

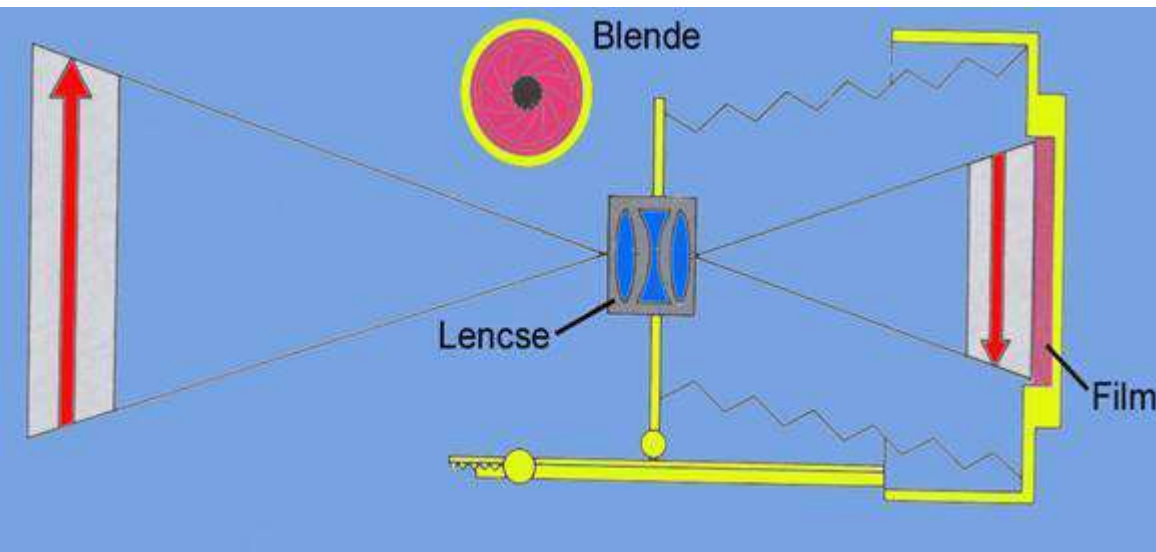
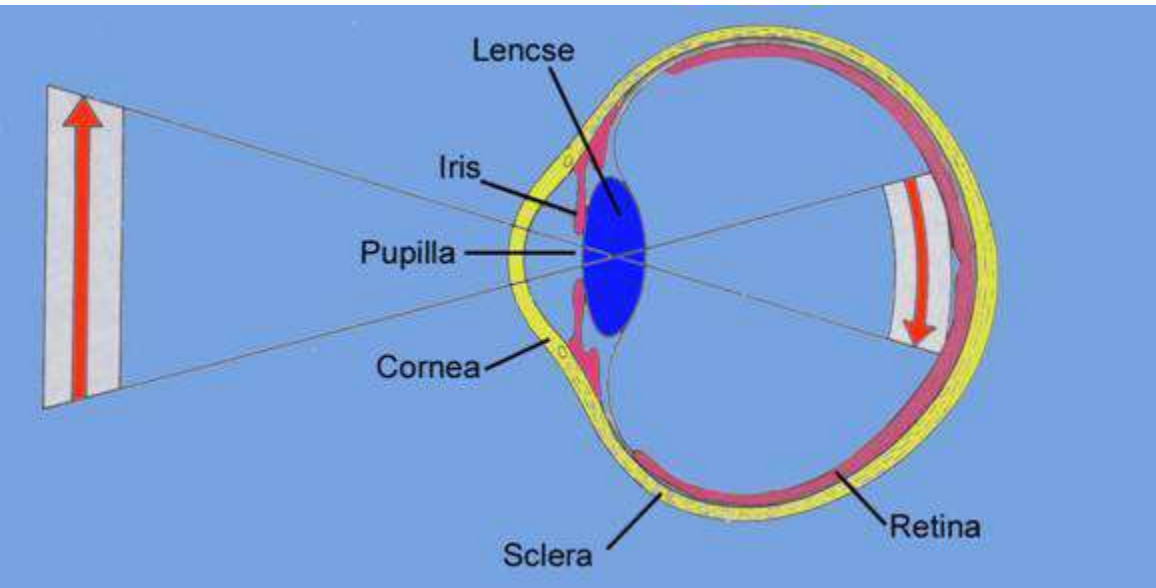
19. Auge und Sehbahn

Csaba Dávid

Organum visus

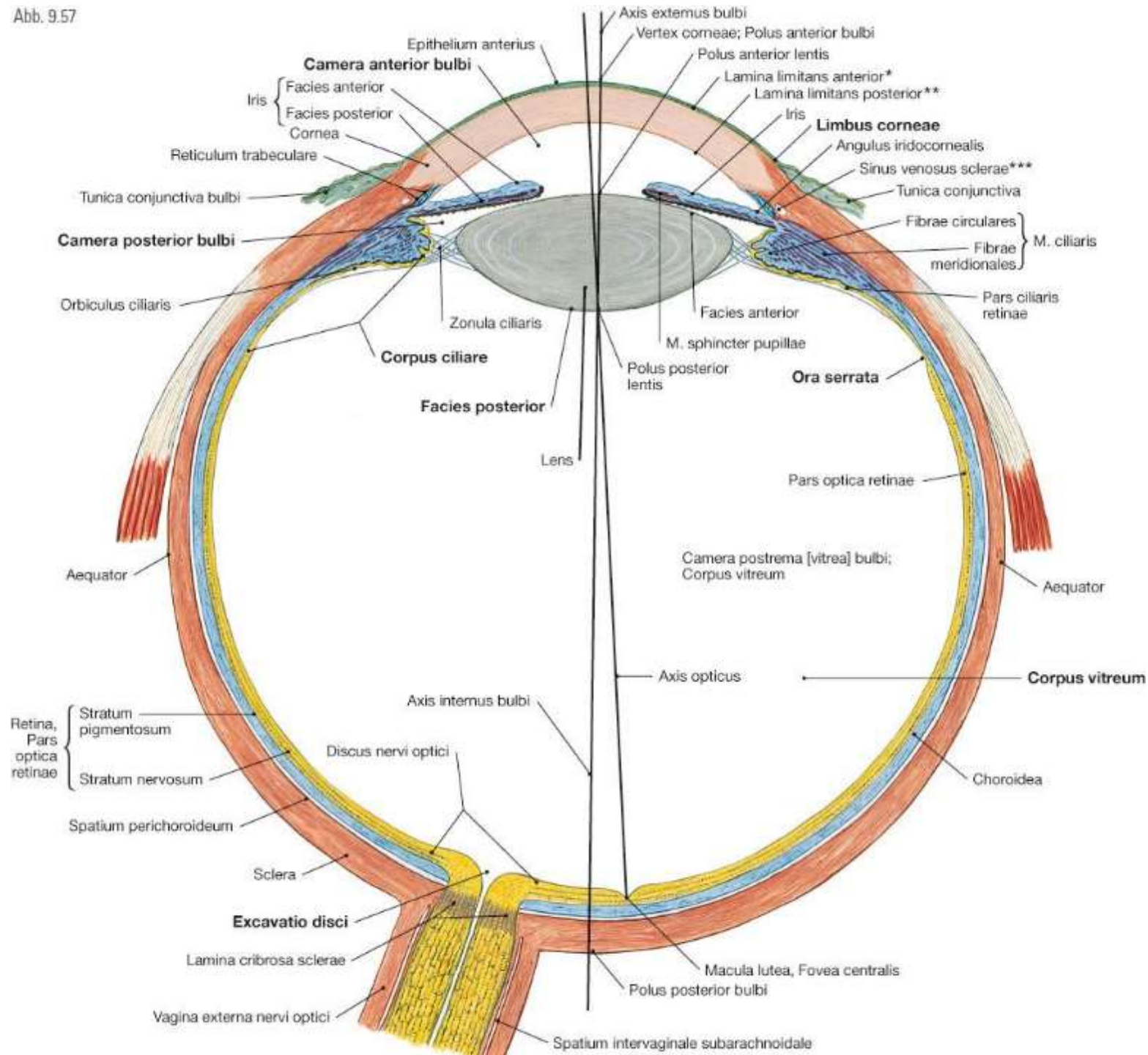
- **Augapfel** (Bulbus oculi)
- Sehnerv, Zentraler Apparat (Nervus opticus, Tractus opticus, Apparatus opticus centralis)
- Akzessorische Organe (Organa accessoria)
 - Äußere Augenmuskeln (Musculi bulbi)
 - Fettkörper (Corpus adiposum orbitae)
 - Schutzapparat (Palpebrae et tunica conjunctiva)
 - Tränenapparat (Apparatus lacrimalis)

Augevs. Kamera

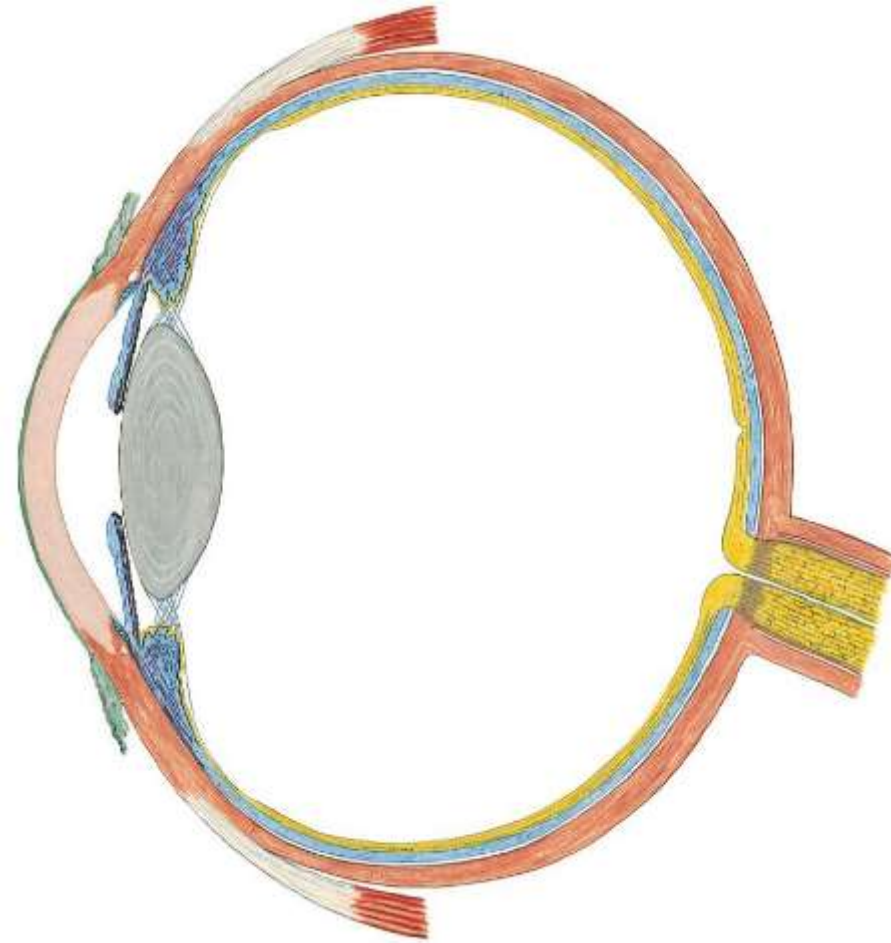


- Fokussierbares Linsensystem (aber unterschiedlicher Mechanismus)
- Verkleinertes, verkehrtes Bild
- Film/Retina
- Blende
- Lichtdichter Kapsel

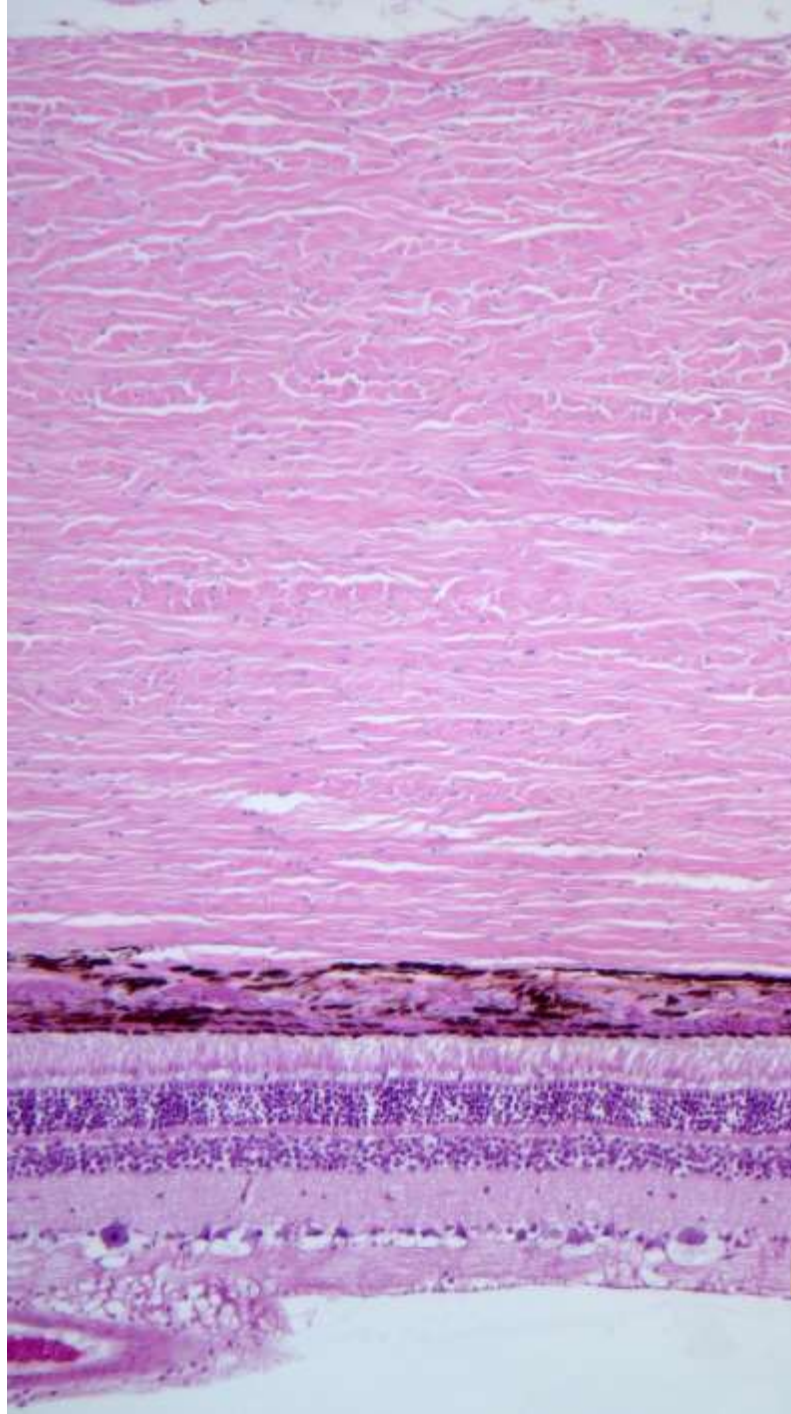
Abb. 9.57



Augenhüllen



- **TUNICA FIBROSA**
 - Cornea
 - Sclera
- **TUNICA VASCULOSA (UVEA)**
 - Choroidea
 - Corpus ciliare
 - Iris
- **TUNICA NERVOSA (RETINA)**
 - Pars optica retinae
 - Pars caeca retinae
 - Pars ciliaris
 - Pars iridica



- **TUNICA FIBROSA**

- Cornea
- Sclera

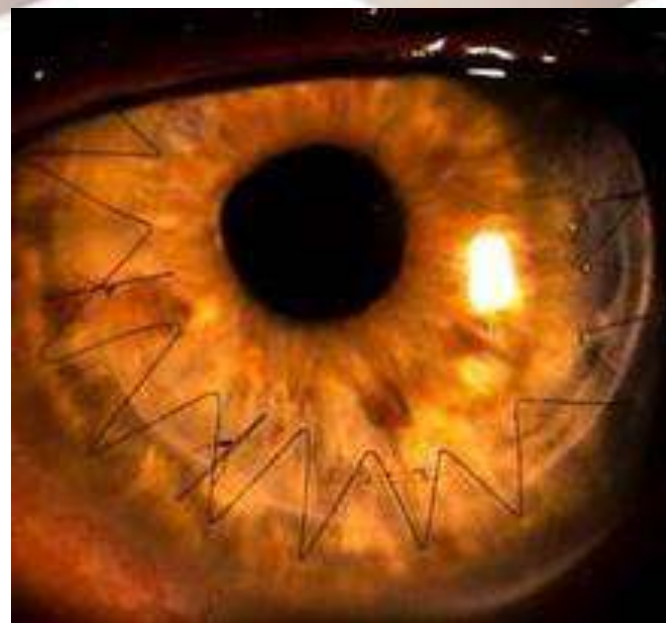
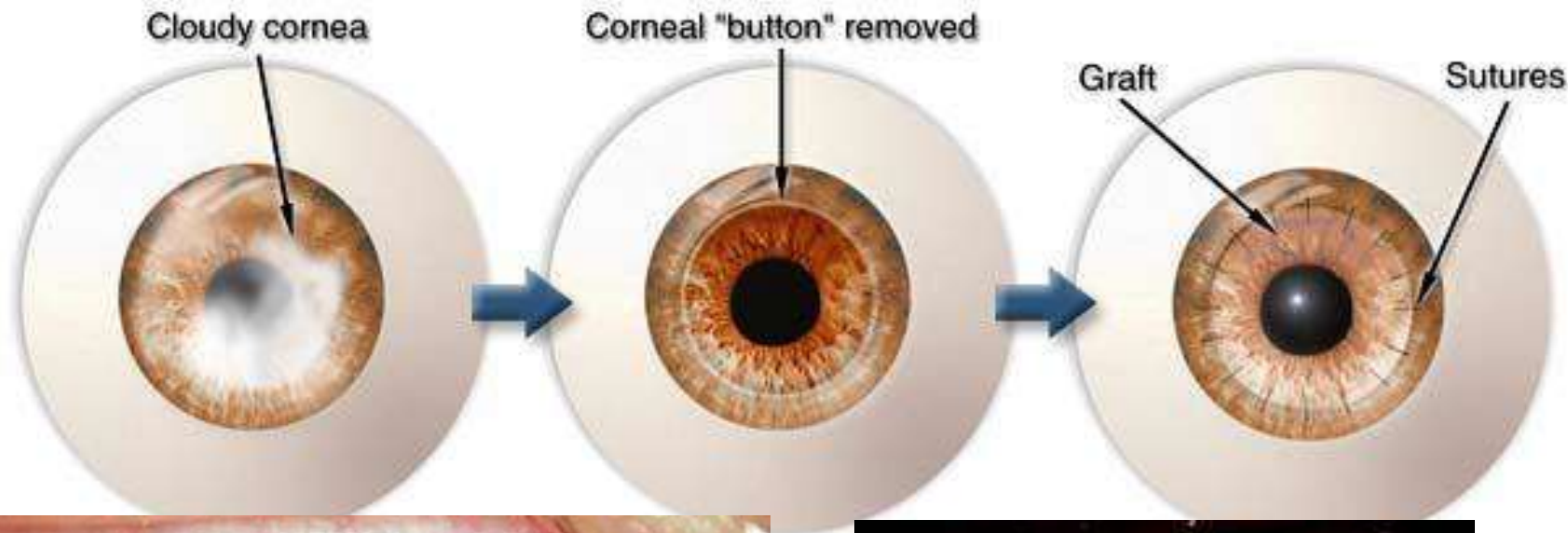
- **TUNICA VASCULOSA (UVEA)**

- Choroidea
- Corpus ciliare
- Iris

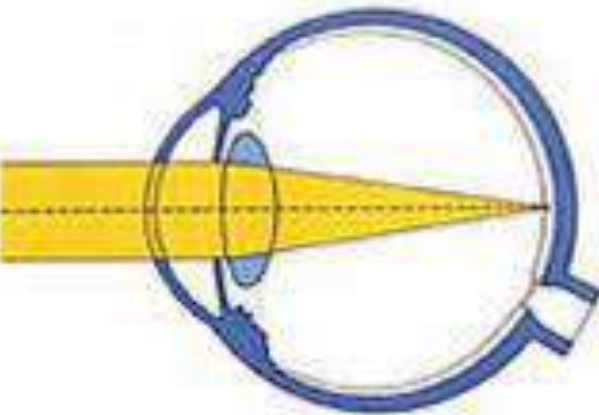
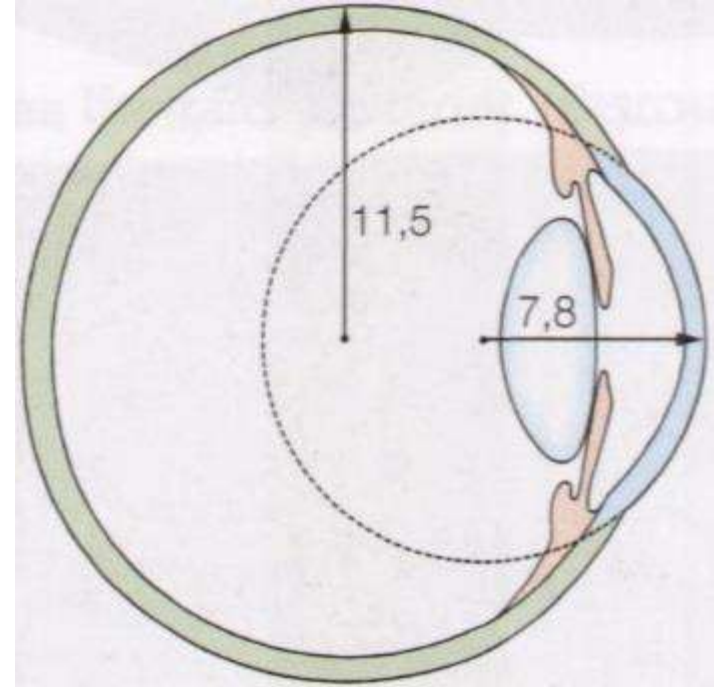
- **TUNICA NERVOSA (RETINA)**

- Pars optica retinae
- Pars coeca retinae
 - Pars ciliaris
 - Pars iridica

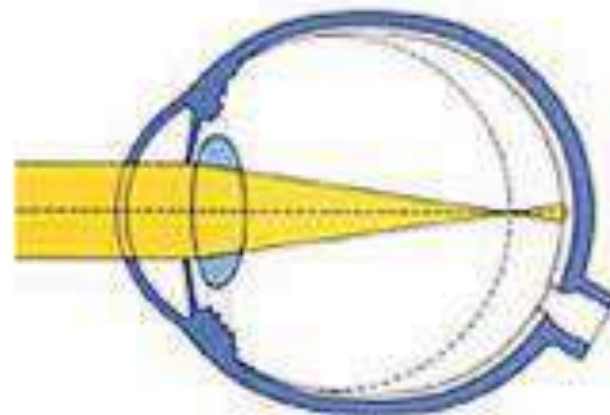
Hornhauttransplantation



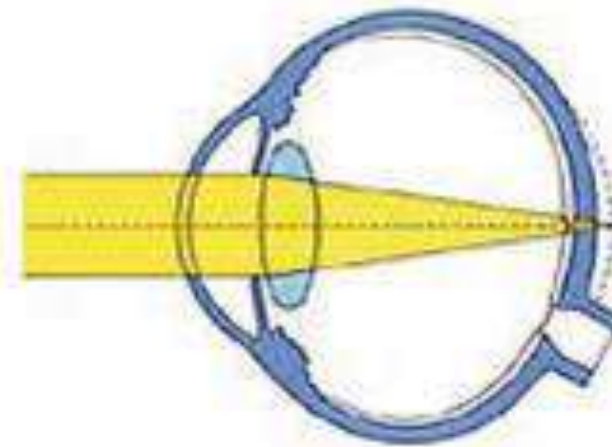
Brechfehler



normal
Emmetropie

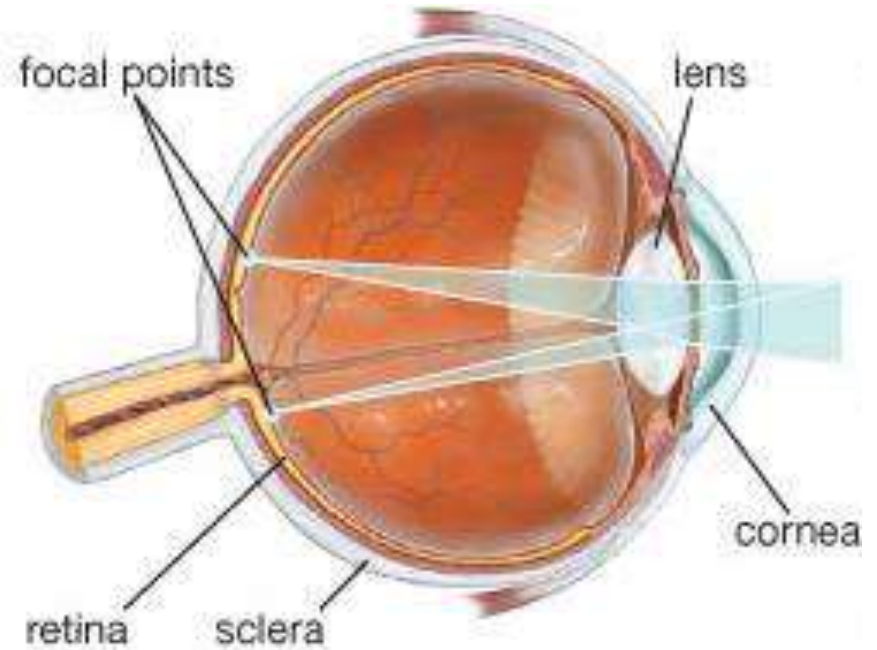
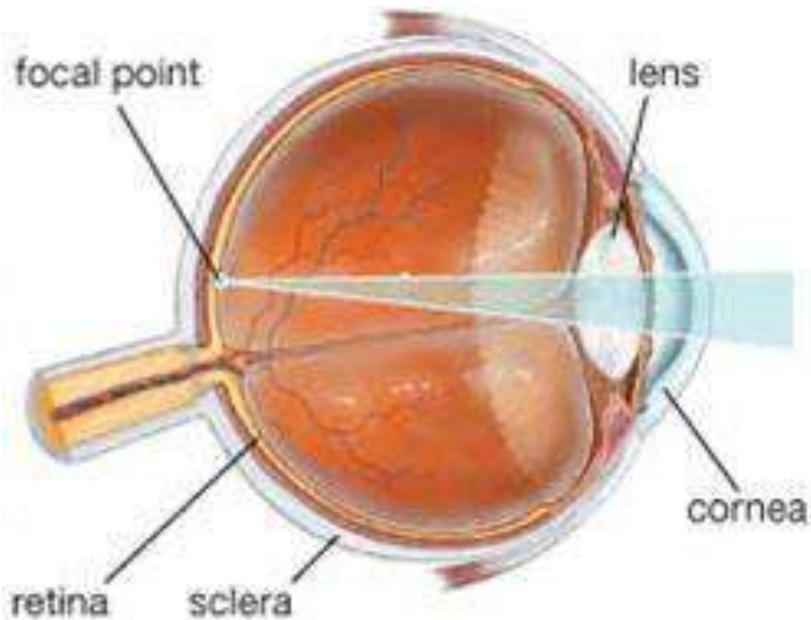
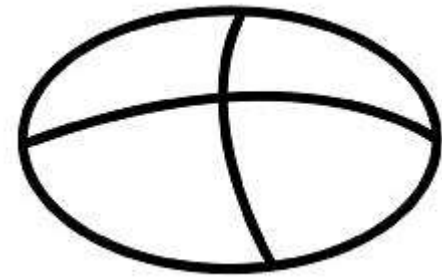
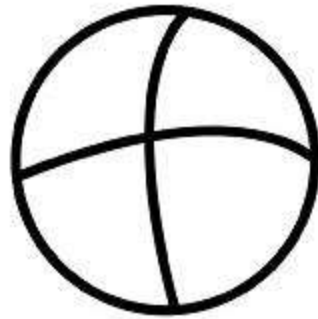
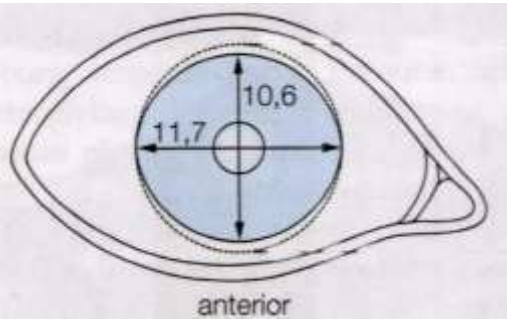


kurzsichtig
Myopie

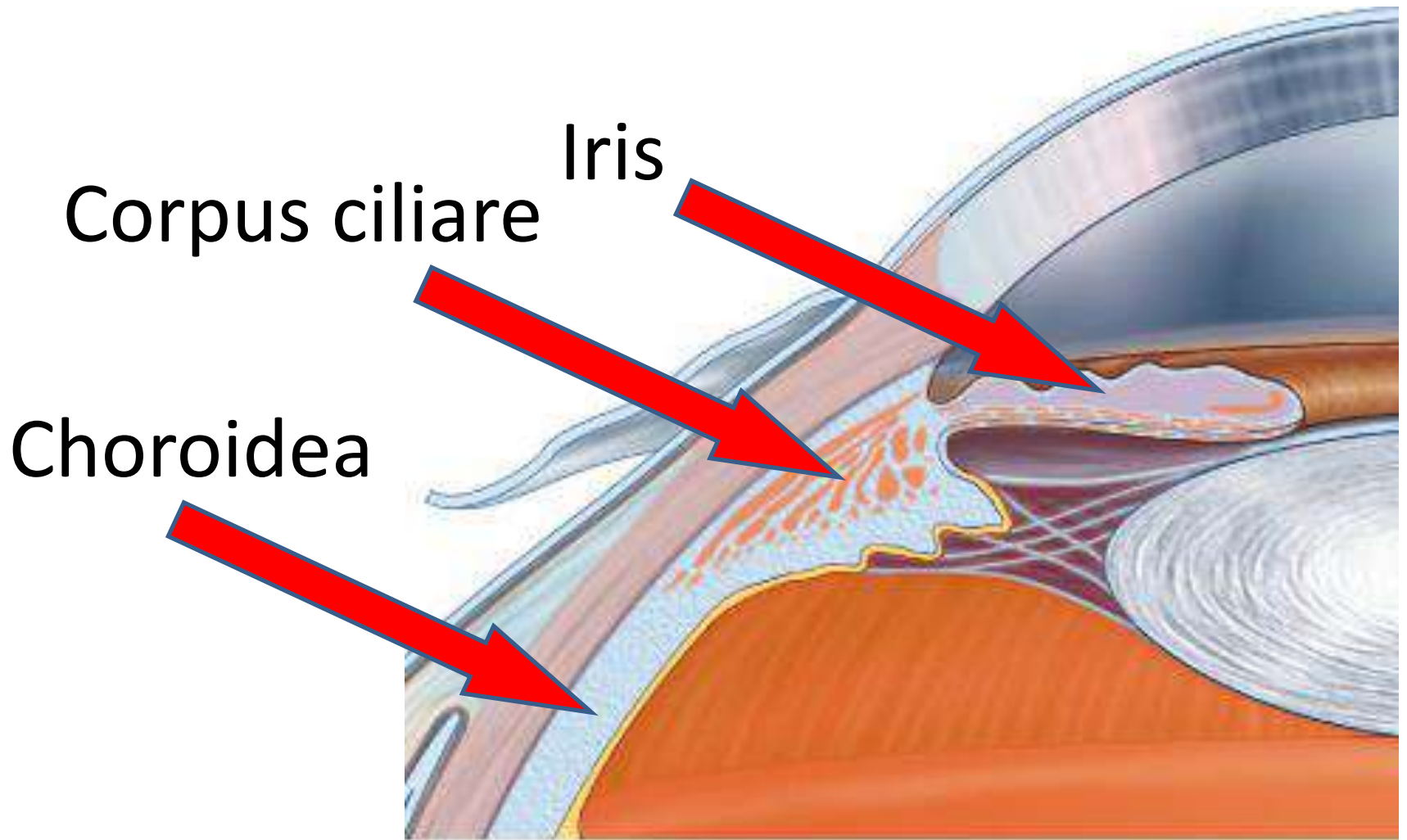


weitsichtig
Hypermetropie

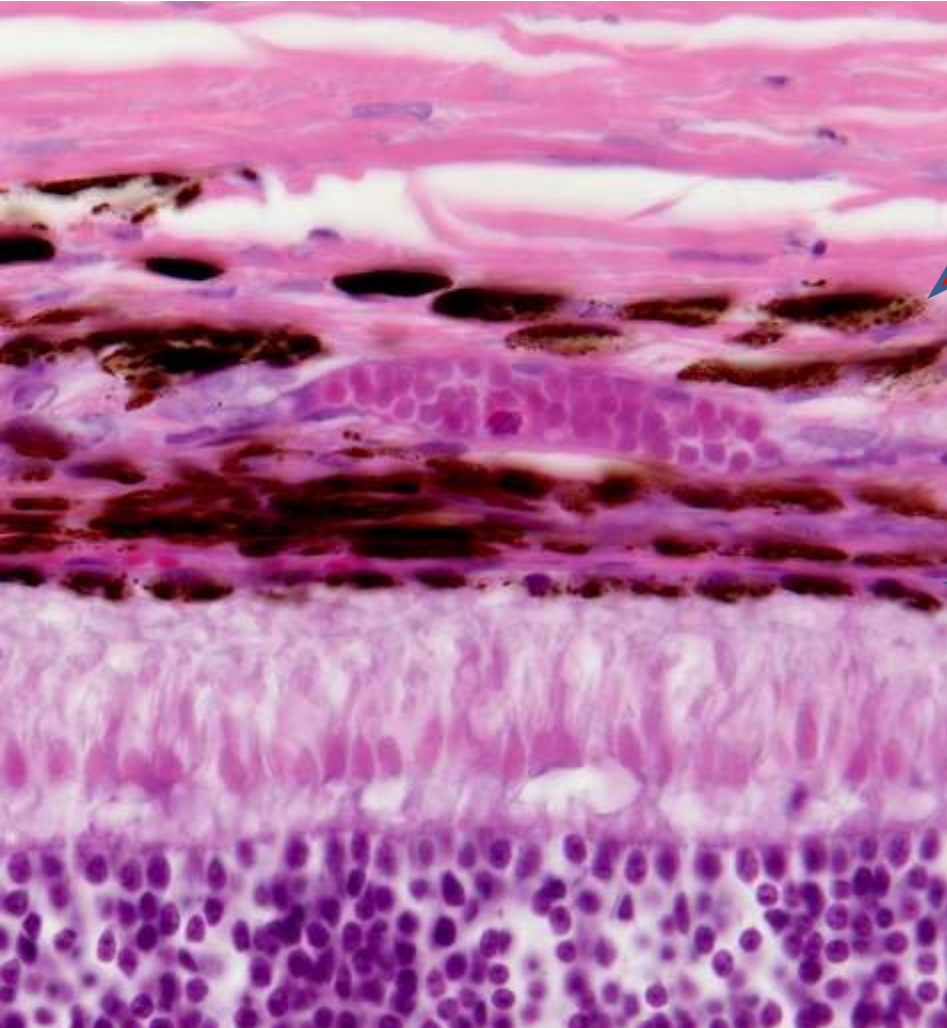
Astigmatismus



Tunica vasculosa

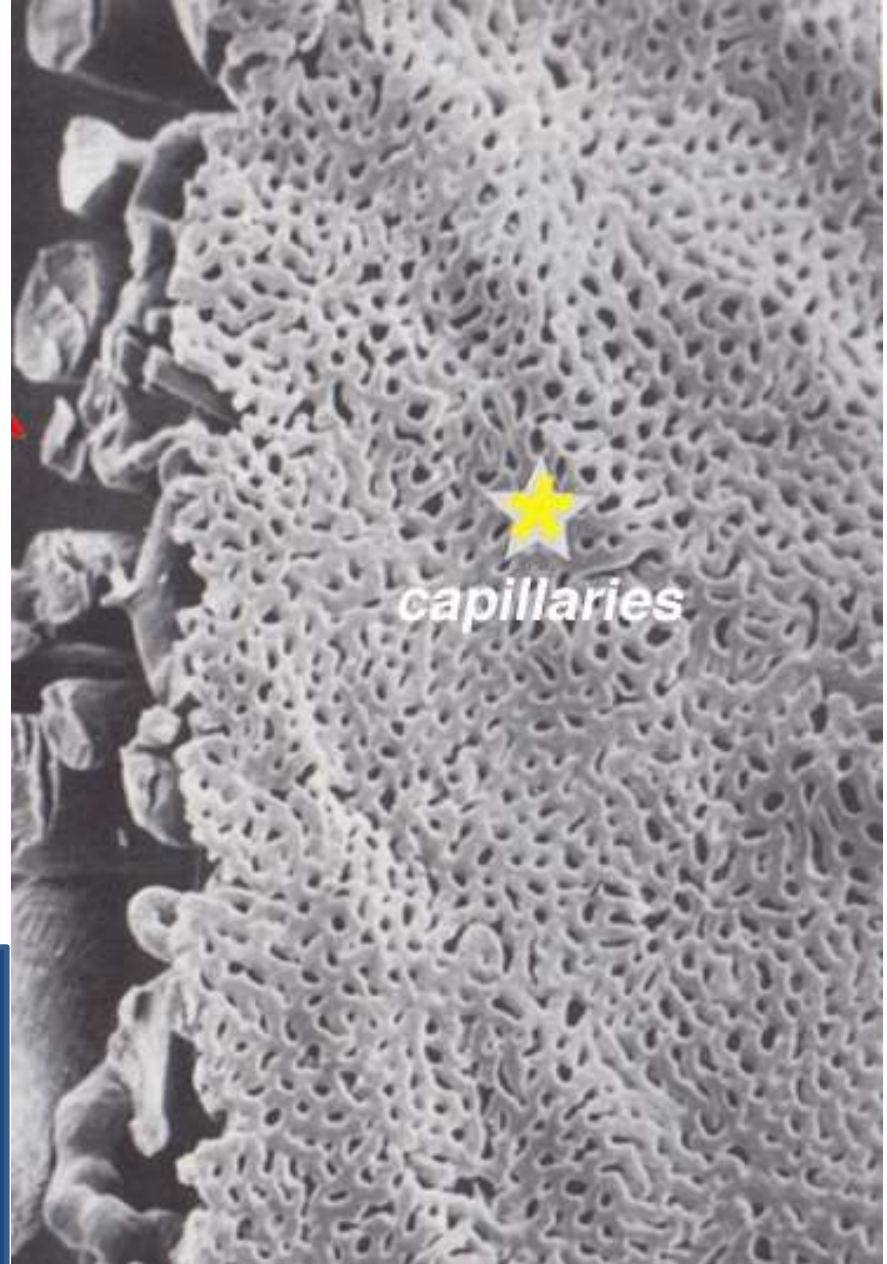


Choroidea

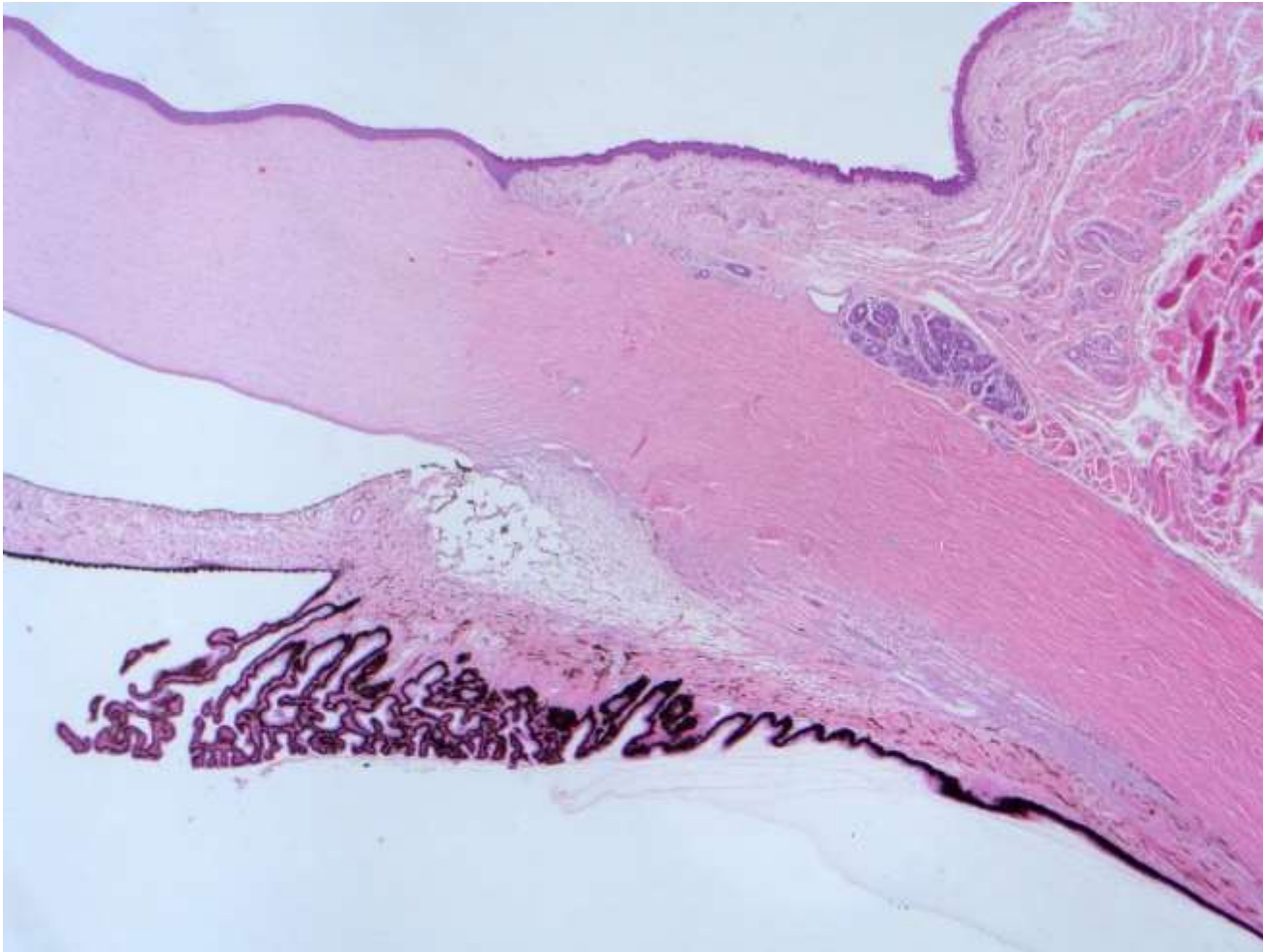


- 1. Lamina suprachoroidea (Lamina fusca sclerae)
- 2. Lamina vascularis
- 3. Lamina chorocapillaris
- 4. Lamina vitrea(Bruch-Membran)

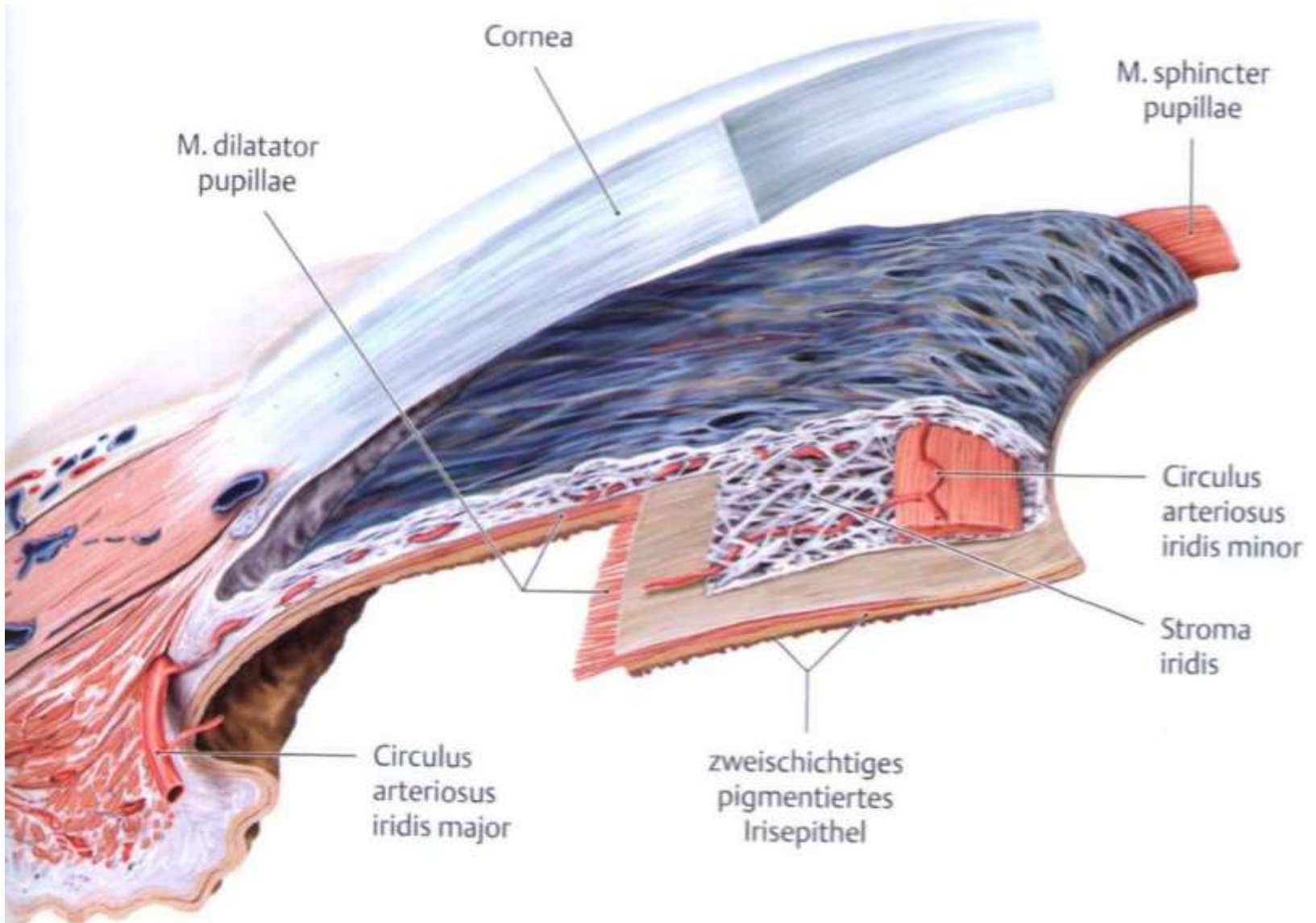
Die Choriocapillaris Schicht
am Korrosionspräparat
(Raster EM). Zhang 1994

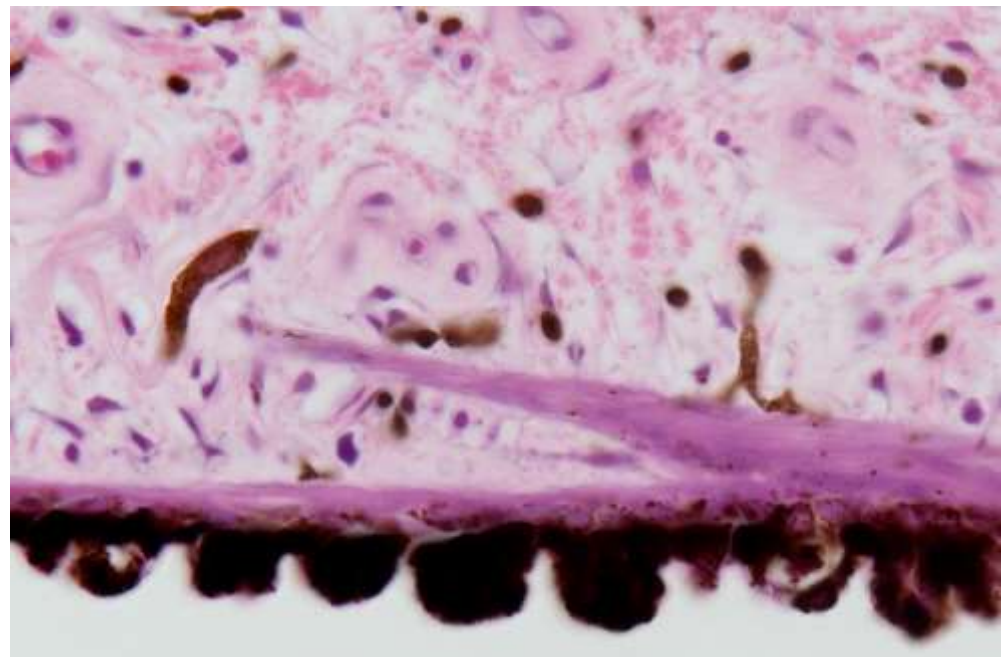
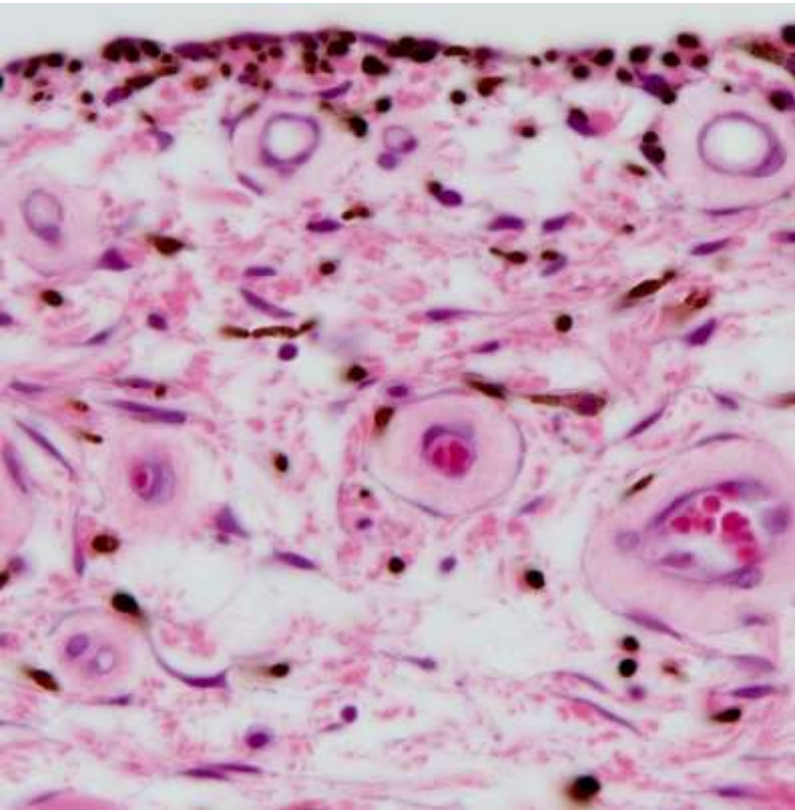


Corpus ciliare



Iris





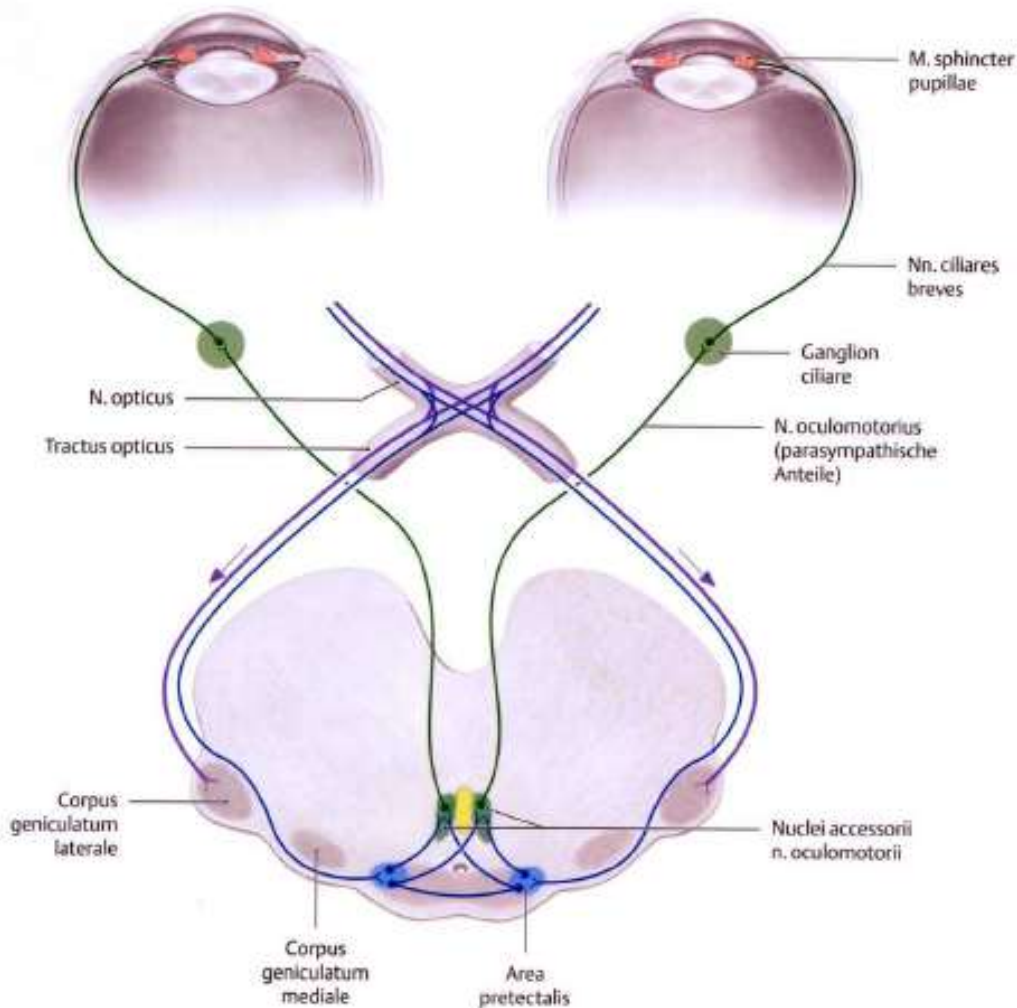


Ludwig Edinger
(1855 – 1918)



Carl Friedrich
Otto Westphal
(1833 – 1890)

Lichtreflex (Pupillenreflex)



Reiz: Beleuchtung

Rezeptor: Photorzeptoren der Netzhaut

Afferenter Schenkel: sich von der Sehbahn abtrennende Fasern, die zur Area pretektalis ziehen

Zentraler Schaltapparat: Area pretektalis

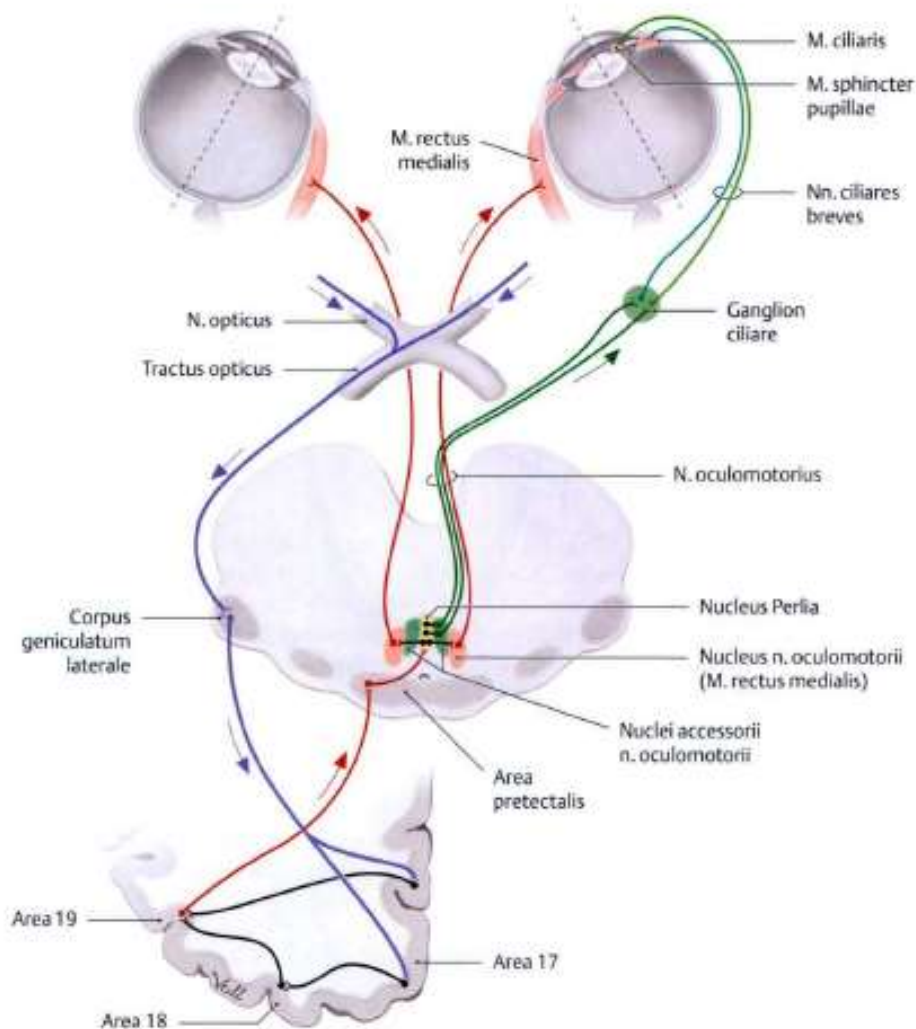
Afferenter Schenkel: von der Area pretektalis zum N. accessorii nervi oculomotorii (N. Edinger-Westphal) ziehende kontra- und ipsilaterale Fasern → N. oculomotorius → Ganglion ciliare → Nn. ciliares breves

Effektor: M. sphincter pupillae auf den beiden Seiten

Direkte Pupillenreaktion: Pupillenverengung (Miosis) auf der beleuchteten Seite

Indirekte (consensuelle) Pupillenreaktion: Pupillenverengung (Miosis) auf der unbeleuchteten Seite

Akkommodation und Konvergenz



Reiz: unscharfes Bild

Rezeptor: Photorezeptoren der Netzhaut

Afferenter Schenkel: Sehbahn

Zentraler Schaltapparat: Sehzentrum

Afferenter Schenkel: die Axone ziehen vom Sehzentrum zur Area preectalis → kontra- und ipsilateraler N. accessorii nervi oculomotorii (N. Edinger-Westphal) und N. motorius n. III

Parasympathische Fasern: N. oculomotorius → Ganglion ciliare → Nn. ciliares breves → M. ciliaris und M. sphingter pupillae

Somatomotorische Fasern: N. oculomotorius → M. rectus medialis

Effektor: M. sphincter pupillae auf den beiden Seiten
M. ciliaris auf den beiden Seiten
M. rectus medialis auf den beiden Seiten

Antwort: Akkommodation (Brechkraft der Linse ↑)
Verengung beider Pupillen
Konvergenz (Adduktion beider Augen)

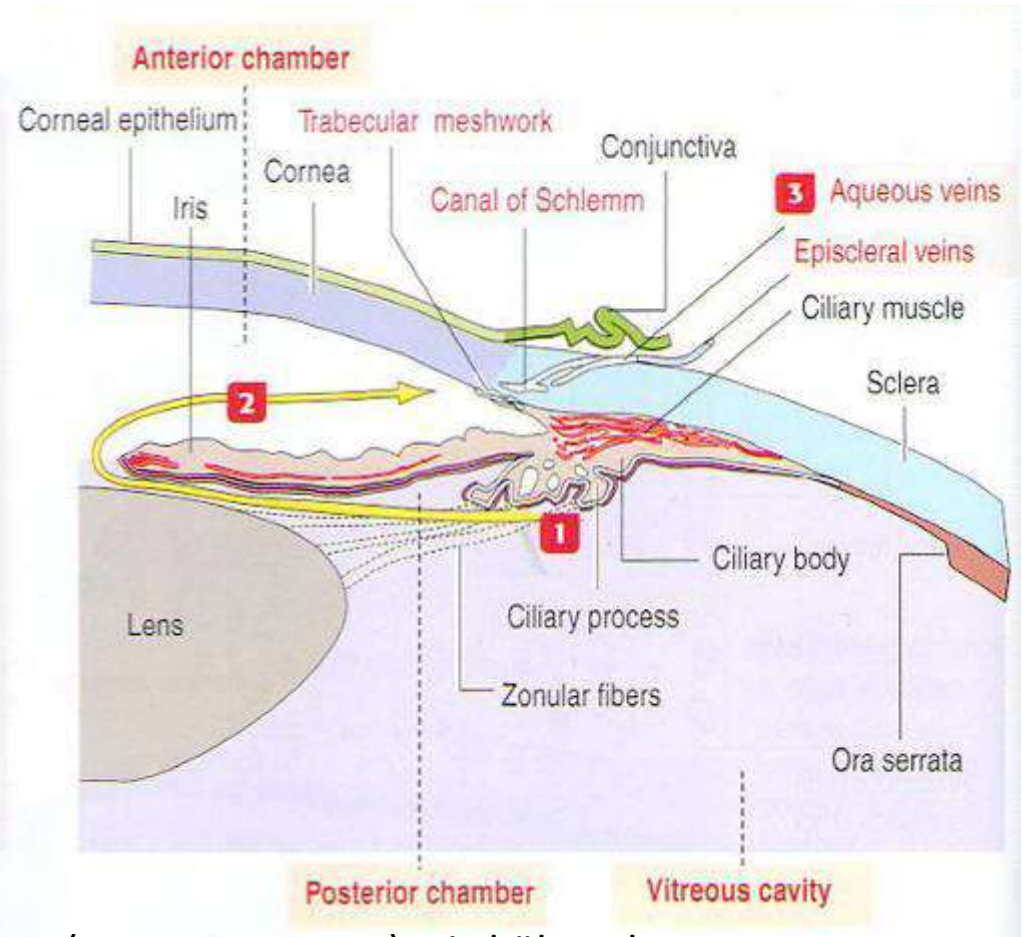
Synthese und Ableitung des Kammerwassers

1 The arrow indicates the pathway followed by the aqueous humor produced by the epithelial lining of the ciliary processes.

2 The aqueous fluid flows from the posterior chamber through the pupil into the anterior chamber. The canal of Schlemm, lined by an endothelium, does not communicate directly with the spaces of the trabecular meshwork. Instead, the fluid percolates through a thin endothelial lining and loose connective tissue.

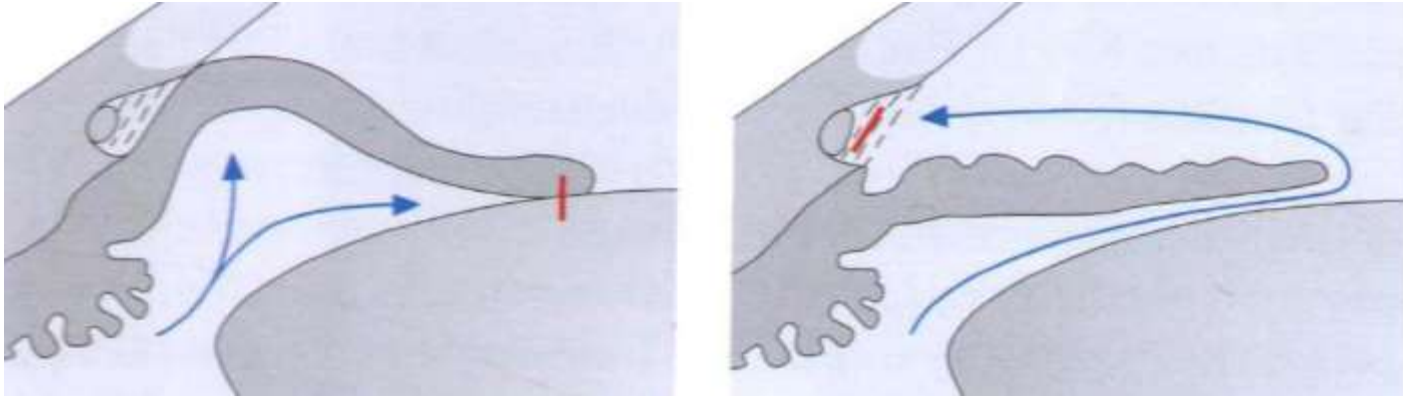
3 Aqueous veins are collector channels draining the canal of Schlemm into the episcleral veins.

The drainage rate of aqueous humor is balanced by the rate of secretion. By this mechanism, the intraocular pressure is maintained constant (23 mm Hg).



Etwa 80 Prozent des Kammerwassers (Humor aqueus) wird über den *Fontana-Räume - Schlemm-Kanal - Venae aqueosae - Vena episcleralis* Wegabgeleitet

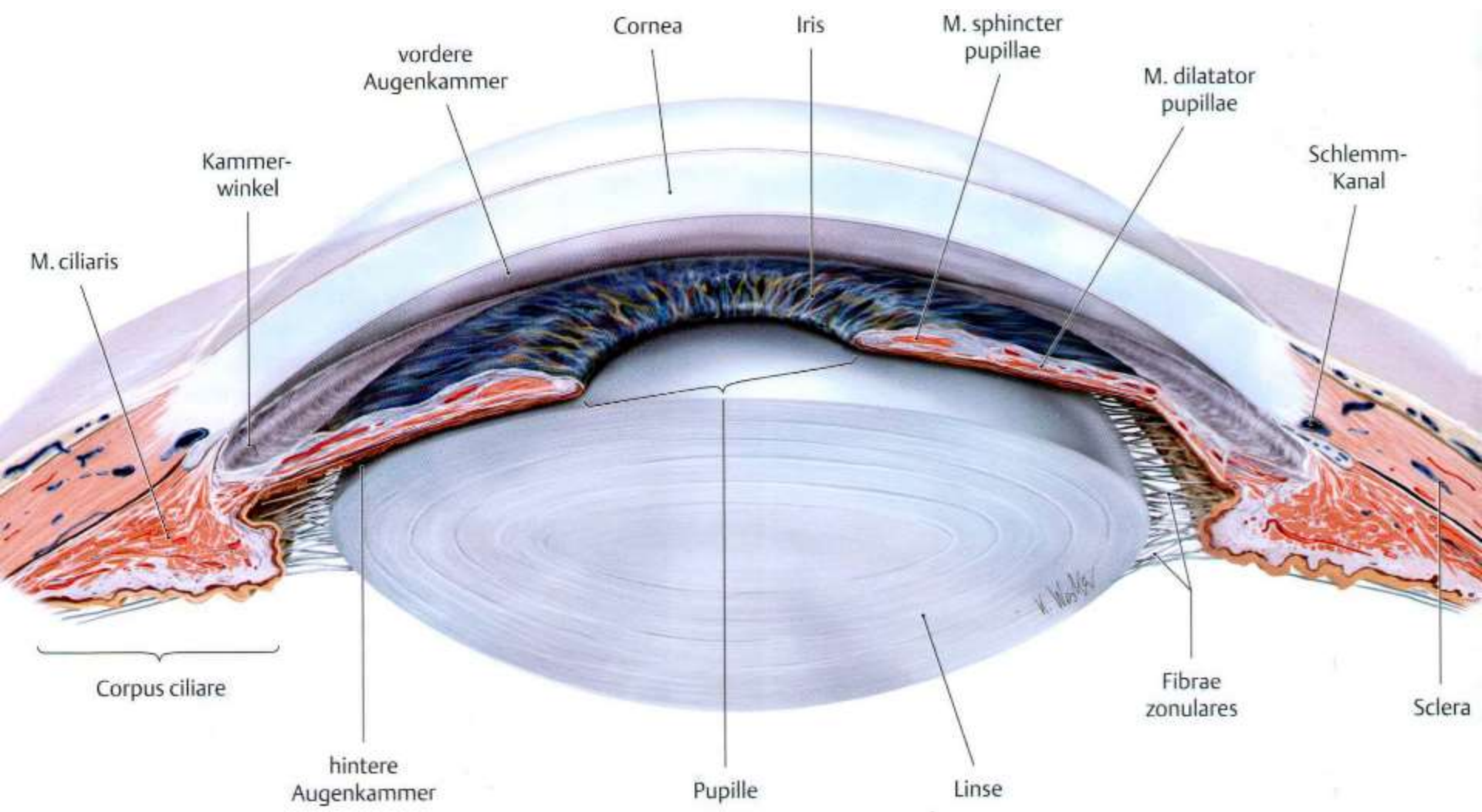
Klinische Bezüge: Glaukom (Grüner Star)

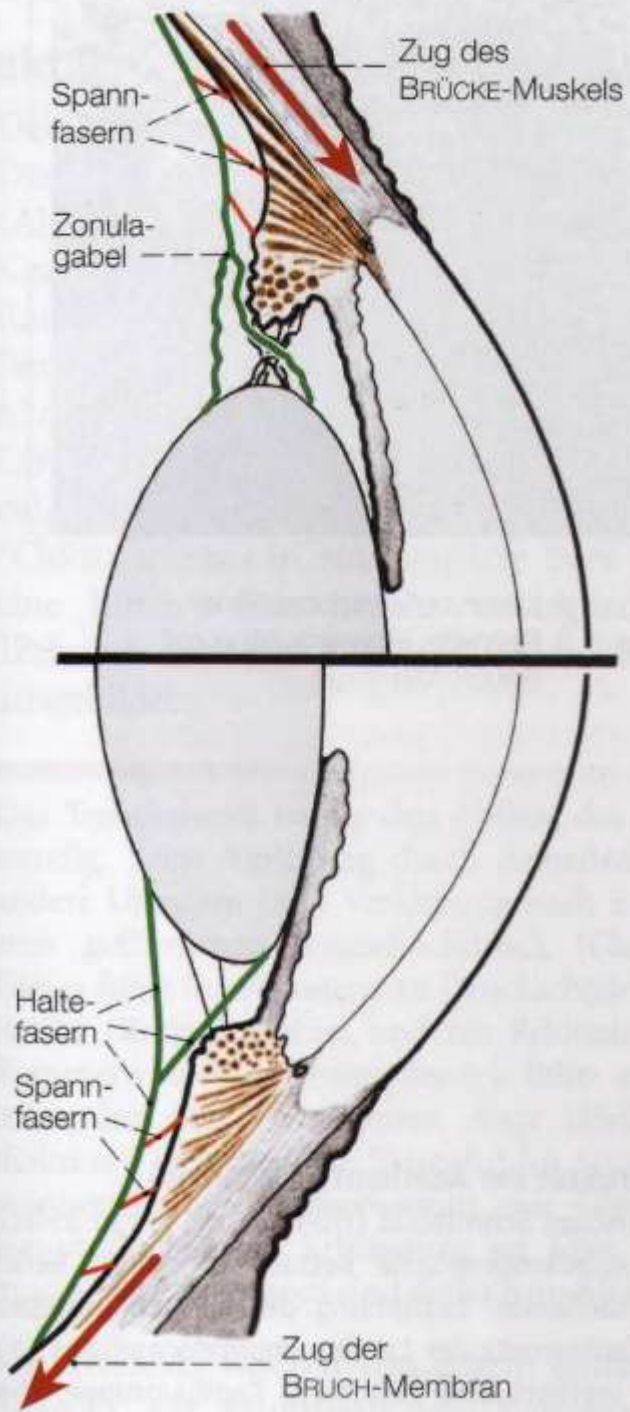


- Gestörtes Gleichgewicht zwischen der Synthese und Resorption des Kammerwassers (Synthese >Resorption)
- Der Augeninnendruck steigt, die die Gefäße und die Zellen der Netzhaut werden unter erhöhten Druck gesetzt. Die Durchblutung des Sehnervenkopfes senkt.
- Die Neuronen der Retina sterben ab, Sehstörungen und nicht heilbare Gesichtsfeldausfälle (Skotom) treten auf.
- Die durch die plötzliche Abflussstörung des Kammerwassers ausgelöste akute Glaukomanfälle treten häufig am Abend auf. (Die Pupille ist bei Dunkelheit erweitert.)
- Symptomen: starke Kopfschmerzen (N. ophthalmicus), Übelkeit, Erbrechen, Sehverlust, extrem hartes Auge
- Beim Glaukomanfall ist akute medizinische Versorgung nötig!!!

Therapeutische Möglichkeiten beim Glaukom

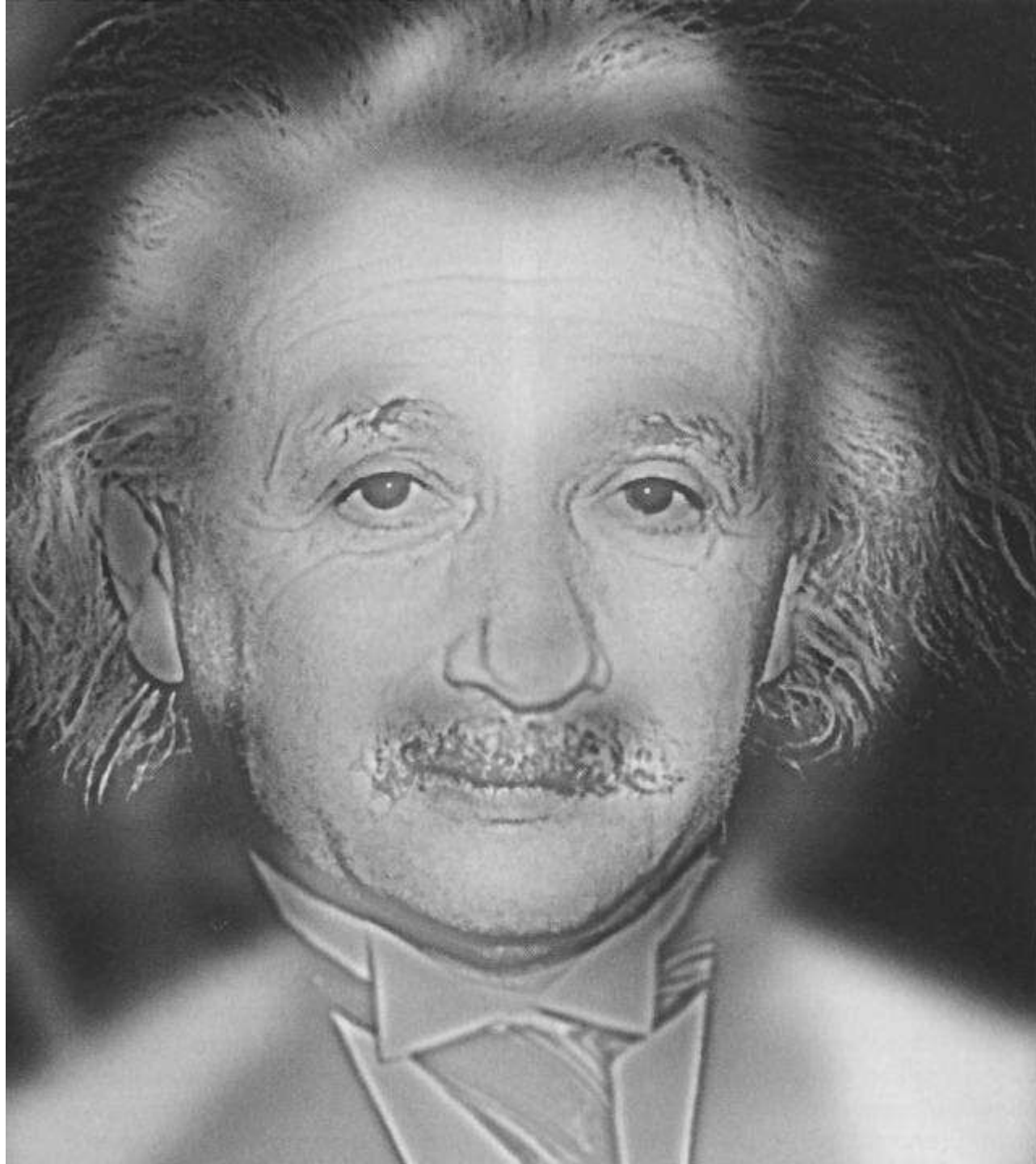
- **Diuretika** (gesteigerte Wasserausscheidung)
- Der Abfluss des Kammerwassers ist besser, wenn die Pupille verengt ist, da das abgeflachte Irisgewebe den Kammerwinkel (Angulus iridocornealis) nicht abschließt.
- **Parasympathomimetika** ahmen die Wirkung des N. oculomotorius nach: der M. sphincter pupillae kontrahiert und die Pupille verengt sich.
- **Hemmstoffe des Sympathikus** hemmen die Kontraktion des M. dilatator pupillae.
- **Operation:** Partielle Entfernung des Irisgewebes (Iridectomie)



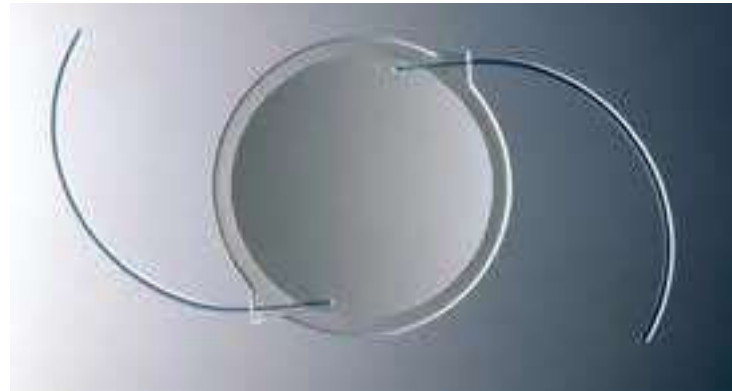
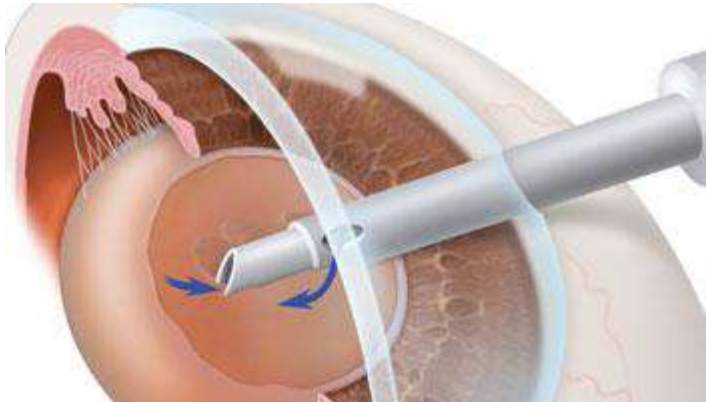
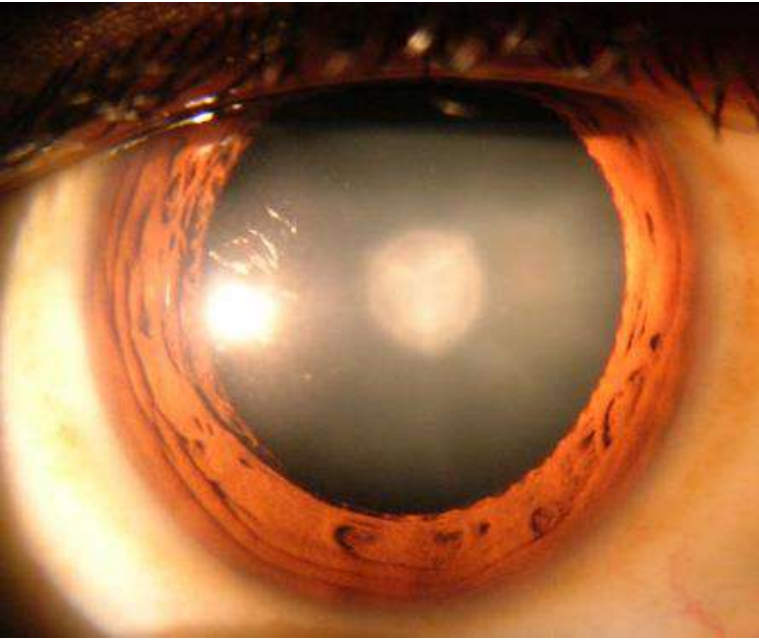


- **AKKOMODATION:**
- Der M. ciliaris kontrahiert
- (N. oculomotorius–parasymphatische Innervation)
- Der Ziliarkörper wird nach vorne gezogen
- Die Zonulafasern erschlaffen sich
- Aufgrund ihrer Eigenelastizität steigt die Krümmung und der Durchmesser der Linse
- **Die Brechkraft der Linse steigt, sie wird für die Nähe eingestellt**

- **DESAKKOMODATION:**
- Der M. ciliaris erschlafft sich
- Der Halteapparat wird durch die Bruch-Membran nach hinten gezogen
- Die Zonulafasern werden angespannt
- Die Linse wird zu der Seite gezogen und wird flacher
- **Die Brechkraft der Linse nimmt ab, sie wird für die Ferne eingestellt**

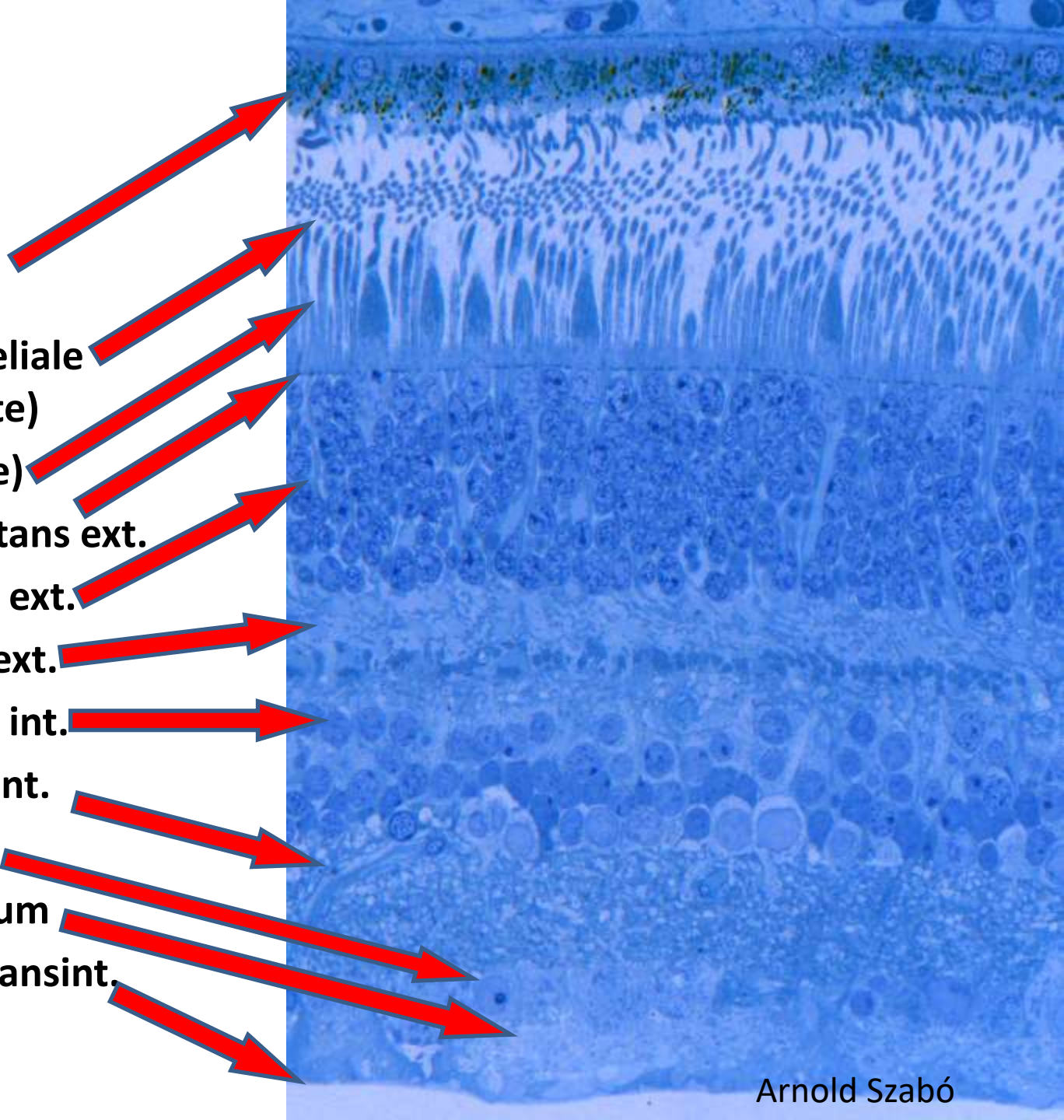


Katarakt (grauer Star)

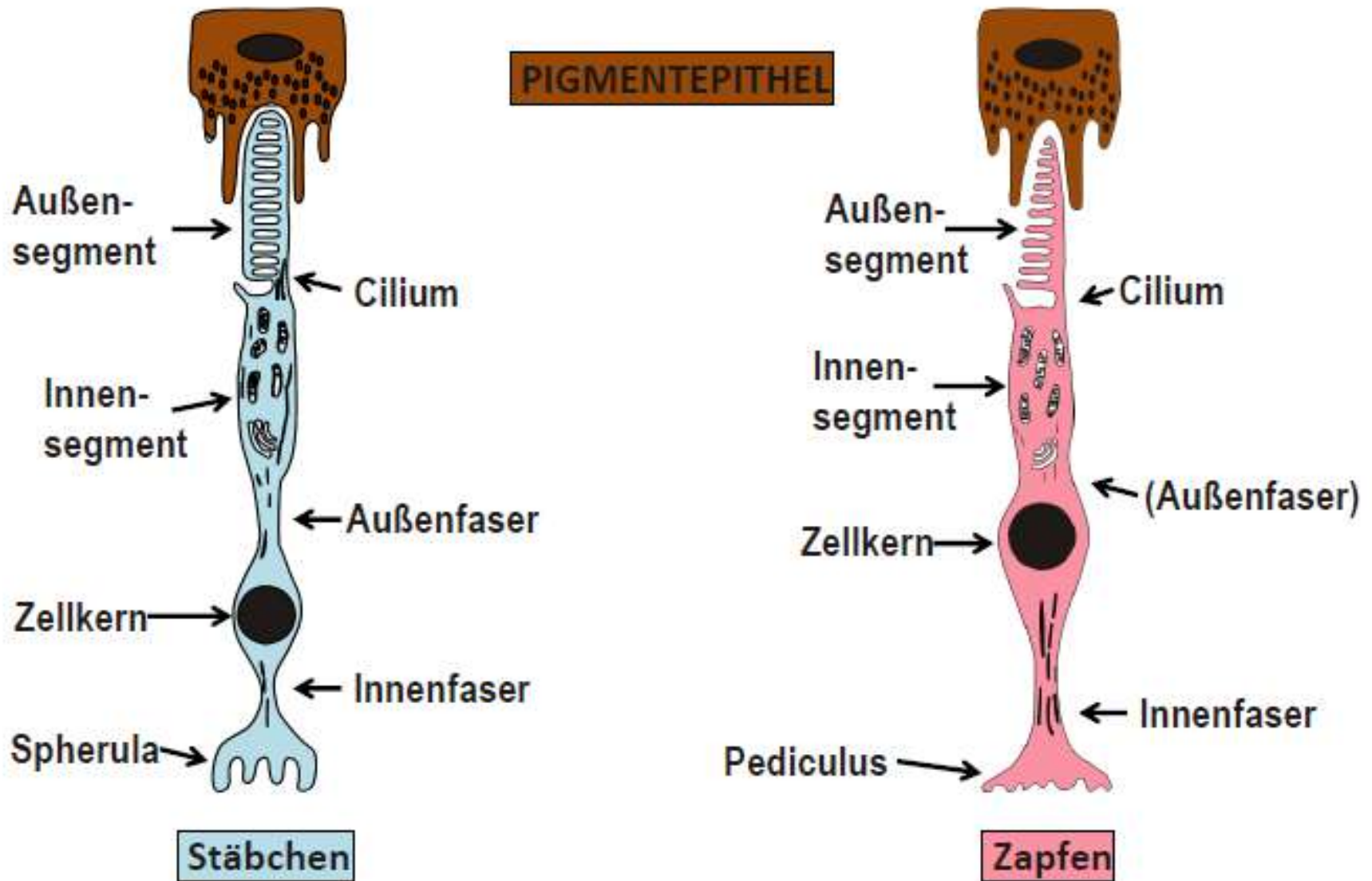


Retina

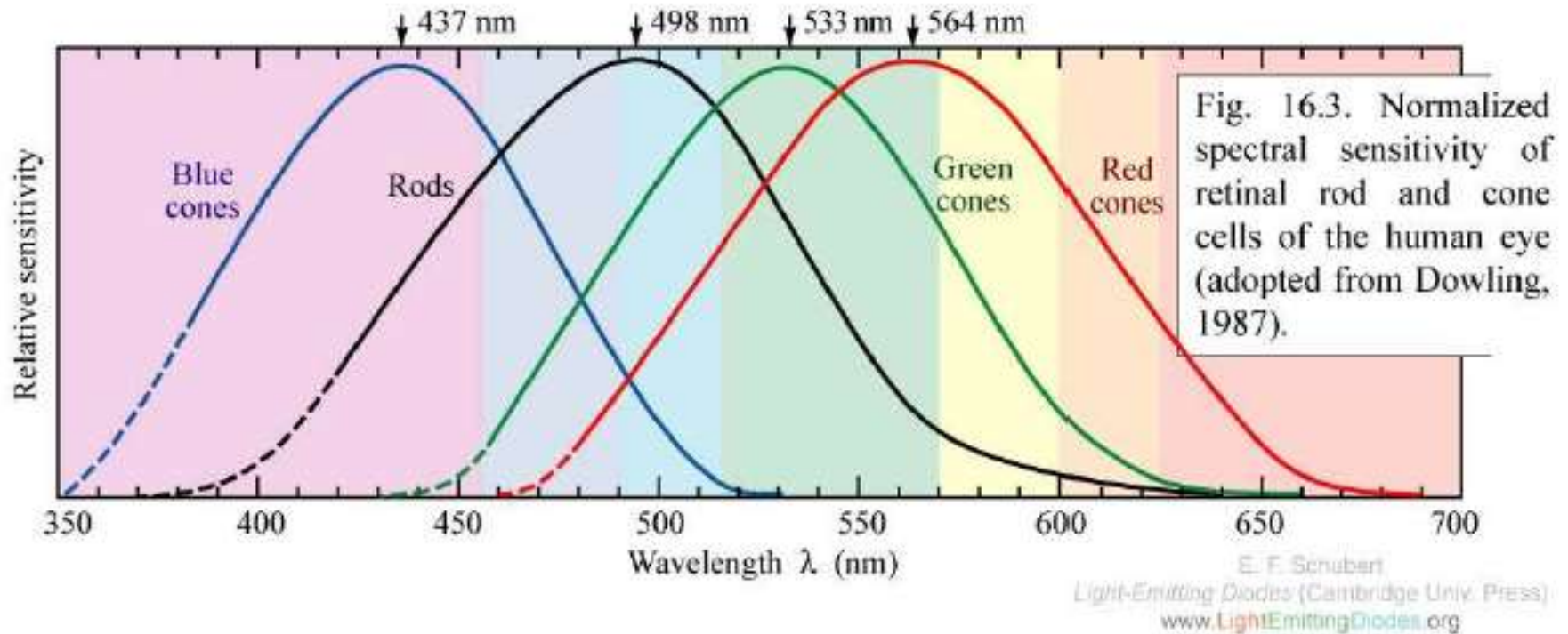
- Pigmentepithel
- Str. neuroepitheliale
(Außensegmente)
(Innensegmente)
- Membrana limitans ext.
- Str. granulosum ext.
- Str. plexiforme ext.
- Str. granulosum int.
- Str. plexiforme int.
- Str. ganglionare
- Str. neurofibrarum
- Membranalimitansint.



Aufbau der Photorezeptoren



Opsine



Skotopisches Sehen: Sehen mit Stäbchen bei niedriger Lichtintensität

Photopisches Sehen: Scharfes Farbsehen mit Zapfen beim Tageslicht

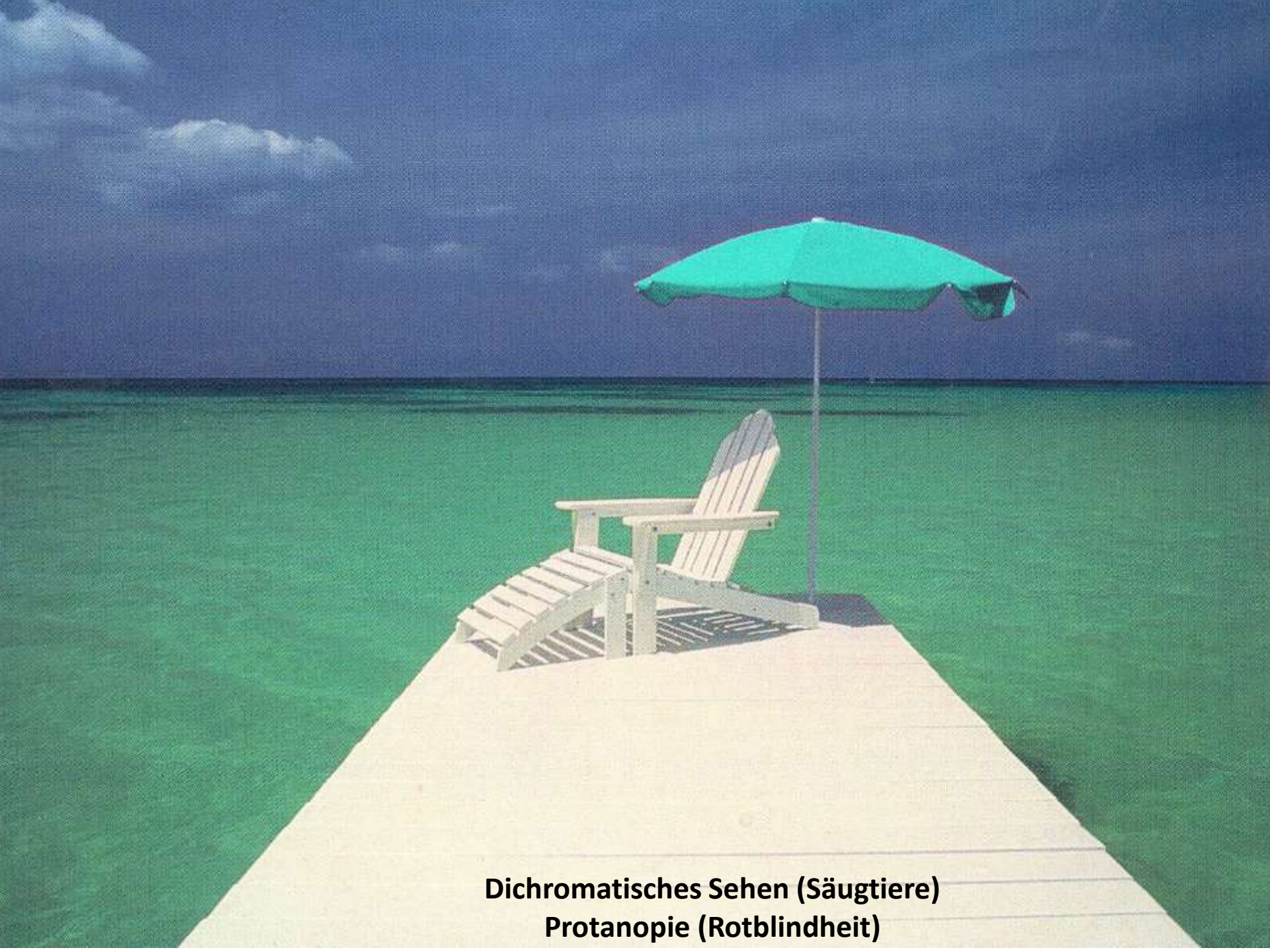
Trichromatisches Farbsehen: **Blaues/S-Opsin** (7. Chromosom), **Grünes/M-Opsin** (q-Arm des X-Chromosoms), **Rotes/L-Opsin** (q-Arm des X-Chromosoms)



Normales(Trichromatisches) Sehen



**Sehen ohne Zapfen (nur mit Stäbchen)
Farbenblindheit (Achromatopsie)**

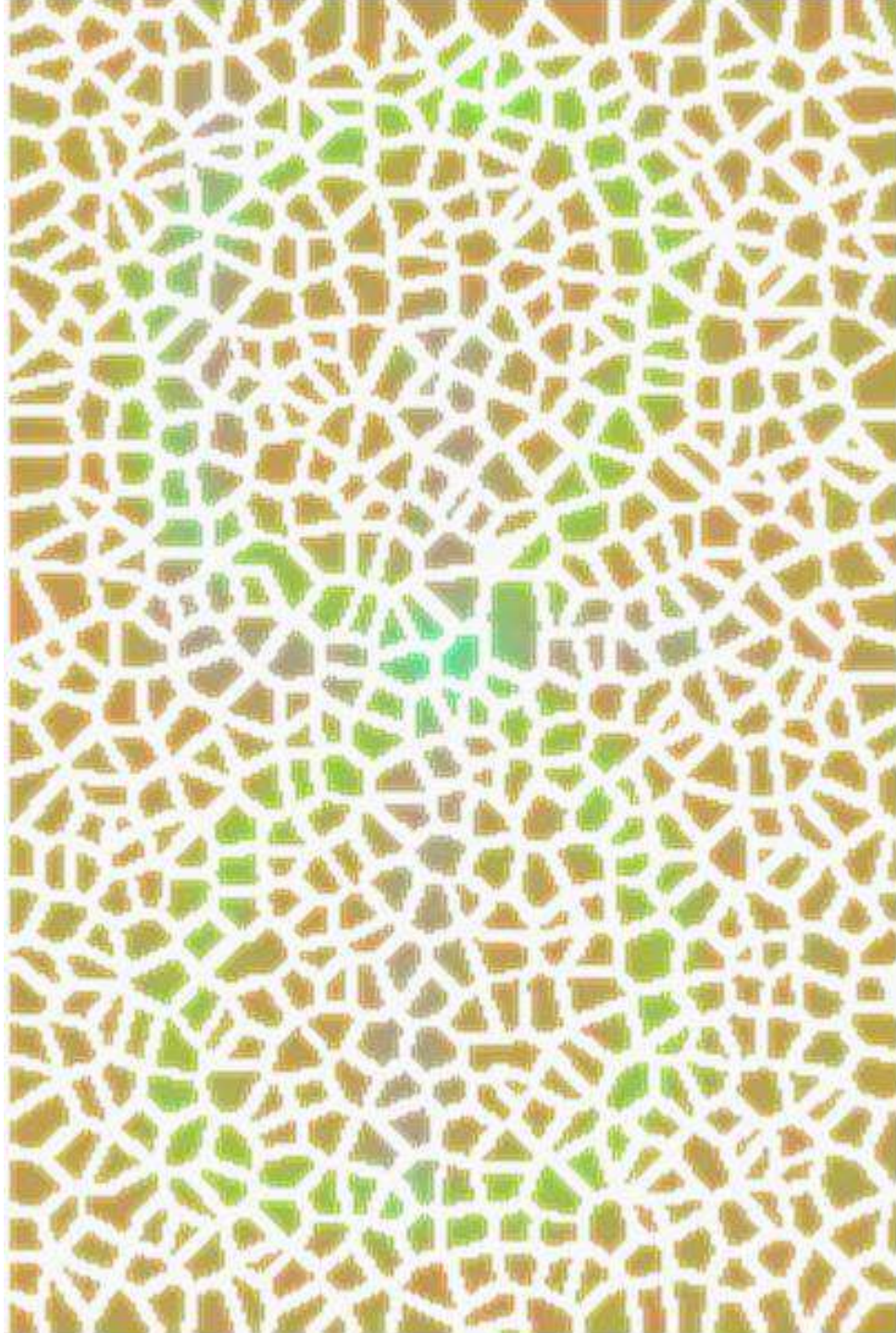


**Dichromatisches Sehen (Säugetiere)
Protanopie (Rotblindheit)**



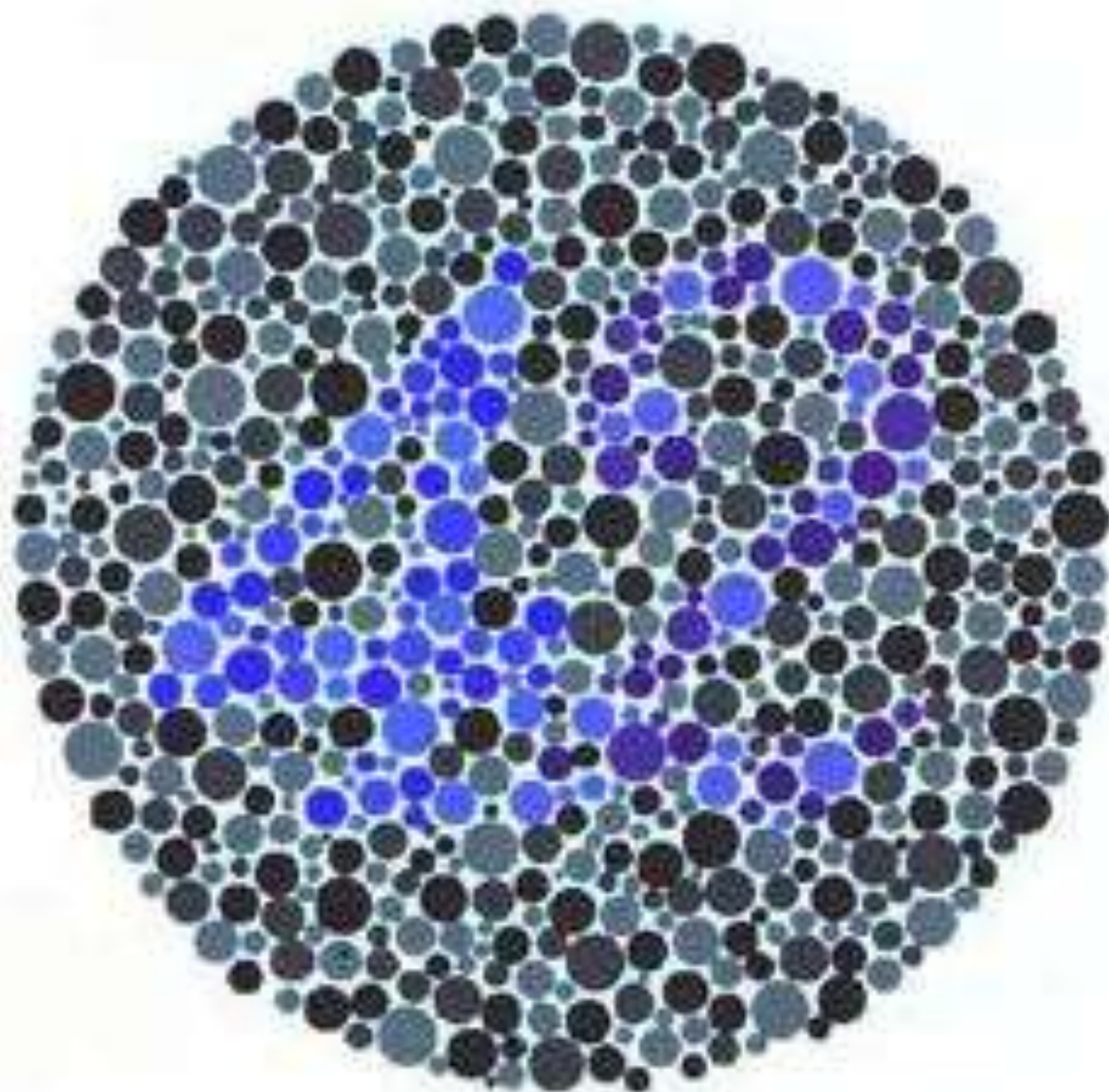


**Sehen ohne M-Zapfen
Deuteranopie(Grünblindheit)**





**Sehen ohne S-Zapfen
Tritanopie(Blaublindheit)**



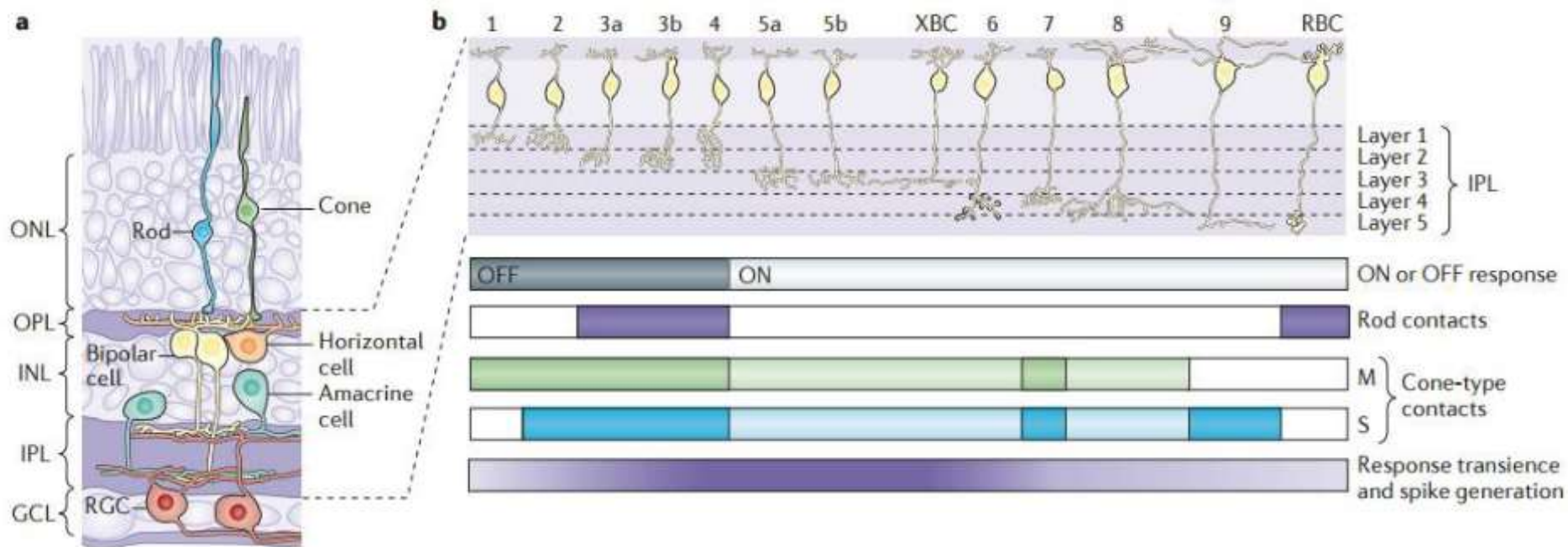


Figure 1 | Organization of the bipolar cells in a mammalian retina.
a | The retina is organized in three nuclear and two synaptic ('plexiform') layers. Light entering the eye passes the entire tissue to reach the light-sensitive outer segments of the rod and cone photoreceptors, where it is transduced into an electrical signal. At the first synaptic layer (the outer plexiform layer (OPL)), this signal is shaped by 1–3 types of horizontal cells and subsequently distributed onto ≥ 13 types of bipolar cells. Bipolar cells form parallel information pathways representing different transformations of the photoreceptor signal and provide the inner retina with highly pre-processed excitatory input. In the inner plexiform layer (IPL), bipolar cell axon terminals synapse onto amacrine cells and retinal ganglion cells (RGCs). Amacrine cells are the most diverse cell class in the retina (~ 42 distinct types exist) and provide bipolar cells and RGCs with mostly inhibitory or neuromodulatory input. Finally, ~ 20 types of RGCs integrate the input from distinct sets of bipolar cells and amacrine cells, and encode the result as trains of spikes to be sent to higher visual centres via their axons, which form the optic nerve. The detailed local interactions between bipolar cells, amacrine cells and RGCs in the inner retina fundamentally underpin the visual feature extraction capabilities of the retina. **b** | Morphologies of the 12 types of

cone bipolar cells and the rod bipolar cell (RBC) in the mouse, which are arranged according to their IPL stratification level (top part of panel)^{6,13,22,23}. Some of the functional differences ('qualities' of the output signals) between bipolar cell types are indicated below this schematic. Depending on the polarity of their light response, bipolar cells can be grouped into ON and OFF cells. Moreover, some bipolar cells can be differentiated on the basis that they relay low-light signals from rods^{20,48,152} (denoted by purple bars). Mice possess short (S; blue) and medium (M; green) wavelength-sensitive cones, with many M-cones co-expressing S-opsin¹⁵³, and depending on the cone type (or types) they contact, bipolar cells can be labelled as chromatic or achromatic^{13,22,78} (contacts denoted by blue and green bars; dimed bars indicate probable but not yet experimentally confirmed contacts). Bipolar cells with terminals in the IPL's central bulk respond more transiently (and often generate spikes) than those closer to the IPL borders (varying response denoted by graded purple bar). GCL, ganglion cell layer; INL, inner nuclear layer; ONL, outer nuclear layer. The top panel of part **b** is adapted with permission from REF. 13, Society for Neuroscience, is adapted with permission from REF. 23 © (2004) Wiley, and is adapted from REF. 6, Nature Publishing Group.

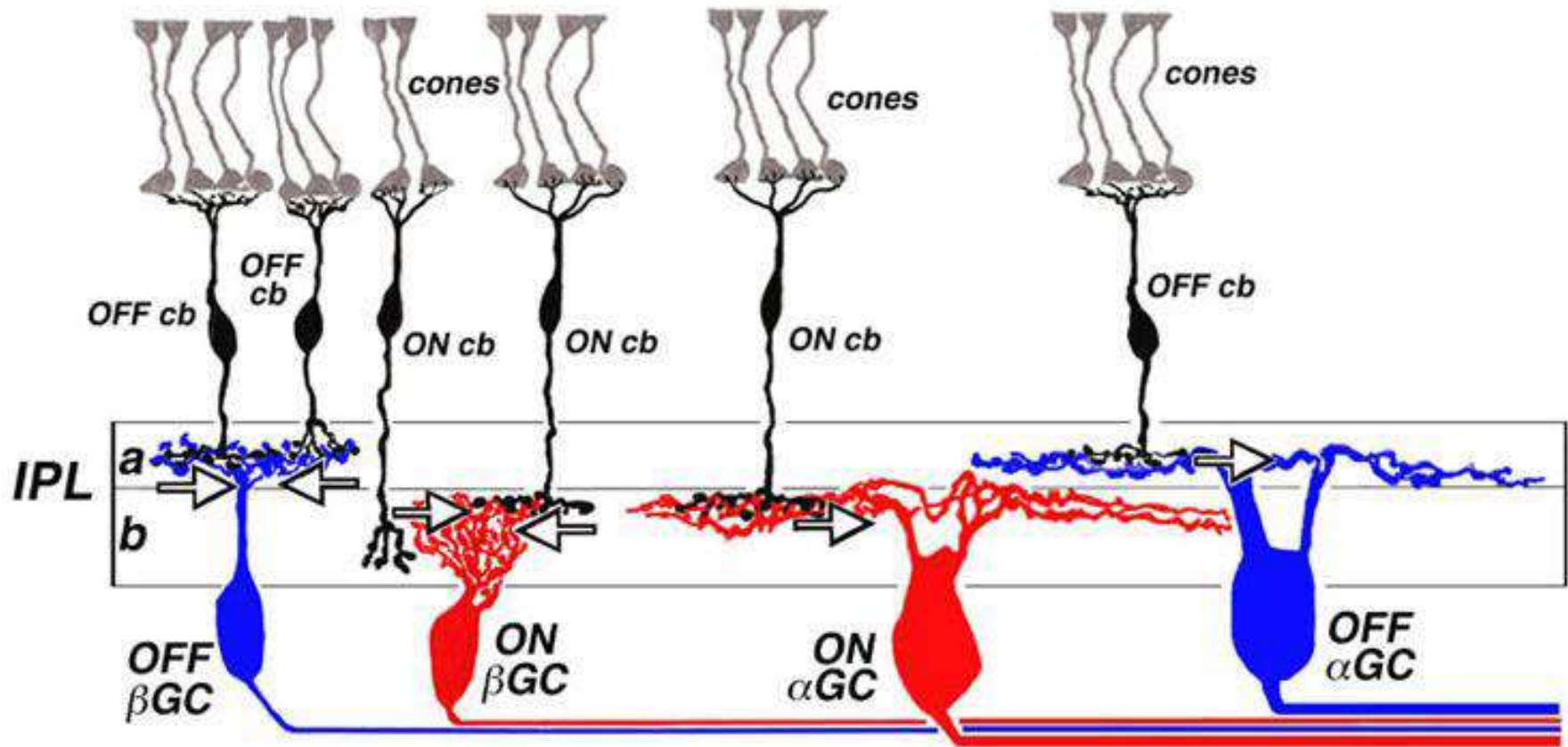
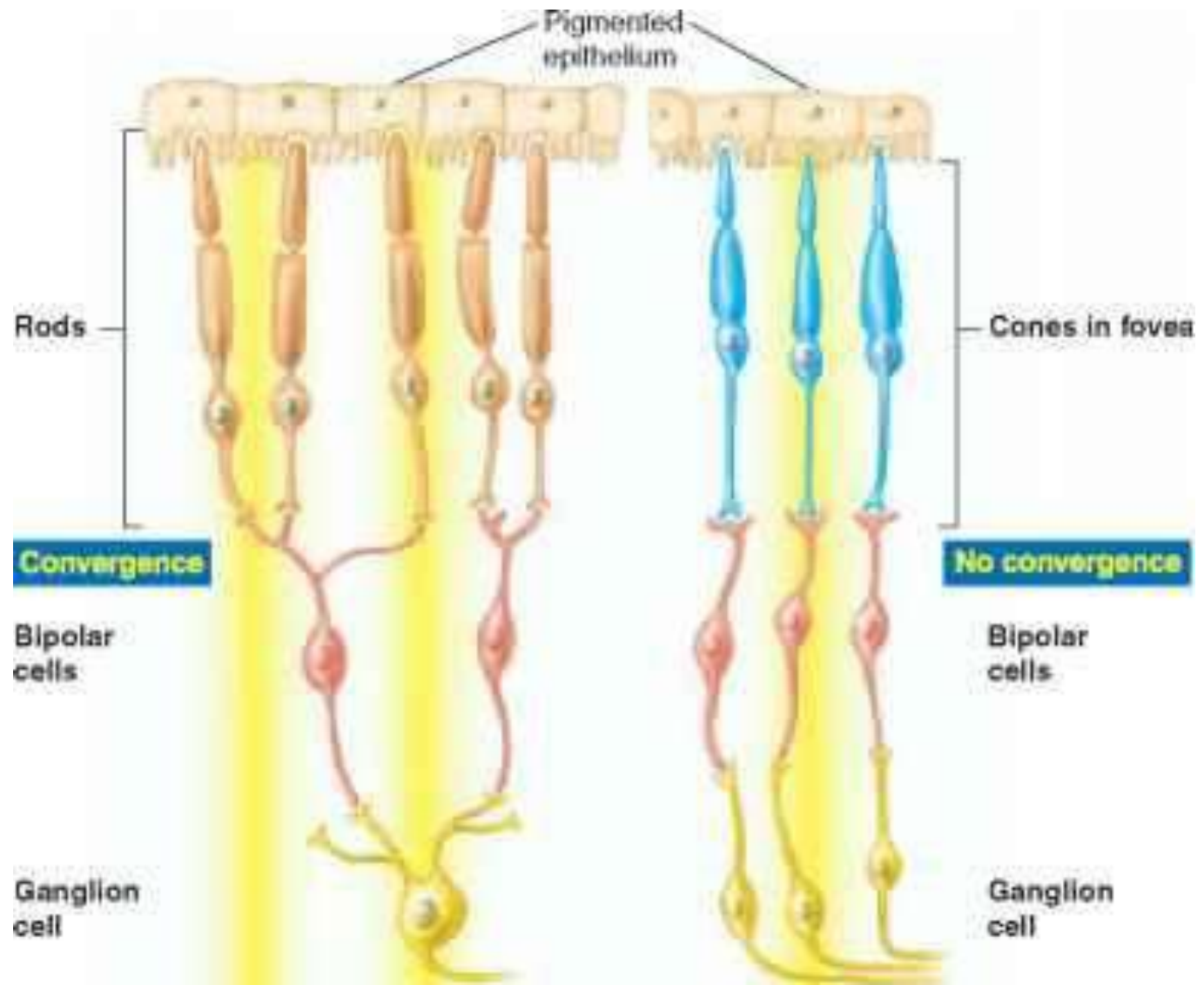
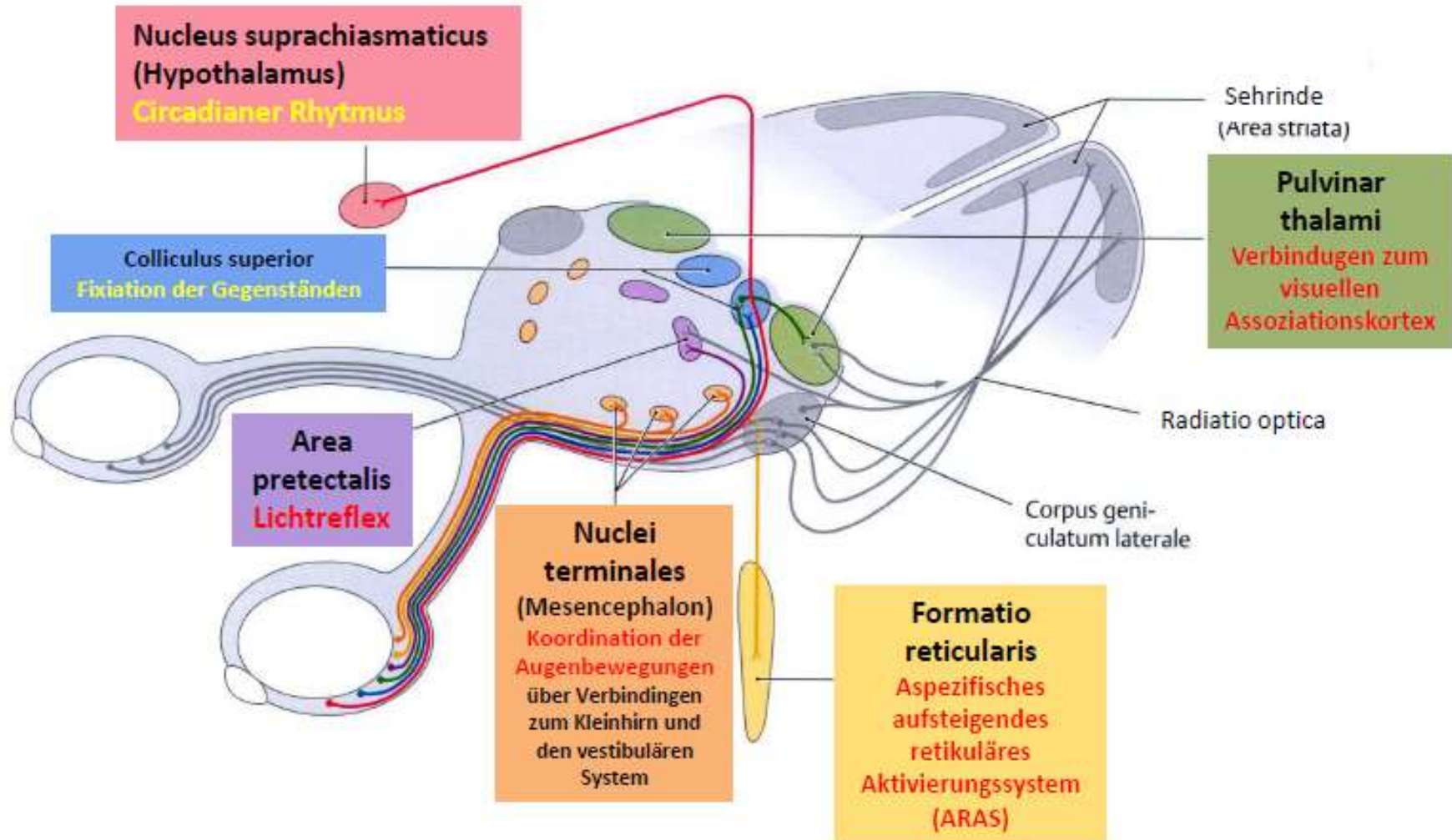


Figure 14. Layering of ON and OFF bipolar cell axons in the cat inner plexiform layer (IPL). OFF ganglion cell (α GC and β GC) dendrites and OFF cone bipolar cell axons (OFF cb) co-stratify in sublamina a of the IPL. ON bipolar axons (ON cb) and ON ganglion cell dendrites co-stratify in sublamina b of the IPL. These are the parallel ON and OFF cone pathways that originate with bipolar-cell dendritic contacts with cones. The illustration is modified from Nelson et al, 1978 (100).



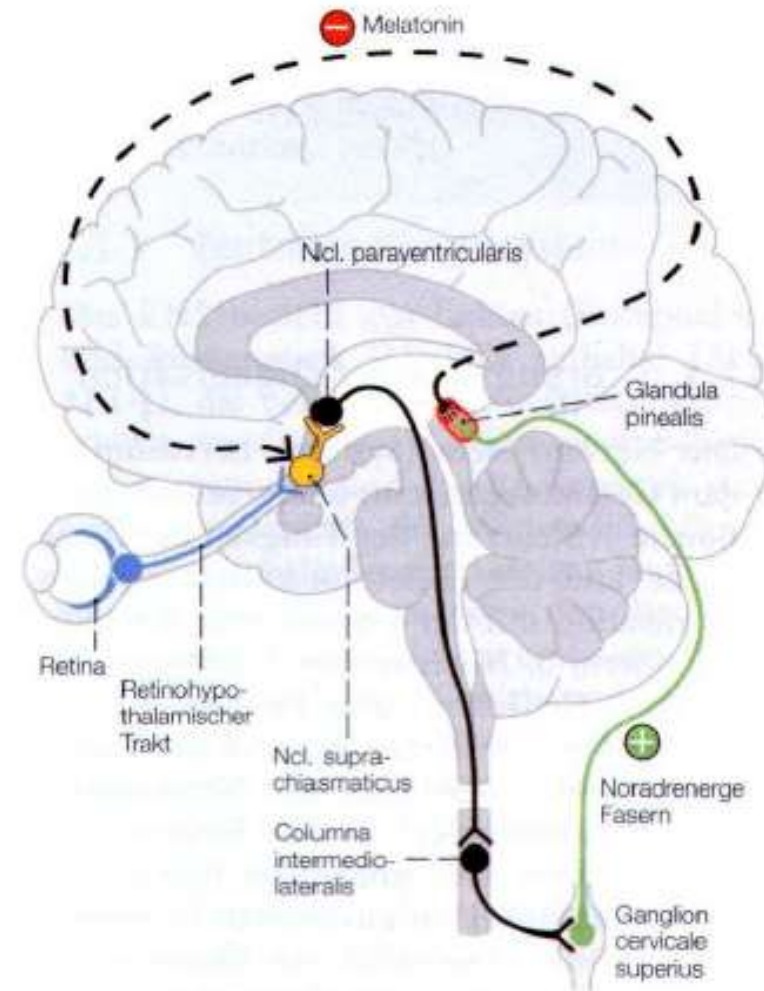
Sehbahn – extragenikuläre Fasern



Non-visuelle Photoperzeption

Nucleus suprachiasmaticus im Hypothalamus

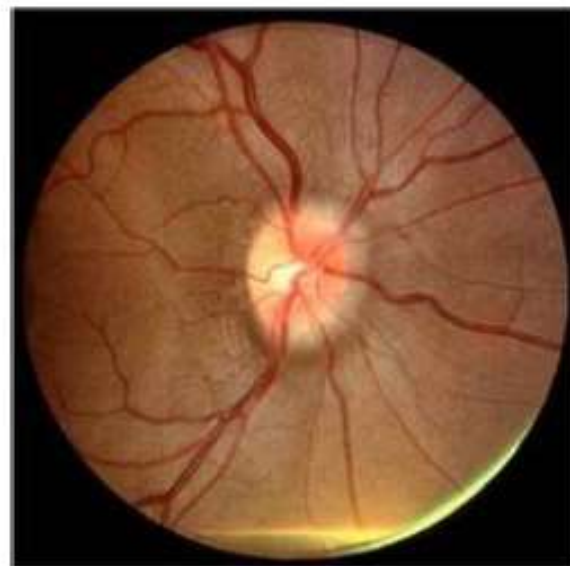
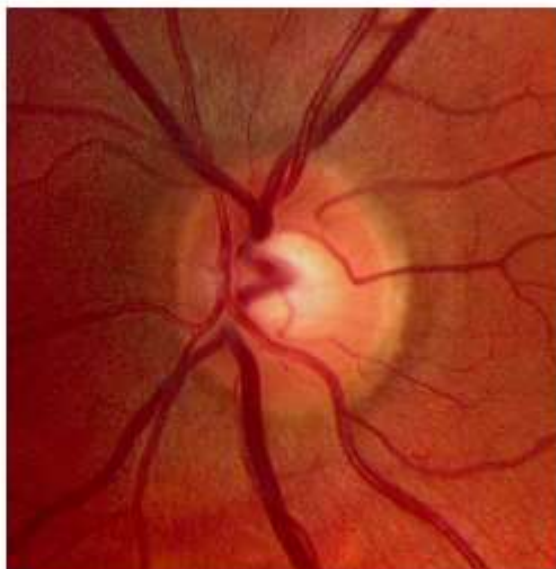
- Er reguliert als intrinsic Zeitgeber den Tag-Nacht-Rhythmus
- Der Kern erhält afferenzen aus der Retina durch Kollateralen der Sehbahn
- Er reguliert die Melatoninsynthese des Corpus pineale
- Die Synthese des Melatonin wird durch das Licht gehemmt, und es wird in Dunkelheit freigesetzt
- Das Melatonin fördert den Schlaf und es hat starke antigonadotrope Wirkung
- *Melatonin kann bei Jetlag und Schlafstörungen (Insomnie) als Arzneimittel verwendet werden*



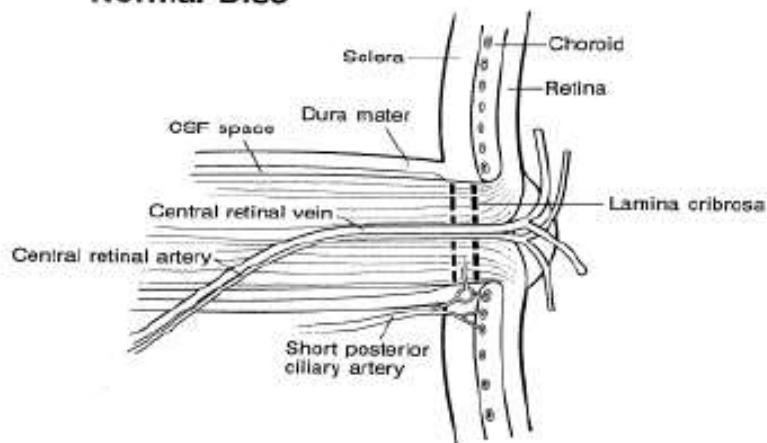
Weitere Zelltypen der Retina

- Neurone:
 - Horizontalzellen
 - Amakrinzellen
- Glia:
 - Müller-Zellen
 - Astrozyten
 - Mikroglia Zellen

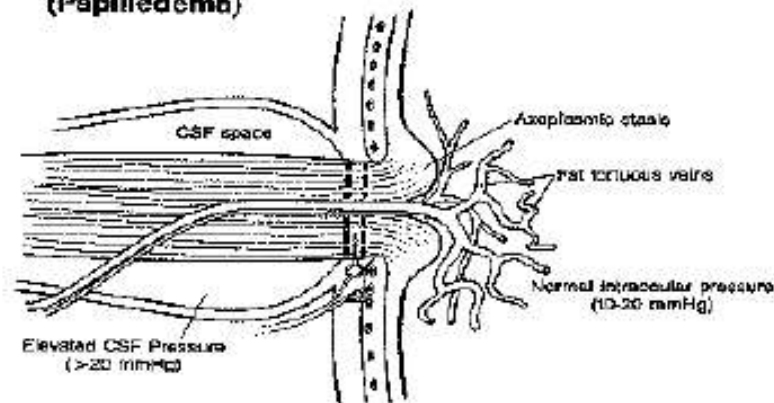
Klinische Bezüge: Intrakranielle Druckerhöhung



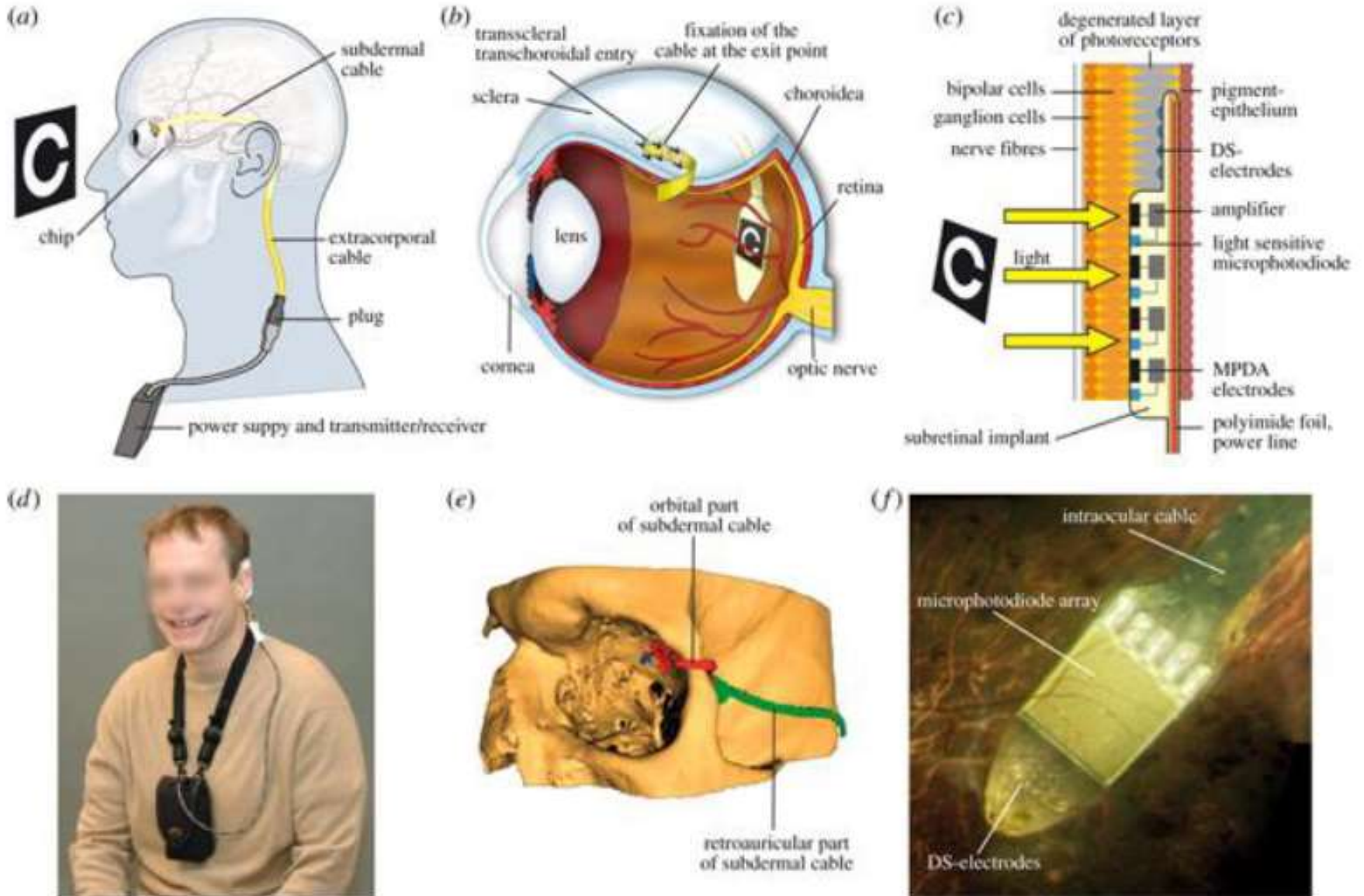
Normal Disc



High CSF Pressure (Papilledema)



Klinische Bezüge: Retina-Implantat



Sehbahn

1. Neuron: Photorezeptor
2. Neuron: Bipolarzelle
3. Neuron: Ganglionzelle

Nervus opticus

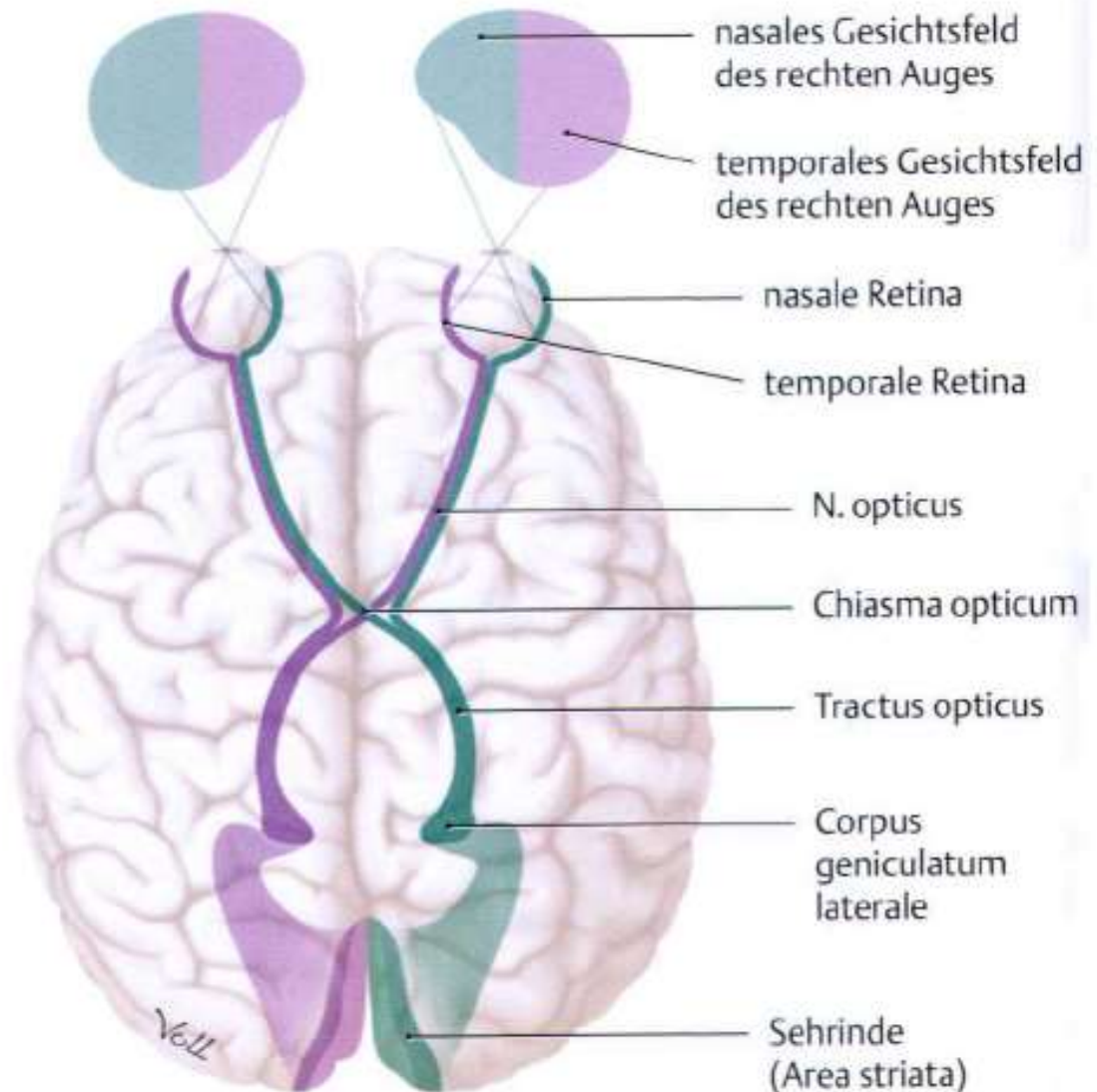
Chiasma opticum

Tractus opticus

4. Neuron: CGL

Radiatio optica

Area striata (Brodmann 17)



Läsionen der Sehbahn

