

# THE FUTURE OF RETINAL IMAGING HAS ARRIVED!

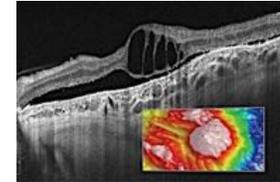
Joseph Pizzimenti, OD, FAAO

## COURSE GOAL

- To provide a broad overview of posterior segment technologies and their clinical applications.

What is it?  
How does it work?  
Interpretation and clinical use

## QUESTIONS AND COMMENTS?



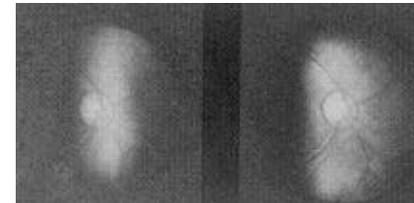
“Most major advances in the understanding of retinal diseases have been preceded by advances in imaging.”

Richard Spaide, MD  
NY Retina Consultants

### *Milestones in Retinal Imaging*

Fundus Photography	1920s
Fluorescein Angiography	1950s
B-Scan Ultrasound	1970s
ICG Angiography (Digital)	1980s
CSLO (HRT), SLP (GDx)	1990s
■ OCT first demonstrated	1991
■ High-res Time Domain OCT	2001
■ Fourier (Spectral) Domain OCT	2006
■ OCT Angiography	2015

### *Milestones in Retinal Imaging*

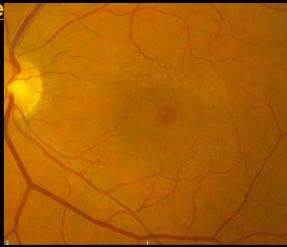


1909-Thorner's Stereo Photos

## Digital Photography

### ■ Features/Advantage

- Mydriatic
- Non-mydriatic
- No film
- Telemedicine
- High resolution
- Documentation
- Patient education

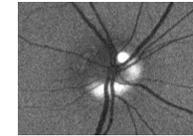


## Red-free

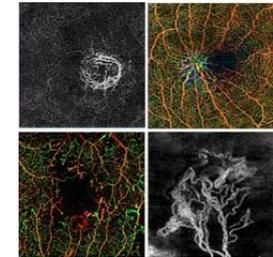


2018

En face OCT angiograms



FAF of ON Drusen



### Invasive

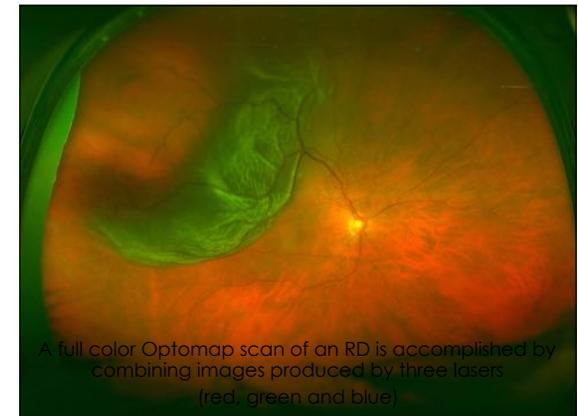
- Fluorescein angiography (FA)
- Indocyanine green angiography (ICGA)

### Non-invasive

- Optical coherence tomography (OCT/OCTA)
- A/B scan ultrasonography
- Fundus photography
- Fundus autofluorescence (FAF)
- Wide field fundus imaging
- Multispectral imaging (MSI)
- Multi-color (multichannel) imaging

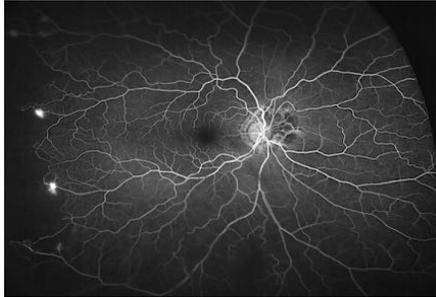
## MILESTONES IN IMAGING

Wide field SLO	2000
Other Wide Field Imaging Confocal Scanner Multi-color/channel/spectral Imaging Fundus Autofluorescence (FAF)	2000-2015
Wide field OCT/OCTA	2018



A full color Optomap scan of an RD is accomplished by combining images produced by three lasers (red, green and blue).

## CALIFORNIA WIDE-FIELD ANGIOGRAPHY



## CAUTION!

WIDE FIELD IMAGING DOES  
NOT  
REPLACE A DILATED RETINAL  
EXAMINATION.

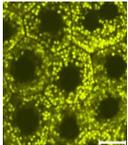
## FUNDUS AUTOFLUORESCENCE

While Angiography images BRB  
integrity, FAF captures  
**metabolic activity.**

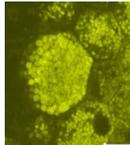
## Imaging Technologies: FAF

What is autofluorescence in the retina?

- FAF is the fluorescence of the lipofuscin molecule within the RPE cell layer that fluoresces with a certain wavelength.



19 years



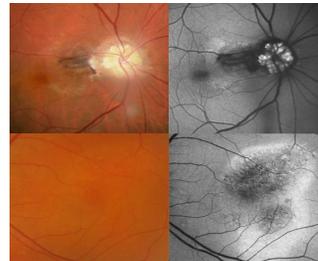
64 years

## AUTOFLUORESCENCE (FAF)

Early ID of disease.  
ON drusen  
CSC

Predictive marker  
increased FAF  
signal precedes  
dry AMD  
progression.

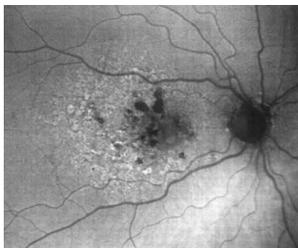
Monitor Dx.  
Functional  
correlation.



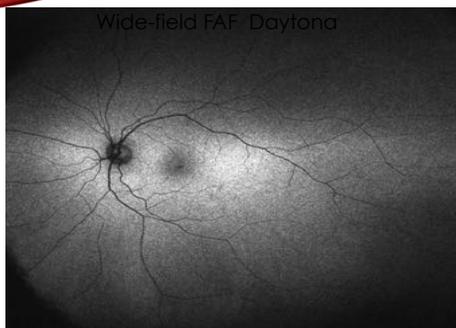
## Fundus Autofluorescence

Will be most useful for detection and  
monitoring of Dry AMD.

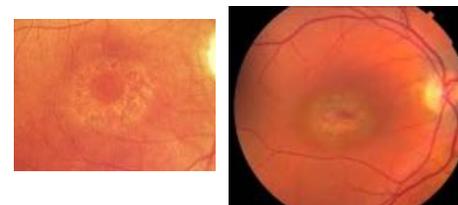
### FAF OF DRY AMD



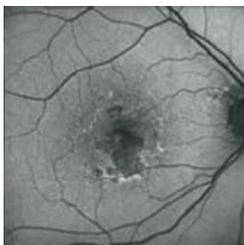
Wide-field FAF Dayton



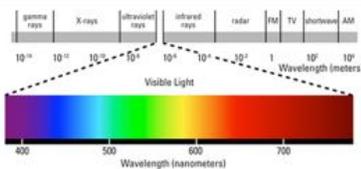
### Ocular Side Effects of Systemic Medications: Plaquenil



### Fundus Autofluorescence (FAF) in Plaquenil Maculopathy

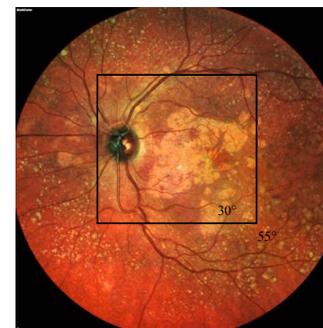


### How does MCI work?



- MCI is achieved using the principle of confocal scanning laser ophthalmoscopy (cSLO).
- Multicolor images are illuminated with three select color wavelengths: infrared, green, and blue.

### Wide Field Multicolor Imaging w/ Spectralis



## MCI and FAF on a Choroidal Mass



Multiple drusen appear well delineated in the Multi Color Image on right. Simultaneous SD-OCT confirms the confluent drusen pattern.

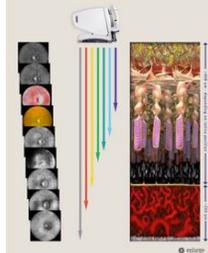


## What is Multispectral Imaging (MSI) ?

- The use of several non-overlapping discrete spectral bands, or slices, to highlight certain features within the field of view.
- Produces a series of en face slices of posterior segment tissue.
- FAF possible.

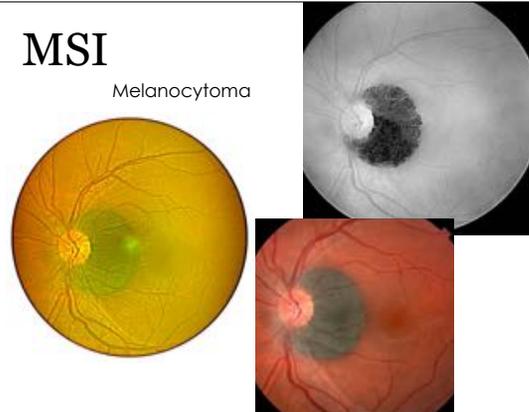
## Multi-spectral Imaging

- The RHA (Annidis)
- CCD camera
- Multiple LED light sources
- Automated spatial and spectral filters
- Operates across range of 450 to 900 nm

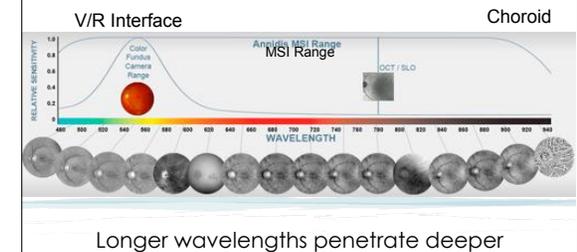


## MSI

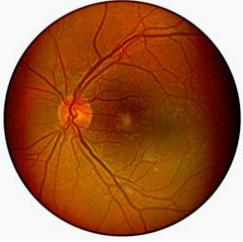
Melanocytoma



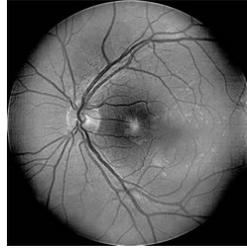
## Multi-spectral Imaging



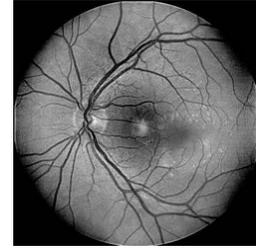
Pattern Dystrophy of RPE



Pattern Dystrophy of RPE



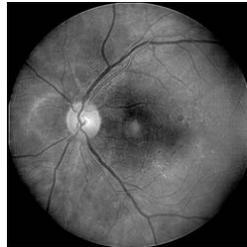
Pattern Dystrophy of RPE



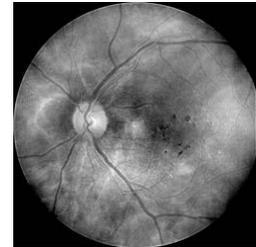
Pattern Dystrophy of RPE



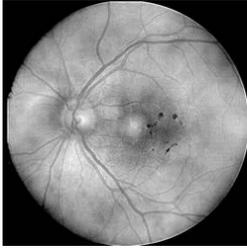
Pattern Dystrophy of RPE



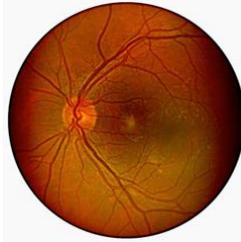
Pattern Dystrophy of RPE



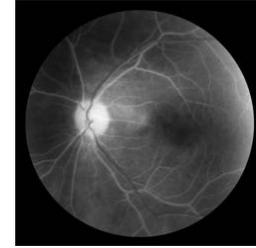
### Pattern Dystrophy of RPE



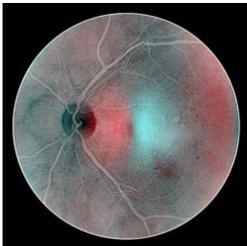
### Pattern Dystrophy of RPE



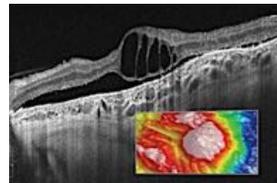
### Pattern Dystrophy of RPE



### Pattern Dystrophy of RPE



### QUESTIONS AND COMMENTS?

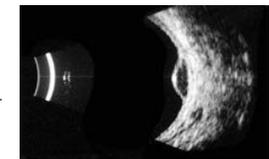


### Echography of Choroidal Melanoma

#### B-Scan Echogram

**B = Brightness**

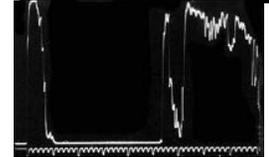
Assess topographic features, including tumor shape, surface contour and boundaries



#### A-Scan Echogram

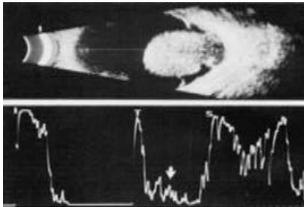
**A = Amplitude**

Internal structure, reflectivity, tumor height (elevation)



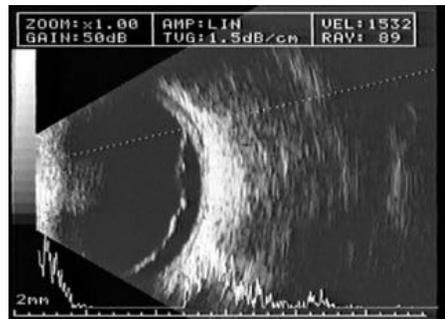
## Large Choroidal Melanoma

- B-scan
  - \*collar button shape (mushroom)
  - high reflectivity
  - \*regular internal structure
  - medium low reflectivity
  - \*choroidal excavation
- A-scan:
  - \*low to medium internal reflectivity
  - \*internal vascularity



## RD on A/B-scan

Acknowledgement: Dr. J. Nyman



## Dark Adaptometry in the Clinic Setting

- AdaptDx™ is an automated adaptometer (biophotometer).
- Measures the time for retinal adaptation after exposure to a light stimulus (Rod Intercept Time).
- Functional biomarker of early AMD.

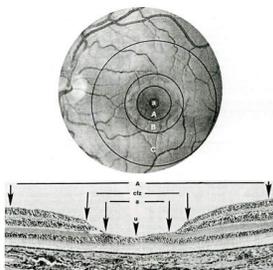


## A Rod-centric Model of Disease

In healthy, young adults, rods outnumber cones in the macula by 9:1.

Therefore, the macula may be described as cone-enriched but rod-dominated.

In the entire retina, rods outnumber cones 20:1.



**\*\*The earliest clinically visible morphologic feature of AMD is Drusen.**



Early detection of degenerative change, "Subclinical AMD" or "Pre-AMD".

Dark Adaptometry

- Rod Intercept (RI): analogous to Hb A1c



## WHAT IS OCT?

## WHAT IS OCT?

An optical imaging modality that performs high-resolution, cross-sectional tomographic imaging of the internal microstructure in materials and biologic systems by measuring back-scattered or back-reflected light. OCT images are two-dimensional data sets which represent the optical backscattering in a cross-sectional plane through the tissue.

-Fujimoto (2000)

## WHAT IS OCT?

A noninvasive high resolution optical imaging technology based on interference between a signal from an object under investigation and a local reference signal. OCT can produce in real time a cross-section image of the object, i.e. a two-dimensional image in the space with a lateral coordinate, axial coordinate.

Podoleanu (2000)

**D'oh!**



## WHAT IS OCT?

### OPTICAL

OCT is an imaging technology that is based on principles of physics, specifically optics.

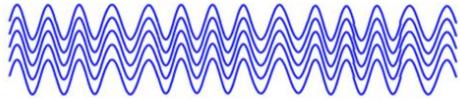
## WHAT IS OCT?

### COHERENCE

Coherent light is used in OCT imaging.

## COHERENT LIGHT

Light in which the photons are all in step.  
The change of phase within the beam occurs for all the photons at the same time.  
There are no abrupt phase changes within the beam.  
Light produced by lasers is both coherent and monochromatic (of one color).



## WHAT IS OCT?

### TOMOGRAPHY

A technique used for displaying a representation of a cross section through a human body or a tissue.

## EXAMPLES OF TOMOGRAPHY

Origin

GREEK

tomos  
slice, section

ENGLISH

-graphy

→ tomography  
1930s

Computed Tomography  
CT Scan

Ultrasonography  
AKA Echography  
A-scan: 1-dimensional  
B-mode: 2-dimensional

LET'S TRY THIS AGAIN

## WHAT IS OCT?

Optical coherence tomography is a technology that uses coherent light to produce cross-sectional images.

-Pizzimenti (2018)



## OCT

The Big Dog in Post Seg Imaging

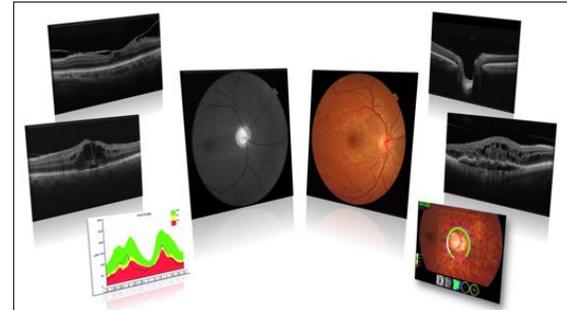


## OCT ADVANTAGES

This non-invasive, hi res imaging can be rapidly performed *in vivo*.

- *Optical biopsy*

AMD, DR, glaucoma, and other conditions can now be analyzed and correlated in real time to the symptomatology and prognosis.



Correlation of OCT results with history and other findings

## OCT PERFORMS MANY FUNCTIONS

- Measures retinal thickness
- Measures the retinal nerve fiber layer (RNFL)
- Measures the volume of the retina
- Creates retinal thickness maps
- Isolates and creates maps of the internal limiting membrane (ILM) and the retinal pigment epithelium (RPE)
- Measures various parameters of the optic disc
- Displays three-dimensional views
- Provides classic *C-scan (en face)* analyses, creating horizontal tissue sections

## OCT ADVANTAGES

**With SD-OCT, clinicians can:**

- Detect disease
- Evaluate treatment efficacy over time
- Quantify lesion thickness and volume
- Track disease progression
- Evaluate postoperative status
- Study 3-D views

## CAUTION!

OCT does  
not  
replace a dilated retinal examination.

## Fundus Biomicroscopy and BIO



A long time ago  
in a galaxy far, far away...

MIT  
Massachusetts  
Institute of  
Technology



## Milestones in OCT Imaging

OCT was first demonstrated in 1991.

Huang D, Swanson EA, Lin CP, Schuman JS, Stinson WG, Chang W, Hee MR, Flotte T, Gregory K, Puliafito CA, Fujimoto JG. Optical coherence tomography. Science. 1991;254:1178-1181.

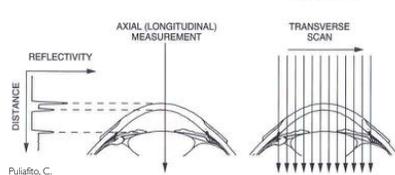
The first *in vivo* tomograms of the human optic disc and macula were demonstrated in 1993.

Swanson EA, Izatt JA, Hee MR, Huang D, Lin CP, Schuman JS, Puliafito CA, Fujimoto JG. In vivo retinal imaging by optical coherence tomography. Opt Lett. 1993;18:1864-1866.

Original research instrument 400 A-scans / second.

Current SD-OCT instruments have imaging speeds up to 85,000 A-scans / second.

AXIAL (A) MODE versus OPTICAL COHERENCE TOMOGRAPHY



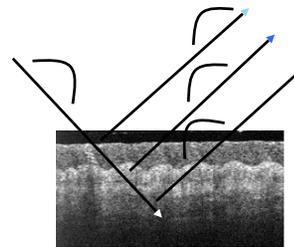
Puliafito, C.

A scan of the reflectivity of a sample tissue as a function of depth is referred to as an A-scan.

A cross-sectional tomograph is achieved by laterally combining a series of A-scans.

Two-dimensional data sets are digitized by a computer and presented as a gray-scale or false-color image.

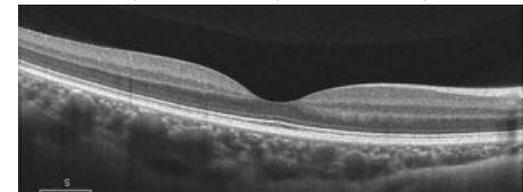
OCT is analogous to B-scan ultrasound.



## THE OCT B-SCAN

Two-dimensional, cross-sectional.

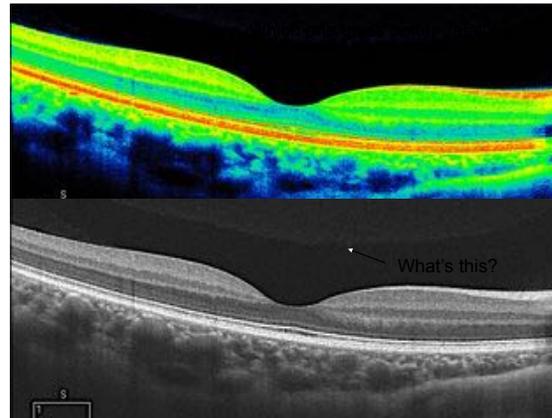
Used for qualitative and quantitative analysis.



## SCAN STRATEGIES

### Common Scan Options

- **Raster Line Scans**
  - Cross-sectional 2-D image
  - Extremely fast acquisition
  - Highest resolution (HD)
  - Enhanced depth imaging (EDI)
- **Cube Scans**
  - Volumetric images
  - Used to generate "en face" and 3-D visualization
  - Slower acquisition time (2.4 sec)
  - More prone to motion artifacts, blinks, etc
  - ON Cube
  - Macula Cube



## REFLECTIVITY

In general, anatomical structures perpendicular to the signal beam, such as nerve fibers and plexiform (synaptic) layers, are more reflective (brighter).

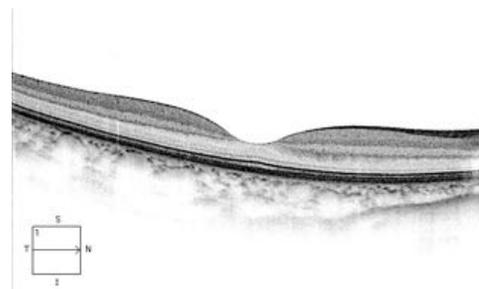
Structures parallel to the signal (such as nuclear layers) are less reflective so not as bright.

## Layers on Cirrus HD OCT

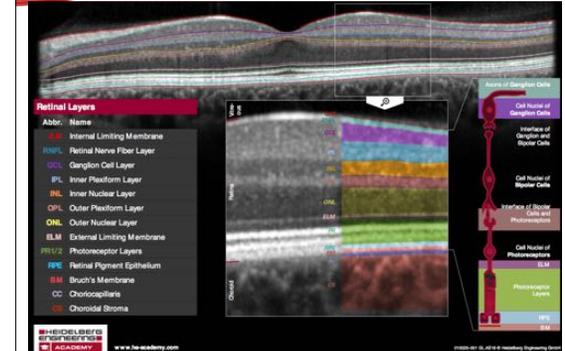


ILM: Inner limiting membrane	ELM: External limiting membrane	NFL: Nerve fiber layer
IPL: Inner plexiform layer	IS/OIS: Junction of inner and outer plexiform segments	GCL: Ganglion cell layer
INL: Inner nuclear layer	OPR: Outer plexiform layer	RPE: Retinal pigment epithelium
OPL: Outer plexiform layer	ONL: Outer nuclear layer	Choroid
		Bruch's Membrane

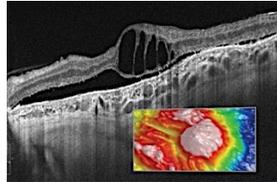
"Negative" OCT scan - Dark/light regions reversed.  
E.g. Vitreous is white rather than black



## ANATOMIC CORRELATIONS



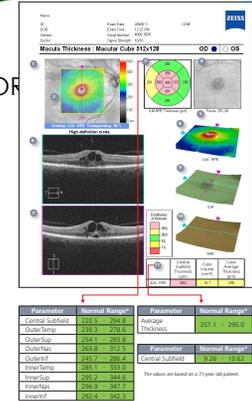
## QUESTIONS AND COMMENTS?



GET UP STAND UP

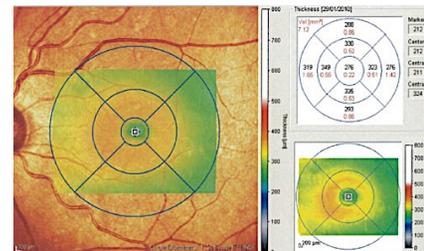
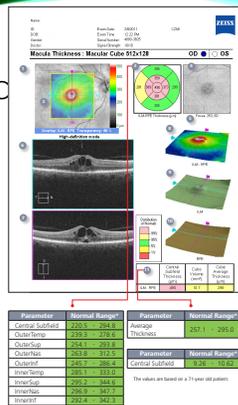
## READING THE REPORT THE REPORT

- 1 **LSO fundus image** is shown here with a ILM-RPE retinal thickness map overlay.
- 2 **Slice navigator** enables a simultaneous view of a selected point on LSO image, OCT fundus image, retinal thickness map, layer maps, and OCT image displays.
- 3 **ETDRS grid** is automatically centered on the fovea with **Fovea Finder™** Retinal thickness values, from ILM to RPE, in microns, are compared to normative data.
- 4 **OCT fundus image** is shown.
- 5 **Fovea Finder** enables precise placement of ETDRS grid.



## READING THE REPORT THE REPORT

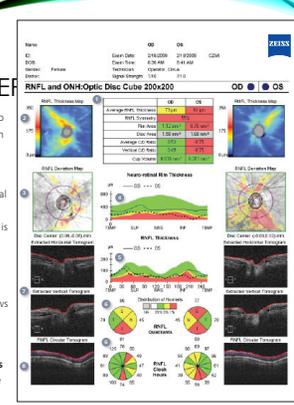
- 6 Framed in blue, this image corresponds to the horizontal crosshair line of the fundus image above.
- 7 Framed in pink, this image corresponds to the vertical crosshair line of the fundus image above.
- 8 **3D macular thickness map** shows retinal thickness in a topographical display.
- 9 Segmented **ILM map**.
- 10 Segmented **RPE map**.
- 11 **Macular parameters**, compared to normative data.



The 9-zone ETDRS Macular Grid

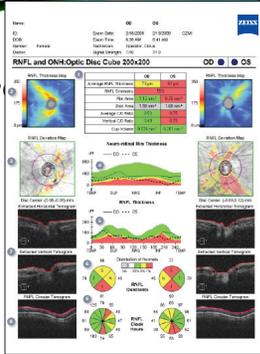
## READING THE REPORT THE REPORT

- 1 **Key parameters**, compared to normative data, are displayed in table format.
- 2 **Nerve Fiber Layer (RNFL)** thickness map is a topographical display of RNFL. An hourglass shape of yellow and red colors is typical of normal eyes.
- 3 **The RNFL Deviation Map** shows deviation from normal. OCT *en face* fundus image shows boundaries of the cup and disc and the RNFL calculation circle.
- 4 **Neuro-retinal Rim Thickness** profile is matched to normative data.



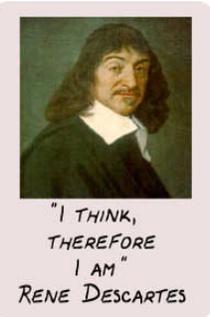
## READING THE REPORT THE REP

- 5 **RNFL TSNIT graph** displays patient's RNFL measurement along the calculation circle, compared to normative data.
- 6 **RNFL Quadrant and Clock Hour** average thickness is matched to normative data.
- 7 **Horizontal and vertical B-scans** are extracted from the data cube through the center of the disc. RPE layer and disc boundaries are shown in black. ILM and cup boundaries are shown in red.
- 8 **RNFL calculation circle** is automatically centered on the optic disc and extracted from the data cube. Boundaries of the RNFL layer segmentation is illustrated.



## OCT INTERPRETATION

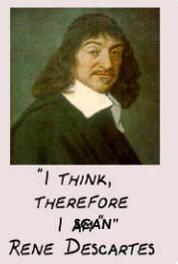
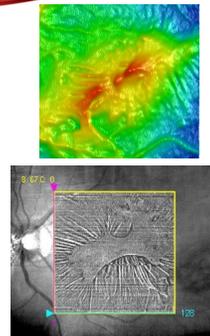
Involves analysis and synthesis of info.  
 René Descartes, 17th-century French philosopher, elucidated the principles of analysis and synthesis in "Le Discours de la Méthode" in 1637.  
 To replace the apparent chaos of data with an ordered and rationally constructed system,  
 There can only be one true method, which consists of separating what is already simple and clear in order to understand that which is complex and obscure.



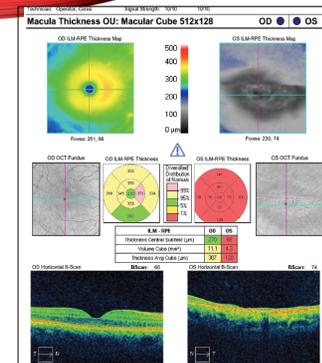
## OCT INTERPRETATION

In a logical process, the analysis of each of the elements is first performed.  
 Then after this phase, the synthesis of all these elements is performed, and the results of these flow into the conclusions.

## ERM IN 3-D



## THE OCT REPORT



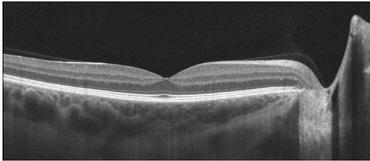
DUSN  
OS

IMAGE CREDIT:  
DR. KIRSTI RAMIREZ  
DR. JEFF RABIN



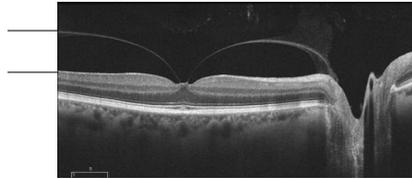
## Posterior Segment Applications

- Vitreous/Vitreoretinal Interface
- Neurosensory retina, RPE/Bruch's
- Choriocapillaris/Deeper Choroid
- Optic Nerve/NFLA

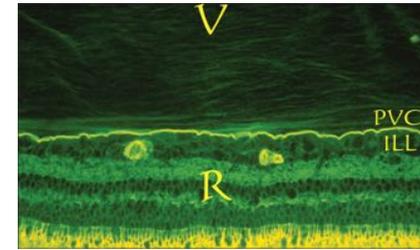


## Posterior Segment Applications

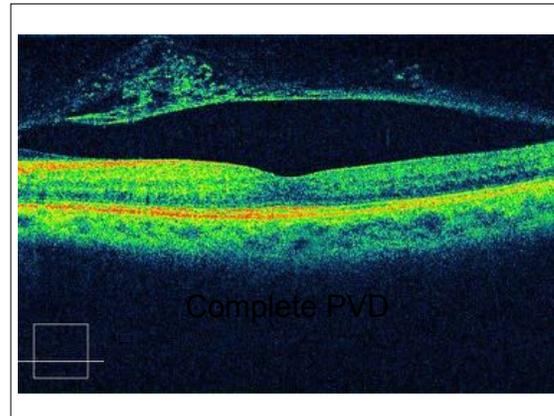
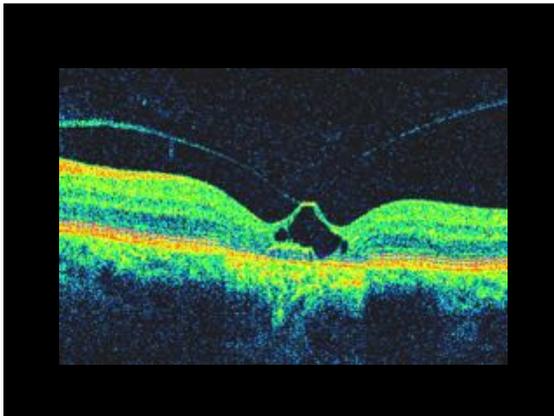
- Vitreous/Vitreoretinal Interface
  - VMA/T



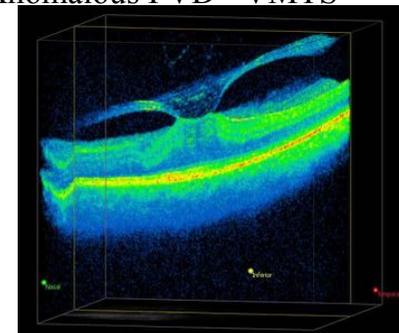
## The Vitreoretinal Interface



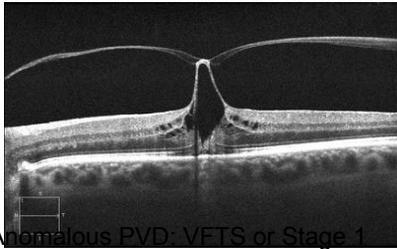
retinalphysician.com



## Anomalous PVD - VMTS

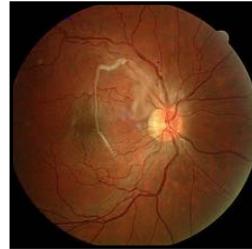


Case: 58 y/o WM  
Gradual blur, VA 20/60

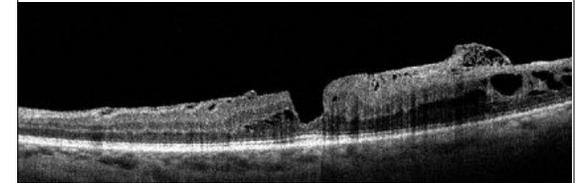


Anomalous PVD: VFTS or Stage 1  
Macular Hole

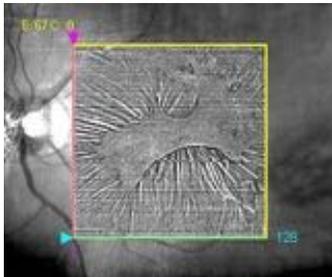
### Vitreoretinal Interface



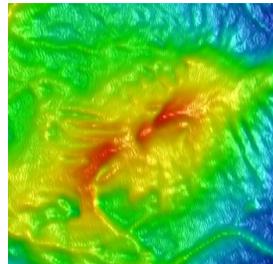
### ERM With Mac Pucker, Pseudohole



### ERM en Face (Slab Analysis)

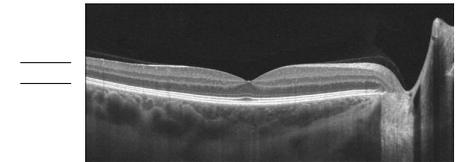


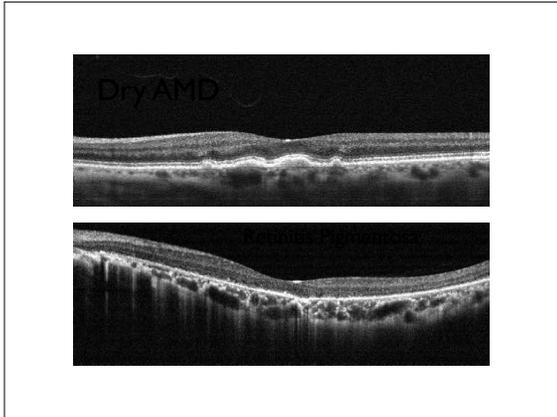
### ERM 3-D



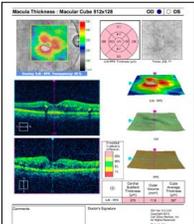
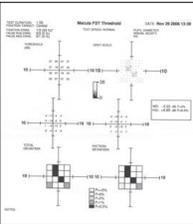
### Posterior Segment Applications

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- Neurosensory retina, RPE/Bruch's
- Choriocapillaris/Deeper Choroid
- Optic Nerve/NFLA



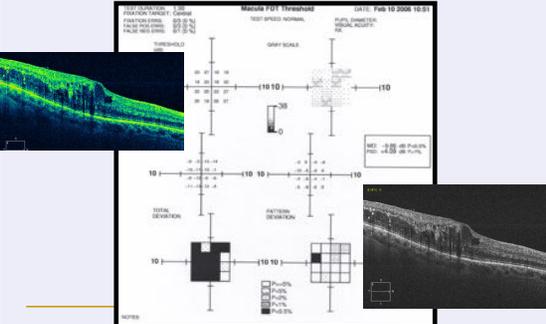
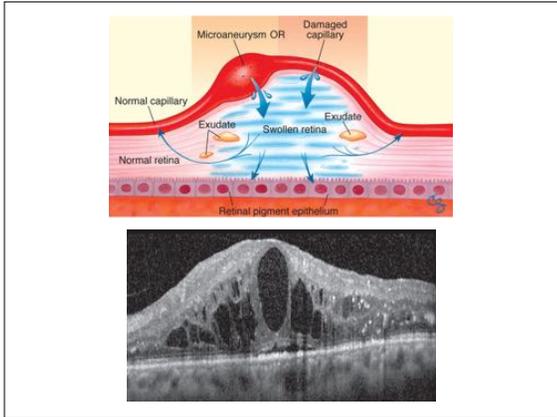


### Clinical Case of Patient RW: Integrating Structure and Function

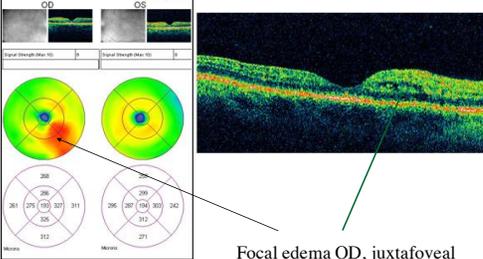



**FDT Macula Threshold Testing**

### 48 y/o WM with DME OD

### CSDME: OCT SHOWS FOCAL ME



Focal edema OD, juxtafoveal  
Thin foveal centers due to ischemia

### Intermediate Dry AMD OD/OS

• AREDS Category 3



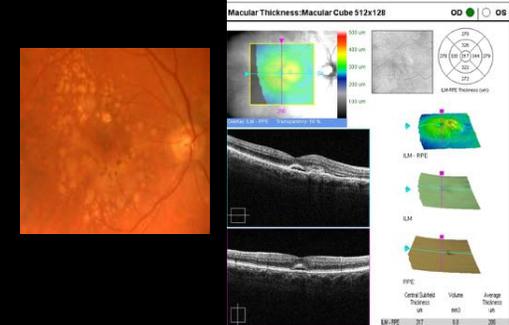
Baseline OCT showed no evidence of CNV in either eye \*

## Follow or Co-manage?

MPOD  
Dark Adaptometry  
OCT/OCTA  
Treatment?

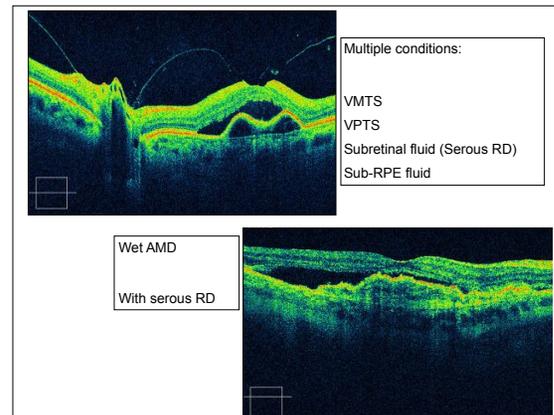
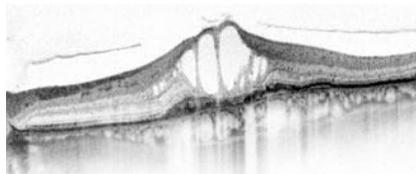


## On 3 mon f/u, OCT Shows Change



## Vitreomacular Adhesion in AMD

- May hasten the AMD process.



## QUESTIONS AND COMMENTS?



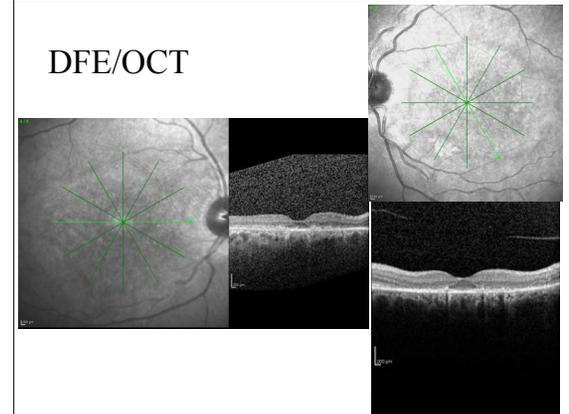
## Case

- 65 Year old Female
- Comes in with complaints of blurred and dimmed vision
- PMH: Rheumatoid Arthritis x 15 years
- OchX: S/P CE and IOL OU

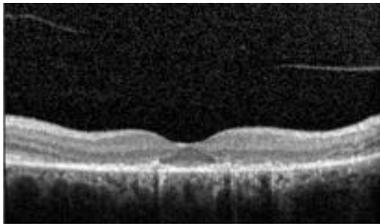
## Ophthalmic Exam

- VA:
  - OD: 20/40    OS: 20/40
- IOP
  - OD: 14        OS: 13
- SLE:
  - OD: PCIOL    OS: PCIOL
- DFE:

## DFE/OCT

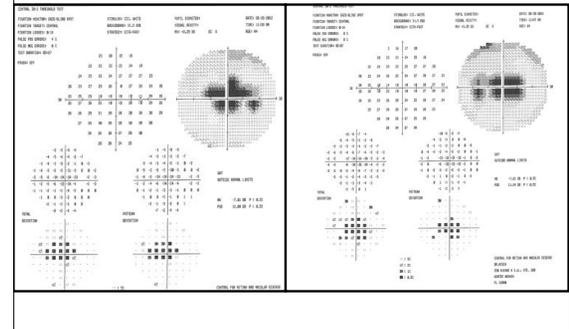


## OS

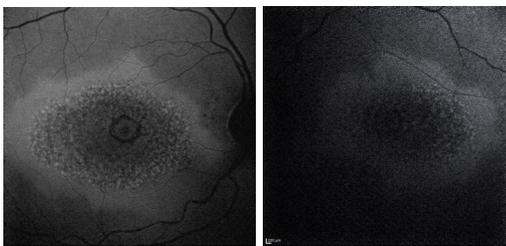


Additional Testing?

## Visual Fields



## Auto Fluorescence

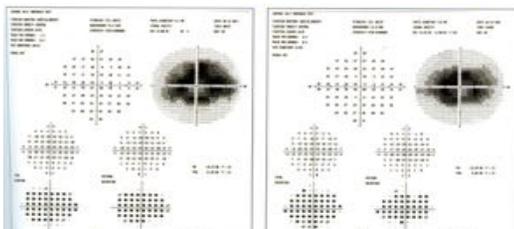


Likely Diagnosis?

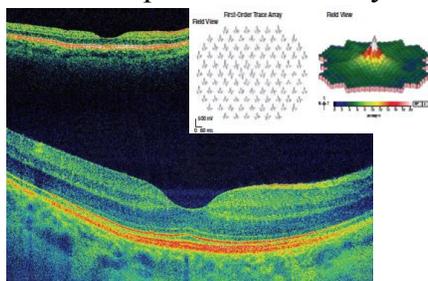
## Plaquenil Maculopathy

- Co-management team includes eye care provider, rheumatology
- Testing guidelines for patients on Plaquenil
- Repeat testing

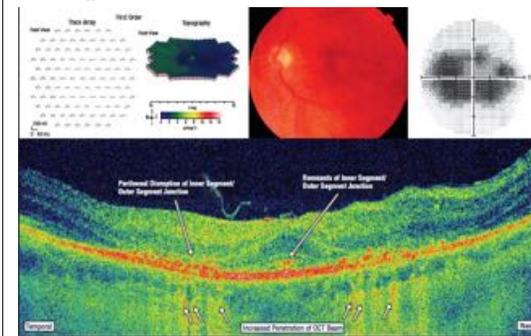
## Central 10-2 in Plaquenil Toxicity



## Patient on Plaquenil--no toxicity

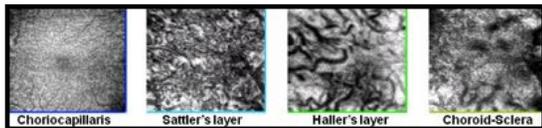


## Plaquenil Toxicity

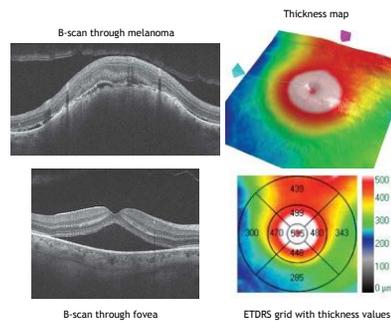
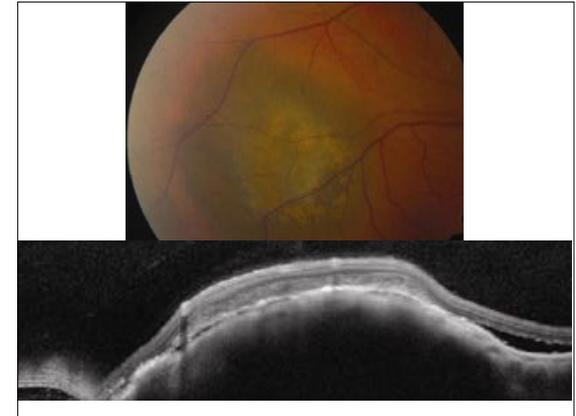
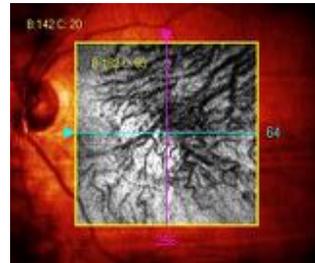


## Posterior Segment Applications

- Vitreous/Vitreoretinal Interface
- Neurosensory retina, RPE
- Choroid
- Optic Nerve/NFLA

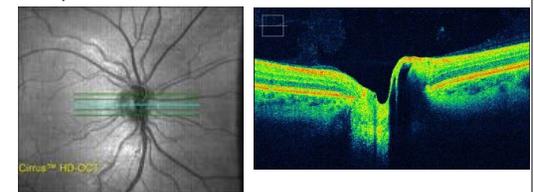


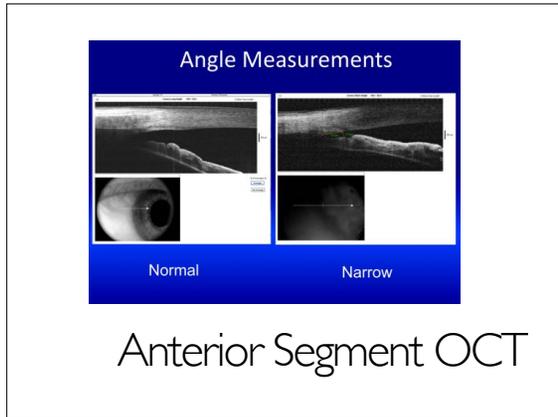
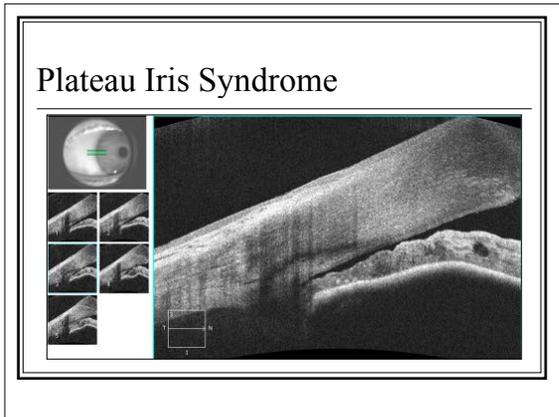
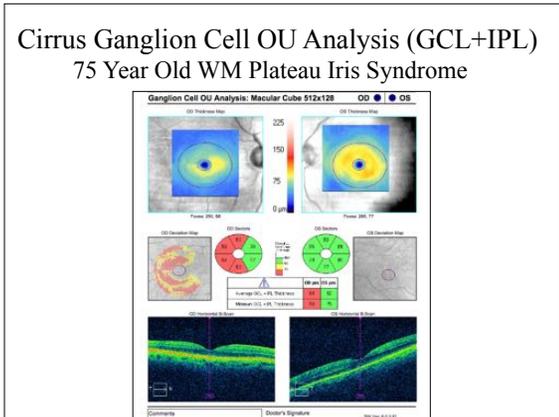
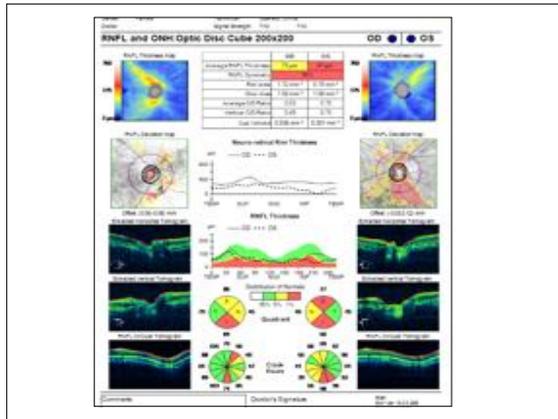
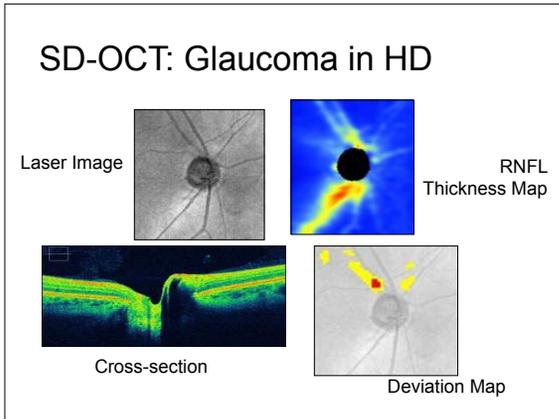
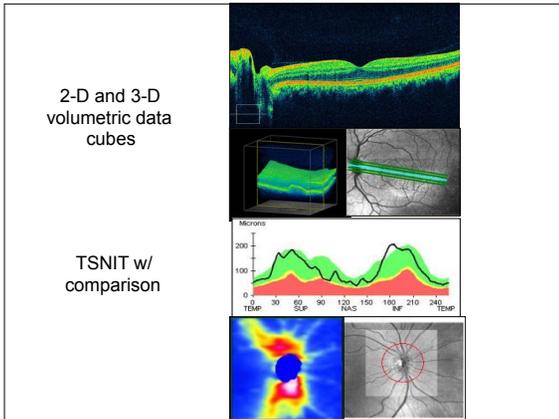
## IMAGING THE CHOROID



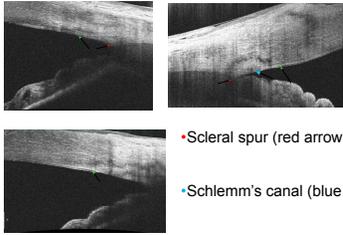
## Posterior Segment Applications of OCT

- Vitreous/Vitreoretinal Interface
- Neurosensory retina, RPE
- Choriocapillaris
- Optic Nerve/NFLA



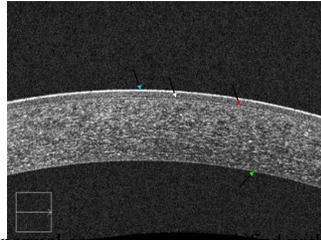


## Anterior Segment Imaging Angle Structures



- Scleral spur (red arrow)
- Schlemm's canal (blue arrow)
- Schwalbe's line (green arrow)

## Anterior Segment Imaging Cornea/CCT



HD-OCT of normal cornea. Layers identified with colored arrows as follows: tear film (blue), epithelium (white), Bowman's layer (red), Descemet's/endothelium (green).

## IMAGE QUALITY

### Conditions that can affect the quality of OCT scans include:

- Transparency of the optic media
- Poor corneal condition or lacrimal film

## ERRORS AND ARTIFACTS

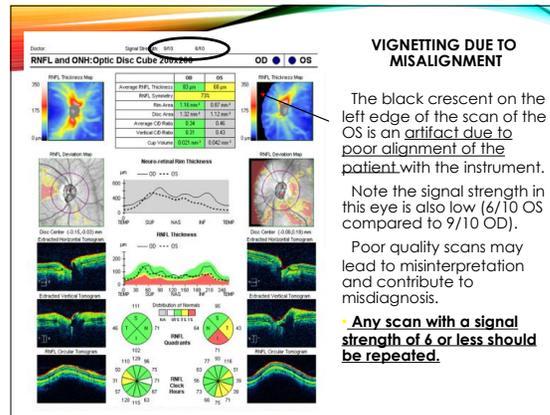
### Signal-to-Noise

A large number of factors may contribute to low signal strength (poor media clarity, misalignment, eye movements)

- Poor signal quality **interferes with segmentation analysis** and results in **errors in quantitative analysis**
- A low signal strength (**S6**) should prompt the examiner to discard the scan or use it with caution

### Alignment errors and blinks

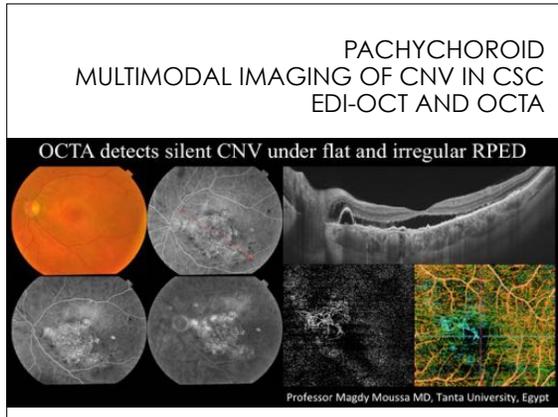
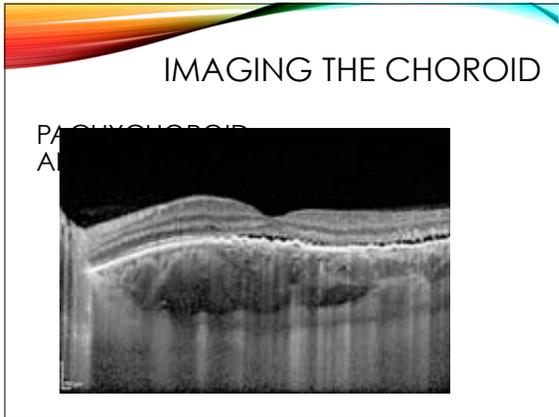
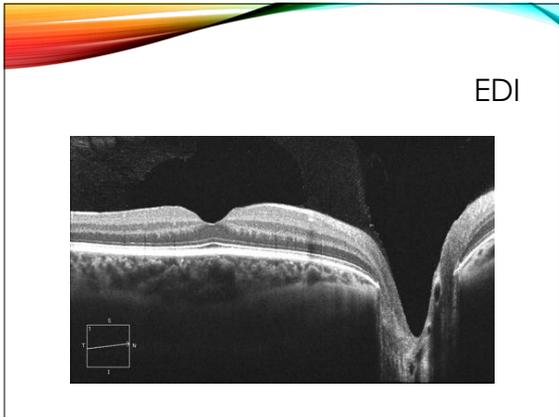
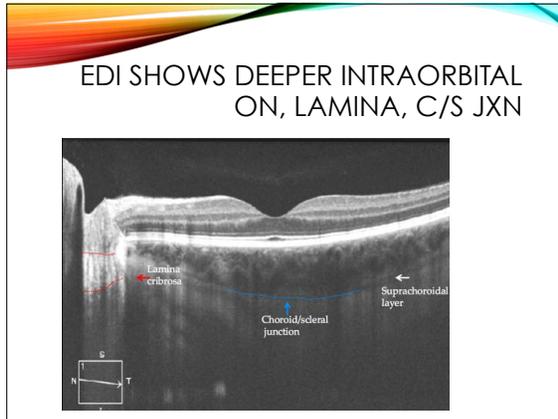
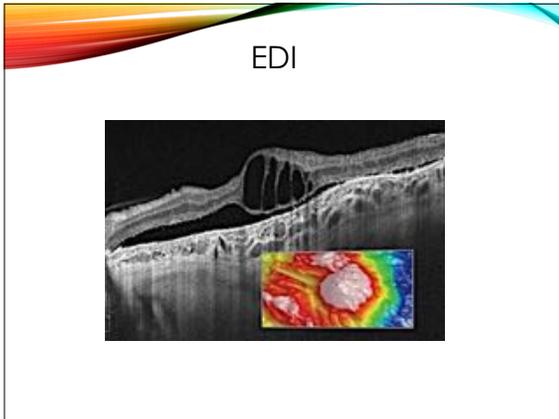
- **Vignetting and black zones** within the scan can be caused by misalignment, inadequate optimization, and patient movement or blinking during capture

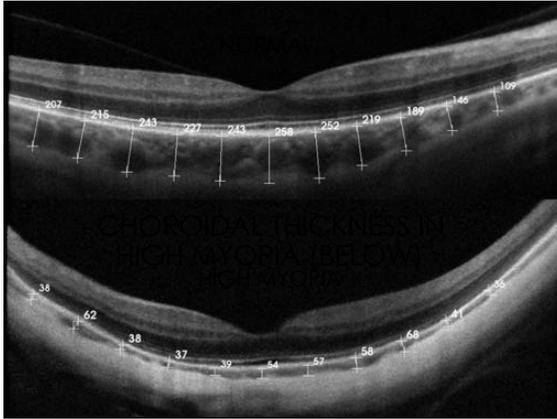


## WHAT IS ENHANCED DEPTH OCT IMAGING?

### EDI-OCT

Enhanced-depth imaging (EDI) OCT modifies the standard technique of image acquisition to better reveal the structural details of the choroid.





TAKEN IN THE "CHOROIDAL" MODE WITH THE RS 3000 ADVANCE (NIDEK).

COMING SOON?

QUESTIONS AND COMMENTS?

CONCLUSIONS

OCT/OCTA is here to stay and will one day be as common in our offices as the slit lamp.

Select an OCT instrument based on your practice needs with an eye toward future upgrades.

OCT, along with traditional examination techniques, will continue to save vision.

THANK YOU!

Joe

allthingsoct@gmail.com