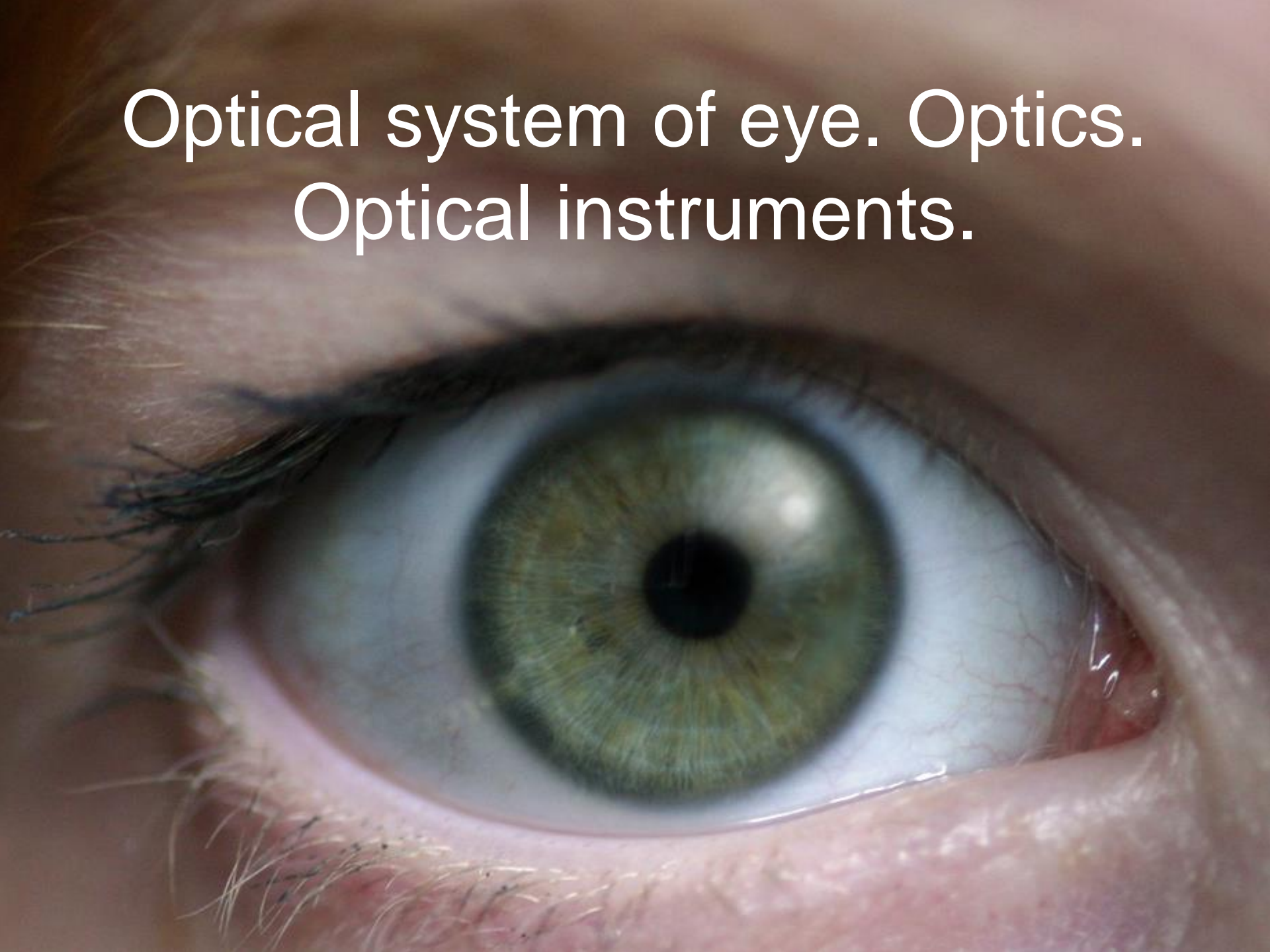


Optical system of eye. Optics.
Optical instruments.



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.



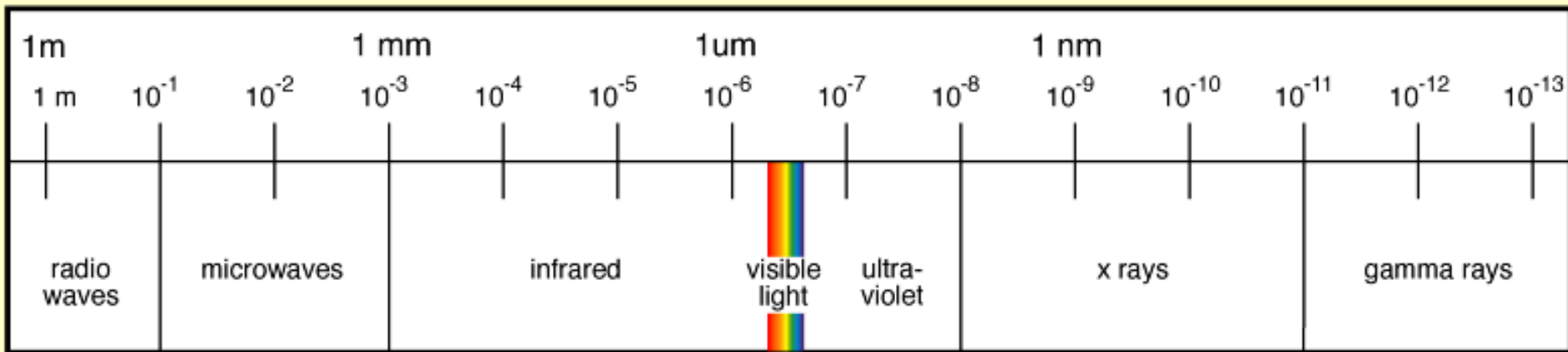
Optics

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

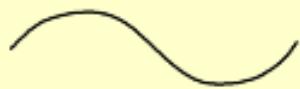


electromagnetic spectrum

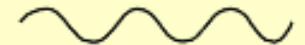
The Electromagnetic Spectrum



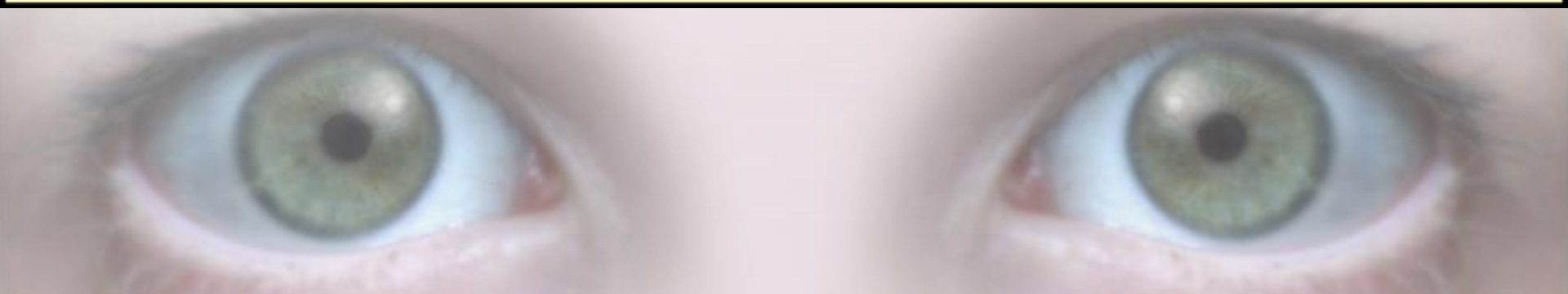
visible light: 0.4 to 0.7 μ m



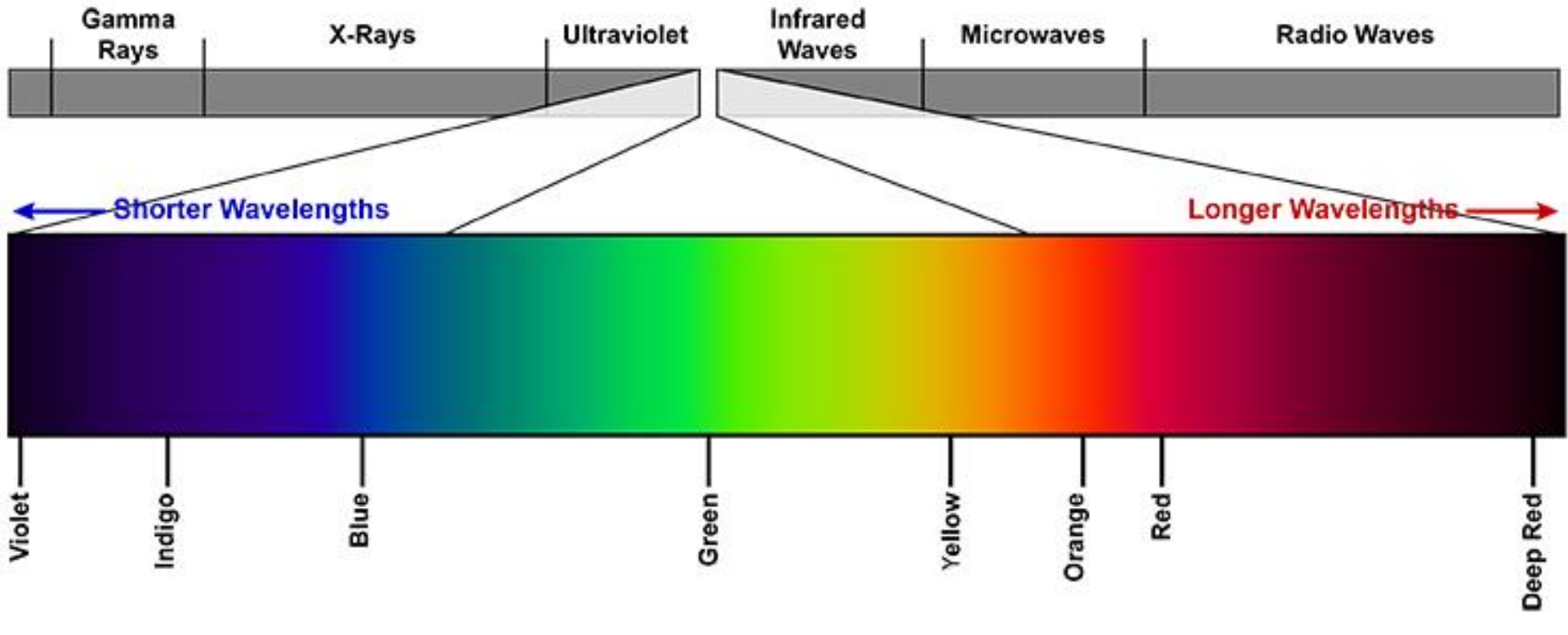
long wavelength
low frequency



short wavelength
high frequency



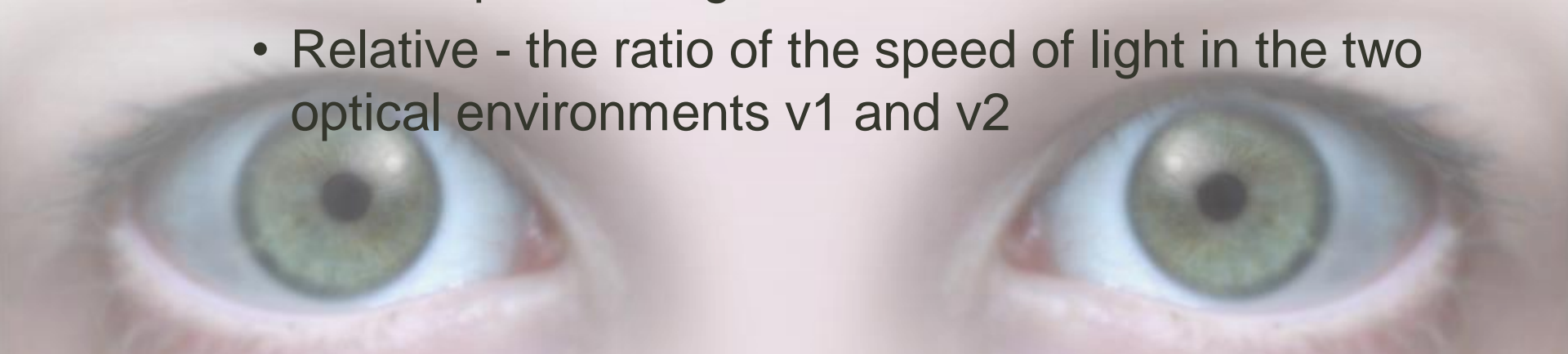
Visible light



Basic terms

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

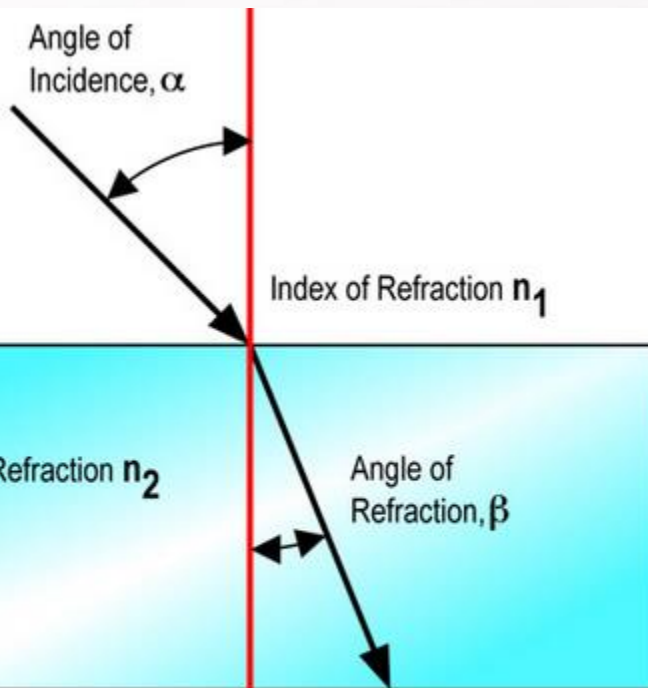
- Refractive index
 - dimensionless value specific to the optical medium (ie. for a given pair of environment)
 - Characterizes the speed of light wave in a given environment.
 - Absolute - the ratio of the speed of light in vacuum c , and speed in a given environment
 - Relative - the ratio of the speed of light in the two optical environments v_1 and v_2



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

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



$$n_1 \sin \alpha = n_2 \sin \beta$$

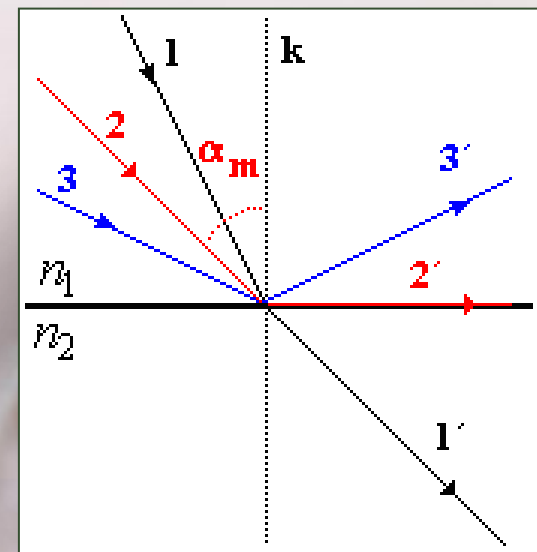
- » From the optically thinner to optically denser = refraction to perpendicular
- » From the optically denser to optically thinner = refraction from perpendicular



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



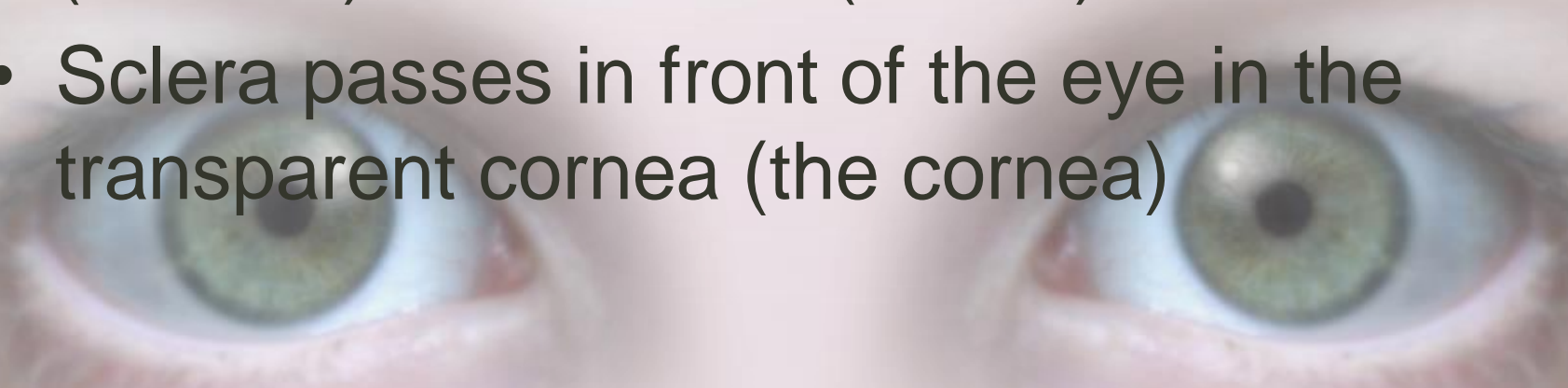
Biophysics of light perception

- Sight
 - Receiving and processing information about the outside world, mediated by photons with $\lambda = 380-780 \text{ nm}$
 - Analyzer
 - Eye
 - Optical nerves
 - Cortex

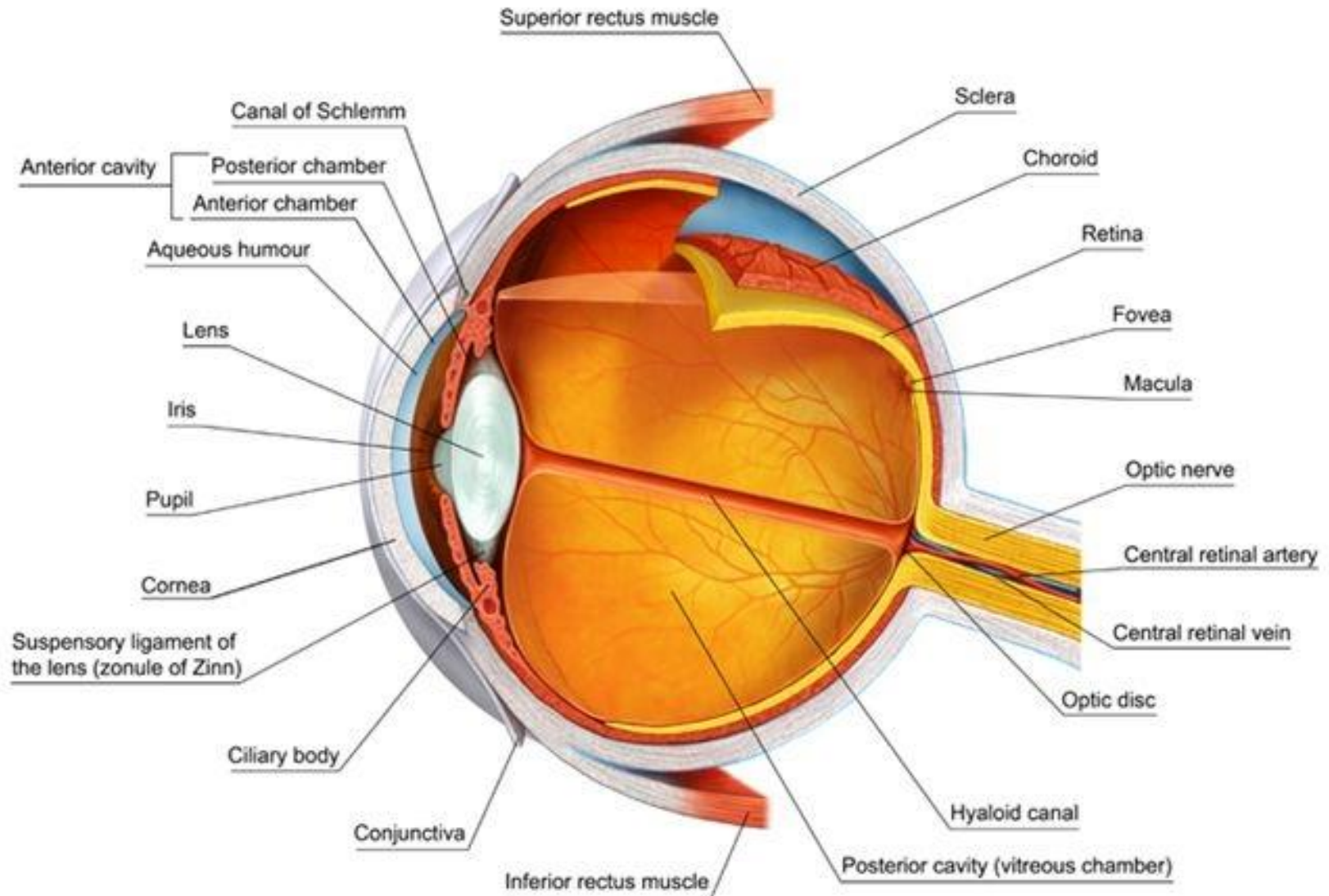


Optical system of eye

- Spherical organ with a diameter of approximately 2.4 cm
- The movement 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)

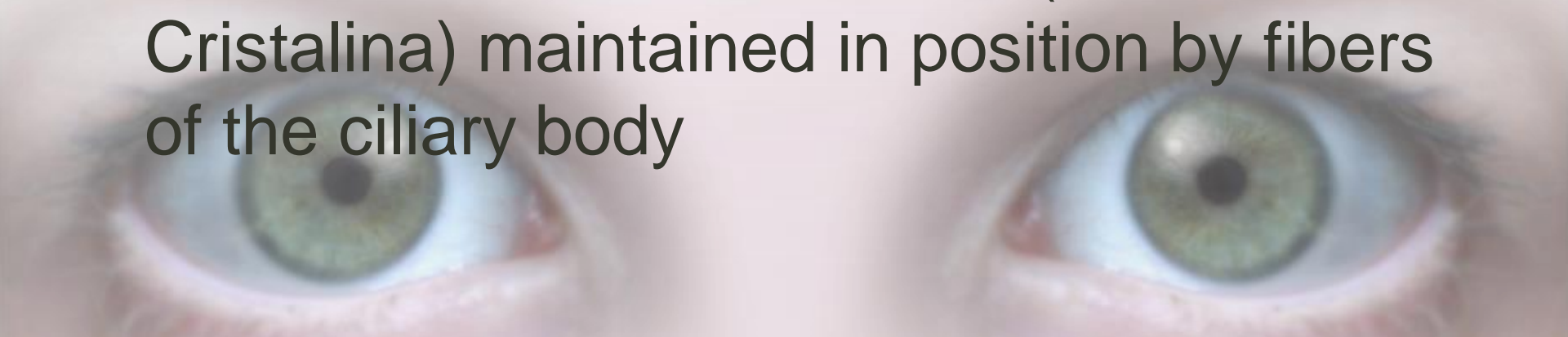


Optical system of eye



Optical system of eye

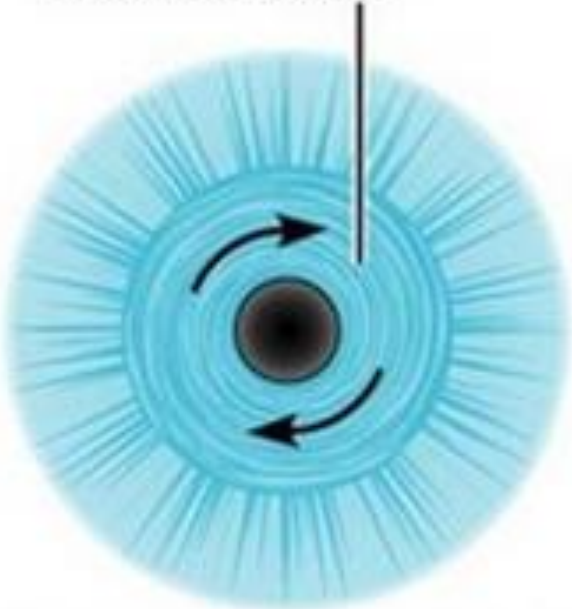
- Choroid passes in front of the eye in the ciliary body (corpus ciliary ganglion) - contains accommodative muscles and their fibers fitted to the lens
- Further, choroid passes in the iris (iris) with a circular hole - pupil - iris function
- Behind the iris is stored lens (lens Cristalina) maintained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



Iris muscle

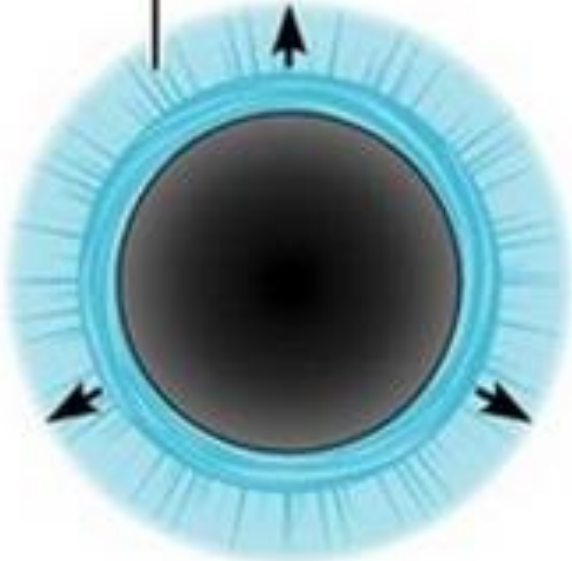
Miosis

Parasympathetic stimulation causes circular muscles to contract



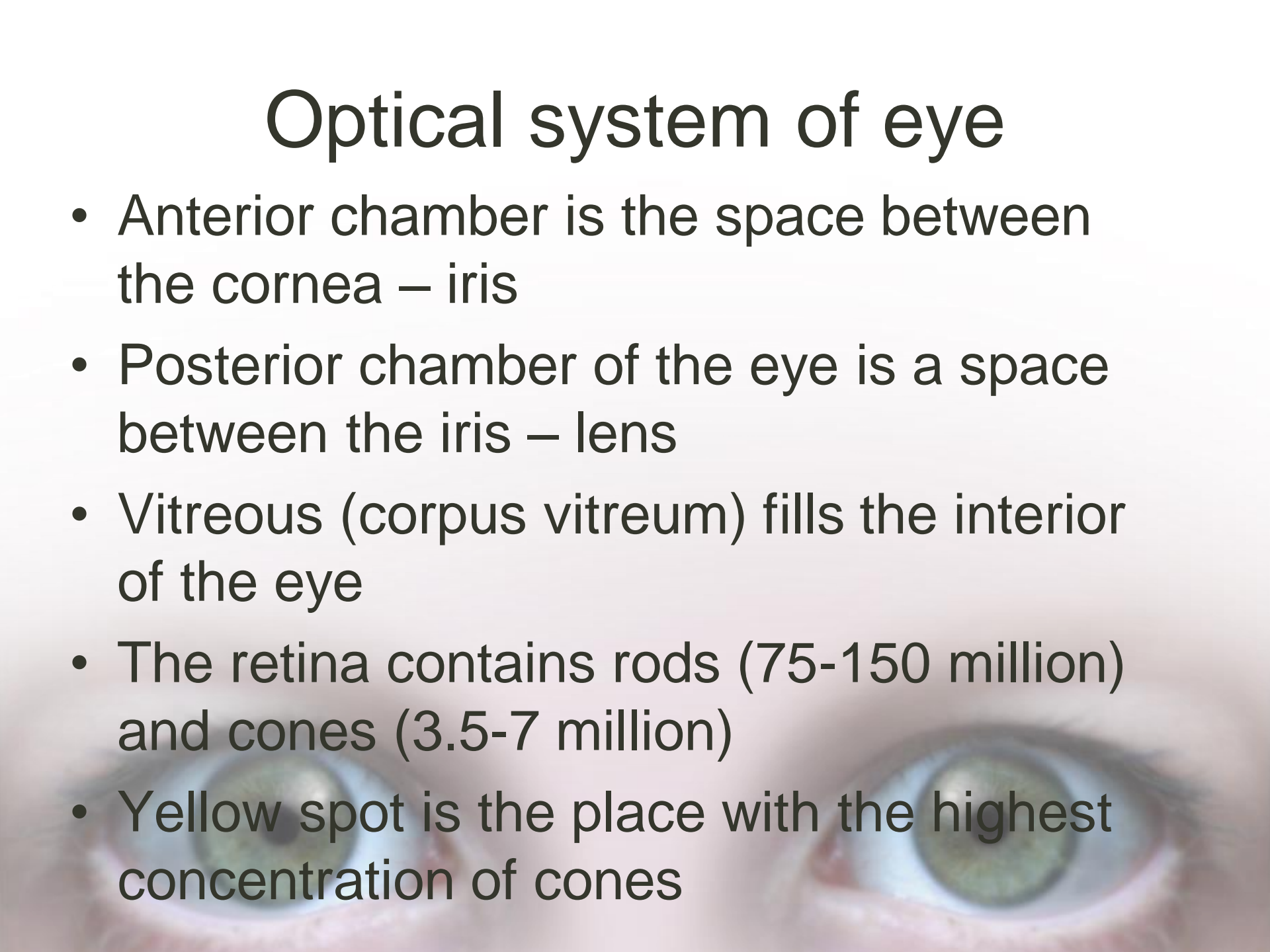
Mydriasis

Sympathetic stimulation causes radial muscles to contract



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



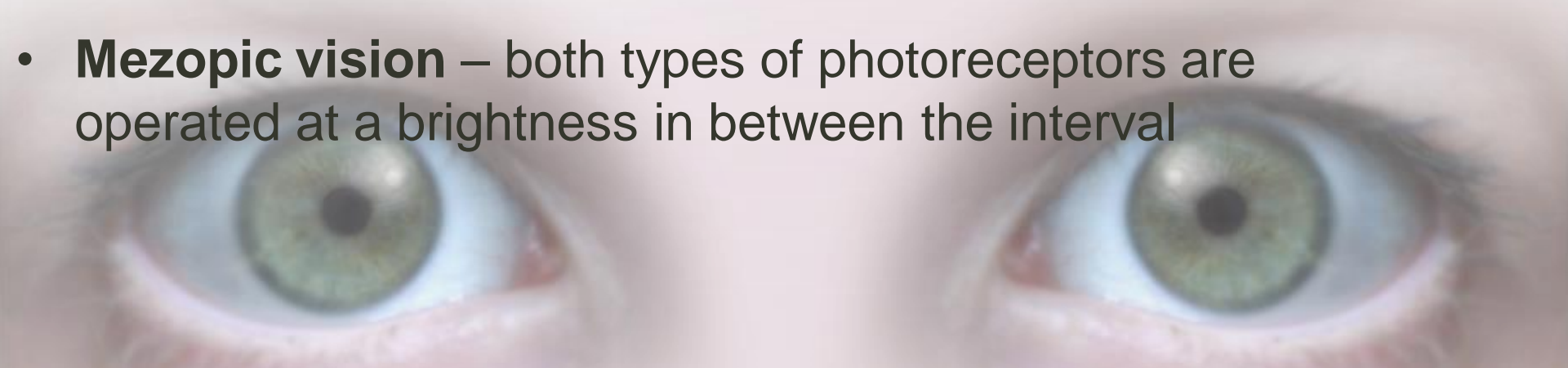
Eye

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 |

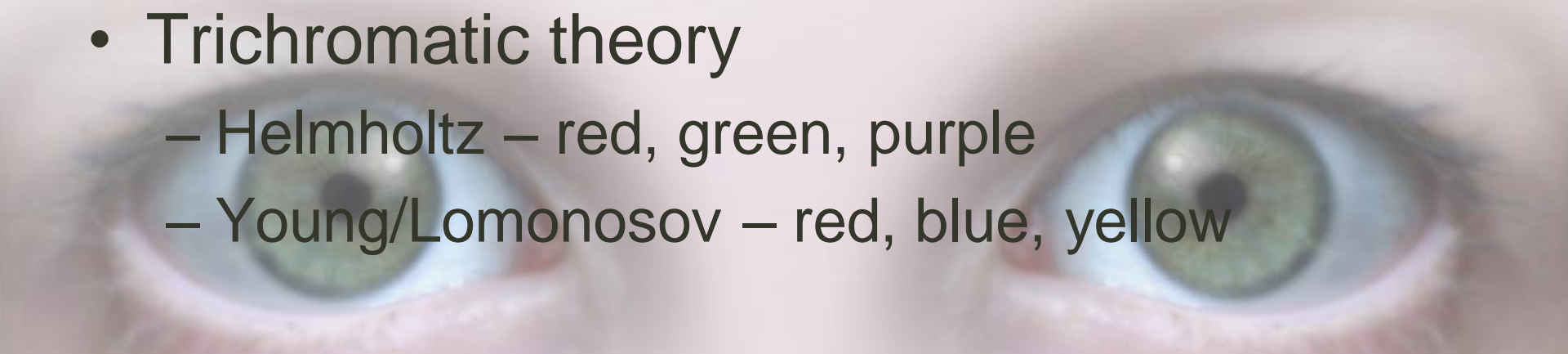
Light adaptation

- **Photopic vision** – day, conveyed by cones 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 color wavelengths 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

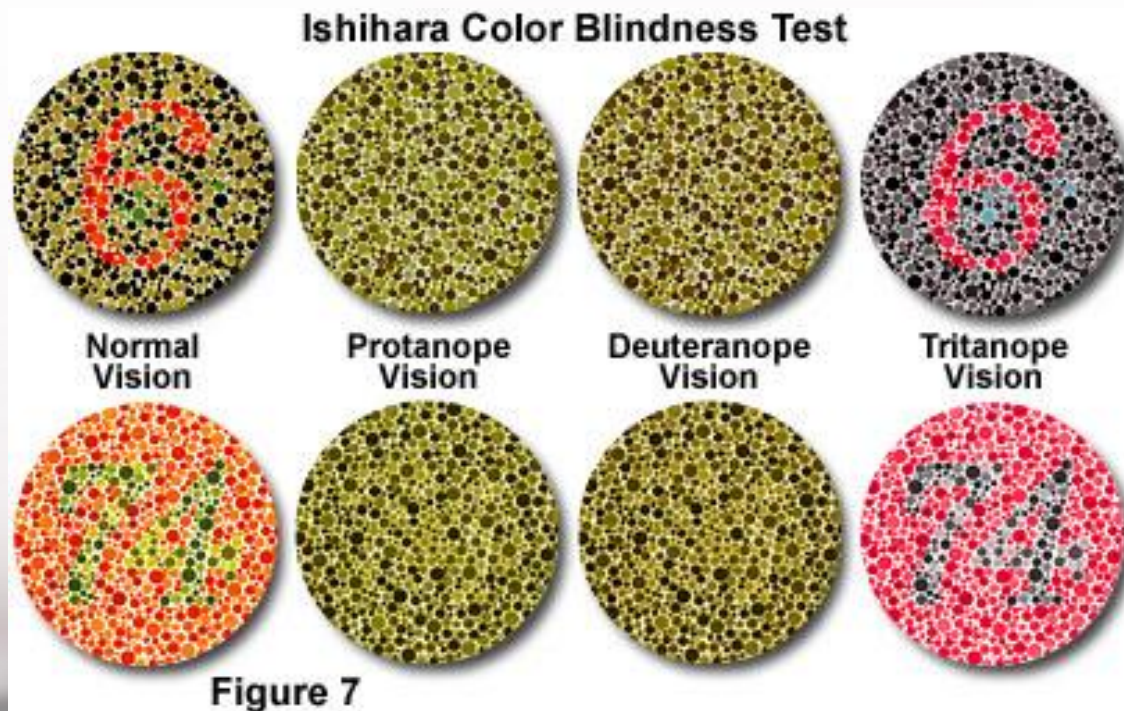


Color vision

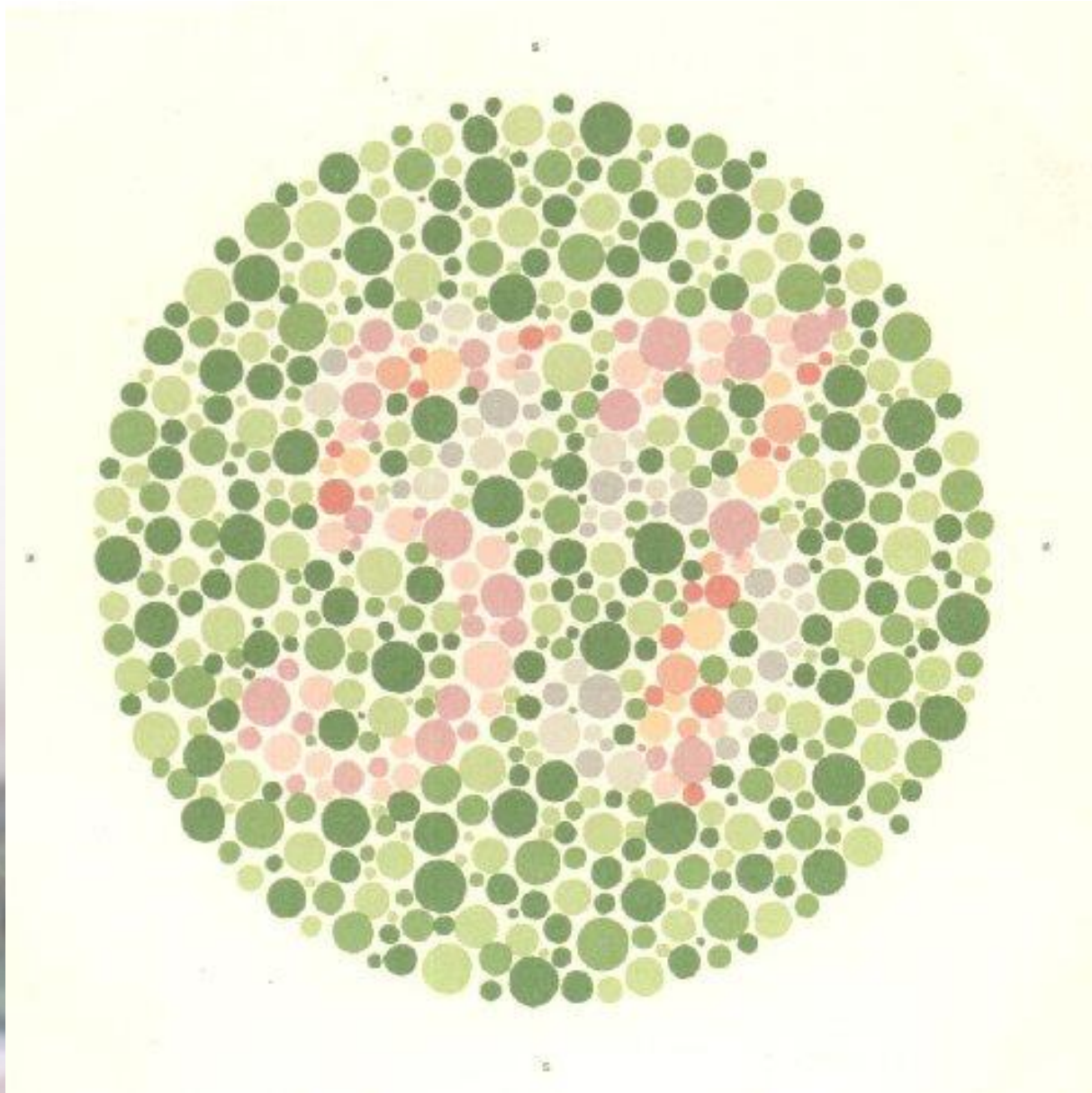
- color perception testing
 - Pseudoisochromatic tables
 - Monochromacy - complete colorblindness
 - Trichromacy - partial disorder of color perception (Protanopia - red; deuteranopia - green; tritanopia - blue)



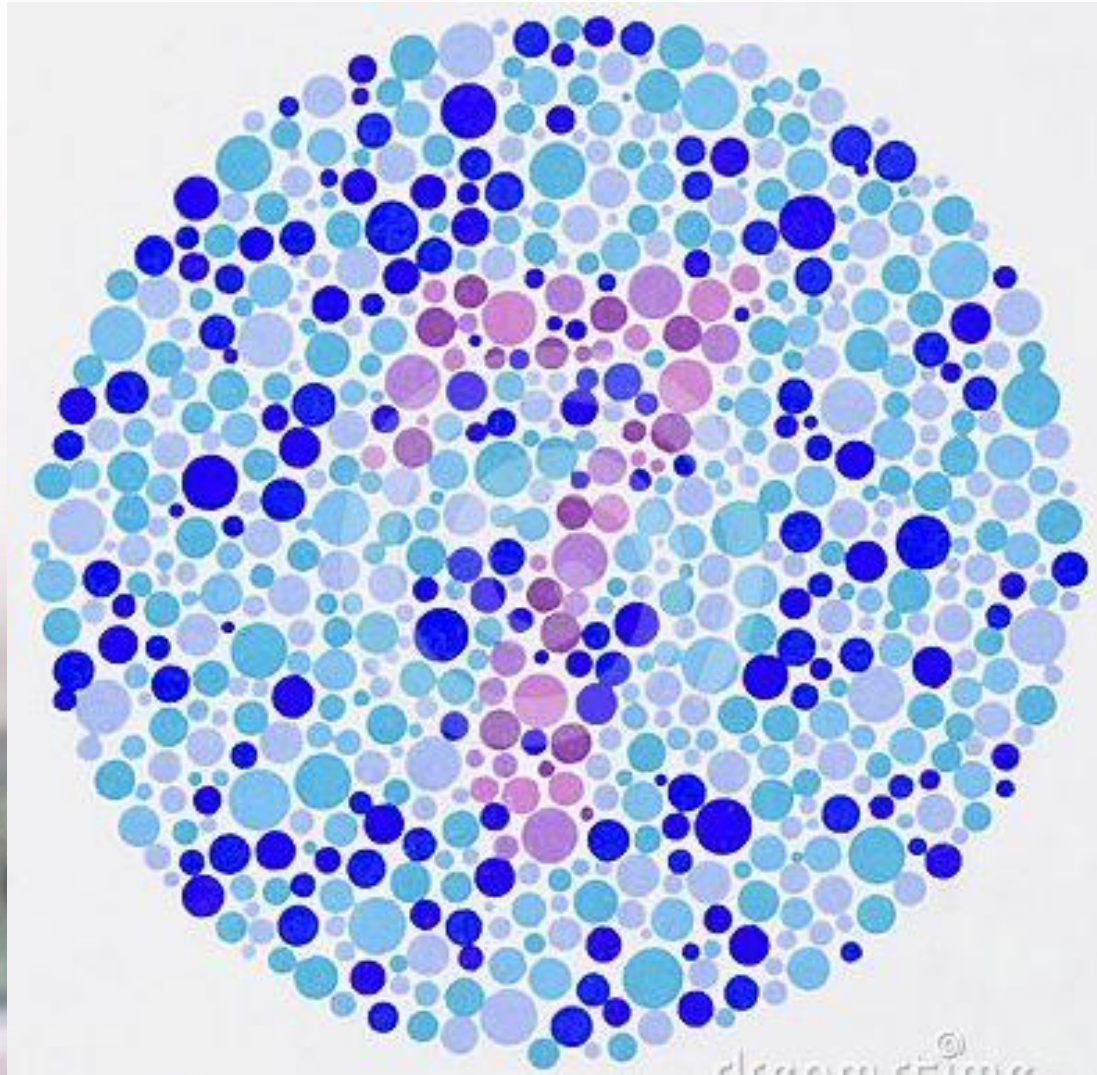
Color vision



Color vision



Color vision



Aqueous humour

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

NORMAL VISION



ADVANCED GLAUCOMA



EARLY GLAUCOMA

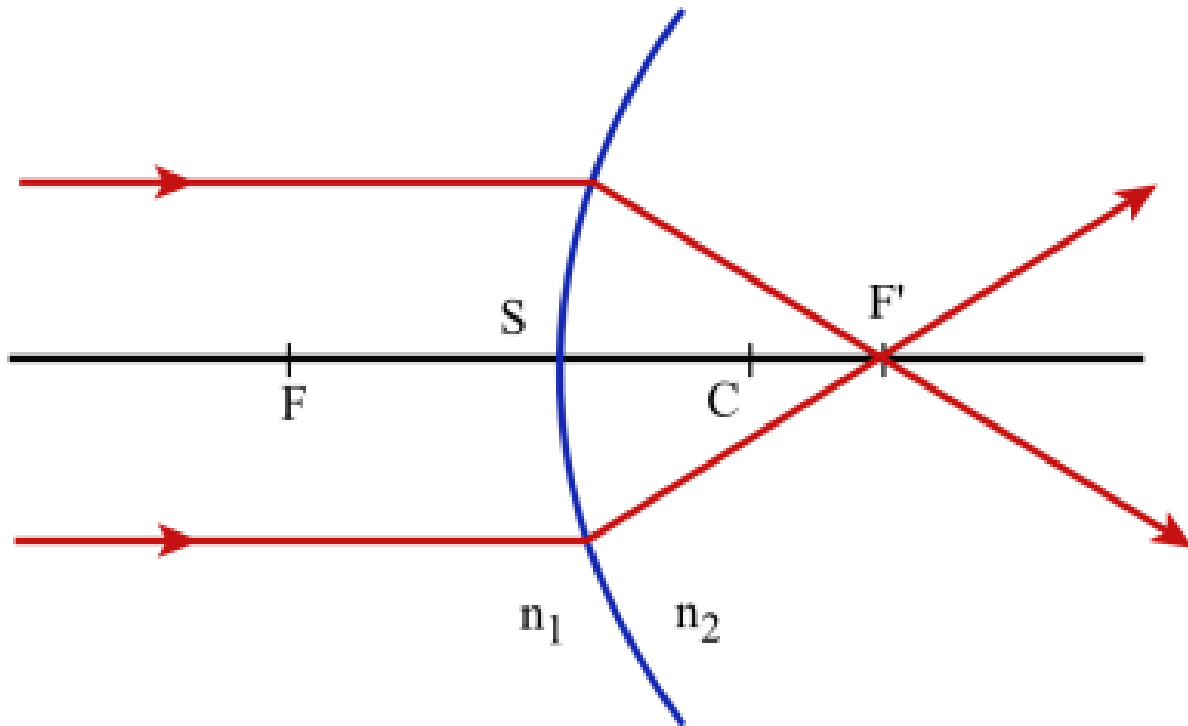


EXTREME GLAUCOMA



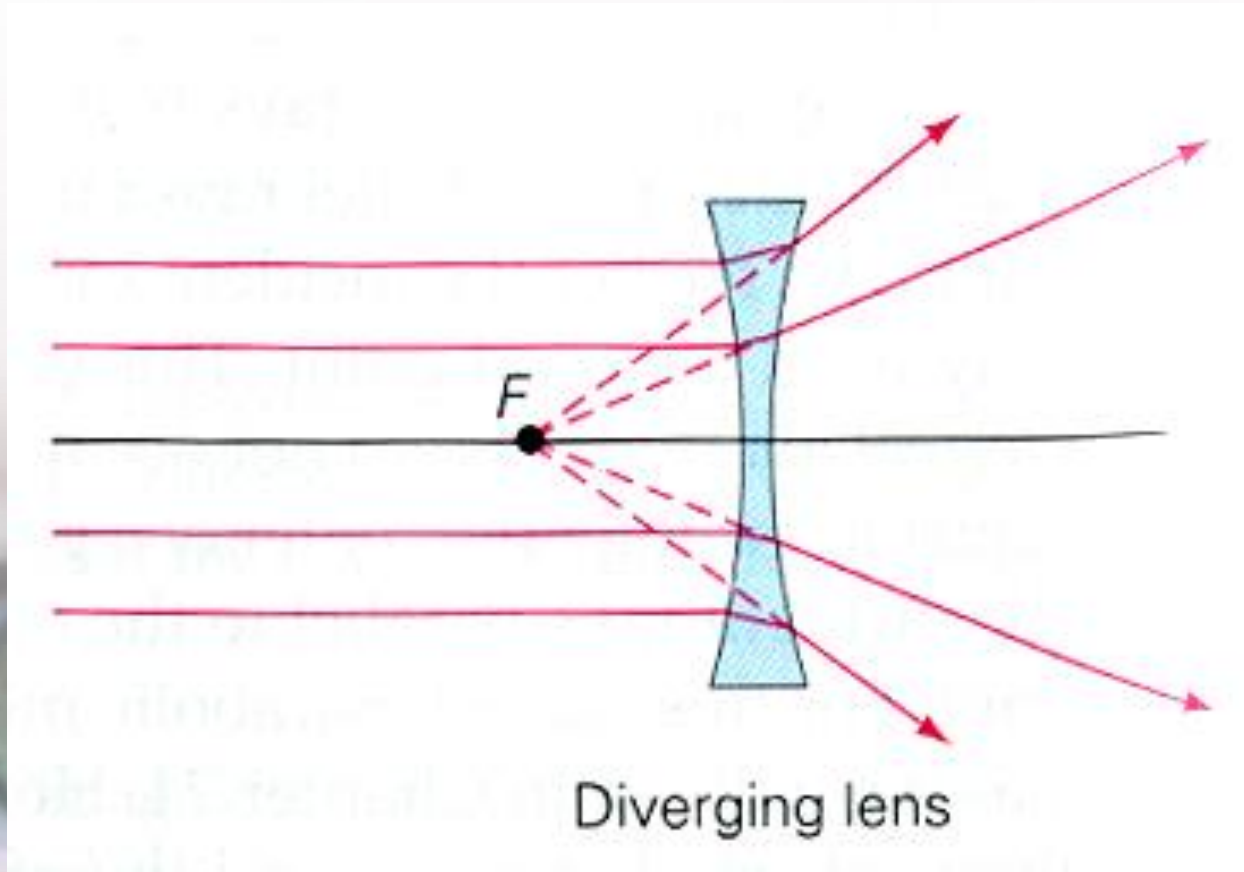
Dioptr

- Dioptr 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**: $F' = 0.5 \text{ m} \approx 1 / 0.5 = +2$ Dioptr [m^{-1}]



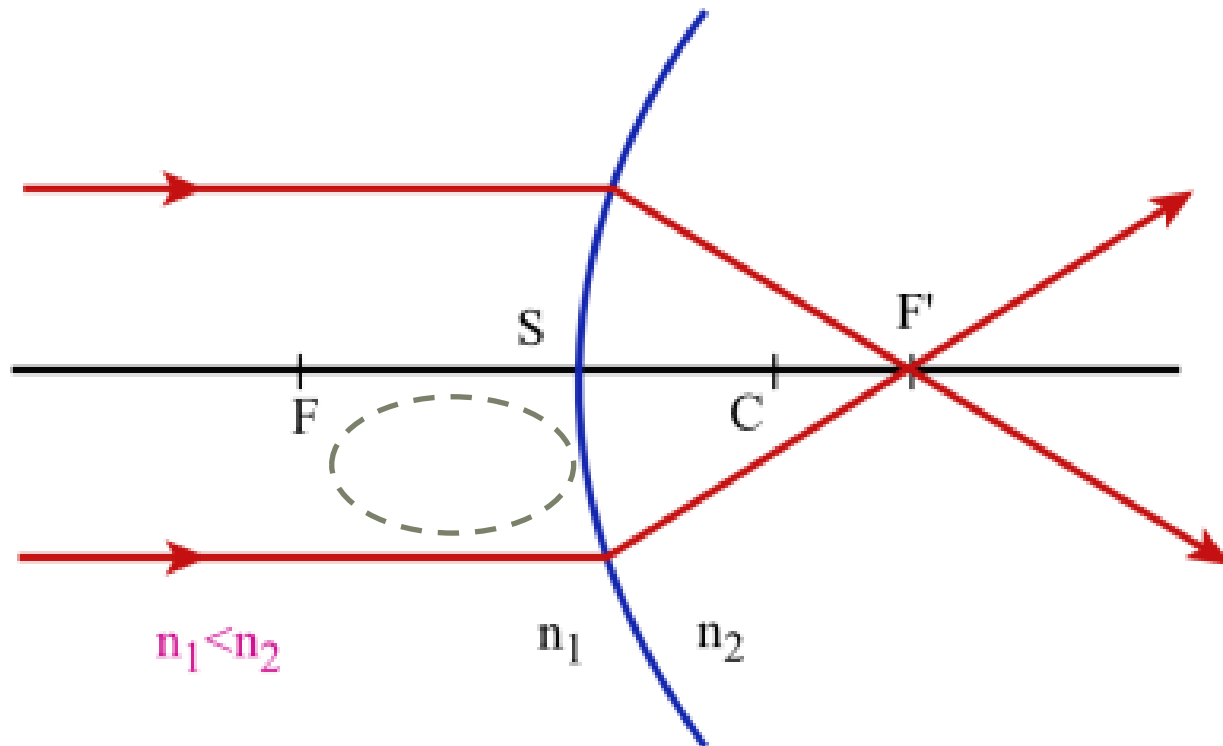
Dioptr

- For diverging lens the dioptr is negative.
- $F' = 0.5 \text{ m} \approx 1 / 0.5 = - 2 \text{ dioptr } [\text{m}^{-1}]$



The optical power

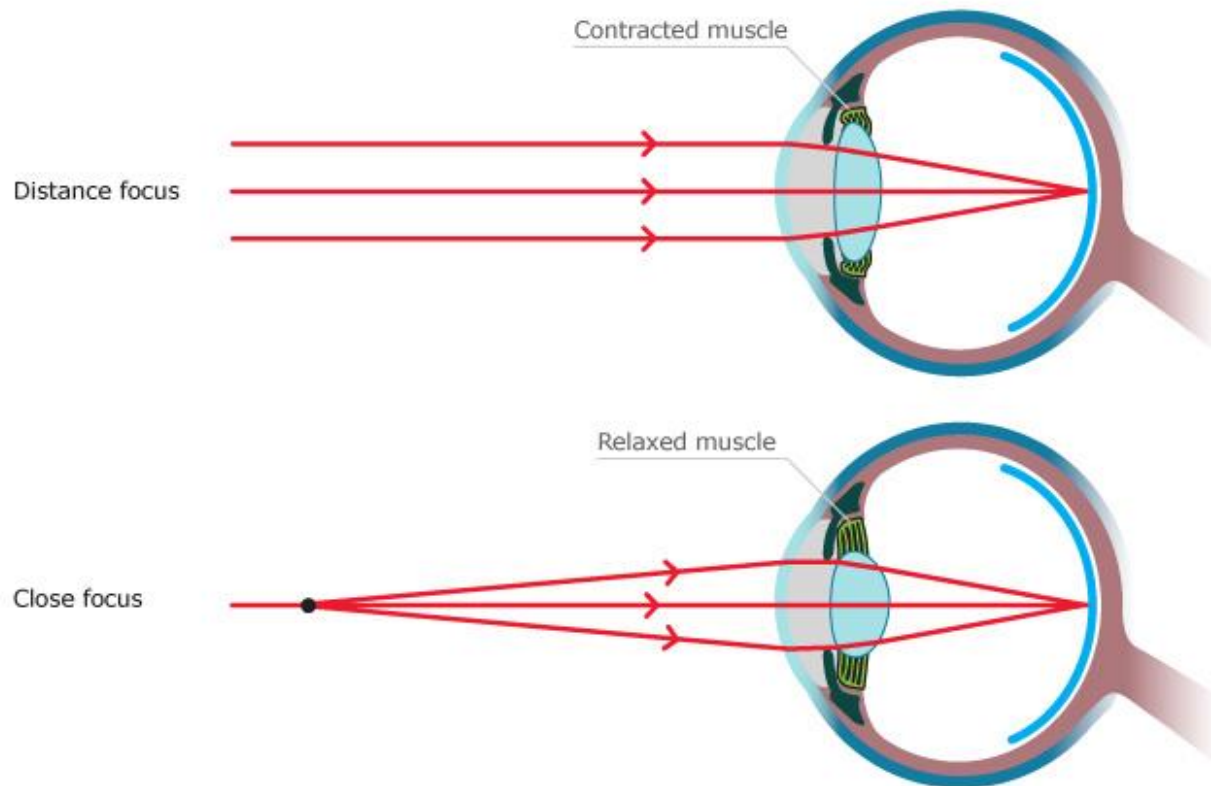
- **The optical power** of the eye is about **+60 D**, which is caused by the curvature and refractive index of eye.



Eye accommodation

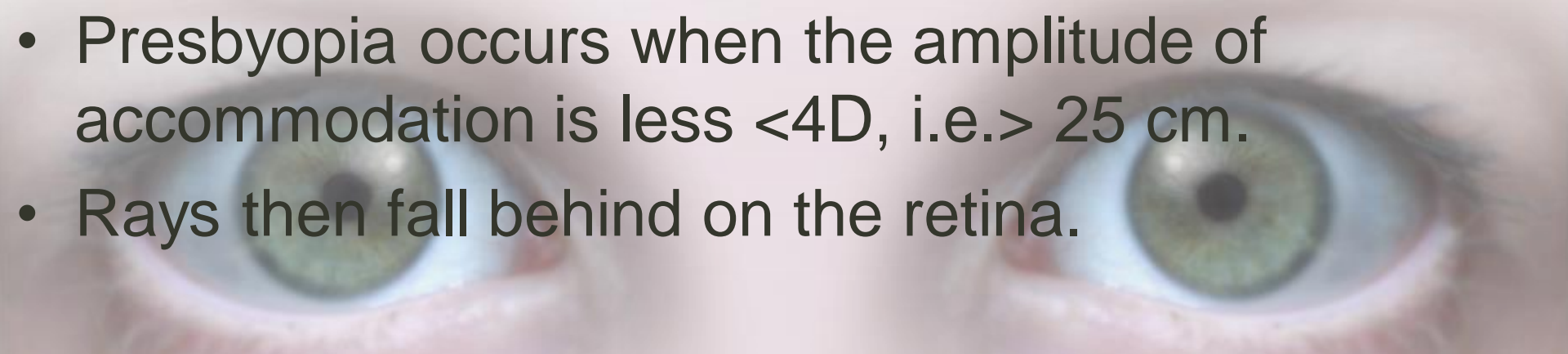
- The ability to change optical power of lens according to the distance of observed object.
- **Far point** is sharply visible without accommodation, the **muscles** that support the lens **are contracted**.
- **Near point** is sharply visible by maximum accommodation, the **muscles of lens are relaxed**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

How the eye focuses light



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

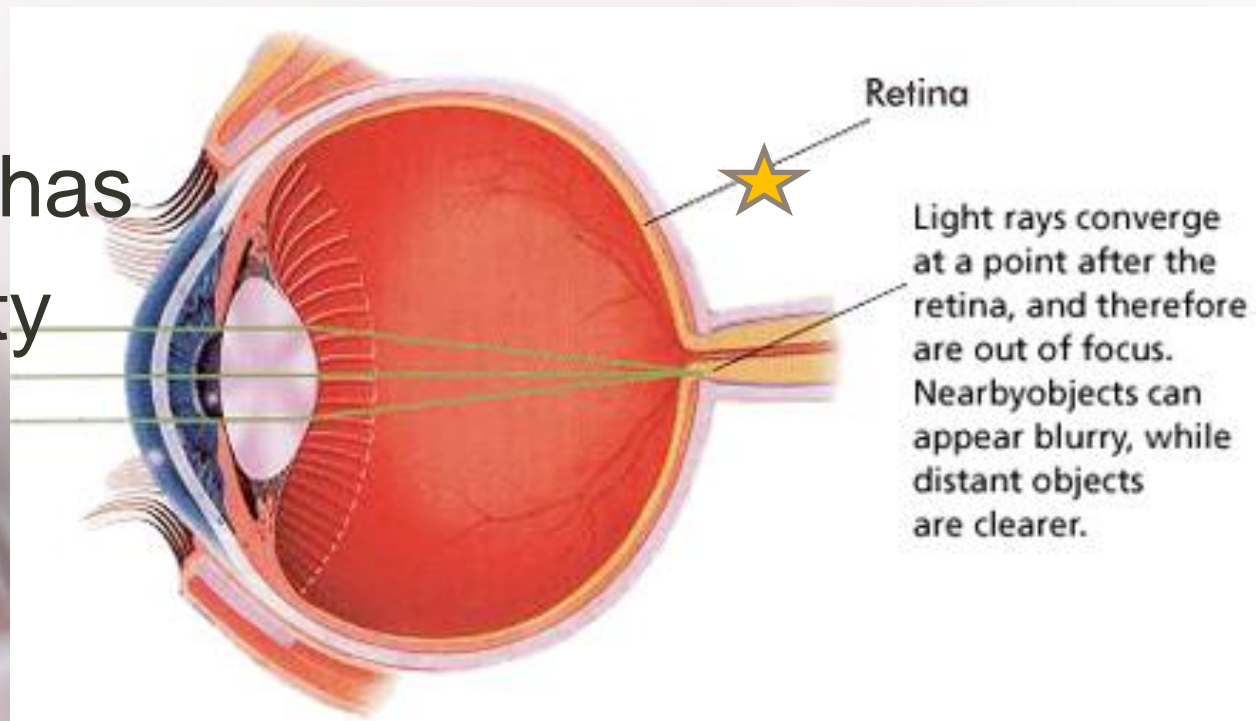
- Spherical ametropy
 - hypermetropia
 - myopia
- Aspherical ametropy
 - Astigmatism



Hypermetropia

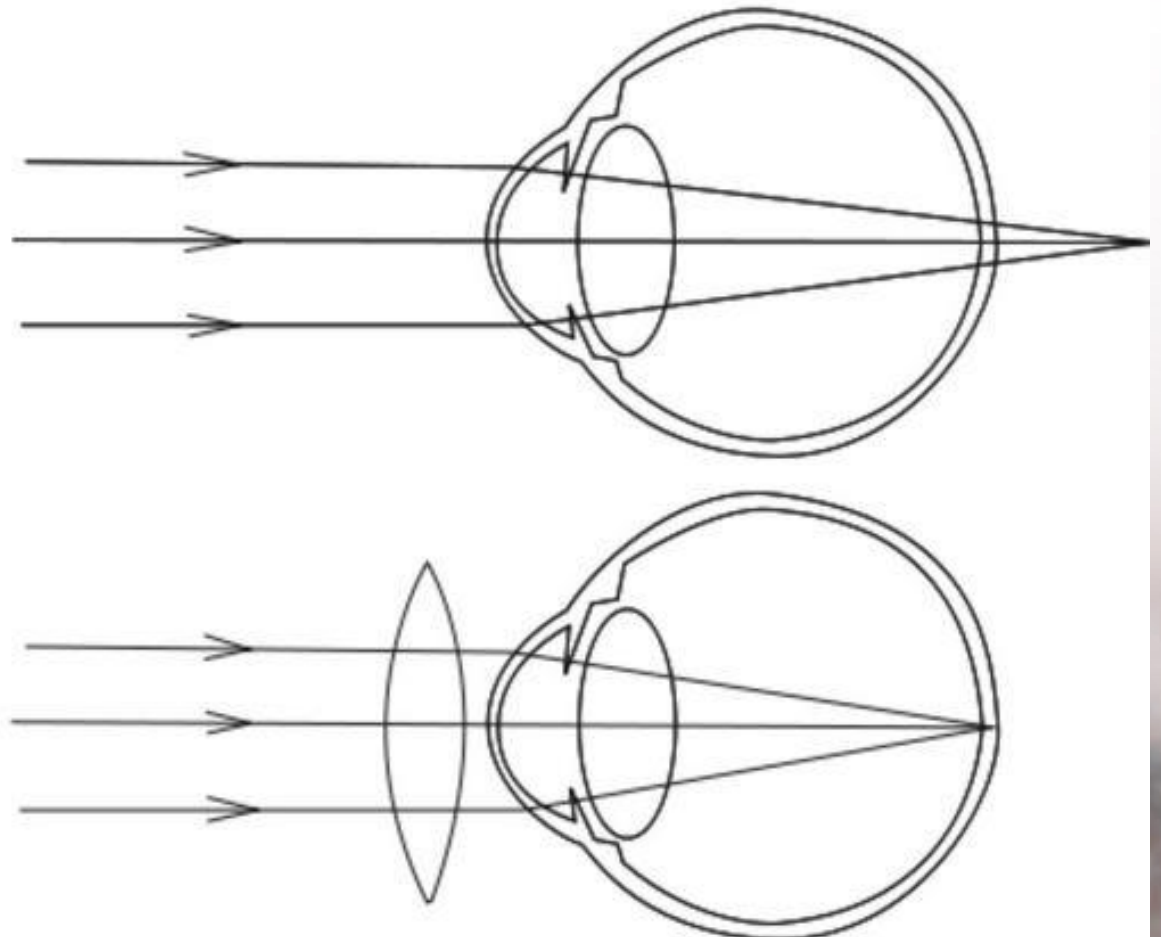
- Is **spherical disorder** when the optical focus lies behind the retina.
- We distinguish between:
Axial: eyeball is too short

Refraction: eye has smaller refractivity



Correction of **Hypermetropia**

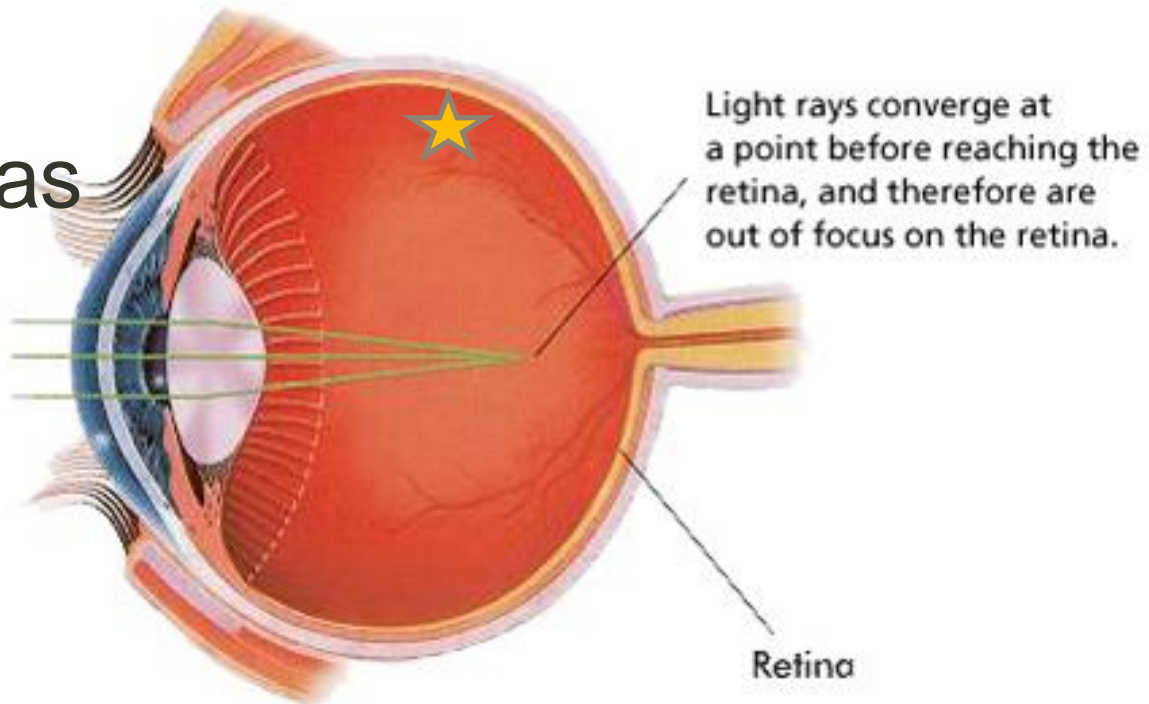
- For correction we use convergence lens.



Myopia

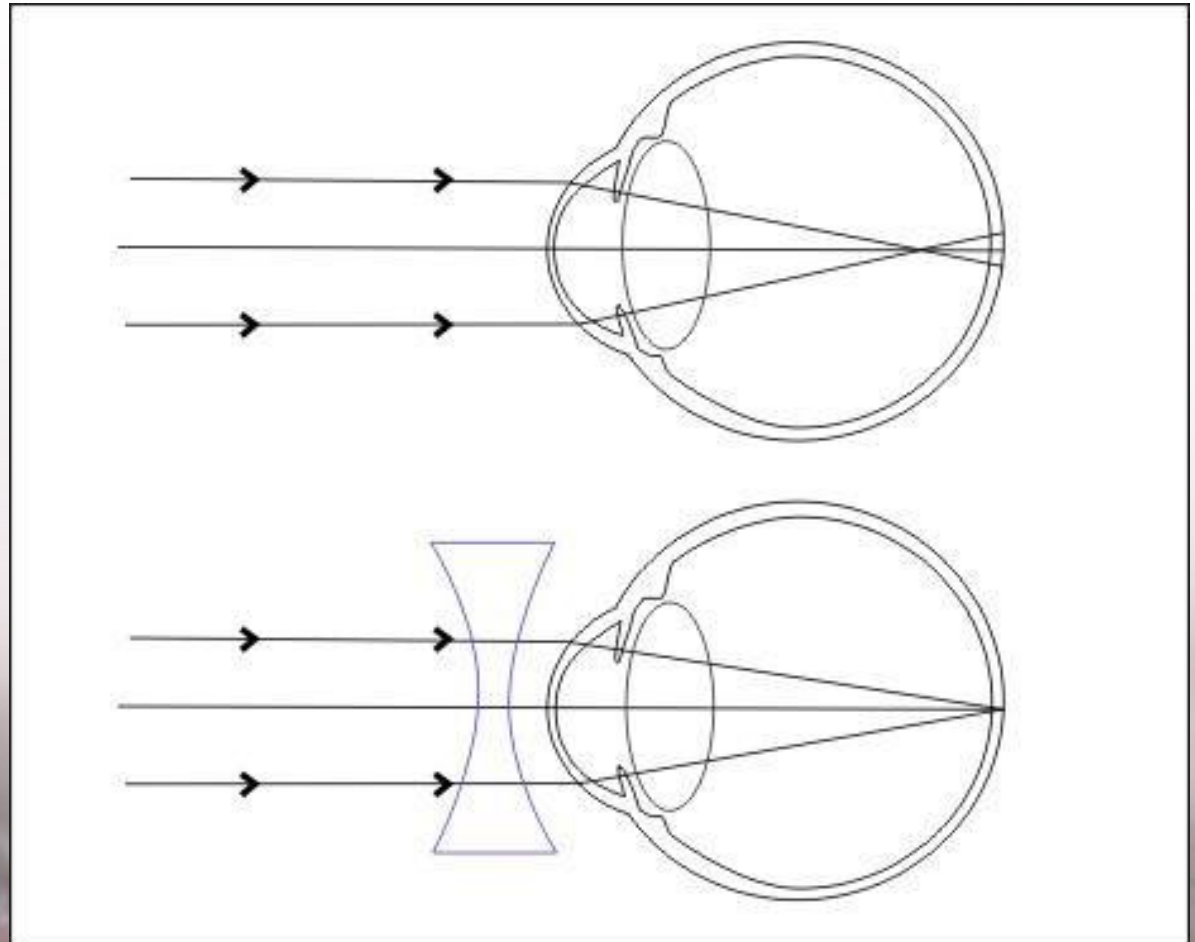
- Is **spherical disorder** when the optical focus lies in front of retina.
- We distinguish between:
Axial: eyeball is too long

Refraction: eye has higher refractivity



Correction of Myopia

- For correction we use divergence lens.

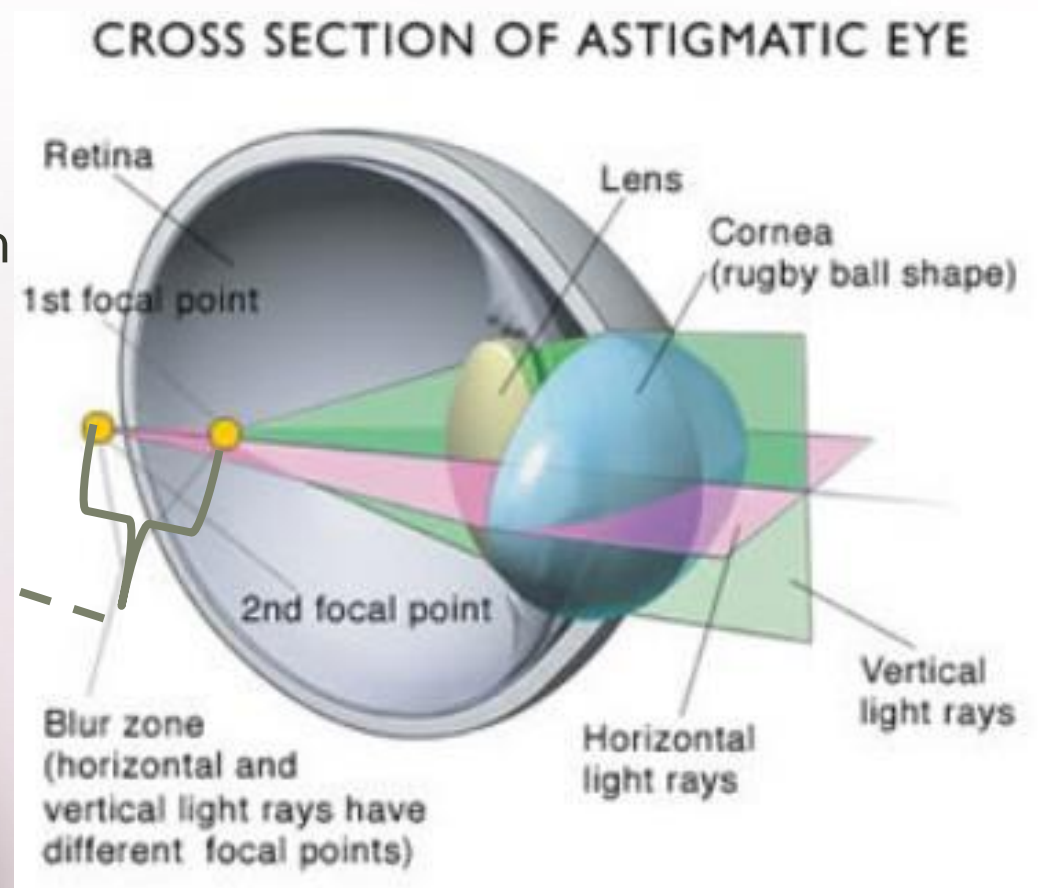


Astigmatism

- 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.com

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:

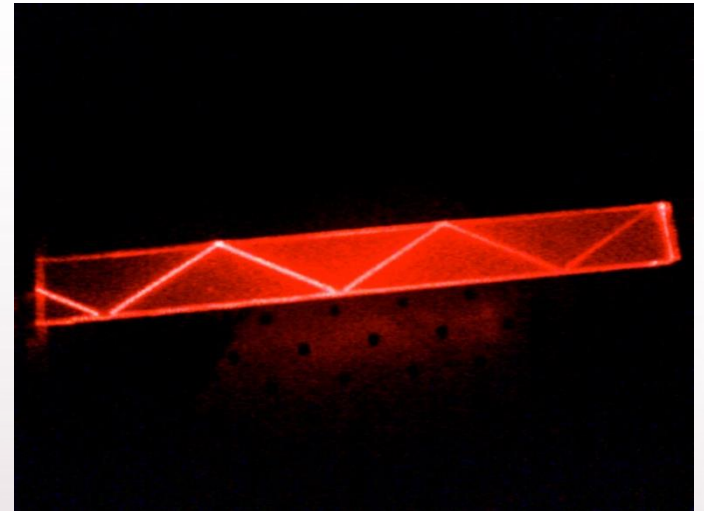
Fiber has a core and a coat

- Optically different environments
 - Core = higher refraction index (1.48)
 - Coat = lower refraction index (1.46)
- Total internal reflection

Material: Glass/Plastic

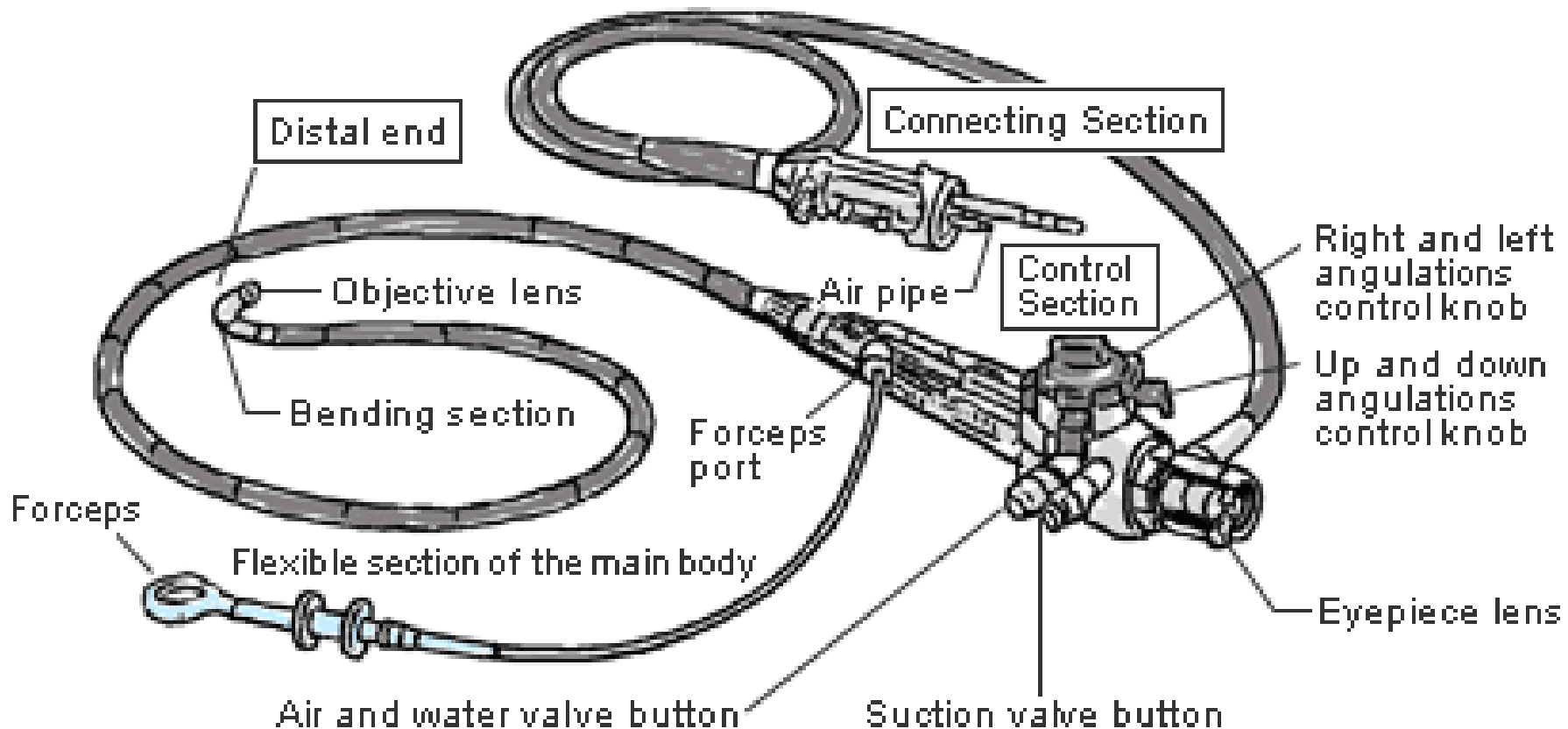
Advantage

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



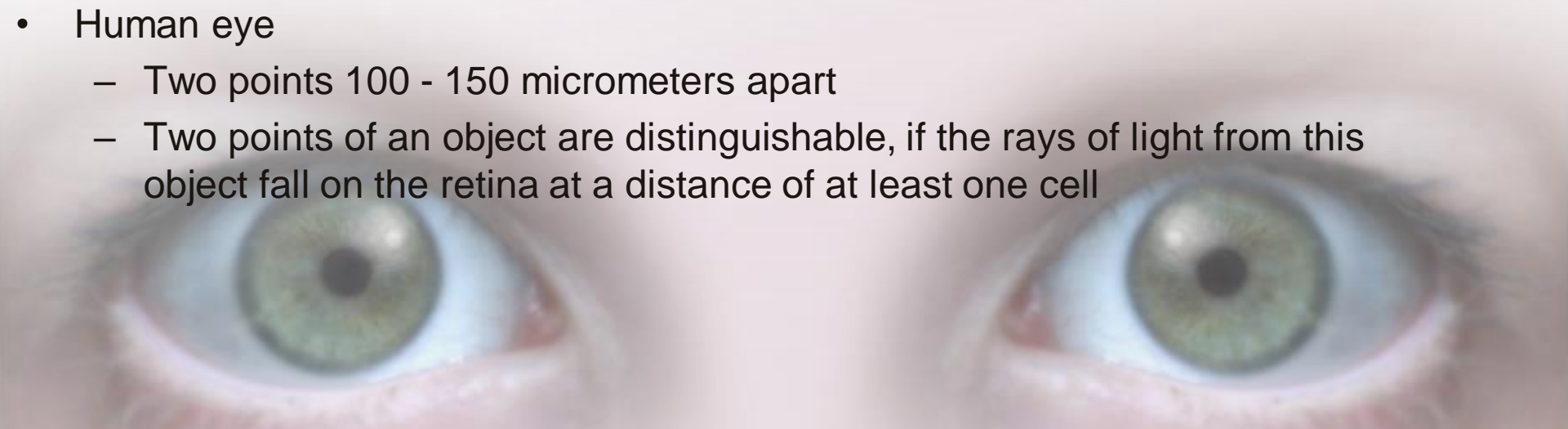
Endoscopic methods

Endoscopic methods are used for the diagnosis and treatment of diseases of the gastrointestinal tract. They are performed through a minimally invasive approach.



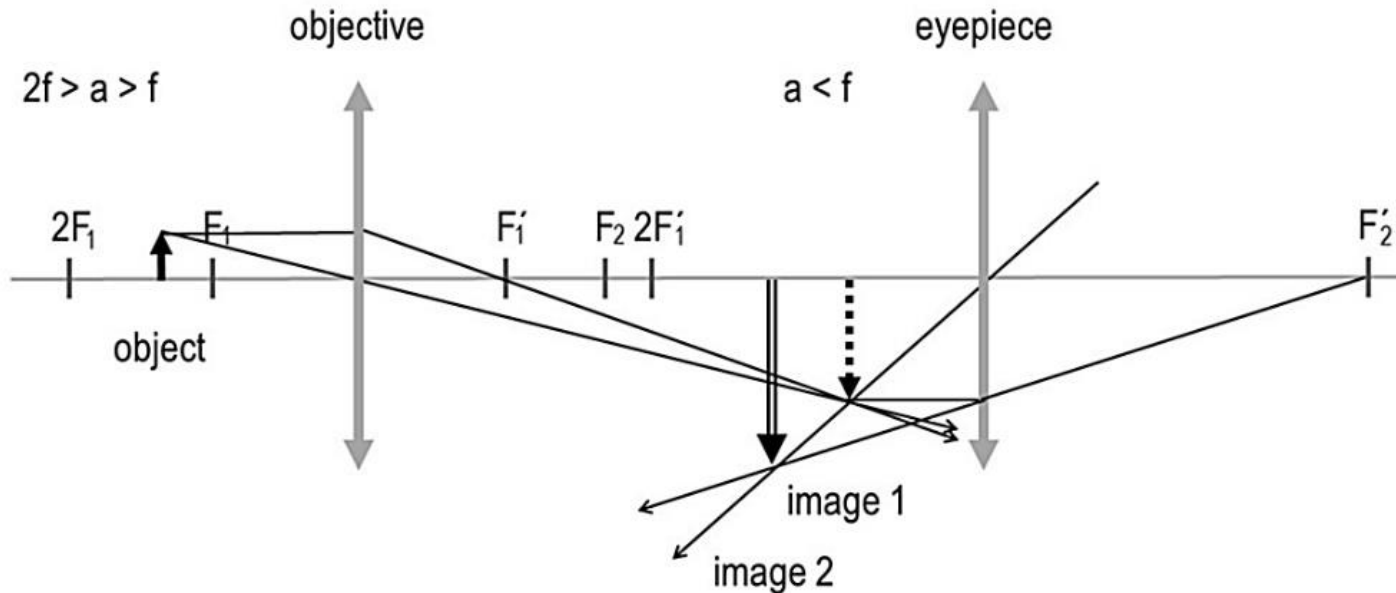
Optical microscopy

- **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

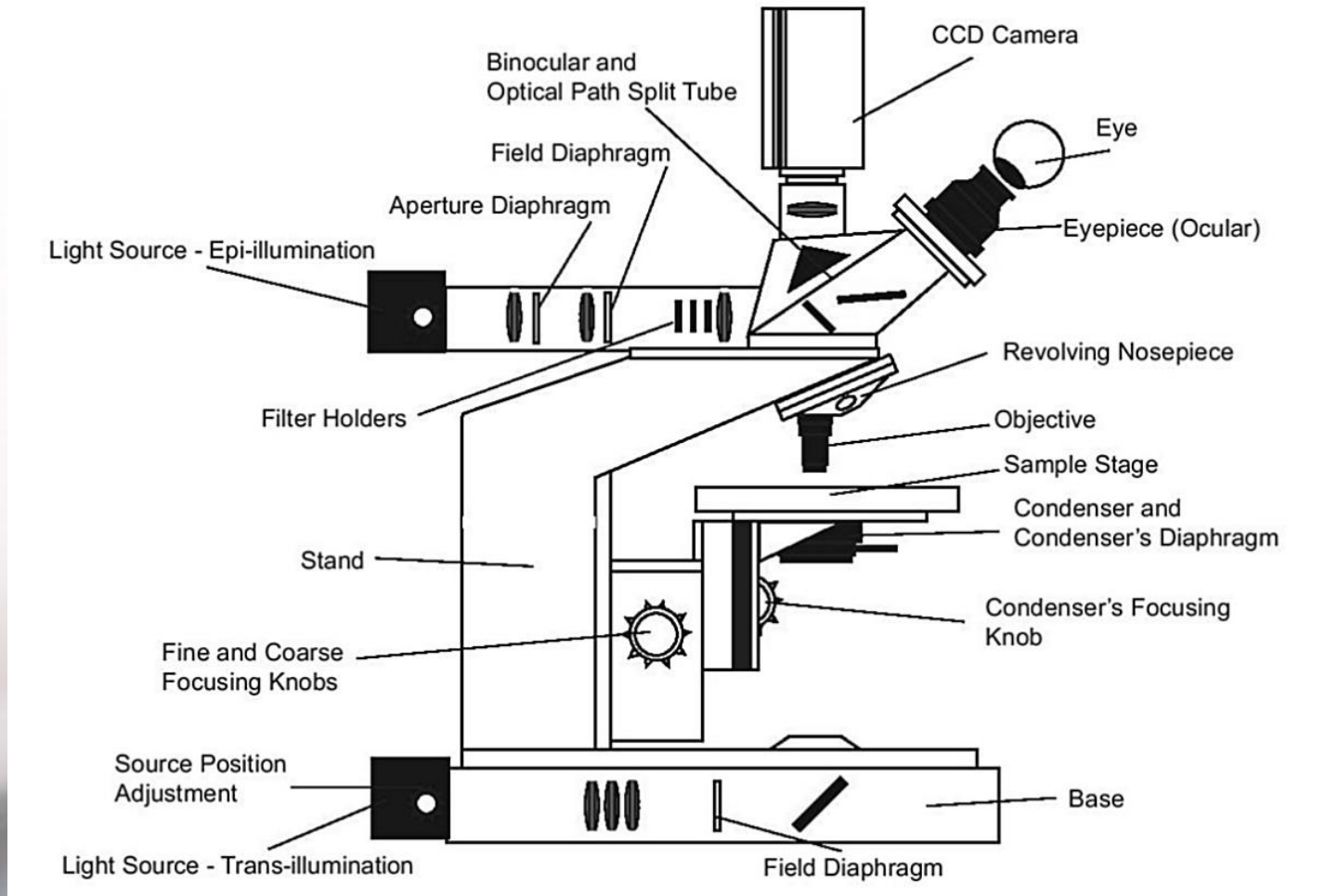


Optical microscopy

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



Optical microscopy



Optical microscopy

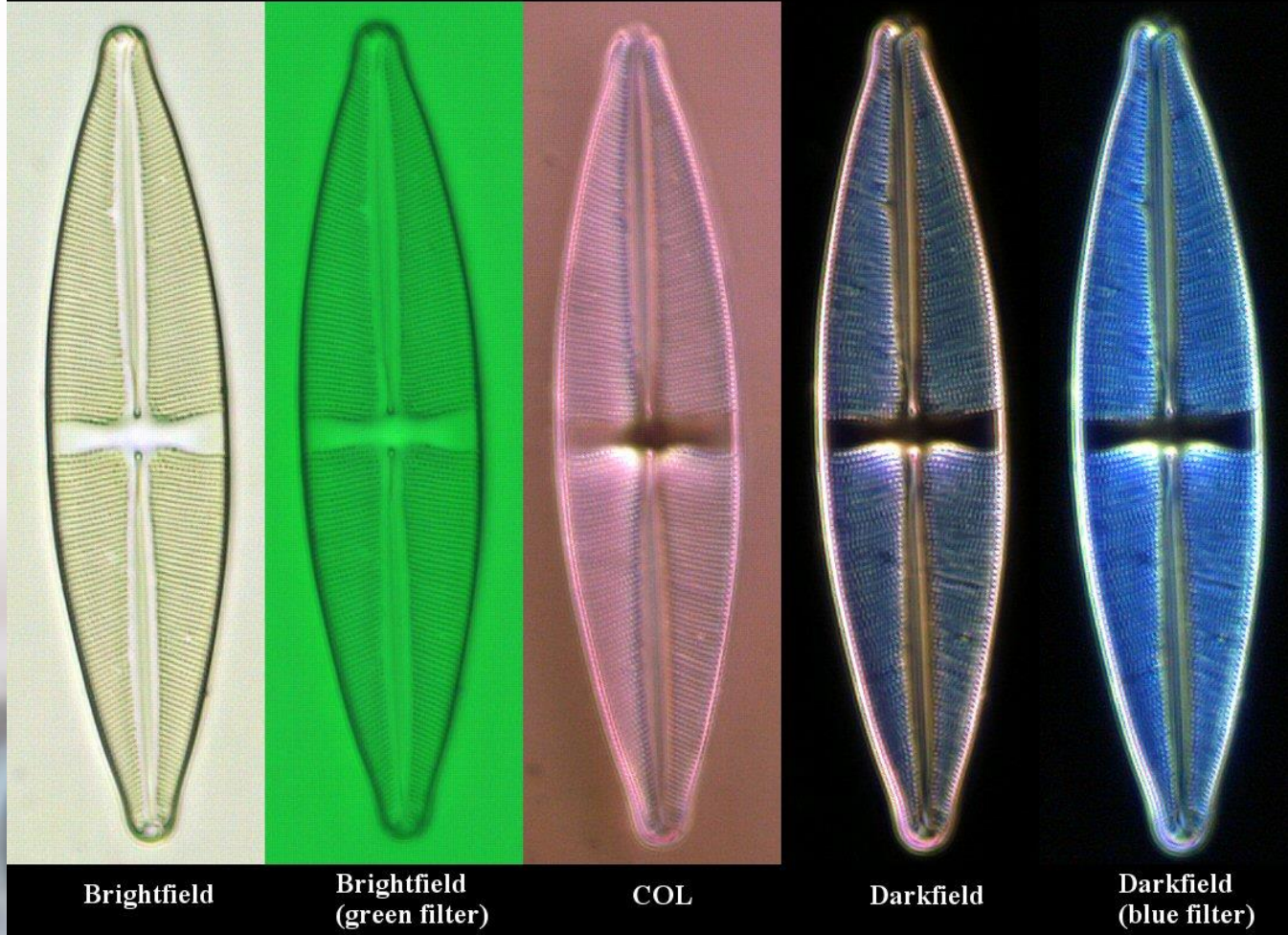
The types of optical microscopes

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



Optical microscopy

Stauroneis phoenicenteron (720 nm frustule spacing)



Electron microscopy

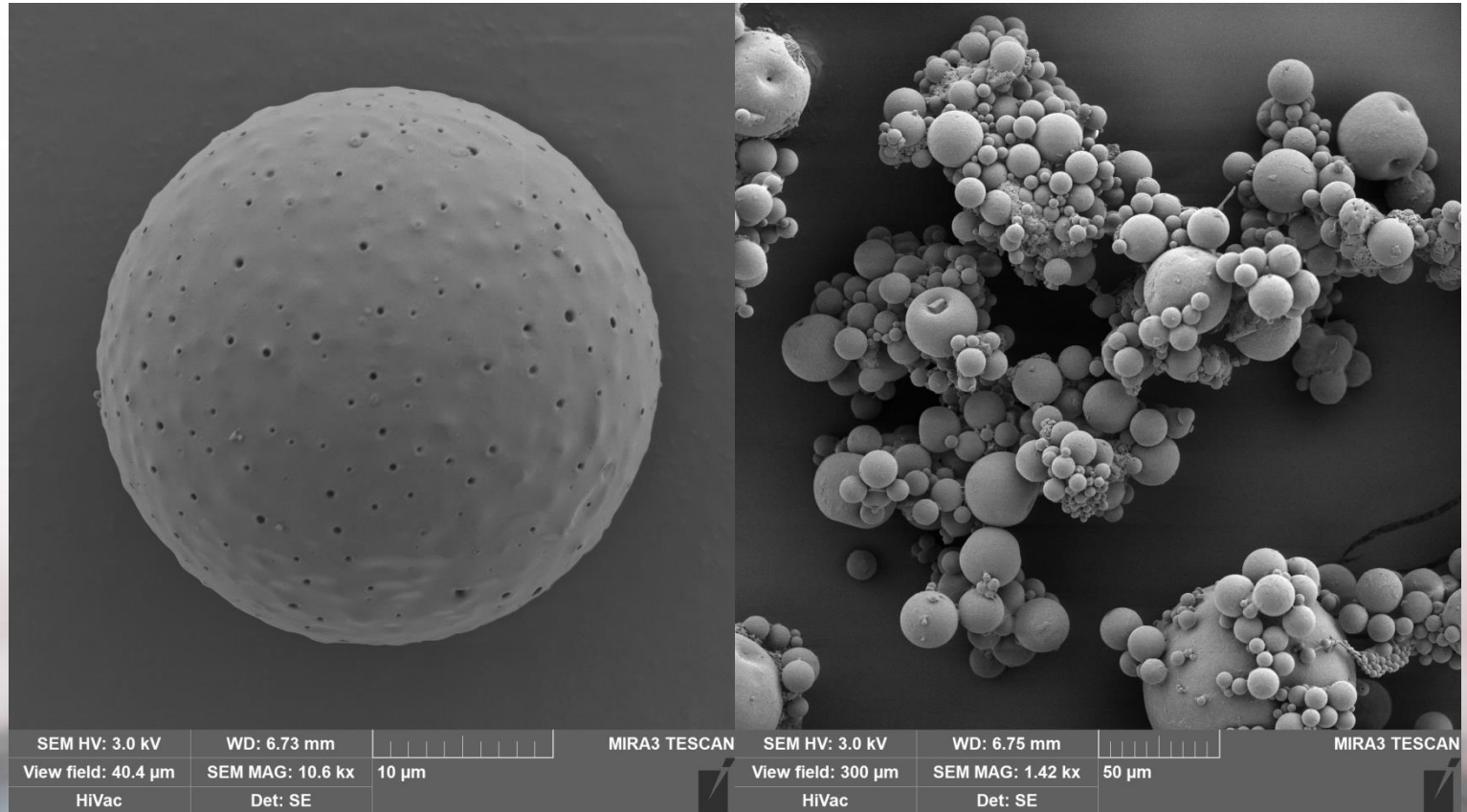
- Photons are replaced by electrons; system of electromagnetic lenses (magnetic field influences electron, its trajectory similar to a spiral)
- Transmission electron microscopy (TEM)
- Scanning electron microscopy (SEM)
 - environmental REM



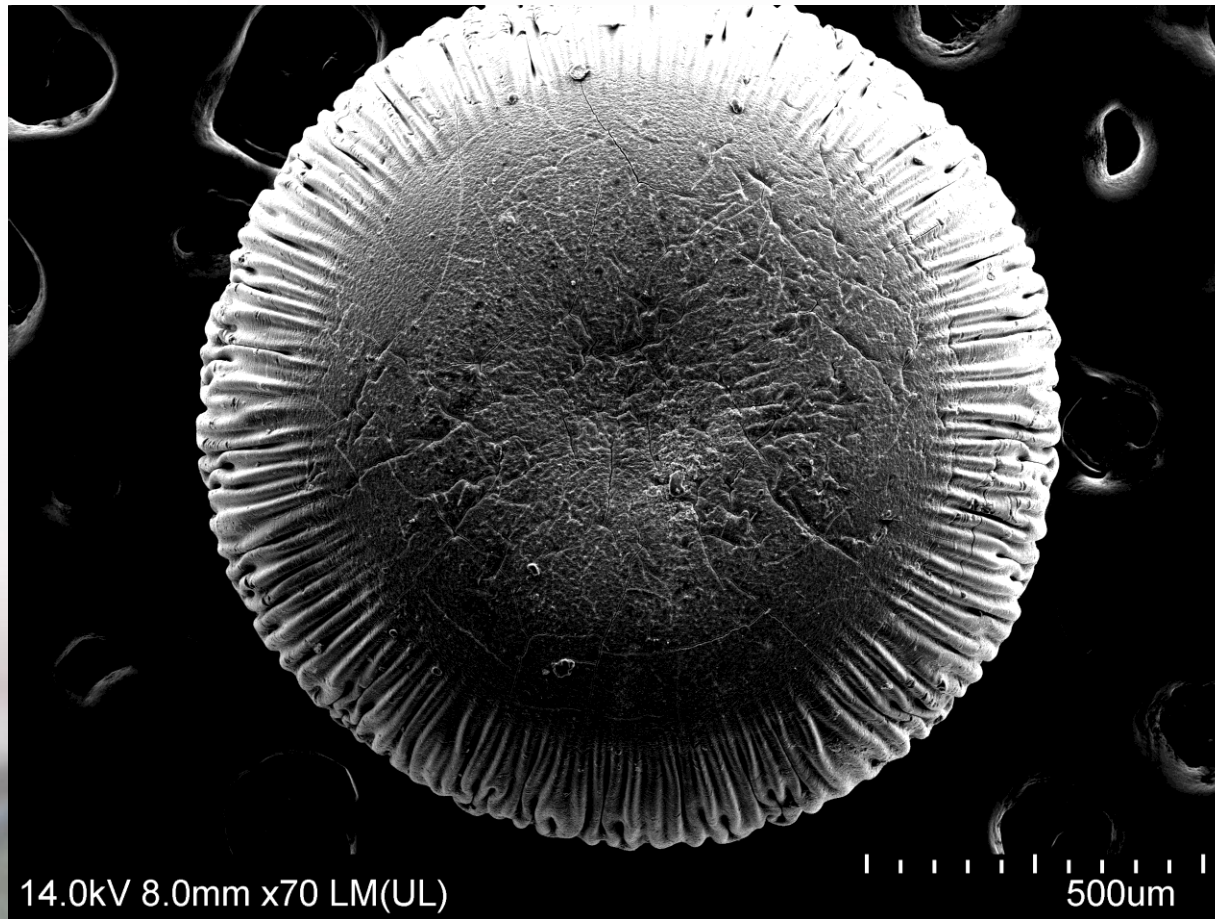
TEM Electron microscopy



SEM Electron microscopy



SEM Electron microscopy



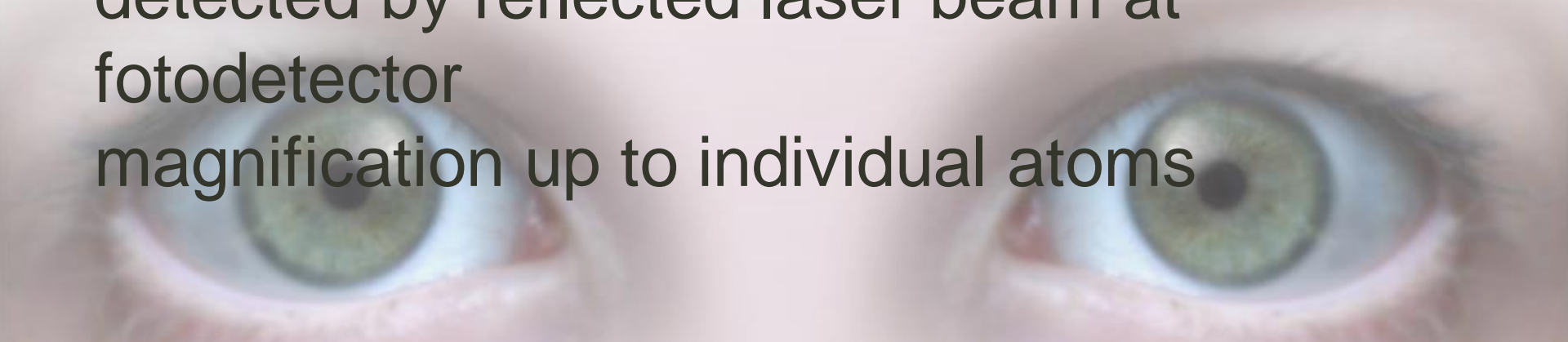
Atomic Force microscopy

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

