# Anatomy and physiology of the eye

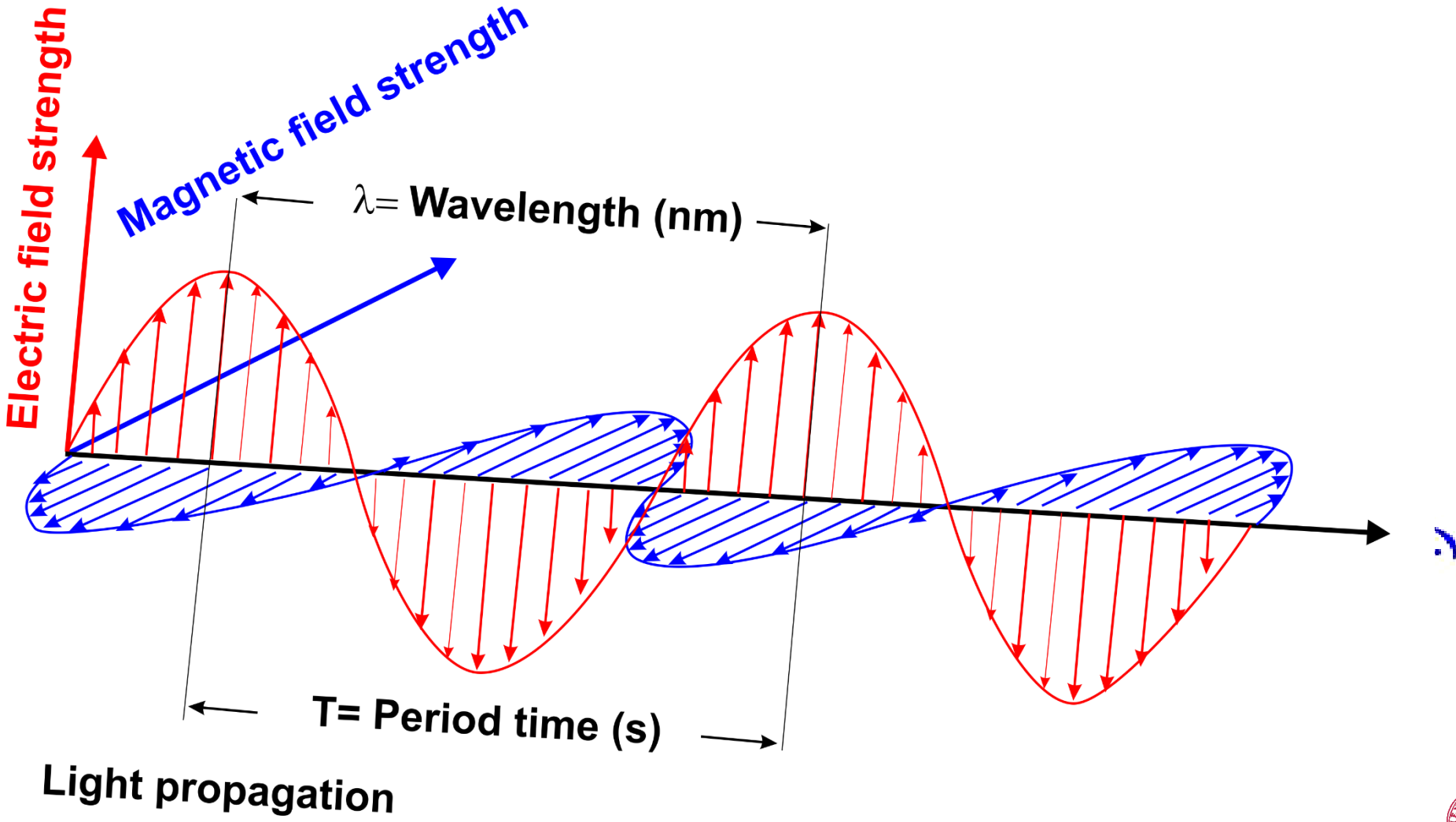

## Per Söderberg

UPPSALA
UNIVERSITET

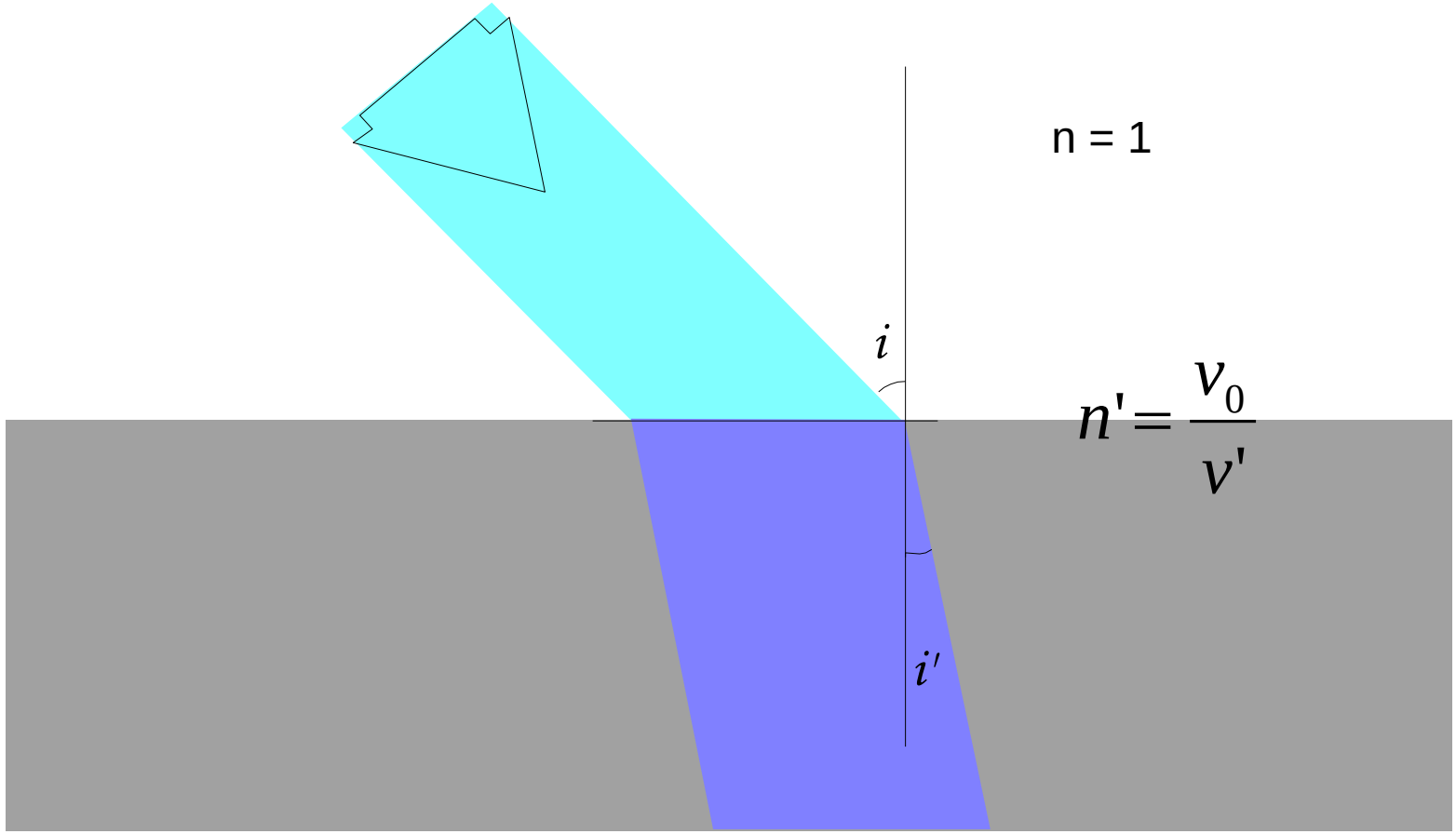
**Gullstrand lab**
**Ophthalmology, Dept. of Neuroscience**
**Uppsala university**
**Sweden**


Downloadable at
http://www2.neuro.uu.se/ophthalmology/Downloads/Miami/OcularAnatomyPhysiology.pdf

# Electromagnetic radiation



# Refraction of light



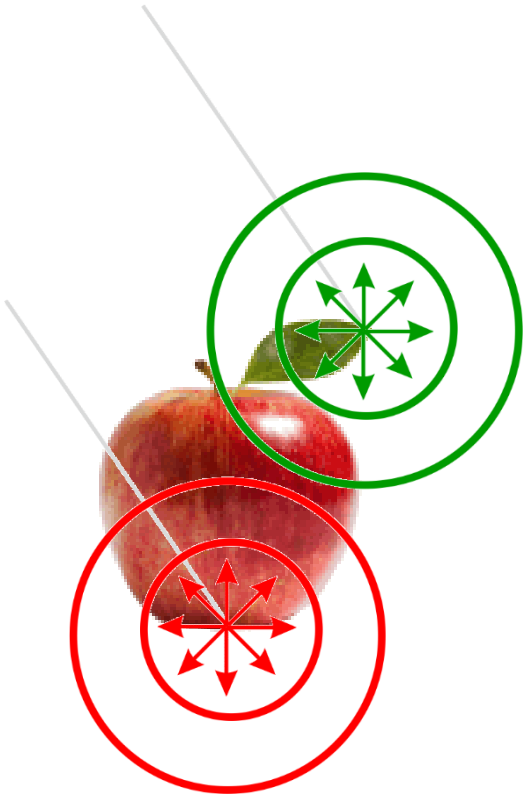

$$n \sin i = n' \sin i'$$

Gullstrand lab

# Light detection in the human visual system

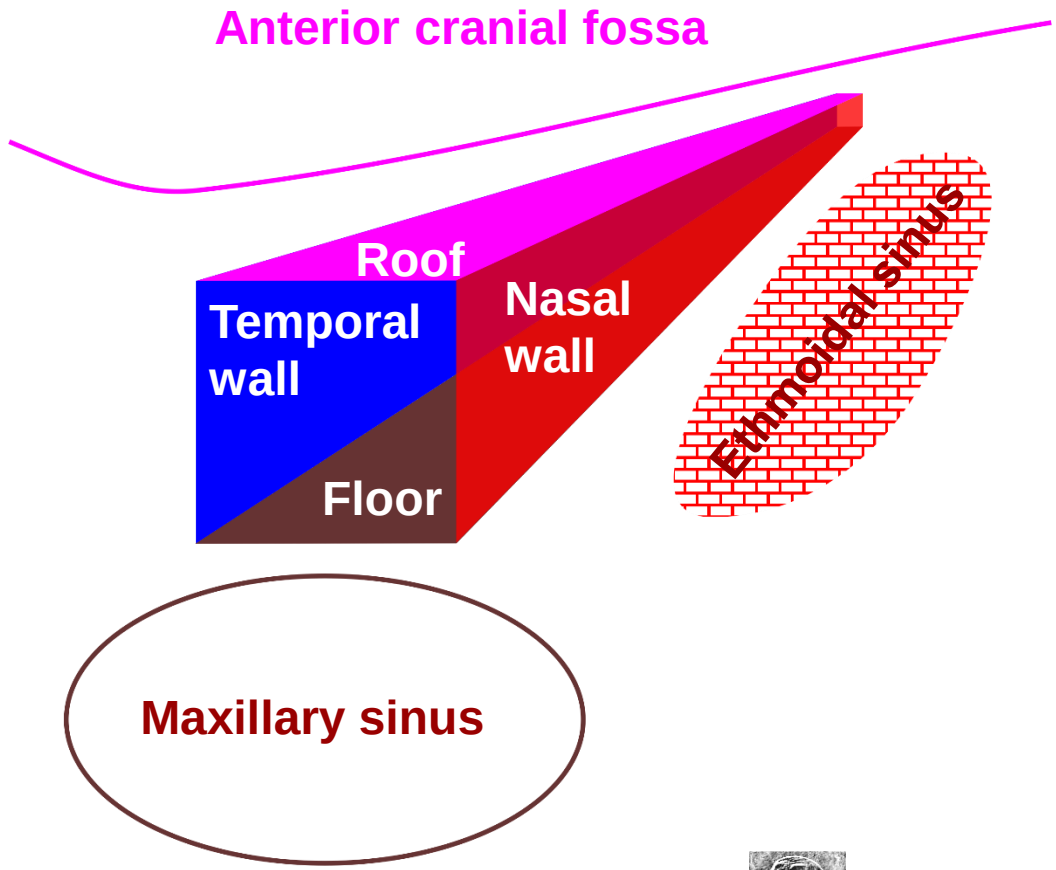
**Natures task**

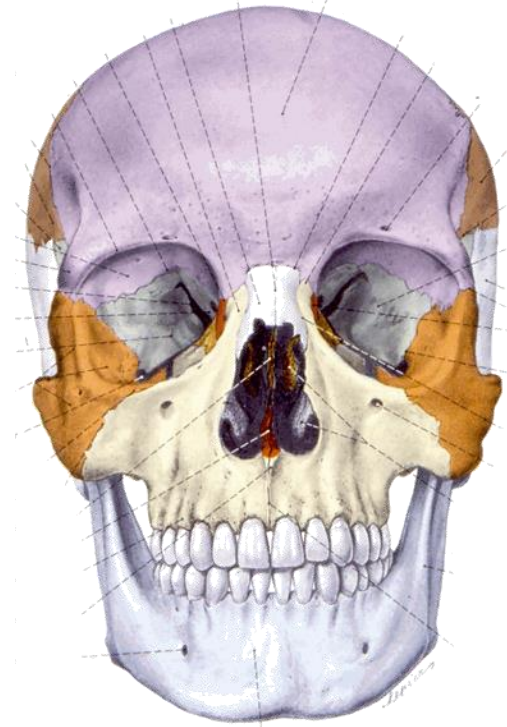
**Spatially resolved stereo-detection of information about objects on the surface of the earth encoded in electromagnetic radiation by scattering of a relatively constant source, the sun**



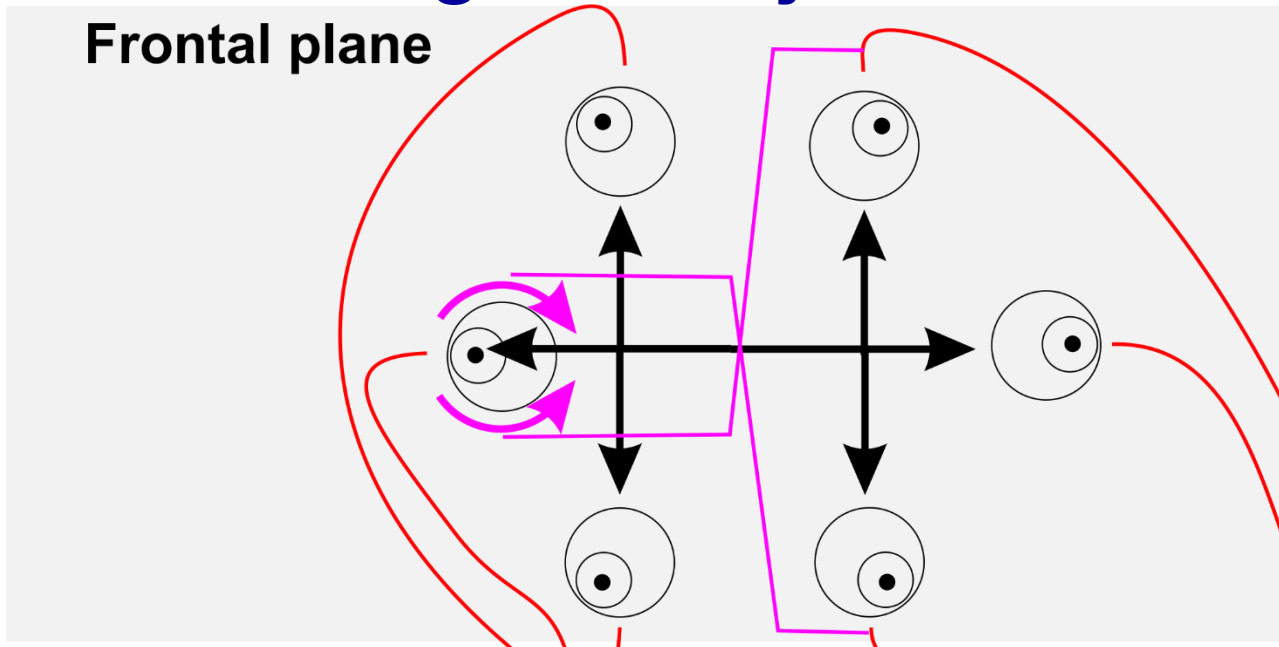
- **Light capture and transfer of light to the retina – the optics of the eye**
- **Phototransduction – transformation of optically encoded signal to electrically encoded signal (photreceptor cells)**
- **Primary information analysis for elimination of irrelevant information (signal compression) - neuroretina**
- **Electrical signal transfer to the brain – cables**
- **Perception of image information – visual cortex of the brain**
- **Steroperception - duplicate systems detecting the signal under slightly different angles**

# Two detectors that are spatially fixed to each other
# Two orbits (chassi)



# Mechanical globe adjustment –ocular muscles




Horisontal plane
Orbit from above

Annulus tendineus

M. obliqus sup.

M. rectus sup.

M. rectus med.

M. rectus lat.

M. obliqus inf.

Trochlea

M. rectus inf.

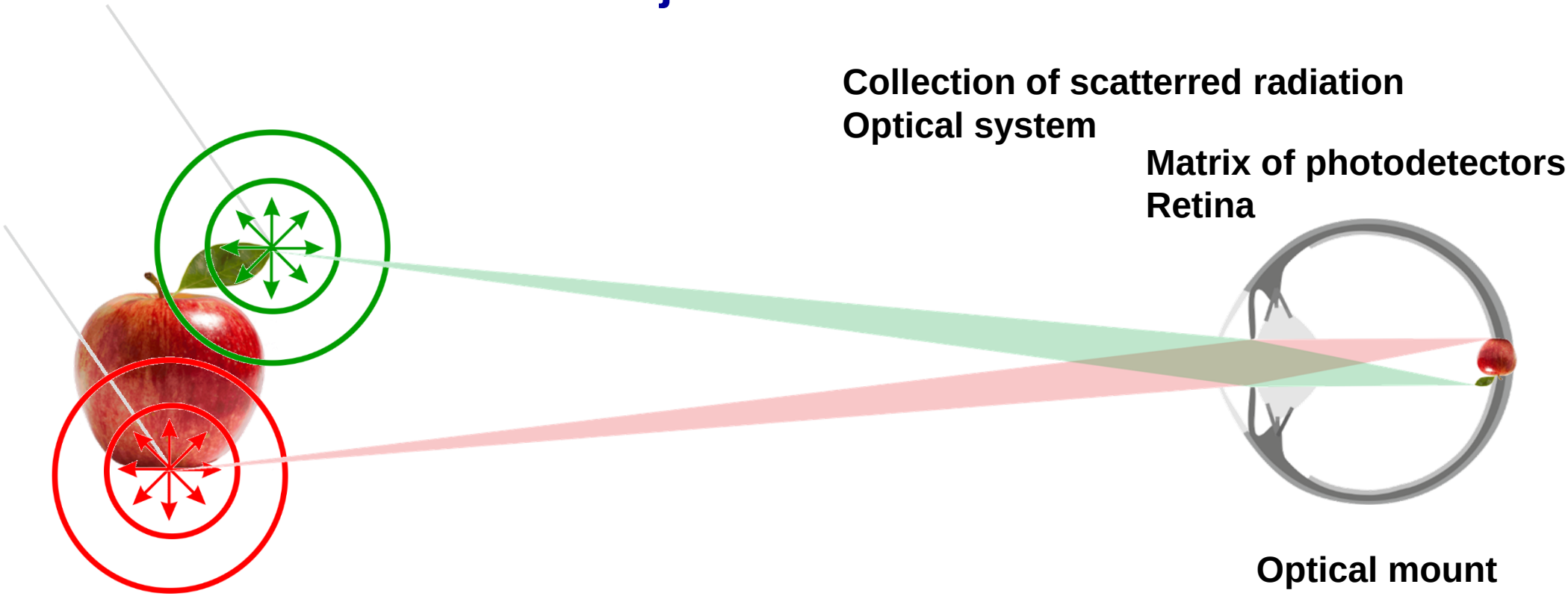
Nose

PS

Gullstrand lab

UPPSALA
UNIVERSITET

# The optics of the eye is an antenna
# Detection of electromagnetic radiation (400-760 nm) emitted from the sun and scattered on objects on the surface of the earth

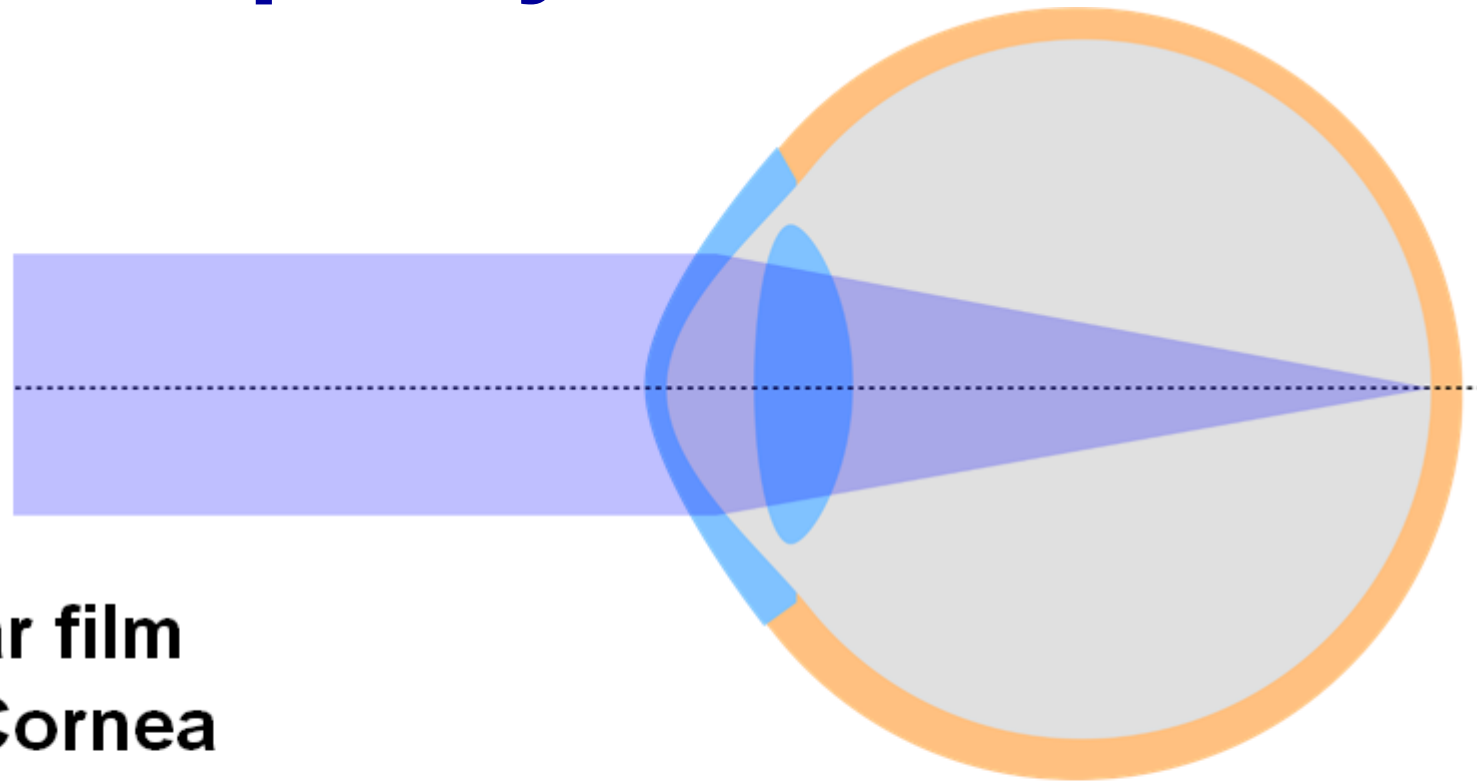


**Collection of scatterred radiation**
**Optical system**

**Matrix of photodetectors**
**Retina**

**Optical mount**
**The eye wall + sligthly higher pressure**

# Emmetropic eye at far distance



Tear film

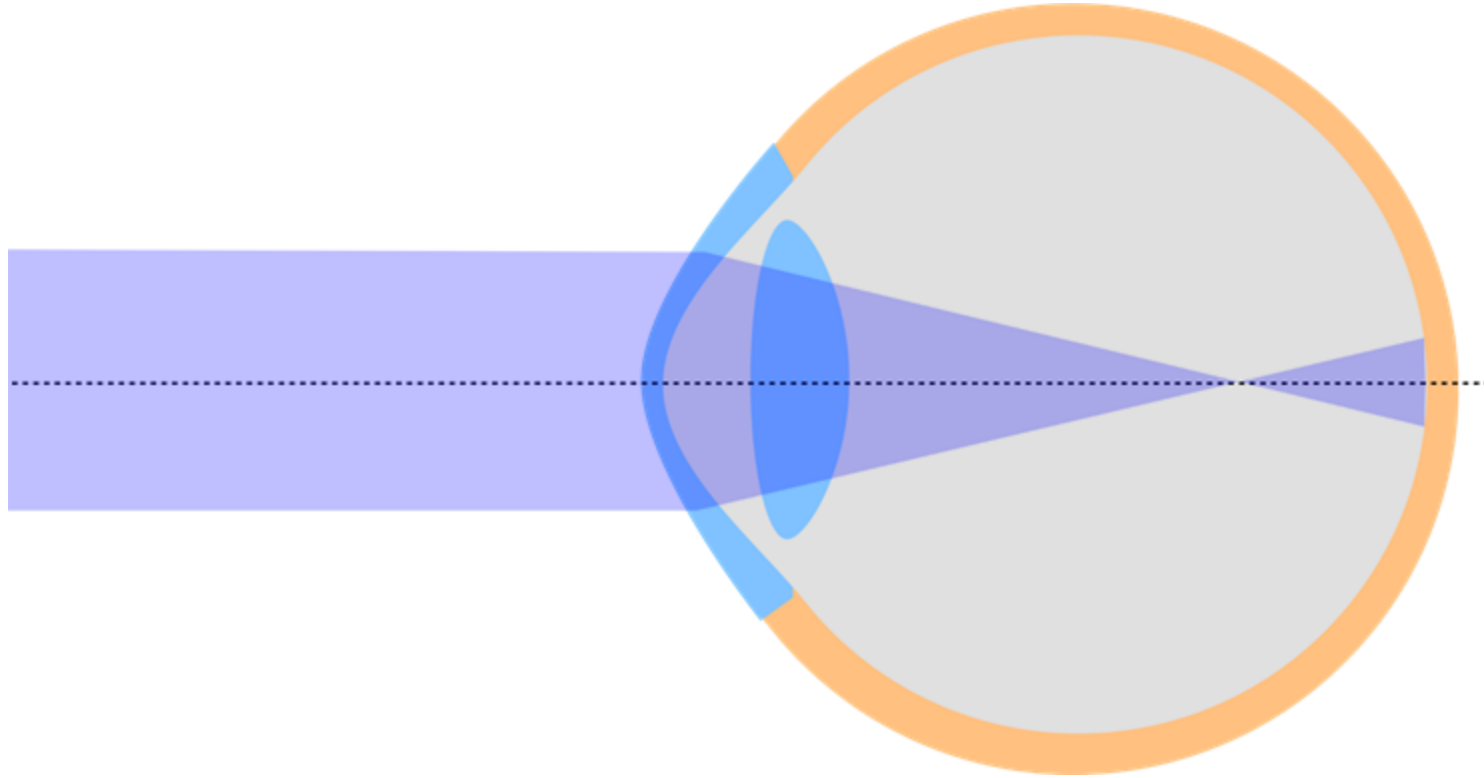
Cornea

Anterior chamber, aqueous humour

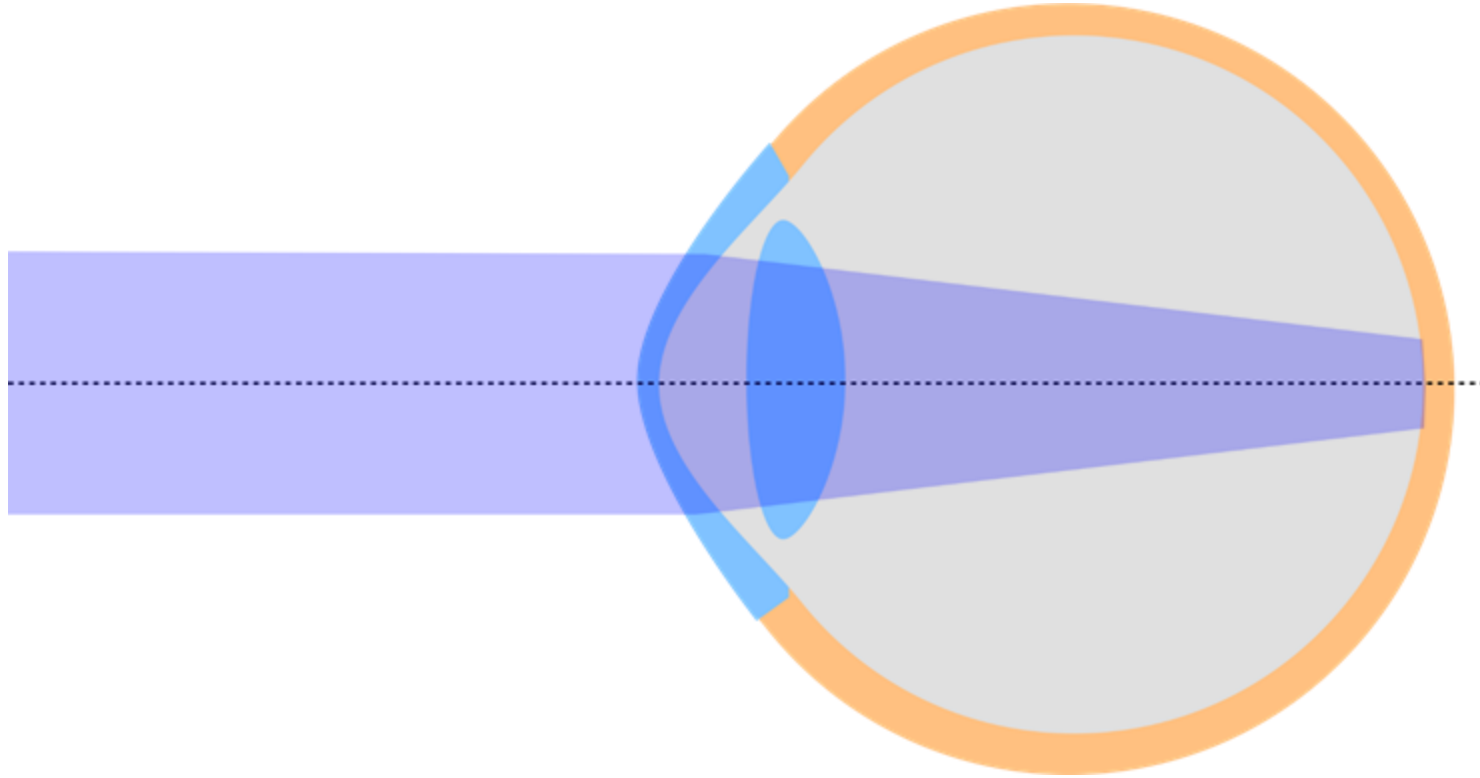
Lens

Vitreous

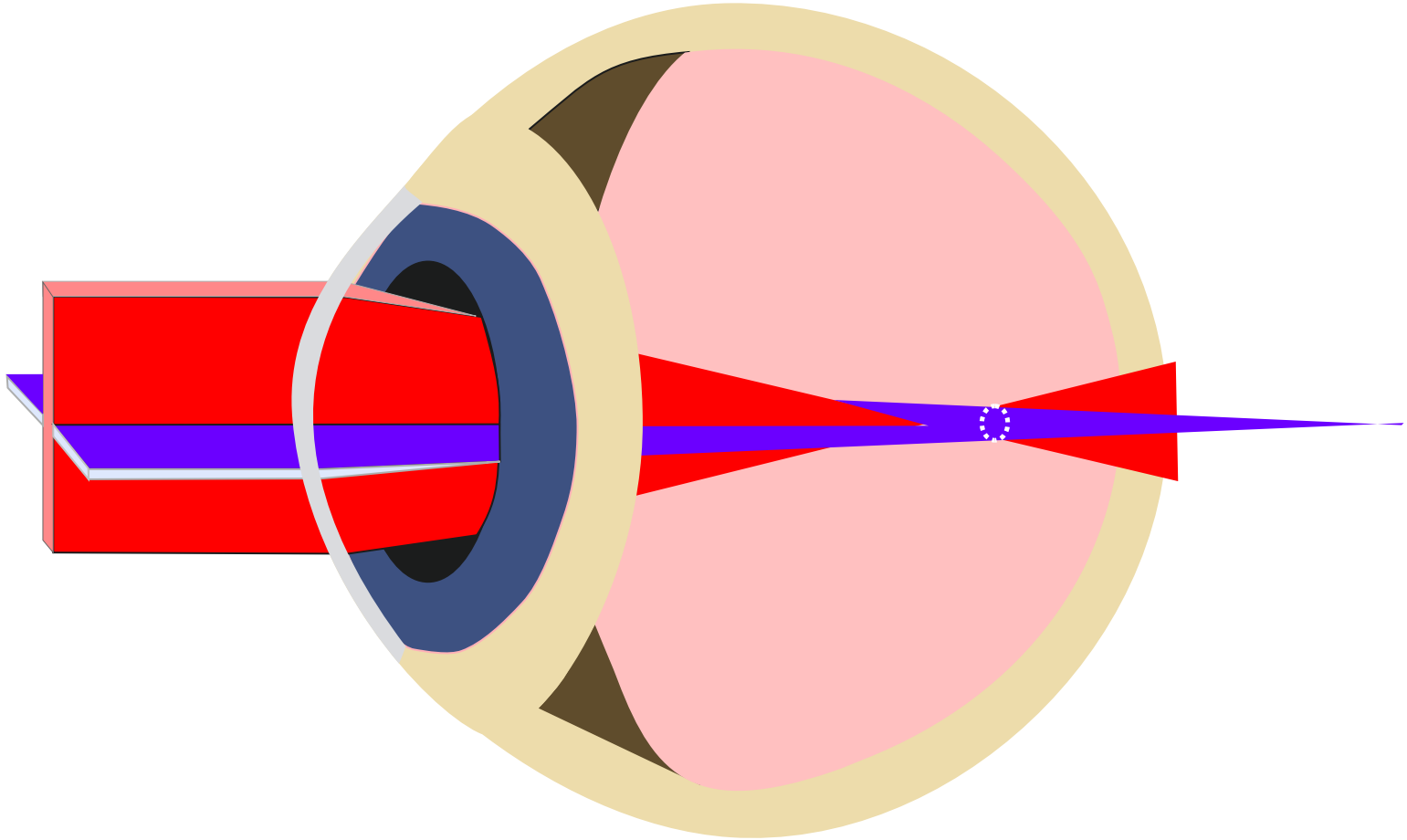
# Myopia



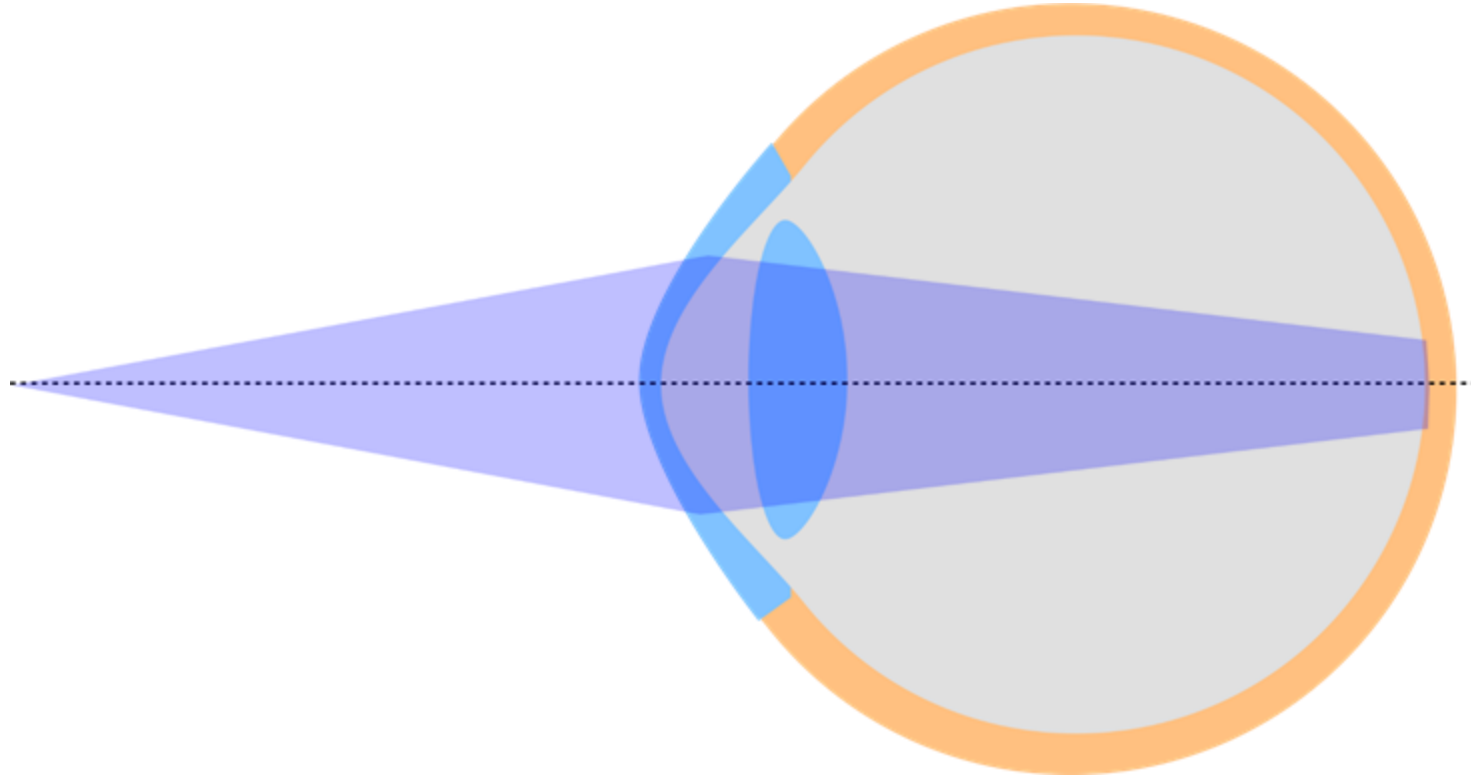
# Hyperopia



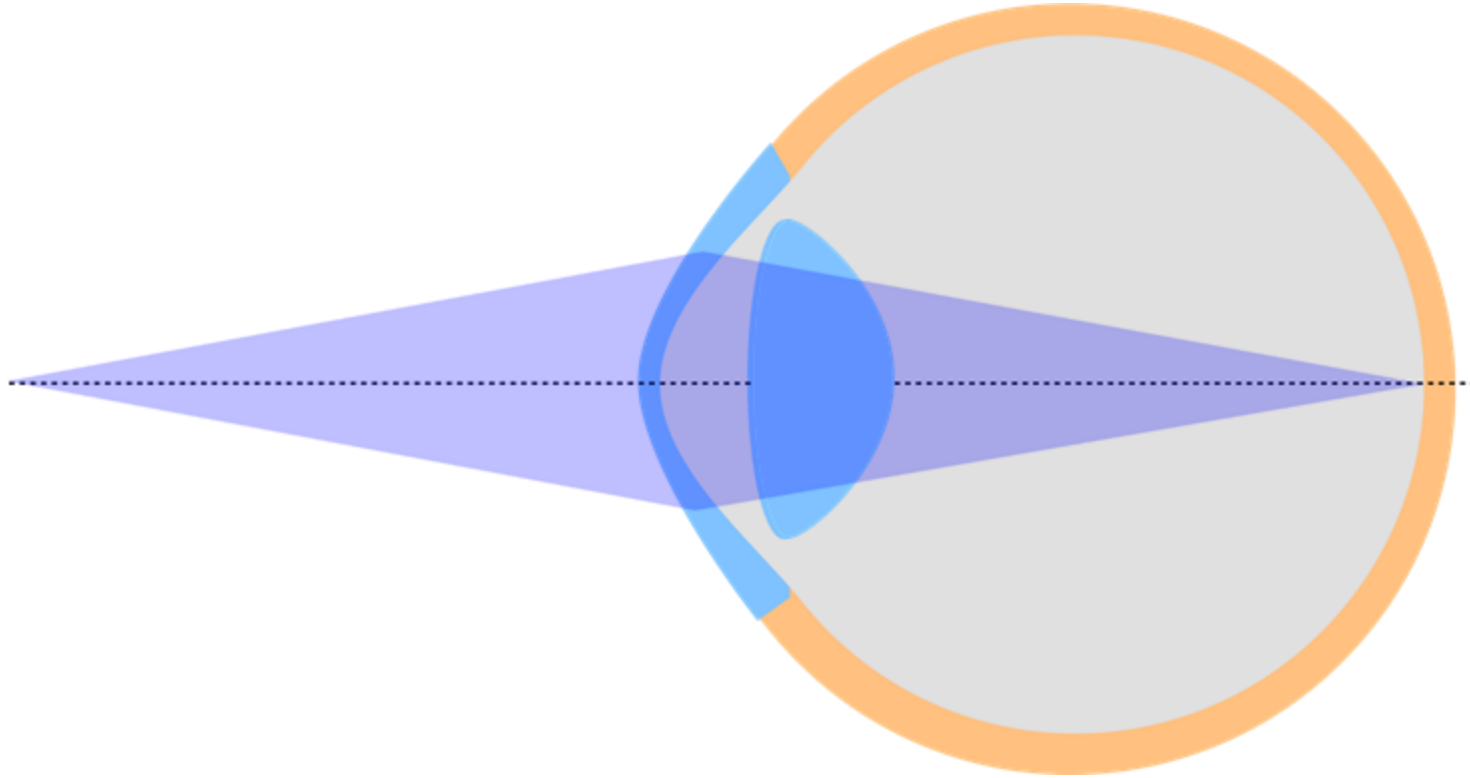
# Astigmatism



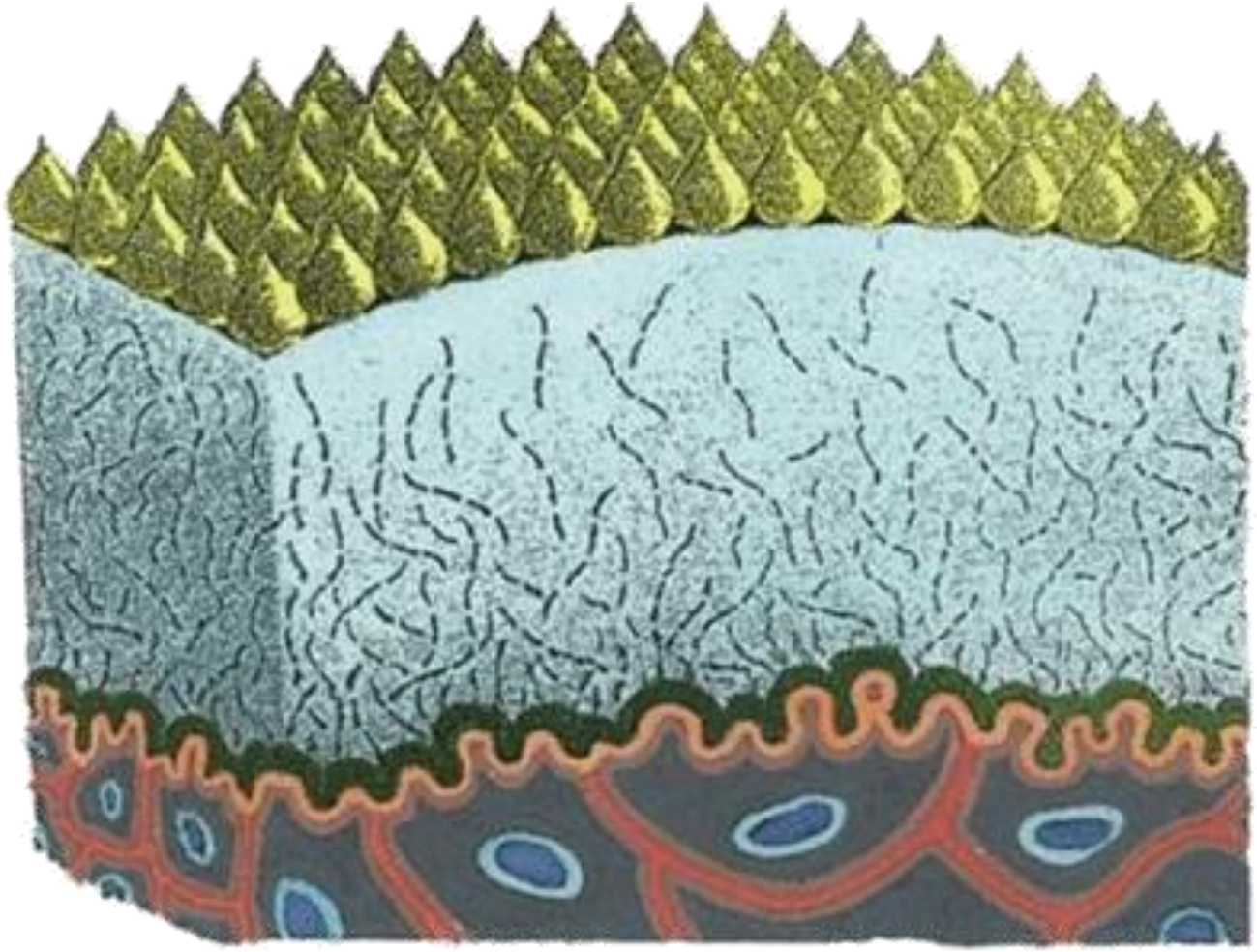
# Near vision



# Accommodated lens



# Tear film structure

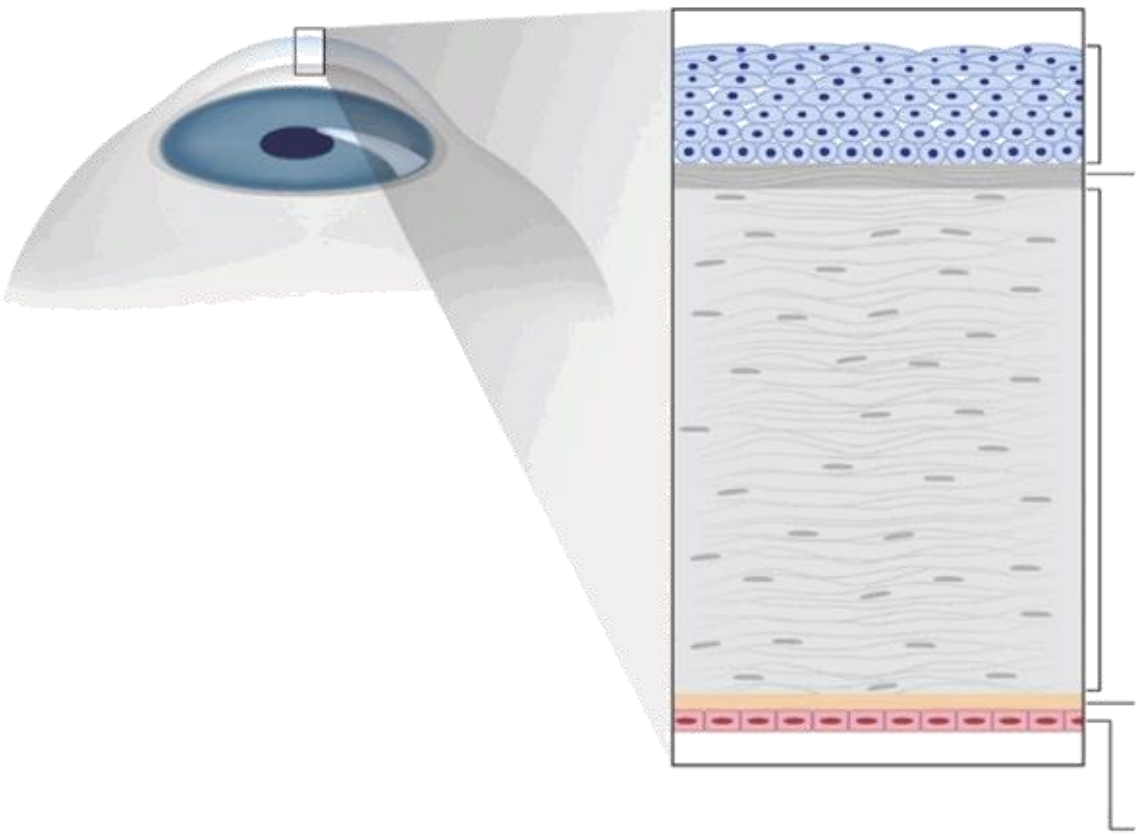


**Lipid layer**

**Aqueous layer**

**Mucus layer**

# Corneal histology



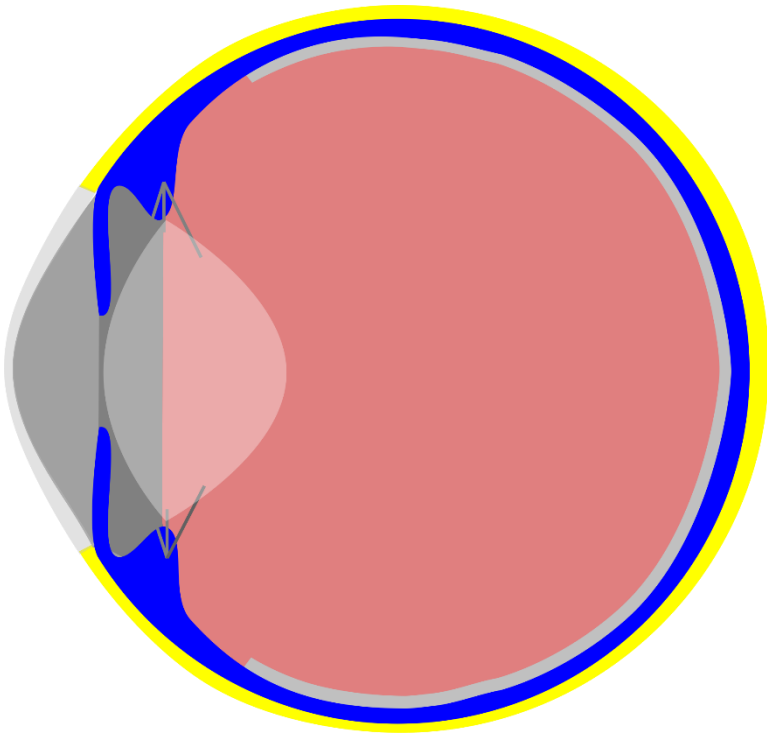
| Structure | Function |
| --- | --- |
| Epithelium | Rub resistance |
| Bowmans membrane | Osmotic counteraction |
| Stroma | Pressure resistance |
| Descemets membrane | |
| Endothelium | Osmotic counteraction |

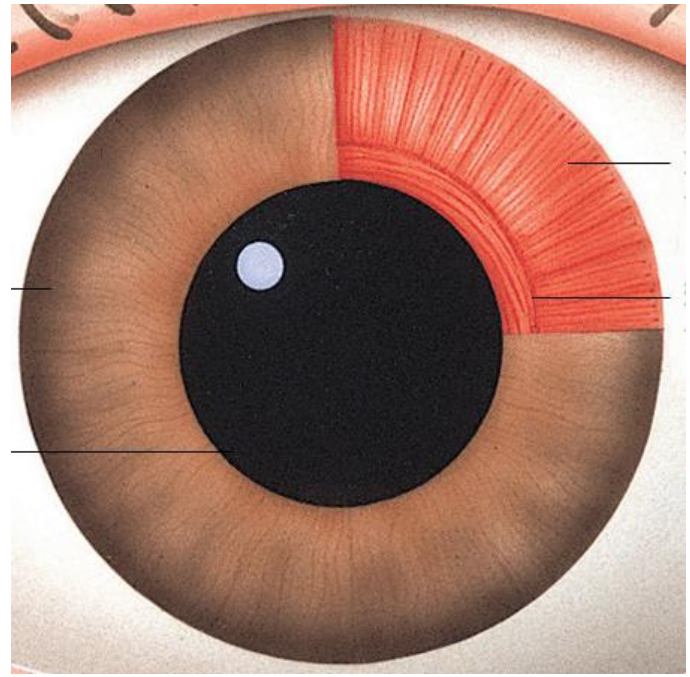
PS

Gullstrand lab

UPPSALA UNIVERSITET

# Light capturing limitation – the pupill





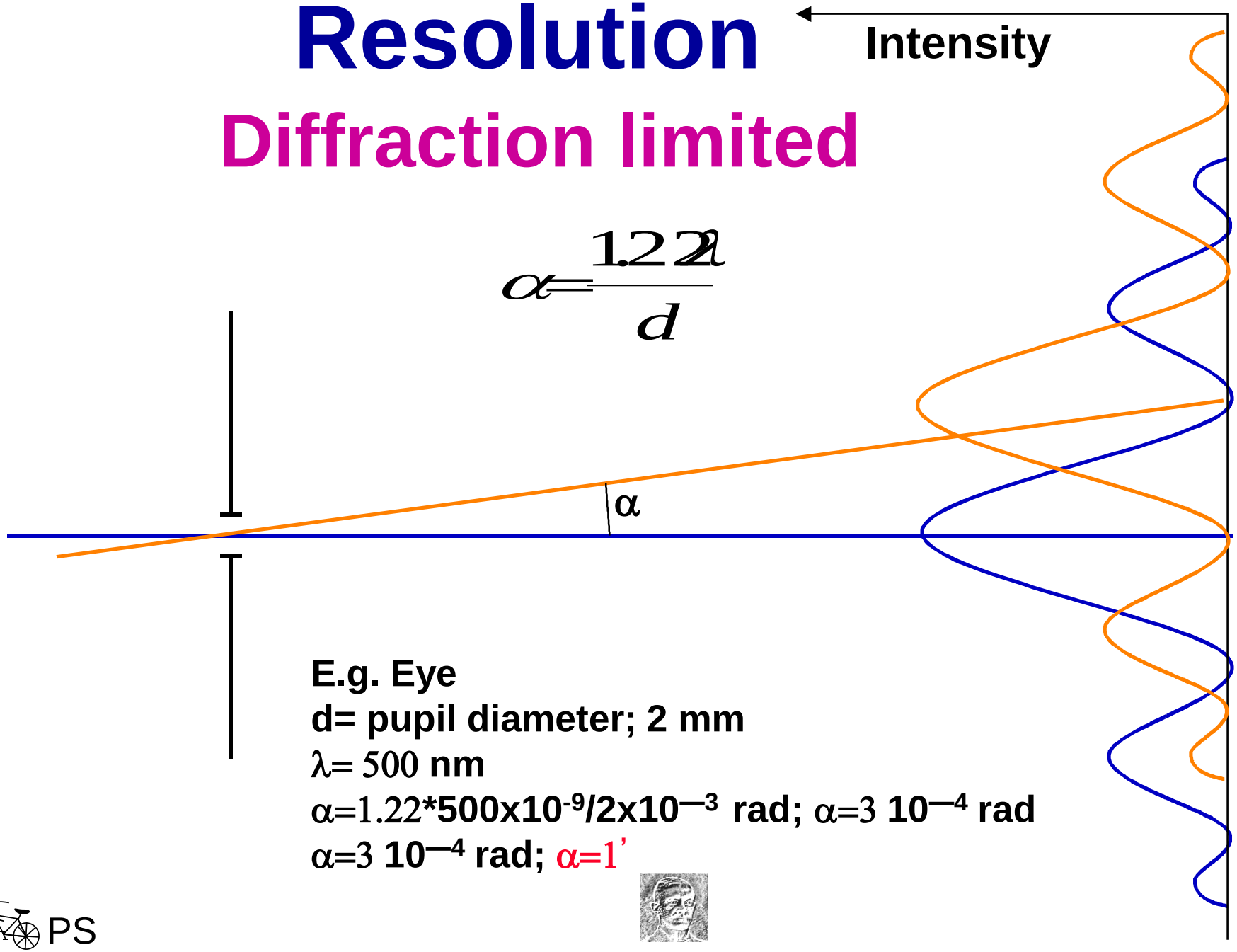
**Dilator muscle (sympathetic)**

**Sphincter muscle (parasympathetic)**

# Resolution

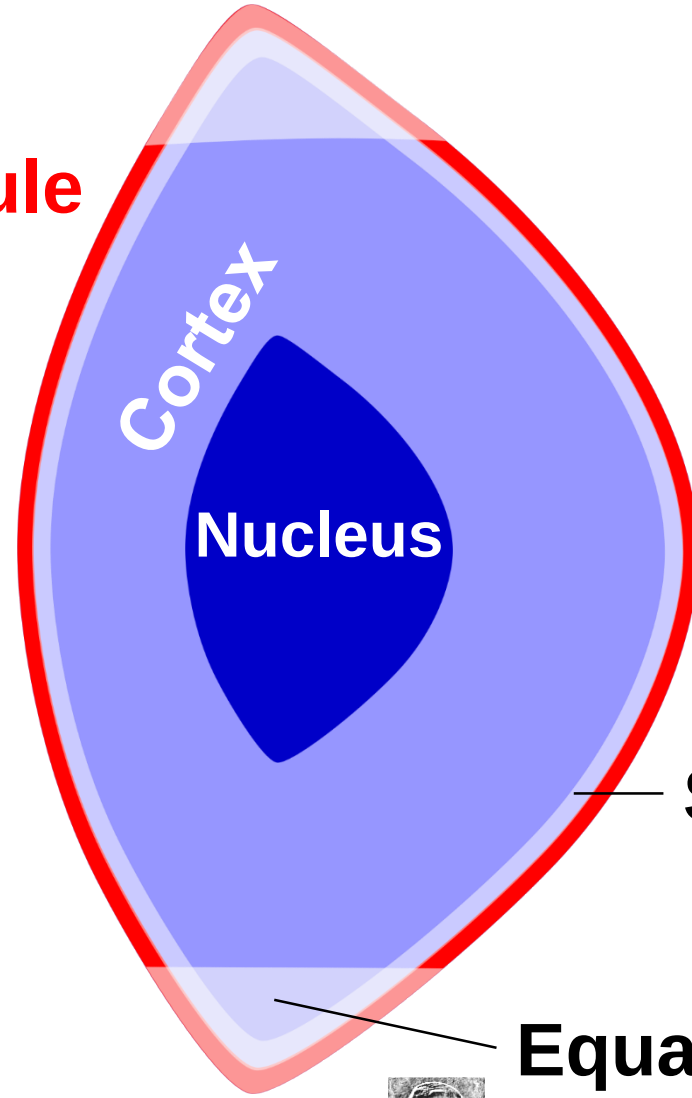
## Diffraction limited

$$\alpha = \frac{1.22\lambda}{d}$$

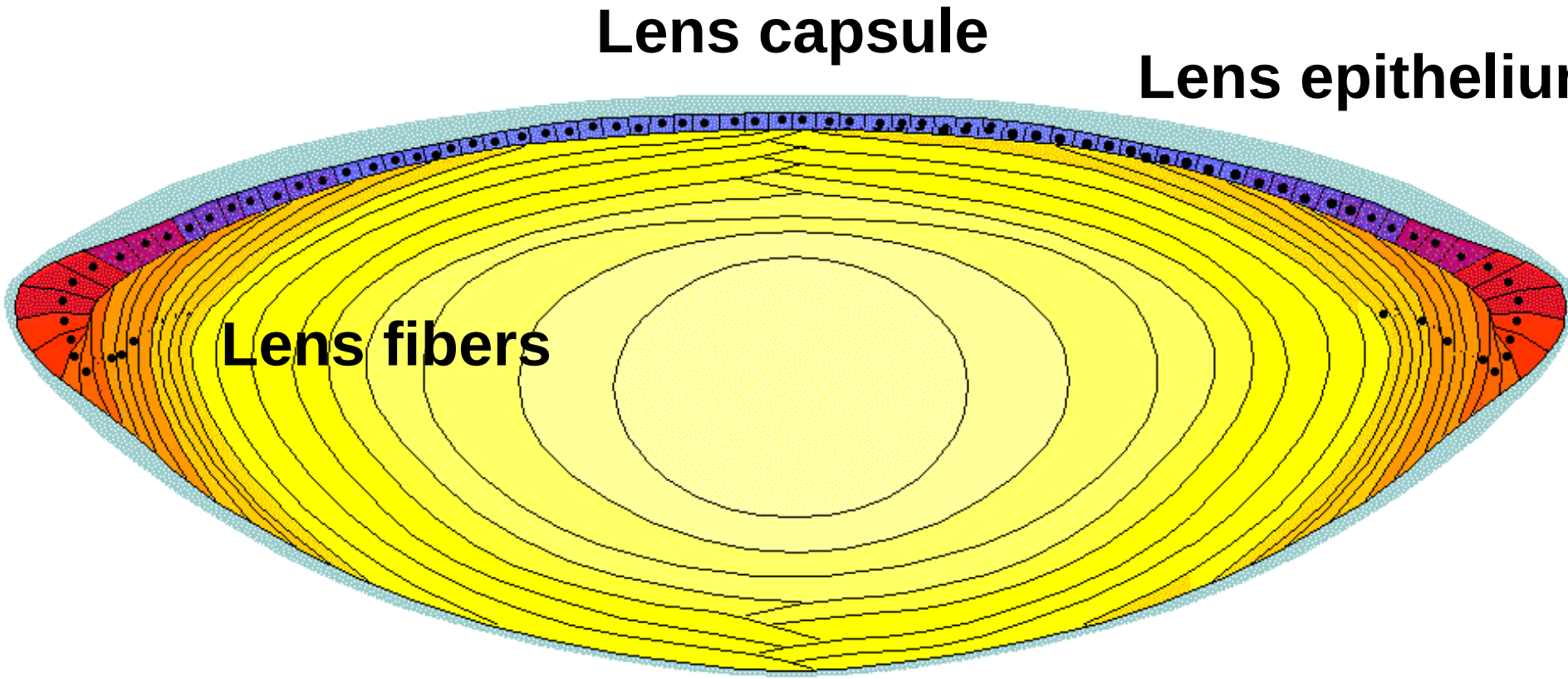



**E.g. Eye**
**d= pupil diameter; 2 mm**
**λ= 500 nm**
**α=1.22*500x10$^{-9}$/2x10$^{-3}$ rad; α=3 10$^{-4}$ rad**
**α=3 10$^{-4}$ rad; α=1'**

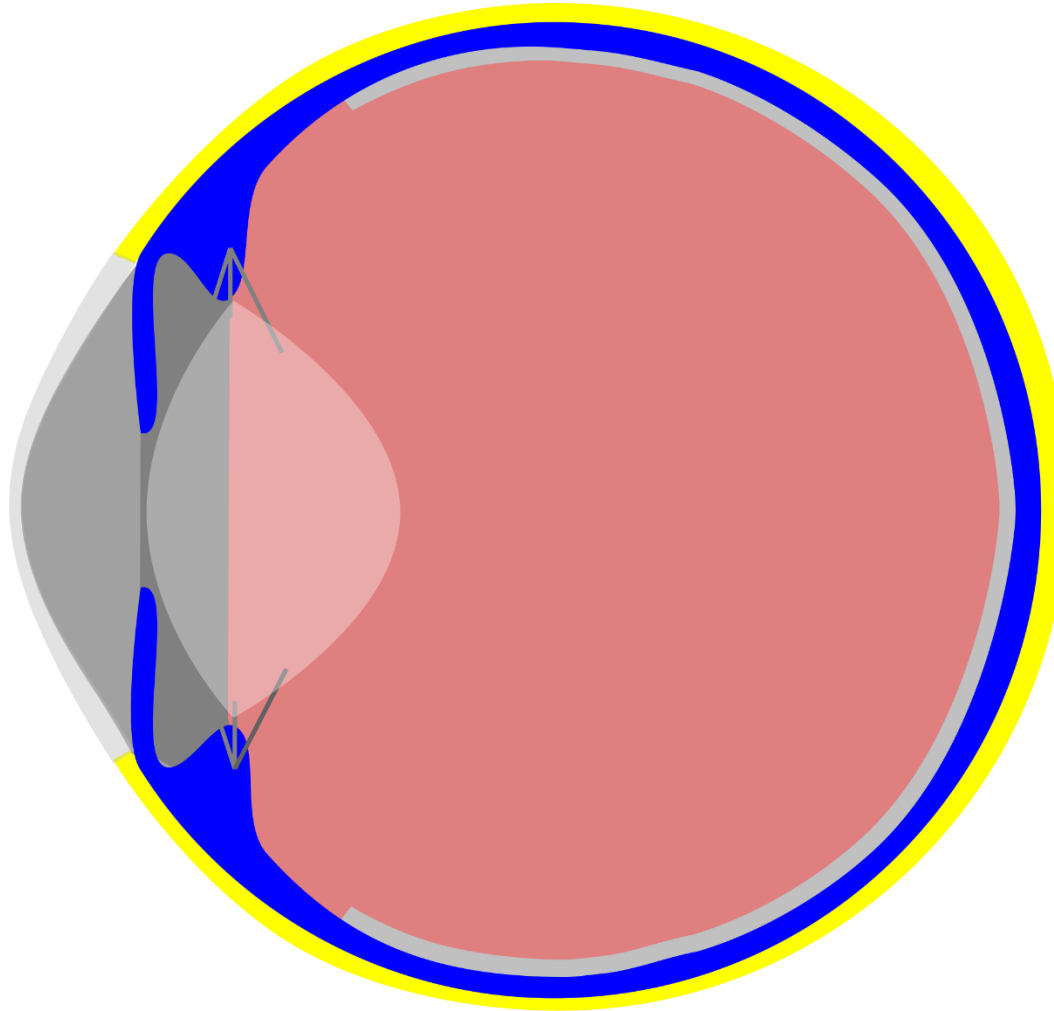
# Lens structure



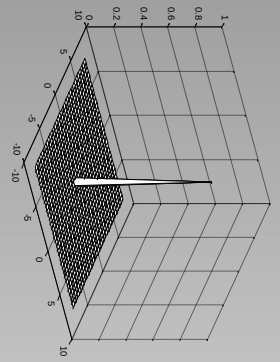
# Lens histology

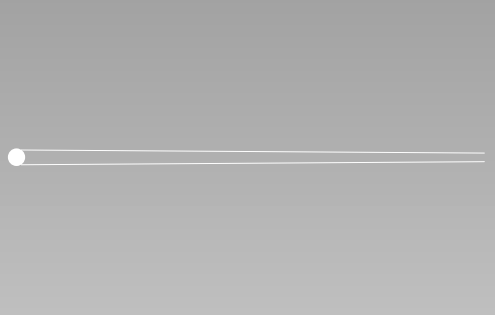


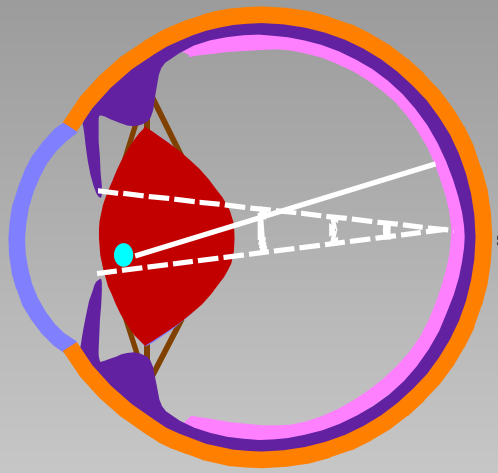
# Eye ball filler – the vitreous

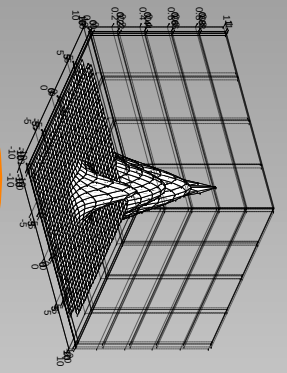


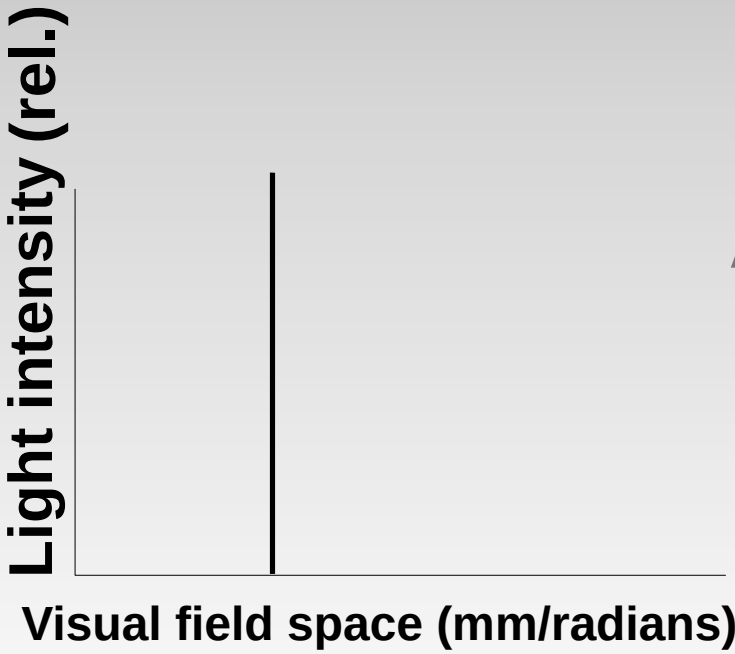
# Optical errors









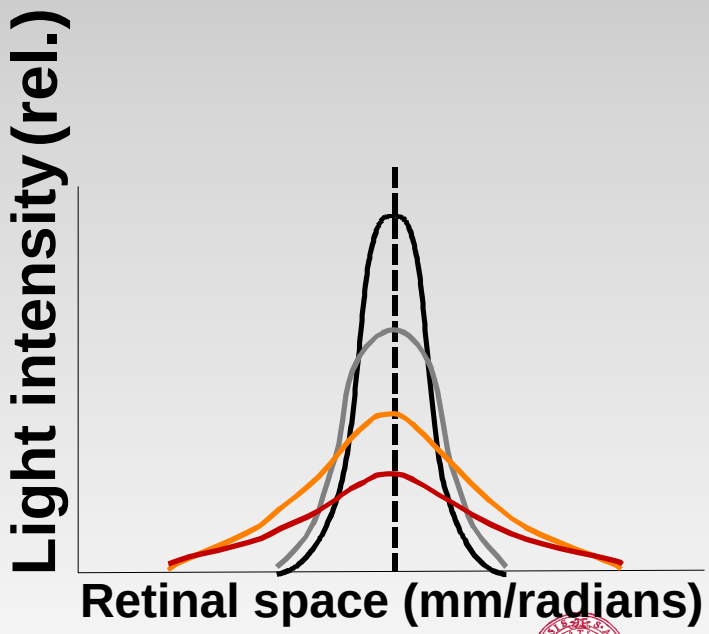



**Diffraction**

**Aberrations**

**Scattering**

**Absorption**



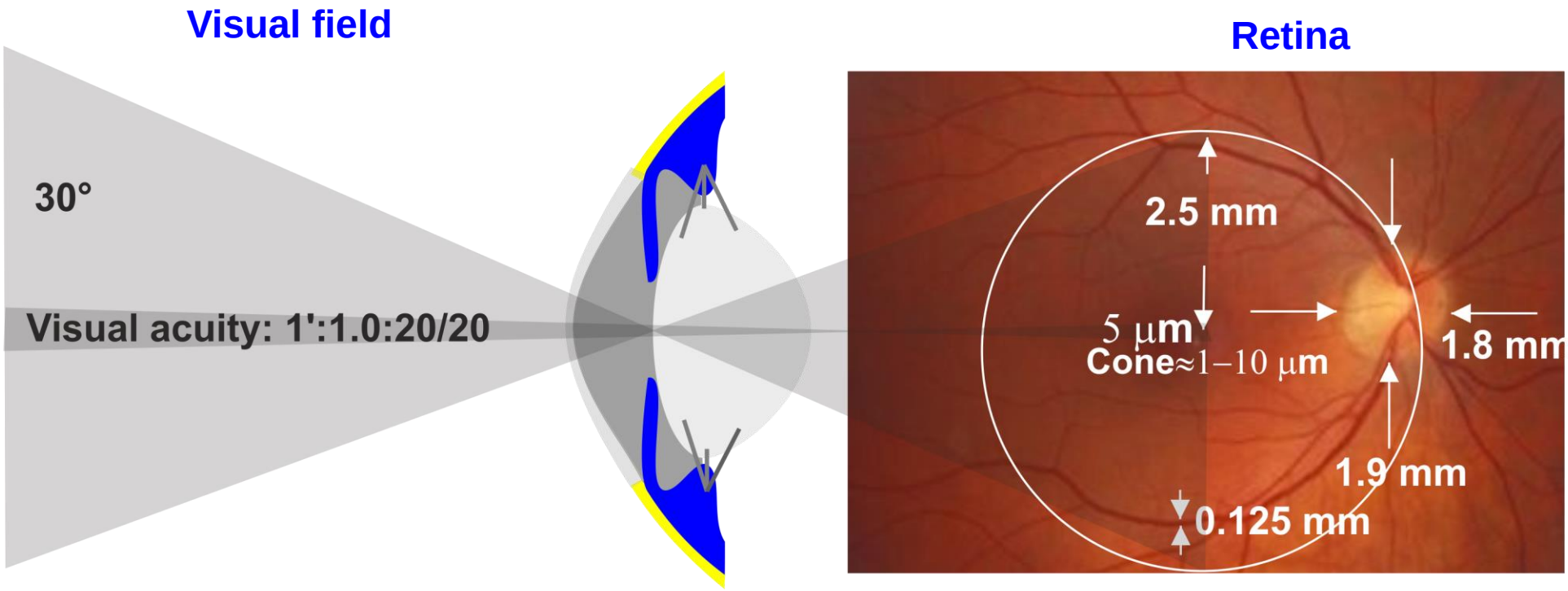

Gullstrand lab

PS

UPPSALA
UNIVERSITET

# Visual field projection on the retina

**1 arc minute (') = 1/60 degree**




**1.3 x10$^8$ photoreceptors in retina**
**1.3 x10$^6$ cables (axons) to the brain**

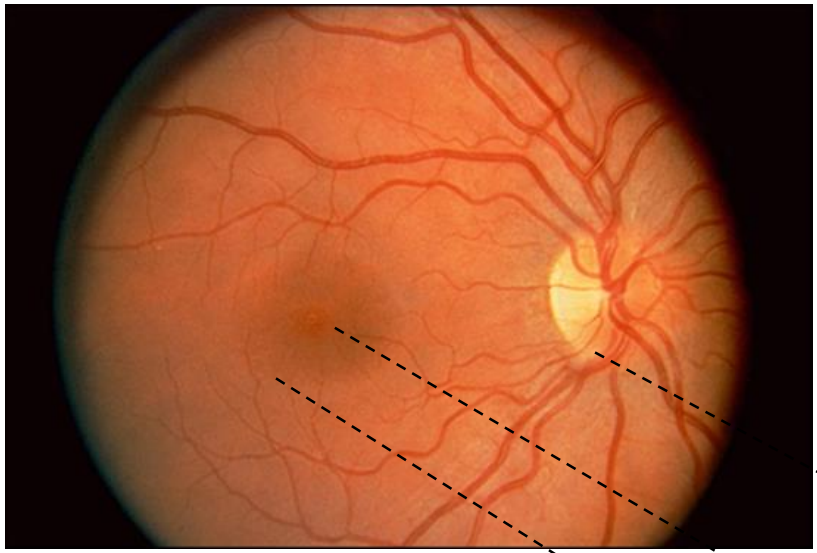
**Snellen E height: 5'**

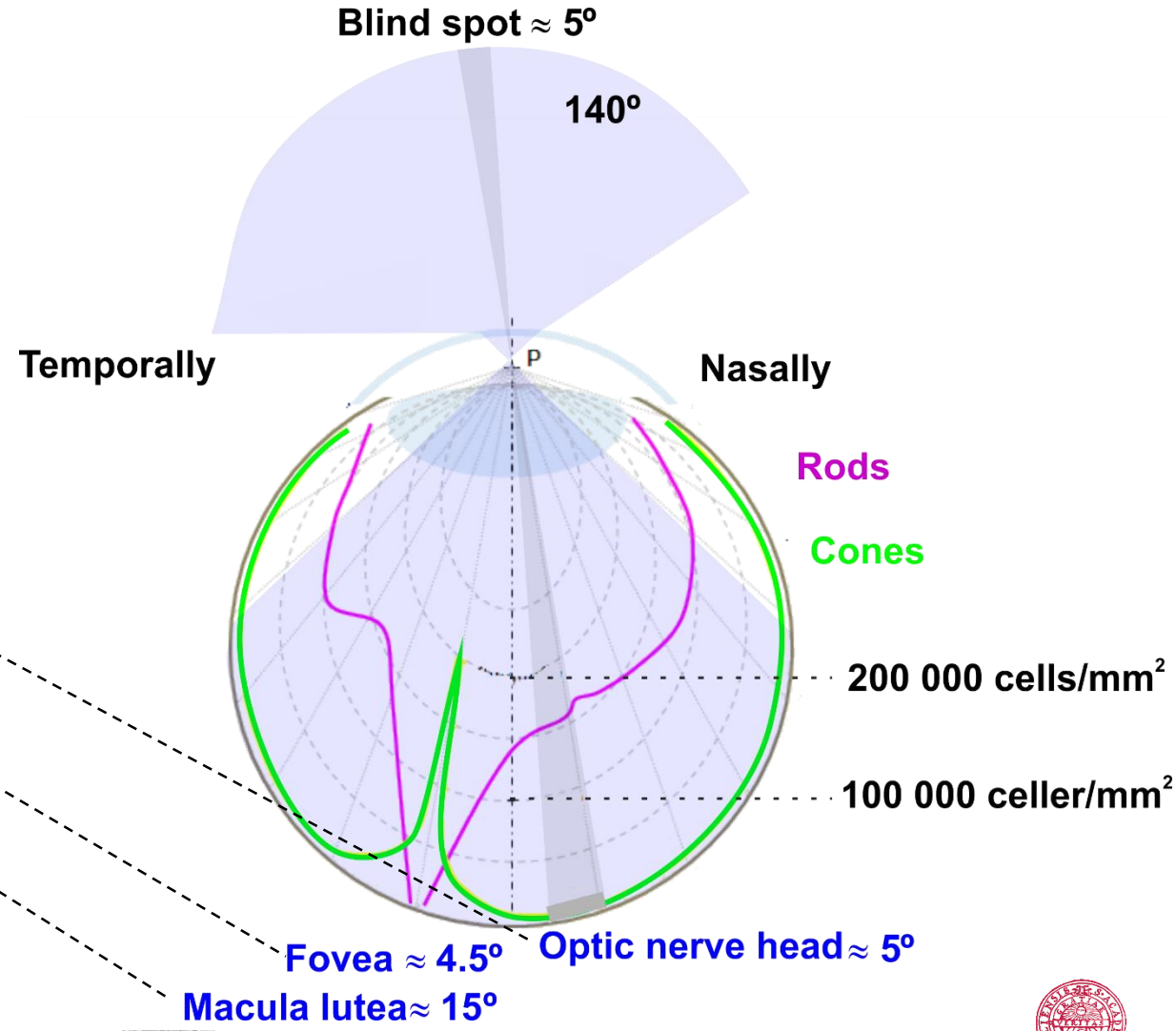
PS

Gullstrand lab

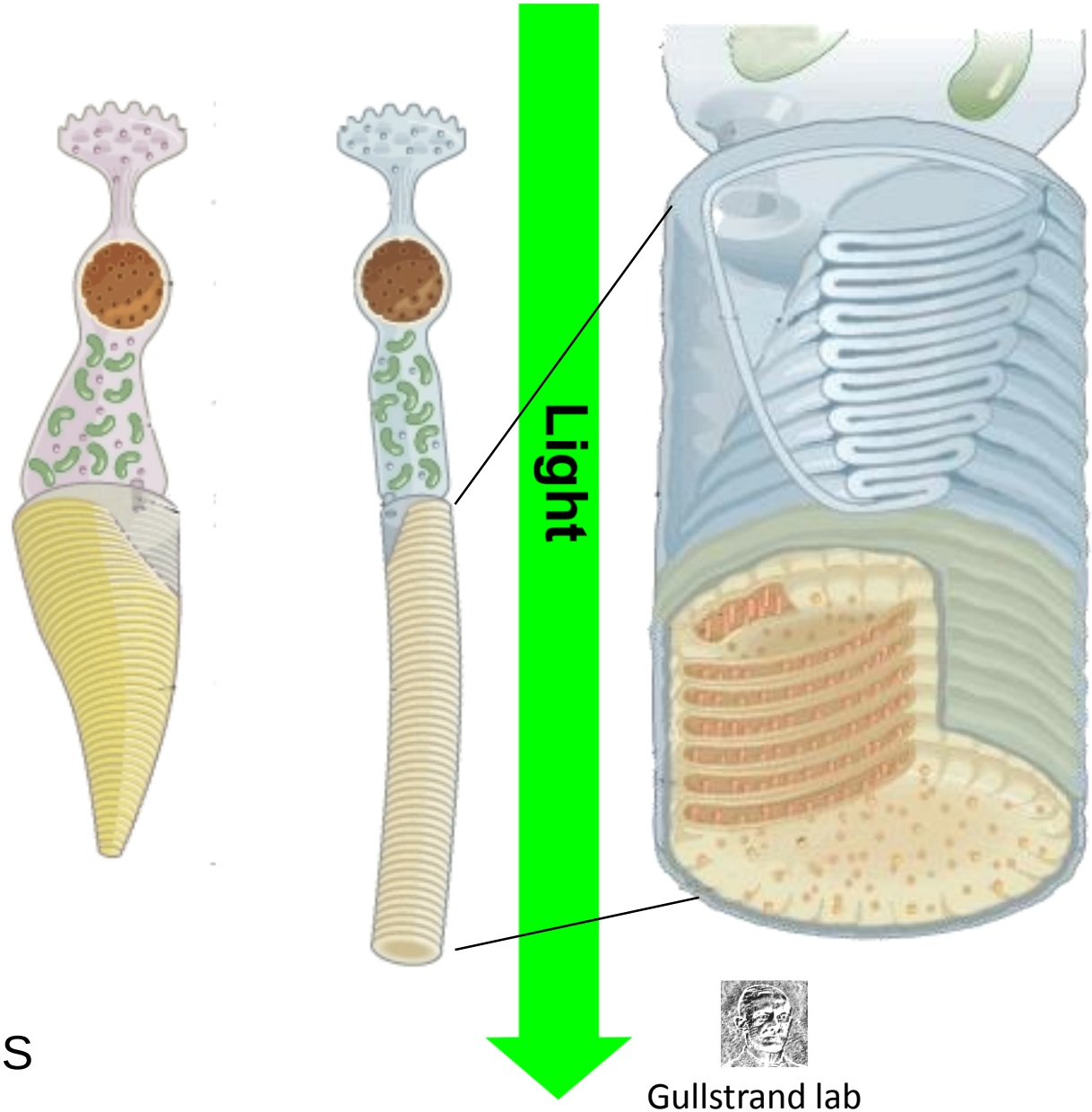
UPPSALA UNIVERSITET

# Photoreceptor distribution






# Structure photoreceptors




**Membrane bound vesicles**

**Rod/Cone-Opsin**

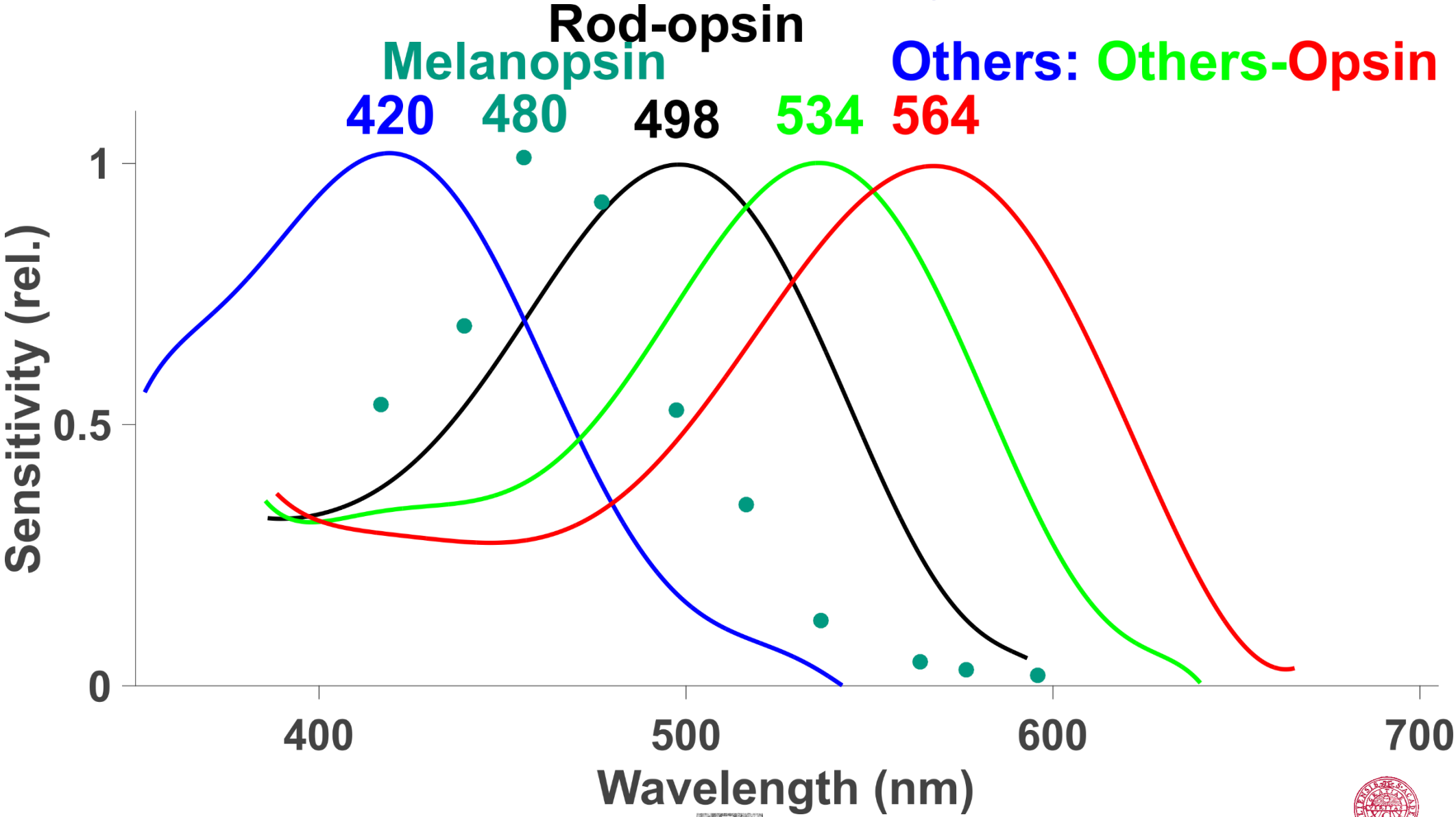


Gullstrand lab

PS

UPPSALA UNIVERSITET

# Photoreceptor and melanopsin pigment sensitivity



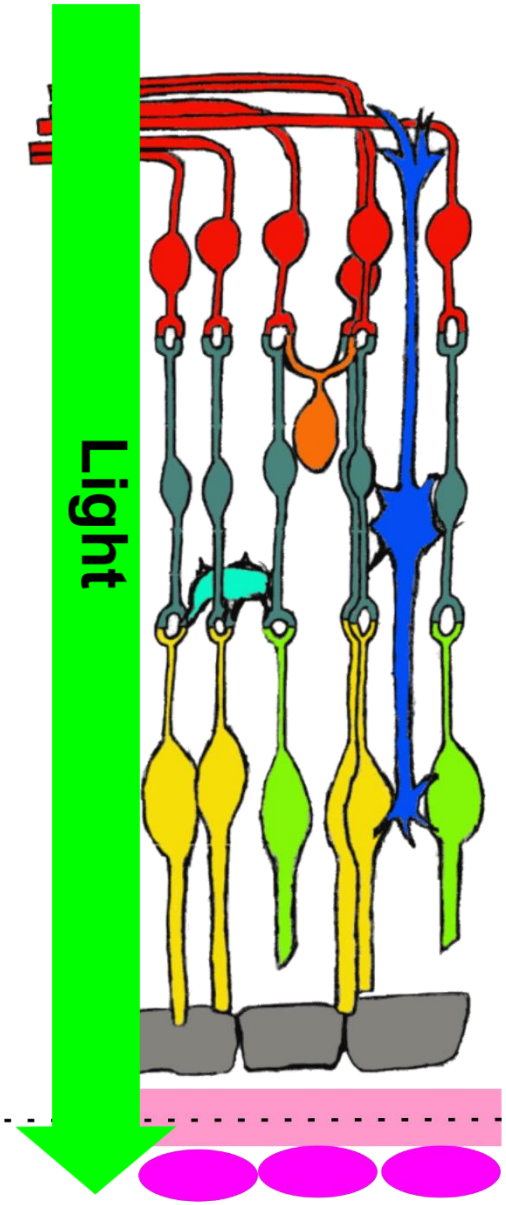

Bailes et al, 2012

PS

Gullstrand lab

UPPSALA UNIVERSITET

# Retina




Proportion

Ganglion cells (Digital) 1

Amacrine cells

Bipolar cells (Analog)

Muller cells

Horisontal cells

Cones (Analog)

Rods (Analog) 100

Pigment epithelilal cells

Bruchs membrane

Chorioid

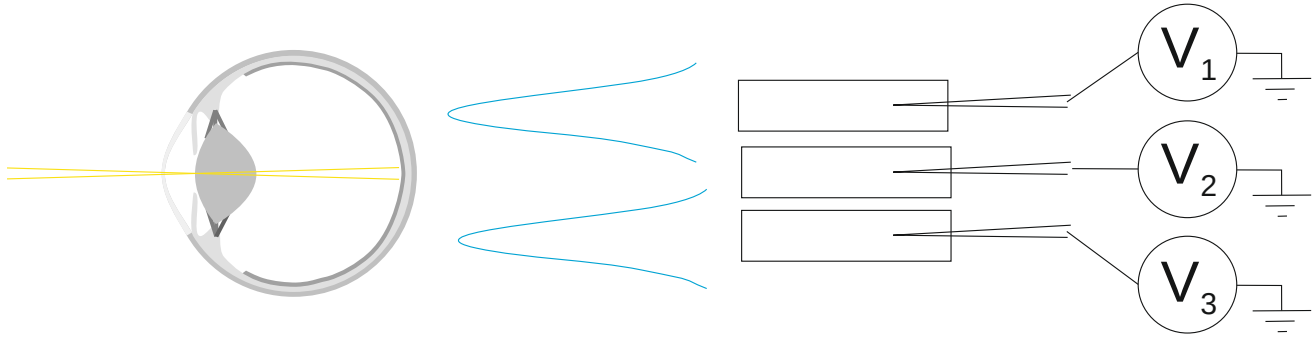
Capillaries

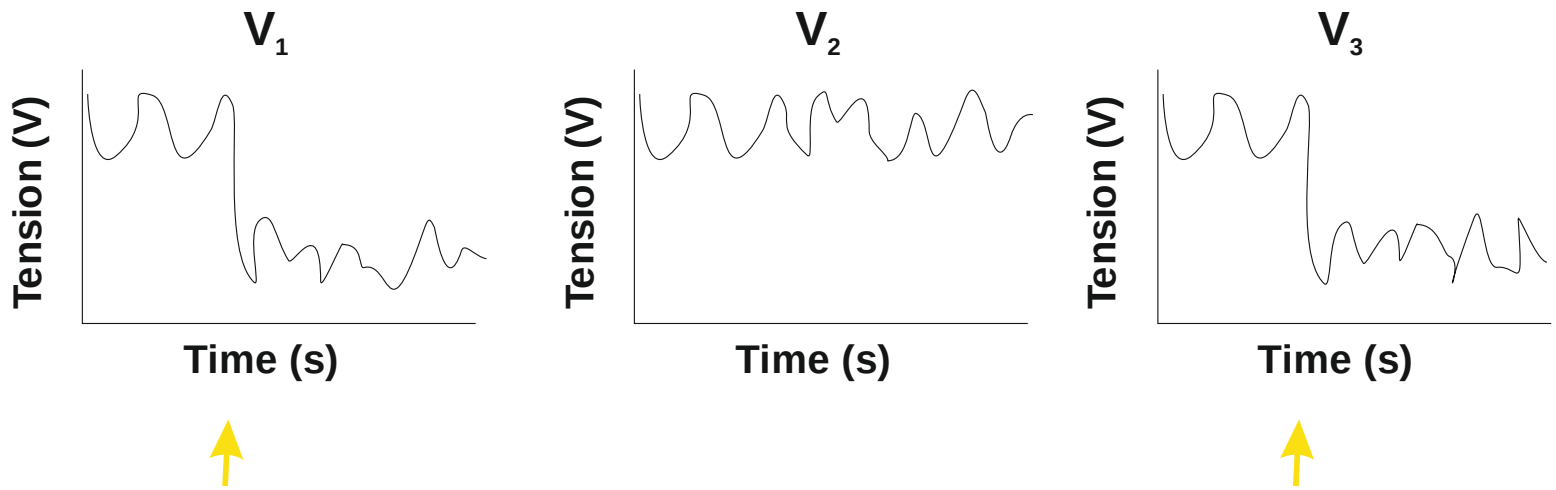
PS

Gullstrand lab

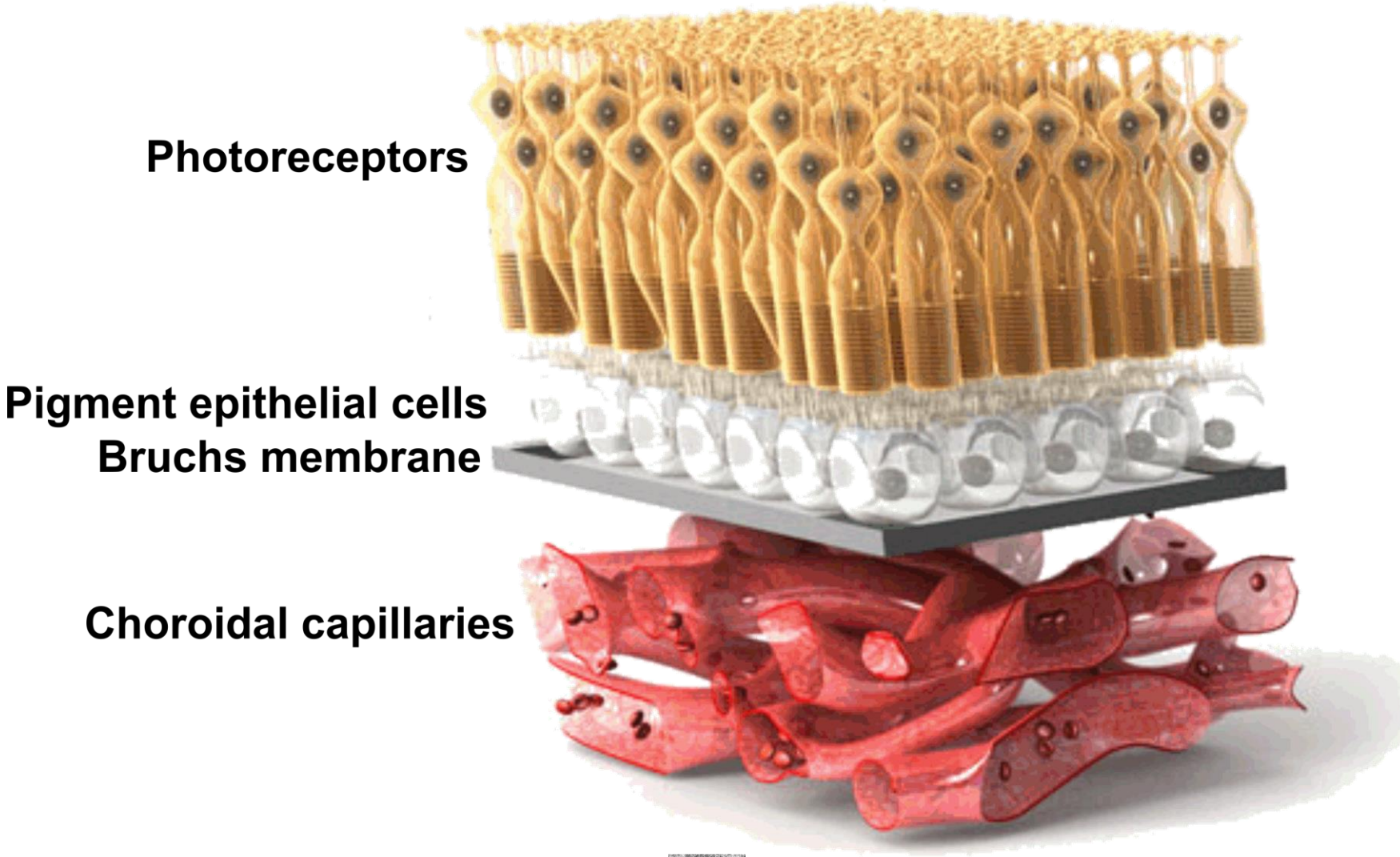
UPPSALA UNIVERSITET

# Retinal signaling, two resolved points

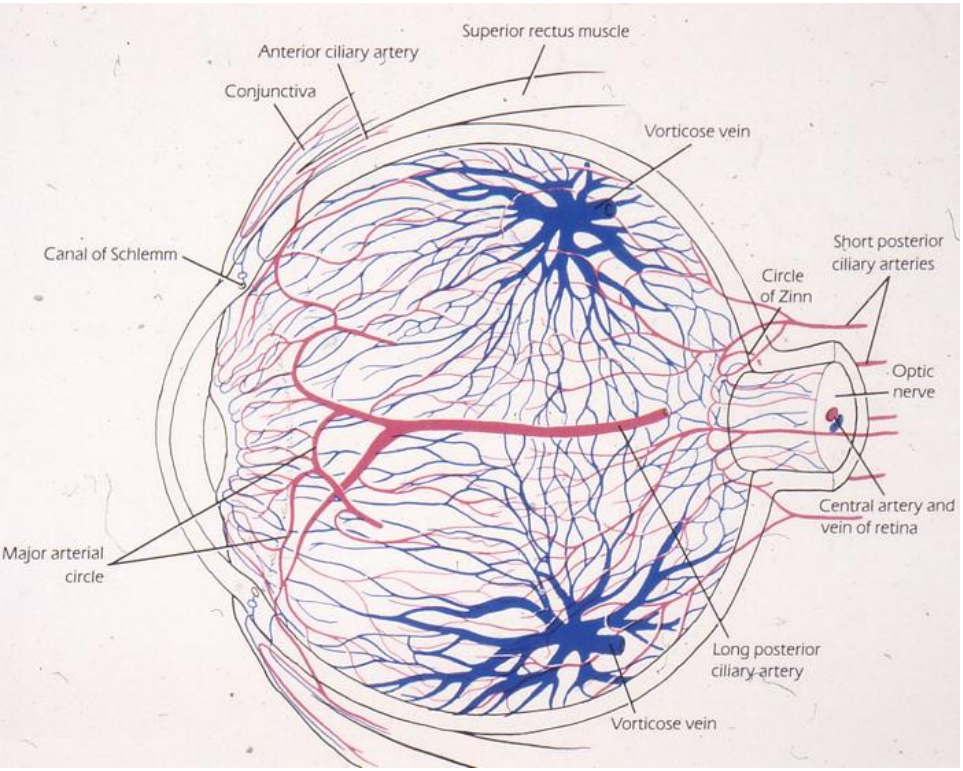


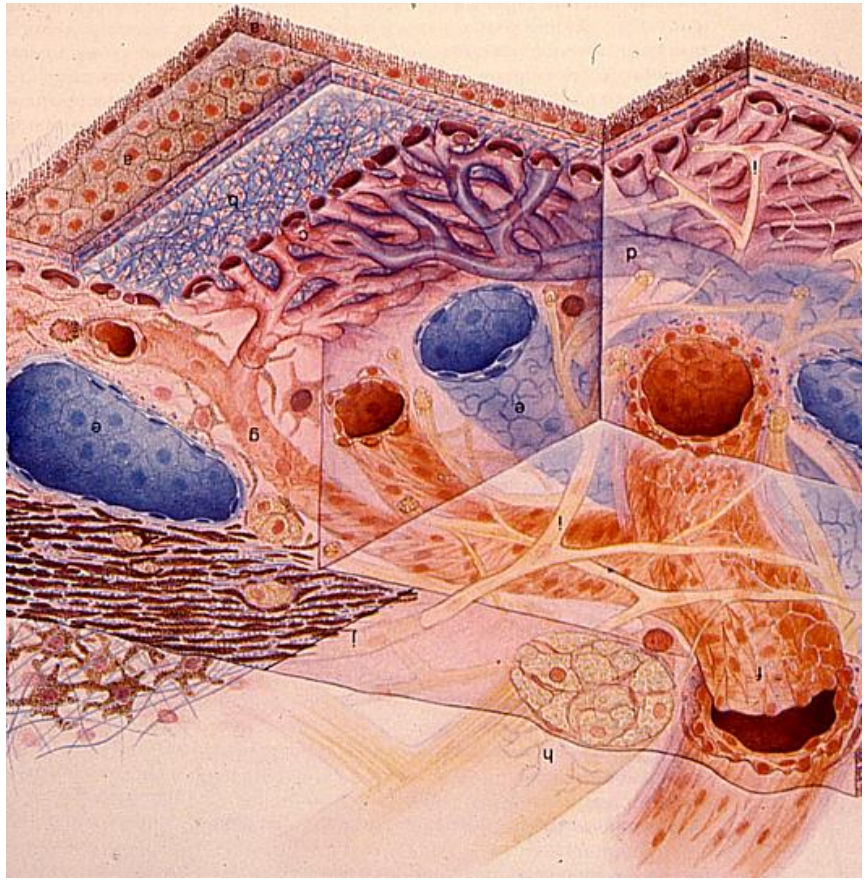
# Photoreceptor blood supply



# Photoreceptor blood supply




**Retinal photoreceptors**



**Choroid**

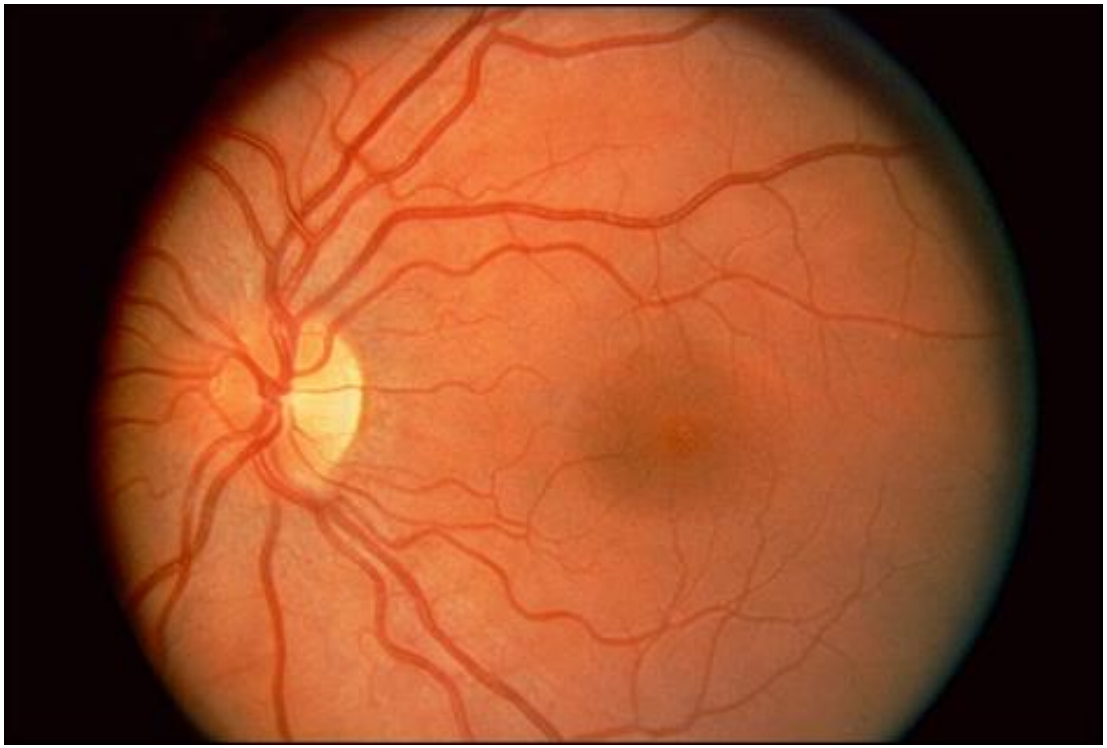
**Scleral wall**

Gullstrand lab

PS

UPPSALA UNIVERSITET

# Inner retina blood supply

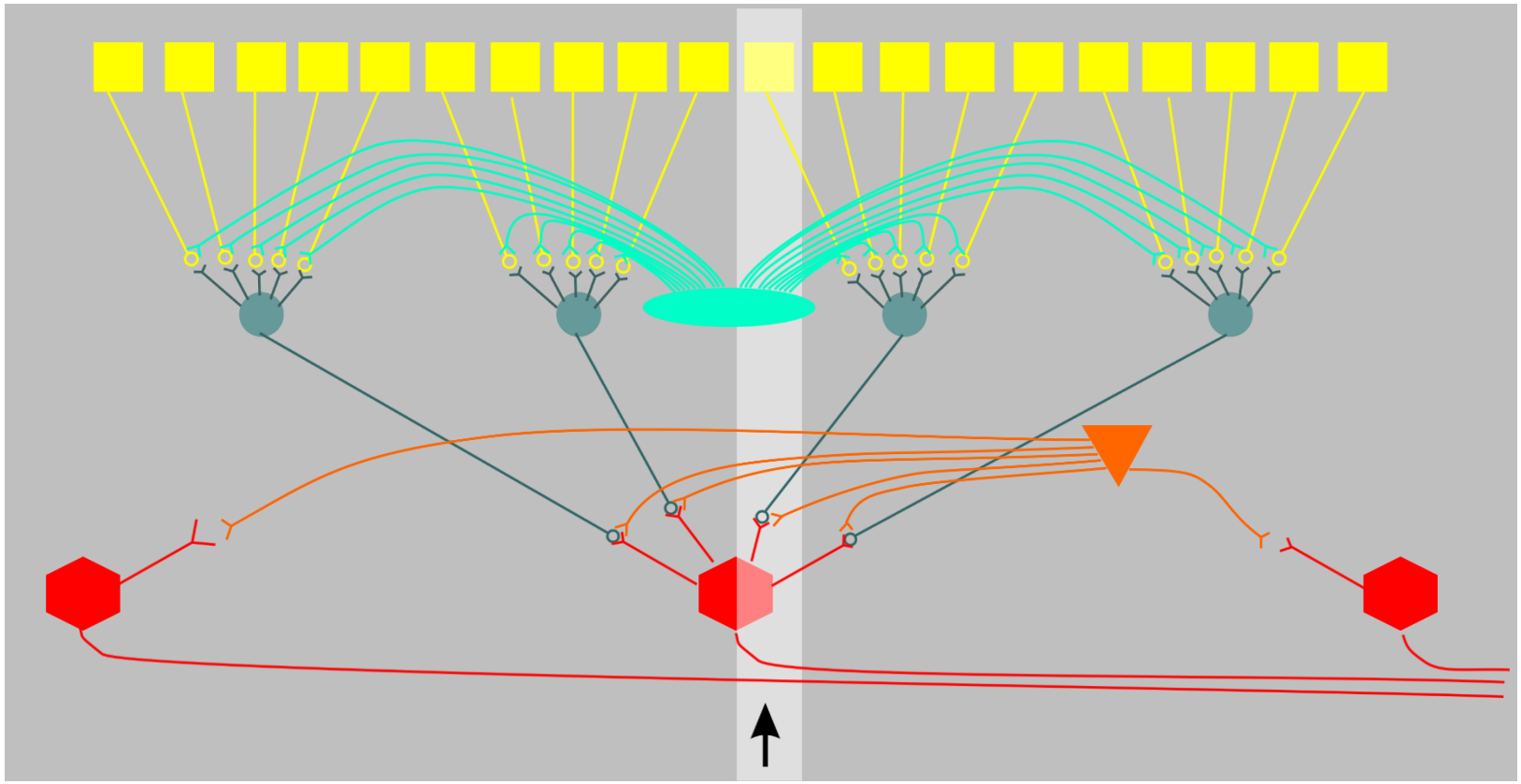


PS

Gullstrand lab

UPPSALA
UNIVERSITET

# Retinal circuitry



Fotoreceptors
Transduction
Analog response

Horisontal cells
Integrating

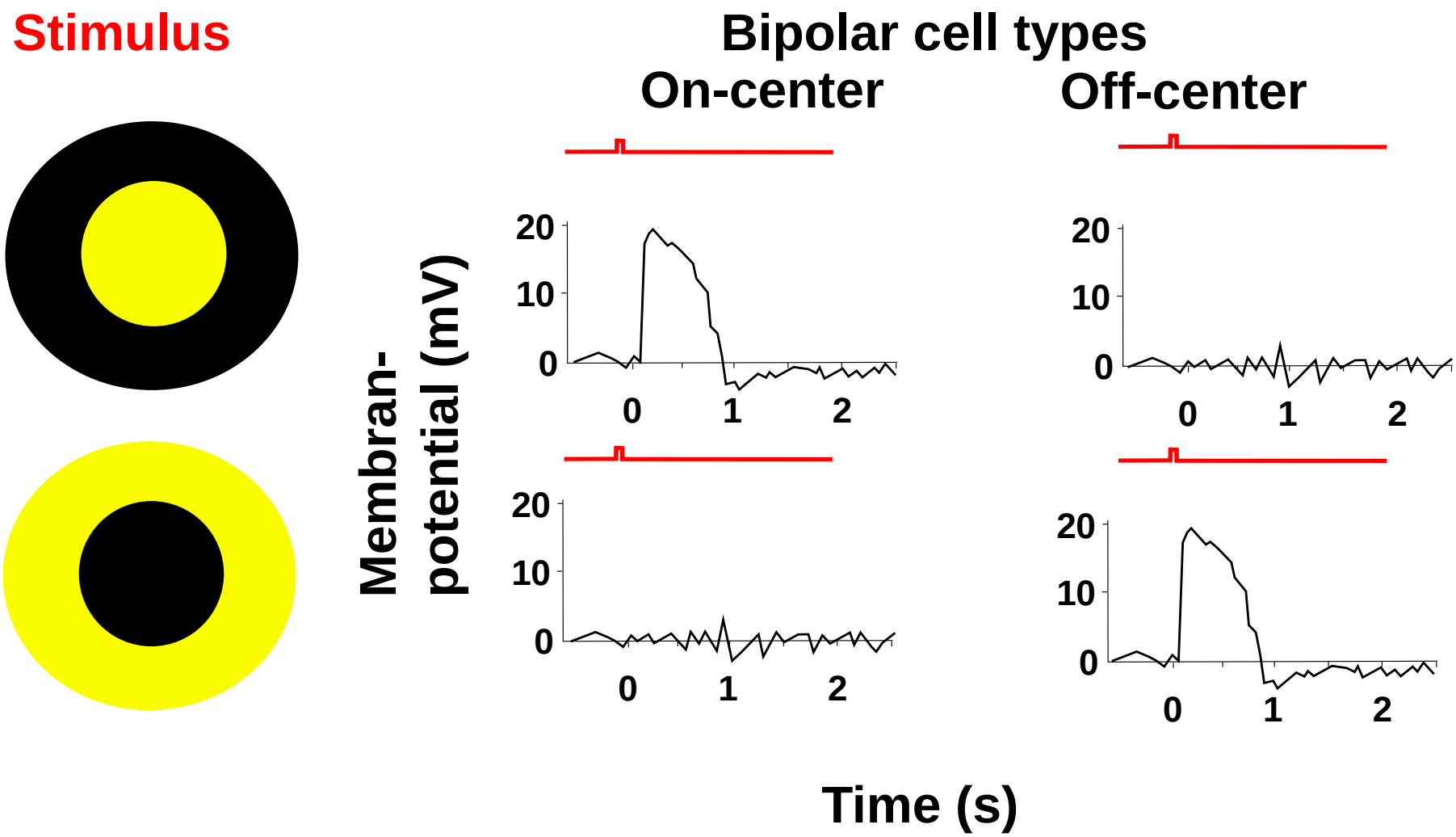
Bipolar cells
Transmission
Analog response

Amacrine cells
Integrating

Ganglion cells
Output
Digital response

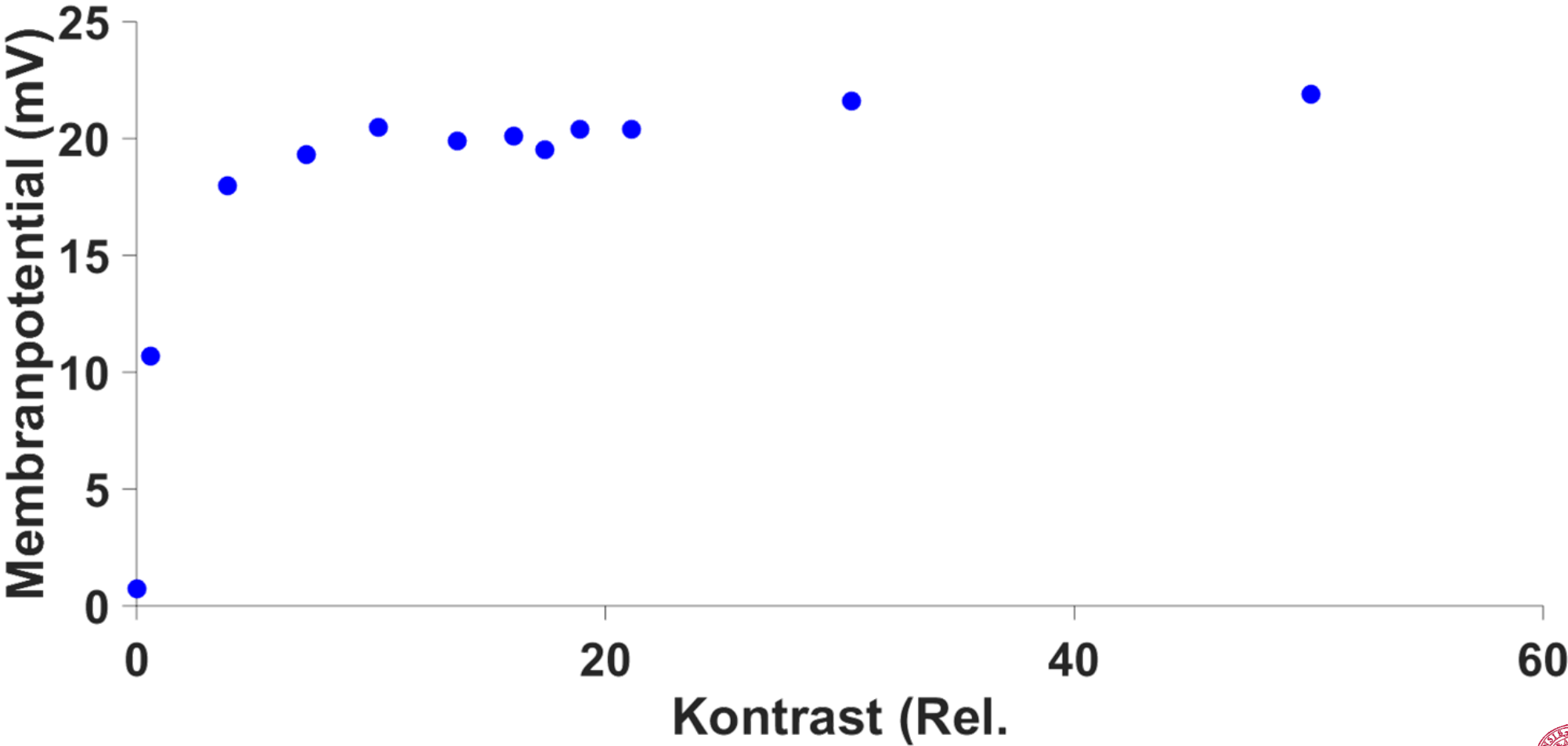
**Center on stimulus**
**(Light in the center of photoreceptor matrix, darkness around)**

# The bipolar cell responds to several photoreceptors in a receptive field



# Membranpotential in the bipolar cell as a function of contrast in the receptive field

**Output signal is analogly coded**




PS

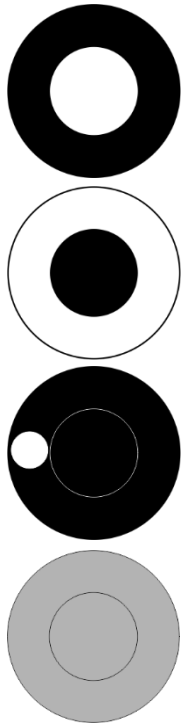
Gullstrand lab

UPPSALA UNIVERSITET

# Response in the ganglion cell
## One ganglion cell covers a receptive field of photoreceptors

**Output signal is digitally coded**

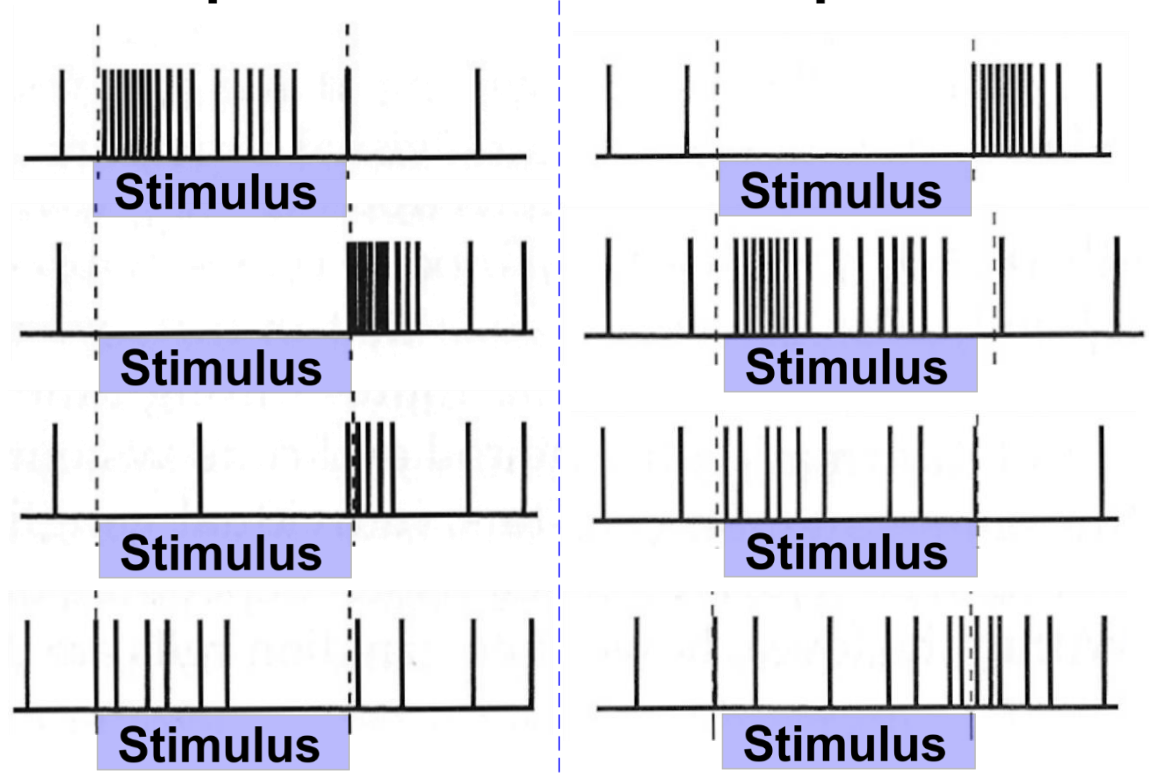
**Stimulus on the retina over several photoreceptors**



**Ganglion cell type**

**On-center response**

**Off-center response**

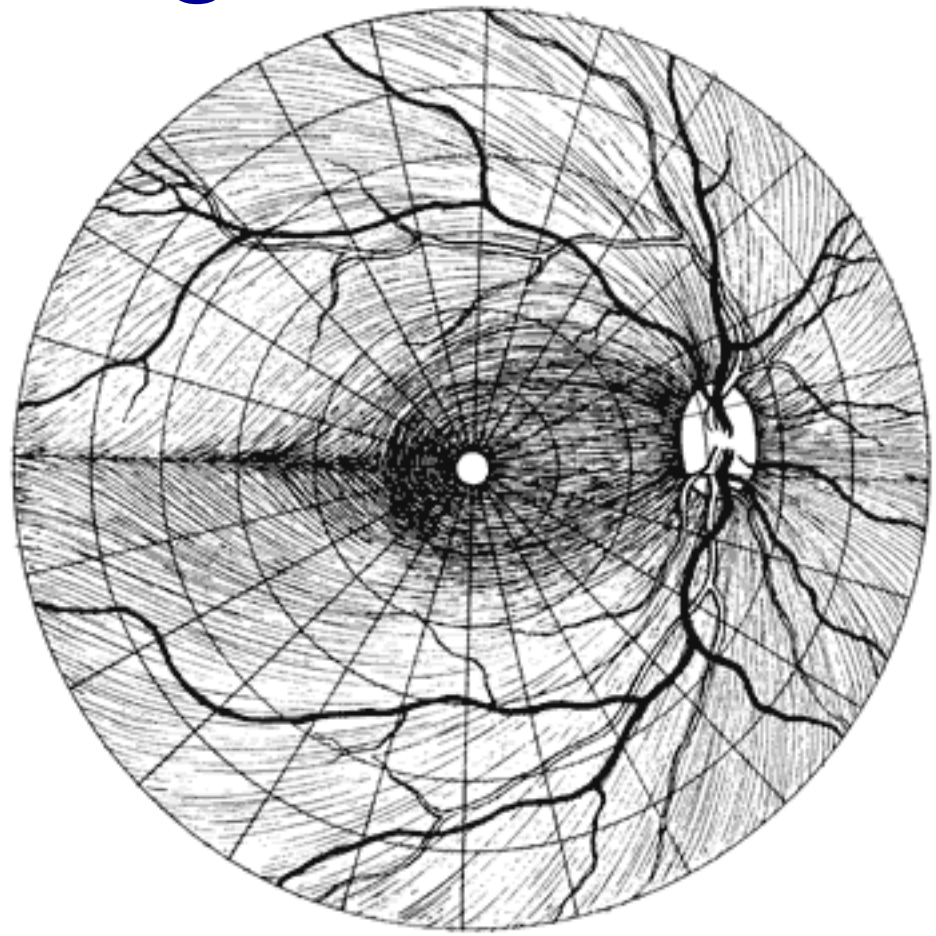



Gullstrand lab

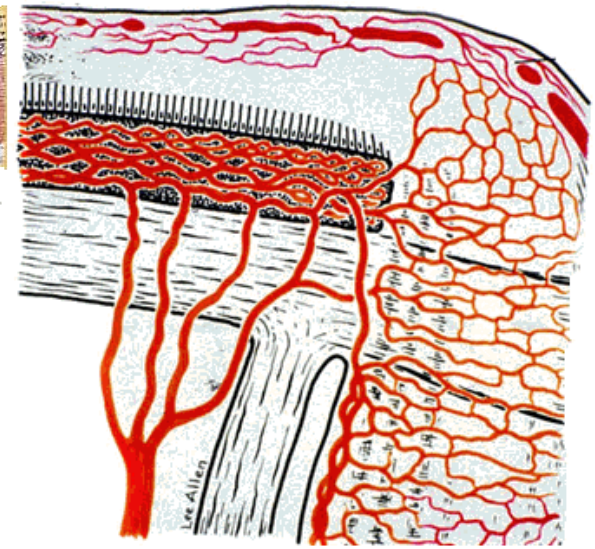
PS

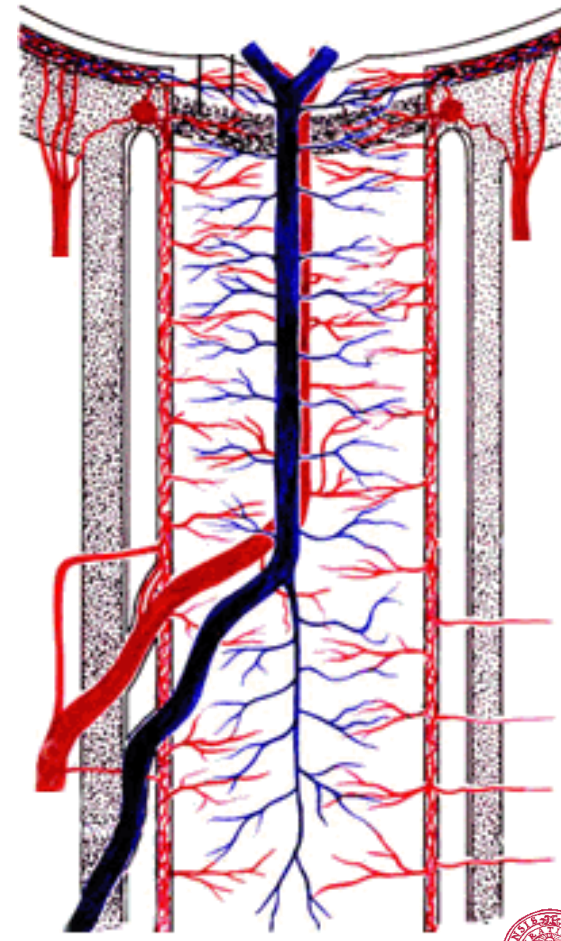
UPPSALA UNIVERSITET

# Retinal output cables
# Ganglion cell axons



# Optic nerve head



PS

Gullstrand lab

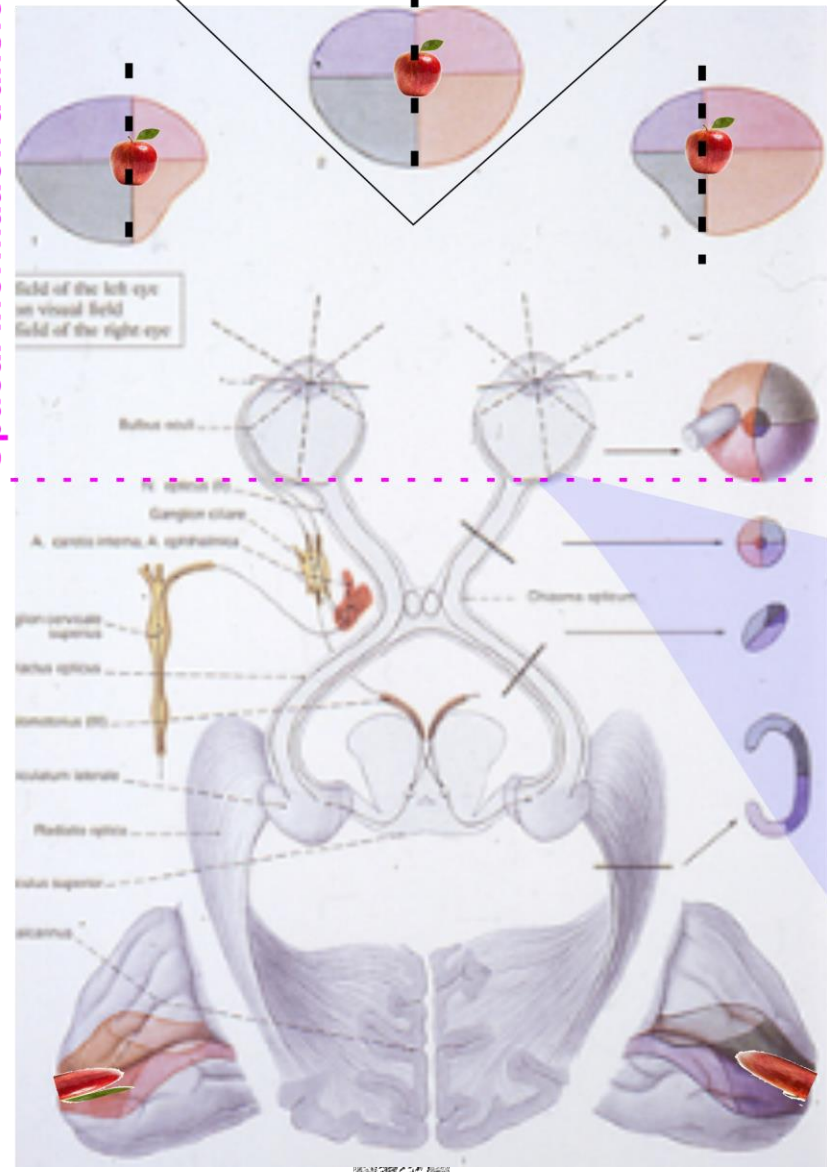
UPPSALA
UNIVERSITET

# ImageTransfer

- The pupil size determines the absolute limit for the resolution of the image. (Amount of information transfer per time).
- Incorrect refraction (aberrations), scattering and absorption reduce the contrast in the image on the retina
- Light scattered from one point in the visual field is spread out over the surface of the pupil.
  The pupil does NOT per se limit the visual field.
- The visual field is limited by the relationship between the border of the orbit/nose and the pupillary border

Optical inormation transfer

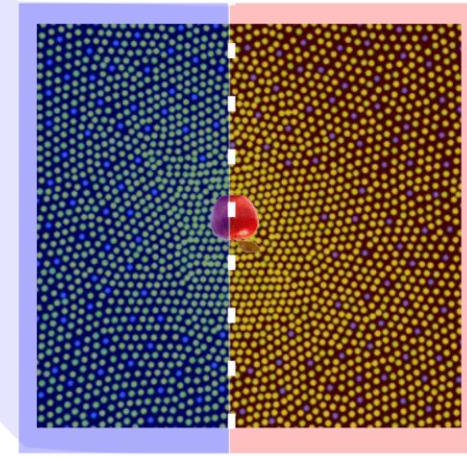
## Binocular visual field



- Loss of photoreceptors reduce the neuronal resolution
- Dislocated photoreceptors cause metamorphopsia
- Structural loss in the visual pathway causes loss of visual field

Neuronal information transfer

## Right macula front view



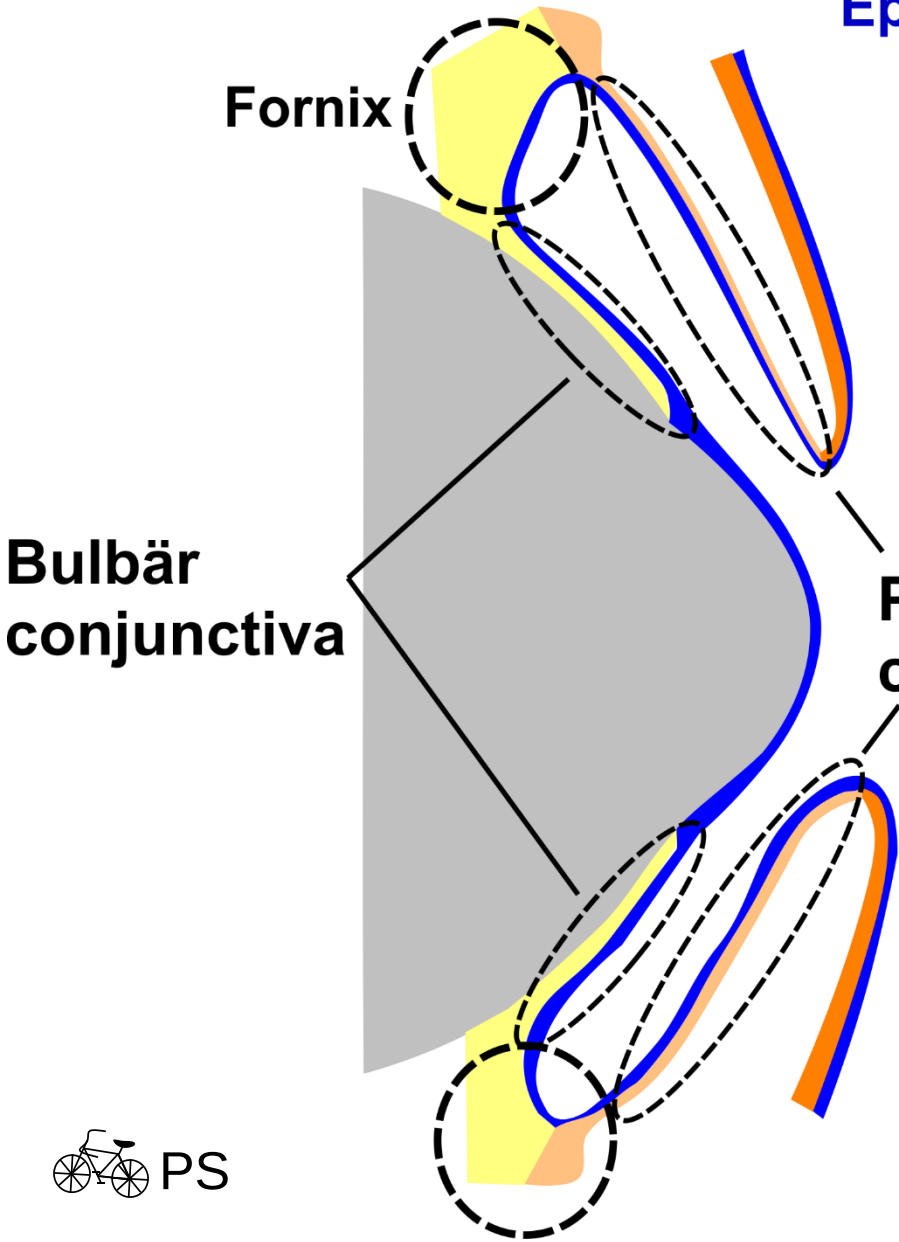
PS

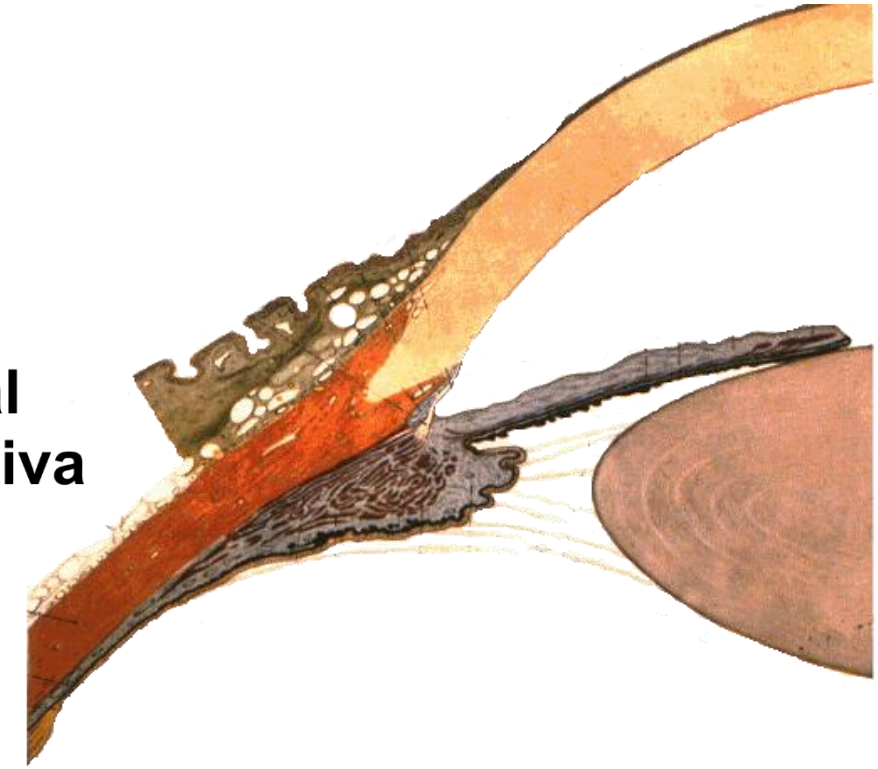
Gullstrand lab

UPPSALA UNIVERSITET

# Ocular surface

## Epithelium



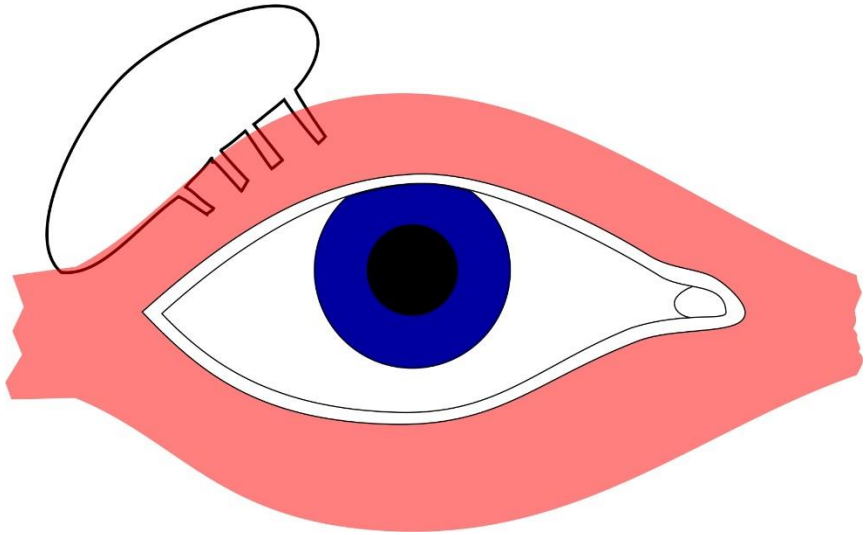
PS

Gullstrand lab

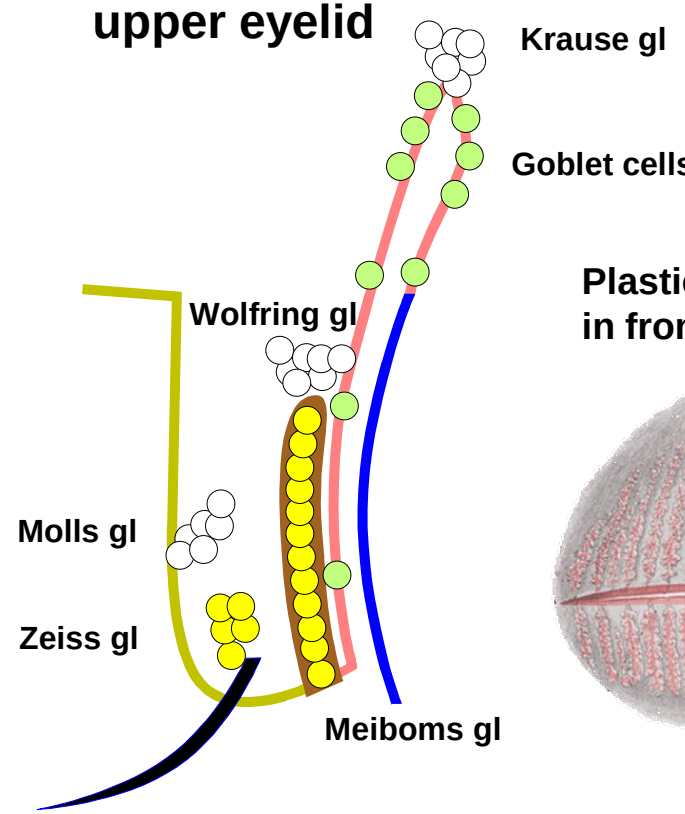
UPPSALA UNIVERSITET

# Tear production

**Glandula lacrimalis**

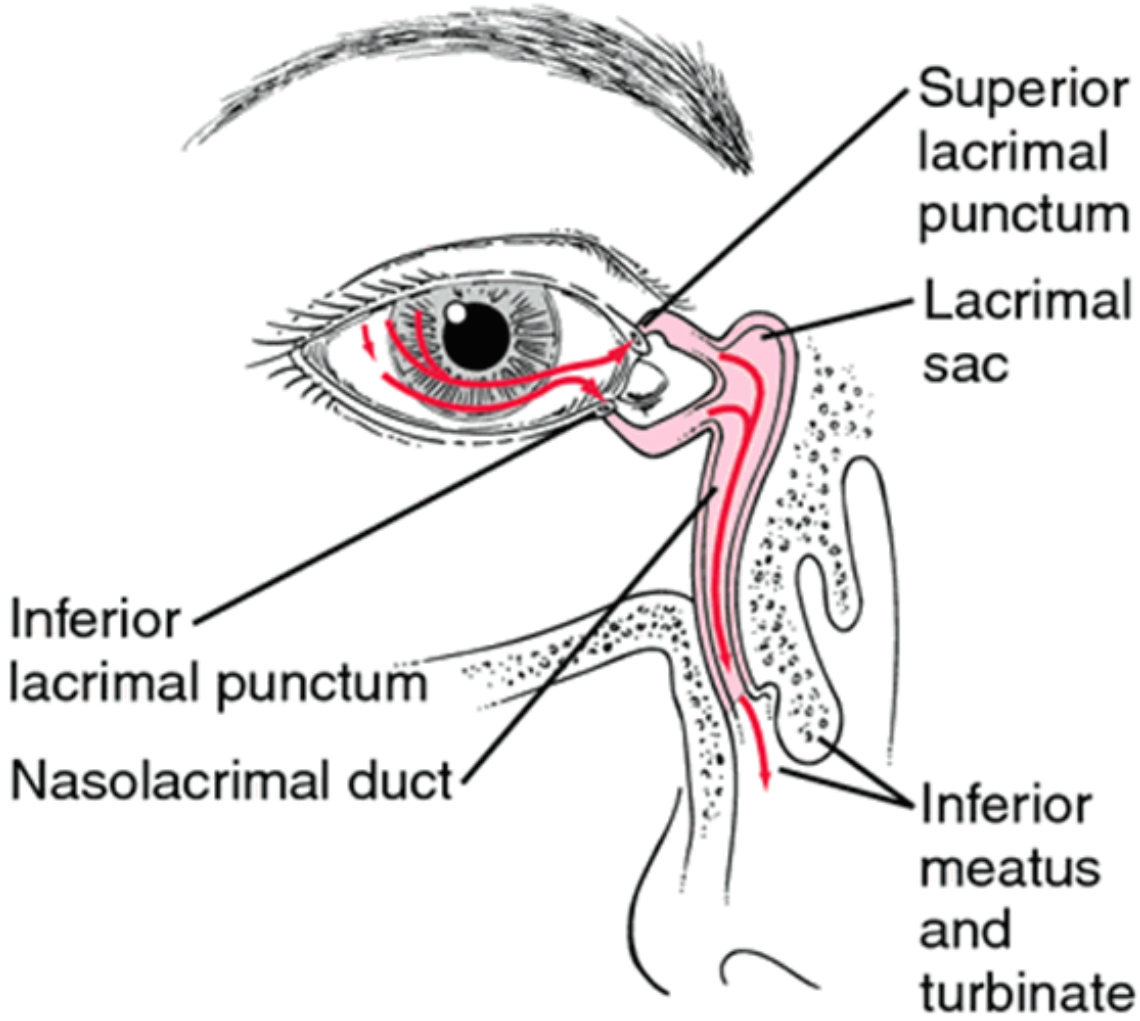


**Sagittal plane through upper eyelid**




**Plastic mold of Meiboms glands in frontal plane**

# Tear drainage




PS

Gullstrand lab

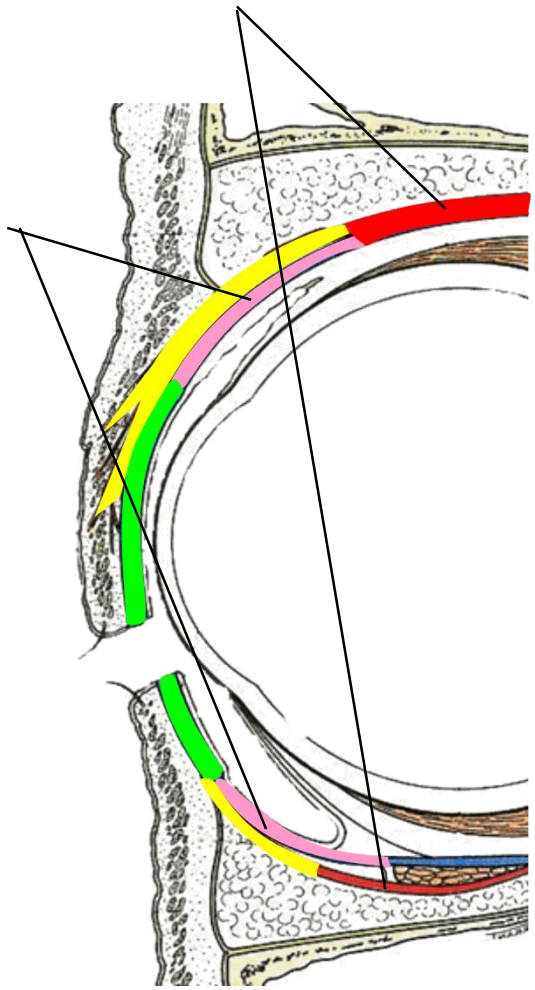
UPPSALA UNIVERSITET

# Eye lid muscles

## Opening

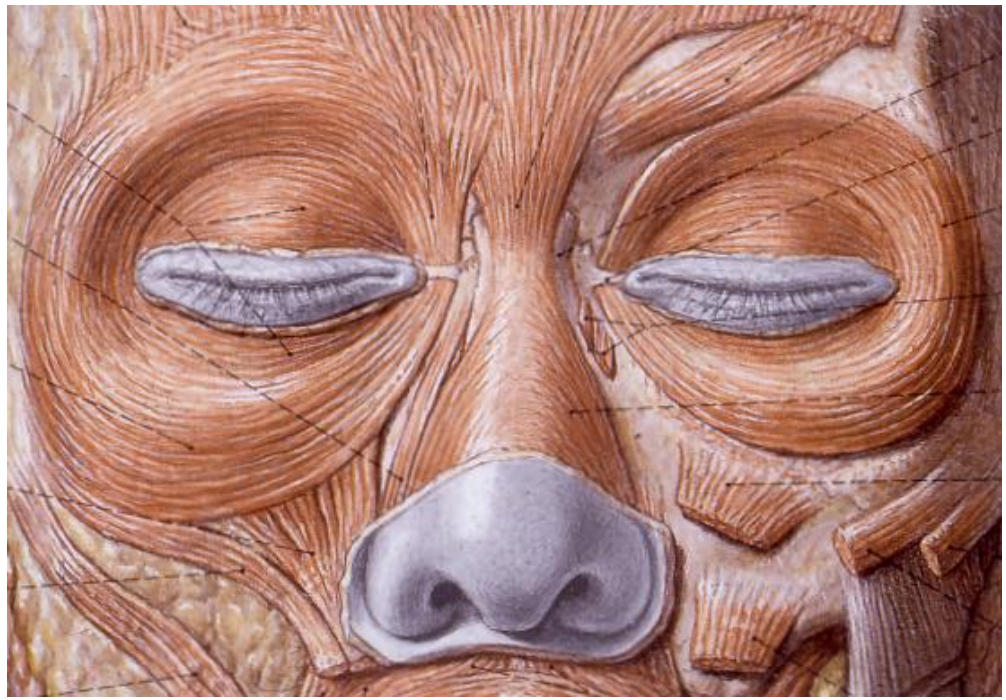
**Levator muscle (voluntary)**

**Tarsal muscle (autonomous sympathetic)**



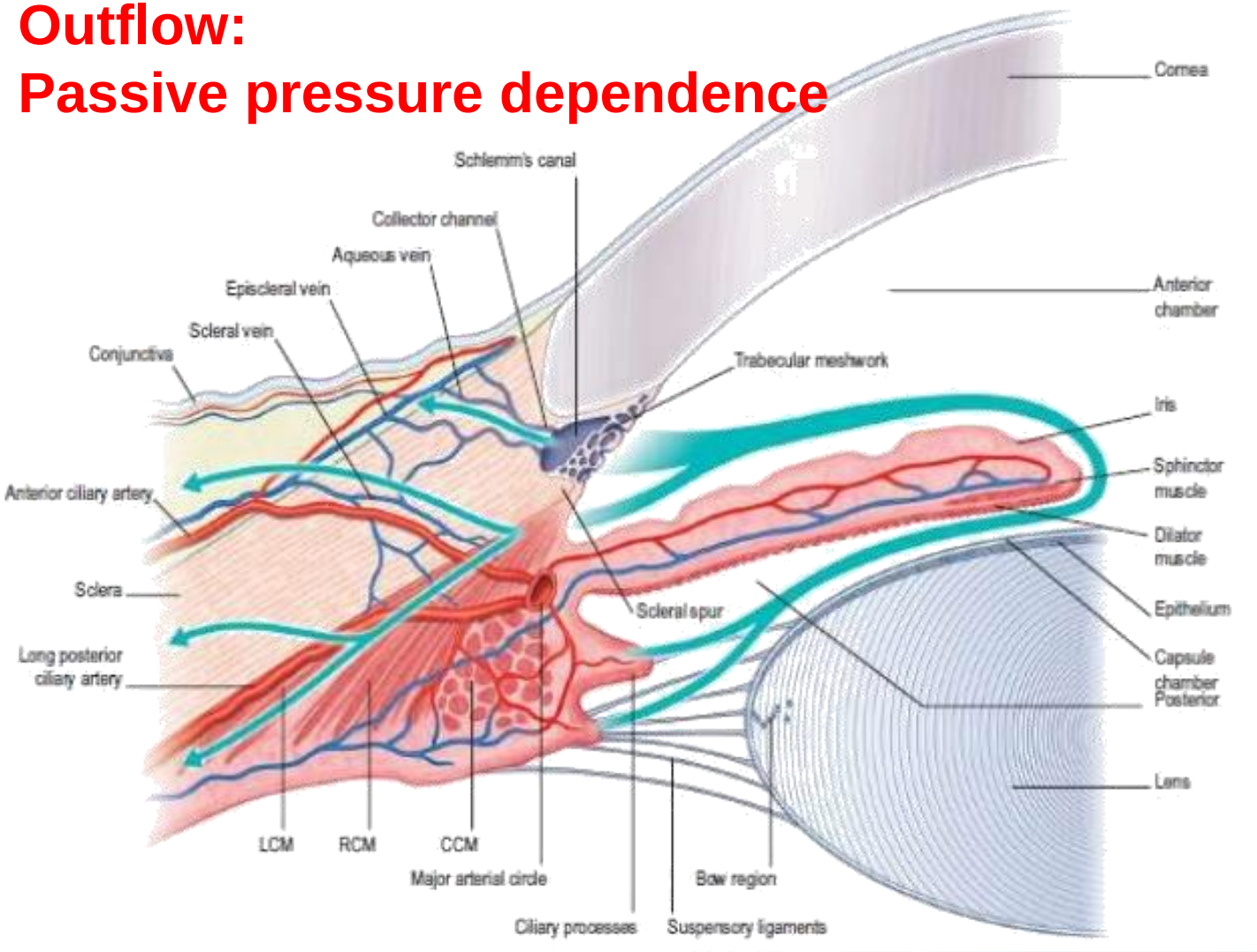
## Closing

**M. orbicularis oculi**



# Aqueous humor flow - IOP

## Outflow:
## Passive pressure dependence




## Poiseuilles law

$$p = R \cdot \Phi$$

p = pressure (N/m$^2$, mmHg)

R = resistance $\frac{\frac{mmHg}{ml}}{\text{min}}$

$\Phi$ = flow (ml/min)

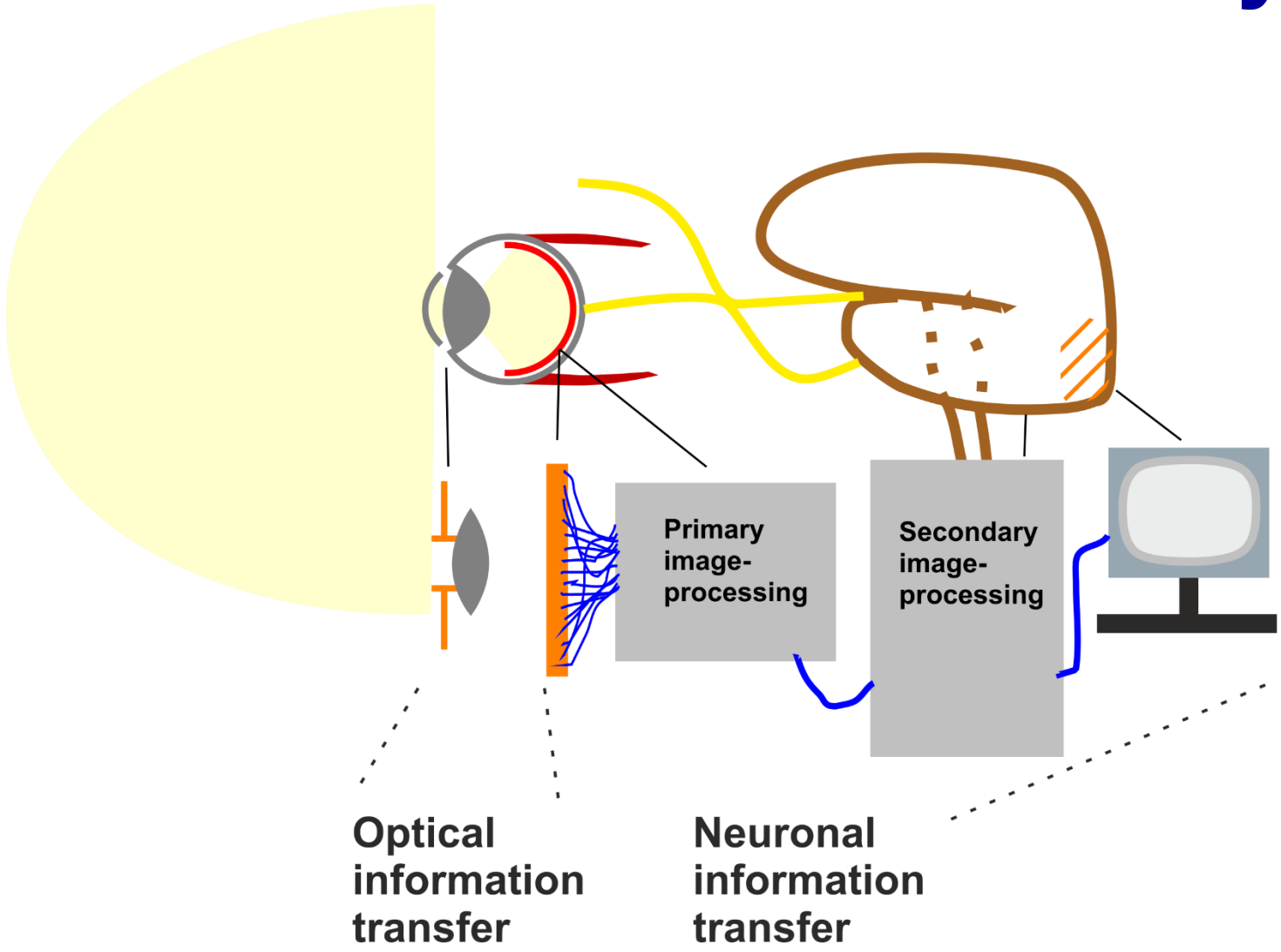
## Inflow: Active transport

PS

Gullstrand lab

UPPSALA UNIVERSITET

# Signal transfer in the visual system




PS

Gullstrand lab

UPPSALA UNIVERSITET