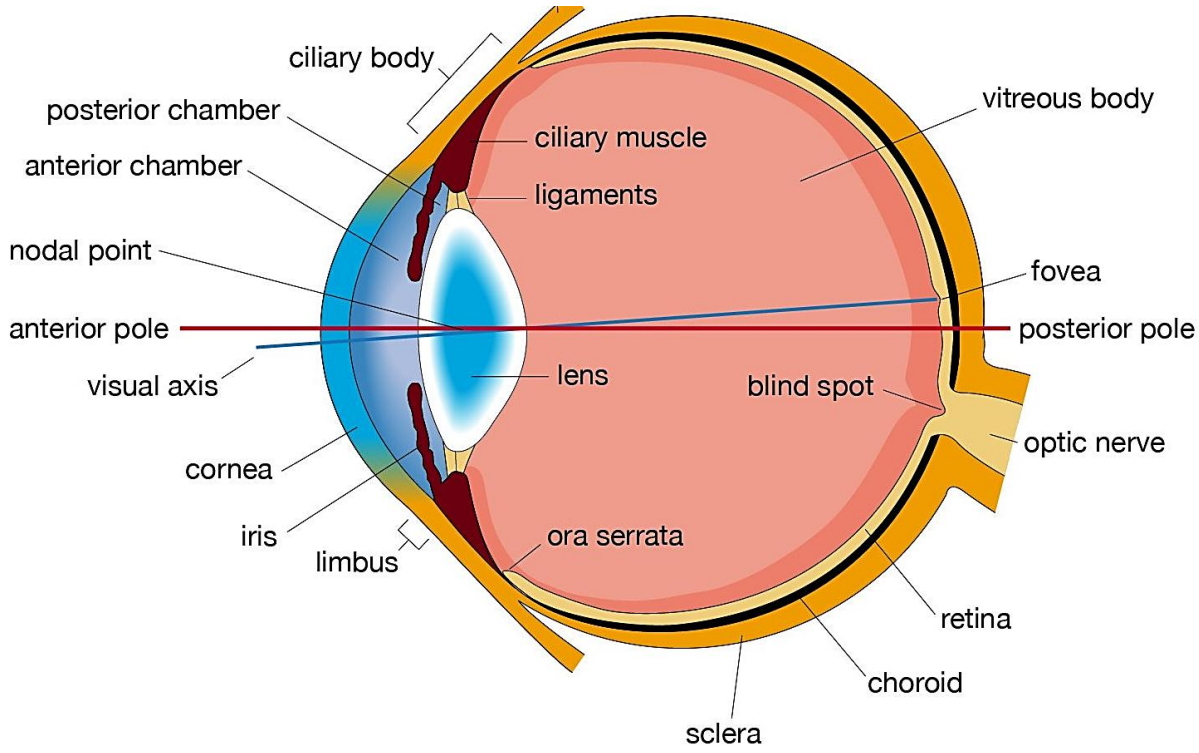


Figure: Human eye

- **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

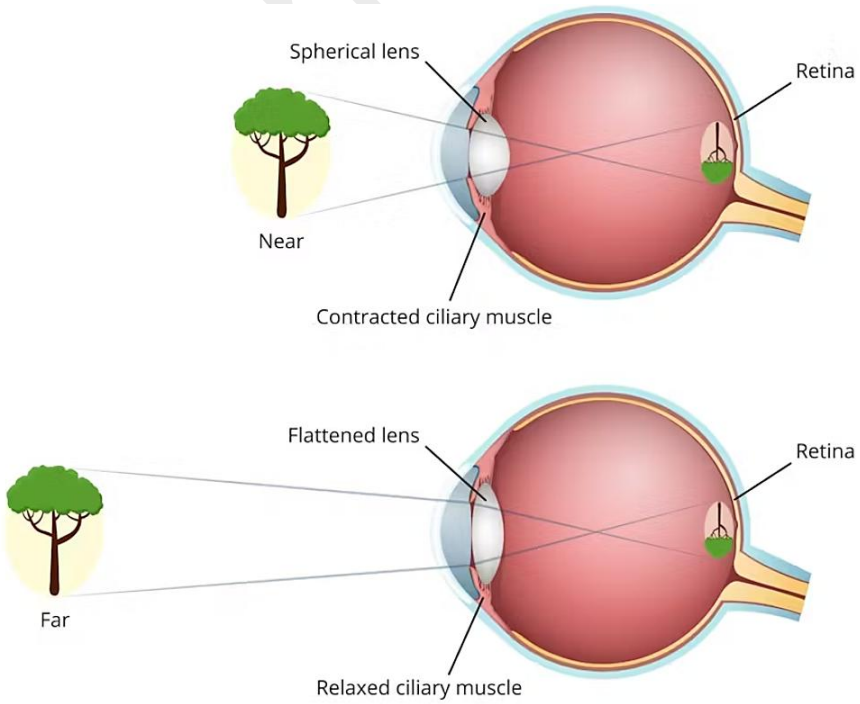
- **Refraction**: The bending of light as it passes through different media (air, cornea, lens) in the eye. This bending is crucial for focusing light on the retina.
- **Focal Point**: Light rays entering the eye are refracted and brought to a focal point on the retina. A sharp image is formed when light 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.

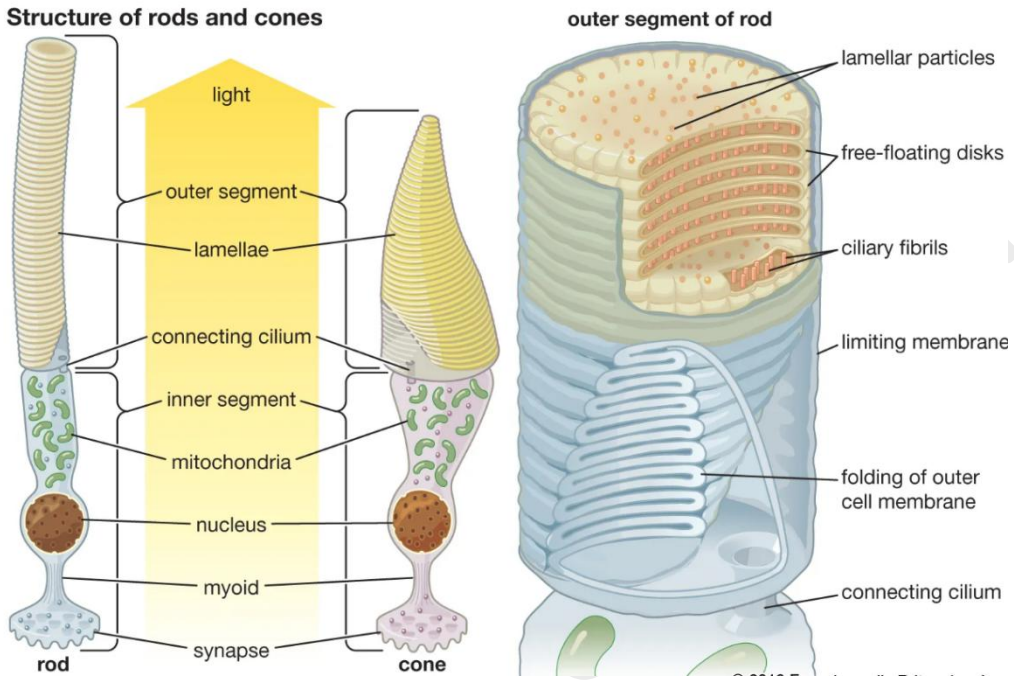
Image Formation

- **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).

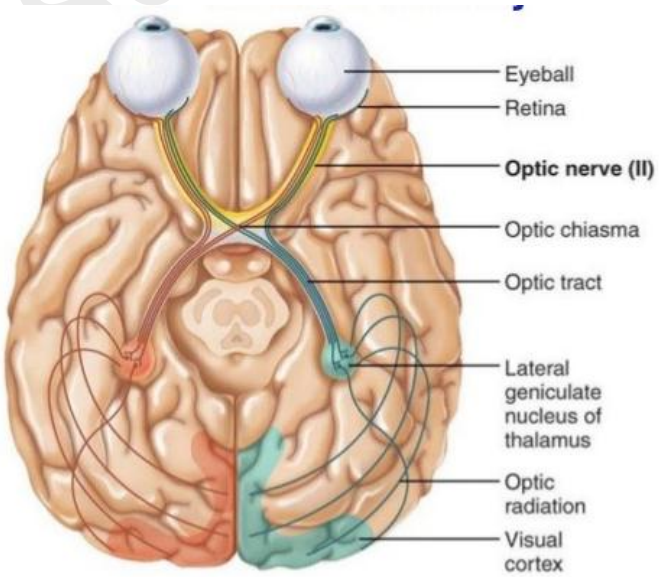


Photoreception

- **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.

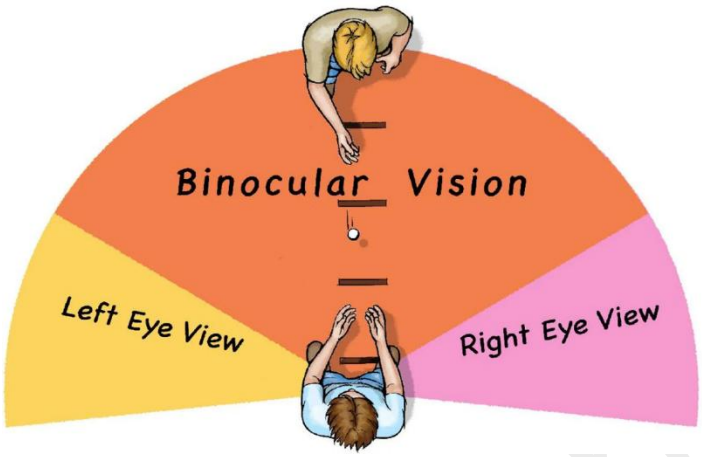


- **Visual Pathway**: Once light is converted into electrical signals by photoreceptors, these signals travel through the optic nerve to the brain's visual cortex, where they are processed into images.



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 +19.11D.
- Total Refractive Power: +58.64 D, so it has a refractive error of +1.00 D (hypermetropic)

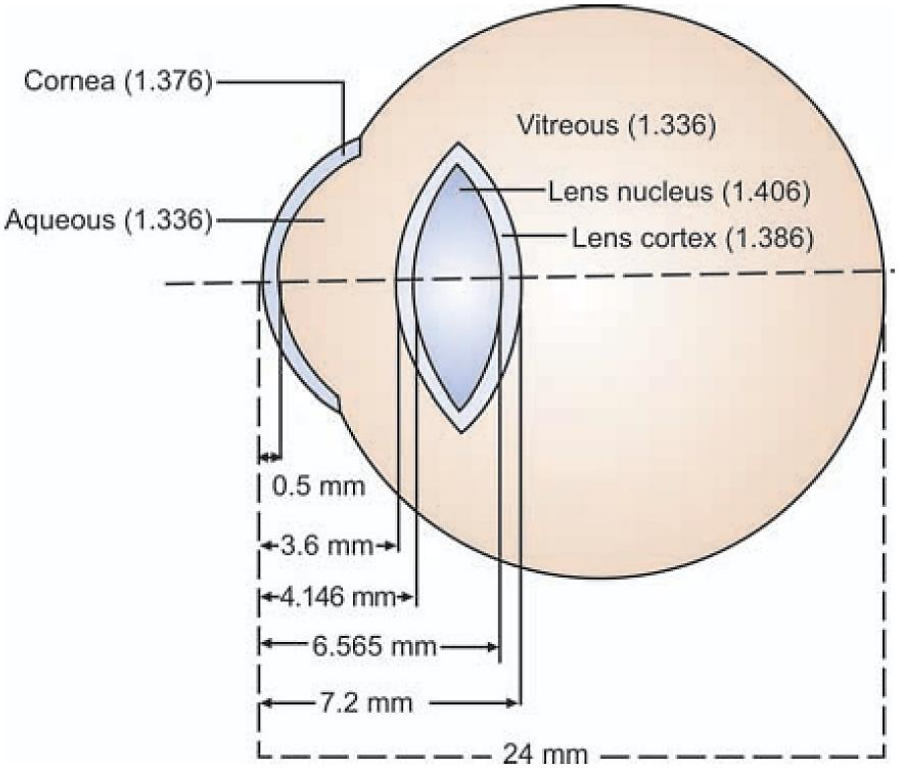


Figure: Gullstrand's Schematic Eyes

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.

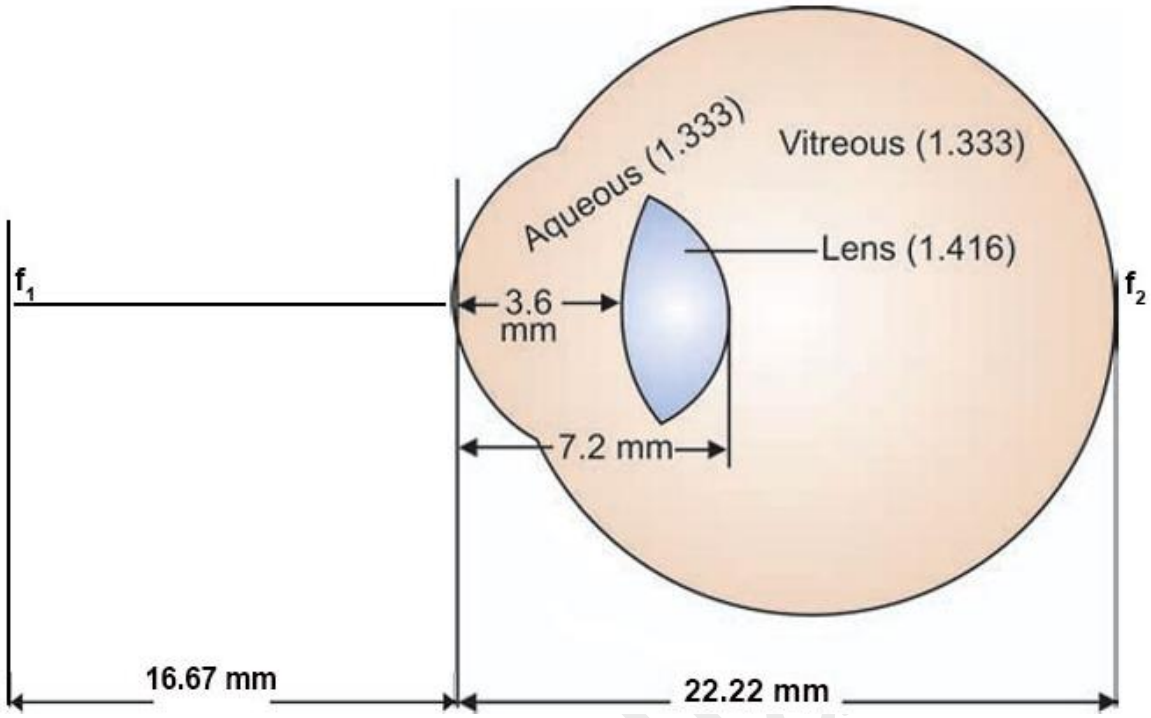


Figure: Gullstrand–Emsley schematic eye

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.
- Its 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, with the second focal point 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.

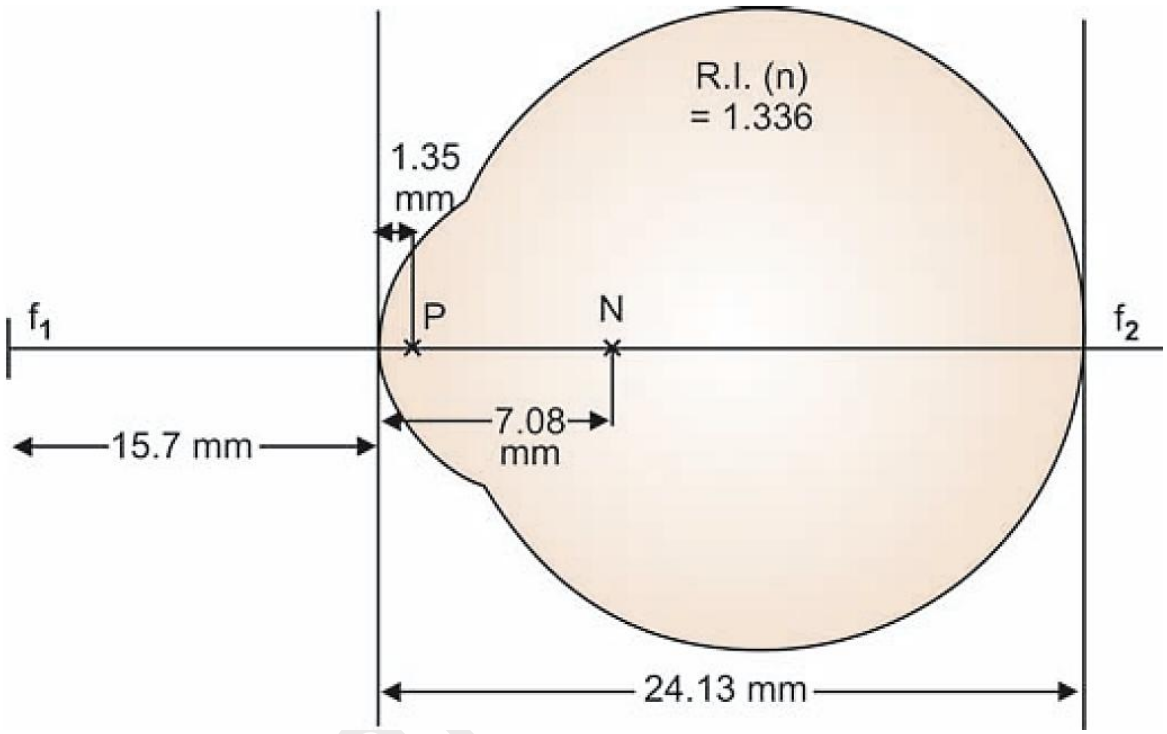


Figure: Donder's reduced eye. P = Principal point; N = Nodal point; f_1 = First focal point; f_2 = Second focal point

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 that 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.

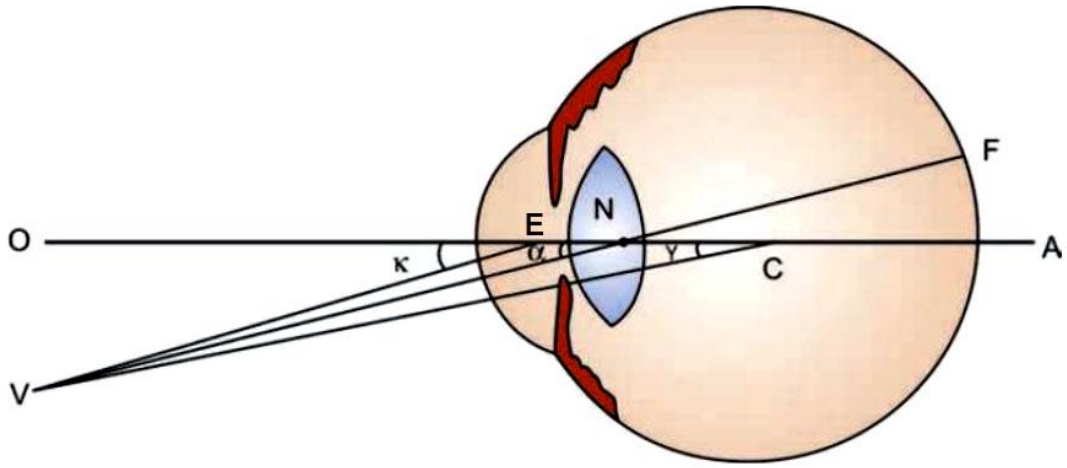


Figure 5: Axes and angles of the eye. OA = Optical axis; VF = Visual axis ; VC = Fixation axis ; VE = Pupillary Axis ; α = VNO ; κ = VEO ; γ = VCO and N = Nodal point

HOME WORK

1. **Explain how the cornea and lens work together to focus light on the retina.** In your answer, mention their refractive indices and relative optical powers.
2. **Describe how accommodation occurs in the eye.** What structural and refractive changes take place in the crystalline lens during near and distant focus?
3. **Differentiate between myopia, hyperopia, and astigmatism** in terms of where the image is formed and what structural changes cause each error.
4. **Define presbyopia** and explain the physiological reason it develops with age.
5. **Explain the difference between binocular vision and stereopsis.** Why is stereopsis considered a higher level of binocular processing?
6. **Discuss the role of the retina and photoreceptors (rods and cones)** in image formation and color vision. How does their distribution affect visual resolution?
7. **Compare the optical and visual axes of the eye.** Then define **Angle Kappa (κ)** and describe its clinical importance.
8. **Explain how the Gullstrand and Emsley schematic eyes differ** in structure and optical power. Why might an optometrist use a simplified model like Emsley's in calculations?
9. **Describe how the image formed on the retina is inverted,** and how the brain processes this image to produce correct visual perception.
10. **A patient after cataract extraction reports that everything appears bluish.** Use your knowledge of ocular optics to explain why this happens and how it can be corrected.

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REFRACTIVE ERRORS 3

Lecture Title

Astigmatism

Lecture Number: 2 / course 1

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Astigmatism

Introduction and Definition

Prevalence and global burden: Astigmatism is the most prevalent form of refractive error. Epidemiological studies indicate that it affects approximately 40% of adults worldwide and roughly 15% of children. Its prevalence varies by region and ethnicity, making it a major contributor to visual impairment and a key public health concern.

Optical mechanism

In an emmetropic eye, all meridians of the cornea and crystalline lens have equal curvature, allowing incoming light rays to focus at a single point on the retina. In astigmatism, one or more meridians differ in curvature, causing unequal refraction of light and the formation of two focal lines instead of a single focus. The steeper meridian has higher refractive power and focuses light sooner, while the flatter meridian focuses light farther back. This results in blurred or distorted vision along specific axes.

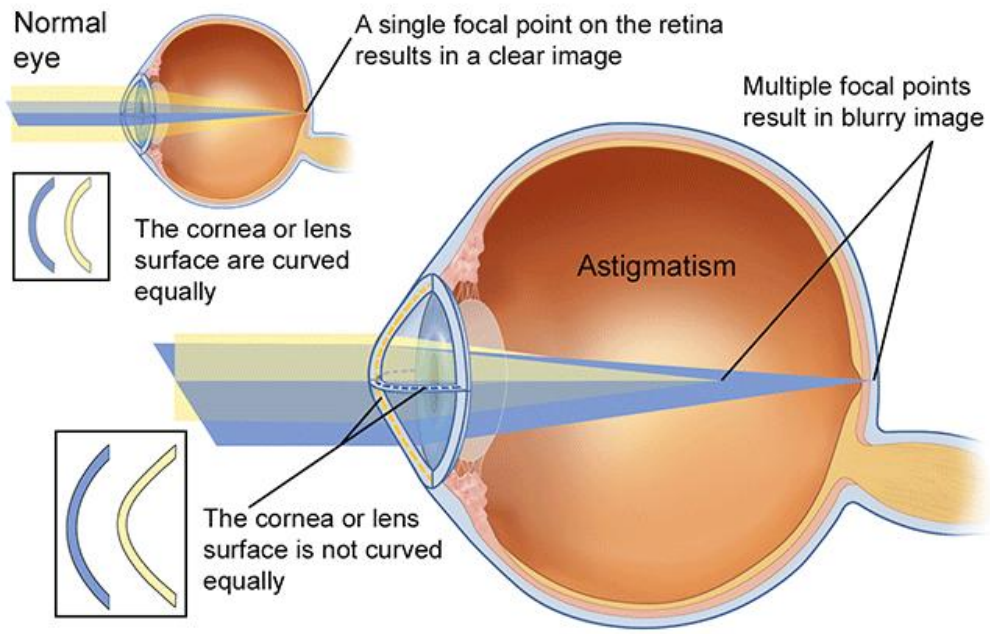


Figure 1. An astigmatic eye showing two focal points.

- **Regular Astigmatism and Sturm's Conoid:** In regular astigmatism, the refracting surface (such as the cornea or lens) is toric, meaning it has two principal meridians that are perpendicular to each other. Each meridian has a different curvature and therefore a different refractive power.

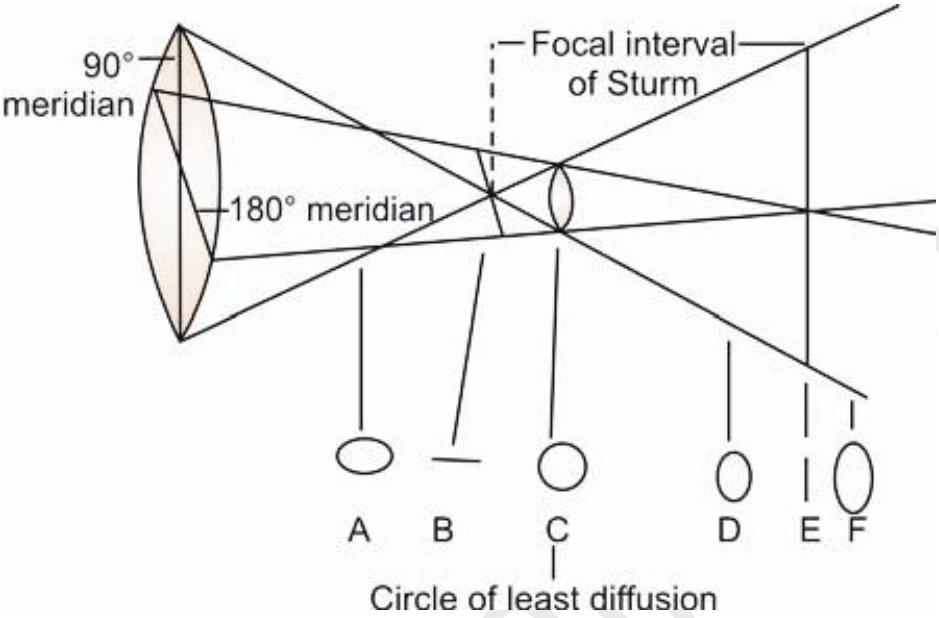


Figure 2. Conoid of Sturm and interval of Sturm.

Figure 2 illustrates a regularly astigmatic surface that has a toric curvature and has the following features:

1. Principal Meridians

- The 90° meridian (vertical) is more curved and has greater refractive power.
- The 180° meridian (horizontal) is flatter and has less refractive power.

2. Focal Lines

When parallel rays of light enter the eye or lens:

- Rays in the more curved meridian (vertical) are refracted more strongly and come to focus closer to the lens.
- Rays in the less curved meridian (horizontal) are refracted less and focus farther away.

As a result, there are two focal lines instead of one focal point:

- The first focal line corresponds to the more powerful meridian.

- The second focal line corresponds to the weaker meridian. The distance between these two focal lines is called the Focal Interval of Sturm.

3. Sturm's Conoid

It is a three-dimensional pattern of refracted rays in astigmatism, formed between two focal lines. The light cross-sections change from elliptical to circular depending on the distance from the lens.

In the diagram (A–F):

A: Vertical ellipse

B: Horizontal line (first focal line)

C: Circle (Circle of least diffusion – best focus)

D: Vertical line (second focal line)

E–F: Vertical ellipse again

4. Circle of Least Diffusion

It is the midpoint between the two focal lines in an astigmatic eye. At this point, the blur is minimal and symmetrical, forming a small, nearly clear circular image. Clinically, it represents the best possible focus when the astigmatism is not fully corrected.

Historical Development of Astigmatism Correction

- Thomas Young first recognized the condition in 1801, and he discovered his own astigmatism.
- George Airy, in 1827, constructed the first cylindrical lens to correct his astigmatism, establishing the foundation for modern optical correction. Over time, optical instruments such as keratometers and topographers enhanced diagnosis.
- In the 20th century, toric contact lenses became available, followed by advanced surgical options like LASIK, PRK, and toric IOL implantation.

Optical Basis and Classification

❖ Based on the angle between the two principal meridians

a) **Regular astigmatism**: the two principal meridians' curvatures are positioned at right angles, i.e., 90° to each other.

b) **Irregular astigmatism (Bi–Oblique)**: Principal meridians are not orthogonal and may vary across the cornea. This type often results from corneal disease (e.g., keratoconus), trauma, or surgical incisions and produces distorted vision that cannot be fully corrected with simple cylindrical lenses.

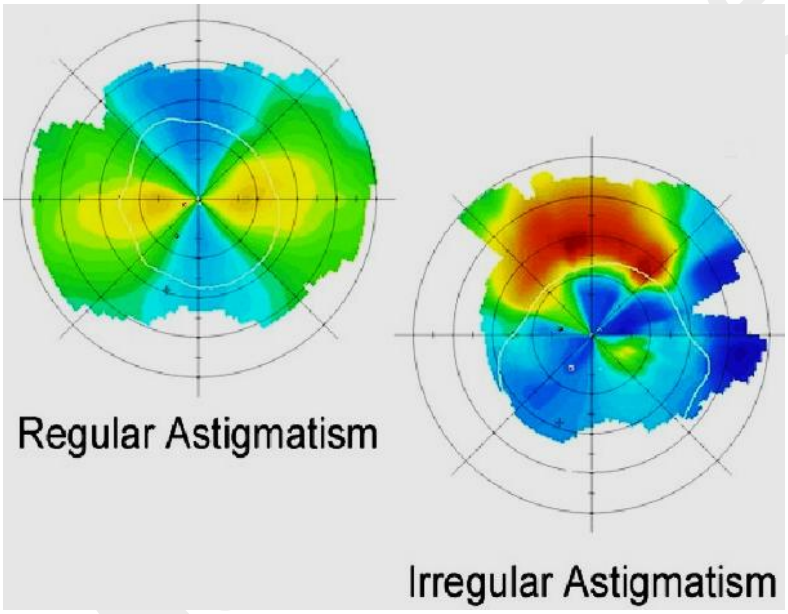


Figure 3. Corneal topography: regular vs irregular astigmatism.

❖ Based on Aetiology

a) **Corneal Astigmatism**

i. ***Astigmatism with–the–rule (WTR)***: usually, the vertical corneal meridian is more curved than the horizontal one, “vertical meridian steeper (~180°)” (Fig. 2A).

ii. ***Astigmatism against-the-rule (ATR)***: the corneal curvature in the horizontal meridian is greater than the vertical one, “horizontal meridian steeper (~90°)” (Fig. 2B).

iii. ***Oblique astigmatism***: here the radii of curvature are aligned at 90° to each other, but the two principal meridians are neither near horizontal nor near vertical "axes between 30–60° or 120–150°" (Fig. 2C).

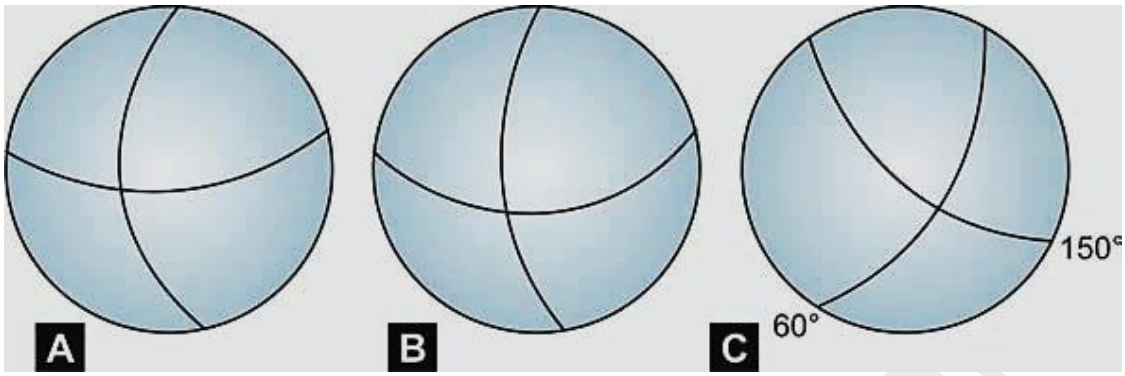


Figure 4. Types of astigmatism based on the orientation of the maximum curvature of the cornea. (A) = With-the-rule, (B) = Against-the-rule and (C) = Oblique

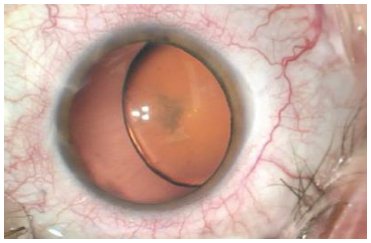
b) Lenticular astigmatism

i. ***Curvature***: It is due to variations in the curvature of one or both surfaces. Lenticular astigmatism is typically against the rule and it tends to neutralize the corneal astigmatism.

ii. ***Index***: It is due to the inequalities of refractive index in different sections of the lens. It is seen in early cataract and is the cause of polyopia in early cataract.

iii. ***Displacement of the refractive element***

- ✓ crystalline lens, i.e., subluxation خلع جزئي
- ✓ decentration or tilting of pseudophakia (IOL).



❖ Based on the refractive status

Regular astigmatism may coexist with myopia or hyperopia and is classified using the refractive status of the two principal meridians:

1. **Simple astigmatism:** here, one image is located in the retinal plane and based on the location of the other image, it may be:

i. ***Simple myopic astigmatism***: The other image is located in front of the retina (Fig.5A).

ii. ***Simple hypermetropic astigmatism***: The other image is located behind the retina (Fig.5B).

2. **Compound astigmatism:** here, both the images are either in front of the retina or behind the retina and are designated as:

i. ***Compound myopic astigmatism***: light focuses in front of the retina in both meridians, but by different amounts (Fig.5C).

ii. ***Compound hypermetropic astigmatism***: both focal lines lie behind the retina, but not at the same distance (Fig. 5D).

3. **Mixed astigmatism:** here, one image is formed in front of the retina and the other image is located behind the retina (Fig. 5E).

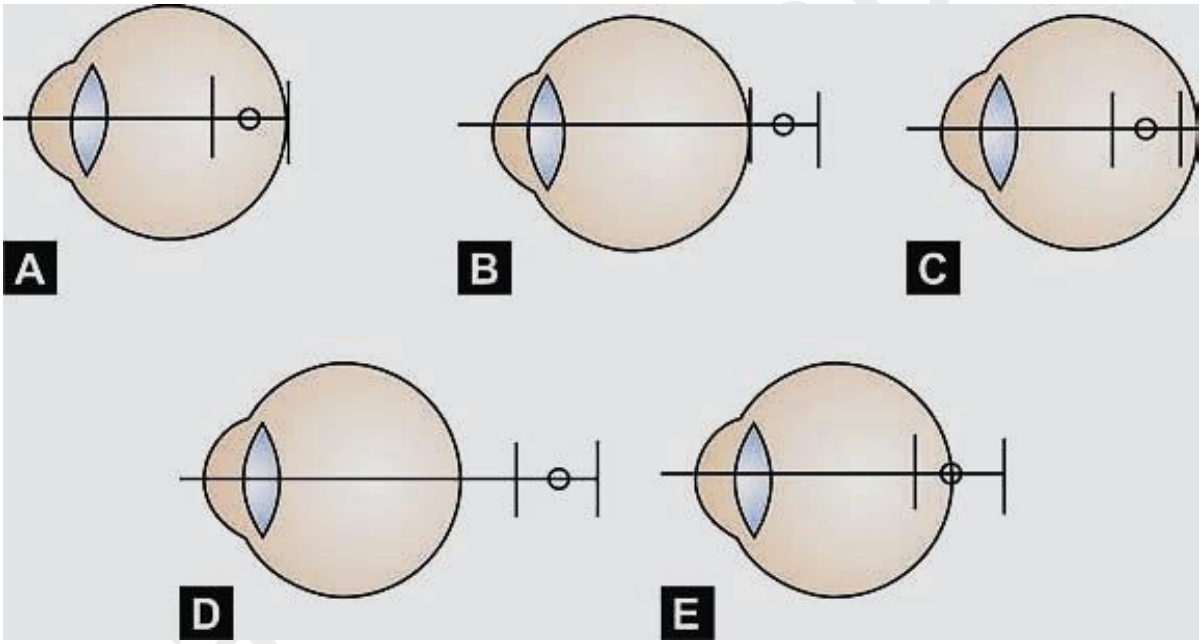


Figure 5. Types of astigmatism, O = Circle of least diffusion

Etiology and Risk Factors

Astigmatism arises when the eye's optical system fails to focus light uniformly across all meridians. Its causes can be genetic, developmental, mechanical, or environmental. Understanding these helps in diagnosis and management.

1. Genetic and developmental factors

- ***Inherited corneal shape***: Many individuals are born with a cornea that is naturally more curved in one meridian than another. Familial clustering and twin studies support a strong genetic component in corneal curvature and toricity.
- ***Embryologic development***: Uneven growth of the cornea or crystalline lens during prenatal and early postnatal periods can establish astigmatism. Developmental anomalies in the eyelids or extraocular muscles may also exert asymmetric pressure on the cornea.

2. Structural and mechanical influences

- ***Eyelid pressure***: The pressure exerted by the eyelids, particularly the upper eyelid, can mould the cornea over time. A tight or asymmetric lid may steepen one meridian more than the other, contributing to with-the-rule astigmatism in youth.
- ***Extraocular muscle tension***: Imbalances in muscle tension can alter globe shape subtly, influencing corneal curvature along specific axes.
- ***Ocular surgery and trauma***: Surgical incisions (e.g., cataract or pterygium surgery) and trauma can induce irregular scarring and alter corneal shape. Suturing technique, incision location and wound healing all affect postoperative astigmatism.

3. Pathologic corneal conditions

- ***Keratoconus and ectasia***: Thinning and progressive steepening of the cornea, as seen in keratoconus or pellucid marginal degeneration, produce irregular astigmatism. These conditions often begin in adolescence and require specialized management.
- ***Corneal scarring***: Injuries or infections that scar the cornea can distort its curvature, leading to unpredictable astigmatism.

4. Lens-related factors

- ***Lenticular toricity or tilt***: Subtle differences in curvature between the anterior and posterior surfaces of the crystalline lens or a slight tilt/decentration of the lens can induce lenticular astigmatism. Changes in lens shape during accommodation can also temporarily modulate the astigmatic component.
- ***Age-related lens changes***: As the crystalline lens ages, it may thicken asymmetrically or undergo nuclear sclerosis, altering its refractive index. These changes can increase pre-existing astigmatism or shift its axis from with-the-rule to against-the-rule.

5. Environmental and Systemic Influences

- ***Ethnicity and gender***: Epidemiologic studies reveal variations in astigmatism prevalence among different ethnic groups, with some populations exhibiting higher rates. Male sex has been associated with a slightly higher risk in certain cohorts.
- ***Refractive errors***: High degrees of myopia or hyperopia often accompany astigmatism. The interplay between axial length and corneal curvature can influence the magnitude and progression of astigmatic error.
- ***Screen exposure and near work***: Excessive screen time and prolonged near tasks during early childhood have been linked to increased risk of

developing astigmatism, possibly due to altered visual feedback and prolonged accommodation.

- ***Prematurity factors***: Maternal smoking during pregnancy, premature birth, and low birth weight have been associated with higher rates of refractive anomalies, including astigmatism.
- ***Systemic conditions and obesity***: Emerging research suggests correlations between higher body mass index and certain types of astigmatism, although the mechanisms remain under investigation.

Symptoms and Clinical Manifestations

A comprehensive understanding of how astigmatism presents clinically enables prompt recognition and appropriate management. Symptoms vary depending on the magnitude and type of astigmatism, age, and the presence of other refractive errors.

1. Visual symptoms

Astigmatism causes light to focus at different depths along separate meridians, leading to characteristic visual disturbances:

- ***Blurred or distorted vision*** at all distances; images may appear stretched or shadowed along one axis.
- ***Ghosting or double images (monocular diplopia)*** in moderate to high or irregular astigmatism, especially in low light.
- ***Poor detail resolution***, making tasks like reading small print or recognizing distant signs difficult.
- ***Night-time visual problems***, including halos, glare and starbursts around lights.

2. Asthenopic symptoms

Persistent attempts to compensate for unequal meridional focus can lead to:

- ***Eye strain and fatigue***: The constant effort to achieve focus across different meridians can lead to fatigue of the ciliary muscles and extraocular muscles. Patients often report tired eyes, especially after prolonged near work or screen use.
- ***Headaches***: Sustained squinting and accommodative strain often cause frontal or brow headaches, typically worse later in the day.
- ***Squinting and frowning***: Patients may narrow their eyelids to create a pinhole effect, temporarily improving clarity by limiting peripheral light rays.

3. Pediatric manifestations

- ***Reading difficulties***: Children with uncorrected astigmatism may struggle with reading, lose their place easily or avoid near tasks. Teachers may misinterpret this as a learning disorder.
- ***Amblyopia (lazy eye)***: High astigmatism during visual development can lead to reduced visual acuity in one or both eyes, a condition that is reversible only if detected and treated early.
- ***Head tilt or abnormal posture***: To find a clearer line of sight, children might tilt their head or hold books very close. Persistent head tilt requires evaluation to distinguish between compensatory behavior and musculoskeletal or neurological issues.

Clinical signs

Examination may reveal:

- Improved acuity with pinhole testing.
- A characteristic “scissor reflex” on retinoscopy.
- Distorted keratometry mires or asymmetric topography rings indicate irregular astigmatism.
- Photophobia and tearing in association with ectatic disorders like keratoconus.

HOME WORK

Questions

1. Define astigmatism and explain how it affects the focusing of light on the retina.
2. What are the principal meridians, and how do they determine the optical properties of an astigmatic eye?
3. Describe the concept of Sturm's conoid and the circle of least confusion. Why are they clinically important?
4. Differentiate between regular and irregular astigmatism with one example of each.
5. Explain the differences between with-the-rule, against-the-rule, and oblique astigmatism based on corneal curvature.
6. Classify astigmatism based on refractive status (simple, compound, and mixed) with examples.
7. List three major causes or risk factors that can lead to the development of astigmatism.
8. Mention two common clinical symptoms of uncorrected astigmatism and explain why they occur.
9. Name two diagnostic tests used to detect and measure astigmatism, and describe the principle of one of them.
10. Why is early detection and correction of astigmatism important in children?

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Lecture Title

Astigmatism

Lecture Number: 3 / course 1

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Astigmatism

Management and Correction Options

The goal of astigmatism management is to align the principal meridians so that incident light converges at a single focal point on the retina, thereby restoring clear vision. Treatment selection depends on the type (regular versus irregular), magnitude, patient age, occupation, lifestyle, ocular surface health, and coexisting conditions.

1. Optical correction

- **Eyeglasses (Spectacles):** Cylindrical or sphero-cylindrical lenses remain the simplest and most widely used method for correcting regular astigmatism. They neutralize the difference in curvature between the principal meridians by introducing an equal and opposite toric power. Modern free-form lens technology enables the custom tailoring of lens power to the wearer's exact prescription and frame position, thereby improving peripheral optics and reducing aberrations. Progressive addition lenses can incorporate toric corrections for presbyopic patients, providing seamless distance, intermediate and near vision.
- **Soft toric contact lenses**: For patients who prefer contact lenses, soft toric lenses offer convenience and good comfort. These lenses employ prism ballast, periballast, dynamic stabilization or other designs to maintain rotational stability on the eye. Advances in silicone hydrogel materials have enhanced oxygen permeability, allowing for extended wear in suitable patients. However, soft toric lenses may be less effective for high degrees of astigmatism (>2.50 D) and can be susceptible to rotation, causing fluctuating vision.
- **Rigid gas-permeable (RGP) lenses**: RGP lenses provide a smooth refracting surface over the cornea, masking moderate corneal irregularities and delivering crisp optics. They are particularly advantageous for moderate to high astigmatism or when soft toric lenses yield inadequate visual quality.

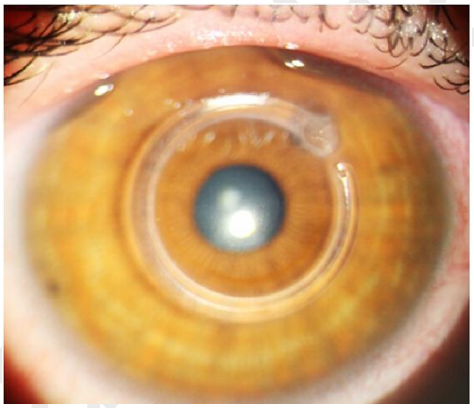
Specialty designs, such as bitoric and front-surface toric RGP lenses, are available for high corneal cylinder. Initial adaptation can be challenging, and lens awareness may limit tolerance.

- **Scleral and hybrid lenses**: When conventional contacts are insufficient, particularly in irregular astigmatism secondary to keratoconus, pellucid marginal degeneration, or post-surgical ectasia, large-diameter scleral lenses vault the cornea entirely and rest on the sclera. This design creates a fluid reservoir between the lens and cornea, neutralizing irregularities and providing stable optics. Hybrid lenses combine a rigid center with a soft skirt, offering improved comfort while maintaining the optical benefits of RGP lenses.
- **Orthokeratology (corneal reshaping therapy)**: Orthokeratology uses specially designed RGP lenses worn overnight to temporarily reshape the cornea by flattening the central area and steepening the periphery. Appropriately fitted, these lenses can correct low to moderate myopia with astigmatism of up to approximately 1.50 D, enabling unaided daytime vision. It is particularly appealing to active individuals and may slow myopia progression in children. Strict adherence to hygiene protocols and regular follow-up is crucial to minimizing the risk of microbial keratitis.

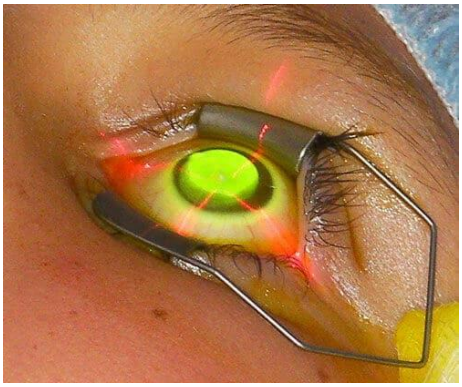
2. Laser and surgical interventions

- **Photorefractive keratectomy (PRK) and laser-assisted in situ keratomileusis (LASIK)**: Excimer laser ablation can sculpt the corneal stroma to correct both spherical and cylindrical components of refractive error. LASIK combines a lamellar flap with stromal ablation, whereas PRK removes the epithelium and ablates the anterior stroma. Wavefront-guided and topography-guided treatments enhance precision and reduce higher-order aberrations, particularly in irregular astigmatism. Candidates require adequate corneal thickness, a healthy ocular surface, and stable refraction.

- **Small incision lenticule extraction (SMILE)**: SMILE uses a femtosecond laser to create and remove an intrastromal lenticule through a small incision, leaving the anterior stroma largely intact. It effectively treats moderate myopic astigmatism with minimal dry eye symptoms and rapid recovery. Nomogram adjustments account for surgical and healing factors to optimize astigmatic outcomes.
- **Arcuate keratotomy (AK) and intrastromal corneal ring segments (ICRS)**: Limbal relaxing incisions or femtosecond-laser arcuate cuts can reduce mild to moderate corneal astigmatism by weakening the steeper meridian. ICRS (e.g., Intacs) flattens the corneal curvature and regularizes the surface in keratoconus or post-LASIK ectasia. These techniques may be combined with cross-linking to halt progression.

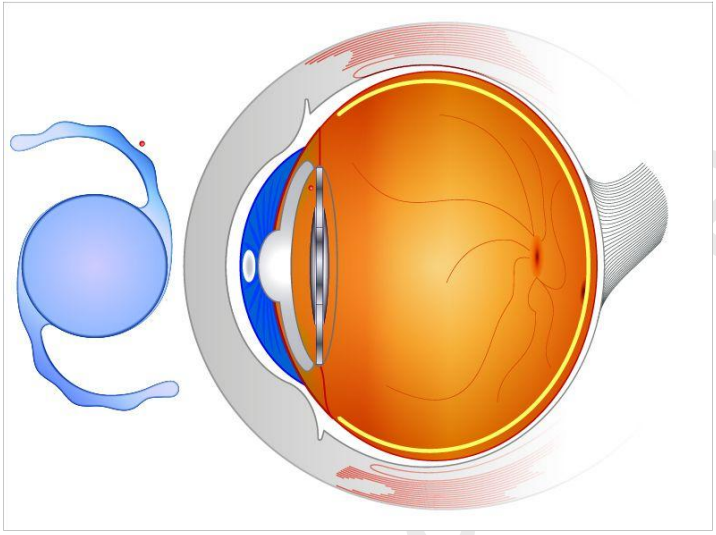


- **Corneal collagen cross-linking (CXL)**: Although not a refractive procedure per se, CXL stiffens the corneal stroma via riboflavin and ultraviolet-A exposure, stabilizing keratoconus and post-surgical ectasia. It is often combined with topography-guided PRK or ICRS to improve corneal regularity and reduce irregular astigmatism.



3. Intraocular lens solutions

- **Toric phakic intraocular lenses (IOLs)**: For patients with high degrees of myopic or hyperopic astigmatism who are unsuitable for corneal refractive surgery, toric phakic IOLs (e.g. implantable collamer lenses) provide predictable and reversible correction. Proper sizing and vaulting are critical to avoid complications such as cataract formation or glaucoma.



4. Management of irregular astigmatism

Irregular astigmatism, frequently due to ectatic disorders or corneal scars, demands a tailored approach:

- Rigid or scleral contact lenses remain the first-line treatment to provide a regular refractive surface.
- Topography-guided excimer ablation combined with CXL can normalize corneal shape and stabilize progression.
- Penetrating or deep anterior lamellar keratoplasty (PK/DALK): Advanced keratoconus or scars not correctable with contact lenses may necessitate corneal transplantation. Post-keratoplasty astigmatism can be significant; suture adjustment, selective suture removal, or secondary refractive procedures are often required.

5. Patient counselling and follow-up

Successful management hinges on patient education, realistic expectations and diligent follow-up. Regular monitoring ensures timely detection of progression, complications, or changes in refractive status. For children, early screening and correction prevent amblyopia. For adults, lifestyle, occupational demands and ocular health guide the choice among spectacles, contact lenses and surgical options. Engaging patients in shared decision-making enhances satisfaction and compliance, ultimately leading to the best visual outcomes.

Diagnostic Instruments & Techniques

The core of astigmatism diagnosis is a comprehensive eye examination that assesses visual acuity, refractive status and corneal geometry. Modern optometry utilises several complementary tests:

Objective assessment tools include:

1. **Retinoscopy:** followed by subjective refraction with a phoropter or trial lenses, determines the spherical and cylindrical components.

2. **Keratometry**: measures curvature of the central anterior cornea by analysing reflections from mires. Manual keratometry is cost-effective but samples only a 3–4 mm zone and assumes orthogonal meridians; it fails to detect peripheral or lenticular astigmatism.

The device measures only the **central area of the cornea (~3 mm)**, since this zone is mainly responsible for vision (the optical zone).

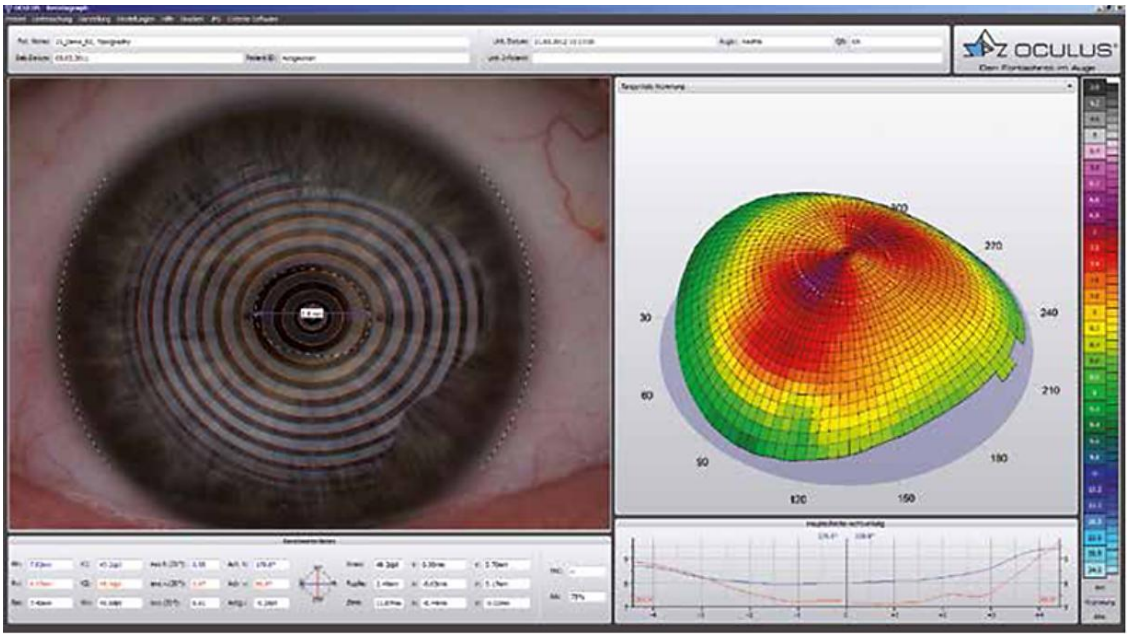
- It is very useful in diagnosing **regular astigmatism**.
- However, it is not sufficient to detect all **irregularities** of the cornea, such as early **keratoconus** or corneal scars, because these changes may appear in the peripheral regions that the keratometer does not measure.

3. **Autorefractometry:** automated devices quickly provide refractive measurements and are particularly useful in pediatric screenings.

4. **Placido keratoscope disc:** This test reflects irregularities on the corneal surface. The examiner looks through a hole in the center of the disc, with alternatingly painted black and white circles, at the corneal image reflected from a light behind the patient.

Figure 6. Placido disc ring patterns – normal vs astigmatic cornea

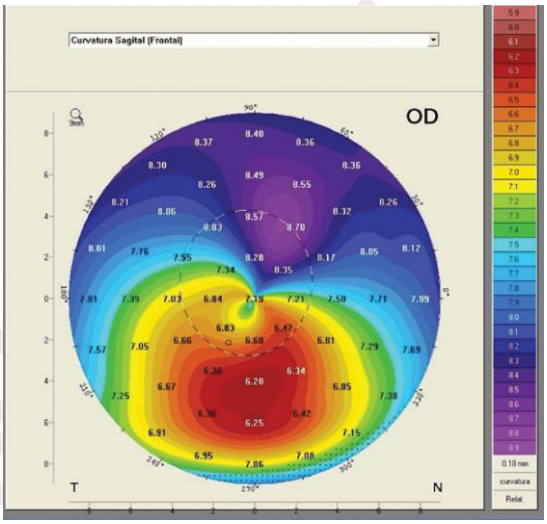
5. **Corneal topography:** generates a color-coded map of the entire cornea (anterior and posterior surfaces).



- Uses Placido disc reflections to map the anterior corneal surface only.
- Provides color-coded curvature maps (steep vs. flat areas).
- Limited: cannot image the posterior surface or corneal thickness.
- Accuracy affected by tear film quality.

6. **Scheimpflug Imaging (Pentacam):** assesses anterior and posterior corneal surfaces and pachymetry.

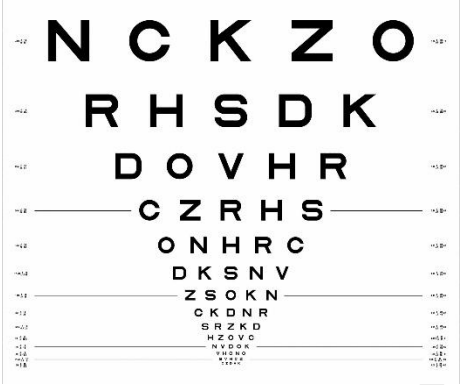
- Uses a rotating Scheimpflug camera to create a 3D model of the anterior eye.
- Measures anterior + posterior corneal surfaces and pachymetry.
- Provides curvature, elevation, and thickness maps.
- More accurate in detecting early keratoconus and ectasia.



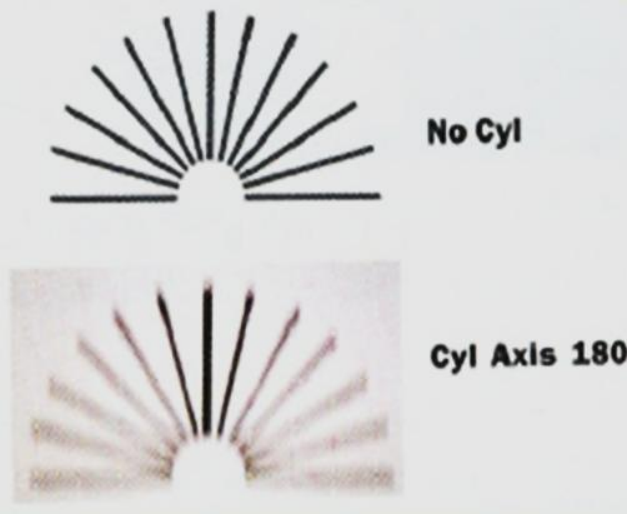
7. **Anterior-segment optical coherence tomography (AS-OCT):** high-resolution imaging that captures cross-sectional views of the anterior eye; it measures anterior and posterior corneal curvature, corneal thickness and lens position, and is useful for surgical planning.

Subjective

1. **Visual acuity testing**: Snellen or ETDRS charts evaluate uncorrected and corrected acuities. Pinhole testing helps differentiate refractive from ocular pathology



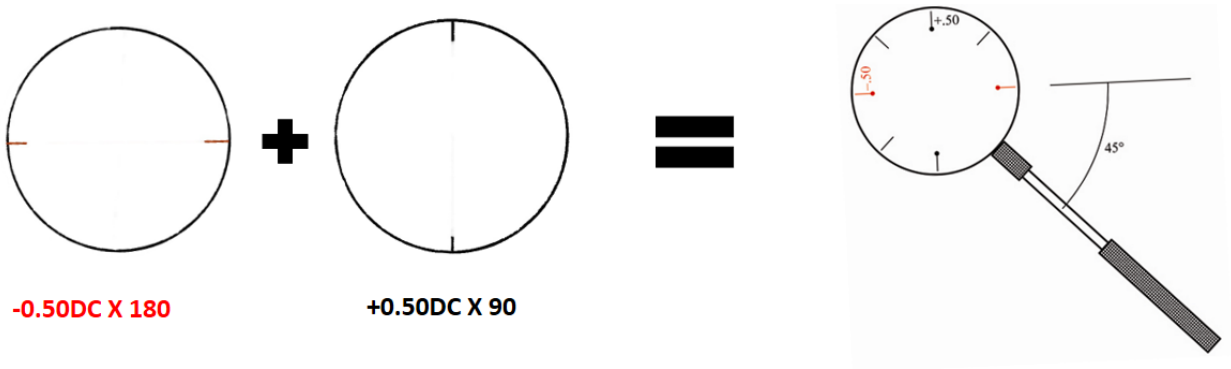
2. **Astigmatic fan:** It is used to measure the strength of the cylindrical lens and its axis. The endpoint of cylindrical lens correction is achieved when the outline of the whole fan becomes equally clear and sharp. The axis of the cylinder is perpendicular to the line that was initially most clearly defined.



3. **Stenopaeic slit test**

S

4. Jackson's cross cylinder test (JCC test)



Astigmatism in Pediatrics

- **Threshold of concern:**
  - ✓ Astigmatism greater than 1.5 D in children requires early correction to prevent amblyopia.
- **Meridional amblyopia:**
  - ✓ Caused by unequal stimulation of retinal neurons.
  - ✓ Results from blurred images confined to a specific meridian.
- **Management:**
  - ✓ Spectacles: first-line correction for most children.
  - ✓ Contact lenses: recommended for older children or when spectacles are poorly tolerated.
- **Public health importance:**
  - ✓ School vision screening programs are essential for early detection and timely correction of refractive errors.

Impact on Quality of Life

- Uncorrected astigmatism impairs reading and learning ability.
- Night vision difficulties: glare, halos.
- Workplace performance is reduced due to visual fatigue.
- Quality of life measured by VFQ-25 shows lower scores in high astigmatism.

Complications of Uncorrected Astigmatism

If left untreated, astigmatism may lead to:

- Meridional amblyopia in children.
- Reduced academic and work performance.
- Chronic asthenopia and headaches.
- Night vision difficulties leading to increased driving hazards.

Case Example

Case: A 22-year-old student presents with blurred vision and headaches during study.

Uncorrected VA: 6/18.

Refraction: -1.25 DS / -2.00 DC × 180 → 6/6.

Topography shows with-the-rule astigmatism.

Management: spectacles first, toric contact lenses for daily wear. If irregular astigmatism is present, scleral lenses provide superior outcomes.

HOME WORK

Questions

1. What is the main goal of astigmatism management, and which factors influence the choice of treatment?
2. Explain how cylindrical or sphero-cylindrical eyeglass lenses correct astigmatism.
3. Compare soft toric contact lenses and rigid gas-permeable (RGP) lenses in terms of effectiveness, advantages, and limitations.
4. In which clinical situations are scleral or hybrid lenses preferred, and why?
5. Describe how orthokeratology works and mention two benefits and one risk associated with its use.
6. Briefly explain the differences between PRK, LASIK, and SMILE laser procedures for correcting astigmatism.
7. What role does corneal collagen cross-linking (CXL) play in managing irregular astigmatism, and why is it often combined with other treatments?
8. When are toric phakic intraocular lenses (IOLs) indicated, and what are two key considerations before implantation?
9. Name two main treatment options for advanced or irregular astigmatism that cannot be corrected with contact lenses, and explain their purpose.
10. Why is patient counselling and regular follow-up essential in the long-term management of astigmatism?

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Third Stage 2025-2026

REFRACTIVE ERRORS 3

Lecture Title

ANISOMETROPIA

Lecture Number: 4 / course 1

Prepared by
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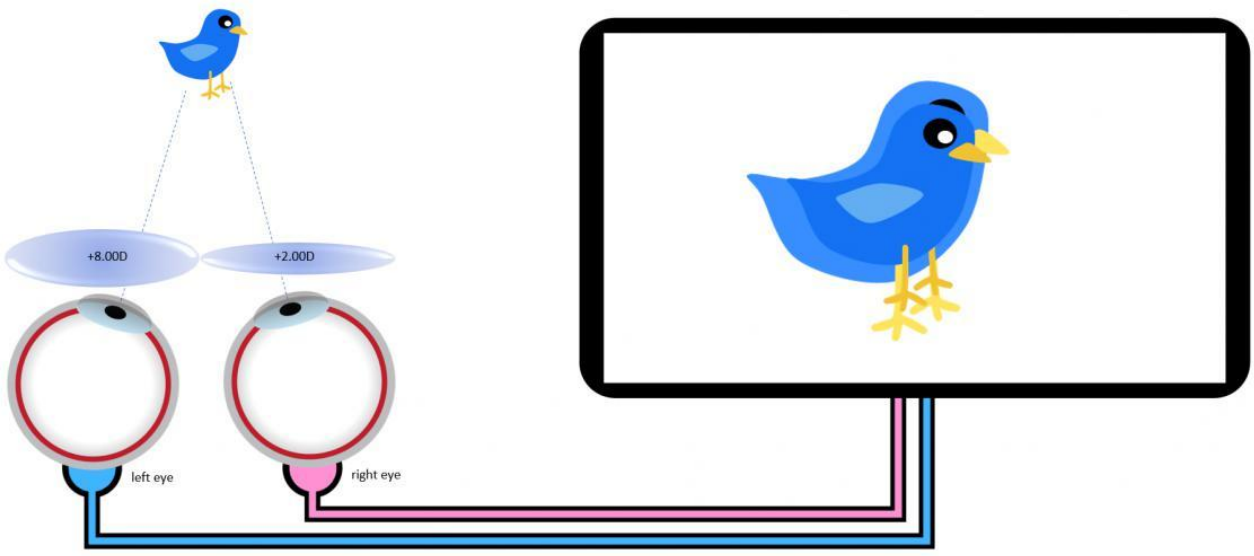
ANISOMETROPIA

1. Definition

Anisometropia: a clinically meaningful difference in refractive error between the two eyes (spherical equivalent and/or astigmatism). Most people have < 1.00 D difference; 0.25 D can be measured but is usually insignificant for everyday tasks. When the difference reaches approximately 1.00 D, spectacles typically produce ≈ 2% difference in retinal image size, which can trigger symptoms in some patients. Key tolerance guidance from your slide: ≈2.5 D (~5%) often tolerated; 2.5 – 4 D variable; >4 D commonly not tolerated with spectacles.

- **Antimetropia**: one eye is myopic and the fellow eye is hyperopic.
- **Aniso-astigmatism**: unequal cylinder power and/or axis between the eyes.



2. Why Lens Power Differences Matter (Position vs Size)

Spectacles sit at a **finite vertex distance** from the cornea.

- **Plus lenses** magnify; **minus lenses** minify.
- If each eye needs a different power, the perceived image size from each eye differs with spectacles. This is why patients may feel strain or distortion even when acuity is good.

- **Prisms** shift the position of images only; they do not correct size mismatch.
- **Contact lenses** reduce the vertex distance (≈0 mm), thereby reducing the size mismatch and often improving tolerance when the interocular difference is large.

3 Practical Tolerance with Spectacles

- **Rule of thumb: 1.00 D** difference → ≈2% image-size difference (with spectacles).
- **≈2.5 D (~5%)**: often tolerated.
- **2.5–4.0 D**: variable depends on tasks and individual reserves.
- **>4.0 D**: commonly not tolerated with spectacles → consider contact lenses or surgical options.

4. Spectacle Magnification (SM)

Spectacle magnification can be expressed as the product of a **power factor** and a **shape factor**:

$$SM = M_p \times M_s$$

Where:

- **Power factor**:

$$M_p = \frac{1}{1 - h.F_2}$$

- **Shape factor:**

$$M_s = \frac{1}{1 - \left(\frac{t}{n}\right).F_1}$$

Where:

h: vertex distance (the distance between the back surface of the spectacle lens and the cornea), measured in meters.

F_2**:** back vertex power of the lens, measured in diopters (D).

t: center thickness of the lens, in meters.

n: refractive index of the lens material (relative to air).

F_1: front surface power of the lens (the base curve), in diopters (D).

Worked Example

Suppose we have a +5.00 D spectacle lens made from a high-index material (n=1.60) with the following parameters:

- Vertex distance (h) = 0.012 m (12 mm)
- Center thickness (t) = 0.004 m (4 mm)
- Front surface power (F_1) = +6.00 D
- Back vertex power (F_2) = +5.00 D

$$M_p = \frac{1}{1-(0.012\times5)} = 1.064$$

$$M_s = \frac{1}{1-\left(\frac{0.004}{1.6}\right)\times6} = 1.015$$

$$\therefore SM = M_p \times M_s = 1.064 \times 1.015 \approx 1.080$$

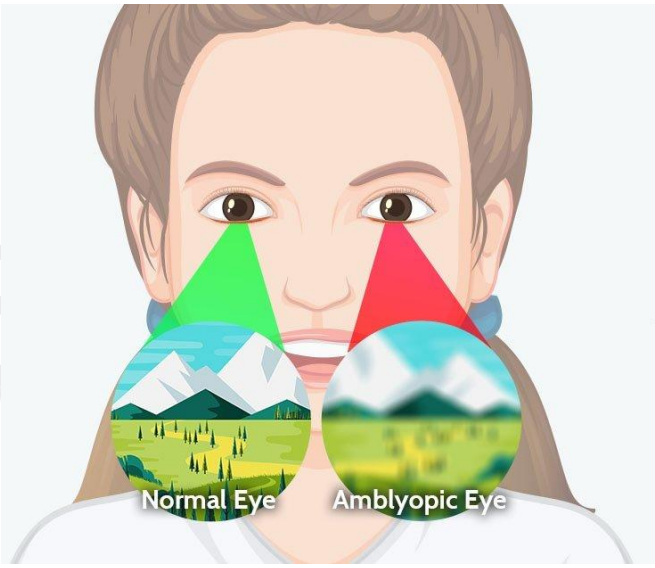
- **Interpretation**
  - SM = 1.080 means the retinal image formed with the lens is **1.08 times larger** than the image without the lens.
  - In other words, the spectacle lens produces approximately **+8% magnification**.
- This example illustrates why high plus lenses can significantly enlarge the retinal image, and why, in anisometropia (different powers between the eyes), such magnification differences can cause symptoms like visual discomfort or double vision when corrected with spectacles.

To reduce interocular size difference in spectacles:

- Minimize vertex distance.
- Use higher index materials to reduce thickness.
- Flatten base curve where optical quality allows.
- Adjust center thickness (especially for high plus).

5. Epidemiology & Clinical Significance

- Occurs in children and adults. Even modest hyperopic or astigmatic asymmetries in children can affect development and increase the risk of amblyopia if left uncorrected.
- In adults, common complaints are spectacle intolerance, spatial distortion, reading fatigue, and headaches.
- Post-operative settings (e.g., unilateral cataract extraction) are frequent modern causes; differences can be temporary (between staged procedures) or persistent (residual refractive error).



6. Etiology

5.1 Congenital

- Differential growth of ocular structures leading to axial length asymmetry.
- Developmental differences in corneal curvature or crystalline lens power.

5.2 Acquired

- Unilateral aphakia after crystalline lens removal.
- Incorrect intraocular lens (IOL) power (postoperative refractive surprise).
- Ocular trauma affecting the cornea or lens.
- Unilateral keratoplasty altering corneal power.
- Asymmetric age-related crystalline lens/corneal changes.

7. Classification

7.1 Relative Anisometropia

When the two eyes have similar overall refraction (i.e., not enough difference to be anisometropic) but different axial lengths, both eyes can form clear images. However, because the eyes differ in size, the retinal images ultimately differ in magnification.

7.2 Absolute Anisometropia

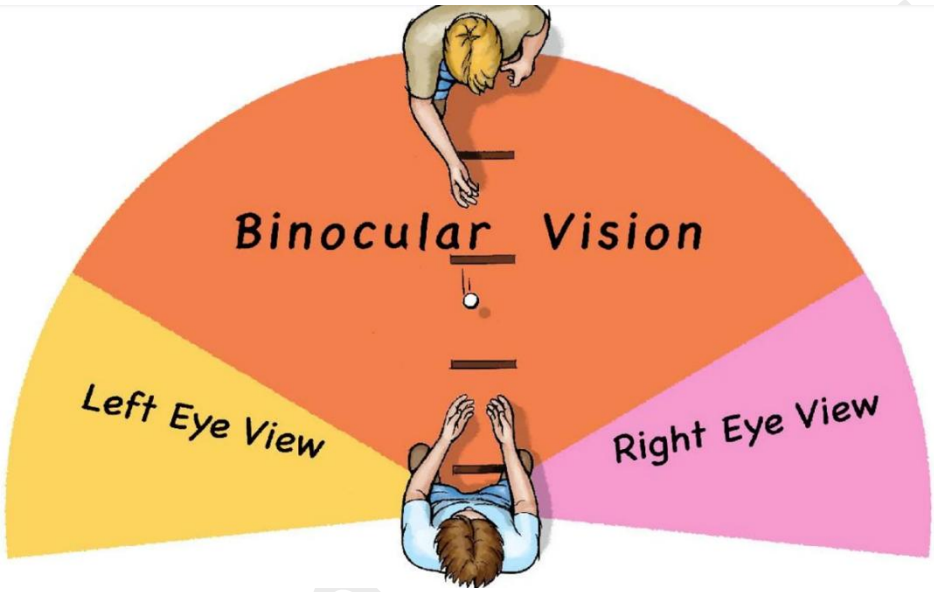
The total refractive power is unequal between eyes (most common).

- ***Simple***: one eye emmetropic, the other myopic or hyperopic. Example: OD Plano, OS −3.00 DS.
- ***Compound***: both eyes same sign, unequal magnitude. Example: OD −6.00 DS, OS −2.50 DS.
- ***Mixed (antimetropia)***: one eye myopic, the other hyperopic. Example: OD −1.50 DS, OS +2.25 DS.
- ***Simple aniso-astigmatism***: one eye emmetropic; the fellow has simple myopic or simple hyperopic astigmatism. Example: OS ±2.50 DC × 180.
- ***Compound aniso-astigmatism***: both eyes are astigmatic to unequal degrees. Example: OD +0.50 DC × 180 ; OS +3.50 DC × 180
- ***Mixed aniso-astigmatism***: one eye has hyperopic astigmatism; the other has myopic astigmatism. Example:
  OD +2.00/−1.00 ×180 ; OS -2.00/+1.00 ×90.

8. Binocular Vision Status & Symptoms

8.1 Expected binocular patterns

- BSV present when anisometropia is small (<3 D).
- Uniocular vision when one eye's error is very high (habitual suppression).
- Alternate vision when one eye is emmetropic/moderately hyperopic and the other myopic: the hyperopic/emmetropic eye is used for distance, and the myopic eye for near



8.2 Symptom complex and mechanisms

- Eye strain
- Headaches
- Nausea
- Light sensitivity
- Tiredness
- Dizziness
- Sometimes diplopia (especially with large differences and spectacles).

HOME WORK

1. Define anisometropia. At what level of inter-ocular difference does it usually become clinically significant with spectacles?
2. Distinguish between anisometropia, antimetropia, and aniso-astigmatism.
3. True or False: Prisms are an effective solution to eliminate image-size differences in anisometropia.
4. A spectacle +4.00 D lens has the following parameters: h = 0.01 m, t = 0.005 m, n = 1.50, F1 = +5.00 D. Calculate the Power Factor (Mp), Shape Factor (Ms), overall Spectacle Magnification (SM), and interpret the clinical meaning of the result (What percentage magnification is produced? Why is this important in anisometropia?
5. Name two congenital causes of anisometropia.
6. Name two acquired causes of anisometropia in adults.
7. Match each prescription to the correct subtype:
   - OD Plano, OS −3.00 DS →
   - OD −6.00 DS, OS −2.50 DS →
   - OD −1.50 DS, OS +2.25 DS →
   - OD Plano, OS −2.00 DC × 180 →
   - OD +2.00/−3.00 × 90, OS −2.00/−1.00 × 85 →
8. What binocular vision pattern is usually present when anisometropia is <3 D?
9. Why might a patient with high anisometropia report dizziness or spatial distortion when wearing spectacles?
10. List four common symptoms of anisometropia.
11. A 6-year-old child presents with: OD +3.50 DS, OS +0.50 DS. What type of anisometropia is this? What is the risk if uncorrected?
12. An adult has: OD −5.00 DS, OS −1.00 DS. They complain of discomfort with glasses. Classify and suggest corrections.

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REFRACTIVE ERRORS 3

Lecture Title

ANISOMETROPIA

Lecture Number: 5 / course 1

Prepared by
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ANISOMETROPIA

Examination

1. History

- Onset, duration, and context (post-surgery, trauma).
- Prior correction history and adaptation to previous prescriptions.
- Near-work demands (study/occupation).
- Symptoms in new vs old spectacles/CLs; tasks that worsen symptoms.

2. Visual function

- Visual acuity (monocular & binocular) with and without correction.
- Stereoacuity (e.g., TNO, Titmus) and suppression checks (Worth/Friend/Bagolini).
- Contrast sensitivity when symptoms persist despite good VA.

- **TNO Test**: This test uses **red–green anaglyph glasses** and presents **random-dot stereograms**. The patient cannot perceive the hidden shapes unless **true binocular fusion** is present.
- **Titmus Test (Fly test)**: This test uses **polarized glasses** and displays figures such as the large **fly** or sets of circles. The patient is asked to identify which figures appear to "stand out" from the page, indicating depth perception.

3. Refraction

- ***Objective***: retinoscopy or autorefractor; verify keratometry for corneal contribution.
- ***Subjective refinement***: maintain binocular balance where possible.
- ***Children or suspected latent hyperopia***: cycloplegic refraction is essential.

4. Alignment & vergence

- Cover/alternate cover tests at distance and near; prism neutralization.
- Near point of convergence; fusional reserves (base-in/base-out).

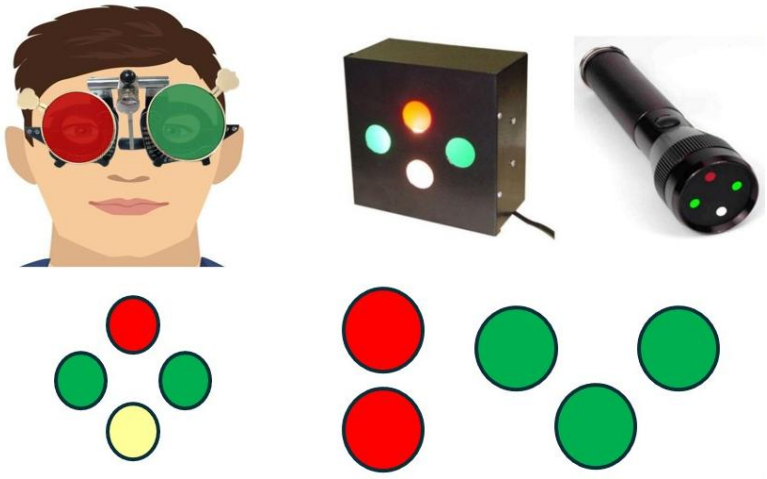
5. Sensory status tests

- **FRIEND test (distance 6 m)**

1. With red/green goggles (red over right, green over left), seat the patient at 6 m.
2. Display the FRIEND target and ask the patient to read what is seen.
3. Interpretation: FRIEND → binocular single vision; FIN or RED only → uniocular (suppression); alternation between FIN and RED → alternate vision.

- **Worth four-dot (distance and near)**

1. With red/green goggles, present a target containing one red, two green, and one white light.
2. Interpretation at a distance (6 m) and repeat at near:
   - Sees four lights without manifest tropia → normal BSV.
   - Sees four lights with manifest tropia → abnormal retinal correspondence (ARC).
   - Sees two red only → left eye suppression.
   - Sees three green only → right eye suppression.
   - Alternates between red and green → alternating vision.
   - Sees five lights (2 red + 3 green) → diplopia.



6. Management

6.1 Decision principles by context

- Treat optics first; address sensory/binocular sequelae second.
- Children: correct fully and reassess; add amblyopia therapy if VA asymmetry persists.
- Adults: prioritize comfort and task performance; escalate to contact lenses earlier for high differences or poor spectacle tolerance.

6.2 Spectacle strategies

- Reasonable up to ~4 D if the patient tolerates them; beyond this, spectacle magnification difference often causes symptoms.

- Anisometropic spectacles: modify the margin of the stronger lens to reduce peripheral prismatic annoyance.

6.3 Contact lenses (SCL, RGP, scleral)

- First-line for high anisometropia (minimizes vertex distance and size difference).
- Toric soft lenses for aniso-astigmatism; RGP/scleral for irregular corneas and superior optical quality.
- Pediatric use: often the most practical solution in unilateral aphakia or large differences; requires education and follow-up.

6.4 Pediatric pathway (anisometropic amblyopia risk)

- Cycloplegic refraction → prescribe full optical correction.
- Reassess VA and stereo after 6–12 weeks.
- If residual amblyopia persists, introduce occlusion therapy (patching) or pharmacologic penalization as age-appropriate.
- Maintain close follow-up to monitor adherence and prevent regression.

7. Case Series (Worked Examples)

◆ Case 1: Simple Hypermetropic Anisometropia

- OD (Right eye): +3.50 DS
- OS (Left eye): Plano (0.00)
- Difference: 3.50 D (all hyperopic vs emmetropic)
- Notes: Often seen in children → high risk of amblyopia in the more hyperopic eye if left uncorrected.

◆ Case 2: Simple Myopic Anisometropia

- OD: −4.00 DS
- OS: Plano (0.00)

- Difference: 4.00 D
- Notes: The myopic eye may be used for near vision while the emmetropic eye is used for distance → "natural monovision, but this may reduce stereopsis.

Case 3: Compound Myopic Anisometropia

- OD: −6.00 DS
- OS: −2.00 DS
- Difference: 4.00 D (both myopic, unequal degree)
- Notes: Common in teenagers/young adults; often poorly tolerated with spectacles if difference >3 D → contact lenses preferred.

Case 4: Compound Aniso-Astigmatism

- OD: −1.00 / −3.00 × 180
- OS: −1.00 / −0.50 × 180
- Notes: Both eyes have astigmatism, but with different amounts → causing unequal blur and potential discomfort in fusion.

Case 5: Mixed Anisometropia (Antimetropia)

- OD: −2.00 DS
- OS: +2.50 DS
- Notes: One eye is myopic, the other hyperopic → images differ in size *and* focus direction. Frequently leads to alternate fixation (myopic eye for near objects, hyperopic for distant objects).

Case 6: Mixed Aniso-Astigmatism

- OD: +3.00 / −1.50 × 180
- OS: −2.50 / −0.75 × 180

- Notes: One eye's principal meridians are hyperopic, while the other's are myopic. This produces significant image disparity and **symptoms, especially with spectacles.**

🔹 Case 7: Post-Surgical Anisometropia

- History: A patient underwent unilateral cataract extraction with IOL implantation.
- OD: +0.50 DS (pseudophakic eye)
- OS: +4.00 DS (phakic eye with cataract not yet operated)
- Notes: Temporary anisometropia until second eye surgery; contact lens for the phakic eye or interim refractive correction may be used.

✨ Teaching Point

- <1 D difference: usually not clinically significant.
- 1–3 D: may be tolerated, but monitor carefully in children.
- >3 D: often symptomatic with spectacles; contact lenses or surgical solutions are preferred.

HOME WORK

Questions

1. What key history elements should be asked when examining a patient with suspected anisometropia?
2. Why is cycloplegic refraction essential in children with suspected anisometropia?
3. What is the role of stereoacuity tests (TNO, Titmus) and suppression tests (Worth, Friend, Bagolini)?
4. How do cover tests and prism neutralization help in anisometropia?
5. In the FRIEND test at 6 m, the patient reports seeing only “FIN”. What does this indicate?
6. In the Worth Four-Dot test, the patient sees five lights (2 red, 3 green). What does this mean?
7. Why are contact lenses considered first-line for high anisometropia?
8. What is the pediatric management pathway for anisometropic amblyopia?
9. List two spectacle strategies to reduce interocular size difference.
10. A 7-year-old child with OD +3.50 DS and OS Plano. Classification and risk?
11. A 20-year-old with OD −6.00 DS, OS −2.00 DS reports spectacle discomfort. Classification and correction?
12. Patient with OD −2.00 DS and OS +2.50 DS. Classification and binocular vision pattern?
13. Post-unilateral cataract surgery: OD +0.50 DS, OS +4.00 DS. Best short-term management?

Al-Furat Al-Awsat Technical University
College of Health and Medical Technologies - Kufa
Department of Vision Screening Techniques

Third Stage 2025-2026

REFRACTIVE ERRORS 3

Lecture Title

ANISEIKONIA

Lecture Number: 6 / course 1

Prepared by
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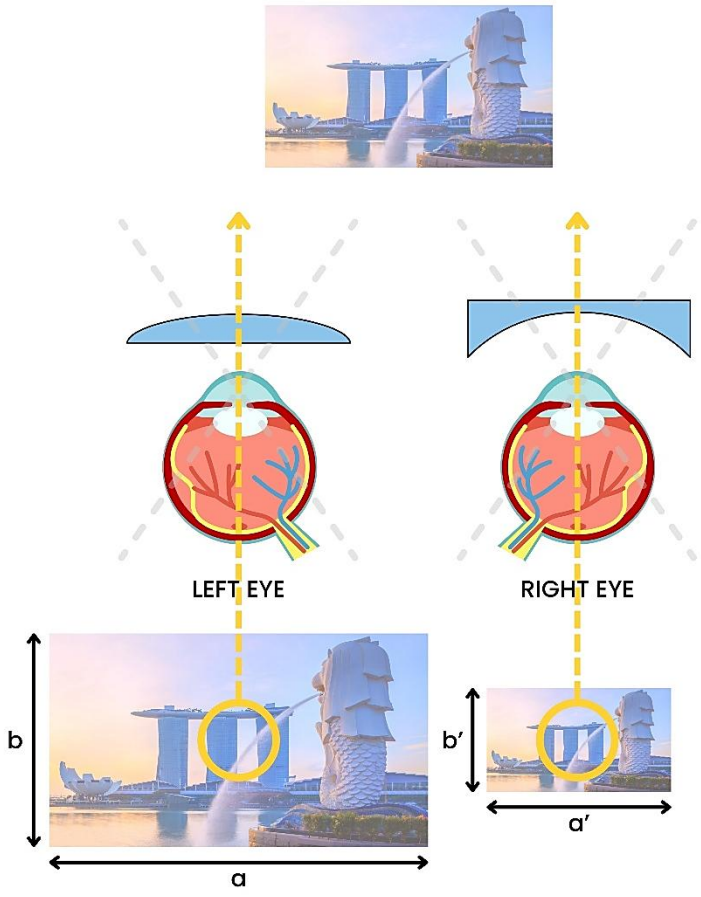
Aniseikonia

- **Definition:** Aniseikonia is a binocular image-size or shape mismatch between the two eyes, large enough to disturb fusion and comfort.
- **Clinical threshold:** Most people tolerate ~≤2–3% difference. >3–5% often symptomatic; >5–7% commonly intolerable.
- **Why it matters:** Size/shape mismatch → asthenopia, diplopia/suppression, reduced stereopsis, spatial disorientation, reading difficulty. Fixing it can be life-changing.



Useful Classifications

- **Physiological vs Pathological**
  - ✓ *Physiological:* tiny, normal differences that aid depth (well tolerated).
  - ✓ *Pathological: due to optical/retinal causes; symptomatic.*

- **Static vs Dynamic**
  - ✓ *Static: size difference in primary gaze.*
  - ✓ *Dynamic (anisophoria): gaze-dependent disparity from unequal prismatic effects (esp. with anisometropic spectacles while looking off-axis).*
- **Symmetrical vs Meridional**
  - ✓ *Symmetrical: uniform magnification difference.*
  - ✓ *Meridional/asymmetrical: magnification varies by meridian (often with astigmatism/retinal distortion).*
- **Optical vs Retinal origin**
  - ✓ *Optical: anisometropia, lens differences, post-surgical optics.*
  - ✓ *Retinal: photoreceptor spacing change or macular distortion (e.g., macular edema).*

Main Causes

Optical

- **Anisometropia** (sphere/astigmatism); antimetropia.
- **Aphakia/pseudophakia asymmetry**, unilateral cataract surgery, unequal IOL targets.
- **Refractive surgery** done in one eye or with unequal outcomes; intentional monovision.
- **Spectacle factors:** vertex distance, base curve, thickness differences; frame fit asymmetry.

Retinal

Retinal causes of aniseikonia occur when retinal structures, especially the macula, are stretched, compressed, or elevated, altering the spacing of photoreceptors and thus changing the perceived image size.

- **Epiretinal membrane (ERM):** The macula is pulled or wrinkled → photoreceptors compressed → image appears *larger* (**macropsia**).

- **Macular edema:** Swelling spreads photoreceptors apart → image appears *smaller* (**micropsia**).
- **Central serous chorioretinopathy (CSR):** Fluid lifts the macula → image appears *smaller*.
- **High myopia with staphyloma:** Posterior retinal stretching → *micropsia*.
- **Post–retinal detachment repair (scleral buckle):** Retinal shape distortion → *unequal or distorted image size*.
- **Macular hole:** Retinal tissue stretched around the hole → *micropsia*.

Symptoms & Functional Impact

- **Asthenopia/HA**, peri-orbital or frontal ache; **photophobia**.
- **Binocular instability:** intermittent **diplopia**, **suppression**, degraded **stereopsis** → poor depth, clumsiness.
- **Spatial distortion/disequilibrium:** room appears tilted/warped; **dizziness**, mild **nausea**.
- **Reading stress:** losing place, "words jump," difficulty scanning lines (dynamic component).
- **Spectacle intolerance** after big Rx changes or unilateral surgery.

Clinical Detection (Practical)

- **History clues:** recent unilateral surgery; large Rx change; long-standing anisometropia; reading fatigue.
- **Simple in-office probes**
  - ✓ Ask: "Does one eye's image look **bigger/smaller**?"
  - ✓ **Monocular alternation** at distance/near to elicit perceived size shift.
  - ✓ **Pinhole** won't solve size mismatch (helps refractive blur only).
- **Quantification options**
  - ✓ **Direct comparison tests:**
    - **New Aniseikonia Test (NAT)** (anaglyph half-moons).

- **Aniseikonia Inspector** (computerized, red/green).

✓ **Maddox/Brecher variants:** compare line vs dots; add **size lenses** (afocal magnifiers) until alignment/subjective equality.

✓ **Trial afocal magnifiers** at the phoropter: increase/decrease % until comfort/fusion peaks → practical target.

✓ **Spectacle magnification estimate:** rough rule **~0.25–0.5% per diopter** anisometropia (depends on power, base curve, thickness, vertex).

✓ **Target to correct:** reduce measured difference to **≤1–2%** (or patient-tolerated level).

Management Strategy

A) First, treat the cause when possible

- **Retina:** manage **edema (anti-VEGF/laser)**.
- **Cataract/pseudophakia asymmetry:** consider **second-eye surgery** or IOL exchange/adjustment if refractively very unequal.

B) Optimize the optical system for minimum magnification difference

1. **Contact lenses (CLs) — first-line for anisometropia**
   - ✓ On-eye correction **minimizes spectacle magnification** and **eliminates differential prism** in downgaze.
   - ✓ Options: full CL correction, or **hybrid** (CL on high-power eye + thin spectacles for both for residual power).
   - ✓ Especially powerful in **high myopes/hyperopes** and **interim unilateral surgery**.
2. **Iseikonic spectacles (size lenses) — when CLs not viable or as an adjunct**
   - ✓ Adjust **shape factor** (front **base curve**, **thickness**) and **vertex** to alter magnification **without changing Rx power**.
   - ✓ **For the smaller image eye:** steeper base curve, greater (appropriate) thickness, possibly slightly greater vertex → **increase**

magnification.

For the larger image eye, opposite adjustments.

- ✓ Use software to design; **verify subjectively** with trial lenses.

3. **Frame and fitting optimization**
   - ✓ **Minimize vertex** and **match vertex** OU; appropriate **pantoscopic tilt**; small, symmetric frames to reduce off-axis effects.
   - ✓ Choose **materials/index** to achieve thickness goals while controlling weight/cosmetics.

C) Surgical/Definitive refractive approaches (case-dependent)

- **Laser refractive surgery (LASIK/PRK/SMILE):** reduce anisometropia to near-zero → **erase optical aniseikonia**; useful when CL-intolerant.
- **Refractive lens exchange / staged bilateral cataract targets:** align refractive endpoints OU.
- **Secondary IOL** for unilateral aphakia to avoid massive spectacle magnification.
- **Last resort: functional monocularity** (occlusion/blur) only when binocularity cannot be salvaged.

Mini-Cases

- **Unilateral pseudophakia + fellow cataract (–5 D):** temporary CL on fellow eye; plan second-eye surgery → equal endpoints.
- **–8.00 / –2.00 myope struggles in specs:** CL on –8 eye; thin low-power specs for both → fusion restored.
- **ERM with micropsia OS ~3%:** manage retina; iseikonic +3% OS spectacles → reading comfort improves.

Exam/Clinic Pearls

- **Dynamic symptoms worse at near?** Suspect **spectacle-induced anisophoria**; CLs often cure it.
- **Don't "wait it out"** with large anisometropic spectacles—prolonged symptoms lead to **suppression** and patient non-compliance.

- **Write what you correct**: record **% target** and **design choices** (base curve, center thickness, vertex).
- **Partial fixes can be big wins**: reducing from 6% → 2% may eliminate symptoms.
- **Re-measure after interventions** (retina treated, second-eye surgery done, etc.).

HOME WORK

Questions

1. **Define aniseikonia** and explain how much image-size difference between the eyes is typically tolerated before symptoms occur.
2. **Differentiate between physiological and pathological aniseikonia.** Give one example of each.
3. **Explain the difference between static and dynamic aniseikonia.** What optical condition commonly causes dynamic aniseikonia?
4. **List two optical and two retinal causes** of aniseikonia and briefly describe how each alters image size.
5. **What are the main symptoms** patients experience with clinically significant aniseikonia?
6. **Describe how the New Aniseikonia Test (NAT)** or similar methods help in quantifying aniseikonia in the clinic.
7. **Why does a pinhole test fail** to correct or identify aniseikonia?
8. **Outline three optical correction strategies** for aniseikonia and explain the principle behind each (contact lenses, iseikonic lenses, and frame adjustments).
9. **Why are contact lenses often considered the first-line management option** for anisometropic aniseikonia?
10. **Discuss one clinical scenario (mini-case)** where retinal or optical aniseikonia occurs and describe the best correction or management approach.

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REFRACTIVE ERRORS 3

Lecture Title

Aphakia & Pseudophakia

Lecture Number: 7 / course 1

Prepared by
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Aphakia & Pseudophakia

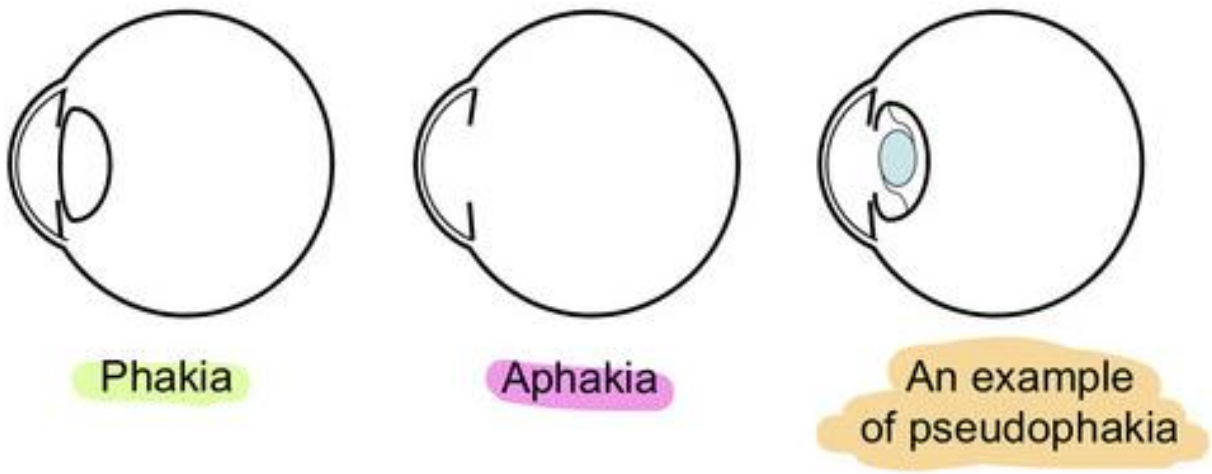
1. Introduction

The crystalline lens contributes approximately +19 diopters (D) to the eye's optical power. When the lens is absent (Aphakia) or replaced by an artificial intraocular lens (Pseudophakia), the optical properties of the eye change dramatically. Understanding these states is essential for optometry and ophthalmology students.

2. Definition

Aphakia: The complete absence of the crystalline lens from the eye. May occur in one (unilateral) or both eyes (bilateral). The lens may be absent congenitally, surgically removed (after cataract extraction), or lost due to trauma. Effect: Marked loss of optical power (+15 to +20 D) leading to high hypermetropia and loss of accommodation.

Pseudophakia: The presence of an intraocular lens implant (IOL) that substitutes for the natural crystalline lens, usually placed during cataract surgery. The IOL restores optical power but not accommodation.



3. Optical and Anatomical Changes in Aphakia

- Loss of +15–20 D refractive power → high hypermetropia.
- Deep anterior chamber and iris tremor (iridodonesis).
- Jet-black pupil with a bright blue fundus reflex.
- Complete loss of accommodation.

Purkinje Images: The third Purkinje image (from the posterior lens surface) disappears.

4. Etiology

Aphakia: congenital (rare, developmental defect) or acquired (after cataract surgery, trauma, lens dislocation, spontaneous absorption).

Pseudophakia: always acquired, following cataract surgery with lens implantation.

5. Clinical Features

Aphakia

Symptoms: blurred vision, photophobia, poor depth perception, monocular diplopia, and glare.

Signs: deep anterior chamber, absent lens, iridodonesis, hyperopia on refraction, blue reflex, and sometimes vitreous prolapse.

Pseudophakia: Clear visual axis, emmetropic or near-emmetropic vision, stable IOL, absent accommodation.

6. Complications

Aphakia: retinal detachment, cystoid macular edema, secondary glaucoma, corneal edema, amblyopia (in children), and aniseikonia (if unilateral).

Pseudophakia: early (corneal edema, inflammation, IOP rise); late (posterior capsule opacification, IOL decentration, glare, halos, or residual refractive error).

7. Optical Correction of Aphakia

1) Spectacles: High-plus convex lenses (+10 to +12 D). Advantages: simple and cheap. Disadvantages: large image magnification (~25–30%), ring scotoma, restricted field, poor cosmesis. Not tolerated in unilateral aphakia.

2) Contact Lenses: Rigid or soft lenses. Advantages: minimal magnification (6–8%), good field and cosmesis. Disadvantages: handling difficulty, hygiene, risk of infection.

3) Intraocular Lens (IOL): Preferred correction. IOL restores optical power internally. Power calculated via biometry (e.g., SRK/T formula).

8. Types of Intraocular Lenses

Posterior Chamber IOL: placed behind the iris in the capsular bag (common, stable).

Anterior Chamber IOL: placed in front of the iris when the capsule is absent.

Iris-Claw IOL: fixed to the iris.

Scleral-Fixated IOL: sutured to the sclera for cases without support.

9. Refractive States in Pseudophakia

- Emmetropic: Clear distance vision.
- Myopic: Improved near vision (monovision setup).
- Hypermetropic: Underpowered IOL outcome.
- Astigmatic: Corrected with toric IOL or corneal laser.

10. IOL Optical Designs

- Monofocal: Single focus (usually distance); reading glasses needed.
- Multifocal: Multiple foci (distance and near) but may cause halos.
- Toric: Corrects astigmatism.
- Aspheric: Reduces spherical aberrations, improving contrast.
- Accommodative: Provides limited near focus by shifting the IOL position

11. Comparison: Aphakia vs Pseudophakia

Feature	Aphakia	Pseudophakia
Lens status	Absent	Replaced by IOL
Refractive effect	High hypermetropia	Normal or slightly hyperopic/myopic
Accommodation	Completely lost	Absent (unless accommodative IOL)
Magnification	High (25–30% with spectacles)	Normal (~1–2%)
Preferred correction	CLs or IOL	Built-in IOL correction
Cosmesis	Poor with thick lenses	Normal appearance
Optical aberrations	Significant	Minimal (modern aspheric IOLs)
Binocular tolerance	Poor if unilateral	Excellent
Visual stability	Depends on external correction	Stable once healed
Surgery needed	May remain unoperated	Surgical implantation mandatory

12. Corneal Refractive Procedures in Pseudophakia

Residual refractive errors after IOL surgery can be corrected with:

- Excimer Laser (LASIK/PRK).
- Piggyback IOL (secondary lens implant).
- IOL exchange in major power miscalculations.

13. Pediatric Considerations

Congenital aphakia causes severe amblyopia if not corrected early. Treatment: contact lenses (unilateral) or spectacles (bilateral). Secondary IOLs may be implanted later when ocular growth stabilizes. Early correction and amblyopia therapy are critical.

14. Clinical Pearls

- Avoid high-plus spectacles in unilateral aphakia.
- IOL implantation is the gold standard for visual rehabilitation.
- Educate pseudophakic patients on reading adds and posterior capsule opacification (YAG laser).
- Always record IOL details (type, power, and position).
- Check centration and retinal status at follow-up.

HOME WORK

Questions

1. Define aphakia and pseudophakia.

Explain how each condition alters the optical state of the eye.

2. Describe the main optical consequences of aphakia. Why does an aphakic eye become highly hypermetropic?
3. List three major clinical signs that help identify an aphakic eye during examination.
4. Compare the image magnification effects produced by aphakic spectacles and contact lenses. Why are contact lenses preferred in unilateral aphakia?
5. Explain why aphakic patients lose accommodation, while pseudophakic patients still cannot accommodate despite having a lens implant.
6. Discuss the differences between anterior chamber, posterior chamber, iris-claw, and scleral-fixated IOLs. Indicate one clinical situation where each might be preferred.
7. What are the common early and late complications of pseudophakia? Include at least one management option for posterior capsule opacification.
8. A patient underwent cataract surgery and received an IOL implant but still reports blurred vision. What possible optical or surgical causes could explain this complaint?
9. Explain how aniseikonia can occur in unilateral aphakia and how it affects binocular vision.
10. In pediatric patients, why is early correction of congenital aphakia essential? Mention the preferred correction methods and the risk of delayed intervention.