Define glaucoma.
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A group of optic neuropathies that present with progressive ONH damage and characteristic VF loss.
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Why isn’t elevated IOP mentioned above?
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Why isn’t elevated IOP mentioned above?
Elevated IOP is a strong risk factor for glaucoma, but it need not be present—IOP can be normal, or even low
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In addition to being the strongest risk factor for glaucoma, IOP has another quality that renders it unique—what is it?
Define glaucoma.
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Why isn’t elevated IOP mentioned above?
Elevated IOP is a strong risk factor for glaucoma, but it need not be present—IOP can be normal, or even low

In addition to being the strongest risk factor for glaucoma, IOP has another quality that renders it unique—what is it?
It is the only risk factor that is modifiable in a manner proven to influence the risk of glaucoma progression
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That’s why glaucoma management concerns nothing but IOP-lowering maneuvers!
Define glaucoma.
A group of optic neuropathies that present with progressive ONH damage and characteristic VF loss.

Why isn’t elevated IOP mentioned above?
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In addition to being the strongest risk factor for glaucoma, IOP has another quality that renders it unique—what is it?
It is the only risk factor that is modifiable in a manner proven to influence the risk of glaucoma progression.

Speaking of IOP…Let’s drill down on the factors that determine it.
Fill in the IOP equation below.

\[ IOP = \text{Aqueous Formation Rate (} \mu \text{L/min)} \, \text{Outflow Facility (} \mu \text{L/min/mmHg)} + \text{Episcleral Venous Pressure (EVP)} \]
Fill in the IOP equation below.

\[ IOP = \frac{\text{Aqueous Formation Rate (}\mu\text{L/min})}{\text{Outflow Facility (}\mu\text{L/min/mmHg})} + \text{Episceral Venous Pressure (mmHg)} \]
Fill in the IOP equation below. What is its eponymous name? The equation is:

\[ IOP = \frac{\text{Aqueous Formation Rate (}\mu\text{L/min})}{\text{Outflow Facility (}\mu\text{L/min/mmHg})} + \text{Episcleral Venous Pressure (mmHg)} \]
Fill in the IOP equation below. What is its eponymous name?

The **Goldmann equation**

\[ IOP = \frac{\text{Aqueous Formation Rate (\( \mu \)L/min)}}{\text{Outflow Facility (\( \mu \)L/min/mmHg)}} + \text{Episceral Venous Pressure (mmHg)} \]
Glaucoma Overview

Fill in the IOP equation below. What is its eponymous name? The **Goldmann equation**

\[
IOP = \frac{\text{Aqueous Formation Rate (\(\mu\text{L/min}\))}}{\text{Outflow Facility (\(\mu\text{L/min/mmHg}\))}} + \text{Episcleral Venous Pressure (\text{mmHg})}
\]

*Note how the \(\mu\text{L/min}\) cancel, leaving IOP in mmHg*
**Glaucoma Overview**

*Fill in the IOP equation below. What is its eponymous name?*

**The Goldmann equation**

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IOP = \frac{\text{Aqueous Formation Rate (} \mu\text{L/min)} }{\text{Outflow Facility (} \mu\text{L/min/mmHg)}} + \text{Episcleral Venous Pressure (mmHg)}
\]

*Note how the $\mu\text{L/min}$ cancel, leaving IOP in mmHg*

**Episcleral venous pressure** (EVP) normally measures about 8-12 mmHg (ie, the same as central venous pressure) in an upright pt. Looking at the Goldmann equation, you can see that, mathematically, it suggests EVP provides a baseline ‘floor’ value for IOP. In other words, even if aqueous formation ceased (which would take the first term in the Goldmann equation down to zero), IOP should not fall below EVP; that is, IOP would be equal to zero plus whatever EVP was at the moment. Further, the Goldmann equation predicts that IOP should vary on a 1-to-1 basis with EVP—that is, each mmHg change in EVP should result in a mmHg change in IOP. However, neither of these extrapolations hold up to empirical scrutiny. The point being, *the Goldmann equation is a simplified, idealized model of IOP determination that does not account for all the real-world factors that influence IOP.*
**Glaucoma Overview**

Fill in the IOP equation below. *What is its eponymous name?*

The **Goldmann equation**

\[
IOP = \frac{\text{Aqueous Formation Rate (}\mu\text{L/min})}{\text{Outflow Facility (}\mu\text{L/min/mmHg})} + \text{Episcleral Venous Pressure (mmHg)}
\]

So to lower IOP, one must:

- **and/or**
- **and/or**
- **and/or**

Three maneuvers implied by the Goldmann equation

- the numerator
- the denominator
- the other thing
Fill in the IOP equation below. **What is its eponymous name?**

The **Goldmann equation**

\[ IOP = \frac{\text{Aqueous Formation Rate (} \mu\text{L/min})}{\text{Outflow Facility (} \mu\text{L/min/mmHg})} + \text{Episcleral Venous Pressure (mmHg)} \]

So to lower IOP, one must:

- decrease aqueous formation, *and/or*
- increase outflow facility, *and/or*
- decrease episcleral venous pressure

*Three maneuvers implied by the Goldmann equation*
Fill in the IOP equation below. What is its eponymous name? **The Goldmann equation**

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- decrease episcleral venous pressure

Three maneuvers implied by the Goldmann equation

Important maneuver not implied by the Goldmann equation: ...and/or ... with a...
Fill in the IOP equation below. What is its eponymous name?

The **Goldmann equation**

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Three maneuvers implied by the Goldmann equation

Important maneuver not implied by the Goldmann equation...

...and/or dehydrate the vitreous with a hyperosmotic agent
Fill in the IOP equation below. What is its eponymous name?
The Goldmann equation

\[ IOP = \frac{\text{Aqueous Formation Rate} (\mu\text{L/min})}{\text{Outflow Facility} (\mu\text{L/min/mmHg})} + \text{Episceral Venous Pressure} (\text{mmHg}) \]

Which classes of meds decrease aqueous formation?
--
--
--

So to lower IOP, one must:
--decrease aqueous formation, and/or
--increase outflow facility, and/or
--decrease episcleral venous pressure

…and/or dehydrate the vitreous with a hyperosmotic agent
Which classes of meds decrease aqueous formation?
- β blockers
- CAIs
- α agonists

So to lower IOP, one must:
- decrease aqueous formation, and/or
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…and/or dehydrate the vitreous with a hyperosmotic agent
Fill in the IOP equation below. What is its eponymous name? The Goldmann equation

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So to lower IOP, one must:
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--increase outflow facility, and/or
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…and/or dehydrate the vitreous with a hyperosmotic agent

What are the two types of outflow?
--
--
Fill in the IOP equation below. *What is its eponymous name?*  
**The Goldmann equation**

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IOP = \frac{\text{Aqueous Formation Rate (\(\mu L/min\))}}{\text{Outflow Facility (\(\mu L/min/mmHg\))}} + \text{Episceral Venous Pressure (mmHg)}
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- Which classes of meds decrease aqueous formation?  
  - \(\beta\) blockers  
  - CAIs  
  - \(\alpha\) agonists  

- So to lower IOP, one must:  
  - decrease aqueous formation, *and/or*  
  - increase outflow facility, *and/or*  
  - decrease episcleral venous pressure  
  - …*and/or* dehydrate the vitreous with a hyperosmotic agent  

- What are the two types of outflow?  
  - Trabecular meshwork  
  - Uveoscleral
So to lower IOP, one must:

--decrease aqueous formation,

and/or

--increase outflow facility,

and/or

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IOP = \frac{\text{Aqueous Formation Rate (\mu L/min)}}{\text{Outflow Facility (\mu L/min/mmHg)}} + \text{Episceral Venous Pressure (mmHg)}

Obviously, aqueous-humor dynamics play a central role in glaucoma. Let’s delve into its production…

So to lower IOP, one must:

--decrease aqueous formation, and/or

--increase outflow facility, and/or

--decrease episcleral venous pressure

Which classes of medications decrease aqueous formation?

--\beta\text{ blockers}

--CAIs

--\alpha\text{ agonists}

What are the two types of outflow?

--Trabecular meshwork

--Uveoscleral
Fill in the IOP equation below. *What is its eponymous name?*  

**The Goldmann equation**

\[ \text{IOP} = \text{Aqueous Formation Rate (µL/min)} + \text{Outflow Facility (µL/min/mmHg)} + \text{Episceral Venous Pressure (mmHg)} \]

What is the rate of aqueous formation?
Fill in the IOP equation below. What is its eponymous name?
The Goldmann equation

\[ IOP = \text{Aqueous Formation Rate (μL/min)} + \text{Outflow Facility (μL/min/mmHg)} + \text{Episceral Venous Pressure (mmHg)} \]

What is the rate of aqueous formation?
2-3 μL/min
Fill in the IOP equation below. **What is its eponymous name?**

The **Goldmann equation**

\[
IOP = \frac{Aqueous \, Formation \, Rate \, (\mu L/min)}{Outflow \, Facility \, (\mu L/min/mmHg)} + \text{Episceral Venous Pressure (mmHg)}
\]

*What is the rate of aqueous formation?*

2-3 \( \mu L/min \)

*What is the aqueous volume of the anterior chamber?*
Fill in the IOP equation below. What is its eponymous name? The **Goldmann equation**

\[ IOP = \text{Aqueous Formation Rate (μL/min)} + \text{Outflow Facility (μL/min/mmHg)} + \text{Episceral Venous Pressure (mmHg)} \]

**What is the rate of aqueous formation?**
2-3 μL/min

**What is the aqueous volume of the anterior chamber?**
270 μL, give or take
Fill in the IOP equation below. **What is its eponymous name?**

**The Goldmann equation**

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IOP = \text{Aqueous Formation Rate (} \mu L/\text{min}) + \text{Outflow Facility (}\mu L/\text{min/mmHg}) + \text{Episceral Venous Pressure (mmHg)}
\]

**What is the rate of aqueous formation?**
2-3 \( \mu L/\text{min} \)

**What is the aqueous volume of the anterior chamber?**
270 \( \mu L \), give or take

**So then, what percent of AC volume is ‘turned over’ every minute?**
Fill in the IOP equation below. **What is its eponymous name?**

**The Goldmann equation**

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\text{IOP} = \text{Aqueous Formation Rate (µL/min)} + \text{Outflow Facility (µL/min/mmHg)} + \text{Episcleral Venous Pressure (mmHg)}
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**What is the rate of aqueous formation?**
2-3 µL/min

**What is the aqueous volume of the anterior chamber?**
270 µL, give or take

**So then, what percent of AC volume is ‘turned over’ every minute?**
About 1%
Fill in the IOP equation below. *What is its eponymous name?* The **Goldmann equation**

\[ \text{IOP} = \text{Aqueous Formation Rate (µL/min)} + \text{Outflow Facility (µL/min/mmHg)} + \text{Episcleral Venous Pressure (mmHg)} \]

*What is the rate of aqueous formation?*
2-3 µL/min

*What is the aqueous volume of the anterior chamber?*
270 µL, give or take

*So then, what percent of AC volume is ‘turned over’ every minute?*
About 1%

*Given this, how long does it take for the aqueous content of the AC to be fully replaced?*
Fill in the IOP equation below. **What is its eponymous name?**

The **Goldmann equation**

\[
IOP = \text{Aqueous Formation Rate (}\mu\text{L/min}) \quad + \quad \text{Outflow Facility (}\mu\text{L/min/mmHg}) \quad + \quad \text{Episceral Venous Pressure (mmHg)}
\]

**What is the rate of aqueous formation?**
2-3 \(\mu\text{L/min}\)

**What is the aqueous volume of the anterior chamber?**
270 \(\mu\text{L, give or take}\)

**So then, what percent of AC volume is ‘turned over’ every minute?**
About 1%

**Given this, how long does it take for the aqueous content of the AC to be fully replaced?**
Roughly 100 minutes
So to lower IOP, one must:
--decrease aqueous formation,
and/or
--increase outflow facility,
and/or
--decrease episcleral venous pressure
...and/or dehydrate the vitreous with a hyperosmotic agent.

IOP = Aqueous Formation Rate (µL/min) + Outflow Facility (µL/min/mmHg) + Episceral Venous Pressure (mmHg)

Speaking of aqueous formation...What specific tissue makes aqueous?
The nonpigmented epithelium of the pars plicata portion of the ciliary body.

What are the two types of outflow?
--Trabecular meshwork
--Uveoscleral

...and/or dehydrate the vitreous with a hyperosmotic agent.
So to lower IOP, one must:

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The eponymous name of the IOP equation is the

**Goldmann equation**

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IOP = \text{Aqueous Formation Rate (μL/min)} + \text{Outflow Facility (μL/min/mmHg)} + \text{Episceral Venous Pressure (mmHg)}
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What specific tissue makes aqueous?

*The nonpigmented epithelium of the pars plicata portion of the ciliary body*

What are the two types of outflow?

-- **Trabecular meshwork**

-- **Uveoscleral**

Speaking of aqueous formation...
So to lower IOP, one must:

-- decrease aqueous formation,
-- increase outflow facility, and/or
-- decrease episcleral venous pressure
...and/or
dehydrate the vitreous with a hyperosmotic agent

\[
\text{IOP} = \text{Aqueous Formation Rate (}\mu\text{L/min}) + \text{Outflow Facility (}\mu\text{L/min/mmHg}) + \text{Episceral Venous Pressure (mmHg)}
\]

**Fill in the IOP equation below. What is its eponymous name?**

The Goldmann equation

---

Speaking of aqueous formation... **What specific tissue makes aqueous?**

The nonpigmented epithelium of the pars plicata portion of the ciliary body

**What is implied by the fact that aqueous is made by the 'nonpigmented' epithelium?**

-- increase outflow facility, and/or
-- decrease episcleral venous pressure

---

**What are the two types of outflow?**

-- Trabecular meshwork
-- Uveoscleral
So to lower IOP, one must:

--decrease aqueous formation,

and/or

--increase outflow facility,

and/or

--decrease episcleral venous pressure

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\[
\text{IOP} = \frac{A\text{queous Formation Rate (µL/min)}}{\text{Outflow Facility (µL/min/mmHg)}} + \text{Episcleral Venous Pressure (mmHg)}
\]

The eponymous name of this equation is the Goldmann equation.

Speaking of aqueous formation... what specific tissue makes aqueous?
The nonpigmented epithelium of the pars plicata portion of the ciliary body.

What is implied by the fact that aqueous is made by the ‘nonpigmented’ epithelium?
The presence of a pigmented epithelium.

What are the two types of outflow?
--Trabecular meshwork
--Uveoscleral

Fill in the IOP equation below. What is its eponymous name?
The Goldmann equation
Glaucoma Overview

Ciliary body: One perspective, two questions
Glaucoma Overview

Ciliary body: One perspective, two questions

This part is the... Pars plicata

This part is the... Pars plana
Ciliary body: Another perspective
Glaucoma Overview

Ciliary body: Another
Glaucoma Overview

Ciliary body: Another
Now let’s look at the CB epithelium. **Low power** photomicrograph.
Now let’s look at the CB epithelium. **Higher.**
Speaking of aqueous formation... What specific tissue makes aqueous? The nonpigmented epithelium of the pars plicata portion of the ciliary body.

What is implied by the fact that aqueous is made by the 'nonpigmented' epithelium? The presence of a pigmented epithelium.

Now let’s look at the CB epithelium. High.
Speaking of aqueous formation…What specific tissue makes aqueous?
The nonpigmented epithelium of the pars plicata portion of the ciliary body

What is implied by the fact that aqueous is made by the ‘nonpigmented’ epithelium?
The presence of a pigmented epithelium

From what embryonic tissue do the two epithelia of the CB derive?
From what embryonic tissue do the two epithelia of the CB derive?

**Neuroectoderm**

Speaking of aqueous formation... What specific tissue makes aqueous?
The nonpigmented epithelium of the pars plicata portion of the ciliary body

What is implied by the fact that aqueous is made by the 'nonpigmented' epithelium? The presence of a **pigmented** epithelium.
From what embryonic tissue do the two epithelia of the CB derive?

**Neuroectoderm**

What other portion of the eye derives from neuroectoderm?

Speaking of aqueous formation... What specific tissue makes aqueous?

The nonpigmented epithelium of the pars plicata portion of the ciliary body

What is implied by the fact that aqueous is made by the 'nonpigmented' epithelium?

The presence of a pigmented epithelium
Glaucoma Overview

From what embryonic tissue do the two epithelia of the CB derive?
Neuroectoderm

What other portion of the eye derives from neuroectoderm?
The retina (ie, the neurosensory retina + RPE)

Speaking of aqueous formation... What specific tissue makes aqueous?
The nonpigmented epithelium of the pars plicata portion of the ciliary body

What is implied by the fact that aqueous is made by the 'nonpigmented' epithelium?
The presence of a pigmented epithelium
Glaucoma Overview

From what embryonic tissue do the two epithelia of the CB derive?
Neuroectoderm

What other portion of the eye derives from neuroectoderm?
The retina (ie, the neurosensory retina + RPE)

How are the neurosensory retinal and RPE cells oriented with respect to one another?

Speaking of aqueous formation... What specific tissue makes aqueous?
The nonpigmented epithelium of the pars plicata portion of the ciliary body

What is implied by the fact that aqueous is made by the 'nonpigmented' epithelium?
The presence of a pigmented epithelium
Glaucoma Overview

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What other portion of the eye derives from neuroectoderm?
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How are the neurosensory retinal and RPE cells oriented with respect to one another?

Apex-to-apex

Speaking of aqueous formation… What specific tissue makes aqueous?
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What is implied by the fact that aqueous is made by the ‘nonpigmented’ epithelium?
The presence of a pigmented epithelium
From what embryonic tissue do the two epithelia of the CB derive?
Neuroectoderm

What other portion of the eye derives from neuroectoderm?
The retina (ie, the neurosensory retina + RPE)

How are the neurosensory retinal and RPE cells oriented with respect to one another?
Apex-to-apex

How are the two epithelial layers of the CB oriented with respect to one another?
**Glaucoma Overview**

**From what embryonic tissue do the two epithelia of the CB derive?**
- **Neuroectoderm**

**What other portion of the eye derives from neuroectoderm?**
- The retina (ie, the neurosensory retina + RPE)

**How are the neurosensory retinal and RPE cells oriented with respect to one another?**
- **Apex-to-apex**

**How are the two epithelial layers of the CB oriented with respect to one another?**
- **The same way--apex-to-apex**

---

**Speaking of aqueous formation…What specific tissue makes aqueous?**
- The nonpigmented epithelium of the pars plicata portion of the ciliary body

**What is implied by the fact that aqueous is made by the ‘nonpigmented’ epithelium?**
- The presence of a pigmented epithelium
Glaucoma Overview

From what embryonic tissue do the two epithelia of the CB derive?

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What other portion of the eye derives from neuroectoderm?

**The retina (ie, the neurosensory retina + RPE)**

How are the neurosensory retinal and RPE cells oriented with respect to one another?

**Apex-to-apex**

How are the two epithelial layers of the CB oriented with respect to one another?

**The same way--apex-to-apex**

Which CB epithelial layer is pigmented--the inner, or the outer?

**The presence of a pigmented epithelium**

Speaking of aqueous formation...What specific tissue makes aqueous?

The nonpigmented epithelium of the pars plicata portion of the ciliary body

What is implied by the fact that aqueous is made by the 'nonpigmented' epithelium?

The presence of a pigmented epithelium
A

From what embryonic tissue do the two epithelia of the CB derive?
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How are the neurosensory retinal and RPE cells oriented with respect to one another?
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How are the two epithelial layers of the CB oriented with respect to one another?
The same way--apex-to-apex

Which CB epithelial layer is pigmented--the inner, or the outer?
The outer

Speaking of aqueous formation... What specific tissue makes aqueous?
The nonpigmented epithelium of the pars plicata portion of the ciliary body

What is implied by the fact that aqueous is made by the 'nonpigmented' epithelium?
The presence of a pigmented epithelium
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How are the two epithelial layers of the CB oriented with respect to one another?

The same way--apex-to-apex

Which CB epithelial layer is pigmented--the inner, or the outer?

The outer

Which portion of the retina is contiguous with the pigmented layer of the CB epithelium?
Glaucoma Overview

From what embryonic tissue do the two epithelia of the CB derive?
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What other portion of the eye derives from neuroectoderm?
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How are the two epithelial layers of the CB oriented with respect to one another?
The same way--apex-to-apex

Which CB epithelial layer is pigmented--the inner, or the outer?
The outer

Which portion of the retina is contiguous with the pigmented layer of the CB epithelium?
The RPE, ie, the outer

Speaking of aqueous formation... What specific tissue makes aqueous?
The nonpigmented epithelium of the pars plicata portion of the ciliary body

What is implied by the fact that aqueous is made by the 'nonpigmented' epithelium?
The presence of a pigmented epithelium
Embryology of the optic vesicle as it invaginates. What you want to take note of is:

---

...not this one!
Embryology of the optic vesicle as it invaginates. What you want to take note of is:

--The pigmented layer of the CB epi derives from the same structure as the RPE (which is, as its name indicates, also pigmented), and

--
Embryology of the optic vesicle as it invaginates. What you want to take note of is:
--The pigmented layer of the CB epi derives from the same structure as the RPE (which is, as its name indicates, also pigmented), and
--the nonpigmented CB epi derives from the same structure that gives rise to the neurosensory retina.

Note: This vesicle...
Embryology of the optic vesicle as it invaginates. What you want to take note of is:
--The pigmented layer of the CB epi derives from the same structure as the RPE (which is, as its name indicates, also pigmented), and
--the nonpigmented CB epi derives from the same structure that gives rise to the neurosensory retina.
In other words, what you already know about eye anatomy can help you understand and remember eye embryology. (For more, see the Embryology made simply ridiculous slide-set.)
Which intraocular structure makes aqueous?
The nonpigmented epithelium of the pars plicata portion of the ciliary body

What is implied by the fact that aqueous is made by the ‘nonpigmented’ epithelium?
The presence of a pigmented epithelium

From what embryonic tissue do the two epithelia of the CB derive?
Neuroectoderm

Hol up Dr Flynn. Looking at this photomicrograph, the pigmented epi layer appears to be the inner one. Did you make a mistake?
Silly rabbit—mistakes are for residents! Remember, for us eye dentists the terms inner and outer are in relation to the globe itself; ie, inner means ‘closer to, or of, the inner aspect of the globe.’ Because the nonpigmented layer faces the vitreous cavity, it is the ‘inner’ layer of the two.

Which CB epithelial layer is pigmented--the inner, or the outer?
The outer?

Which portion of the retina is contiguous with the pigmented layer of the CB epithelium?
The RPE, ie, the outer
**Glaucoma Overview**

*Which intraocular structure makes aqueous?*
The nonpigmented epithelium of the pars plicata portion of the ciliary body

*What is implied by the fact that aqueous is made by the ‘nonpigmented’ epithelium?*
The presence of a pigmented epithelium

*From what embryonic tissue do the two epithelia of the CB derive?*
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*The same way—apex-to-apex*

*Which CB epithelial layer is pigmented—*the inner, or the outer?*
*That’s what I said—*the outer!

*Which portion of the retina is contiguous with the pigmented layer of the CB epithelium?*
The RPE, ie the outer
Fill in the IOP equation below. What is its eponymous name? The **Goldmann equation**

\[
\text{IOP} = \frac{\text{Aqueous Formation Rate (\(\mu\text{L/min}\)} \right)}{\text{Outflow Facility (\(\mu\text{L/min/mmHg}\)} \right)} + \text{Episceral Venous Pressure (mmHg)}
\]

Now let’s look at IOP measurement via **Goldmann applanation tonometry**

So to lower IOP, one must:

--- decrease aqueous formation, *and/or*
--- increase outflow facility, *and/or*
--- decrease episcleral venous pressure

…*and/or dehydrate the vitreous* with a **hyperosmotic** agent

What are the two types of outflow?
--- **Trabecular meshwork**
--- **Uveoscleral**

Which classes of meds decrease aqueous formation?
--- *β* blockers
--- CAIs
--- *α* agonists
Based on the two-name eponym principle: $P = \frac{F}{A}$

(P is for Pressure)
Based on the *Imbert-Fick principle*: $P = \frac{F}{A}$
Based on the *Imbert-Fick principle*: $P = \frac{F}{A}$

Pressure inside a sphere equals force needed to flatten its surface divided by the area of flattening.

$F$ stands for what the... $A$ stands for what the...
Based on the *Imbert-Fick principle*: \( P = \frac{F}{A} \)

Pressure inside a sphere equals the force needed to flatten its surface divided by the area of flattening.
Based on the **Imbert-Fick principle**: \( P = \frac{F}{A} \)

- Pressure inside a sphere equals **force needed to flatten its surface** divided by the **area of flattening**.
- Assumes surface is **two words**, and **neither**, obviously.
Based on the **Imbert-Fick principle**: $P = \frac{F}{A}$

- Pressure inside a sphere equals *force needed to flatten its surface* divided by the *area of flattening*.
- Assumes surface is *infinitely thin*, and *dry* (cornea is neither, obviously).
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- Pressure inside a sphere equals force needed to flatten its surface divided by the area of flattening.
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- K thickness \( \rightarrow \) resists applanation \( \rightarrow \) increase vs decrease IOP reading.
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For the Imbert-Fick principle to hold, the only force resisting applanation should be the pressure within the sphere. However, real objects such as the cornea have *intrinsic* resistance to deformation owing to their physical nature, ie, because they’re made of ‘stuff.’
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For the Imbert-Fick principle to hold, the **only** force resisting applanation should be the pressure within the sphere. However, real objects such as the cornea have *intrinsic* resistance to deformation owing to their physical nature, *ie*, because they’re made of ‘stuff.’ This inherent structural resistance of the cornea will be additive to whatever pressure is inside the eye, thereby causing the pressure reading to be falsely **high**. (And the thicker the cornea is, the higher the reading will be.)
Based on the *Imbert-Fick principle*: $P = \frac{F}{A}$

- Pressure inside a sphere equals force needed to flatten its surface divided by the area of flattening.
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  - Tear film $\rightarrow$ capillary attraction $\rightarrow$ *decrease* IOP reading.
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*On the other hand:* The first ocular structure encountered by the applanator tip is the tear film. When contact with the tear film is made, a fluid bridge forms between the cornea and the tip. Surface tension of the water in this fluid bridge produces *capillary attraction*, which exerts a slight ‘pull’ on the applanator tip, drawing it toward the cornea.
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*To be useful, an applanator-type device has to account for these factors. Fortunately, the brilliant Dr. Goldmann was (mostly) up to the challenge…*
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- Pressure inside a sphere equals force needed to flatten its surface divided by the area of flattening.
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- $K$ thickness → resists applanation → *increases* IOP reading.
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- Dr. Goldmann realized if the diameter of the circle applanated by the device is #.# mm, capillary attraction and corneal thickness would cancel each other out (assuming CCT is # \(\mu\)m).

*(CCT = Central corneal thickness)*
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Dr Goldmann realized if the diameter of the circle applanated by the device is 3.06 mm, capillary attraction and corneal thickness would cancel each other out (assuming CCT is 520 \(\mu\)m).

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  - Goldmann believed CCT was ~520, with little variation

(We now know that CCT averages about 550, with wide variation among individuals)
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  - When the mires line up, the diameter of the applanated area is 3.06 mm
Define glaucoma. A group of optic neuropathies that present with progressive ONH damage and characteristic VF loss.

Why isn’t elevated IOP mentioned above? Elevated IOP is a strong risk factor for glaucoma, but it need not be present—IOP can be normal, or even low.

In addition to being the strongest risk factor for glaucoma, IOP has another quality that renders it unique—what is it? It is the only risk factor that is **modifiable** in a manner proven to influence the risk of glaucoma progression.

*We mentioned previously that glaucoma presents with “progressive ONH damage.” Let’s drill down on the structure of the ONH.*
The optic nerves are composed of what?
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The axons of retinal ganglion cells
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How many fibers (axons) comprise an optic nerve?
The optic nerves are composed of what?
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How many fibers (axons) comprise an optic nerve?
Depends upon which book you ask, but the answer 1.2M works

Per the...
- Glaucoma book: 1.2-1.5M
- Neuro book: 1-1.2M
- Fundamentals book: “more than a million”
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Do they synapse in the region of the optic nerve head?
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There’s that word again—’most.’ Where will the others synapse, and what are they responsible for?
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Glaucoma Overview

ONH: Blood supply
For reasons that have yet to be fully elucidated, glaucomatous optic neuropathy tends to damage the superior and inferior poles of the ONH preferentially and early. This leads to thinning at the poles (focal thinning is often referred to as a ‘notch.’)
Because of this tendency, ophthalmologists focus on the *vertical cup-disc ratio* (VCDR) when assessing a pt’s glaucoma status.

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Thus, in determining the glaucomatous-ness of an ONH, don’t just rely on the VCDR--make sure you also inspect and critically evaluate the status of the neuroretinal rim.
The nonglaucomatous neuroretinal rim tends to follow what’s known as the *ISNT rule*: In decreasing order, the rim is thickest at its *I*inferior, *S*uperior, *N*asal, and *T*emporal portions. If an ONH’s rim adheres to this rule, it *ISNT* glaucomatous.
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Note: Not all glaucoma docs find the ISNT rule to be helpful—YMMV. Ask!
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Now consider the ONH and retina in cross section. Note that the RNFL and ONH are both organized in a specific fashion:
--The RNFL is stacked *vertically*, with fibers that originate at points distant from the ONH running at the bottom (ie, closer to the RPE); and
--The ONH is stacked *horizontally*, with its peripheral-most fibers being those originating in the far retina, and its innermost fibers originating in the peripapillary region.
Now let’s look at the *topography of the retinal nerve fiber layer*, and how that topography relates to the structure of the ONH.
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Next, the papillomacular (PM) bundle—the swath of nerve fibers originating in the foveal region. Note how this bundle takes up the lion’s share of the temporal ONH.
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Finally, note how the PM bundle impacts the structure of the ONH. Because the bundle takes up the temporal ONH, fibers from the temporal perifoveal region and beyond are forced to ‘loop around’ it, and end up joining the ONH near its superior and inferior poles.
Because there are so many fibers at the superior and inferior poles, the normal ONH rim tends to be thicker at these sites. (This accounts for the relative proportions of the rim segments as captured by the ISNT rule described previously.)
Note also that a *vertical meridian* can be described in the retina as well. Unlike the horizontal raphé (which is physically instantiated in the anatomy of the retina), this vertical meridian is purely functional—it cannot be identified via histological examination of the retina.
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*If not within the retina, where is the anatomic location for the vertical meridian found in the visual fields?* The optic chiasm. Recall that it is there that the visual field is divided vertically.
Note also that a *vertical meridian* can be described in the retina as well. Unlike the horizontal raphé (which is physically instantiated in the anatomy of the retina), this vertical meridian is purely functional—it cannot be identified via histological examination of the retina. Instead, it is identified via *visual field testing*. Fixation divides the VF into nasal and temporal fields, with the photoreceptors (PRs) responsible for the temporal VF being nasal to the vertical meridian, and those responsible for the nasal VF located temporal to it.

Finally, note that fixation also divides the VF into superior and inferior VFs. The corresponding portions of the retina related topographically to the horizontal raphé.
**Putting it all together:** The VF can be divided into four quadrants. Together, retinal topography and ONH structure dictate that each quadrants corresponds with a particular anatomic location on the ONH. This relationship is important to understand as it allows the clinician to determine whether VF changes correlate with structural changes in the ONH as detected via DFE and/or imaging technology.
Here is a representation of the VF for each eye. Which is OD, and which OS?
Here is a representation of the VF for each eye. Which is OD, and which OS? Remember, VFs are not drawn as if the pt is looking at you; they’re drawn as if you are the pt!
Measured in degrees from fixation, how far does the normal VF extend superiorly, inferiorly, nasally and temporally?
(Don’t get too fixated on these specific numbers--different sources will give slightly different values.)
Measured in degrees from fixation, how far does the normal VF extend superiorly, inferiorly, nasally and temporally? (Don’t get too fixated on these specific numbers--different sources will give slightly different values.)
Measured in degrees from fixation, how much of the VF is assessed via the automated perimetry machines found in most ophthalmology practices?
Measured in degrees from fixation, how much of the VF is assessed via the automated perimetry machines found in most ophthalmology practices? The central 24 degrees
How far in degrees from fixation is the blind spot?
How far in degrees from fixation is the blind spot?
About 15 (again, don’t get too hung up on that specific number.)
For reasons that have yet to be fully elucidated, glaucoma initially ‘prefers’ to damage the superior and inferior poles of the ONH. This leads to thinning at the poles (focal thinning is referred to as a ‘notch.’)
Glaucoma Overview

For reasons that have yet to be fully elucidated, glaucoma initially ‘prefers’ to damage the superior and inferior poles of the ONH. This leads to thinning at the poles (focal thinning is referred to as a ‘notch.’) Specifically, glaucoma tends initially to affect fibers that originate on the temporal side of the vertical meridian.

VCDR ~.8

Glaucomatous ONH
For reasons that have yet to be fully elucidated, glaucoma initially ‘prefers’ to damage the superior and inferior poles of the ONH. This leads to thinning at the poles (focal thinning is referred to as a ‘notch.’) Specifically, glaucoma tends initially to affect fibers that originate on the temporal side of the vertical meridian.

The result of this is that glaucomatous VF defects appear in and extend from the nasal visual field.
Define glaucoma. A group of optic neuropathies that present with progressive ONH damage and characteristic VF loss.

Why isn’t elevated IOP mentioned above? Elevated IOP is a strong risk factor for glaucoma, but it need not be present—IOP can be normal, or even low.

In addition to being the strongest risk factor for glaucoma, IOP has another quality that renders it unique—what is it? It is the only risk factor that is modifiable in a manner proven to influence the risk of glaucoma progression.

It was noted initially that glaucoma presents with “characteristic VF loss.” That’s what we’re getting at here. Let’s take a detailed look at the way glaucomatous VF defects appear and progress.
Note: The following set of VFs are from a pt who suffered severe, progressive VF loss in a manner classic for glaucomatous optic neuropathy. I am not personally familiar with this case, and thus cannot provide context regarding the clinical circumstances that resulted in such profound, unchecked VF loss.
The first location at which glaucomatous VF manifests is near the nasal limit of a 24-2 field, sitting on (or ‘hanging’ just below) the horizontal midline. This pattern of loss is called a *nasal step*. 
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The first location at which glaucomatous VF manifests is near the nasal limit of a 24-2 field, sitting on (or ‘hanging’ just below) the horizontal midline. This pattern of loss is called a *nasal step*. 

This location in the VF…is associated with this location on the retina, meaning that the affected nerve fibers originated there…and entered the ONH peripherally.
If left untreated, the nasal step will gradually enlarge.

Glaucoma Overview

‘Early superior nasal step’

‘Superior nasal step’

(told ya)
If left untreated, the nasal step will gradually enlarge.
As glaucoma damage progresses, further loss of nerve fibers joining at that portion of the ONH will cause the VF defect to arc toward the blind spot. Once the VF loss has connected to the blind spot, the resulting defect is termed an *arcuate*.
As glaucoma damage progresses, further loss of nerve fibers from the superior portion of the ONH will cause the VF defect to arc toward the blind spot. Once the VF loss has connected to the blind spot, this is termed an *arcuate*.

*Note the area of origin for affected fibers now extends all the way to the ONH itself.*
As glaucoma damage progresses, further loss of nerve fibers joining at that portion of the ONH will cause the VF defect to arc toward the blind spot. Once the VF loss has connected to the blind spot, the resulting defect is termed an *arcuate*.

Note also that an early *inferior* nasal step is now present.
Glaucoma Overview

- 'Early superior nasal step'
- 'Superior nasal step'
- 'Superior arcuate'
- 'Advanced arcuate'
- 'Early inferior nasal step'
- 'Early inferior nasal step'

If left unchecked, an arcuate will expand into the surrounding portion of the VF.
Once an arcuate has expanded sufficiently, it becomes an altitudinal defect. The superior visual field is now all but gone. The inferior nasal step continues to enlarge.
The inferior step is now an arc, and appears destined to become altitudinal, resulting in blindness.
A note on the ‘Glaucoma Continuum’

Glaucoma is a progressive condition, passing from undetectable early disease to asymptomatic-but-detectable (via RNFL imaging) disease to functional (ie, marked by VF loss) disease, the last stage of which is severe vision loss and blindness.
In this regard, a word on the notion of ‘early’ glaucoma. We previously described the above VF defect as an ‘early’ nasal step.
In this regard, a word on the notion of ‘early’ glaucoma. We previously described the above VF defect as an ‘early’ nasal step. But take note of the point along the glaucoma continuum at which such a VF defect occurs—clearly, it doesn’t qualify as ‘early’ disease with respect to the continuum. Don’t mistake early VF changes for early disease!
Finally, let’s look briefly at how one should think through the new glaucoma case sitting in your exam chair.
The first thought you should have when encountering a pt you suspect has glaucoma is...
The first thought you should have when encountering a pt you suspect has glaucoma is…

*What is the status of the angle?*
Glaucoma Overview

Glaucoma

Open-angle

Closed- or narrow-angle

The first thought you should have when encountering a pt you suspect has glaucoma is…

What is the status of the angle?

How does one determine the status of the angle?
The first thought you should have when encountering a pt you suspect has glaucoma is…

What is the status of the angle?

How does one determine the status of the angle? **Gonioscopy.** Don’t assume your glaucoma pt has open angles—**prove** it by gonioing them!
Once you have determined a pt has open-angle glaucoma, the next ‘first thought’ is to ask…
Once you have determined a pt has open-angle glaucoma, the next ‘first thought’ is to ask…

*Is it high-pressure OAG, or low (aka normal) tension OAG?*
Untreated IOP consistently above **22 mmHg**

Untreated IOP consistently below **# mmHg**

**Normal-tension glaucoma (NTG)**
Untreated IOP consistently above 22 mmHg

Untreated IOP consistently below 22 mmHg

(Note that this distinction is somewhat controversial, as some glaucomalogists contend NTG is not a separate condition.)
Once you have determined a pt has high-pressure open-angle glaucoma, the next ‘first thought’ is to ask…
Once you have determined a pt has high-pressure open-angle glaucoma, the next ‘first thought’ is to ask…

*Is it primary open-angle glaucoma (POAG), or secondary OAG?*
How prevalent is POAG in the US?
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Very. It affects about $2\%$ of the over-40 population.
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**Glaucoma Overview**

How prevalent is POAG in the US?

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Where does POAG rank worldwide as a cause of blindness?
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It is second only to **cataract**.
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It is second only to **cataract**.

*Is there a racial predilection?*  
Yes, individuals of **black** and **Hispanic** heritage are at a 4x greater risk than are **whites** (and their relative risk of going blind is even higher than that).

*Is age a risk factor?*  
Yes, POAG rates increase dramatically with age.
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**Glaucoma Overview**

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Elevated IOP.
Glaucoma Overview

↑ IOP OAG

Primary → Secondary
Glaucoma Overview

↑ IOP OAG

Primary ➔ Secondary

Glaucoma Overview

↑ IOP OAG

Primary

Secondary

PXS

Pigmentary

Tumor-Induced

Lens-Induced

Inflammation-Induced

Drug-Induced

Trauma-Related

↑ EVS

Schwartz syndrome
Glaucoma Overview

↑ IOP OAG

Primary

Secondary

PXS

Pigmentary

Tumor-Induced

- Phacolytic
- Phacoantigenic
- Lens particle

Lens-Induced

Inflammation-Induced

- Posner-Schlossman
- Fuchs heterochromic iridocyclitis

Drug-Induced

- Steroids
- Mydriatics

Trauma-Related

- Angle recession
- Cycloidalysis cleft
- Hyphema
- Hemolytic
- Ghost cell

↑ EVS

Schwartz syndrome

(Most of these conditions are addressed in detail in other slide-sets—see the Table of Contents)
Once you have determined a pt has angle-closure glaucoma, the next ‘first thought’ is to ask…
Once you have determined a pt has angle-closure glaucoma, the next ‘first thought’ is to ask…

*is it primary or secondary?*
Is there a racial predilection regarding the risk of PACG?
Is there a racial predilection regarding the risk of PACG?
Yes, individuals of [Inuit] heritage have the highest known risk of PACG--their relative risk has been estimated to be as high as [40x] that of whites.
Is there a racial predilection regarding the risk of PACG?
Yes, individuals of Inuit heritage have the highest known risk of PACG--their relative risk has been estimated to be as high as 40x that of whites.
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What about people of Asian descent?
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**What about people of Asian descent?**
Their relative risk is somewhere between that of the Inuit and whites.
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Yes, the incidence increases with age
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Is gender a risk factor?
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Is age a risk factor?
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Is gender a risk factor?
Yes, women are at higher risk
Angle-Closure Glaucoma

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Is refraction a risk factor?
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Yes, the incidence increases with age.

**Is gender a risk factor?**
Yes, women are at higher risk.

**Is refraction a risk factor?**
Yes; PACG is more likely to occur in hyperopes.
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Angle-Closure Glaucoma

What are the four subtypes of PACG?
Glaucoma Overview

Angle-Closure Glaucoma

Primary
- Acute
- Subacute
- Chronic
- Plateau Iris

Secondary

What are the four subtypes of PACG?
The first thought you should have when encountering a pt you suspect has secondary angle-closure glaucoma is…
The first thought you should have when encountering a pt you suspect has secondary angle-closure glaucoma is…

*is it with or without pupillary block*
Angle-Closure Glaucoma

Primary
- Acute
- Subacute
- Chronic
- Plateau Iris

Secondary

w/ Pupillary Block  w/o Pupillary Block

The first thought you should have when encountering a pt you suspect has secondary angle-closure glaucoma is… is it with or without pupillary block

More information is available regarding the various forms of angle-closure glaucoma, check the Table of Contents to find it