Fill in the IOP equation below.

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

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

The equation

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

The **Goldmann equation**

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

Note how the \(\mu\text{L/min}\) cancel, leaving IOP in mmHg
Fill in the IOP equation below. What is its eponymous name?
The Goldmann equation

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

*Note how the μL/min cancel, leaving IOP in mmHg*

**Episcleral venous pressure** (EVP) normally measures about 8-10 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 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 clinical 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.
Fill in the IOP equation below. What is its eponymous name?

The Goldmann equation

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

So to lower IOP, one must:

- Decrease the numerator (Aqueous Formation Rate)
- Increase the denominator (Outflow Facility)
- Decrease Episceral Venous Pressure

Three maneuvers implied by the Goldmann equation

- Decrease the numerator (Aqueous Formation Rate)
- Increase the denominator (Outflow Facility)
- Decrease Episceral Venous Pressure

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 (\(\mu L/\text{min}\))}}{\text{Outflow Facility (\(\mu L/\text{min/mmHg}\))}} + \text{Episceral 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*
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, \textit{and/or}
- increase outflow facility, \textit{and/or}
- decrease episcleral venous pressure

\textbf{Important maneuver not implied by the Goldmann equation: ...\textit{and/or} with a three words agent one word}

\textbf{Three maneuvers implied by the Goldmann equation:}

- \textit{and/or}
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)}
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So to lower IOP, one must:

- decrease aqueous formation, \textit{and/or}
- increase outflow facility, \textit{and/or}
- decrease episcleral venous pressure

Three maneuvers implied by the Goldmann equation

Important maneuver not implied by the Goldmann equation

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

\[ \text{IOP} = \frac{\text{Aqueous Formation Rate (\(\mu\text{L/min}\))}}{\text{Outflow Facility (\(\mu\text{L/min/mmHg}\))}} + \text{Episcleral Venous Pressure (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
-- increase outflow facility, and/or
-- decrease episcleral venous pressure

... and/or dehydrate the vitreous with a hyperosmotic agent

---

The Goldmann equation

\[ IOP = \frac{\text{Aqueous Formation Rate (μL/min)}}{\text{Outflow Facility (μL/min/mmHg)}} + \text{Episcleral Venous Pressure (mmHg)} \]
So to lower IOP, one must:
--decrease aqueous formation,
and/or
--increase outflow facility,
and/or
--decrease episcleral venous pressure
...and/or dehydrate the vitreous with a hyperosmotic agent.

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

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

Which classes of meds decrease aqueous formation?
--β blockers
--CAIs
--α agonists

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

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

What are the two types of outflow?
- Trabecular meshwork (TM)
- Uveoscleral (U/S)
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 = \frac{\text{Aqueous Formation Rate (\(\mu L/min\))}}{\text{Outflow Facility (\(\mu L/min/mmHg\))}} + \text{Episcleral Venous Pressure (mmHg)}

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What are the two types of outflow?

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One of these is referred to as ‘conventional outflow,’ the other, ‘unconventional.’ Which is which?

TM = U/S =

The Goldmann equation
So to lower IOP, one must:
-- decrease aqueous formation, and/or
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-- decrease episcleral venous pressure, and/or
-- dehydrate the vitreous with a hyperosmotic agent.

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

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TM = conventional
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One of these is referred to as ‘conventional outflow,’ the other, ‘unconventional.’ Which is which?
TM = conventional
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To lower IOP, one must:

- Decrease aqueous formation,
- Increase outflow facility,
- Decrease episcleral venous pressure,
- And/or dehydrate the vitreous with a hyperosmotic agent.

The equation for IOP is:

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

**Which classes of meds decrease aqueous formation?**
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- TM = conventional = pressure-dependent
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- Decrease episcleral venous pressure
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*What does this mean, pressure-dependent vs pressure-independent?*

---

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---

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**What does this mean, pressure-dependent vs pressure-independent?**

It refers to the effect of intraocular pressure on Outflow Facility. Increases in IOP result in increased Outflow Facility at the TM; thus, TM outflow is said to be pressure-dependent. On the other hand, changes in IOP do not effect U/S outflow, therefore, it is pressure-independent.
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and/or
--decrease episcleral venous pressure.

Dehydration the vitreous with a hyperosmotic agent...

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

What does this mean, pressure-dependent vs pressure-independent?
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U/S = unconventional

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--Trabecular meshwork (TM)
--Uveoscleral (U/S)
Speaking of Aqueous Formation…

Where is it formed? What cells specifically?
Q/A

- Speaking of Aqueous Formation…
  - Where is it formed? What cells specifically?
    - Pigmented vs nonpigmented
    - Epithelial cells of the portion of the
    - Two words
    - Two different words
Speaking of Aqueous Formation...

- Where is it formed? What cells specifically?
  Nonpigmented epithelial cells of the pars plicata portion of the ciliary body
Speaking of Aqueous Formation...

Where is it formed? What cells specifically?

Nonpigmented epithelial cells of the pars plicata portion of the ciliary body

The ciliary body has two parts. One is the pars plicata; what is the other?
Speaking of Aqueous Formation…

Where is it formed? What cells specifically?

Nonpigmented epithelial cells of the pars plicata portion of the ciliary body

The ciliary body has two parts. One is the pars plicata; what is the other?
The pars plana
Speaking of Aqueous Formation…
- Where is it formed? What cells specifically? Nonpigmented epithelial cells of the pars plicata portion of the ciliary body
- What is the normal rate of production?
Speaking of Aqueous Formation...

- Where is it formed? What cells specifically?
  Nonpigmented epithelial cells of the pars plicata portion of the ciliary body

- What is the normal rate of production? 2-3 µL/min
Speaking of Aqueous Formation…

- Where is it formed? What cells specifically?
  Nonpigmented epithelial cells of the pars plicata portion of the ciliary body
- What is the normal rate of production? 2-3 μL/min
- What is the average AC aqueous volume?
● Speaking of Aqueous Formation…
  ● Where is it formed? What cells specifically? Nonpigmented epithelial cells of the pars plicata portion of the ciliary body
  ● What is the normal rate of production? 2-3 μL/min
  ● What is the average AC aqueous volume? ~260 μL
Speaking of Aqueous Formation…

- Where is it formed? What cells specifically? Nonpigmented epithelial cells of the pars plicata portion of the ciliary body
- What is the normal rate of production? 2-3 \( \mu \text{L/min} \)
- What is the average AC aqueous volume? \( \sim 260 \, \mu \text{L} \)
- So, what percent of AC volume is formed per minute?
Speaking of Aqueous Formation…

- Where is it formed? What cells specifically? Nonpigmented epithelial cells of the pars plicata portion of the ciliary body
- What is the normal rate of production? 2-3 μL/min
- What is the average AC aqueous volume? ~260 μL
- So, what percent of AC volume is formed per minute? ~1%
Speaking of Aqueous Formation…

- Where is it formed? What cells specifically? **Nonpigmented epithelial cells of the pars plicata portion of the ciliary body**
- What is the normal rate of production? **2-3 \( \mu \)L/min**
- What is the average AC aqueous volume? **\(~260 \mu \)L**
- So, what percent of AC volume is formed per minute? **\(~1\)%**
- How long does it take to have a complete turnover of aqueous?
Speaking of Aqueous Formation…

- Where is it formed? What cells specifically? Nonpigmented epithelial cells of the pars plicata portion of the ciliary body
- What is the normal rate of production? 2-3 μL/min
- What is the average AC aqueous volume? ~260 μL
- So, what percent of AC volume is formed per minute? ~1%
- How long does it take to have a complete turnover of aqueous? About 100 minutes
Speaking of Aqueous Formation...

Where is it formed? What cells specifically?

Nonpigmented epithelial cells of the pars plicata

From what embryonic tissue does the nonpigmented epithelium of the pars plicata derive?

The neurosensory component
• Speaking of Aqueous Formation…
  • Where is it formed? What cells specifically?
    Nonpigmented epithelial cells of the pars plicata
  From what embryonic tissue does the nonpigmented epithelium of the pars plicata derive?
    Neuroectoderm
Speaking of Aqueous Formation…

Where is it formed? What cells specifically?
Nonpigmented epithelial cells of the pars plicata

From what embryonic tissue does the nonpigmented epithelium of the pars plicata derive?
Neuroectoderm

What portion of the retina derives from the same neuroectodermal layer?
Aqueous Formation

Where is it formed? What cells specifically?
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What portion of the retina derives from the same neuroectodermal layer?
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What portion of the retina derives from the same neuroectodermal layer?
The neurosensory component

From what embryonic tissue does the pigmented epithelium of the ciliary processes derive?
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Speaking of Aqueous Formation…

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**Nonpigmented epithelial cells of the pars plicata**

*From what embryonic tissue does the nonpigmented epithelium of the pars plicata derive?*

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*What portion of the retina derives from the same neuroectodermal layer?*

**The neurosensory component**

*From what embryonic tissue does the pigmented epithelium of the ciliary processes derive?*

**Neuroectoderm**

*What portion of the retina derives from the same neuroectodermal layer?*
Speaking of Aqueous Formation...

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From what embryonic tissue does the nonpigmented epithelium of the pars plicata derive?
Neuroectoderm

What portion of the retina derives from the same neuroectodermal layer?
The neurosensory component

From what embryonic tissue does the pigmented epithelium of the ciliary processes derive?
Neuroectoderm

What portion of the retina derives from the same neuroectodermal layer?
The RPE
Speaking of Aqueous Formation…

- Where is it formed? What cells specifically?
  Nonpigmented epithelial cells of the pars plicata

*From what embryonic tissue does the nonpigmented epithelium of the pars plicata derive?*
- Neuroectoderm

*What portion of the retina derives from the same neuroectodermal layer?*
- The neurosensory component

*From what embryonic tissue does the pigmented epithelium of the ciliary processes derive?*
- Neuroectoderm

*What portion of the retina derives from the same neuroectodermal layer?*
- The RPE

*How are the two epithelial layers of the ciliary body oriented with respect to one another?*
- Speaking of Aqueous Formation...
  - Where is it formed? What cells specifically?
    - **Nonpigmented epithelial cells of the pars plicata**

    *From what embryonic tissue does the nonpigmented epithelium of the pars plicata derive?*
    - Neuroectoderm

    *What portion of the retina derives from the same neuroectodermal layer?*
    - The neurosensory component

    *From what embryonic tissue does the pigmented epithelium of the ciliary processes derive?*
    - Neuroectoderm

    *What portion of the retina derives from the same neuroectodermal layer?*
    - The RPE

    *How are the two epithelial layers of the ciliary body oriented with respect to one another?*
    - The cells are apex-to-apex
Speaking of Aqueous Formation…

Where is it formed? What cells specifically?

Nonpigmented epithelial cells of the pars plicata

From what embryonic tissue does the nonpigmented epithelium of the pars plicata derive?
Neuroectoderm

What portion of the retina derives from the same neuroectodermal layer?
The neurosensory component

From what embryonic tissue does the pigmented epithelium of the ciliary processes derive?
Neuroectoderm

What portion of the retina derives from the same neuroectodermal layer?
The RPE

How are the two epithelial layers of the ciliary body oriented with respect to one another?
The cells are apex-to-apex

How are the neurosensory retinal and RPE cells oriented with respect to one another?
Speaking of Aqueous Formation…
- Where is it formed? What cells specifically? Nonpigmented epithelial cells of the pars plicata

From what embryonic tissue does the nonpigmented epithelium of the pars plicata derive? Neuroectoderm

What portion of the retina derives from the same neuroectodermal layer? The neurosensory component

From what embryonic tissue does the pigmented epithelium of the ciliary processes derive? Neuroectoderm

What portion of the retina derives from the same neuroectodermal layer? The RPE

How are the two epithelial layers of the ciliary body oriented with respect to one another? The cells are apex-to-apex

How are the neurosensory retinal and RPE cells oriented with respect to one another? The same way--apex-to-apex
You know that the **Optic Vesicle** is composed of neuroectoderm.
You know that the Optic Vesicle is composed of neuroectoderm.

And that both the Embryonal Ciliary Body Epithelium and the Embryonal Retina derive from it.
You know that the **Optic Vesicle** is composed of neuroectoderm.

And that both the **Embryonal Ciliary Body Epithelium**

And the **Embryonal Retina** derive from it.

And you know the RPE and photoreceptors are oriented apex-to-apex, and of course that the RPE is heavily pigmented, whereas the PRs are not.
You know that the **Optic Vesicle** is composed of neuroectoderm.

And that both the **Embryonal Ciliary Body Epithelium** and the **Embryonal Retina** derive from it.

And you know the RPE and photoreceptors are oriented apex-to-apex, and of course that the RPE is heavily pigmented, whereas the PRs are not.

And because the CB epithelium has the same embryologic origins as the RPE…
You know that the **Optic Vesicle** is composed of neuroectoderm.

And that both the **Embryonal Ciliary Body Epithelium** and the **Embryonal Retina** derive from it.

And you know the RPE and photoreceptors are oriented apex-to-apex, and of course that the RPE is heavily pigmented, whereas the PRs are not.

**And because the CB epithelium has the same embryologic origins as the RPE...**
And Speaking of Aqueous Outflow...

What are the major structures aqueous encounters along the conventional outflow pathway?

Start here—name the first structure crossed by aqueous on the way out via the conventional pathway

- The TM
- Schlemm’s canal
- Episcleral veins
- Anterior ciliary and superior ophthalmic veins
- Cavernous sinus
Q/A

And Speaking of Aqueous Outflow...

What are the major structures aqueous encounters along the conventional outflow pathway?

- The TM

Next structure—a space, of sorts
Q/A

And Speaking of Aqueous Outflow...

What are the major structures aqueous encounters along the conventional outflow pathway?

- The TM
- Schlemm’s canal

Next—vascular structures
And Speaking of Aqueous Outflow…

What are the major structures aqueous encounters along the conventional outflow pathway?

- The TM
- Schlemm’s canal
- Episcleral veins

Next, more and larger vascular structures
And Speaking of Aqueous Outflow...

What are the major structures aqueous encounters along the conventional outflow pathway?

- The TM
- Schlemm’s canal
- Episcleral veins
- Anterior ciliary and superior ophthalmic veins

*Finally, a major vascular space*
And Speaking of Aqueous Outflow...

What are the major structures aqueous encounters along the conventional outflow pathway?

- The TM
- Schlemm’s canal
- Episcleral veins
- Anterior ciliary and superior ophthalmic veins
- Cavernous sinus
And Speaking of Aqueous Outflow...

What are the major structures aqueous encounters along the conventional outflow pathway?

- The TM

The TM has three layers. From innermost (ie, nearest the anterior chamber) to outermost, what are they?

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- Cavernous sinus
And Speaking of Aqueous Outflow...

What are the major structures aqueous encounters along the conventional outflow pathway?

- **The TM**

*The TM has three layers. From innermost (i.e., nearest the anterior chamber) to outermost, what are they?*
  - Uveal layer
  - Corneoscleral layer
  - Juxtacanalicular layer

- Cavernous sinus
And Speaking of Aqueous Outflow...

- What are the major structures aqueous encounters along the conventional outflow pathway?
  - The TM

The TM has three layers. From innermost (ie, nearest the anterior chamber) to outermost, what are they?
- Uveal layer?
- Corneoscleral layer?
- Juxtacanalicular layer?

Of the three, which is the major site of resistance to aqueous outflow?

- Cavernous sinus
And Speaking of Aqueous Outflow…

What are the major structures aqueous encounters along the conventional outflow pathway?

- The TM
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Of the three, which is the major site of resistance to aqueous outflow?

The juxtacanalicular layer

- Cavernous sinus
And Speaking of Aqueous Outflow…

What are the major structures aqueous encounters along the conventional outflow pathway?

- The TM
- Schlemm’s canal
- Episceral veins
- Anterior ciliary and superior ophthalmic veins
- Cavernous sinus

What are the major structures aqueous encounters along the unconventional outflow pathway?

Start here—name the first structure crossed by aqueous on the way out via the unconventional pathway

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Q/A

- And Speaking of Aqueous Outflow...

  - What are the major structures aqueous encounters along the conventional outflow pathway?
    - The TM
    - Schlemm’s canal
    - Episceral veins
    - Anterior ciliary and superior ophthalmic veins
    - Cavernous sinus

  - What are the major structures aqueous encounters along the unconventional outflow pathway?
    - Ciliary body

- And next, a space(s) associated with the CB
And Speaking of Aqueous Outflow…

- What are the major structures aqueous encounters along the conventional outflow pathway?
  - The TM
  - Schlemm’s canal
  - Episcleral veins
  - Anterior ciliary and superior ophthalmic veins
  - Cavernous sinus

- What are the major structures aqueous encounters along the unconventional outflow pathway?
  - Ciliary body
  - Supraciliary/suprachoroidal spaces

And next, another major component of the eye
And Speaking of Aqueous Outflow…

- What are the major structures aqueous encounters along the conventional outflow pathway?
  - The TM
  - Schlemm’s canal
  - Episceral veins
  - Anterior ciliary and superior ophthalmic veins
  - Cavernous sinus

- What are the major structures aqueous encounters along the unconventional outflow pathway?
  - Ciliary body
  - Supraciliary/suprachoroidal spaces
  - Sclera

And finally…another major component of the eye
A

- And Speaking of Aqueous Outflow...
  - What are the major structures aqueous encounters along the conventional outflow pathway?
    - The TM
    - Schlemm’s canal
    - Episceral veins
    - Anterior ciliary and superior ophthalmic veins
    - Cavernous sinus
  - What are the major structures aqueous encounters along the unconventional outflow pathway?
    - Ciliary body
    - Suprarciliary/suprachoroidal spaces
    - Sclera
    - Conjunctiva
And Speaking of Aqueous Outflow…

What are the major structures aqueous encounters along the conventional outflow pathway?
- The TM
- Schlemm’s canal
- Episceral veins
- Anterior ciliary and superior ophthalmic veins
- Cavernous sinus

What are the major structures aqueous encounters along the unconventional outflow pathway?

What proportion of egressed aqueous leaves via the unconventional pathway?

Does the proportion leaving via this pathway increase, or decrease with age?
Decrease
And Speaking of Aqueous Outflow…

- What are the major structures aqueous encounters along the conventional outflow pathway?
  - The TM
  - Schlemm’s canal
  - Episcleral veins
  - Anterior ciliary and superior ophthalmic veins
  - Cavernous sinus

- What are the major structures aqueous encounters along the unconventional outflow pathway?
  - **What proportion of egressed aqueous leaves via the unconventional pathway?**
    - The most recent version of the BCSC Glaucoma book in my possession puts it at 5-15%, but acknowledges that it may be higher than that
  - [Other points]
And Speaking of Aqueous Outflow...

- What are the major structures aqueous encounters along the conventional outflow pathway?
  - The TM
  - Schlemm’s canal
  - Episceral veins
  - Anterior ciliary and superior ophthalmic veins
  - Cavernous sinus

- What are the major structures aqueous encounters along the unconventional outflow pathway?

**What proportion of egressed aqueous leaves via the unconventional pathway?**

The most recent version of the BCSC *Glaucoma* book in my possession puts it at 5-15%, but acknowledges that it may be higher than that.

**Does the proportion leaving via this pathway increase, or decrease with age?**

Decrease
And Speaking of Aqueous Outflow...

- What are the major structures aqueous encounters along the conventional outflow pathway?
  - The TM
  - Schlemm’s canal
  - Episcleral veins
  - Anterior ciliary and superior ophthalmic veins
  - Cavernous sinus

- What are the major structures aqueous encounters along the unconventional outflow pathway?

  What proportion of egressed aqueous leaves via the unconventional pathway? The most recent version of the BCSC Glaucoma book in my possession puts it at 5-15%, but acknowledges that it may be higher than that.

  Does the proportion leaving via this pathway increase, or decrease with age? Decrease