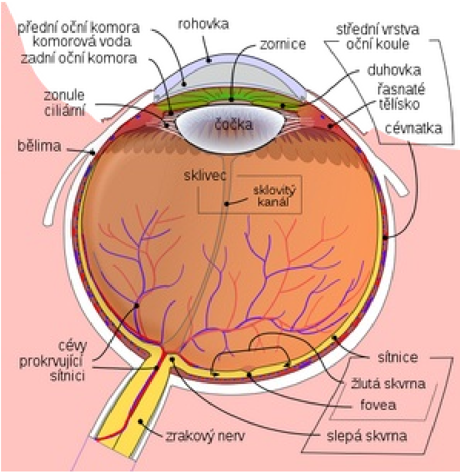
Eye (biophysics)



Schematic diagram of the human eye

The eye is the sensory organ of sight, it consists of a photosensitive layer containing light-sensitive cells and an optical system that directs the rays so that they fall on the retina. The eye is approximately spherical in shape **with a radius of 12 mm**.

The refractive system of the eye

For more information go to: Refractive system of the eye.

Light passes through the following parts of the eye before it hits the photoreceptors:

1. **Cornea** - refractive index 1.377;
2. **anterior chamber of the eye** – filled with aqueous humor with a refractive index of 1.336;
3. **iris** , or an opening in the iris called the **pupil** ;
4. **posterior chamber of the eye** – between the posterior surface of the iris and the ciliary apparatus, n = 1,336;
5. **lens** – n = 1.42, which can change the curvature and thus the optical power through the ciliary apparatus;
6. **vitreous ;**
7. **retina**- a person has a so-called inverse type of retina, i.e. the photoreceptors are only on the side away from the lens.

The optical power of a healthy eye as an optical system is infinite for an object, it increases during accommodation .

Photosensitive cells

For more information go to: Photosensitive cells and their functions.

Photosensitive cells of the retina are cells that create nerve stimulation based on the absorption of a photon arriving at the retina. These cells are of two types: rods and cones.

Suppositories are sensitive to light of different colors, i.e. different wavelengths, different intensities and different color saturations. They are the first neurons of the retina. They ensure **photopic vision**, are responsible for visual acuity. They are found most abundantly in the central fovea (fovea centralis), which is a small pit in the macula. Towards the periphery of the retina, their density gradually decreases. In total, we find 6 million cones on the retina. We distinguish 3 types of cones, which can only be distinguished by the pigment in the cytoplasm, not by the shape of the cell.

Sticksare light-sensitive cells responding to lower light intensity than cones, but are unable to distinguish colors. They provide scotopic vision.

Fields of vision

Photopic (day) vision

Color vision;

- secured barrel cones ;
- perceived brightness >10 2 cd/m 2 ;
- fast adaptation to light (20–60 s);
- maximum sensitivity for a wavelength of 555 nm;
- perceived wavelengths of 400 to 750 nm.

Scotopic (night) vision

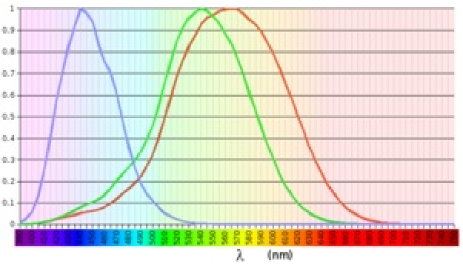
- Perception of only brightness (changes in intensity);
- secured by sticks only ;
- perceived brightness 10 -3 cd/m 2 ;
- two-phase adaptation, full adaptation after 40 to 60 minutes;
- the maximum for wavelengths is around 500 nm.

Mesopic (twilight) vision

- Brightness between the two previous values;
- vision is provided by both rods and cones;
- the spectral sensitivity of the eye is different from the spectral sensitivity in photopic vision.

Spectral sensitivity of the human eye

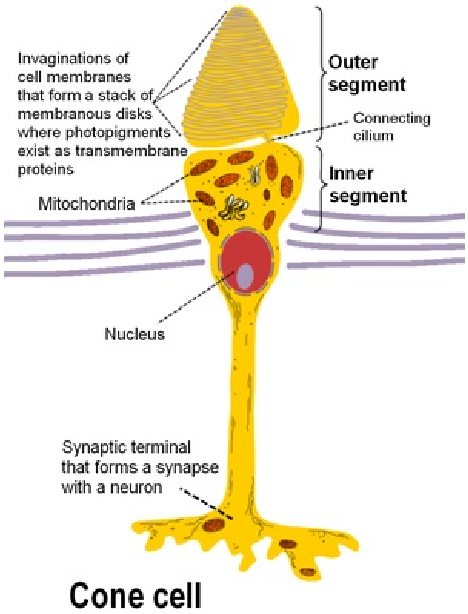
The human eye is only able to perceive a small part of electromagnetic radiation . At normal light intensity, the retina is sensitive to radiation with a wavelength from **380 nm to 760 nm** (the visible light region of the electromagnetic spectrum). This region also overlaps with one of the permeability bands of the Earth's atmosphere. Another reason why the human eye perceives the most in this area is the fact that it corresponds to the **maximum spectral radiation of the Sun**. From the graph of the spectral sensitivity of the human eye, we can see that the human eye is also sensitive to red light with a wavelength of, for example, 660 nm. However, in order to achieve a visual perception of the same intensity as for the radiation of light with a wavelength of 550 nm, the luminous flux must befrom the same area 10,000 times larger.



Spectral sensitivity of a cone cell

Light-sensitive cells of the human eye

There are about 6 million cones in the human retina . There are **three functional types**, containing different types of photopsin. Each of them has a somewhat different iodopsin (specialization in green, blue and red). Suppositories need quite a **lot of light** to work , but on the other hand, they provide **more precise** vision than rods .



Cone cell

Quantities important for determining the spectral sensitivity of the eye

If electromagnetic radiation emanates from a certain source, then E(t)/S is called **radiant flux Φe** , unit − Watt (W). The performance of radiant energy, evaluated according to the magnitude of the light sensation it causes, is called **the luminous flux Φ** , unit − lumen (lm). We call Φ/Φe **the luminous efficiency of the radiation** . The normalized function of the luminous efficiency for different wavelengths is called the **relative luminous efficiency of radiation** , 3 examples of which can be seen in the graph above. The maximum light efficiency is 680 lm/W . In other words: monochromatic radiation with a wavelength of 550 nm at a power of 1 W is equal to a luminous flux of 680 lm.

By adaptation we mean the ability of vision to adapt to different levels of illumination.

If the luminous flux falls on the body, its surface is **illuminated** . This property of the body is characterized by the quantity **illuminance** . The main unit of illuminance is **lux** (lx). An area of 1 m^2 has an illuminance of 1 lx if a **light flux of 1 lumen** falls evenly on it. A healthy human eye is able to register an object whose illuminance is at least 2 nlx. Only rods and cones , except for larger ones, react to this illumination. The illuminance of the object on a bright sunny day is about 0.1 Mlx. The recommended value for reading is 100 lx, for fine mechanical operations and drawing 200 lx, for corridor lighting 20 lx.

Retinal sensitivity

The sensitivity of the retina is very high, about 10^4 times greater than the sensitivity of photographic emulsion, but it is not the same everywhere. The largest is around the intersection of the optical axis of the eye, where the so-called **yellow spot** lies . It is known that during the transition from light to dark, individual objects can be recognized with sufficient sensitivity only after a certain time (about 10-20 min, max. 45 min). During this time, the eye adapts to the dark. Objects whose image is formed in the peripheral areas of the retina are recognized earlier . During the transition from dark to light, the eye also needs a certain amount of time to adapt, but this time is significantly shorter. After a sharp illumination, the eyes are dazzled, but due to the rapid reaction of the pupils, they quickly adapt (miosis , mydriasis).

Functions of rods and cones

Suppositories and **rods** have relatively independent properties. At high intensities the cones provide vision, at low intensities the rods become more sensitive than the cones. All colors are registered by both cones and rods, but only cones are sensitive to red. The differences in **the speed of adaptation of the eye** to darkness after previous illumination is explained by the function of the rods. Rods contain rhodopsin - the so-called visual purple, composed of the protein opsin and retinal, which is an aldehyde of vitamin A. Under the influence of light, rhodopsin breaks down into these components and changes its color to yellow. The reaction is reversible and very fast. However, under too much light, retinal turns into retinol and its color turns white, this reaction is reversible by a slow process. Thus, rhodopsin regeneration can take place via a slow or a fast pathway.

Hemeralopia (night blindness) is a reduced ability to adapt. It can be hereditary or arise, for example, with avitaminosis A. A sufficient amount of rhodopsin is not produced, which manifests itself in dim vision, night blindness.

Defects of the eye

For more information go to: Refractive defects of the eye.

Refractive defects of the eye are caused by poor properties of its refractive surfaces. Parallel rays entering the eye are not concentrated on the retina. Therefore, the image focus of the eye's optical system does not lie on it. This phenomenon may not be caused only by incorrect refraction of light rays. More often the problems are caused by axial defects of the eye - the refractive medium is fine, but the eye is of different length. Axial and refractive errors manifest themselves in the same way and can even be combined. In general, larger refractive errors cause fewer secondary problems. The image is hazy or blurred and the eye cannot correct this defect. The situation is different for smaller refractive errors. The eye is able to compensate for these to a certain extent, this effort leads to muscle and nerve exhaustion. This results in tiredness and watery eyes, headaches, and other symptoms. In an eye without a refractive error, the rays passing through the optical system intersect at the focus on the surface of the retina, such an eye is called emmetropic. We often encounter an ametropic eye, when the rays on the retina do not intersect. We distinguish between spherical and aspheric defects. Spherical defects are corrected with spherical lenses. These include myopia – Myopia and hypermetropia - Farsightedness. **Myopia** - the eye is physiologically too long. A sharp image is projected in front of the retina. The patient sees poorly at a distance, but well at near. **Hypermetropia** - the eye is physiologically too short. A sharp image would be projected behind the retina, the image is out of focus on the retina. We correct aspheric defects with aspheric, so-called toric, lenses. The most common aspheric disorder is **astigmatism**, where the patient sees unsharply both near and far. It causes asymmetry of the optical power of the cornea, or rarely of the lens.

The cornea has different curvatures in two mutually perpendicular axes.

Eye defects include presbyopia (farsightedness). Here, however, it is a natural process of loss of flexibility of the optical apparatus of the eye and thus a reduction of accommodation abilities in older age.

Correction of eye defects

For more information go to: Methods of correction of refractive errors.

Eye defects can be corrected with lenses (glasses, contact lenses) or laser surgery, the goal being to induce emmetropia. Dispersions are used to correct myopia . The ideal optical strength of the dispersion is such that the patient can see clearly to infinity (5-6 meters in practice). To correct hypermetropia , couplings are used, the optical power is chosen so that the patient can read the text at a distance of 25 cm. Astigmatism is corrected with cylindrical or toric glasses, in the case of irregular astigmatism, correction is difficult. For Presbyopia , the patient can use monofocal glasses for multiple distances or bifocal (and multifocal) glasses.

Links

related articles

- Defects of the eye
- The principle of vision
- The optical system of the eye
- Eye (histology)
- Biochemistry of the vision process
- Corneal and conjunctival burns

Source

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External links

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