

# Inner coat of the eyeball: retina



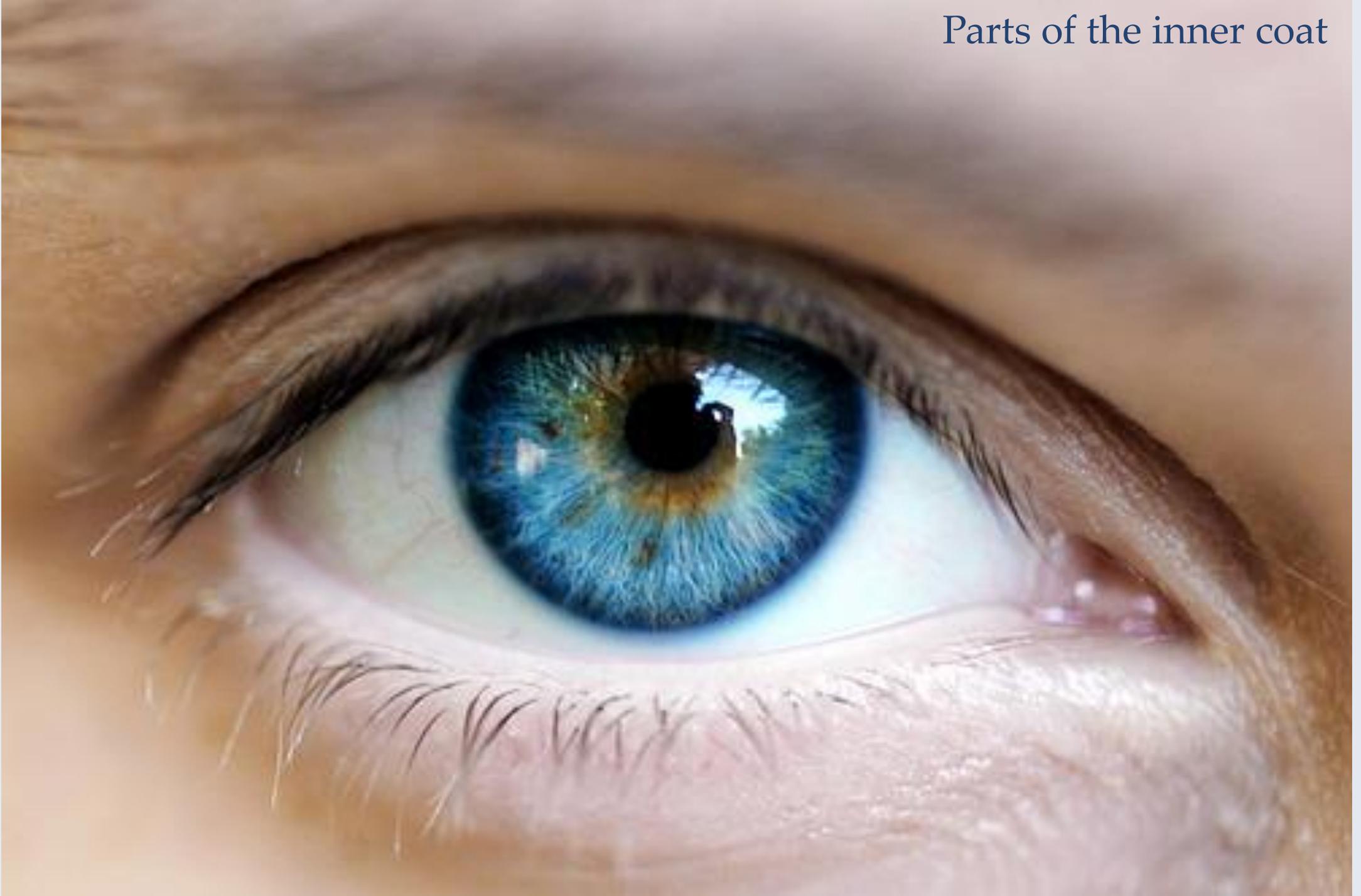
**Ph.D, Dr. David Lendvai**

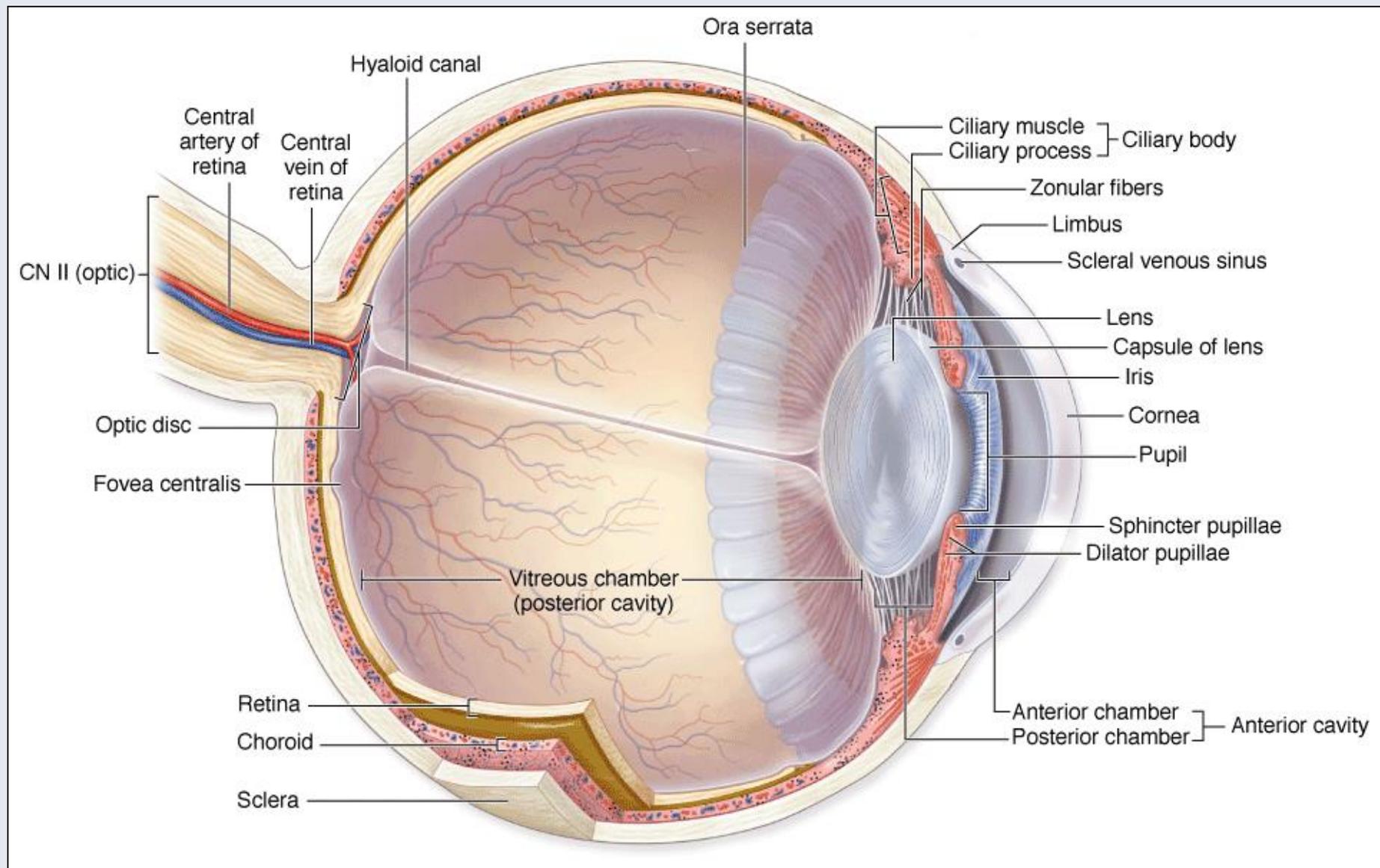
*Your eye is the lamp of your body. When your eye is healthy, your whole body is full of light. But when it's evil, your body is full of darkness.*

*Luke 11:34*

After: Dr. Mark Kozsurek

Parts of the inner coat



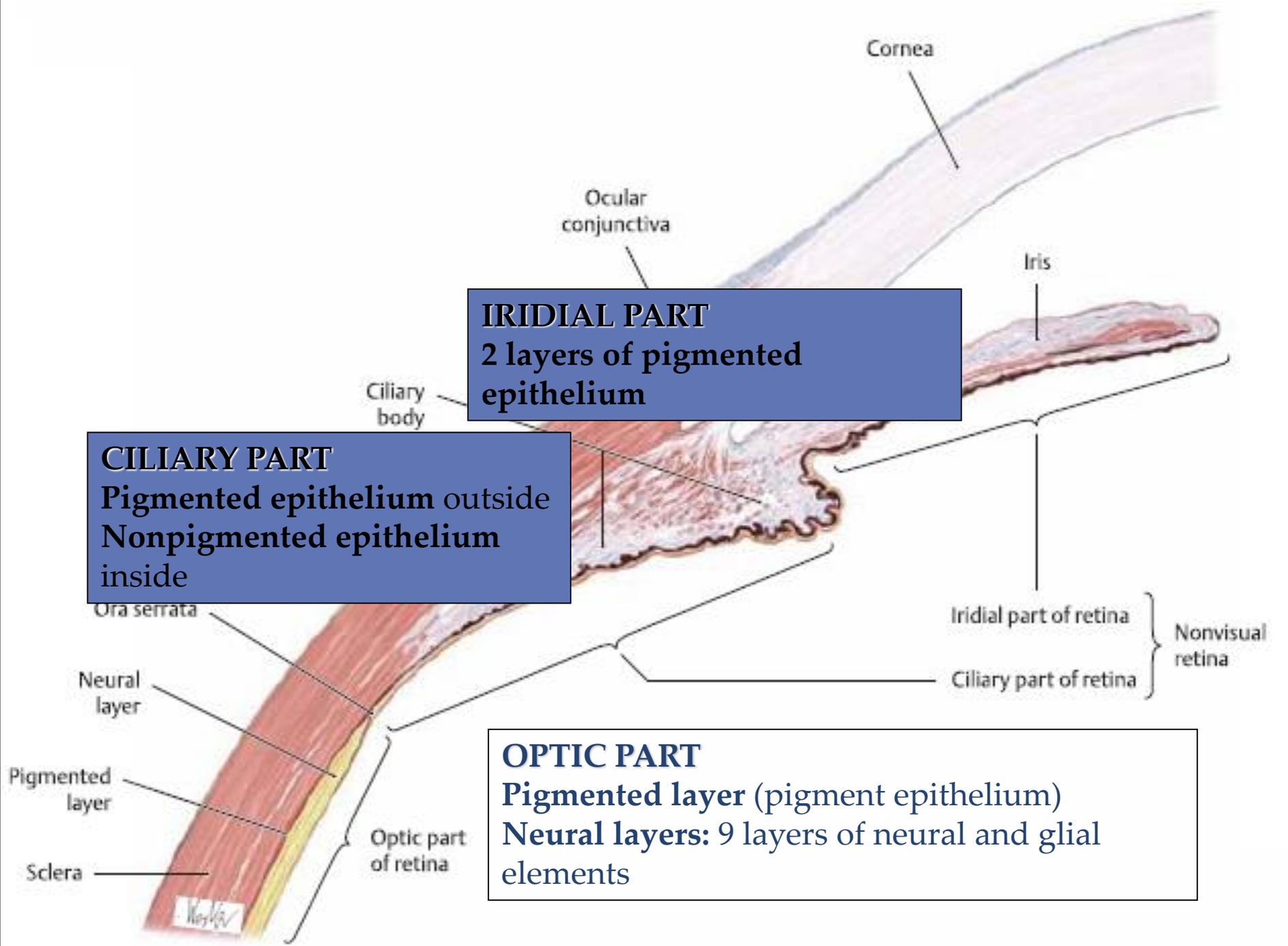


**Inner coat:** 1. optic part of the retina  
retina

2. nonvisual part of the

- ciliary part

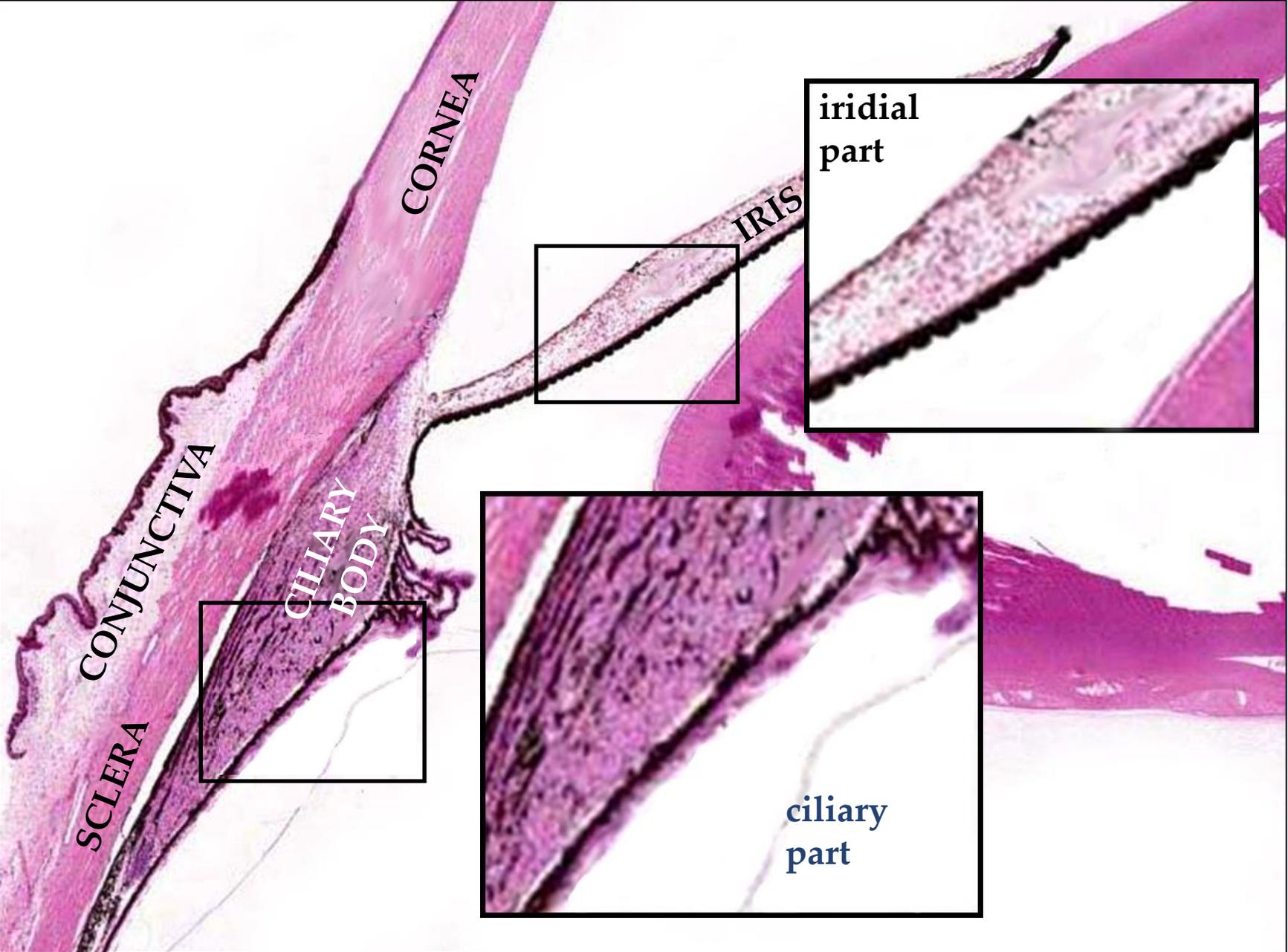
iris



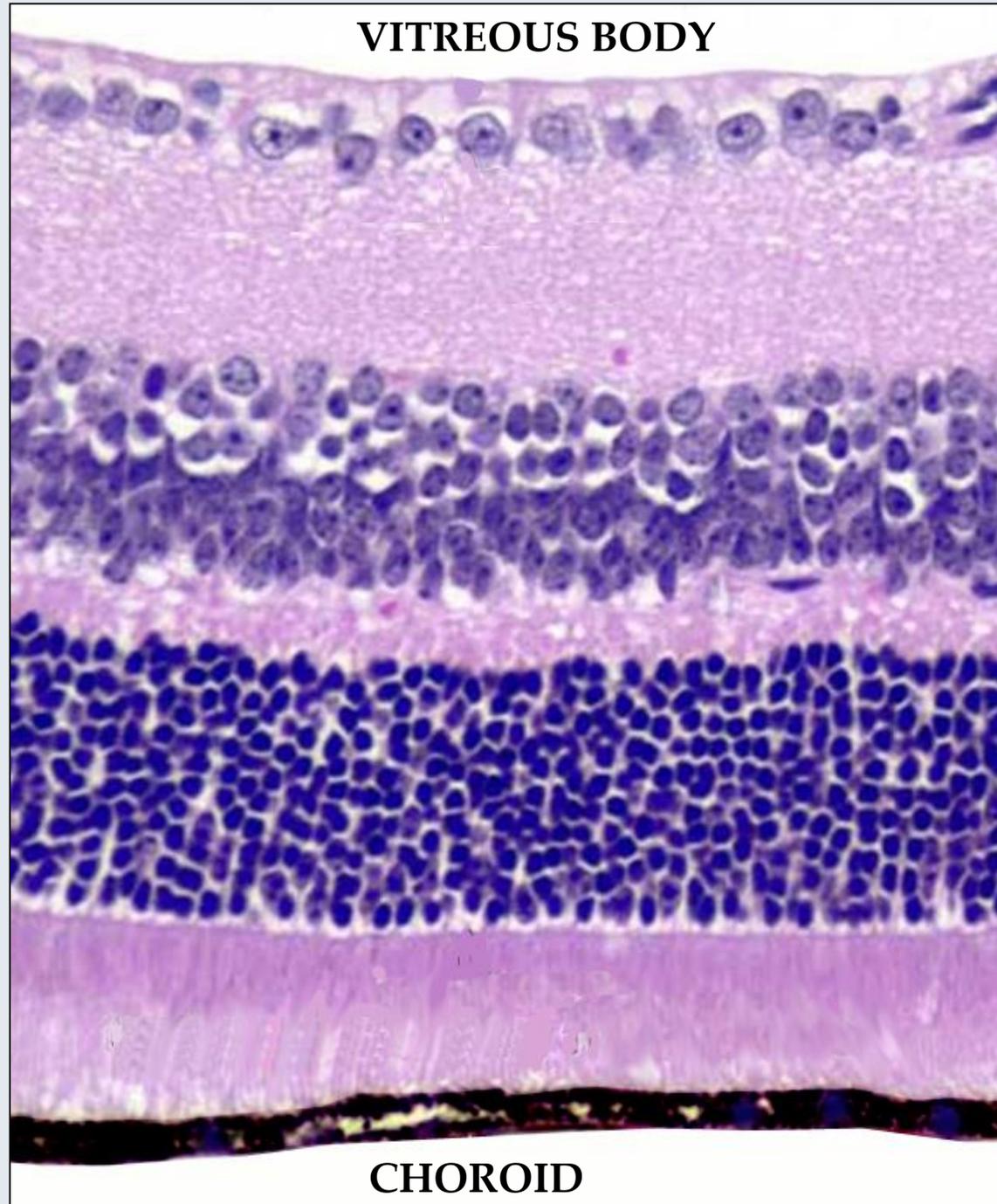
**IRIDIAL PART**  
2 layers of pigmented epithelium

**CILIARY PART**  
Pigmented epithelium outside  
Nonpigmented epithelium inside

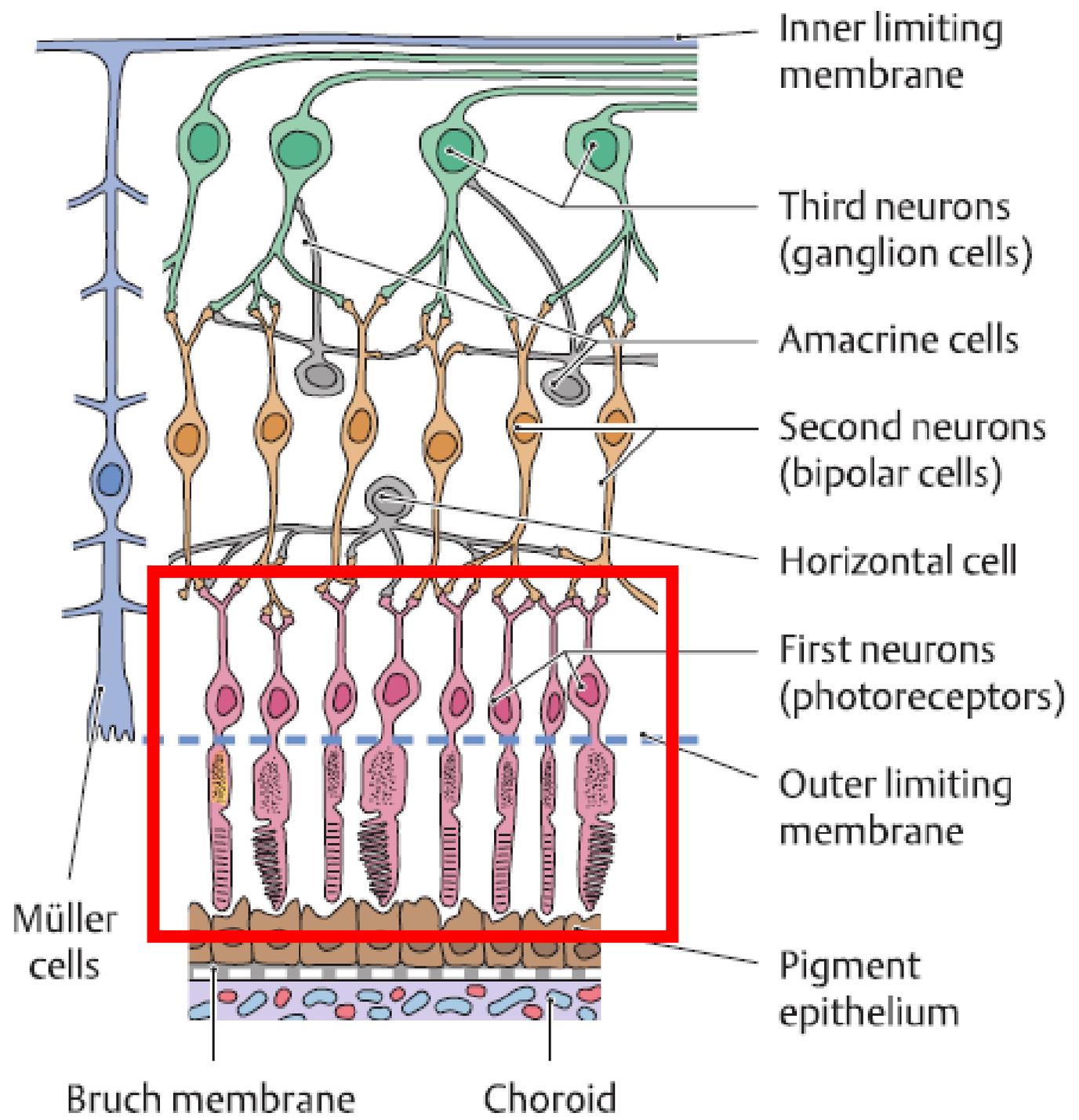
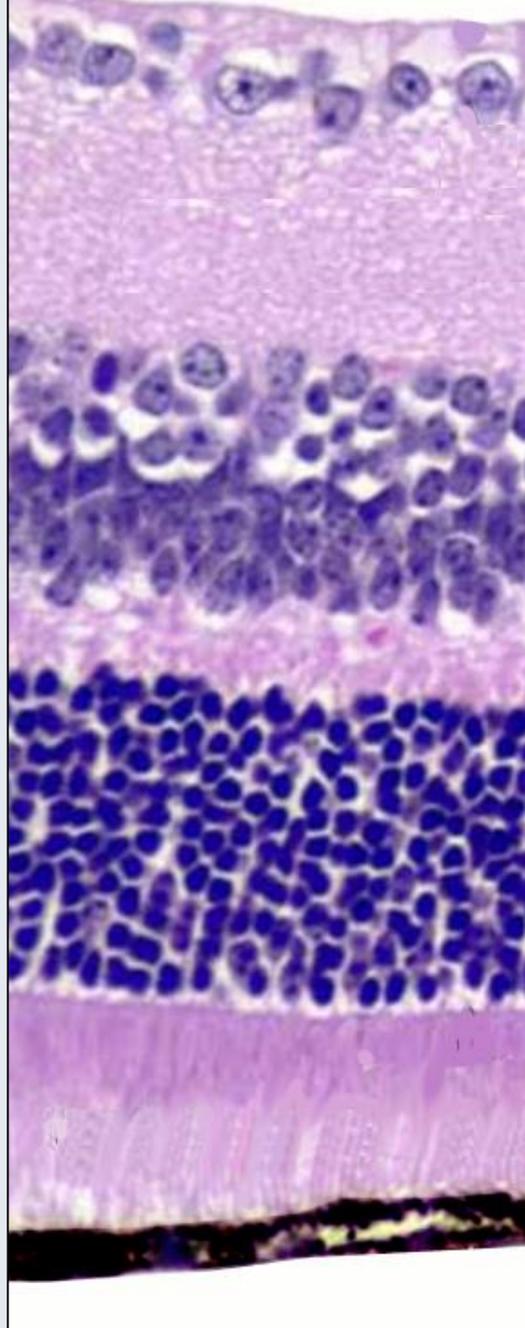
**OPTIC PART**  
Pigmented layer (pigment epithelium)  
Neural layers: 9 layers of neural and glial elements



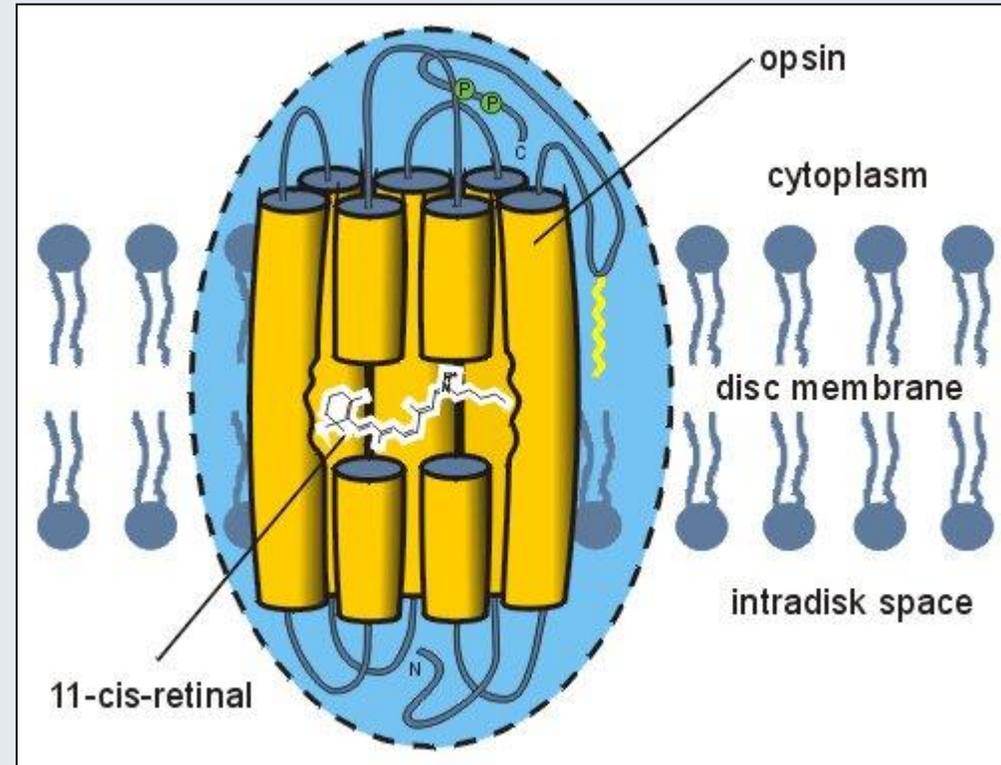
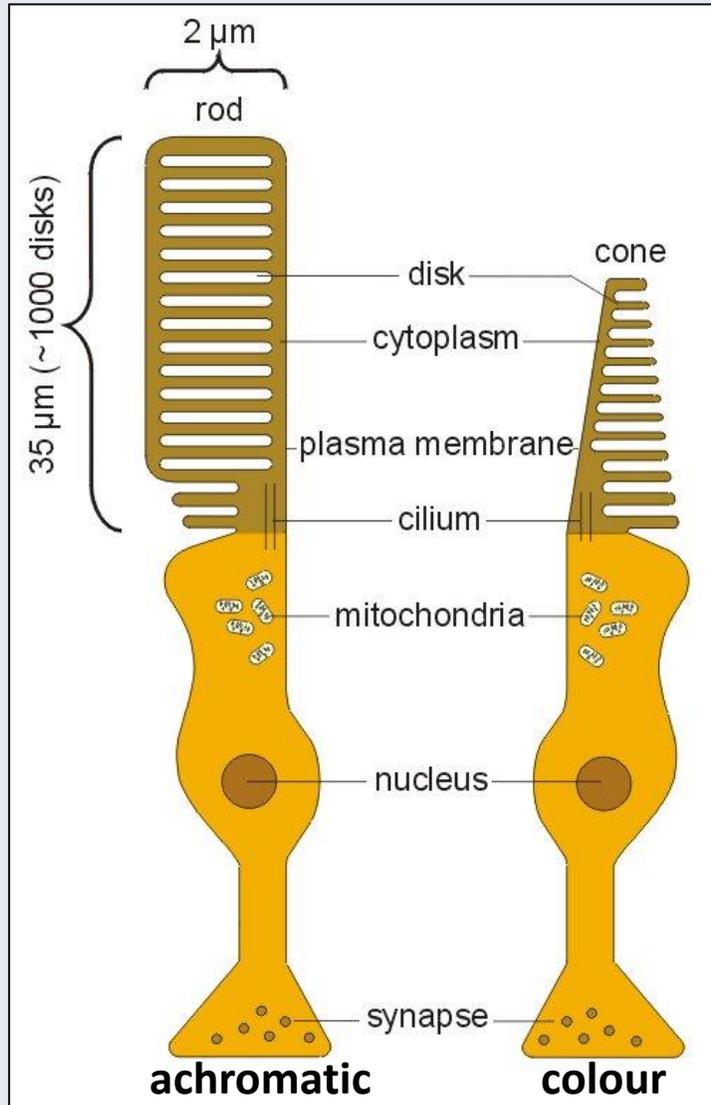
**VITREOUS BODY**



**CHOROID**



# Rods and cones: photoreceptors



**visual pigment:**

opsin protein + retinal as a  
chromophor

# The visual pigments: the opsin family



# 1. The visual pigments: the opsin family

in rods:

**rhodopsin**

in cones:

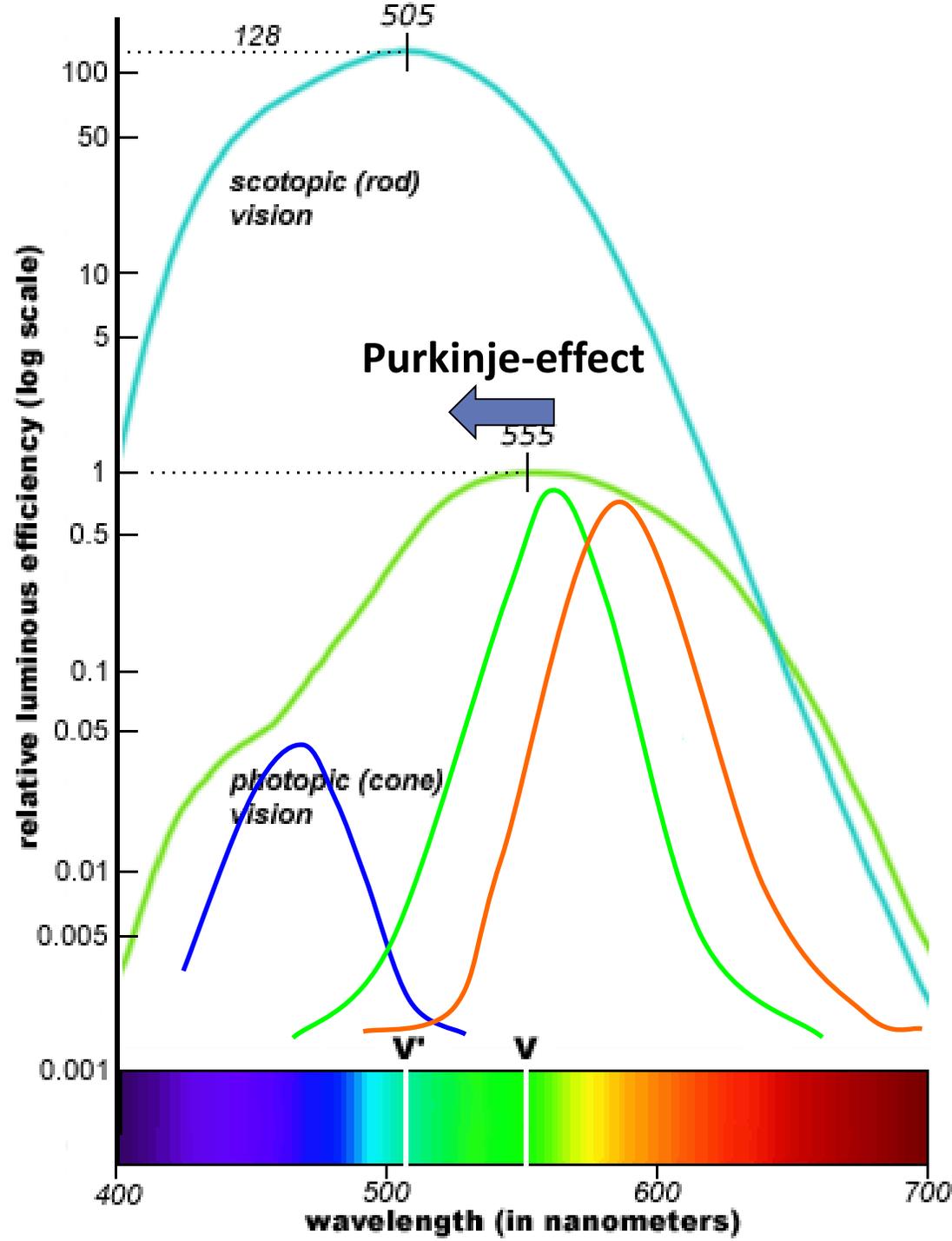
**short wavelength sensitive opsin** in  $\beta$  (blue) or S cones

**medium wavelength sensitive opsin** in  $\gamma$  (green) or M cones

**long wavelength sensitive opsin** in  $\rho$  (red) or L cones

Absorption properties of the visual pigments are exclusively determined by the highly variable opsin peptides, the chromophore is the retinal in all the four types of human photoreceptors!

# Spectral sensitivity of the photoreceptors



## 2. Spectral sensitivity of the photoreceptors

**Rods:** much more sensitive, but not selective for the wavelengths (colours). Due to their lower threshold, they work also in the dark.

**Cones:** three types with three different opsins; less sensitive, but selective for wavelength (colour). As they have higher threshold, are active only in light.

The effect occurs because the color-sensitive [cones](#) in the [retina](#) are most sensitive to [yellow](#) light, whereas the [rods](#), which are more light-sensitive (and thus more important in low light) but which do not distinguish colors, respond best to green-blue light.

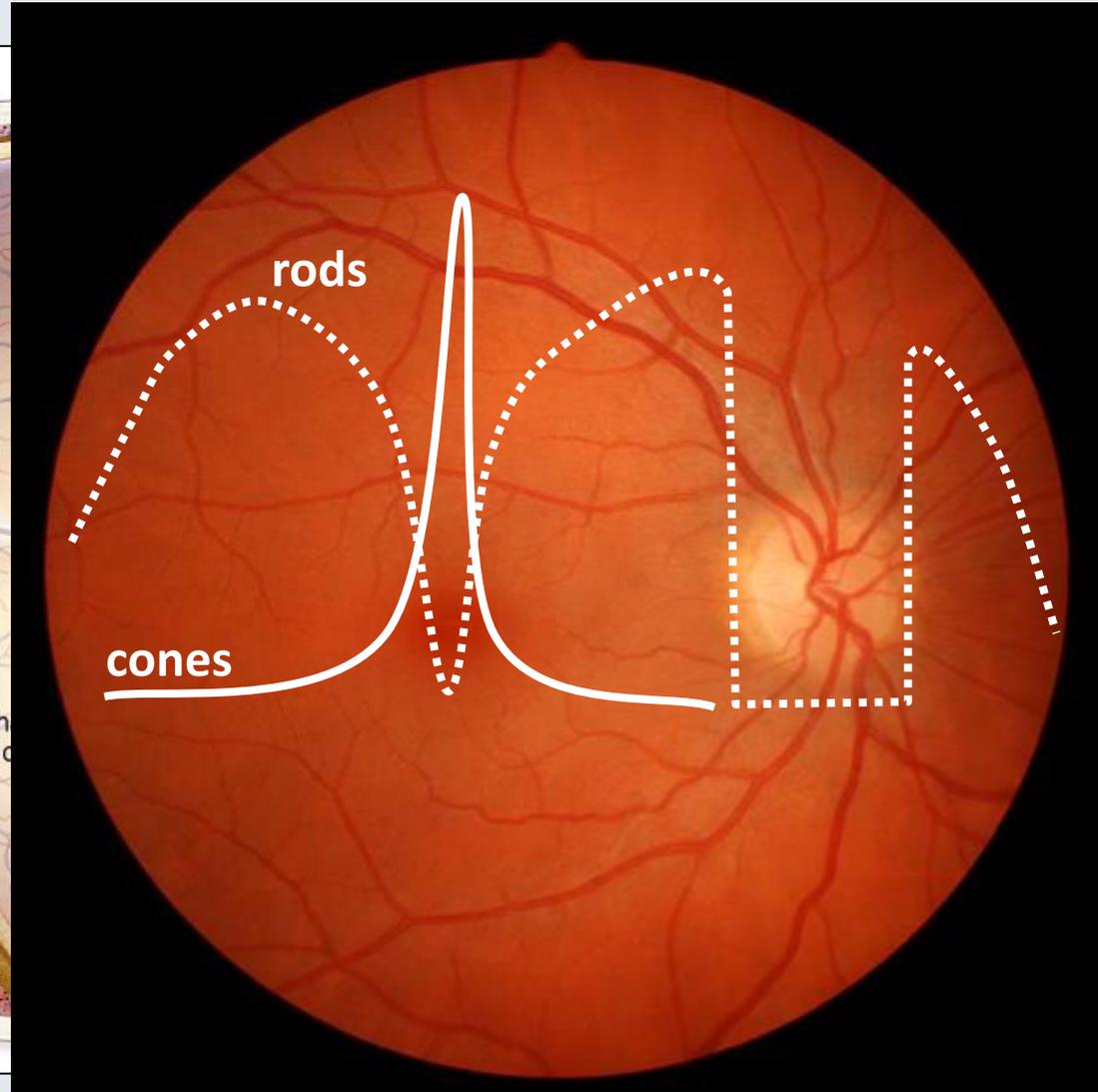
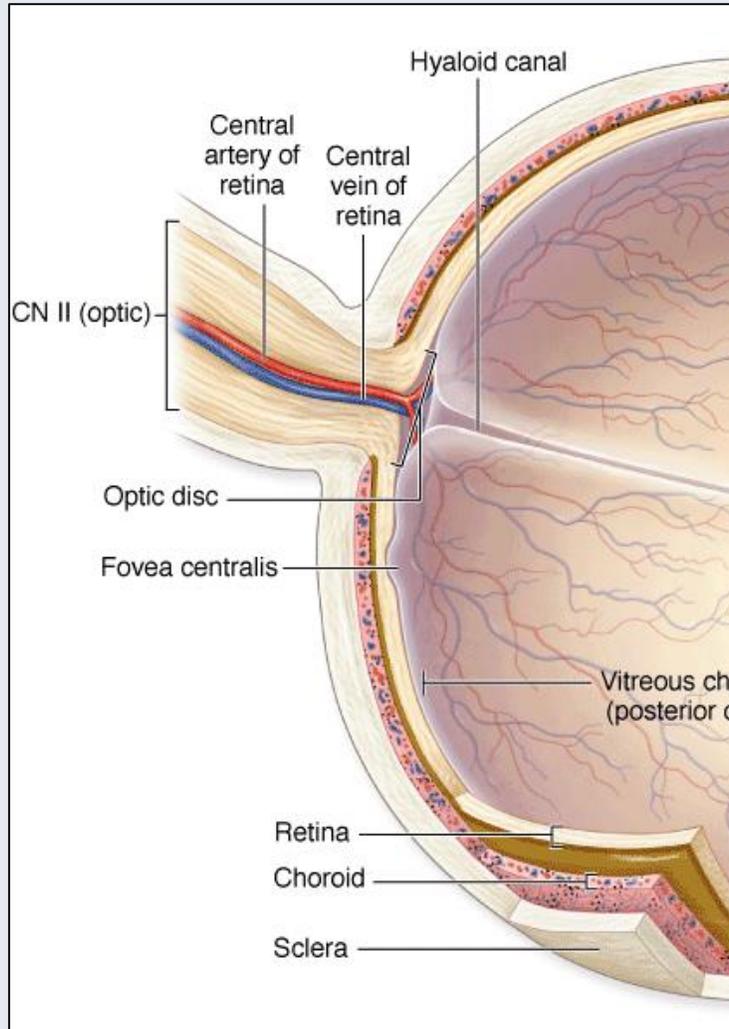
This is why humans become virtually color-blind under low levels of illumination, for instance [moonlight](#).

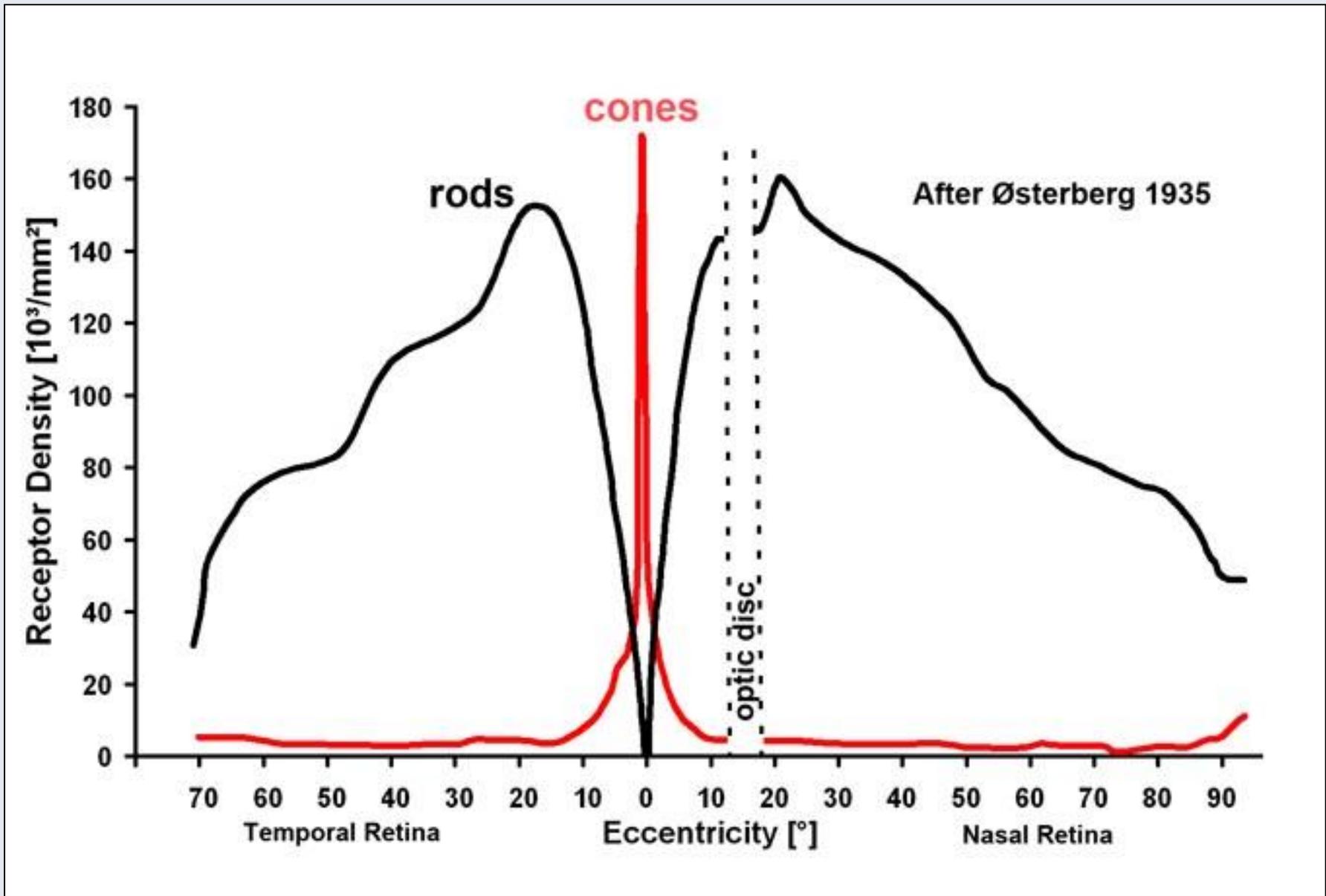


scotopic vision (rods)

# Spatial distribution of rods and cones

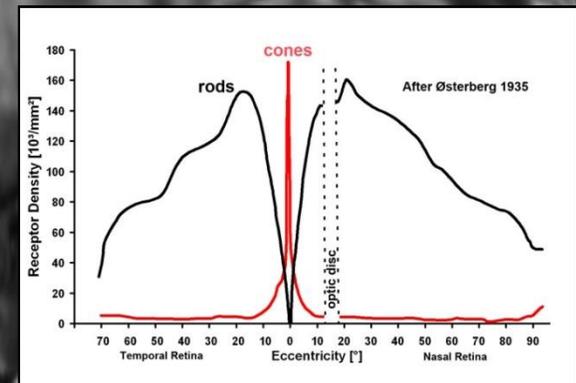
### 3. Spatial distribution of cones and rods





MACULA

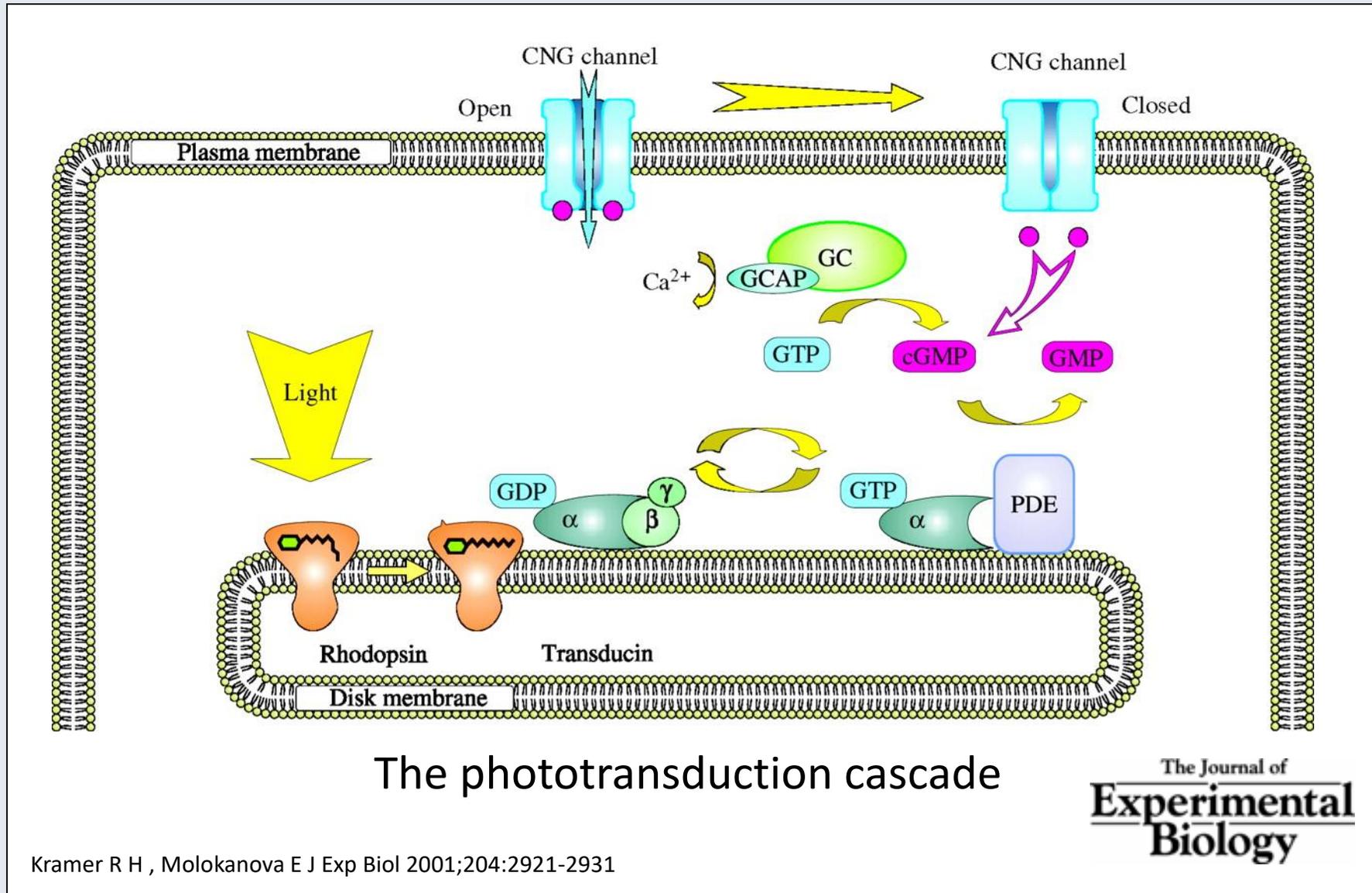
BLIND SPOT





# Physiology of the fotoreceptors

# 4. Physiology of the fotoreceptors



Light causes photoisomerization of rhodopsin, activating the heterotrimeric G-protein transducin. The GTP-bound  $\alpha$ -subunit activates phosphodiesterase (PDE), which degrades cGMP to GMP. The decrease in cGMP concentration leads to closure of cyclic-nucleotide-gated (CNG) channels, resulting in two effects, a decrease in  $\text{Ca}^{2+}$  influx and hyperpolarization of the membrane potential. Lowered intracellular  $\text{Ca}^{2+}$  concentration disinhibits guanylate-cyclase-activating protein (GCAP), leading to activation of guanylate cyclase (GC) and resynthesis of cGMP.



**Photoreceptors are slightly depolarized in dark  
and hyperpolarize when lit! Illumination  
decreases or stops the transmitter release!!!**

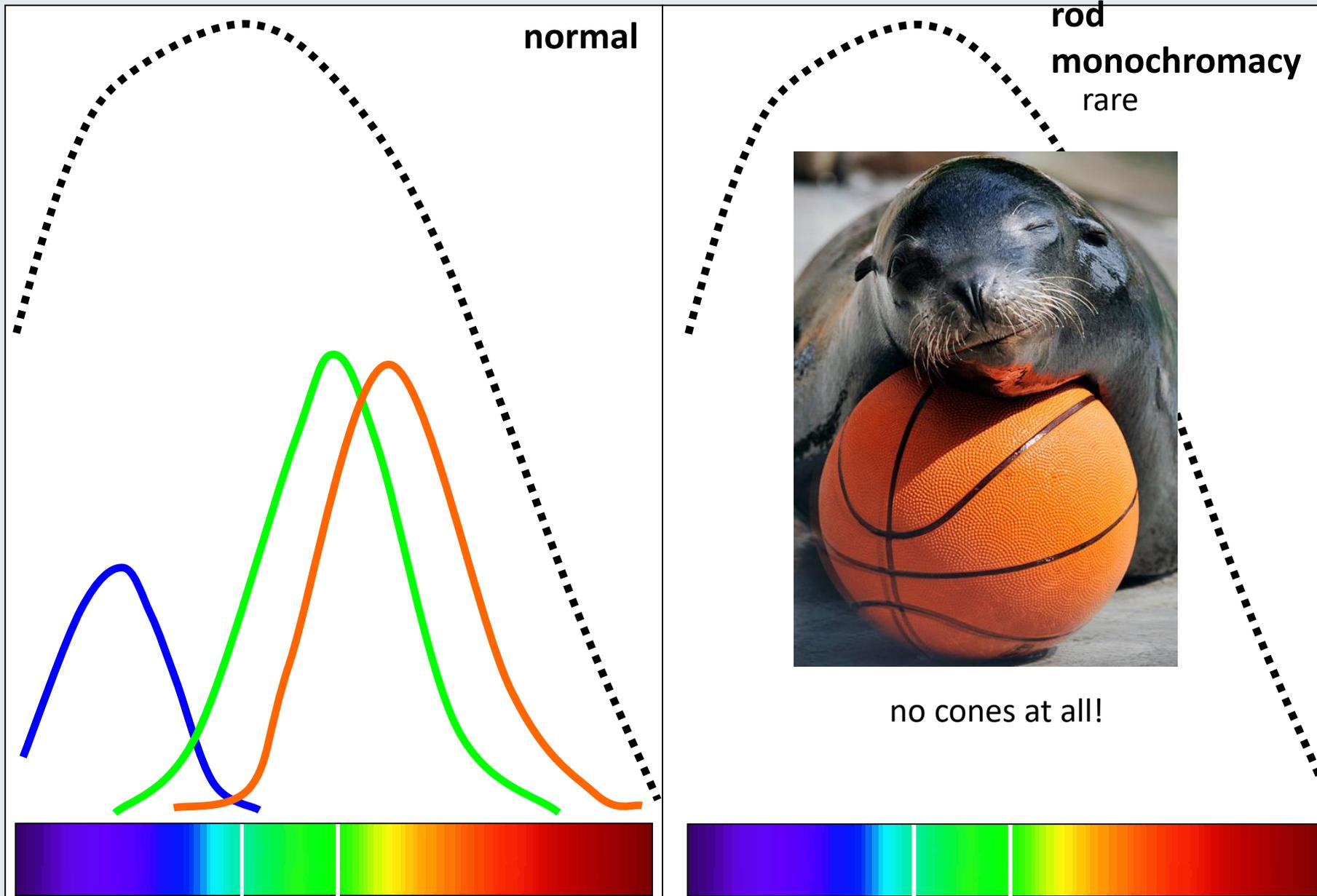
# Colour vision deficiencies



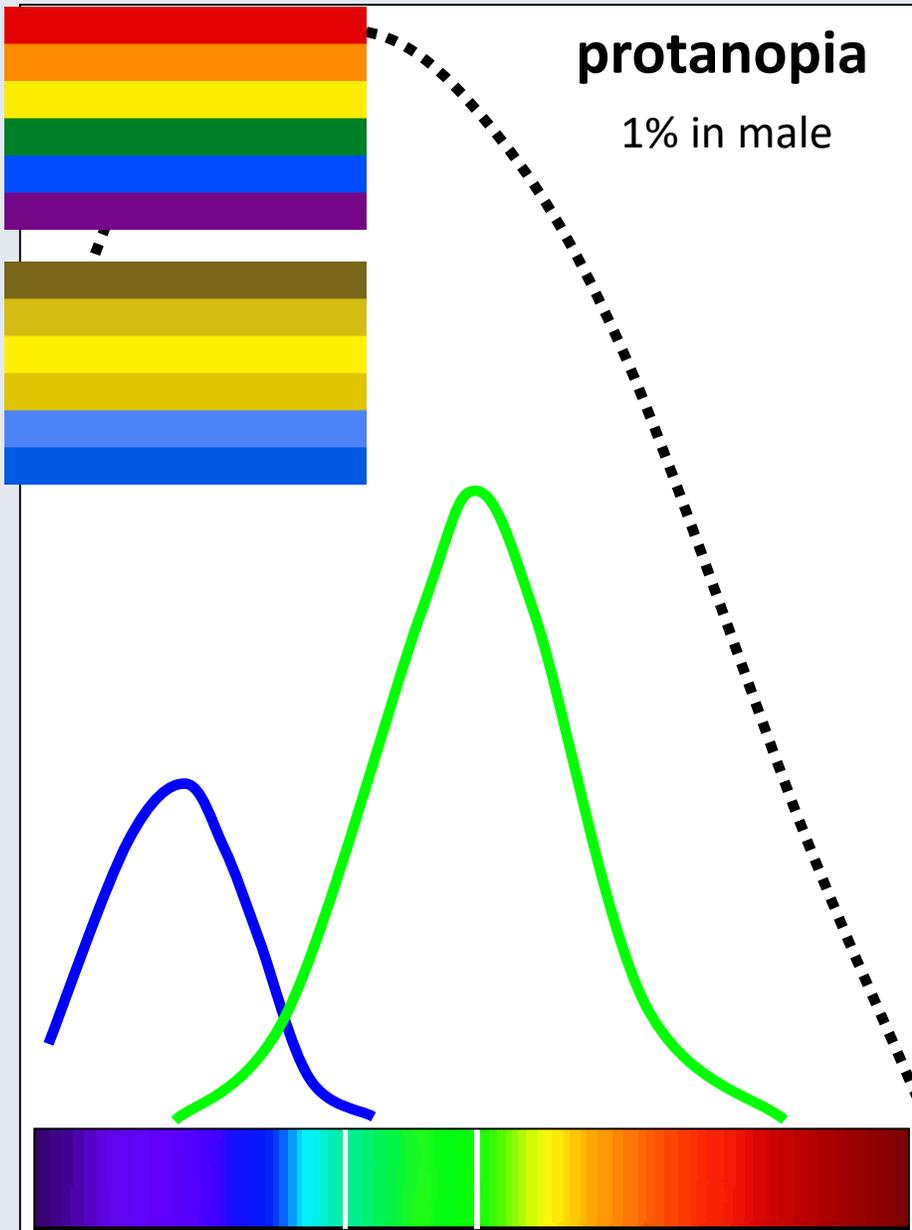
THE AMERICAN FLAG  
AS SEEN

- I.- BY MOST PEOPLE.
- II.- BY RED-BLIND PERSONS.
- III.- BY GREEN-BLIND PERSONS.
- IV.- BY VIOLET-BLIND PERSONS.
- V.- BY TOTALLY COLOR-BLIND PERSONS.

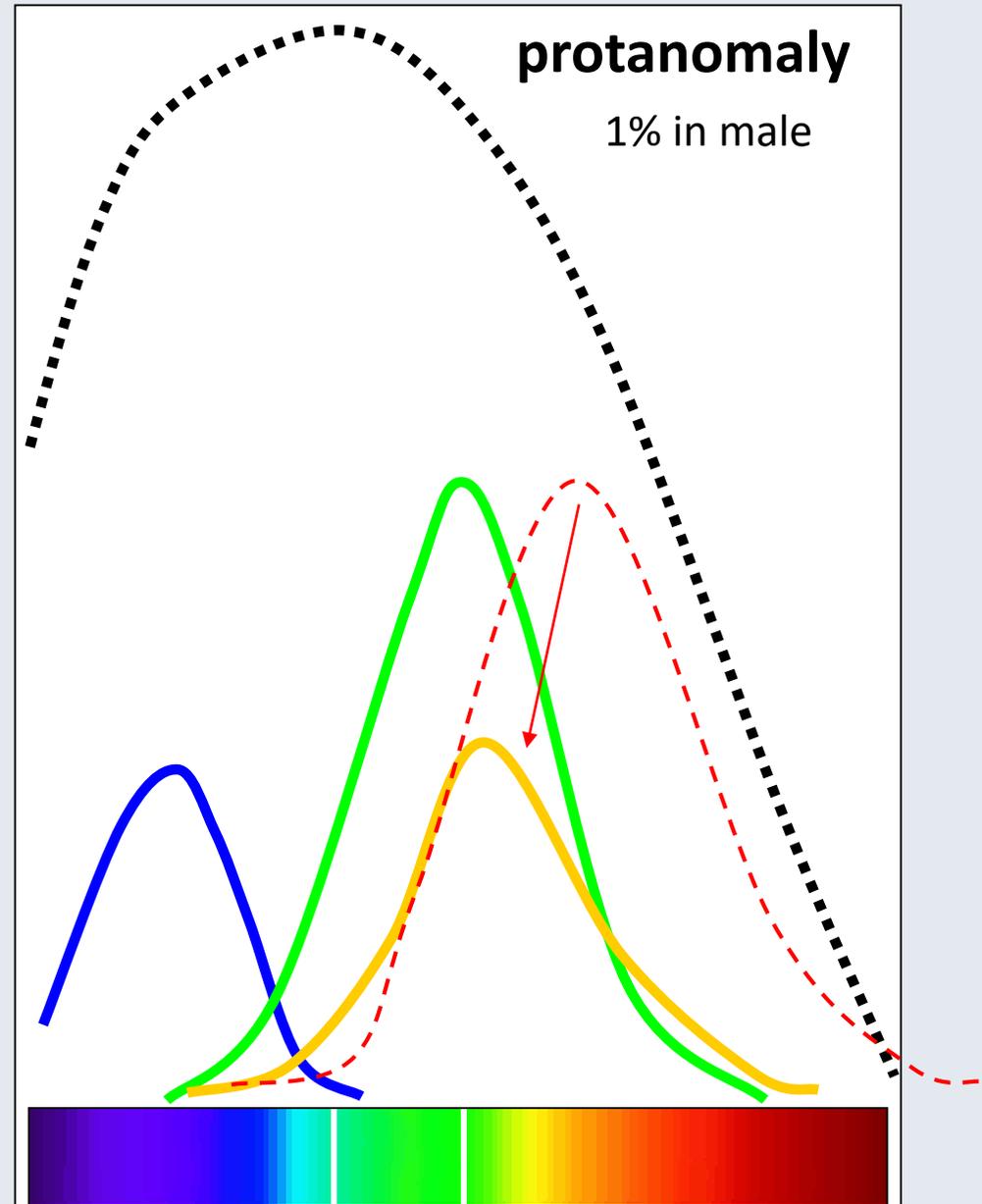
# 5. Colour vision deficiencies

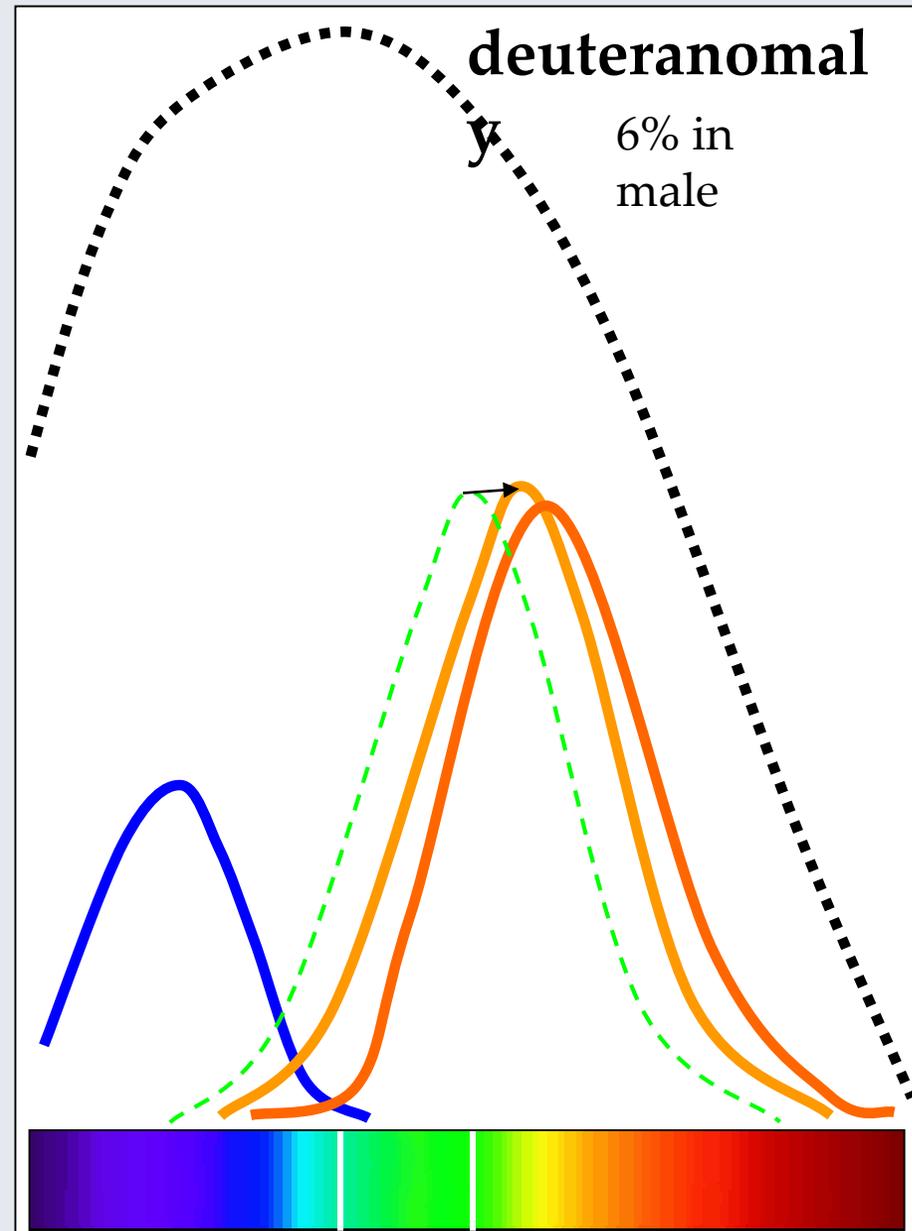
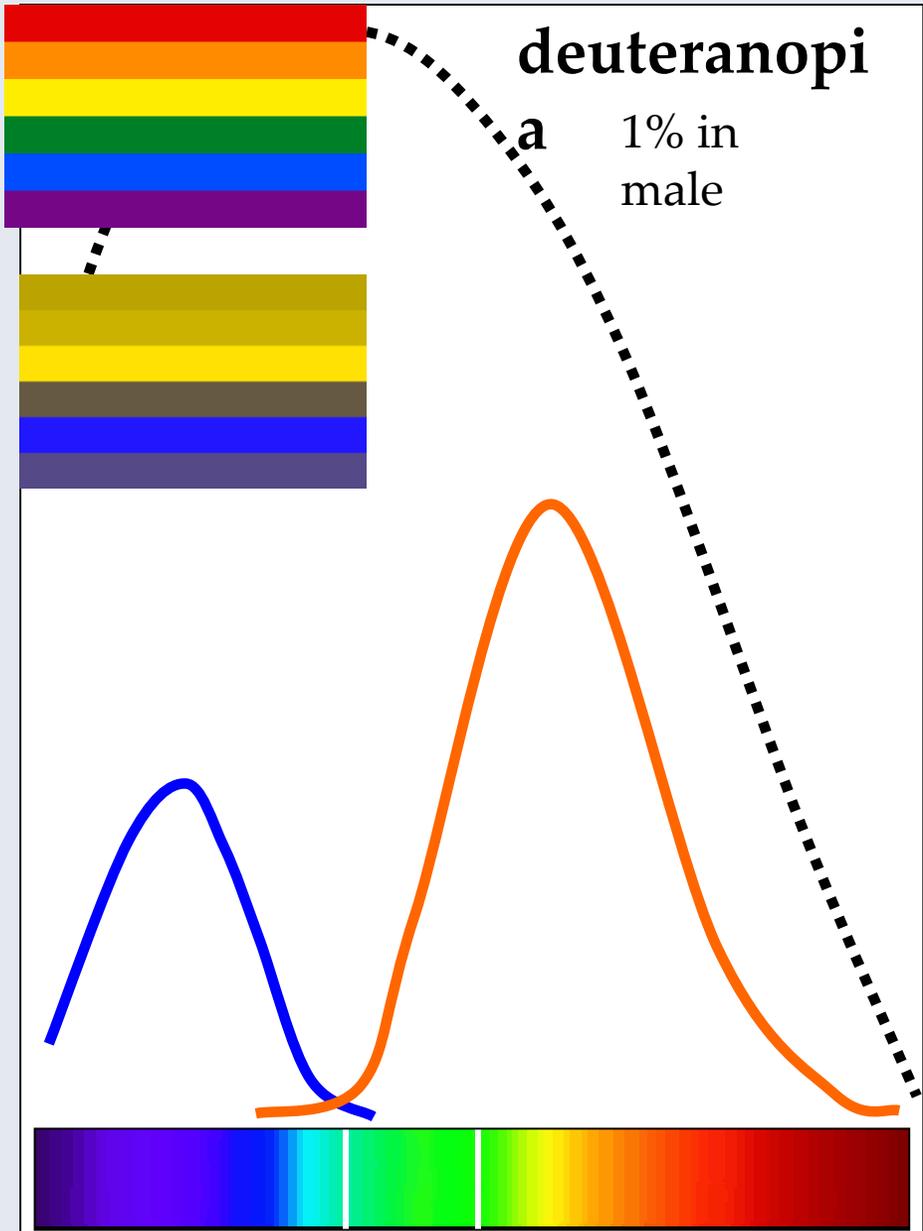


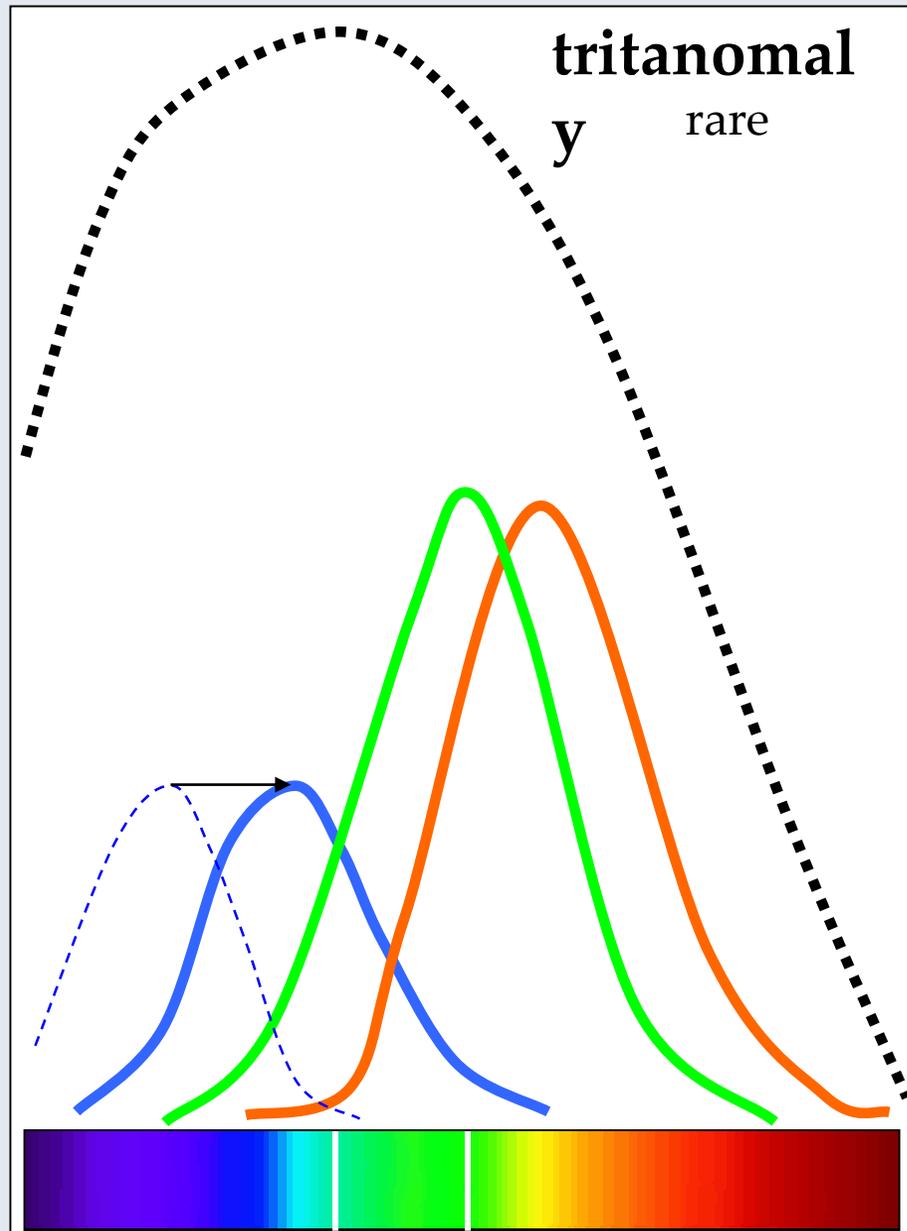
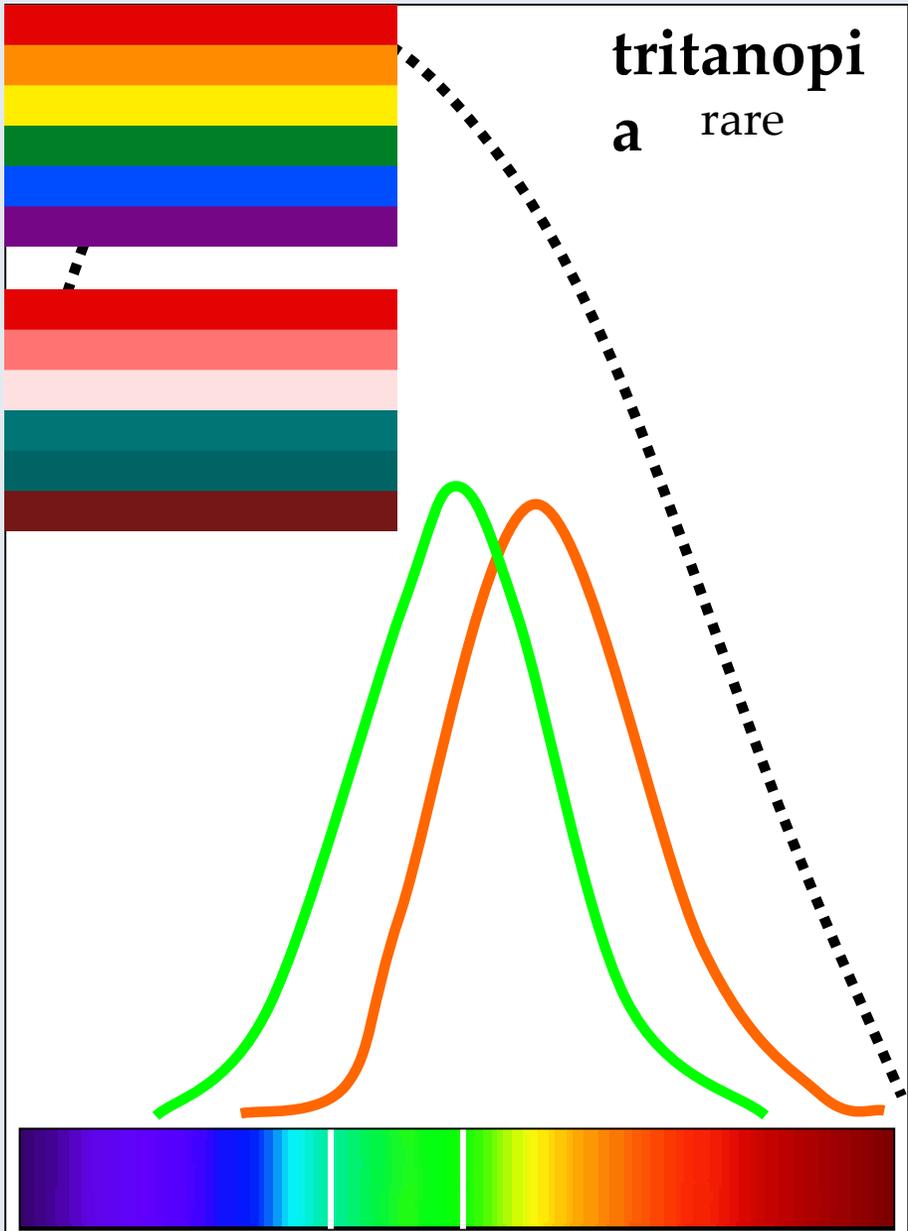
one of the three basic colour mechanisms is absent or not functioning



one of the three cone pigments is altered in its spectral sensitivity









DEUTERANOMALY

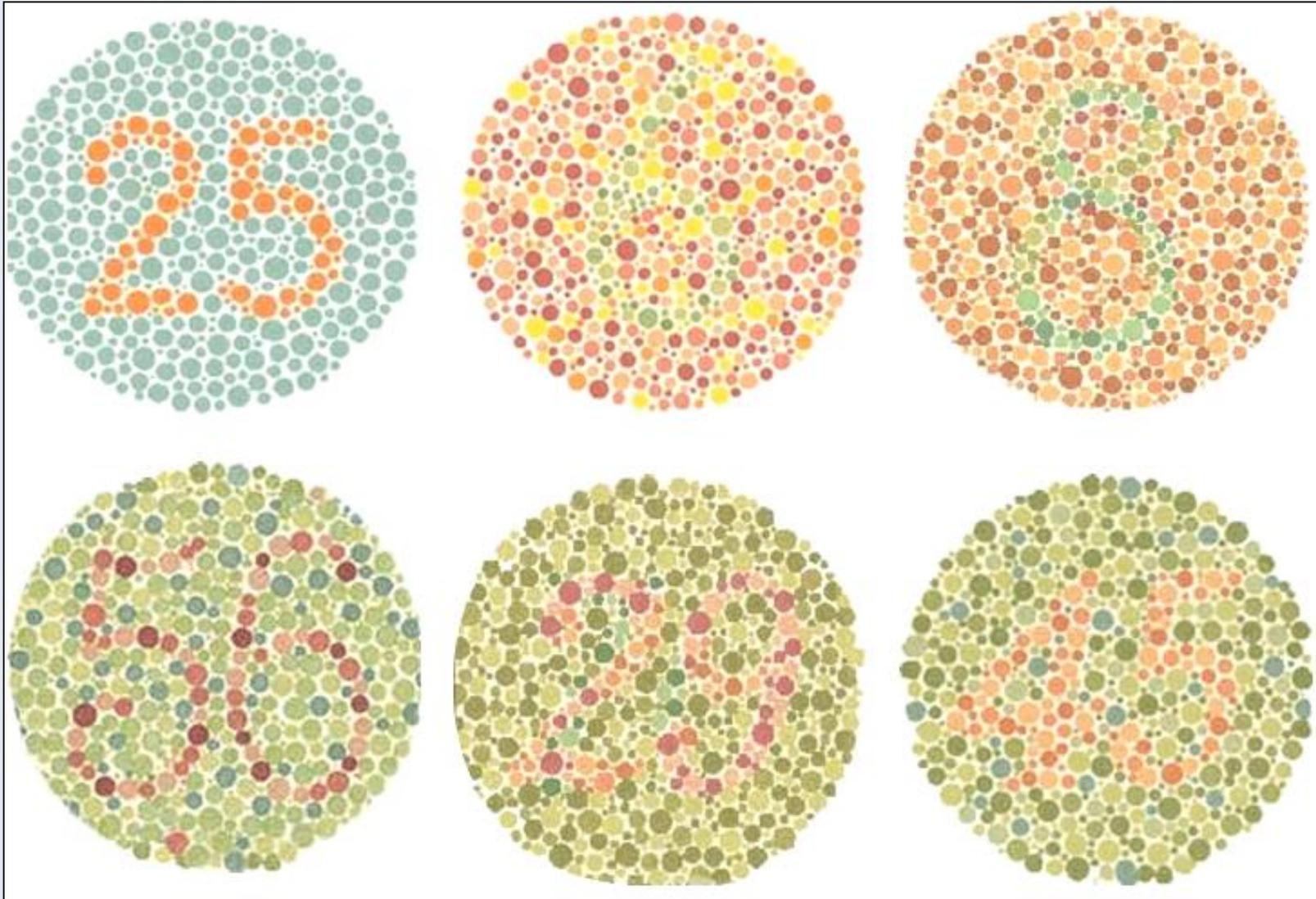
Approximately 10% (!) of male are involved in colour vision deficiencies.

Most frequently the red and green hues are indistinguishable.

Genes encoding the red and green visual pigment proteins are found on the X chromosome, this is why the majority of colour vision deficiencies occur in men.

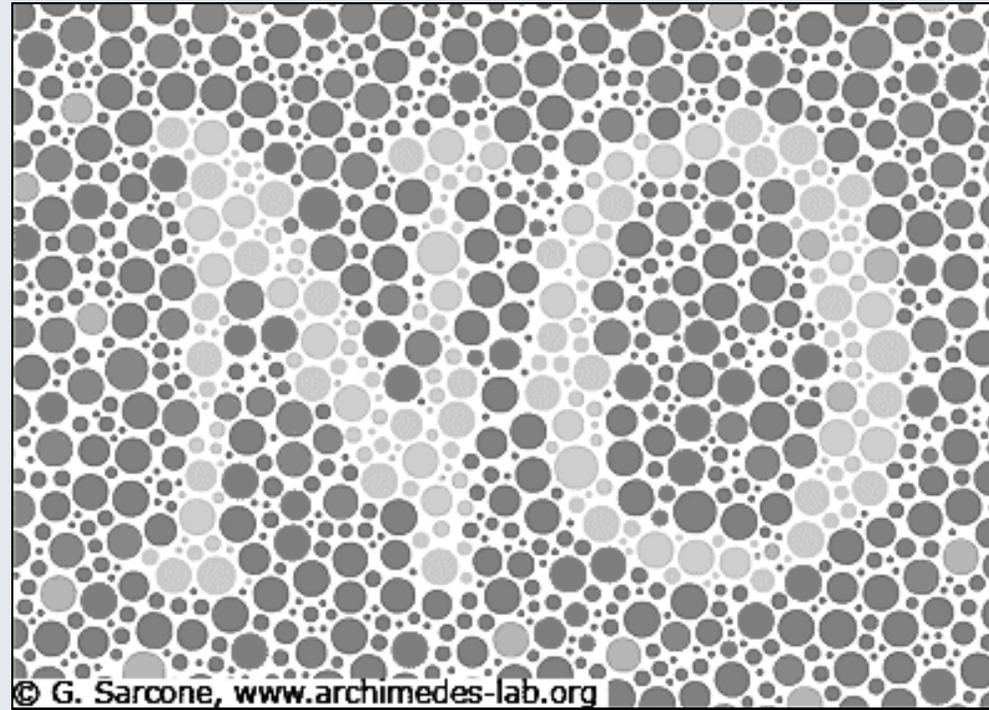


Founder of Facebook, Mark Zuckerberg is green-red colour-blind and as he said, "blue is the richest color for me - I can see all of blue."



## Ishihara Colour Vision Test Plates

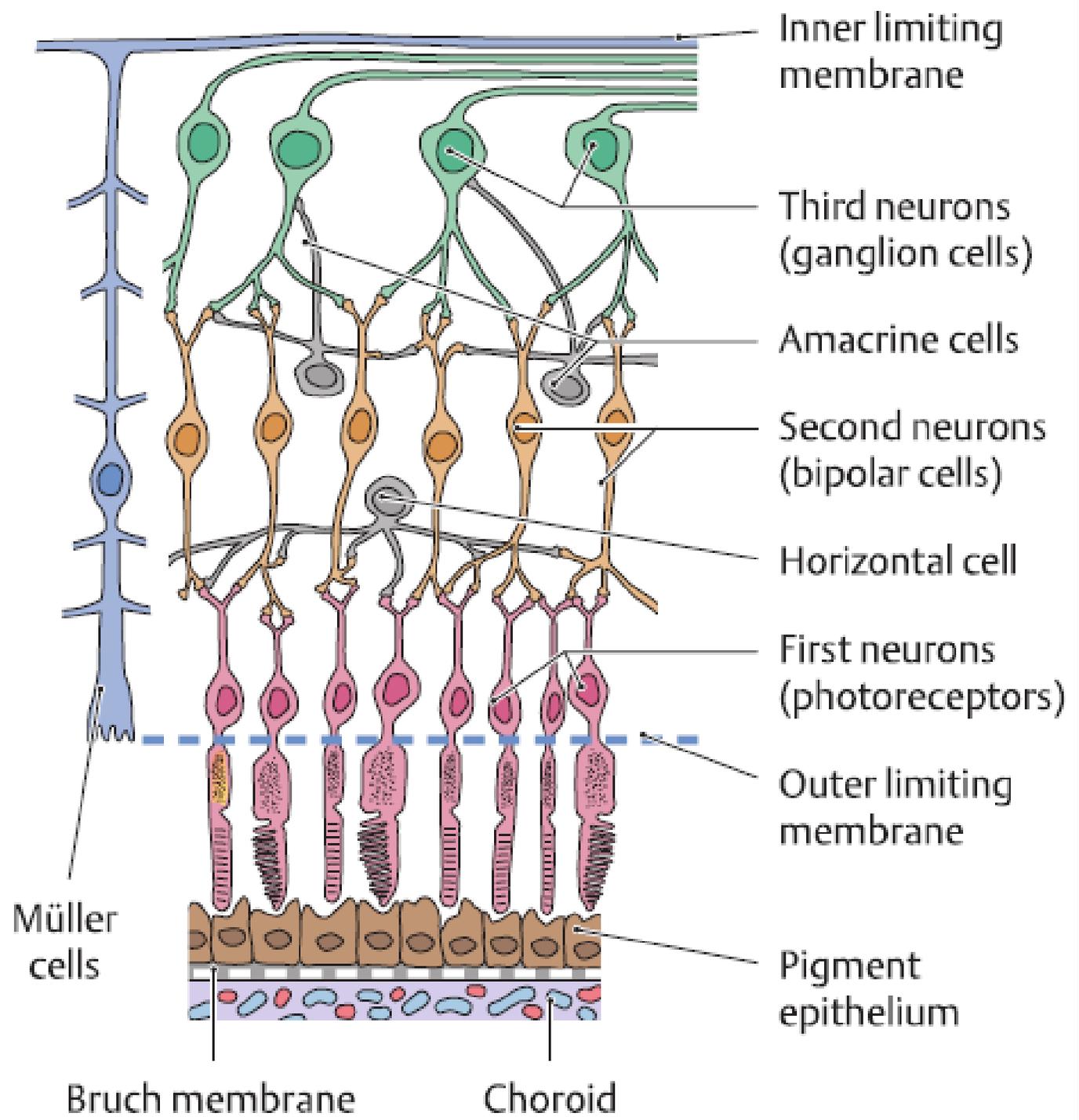
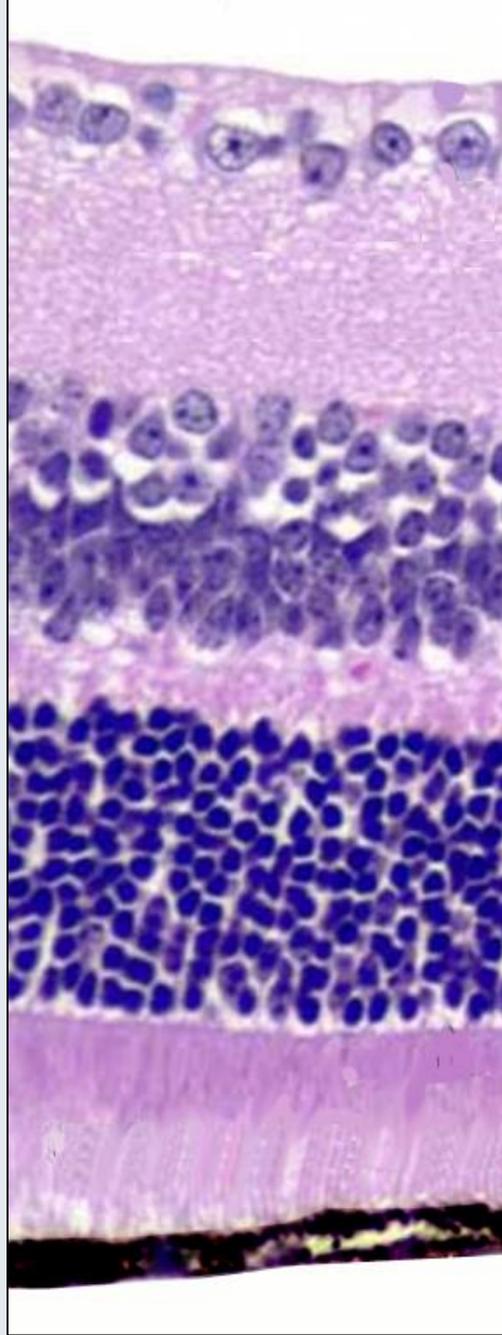
[http://www.youtube.com/watch?feature=player\\_embedded&v=OkRiz--qexY](http://www.youtube.com/watch?feature=player_embedded&v=OkRiz--qexY)

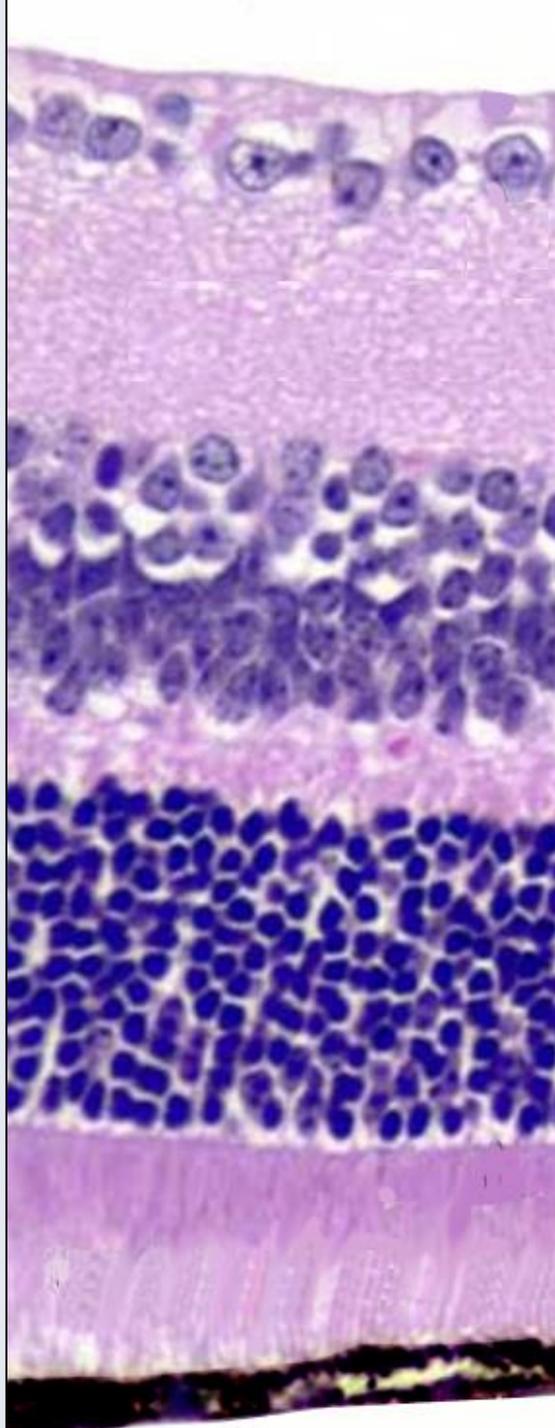


„Inverted” Ishihara plate: colours disturb people with normal vision, so they see nothing, but those suffering from colour-blindness can read the text! If the image is converted to grayscale, thus, the disturbing colours are removed, even healthy people can recognize the message!

# Visual information processing following phototransduction

(phototransduction = conversion of light into neural electric signal)





**10. Internal limiting membrane** (foot processes of Müller cells)

**9. Nerve fibre layer** (axons of ganglion cells)

**8. Ganglion cell layer**

**7. Internal plexiform layer**

**6. Internal nuclear layer**

(cell bodies of bipolar, horizontal, amacrine and Müller cells)

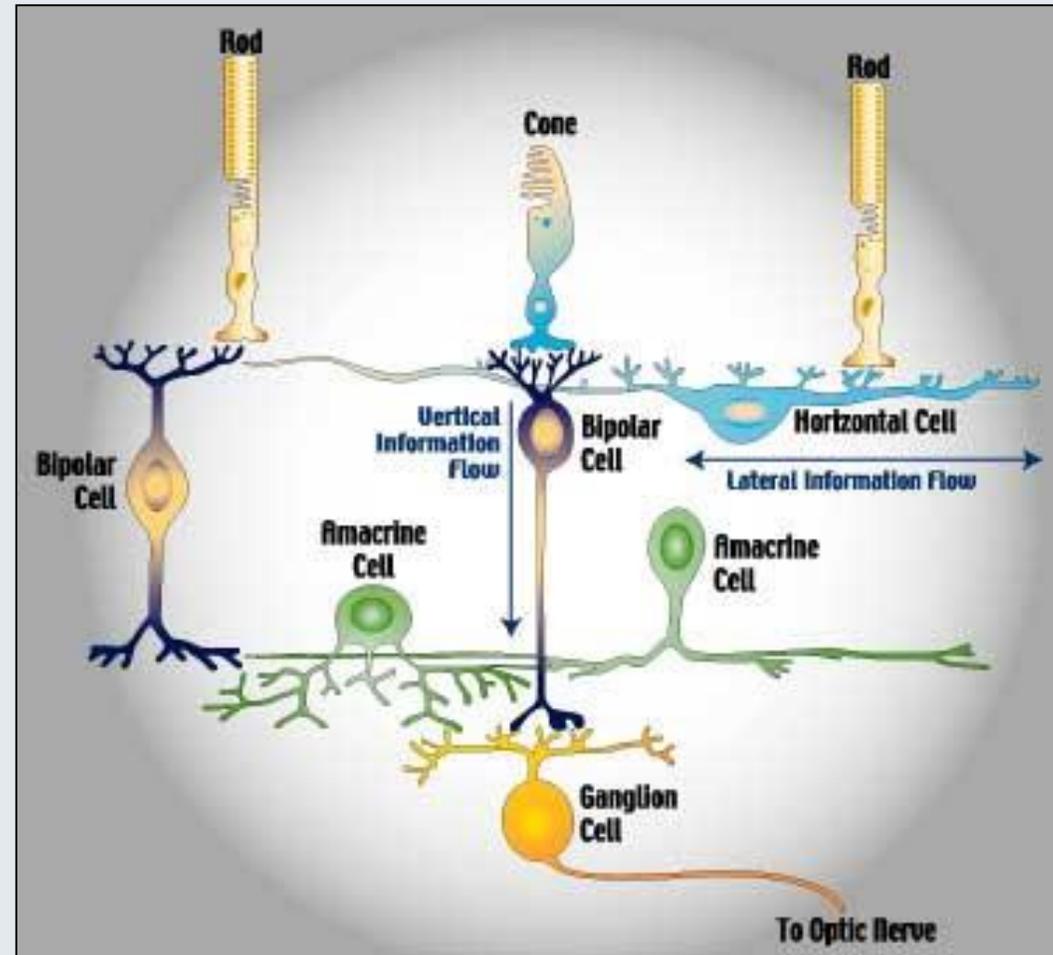
**5. External plexiform layer**

**4. External nuclear layer** (cell bodies of cones and rods)

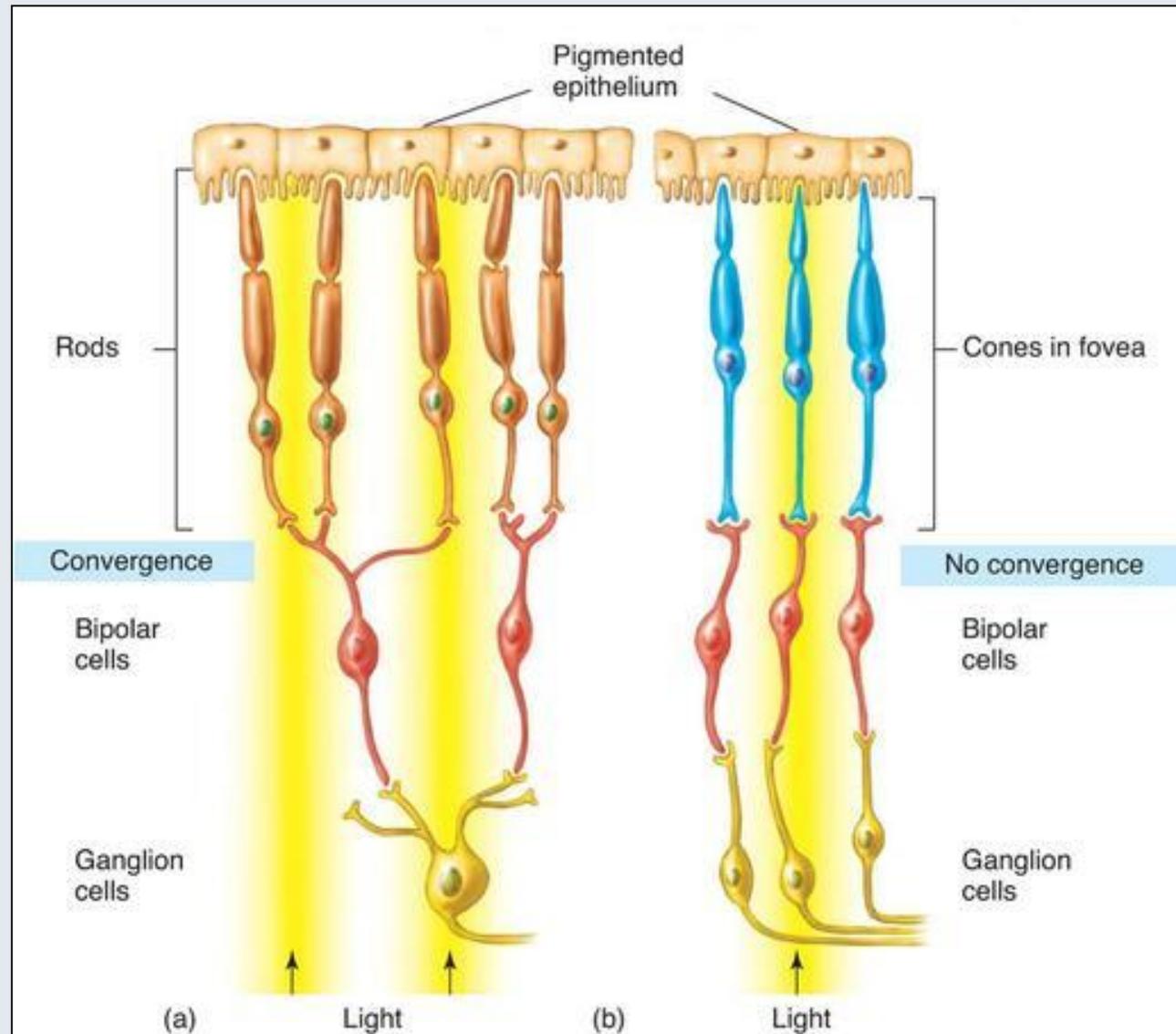
**3. External limiting membrane** (foot processes of Müller cells)

**2. Neuroepithelial layer** (outer parts of rods and cones)

**1. Pigment epithelium**



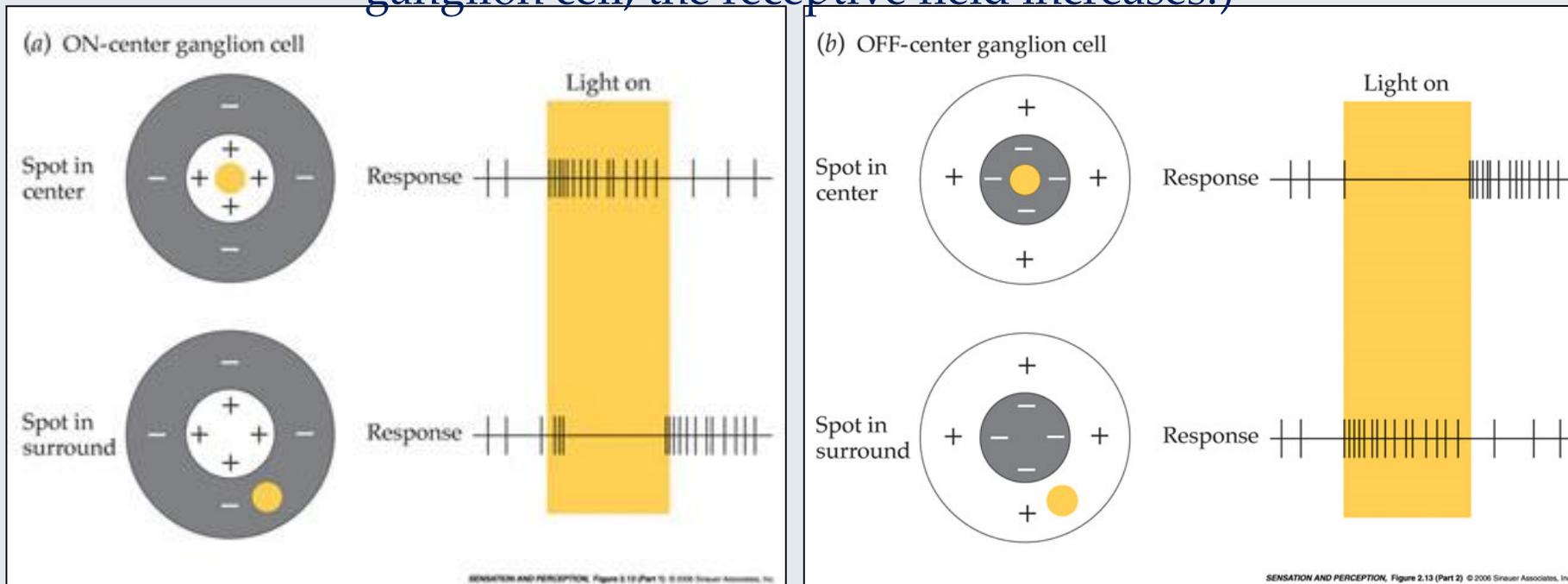
Horizontal and amacrine cells are predominantly inhibitory (GABAergic) and contribute to contrast enhancement.

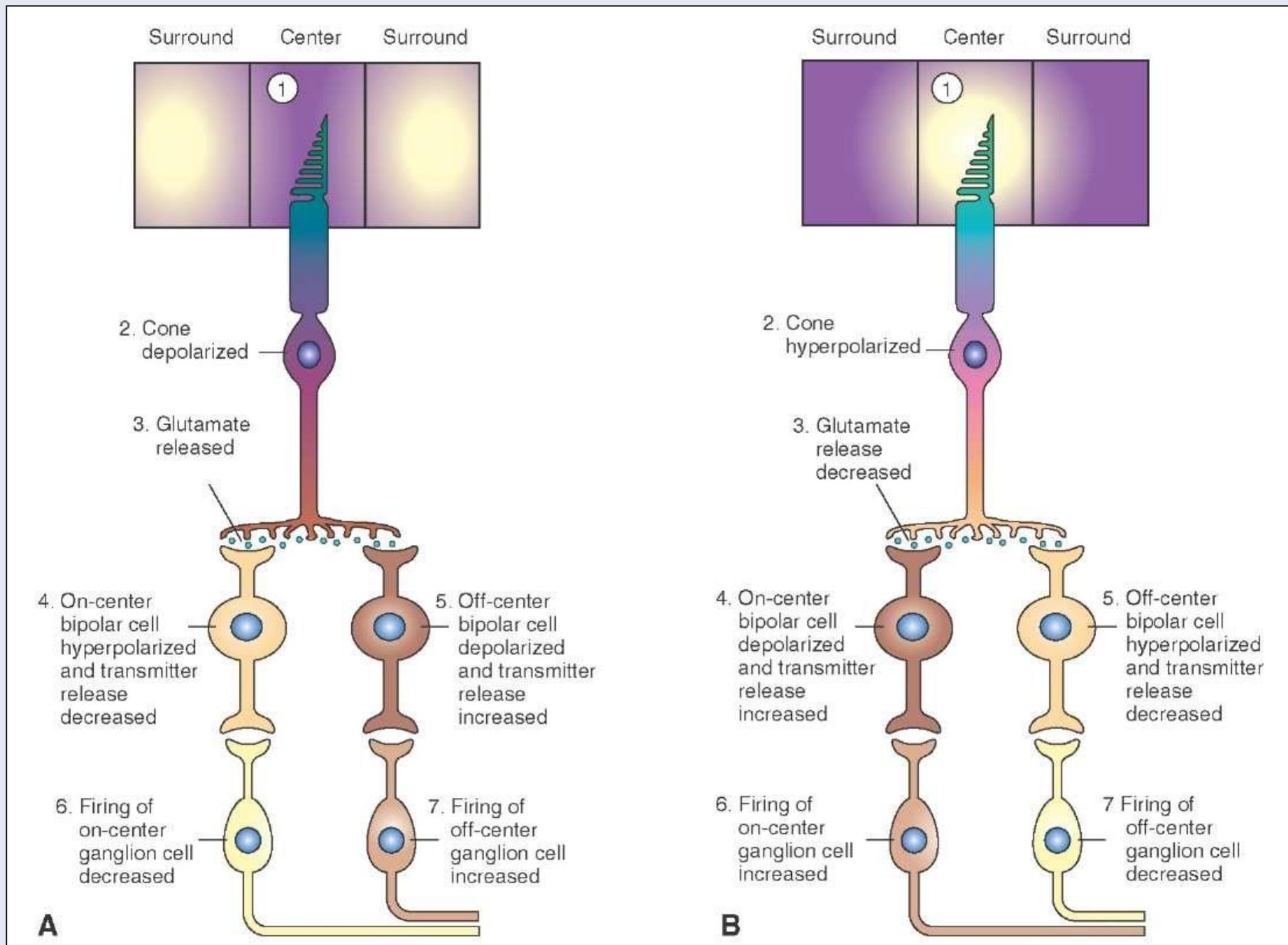


Significant convergence (not including the macula): 5 million cones, 120 million rods, but only 1 million ganglion cells!!!

**Receptive field of ganglion cells:** a spot within the whole visual field perceived by those photoreceptors which converge on the particular ganglion cell.

(Lateral spreading of information and together with this the convergence of the visual signals within the retina is mainly determined by the action of the inhibitory amacrine and horizontal cells, e.g. in the dark more rods converge on one ganglion cell, the receptive field increases!)





# Blood supply of the retina



outer layers:  
**choroid**

inner layers:  
**central retinal artery**

- branch of ophthalmic artery of internal carotid artery
- superior and inferior, nasal and temporal and macular branches

# Must be known for the semifinal:

Parts of the inner coat of the eyeball: optic, ciliary and iridial parts of the retina

Cell types of the retina: cones/rods, bipolar cells, amacrine and horizontal cells, ganglion cells, Müller cells

Layers of the optic retina, regions of interest: the optic disk and the macula/fovea centralis.

Basic physiological differences of cones and rods and their spatial distribution.

**Biochemistry and physiology of vision as well as colour vision deficiencies will not be asked!**

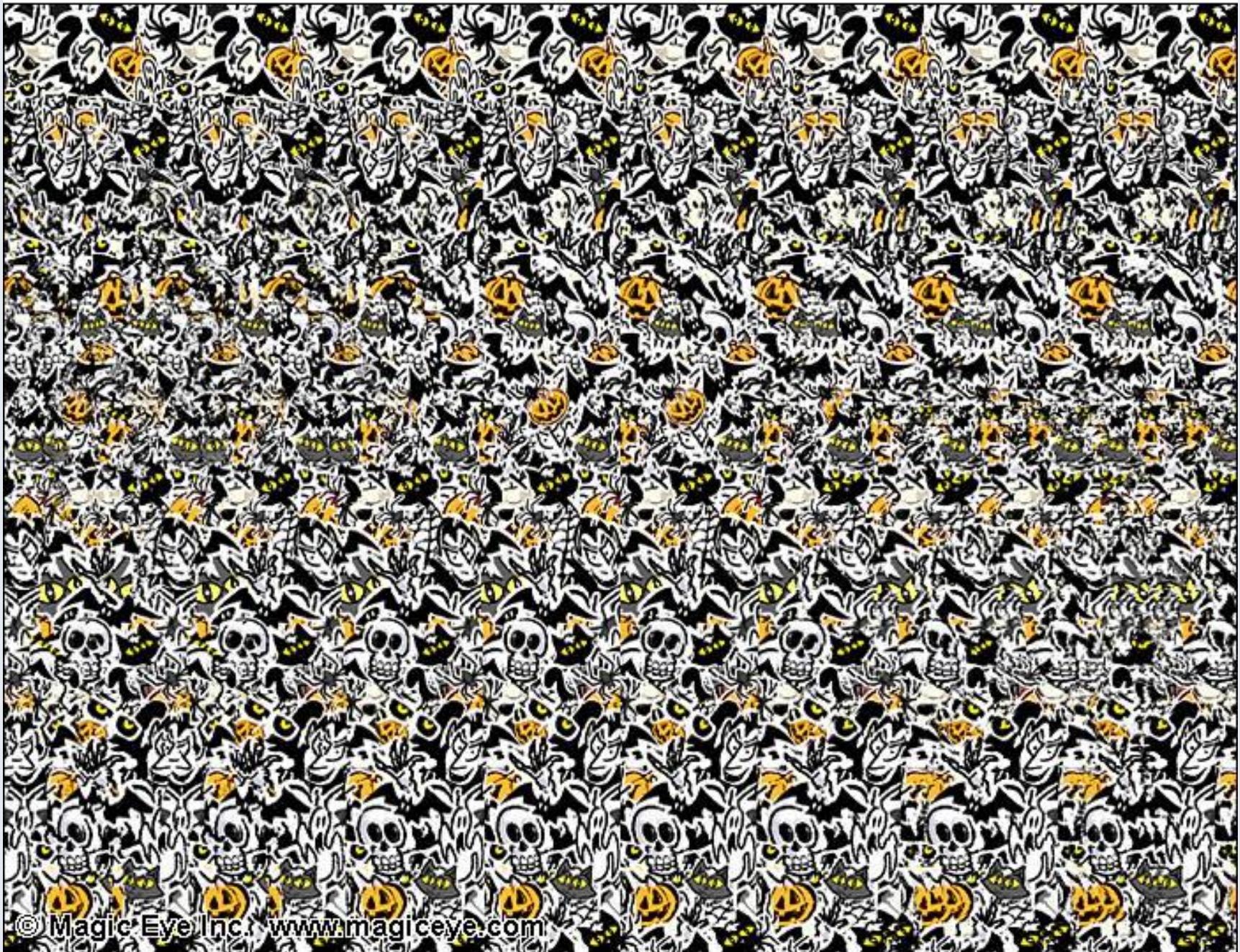
# Magic eyes

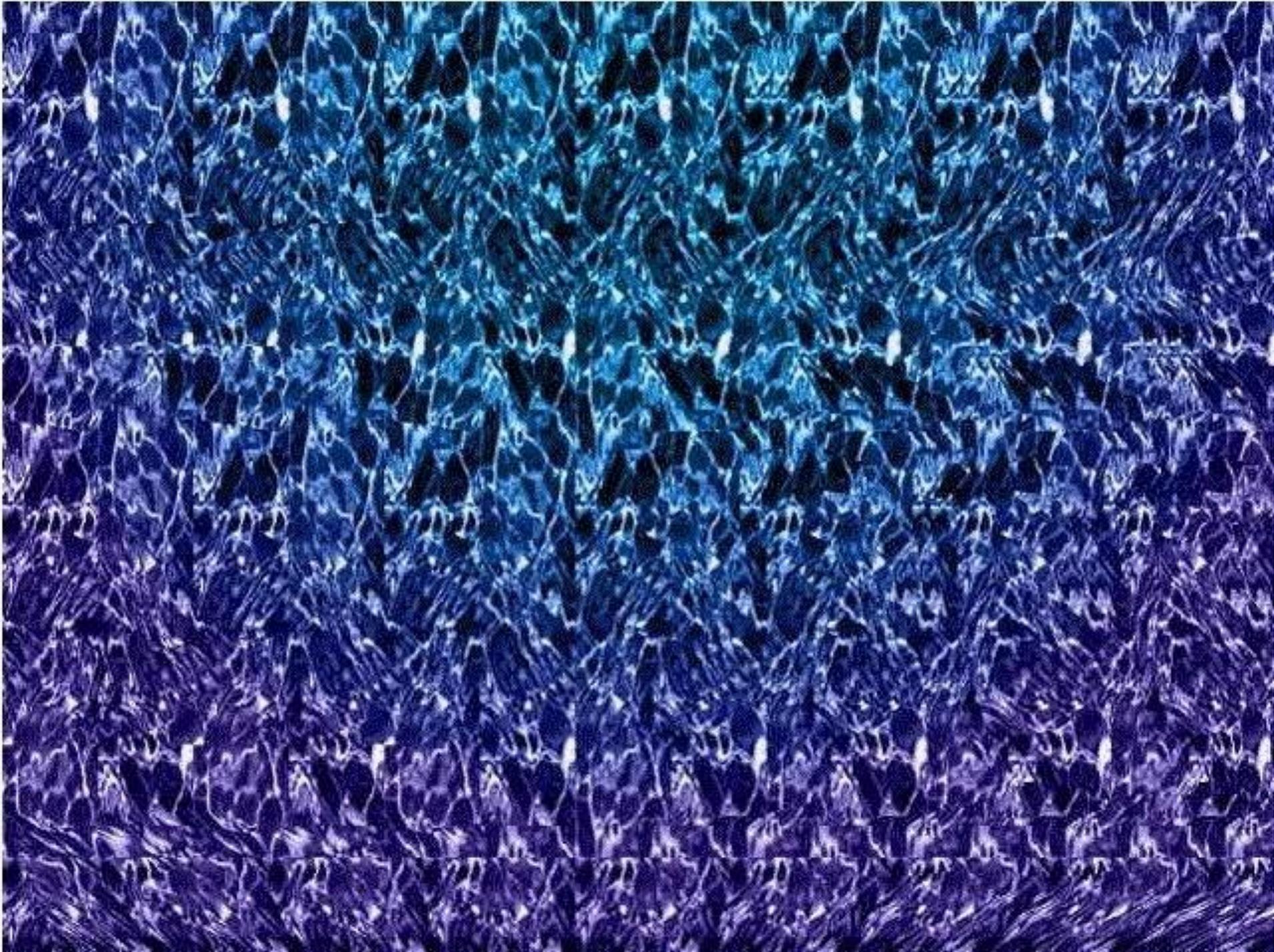
Instructions:

Hold the center of the printed image *right up to your nose*. It should be blurry. Focus as though you are looking *through* the image into the distance. *Very slowly* move the image away from your face until the *two squares* above the image turn into *three squares*. If you see four squares, move the image farther away from your face until you see three squares. If you see one or two squares, start over!

When you clearly see three squares, hold the page still, and the hidden image will magically appear. Once you perceive the hidden image and depth, you can look around the entire 3D image. The longer you look, the clearer the illusion becomes. The farther away you hold the page, the deeper it becomes. Good Luck!







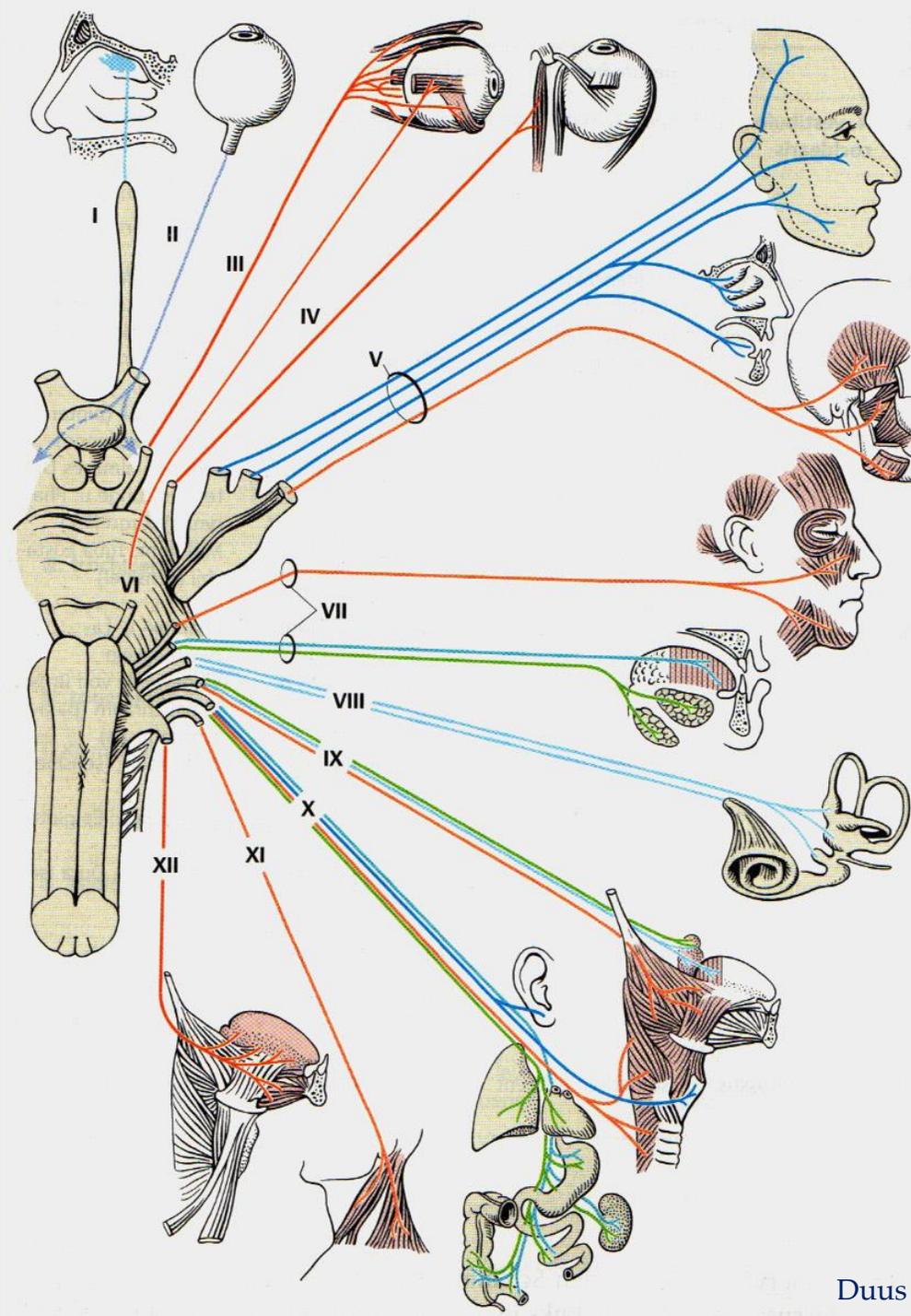




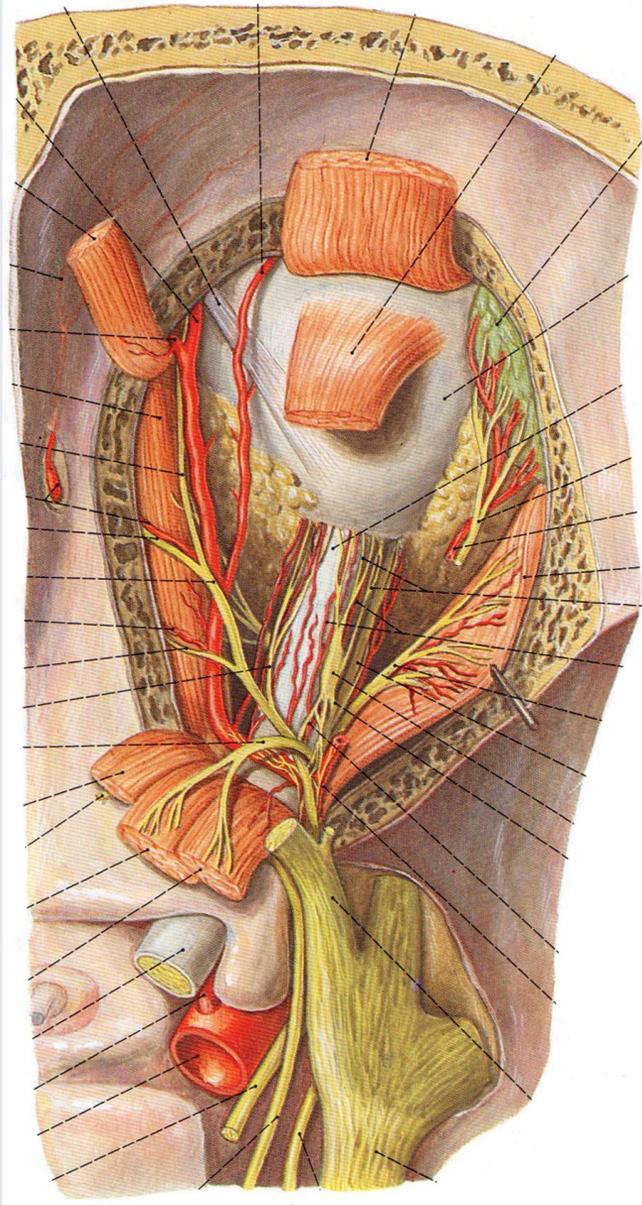


Optic nerve, visual pathway, visual cortical fields. Failure symptoms; Reflexes of the visual system

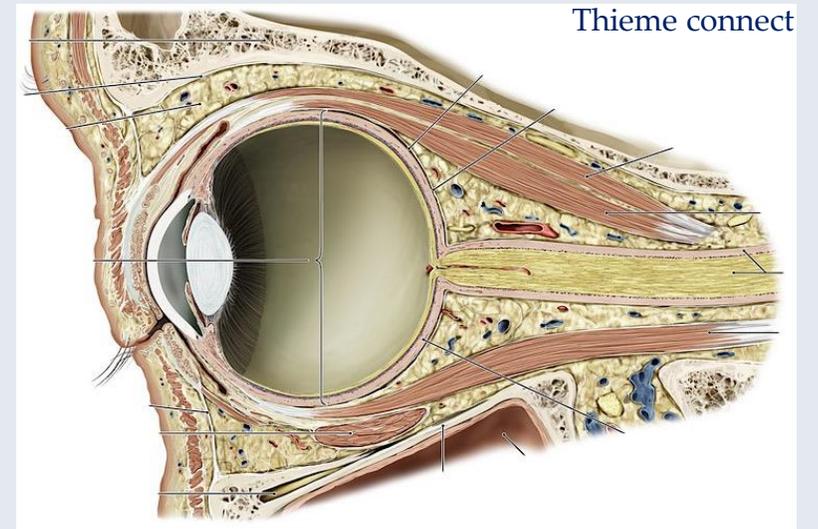




# Optic nerve



Sobotta



## Position and parts:

a) **Pars intraocularis** (2 mm):

to the cribriform plate of the sclera with physiological excavation disci

b) **Pars orbitalis** (25-30 mm):

slightly wavy, rolled before entrance into the bulb 15-20 mm:  
central retinal artery and vein

c) **Pars canalicularis** (5 mm):

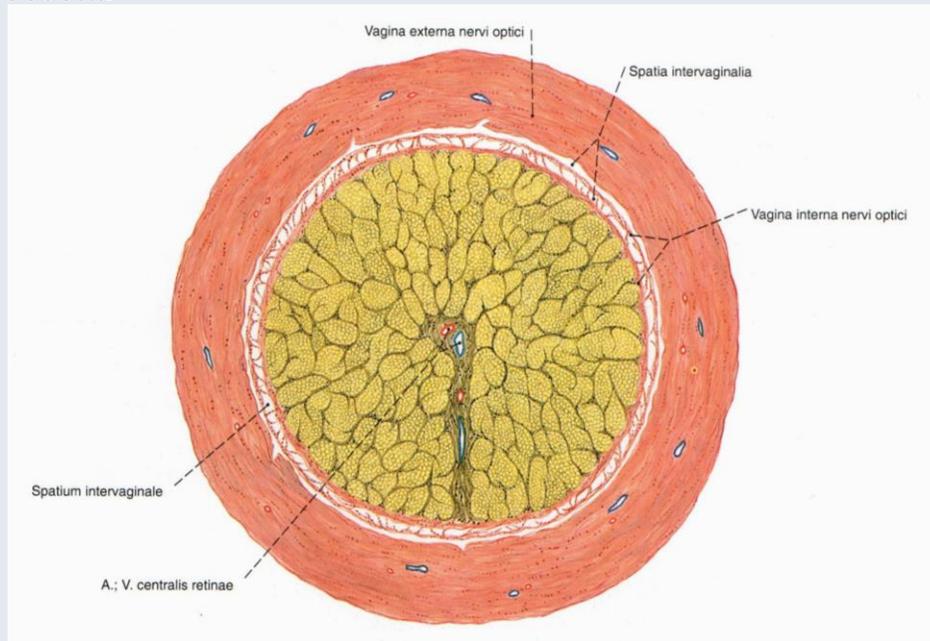
in the optic canal, more attached → increased risk of injury

d) **Pars intracranialis** (13 mm):

to the optic chiasm

# Optic nerve

Sobotta



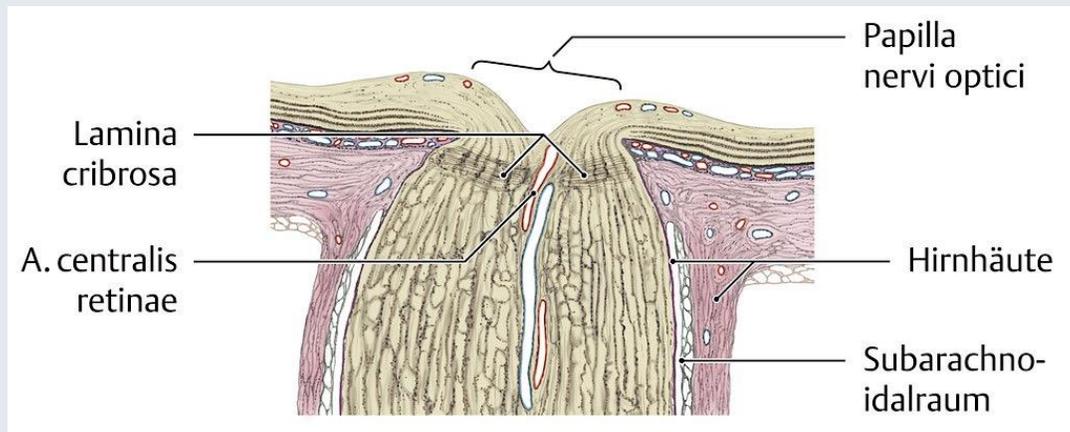
Not a real cranial nerve, it's another nerv:

The optic nerve is a pathway formed about 1,2 million(!) axons,

Myelin sheat by oligodendroglia cells

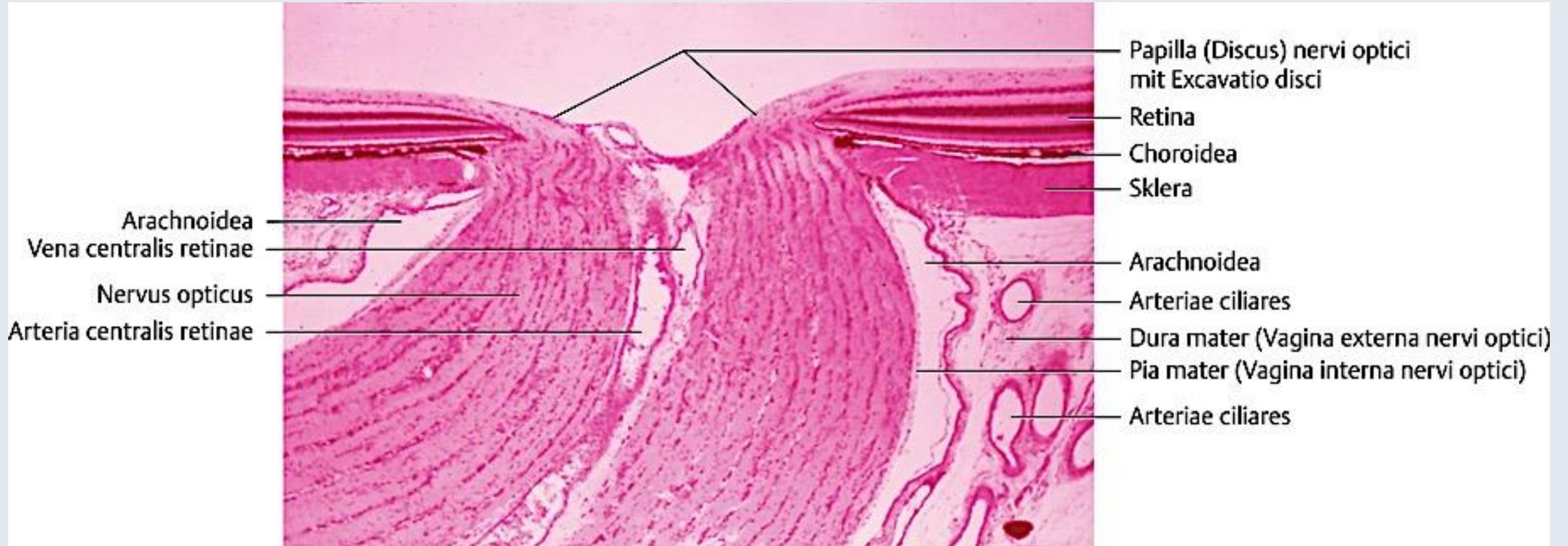
Layers:

1. Ext. vagina (Dura mater), towards the inside
2. Arachnoid; below:  
intervaginale subarachnoideal space, below:
3. Int. vagina (Pia mater) → Septa,  
800-1200 fascicles

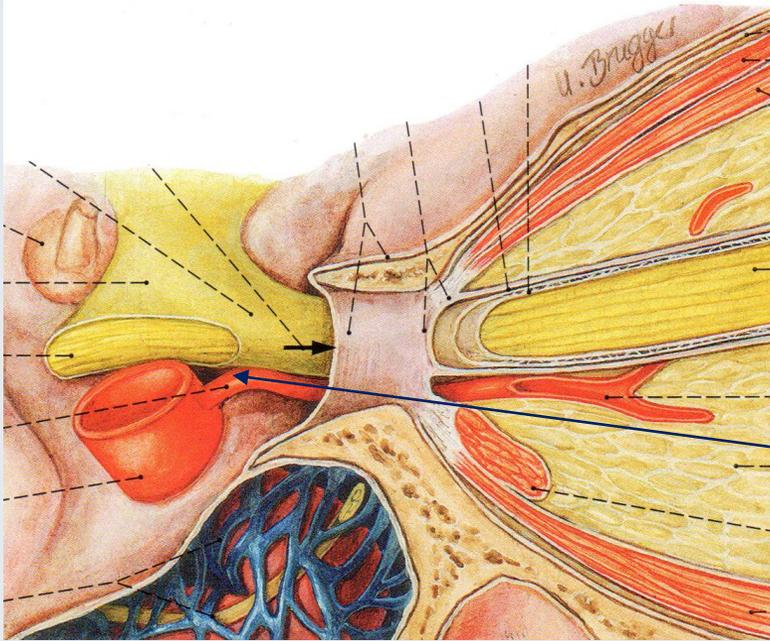


Thieme connect

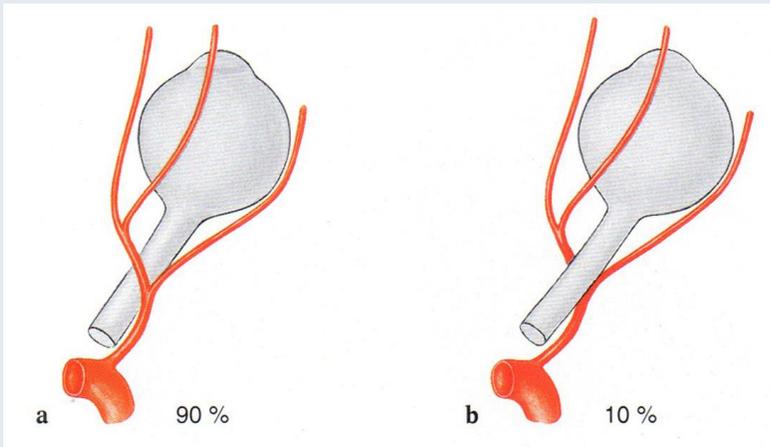
# Optic nerve



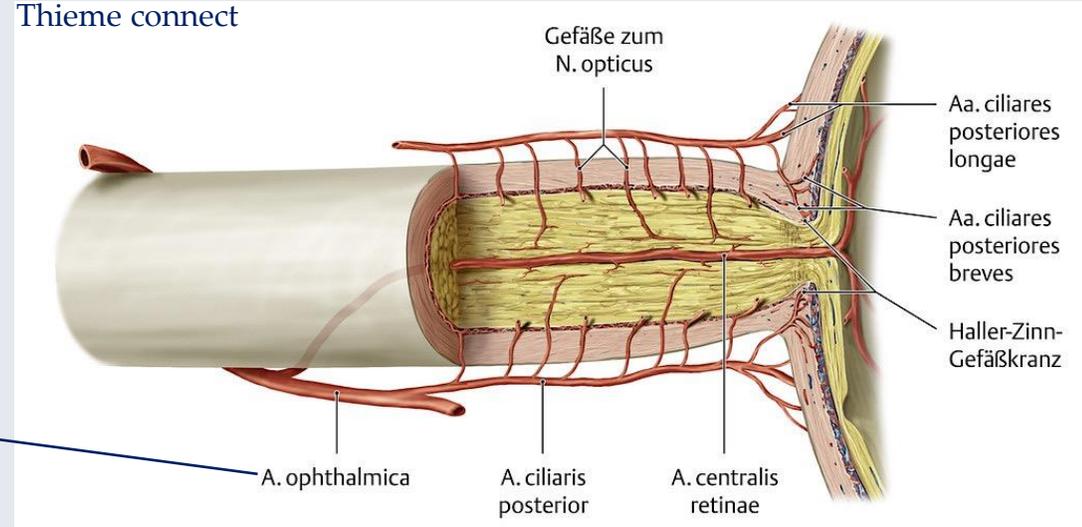
# Optic nerve



Sobotta



Thieme connect



Blood supply from the ophthalmic a. (1st branch of the ICA)

Central retinal A. and V.

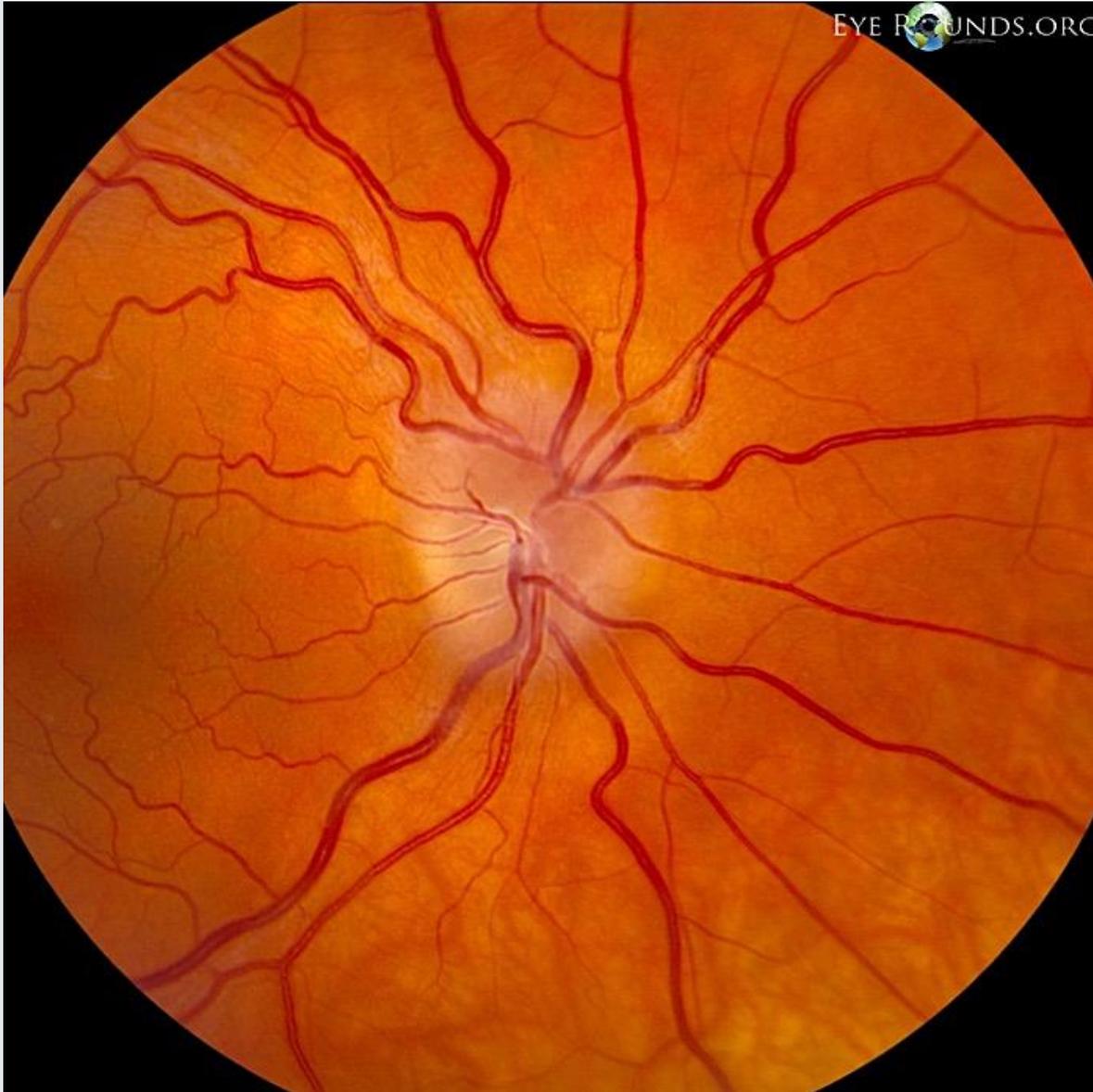
From the posterior ciliar aa.

Damage to the blood supply

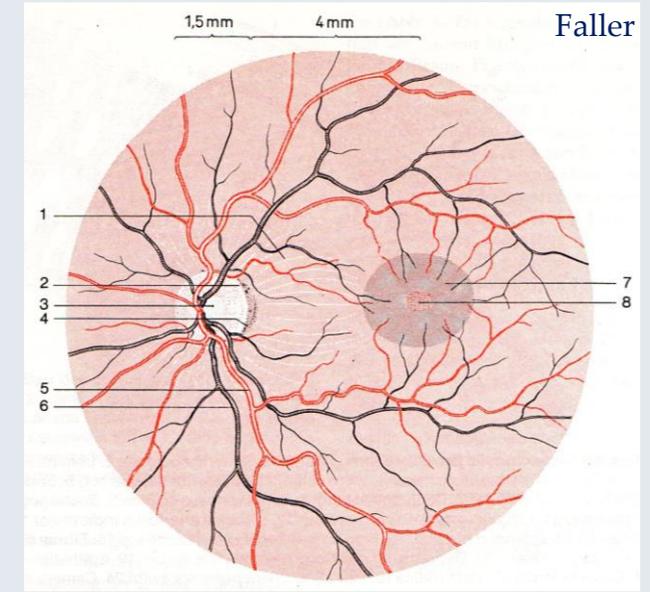
Optic neuropathy



# Optic nerve

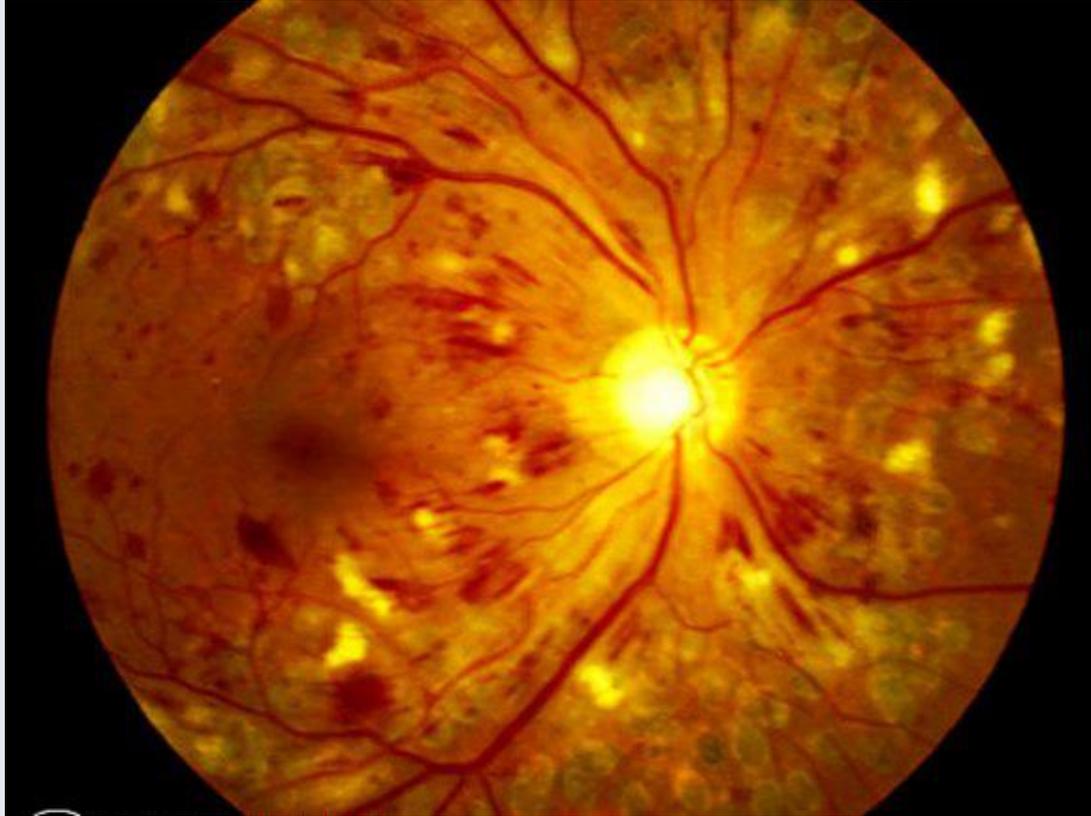


webeye.ophth.uiowa.edu

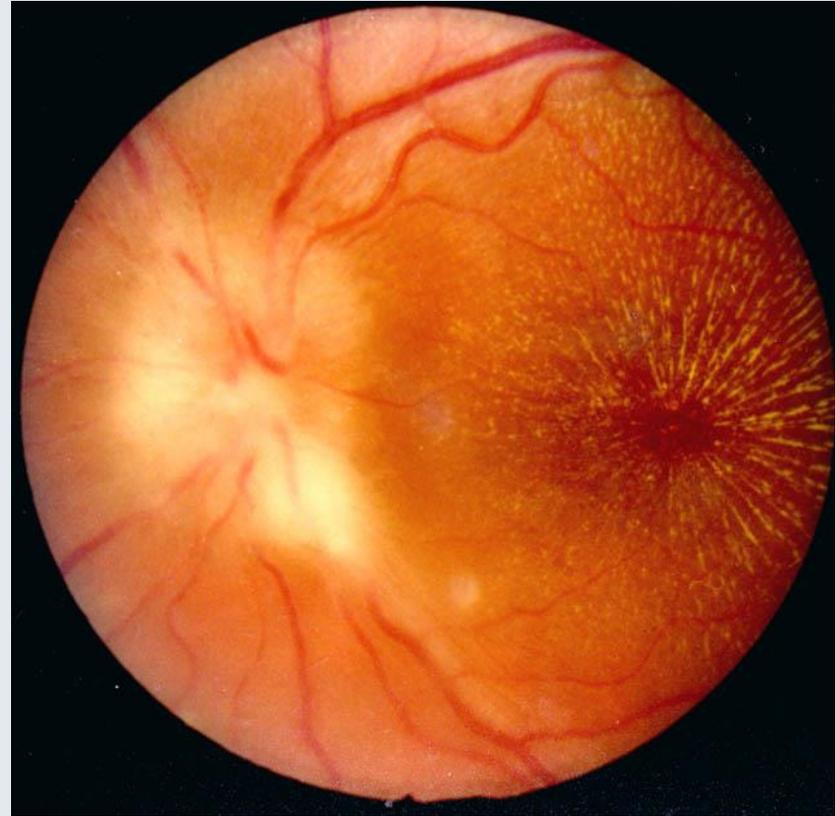


- 2: Sclera ring
  - 3: Excavation
  - 4: Pigmental ring
- } optic nerve papilla
- 
- 7: Macula lutea
  - 8: central Fovea

**Arterioles immediately accessible to medical Examination!!**



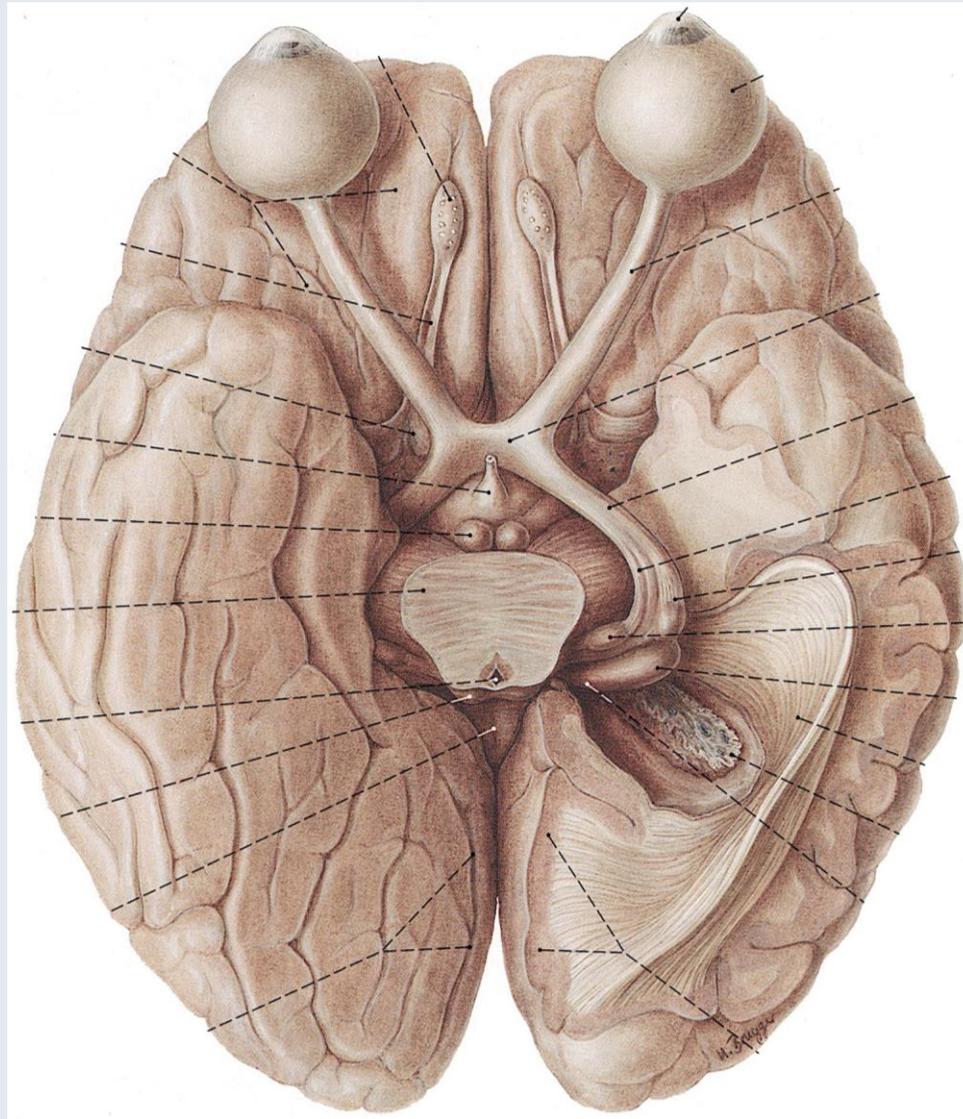
Retinopathia diabetica



Fundus hypertonicus

# Visual pathway

From the retina...



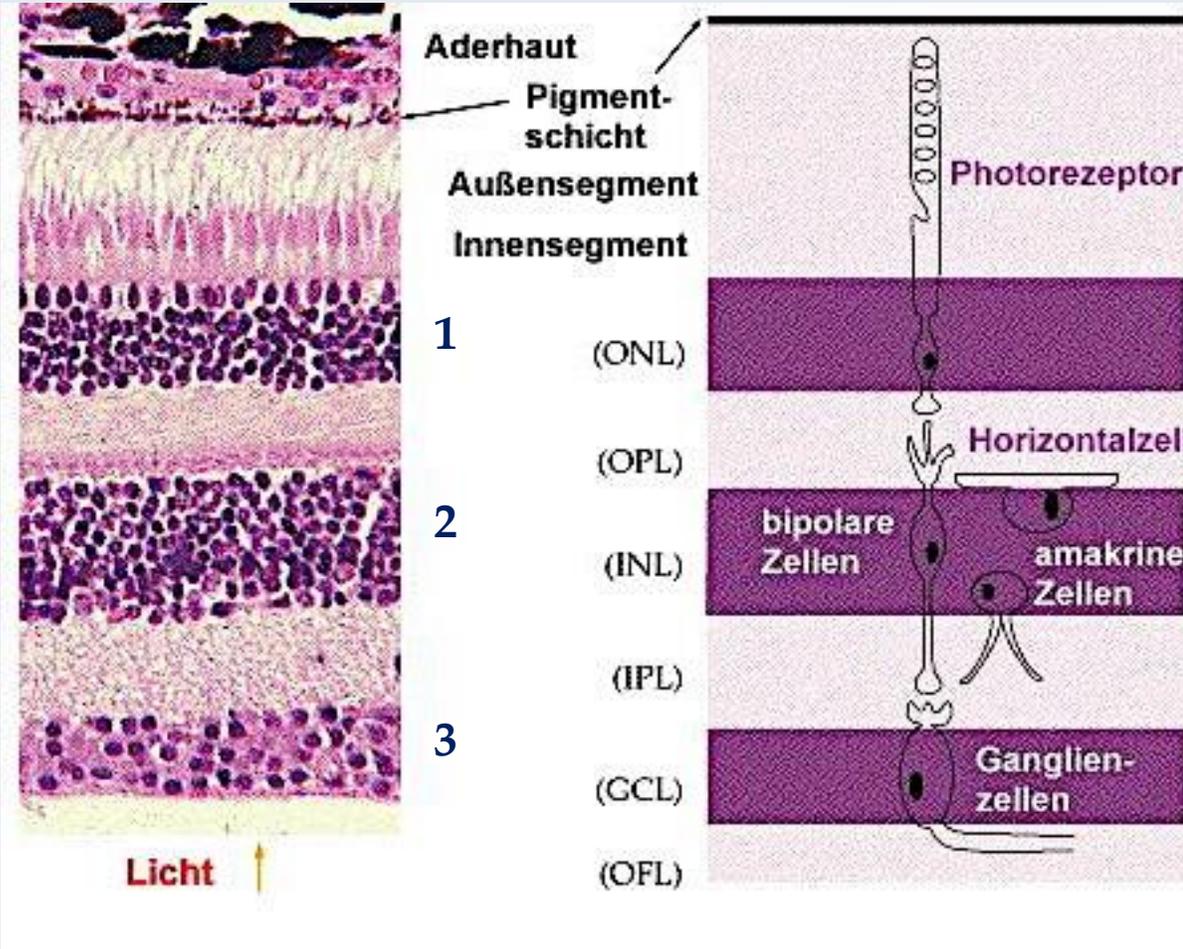
Sobotta

...to the visual cortex

# Visual pathway

images

www.zum.de



The first 3 neurons are in the:

Retina:

## 1. Rods and cones

(Str. neuroepitheliale et granulosum externum)

## 2. Bipolar neurons

(Str. granulosum internum)

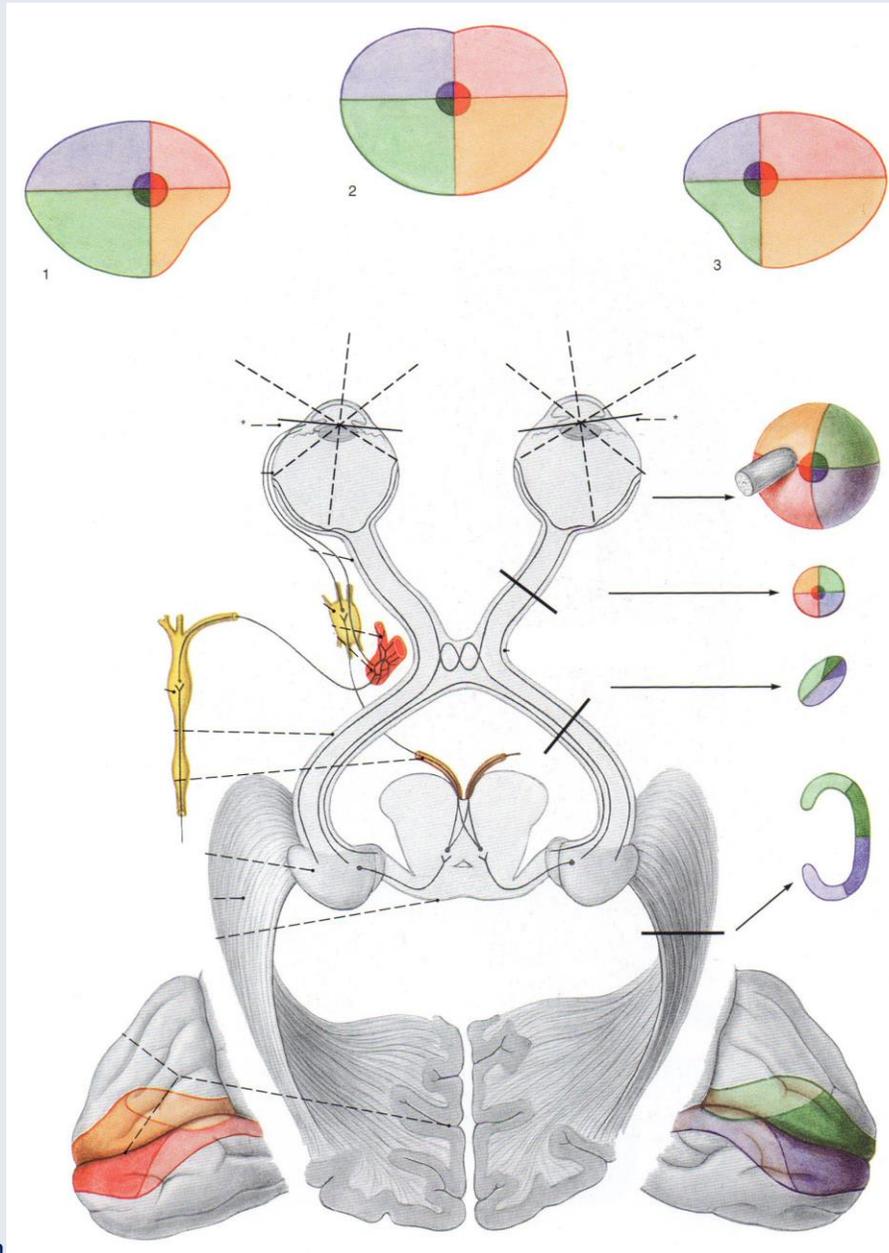
## 3. (multipolare) Ganglionic layer

(Str. ganglionare),

The axons (Str. neurofibrarum)

to gather to the optic nerve

# Visual pathway



Informations from the **fields of vision** of two eyes will be in strict, point-to-point **retinotopic** arrangement to the visual cortex determined.

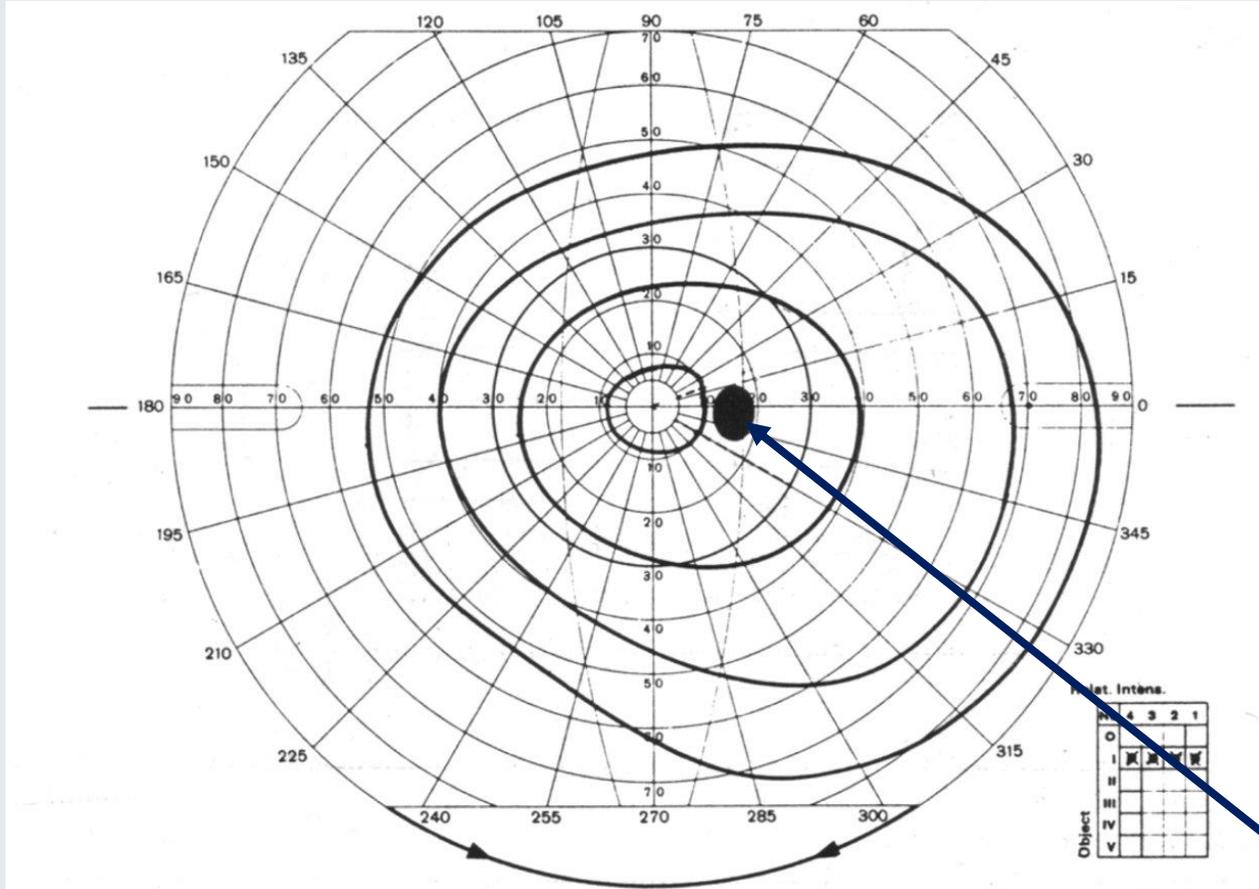
Visual field:

Part of the view that with unmoved eye caught can be.

Retinotopy:

The spacial relationships in the position relationships of the nerve tracts.

# Visual pathway



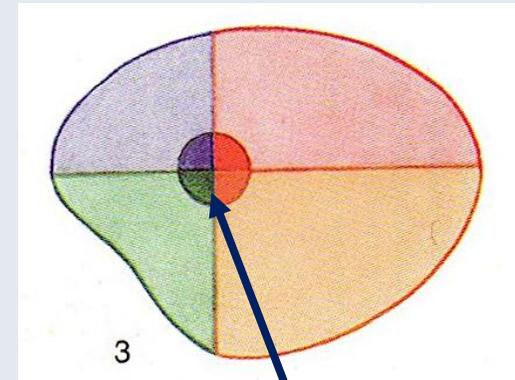
wikipedia.de

normal visual field of the right eye  
determined by perimetry

nasale Hälfte    temporale Hälfte

Upper

Lower



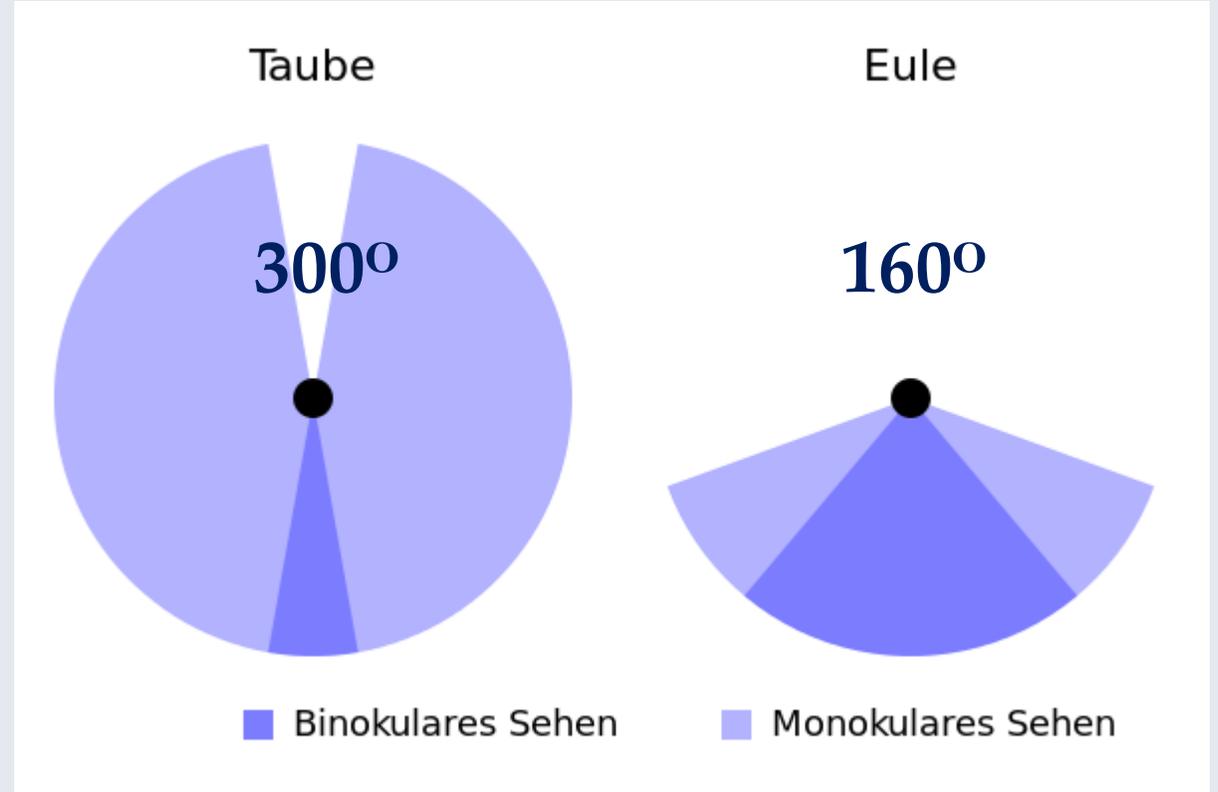
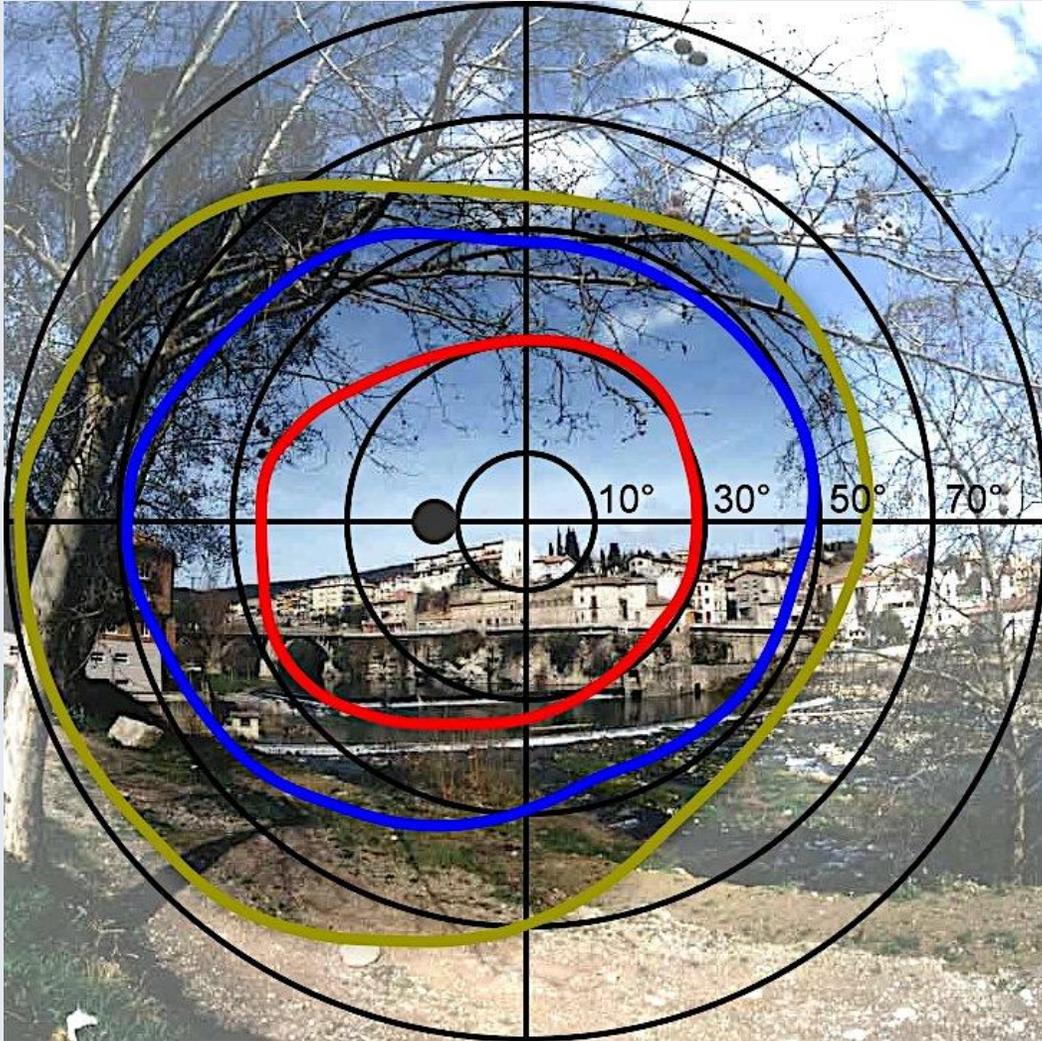
Quadrat

Quadrat

Place of the sharpest vision  
(fovea)

The blind spot is 18° temporal  
from the fovea

# Visual pathway



By human is monocular

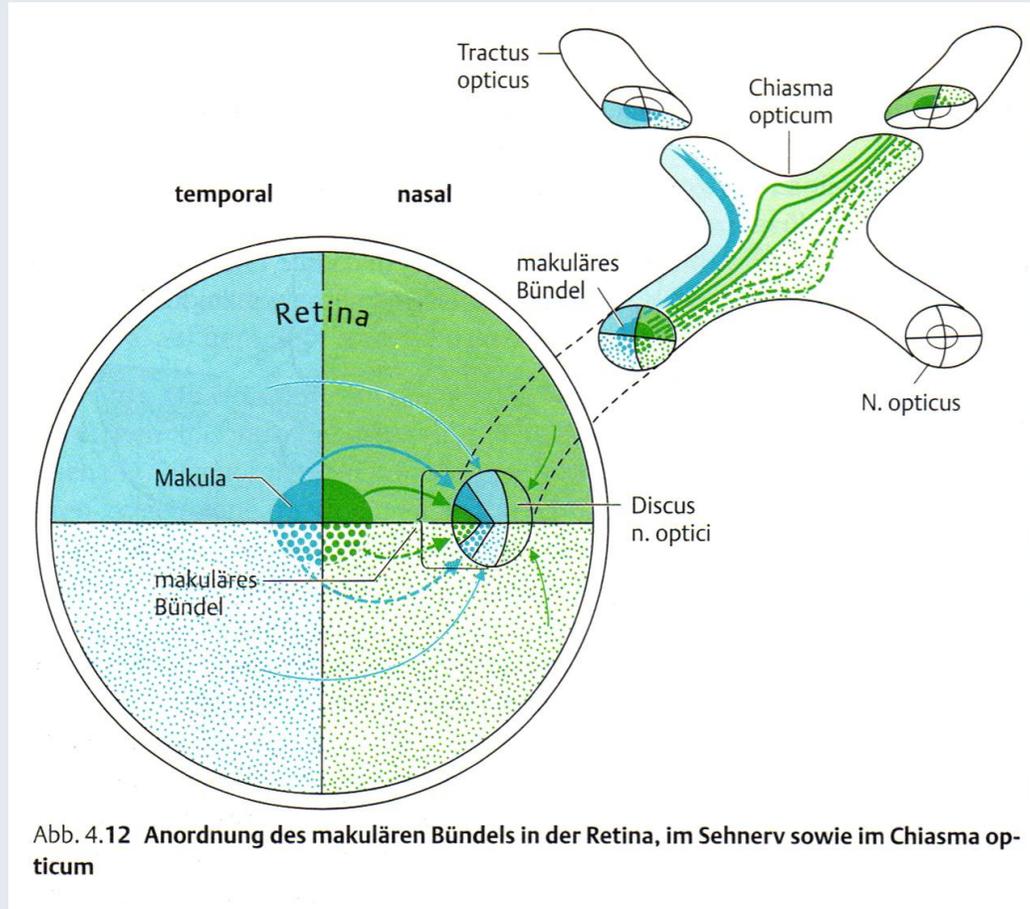
horisontal  $107^{\circ}$  ( $214^{\circ}$  binokulär)

upwards vertikal  $60-70^{\circ}$

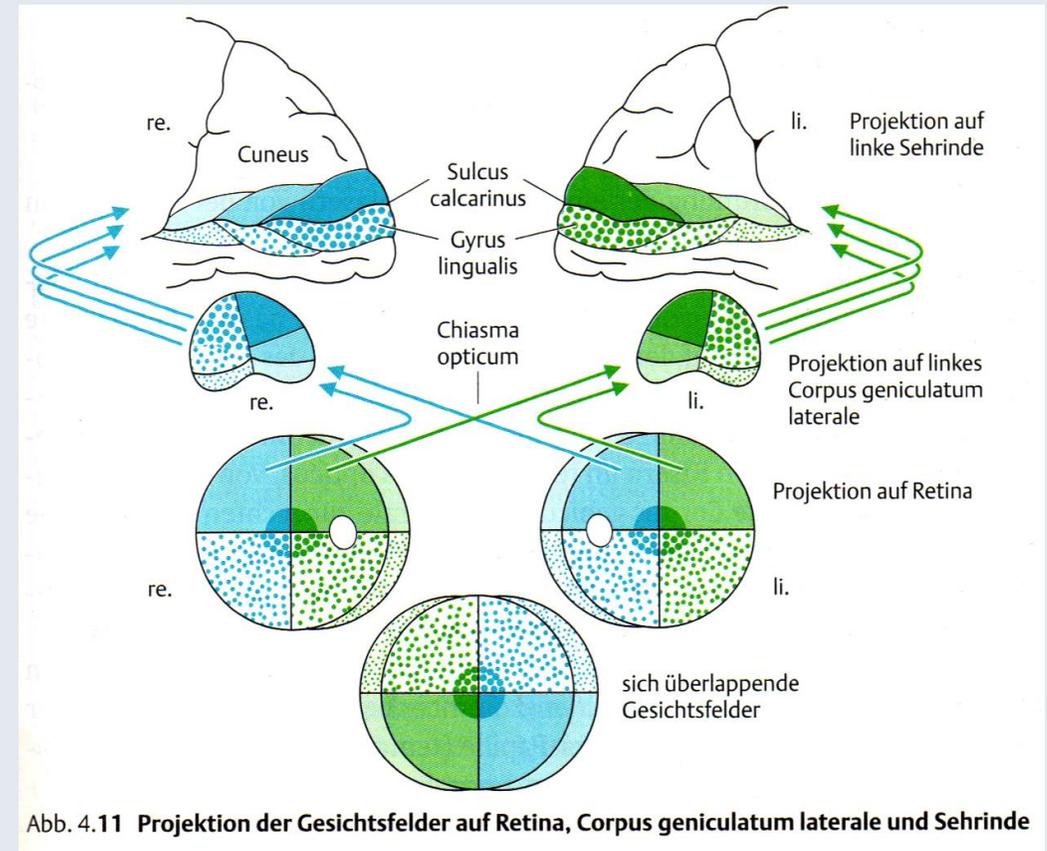
downwards vertikal  $70-80^{\circ}$



# Visual pathway



Fibers from the sharpened vision have bilateral Projection. (Basics of „macular sparing“)

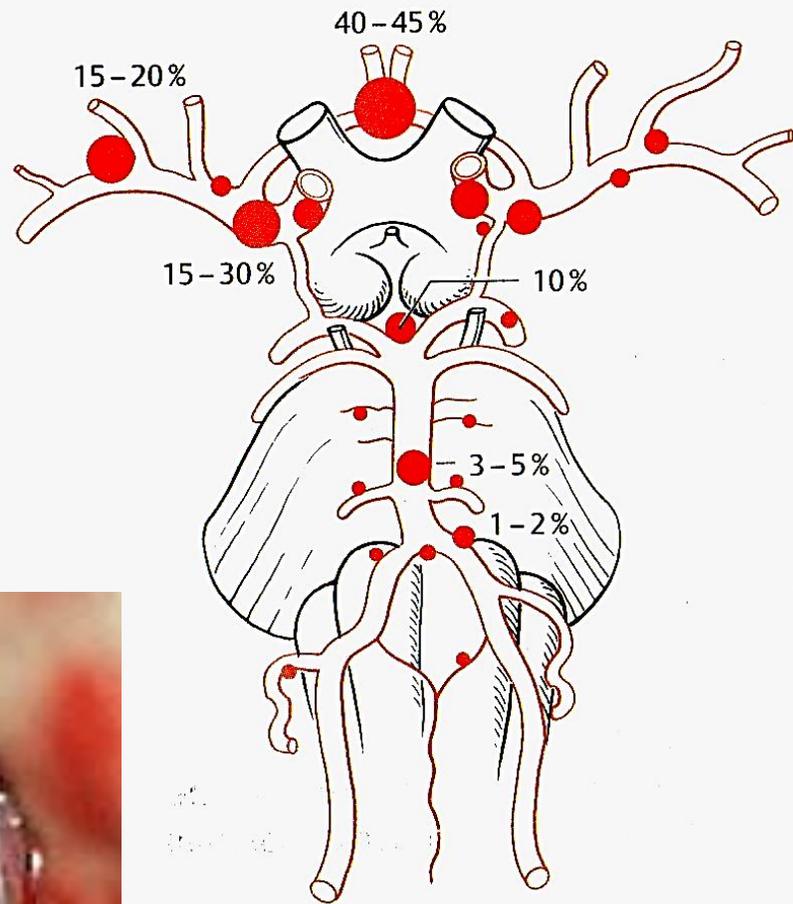


Duus

Projecting fibers from the lower halves of the retina projects on the upper lip of the sulcus calcarinus. The periphery is at the front, the center more at the occipital pole.



Duus



[takvim.pw](http://takvim.pw)

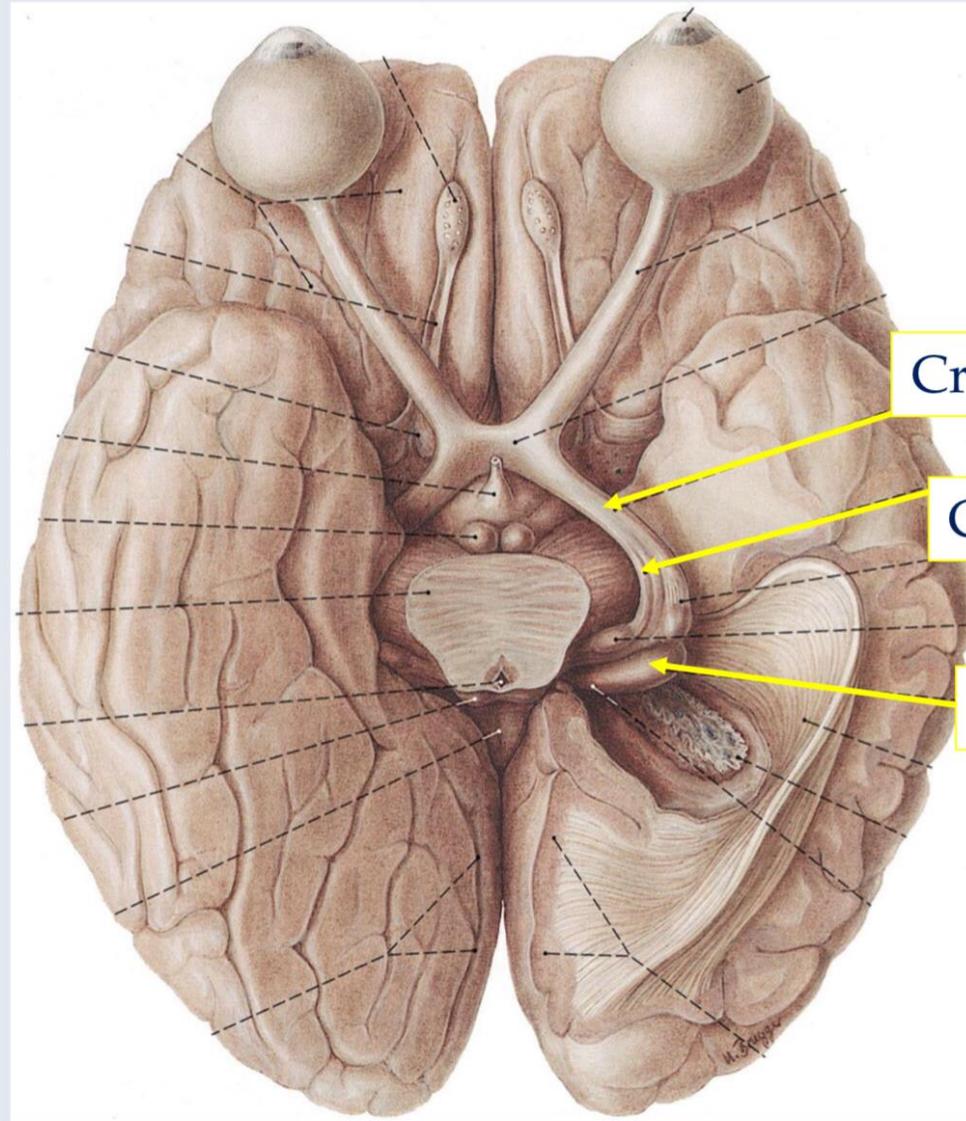


# Visual pathway

Optic tract divide into a medial and lateral crus:

medial crus goes into the superior colliculus via the brachium of the superior colliculus (ca. 10% of the fibers)

lateral crus goes into the LGB (ca. 90% of the fibers)



Crus laterale of the optic tract

Crus mediale of the optic tract

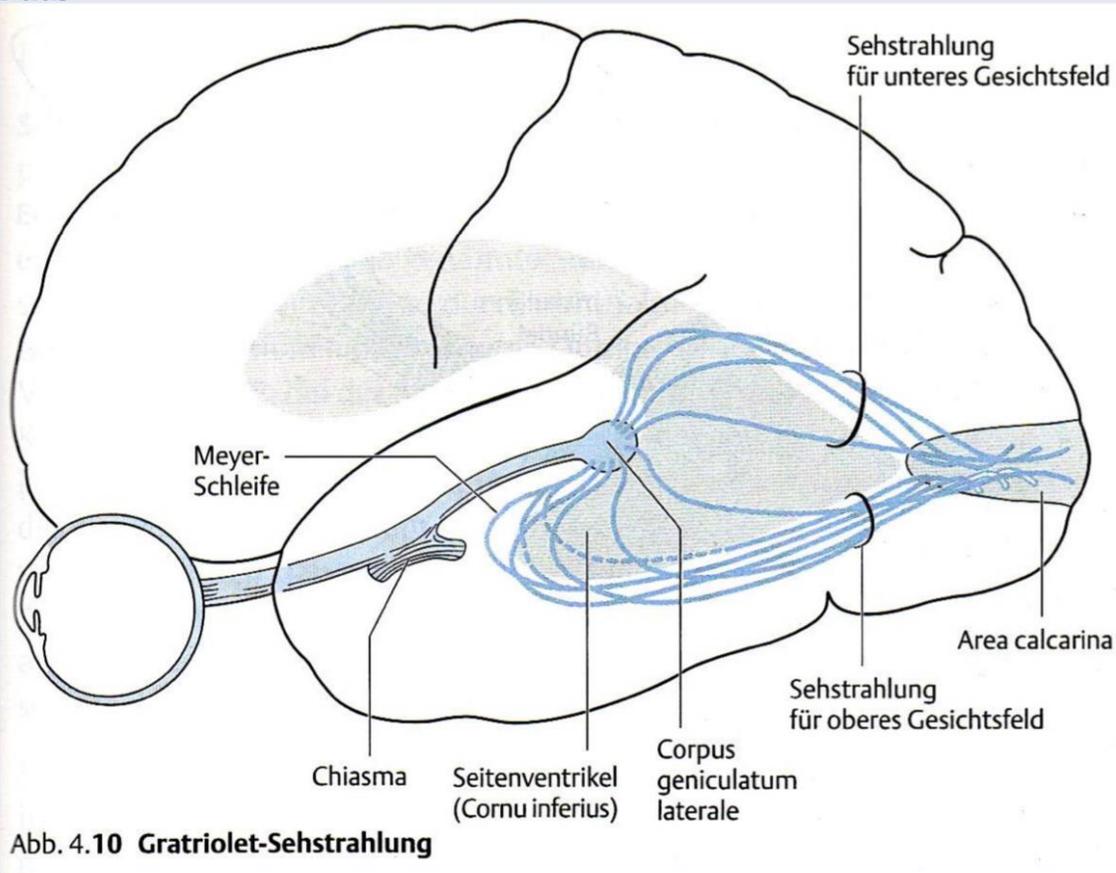
LGB

or:  
extrageniculate and  
geniculate tracts



# Visual pathway

Duus



Altogether **optic radiation** from the methathalamus, in the post. **crus of the internal capsulae**: „Gratiolet-optic radiation“

Axons of the ggl. cells (3rd neurons) in the optic nerve and in the tractus opticus reach the **4th neurons in LGB**.

From here they take the further course to the **cortex (5th neuron)**.

Fibers from the upper visual field become a temporal bundle beside the lateral horn. Forming a loop: „Meyer-loop“ (lower lip of the calcarine sulcus).

Fibers from the lower visual field above the parietal part of lateral ventricle to the cortex (upper lip of the calcarine sulcus).

# Visual cortex

Duus

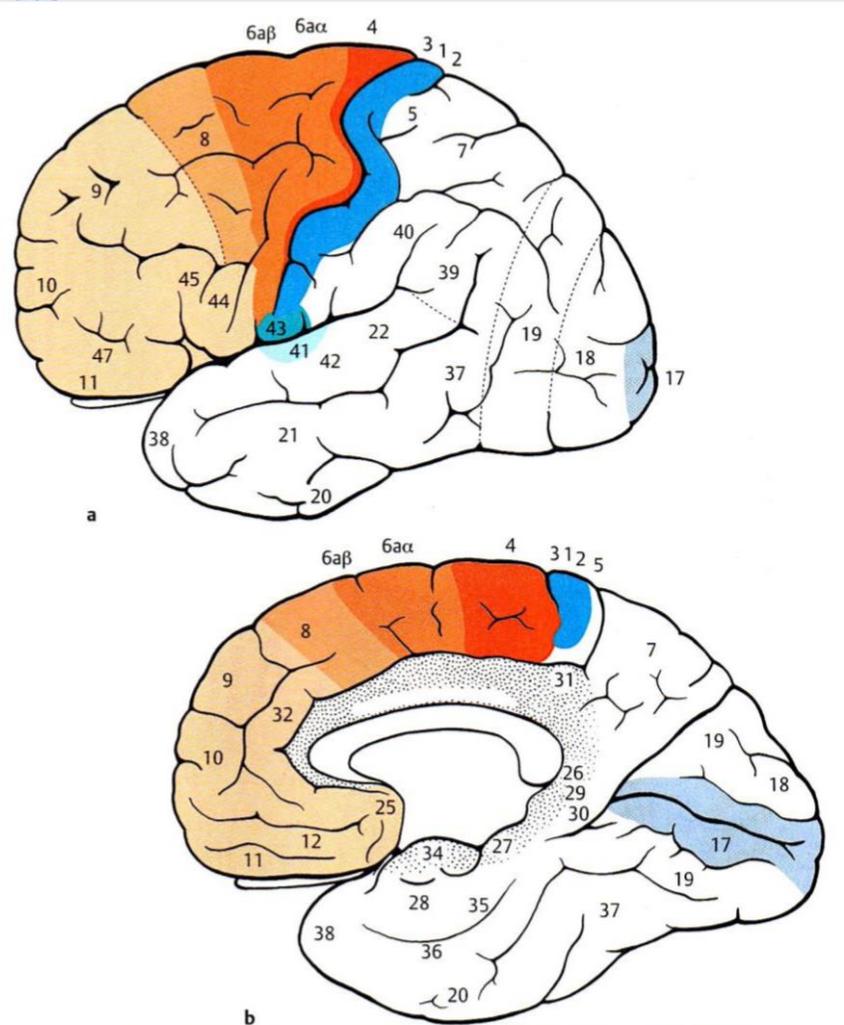
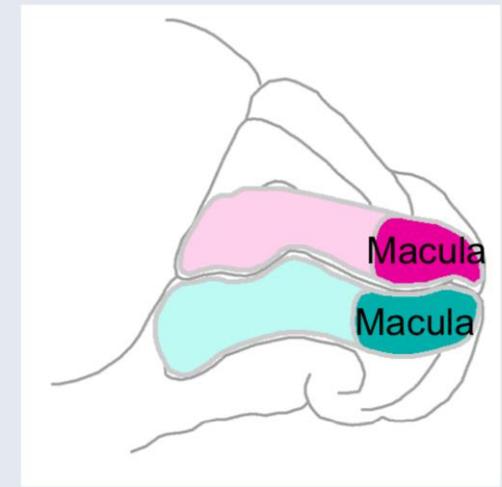


Abb. 9.18 Primäre Rindenfelder sowie prämotorisches und präfrontales Rindengebiet, schematische Darstellung. a Äußere Ansicht, b mediale Ansicht.



primary visual cortex:

Along the calcarine sulcus ("upper" and "lower" lips)  
and occipital pole

Brodman 17 Areal / V1 / Area striata (Gennari)

Sensory cortex type: specially developed lamina IV.

Retinotopic arrangement: ipsilateral temporal and  
contralateral nasal visual fields (like in the LGB);

Macula - Occipital pole, periphery - rostral

# Visual cortex

Columnar architecture:

1. 30-100  $\mu\text{m}$  wide cell columns respond to stimuli same orientation

2. **Orientation columns** are organized regions of neurons that are excited by visual line stimuli of varying angles. These columns are located in the primary visual cortex (V1) and span multiple cortical layers. The geometry of the orientation columns are arranged in slabs that are perpendicular to the surface of the primary visual cortex. Pinwheel formations (also known as whorls) of orientation columns were discovered. Pinwheels are the location where multiple orientation columns converge. Orientation columns are organized radially around a point known as a singularity. The arrangement, around the singularity, can be observed to be in both a counter-clockwise or clockwise fashion.

3. Regularly occurring **blobs** under the columns: responsible for color vision

4. **ocular dominance columns**: are stripes of neurons in the visual cortex of certain mammals (including humans) that respond preferentially to input from one eye or the other. The columns span multiple cortical layers, and are laid out in a striped pattern across the surface of the striate cortex (V1). The stripes lie perpendicular to the orientation columns.

5. **cortical column**, also called **hypercolumn**, **macrocolumn**, **functional column** or sometimes **cortical module**, is a group of neurons in the cortex of the brain that can be successively penetrated by a probe inserted perpendicularly to the cortical surface, and which have nearly identical receptive fields.

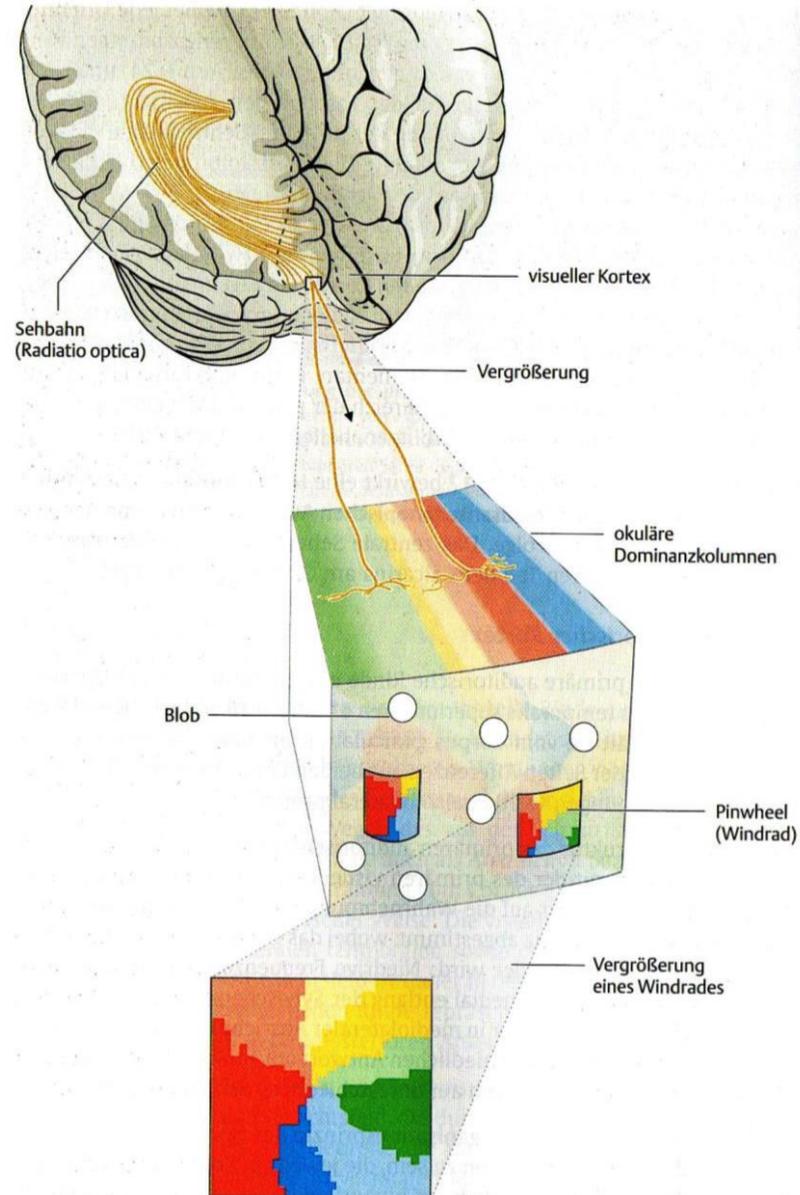
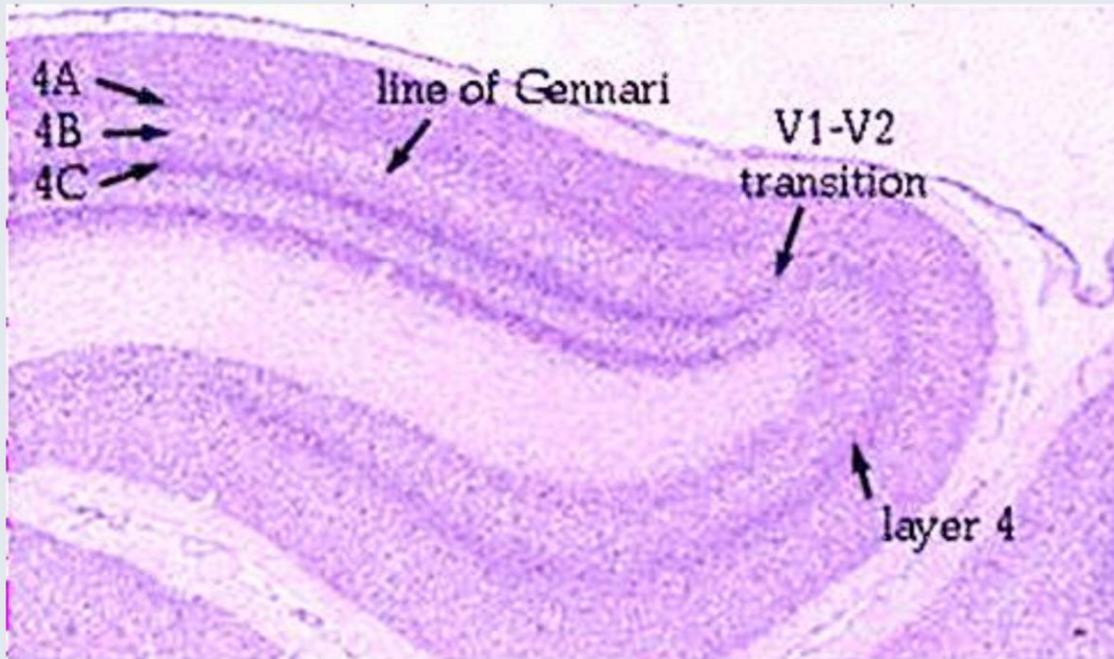


Abb. 9.24 Struktur des visuellen Kortex. Windräder (Pin-Wheels) und Blobs, schematische Darstellung.

(B) Stimulus orientation



# Visual cortex

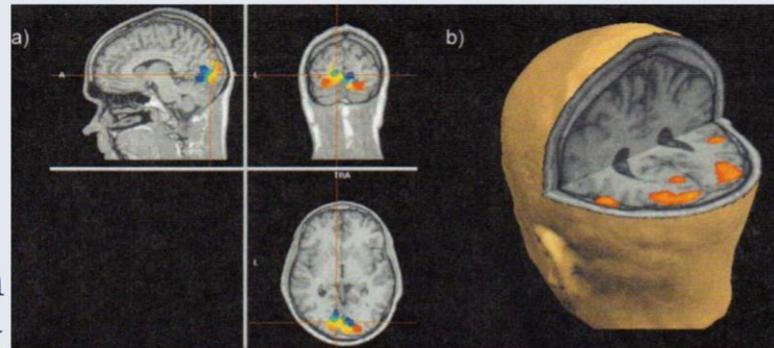


in the primary visual cortex the IV. lamina becomes further subdivided into A, B, C $\alpha$  and C $\beta$  layers

C $\alpha$  gets input from a large receptive field by LGB laminae 1-2.  
(Motion perception, flight)

C $\beta$  gets more input from the macula area by LGB laminae 3-6.  
(Color, tone, texture, orientation)

The primary cortex can not yet recognize complex shapes, form pictures

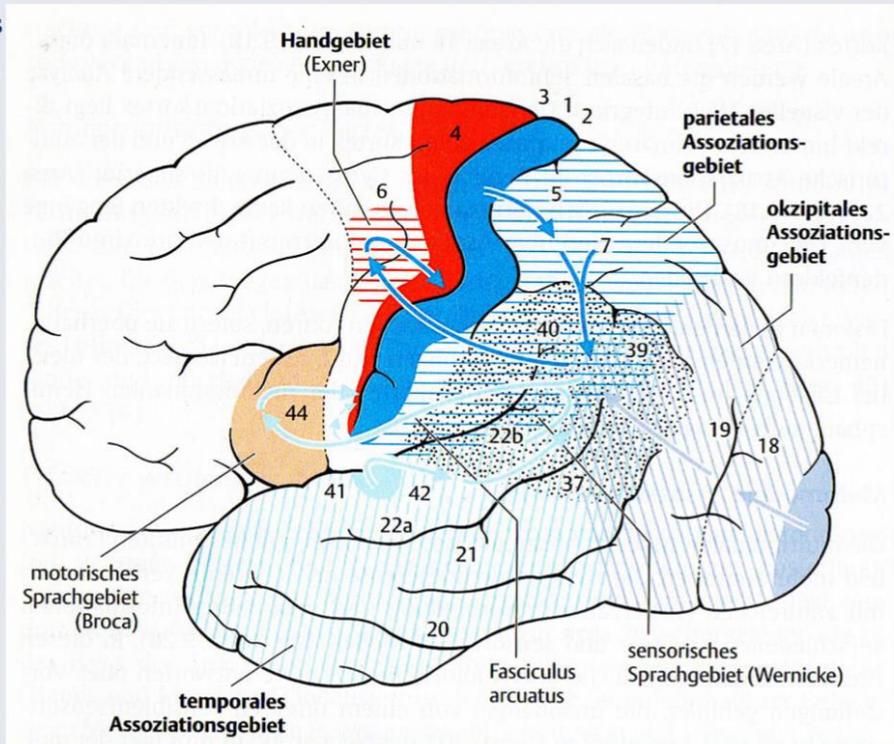


Association areas are needed...

fMRI des visuellen  
Cortex

# Visual cortex

Duus



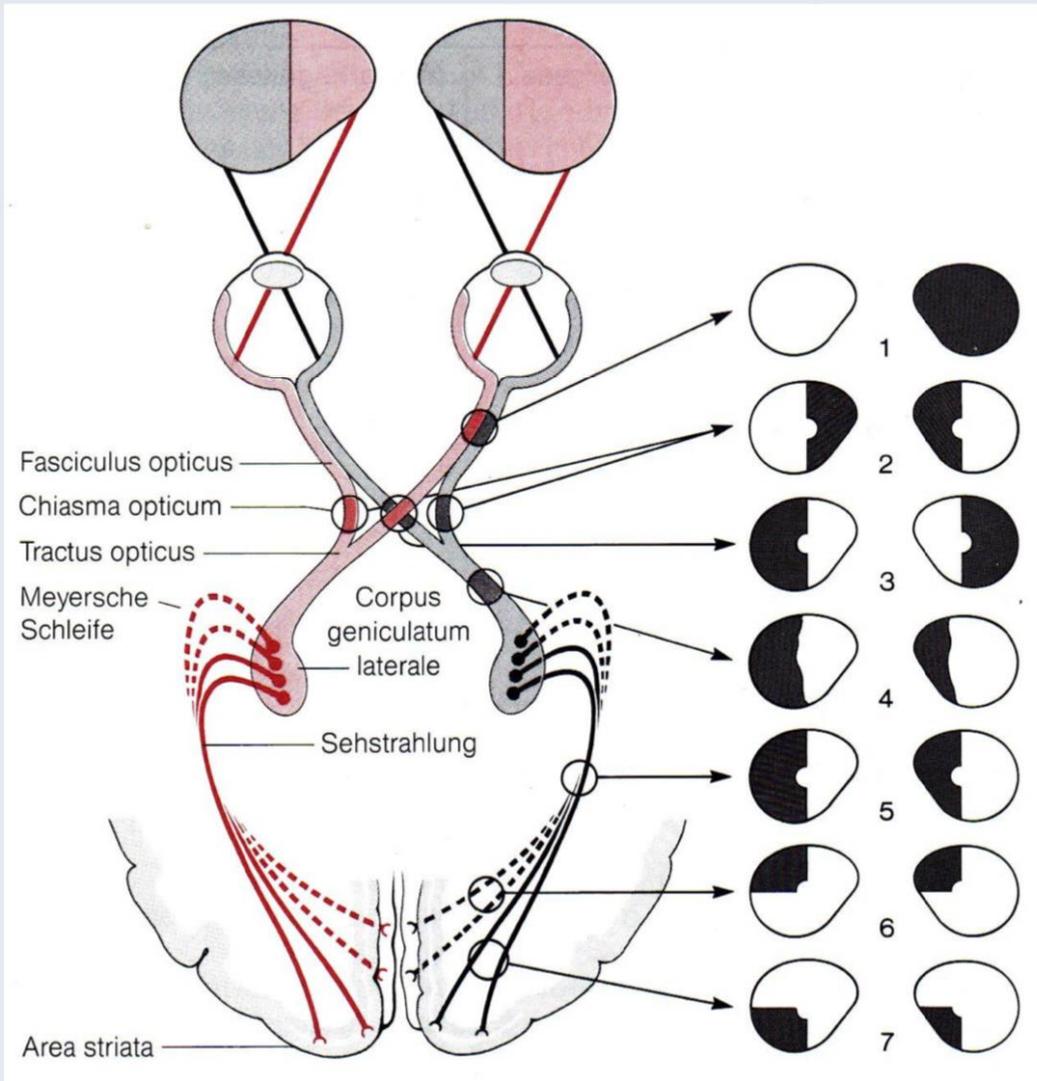
Brodmann 18: secondary visual cortex / V2

Brodmann 19: tertiary visual cortex

allow: the perception of the movement

the perception of colors the spatial resolution

Efferents to higher cortical centers



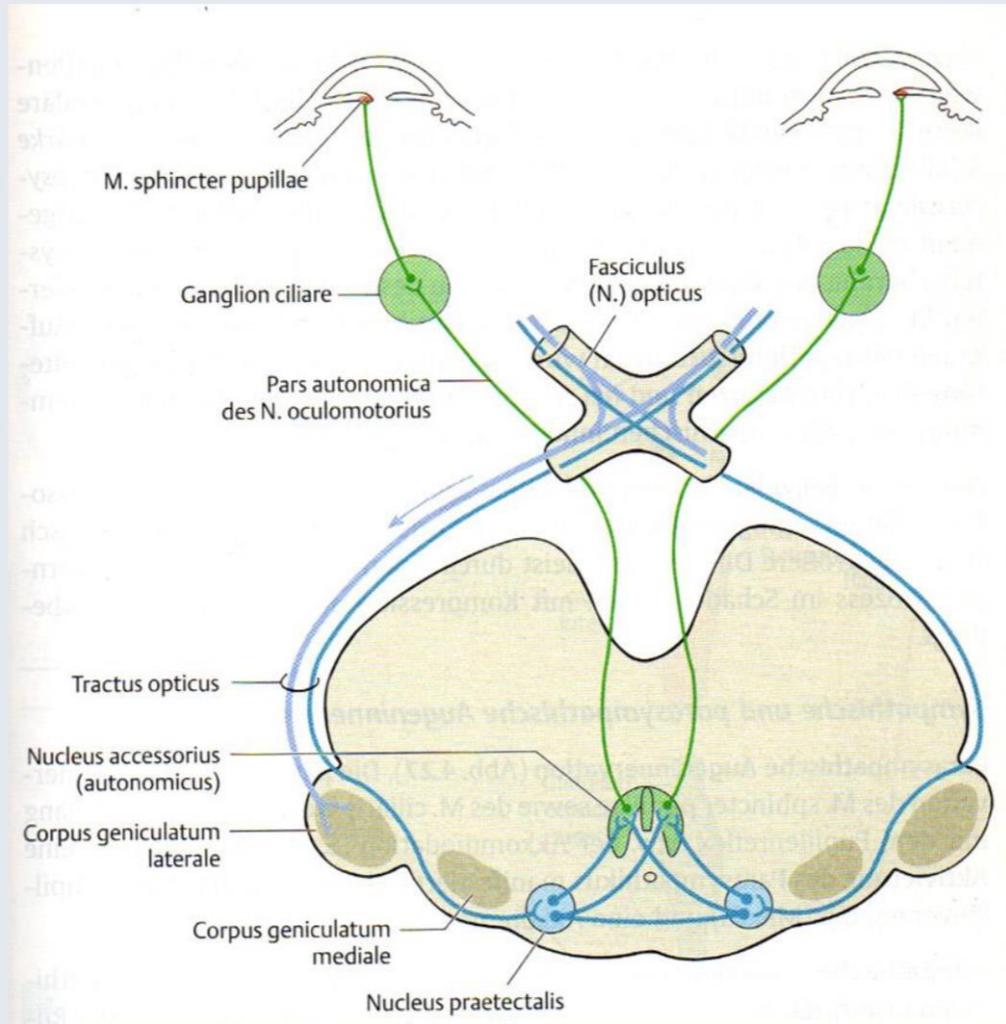
Laesion of the optic nerve: **heteronymous hemianopia**:  
the visual field of the same eye fails

Laesion of the optic tract: **homonymous hemianopia**:  
fall off the equilateral halves of the retina

"**Macular sparing**": fibers from the macula lutea are ending in the two LGBs + the occipital lobe get a great caudal representation of the macula  
in most anopsia forms, therefore, vision remains spared with the macula, if not the optic nerve or the occipital pole (both sides) injured

The visual cortex not only receives fibers from the LGB but also sends fibers to the brain stem, back to the tectum mesencephali, which is indispensable for reflexes of the visual system.

# Pupillary reflex



Duus

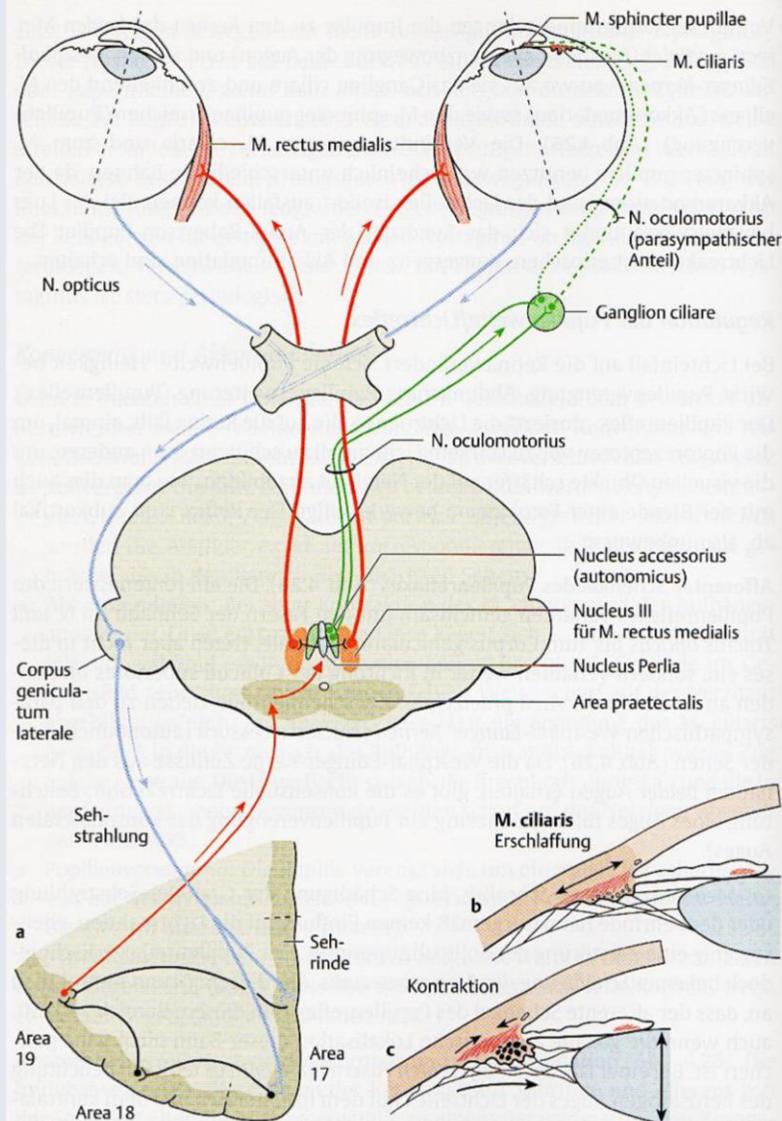


Fibers from the medial limb of the optic tract through the brachium of the sup. collicle to the nuclei praetectales, switch to the Edinger-Westphal nuclei: allow the sphincter pupillae mm. contracts together when light falls.

on the side of the incidence of light: direct reaction  
on the other side: consensual reaction

# Convergence and accommodation

Duus



by approaching objects

- Convergence of the eyeballs (Mm. Recti mediales)
- Accommodation of the lens (M. ciliaris)
- Pupil narrowing (M. sphincter pupillae)

reflexively

Afference: visual path to the visual cortex

Efference: fibers from the visual cortex to

Nucleus Perlia (between the Edinger-Westphal nuclei) and from here to the Edinger-Westphal nuclei and the oculomotor nucleus (areas for Mm. recti mediales)



Thank you for your attention!