

**The Optics of Color  
from Lenses to Vision**

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Phernell Walker, MBA, ABOM, NCLEC, LDO  
Renowned International Speaker  
Chair-elect ABO-NCLE Board of Directors



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**PURE OPTICS**

**Optometric  
Strategy** | **Business  
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Education**

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- ❖ Author | Pure Optics
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- ❖ American Board of Opticianry | Chair-elect Board of Directors
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- ❖ National Contact Lens Examiners Certified (NCLEC)

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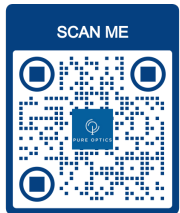
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e: phernell@pure-optics.com

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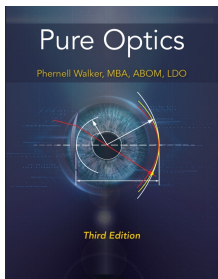
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Reference Resource

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Pure Optics  
by  
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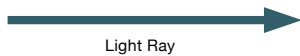
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Light Propagation

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- Light is composed of particles of energy called light quantum or photon
- A light quantum has energy with zero mass



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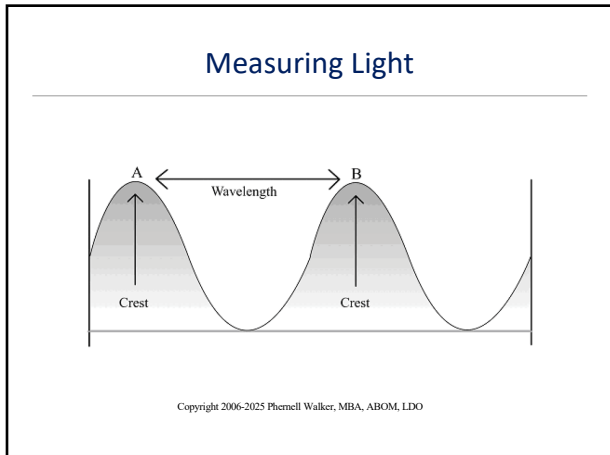
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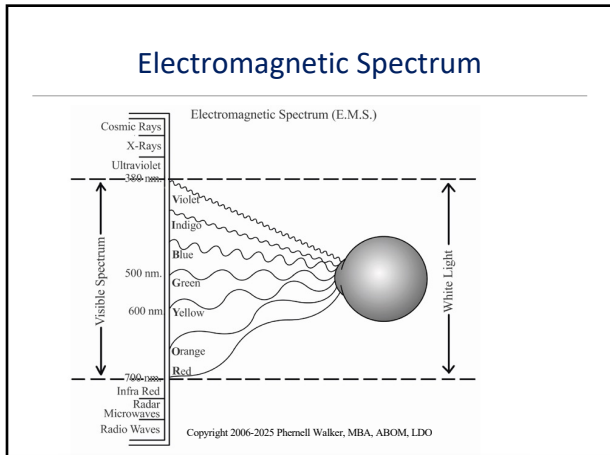
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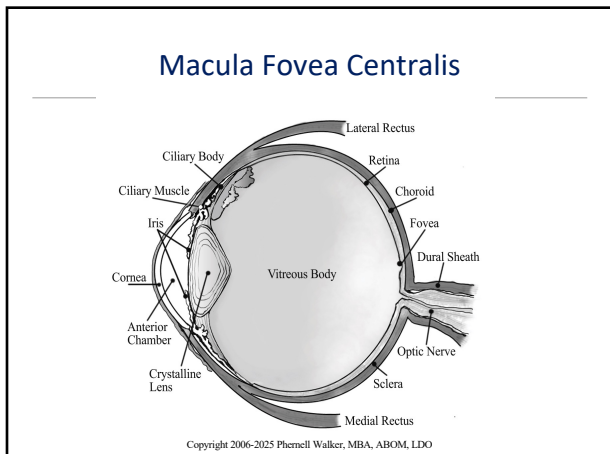
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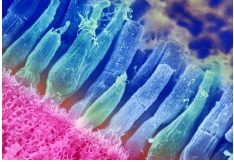
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### Photoreceptors

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Photoreceptors collect light and transform the light energy into chemical energy.

- Rods (125 million) - cylindrical shaped. Detects movement, peripheral and night vision (photopigment rhodopsin)
- Cones (6 million) - conic share receptors located at the macula fovea centralis (photopigment iodopsin)



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### Photoreceptors

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- Cones (6 million) - conic share receptors located at the macula fovea centralis
- Photopigment iodopsin
- Three different types of cones:

Cone Types		
S	detects Blue	460nm
M	detects Green	525nm
L	detects Red	650nm

Approximately 60% of the cones are red, 30% are green, and only 2% are blue sensitive. The remaining 8% is a blend

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### Visual Pathway

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- Ganglion cells - located in the inner retina. Responsible for sending the information in the form of chemical energy to the optic nerve
- Optic Nerve - sends the data to the brain for interpretation in the visual cortex

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## Color Deficiency

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### Dichromatic Deficiency

- Protanopia- Red
- Deuteranopia- Green
- Tritanopia- Blue

### Monochromat & Trichromat

- Monochromat- sees shades of grey
- Trichromat- has all three pigments (normal)

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## ICD-10

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 H53.50 **billable diagnosis code** used to specify a medical diagnosis of unspecified color vision deficiencies

 H53.53 deuteranopia

 H53.54 protanopia

 Valid during the fiscal year 2021 from October 01, 2020, through September 30, 2021, for the submission of HIPAA-covered transactions.

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## Pseudoisochromatic Plates

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- Ishihara Plates
- Hardy-Rand-Rittler Plates
- Farnsworth D-15 Dichotomous

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### Farnsworth D-15 Dichotomous

- Color arrangement test
- Focus on color likeness
- Performed with a dark back ground
- Colorblindness type
- Colorblindness severity
- 1988 by Vingrys and King-Smith



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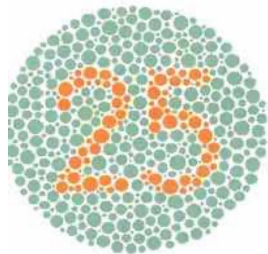
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### Pseudoisochromatic Plates



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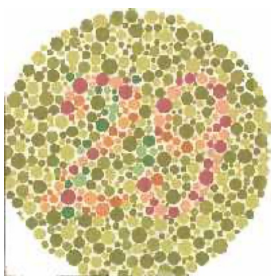
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### Pseudoisochromatic Plates



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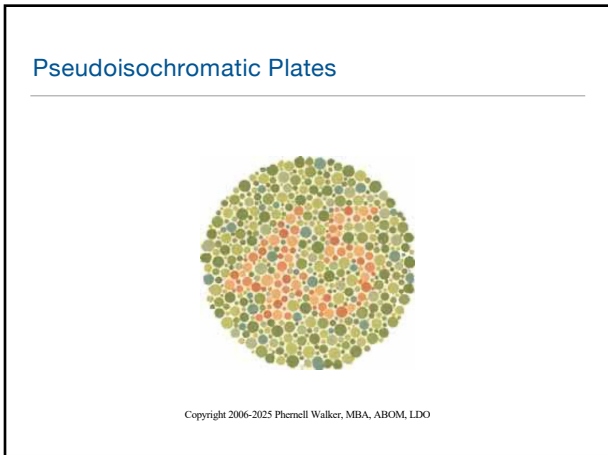
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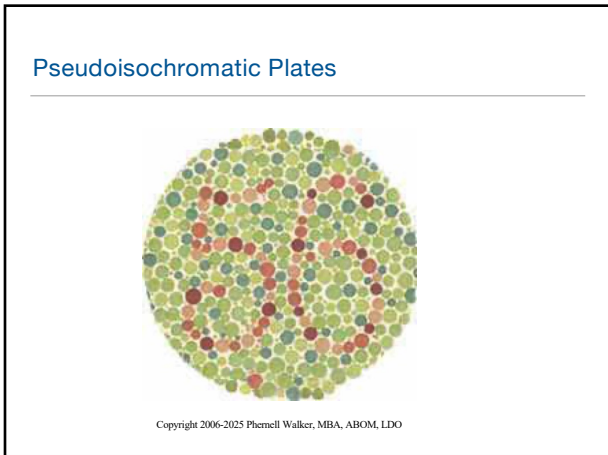
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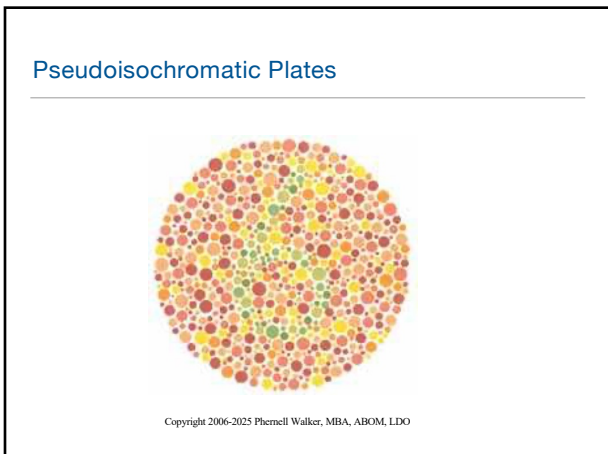
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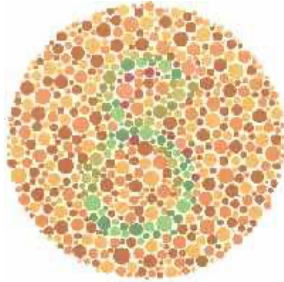
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Pseudoisochromatic Plates



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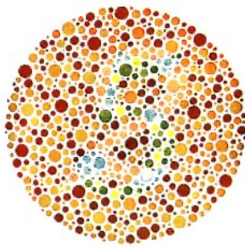
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Pseudoisochromatic Plates



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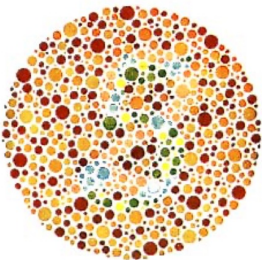
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Pseudoisochromatic Plates

- Normal color vision will see a 5 revealed in the dot pattern
- Persons with red - green color blindness will see a 2 revealed in the dots



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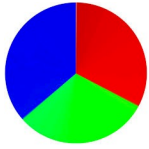


### Primary Colors

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**Primary colors** - include colors that can be combined to create a series of colors

- Red
- Green
- Blue



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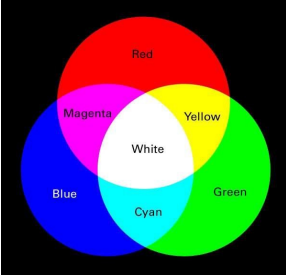
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### Additive Colors

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RGB Color Model

- **Red**
- **Green**
- **Blue**



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### Seeing in Color

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- Objects do not have color
- Color is in the light that shines upon it and is ultimately reflected to our eyes



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### Seeing in Color

- When visible light strikes an object and a specific frequency becomes absorbed, that frequency of light will never make it to our eyes
- Any visible light that strikes the object and becomes reflected to our eyes will contribute to the color appearance of that object. So the color is not in the object itself, but in the light that strikes the object and ultimately reaches our eye

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### Color Absorption

- Objects contain atoms capable of selectively absorbing one or more frequencies of the visible light that shine upon it
- If an object absorbs all of the frequencies of visible light except for the frequency associated with blue light, then the object will appear blue



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### Transparent Substrates

- Transparent substrates allow one or more visible frequencies light through them
- Colors not transmitted are absorbed



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### Cognitive Load

1. Red, Blue, Green, Green, Blue, Red, Red, Blue, Green, Green
2. Blue, Blue, Red, Green, Blue, Blue, Green, Red, Red, Blue
3. Blue, Red, Green, Green, Blue, Red, Green, Blue, Red, Blue
4. Green, Blue, Green, Blue, Red, Red, Green, Blue, Red, Green
5. Blue, Blue, Red, Green, Blue, Blue, Green, Red, Red, Blue

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### Decreased Cognitive Load

1. Red, Blue, Green, Green, Blue, Red, Red, Blue, Green, Green
2. Blue, Blue, Red, Green, Blue, Blue, Green, Red, Red, Blue
3. Blue, Red, Green, Green, Blue, Red, Green, Blue, Red, Blue
4. Green, Blue, Green, Blue, Red, Red, Green, Blue, Red, Green
5. Blue, Blue, Red, Green, Blue, Blue, Green, Red, Red, Blue

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### Increased Cognitive Load

1. Red, Blue, Green, Green, Blue, Red, Red, Blue, Green, Green
2. Blue, Blue, Red, Green, Blue, Blue, Green, Red, Red, Blue
3. Blue, Red, Green, Green, Blue, Red, Green, Blue, Red, Blue
4. Green, Blue, Green, Blue, Red, Red, Green, Blue, Red, Green
5. Blue, Blue, Red, Green, Blue, Blue, Green, Red, Red, Blue

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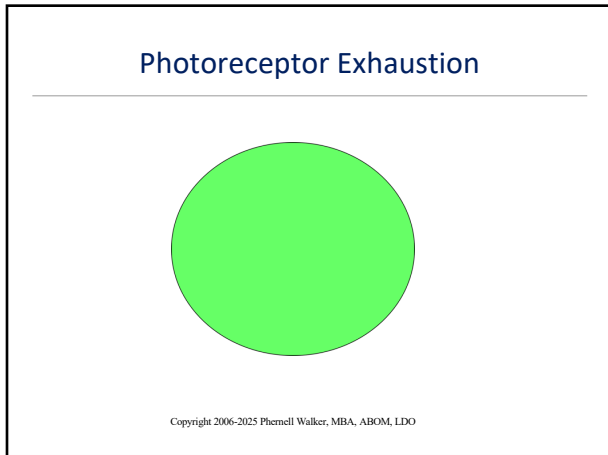
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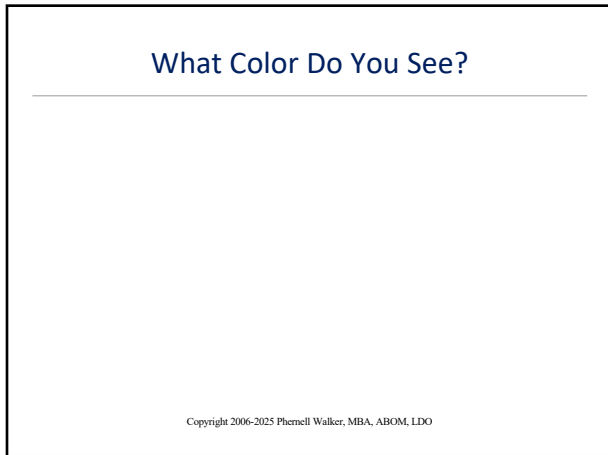
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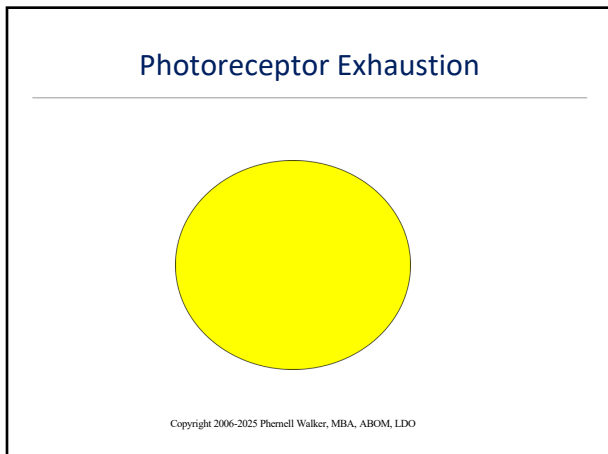
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What Color Do You See?

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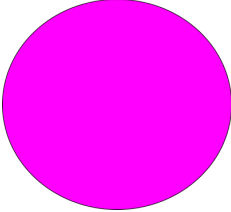
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Photoreceptor Exhaustion

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What Color Do You See?

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### Avulux

- Migraines – 60% triggered by light
- Blue and amber light affect cells that secrete melatonin
- Leads to migraine attacks and increased light-triggered pain
- FDA approved
- Filters 97% blue, amber, and red-light (nm)

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### Enchroma Lenses Shift Color Saturation

- Special Low Pass filters (LP Filter Optimization) can be used to shift the color saturation between colors.
- 10 to 110 nm (within the 400 to 700 nm range).
- These filters work by filtering specific wavelengths of light creating a divide in the overlap of colors.
- Substrate is Trivex

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### Low Pass Filters Shift Color Saturation

Parameter	Value
Default thickness	¼ wavelength of color
Tolerance	+/- 0.2
Thin Film	MgF2
Effective area	90%
Surface Flatness	3 fringes
Inclusion and Dig	<40 µm within the effective area
Scratch Width	<10 µm within the effective area

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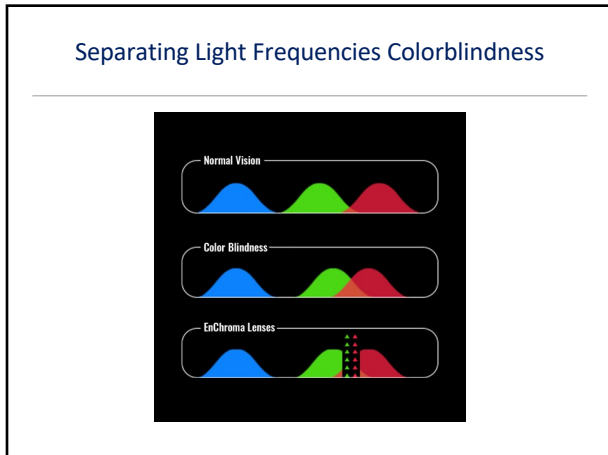
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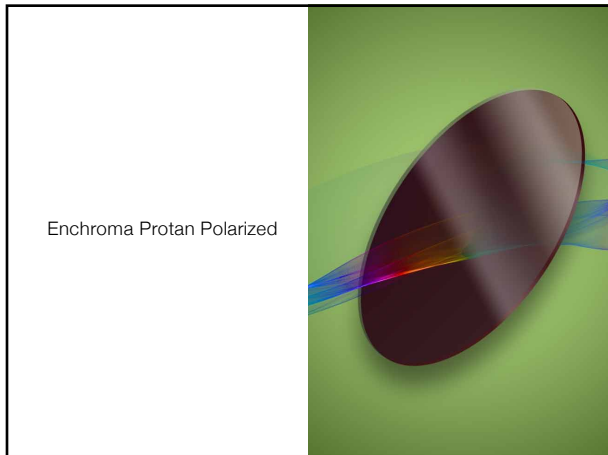
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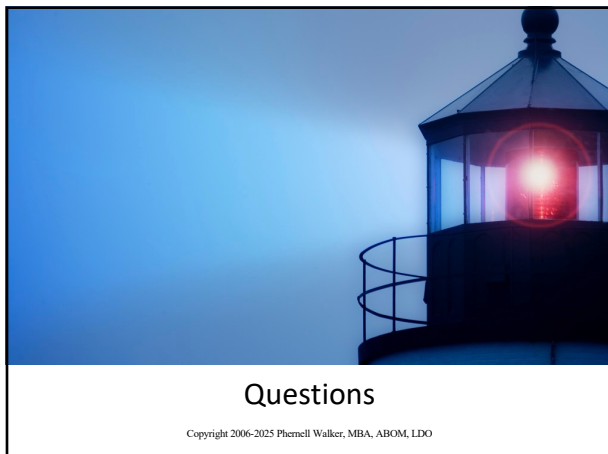
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