

# **Introduction to Ophthalmic Pathology**

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# Objectives

- **To be familiar with the pathological features of the most common blinding diseases in the U.S.A.**

- » **Cataracts**
- » **Glaucoma**
- » **Diabetes mellitus**
- » **Age-related macular degeneration**

**Take a moment to memorize these common causes of blindness.**

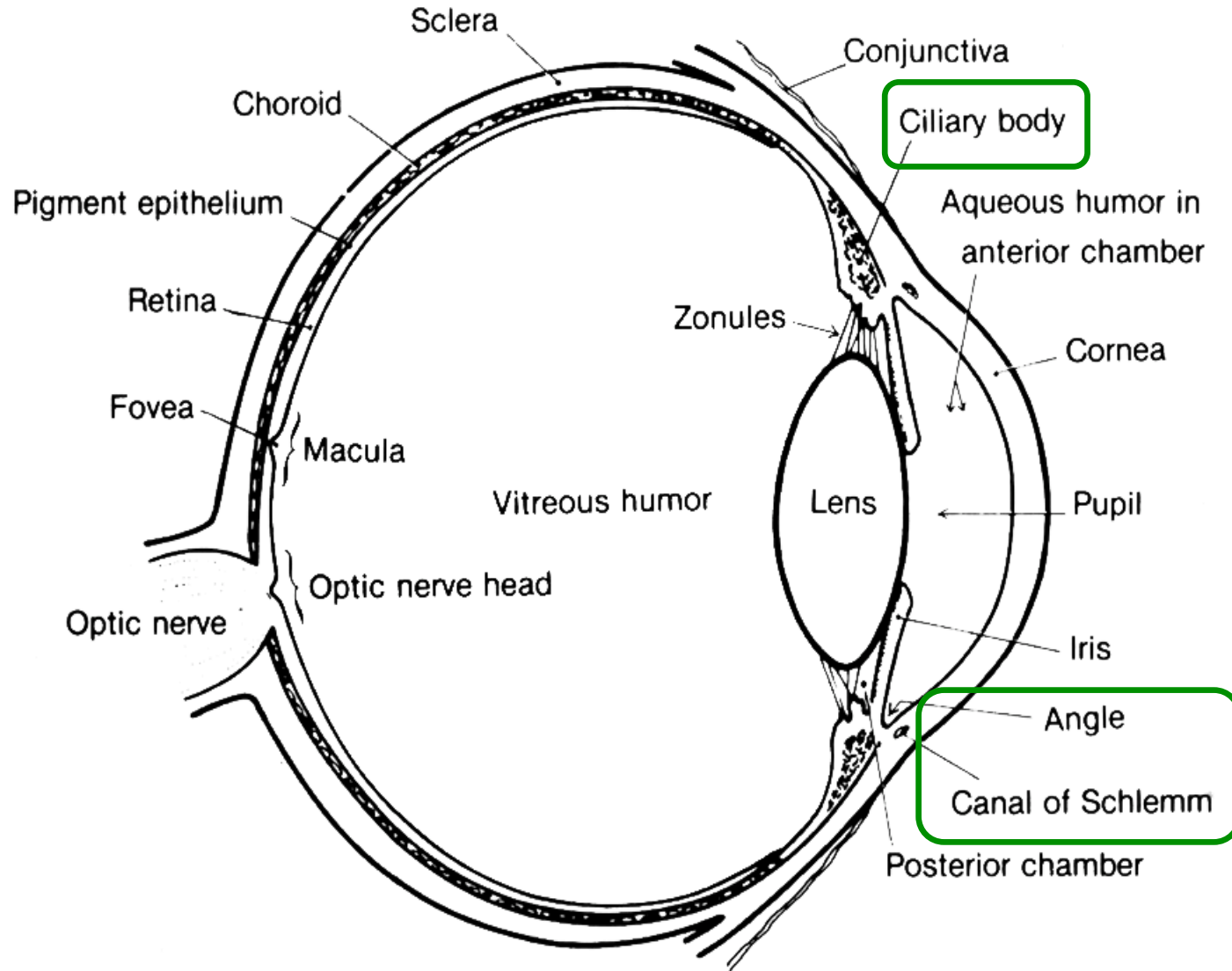
- **To be aware of the most common primary intraocular malignant tumors of adults and children**

- » **Uveal melanoma**
- » **Retinoblastoma**

**Adults typically**

**Children typically**

# Anatomy of the Eye



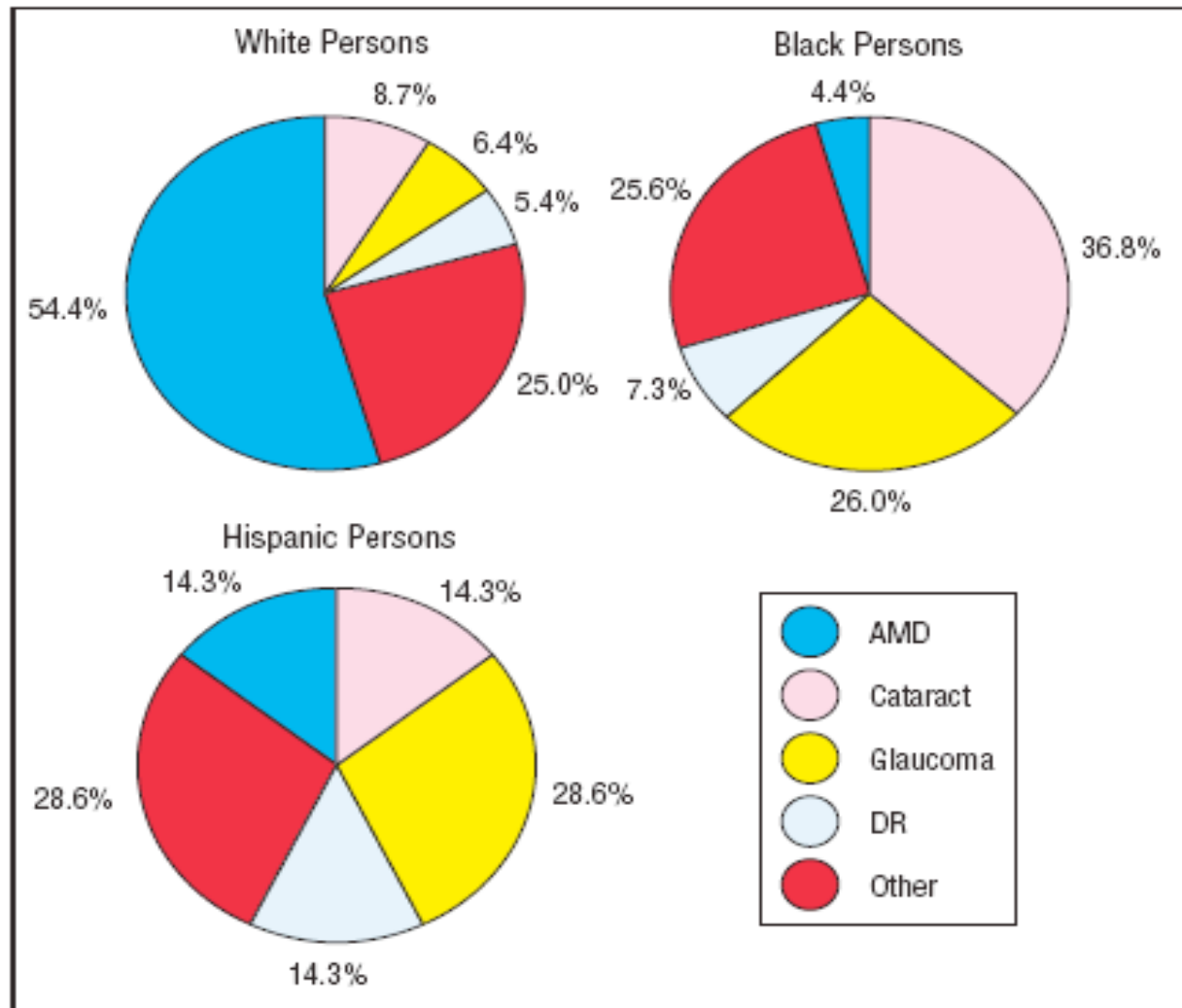
# CATARACTS

**are extremely common and many people have cataract surgery by the time they are ~70.**

# Crystalline Lens

- **Provides refraction, in addition to that from the cornea**
- **Lens capsule (basement membrane) encloses the epithelium and lens fibers**
- **Cataract: lenticular opacity**
  - » **Many histological forms depending on location of cataractous change within the lens**
  - » **A major cause of blindness**

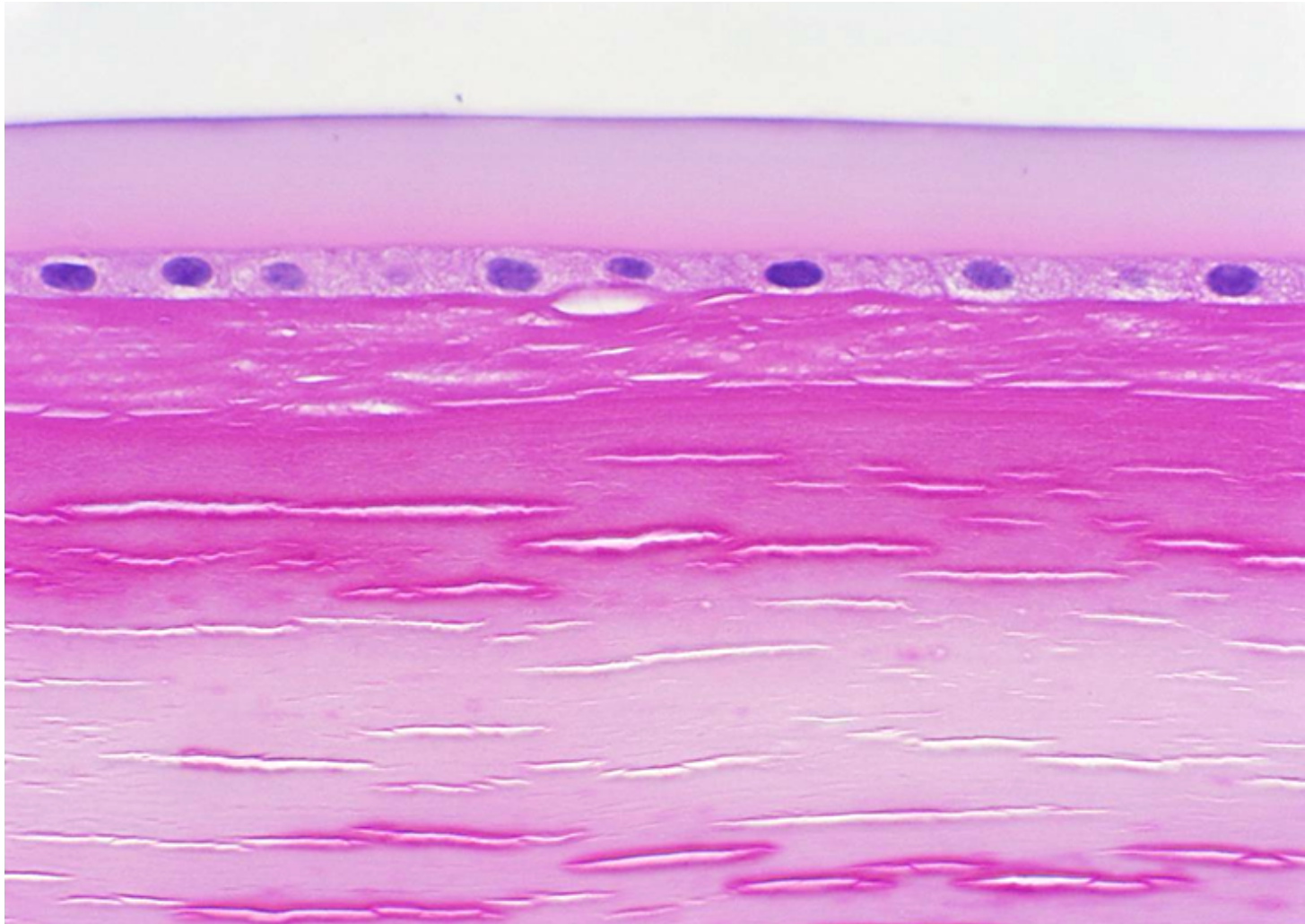
There are many ways to get opacity in the lens. The variants are described next.



**Definition of blindness is: vision worse than 20/200 in the best eye with corrections.**

**Figure 2.** Causes of blindness (best-corrected visual acuity <math><6/60</math> [ $<20/200</math>] in the better-seeing eye) by race/ethnicity. AMD indicates age-related macular degeneration; DR, diabetic retinopathy.$

# Crystalline Lens - Anterior



← Capsule

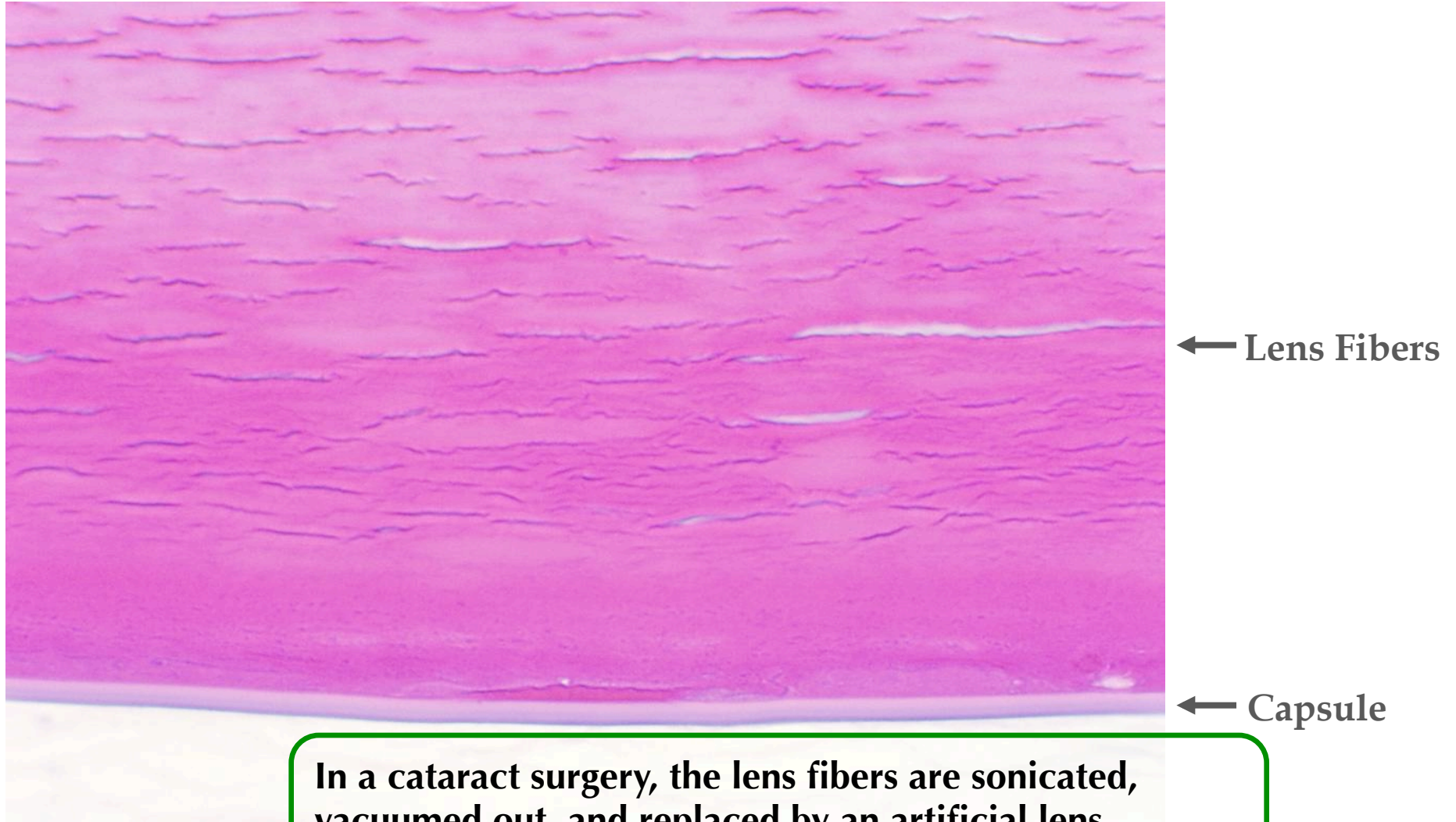
← Epithelium

← Lens Fibers

**The lens capsule is thicker anteriorly than posteriorly. Also, there are no epithelial cells in healthy lenses posteriorly.**



# Crystalline Lens - Posterior



# Brunescent (Brown) Cataract

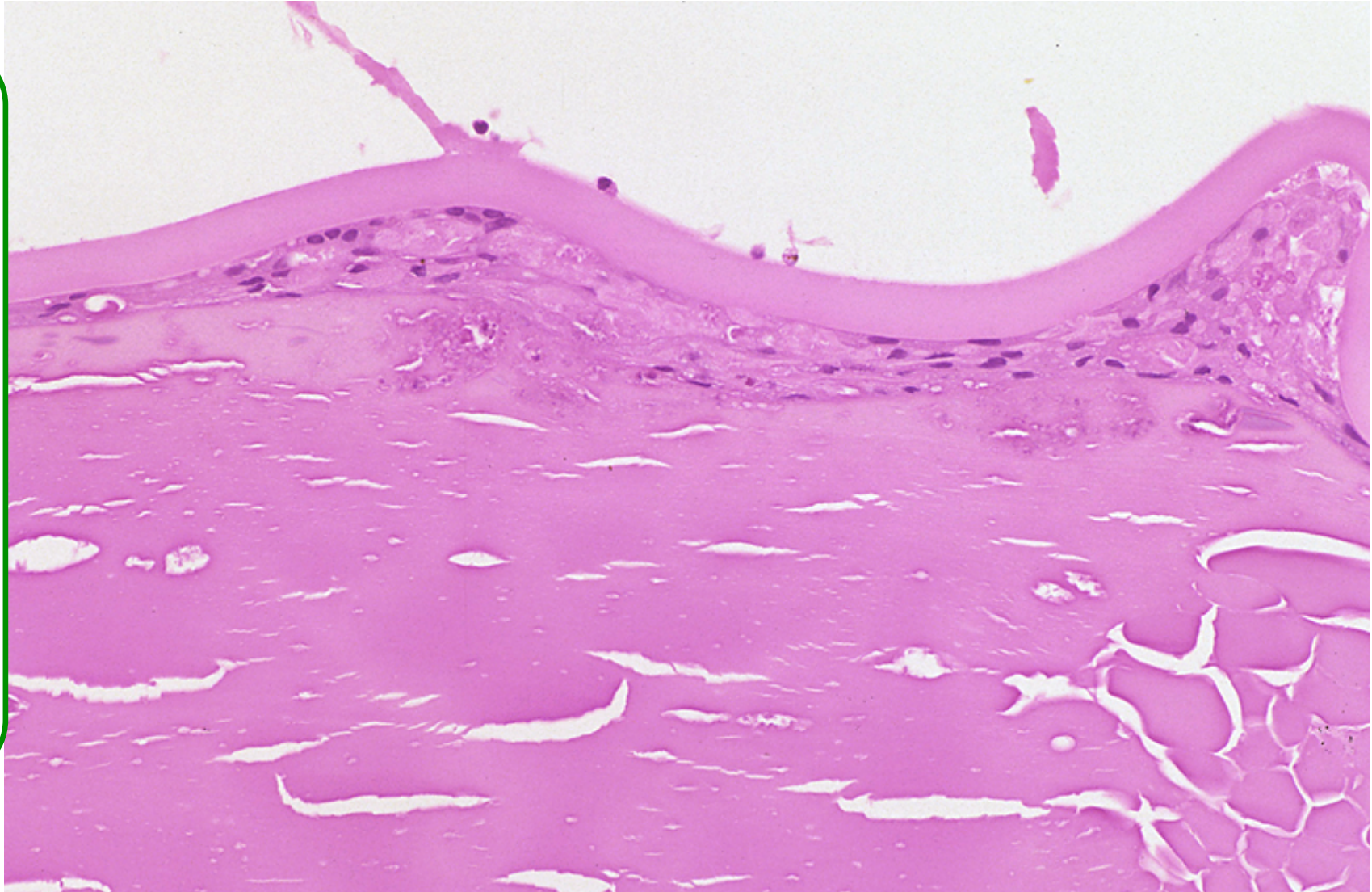


This discoloration will cause changes in color vision.

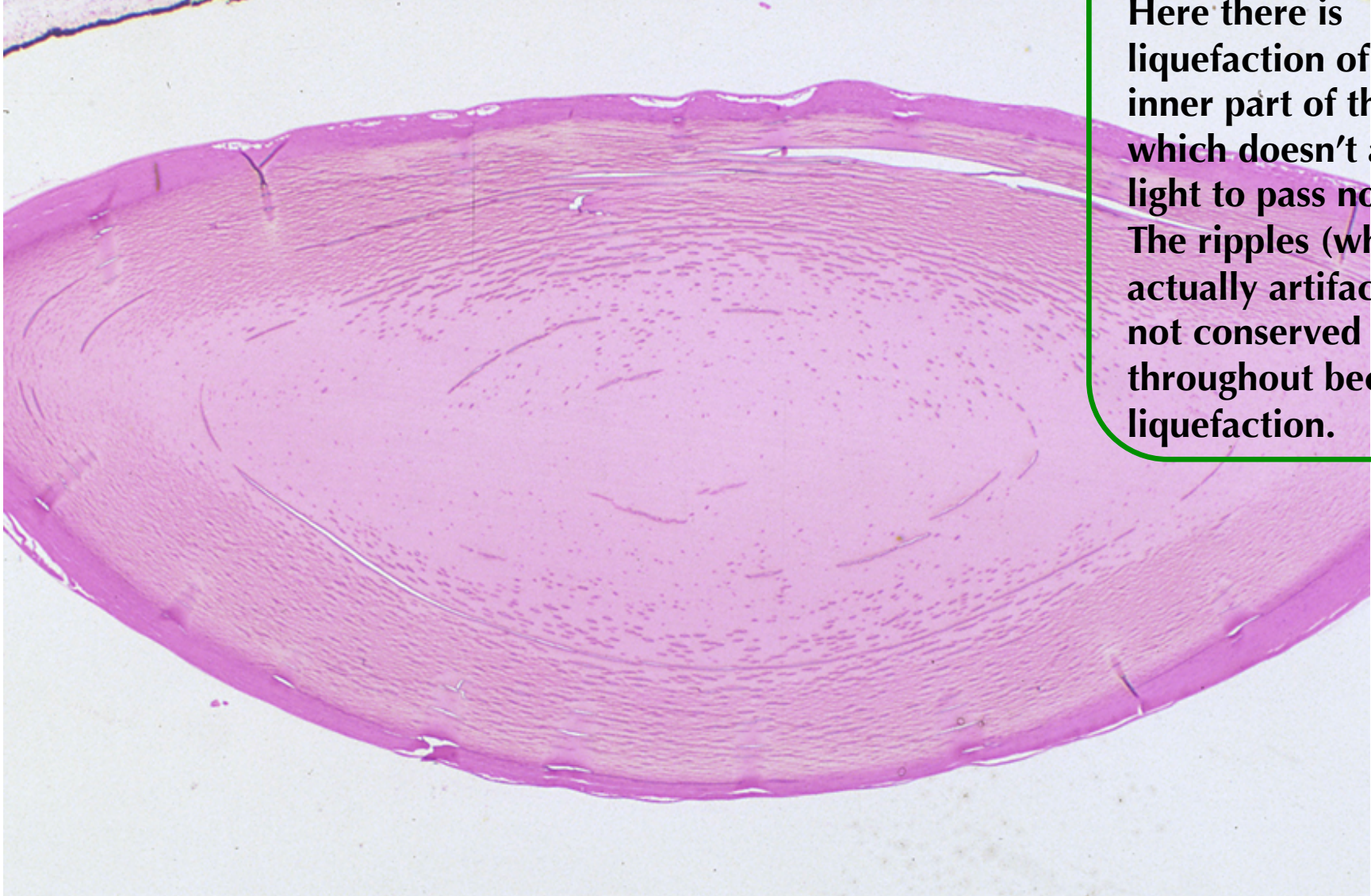
# Anterior Subcapsular Cataract

## Ant. Subcap. Cataract

Note the proliferation in the epithelial cell layer beneath the capsule, which does not allow light to pass normally.

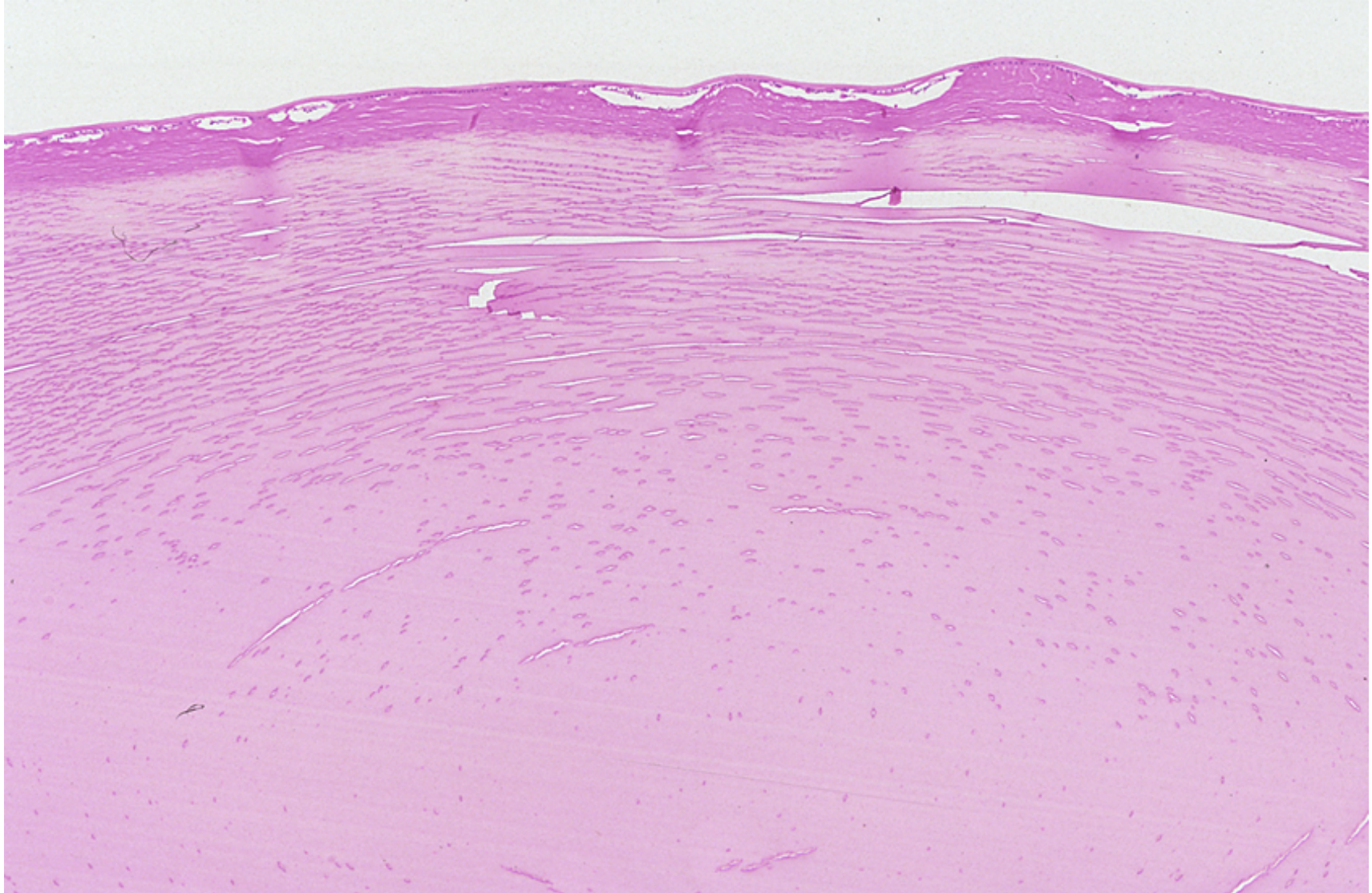


# Nuclear Cataract

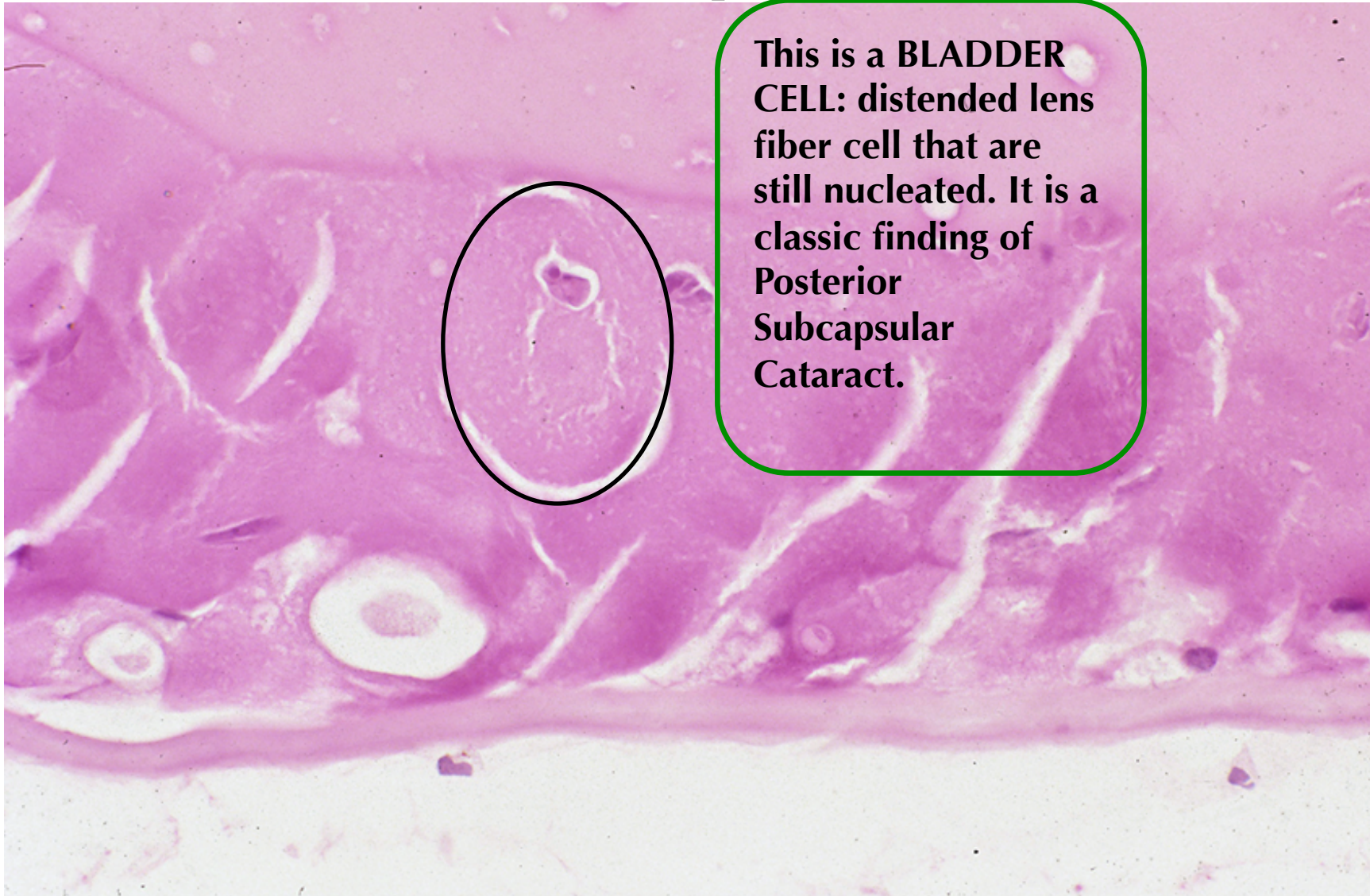


**Nuclear Cataract:**  
Here there is liquefaction of the inner part of the lens, which doesn't allow light to pass normally. The ripples (which are actually artifacts) are not conserved throughout because of liquefaction.

# Nuclear Cataract



# Posterior Subcapsular Cataract



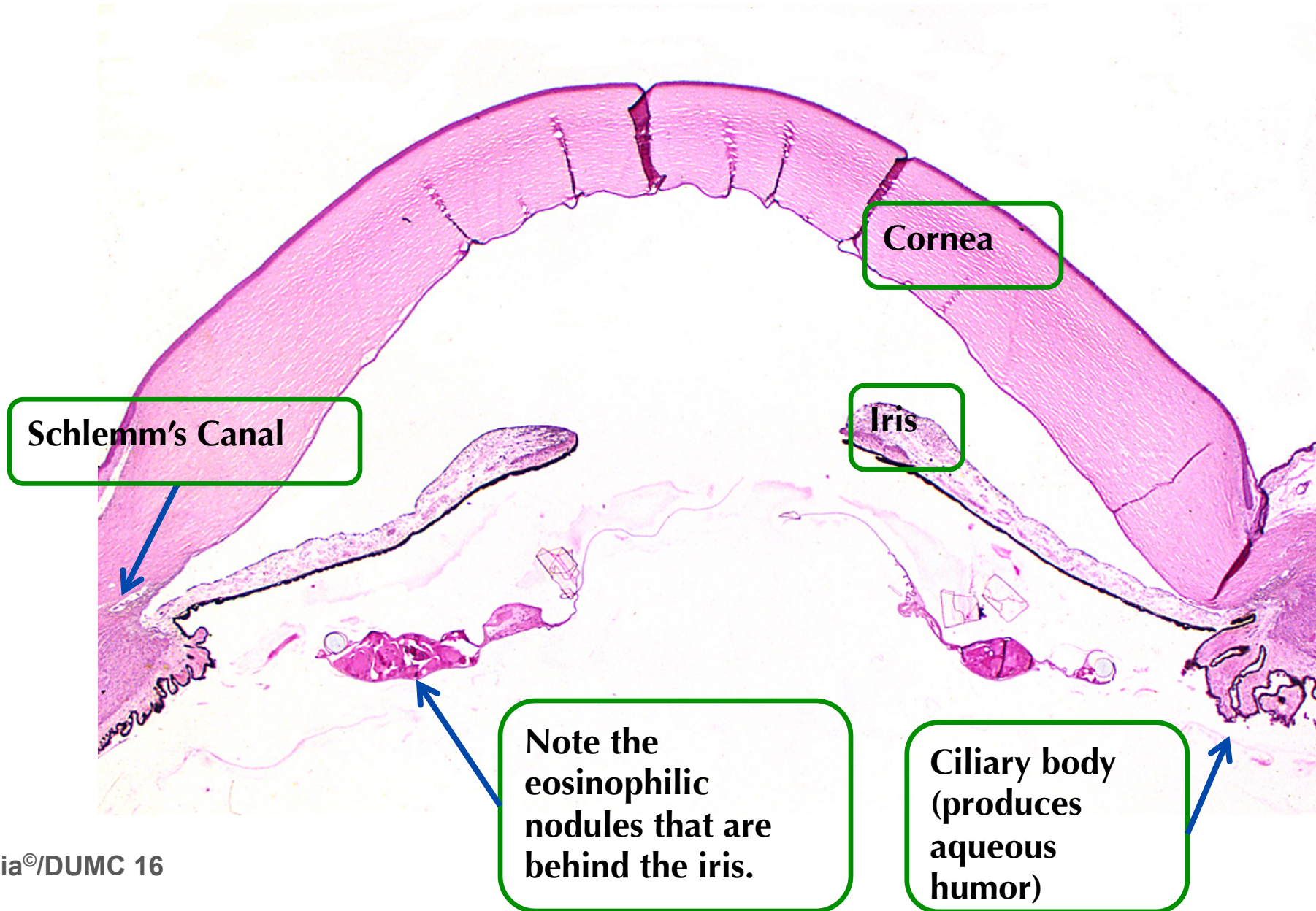
This is a **BLADDER CELL**: distended lens fiber cell that are still nucleated. It is a classic finding of **Posterior Subcapsular Cataract**.

# Soemmerring Ring Cataract



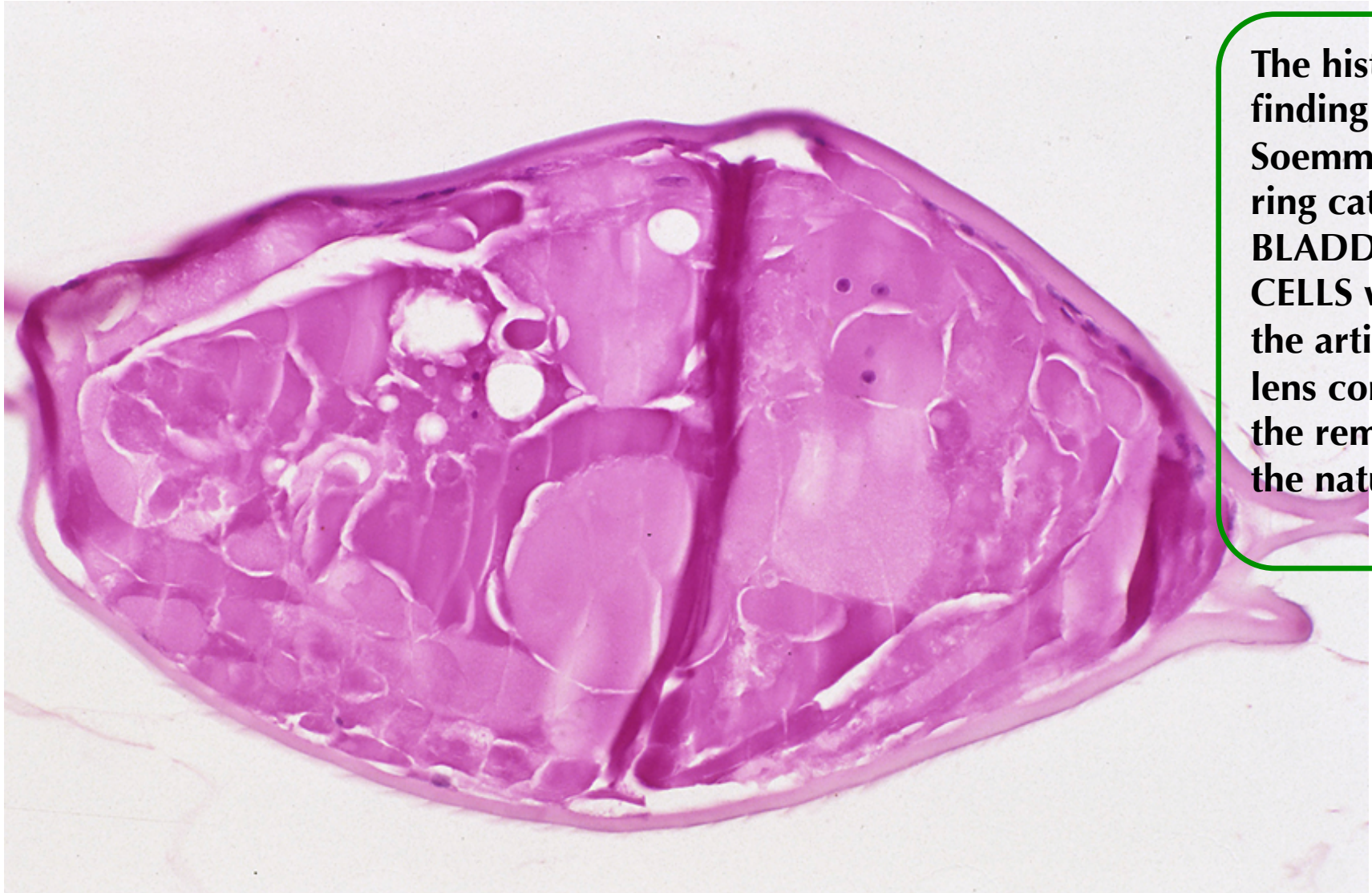
Soemmerring Ring Cataract is a BENIGN side effect of cataract surgery. There is proliferation of lens epithelial cells at the lens margins that do NOT obstruct vision because it is behind the iris.

# Soemmerring Ring Cataract



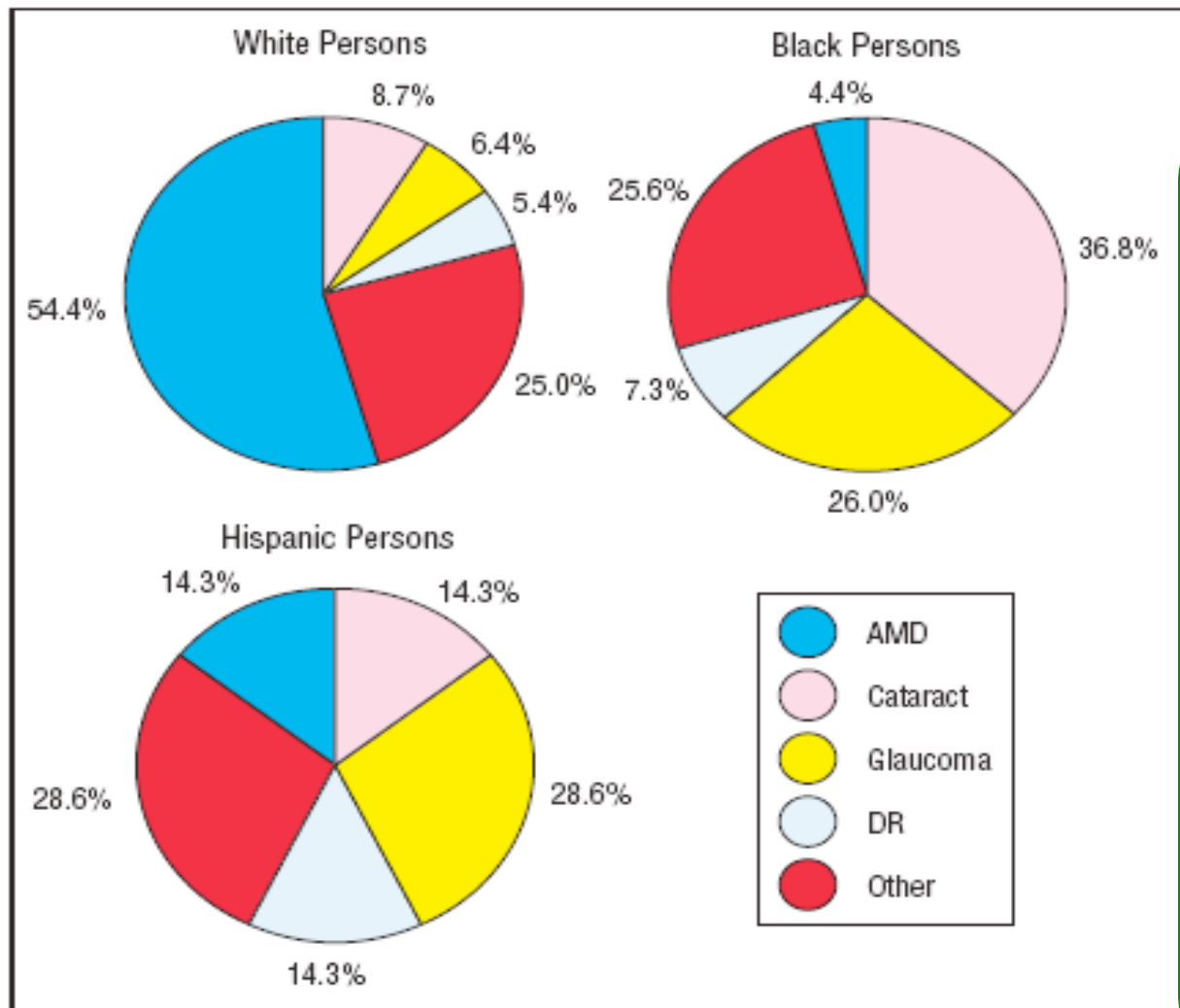


# Soemmerring Ring Cataract



The histological finding in Soemmerring ring cataracts is **BLADDER CELLS** where the artificial lens contacts the remnants of the natural lens.

# GLAUCOMA

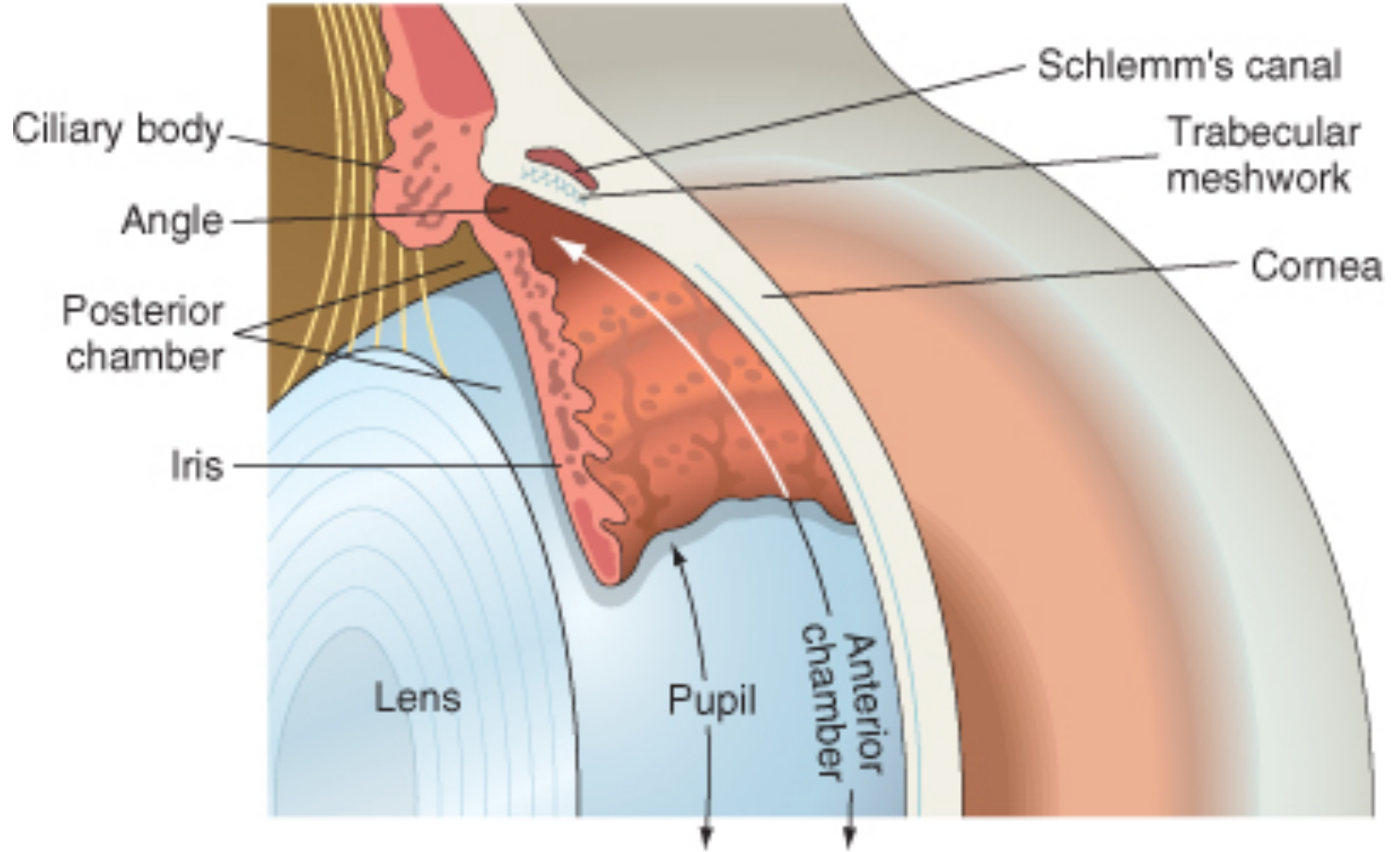


**Glaucoma is a more common cause of blindness in blacks and Hispanics. This is unrelated to the higher rates of diabetes because most glaucoma is “open-angle” not diabetes-related “angle-closure glaucoma.” There is more about this distinction in Tuesday’s lecture.**

**Figure 2.** Causes of blindness (best-corrected visual acuity <6/60 [ $<20/200$ ] in the better-seeing eye) by race/ethnicity. AMD indicates age-related macular degeneration; DR, diabetic retinopathy.

# Anterior Segment Anatomy

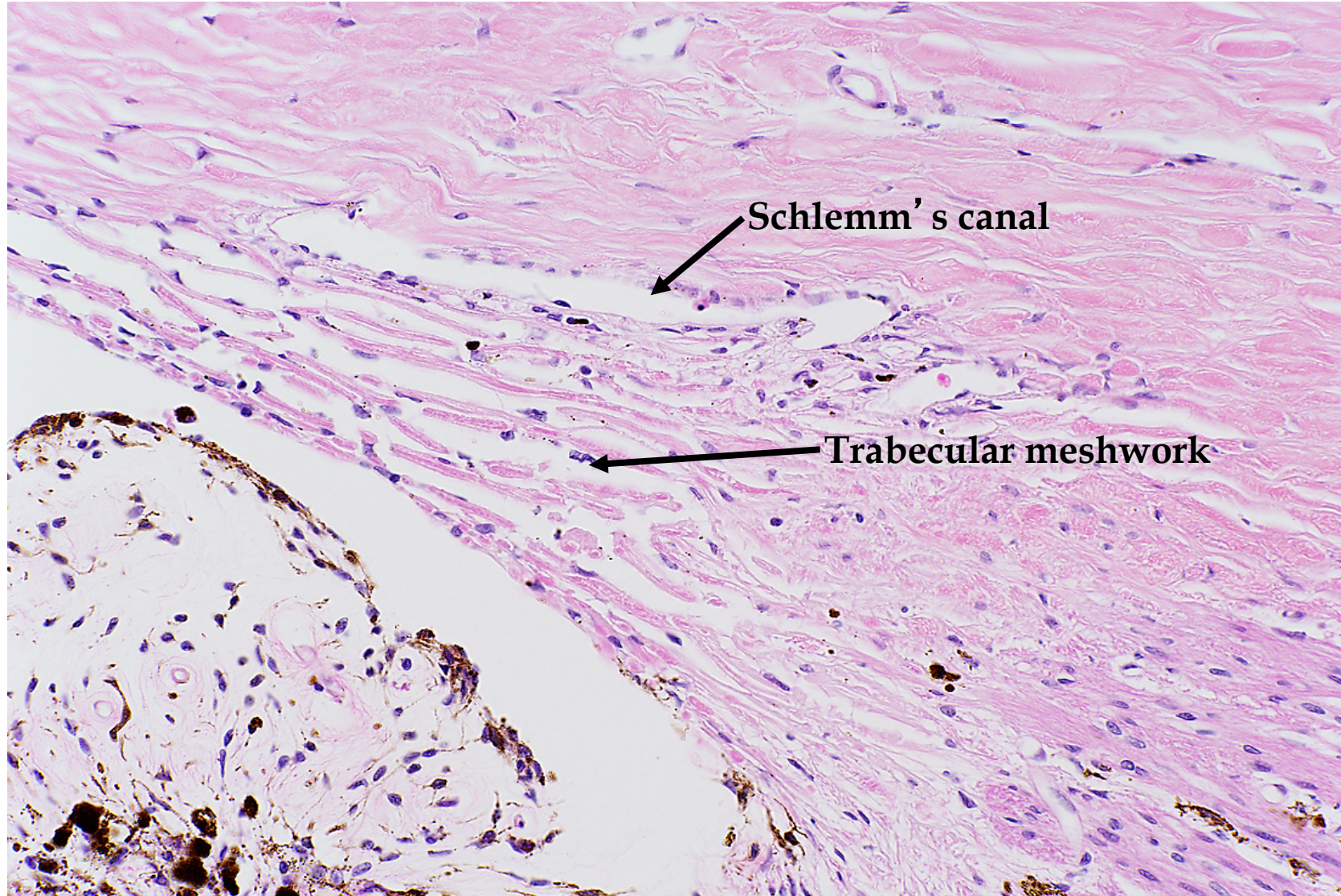
ANTERIOR AND POSTERIOR CHAMBERS



Aqueous humor is produced in the ciliary body, flows out the pupil, is strained in the trabecular meshwork, enters Schlemm's canal, and finally is resorbed into a venous plexus surrounding the canal.

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# Anterior Chamber Angle



# Retina

The damage of increased intra-ocular pressure (aka glaucoma) manifests in the retina, not the anterior structures of the eye.

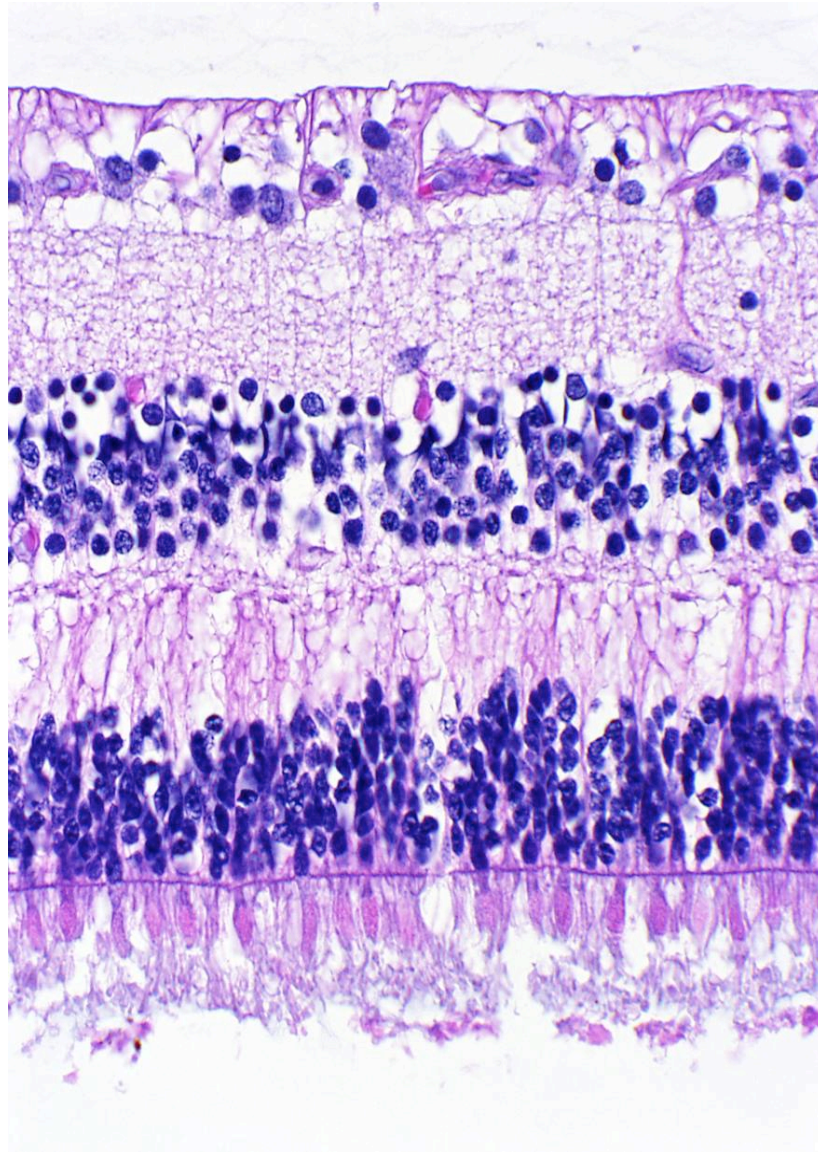
- **Neurosensory retina**

- » **Converts light into electrical impulses for transmittal to brain**
- » **Rods: “black and white” picture**
- » **Cones: “color” picture**

- **Retinal pigment epithelium**

- » **Absorbs light passing through retina (prevents reflection)**
- » **Phagocytosis and degradation of shed photoreceptor discs**
- » **Part of blood-retinal barrier**

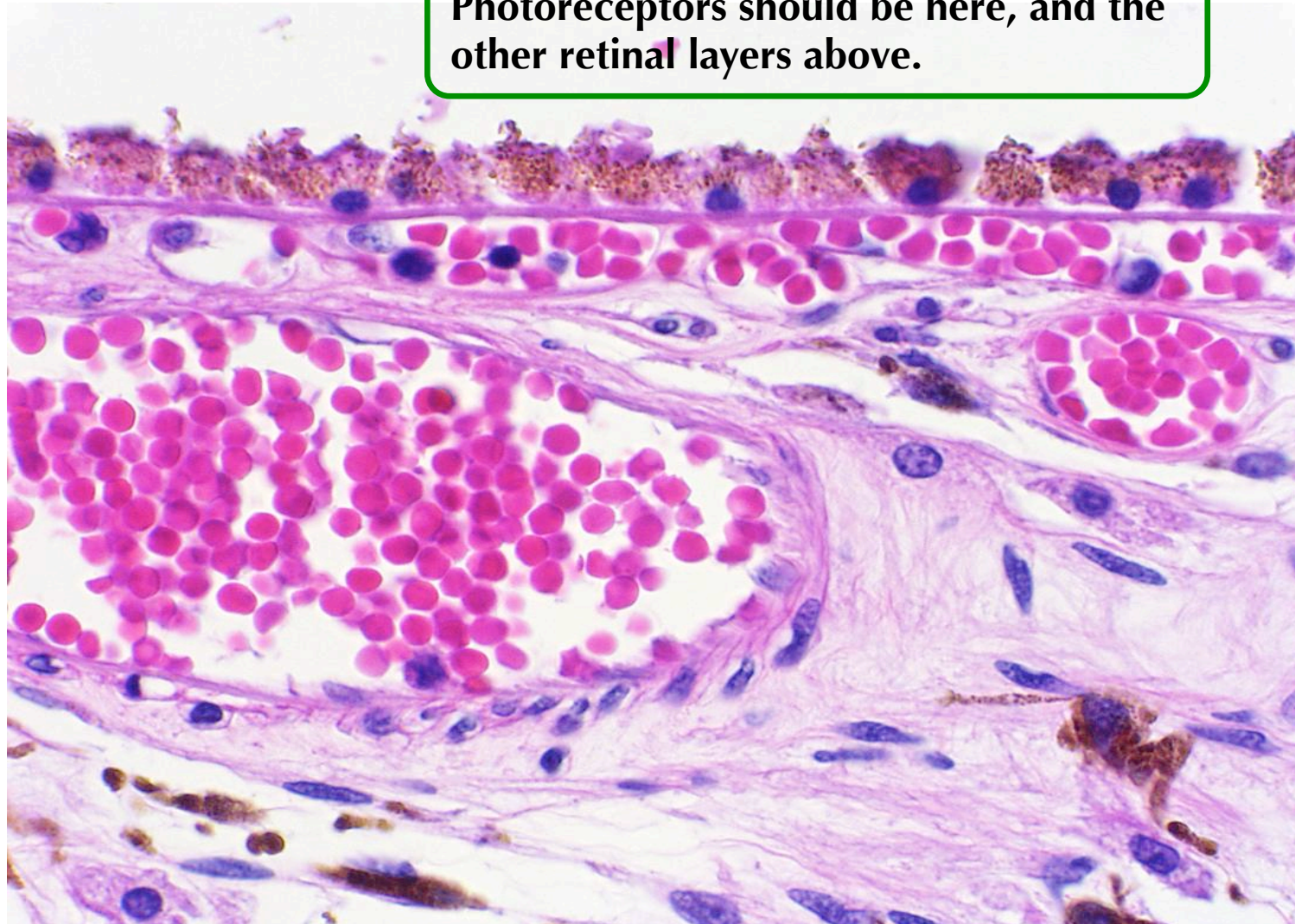
# Neurosensory Retina



- ← Inner limiting membrane
- ← Nerve fiber layer
- ← Ganglion cell layer
- ← Inner plexiform layer
- ← Inner nuclear layer
- ← Outer plexiform layer
- ← Outer nuclear layer
- ← External limiting membrane
- ← Outer segments of photoreceptors (rods and cones)

# Retinal Pigment Epithelium & Choroid

Photoreceptors should be here, and the other retinal layers above.



RPE  
Bruch's membrane  
Choriocapillaris

The choriocapillaris is a rich capillary network essential for supplying the RPE and outer retina.



# Glaucomatous Damage

## Causes of glaucoma.

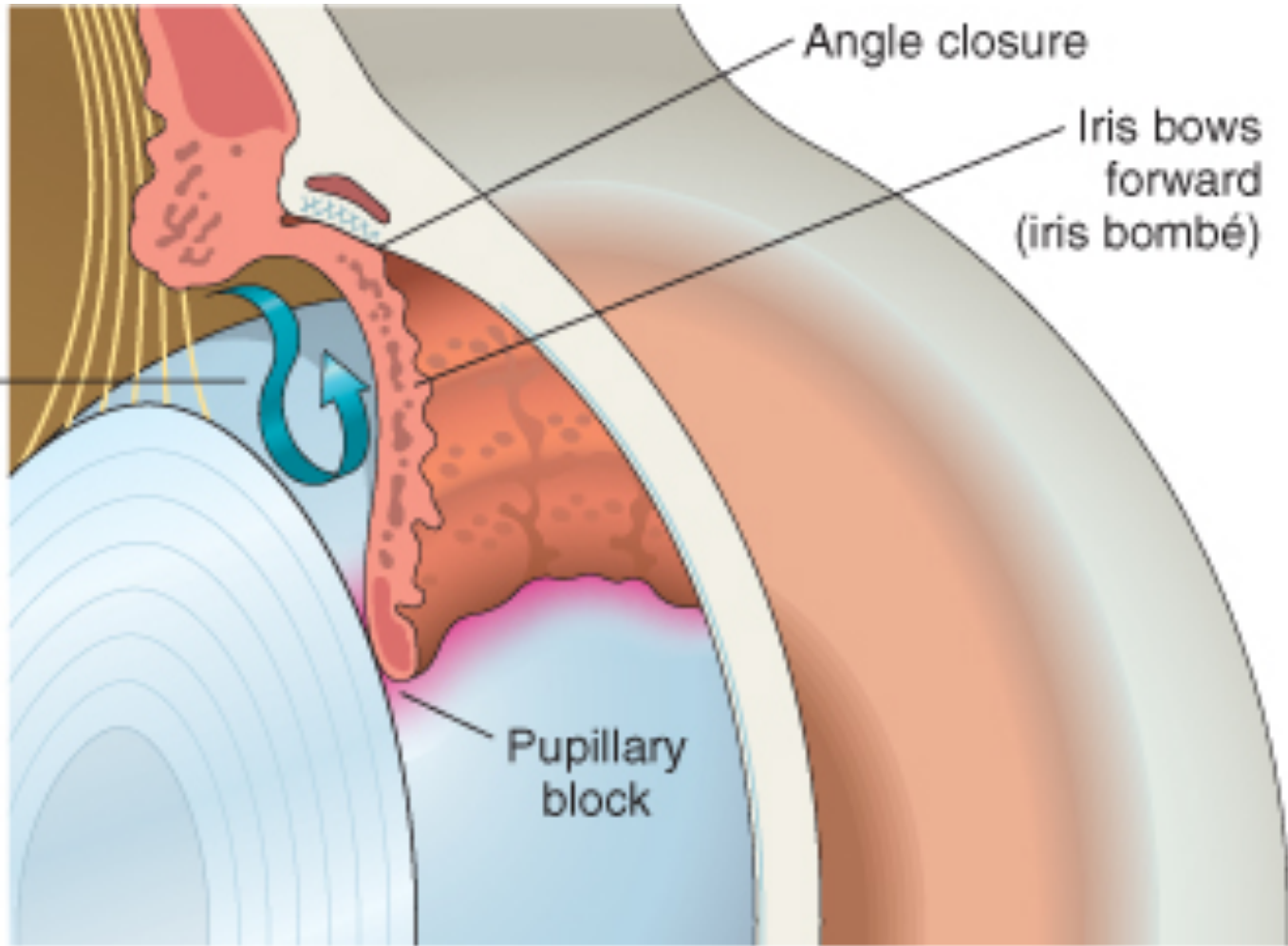
- +/- changes in anterior chamber angle
  - » Primary open-angle glaucoma most common
  - » Secondary open-angle glaucoma
    - Particles in trabecular meshwork)
  - » Angle-closure glaucoma
    - Many causes

## Effects of glaucoma on retina.

- Atrophy of the retinal ganglion cell layer
- Atrophy of the optic nerve
- Blindness

**Angle Closure  
Glaucoma: One  
type of glaucoma –  
more on how this  
happens in lecture  
04.12.1**

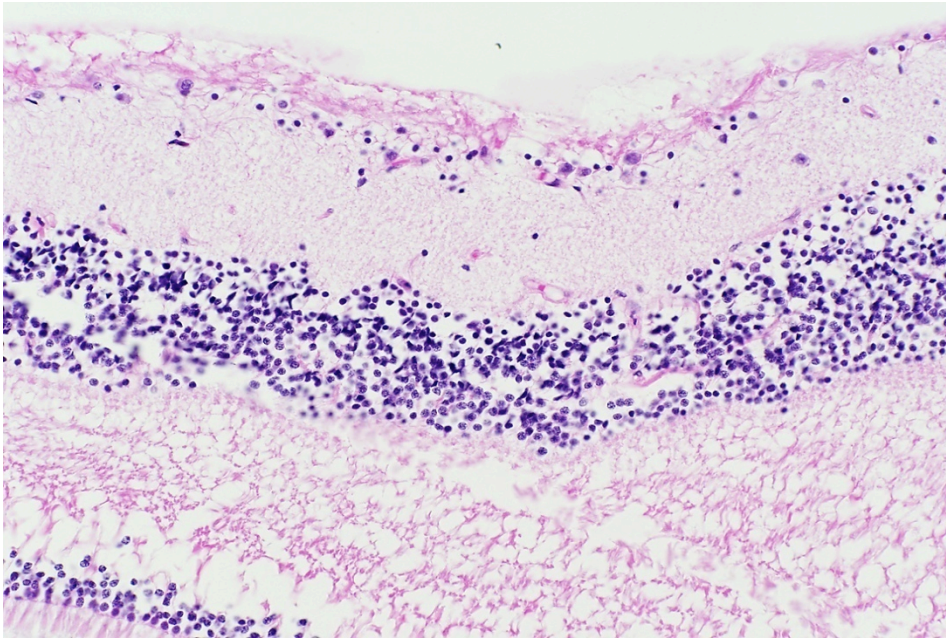
Obstructed  
flow leads  
to increased  
posterior  
chamber  
pressure



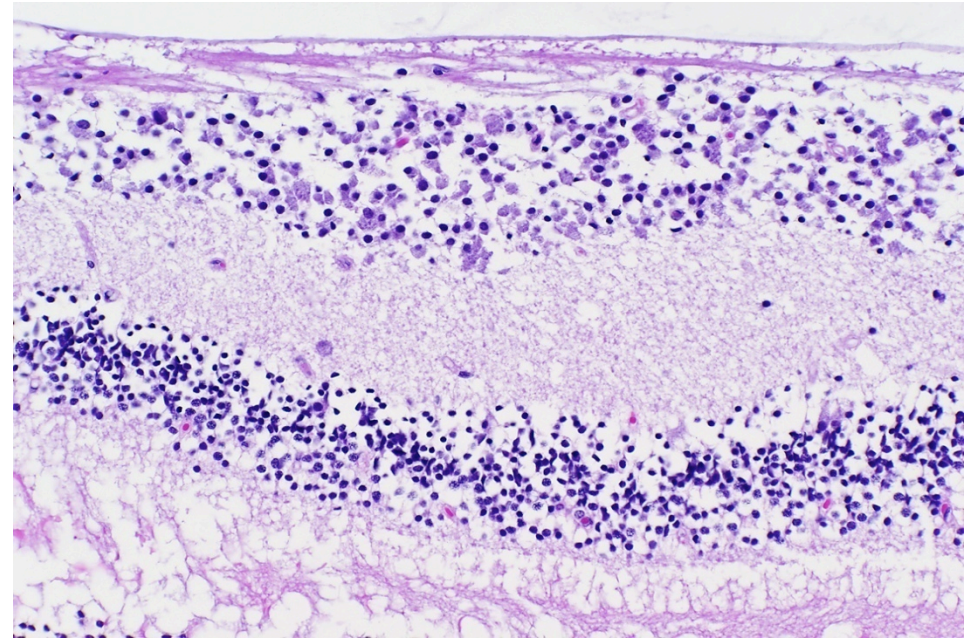
**PRIMARY ANGLE CLOSURE GLAUCOMA**

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# Glaucomatous Retinal Damage



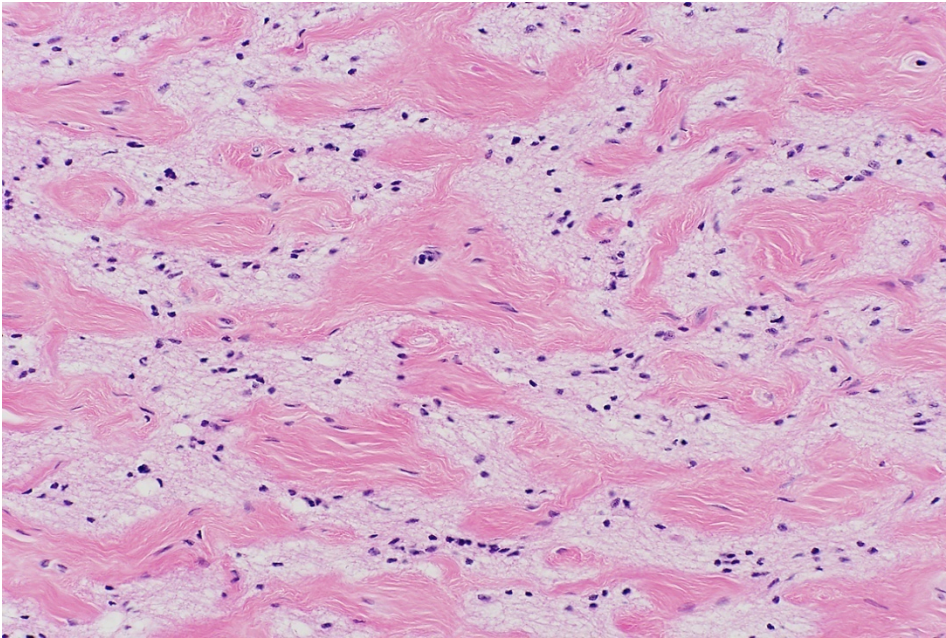
Macula with severe loss of ganglion cells



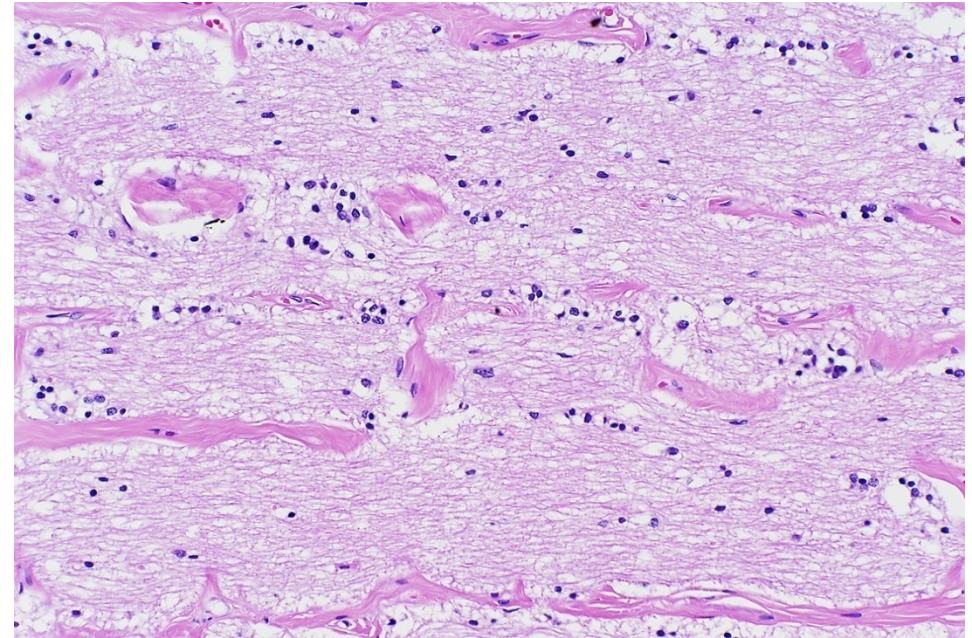
Macula with no loss of ganglion cells

**Note the loss of ganglion cells in inner layer. The loss of these cells leads to blindness and optic nerve atrophy.**

# Glaucomatous Optic Nerve Damage



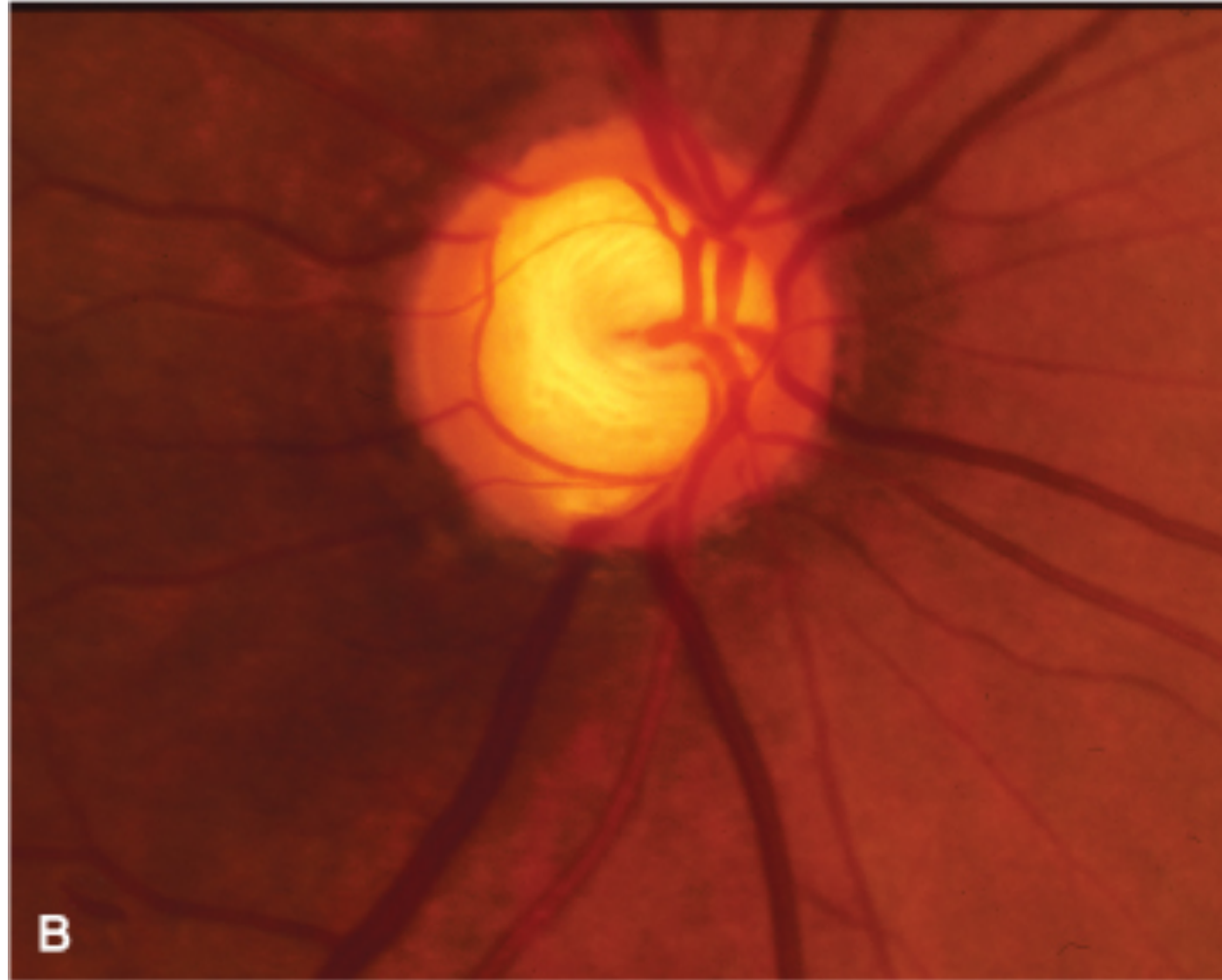
Optic nerve with moderate atrophy



Optic nerve with no atrophy

**Without normal signaling from ganglion cells, the optic nerve axons degenerate and undergoes fibrosis progressively with glaucoma.**

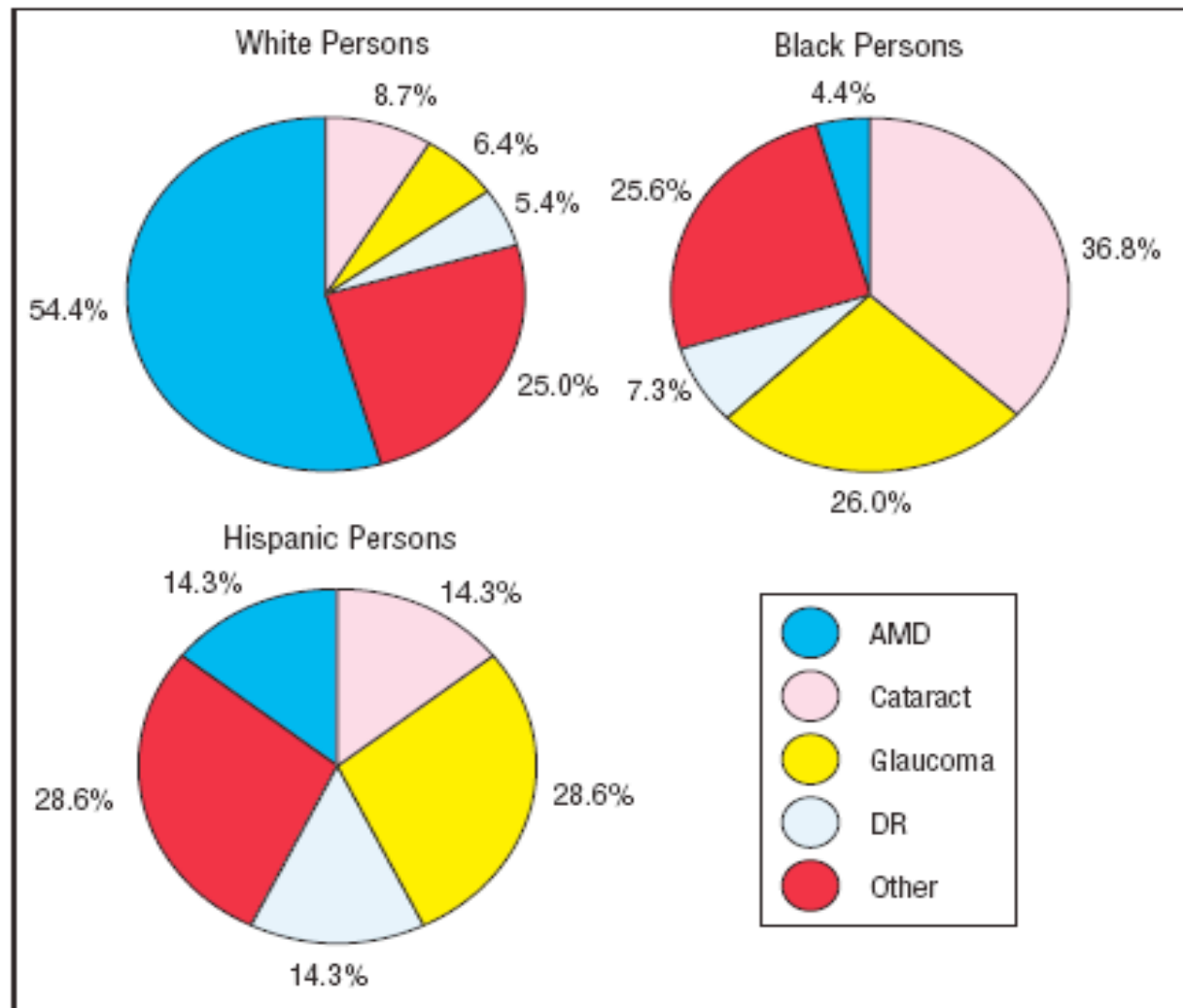
# Glaucomatous Optic Nerve Cupping



The optic nerve begins to look like a “rabbit burrow” due to atrophy. It also becomes whiter as it undergoes fibrosis and loses vascularization.

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# DIABETES MELLITUS



**Figure 2.** Causes of blindness (best-corrected visual acuity <math><6/60</math> [ $<20/200</math>] in the better-seeing eye) by race/ethnicity. AMD indicates age-related macular degeneration; DR, diabetic retinopathy.$

# Diabetic Retinopathy

- **Frequency after 3-4 years of diabetes:**
  - » **Insulin-dependent: 19%**
  - » **Non-insulin-dependent: 24%**
- **Frequency after 20 years of diabetes**
  - » **Insulin-dependent: “nearly all” (50% proliferative)**
  - » **Non-insulin-dependent: About 60% (10% proliferative)**
- **Fourth or fifth most common cause of blindness in U.S.A. depending on race/ethnicity**

Diabetic retinopathy is one of the reasons why tight control of blood glucose is so important.

There are two types:  
1. Background  
2. Proliferative

Diabetic nephropathy and peripheral neuropathy are two other major sequelae with diabetes.



# Diabetic Retinopathy

Diabetic retinopathy's underlying pathology is blood vessel changes with the following properties, possibly due to pericyte death.

## ● **Background (preproliferative) diabetic retinopathy**

- » **Thickened basement membrane of retinal blood vessels**
- » **Decreased pericytes**
- » **Microaneurysms**

- » **Macular edema**
- » **Hemorrhages**
- » **Cotton wool spots (nerve fiber layer microinfarcts)**
- » **Intraretinal angiogenesis (intraretinal microangiopathy)**

**Physical findings by fundoscopic exam.**

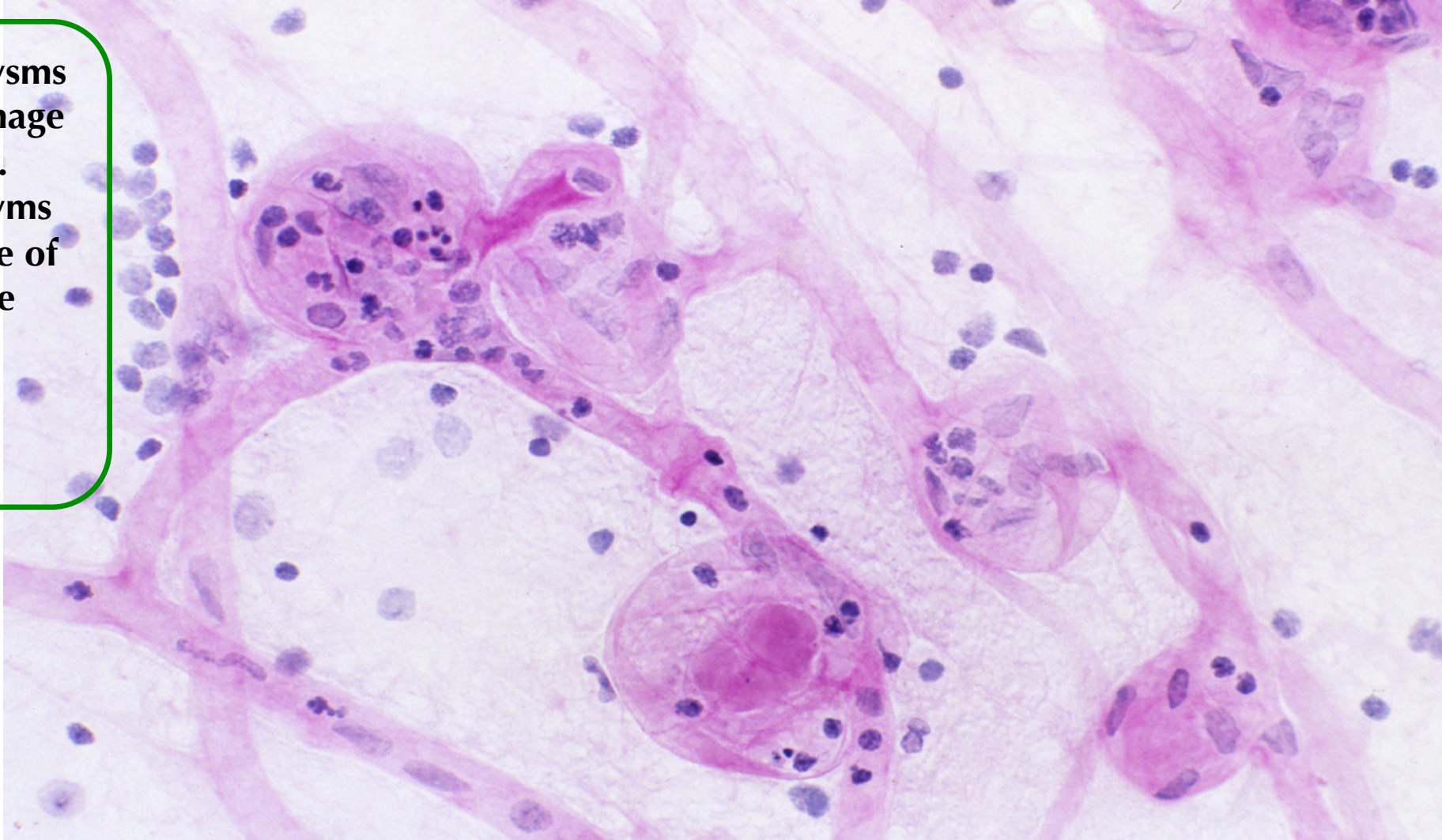
# Diabetic Retinopathy

- **Proliferative** diabetic retinopathy
  - » **New vessels on either surface of optic disc or retina**
    - **Vessels must penetrate internal limiting membrane**
    - **Complications**
      - **Traction retinal detachment**
      - **Hemorrhage**
      - **Iris neovascularization**

**Neovascularization occurs because of ischemia, which is problematic because of retinal detachment, hemorrhage, light obstruction.**

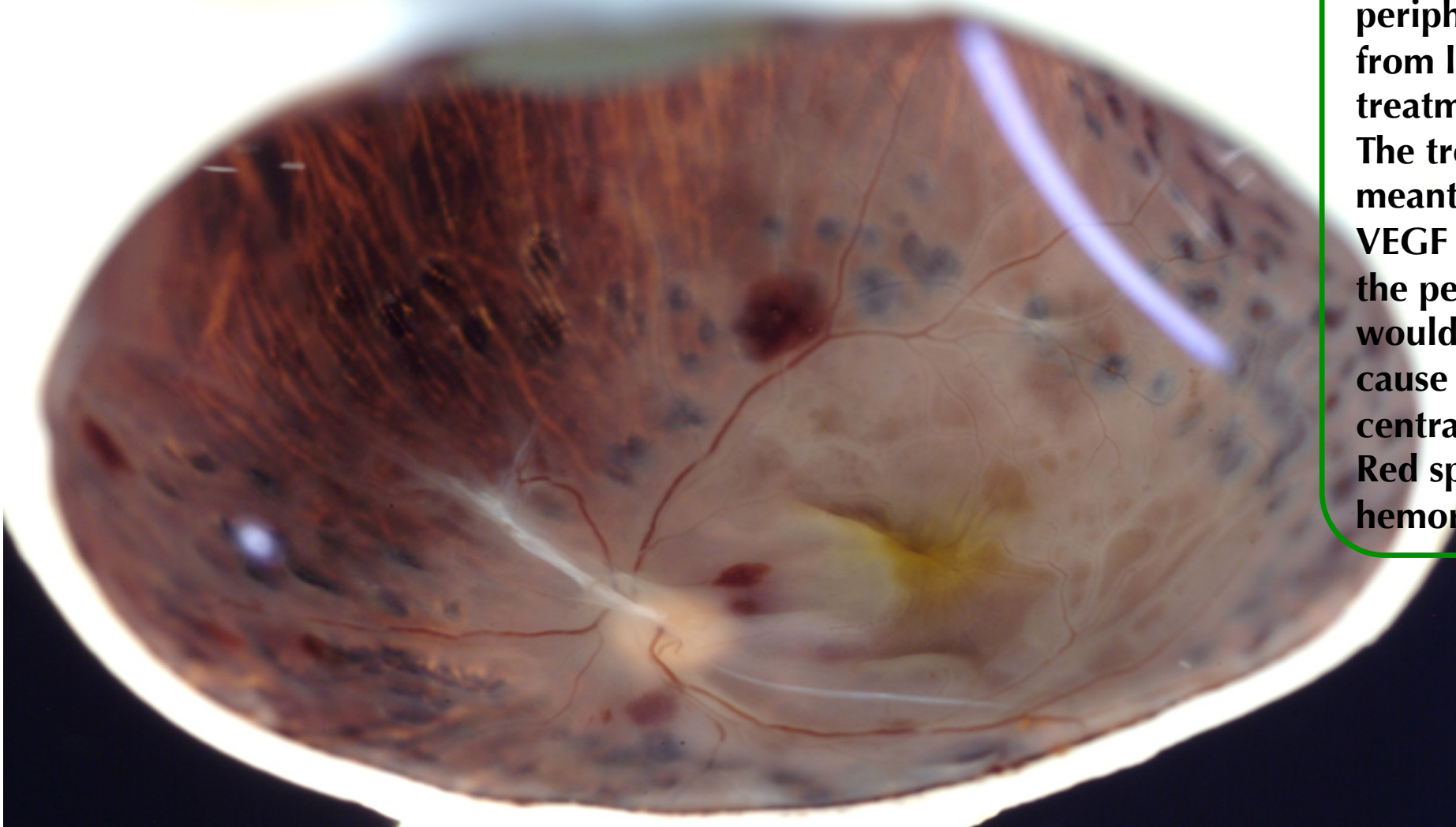
# Diabetic Microaneurysms

Microaneurysms will hemorrhage and be leaky. Microaneurysms arise because of poor pericyte health.



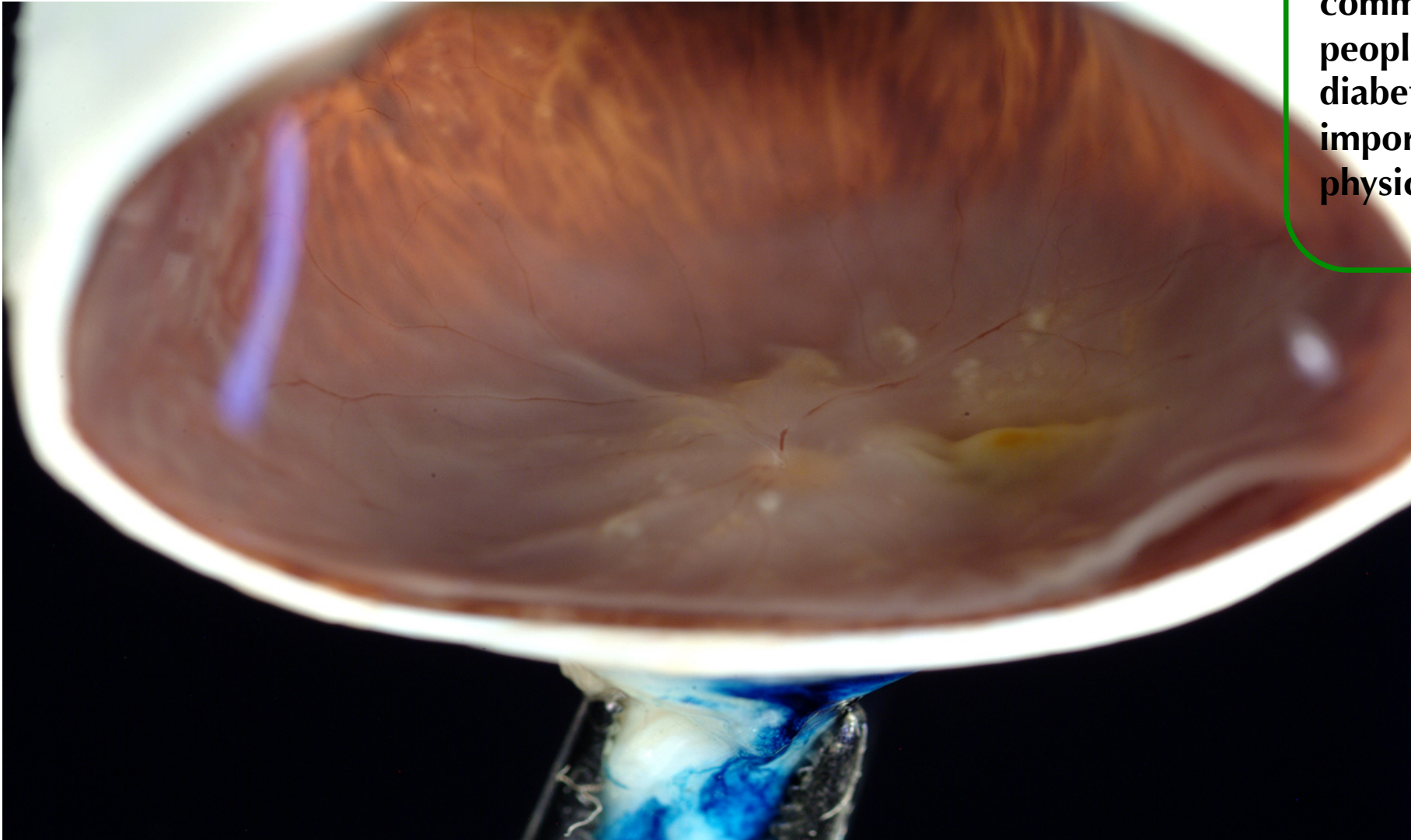
# Diabetic Retinal Hemorrhages

**Black spots peripherally are from laser burn treatment. The treatment is meant to reduce VEGF release from the periphery that would otherwise cause angiogenesis centrally. Red spots are hemorrhages.**



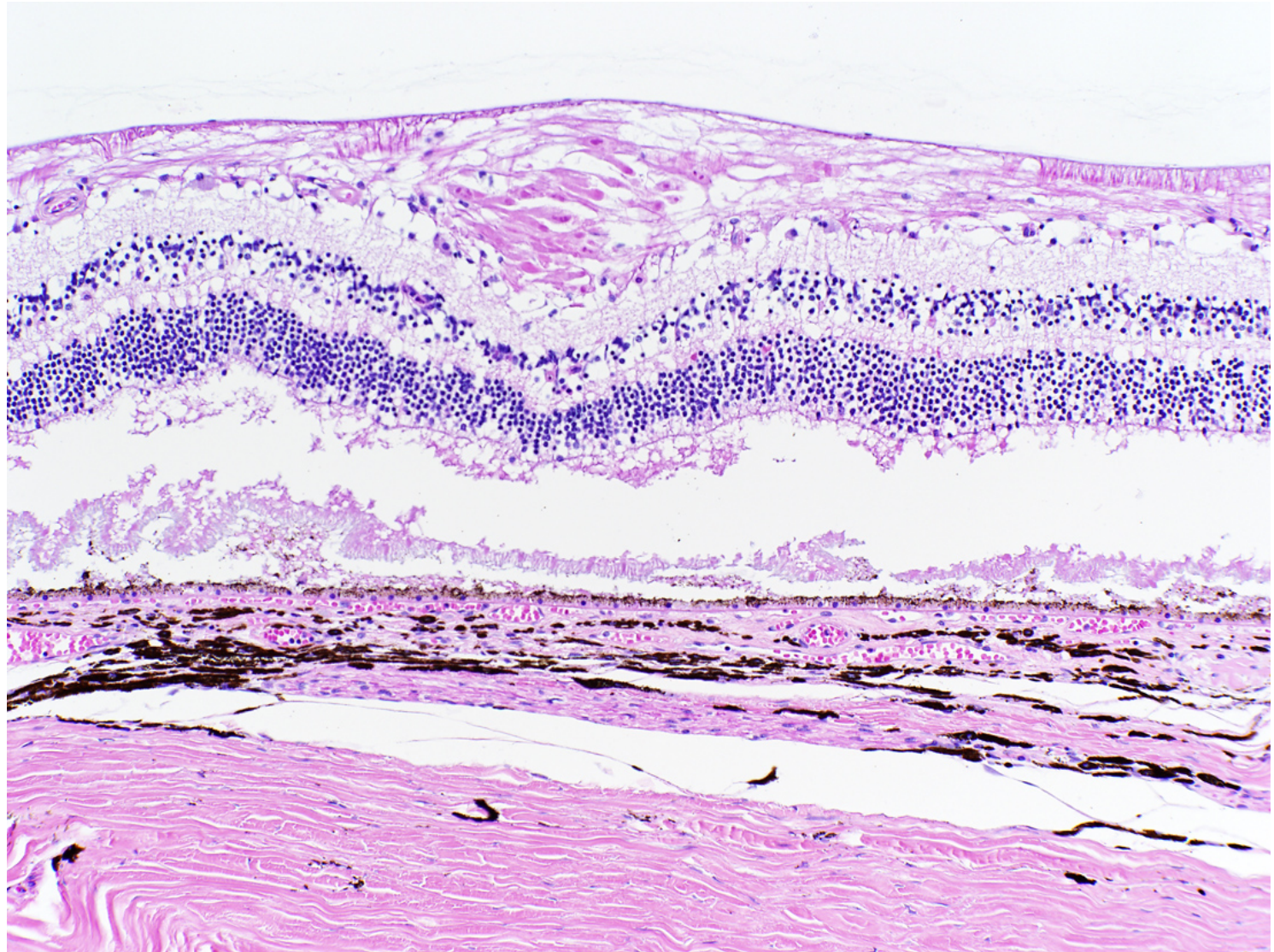
# Cotton Wool Spots

Cotton wool appears on surface of retina, commonly in people with diabetes. This is an important physical finding.

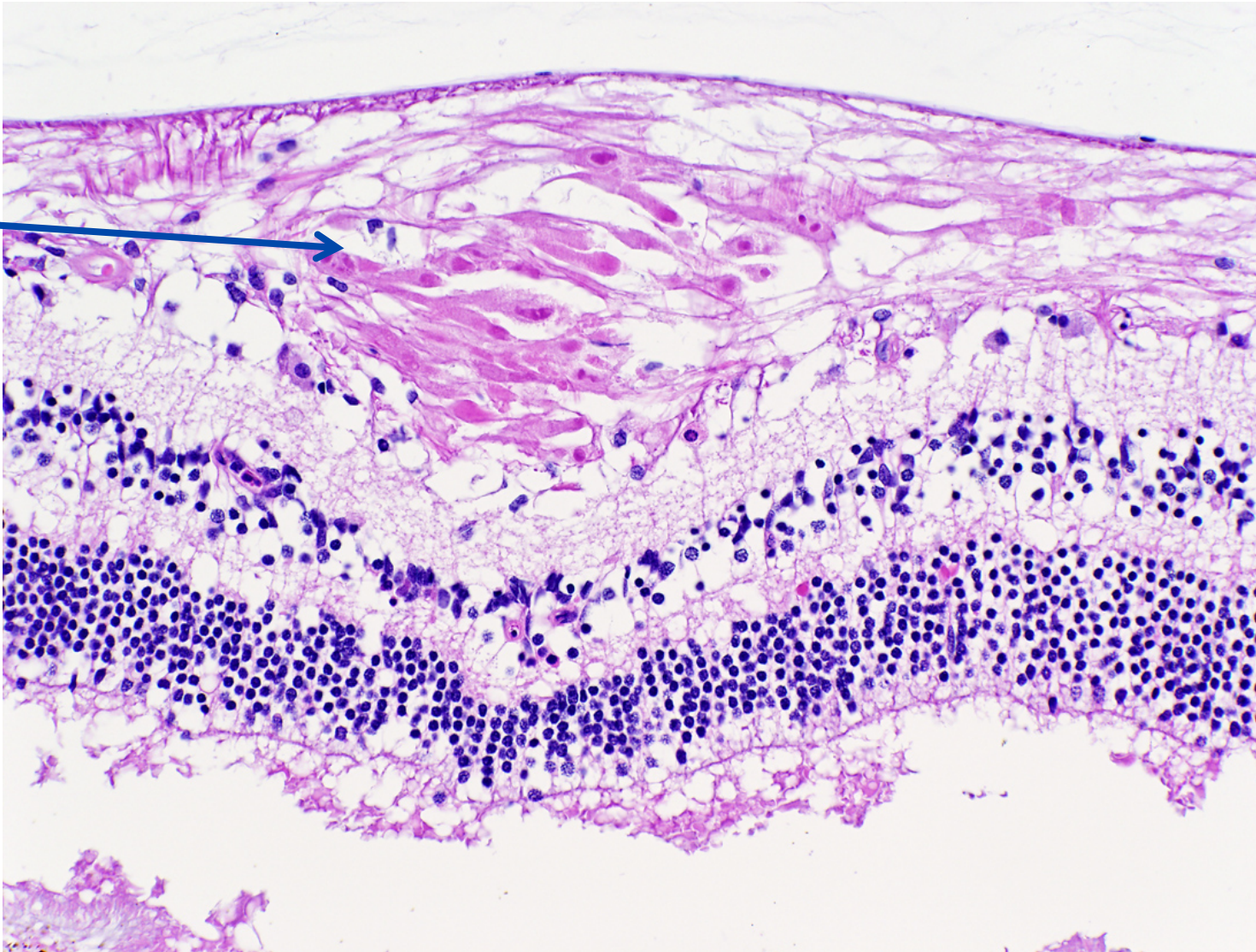


# Cotton Wool Spot

A pathology resident gets this slide from autopsy. He asks you what you notice. Well... what do you notice?

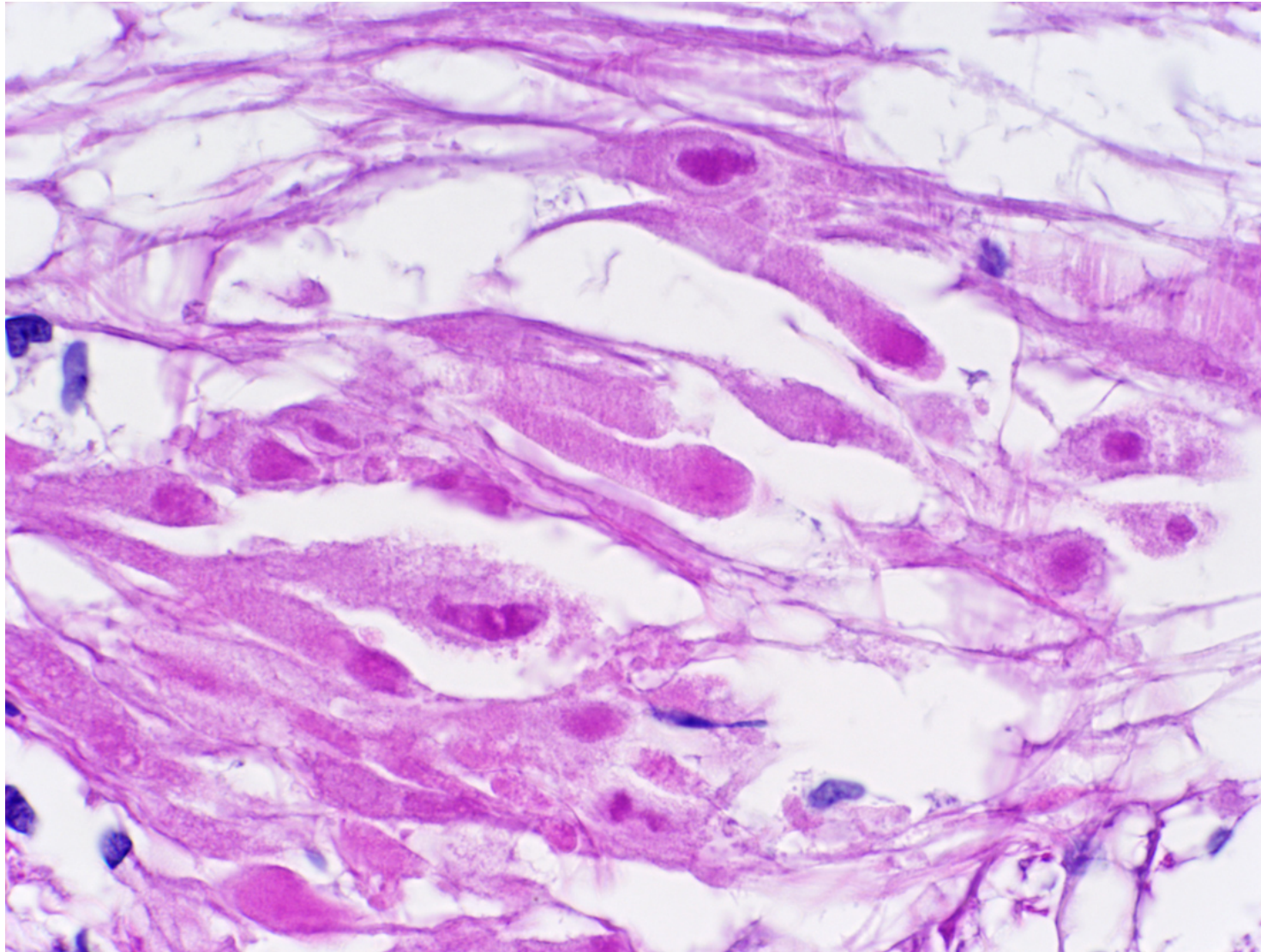


# Cotton Wool Spot



You notice swelling of axons due to ischemia. This is clearly diabetic retinopathy.

# Cotton Wool Spot

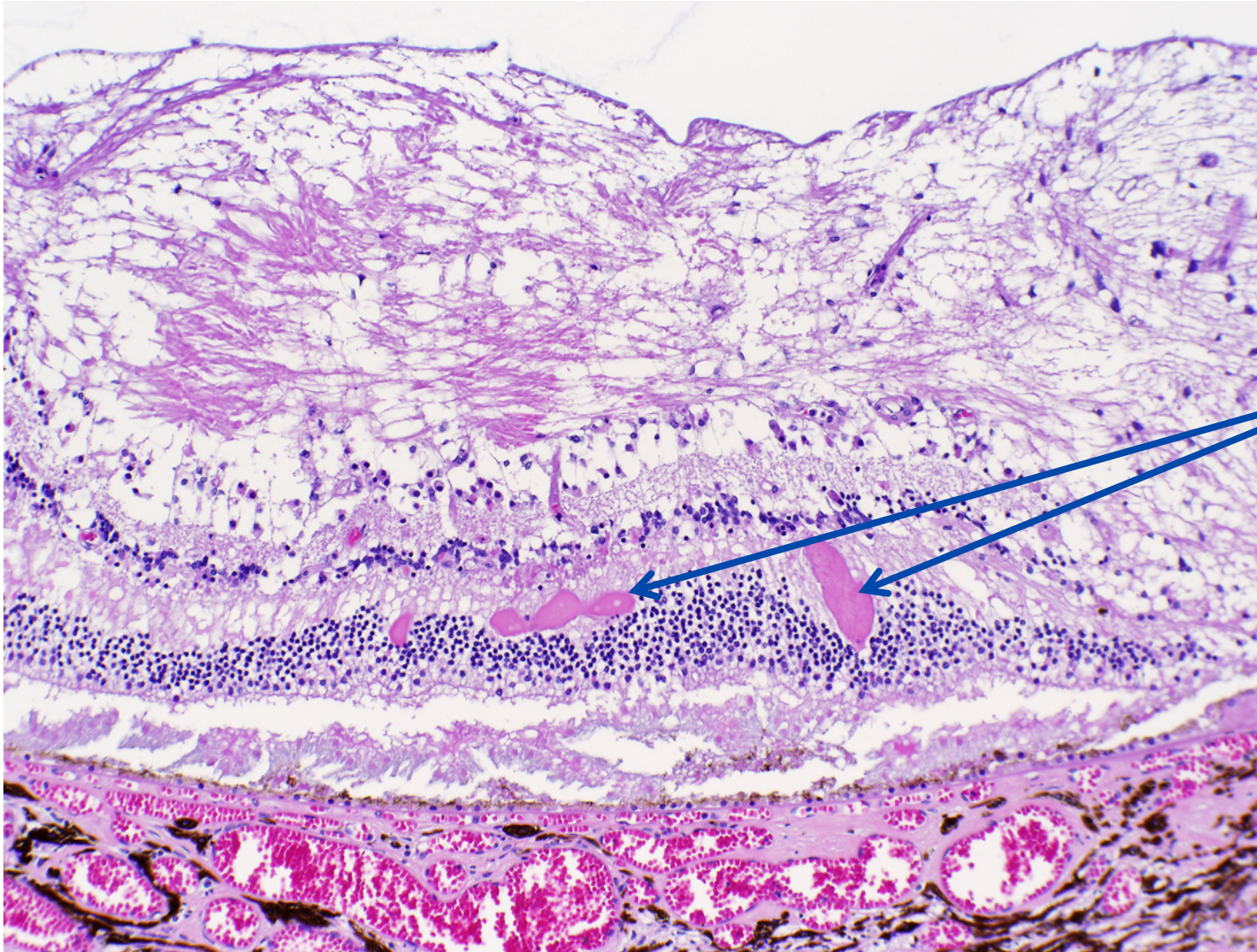


He then asks:

What is another classic finding associated with cotton wool spots other than axonal swelling?

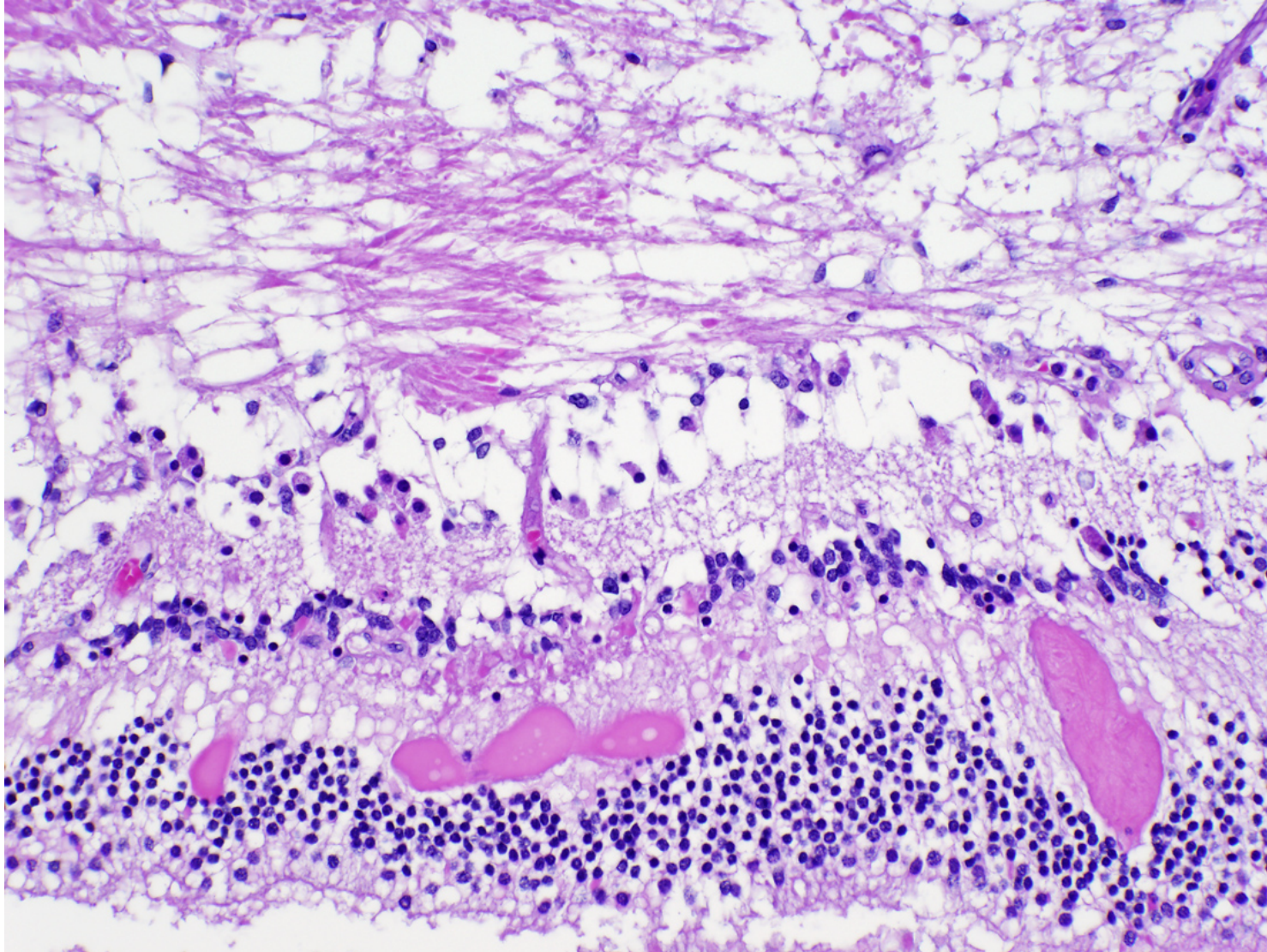


# Fluid Leakage (Exudate)



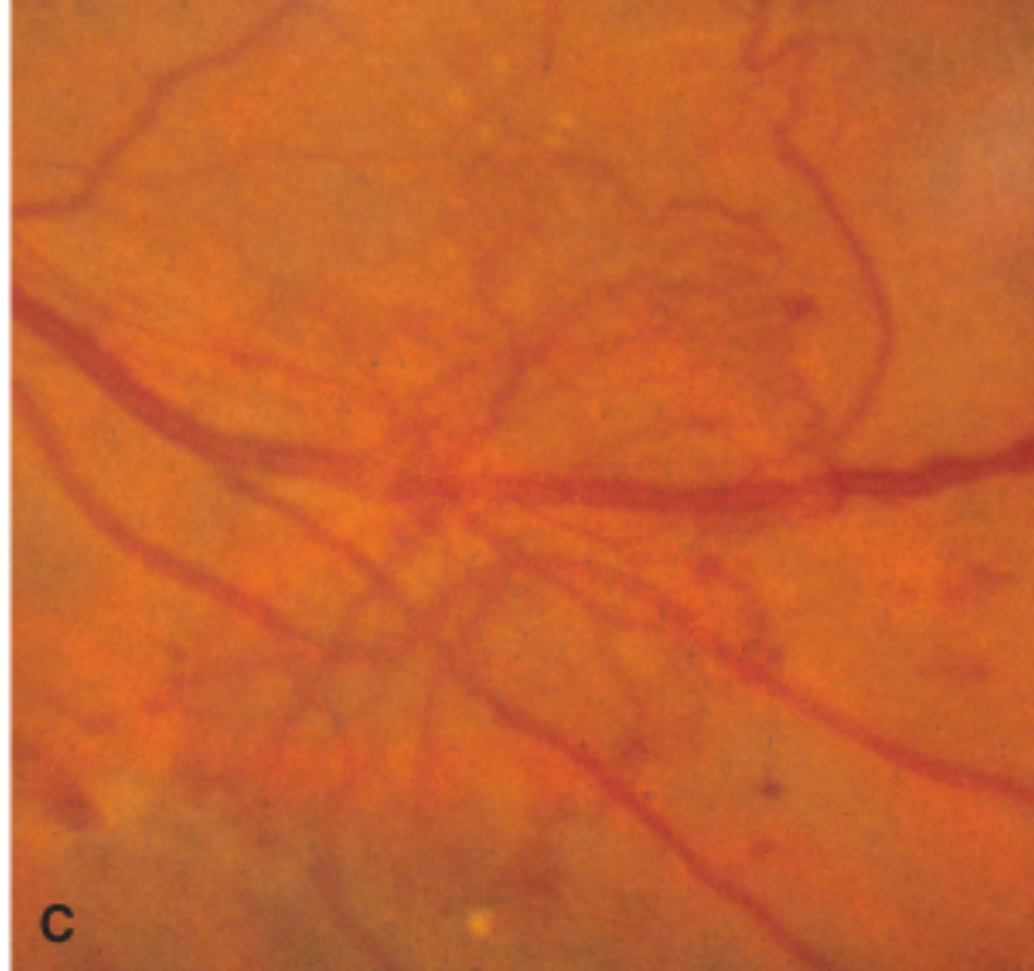
**You reply:  
Exudate is also  
common in  
cotton wool  
spots. There is  
a lot of fluid  
filled space  
here. This  
interferes with  
vision obvi.**

# Fluid Leakage (Exudate)



# Proliferative Diabetic Retinopathy

Vessels will proliferate in proliferative diabetic retinopathy.



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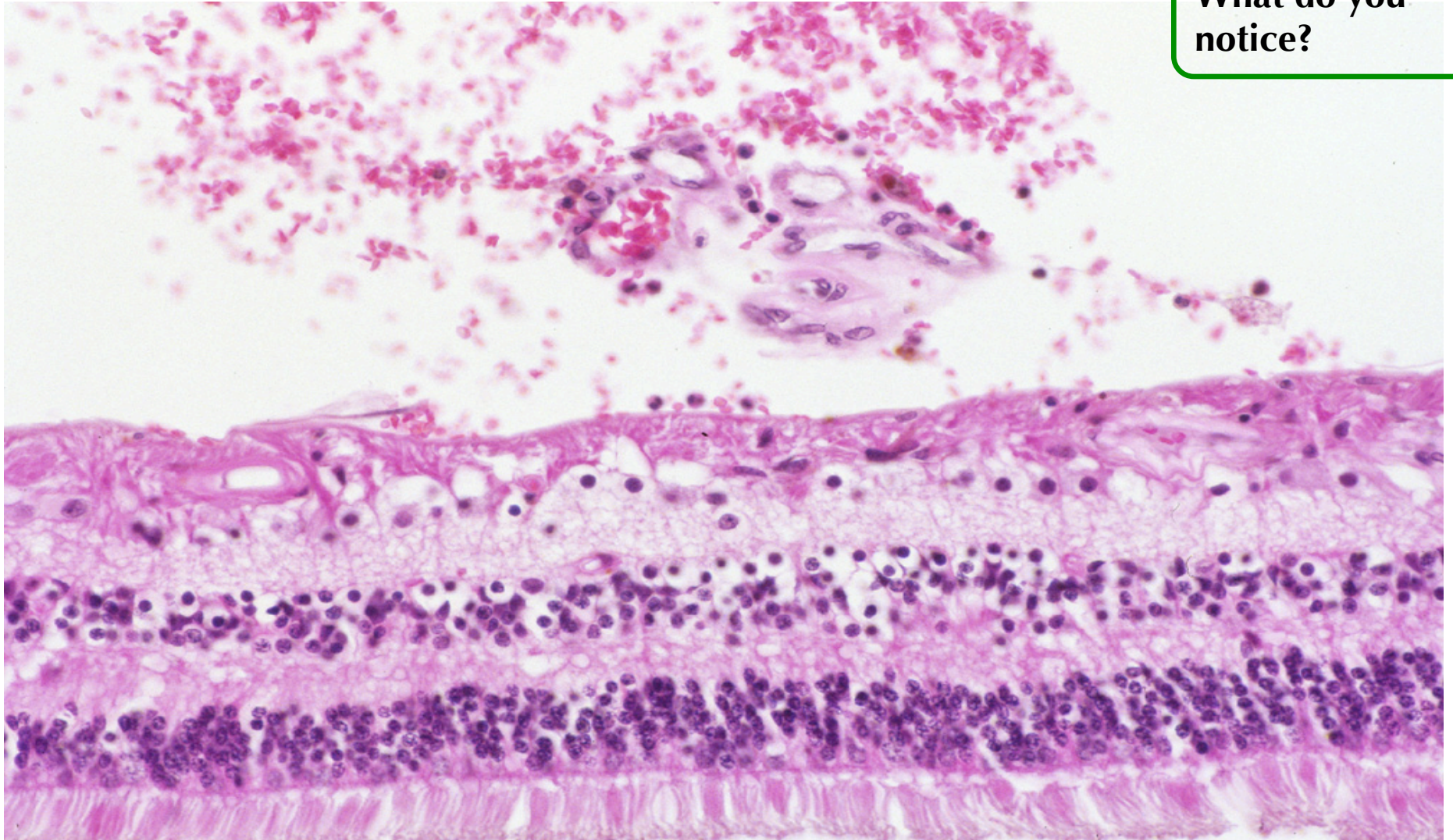
# Proliferative Diabetic Retinopathy

Proliferation can become quite severe.



# Proliferative Diabetic Retinopathy

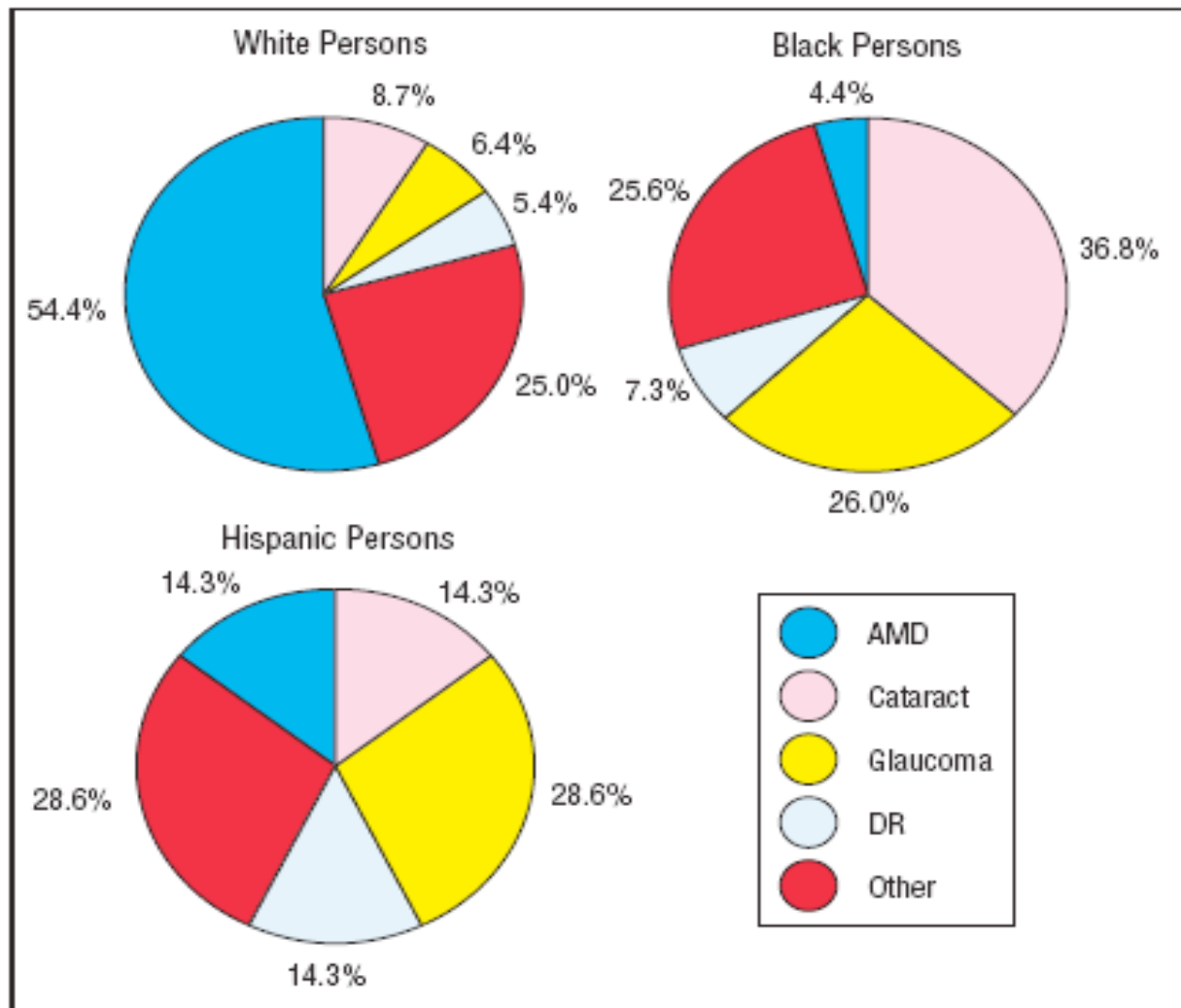
What do you notice?



**On the previous slide you should have noticed the cluster of hemorrhagic vessels on the surface of the retina.**

# **AGE-RELATED MACULAR DEGENERATION**

Half of blind white persons are blind because of AMD.



**Figure 2.** Causes of blindness (best-corrected visual acuity <math><6/60</math> [ $<20/200</math>] in the better-seeing eye) by race/ethnicity. AMD indicates age-related macular degeneration; DR, diabetic retinopathy.$

# Age-related Macular Degeneration

- **Prevalence estimated to be approximately 1.5-1.9% in developed countries, with a dramatic increase with advancing age**
- **Estimated that more than 15% of white women older than 80 years of age have neovascular AMD and/or geographic atrophy**



# Age-related Macular Degeneration

- **Risk factors: Older age, female sex, white race, cigarette smoking, consumption of angiotensin-converting enzyme inhibitors**
- **Genetic factors: Complement factor H variants**
  - » **Complement factor H in circulation and on surface of cells inhibits the activation of C3 to C3a and C3b and inactivates C3b**
  - » **Ameliorates inflammation secondary to activation of the complement cascade**

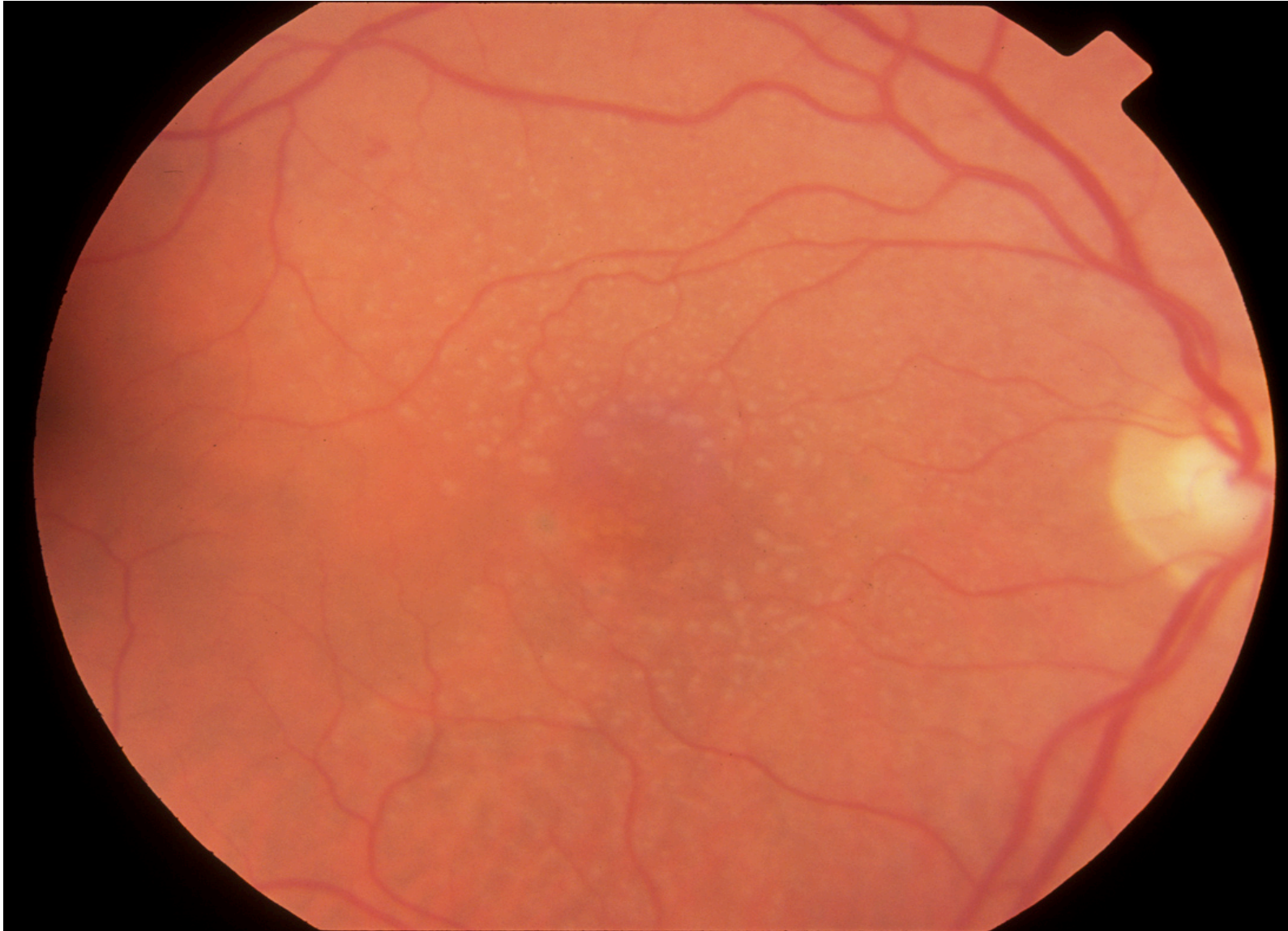
**Genetics not important. Age, sex, smoking and ACEi use are important risk factors.**

# Age-related Macular Degeneration

- **Complement factor H variants**

- » **Drusen are a manifestation of a chronic inflammatory stimulus**
- » **I have not observed any increased numbers of inflammatory cells in the choroid of eyes with AMD versus age-matched controls without AMD (unpublished observation)**
- » **If AMD is truly a chronic inflammatory state, then it is chemically and not cellularly mediated**

**Genetics not important.**

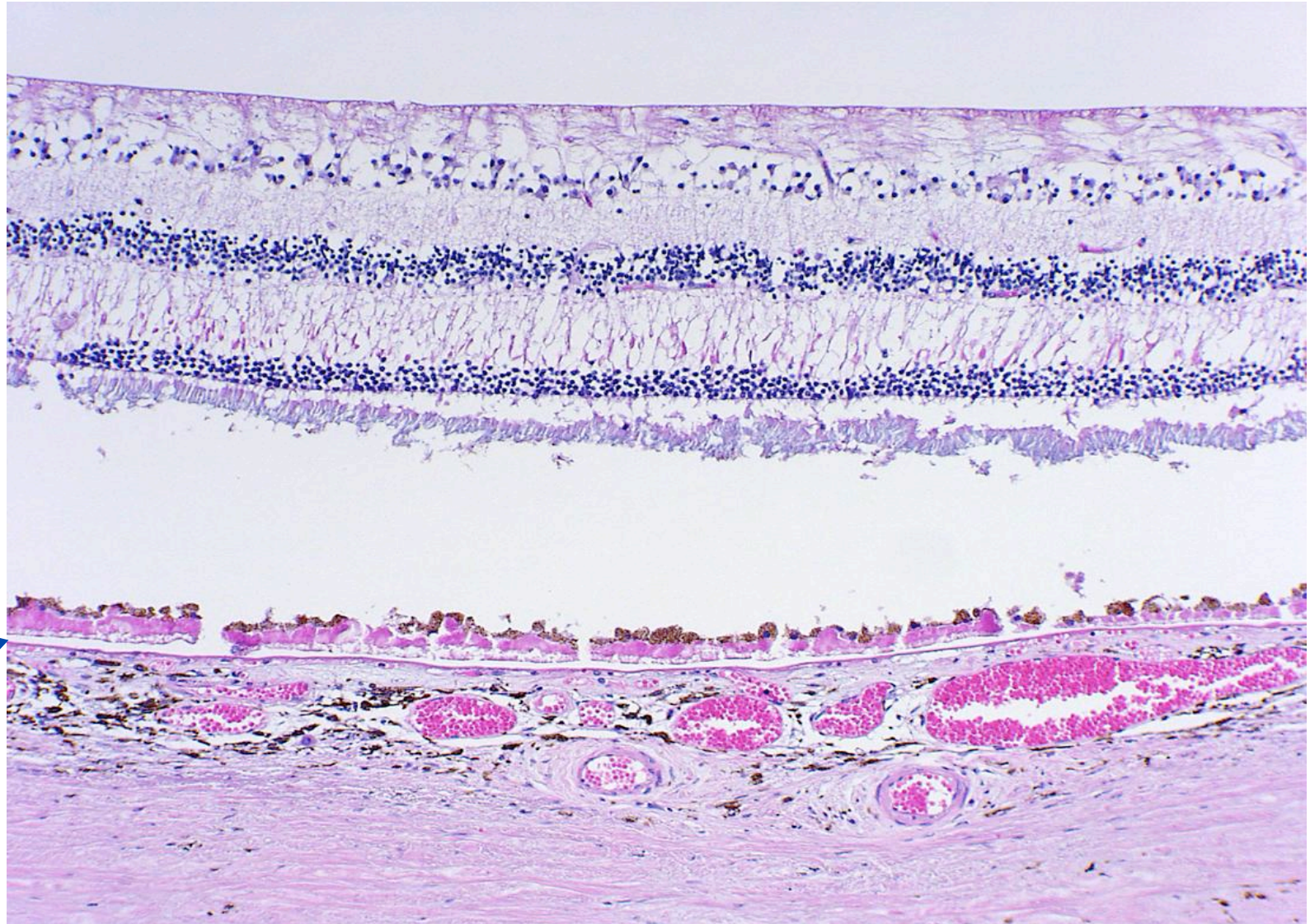


**What do you see?**

# Atrophic (“dry”) AMD

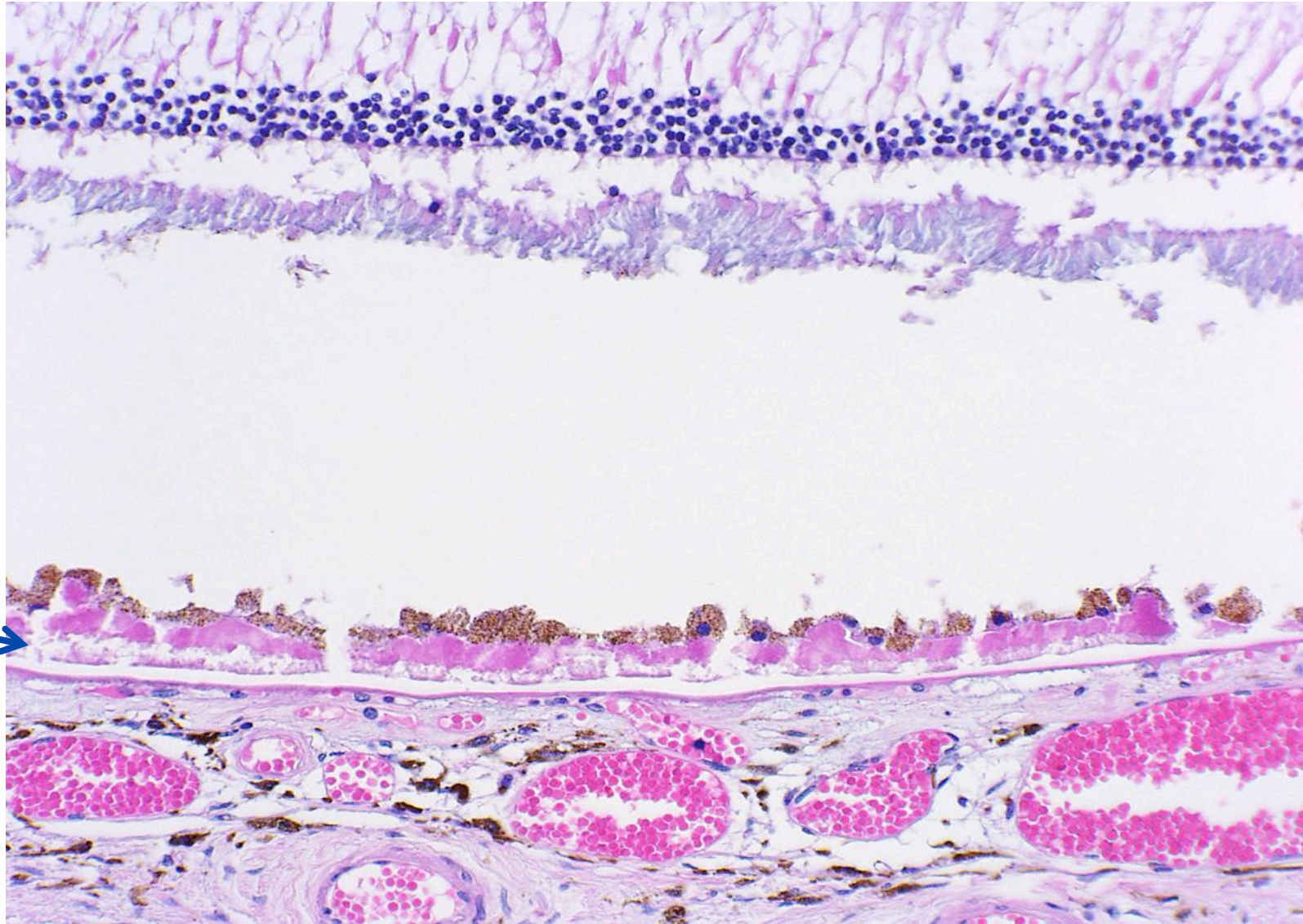
On the previous slide you should have seen small white spots (called drusen) in the macula.

In dry AMD, there is buildup of material between RPE and Bruch’s membrane



# Atrophic (“dry”) AMD

Material builds up  
causes  
photoreceptor  
dysfunction.



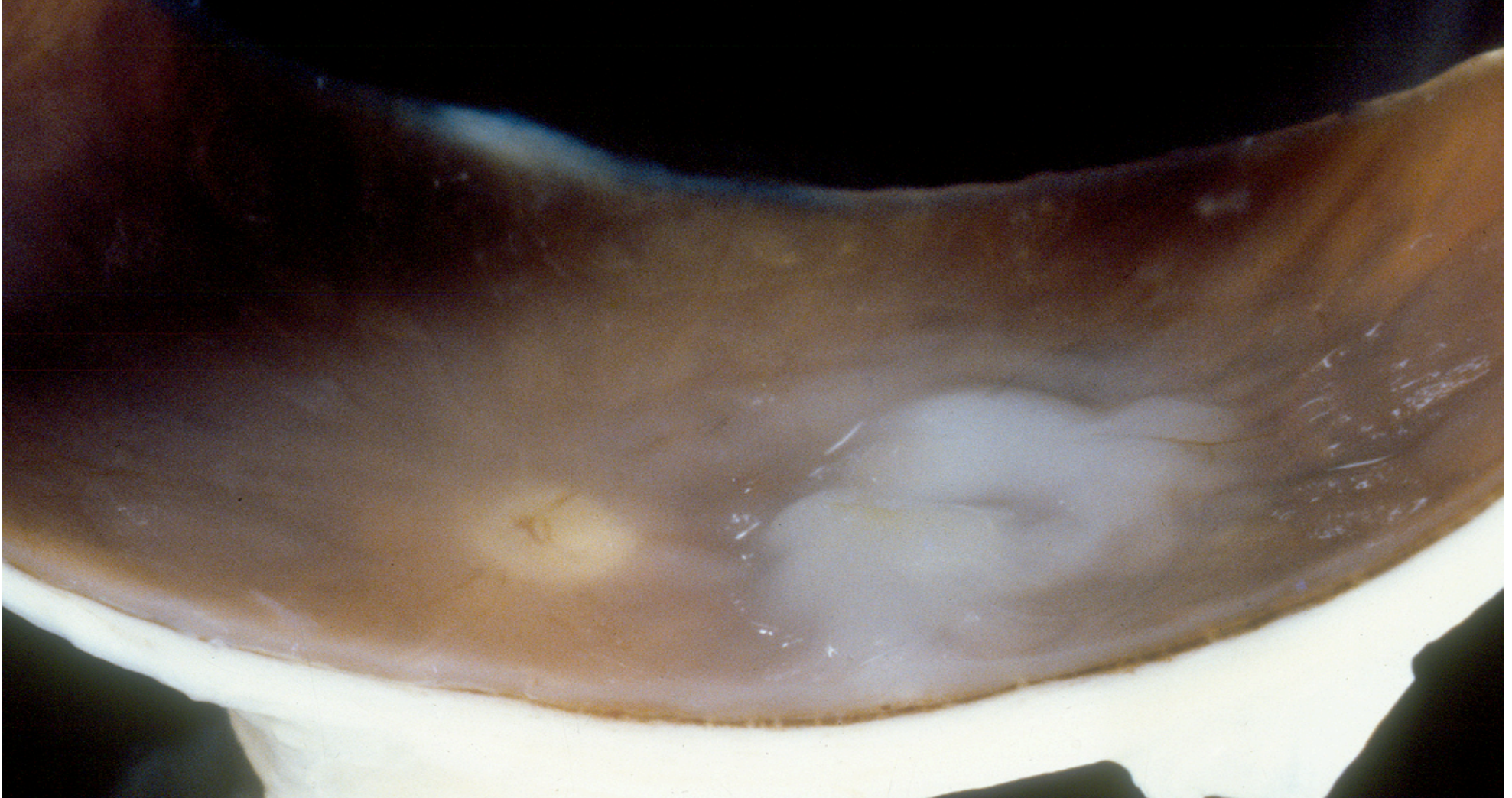
# Exudative (“wet”) AMD

Note the color change. This is hemorrhage in the macula due to wet AMD.

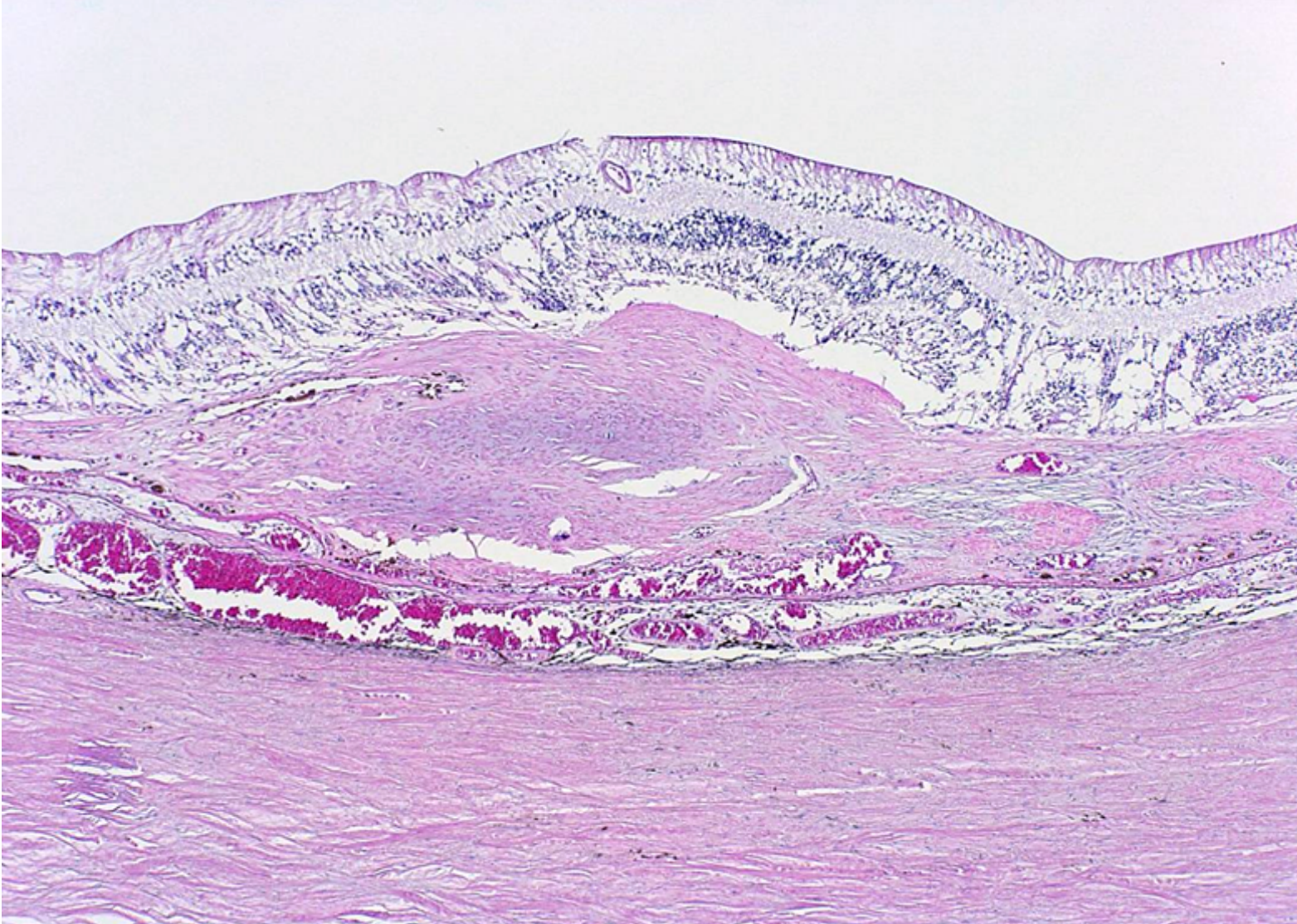


# Exudative (“wet”) AMD

Large fibrous proliferation in macula.



# Exudative (“wet”) AMD

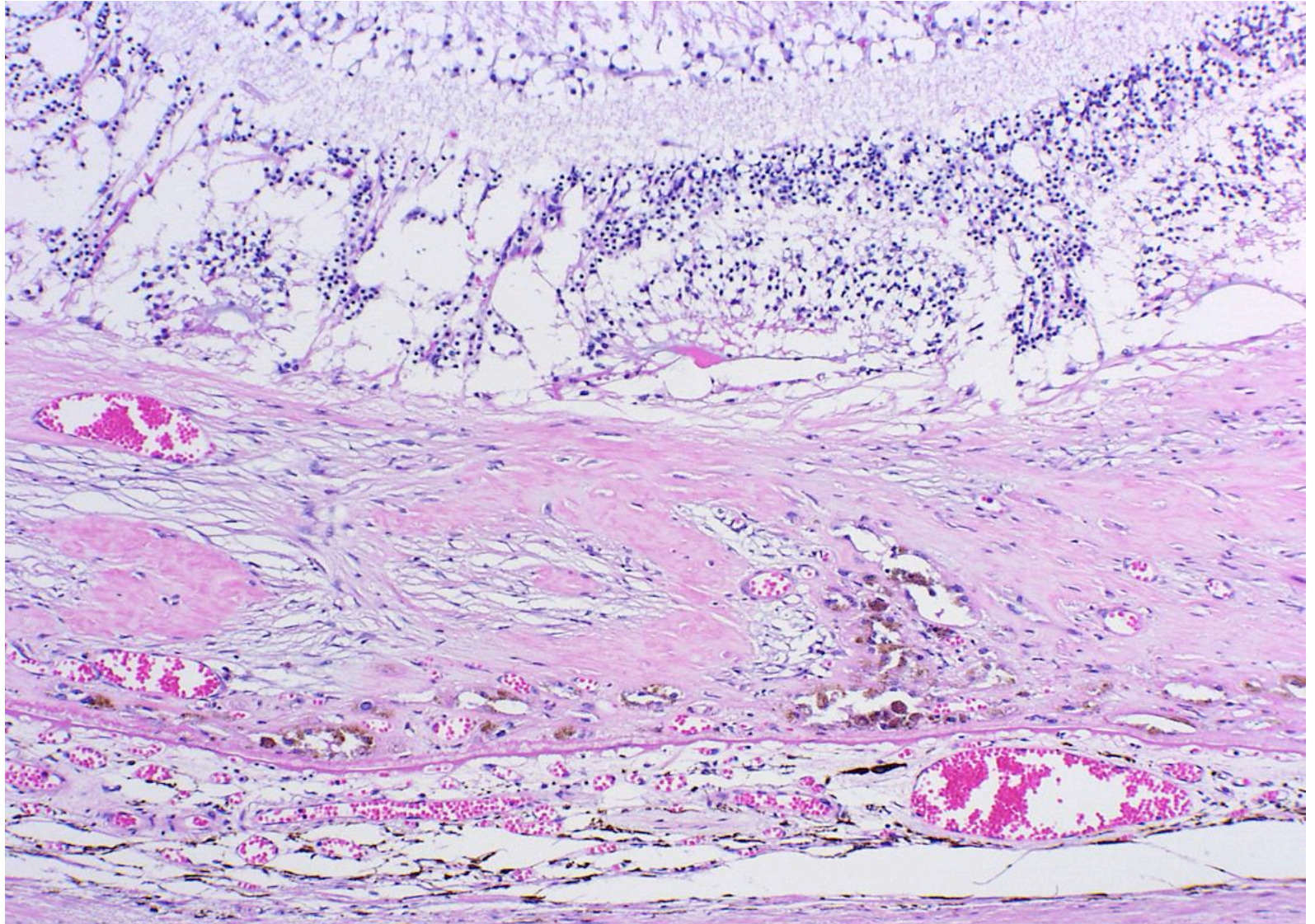


What do you notice?



# Exudative (“wet”) AMD

Note the scar tissue located on the retina side of Bruch’s membrane and the blood vessel proliferation.



# PRIMARY INTRAOCULAR MALIGNANT TUMORS

**Intraocular tumors are quite rare. There are two main types:**

- 1. uveal melanoma**
- 2. retinoblastoma.**

# Uvea

## ● Iris

- » **Regulates amount of light passing through lens**
  - Sphincter muscle around pupillary margin
  - Dilator muscle in peripheral iris

## ● Ciliary body

- » **Adjusts shape of lens to focus light**
- » **Produces aqueous humor to nourish cornea and regulate intraocular pressure**

## ● Choroid

- » **Provides nutrients and oxygen to outer retina**
- » **Melanin reduces glare within the eye**

**What is the Uvea?**

**The cell layer between the sclera and retina. It includes the iris, ciliary body, and choroid (and RPE).**

# Uveal Melanoma

## ● Melanoma

» Uncommon

Rare!

» Incidence increases with age (>20 per million per year by age 70)

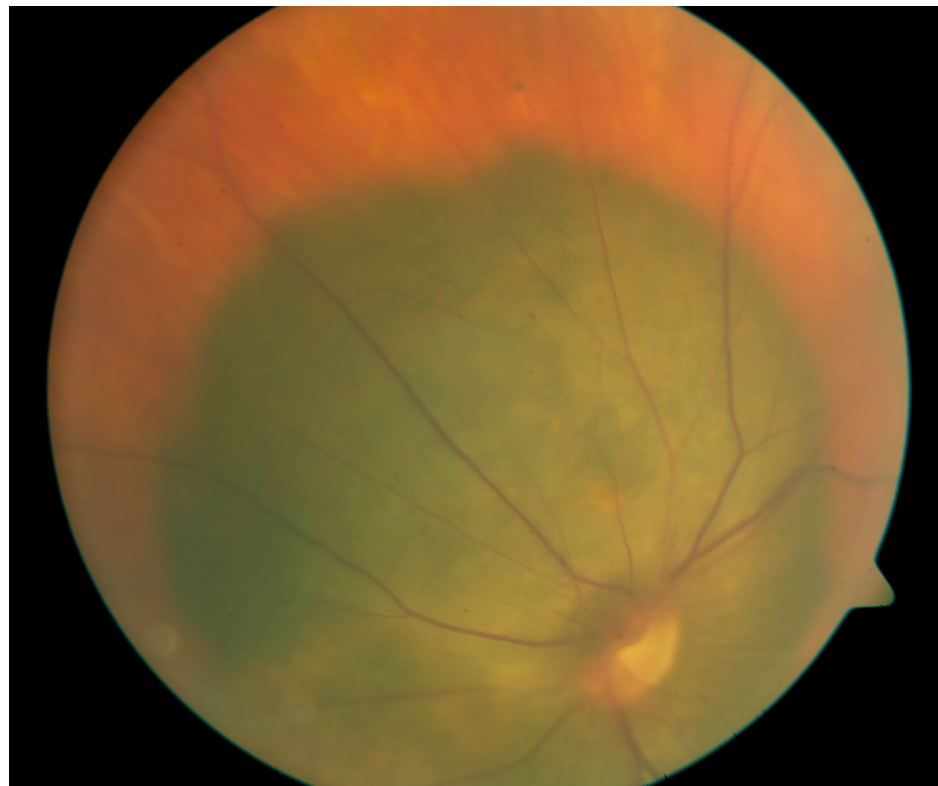
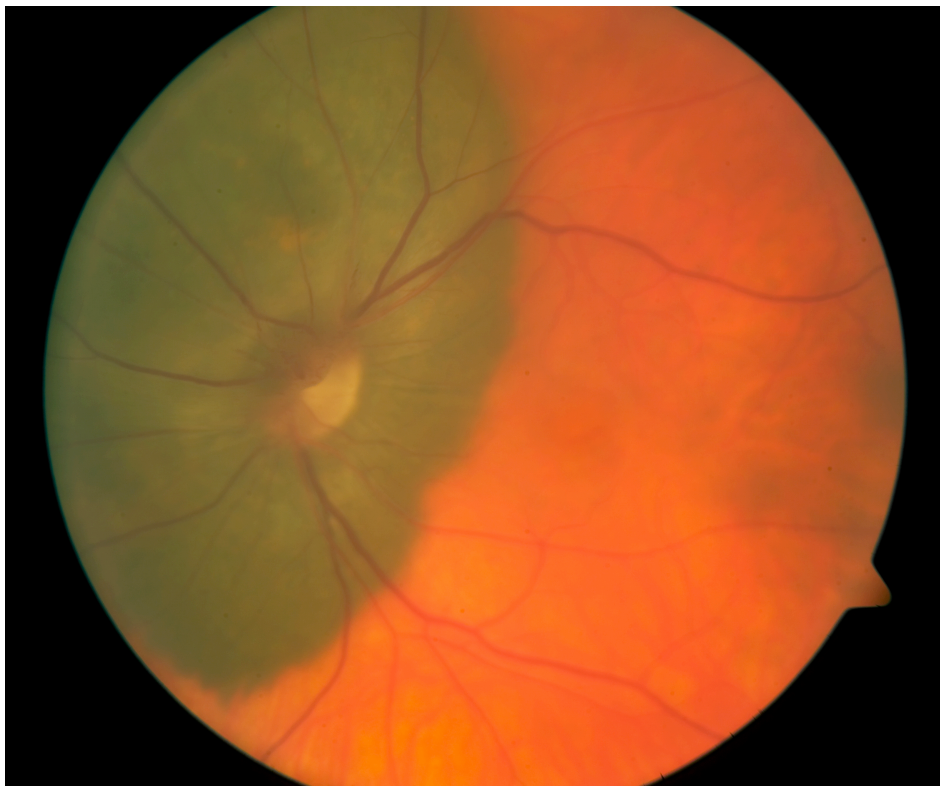
» Choroid > ciliary body > iris

» Major prognostic factors: location (iris tumors more indolent), tumor size, tumor cell morphology

» Hematogenous metastasis (liver usually first)

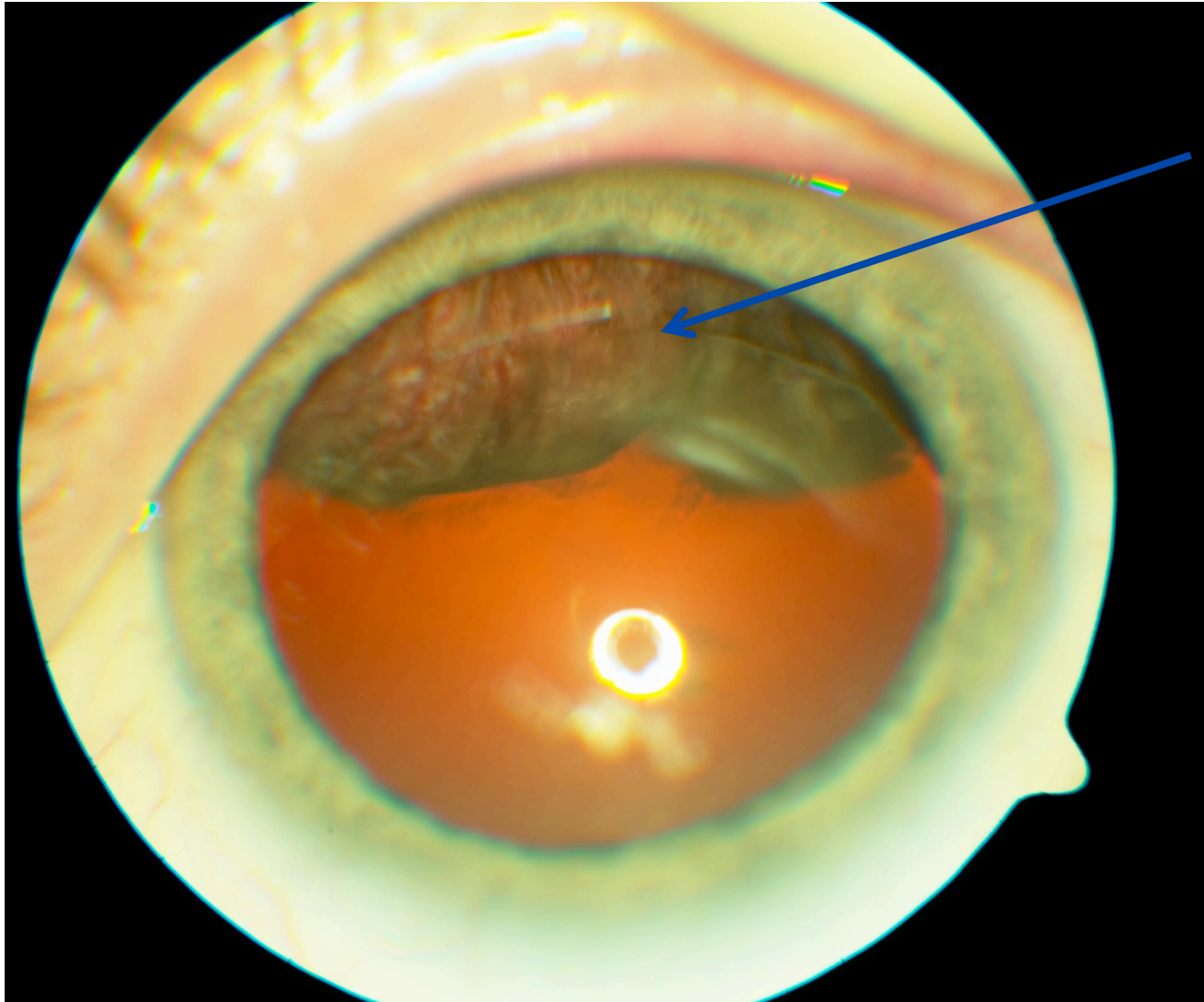
» May metastasize many years after treatment

# Choroidal Melanoma



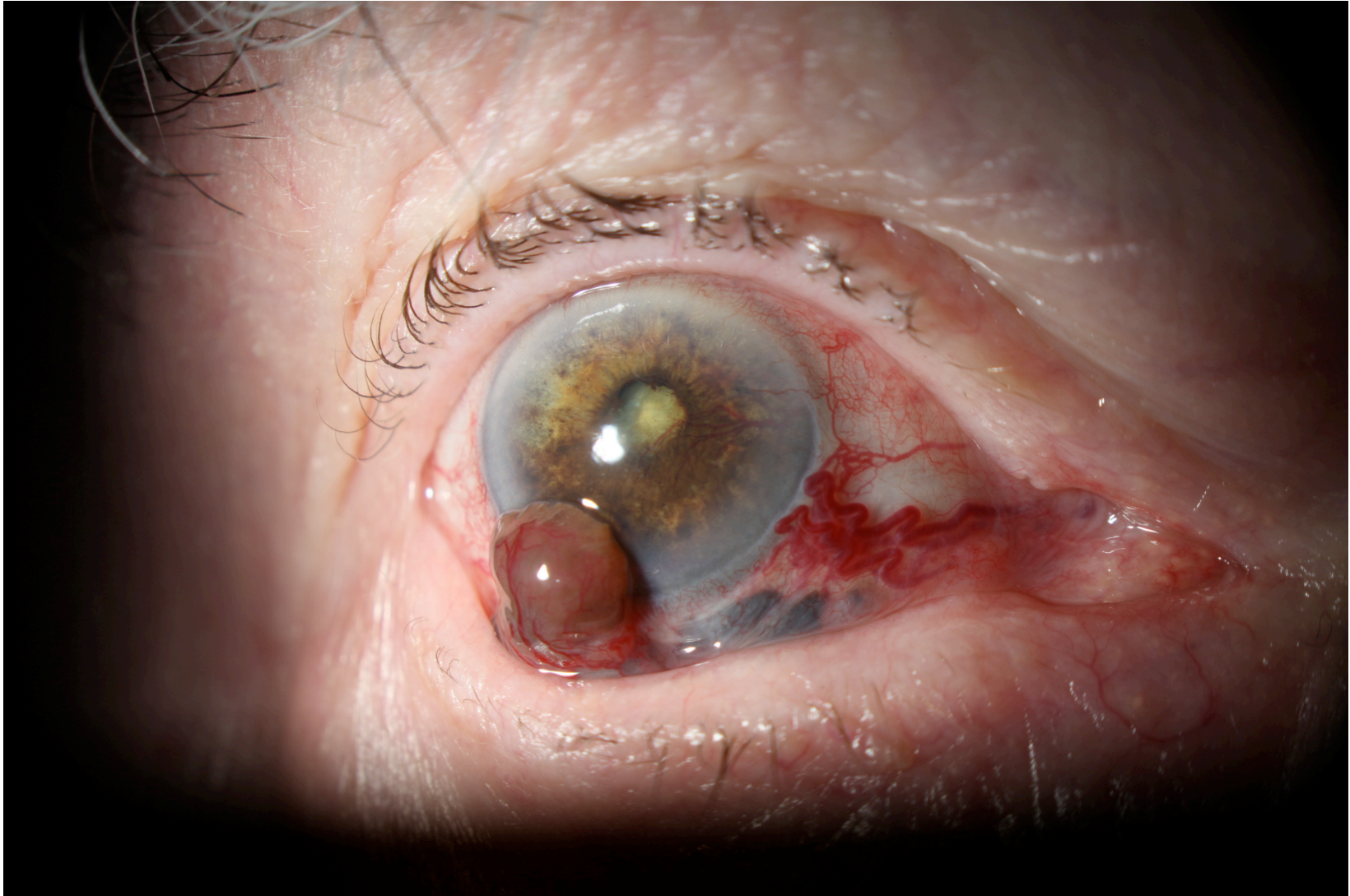
**Note the hyperpigmented, dome-shaped mass on fundus.**

# Ciliary Body-Choroidal Melanoma

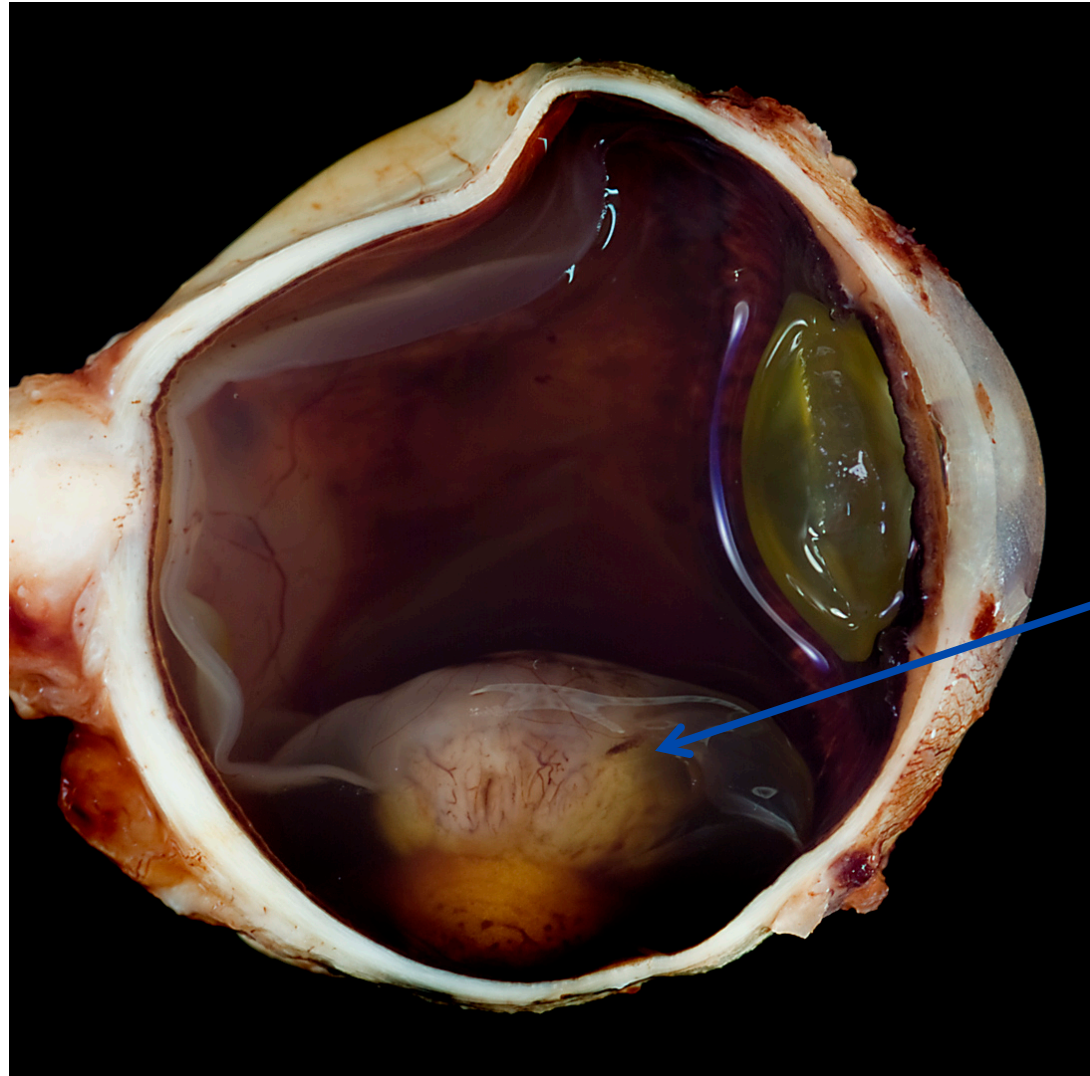


This is a dilated pupil with a uveal melanoma of the ciliary body.

# Uveal Melanoma – Extraocular Extension

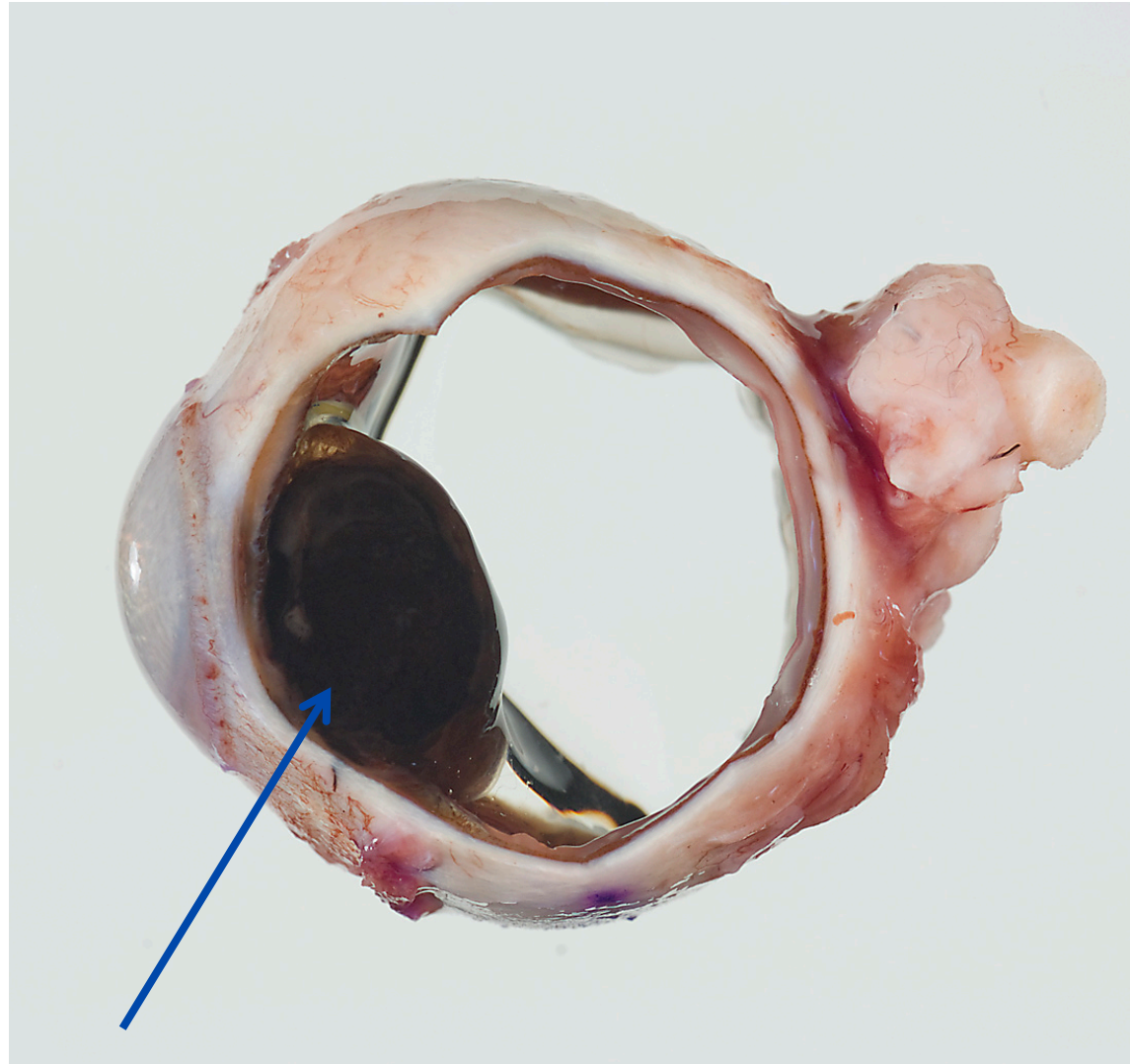


# Choroidal Melanoma

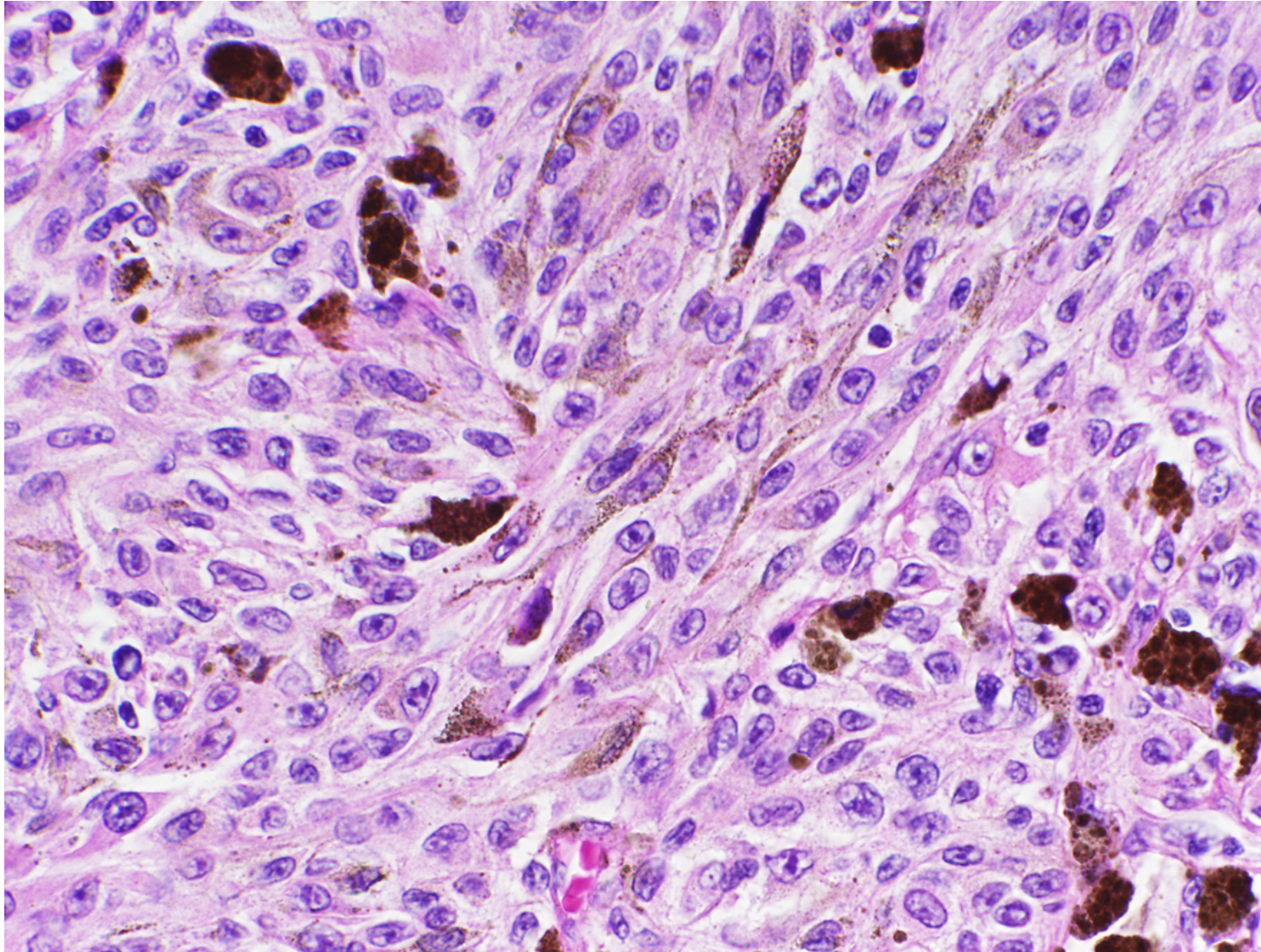




# Ciliary Body Melanoma



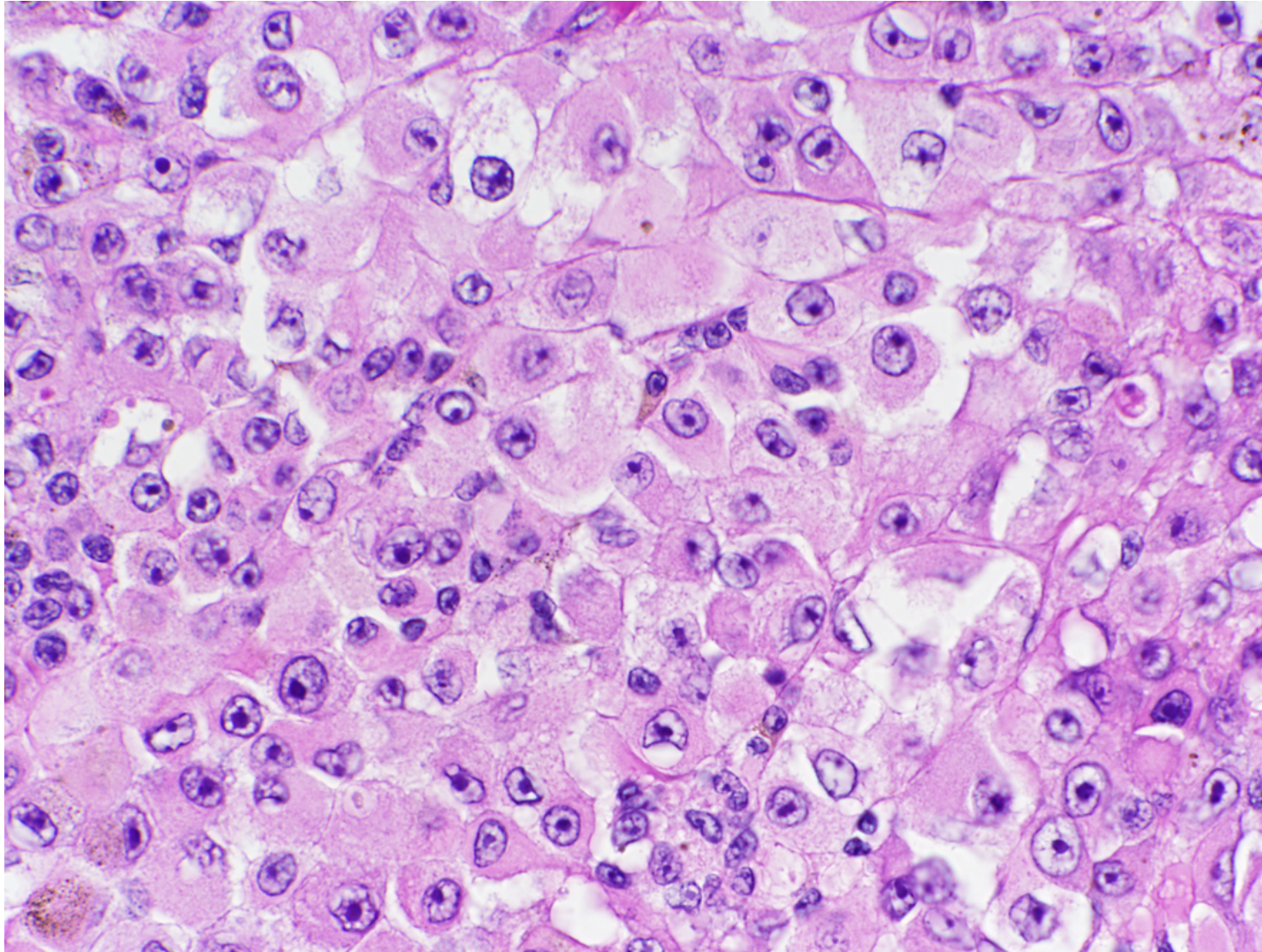
# Choroidal Melanoma



Most uveal melanoma is a mixture of spindle and epithelioid tumor cells.

Spindle tumor cells:  
Oblong cells,  
small nucleoli;  
lots of melanin

# Choroidal Melanoma



Epithelioid tumor cells:  
Larger nucleoli,  
epithelioid  
shape cells.  
Carries a worse  
prognosis.

# Retinoblastoma

- **Most common primary intraocular malignancy of children**
- **By far the most common retinal neoplasm**
- **Cell of origin is neuronal**
- **≈40% of cases in children with germ-line mutation of one *RB* allele**
  - » **First tumor suppressor gene discovered**
  - » **May be bilateral**
  - » **“Trilateral” retinoblastoma: tumors in both eyes along with a pinealoblastoma**

# Retinoblastoma

- **Pathology of hereditary and sporadic types of retinoblastoma is the same**
- **Tumor cells may be undifferentiated**
  - » Small, round cells with hyperchromatic nuclei
- **Well-differentiated tumors have photoreceptor differentiation**
  - » Flexner-Wintersteiner rosettes
  - » Fleurettes (rare in my experience)

These do not affect prognosis, but it gives pathologists something to do.

# Retinoblastoma

- **Prognostic factors**

- » **Adversely affected by:**

- **Extraocular extension**
- **Invasion along the optic nerve**
- **Possibly by choroidal invasion**

- » **Not affected by degree of tumor differentiation**

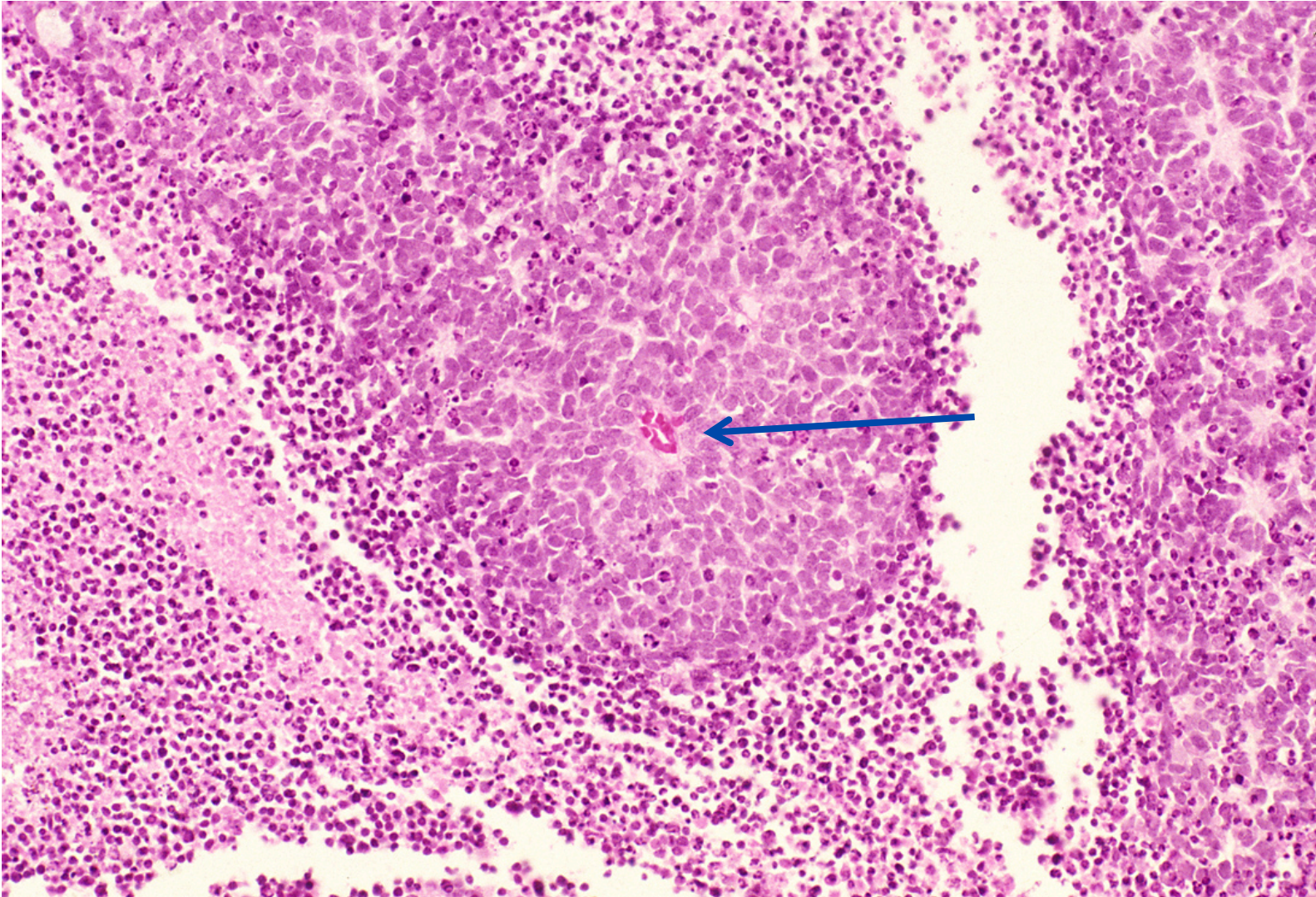
# Retinoblastoma



**Typical Rb:  
multi-lobular,  
very large at  
presentation  
with calcified,  
white specks.**

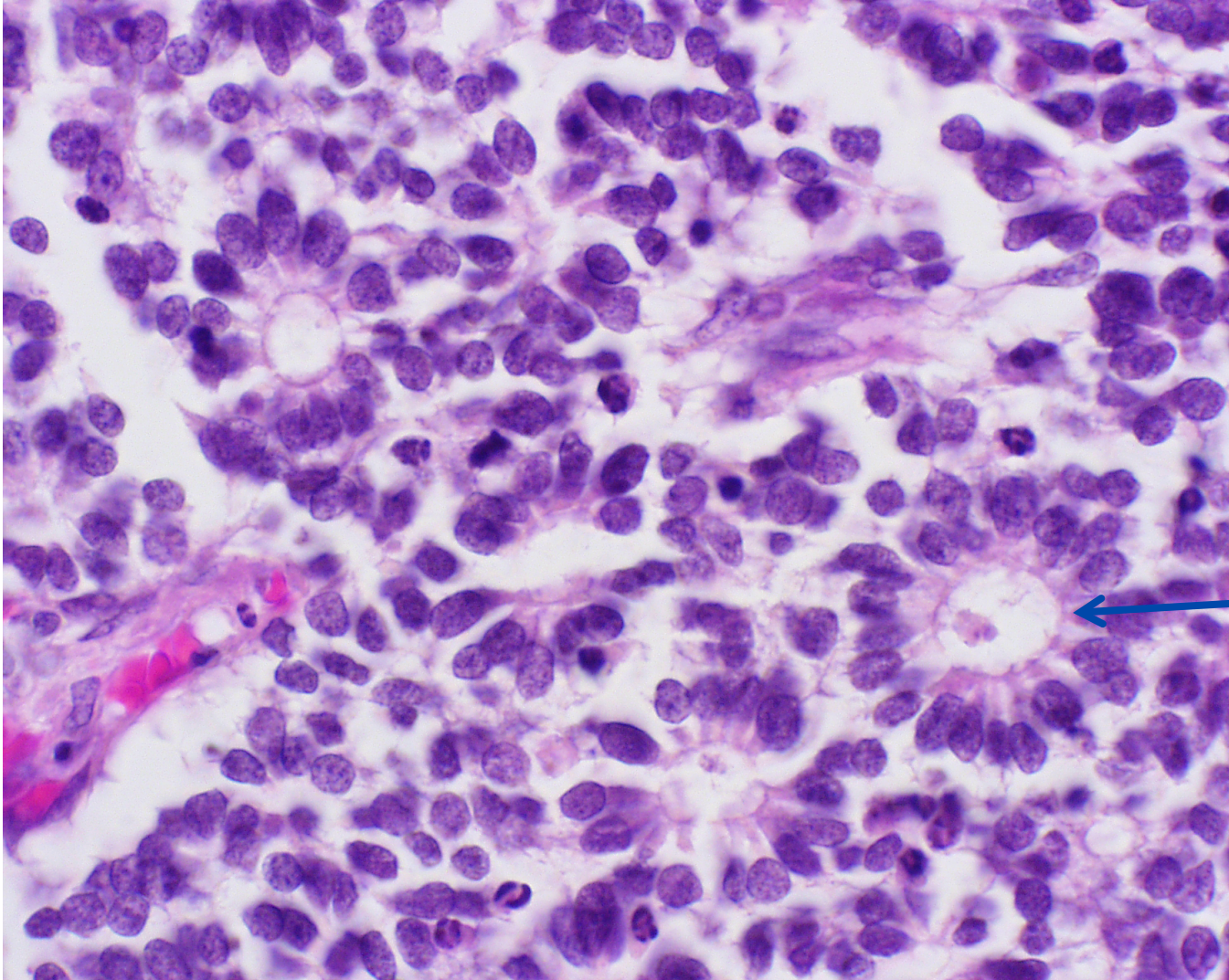
# Retinoblastoma

Necrosis is very prevalent in Rb. Note the survival of cancer cells around artery.

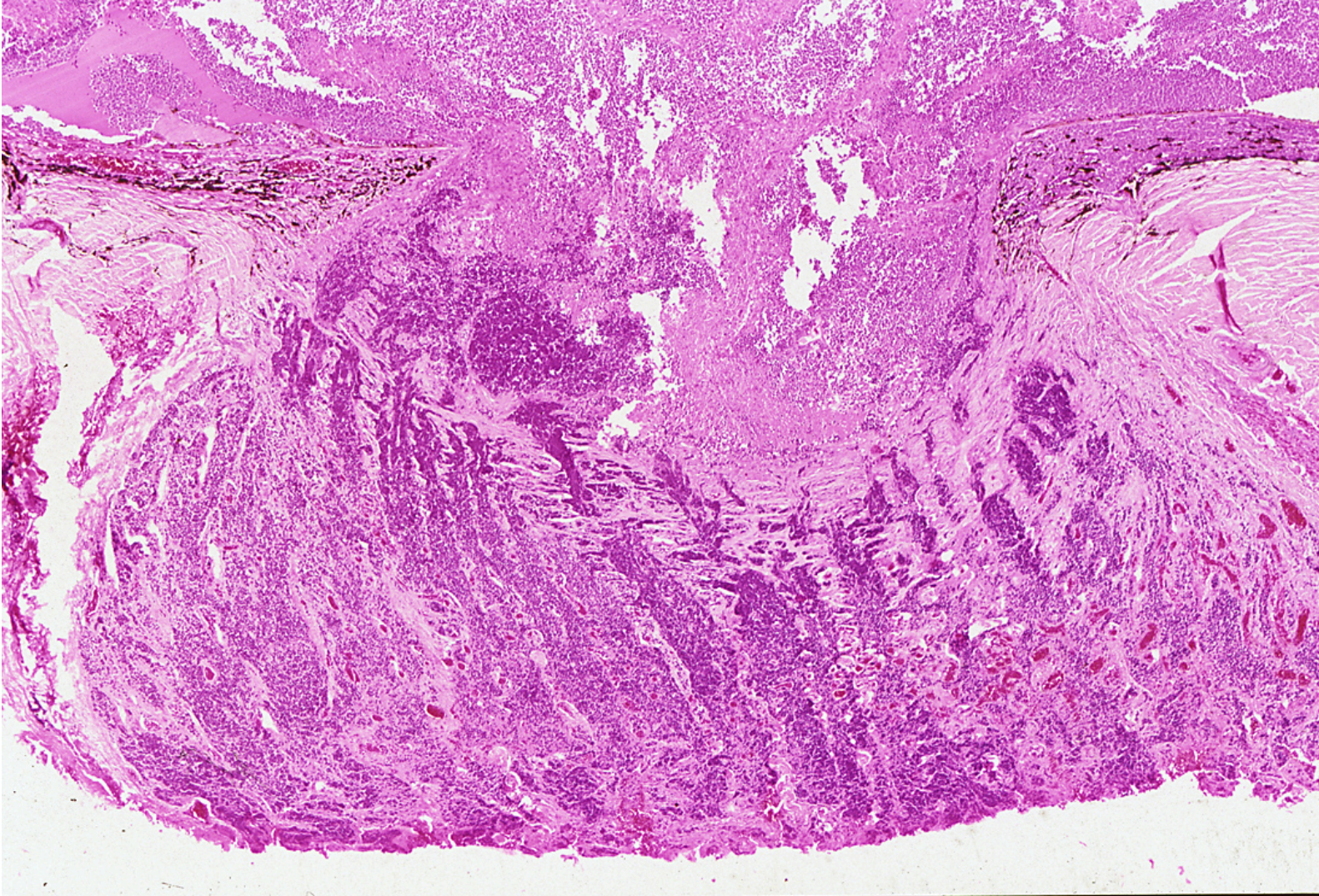




# Retinoblastoma



# Retinoblastoma



How far back does the tumor go into the optic nerve? This informs prognosis.

# **Write down the answers to these questions. Answers to follow.**

- 1. A patient presents with blindness. What is on the differential?**
- 2. What is the role of the RPE?**
- 3. A patient presents with cotton wool spots. What is the likely diagnosis?**
- 4. What canal drains aqueous humor?**
- 5. A patient presents with a pale and invaginated optic disc. What is the diagnosis?**

# Image Challenge

Just for fun – not tested.

Q: What is the diagnosis?

1. Anterior uveitis
2. Carotid cavernous sinus fistula
3. Graves' disease
4. Orbital lymphoma
5. Scleral rupture



# Image Challenge

**Q: What is the diagnosis?**

**Answer:**

**2. Carotid cavernous sinus fistula**

**Just for fun – not tested.**

The patient had inferior chemosis and conjunctival injection. Contrast-enhanced computed tomography of the orbit showed a dilated left superior ophthalmic vein, and angiography confirmed the presence of a carotid cavernous sinus fistula. The patient had complete resolution following embolization of the fistula.

*Read More: [N Engl J Med 2011;364:e15](#)*

# Answers to mini quiz

- 1. Cataracts, AMD, glaucoma, diabetic retinopathy**
- 2. Prevent light reflection, recycle spent photoreceptor discs, blood-retina barrier**
- 3. Diabetic retinopathy**
- 4. Schlemm's**
- 5. Glaucoma**