Ministry of Health of Ukraine
Ukrainian Medical Stomatological Academy

It is approved
on meeting of department of
medical informatics, medical and biological physics
27 August 2020
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Head of department ________O.V.Silkova

Methodical instructions
for students' self-preparation work at preparation for a practical lesson
at home and at the classroom

Subject matter	**Medical and biological physics**
The unit	2. Bases of medical physics
Theme of lecture:	**Biophysics of vision.**
Year	1
Faculty	Medical
Speciality	Medicine

Poltava - 2020

The topic significance:

Person receives through visual analyzer more then 90% of information about environment. Vision gives us information about shape, size, color of outer objects and about distances to them. It gives us possibility to orientate in space.

Peripheral part of visual analyzer is paired organs – eyes. Correspondingly, studying of eye, its structure, function and characteristics, methods of vision hygiene is important task.

Specific targets:

To have general knowledge of the studied topic ;

To understand, to remember and to use the received knowledge ;

To master concepts of visual acuity, field of vision, vision defects, correction methods ;

To take possession of measurement skills of visual acuity, field of vision ;

To seize technique of experiment on determination of visual acuity by special tables;

To seize technique of experiment on determination of field of vision – perimetry method ;

To be able to carry out laboratory and experimental work :

To measure visual acuity of every student ;

To measure field of vision for mane colors (white, yellow, red, blue and green) of one student .

Basic knowledge, experience, skills necessary for studying the topic in connection with other subjects*:*

Disciplines	Obtainable skills
Previous (providing disciplines): Physics; biology.	To use follows concepts at tasks decision: basic concepts of optics: refraction in lenses, construction of image in lenses; basic concepts of eye anatomy: refracting eye apparatus, light guiding optic system of eye, light perceiving system of eye
Next: Normal physiology;	Constitution and functions of structures of an eye. Processes of accommodation and adaptation of eye. Processes of light perception. To explain the causes of disturbances of sight and methods of their correction. Methods of studying of sight characteristics.

Materials for the before-class self-preparation work:

List of main term, parameters, characteristics, which student have to learn at preparation to class:

Term	Definition
Eye	A pair organ of sight, the composite photooptical physiological system.
Accomodation of an eye	Property of an eye to formation on a retina is equal a sharp image of equidistant subjects. The accomodation is carried out due to change of a focal power of an eye at change of curvature of a surface of a lens.
Normal viewing distance	Distance on which an eye is given with the different image of subjects without an excessive voltage of an accomodation (25 sm)
Visual angle	A corner which is formed by the beams which have been lined from extreme points of an object through an optical centre of an eye.
Sharpness of an eye	Ability of an eye to discriminate fine details of apparent subjects. Visual acuity is characterized by the least angular distance (visual angle) between two points which are still accepted by an eye separately.
Hypermetropia	Flaw of vision, the bound with a poor refractive power of an eye or with the diminished shape of an eye globe owing to what the image of the back-country subjects places behind of a retina.
Myopia	Flaw of vision at which the sharp image of the subjects back-country from an eye is framed in a plane which lays before a retina. It can be consequence of the prolate shape of an eye globe or extremely high refractive power of mediums of an eye.
Astigmatism	Lack of the sharp image on a retina of an eye, a diffuseness and contortion of contours of the image. It is bound with infringement of the spherical shape of an exterior surface of a cornea or its unequal refractive power.
Monocular vision	Vision one eye
Binocular sight	Vision two eyes and reception thus of the uniform conterminous image of a subject.
Vision	Feeling (sensory sensation) which accepts light colour and structure of world around as the image or a picture.
Daltonism	Daltonism is a vision deficiency, the bound with infringement of a colour vision of the person. In that case on an eye retina the perception of one of three base colours (red, green and blue-violet)

	is lost or is attenuated. The corresponding colours are accepted as grey.
Achromasia	Achromasia is the complete absence of an eye colour sensation, color-blindness.
Presbyopy	Presbyopy is decrease of an eye ability to an accomodation owing to age changes (a stretching of visual muscles, and densification of a lens). It is observed in the age of the after 40 years.
Light adaptation	Light adaptation is adaptation of a sight organ to more intensive or more weak lighting.

Theoretical questions to class:

1. Structura of eye: layers of eyeball envelope, structure of the anterior and posterior parts of eye.
2. Structure of retina.
3. What is accomodation of an eye? Describe it mechanism.
4. Characterize normal viewing distance.
5. What is visual angle? It value?
6. Acute of vision.
7. Describe vision mechanism.
8. What is hypermetropia? Describe methods of it correction.
9. What is myopia? Describe methods of it correction.
10. What is presbyopy? Describe methods of it correction
11. What is astigmatism? Describe methods of it correction.
12. View field.
13. Characterize binocular sight.
14. Mechanism of light reception.
15. Achromatic and color vision mechanisms; characteristics and roles of cones and rods.
16. What is daltonism?
17. What is achromasia?
18. Mechanisms of adaptation.

Practice work executed at class.

The list of educational practical tasks which are necessary for executing on practical training:

1. To seize habits of work with Sivtsev table.
2. To seize habits of work with perimeter.
3. To determine visual acuity.
4. To determine field of vision.

Devices and goods: the table for definition of visual acuity, the screen for occluding of one eye. Perimeters, pointers with color circles (white, dark blue, red, green), form-plans for a sketch of a field of vision.

Determination of visual acuity (distant vision).

In the table there are horizontal parallel series of letters which size decreases from the upper lines to lower. For each lines the distance is determined, from which two points (restricting accents of letters) are perceived at visual angle 1' (and letters - 5 minutes). Letters of the uppermost lines are perceived by a normal eye from distance of 50 meters, and inferior (or the third from below of some in Sivtsev table) - 5 meters. For determination of visual acuity in relative unit the distance from which the patient can read a line, is divided into distance from which it should be read under condition of normal vision: V = d/D, where d – distance, from which patient can see certain line and can not see lower line, D – standard distance, noted near the line. Patients discriminate only the uppermost table line at visual acuity 0,1.

Procedure of operation:

Offer a seat the patient apart 5 meters from the table which should be well illuminated.

Close one eye of patient by the screen.

Ask patient to term letters in the table, specifying them in a direction from top to down.

Note last of lines which the patient could read correctly (it is supposed no more than 25 % of errors).

Calculate visual acuity. For example, last of lines discriminated by patient is read in norm from 10 meters. If patient stays at 5 meters from the table, him visual acuity is equal 5/10 = 0,5.

Repeate experiment with another eye.

Visual acuity of two eyes is almost always little bit higher (on 0,1 – 0,3), than what is achieved by everyone an eye separately.

If the patient does not discriminate from distance of 5 m even the first line of the table, it is necessary to approach him (her) to the table while he (she) will not see clear the first line, and then to carry out calculation by formula.

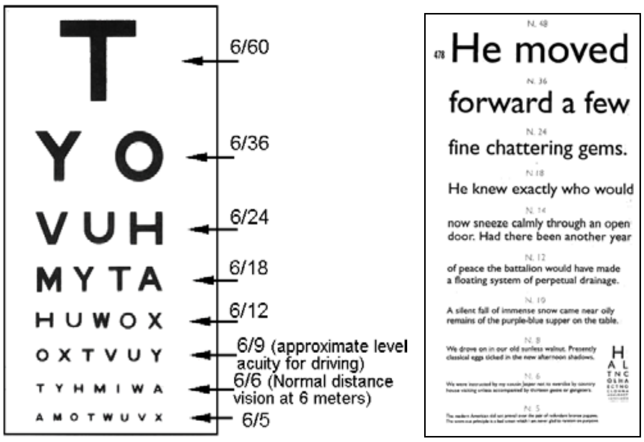
The visual acuity is tested firstly without, and then with the use of corrective spectacles, or contact lenses.

Snellen Visual Acuity Chart

It is used when the person sits or stands at 6 meters (fig.1, A) in Great Britain.

Determination of visual acuity for near vision:

Near vision is tested by using a test card (fig.1, B) and each eye is tested individually. The card has number of printed paragraphs with print of varying sizes. Each paragraph is described in terms of "points" measuring the body of the print – where a "point" is 1/72 of an inch. In a common test, N48 is the largest type, and N5 is the smallest,



A B

Fig. 1. A) Snellen visual acuity chart. B) Snellen test card.

which an unimpaired eye can see, held at a comfortable reading distance, (usually 14 inches), from the eyes.

Determination of a field of vision by a perimetry method.

Visual field is determine by means of the device with the name ***Forster's perimeter***, and the method, accordingly, is termed ***perimetry***.

Desktop perimeter ПНР-2

The desktop perimeter ПНР-2 intended for examination of a field of vision.

Perimeter ПНР-2 consists of the basis, an arc, a chin seat, disk scale and linear scale (arc scale).

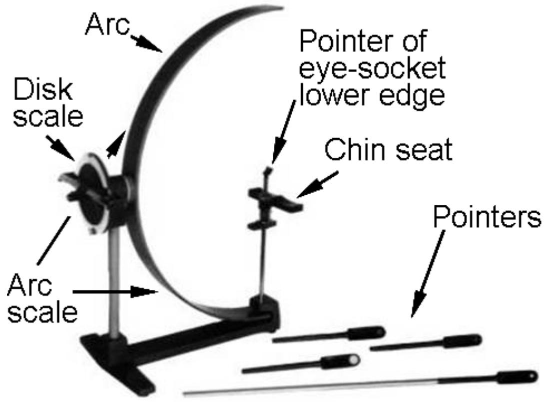


Fig.2. Desktop perimeter ПНР-2.

During examination of a vision field of one eye it is necessary to ungear another eye with the help of blinder, which enters a complete set of the device.

The desktop perimeter ПНР-2 is completed with one set of white and color objects for perimetry (with blinder) and plans of a sinistral and dextral fields of vision.

The sizes of a field of vision vary considerably at various people. These individual differences depend, for example, on professional work, in particular, from exercising by various kinds of sport. Boundary of a field of vision is much wider at football players, hockey players, volleyball players and other representatives of game sport kinds, than at people, which are not occupied with sports.

The visual field is incremented with the years also. The visual field especially intensively develops in preschool and younger school age. So, for example, for a period from 6 till 7,5 years of a visual field increases in 10 times. In the age of 7 years it makes 80 % from the sizes of a field of vision of the adult.

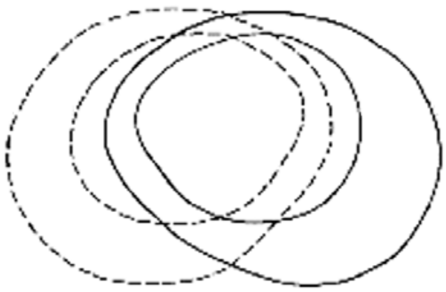


Fig.3. Covering of visual field of right and left eyes. Areas of achromatic (outer curve) and chromatic (inner curve) vision are shown.

Expansion of a field of vision is prolonged up

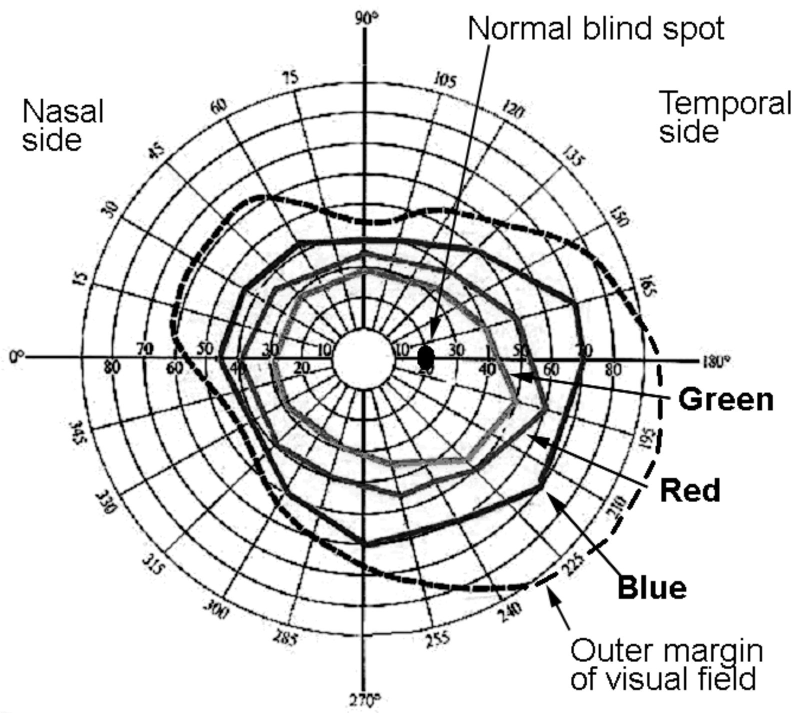


Fig.4. Visual fields of left eye.
The ***dot line*** shows a visual field for a white. ***Blue*** - a visual field for blue colour; ***Red*** - a visual field for red colour; ***Green*** - a visual field for green colour.

to 20 - 30 age. In an old age of boundary of a field of vision converge a little. This waist goes non-uniform on all directions, has no direct correlation with the years and depends on lines of factors, including from an occupation.

A color (chromatic) and achromatic visual fields are discriminated.

The achromatic visual field more chromatic, that is is greatest a visual field for a white – for the mixed colour. It explains that rods, sensing to all visual beams and accepting not colour, but light, are in major quantity on periphery of a retina.

Boundaries of an achromatic field of vision make: outward approximately 100º, inward and upward – 60º, and downward – 65º.

For various colours of a visual fields are unequal also. The visual field for yellow colour is little bit less, than for white, for dark blue colour is even less, further there is a red colour and the narrowest visual field is for green colour (see on fig. 4).

Many individuals with a retinal dystrophy or degeneration will experience loss of their peripheral (or side) vision. Individuals with macular dystrophy may have blind spots in their ***central vision. In clinic, it is necessary to measure this loss with a visual field test.***

1. Determination of visual acuity

Carry out in such sequence:

1. Offer a seat the patient apart 5 meters from the Sivtsev table (russian analogue of Snellen visual acuity chart) which should be well illuminated.
2. Close one eye of patient by the screen.
3. Ask patient to term letters in the table, specifying them in a direction from top to down.
4. Note last of lines which the patient could read correctly (it is supposed no more than 25 % of errors).
5. Calculate visual acuity.
6. Repeate experiment with another eye.
7. Fill the table:

The report of examination			
#	Name	Visual acuity for a dextral eye (in the conditional units)	Visual acuity for a sinistral eye (in the conditional units)
1.			
2.			
3.			
4.			
5.			

2. Determination of a field of vision

Carry out in such sequence:

1. Seat a patient before perimeter with a back toward light source.
2. Chin set on chin seat. Change position of chin seat in order to exact allocation of pointer of eye-socket lower edge.
3. Close other eye.
4. During all examination patient must look by open eye on the white point in the center of arc.
5. Set perimeter arc in horizontal position.
6. Move white pointer mark from periphery to the center of arc.
   Arc scale is graduated in degrees.
   Note angle, at which white pointer mark appears in patient field of vision.
7. Use every color pointer marks for determination of chromatic perceptibility zones. Not warn patient about used color. Move pointer till patient will call color correctly; do not stop at patient mistakes. Note corresponding angles.
8. Carry out this experiment from other side of arc.
9. Set perimeter arc in vertical position.

10. Repeat experiments from both sides of arc.
11. Rotate perimeter arc on 45° and 135° by order; repeat experiments from both sides of arc.
12. Create achromatic and chromatic fields of vision.
13. Repeat experiments for other eye.
14. Note points (black and colors) on the axes on the scheme in your note-book with distances from the center of scheme corresponding to angular visual field borders of the patient. See the sample of the scheme on fig.5.
15. Connect points with one color for obtaining of limiting curves for visual fields for studying colors.

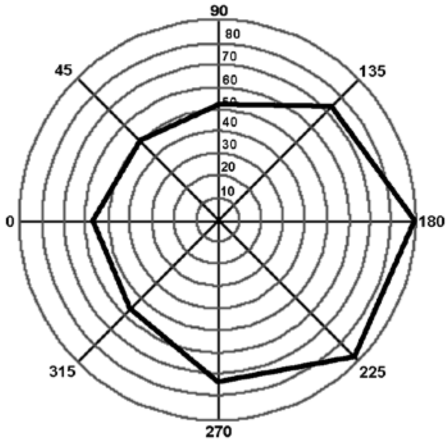


Fig.5. Form for visual fields of left eye with the sample of graph.

3. To draw a conclusions.

Do recommendations about necessities of further examination by a doctor; about necessities of exercises for vision correction.

The content of the topic:

The human eye structure is shown in Fig. 6. A human eye has spherical form with diameter *d=23 mm.* The eyeball contains three coats (or layers): outer, middle and internal, which are called *sclera, choroid* and *retina* correspondingly. The eyeball is divided into two cavities, *anterior* and *posterior,* by the lens. *Anterior* cavity is divided into two *chambers, anterior* and *posterior,* by the *iris.*

Outer coat of the eyeball sclera or fibrous coat protects the eyeball and assists in maintaining its shape. Six exterior muscles are attached to the sclera; they turn eyeball and enable to look left, right, up and down.

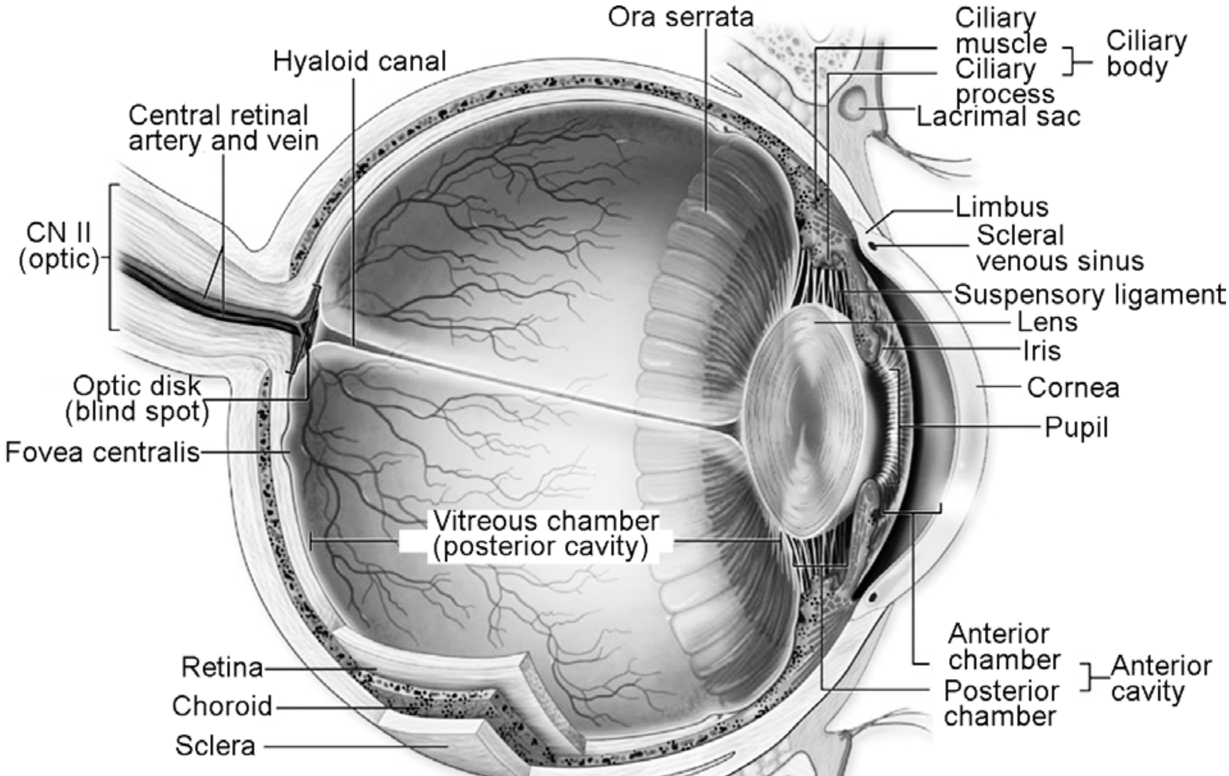


Fig.6. The human eye structure.

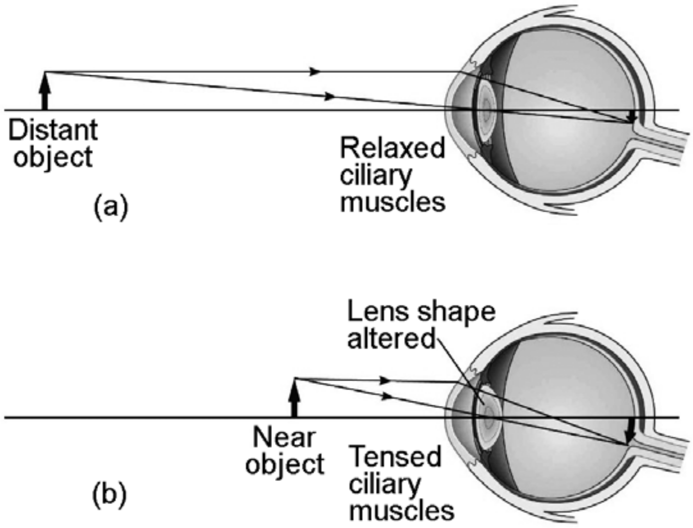


Fig. 7. Eye accomodation principle.

The front part of the sclera is called the ***cornea***. Light enters the eye through the cornea. The cornea is transparent, and it has a bigger curvature and strength than the remaining part of the sclera. The relative index of refraction equals ***n=1,38***; the focal power approximately equals to ***40 dptr***.

Cornea is mostly a refracting part of the eye, so its external surface borders on air and its internal surface borders on ***aqueous humour*** (a watery fluid, which fills the anterior chamber of the eyeball). Near 70% of the total focusing of the eye happens at light passing through cornea. Aqueous humour is a transparent liquid with optical properties like those of water, ***n=1,33***.

The middle layer of the eyeball is the ***choroid****.* The choroid is behind the retina and, at the front of the eye, forms the ciliary body. It contains numerous blood vessels. Its function is to absorb light to prevent internal reflection in the eyeball and to provide nourishment for the retina, to supply the eye with nutrients and oxygen, to remove waste. The choroid is continuous with the iris in the front of the eye.

The iris is a thin diaphragm that lies behind the cornea. Iris determines the colour of a human's eyes. There is a small aperture – the ***pupil*** – the opening in the centre of the iris. Light enters the eye through the pupil. Pupil dilates and constricts to regulate the light that reaches the retina.

The space between the cornea and the iris is called the eye ***anterior chamber.*** The anterior chamber is filled with a liquid whose index of refraction is almost equal to the index of refraction of water (***n=1,33***). This liquid is called the ***anterior humour*** or ***aqueous humour***. It is the watery liquid at the front of the eye, secreted mainly by the ciliary body.

The ***ciliary body*** comprises two parts – the ***ciliary process*** and the ***ciliary muscle*****.** Ciliary muscles causes the lens to change shape. If the eye is focusing on a distant object the muscles relax, causing the ligaments to tighten and the lens to lengthen. When we focus on an object nearby the muscles tighten, the ligaments slacken, and the lens shortens.

There is a ***crystalline lens*** (or just lens), which is situated immediately behind the pupil. The crystalline lens is a transparent elastic structure. It has the shape of a biconvex (converging) lens. It refracts light onto the retina. The focal power of the crystalline lens at rest is ***about 20 dptr***; relative index of refraction is ***1,44***.

The structure of the lens is very interesting. It consists of a number of transparent layers just like an onion.

The posterior camera of the eyeball is behind the crystalline lens. It is filled with a transparent jelly-like substance called ***vitreous humour****.* Its relative index of refraction is ***1,33***. Vitreous humour helps maintain the shape of eyeball and assists in the refraction of light.

All these parts of the human eye form a light conducting system of eye.

The innermost layer lining the inside of the eyeball is retina. It is composed of nervous tissue and does not cover the front region of the eyeball. The retina contains ***photoreceptors****,* i.e. the retina serves as the light perceiving system of the eye.

The total focal power of the eye at rest is $D_{eye} = 63 \div 65$ ***dptr***. Thus, among all the parts of the light conducting system the cornea has the maximum focal power.

The process of eye adaptation to clear vision of objects located at different distances is called ***accommodation****.* During accommodation, the lens curvature changes to alter its optical power. When the eye muscles are stressed, the crystalline lens becomes rounder, making the eye focal power to ***increase to 70 dptr*** (at this the focal power of the crystalline lens run up about ***30 dptr***).

Eye accommodation for clear vision of objects, which are no more than 25 cm from the eye, requires no excess tension of the eye. Therefore, man usually tends to locate the object being viewed at this distance from the eyes. The distance of ***25 cm*** is called the ***distance of best vision****.*

The least distance from the eye to the object, at which one can get its clear image on the retina, is called eye's *nearest point* or the nearest point of clear vision.

People can have congenital defects of the fight conducting system, or those acquired due to age. These are ***myopia****,* ***hypermetropia*** and ***astigmatism****.*

Myopia (nearsightedness, shortsightedness). An eye has too little refractive power to focus light onto retina has a refractive error. A myopic eye has too much power so light is focused in front of the retina (the focal length of the lens is too short or eyeball is too long). At myopia (short-sightedness), the image of the viewed object is formed in front of the retina rather than on it. The most frequent cause of myopia is a prolonged form of the eyeball.

Refractive myopia occurs less frequently. It is related to the excessive refracting ability (curvature) of different elements of the eye light conducting system. For myopia correction, it is necessary to decrease the eye's optical power; for this, concave lenses (glasses, contact lenses) are used.

Hyperopia (hypermetropia, farsightedness, longsightedness). Conversely a hyperopic eye focuses beyond the retina. At hypermetropia (long-sightedness), the image of the viewed object is formed behind the retina rather than on it.

The cause of presbyopia, which occurs most frequently, is loss of lens elasticity. The lens fails to change its form to a sufficient extent, thus disturbing the process of accommodation. Sometimes hypermetropia is related to the shortened size (oblate form) of the eyeball. To correct hypemetropia, it is necessary to increase the optical power of the eye; for this convex lenses are used.

Presbyopia. As people grow older, the lens hardens and does not return to its rounded shape when the ciliary muscles contract, producing the age related farsightedness called presbyopia. It is accompanied by short-sightedness manifestations as result of lack of lens flattening restoration at survey of distant objects.

At ***astigmatism***, the curvature of the eye's refracting surfaces is unequal in different meridian planes, for example, in the vertical and horizontal ones. Due to this, the rays, which are incident on the eye in different planes, are focused in different ways, and a blurred picture is received by the retina.

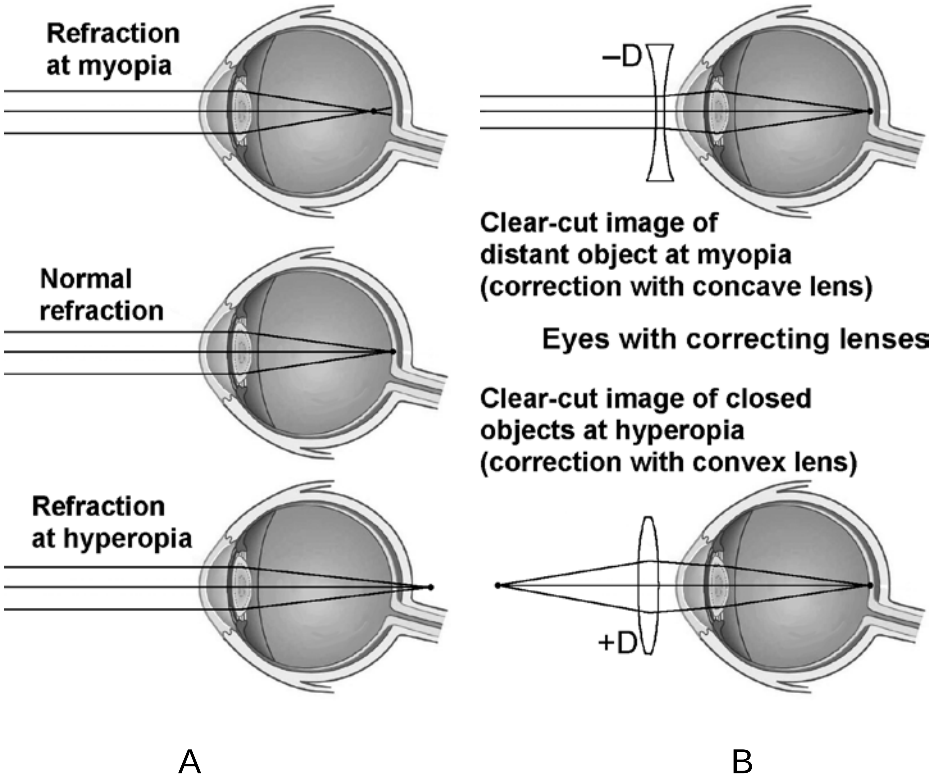


Fig.8. A) Myopic eye and correction of myopia with lens.
B) Hyperopic eye and correction of hypermetropia with lens.

To correct astigmatism, cylindrical lenses are used. They have a curvature only in one of the meridian planes, thereby providing equal refraction of the rays, which are incident on the eye in different planes. Note that astigmatism is corrected relatively easily in the case of simple astigmatism, i.e. when the planes of maximum and minimum curvature are mutually perpendicular. If these planes are not perpendicular, the case is squinting astigmatism, making it considerably harder to select correcting lenses.

The eye's light perceiving system is formed by vision cells (receptors) arranged on the retina. Man has two kinds of vision cells differing in form, which is reflected in their names, viz. ***rods*** and ***cones***. The number of rods on the retina is about 130 million, and that of cones is about 7 million. The rods and cones are irregularly distributed over the retina. There are mainly cones in the ***macula lutea.***

In the visual center of the eye there is a slight depression in the retina less than 2 mm wide, the ***fovea centralis*** (the Latin *fovea* means "small pit"). The fovea provides the perception of contrast edges at an extremely high level of detail within a visual field approximately 1,5° wide — the width of three full moons. The fovea is slightly displaced from the visual axis (the focal point behind the lens) away from the nasal side of each eye. As a result the fovea locates under the image of relatively close, centrally fixated objects. It allows us to determine not only distances (binocular vision) yet many details of target objects.

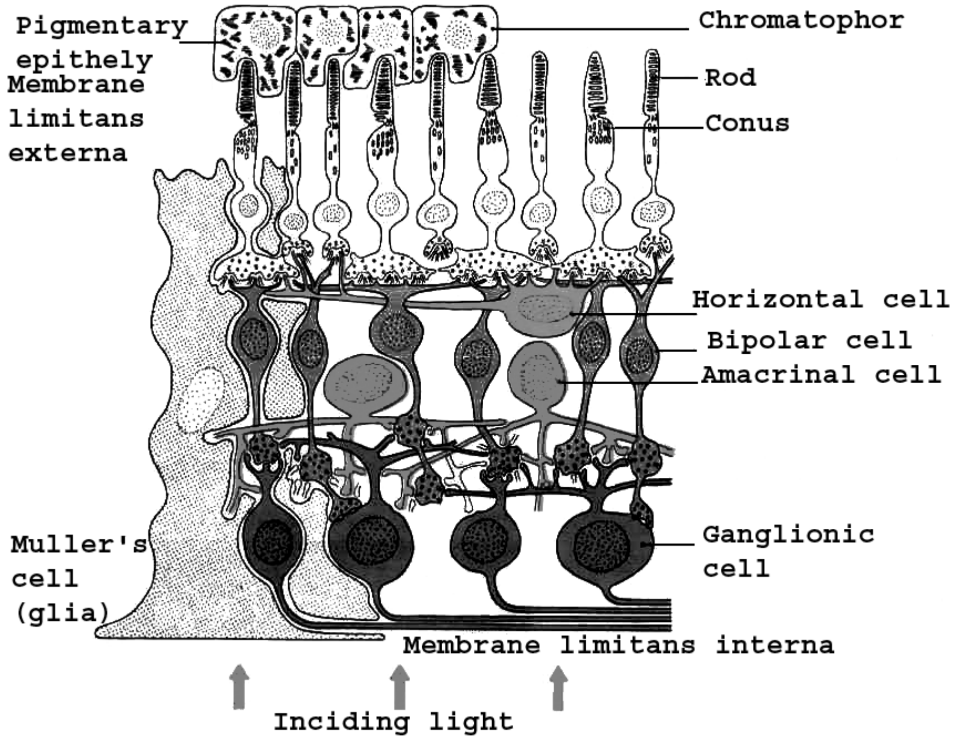


Fig.9. Retina structure.

The number of cones decreases with an increase in the distance between the macula retinae and the retina periphery, whereas the number of rods increases under these conditions. Visual receptors are only absent in that area of the retina where the optic nerve enters the eye. This area is called the ***black spot***. The line, which passes through the optical centre of the lens and the centre of the macula lutea, is called the ***fine of vision***. The line of vision forms an angle of approximately 5° with eye's principal optical axis.

The cones make the human eye able to distinguish colors, i.e. they form the apparatus of colored daylight vision. They lack very high photosensitivity, so they require sufficiently bright light for functioning. The rods do not distinguish colors, but they possess very high photosensitivity. They function sufficiently well at twilight when lighting conditions are low, and the cone apparatus does not function. So, the rods form the apparatus of achromatic twilight vision.

The maximum total sensitivity of cones is in the yellow-green band of the spectrum and it corresponds to light with the wavelength of $\lambda = 555$ nm. This is because the spectrum of solar radiation incident on Earth also has a maximum in this wavelength band.

The ***maximum sensitivity of rods*** corresponds to light with the wavelength of ***λ = 510 nm***. This is because the rods function mainly in twilight, when lighting is provided by light scattered in the upper layers of the atmosphere. As will be shown further in detail, light is scattered more when its wavelength decreases.

Human's ability to distinguish colors is based on the normal eye having ***three groups of cones*** on the retina, which have maximum sensitivity at the wavelengths ***of λ= 445; 535 and 570 nm***, i.e. in the blue, green and red bands of the spectrum. The brain distinguishes colors according to the degree of exciting of one or other group of cones. Disturbed functioning of one of the groups of cones causes such a disease as ***daltonism,*** when a person fails to distinguish, for example, red and green colours.

The eye's ability to adapt vision at different brightness levels is called ***adaptation.*** The eye regulates the quantity of light, which arrives to the retina, because for normal functioning of visual cells their lighting must be within certain limits. Adaptation is effected by the following mechanisms: 1) change of pupil diameter within 2 to 8 mm; 2) change of concentration of the photosensitive substance contained in the visual receptors, its decomposition causing receptor excitation.

Visual acuity reflects ability of an eye optical system to build a sharp image in a retina, that is characterizes spatial resolving ability of an eye. It is measured by definition of the least distance between two points, sufficient that they did not merge, that beams from them got on different receptors of a retina.

As criterion of visual acuity the angle serves, which is formed between the beams going from two points of a subject to the optical centre of the eye, – a ***visual angle (angle of vision)***. The eye distinguishes an object if the angle of vision is not less than a certain minimum value, because to distinguish two points of an object as two distinct points, the rays from these points should arrive to two different cones (or rods, but cones prevail in the eye optical centre). The ***minimum angle of vision*** is equal to ***1'*** for the normal eye. The less this angle, the higher visual acuity. Acuity of vision is equal to 1 unit in this case. At some people visual acuity can becomes less unit (for example, at myopia or some other infringements of sight the sharpness worsens). At children till 15 years visual acuity raises with the years. At youth and adults visual acuity can be more than unit.

Age changes of visual acuity at normal refractive properties of an eye

Age	Visual acuity (in conditional units)
1 week	0,003
1 year	0,45
3 year	0,75
7-8 year	0,96
15 year	1,15
Adults	1,00

Except for visual acuity the major spatial characteristics of the visual analyzer is ***the visual field***.

The field of vision is termed space, all which points are visible at the fixed state of an eye. The visual field determines substantially ***throughput capacity (transfer capability)*** of the visual analyzer, that is that maximum quantity of the information which organs of sight for unit time are capable to register. Between the sizes of a field of vision and throughput capacity of the visual analyzer there is a direct dependence - the more a visual field, the more its throughput capacity.

Self-control material (Tasks for self-checking):

***A. Questions to be answered*:**

1. General eye structure
2. Light guiding optic system of eye
3. Refracting eye apparatus.
4. Light perceiving system of eye
5. Structure of retina .
6. What is acuity of vision?
7. What is *viewfields? What is characterized by viewfields*?
8. What influes on *viewfield size*?
9. For what color *viewfield is maximal, for what – minimal? Why?*
10. Infringements of sight. Methods of them corrections
11. Peculiarities of photopic and scotopic vision.
12. Accommodation of eye.
13. Adaptation of eye. Types of adaptation.
14. Hygiene of vision.

B. Test tasks to be done:

1. Patient discriminates last of lines, which is read in norm from 30 meters. Patient stays at 5 meters from the table. Calculate visual acuity.
2. Patient stays at 3 meters from the table and discriminates only upper line, which is read in norm from 50 meters. Calculate visual acuity.

Materials for after auditorium independent work.

Prepare the abstract on a theme by choice: “Modern methods of correction of infringements of sight”, “Methods of prophylaxis of infringements of sight”.

Literature recommended

Main sources.

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Methodical elaboration have prepared by senior lecturer, PhD biol.Sc. Korovina L.D.