

# Augenentwicklung

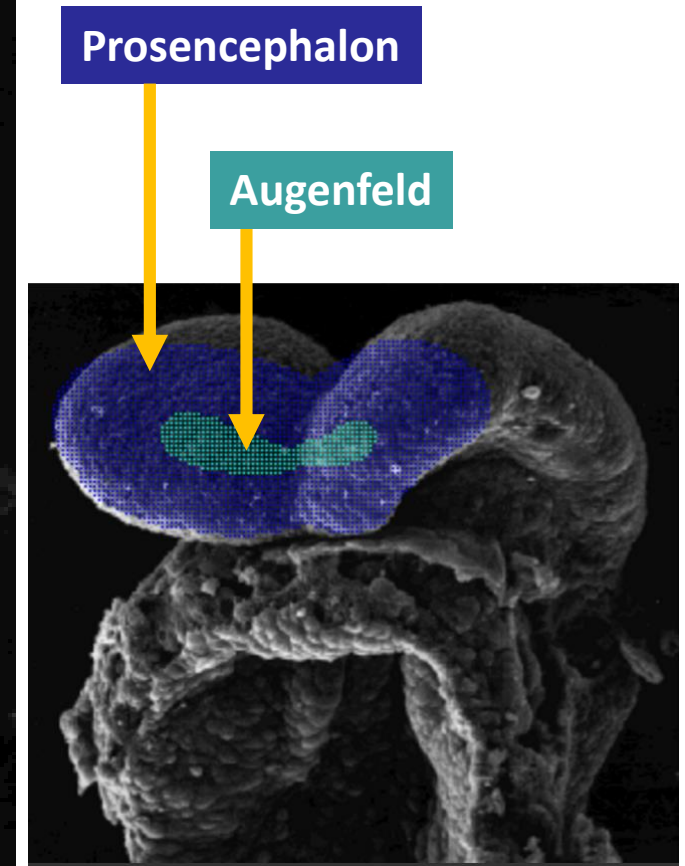
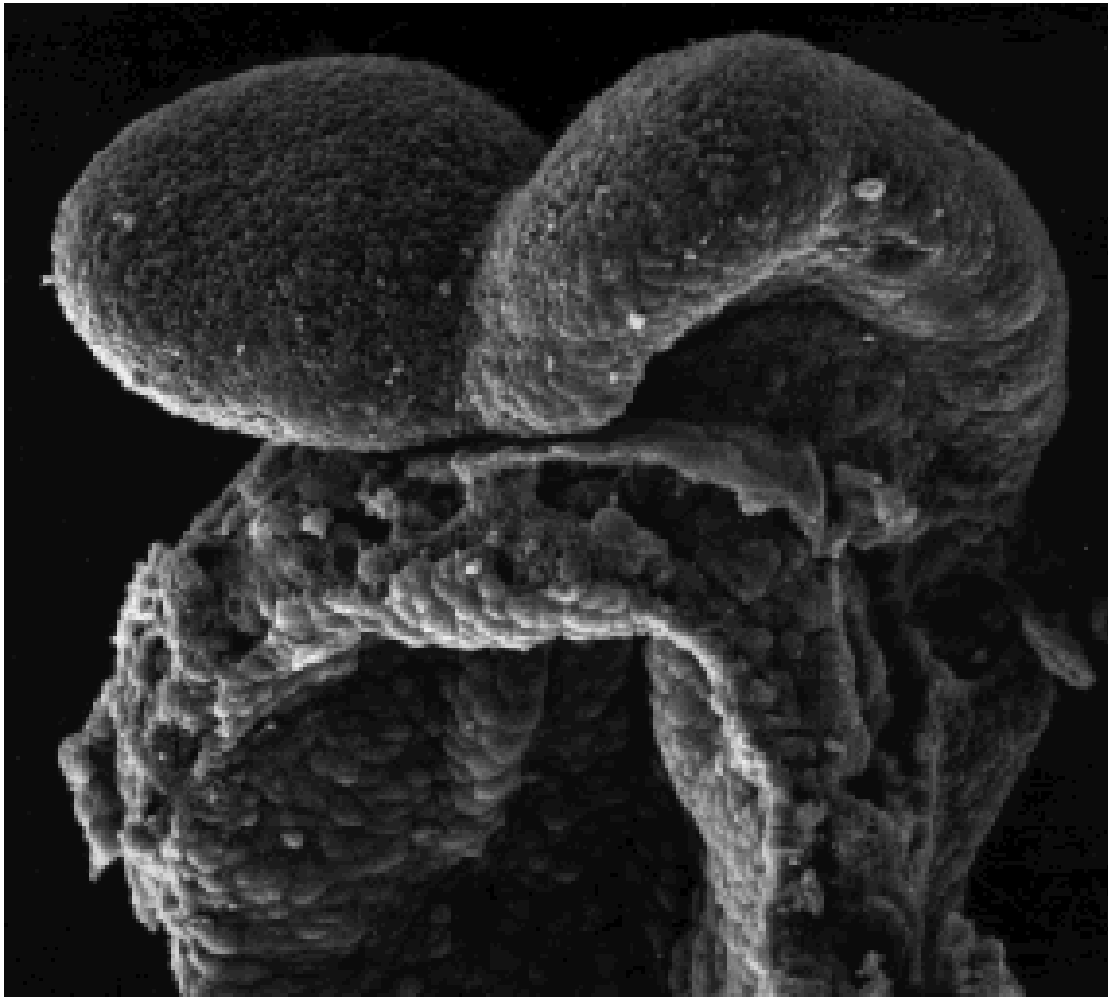
Dr. Szabó Arnold

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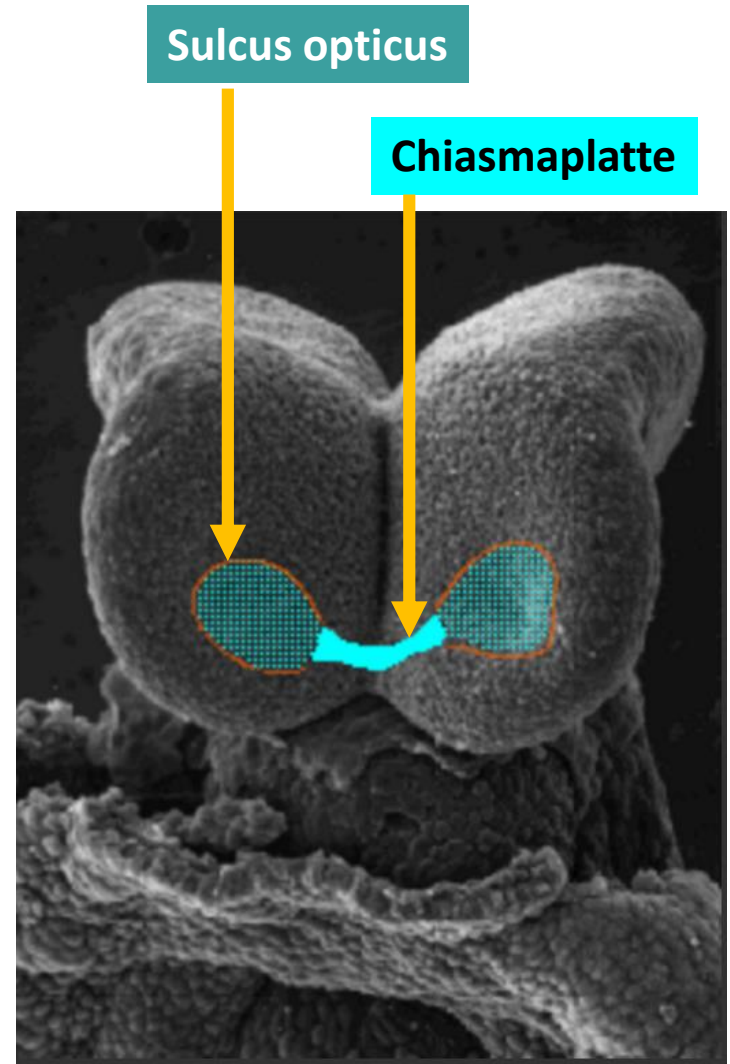
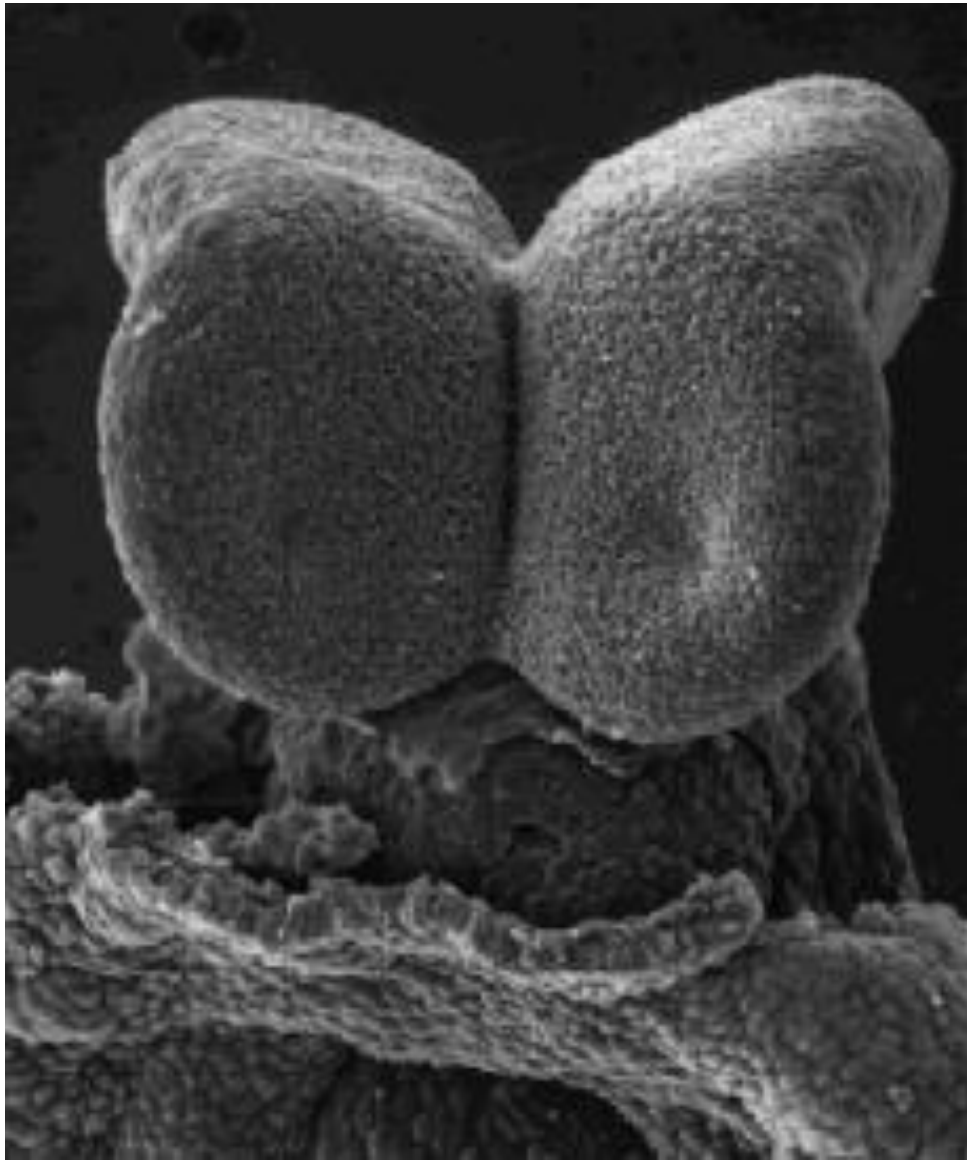
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Anatomisches, Histologisches und Embryologische Institut

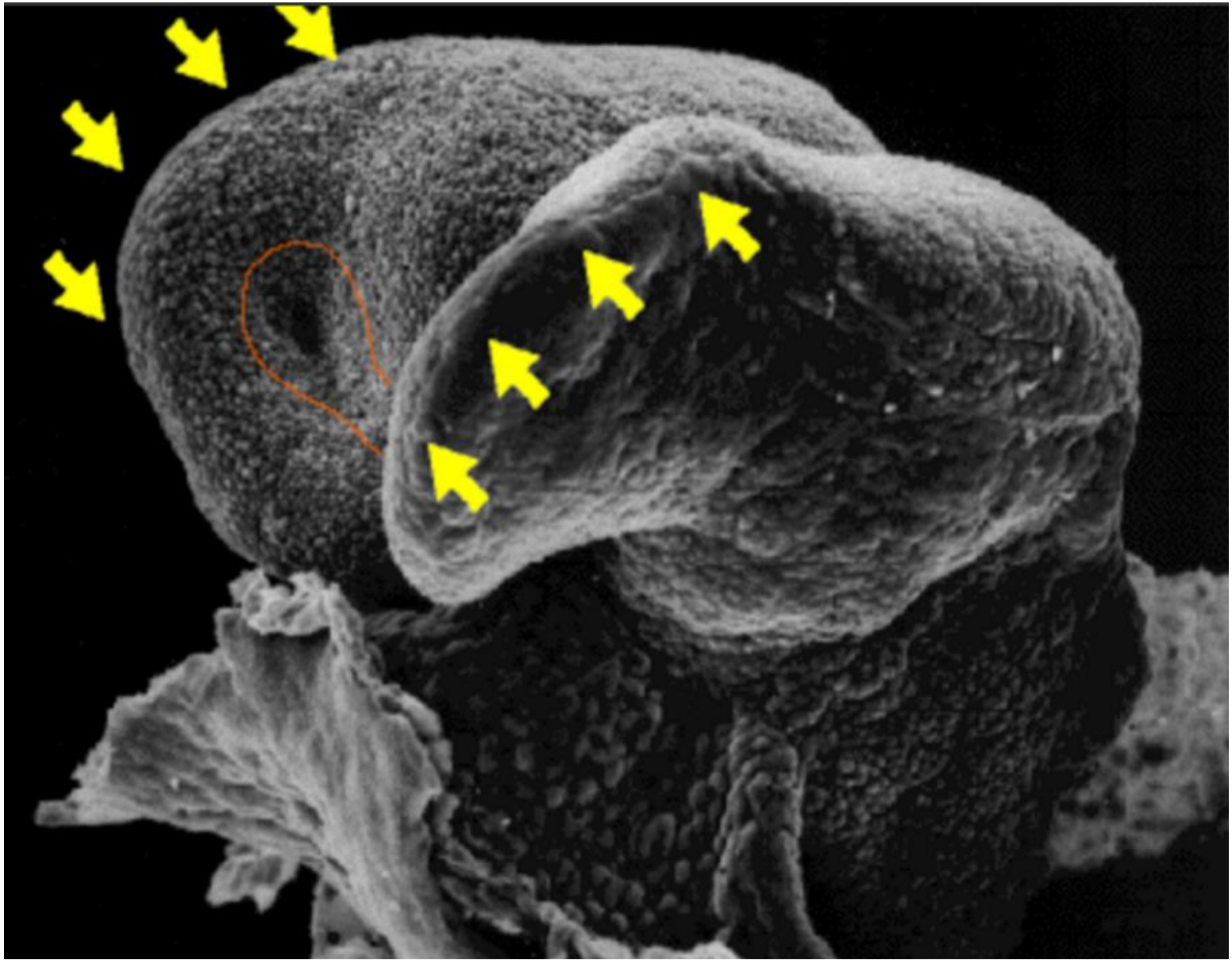
15. November 2015



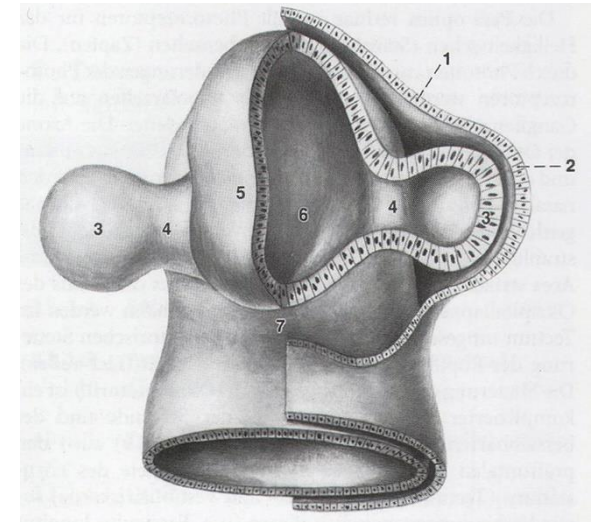
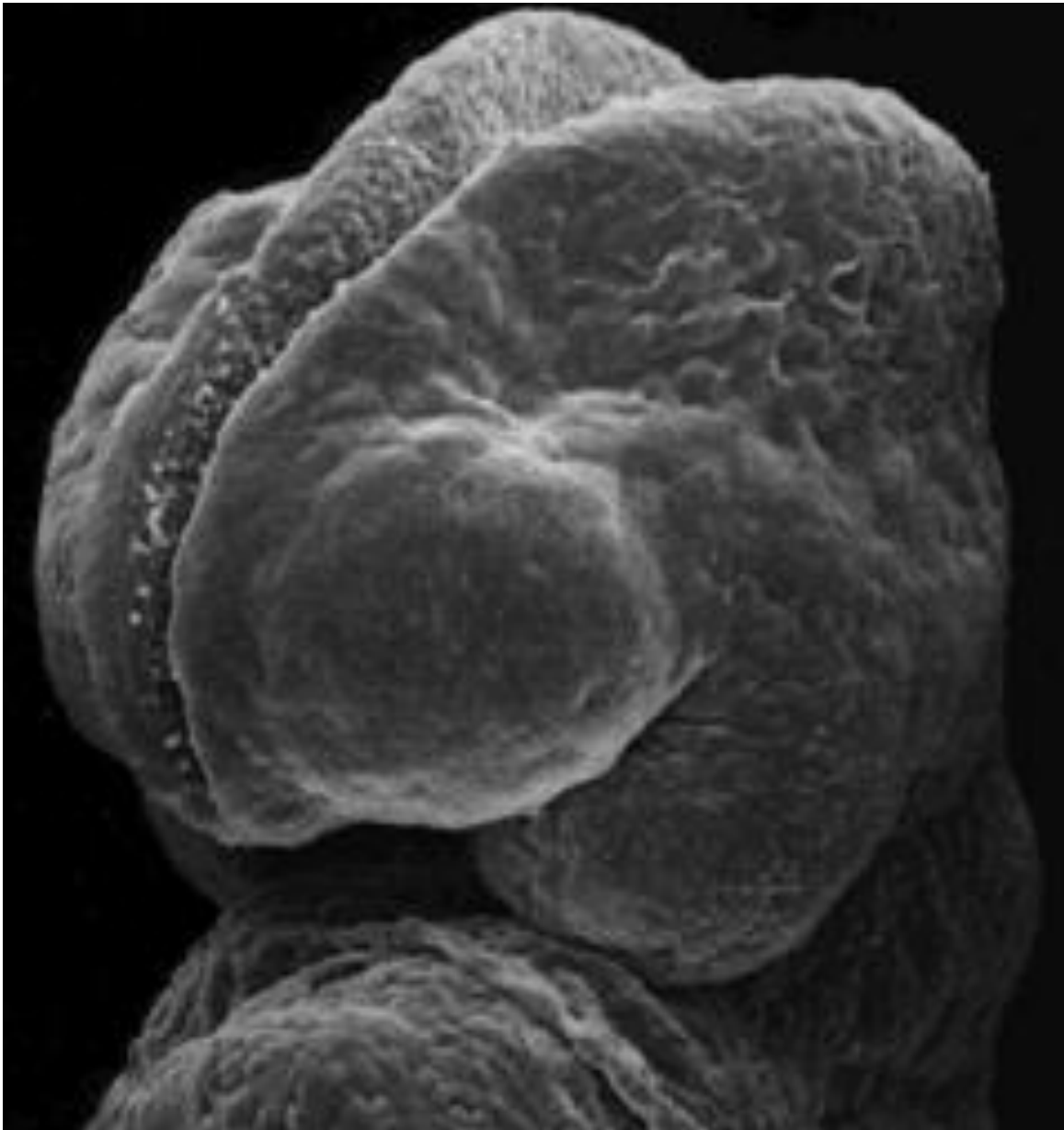
Während der dritten Embryonalwoche erscheinen im späteren Diencephalon die Augenfelder.



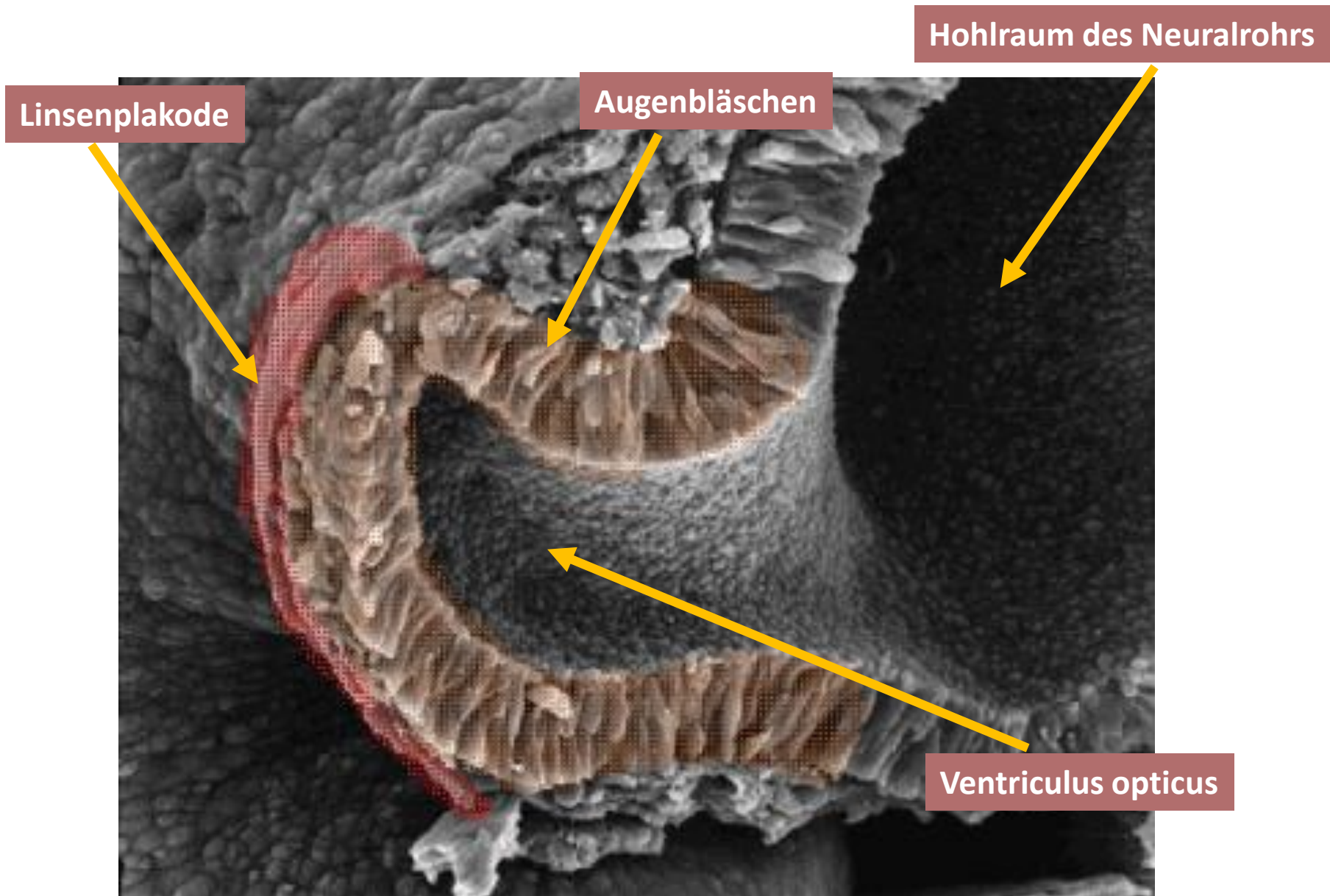
Die ektodermalen Zellen vertiefen das Augenfeld durch Proliferation zum Sulcus opticus.



Durch Faltung des Neuroporus anterior verschließt sich das Neuralrohr.



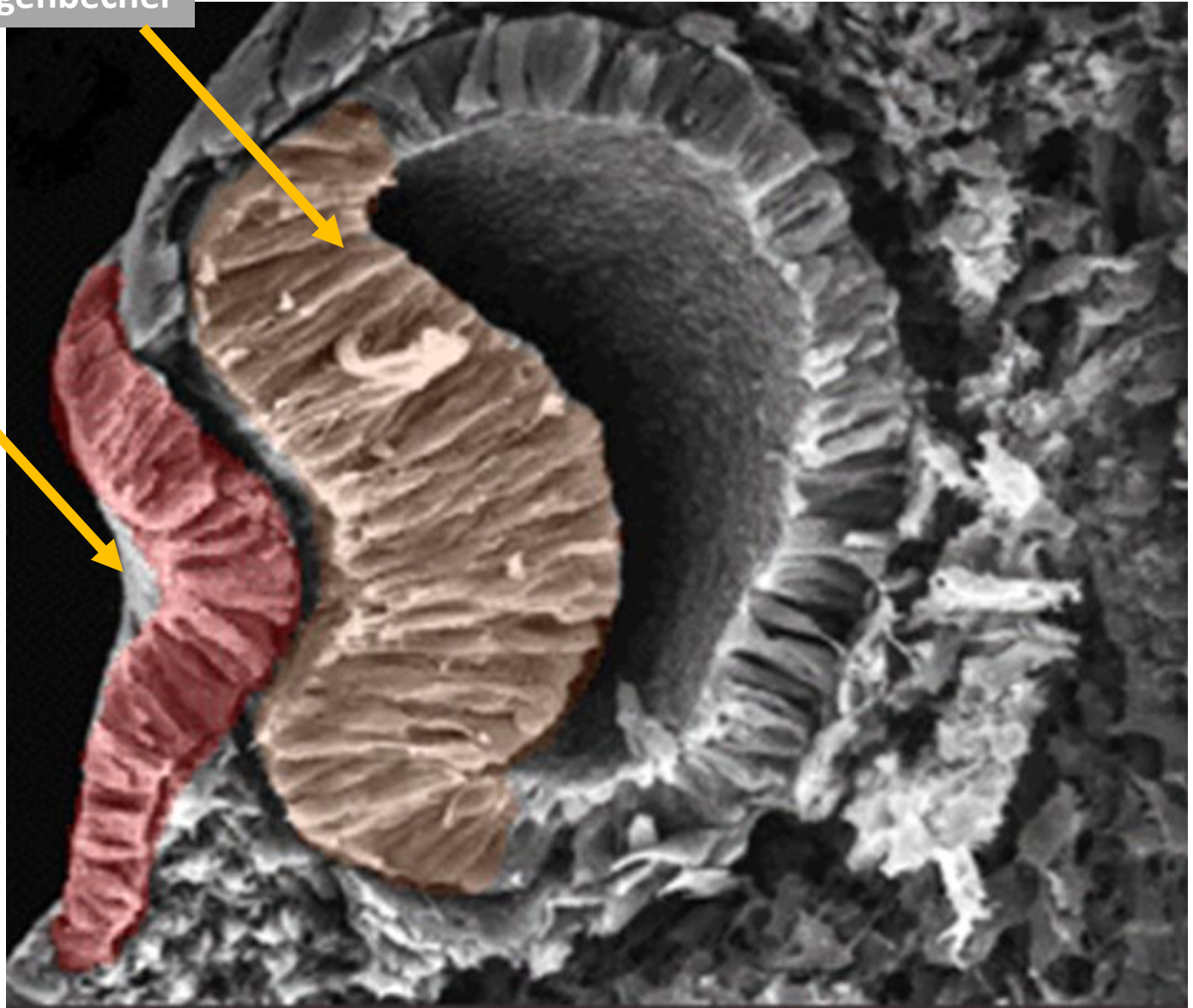
Anfang der 4. Woche erweitert sich der Sulcus opticus nach lateral. Der Sulcus opticus wird zum Augenbläschen (Vesicula optica), dessen Hohlraum in den Hohlraum der späteren III. Ventrikel übergeht.



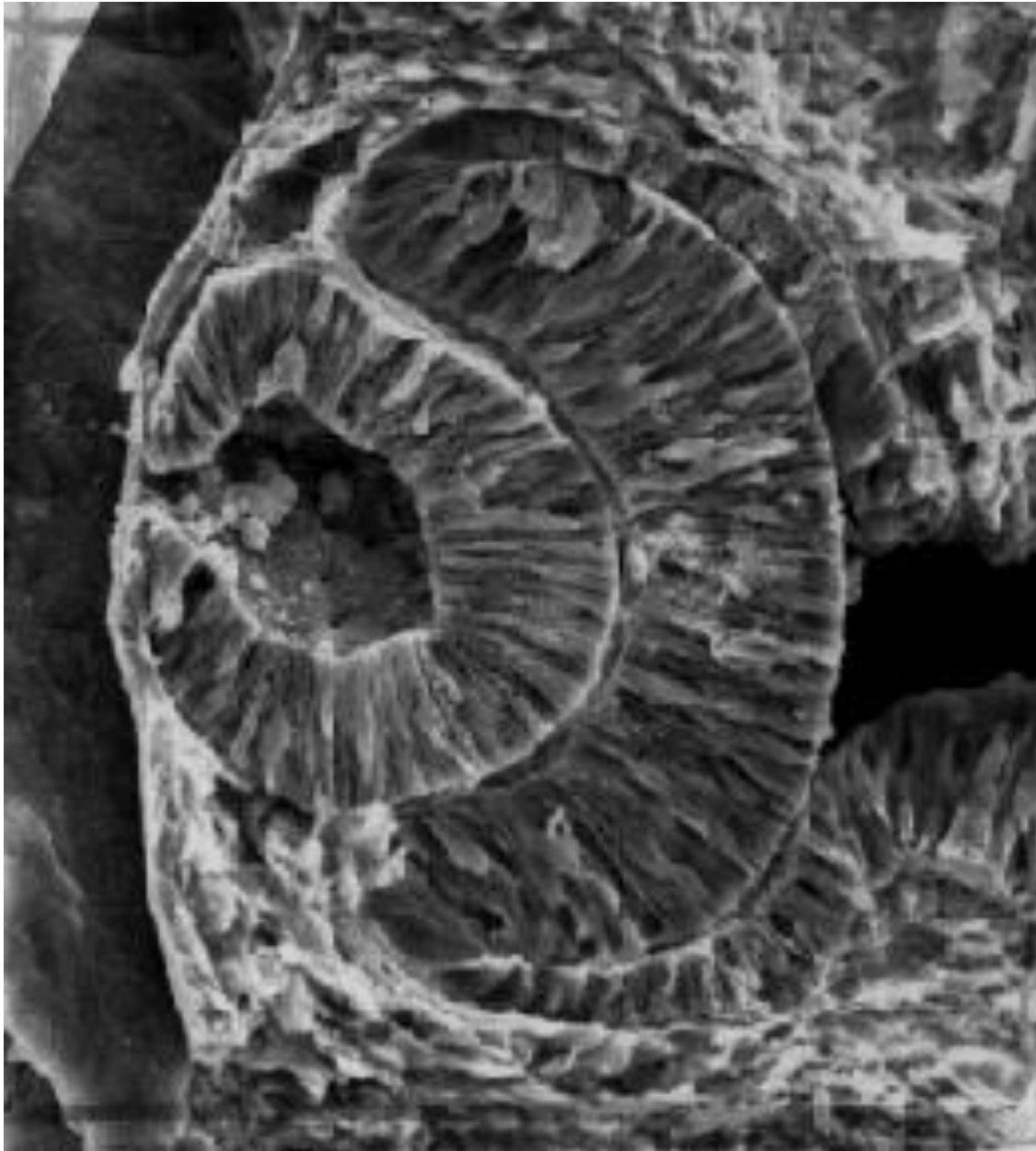
Das Augenbläschen bleibt im direkten Kontakt mit dem Oberflächenektoderm.

Augenbecher

Linsengrube



Die Linsenplakode sinkt zur Linsengrube ein. Der laterale Abschnitt des Augenbläschens stülpt sich ein, wodurch ein zweiblättriger Augenbecher entsteht.

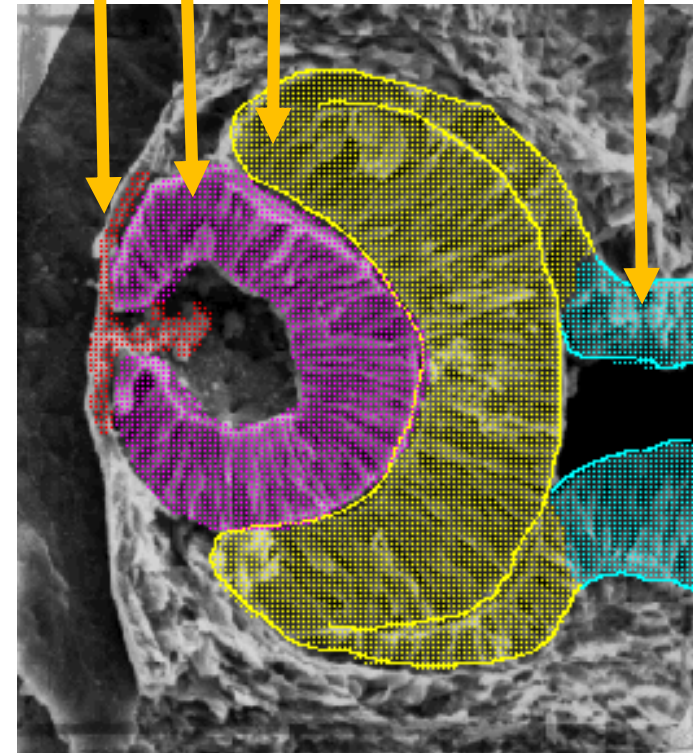


Oberflächenektoderm

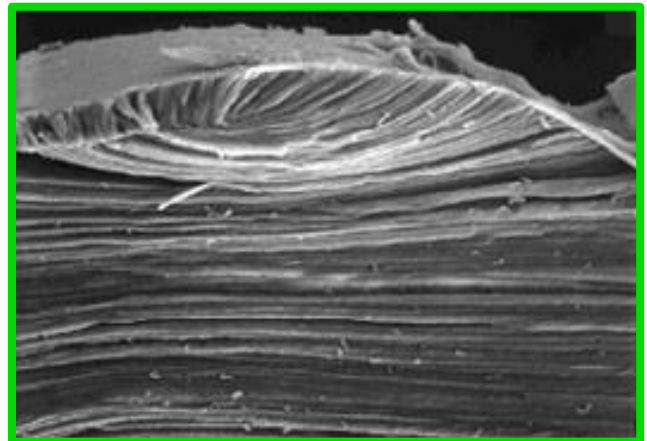
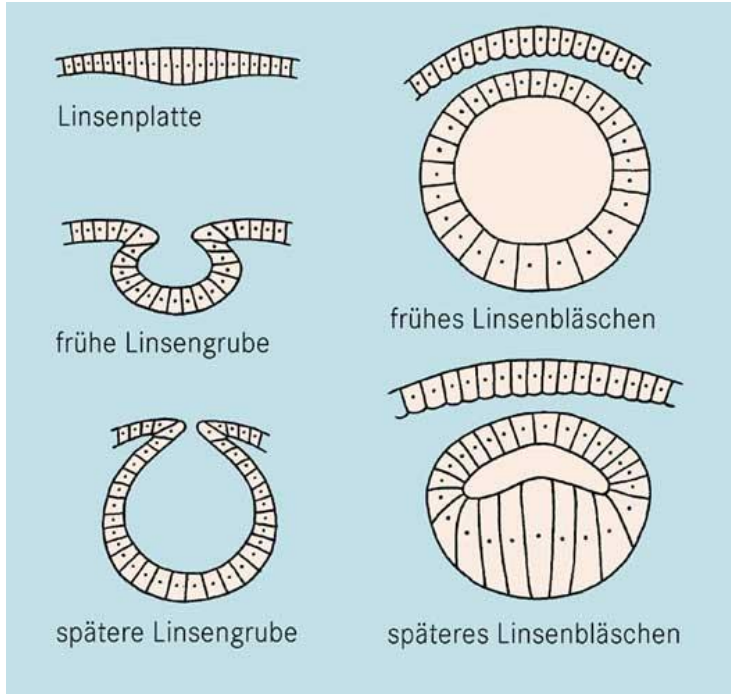
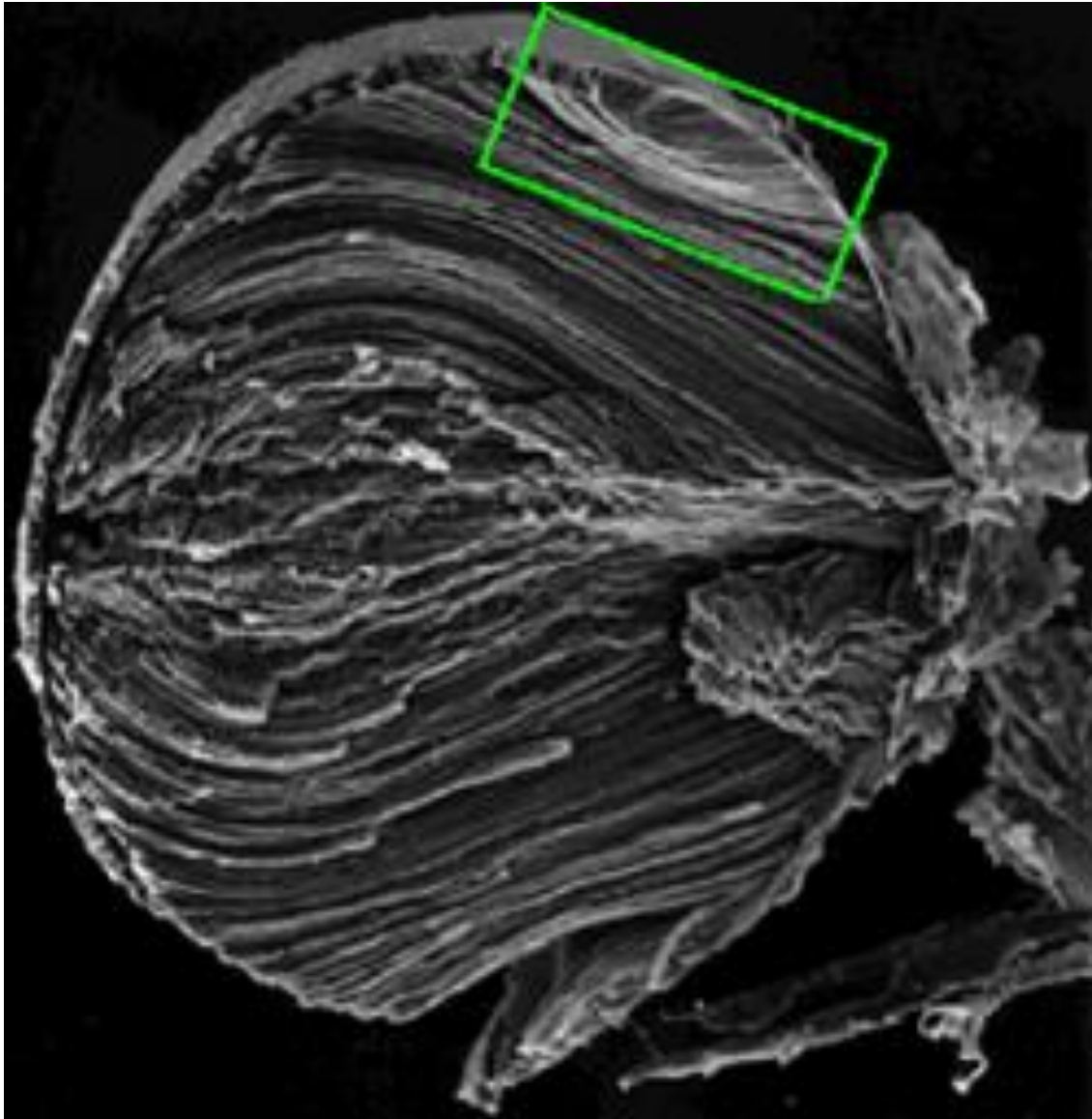
Linsengrube

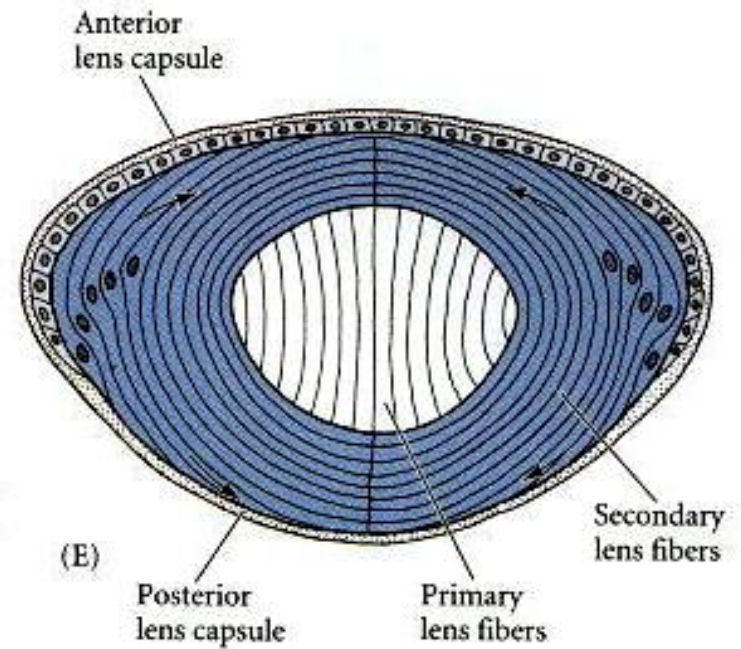
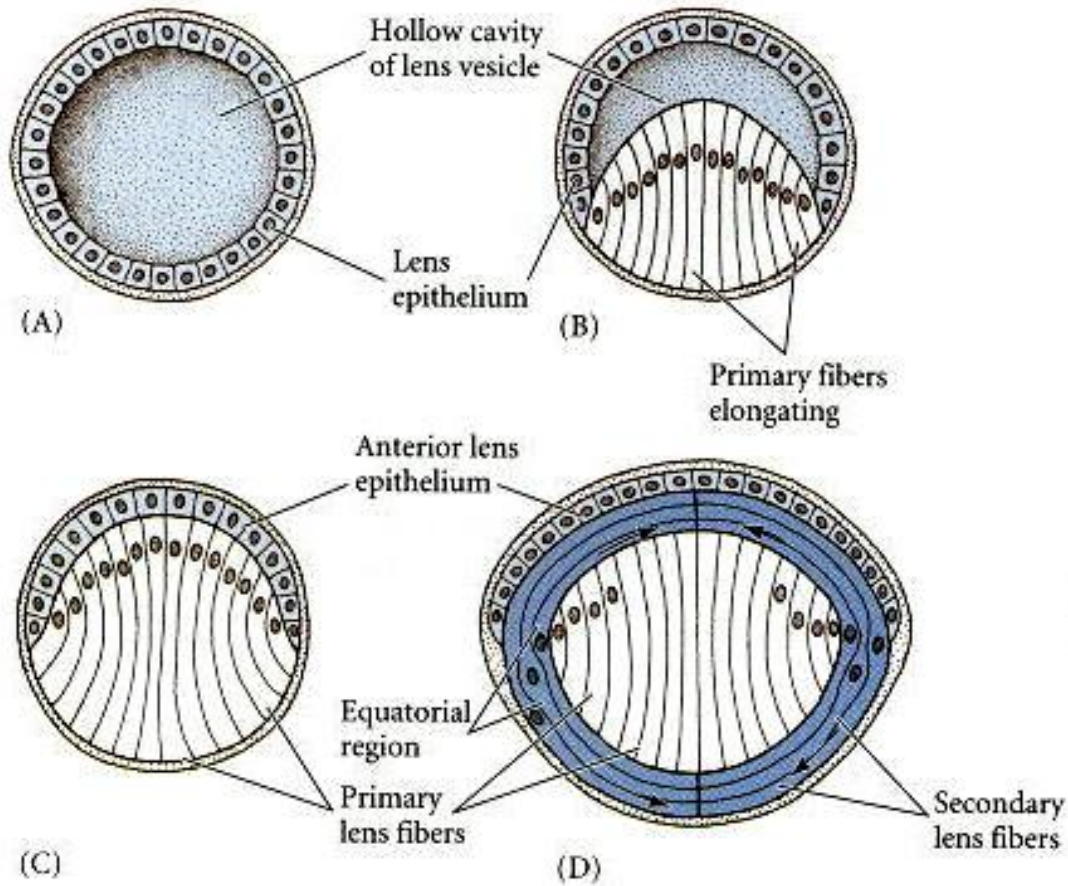
Augenbecher

Augenbecherstiel





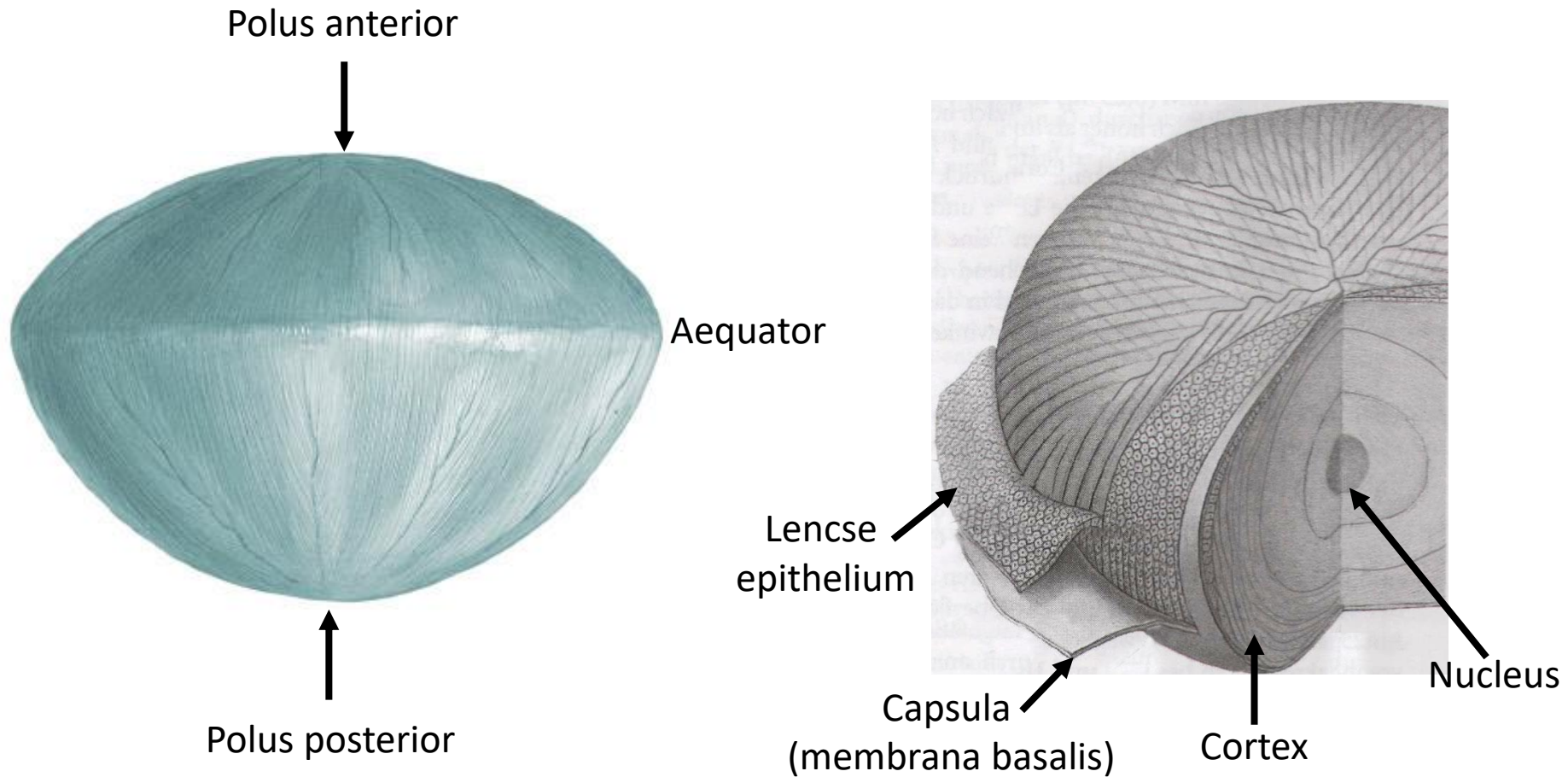




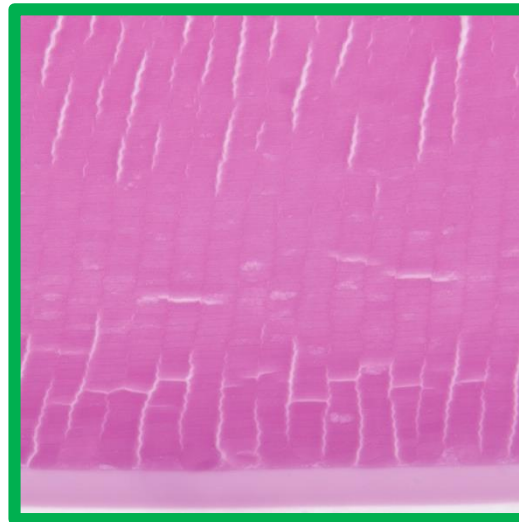
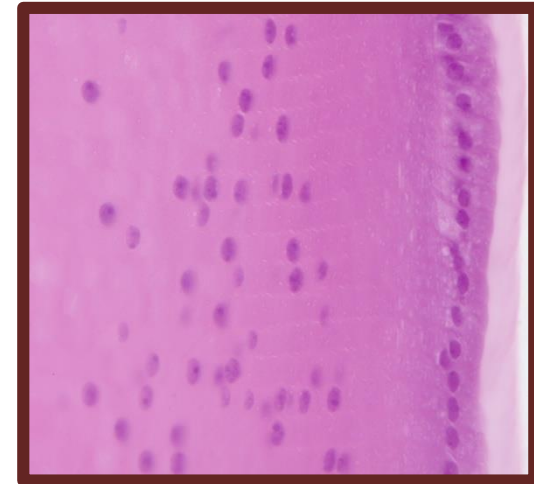
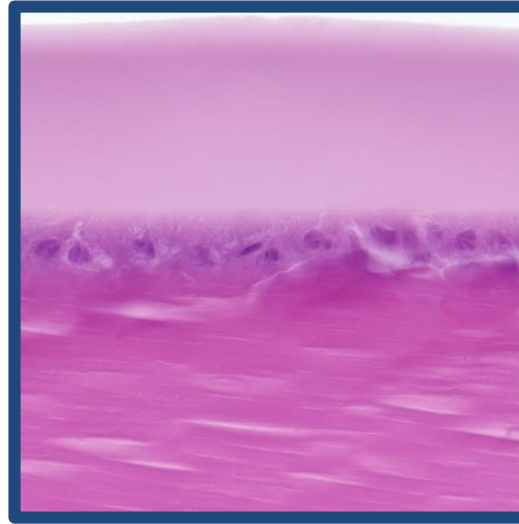
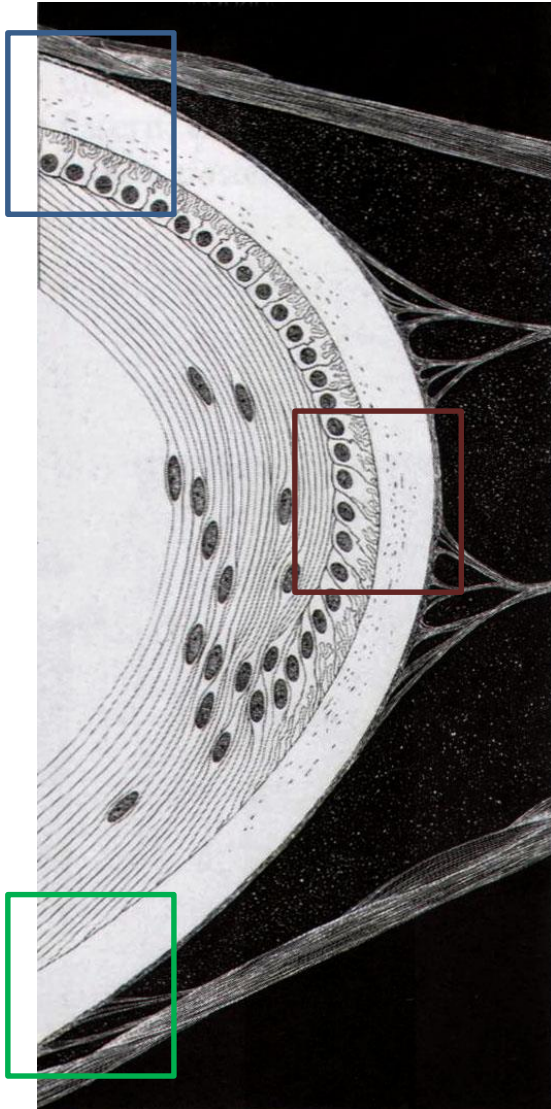
Das Linsenbläschen trennt sich von dem Oberflächenektoderm schon an der 5. Woche ab. Seine Basalmembran wird zur Capsula lentis. Die Linsenepithelzellen der dorsalen Linsenbläschenwand verlängern sich und wandeln sich in primären Linsenfasern um. Die sekundäre Linsenfasern bilden sich ab dem 3. Embryonalmonat.

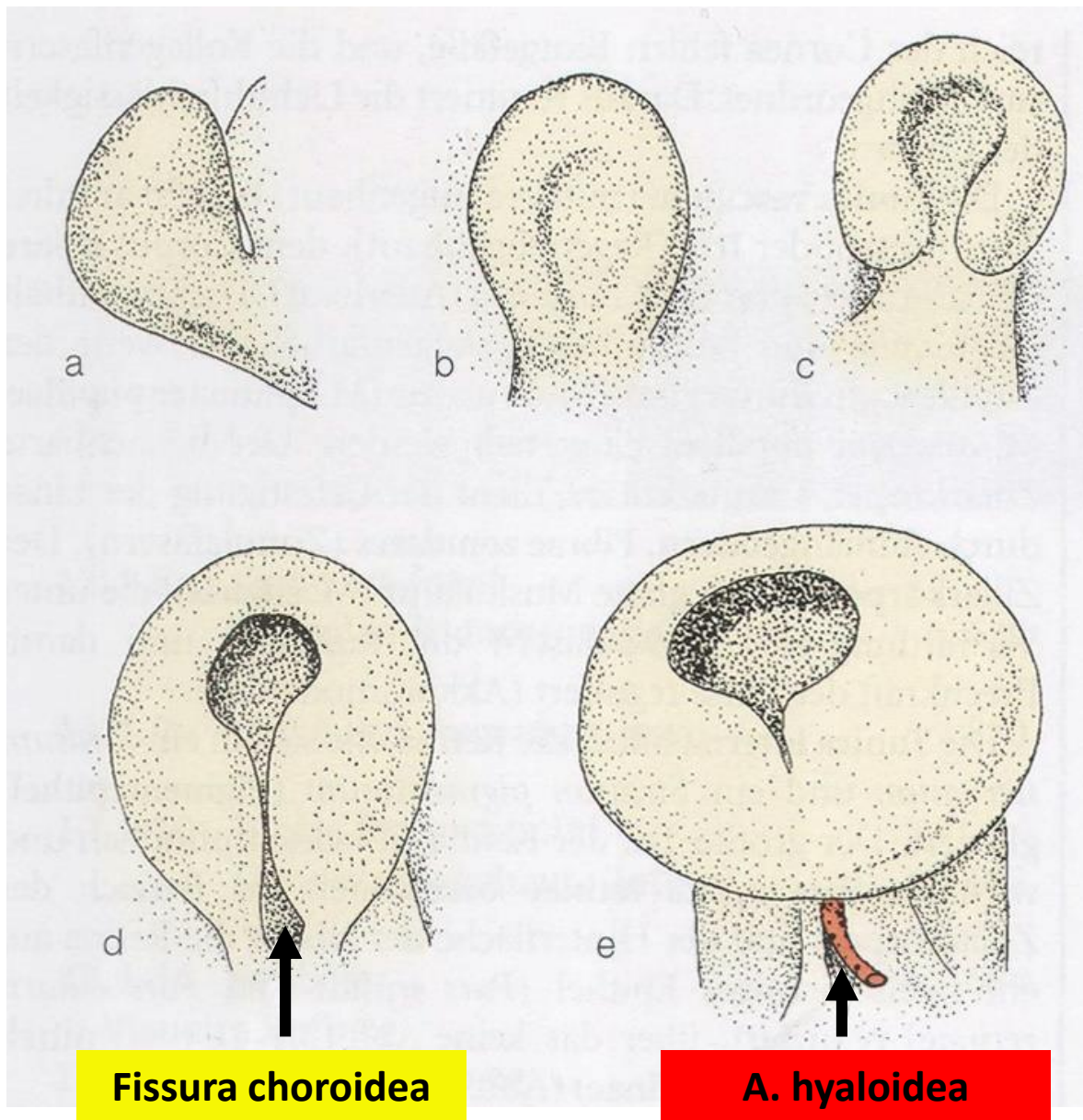
**Cataracta congenita:** angeborene Katarakt (zB. Rubeola Infektion an der 4-7. Woche!!!)

# Aufbau der Linse



# Histologie der Linse



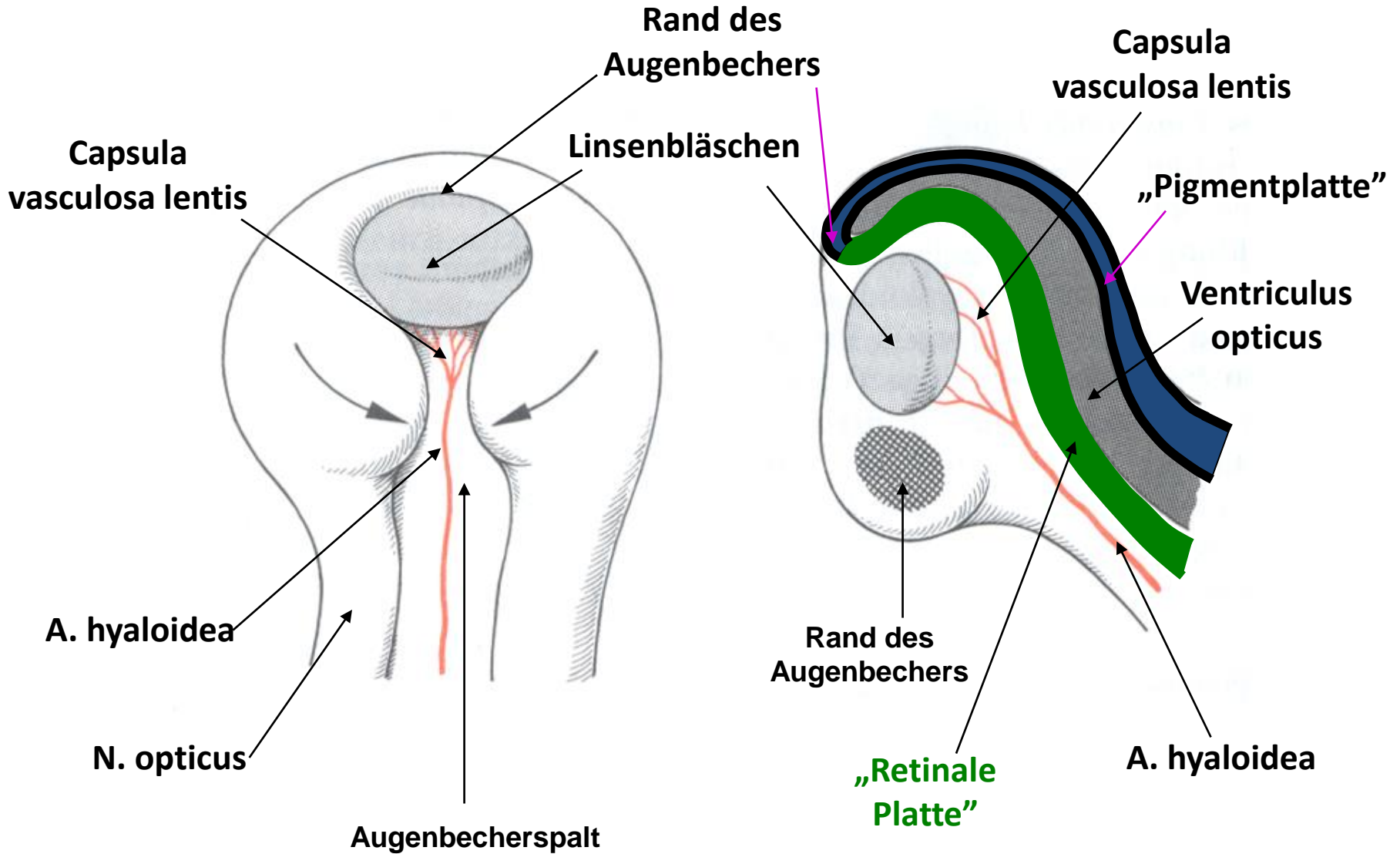


**Fissura choroidea**

**A. hyaloidea**

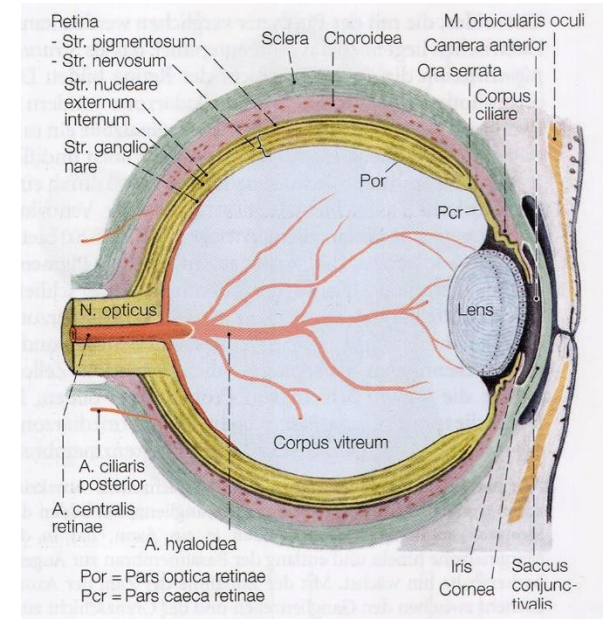
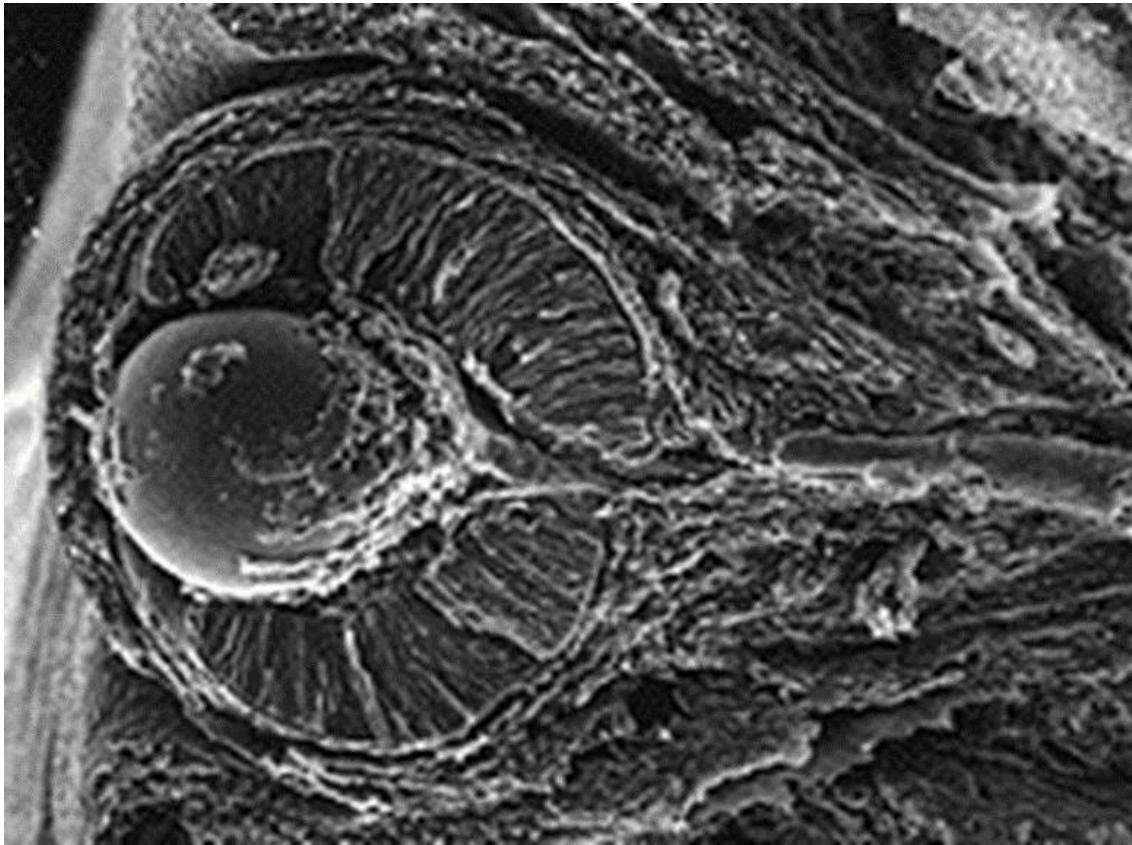
Die Eindellung des Augenbechers ist asymmetrisch. Auf der ventralen Seite des Augenbecherstiels entsteht der Augenbecherspalt (Fissura choroidea), der als Leitstruktur für die Axonen des Nervus opticus dient. Durch die Fissura choroidea tritt die Arteria hyaloidea in den Augenbecher ein.

# Entwicklung des Augenbecherstiels



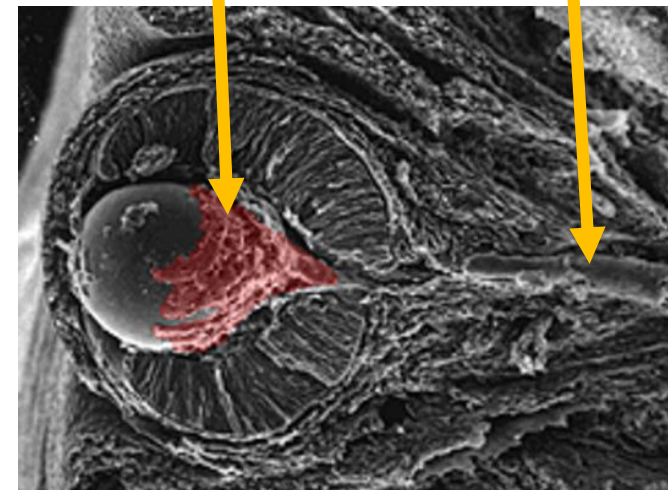
# Kolobom



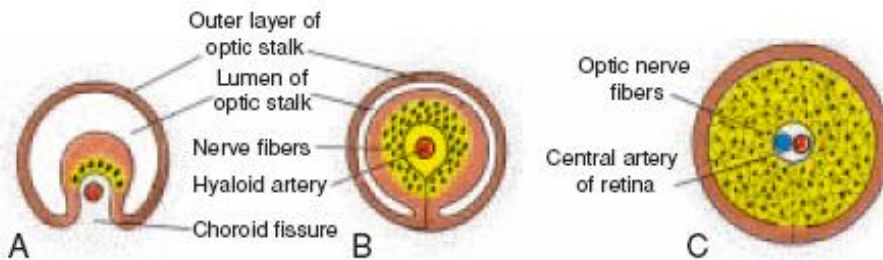


**A. hyaloidea**

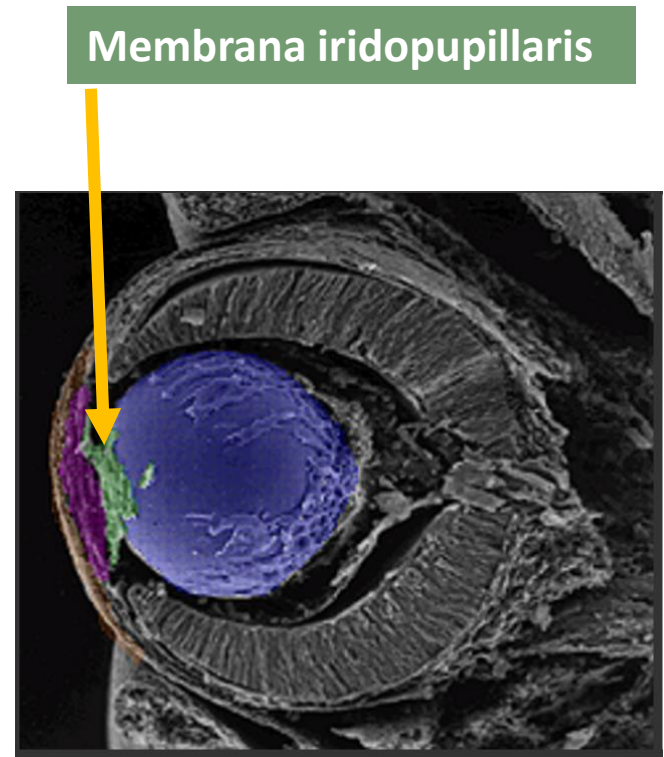
**A. centralis retinae**



Der distaler Teil der Arteria hyaloidea bildet sich im achten Embryonalonat zurück. Ihr proximaler Teil verbleibt und wird zur Arteria centralis retinae.

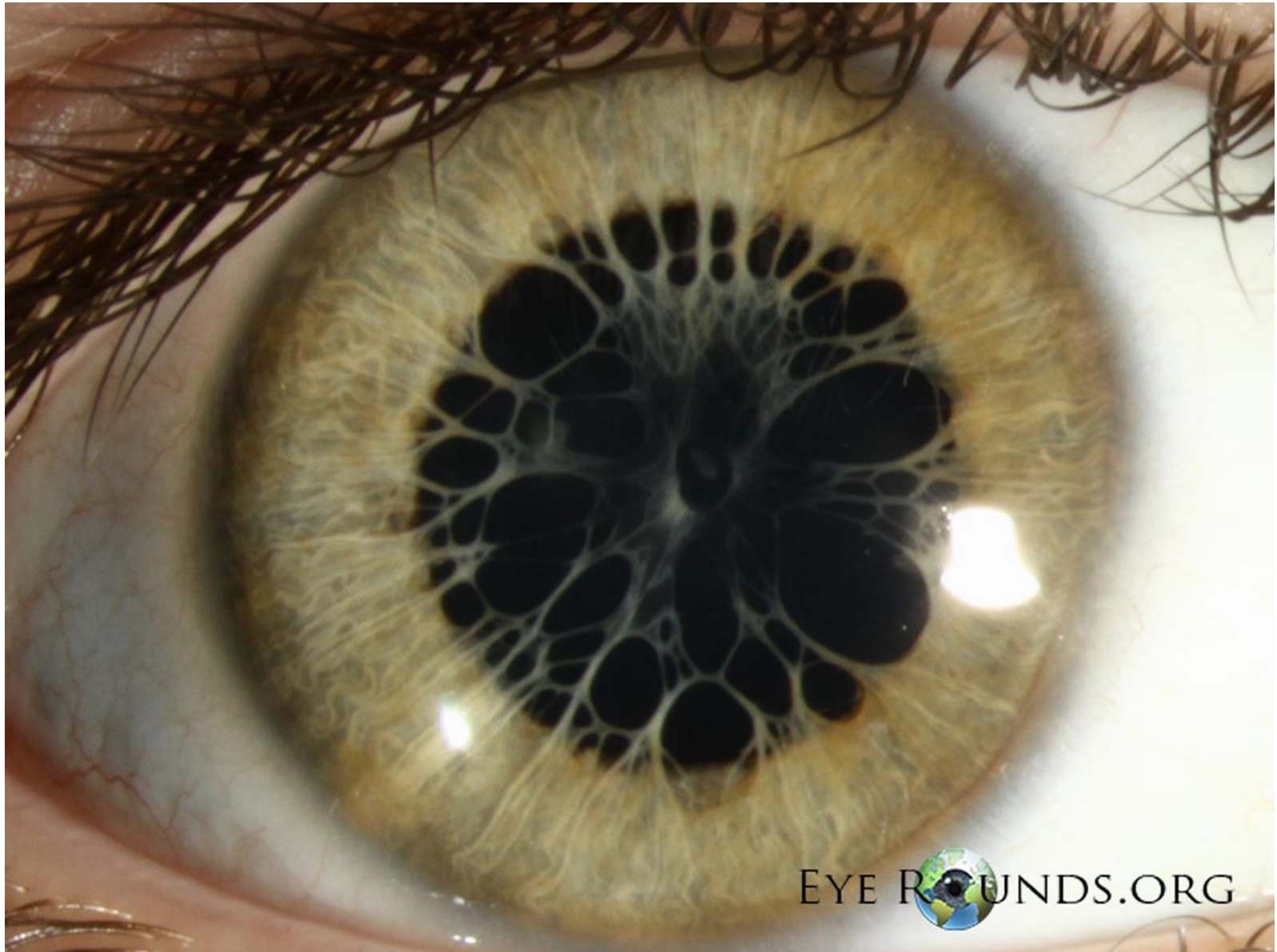


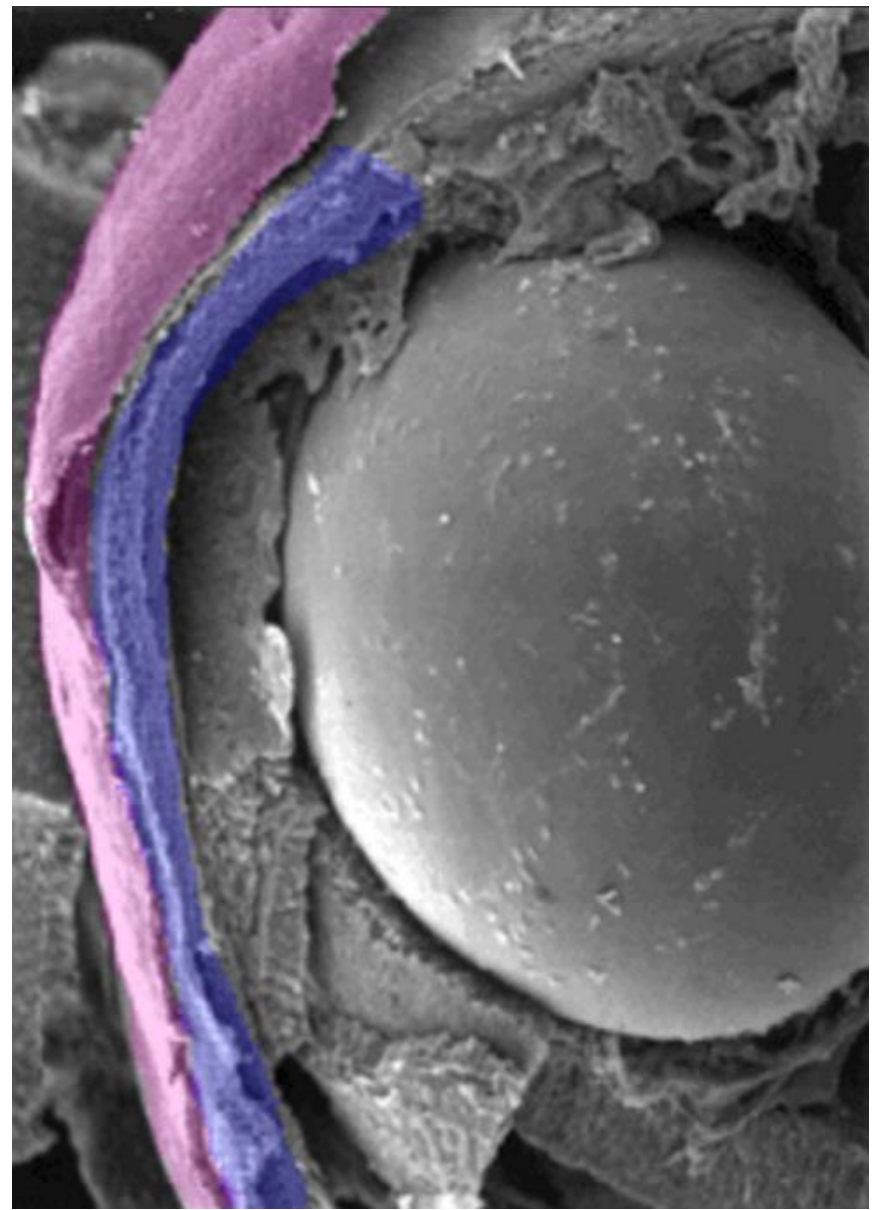
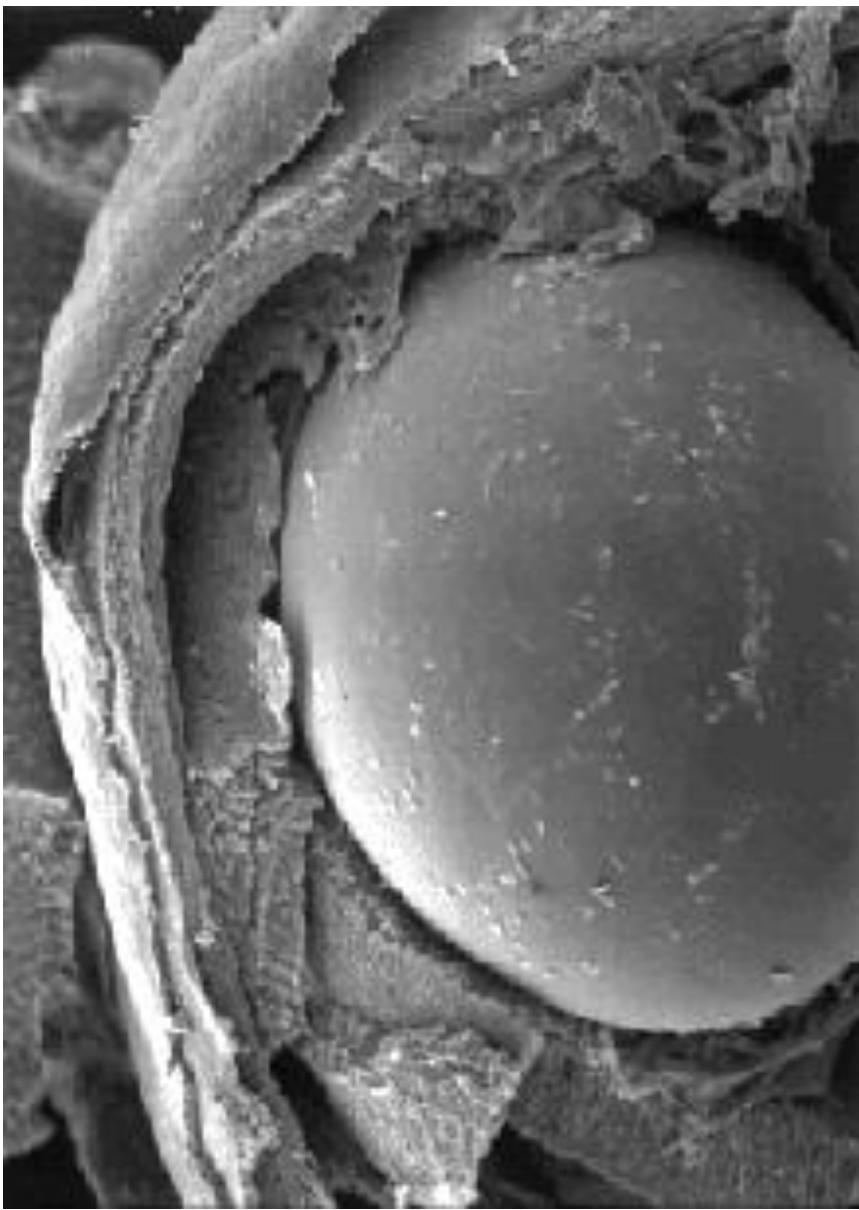




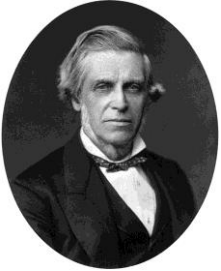
In dem zweiten Monat entsteht ein stark vaskularisiertes Mesenchym um die Linse. Der Vorderer Teil dieser Zellmasse wird zur Pupillenmembran (Membrana iridopupillaris). Mit der Rückbildung der Gefäßen bildet sich auch die Pupillenmembran zurück.

# Pupillenatresie





Die Cornea entsteht aus zwei Anlagen. Das Epithelium corneae ist ein Derivat des Oberflächenektoderms, während die Stroma und das innere Endothelium entsteht aus Zellen der Leurralleiste.

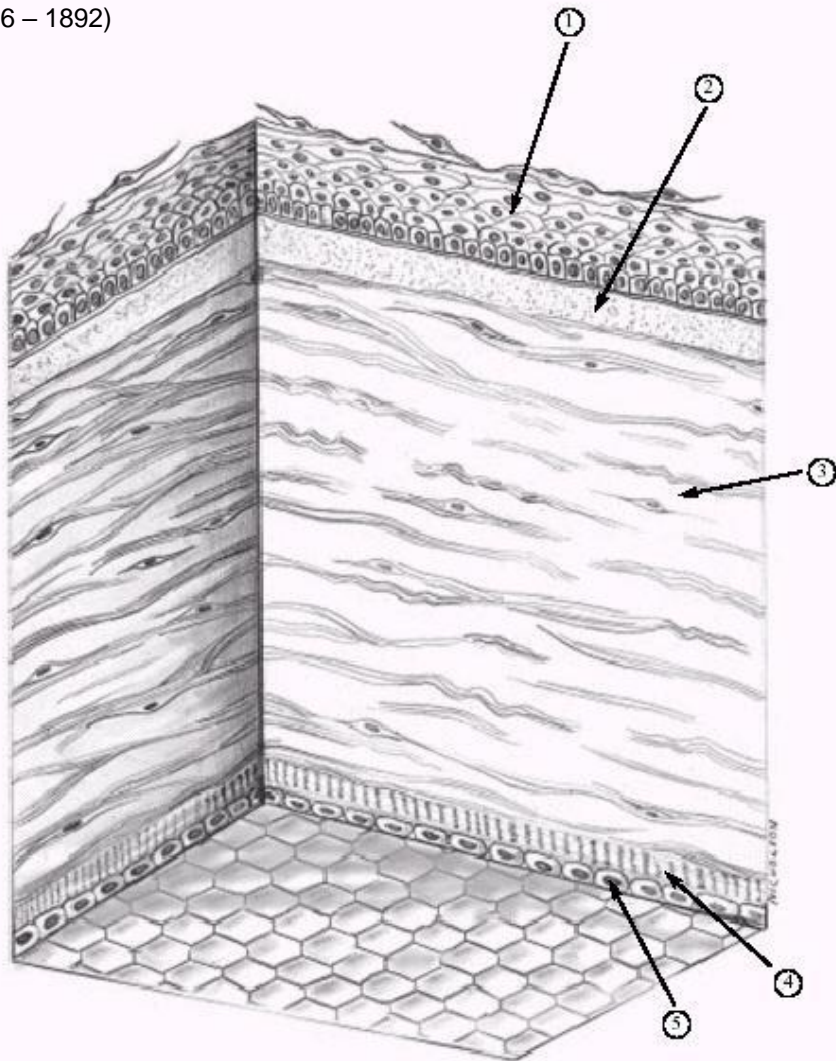


Sir William  
Bowman  
(1816 – 1892)

# Cornea



Jean Descemet  
(1732-1810)



1. Epithelium anterius corneae

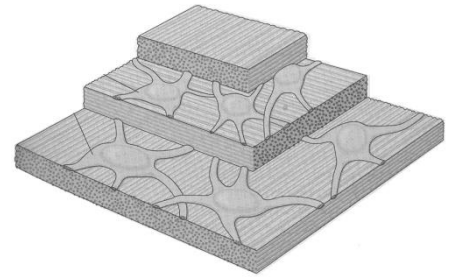
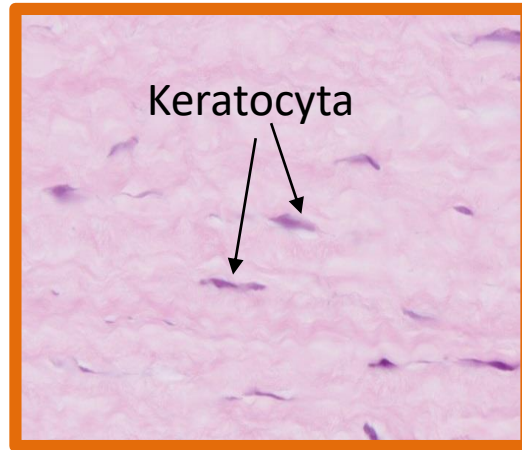
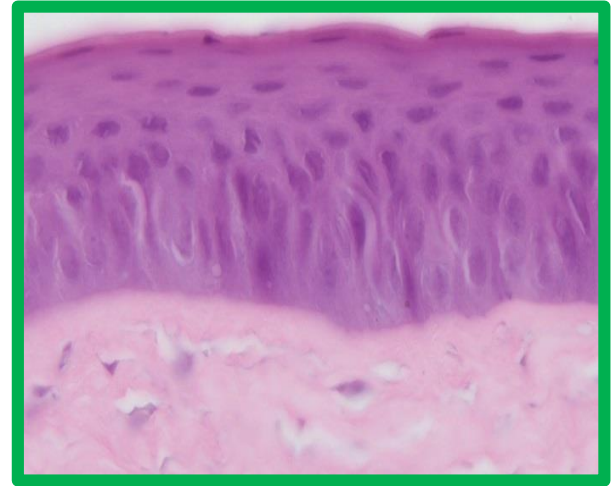
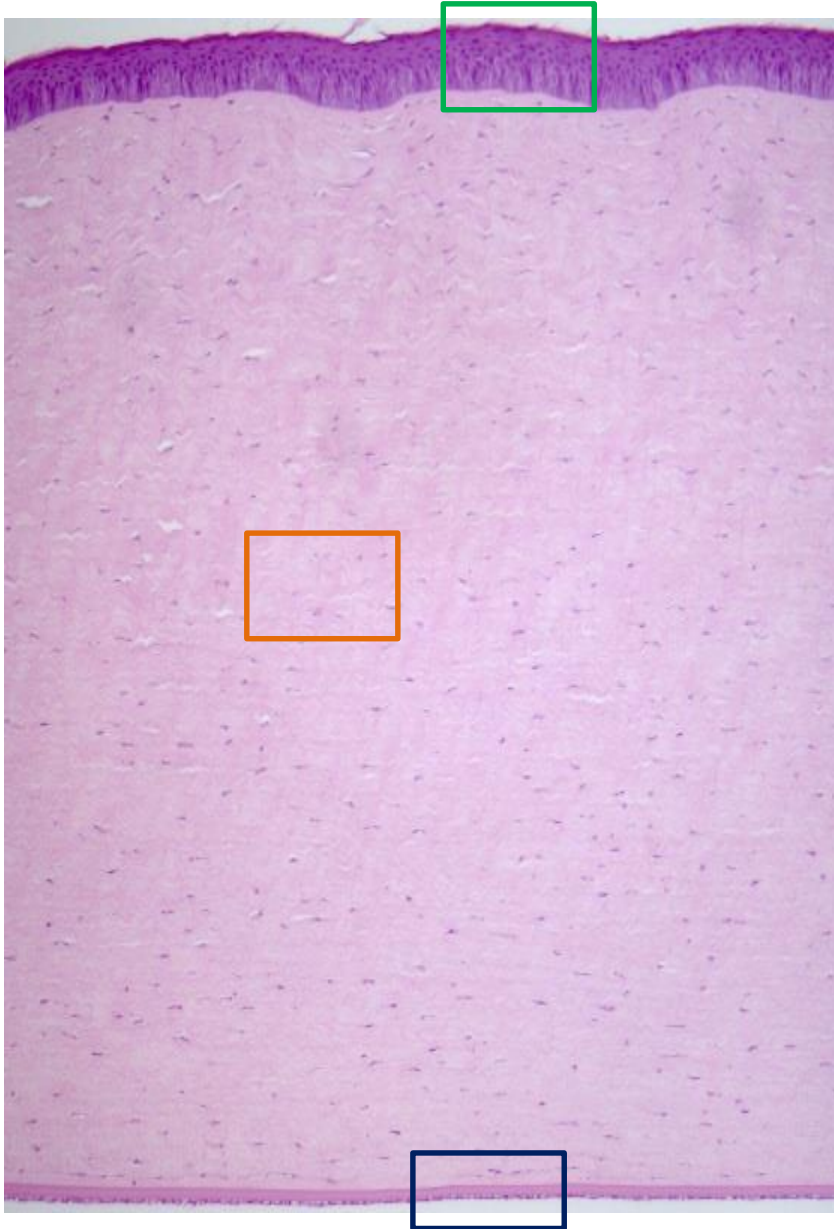
2. Membrana limitans anterior  
(Bowman-féle membrán/réteg)

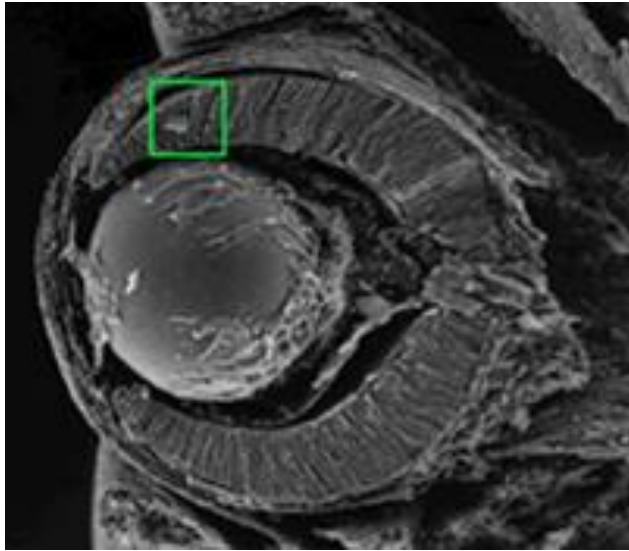
3. Substantia propria (Stroma)

4. Membrana limitans posterior  
(Descemet-féle membrán)

5. Endothelium corneae (endothelium  
camerae anterioris)

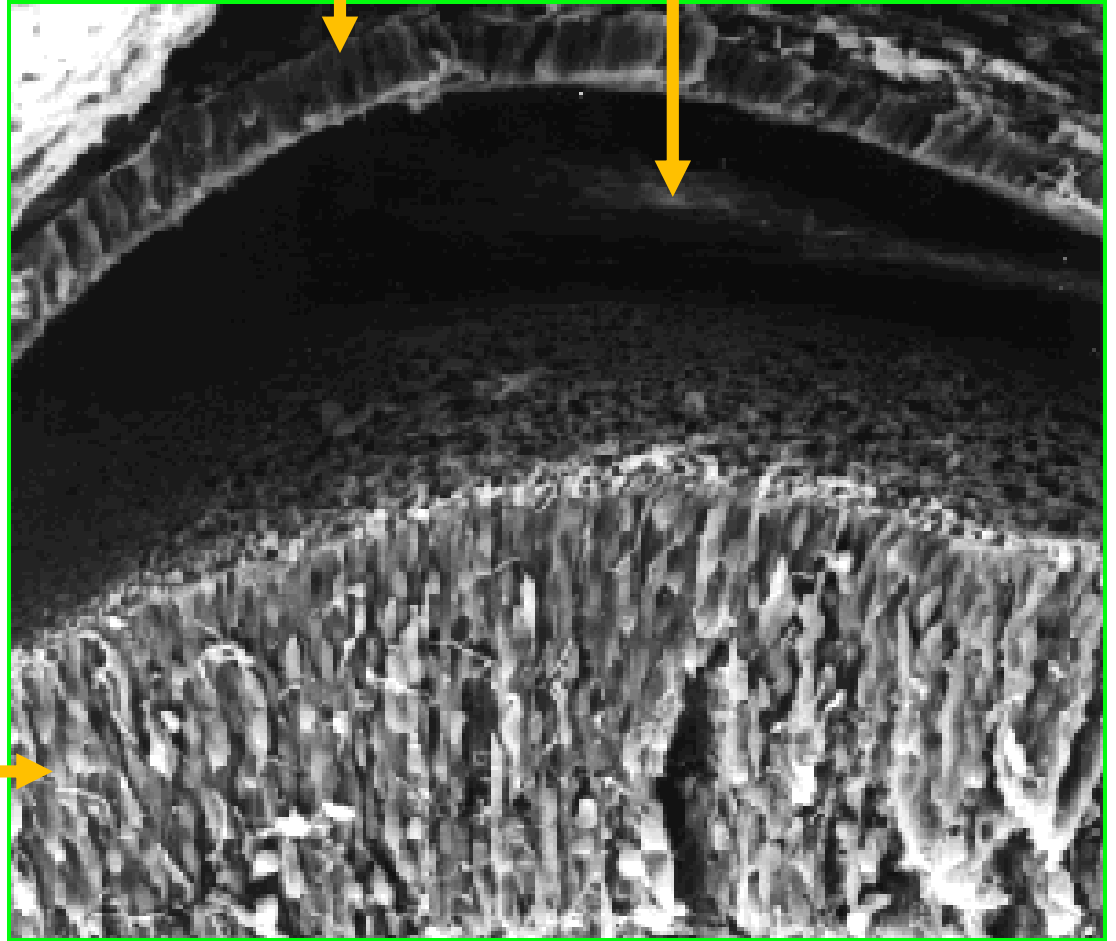
# Cornea





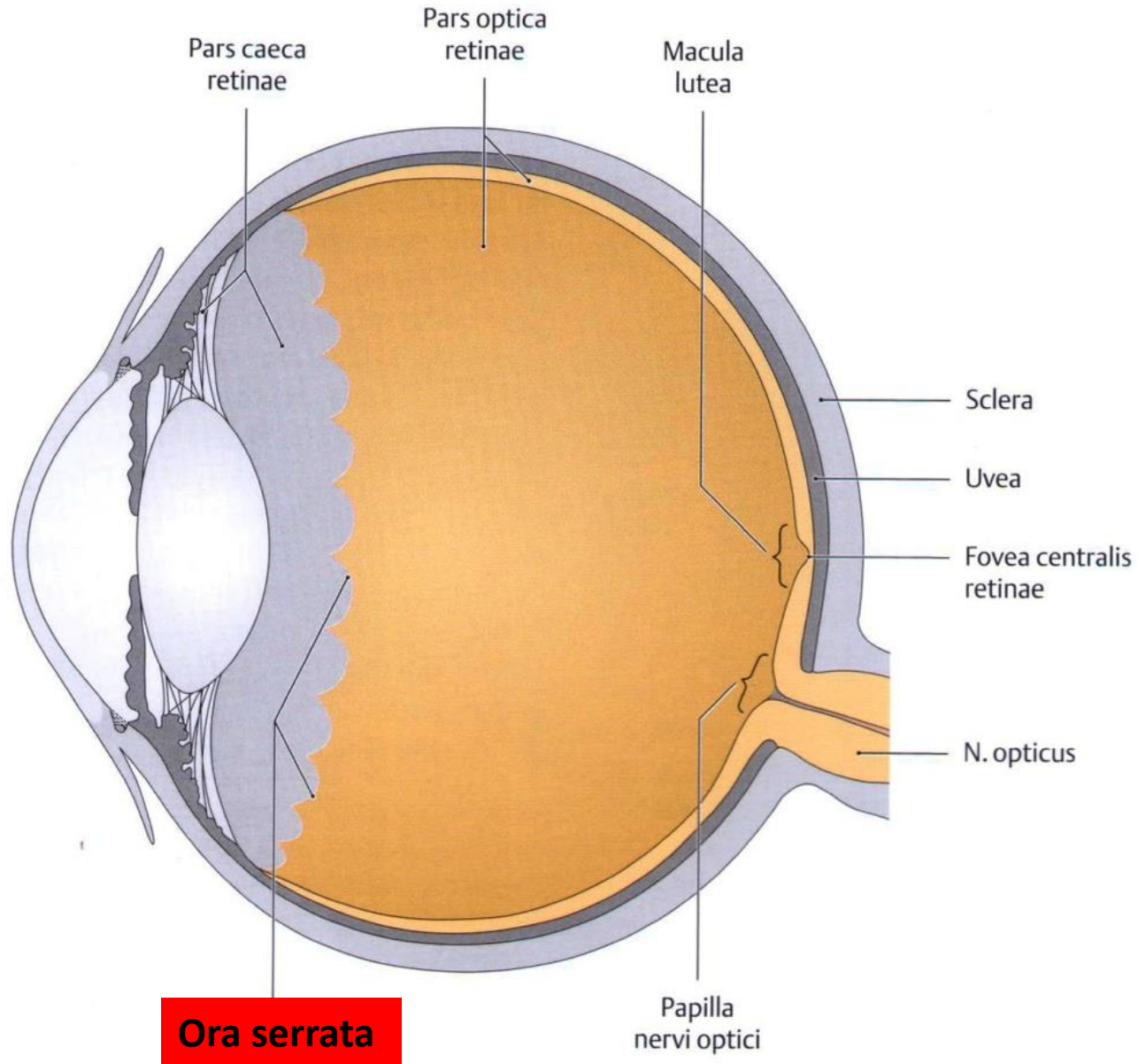
Pigmentepithel

Ventriculus opticus

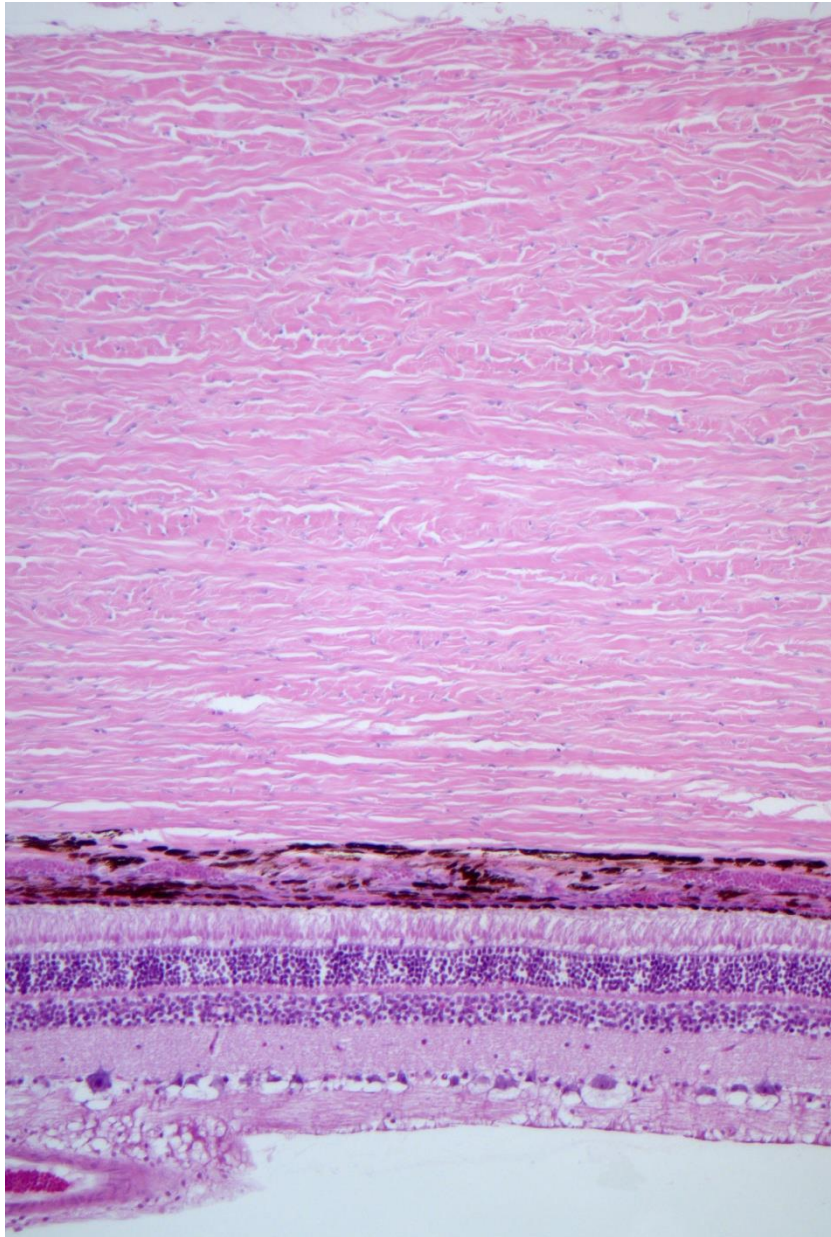


Stratum nervosum retinae

# Pars optica retinae



# Pars optica retinae

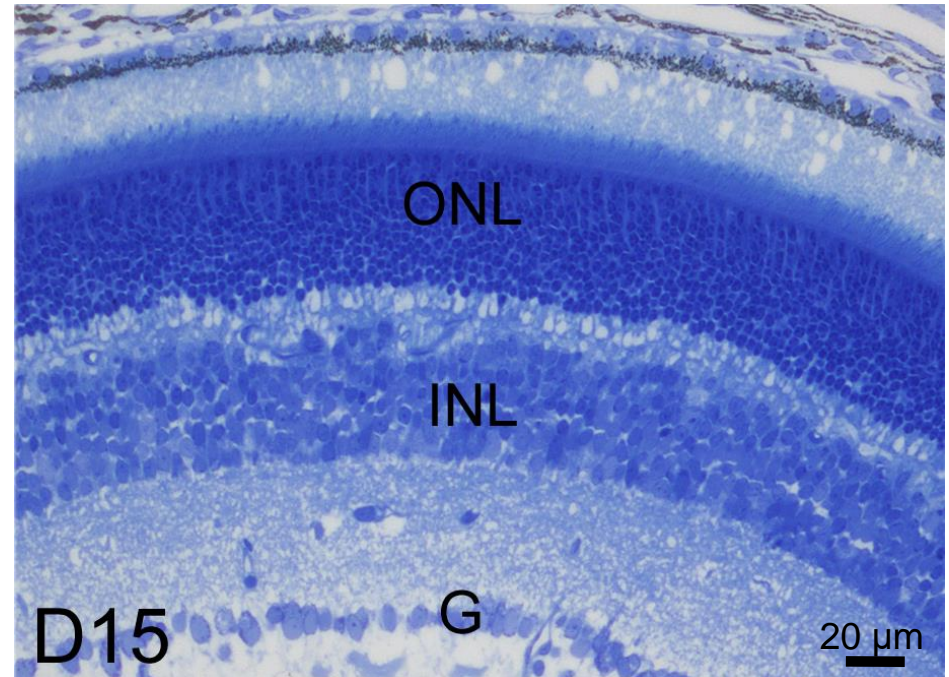
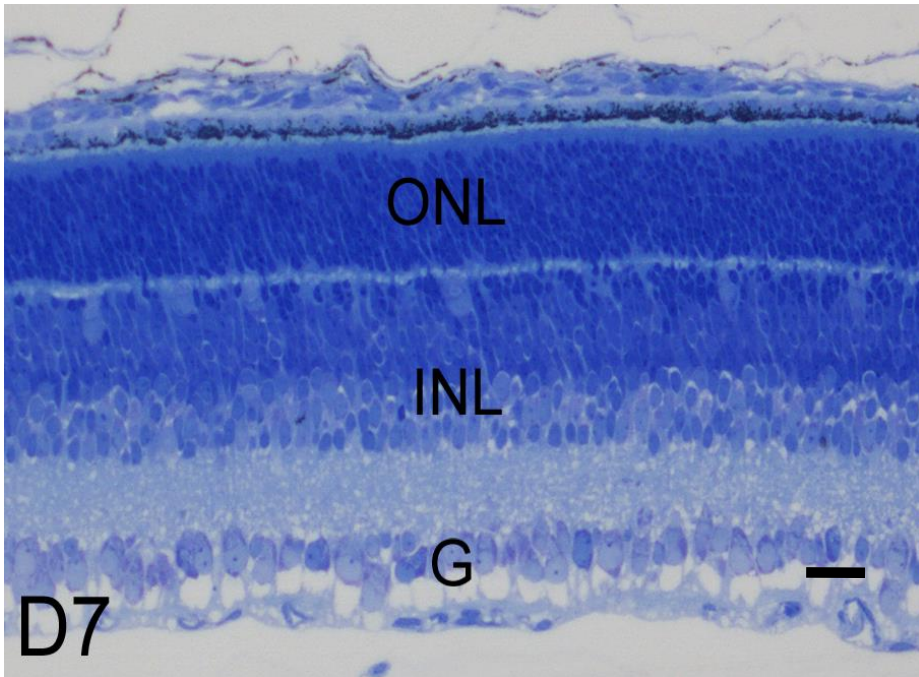
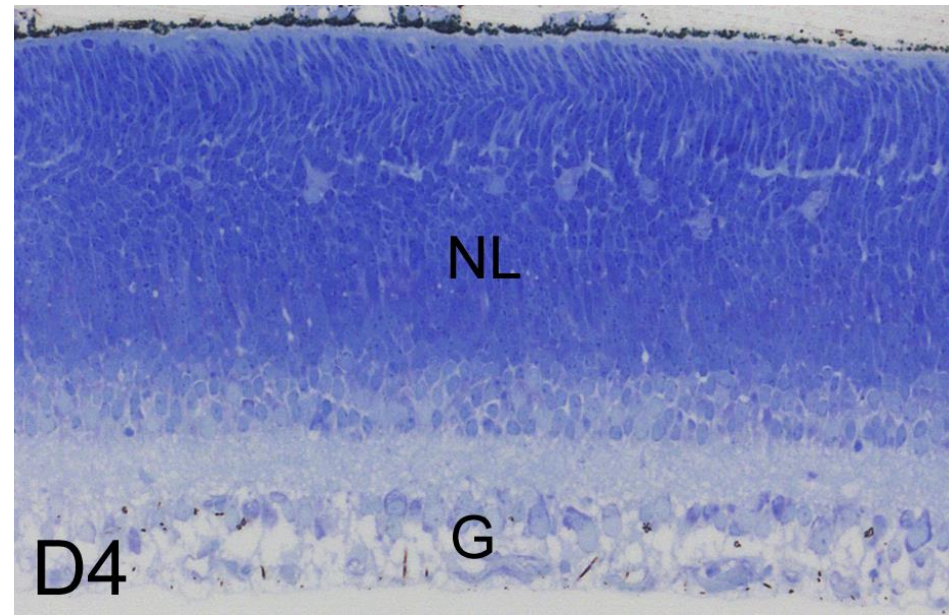
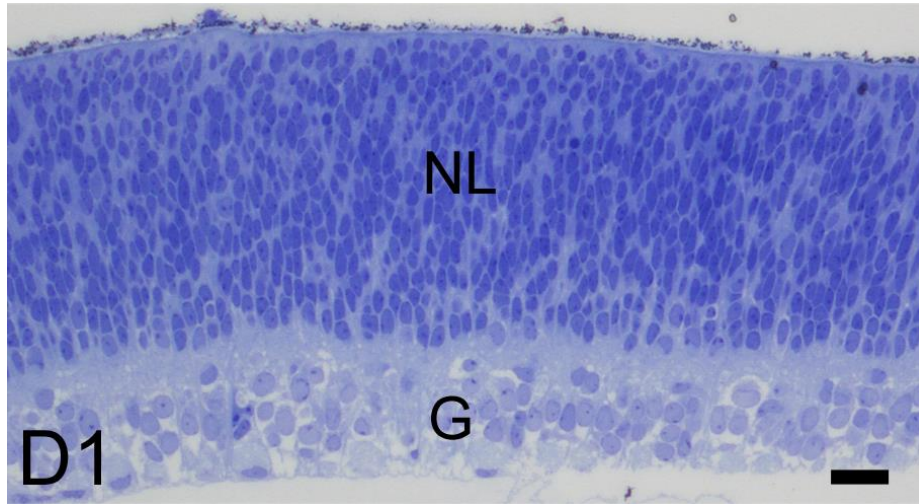


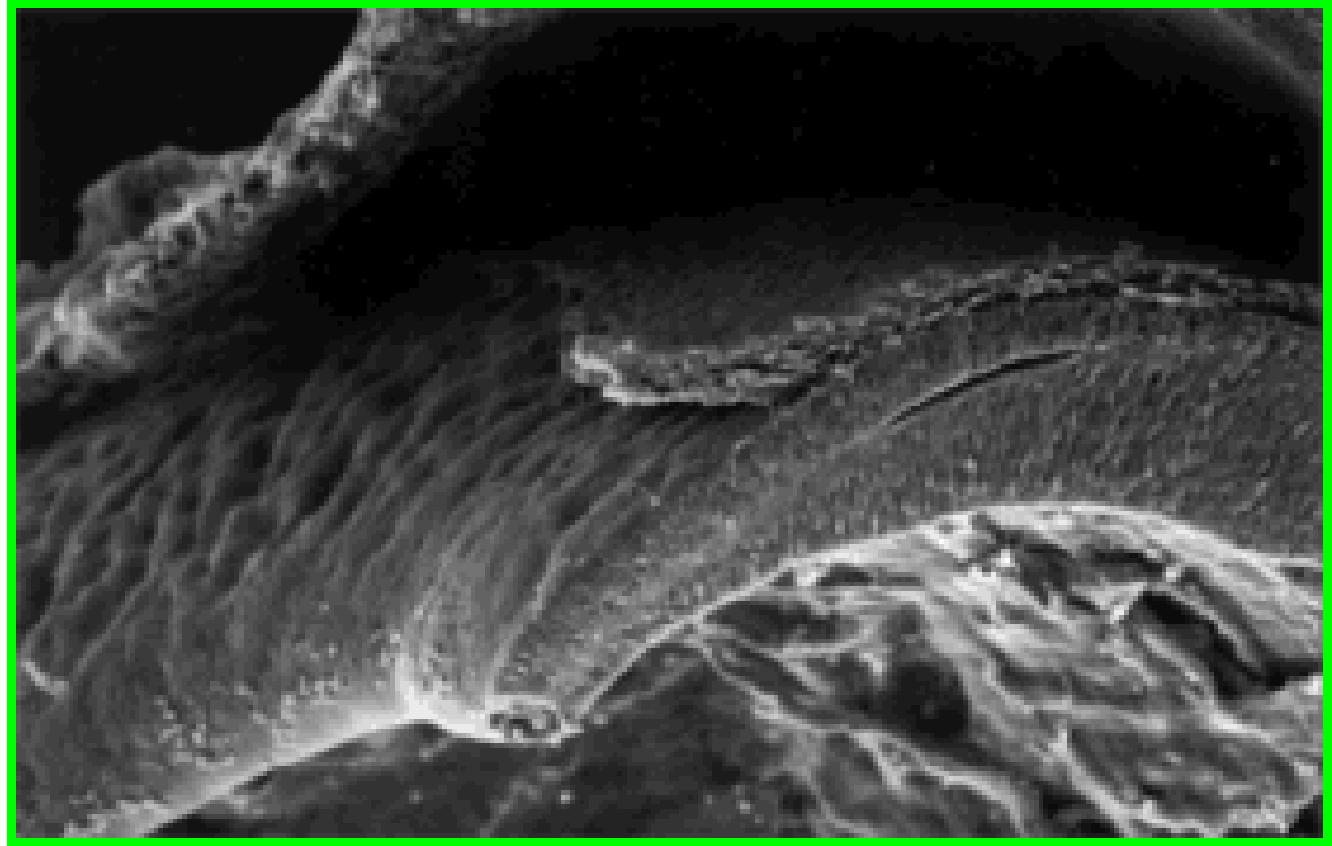
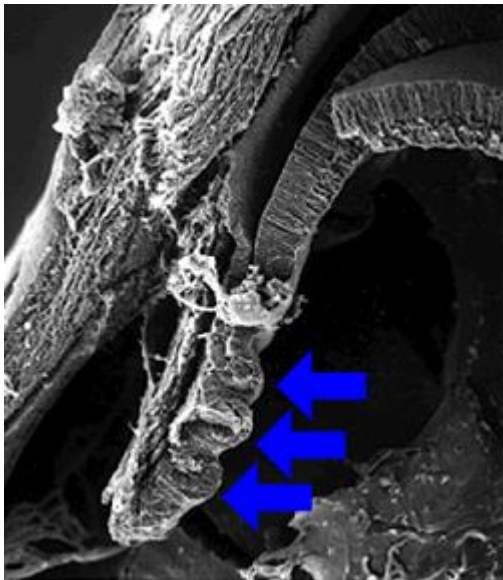
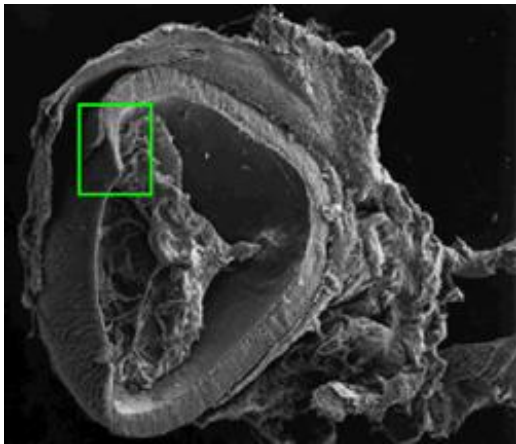
**Sclera**

**Choroidea**

**Pars optica retinae**

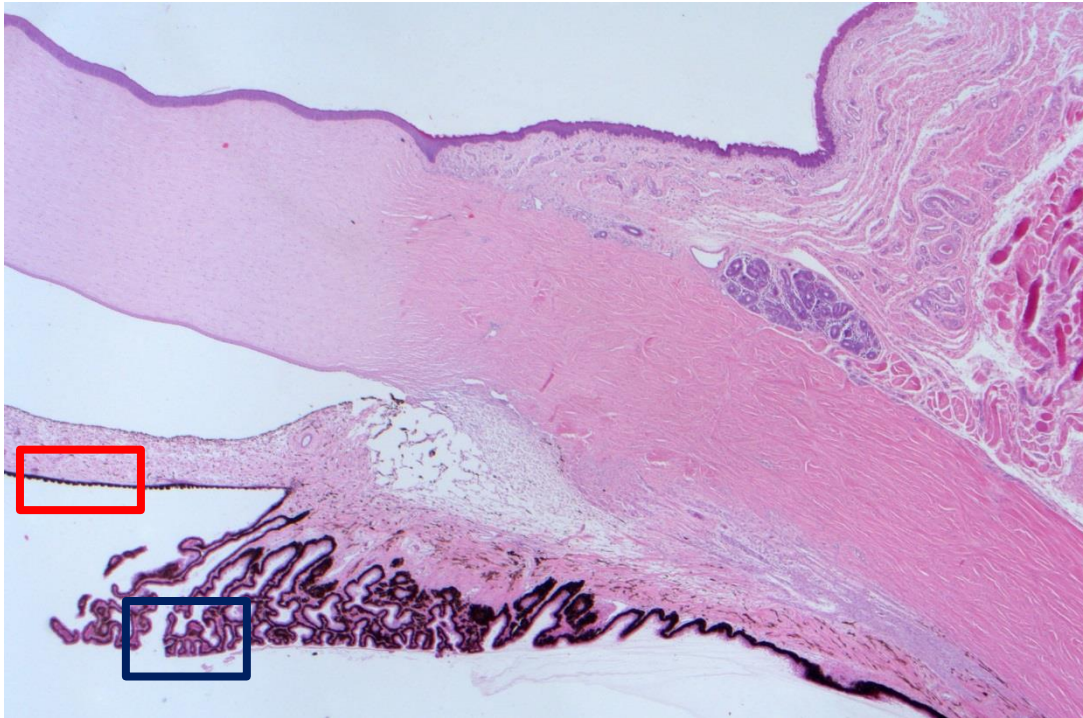




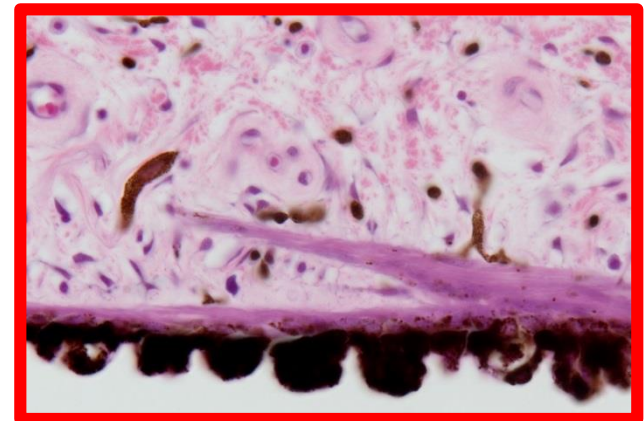


Der Ziliarkörper und die Iris entstehen am Rand des Augenbechers.

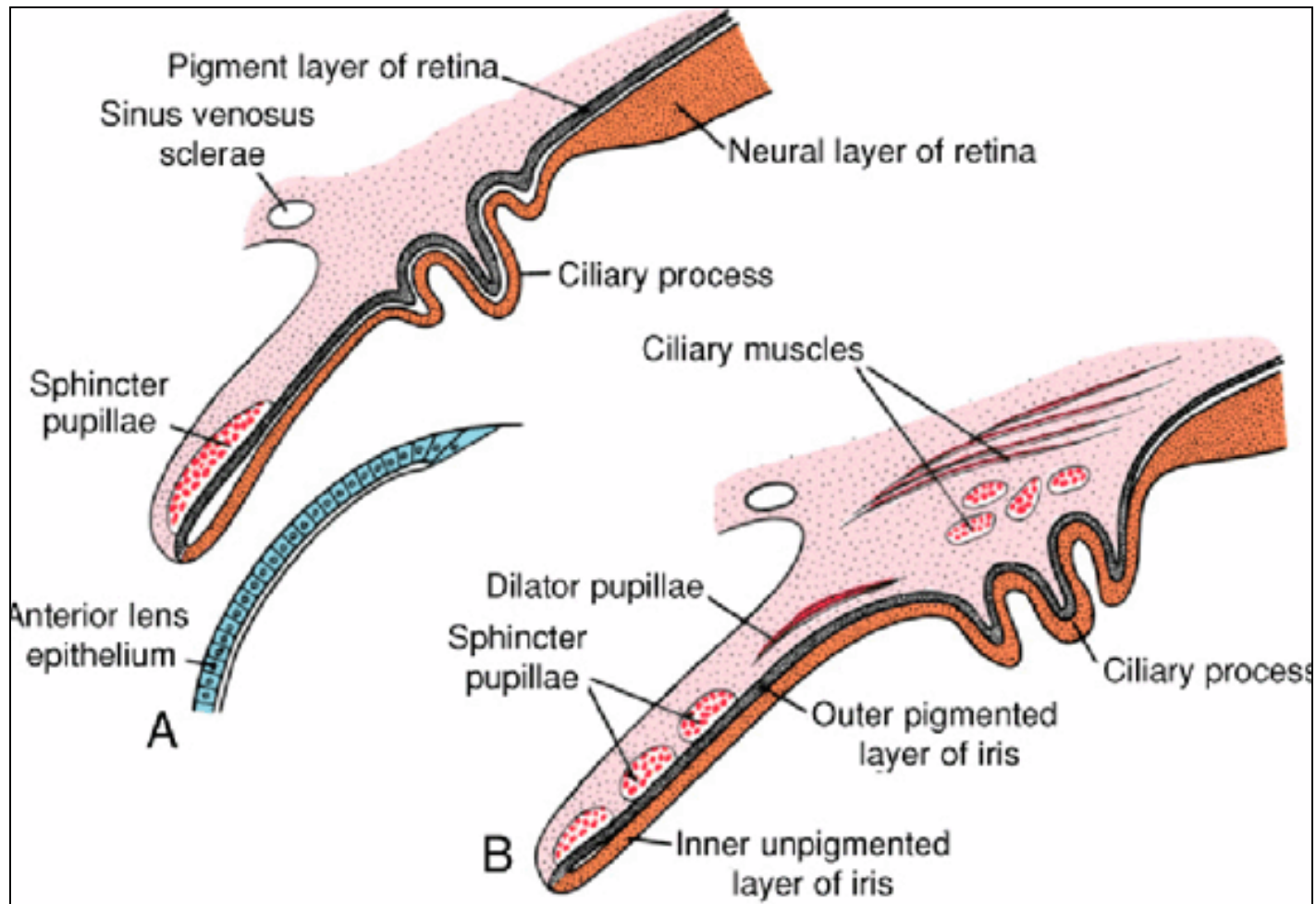
# Pars coeca retinae



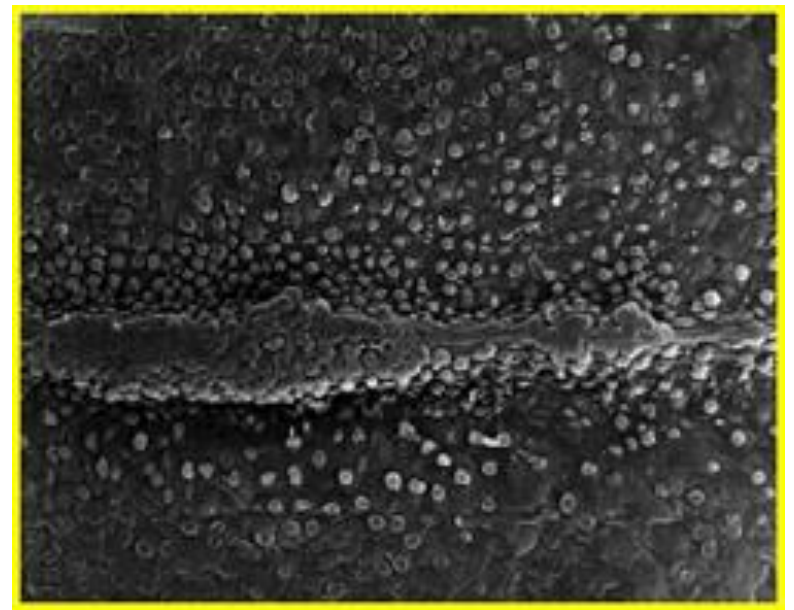
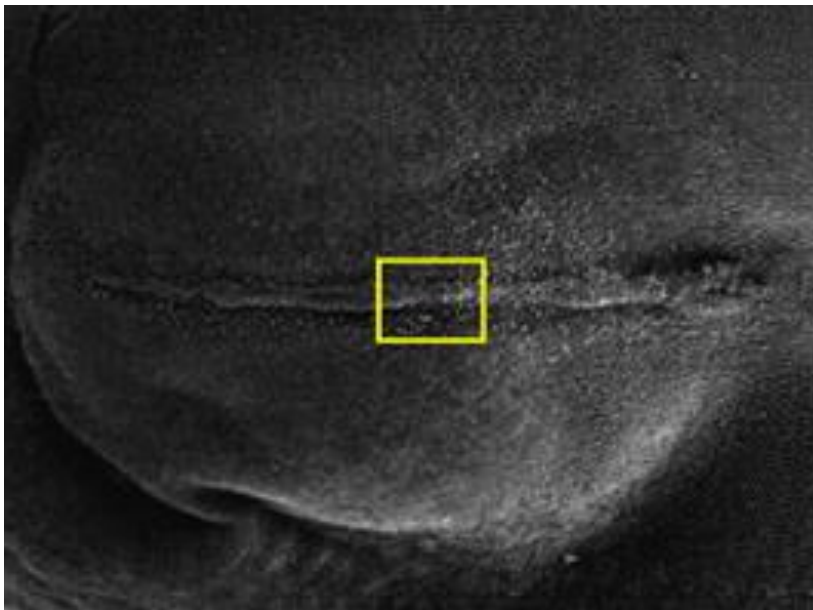
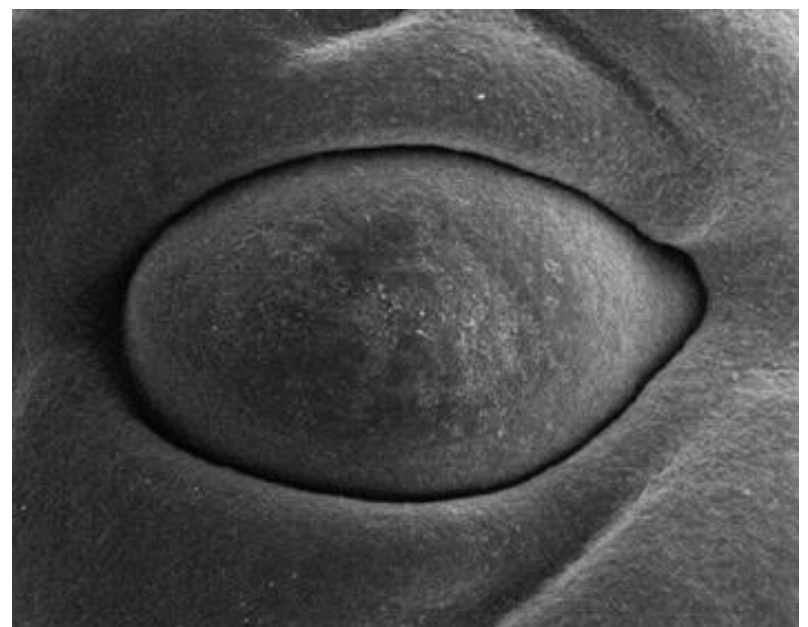
**Pars ciliaris retinae**



**Pars iridica retinae**



Der M. sphincter pupillae und der M. ciliaris entstehen aus dem Ectoderm (Placode und/oder Neuralleiste). Der M. dilatator pupillae entsteht aus dem äußeren Blatt des Augenbechers.



Die Augenlider und die akzessorischen Sehorgane entstehen in einem späteren Zeitpunkt. Die Augenlider wachsen am Anfang des zweiten Trimesters zusammen, und lösen sich nur im dritten Trimester voneinander.

# Genetische Kontrolle der Augenentwicklung

Gene	Role
<b>Eye field, Optic vesicle</b>	
<i>Rx</i>	Transcription factor, mutations result in anophthalmia in humans and mice
<i>Pax6</i>	Transcription factor, loss of function results in microphthalmia and anophthalmia in rodents
<i>Otx2</i>	Transcription factor, loss of function results in missing forebrain, microphthalmia, and cyclopia in mouse
<i>Six6</i>	Transcription factor, regulates proliferation of eye field in frog; haploinsufficiency causes anophthalmia in humans
<i>Six3</i>	Transcription factor, mutations are associated with holoprosencephaly in humans; loss of forebrain when mutated in mouse; overexpression results in ectopic eye formation in zebrafish
Retinoic acid signaling	Vitamin and morphogen, deficiency results in microphthalmia in mouse; vitamin A deficiency might cause developmental eye defects such as coloboma in humans
<i>Shh</i>	Secreted protein, mutations can result in holoprosencephaly and cyclopia in humans and other vertebrates
<b>Neural retina</b>	
<i>Pax6</i>	Transcription factor, required for survival and multipotency of retinal progenitor cells in mouse and chick
<i>Chx10</i>	Transcription factor, regulates progenitor cell differentiation; loss of function causes microphthalmia and congenital cataract in humans and ocular retardation in mouse
<i>Sox2</i>	Transcription factor, mutation causes microphthalmia in humans and mouse; functions to maintain neuronal progenitor identity
<i>Notch</i>	Transmembrane protein, regulates multipotency and proliferation of retinal progenitors
<b>Pigmented epithelium</b>	
<i>Otx2</i>	Transcription factor, required for pigmented epithelium specification and differentiation in vertebrates
<i>Mitf</i>	Transcription factor, required for pigmented epithelium specification and differentiation in vertebrates
<i>Rx3</i>	Transcription factor, required for earliest pigmented epithelium specification in zebrafish

<b>Lens</b>	
<i>Six3</i>	Transcription factor, sufficient and required for lens formation in mouse
<i>Pax6</i>	Transcription factor, expression in lens ectoderm is required for lens induction in mouse
<i>FoxE3</i>	Transcription factor, mutations cause anterior segment dysgenesis in humans and lens defects in "Dysgenetic lens" mice
<i>Fgf</i> pathway	Secreted protein, required for lens induction and differentiation
<i>Pitx3</i>	Transcription factor, recessive mutation in mouse ("Aphakia") results in absence of lens and microphthalmia
<i>Prox1</i>	Transcription factor, required for lens fiber differentiation in mouse

# Pax6

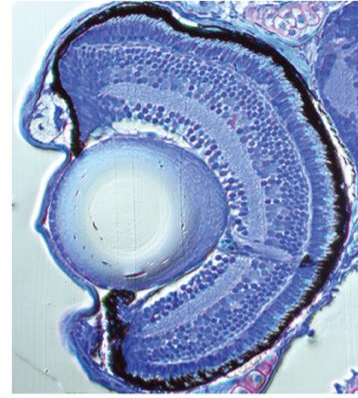
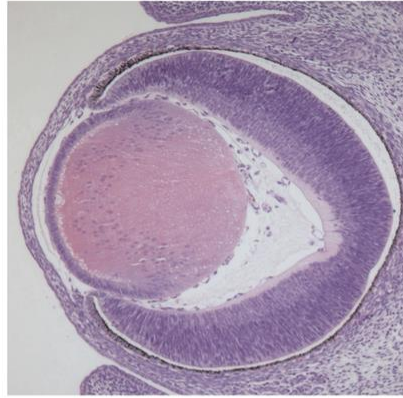
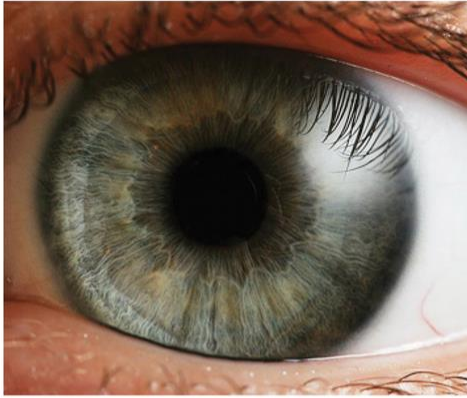
Human

Mouse

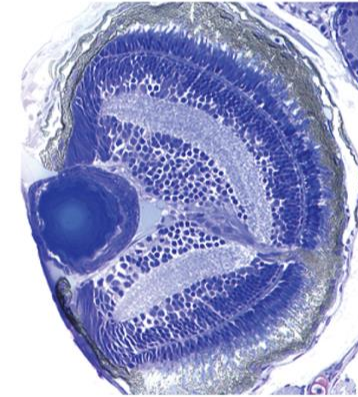
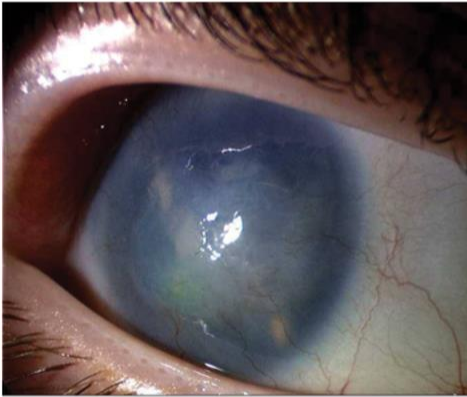
Zebrafish

*Drosophila*

WT



mut



*PAX6*<sup>+/-</sup>

*Pax6*<sup>-/-</sup>

*pax6b*<sup>-/-</sup>

*ey*<sup>-/-</sup>

EQs

cornea opaque  
iris absent  
retina degenerate  
lens opaque  
aqueous humor of eyeball  
increased pressure

eye decreased size  
lens fused\_to cornea  
iris morphology  
anterior chamber  
absent

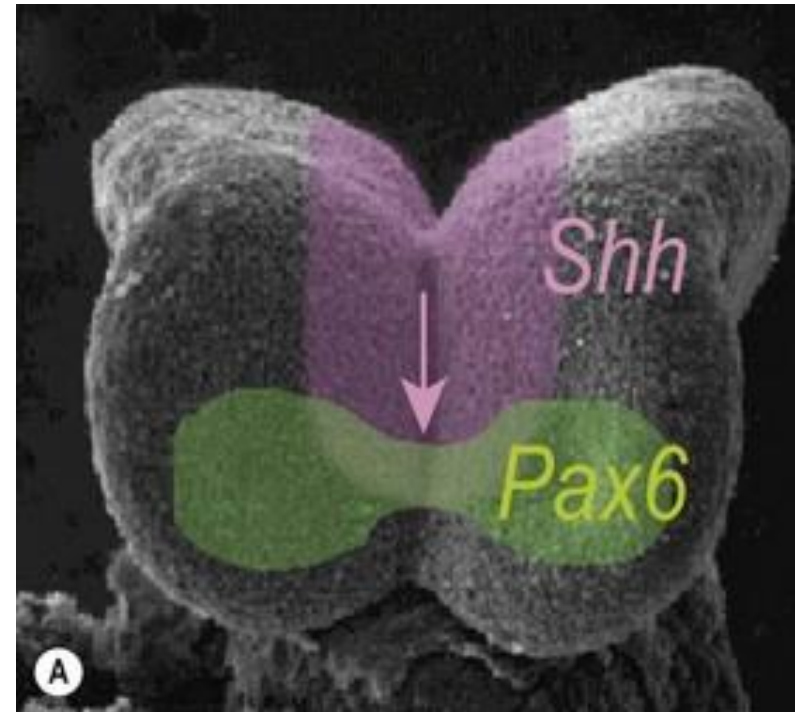
eye decreased size  
lens decreased size  
retina malformed

eye absent





# Cyclopia – Mutation von Shh



# Angewändete Literatur

- Benninghoff, Drenckmhahn: Anatomie, *16. Auflage, Elsevier Urban Fischer, Stuttgart*
- [http://www.med.unc.edu/embryo\\_images/](http://www.med.unc.edu/embryo_images/)
- Eigene histologische Aufnahmen
- Vorlesung von Krisztina Herbert-Minko