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Vision

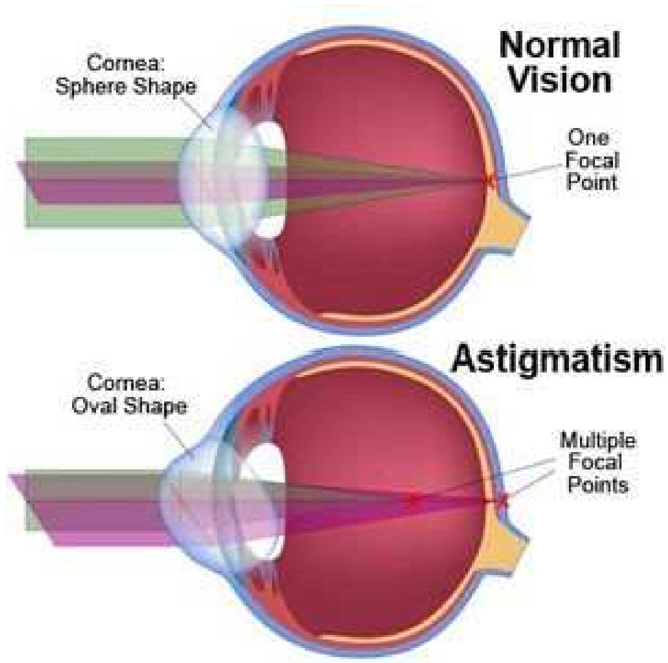
Physiology I – practice
Autumn, weeks 4–6

Astigmatism

- is a **refractive error**, in which vision is blurred due to the inability of the optics of the eye to focus a point object into a sharp focused image on the retina. Astigmatism may be present on its own or more commonly it accompanies myopia (short-sightedness) or hyperopia (long-sightedness). Astigmatism is called also **cylindrical eyesight**.
- It is caused by a **discrepancy in refractive power of cornea in its various axes** thus leading to the loss of „sphere-shape“ of the cornea and its irregularity. In sites with lesser refractive power, the light is refracted differently than in those with higher refractive power resulting in the **inability to focus those light rays into one point on the retina**.
- Nearly everyone has at least a small degree of astigmatism which is in most cases inborn and asymptomatic. But higher degrees of astigmatism may cause symptoms such as blurry vision, squinting, eye strain, fatigue, or headaches.

Types of astigmatism

- 1. Regular astigmatism
  - There are two focal points and their principal meridians are perpendicular.
  - **I. Simple astigmatism** – the first focal point is on the retina, while the second is located behind the retina. Or the first focal point is in front of the retina, while the second is on the retina.
  - **II. Compound astigmatism** – both focal points are located behind or before the retina.
  - **III. Mixed astigmatism** – focal lines are on both sides of the retina (straddling the retina).
- 2. Irregular astigmatism
  - There are no two focal points because principal meridians are not perpendicular. This type cannot be fixed by the lens.



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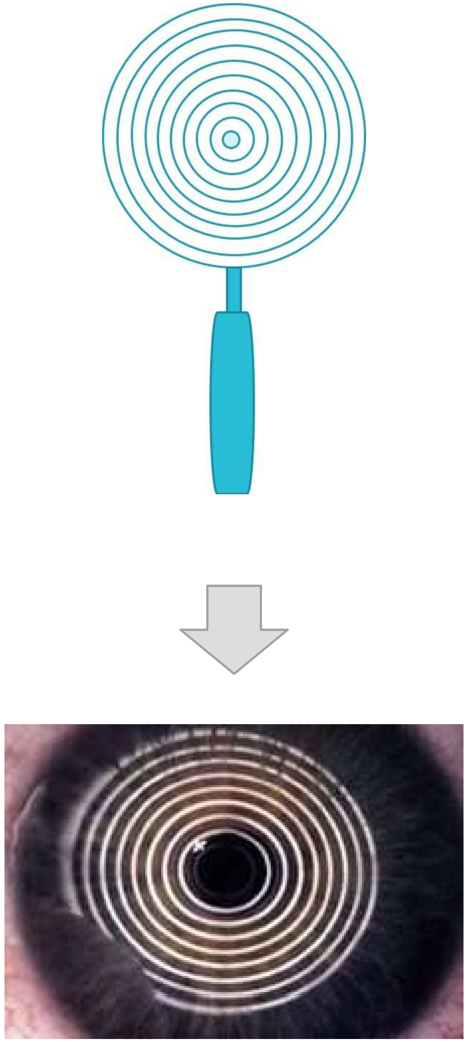
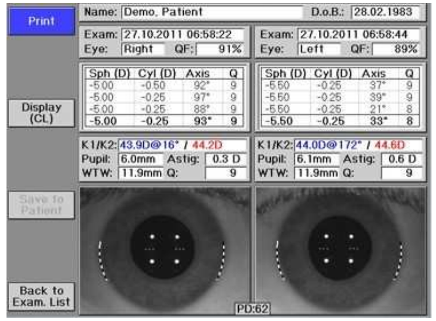
Testing of astigmatism

– 1. Objective
  – **I. Refractometer, autorefractometer**
  – **II. Placid keratoscope** – it consists of a handle and a circular part with a hole in the middle. The hole with a magnifying glass is viewed from a distance of 10–15 cm to a patient's cornea. Up to 200 mm wide circular portion is concentric alternating black and white circles. They reflect the patient's cornea. In the case of astigmatism, deformation appears at the corresponding location.
  – **III. Sciascope**
  – **IV. Ophthalmometry**



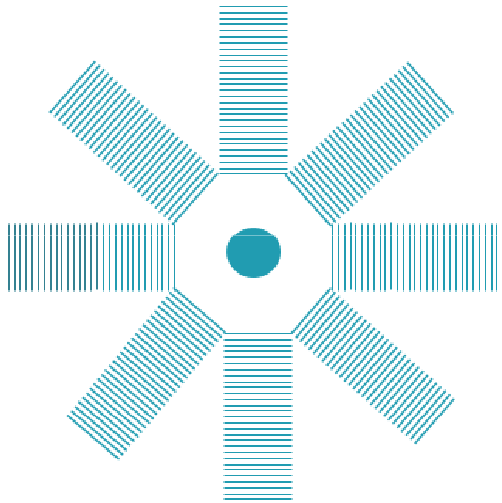
Placido keratoscope



Ophtalmometer

Testing of astigmatism

- 2. Subjective
  - **Fuchs keratoscope** – a tool for evaluating astigmatism. An examinee stands up against the pattern of a circular shape (circulars or stripe rectangles) and fixes the centre of the pattern with one eye open. Examinee himself monitors whether its image appears evenly or is somewhere distorted.



Fuchs keratoscope

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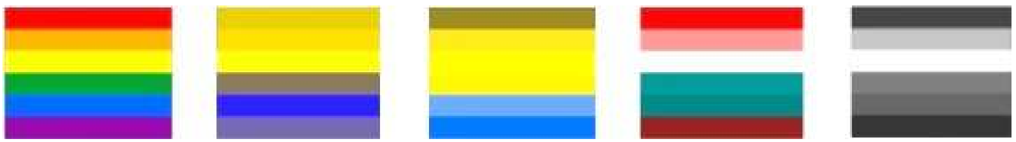
Colour vision deficiency

- = the collective name for the inability to distinguish colours correctly called colour blindness
- 1. Monochromacy – colour blindness
  - **Rods monochromacy** (achromatopsia) - inability to distinguish any colours as a result of absent or nonfunctioning all retinal cones
  - **Cones monochromacy** – absence or nonfunctioning of at least two retinal cones, most commonly red and green.
- 2. Dichromacy (Daltonismus)
  - **Protanopia** – the absence of cones sensitive to red light
  - **Deuteranopia** – the absence of cones sensitive to green light
  - **Tritanopia** – the absence of cones sensitive to blue light



Trichromacy Protanopia Deuteranopia Tritanopia Monochromacy

Colour vision deficiency

- 3. Anomalous trichromacy – is a common type of inherited colour vision deficiency, occurring when one of the three cone pigments is altered in its spectral sensitivity.
  - **Protanomaly** – is a mild colour vision defect in which an altered spectral sensitivity of red retinal receptors (closer to green receptor response) results in poor red-green hue discrimination.
  - **Deuteranomaly** – is caused by a similar shift in the green retinal receptors. It is by far the most common type of colour vision deficiency.
  - **Tritanomaly** – is a rare, hereditary colour vision deficiency affecting blue–green and yellow–red/pink hue discrimination.

Colour vision deficiency – tests

- 1. Anomalous trichromacy, dichromacy, monochromacy, decreased sensitivity to hue
  - **Farnsworth** (Munsel 100 hue test) – it tests not only the perception of different colours but also of their hues. By arranging colours in order we can detect reduced cones‘ sensitivity or their disrupted function.
- 2. Monochromacy, Dichromacy, Anomalous trichromacy
  - **Nagel anomaloscope** – an examined person is adjusting the level of green and red light (or lesser also other colours) which may discover an abnormal reaction of cones.

Farnsworth-Munsel hue test

Anomaloscope

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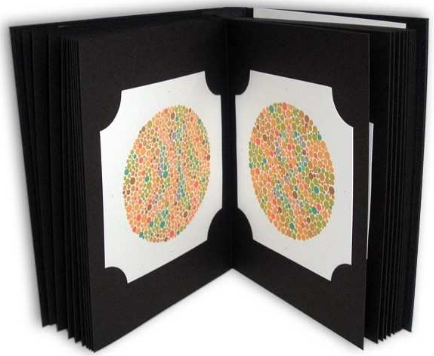
Colour vision deficiency – tests

- 3. Dichromacy, Monochromacy
  - **Ishihara test** – The test consists of several coloured plates. Each of them contains a circle of dots appearing randomized in colour and size. Within the pattern are dots which form a number or shape visible to those with normal colour vision, and invisible, or difficult to see, to those with a red-green colour vision defect, or the other way around.
  - **Holgrem test** – The patient has to match one piece of wool to the samples in the box in this colour blindness test. There are light and dark shades to confuse the patient. This helps detect the problems.



Ishihara test

Holgrem test

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1. Numbers

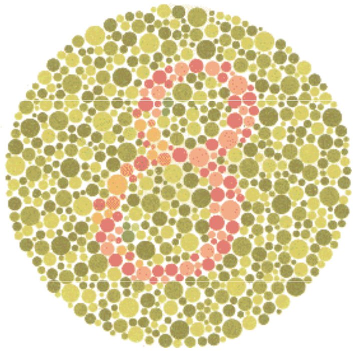
- Colourful dots are mixed to form shapes of numbers and an examined person can either distinguish them or not depending on his colour vision.

2. Pictures

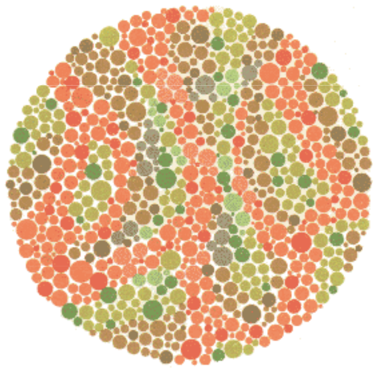
- Colourful dots can also form various pictures and numbers at the same time. In many cases it is designed so a trichromatic person does not see any picture or number, a person with abnormal colour vision sees a number or a picture.

3. Finding path

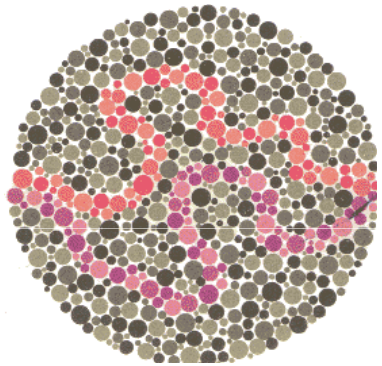
- The examined person has a task to point at the pathway made by colourful dots. An affected person may not see any pathway or see a different one.



'8'	trichomacy
‚3'	red-green blidness (protanopia, deuteranopia, protanomaly)
none	monochromacy

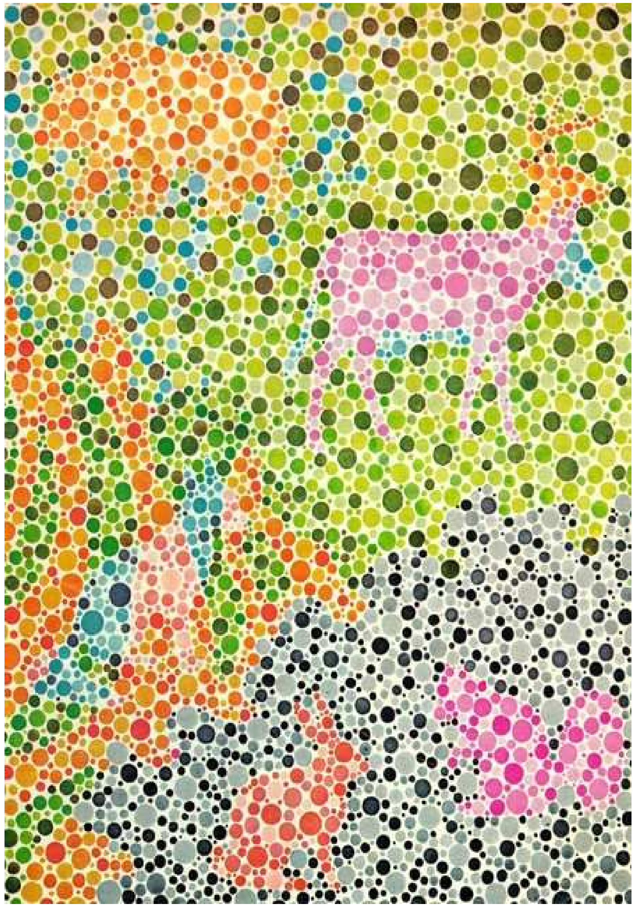


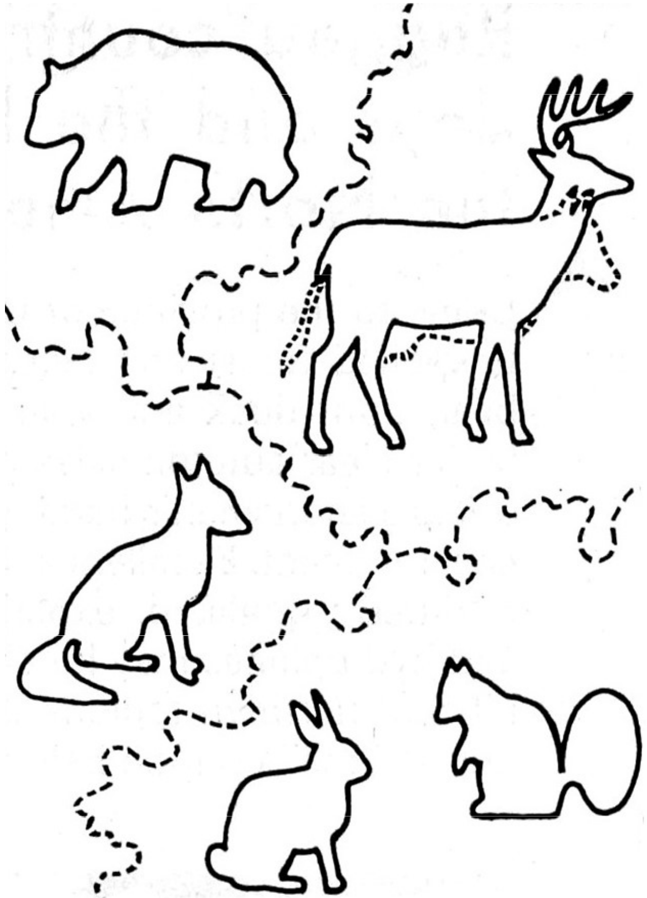
none	trichomacy
'5'	red-green blidness (protanopsia, deuteranopia, protanomaly)



both	trichomacy
purple	protanopia (easily) deuteranomy (with difficulty)
red	protanomaly (with difficulty), deuteranopia (easily)

Children‘s pseudo-isochromatic plates





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Accommodation

- **Accommodation** is the process by which the vertebrate eye changes optical power to maintain a clear image or focus of an object as its distance varies. It is done by changing the optical power of an eye’s lens thus increasing or decreasing light rays‘ refraction.
- The ability to focus is influenced by **two factors**:
  - The ability of the lens to change its shape and strength of the ciliary muscle.
  - The actual physical deformation of the lens, which is measured in diopters, is called physical accommodation. Physiological accommodation expresses the contractile force of the ciliary muscle, which is necessary to change the refractive state of the eye by 1D.

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Accommodation

- Accommodation at the near point:
  - In the process of the accommodation to the near point, there is a contraction of the circular fibres of the ciliary muscle (Muller's muscle) and relaxes the zonulas. But the lens, thanks to its elasticity, protrudes. The lens after releasing the contraction of zonules changes the radius of the curvature of anterior and posterior refracting surface, due to its high elasticity.
  - Innervation of the ciliary muscle to the accommodation at the near point provides a parasympathetic pathway.
- Accommodation at the distant point:
  - Accommodation on a distant point is also an active action. Meridional ciliary muscle fibres (Brücker´s muscle) are contracting. The fibres are arranged so that the pulling on the lens toward the periphery, there is a flattening of the lens.
  - Innervation of the meridional muscle to accommodation at the distant point provides a sympathetic pathway.

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Far and near point

- Far point R
  - Punctum remotum is a point lying on the optical axis that is displayed on the retina at the **minimum** accommodation.
  - The far point of a healthy eye is **at infinity**.
  - The hypermetropic eye has a far point at a finite distance behind the eye. Major hyperopia causes the far point to be moved closer to the final distance to the bulb of the eye.
  - The myopic eye has a far point at a finite distance in front of the eye. The distance of the far point from the subject of the major plane of the eye is called aR and it is measured in meters. The reciprocal value of this distance is called an axial refraction aR. Using this data, the current refractive state of the eye is defined.

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Far and near point

- Near point P
  - Punctum proximum is a point lying on the optical axis that appears on the retina at the **maximum** accommodation. The distance from the main plane of the eye is called the aP and it is also measured in meters (a healthy eye: 8 -10 cm).
  - The near point is of fundamental importance in assessing the performance of the accommodation of the eye. Along with the far point, it encloses an accommodative area.
- Accommodative area
  - Is the area between the far point and the near point; therefore it indicates the range in which we see the individual dots sharply. It is measured in meters.

Accommodation – defects

- Myopia
  - **Cause**: the eyeball is too long compared to its optical power or the lens executes too strong optical power.
  - **Manifestation**: the light that comes into the eye does not directly focus on the retina but in front of it, causing the image that one sees when looking at a distant object to be out of focus. For the image to be sharp, the light rays coming to the eye have to be divergent which is happening when the light is coming from objects in 6 m proximity. So this defect does not affect focus when looking at a close object. The far point in this case is not located at infinity but at a distance shorter than 6 m. The accommodative apparatus of the eye is relaxed in the myopic eye thus the near point is closer to the eye than in the emmetropic eye.
  - **Correction**: myopia is most commonly corrected through the use of corrective lenses, such as glasses or contact lenses. The corrective lenses have a negative optical power (i.e. have a net concave effect) that ensures that light coming to the eye even from objects further than 6 m is divergent thus compensating for the excessive positive diopters of the myopic eye.

Accommodation – defects

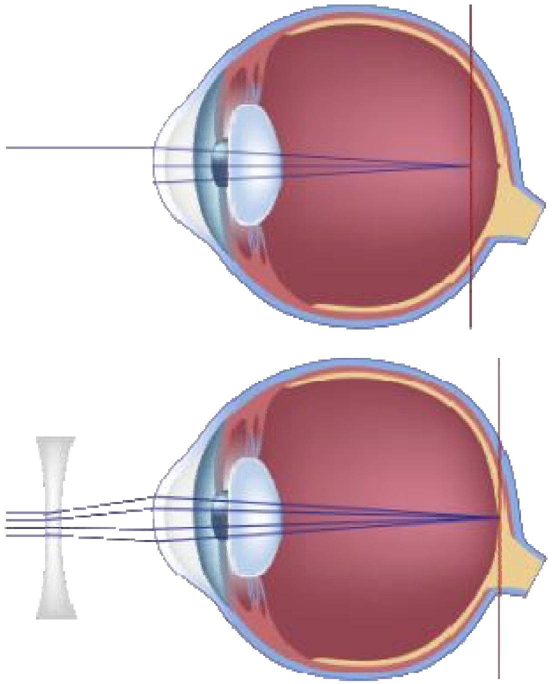
- Hypermetropia (farsightedness)
  - **Cause**: the eyeball is too short compared to its optical power, the lens cannot become round enough, the lens has insufficient optical power
  - **Manifestation**: the light rays coming to the eye from far objects are parallel and the accommodative apparatus of the hypermetropic eye is unable to refract these rays to meet on the retina so the focus is theoretically behind it. The picture of a far object is imaginary and behind the retina. The hypermetropic eye compensates for it by accommodating also for far objects thus the near point is also at a bigger distance than in the emmetropic eye. For near objects, the eye has to accommodate even more. Depending on the amount of hyperopia and the age of the person which directly relates to the eye's accommodative ability, the symptoms can be different.
  - **Correction**: hypermetropia can be corrected through the use of convex (converging) lenses with accurate optical power to focus the light coming from far objects directly on the retina without any accommodation of the crystalline lens.

Accommodation – defects

- Presbyopia
  - **Cause**: a condition associated with ageing in which the eye exhibits a progressively diminished ability to focus on near objects. The most probable cause is a loss of elasticity of the crystalline lens and diminished accommodative ability.
  - **Manifestation**: the far point is still at infinity but the near point is moving away from the eye. This leads to the blurred vision of near objects usually recognized while reading and the need to move the text further.
  - **Correction**: the usage of converging or bifocal lenses.

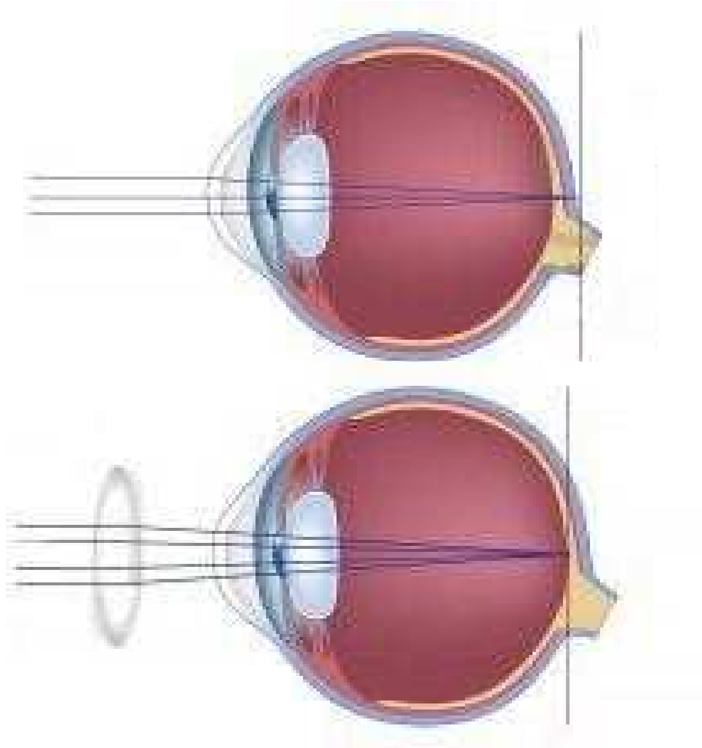
Accommodation – defects

Myopia



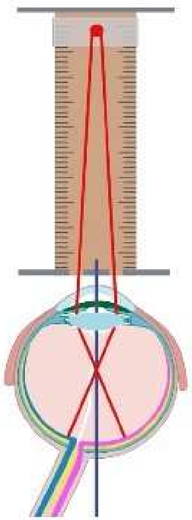
Correction

Hypermetropia



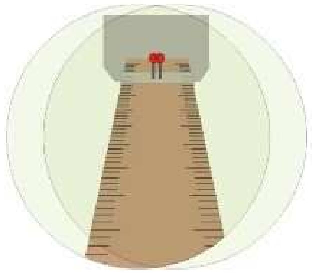
Correction

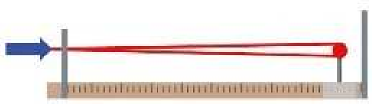
1. A examinee looks through a thin window at a pin. At the maximum distance of the optometer, the examinee reports if he sees or does not see the pin out of focus (double). A healthy eye has the punctum remotum in 5 meters, an unfocused pin in the distance of 1 meter is seen only by the myopic eye.



Scheme of the Scheiner´s optometer (a top view)

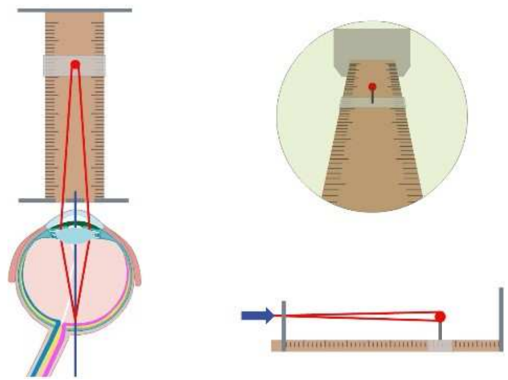
Scheme of the optometer through the slot (double vision)



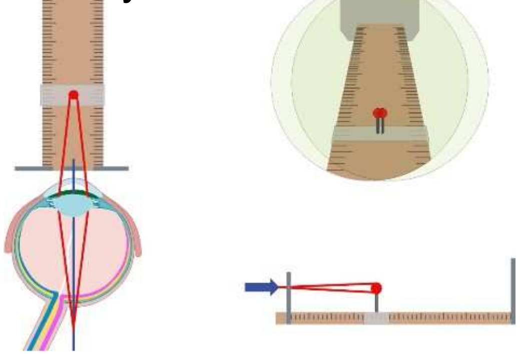


Scheme of the Scheiner´s optometer (a side view)

2. The examinating person moves progressively the pin closer to the eye and the examinee reports if he/she sees a sharp pin or not.



3. Punctum proximum in a healthy eye is about 8 -10 cm (in young people), its value is dependent on age. At this point, the healthy eye should not be able to see a sharp pin. E.g.: for the hyperopic eye, depending on the size of the defect this point is closer to 30-35 cm; in the myopic eye depending on the size of a defect is punctum proximum closer to the eye to 10-15 cm.



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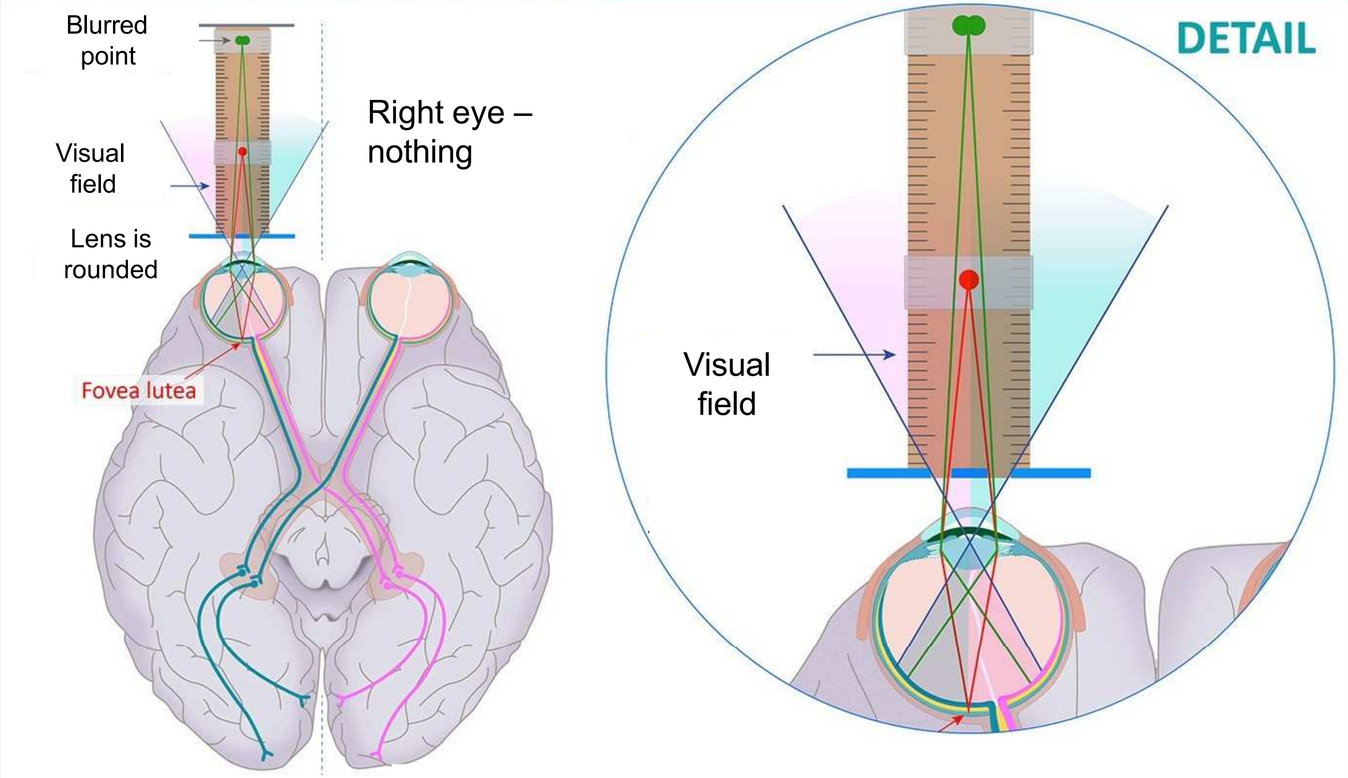
Scheiner‘s experiment

- The experiment aims to understand the connection between the refraction at the interface of two media (depending on the curvature of the lens) and the way of perception of the image. Thus, it depends on the lens, which side of the retina will handle the beam and how the resulting image will appear.
- Scheiner´s attempt is an essential part of a refractometer and it helps to detect astigmatism, hypermetropia and myopia.

Scheiner‘s experiment

- Basic theory:
  - An examinee is watching the two objects at different spatial depths (red and green pin) through the clips, which allows the examinee to watch a limited number of incident rays. When the examinee looks at the closer pin, it is seen as sharp and the distant pin is seen as blurred – the eye accommodates at the near point so that the beams converge on the fovea centralis. Rays going from a distant point can not be sharp.
  - The blurring of the pin depends on the imaging field of view – the right side of the retina processes the left side of the visual field and vice versa (regardless of the left and right eye). It also means that if one beam from one place falls to the right side and the other on the other side of the retina, the resulting image (composed of both sides of the retina) is blurred.

Near point – both clips are open (left eye)



Both clips are open

Left eye	Right eye

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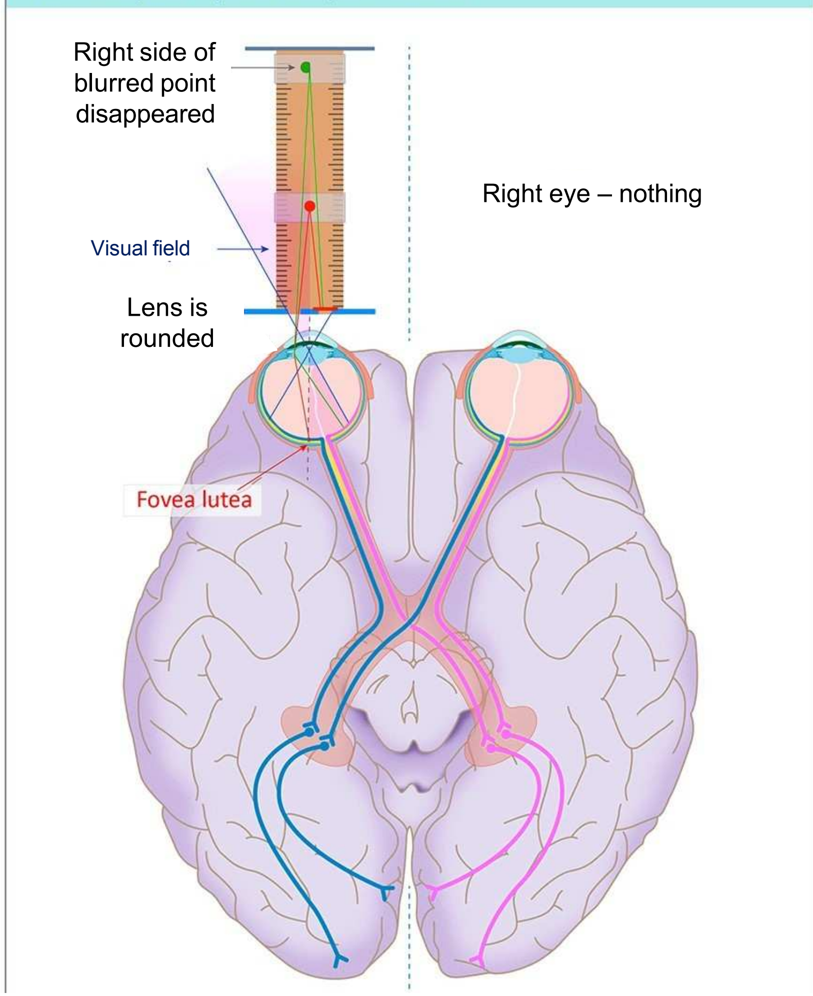
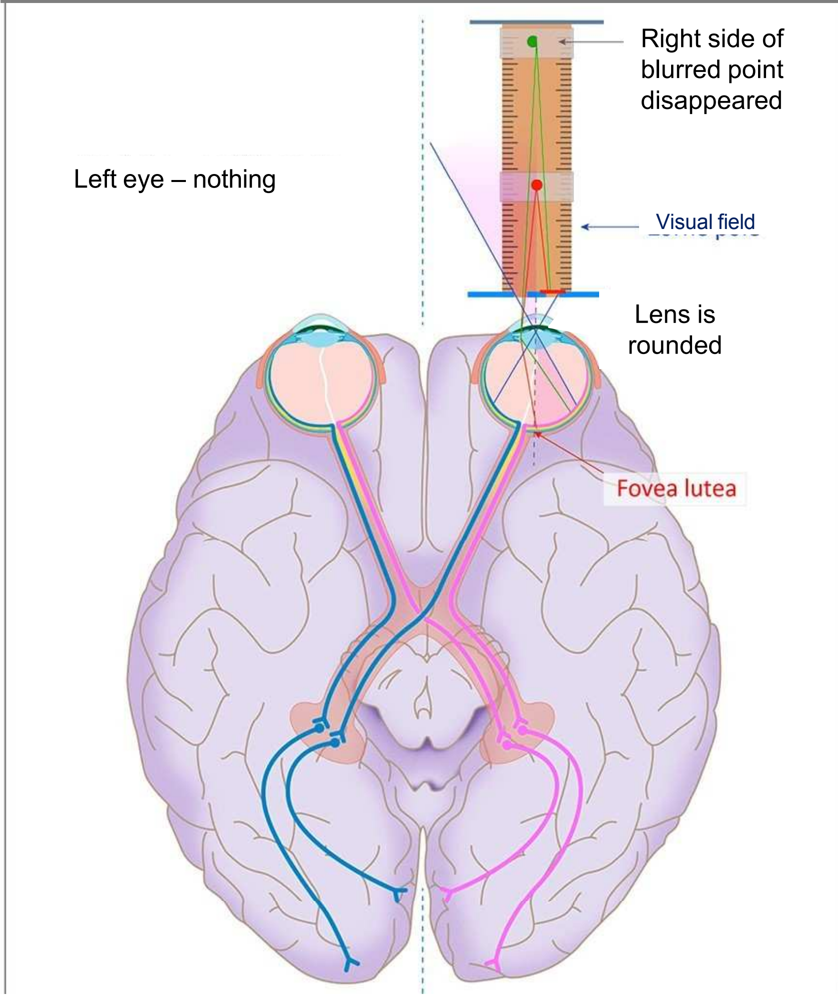
Scheiner‘s experiment

  - The first part of the experiment consists of closing one clip and observing changes in the view. At first, the examined person is **focusing on the near point**. If we close one clip, thus obstructing the light from one direction, **the same-sided blurred point of the far pin disappears**.
- Cause:
  - **Visual field**: the right side of the retina processes the left side of the visual field and visa versa on both eyes. If we obstruct the light coming from one side of the visual field, the corresponding side of the retina will not record any picture and this subject will disappear in the visual field.
  - **Refraction of the light at the interface of two media**: the refraction of light when it passes from a fast medium (with lower refractive index) to a slow medium (with higher refractive index) bends the light ray toward the normal – rays are convergent.
  - **Optical power**: while the lens is accommodating to a near object, its optical power is higher than while it is relaxed. Light rays are much more refracted in near viewing than in distance viewing because the refractive index in the lens is much higher than in air or cornea.

Near point – right clip is closed (left eye)



Near point – right clip is closed



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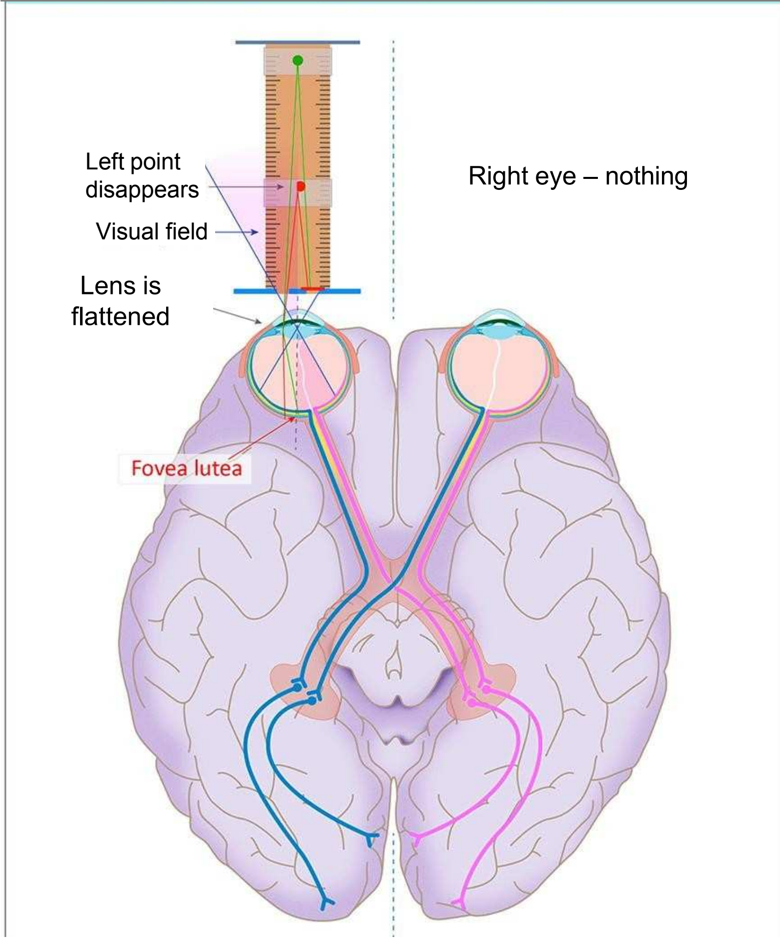
– If the examined person is **focusing on the far point**, the near point becomes blurred for the same reasons as in focusing on the near point. But if we close one clip, thus obstructing the light from one direction, the **opposite-sided blurred point of the near pin disappears**.

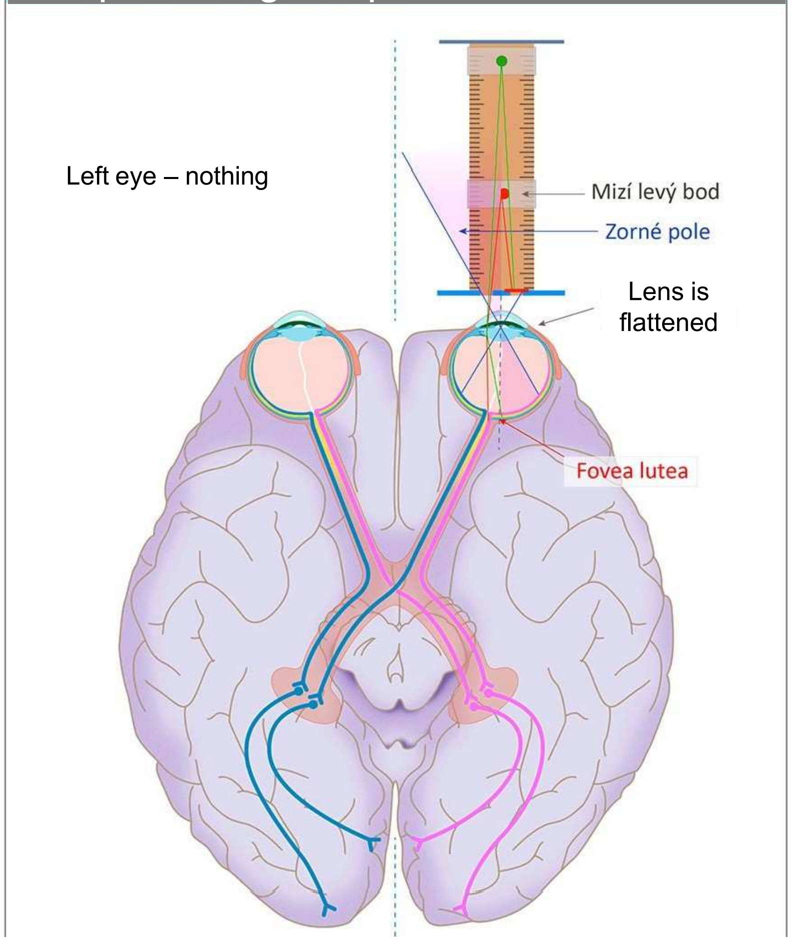
– Cause:

- Visual field: the right side of the retina processes the left side of the visual field and visa versa on both eyes. If we obstruct the light coming from one side of the visual field, the corresponding side of the retina will not record any picture and this subject will disappear in the visual field.
- Refraction of the light at the interface of two media: The refraction of light when it passes from a fast medium (with lower refractive index) to a slow medium (with higher refractive index) bends the light ray toward the normal – rays are convergent. But while watching the far object, the lens is relaxed and the light refraction is happening to a lesser degree than in the accommodating lens. Thus the refracted rays are less convergent or even parallel.
- Optical power: while the lens is accommodating to a far object, its optical power is lower than while it is accommodating to near objects. Light rays are much less refracted in distance viewing than in near viewing because the refractive index in the lens is more similar to the refractive index of the air.

Far point – right clip is closed (left eye)



Far point – right clip is closed



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Scheiner‘s experiment

– Fill this table in your protocol and explain the findings:

Accommodating to	Watching eye	Which clip is closed	Which blurred point disappears
The near point	Right eye	Right clip	
		Left clip	
	Left eye	Right clip	
		Left clip	
The far point	Right eye	Right clip	
		Left clip	
	Left eye	Right clip	
		Left clip	

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Examination of the visual field = perimetry

- 1. Kinetic perimeter:
  - The examination is performed on a rotating perimeter with moving targets. The task of the examinee is to report the changes in the visibility of the target or colour.
  - The method is less accurate than static perimetry.
- 2. Static perimeter:
  - The examinee is focused on a point located in the middle of a screen. When another light point appears elsewhere on the screen, the examinee presses a button. Successively both eyes are examined.
  - Static perimetry is more sensitive than kinetic.

  - Defects in registering red and green colours can point to the disease of the optic nerve. Diseases of the retina may be signalized by defects in registering blue colour. Colour computerized perimetry may be able to detect even hardly diagnosed diseases.

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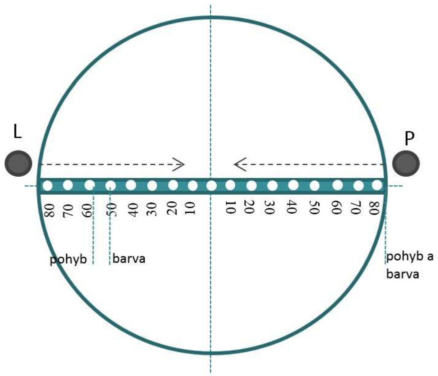
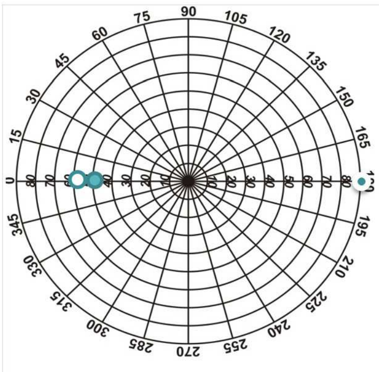
Kinetic perimeter

1. 0° orientation

On the left side – a schematic drawing of the perimeter in front of the face of the patient, who focuses with one eye on the white dot in the centre. The examinating person moves a dot of one colour first from one side to the middle and then from the other side.

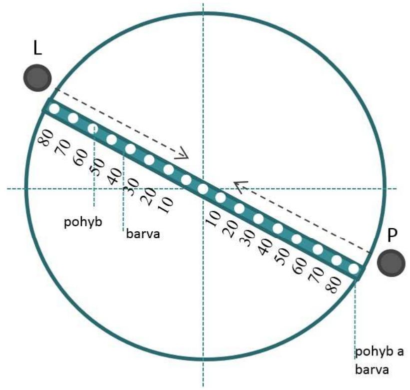
On the right side – results for the movement and colour are drawn on the opposite angular sides (in this case, 0° and 180°, where 0° is on the left side of the visual field and 180° is on the right side of the visual field).

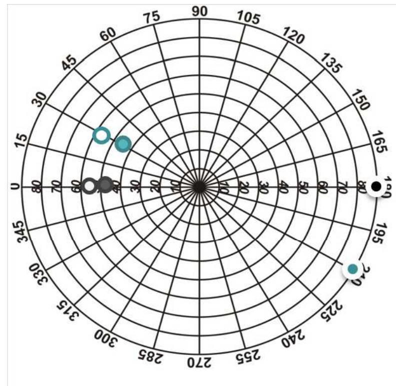




2. 30° orientation

Do the same for 30° orientation.

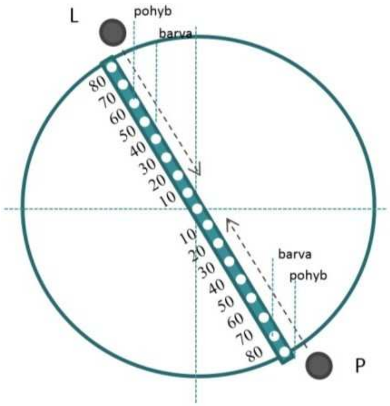


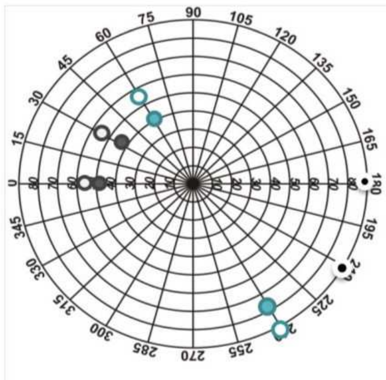


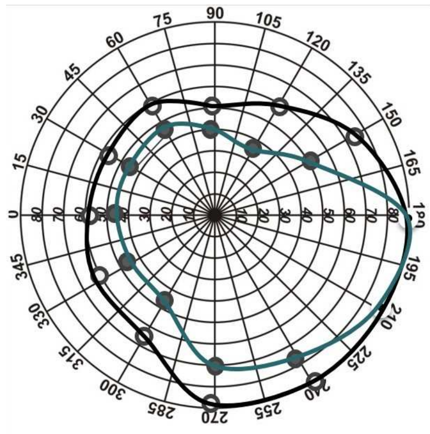
Kinetic perimeter

3. 60° orientation
Do the same for 60° orientation and others to fill the whole circle.

4. Results
Connect points for colour and movement. The movement field should have a greater range than the colour field and it represents the areas with rods and cones within the eye.

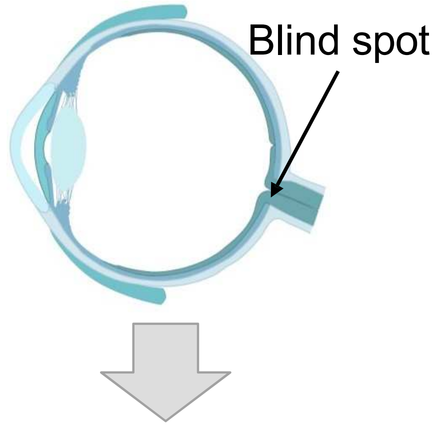


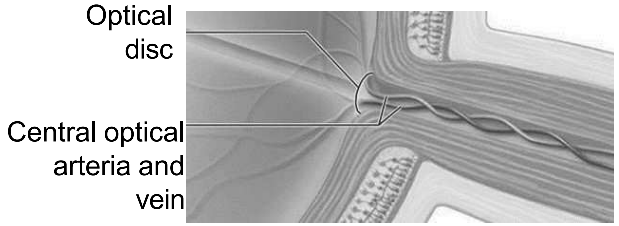


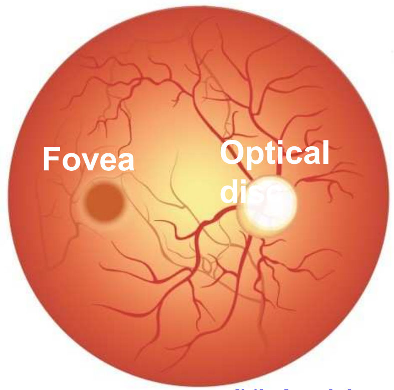


Blind spot

- Blind spot
  - is a small area on the retina, where the optic nerve protrudes. It is a space which does not contain sensitive cells, i.e. rods or cones.
- 1. Ophthalmoscopic examination:
  - An objective examination of the ocular fundus - accurate measuring of the size and changes in the background of the retina.
- 2. Perimetry:
  - Using perimetry, physiological scotoma can be captured at 18-20°.



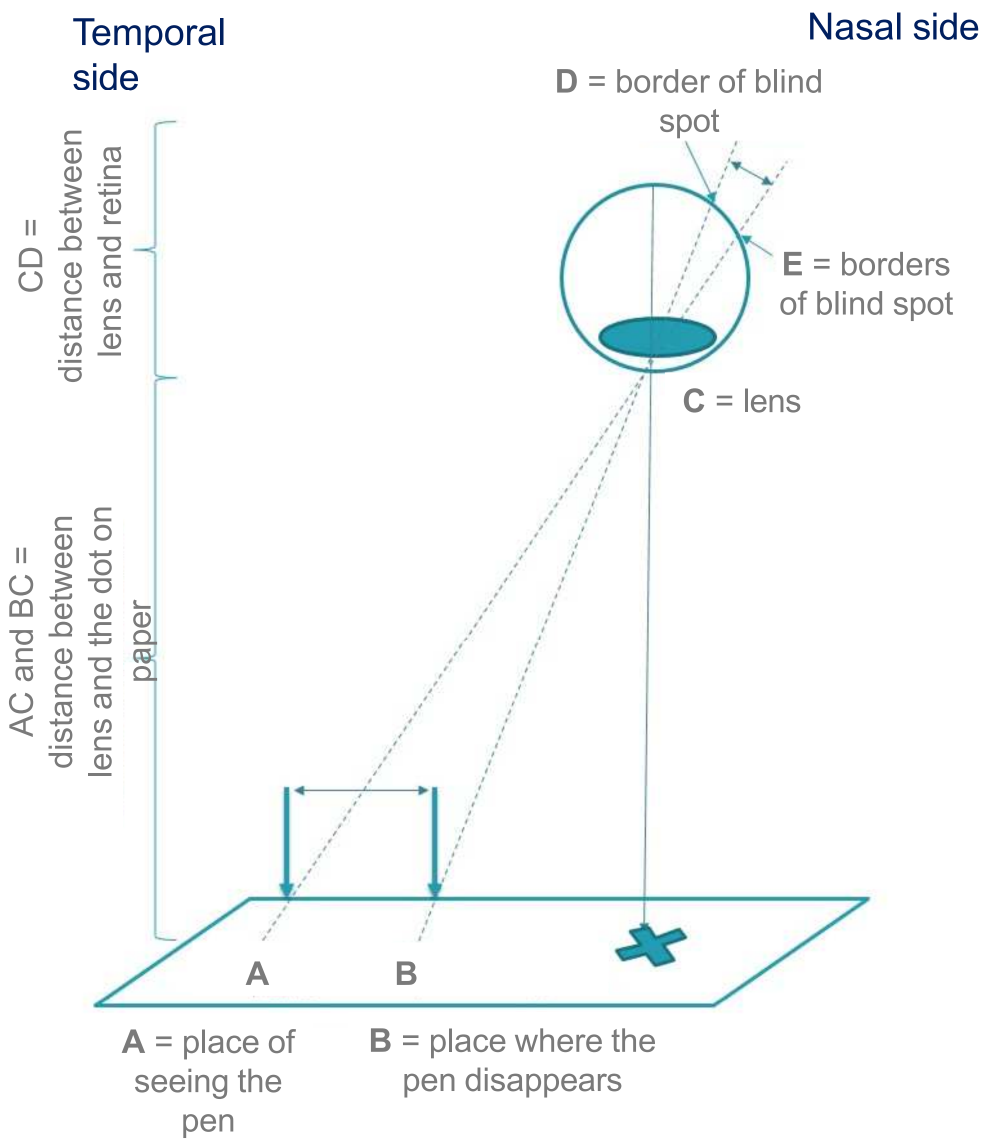




Examination the ocular fundus

Blind spot

- 3. Marriott´s test:
  - Evidence of the blind spot – basic subjective method for the detection of the blind spot using the Marriott´s image (paper with a dot on one side and with a cross on the other). Focusing with one eye on the point avoids saccadic movements. It enables the cross to get into such an angle at some distance that it falls into the blind spot.
  - The approximate shape and size of the blind spot – on the principle of proportional triangles and principles of Marriot´s attempt, we can roughly display the shape of the blind spot and calculate its size.



Results:

Calculation:

- We assume that triangles ABC and CDE are right-angled (we are omitting the curvature of the retina). They are also similar triangles.
- The distance between the lens and retina is 17 mm (CD).
- The distance between the lens and the dot on the paper (BC) is 300 mm (30cm)
- The side CD of the triangle CDE is 17 mm, the side DE is unknown.
- The side BC of the triangle ABC is 300 mm, the side AB side can be measured (e.g.: 25 mm).
- Then:

CD/BC = DE/AB

DE = AB * CD/BC = AB * 17/300=25*17/300=1.4 mm

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