What is the difference between the retina and the neurosensory retina? While often used interchangeably (including, on occasion, in this slide-set), these are technically not synonyms. The term neurosensory retina refers to the neural lining on the inside of the eye, whereas the term retina refers to this neural lining along with the retinal pigment epithelium (RPE).
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The neurosensory retina contains three classes of cells:

--Neurons

--Glial

--Vascular
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The neurosensory retina contains three classes of cells:

There are five types of neural elements:

--Neurons:
---Photoreceptors (PRs)
---Bipolar cells
---Ganglion cells
---Amacrine cells
---Horizontal cells
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----Müller cells
----Astrocytes
----Microglia

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One of the glial cells is of particular note—Müller cells. These large cells extend the breadth of the neurosensory retina, and their foot-processes form the internal limiting membrane of the retina.

----Astrocytes
----Microglia
--Vascular
Müller cells
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The amacrine cells and horizontal cells are interneurons connecting other neural elements.
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The amacrine cells and horizontal cells are interneurons connecting other neural elements. The horizontal cells interconnect PRs with one another; the amacrine cells interconnect bipolar cells, and ganglion cells.
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  - Pericytes

Noting that amacrine and horizontal cells are interconnectors dovetails nicely with a fundamental way you should think about the neural elements of the neurosensory retina. Specifically, all of the neural elements can be conceptualized as belonging to one of two pathways:

- The vertical pathway comprised of (in order) the PRs, bipolar cells, and ganglion cells;
- The horizontal pathway comprised of amacrine and horizontal cells.

And lastly, two vascular cell types:

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  - Photoreceptors (PRs)
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What does it mean to say the vertical pathway is, well, vertical? It means that this is the direct path that neural impulses take in getting out of the eye and to the visual cortex.
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In contrast, the horizontal pathway conducts impulses from one area of the retina to another.
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There are five types of neural elements:
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And lastly, two vascular cell types:

--Neurons:
----Photoreceptors (PRs)

Let's drill down on the PRs. Their fundamental role is to convert light energy into electrical (neural) impulses, ie, they are the site at which phototransduction occurs. There are two basic PR types: Rods and cones, each named for the shape of their outer segments (we'll explain what an outer seg is shortly). In the average human retina there are 100-125M rods, and 6-7M cones.

----Bipolar cells

--Glial:
----Müller cells
----Astrocytes
----Microglia

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**Retinal Anatomy and Histology**

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Rods and cones differ in many ways, but the most fundamental is that cones provide color vision, whereas rods provide monochromatic vision. There are three types of cones; they differ in terms of the wavelength of light to which they are most responsive: Short wavelength (S cones), medium (M cones), and long (L cones).

--Bipolar cells
---Horizontal cells
---Amacrine cells
---Bipolar cells

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Let’s talk PR morphology. PRs have several portions, one being the outer segment (outer means ‘closer to the eye wall’). As mentioned, the outer segs of rods and cones are rod-shaped and conical, respectively.
Retinal Anatomy and Histology

- Cone
- Rod

- Outer segment
- Retinal pigment epithelium
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The dominant morphologic feature of a PR outer seg are its discs. The disc membranes contain the protein rhodopsin, which is the substance that reacts to the incoming light and kicks off the process of phototransduction. After a disc’s phototransduction ability is spent, it is ‘shed’ by the PR, and gobbled up by adjacent RPE cells.
Retinal Anatomy and Histology

Cell body

Synaptic processes

Outer segment

Discs

Retinal pigment epithelium
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----Pericytes
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Next to the outer segment is, perhaps not surprisingly, the inner segment.

--Vascular:
----Endothelial cells
----Pericytes
Retinal Anatomy and Histology

- Cone
- Rod
- Inner segment
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- Discs
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Next to the outer segment is, perhaps not surprisingly, the inner segment. The inner and outer segments are connected by a nonmotile cilium. Disorders affecting the integrity of the cilia have enormous consequences for PR/retinal health and visual function, as they can produce a retinitis pigmentosa-like clinical picture.

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The inner segment has two subsections—an ellipsoid immediately adjacent to the cilium, then a myoid. Each area is known for its contents, with the ellipsoid being chock full of mitochondria, and the myoid full of glycogen.

--Vascular:
----Endothelial cells
----Pericytes
Retinal Anatomy and Histology

Cone
- Inner segment
- Cilium
- Outer segment
- Discs

Rod
- Inner segment
- Cilium
- Outer segment
- Discs

Myoid
Ellipsoid
Retinal pigment epithelium
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Continuing on...The portion of the PR next to the inner segment is the cell body, which houses the cell’s nucleus.
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While not a part of the PRs per se, they (the PRs) contribute to an important retinal structure located at the juncture of the inner segment and cell body—the external limiting membrane (ELM). The ELM is not an actual membrane, rather, it is a barrier created by connections between Mueller cells and PRs.
Retinal Anatomy and Histology

Cell body

External limiting membrane

Inner segment

Cilium

Outer segment

Retinal pigment epithelium

Nucleus

Myoid

Ellipsoid

Discs
Retinal Anatomy and Histology

ELM, Müller cells and PRs
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After the cell body, the final portion of the PR is an axon-like fiber terminating in the PR’s synaptic processes.
Retinal Anatomy and Histology

- **Cell body**
- **Synaptic processes**
- **External limiting membrane**
- **Inner segment**
- **Cilium**
- **Outer segment**
- **Cone**
- **Rod**
- **Nucleus**
- **Myoid**
- **Ellipsoid**
- **Discs**
- **Retinal pigment epithelium**
Next we will look at the layers of the neurosensory retina. But before we do, let’s make sure you’re on fleek* regarding the critical aspects of retinal histology we’ve seen thus far.

*You’re so cool, Dr Flynn
Next we will look at the layers of the neurosensory retina. But before we do, let’s make sure you’re on fleek* regarding the critical aspects of retinal histology we’ve seen thus far. Why? Because as we will see later in the slide-set, a firm grasp of this info is absolutely required to read OCTs. So go through the next section of slides over and over until they’re burned into your brain. (You’ll thank me later.)

*You’re so cool, Dr Flynn
Retinal Anatomy and Histology

Working out in: The first structure to be particularly aware of is...

RPE/Bruch’s membrane complex
Retinal Anatomy and Histology

The next is…

- The interdigitation zone
- RPE/Bruch’s membrane complex
Retinal Anatomy and Histology

The next is…

- PR outer segs
- The interdigititation zone
- RPE/Bruch’s membrane complex
Retinal Anatomy and Histology

The next is…

- The ellipsoid zone
- PR outer segs
- The interdigitation zone
- RPE/Bruch’s membrane complex
Retinal Anatomy and Histology

The myoid zone
The ellipsoid zone
PR outer segs
The interdigitation zone
RPE/Bruch’s membrane complex
Retinal Anatomy and Histology

And the last is…

- The ELM
- The myoid zone
- The ellipsoid zone
- PR outer segs
- The interdigitation zone
- RPE/Bruch’s membrane complex
Retinal Anatomy and Histology

Re-rack those until you know them cold!

- The ELM
- The myoid zone
- The ellipsoid zone
- PR outer segs
- The interdigitation zone
- RPE/Bruch’s membrane complex
Now we’re ready to review the layers of the retina
Neurosensory Retina Layers
- Internal limiting membrane
- Nerve fiber layer
- Ganglion cell layer
- Inner plexiform layer
- Inner nuclear layer
- Outer plexiform layer
- Outer nuclear layer
- External limiting membrane
- Rod & cone inner and outer segments

RPE
Bruch’s membrane

Here they are, but don’t try to memorize them at this point—instead, let’s work through them.
Neurosensorial Retina Layers

- Internal limiting membrane
- **Nerve fiber layer**
- Ganglion cell layer
- **Inner plexiform layer**
- Inner nuclear layer
- **Outer plexiform layer**
- Outer nuclear layer
- External limiting membrane
- Rod & cone inner and outer segments

**RPE**

**Bruch’s membrane**

These three layers consist of fibers, ie, axons and/or dendrites. (A plexus is an interlaced group of fibers.)
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RPE
Bruch’s membrane

In contrast, these layers composed of the cell bodies that give rise to the axons and/or dendrites of the other layers.
Neurosensory Retina Layers

- Internal limiting membrane
- Nerve fiber layer
- Ganglion cell layer
- Inner plexiform layer
- Inner nuclear layer
- Outer plexiform layer
- Outer nuclear layer
- External limiting membrane

RPE

Bruch’s membrane

Note that this section of the retina consists of alternating layers of cell processes and cell bodies. This pattern can help you remember which layer is next to which!
Neurosensory Retina Layers

- Internal limiting membrane
- Nerve fiber layer
- Ganglion cell layer
- Inner plexiform layer
- Inner nuclear layer
- Outer plexiform layer
- Outer nuclear layer
- External limiting membrane
- Rod & cone inner and outer segments

RPE

Bruch’s membrane

Further, we can see the origins of the fibers that comprise each fiber/plexiform layer.
The first layer after the ILM is the retinal **nerve fiber layer**. The NFL is composed of the axons of the ganglion cells.

**Neurosensor...**

- Internal limiting membrane
- **Nerve fiber layer**
- Ganglion cell layer
- Inner plexiform layer
- Inner nuclear layer
- Outer plexiform layer
- Outer nuclear layer
- External limiting membrane
- Rod & cone inner and outer segments
- RPE
- Bruch’s membrane

**Ganglion-cell axons**
Neurosensory Retina Layers

- Internal limiting membrane
- Nerve fiber layer
- Ganglion cell layer
- Inner plexiform layer
- Inner nuclear layer
- Outer plexiform layer
- Outer nuclear layer
- External limiting membrane
- Rod & cone inner and outer segments
- RPE
- Bruch’s membrane

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Neurosensory Retina Layers

- Internal limiting membrane
- **Nerve fiber layer**
  - Processes
- **Ganglion cell layer**
  - Bodies
- Inner plexiform layer
  - Processes
- **Outer plexiform layer**
- **Outer nuclear layer**
- **Internal limiting membrane**
- **Ganglion-cell axons**
- **Bruch’s membrane**
- RPE

The first layer after the ILM is the retinal nerve fiber layer. The NFL is composed of the axons of the ganglion cells. The cell bodies of the ganglion cells are located in the ganglion cell layer.

The NFL fibers run toward the lamina cribrosa of the sclera where they exit the eye, in the process forming first the optic nerve head, and then the optic nerve.
The first layer after the ILM is the retinal **nerve fiber layer**. The NFL is composed of the axons of the ganglion cells. The cell bodies of the ganglion cells are located in the **ganglion cell layer**.

The NFL fibers run toward the lamina cribrosa of the sclera where they exit the eye, in the process forming first the optic nerve head, and then the optic nerve. Most of these fibers will synapse in the lateral geniculate nucleus (LGN); others will synapse elsewhere as part of the pupillary light reflex or circadian rhythm modulation.
The **inner plexiform layer** consists of connections between the dendrites of the ganglion cells as they synapse with axons originating from bipolar cells.
**Neurosensory Retina Layers**
- Internal limiting membrane
- **Nerve fiber layer** → Processes
- **Ganglion cell layer** → Bodies
- **Inner plexiform layer** → Processes
- **Inner nuclear layer** → Bodies

The **inner plexiform layer** consists of connections between the dendrites of the ganglion cells as they synapse with axons originating from bipolar cells. The bodies of these bipolar cells reside in the **inner nuclear layer**.

- **RPE**
- Bruch’s membrane
Neurosensory Retina Layers

- Internal limiting membrane
- Nerve fiber layer
- Ganglion cell layer
- Inner plexiform layer
- Inner nuclear layer
- Outer plexiform layer
- Outer nuclear layer
- External limiting membrane
- Bruch’s membrane

The outer plexiform layer consists of connections between the dendrites of the bipolar cells as they synapse with axons originating from the PRs.
Neurosensory Retina Layers

- Internal limiting membrane
- Nerve fiber layer
- Ganglion cell layer
- Inner plexiform layer
- Inner nuclear layer
- Outer plexiform layer
- Outer nuclear layer
- External limiting membrane
- Bruch’s membrane

The outer plexiform layer consists of connections between the dendrites of the bipolar cells as they synapse with axons originating from the PRs. The cell bodies of the PRs reside in the outer nuclear layer.
Neurosensory Retina Layers
- Internal limiting membrane
- Nerve fiber layer
- Ganglion cell layer
- Inner plexiform layer
- Inner nuclear layer
- Outer plexiform layer
- Outer nuclear layer
- External limiting membrane
- Rod & cone inner and outer segments

(We’ve already covered at length the ELM, as well as the PR inner and outer segs)
Neurosensorv Retina Layers
- Internal limiting membrane
- Nerve fiber layer
- Ganglion cell layer
- Inner plexiform layer
- Inner nuclear layer
- Outer plexiform layer
- Outer nuclear layer
- External limiting membrane
- Rod & cone inner and outer segments

Ganglion cells (in GCL)
Bipolar cells (in INL)

Ganglion-cell dendrites
Bipolar-cell dendrites

IPL
OPL
PR axons
Photoreceptors (cell bodies in ONL)

We’ll look at the RPE and Bruch’s in-depth shortly.
**Neurosensory Retina Layers**
- Internal limiting membrane
- Nerve fiber layer
- Ganglion cell layer
- Inner plexiform layer
- Inner nuclear layer
- Outer plexiform layer
- Outer nuclear layer
- External limiting membrane

Note that all we’ve done here is lay out in detail the *vertical pathway* discussed earlier

**Bruch’s membrane**
Neurosensorary Retina Layers
- Internal limiting membrane
- Nerve fiber layer
- Ganglion cell layer
- Inner plexiform layer
- Inner nuclear layer
- Outer plexiform layer = *Henle’s layer*

Important aside: The outer plexiform layer is often referred to by an eponym: *Henle’s layer*.

RPE

Bruch’s membrane
**Neurosensorial Retina Layers**
- Internal limiting membrane
- Nerve fiber layer
- Ganglion cell layer
- Inner plexiform layer
- Inner nuclear layer
- **Outer plexiform layer = Henle’s layer (sort of)**

Important aside: The outer plexiform layer is often referred to by an eponym: *Henle’s layer*. However, as we will see when we correlate retinal anatomy with OCT imaging later in the slide-set, these terms are in fact **not** synonyms.

- RPE
- Bruch’s membrane
● **Neurosensoric Retina Layers**
  - Internal limiting membrane
  - Nerve fiber layer
  - Ganglion cell layer
  - Inner plexiform layer
  - Inner nuclear layer
  - Outer plexiform layer
  - Outer nuclear layer
  - External limiting membrane
  - Rod & cone inner and outer segments

● **RPE**

● **Bruch’s membrane**

*Review slide—no questions*
macula
Now that we’re familiar with the histology of the retina, we’re ready to tackle the topography of the *macula*
We define the term *macula*...

- **anatomically**
  as well as both

- **histologically**
  and of course

- **clinically**
We define the term *macula*...

- **anatomically**, it is the retinal area in which the ganglion-cell layer is ≥ 2 cells thick
- **histologically**

- **clinically**

The latest iteration of the *Retina* book refers to this pigment as “oxygenated carotenoids, in particular lutein and zeaxanthin”
Changes in retinal thickness. Two sections through the central (A) and peripheral (B) regions of the retina, aligned at the retinal pigment epithelium. The peripheral retina is thinner and has only rare cell nuclei in the ganglion cell layer (the uppermost layer of nuclei).
We define the term *macula*…

- **anatomically**, it is the retinal area in which the ganglion-cell layer is $\geq 2$ cells thick
- **histologically**, it is the retinal area containing xanthophyll pigment
- **clinically**
We define the term *macula*…

- **anatomically**, it is the retinal area in which the ganglion-cell layer is ≥ 2 cells thick
- **histologically**, it is the retinal area containing xanthophyll pigment
- **clinically**...Xanthophyll gives the macula a slight yellowish hue (hence the ‘full’ name of the macula being the *macula lutea*)
**Retinal Anatomy and Histology**

*Macula lutea* If you use your imagination, you can sort of see that the macula has a yellow tint
We define the term *macula*…

- **anatomically**, it is the retinal area in which the ganglion-cell layer is $\geq 2$ cells thick
- **histologically**, it is the retinal area containing xanthophyll pigment
- **clinically**, it is the retinal area bounded by the temporal vascular arcades
The clinical macula
Speaking of the clinical macula… Let’s look in some detail at its topography
As said previously, the *macula* is defined clinically as the area bounded by the temporal arcades. It has a diameter of 5.5 to 6 mm or so.
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The macula is organized around the *fovea*. The fovea is the central ~1.5 mm of the macula—about the size of an ONH. Its outer edge is the location at which the foveal depression starts. It contains mostly (but not exclusively) cones.
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The ‘floor’ of the fovea is the *foveola*, an area ~0.35 mm in diameter—about the size of a small optic-disc cup. The foveola contains only cones and a few glial cells; the rest of the retinal layers were left behind along the walls of the fovea.
Foveola
Foveola starts about here
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*Next we’ll describe the rest of the macula from the fovea outward*
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The *parafoveal zone* is the donut-shaped area about 0.5 mm in width that surrounds the fovea. (The inner edge of the donut = the outer edge of the fovea.)
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Next we'll describe the rest of the macula from the fovea outward.
The *parafoveal zone* is the donut-shaped area about 0.5 mm in width that surrounds the fovea. (The inner edge of the donut = the outer edge of the fovea.). The parafoveal zone is where the GCL, INL and OPL are all at their thickest.

Next we’ll describe the rest of the macula from the fovea **outward**.
The **parafoveal zone** is the donut-shaped area about 0.5 mm in width that surrounds the fovea. (The inner edge of the donut = the outer edge of the fovea.). The parafoveal zone is where the GCL, INL and OPL are all at their thickest.

The remainder of the clinical macula—ie, the portion beyond the parafoveal zone—is the **perifoveal zone**. It is about 1.5 mm wide.

*Next we’ll describe the rest of the macula from the fovea outward*
In the fovea lies an area—the foveal avascular zone (FAZ)—within which no vasculature is present. The FAZ is typically about the same size as the foveola, but considerable variability exists among individuals.
Next let’s look at the retina’s blood supplies.
How many **blood supplies** does the retina receive?
How many blood supplies does the retina receive? Two
Blood supply:
Central retinal artery

These are the sources of the retina’s two blood supplies

Blood supply:
Choriocapillaris
Retinal Anatomy and Histology

- Retinal Layers
  - Internal limiting membrane
  - Nerve fiber layer
  - Ganglion cell layer
  - Inner plexiform layer
  - Inner nuclear layer
  - Outer plexiform layer
  - Outer nuclear layer
  - External limiting membrane
  - Rod & cone inner and outer segments

- RPE
- Bruch’s membrane

Blood supply:
- Central retinal artery
- Choriocapillaris

These are the layers supplied by each source
Here is a photomicrograph of the normal human retina.

- Internal limiting membrane
- Nerve fiber layer
- Ganglion cell layer
- Inner plexiform layer
- Inner nuclear layer
- Outer plexiform layer
- Outer nuclear layer
- Layer of Rods and Cones
- Retinal pigmented epithelium
- Choroid

(No question—proceed when ready)
Here is a photomicrograph of the normal human retina. Here, approximately, is the demarcation between the layers perfused by the CRA vs the choriocapillaris.
Here is a photomicrograph of the normal human retina. Here, approximately, is the demarcation between the layers perfused by the CRA vs the choriocapillaris.

Standard (ie, dye-based) FA allows visualization of the retinal and choroidal vasculatures, but the layers are all superimposed upon one another, making it impossible to distinguish among them.

(No question—proceed when ready)
Here is a photomicrograph of the normal human retina. Here, approximately, is the demarcation between the layers perfused by the CRA vs the choriocapillaris.

Instead, let’s use *en face* OCTA to look at the ultrastructure of foveal circulation.

Optical coherence tomography (OCT) through the fovea (cross-sectional, not *en face*).

(No question—proceed when ready)
Here is a photomicrograph of the normal human retina. Here, approximately, is the demarcation between the layers perfused by the CRA vs the choriocapillaris. Instead, let’s use *en face* OCTA to look at the ultrastructure of foveal circulation. For illustration purposes, we’re gonna pretend this is a photomicrograph of the fovea (it’s not).

Optical coherence tomography (OCT) through the fovea (cross-sectional, not *en face*).

The A in OCTA stand for ‘angiography.’ OCTA makes possible the visualization of the retinal vasculature without the need for intravascular dye as in FA.
Here is a photomicrograph of the normal human retina. Here, approximately, is the demarcation between the layers perfused by the CRA vs the choriocapillaris.

Instead, let’s use en face OCTA to look at the ultrastructure of foveal circulation. For illustration purposes, we’re gonna pretend this is a photomicrograph of the fovea (it’s not).

Optical coherence tomography (OCT) through the fovea (cross-sectional, not en face)

Retinal Anatomy and Histology

The A in OCTA stand for ‘angiography.’ OCTA makes possible the visualization of the retinal vasculature without the need for intravascular dye as in FA. Further, en face OCTA not only allows us to see the vasculature, it allows us to ‘slice’ and inspect it layer by layer—something that cannot be done via conventional FA.

(No question—proceed when ready)
Here is a photomicrograph of the normal human retina. Here, approximately, is the demarcation between the layers perfused by the CRA vs the choriocapillaris.

Instead, let’s use en face OCTA to look at the ultrastructure of foveal circulation. For illustration purposes, we’re gonna pretend this is a photomicrograph of the fovea (it’s not).

Optical coherence tomography (OCT) through the fovea (cross-sectional, not en face)
Pics A, B and C depict the parafoveal vasculature as we progress deeper into the retina.
Pics A, B and C depict the parafoveal vasculature as we progress deeper into the retina.
Pics A, B and C depict the parafoveal vasculature as we progress deeper into the retina.
Note the foveal avascular zone (FAZ) is present in all three layers.
As expected, imaging of the deeper retina (D) reveals the absence of intraretinal vasculature.
A clinical aside: Note that vessels in the deep retina, as seen here, often represent a CNVM such as is encountered in ARMD.

**CNVM:** Choroidal neovascular membrane  
**ARMD:** Age-related macular degeneration
Imaging of the choriocapillaris (E) indicates it contains a dense, robust vasculature.
Imaging of the choriocapillaris (E) indicates it contains a dense, robust vasculature. As expected, note the absence of a void corresponding to the FAZ.
Next let’s look in detail at the function and structure of the RPE
RPE: Functions

1) Outer blood-ocular barrier
   - Formed by zonulae occludens near cell apices

2) Phagocytosis of rod/cone outer segments

3) Vitamin A metabolism
   - Retinol acquired, stored and transported by RPE
RPE: Functions

1) Outer \textit{blood-retinal barrier}

2)

3)
RPE: Functions

1) Outer blood-retinal barrier
   - Formed by zonulae occludens near cell apices

2)

3)
RPE: Functions

1) Outer **blood-retinal barrier**
   - Formed by *zonulae occludens* near cell apices

2) As an aside, the *inner* blood-retinal barrier is formed by tight junctions between endothelial cells of the retinal vasculature
RPE: Functions

1) Outer **blood-retinal barrier**
   - Formed by **zonulae occludens** near cell apices

2) **Phagocytosis of rod/cone outer segments**

3)
RPE: Functions

1) Outer blood-retinal barrier
   - Formed by zonulae occludens near cell apices

2) Phagocytosis of rod/cone outer segments

3) Vitamin A metabolism
RPE: Functions

1) Outer blood-retinal barrier
   - Formed by zonulae occludens near cell apices

2) Phagocytosis of rod/cone outer segments

3) Vitamin A metabolism
   - Retinol acquired, stored and transported by RPE
The five layers of Bruch’s membrane:

1) **Basement membrane** of RPE
2) 
3) 
4) 
5)
The five layers of Bruch’s membrane:

1) **Basement membrane** of RPE
2) Inner **collagenous** layer
3) 
4) 
5)
The five layers of Bruch’s membrane:

1) **Basement membrane** of RPE
2) Inner **collagenous** layer
3) **Elastic** layer
4) 
5) 

Innermost

Outermost
The five layers of Bruch’s membrane:

1) **Basement membrane** of RPE
2) Inner **collagenous** layer
3) **Elastic** layer
4) Outer **collagenous** layer
5)
The five layers of Bruch’s membrane:

1) **Basement membrane** of RPE
2) Inner **collagenous** layer
3) **Elastic** layer
4) Outer **collagenous** layer
5) **Basement membrane** of choriocapillaris

**Innermost**

**Outermost**
The five layers of Bruch’s membrane:

0) **RPE cells**

1) **Basement membrane** of RPE
2) Inner **collagenous** layer
3) **Elastic** layer
4) Outer **collagenous** layer
5) **Basement membrane** of choriocapillaris

The RPE cells themselves go here.
The five layers of Bruch's membrane:

1) Basement membrane of RPE
2) Inner collagenous layer
3) Elastic layer
4) Outer collagenous layer
5) Basement membrane of choriocapillaris

So, the plasma membranes of the RPE cells...
The five layers of Bruch’s membrane:

1) Basement membrane of RPE
2) Inner collagenous layer
3) Elastic layer
4) Outer collagenous layer
5) Basement membrane of choriocapillaris

So, the plasma membranes of the RPE cells... sit directly on their BM

0) RPE cells

Innermost

Outermost
The five layers of Bruch's membrane:

1. Basement membrane of RPE
2. Inner collagenous layer
3. Elastic layer
4. Outer collagenous layer
5. Basement membrane of choriocapillaris

PR outer segs are next
The five layers of Bruch’s membrane:

- Basement membrane of RPE
- Inner collagenous layer
- Elastic layer
- Outer collagenous layer
- Basement membrane of choriocapillaris

Note that both the RPE apical membranes…
The five layers of Bruch’s membrane:

1. Basement membrane of RPE
2. Inner collagenous layer
3. Elastic layer
4. Outer collagenous layer
5. Basement membrane of choriocapillaris

Note that both the RPE apical membranes and their basal membranes...
The five layers of Bruch’s membrane:

1) Basement membrane of RPE
2) Inner collagenous layer
3) Elastic layer
4) Outer collagenous layer
5) Basement membrane of choriocapillaris

Note that both the RPE apical membranes and their basal membranes are highly infolded.
The five layers of Bruch's membrane:

1. Basement membrane of RPE
2. Inner collagenous layer
3. Elastic layer
4. Outer collagenous layer
5. Basement membrane of choriocapillaris

But note further that, while the PRs closely interdigitate with these infoldings…
The five layers of Bruch's membrane:

- Baseline membrane of RPE
- Inner collagenous layer
- Elastic layer
- Outer collagenous layer
- Baseline membrane of choriocapillaris

But note further that, while the PRs closely interdigitate with these infoldings…
The five layers of Bruch's membrane:

1. Basement membrane of RPE
2. Inner collagenous layer
3. Elastic layer
4. Outer collagenous layer
5. Basement membrane of choriocapillaris

Recall that a central function of the RPE is to provide metabolic support for the PRs. The interdigitations greatly increase the total surface area of PR-RPE contact, thereby facilitating these metabolic efforts.

But note further that, while the PRs closely interdigitate with these infoldings…
The five layers of Bruch's membrane:

- **Basement membrane of RPE**
- **Inner collagenous layer**
- **Elastic layer**
- **Outer collagenous layer**
- **Basement membrane of choriocapillaris**

- **1)** Bipolar cells
- **0) PR outer segs**
- **-2) RPE cells**
- **-1) RPE cells**
- **-1) PR outer segs**

Retinal Anatomy and Histology
The five layers of Bruch’s membrane:

1. Basement membrane of RPE
2. Inner collagenous layer
3. Elastic layer
4. Outer collagenous layer
5. Basement membrane of choriocapillaris

-2) Bipolar cells
-1) PR outer segs
0) RPE cells
1) Retinal Anatomy and Histology

Innermost
Outermost
Down here is…
The five layers of Bruch’s membrane:

1. Basement membrane of RPE
2. Inner collagenous layer
3. Elastic layer
4. Outer collagenous layer
5. Basement membrane of choriocapillaris

The choriocapillaris

Retinal Anatomy and Histology
The five layers of Bruch’s membrane:

1) Basement membrane of RPE
2) Inner collagenous layer
3) Elastic layer
4) Outer collagenous layer
5) Basement membrane of choriocapillaris

Retinal Anatomy and Histology

-2) Bipolar cells

-1) PR outer segs

0) RPE cells RPE cells

And the choroid
Next we will look at macular OCT, and relate it to what we’ve learned about the anatomy of the retina.
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OCT stand for optical coherence tomography. It allows cross-sectional imaging of ocular structures, including the retina (tomography means ‘cross-sectional image’).
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OCT stand for *optical coherence tomography*. It allows cross-sectional imaging of ocular structures, including the retina (tomography means ‘cross-sectional image’).

It works via *interferometry*: A beam of coherent light is directed toward the retina, and reflects when it encounters boundaries between tissue layers of differing optical properties. The device gathers the reflected light and compares it to a standardized beam of light reflected from a reference mirror.
OCT stand for *optical coherence tomography*. It allows cross-sectional imaging of ocular structures, including the retina (tomography means ‘cross-sectional image’).

It works via **interferometry**: A beam of coherent light is directed toward the retina, and reflects when it encounters boundaries between tissue layers of differing optical properties. The device gathers the reflected light and compares it to a standardized beam of light reflected from a reference mirror. In *spectral-domain OCT* (sdOCT), differences in the frequencies of the two reflected beams are used to infer the ultrastructure of the retina.
Recall this slide from earlier. The time/effort you spent committing it to memory is about to pay off.

The ELM
The myoid zone
The ellipsoid zone
PR outer segs
Interdigitation zone
RPE/Bruch’s membrane
Recall this slide from earlier. The time/effort you spent committing it to memory is about to pay off. As we will see, these structures are visible on sdOCT, and it’s vital you be able to recognize them.

- The ELM
- The myoid zone
- The ellipsoid zone
- PR outer segs
- Interdigitation zone
- RPE/Bruch’s membrane
Let's identify the RPE/Bruch’s complex first.

RPE/Bruch’s membrane

The ELM
The myoid zone
The ellipsoid zone
PR outer segs
Interdigitation zone

Ignore this line
(And this one)
Retinal Anatomy and Histology

Let’s identify the RPE/Bruch’s complex first. The RPE/Bruch’s complex is the outermost heavy white line.

The ELM
The myoid zone
The ellipsoid zone
PR outer segs
Interdigitation zone

RPE/Bruch’s membrane
(The green line is pointing to it)

Now down here
Retinal Anatomy and Histology

Let’s identify the **RPE/Bruch’s complex** first. The RPE/Bruch’s complex is the outermost heavy white line.

(Locating the same structure on a full-size OCT image)

It’s hard to make out here…
Let’s identify the **RPE/Bruch’s complex** first. The RPE/Bruch’s complex is the outermost heavy white line.

(Locating the same structure on a full-size OCT image)
Let’s identify the **RPE/Bruch’s complex** first. The RPE/Bruch’s complex is the outermost heavy white line...

It’s hard to make out here... ...but you can see it clearly here.

You must identify **and** assess the integrity of the RPE/Bruch’s complex **on every OCT you read!**

(Locating the same structure on a full-size OCT image)
Next is the interdigitation zone.
Next is the interdigitation zone.
It is the next heavy white line.

The interdigitation zone
RPE/Bruch’s membrane
PR outer segs
The ELM
The myoid zone
The ellipsoid zone
(Ditto)
Next is the interdigitation zone. It is the next heavy white line.

Again, it's hard to make out here...

(Locating the same structure on a full-size OCT image)
Next is the **interdigitation zone**.

It is the next heavy white line

Again, it's hard to make out here...

...but it can be seen clearly over here.

(Locating the same structure on a full-size OCT image)
Retinal Anatomy and Histology

Next is the interdigitation zone. It is the next heavy white line...but it can be seen clearly over here.

The interdigitation zone is not always clearly visible on OCT

(Locating the same structure on a full-size OCT image)
Next is the PR outer segs.

RPE/Bruch’s membrane

Interdigitation zone

PR outer segs

Interdigitation zone

RPE/Bruch’s membrane
Next is the PR outer segs.
In the dark band just inside the interdigitation zone
Next is the **PR outer segs**.
In the dark band just inside the interdigitation zone

![Image of retinal anatomy](image)

*This band is easiest to see here…*
*…and harder over here.*

**The PR outer segs band is taller at the fovea because the outer segs are longer here**

*(Locating the same structure on a full-size OCT image)*
Next is the ellipsoid zone.
Next is the ellipsoid zone. It is the heavy white band inside the outer segs.
Next is the **ellipsoid zone**. It is the heavy white band inside the outer segments.

Many PR and other outer-retinal diseases manifest as changes to the EZ. Like the RPE/Bruch’s complex, **the EZ must be identified and assessed on every retinal OCT!**

(Locating the same structure on a full-size OCT image)
Next is the myoid zone.

The ELM

The myoid zone

The ellipsoid zone

PR outer segs

Interdigitation zone

RPE/Bruch’s membrane

RPE/Bruch’s membrane

Ellipsoid zone (the white line)

Interdigitation zone

PR outer segs (dark area)
Next is the myoid zone.
The dark band just inside the ellipsoid zone.
Retinal Anatomy and Histology

Next is the **myoid zone**. The dark band just inside the ellipsoid zone.

(Locating the same structure on a full-size OCT image)
Next is the ELM.

**The ELM**
The myoid zone

**The ellipsoid zone**

**PR outer segs**

**Interdigitation zone**

RPE/Bruch’s membrane

Ellipsoid zone (the white line)

Interdigitation zone

RPE/Bruch’s membrane
Next is the ELM. It’s the thin white band just inside the myoid zone.
Next is the ELM. It’s the thin white band just inside the myoid zone.

(Locating the same structure on a full-size OCT image)
Quiz yourself by toggling back and forth between this slide and the next
Retinal Anatomy and Histology

Quiz yourself by toggling back and forth between this slide and the next
An important meta-point to come away with from all this is, OCT bands are determined by differences in tissue reflectivity, but *differences in reflectivity don't necessarily correlate 1:1 with retinal anatomy.*
An important meta-point to come away with from all this is, OCT bands are determined by differences in tissue reflectivity, but *differences in reflectivity don’t necessarily correlate 1:1 with retinal anatomy*. Consider the ellipsoid and myoid of the PRs. They are parts of the same anatomic structure (the PR inner seg), but to the OCT scanner, they look *radically* different from one another.
An important meta-point to come away with from all this is, OCT bands are determined by differences in tissue reflectivity, but differences in reflectivity don't necessarily correlate 1:1 with retinal anatomy. Consider the ellipsoid and myoid of the PRs. They are parts of the same anatomic structure (the PR inner seg), but to the OCT scanner, they look radically different from one another. Remember, the OCT is under no obligation to ‘see’ the retina the way an anatomist sees it.
For the remainder of our intro to OCT, we’re going to switch gears and work outward from the inner aspect of the scan.

(No question—proceed when ready)
First things first: In order to ‘set the floor’ re how far down we need to go, locate the ELM:
First things first: In order to ‘set the floor’ re how far down we need to go, locate the ELM:
Next, let’s identify the following preretinal structures:
--The formed vitreous
Next, let’s identify the following preretinal structures:

-- The formed vitreous
-- The posterior cortical vitreous
Next, let’s identify the following preretinal structures:

-- The formed vitreous
-- The posterior cortical vitreous
-- The preretinal space
Next, let's identify the following preretinal structures:

-- The formed vitreous
-- The posterior cortical vitreous
-- The preretinal space

And now the innermost **retinal** structure, the ILM:
Next commences the layers of neural elements, starting with the **nerve fiber layer**
Next commences the layers of neural elements, starting with the nerve fiber layer (NFL). On this scan, this side is temporal, and this side is nasal.
Next commences the layers of neural elements, starting with the nerve fiber layer (NFL). On this scan, this side is temporal, and this side is nasal. You can tell because the NFL is always thicker on the nasal side, owing to the fact that this is the side the papillomacular bundle is located on.
Next commences the layers of neural elements, starting with the nerve fiber layer (NFL). On this scan, this side is temporal, and this side is nasal. You can tell because the NFL is always thicker on the nasal side, owing to the fact that this is the side the papillomacular bundle is located on. The PMB is the set of fibers running from the fovea directly to the ONH.
Retinal Anatomy and Histology

Papillomacular bundle

Arcuate bundles

Optic disc

Fovea

Horizontal raphe
Next commences the layers of neural elements, starting with the nerve fiber layer. As the composition of the layers alternate, the next one must contain cell bodies; sure enough, it is the ganglion cell layer.
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But this is incorrect!
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Why is it incorrect? Because the OCT has three layers left—not two!
Look carefully at the remaining darker portion, and you will note the presence of a subtle demarcation line within it. (I will point it out on the next slide.)
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Look carefully at the remaining darker portion, and you will note the presence of a subtle demarcation line within it. (I will point it out on the next slide.) This line demarcates between the outer nuclear layer and Henle’s layer.
We mentioned Henle’s layer earlier in the context of the OPL, when we noted that the terms were often (and erroneously) treated as synonyms.
We mentioned Henle’s layer earlier in the context of the OPL, when we noted that the terms were often (and erroneously) treated as synonyms. Here’s why they’re not synonymous. Recall that the OPL consists of the axonal processes of the PRs and the dendritic processes of the bipolar cells. (There’s some horizontal-cell processes in there as well.)
However, in the fovea/parafoveal region, the axonal processes of the PRs are elongated, and radiate directly away from the foveal center in all directions, running almost parallel to the retinal surface (see above). *These long, radially oriented axonal fibers comprise the Henle’s layer portion of the OPL.*
You can now appreciate the appearance of the OCT in the foveal region. The orientation of the PR axons leads the OCT to ‘see’ them as a layer separate and distinct from that of the bipolar-cell dendrites with which they form the outer plexus.
You can now appreciate the appearance of the OCT in the foveal region. The orientation of the PR axons leads the OCT to ‘see’ them as a layer separate and distinct from that of the bipolar-cell dendrites with which they form the outer plexus. This is why it’s misleading to treat the terms *Henle’s layer* and *OPL* as synonyms: Technically speaking, *Henle’s layer* is the axonal portion of the OPL in the foveal and parafoveal region.
Highly relevant sidebar: The condition depicted above is *neuroretinitis*. (The *neuro-* part refers to the ONH swelling.) The classic cause is infection with *Bartonella henselae*; it is a form of *cat-scratch disease*. The descriptive term for the appearance of the macula in neuroretinitis is a *macular star*.
Highly relevant sidebar: The condition depicted above is *neuroretinitis*. (The *neuro-* part refers to the ONH swelling.) The classic cause is infection with *Bartonella henselae*; it is a form of *cat-scratch disease*. The descriptive term for the appearance of the macula in neuroretinitis is a *macular star*.

The point of this sidebar: The reason a macular star looks the way it does is that the exudate is located in Henle’s layer, and thus it mirrors Henle’s radial orientation.
Make a connection in your head between the clinical appearance of a macular star…
Make a connection in your head between the clinical appearance of a macular star… and the OCT appearance of Henle’s layer.
Make a connection in your head between the clinical appearance of a macular star… and the OCT appearance of Henle’s layer. While they look nothing like one another, each arises from the same fundamental fact of retinal anatomy/histology!
One last word about this OPL/Henle’s layer issue—you will find that the BCSC books are not consistent in how they use these terms. (For example, the Retina book uses them as synonyms on one page, and as referring to separate layers two pages later.)
One last word about this OPL/Henle’s layer issue—you will find that the BCSC books are not consistent in how they use these terms. (For example, the Retina book uses them as synonyms on one page, and as referring to separate layers two pages later.) Likewise, you will frequently encounter OCT images labeled in a manner that is unclear or misleading regarding what is the OPL, what is Henle’s, and what is the ONL (eg, the above). You may also find that your program’s retina specialist disagrees with how I’ve laid things out here. Caveat emptor.
Quiz yourself by toggling back and forth between this slide and the next. When you’ve got it, you’re done!
Retinal Anatomy and Histology

- Posterior cortical vitreous
- Preretinal space
- ILM
- Formed vitreous
- ELM
- Outer nuclear layer
- NFL
- Ganglion cell layer
- Inner plexiform layer
- Inner nuclear layer
- Axonally portion of the OPL
  - Dendritic portion of the OPL
  - Axonal portion of the OPL
- aka Henle’s layer
That’s it! Go through this slide-set a couple of times (at least) until you feel like you have a handle on it. When you’re ready, do slide-set R17, which covers this material in a Q&A format (and more detail).