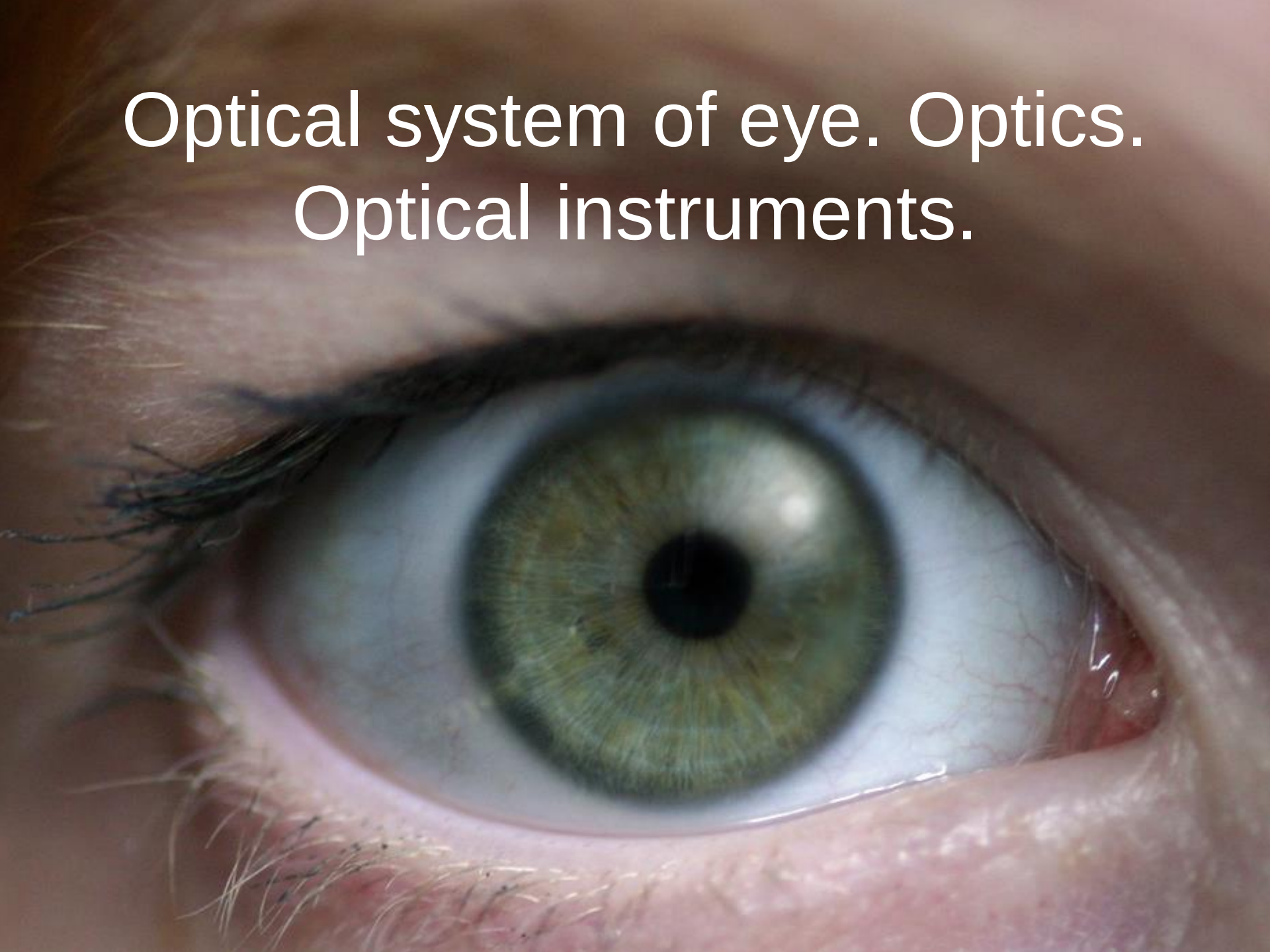
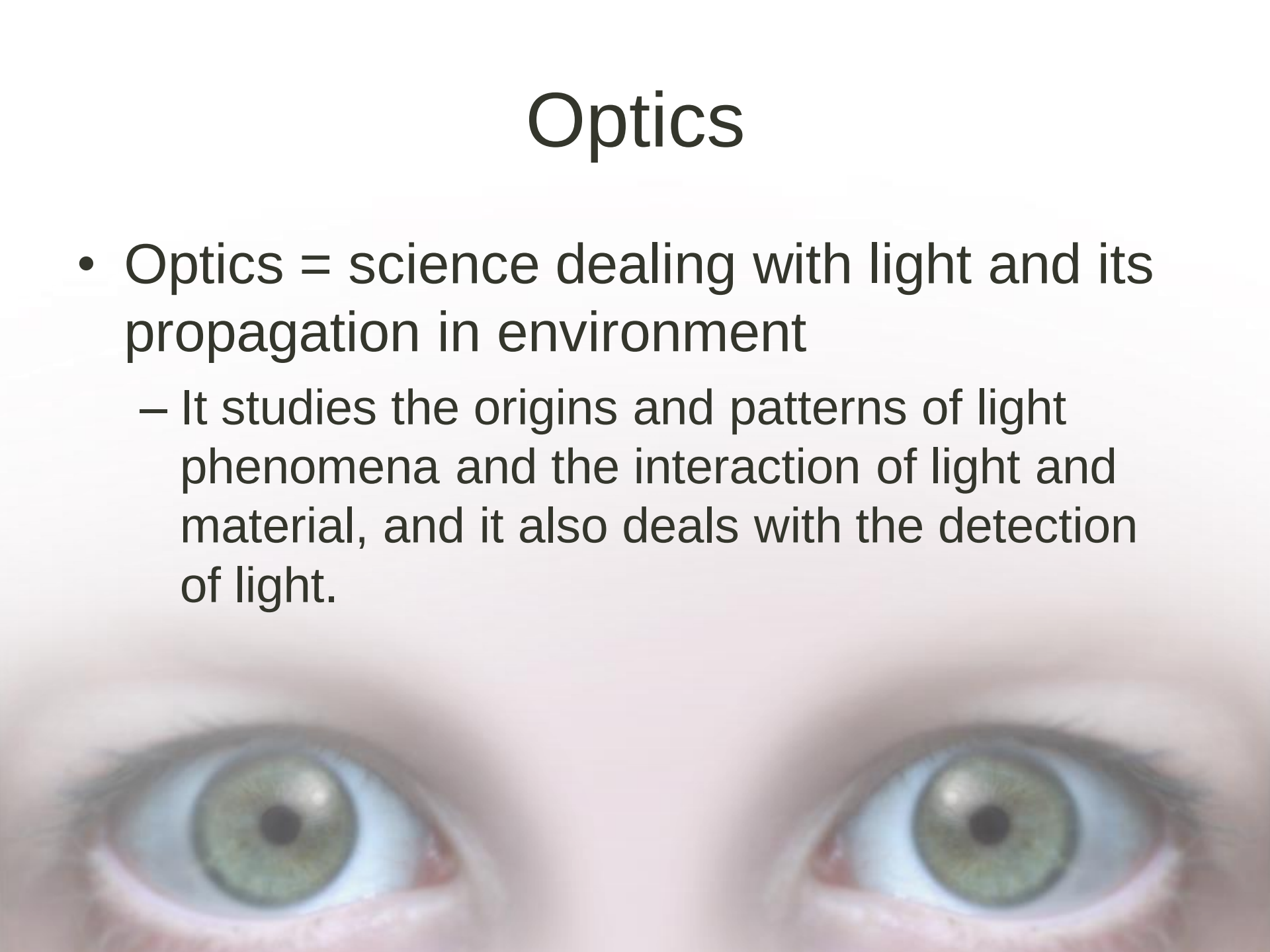
Optical system of eye. Optics. Optical instruments.



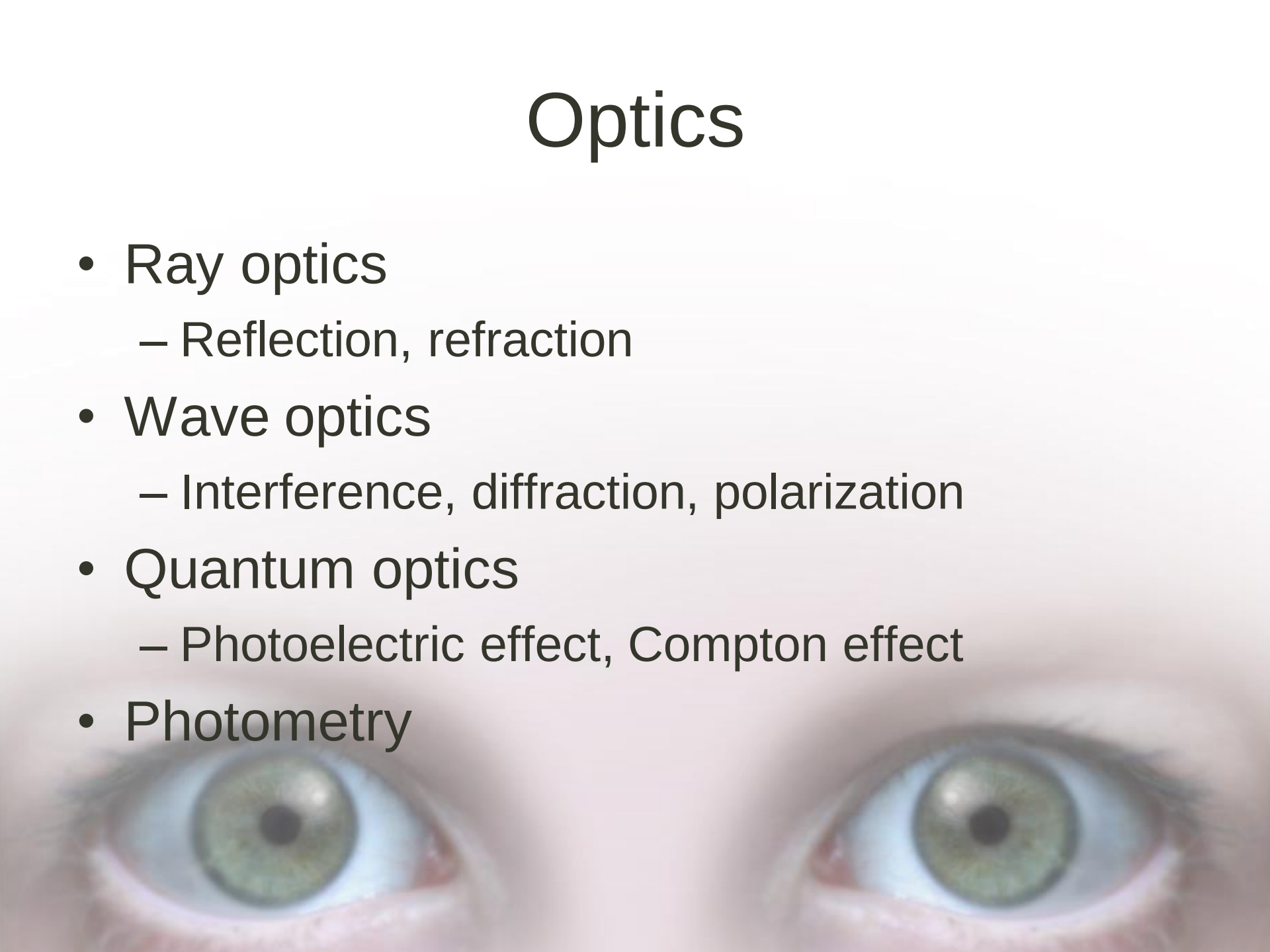
Optics

- Optics = science dealing with light and its propagation in environment
  - It studies the origins and patterns of light phenomena and the interaction of light and material, and it also deals with the detection of light.

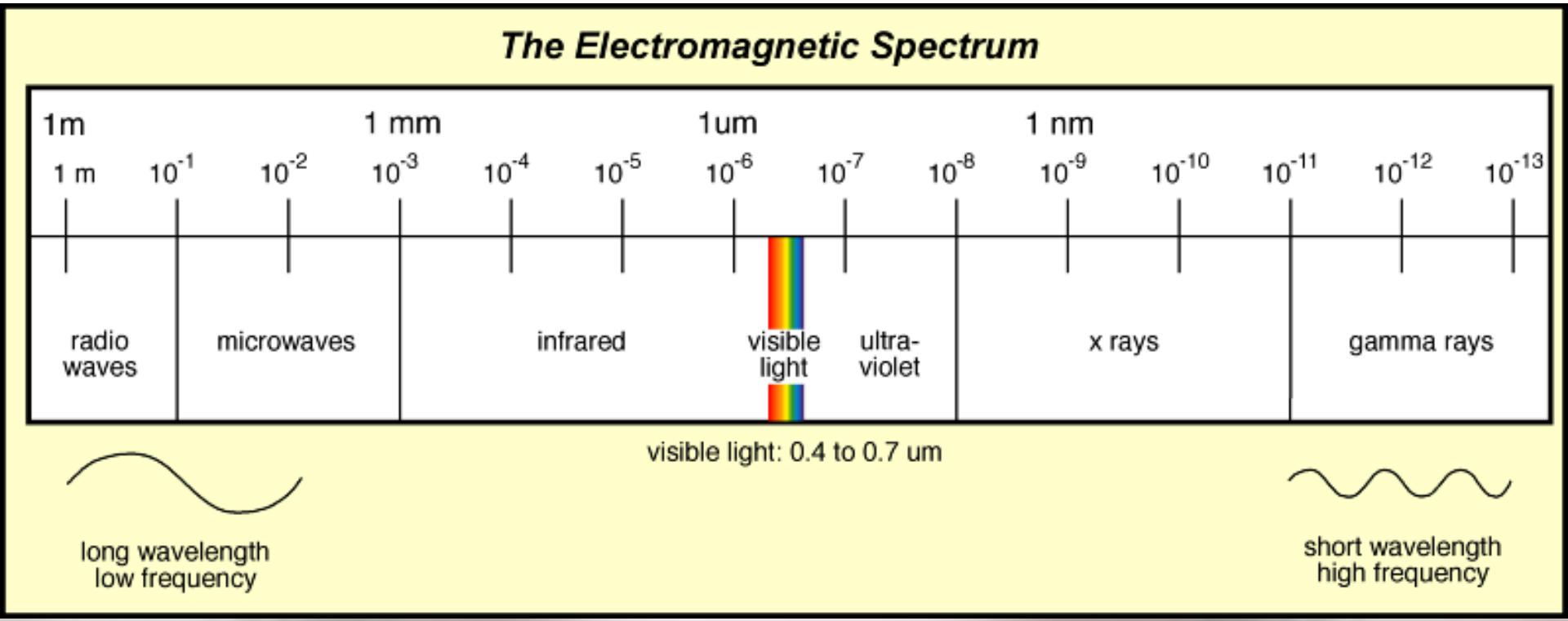


Optics

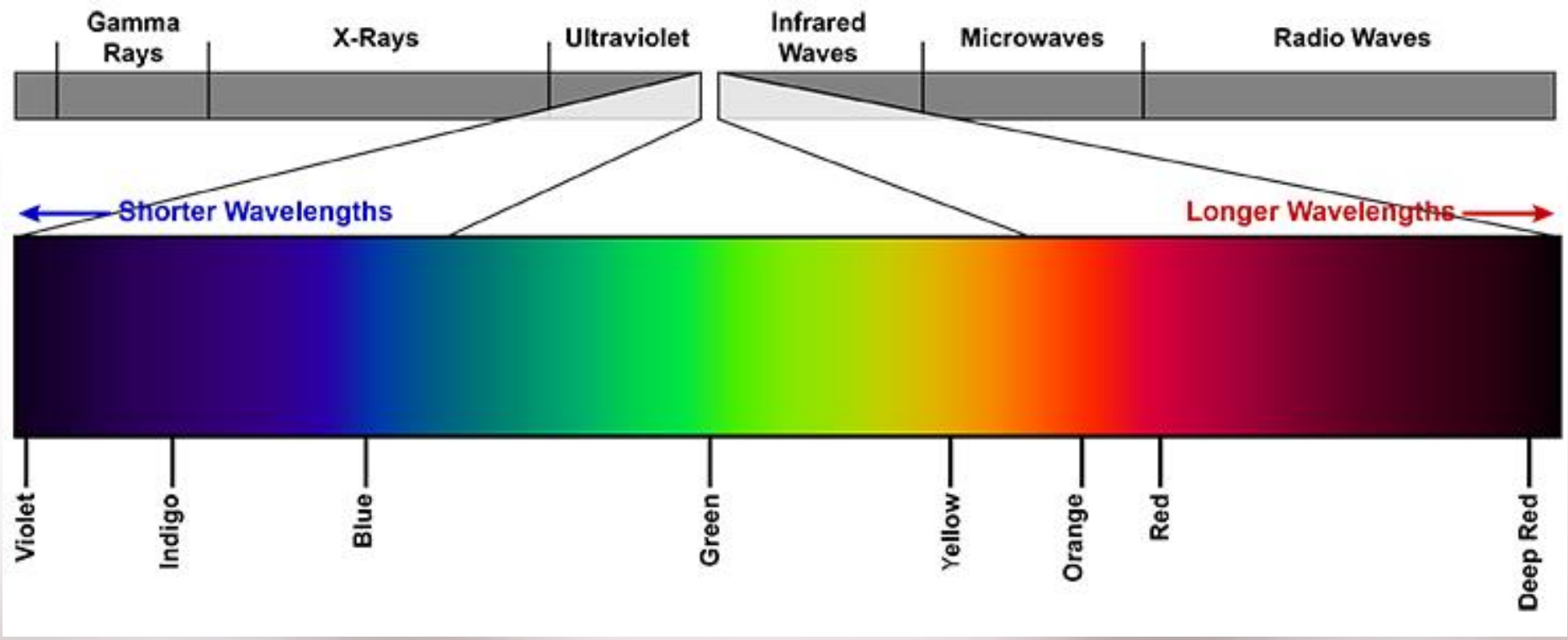
- Ray optics
  - Reflection, refraction
- Wave optics
  - Interference, diffraction, polarization
- Quantum optics
  - Photoelectric effect, Compton effect
- Photometry



electromagnetic spectrum



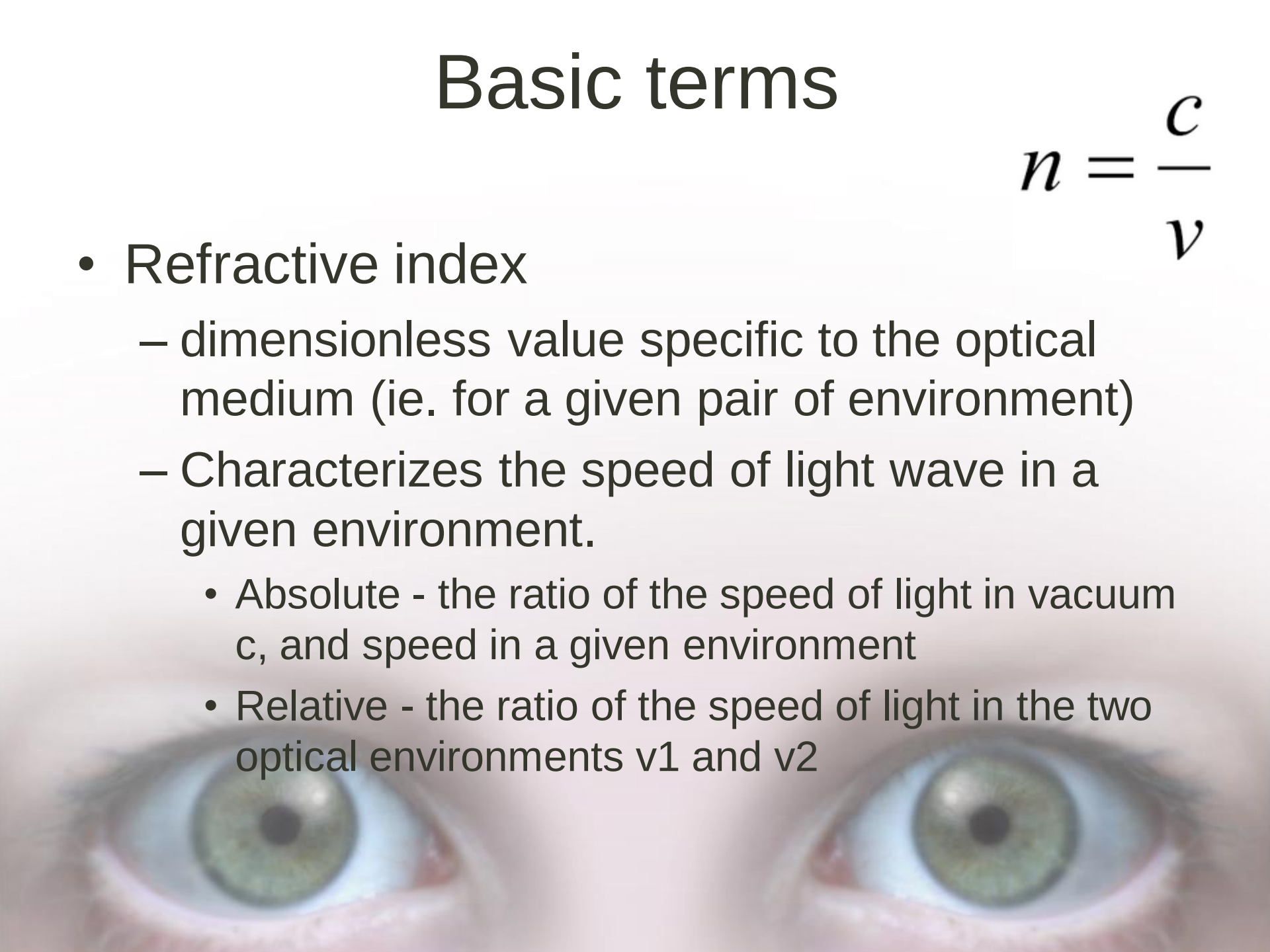
Visible light



Basic terms

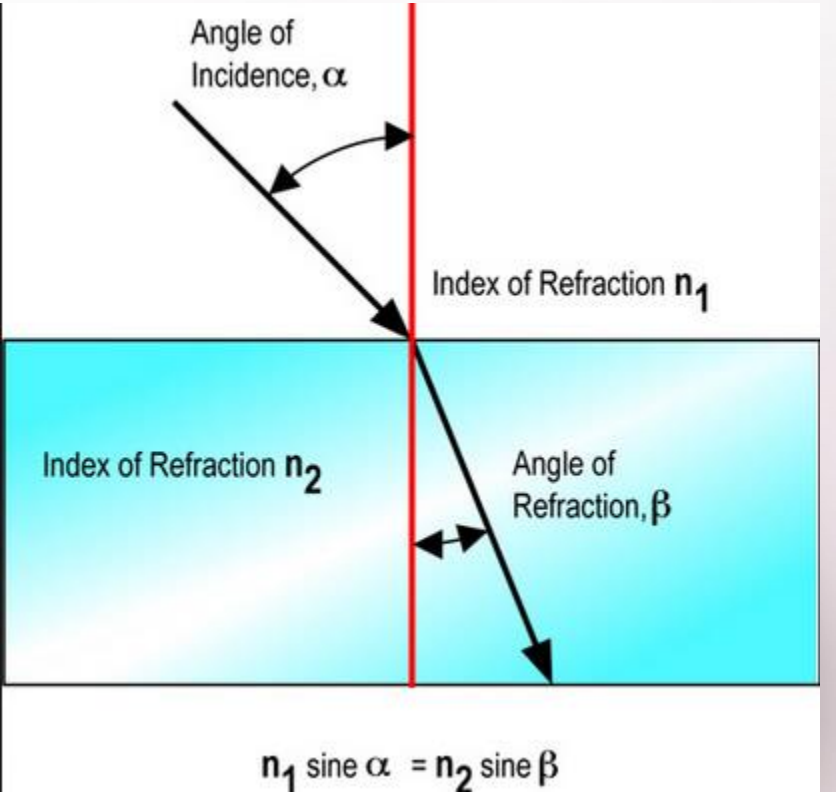
$$n = \frac{c}{v}$$

- Refractive index
  - dimensionless value specific to the optical medium (ie. for a given pair of environment)
  - Characterizes the speed of light wave in a given environment.
    - Absolute - the ratio of the speed of light in vacuum c, and speed in a given environment
    - Relative - the ratio of the speed of light in the two optical environments v1 and v2



Basic terms

- The propagation of light through the interface of two media:
  - Reflection (reflection) - angle of reflection = angle of incidence
  - Refraction (refraction) - Snell's law of refraction



$$\frac{\sin\alpha}{\sin\beta} = \frac{v_1}{v_2} = \frac{n_2}{n_1}$$

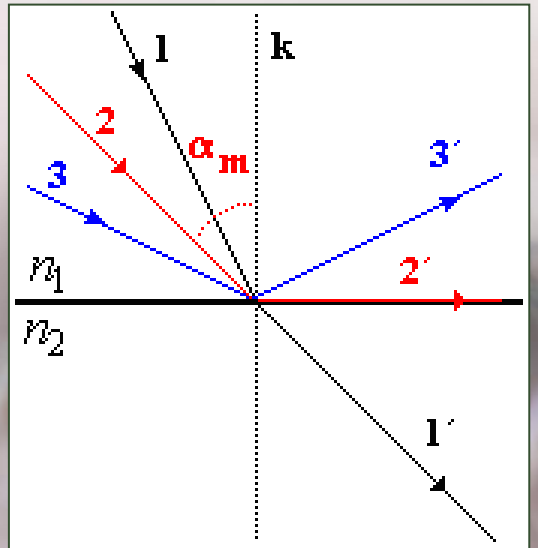
» From the optically thinner to optically denser = refraction to perpendicular

» From the optically denser to optically thinner = refraction from perpendicular

Basic terms

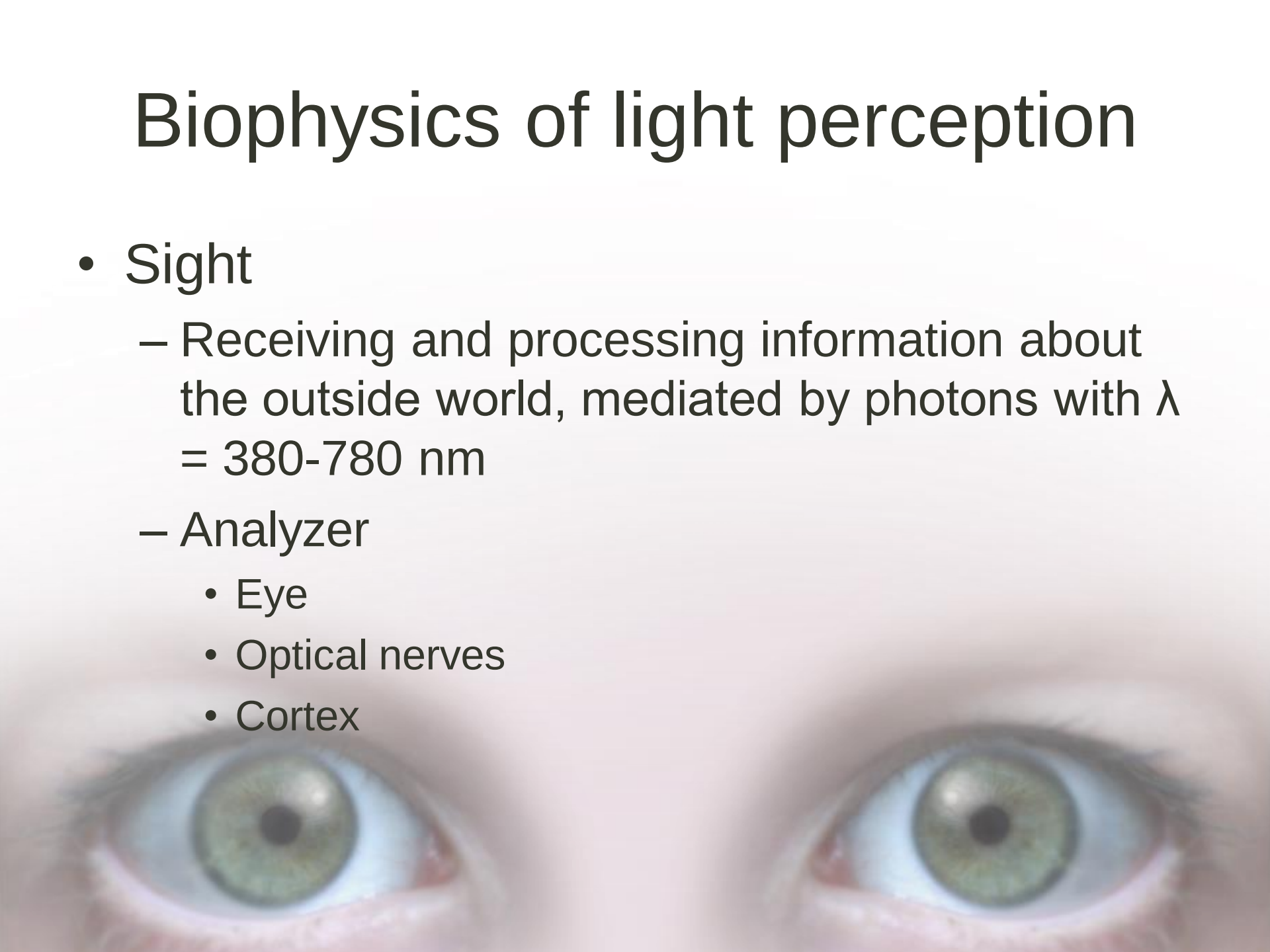
Total internal reflection

- From the optically denser to optically thinner
- As the angle of incidence increases, so does the angle of refraction
- When the limit angle value is reached, refraction occurs at 90°
- After the value is exceeded, total reflection happens
- Fiber optics



Biophysics of light perception

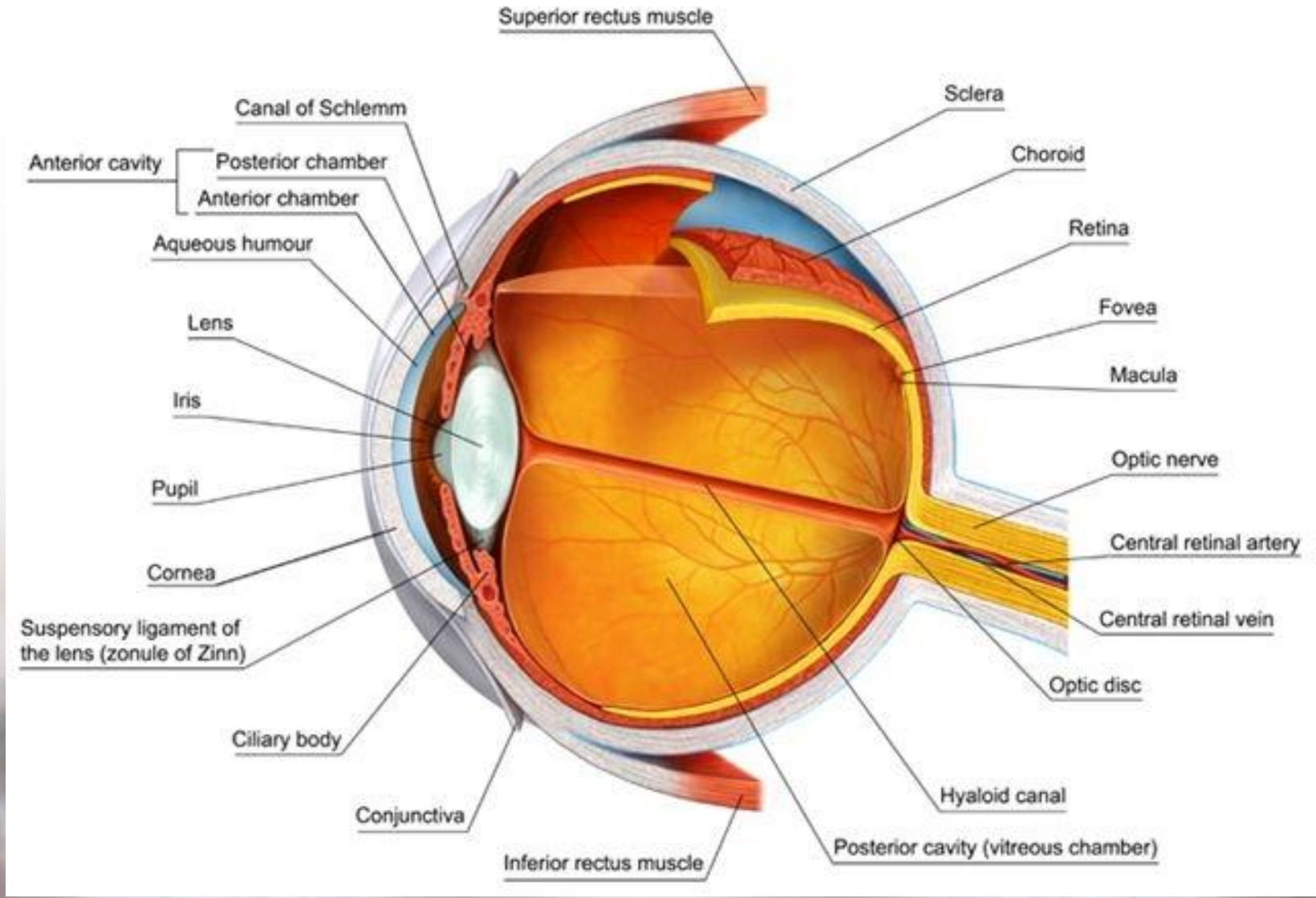
- Sight
  - Receiving and processing information about the outside world, mediated by photons with λ = 380-780 nm
  - Analyzer
    - Eye
    - Optical nerves
    - Cortex



Optical system of eye

- Spherical organ with a diameter of approximately 2.4 cm
- The momentum is ensured by 6 eye moving muscles
- The wall of the eyeball is formed by the outer sclera (sclera), middle choroid (choroid), inner retina (retinal)
- Sclera passes in front of the eye in the transparent cornea (the cornea)

Optical system of eye



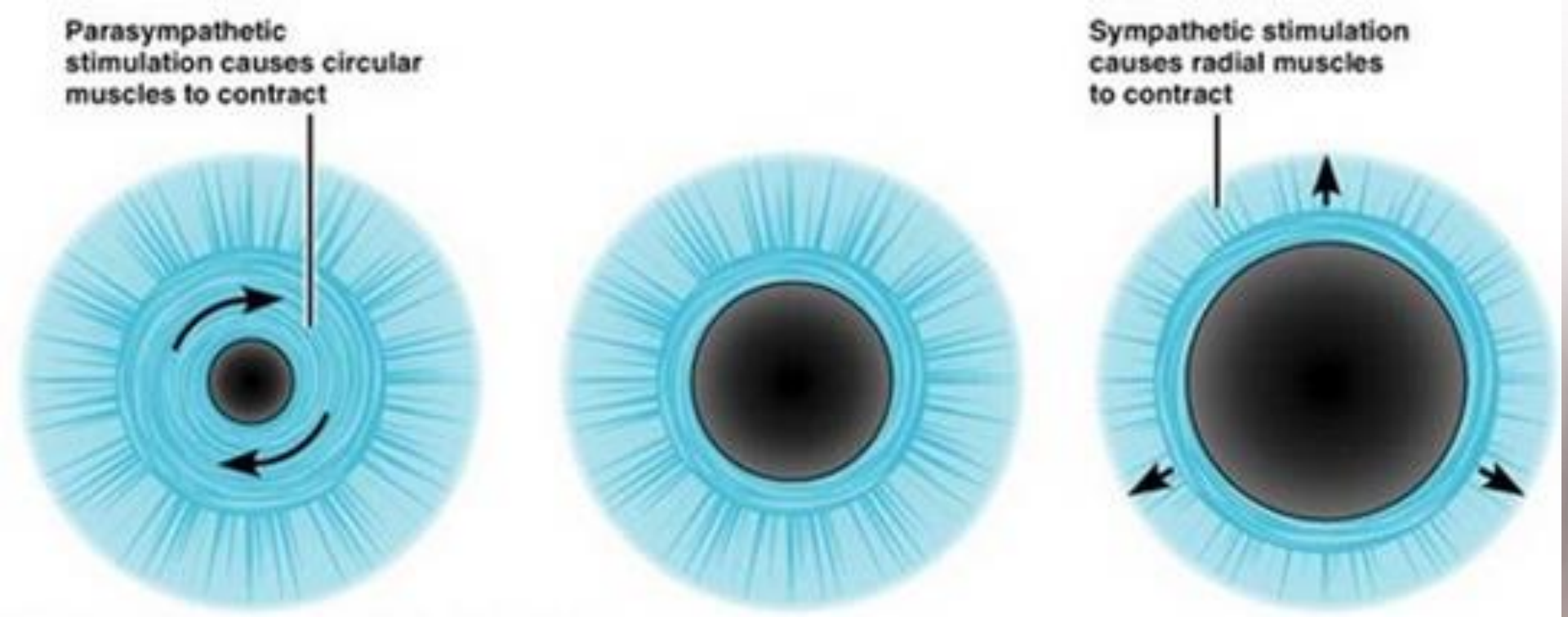
Optical system of eye

- Choroid passes in front of the eye in the ciliary body (corpus ciliary ganglion) - contains accommodative muscles and their fibers fitted to the lens
- Further, choroid passes in the iris (iris) with a circular hole - pupil - iris function
- Behind the iris is stored lens (lens Cristalina) maintained in position by fibers of the ciliary body

Iris muscle

Miosis

Mydriasis



Optical system of eye

- Anterior chamber is the space between the cornea – iris
- Posterior chamber of the eye is a space between the iris – lens
- Vitreous (corpus vitreum) fills the interior of the eye
- The retina contains rods (75-150 million) and cones (3.5-7 million)
- Yellow spot is the place with the highest concentration of cones

Eye

The light beam passes through several different environments; for simplification Gullstrand model is used

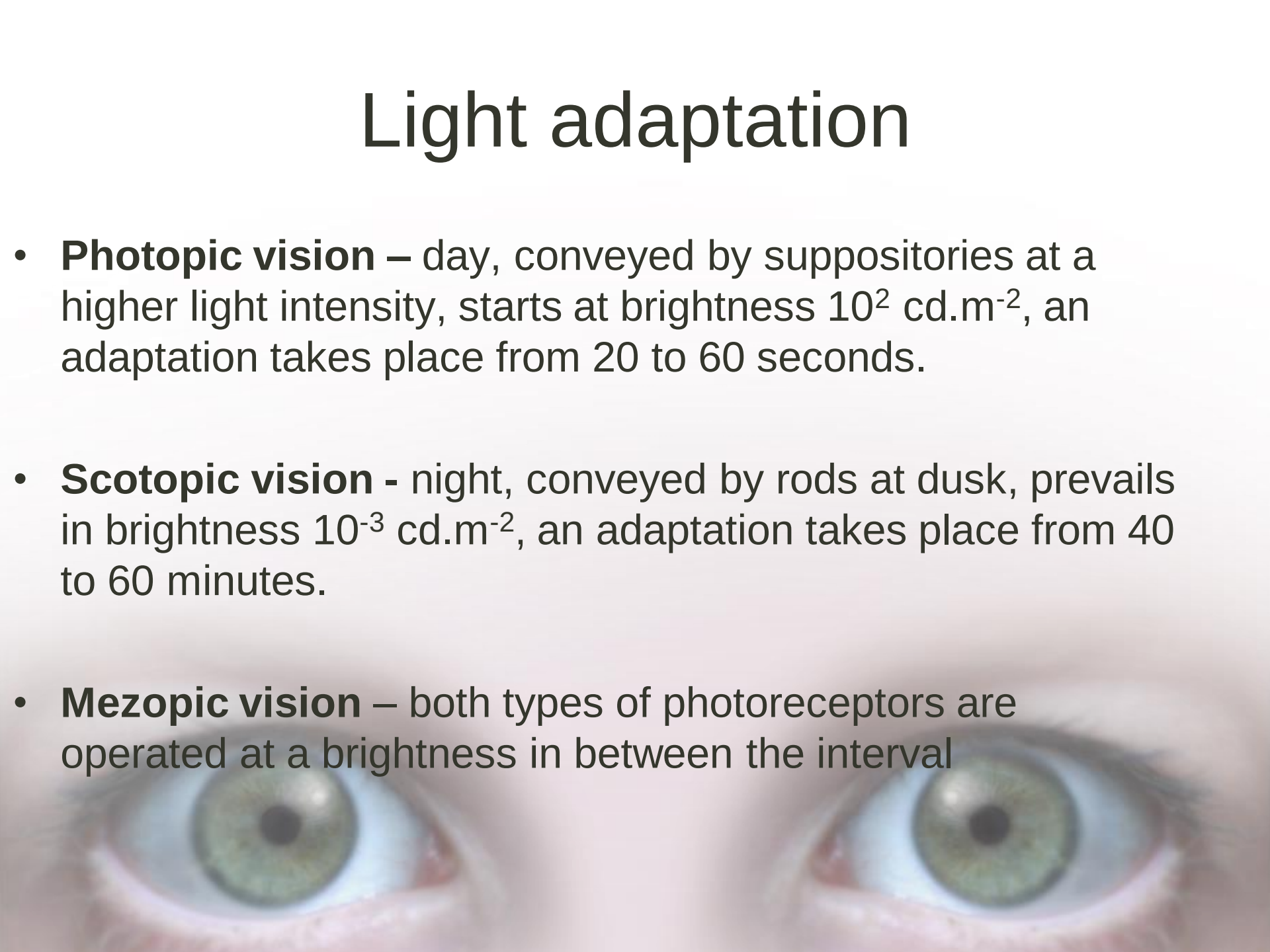
Refraction Index	Cornea	1,376
	Aqueous humor	1,336
	Lens	1,413
	Vitreous	1,336
Curvature radius	Cornea	7,8 mm
	Front surface lens	10,0 mm
	Rear surface lens	- 6,0 mm
Optical power	Cornea	42,7 D
	Lens	21,7 D
	Eye	60,5 D
Focus location	Subject focus	- 14,99 mm
	Image focus	23,9 mm
	Retina position	23,9 mm

Light adaptation

- **Photopic vision –** day, conveyed by suppositories at a higher light intensity, starts at brightness 10^2 cd.m^{-2}, an adaptation takes place from 20 to 60 seconds.

- **Scotopic vision -** night, conveyed by rods at dusk, prevails in brightness 10^{-3} cd.m^{-2}, an adaptation takes place from 40 to 60 minutes.

- **Mezopic vision** – both types of photoreceptors are operated at a brightness in between the interval

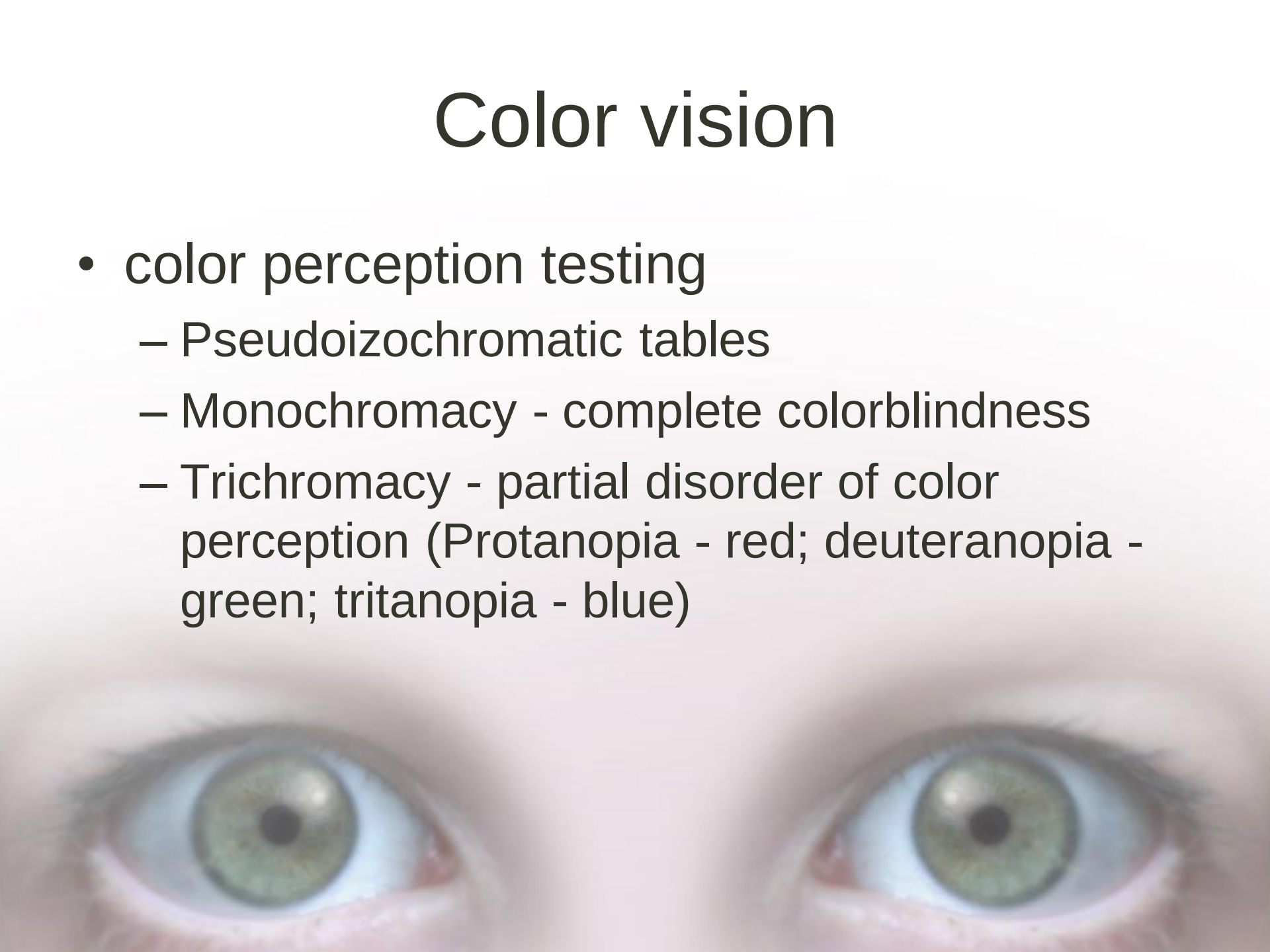


Color vision

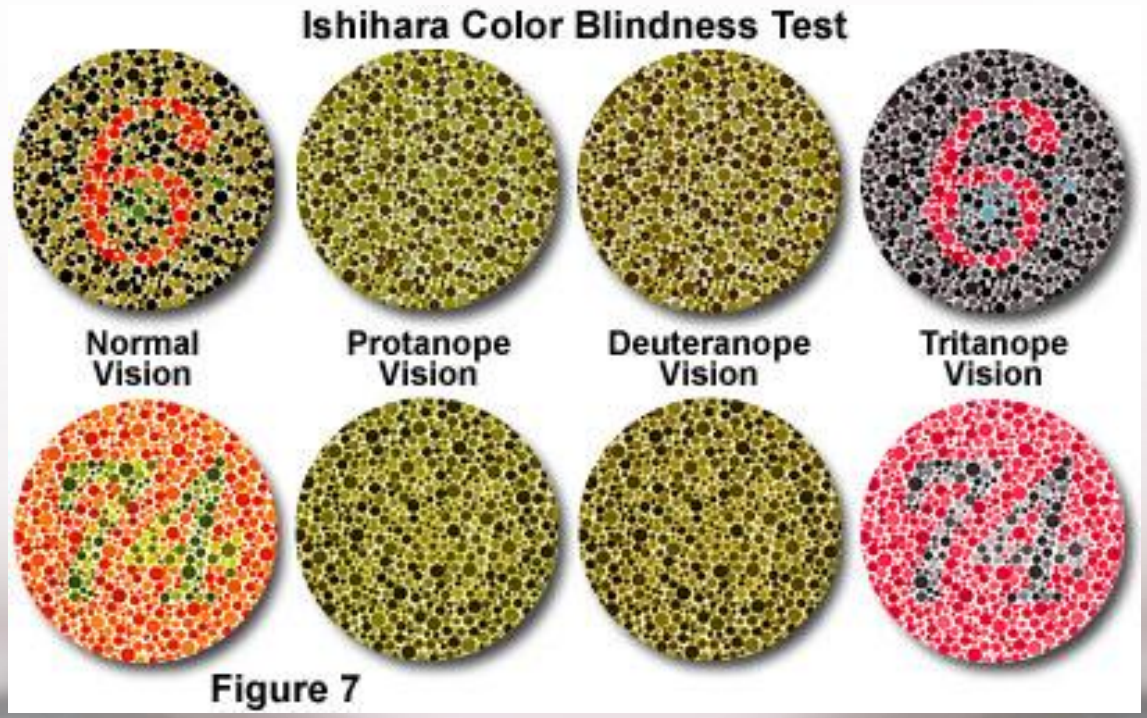
- Color perception – cones -the theory assumes three types of cones with differing spectral sensitivities
- Rods register all colors except red, but do not take place in color vision - at low intensities reduced color vision
- Trichromatic theory
  - Helmholtz – red, green, purple
  - Young/Lomonosov – red, blue, yellow

Color vision

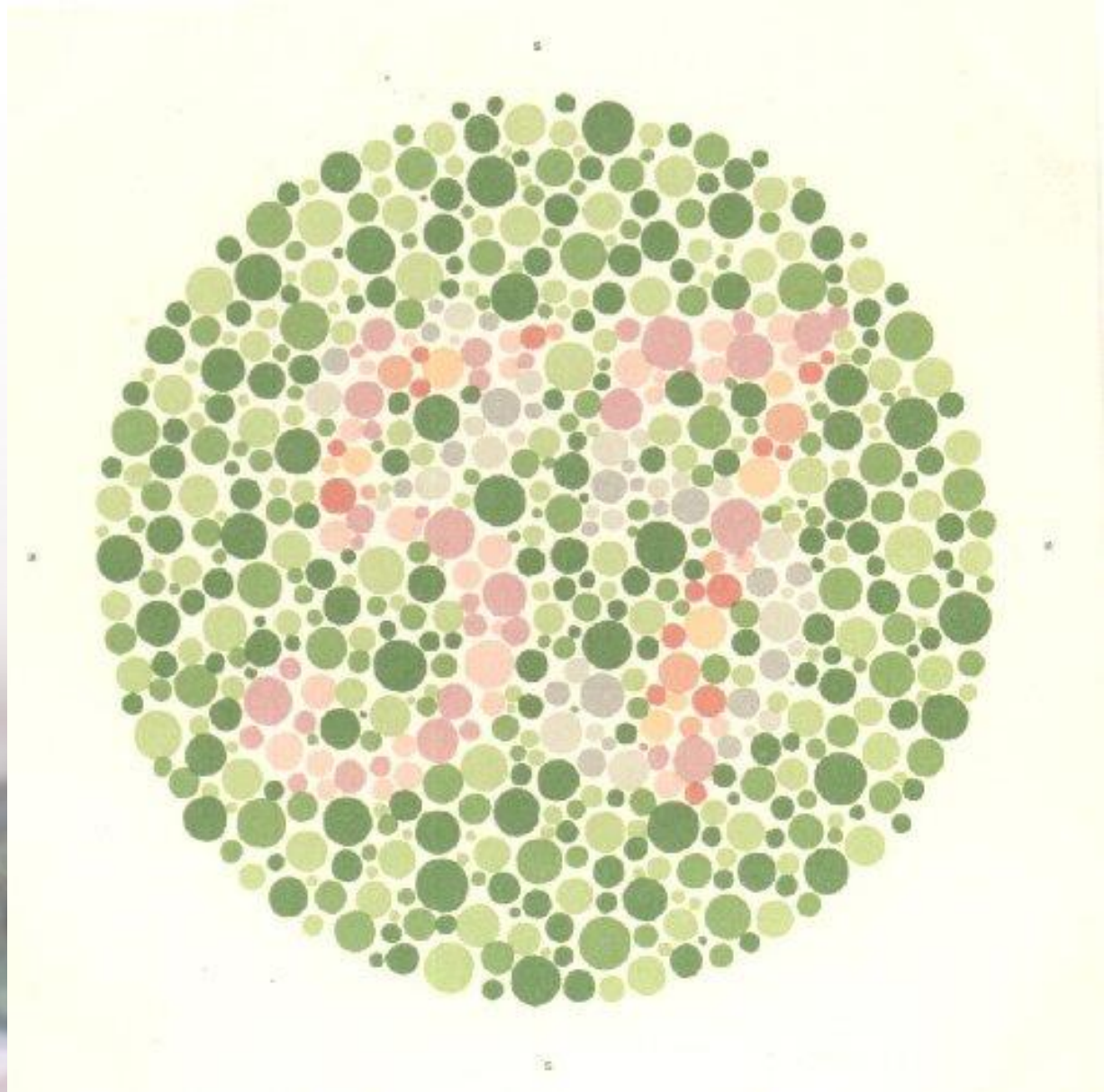
- color perception testing
  - Pseudoizochromatic tables
  - Monochromacy - complete colorblindness
  - Trichromacy - partial disorder of color perception (Protanopia - red; deuteranopia - green; tritanopia - blue)



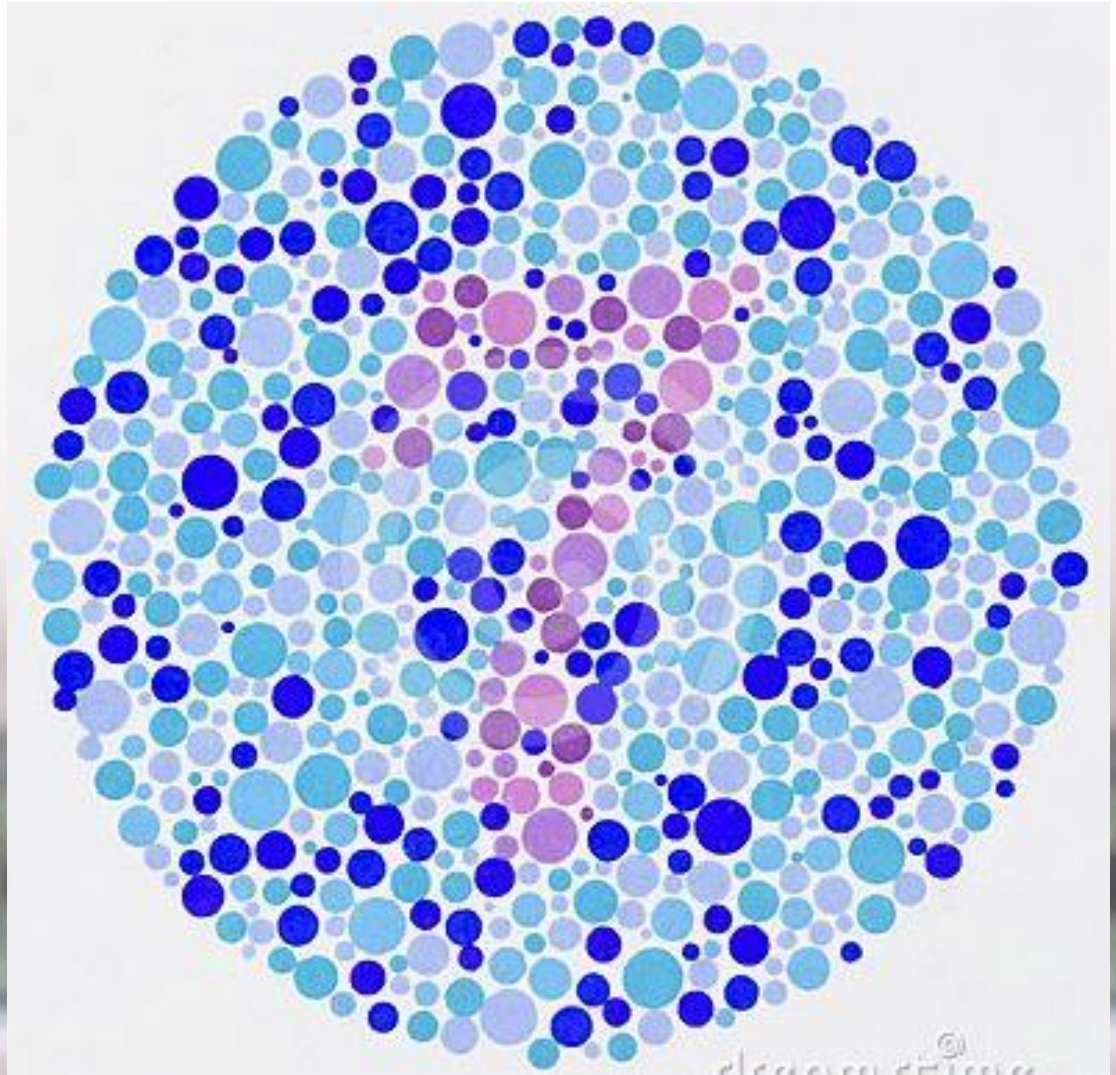
Color vision



Color vision



Color vision

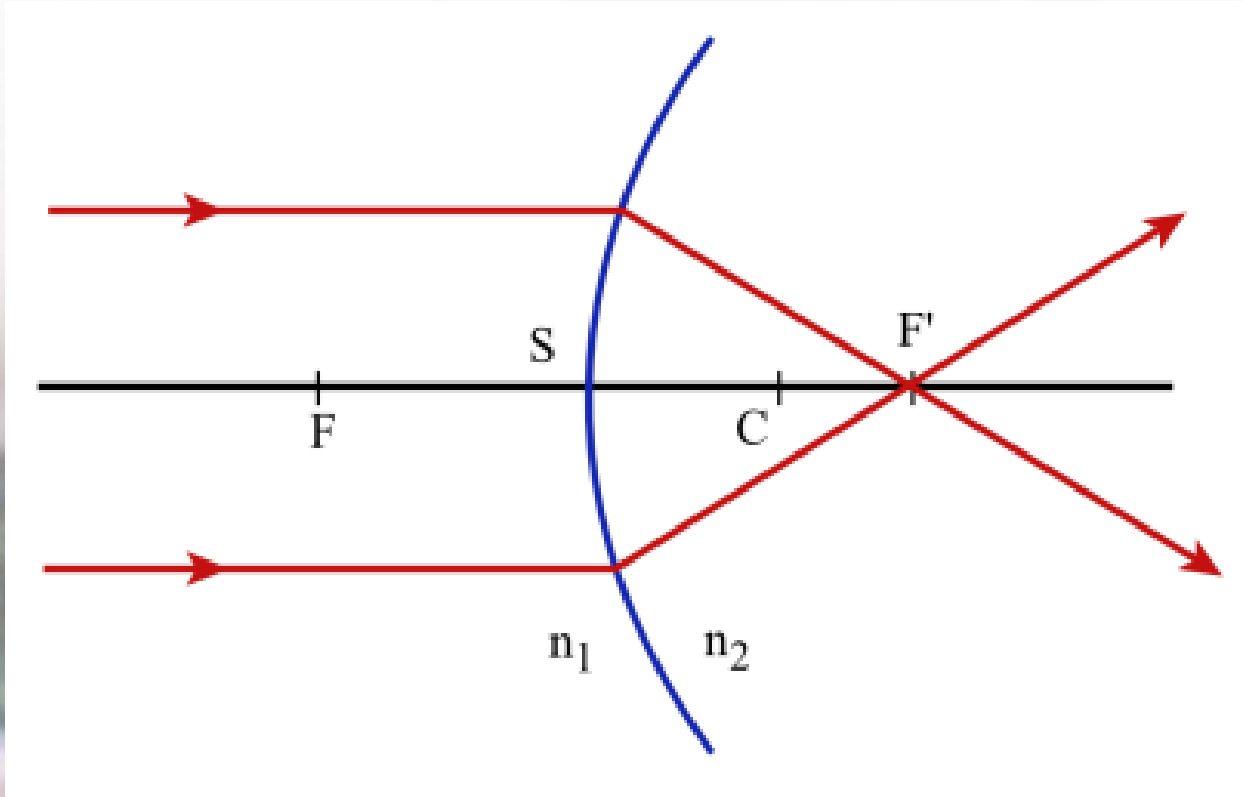


Aqueous humour

- Aqueous humour production
  - Stable pressure 2,66 kPa
    - Deviations +/- 0,3 kPa signs serious eye disorder

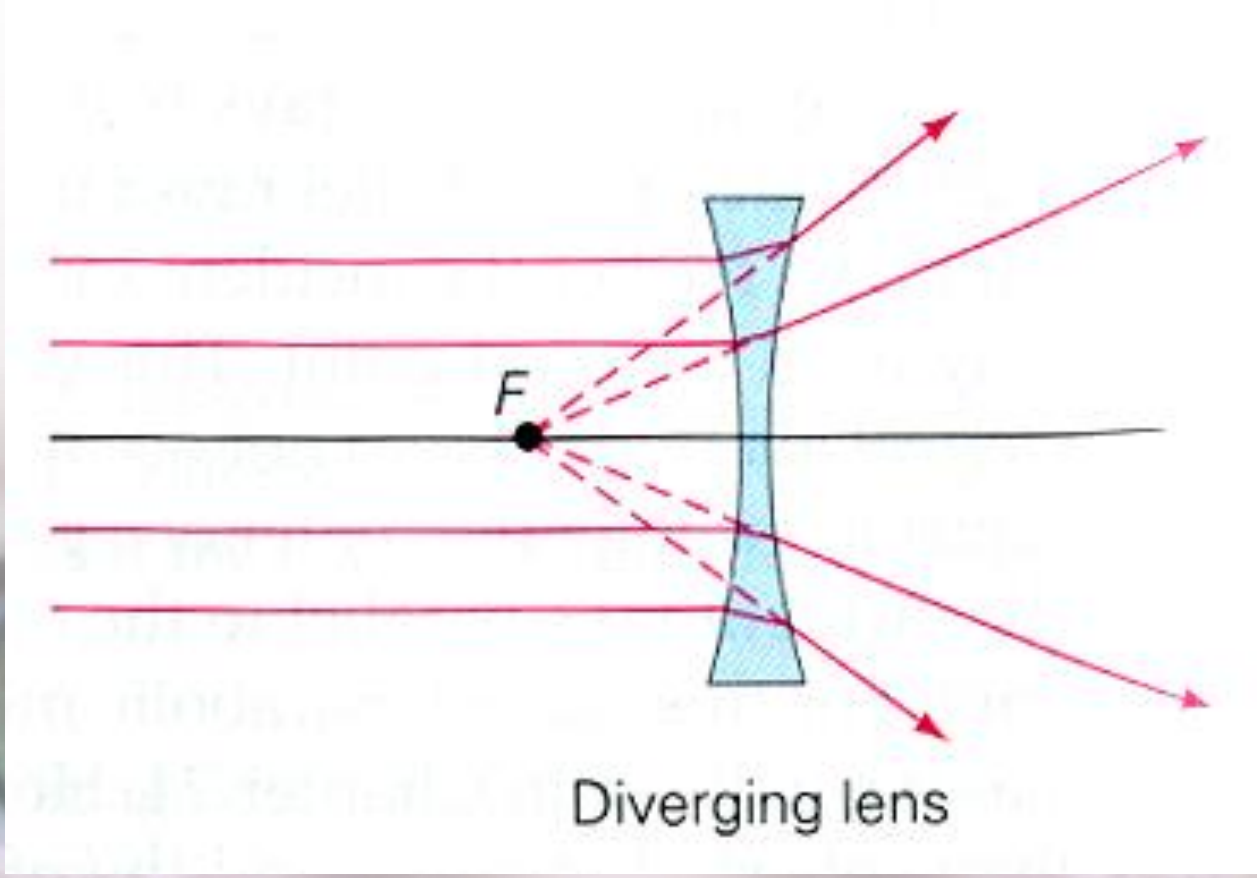
Diopter

- Diopter as a unit of optical power of spherical lens is defined as the reciprocal value of the focal length.
- Therefore it has a dimension of m^{-1}
- For ***converging*** *lens:* **F '= 0.5 m ≈ 1 / 0.5 = +2** Diopter [m^{-1}]



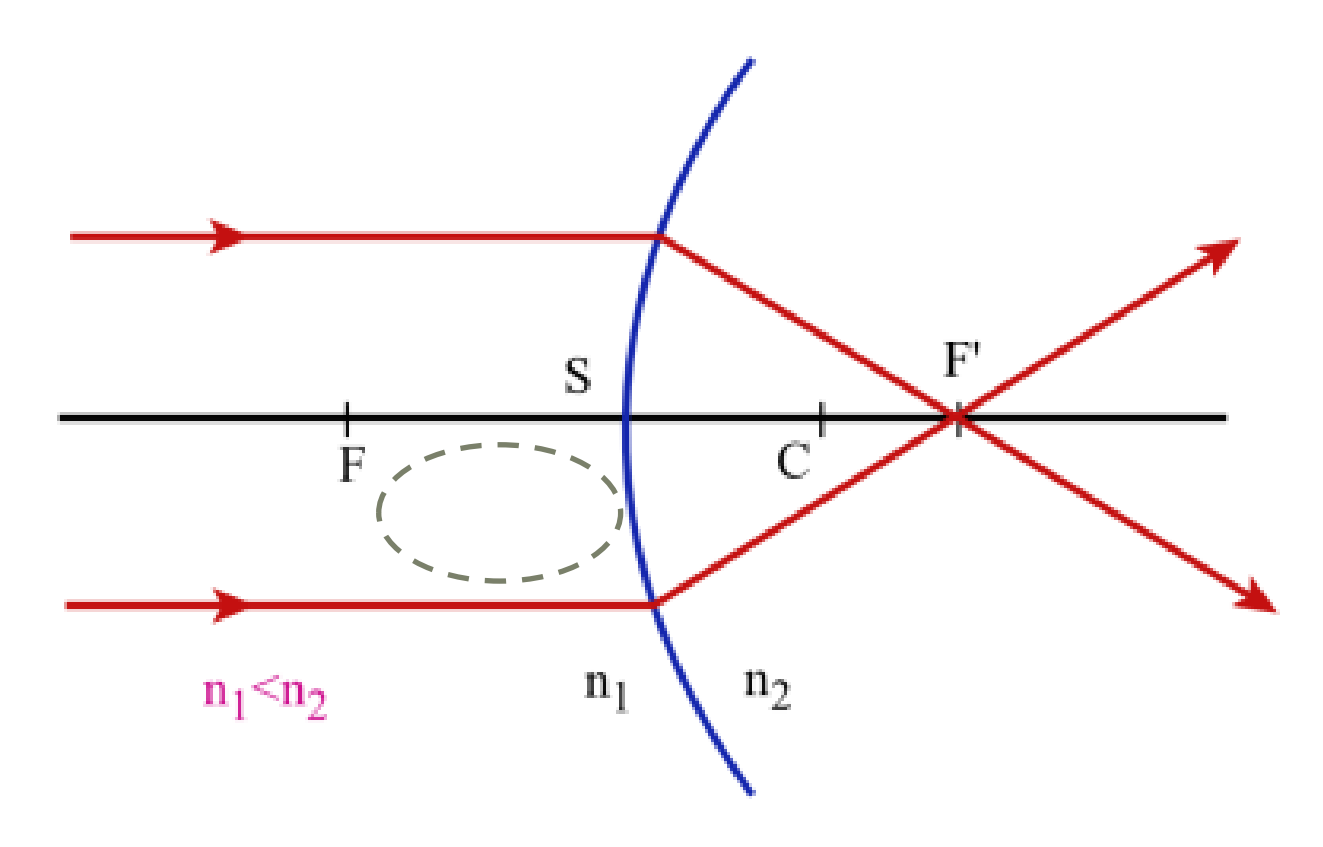
Diopter

- For diverging lens the diopter is negative.
- F '= 0.5 m ≈ 1 / 0.5 = - 2 diopter [m^{-1}]



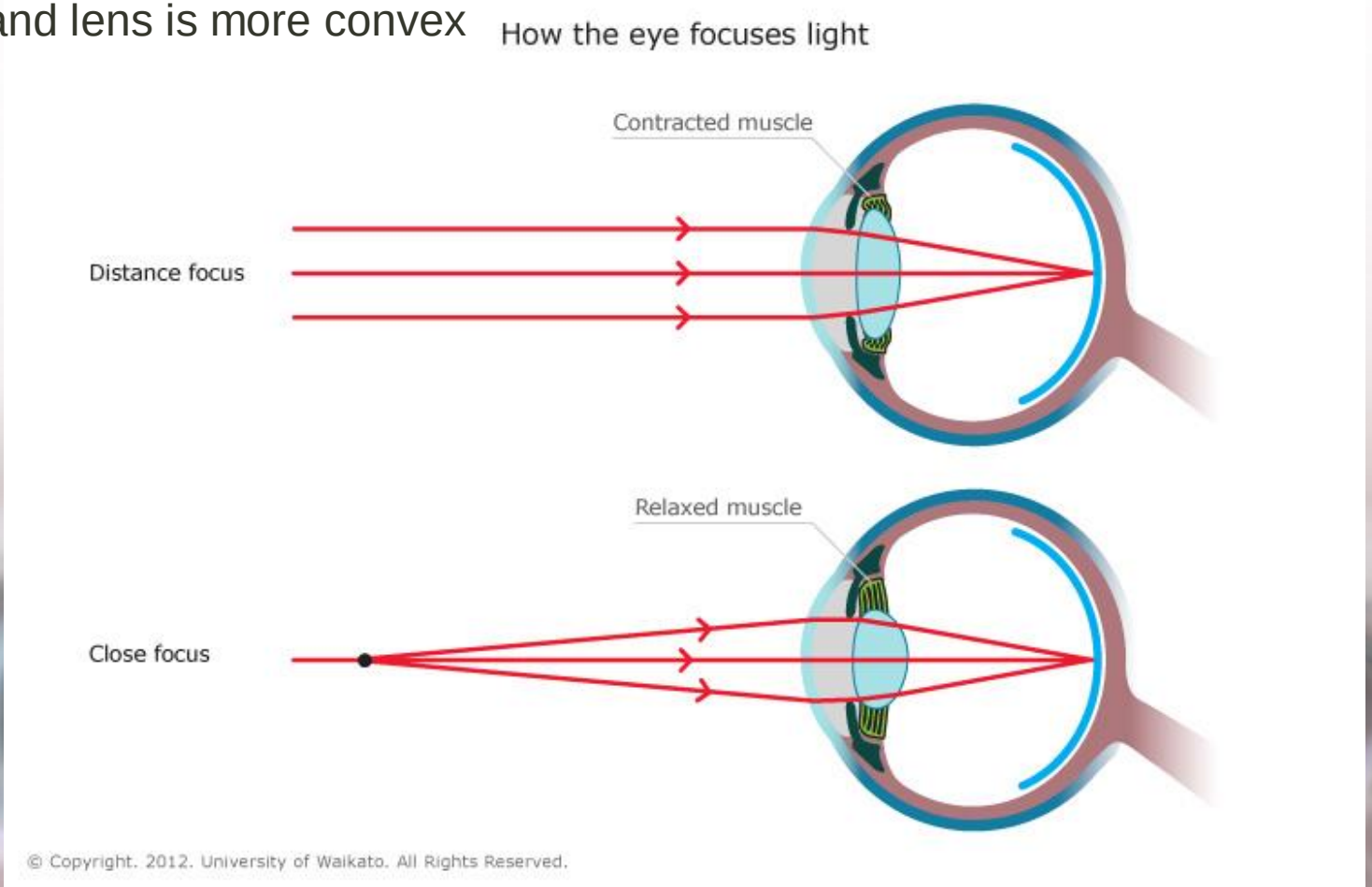
The optical power

- **The optical power** of the eye is about **+60 D**, which is caused by the curvature and refractive index of eye.



Eye accommodation

- The ability to change optical power of lens according to the distance of observed object.
- **Far point** is sharply visible without accommodation, the **muscles** that support the lens **are contracted.**
- **Near point** is sharply visible by maximum accommodation, the **muscles of lens are relaxed** and lens is more convex

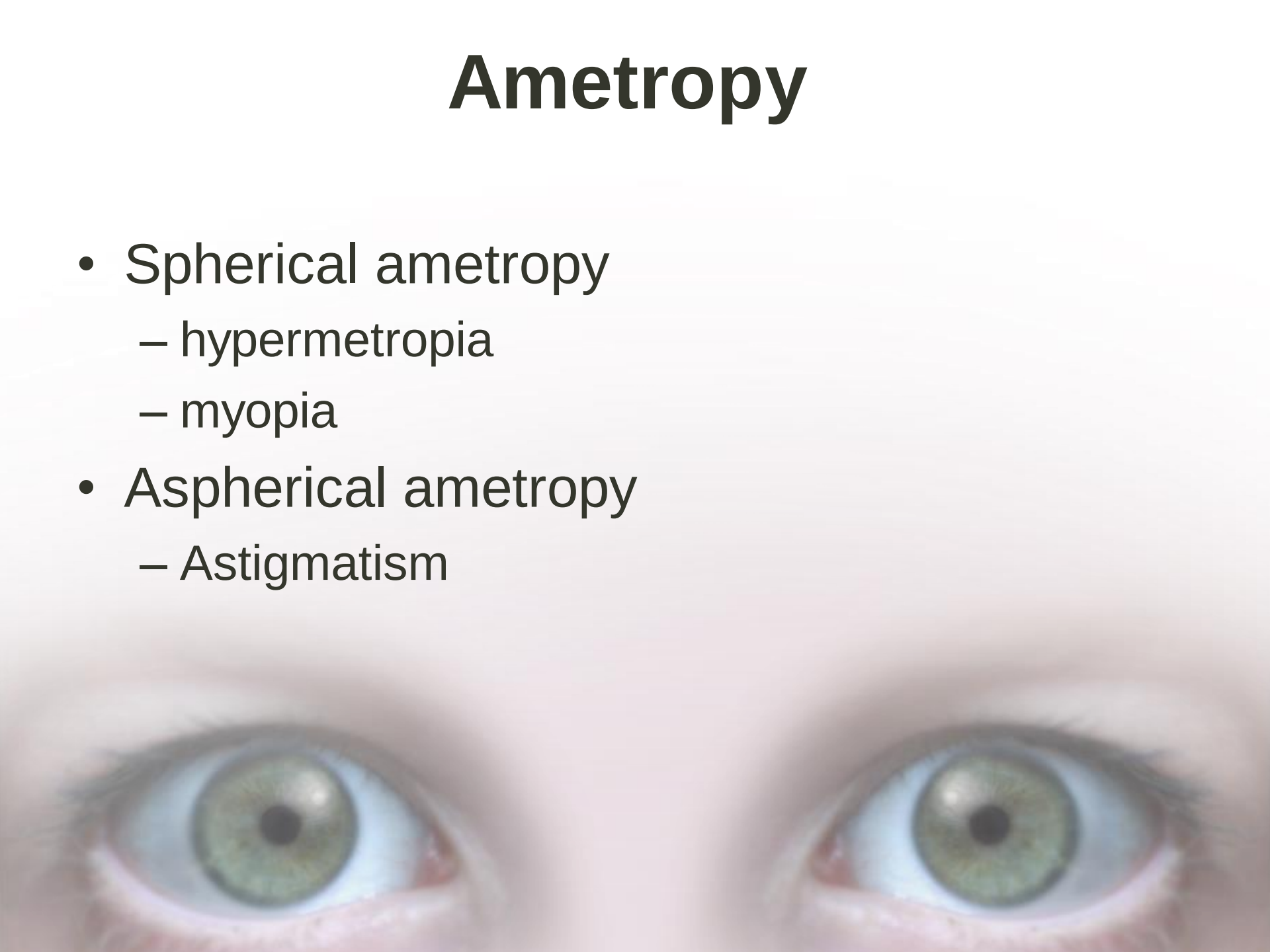


Presbyopy

- Accommodation is ability of eye to focus on near point, but it decreases with age.
- The **elasticity of lens** begins to decrease between 40-45 years and completely disappears between 70-80 years.
- For a healthy adult is the ability to focus at a distance of less than 25 cm, ie. 4 D.
- Presbyopia occurs when the amplitude of accommodation is less <4D, i.e.> 25 cm.
- Rays then fall behind on the retina.

Ametropy

- Spherical ametropy
  - hypermetropia
  - myopia
- Aspherical ametropy
  - Astigmatism

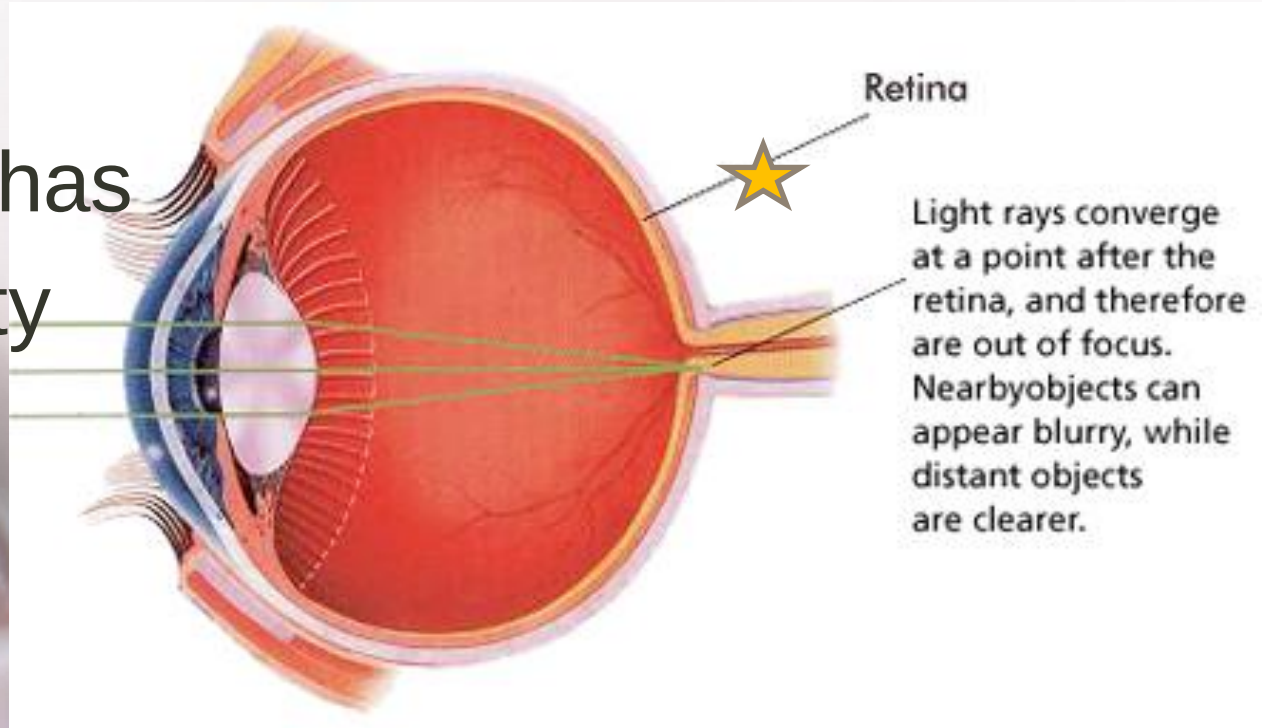


Hypermetropia

- Is **spherical disorder** when the optical focus lies behind the retina.
- We distinguish between:

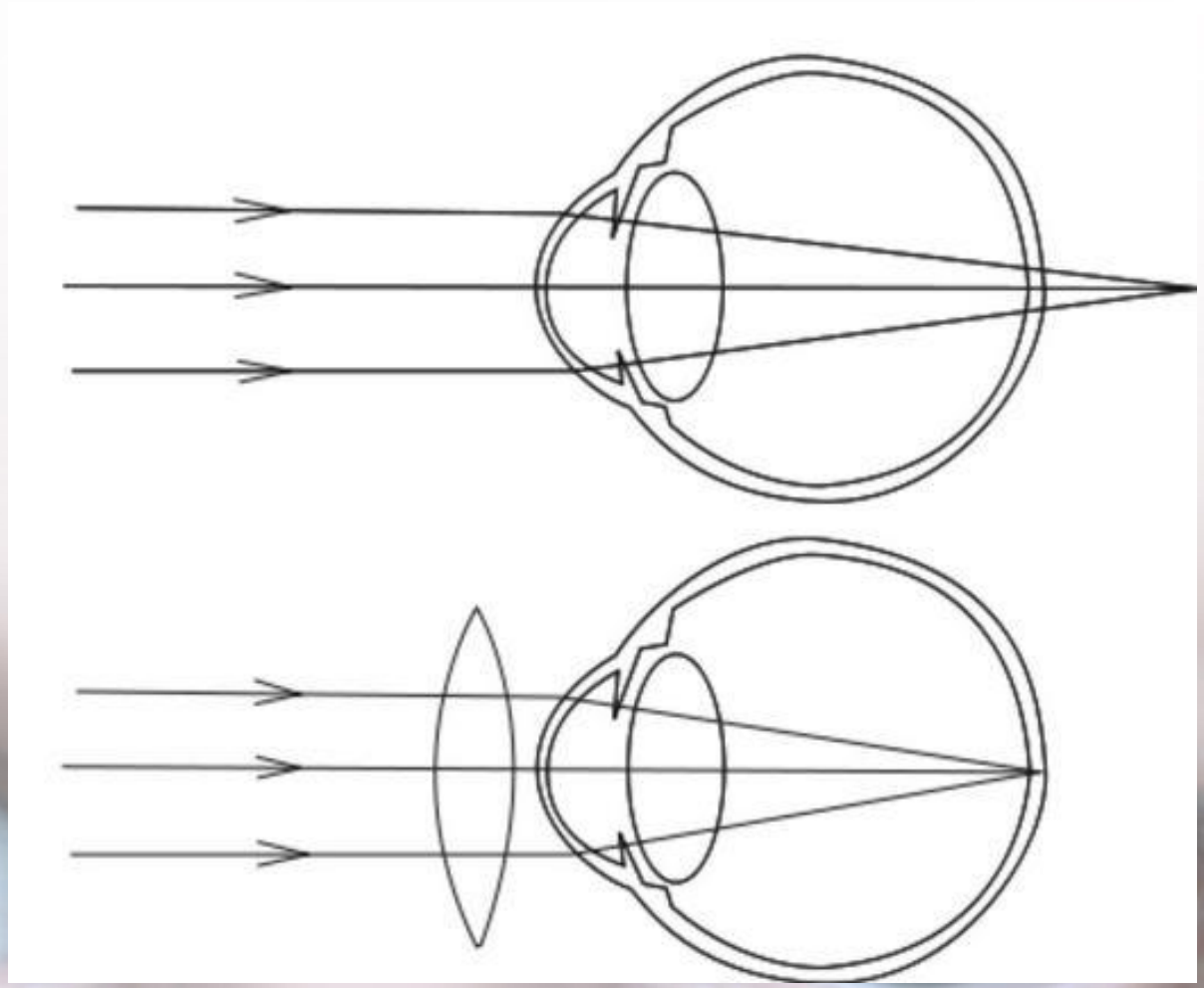
Axial: eyeball is too short

Refraction: eye has smaller refractivity



Corection of **Hypermetropy**

- For correction we use convergence lens.

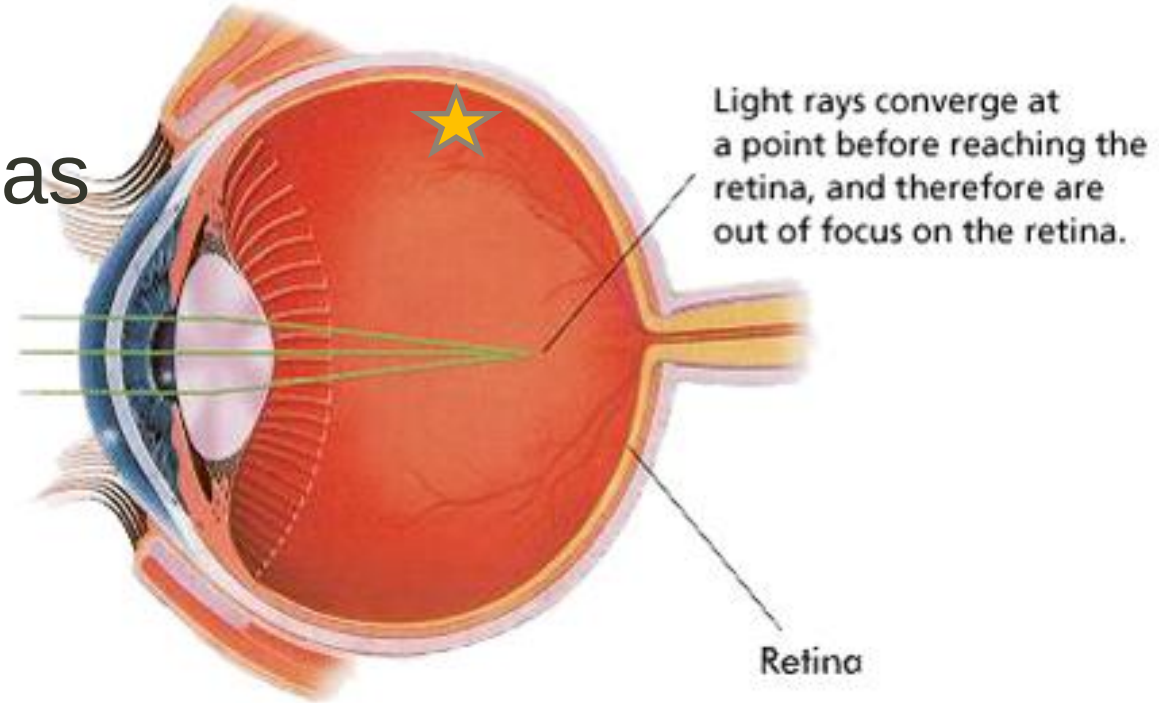


Myopia

- Is **spherical disorder** when the optical focus lies in front of retina.
- We distinguish between:

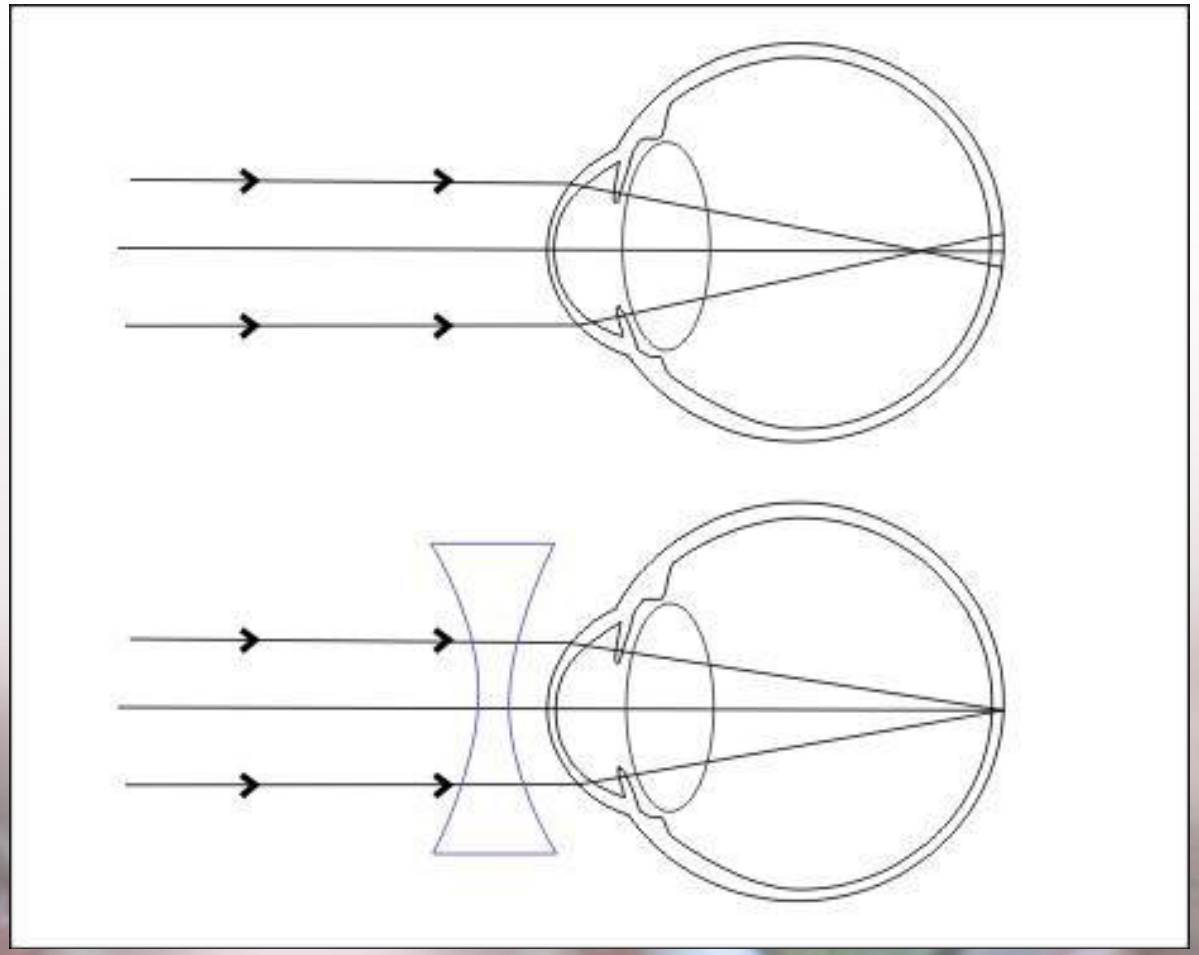
Axial: eyeball is too long

Refraction: eye has higher refractivity



Corection of **Myopia**

- For correction we use divergence lens.

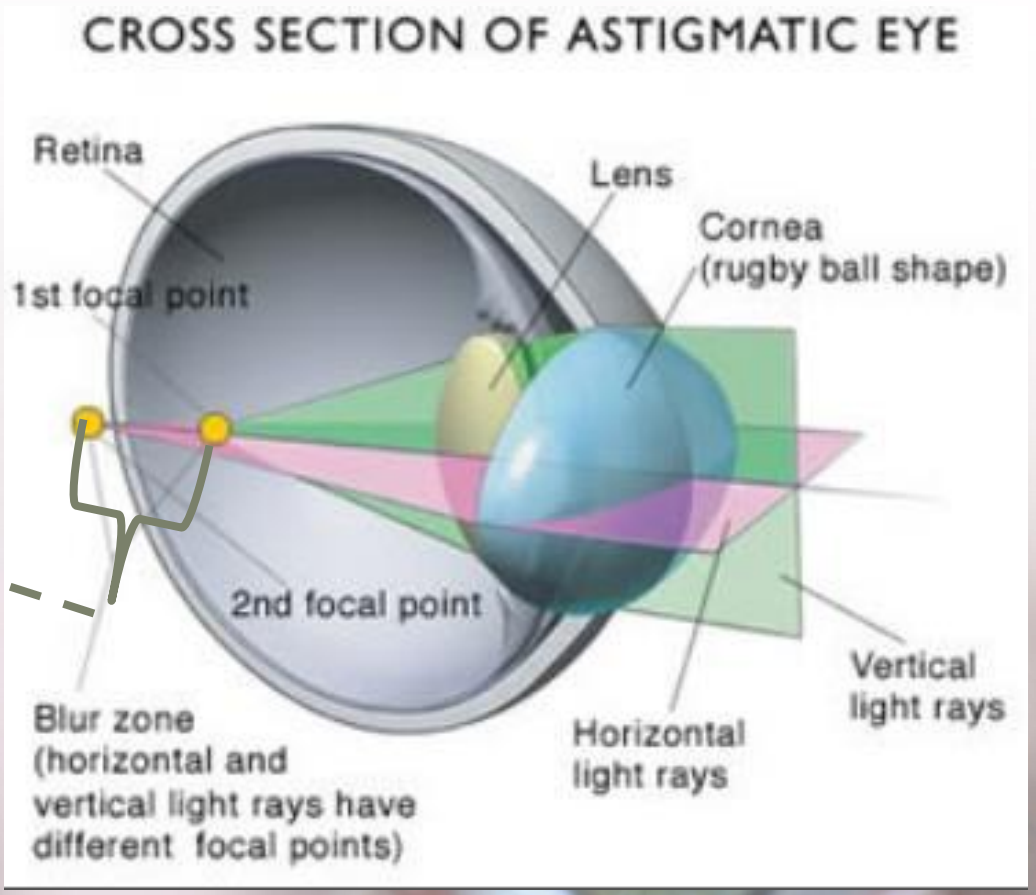


Astigmatism

- It is caused by the **asymmetry of optical power** of the cornea. The cornea has not the same curvature along optical axis. **It is the aspherical defect.**

- **The degree of astigmatism**

The difference in diopters between the maximum and minimum curvature of the cornea



Keratometer

Keratometer

- by mirroring the test light to measure corneal curvature

Endoscopic methods

Endoscopic mirrors

- Laryngoscopic mirror (laryngoscope)
- Ear speculum (otoscope)
- Nose pliers (rhinoscope)
- Eye mirror - was used to monitor the reflection of light rays from the retina to detect defective refractive defects of the eye refraction.
  - Today using automatic refractometers

www.medical-centar.hr

www.meier-medizintechnik.de

www.perivet.

Endoscopy

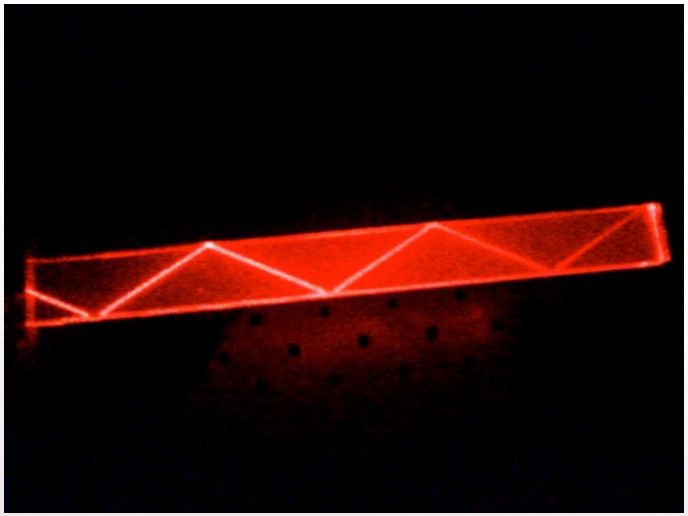
- Rigid endoscope - a metal tube (lens, an eyepiece, a transfer system); bulb at the end of the tube; laparoscope, gastroscope...
- Fibroendoscope - fiber bundle - the system transmits light (a source outside of the patient) and sends back the image; up to 30,000 fibers

Optic fibers

Principle:

Fiber has a core and a coat

- Optically different environments
  - Core = higher refraction index (1,48)
  - Coat = lower refraction index (1,46)
- Total internal reflection



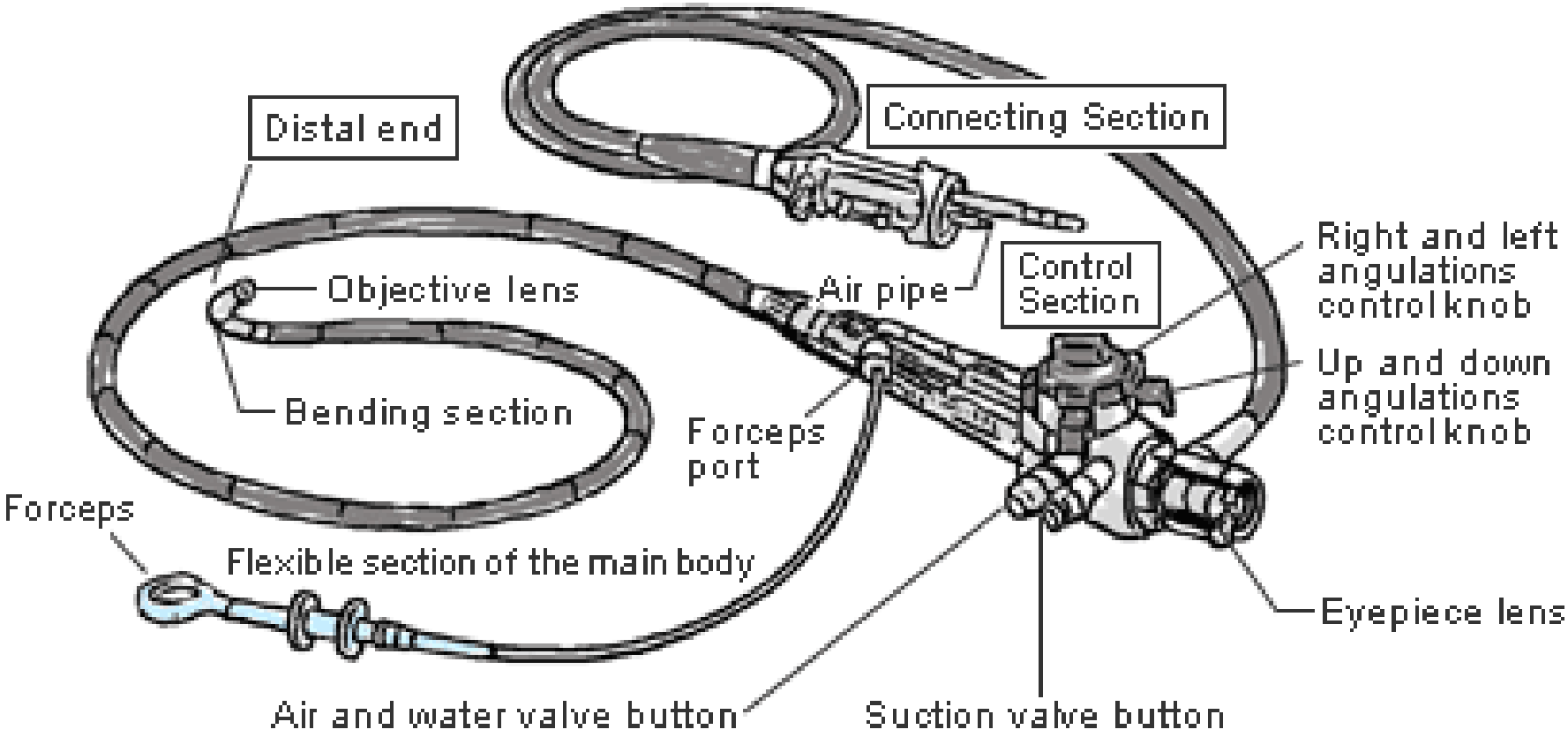
Material: Glass/Plastic

Advantage

- Lower signal loss/per length
- Higher transmission speed
- EM interference resistance

Endoscopic methods

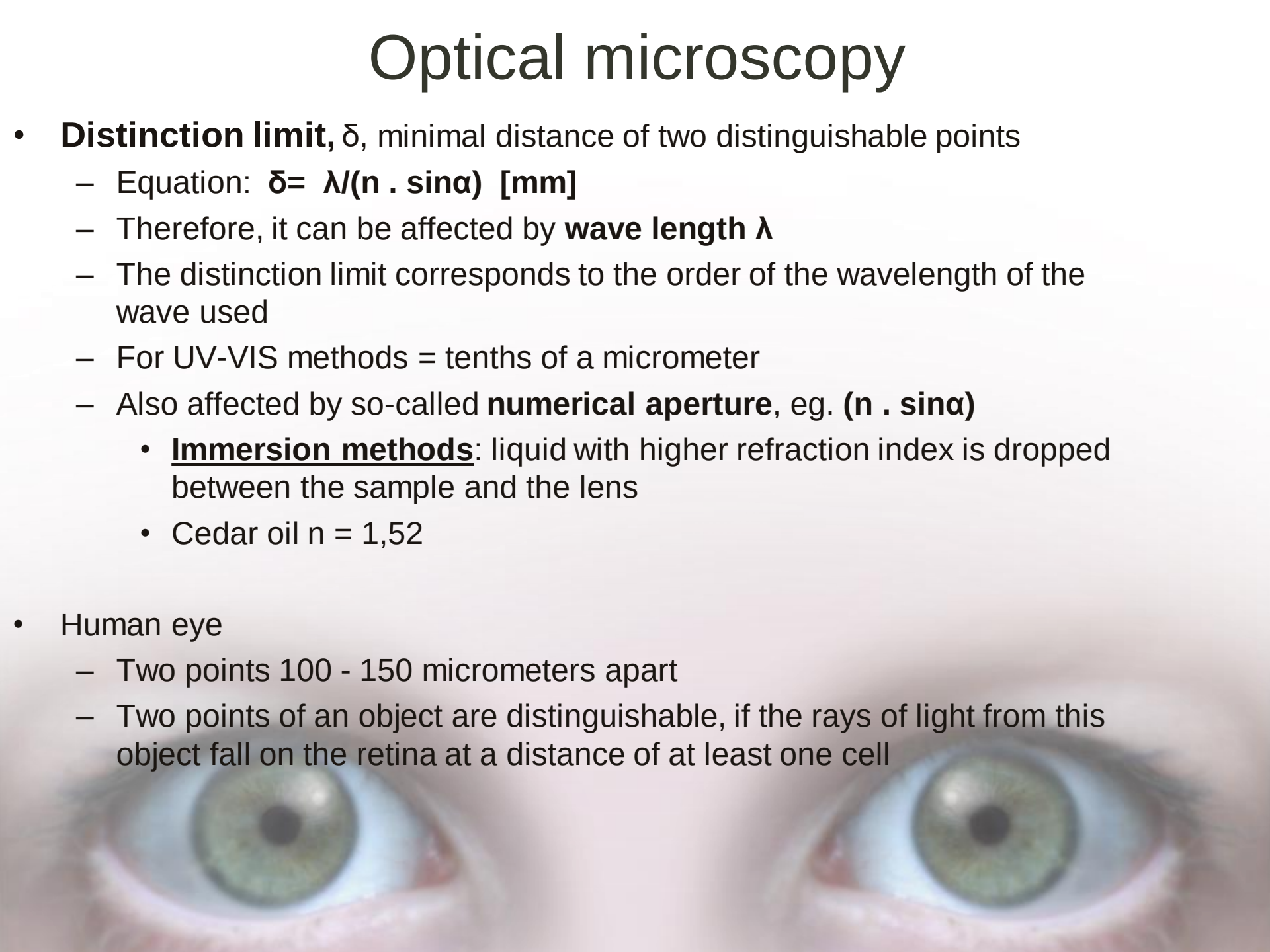
- princip – optické vlákno (světlovod)
- Paprsek je veden s minimálními ztrátami, překonává mozní ohyb



Optical microscopy

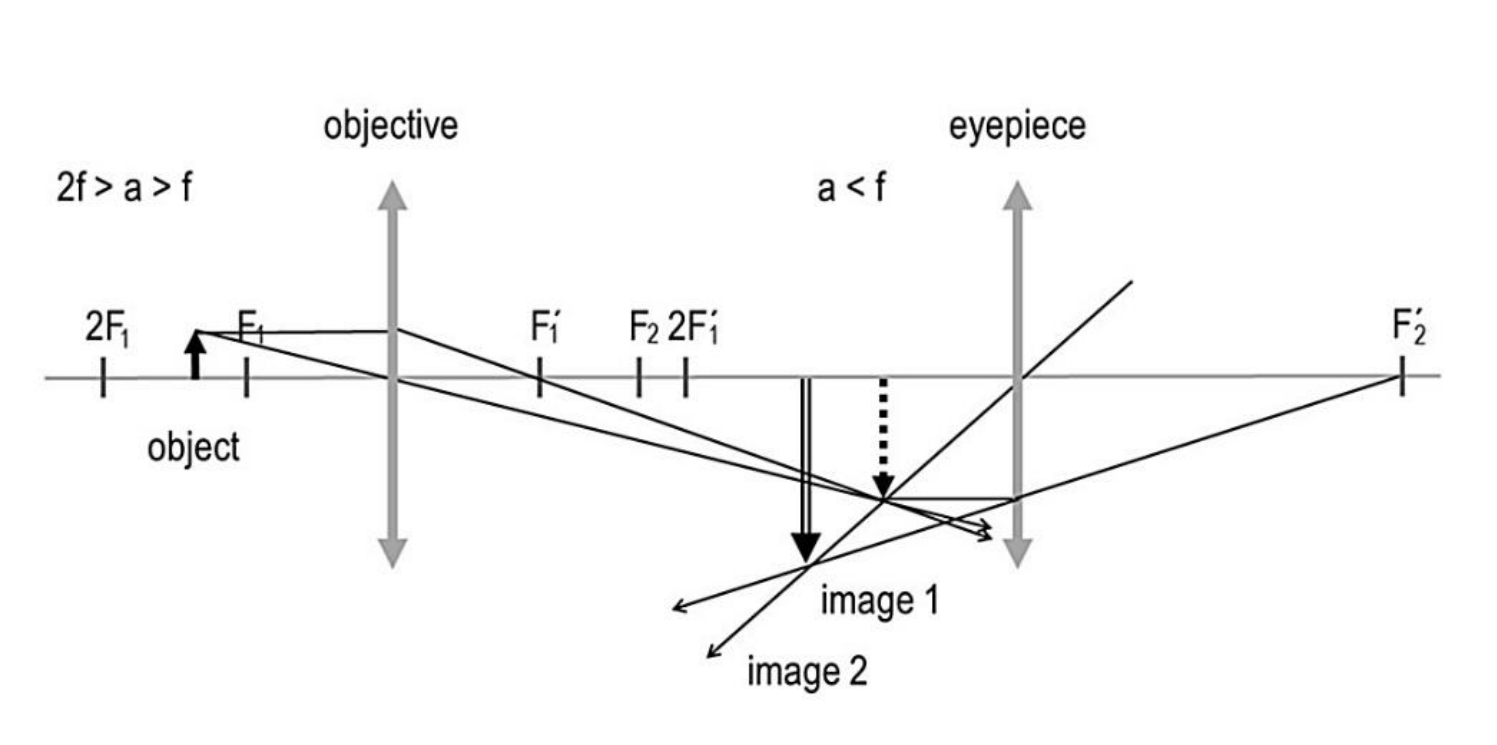
- **Distinction limit,** δ, minimal distance of two distinguishable points
  - Equation: **$\delta = \lambda/(n \cdot \sin\alpha)$ [mm]**
  - Therefore, it can be affected by **wave length λ**
  - The distinction limit corresponds to the order of the wavelength of the wave used
  - For UV-VIS methods = tenths of a micrometer
  - Also affected by so-called **numerical aperture**, eg. **$(n \cdot \sin\alpha)$**
    - **Immersion methods**: liquid with higher refraction index is dropped between the sample and the lens
    - Cedar oil n = 1,52

- Human eye
  - Two points 100 - 150 micrometers apart
  - Two points of an object are distinguishable, if the rays of light from this object fall on the retina at a distance of at least one cell

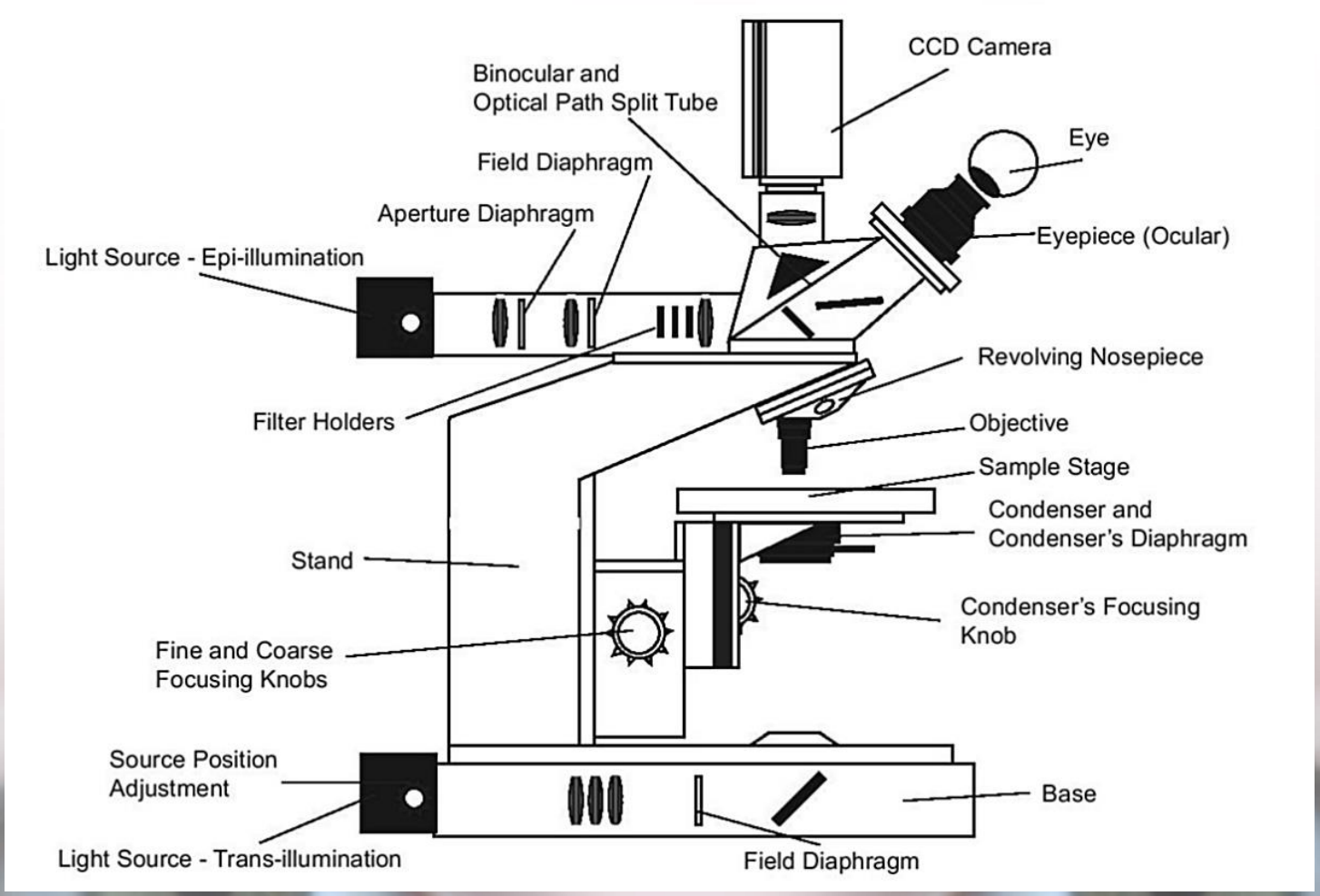


Optical microscopy

- **Objective-** convergin lenses, low focal distance (1,5–20 mm), image is **inverted, real and enlarged**, image can be increased up to 150×
- **Eyepiece-** convergin lenses, image enlarged up to 20×), does not increase distinction, **final image** is **inverted, virtual, enlarged**
- Total zoom is a product of objective and eyepiece zoom



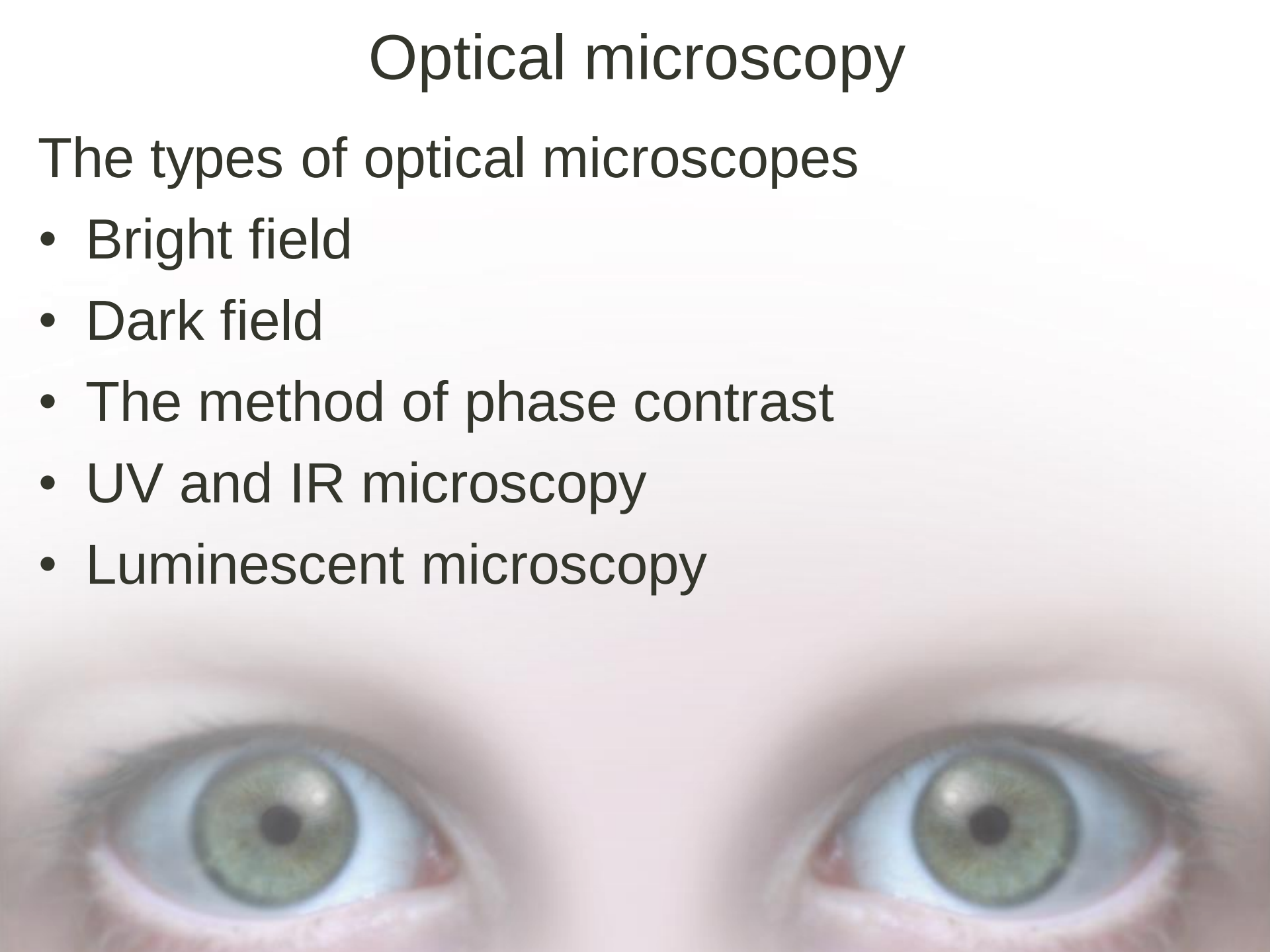
Optical microscopy



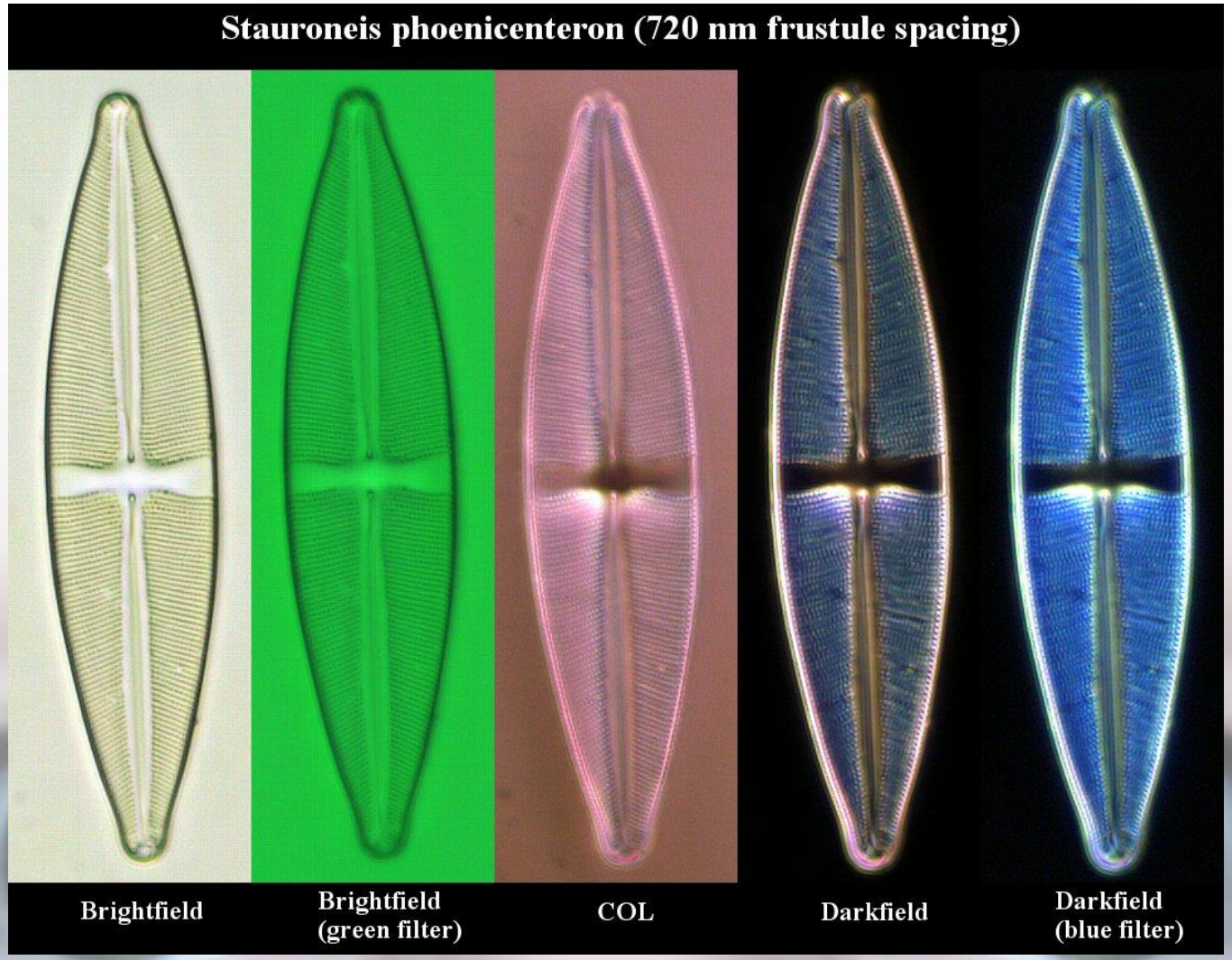
Optical microscopy

The types of optical microscopes

- Bright field
- Dark field
- The method of phase contrast
- UV and IR microscopy
- Luminescent microscopy

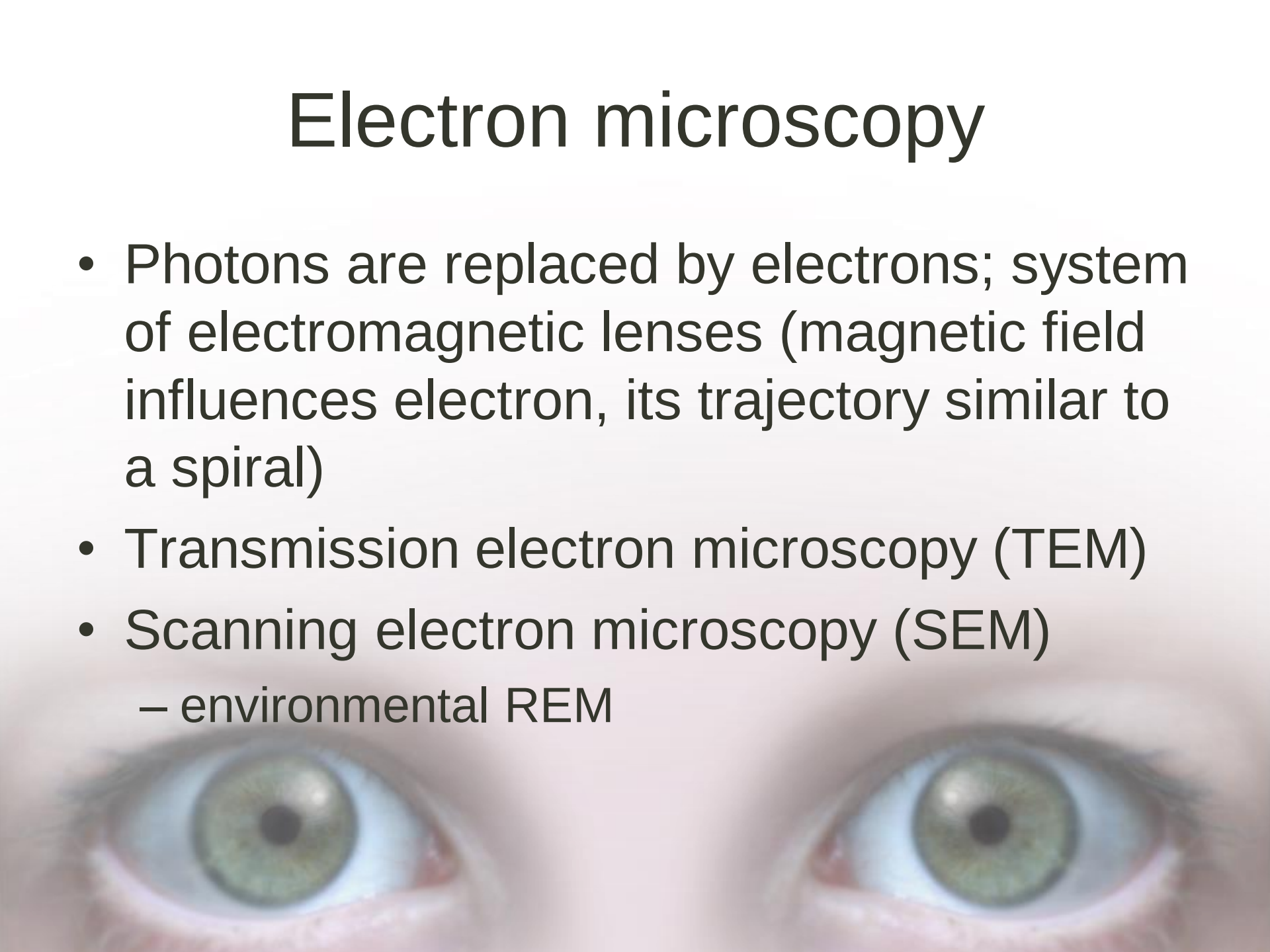


Optical microscopy



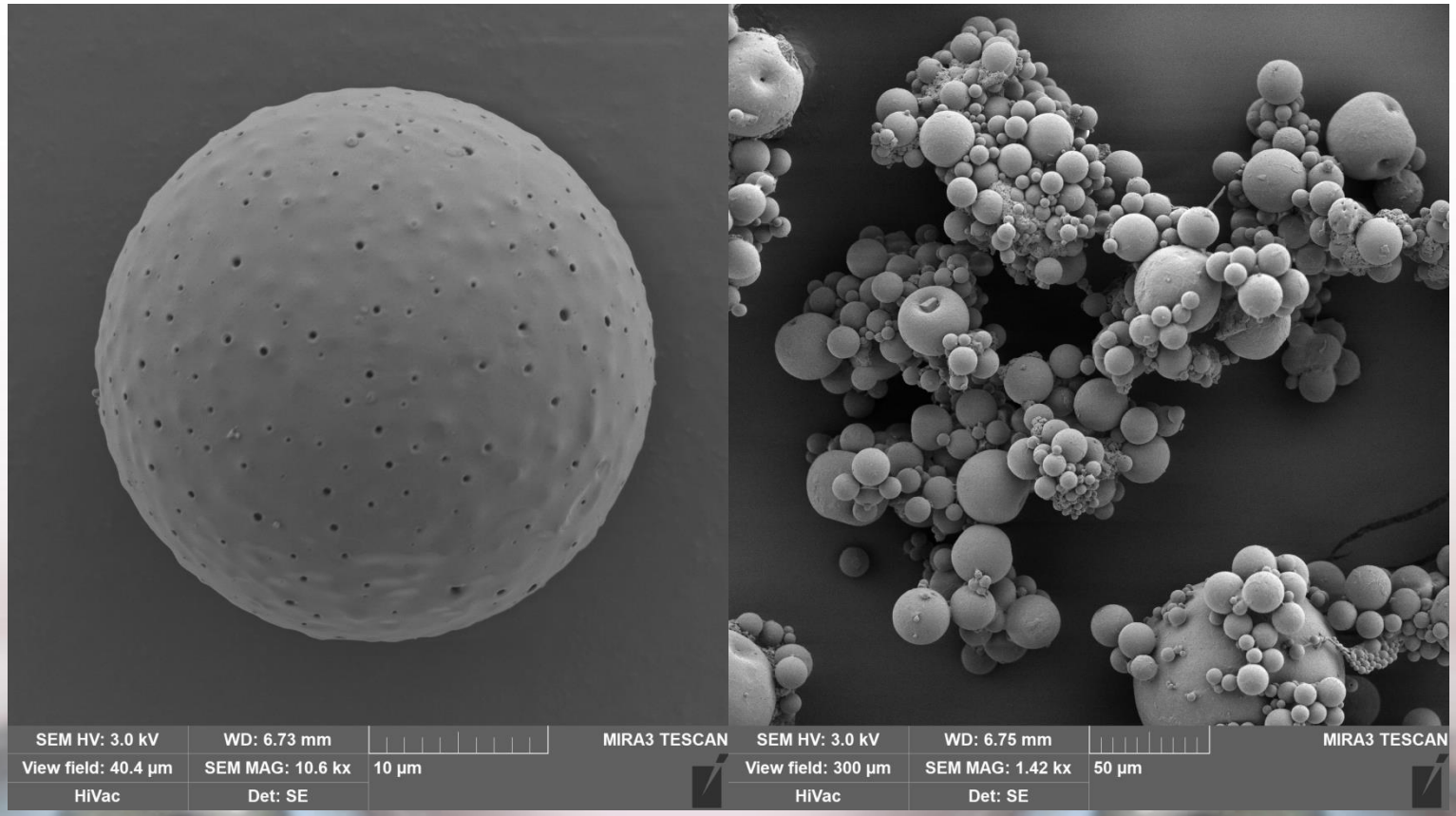
Electron microscopy

- Photons are replaced by electrons; system of electromagnetic lenses (magnetic field influences electron, its trajectory similar to a spiral)
- Transmission electron microscopy (TEM)
- Scanning electron microscopy (SEM)
  - environmental REM

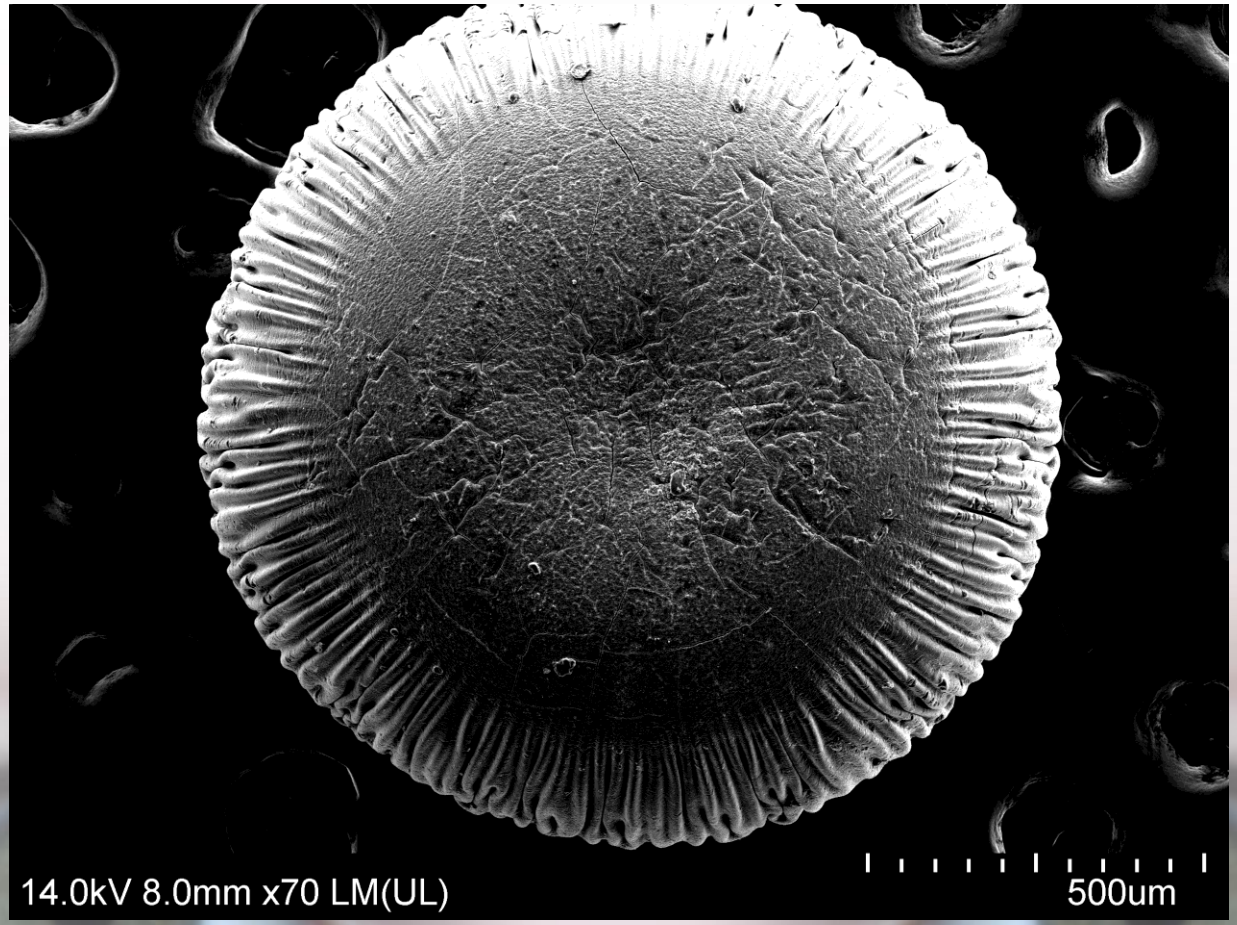


TEM Electron microscopy

SEM Electron microscopy



SEM Electron microscopy



Atomic Force microscopy

Probe microscopy
Probe on the spring, scanning surface at distance similar to effective distance of van der Waals forces
Spring deformation caused by the interaction of the probe with the surface is detected by reflected laser beam at fotodetector
magnification up to individual atoms

Atomic Force microscopy