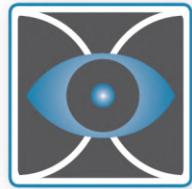




Deep Learning for Ophthalmology

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Department of Ophthalmology
Medical University of Vienna



OPTIMA
Ophthalmic Image Analysis



Christian Doppler
Forschungsgesellschaft



MEDICAL UNIVERSITY
OF VIENNA

DEPARTMENT OF OPHTHALMOLOGY AND OPTOMETRY

<https://optima.meduniwien.ac.at>

ABOUT US

RESEARCH

PUBLICATIONS

PARTNERS

CAREER



Mission

*"Innovation in
ophthalmic image analysis
and translation to
precision medicine"*

Peer-reviewed studies of AI vs. doctors

Retrospective Validation

Specialty	Images	Publication
Radiology/Neurology	CT head, acute neuro events	Titano, Nature Medicine, 2018
	CT head for brain hemorrhage	Arbabshirani, NPJ (Nature) Digital Medicine, 2018
	CT head for trauma	Chilamkurthy, Lancet 2018
	CXR for metastatic lung nodules	Gang Nam, Radiology 2018
	CXR for multiple findings	Singh, PLOS One, 2018
Pathology	Breast cancer	Bejnordi, JAMA, 2017
	Lung cancer (+ driver mutation)	Coudray, Nature Medicine 2018
	Brain tumors (+ methylation)	Capper, Nature, 2018
	Breast cancer metastases*	Steiner, Am J Surgical Pathology, 2018
Dermatology	Breast cancer metastases	Liu, Arch Path Lab Med, 2018
	Skin cancers	Esteva, Nature, 2017
	Melanoma	Haenssle, Annals of Oncology, 2018
Ophthalmology	Skin lesions	Han, Journal of Investigative Dermatology
	Diabetic retinopathy	Gulshan, JAMA, 2016
	Diabetic retinopathy*	Abramoff, NPJ (Nature) Digital Medicine, 2018
	Diabetic retinopathy*	Kanagasingam, JAMA Open 2018
	Congenital cataracts	Long, Nature Biomedical Engineering, 2017
	Retinal diseases (OCT)	De Fauw, Nature Medicine, 2018
	Macular degeneration	Burlina, JAMA Ophthalmology, 2018
	Retinopathy of Prematurity	Brown, JAMA Ophthalmology, 2018
Gastroenterology	AMD and diabetic retinopathy	Kermany, Cell, 2018
	Polyps at colonoscopy*	Mori et al, Annals Internal Medicine, 2018
Cardiology	Echocardiography	Madani, NPJ (Nature) Digital Medicine, 2018
	Echocardiography	Zhang, Circulation 2018

Prospective Validation

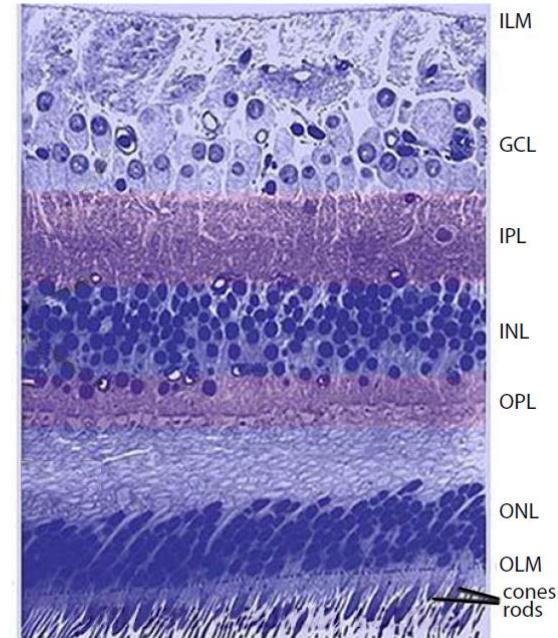
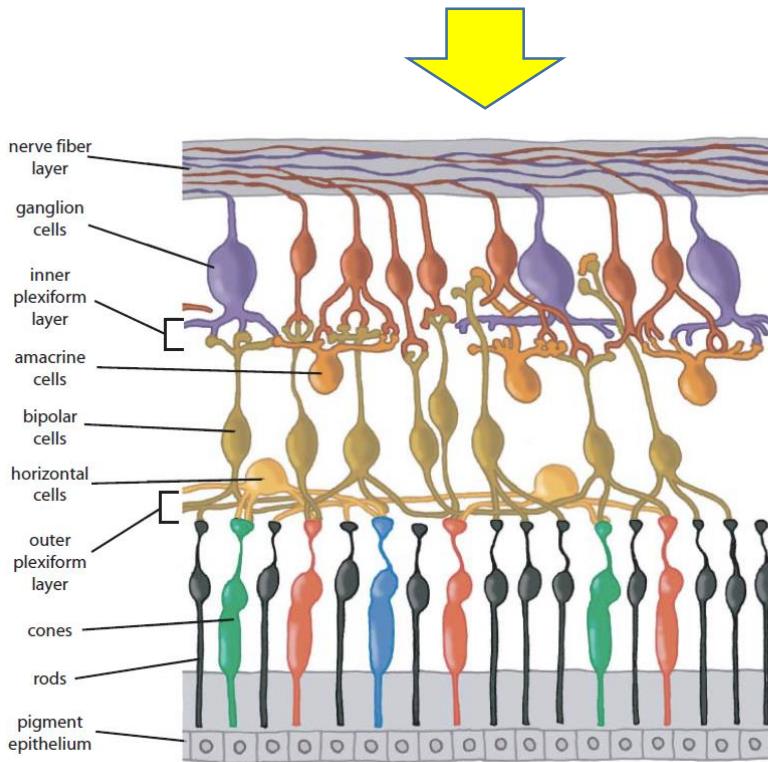
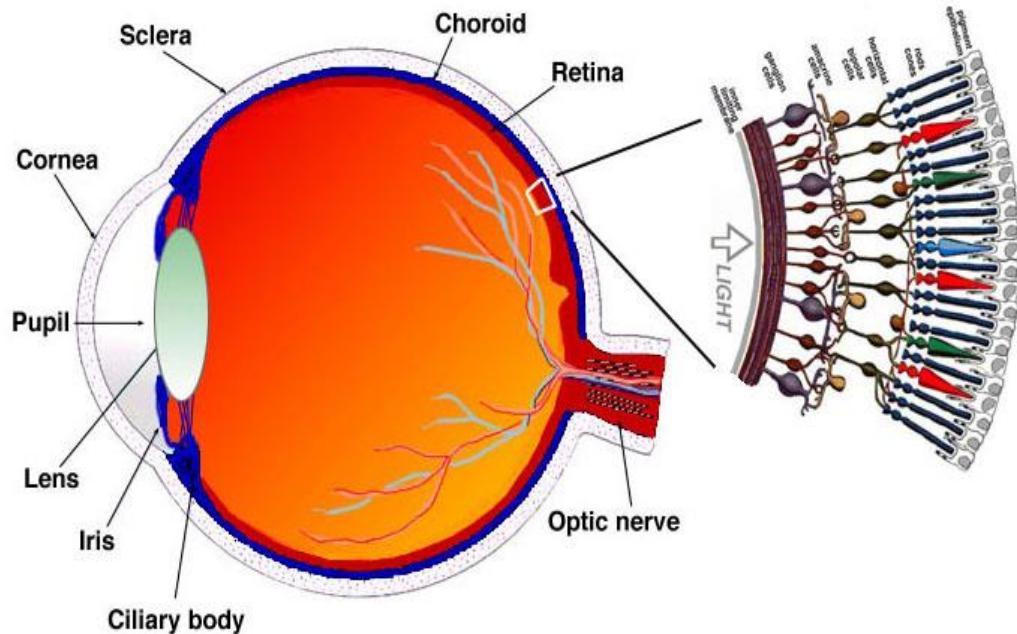
Specialty	Input	Citation
Radiology	Mammography for breast density	Lehman, Radiology 2018
Pathology	Breast cancer metastases	Steiner, Am J Surgical Pathology, 2018
Ophthalmology	Diabetic retinopathy	Abramoff, NPJ (Nature) Digital Medicine, 2018
	Diabetic retinopathy	Kanagasingam, JAMA Open 2018
	Congenital cataracts	Long, Nature Biomedical Engineering, 2017
Gastroenterology	Polyps at colonoscopy	Mori et al, Annals Internal Medicine, 2018

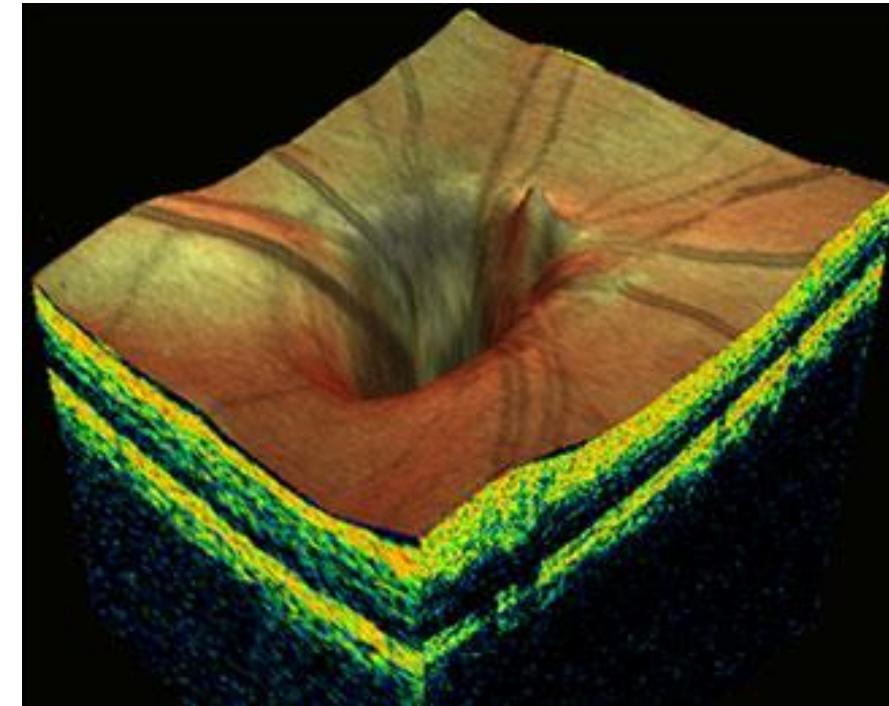
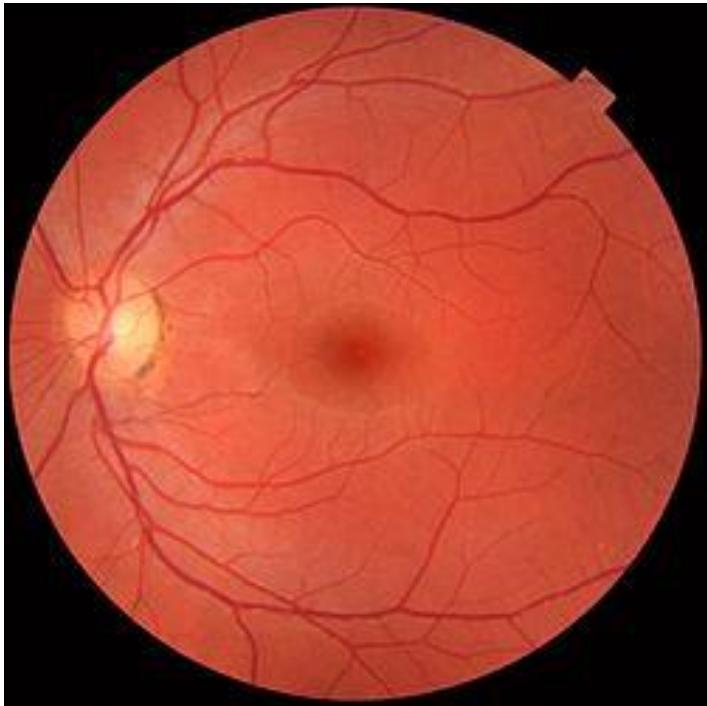
Why Ophthalmology?

- Ophthalmology is image-intensive medical discipline
 - Diagnosis based on image patterns
- Retinal condition leading to severe vision loss and blindness on the global level: 100s Mio affected
- Eye is easily accessible
 - Non-invasive, fast, high-res imaging
 - 2D and 3D
- Deep Learning excellent for pattern recognition
 - well-defined task
 - “closed” environment

Eye

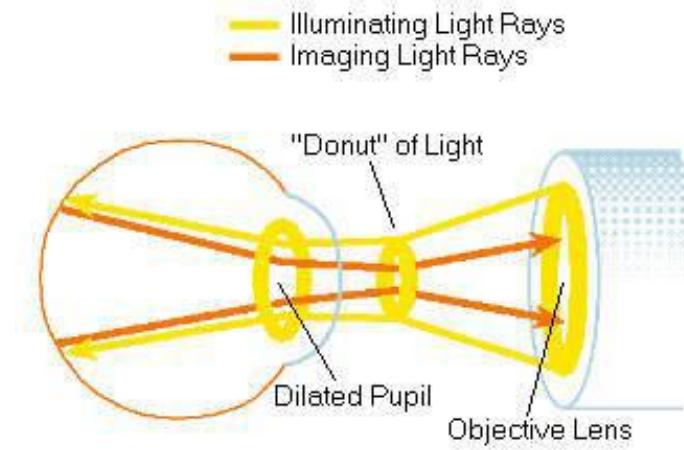
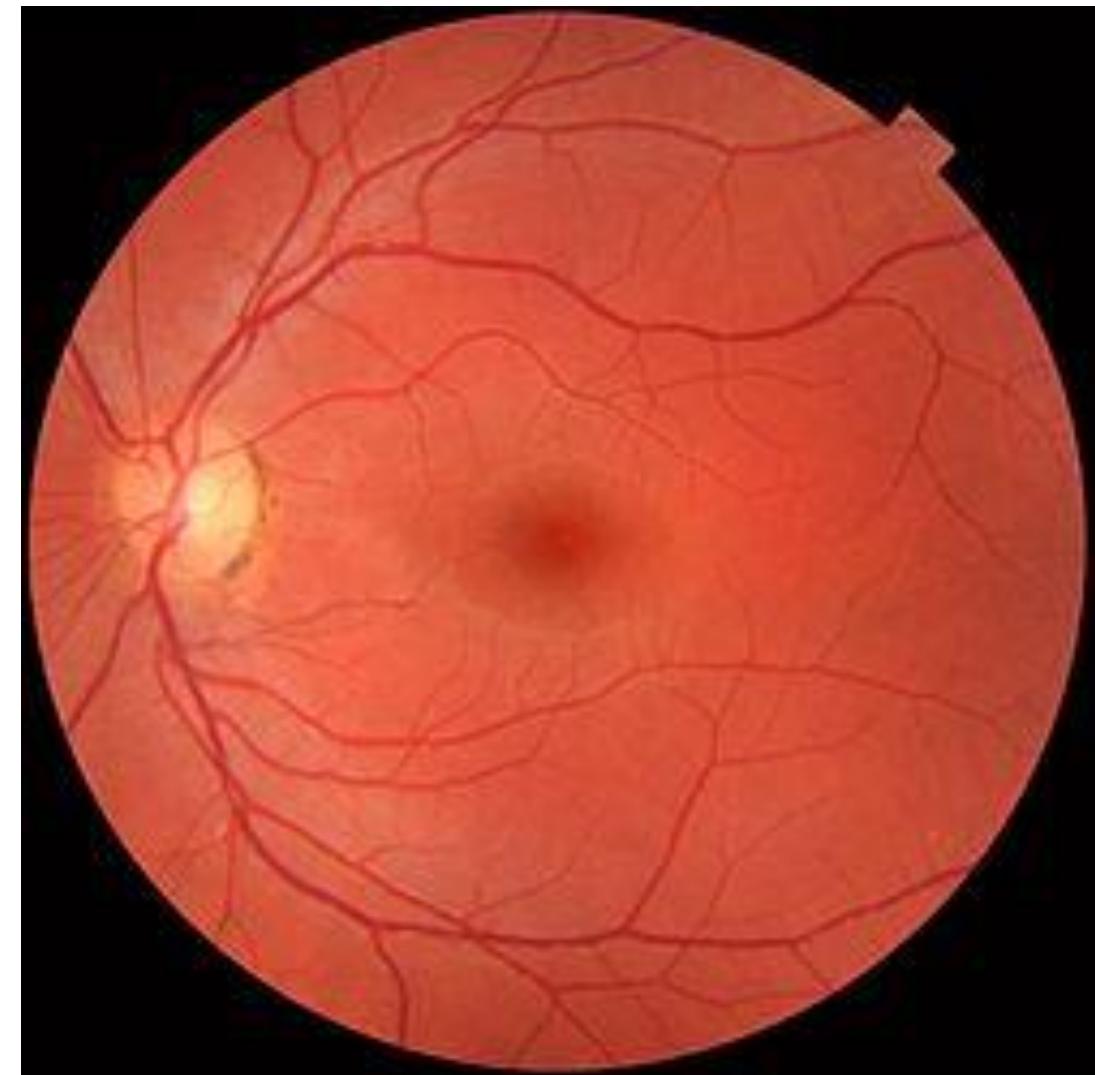
- Made to see: Transparency of cornea, lens, vitreous, retina



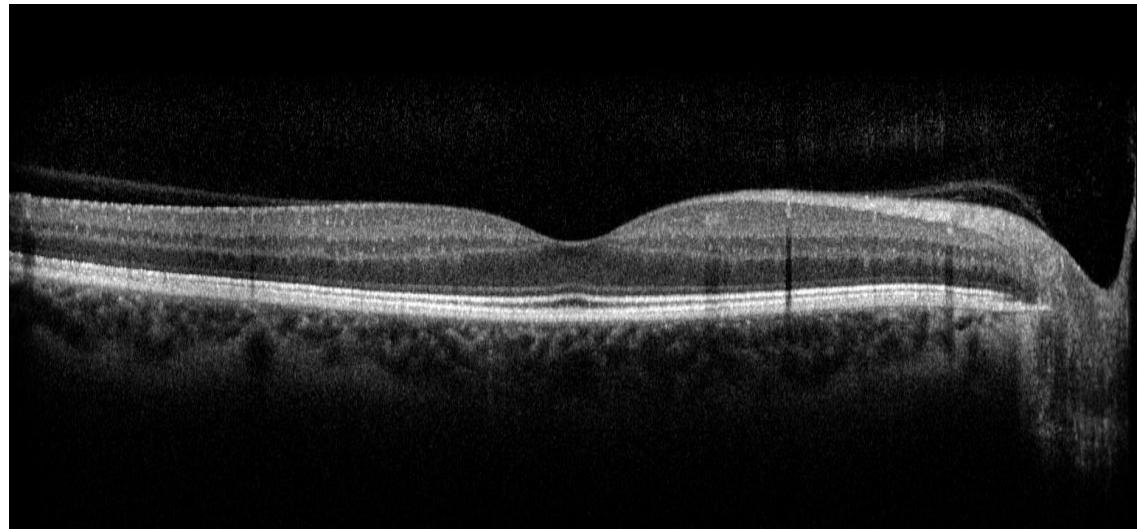
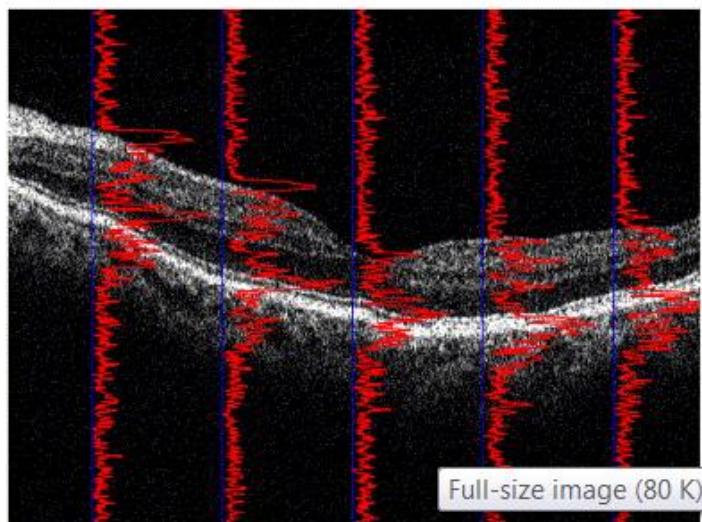
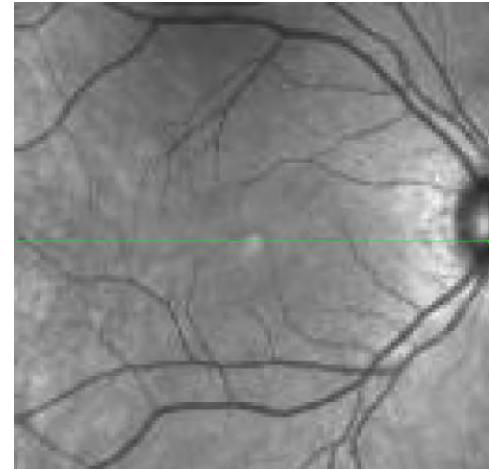
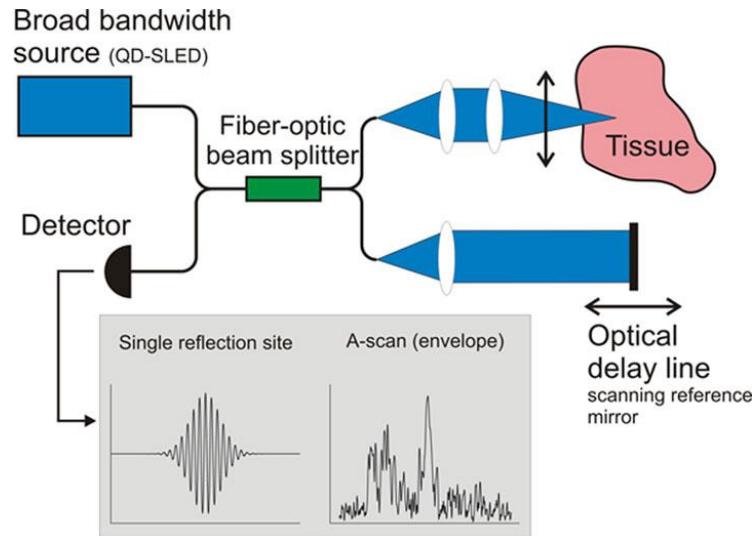


Retinal Imaging

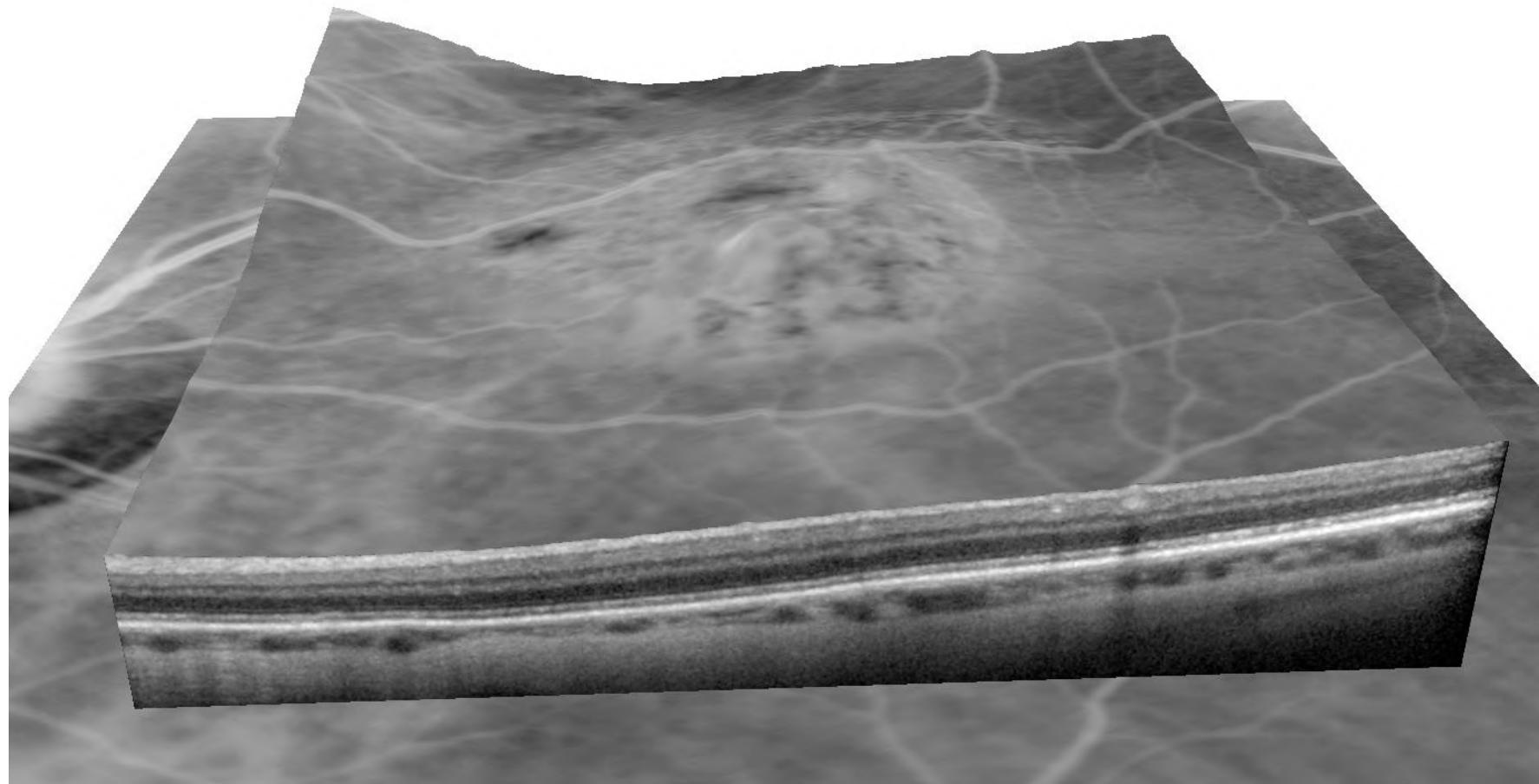
Fundus Photography



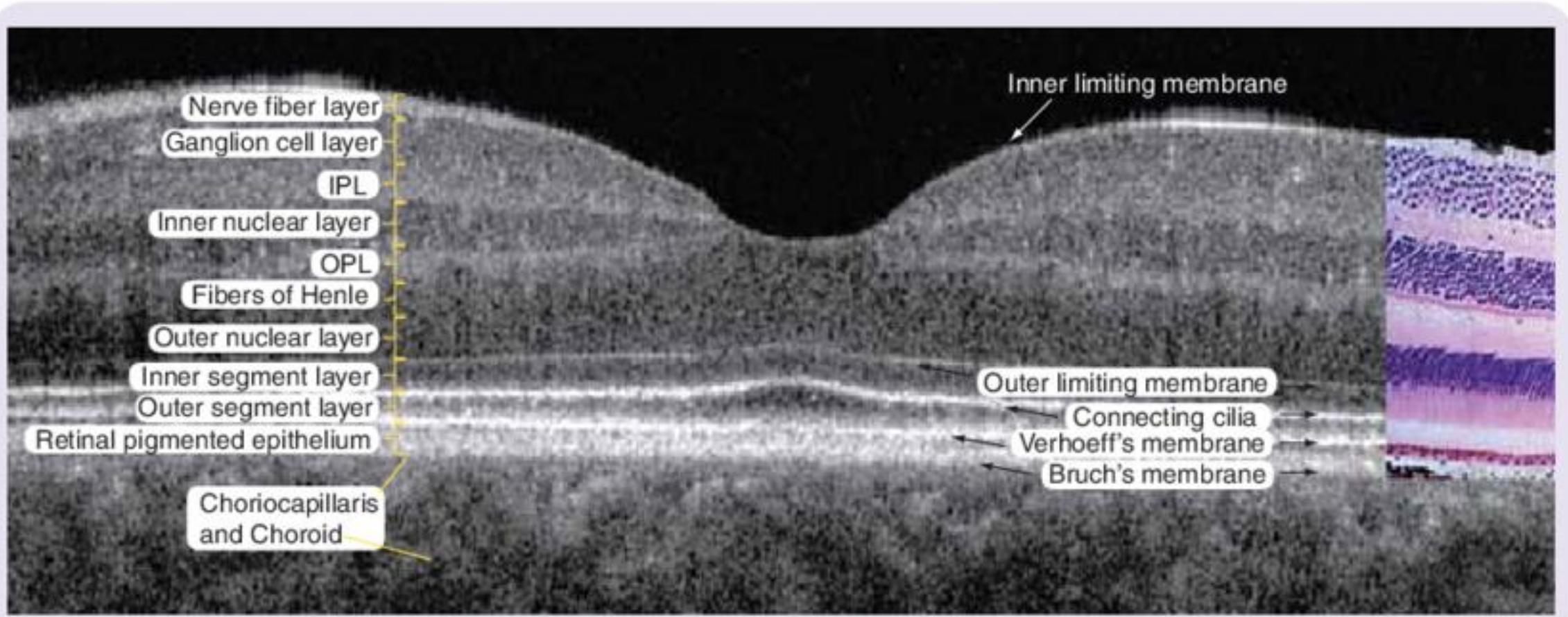
Optical coherence tomography (OCT)



OCT offers volumetric 3D scan

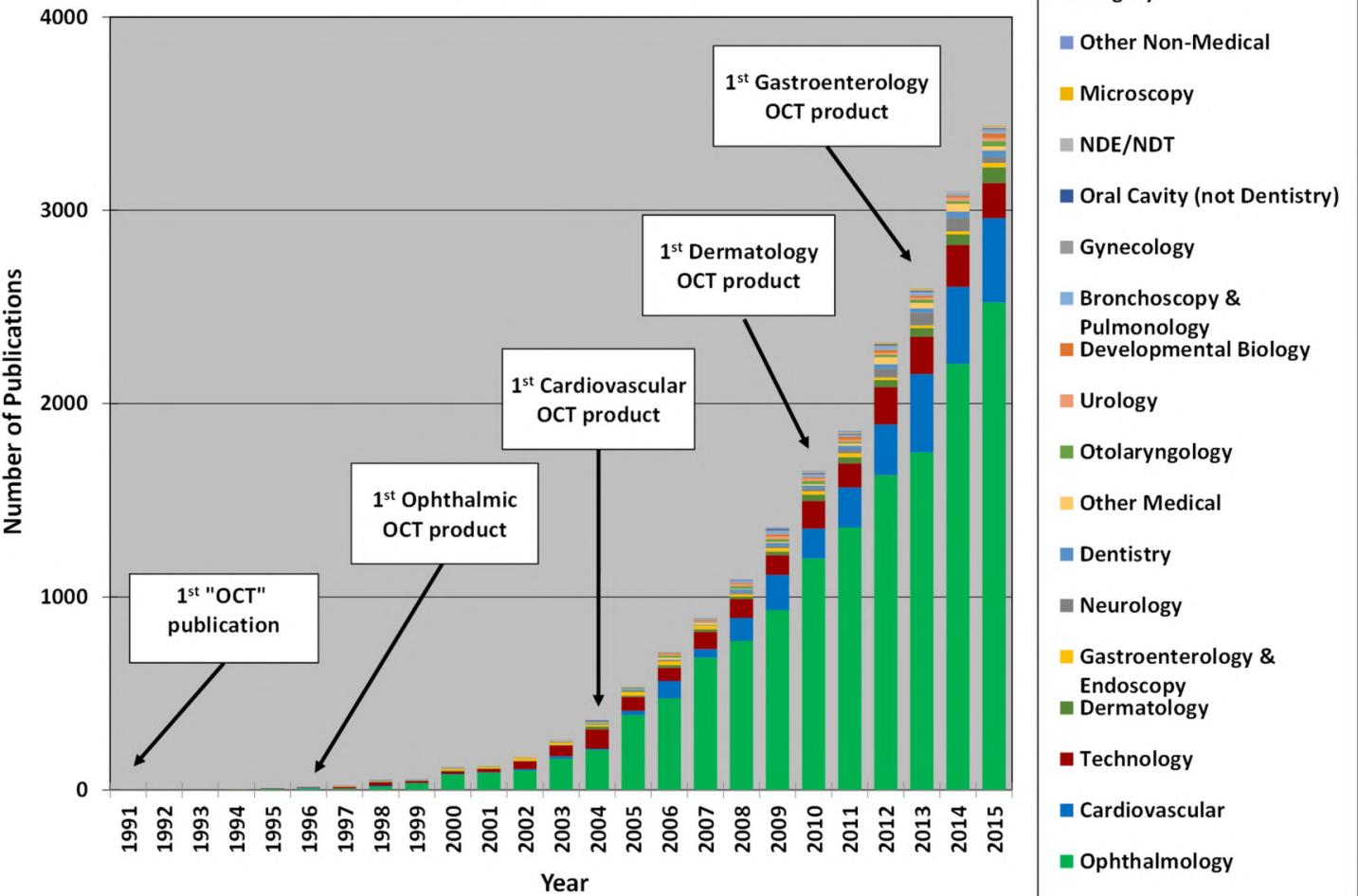


OCT offers close-to microscopy resolution



OCT Impact

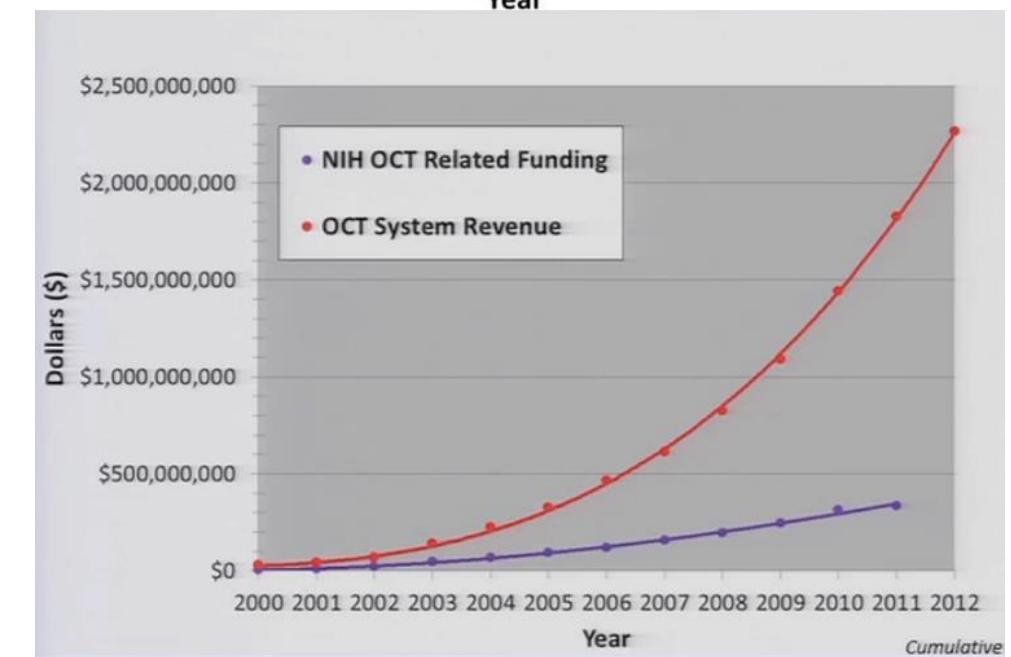
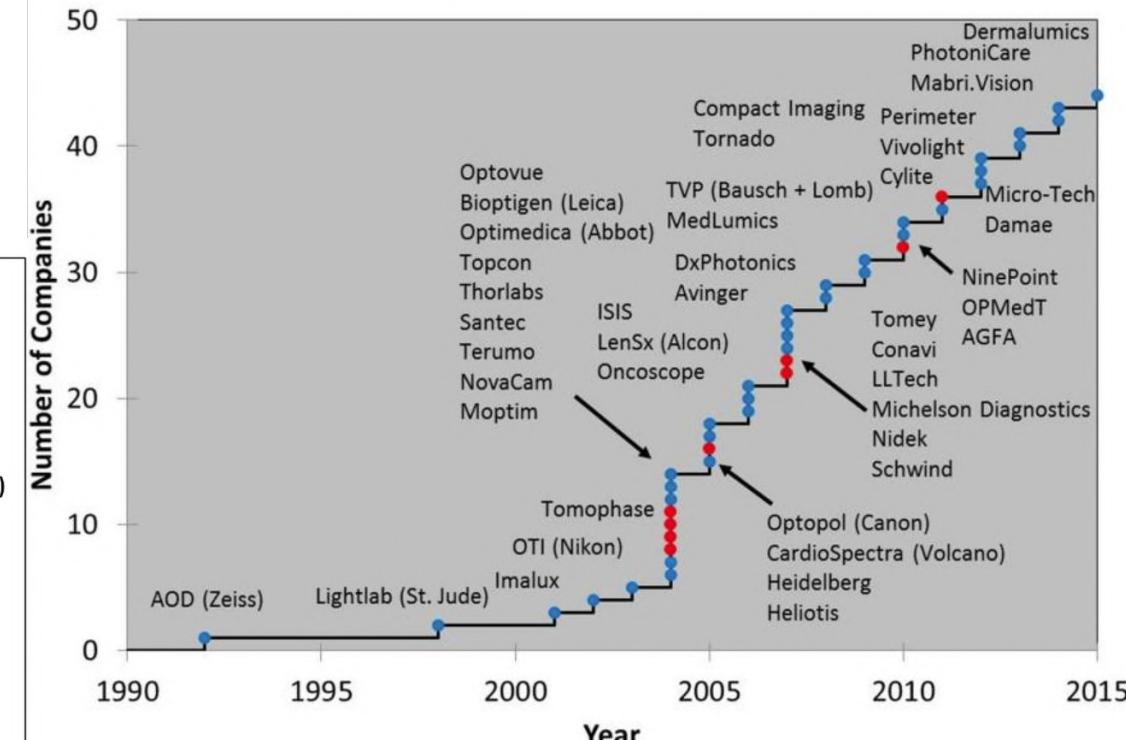
Scientific Publications



E. Swanson, SPIE Photonics West, 2014

J. Fujimoto, E. Swanson, IOVS, 2016

Companies Developing OCT Systems



Retinal disease - The leading cause of blindness



Normal Vision



Glaucoma



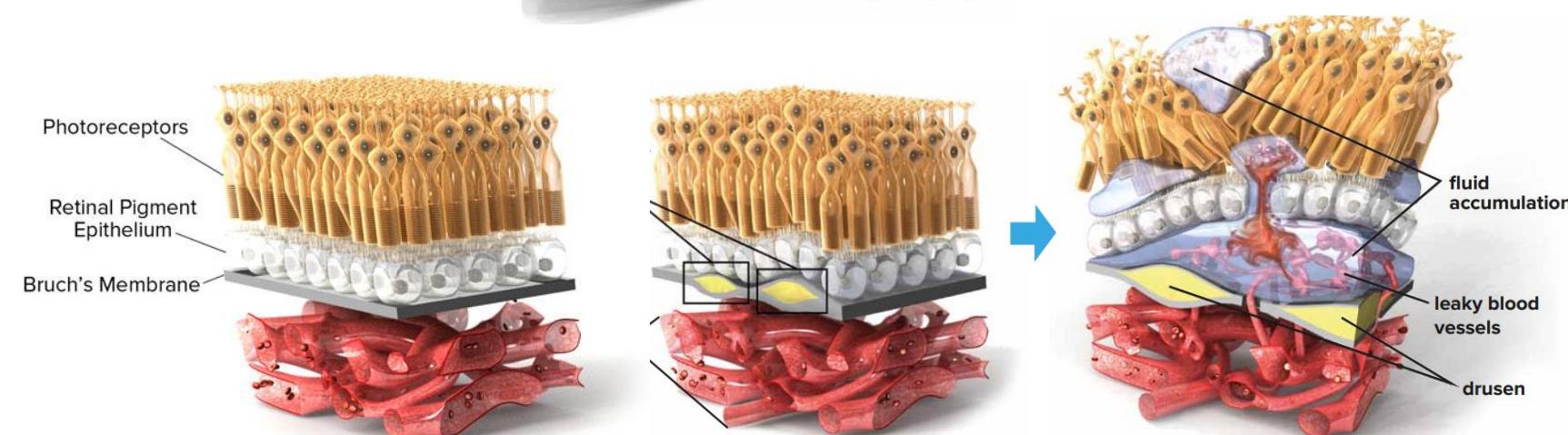
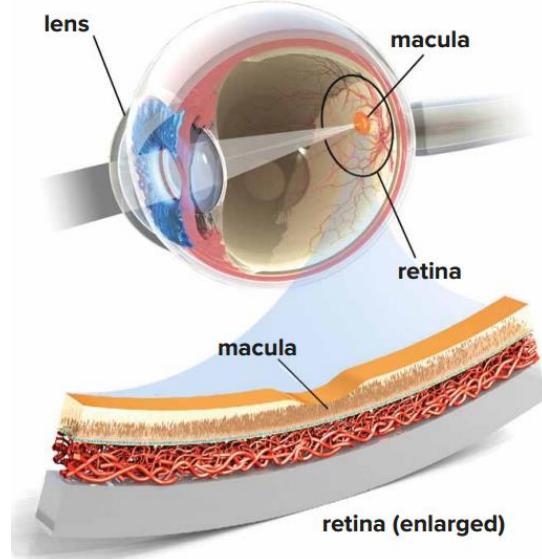
Diabetic Retinopathy



Age-related Macular Degeneration

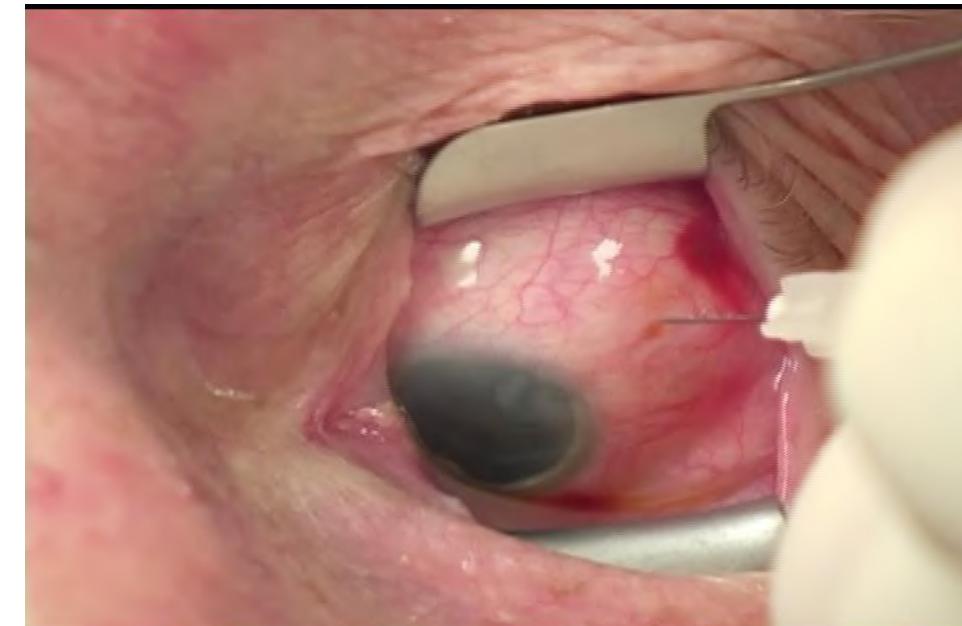
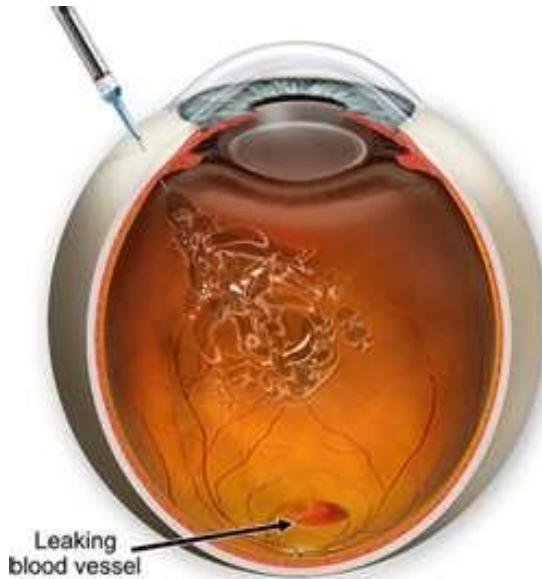
* Simulation images courtesy of National Eye Institute, National Institutes of Health

Age-related macular degeneration (AMD) - Wet

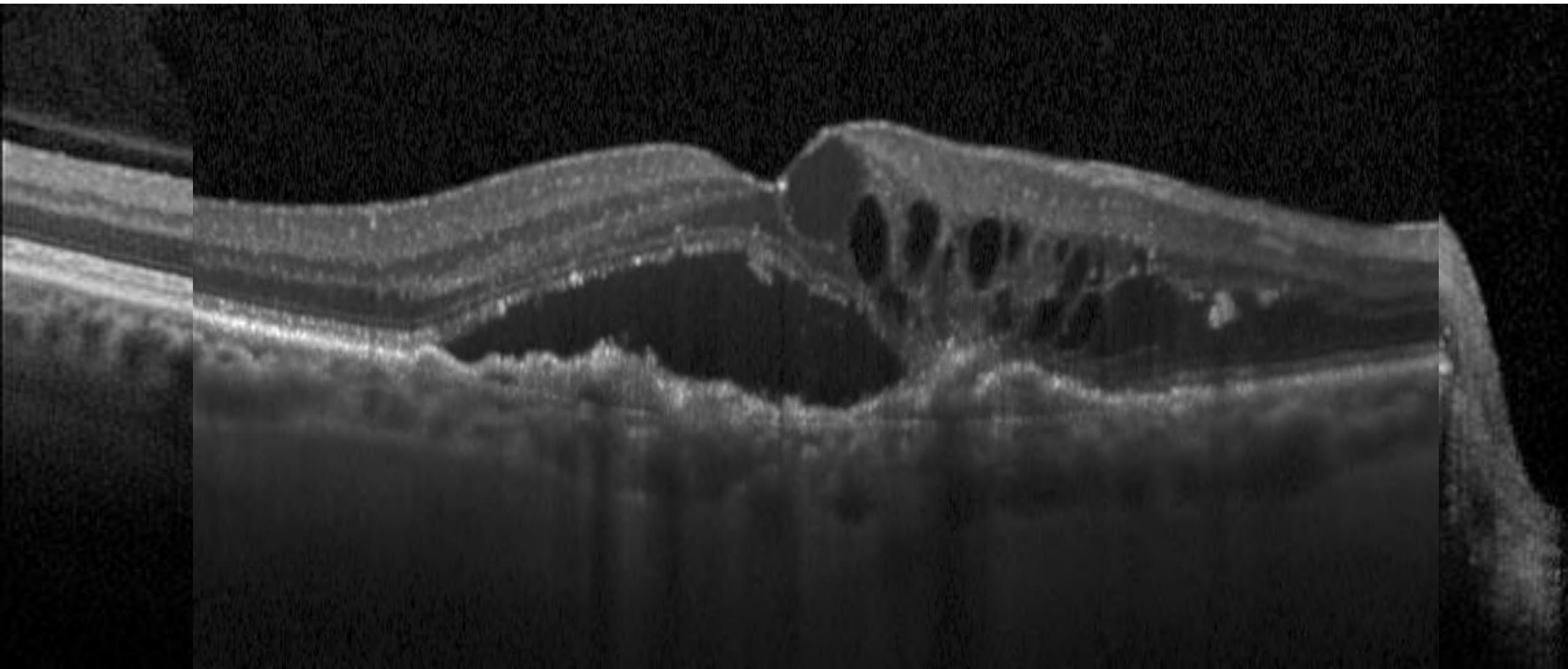


Highly effective drugs for wet AMD

- Treatment: Anti-Vascular Endothelial Growth Factor (anti-VEGF)
- Frequent intravitreal = intraocular injections



Wet AMD induces swelling as seen with OCT



Glaucoma

- Slowly progressing “silent thief of sight”
- Damage to the optic nerve
- (Often) increased eye pressure
- Leading cause of **irreversible** blindness

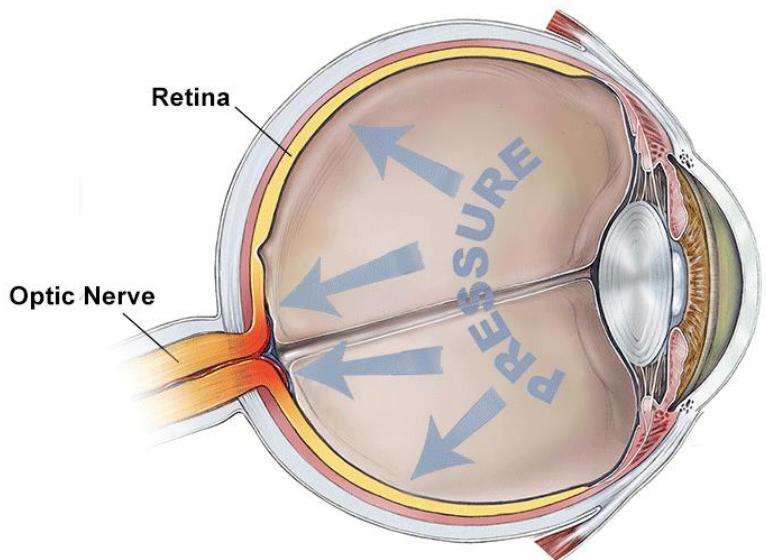
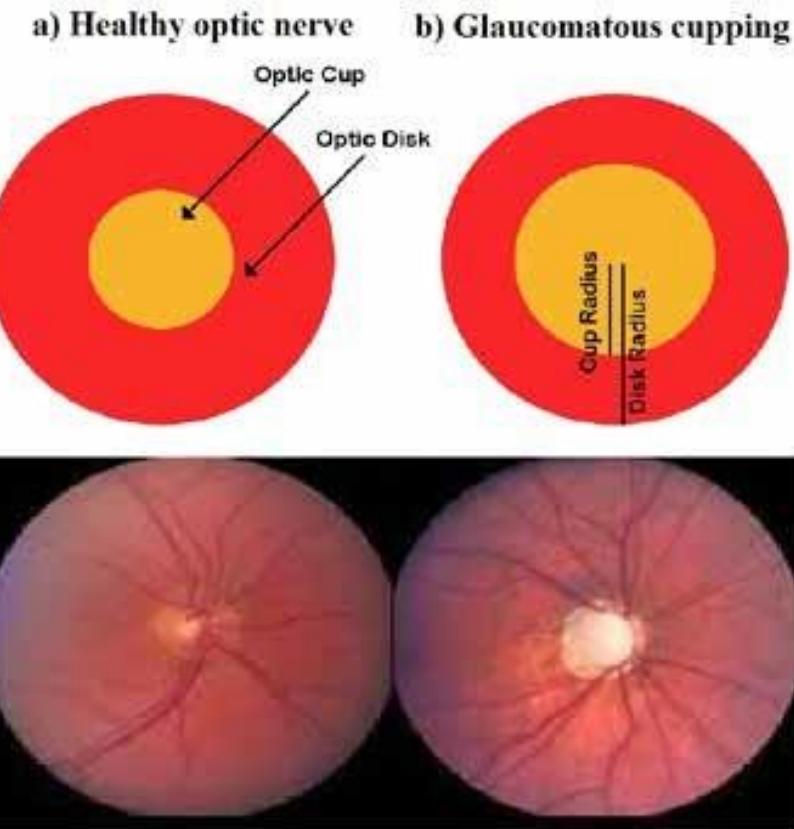


Illustration by Bob Morreale, provided courtesy of BrightFocus Foundation

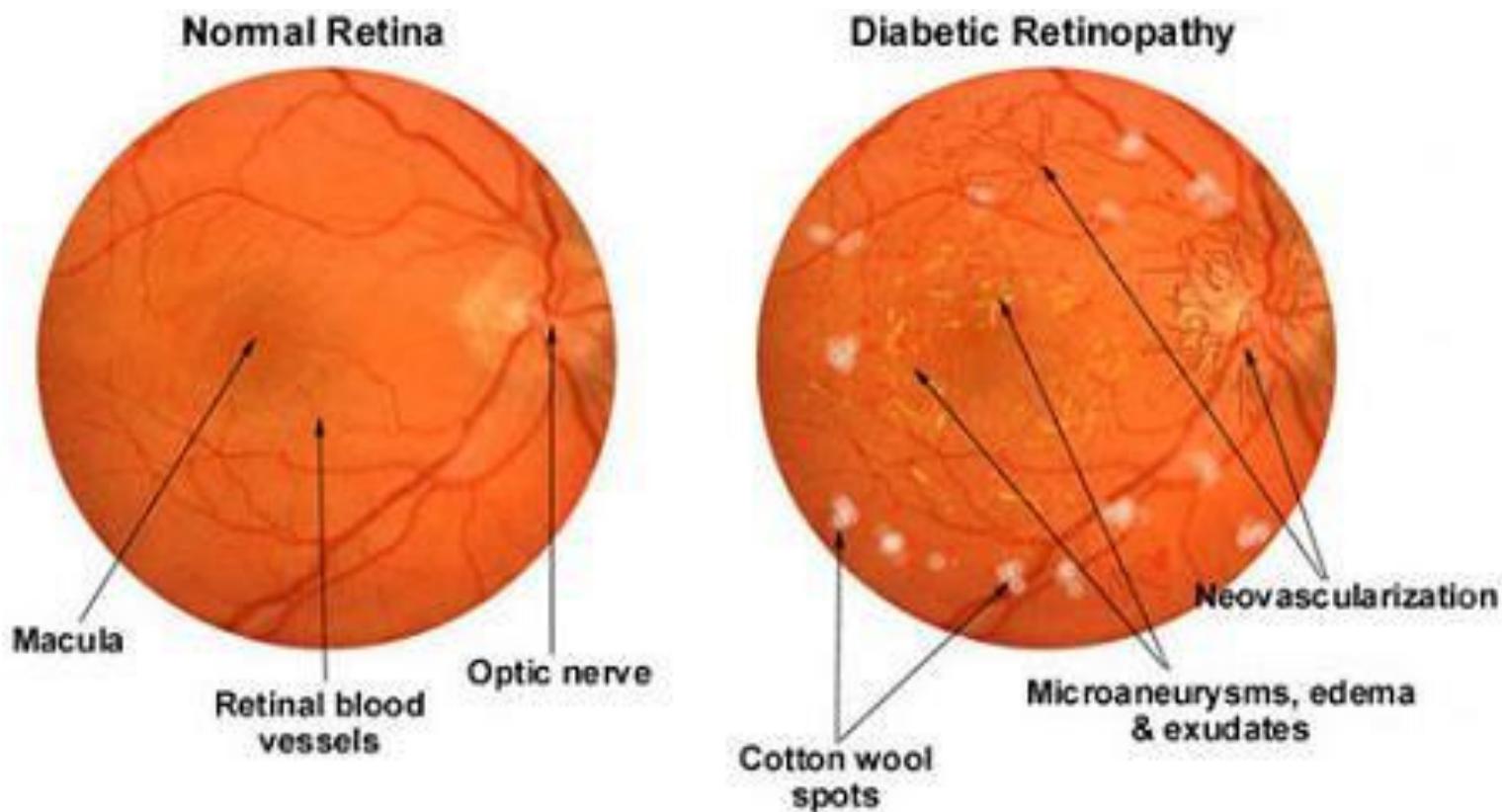


Diabetic retinopathy (DR)

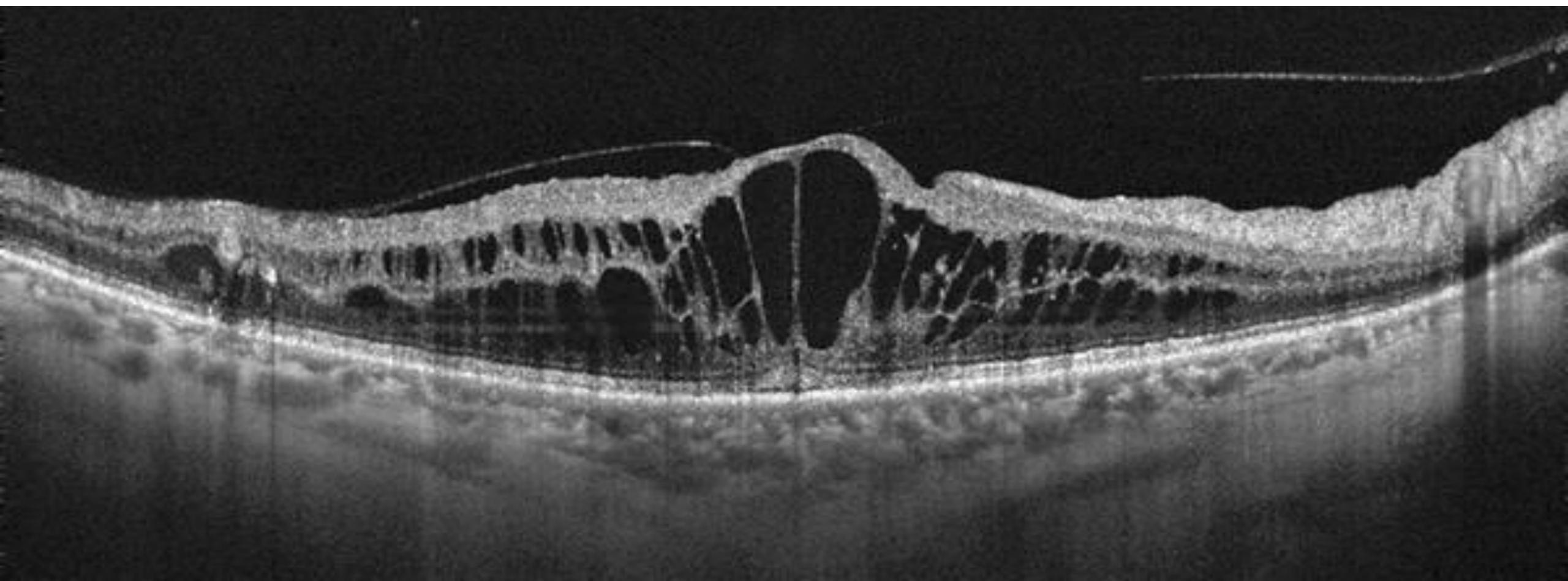
- Most common cause of vision impairment in working age people

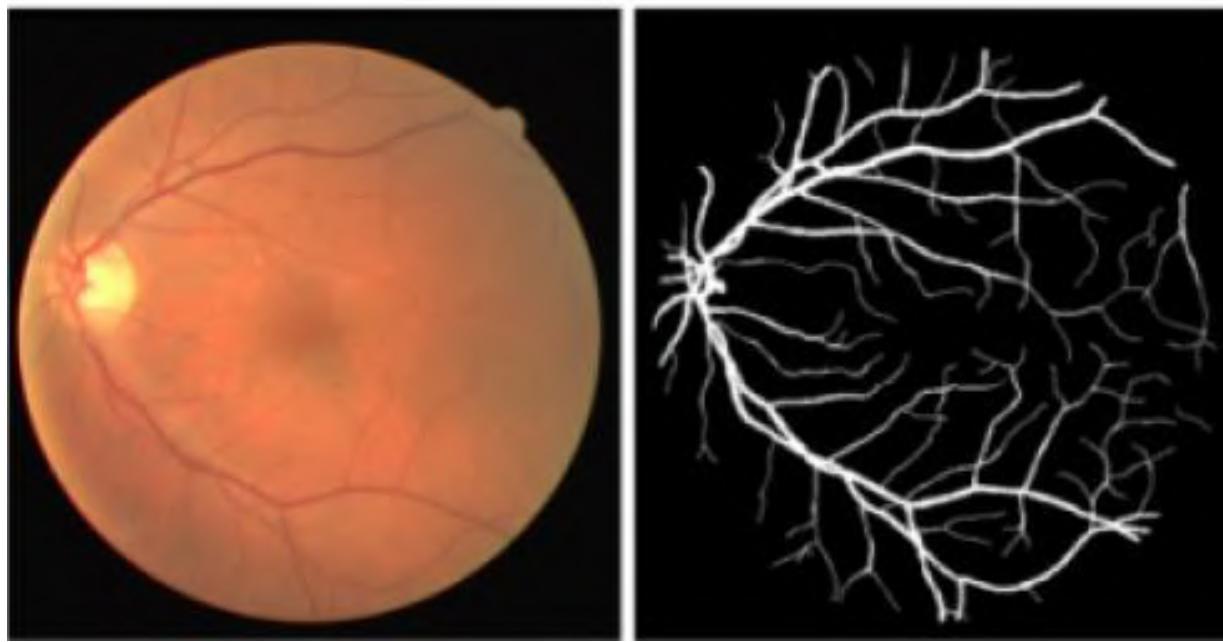
- Austria:

- 6000 new patients per year
- 600-1000 diabetics loose eye sight per year



Diabetic macular edema (DME) on OCT

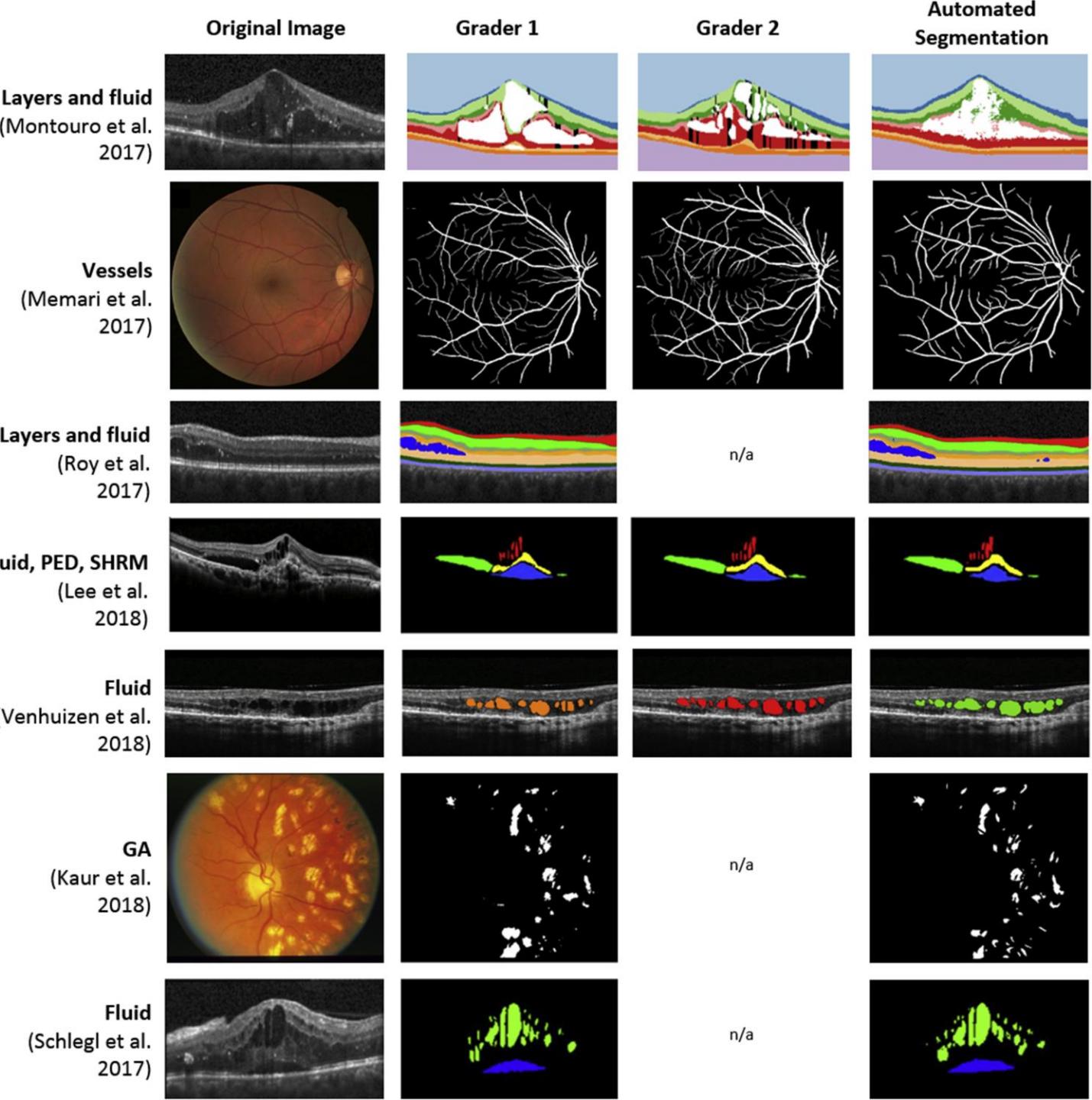




DL for Ophthalmic Image Segmentation

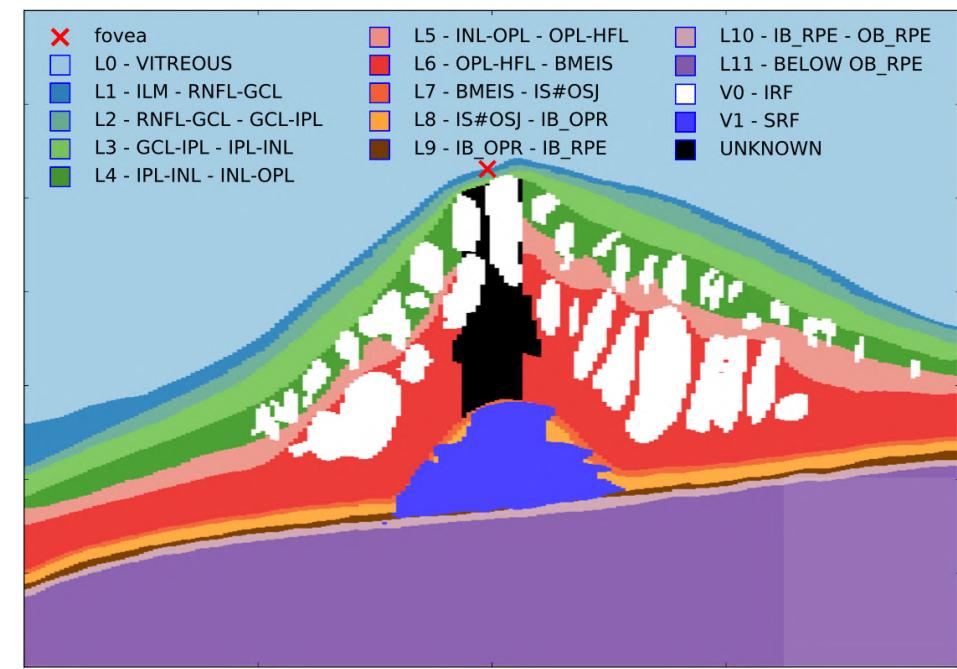
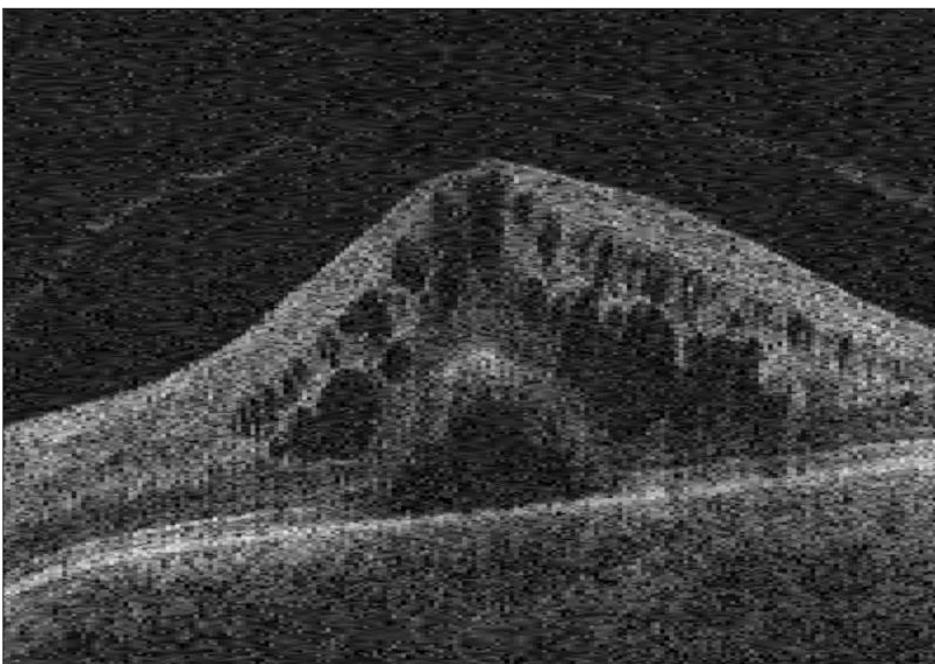
Imaging Biomarkers

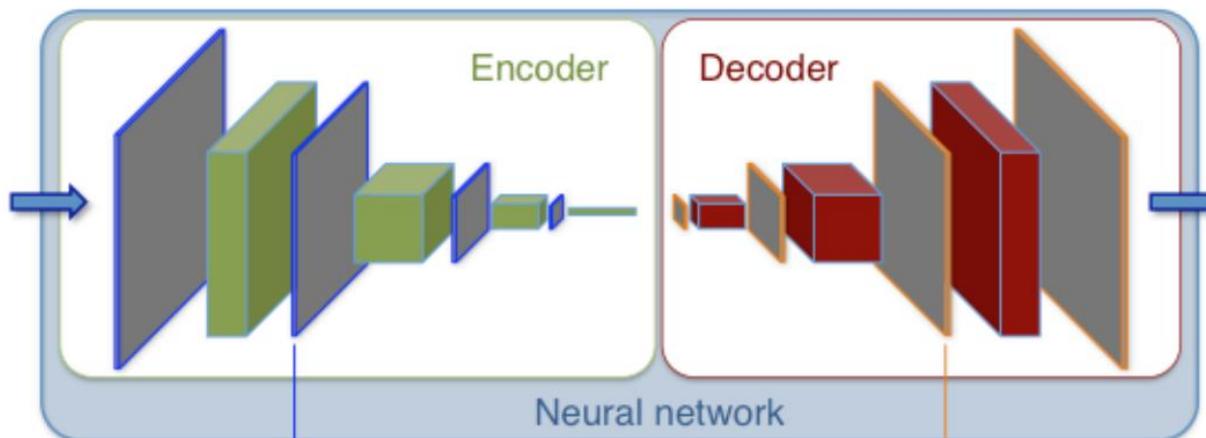
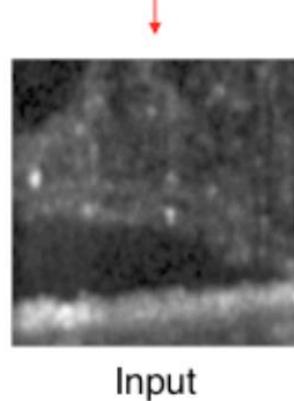
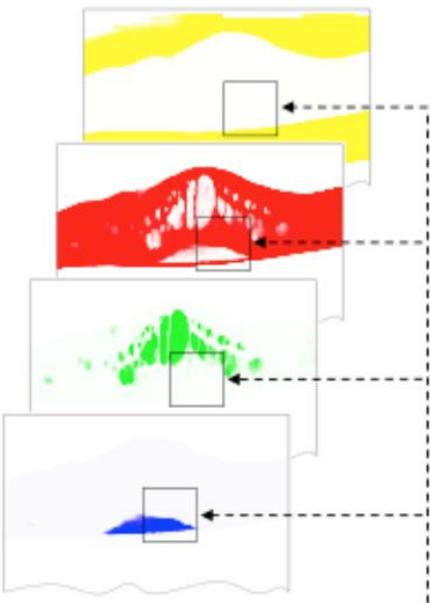
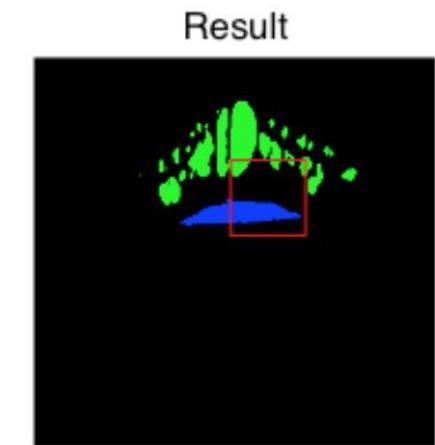
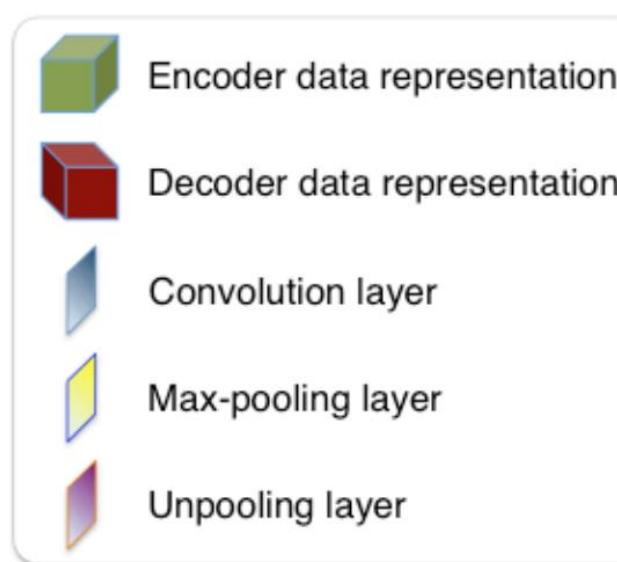
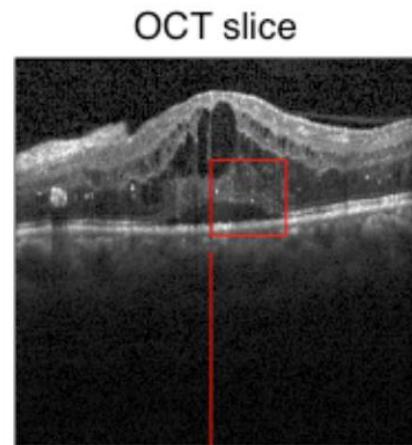
- Task: image segmentation
- Images: CFP or OCT
- Requires substantial effort in manual annotations



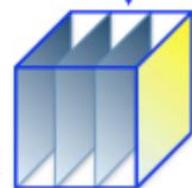
Semantic Segmentation

- Assign a semantic label, e.g., tissue, to each pixel of the image
- Often the label is binary denoting the organ/tissue of interest, e.g., blood vessels or a retinal layer.





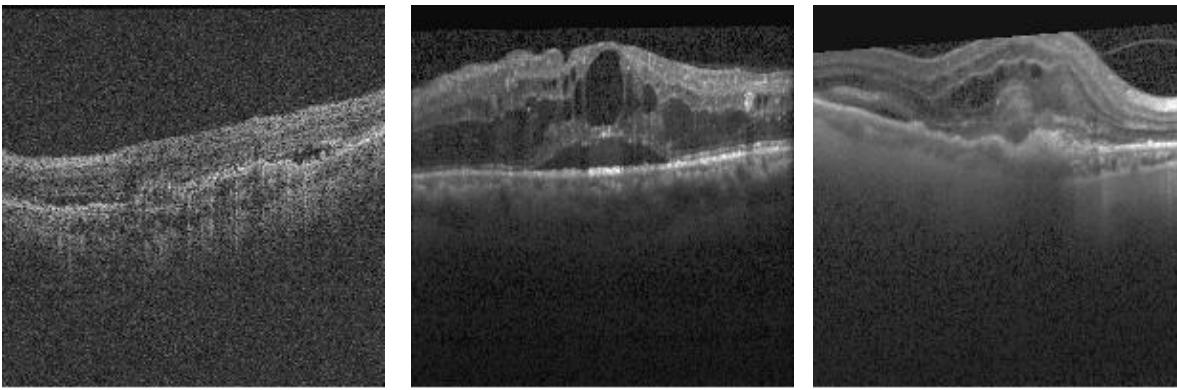
Convolution block



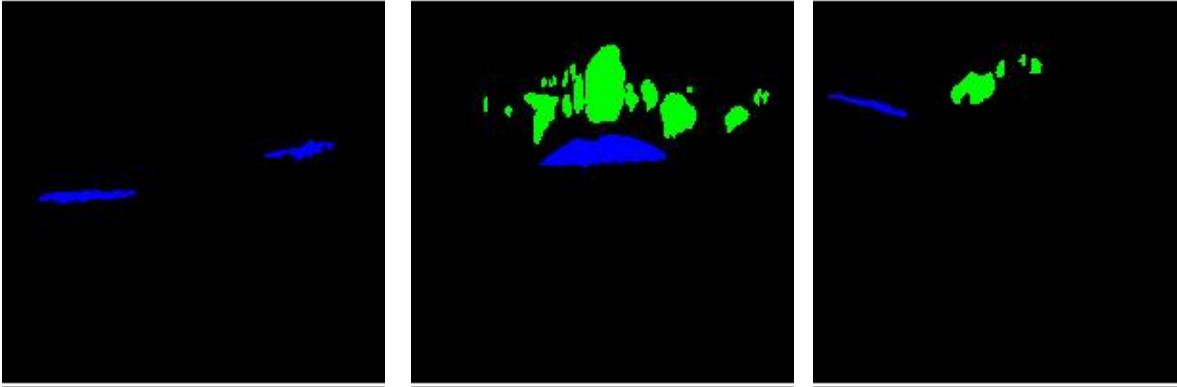
Transposed convolution block



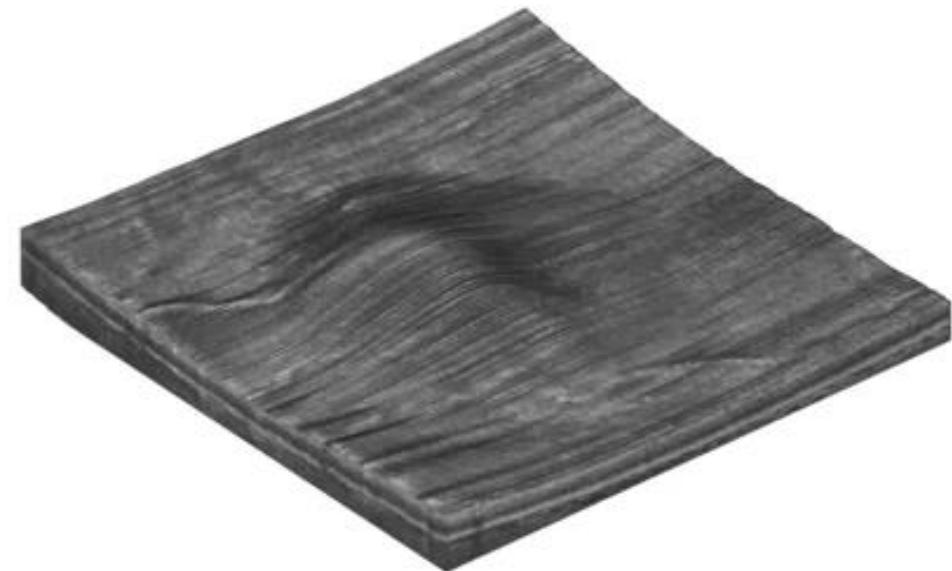
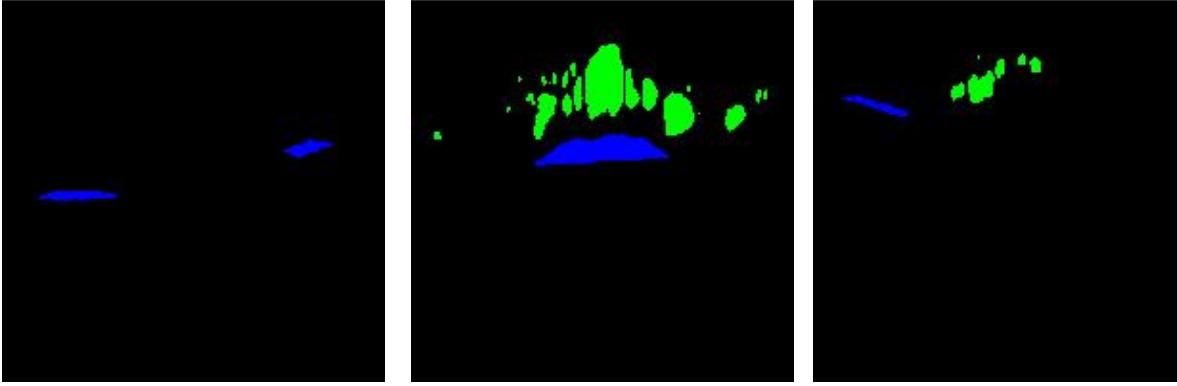
Original
B-Scans



Ground Truth
Annotations



Automated
Segmentation



State of the art: U-net

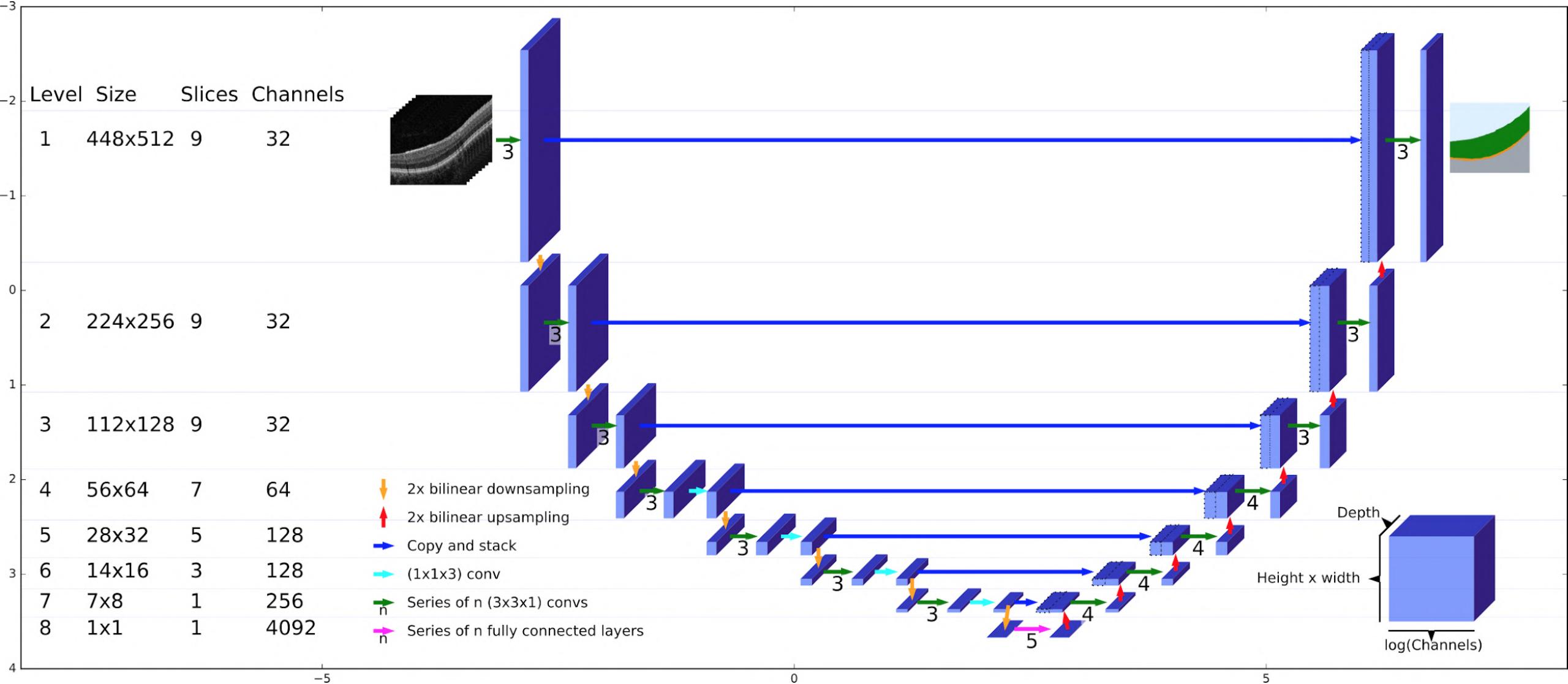
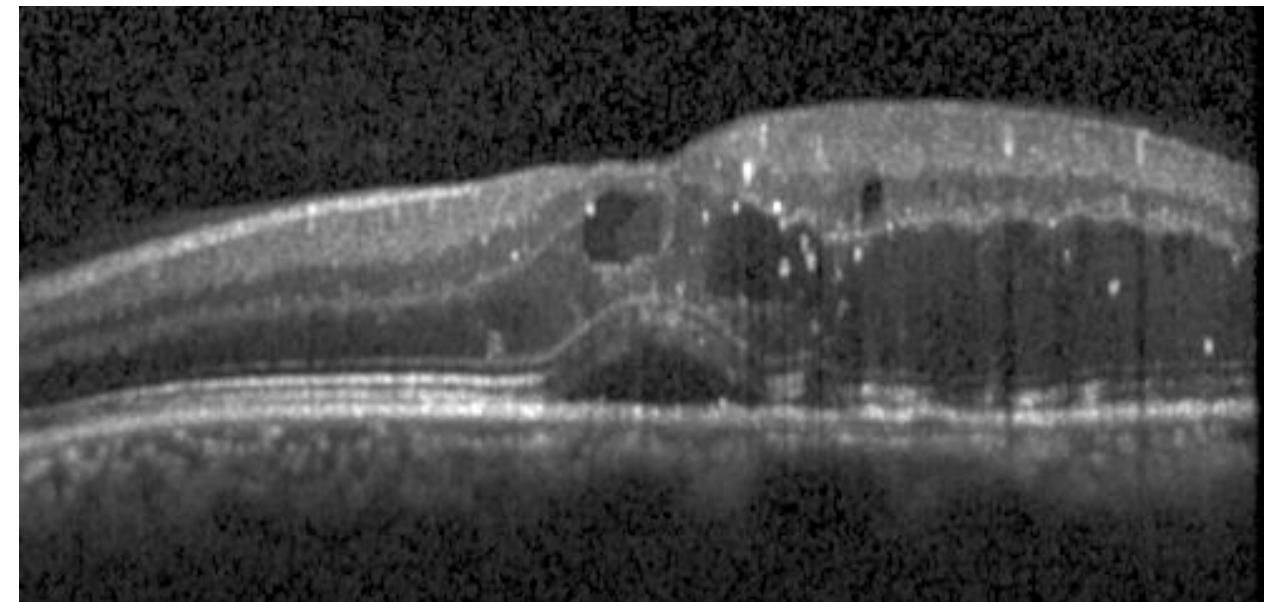


Image segmentation across OCT devices

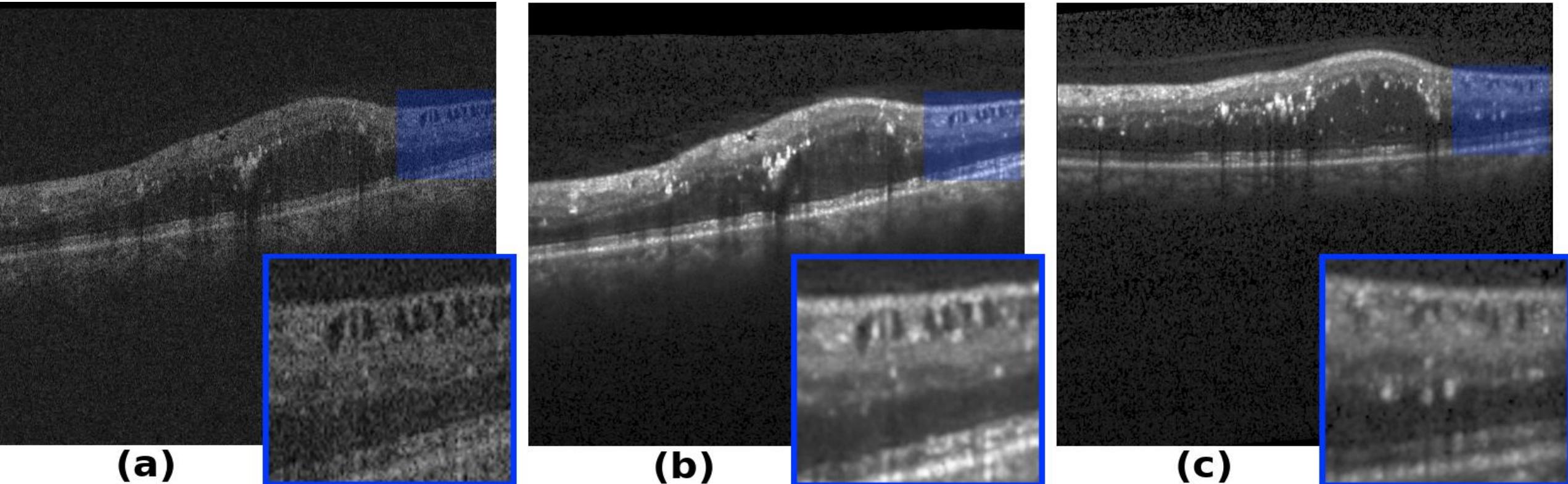


Cirrus, Zeiss Meditec
128 B-scans per volume



Spectralis, Heidelberg Engineering
49 B-scans per volume

CycleGAN to deal with OCT device variability

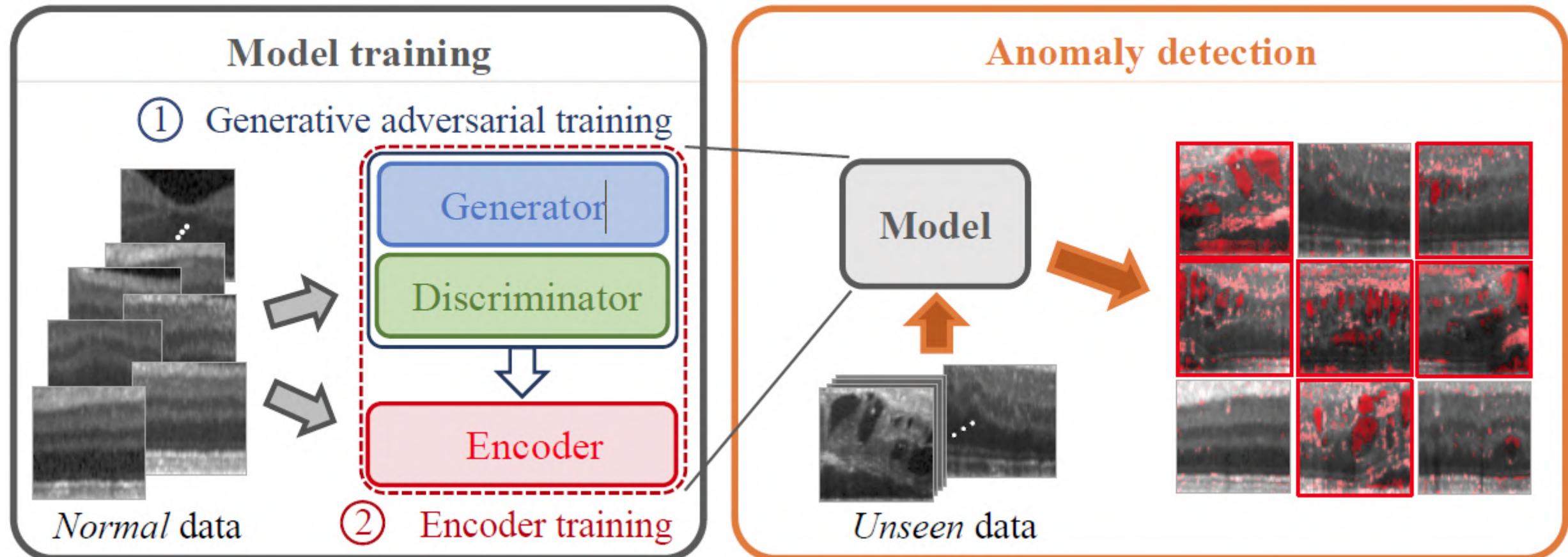


(a)

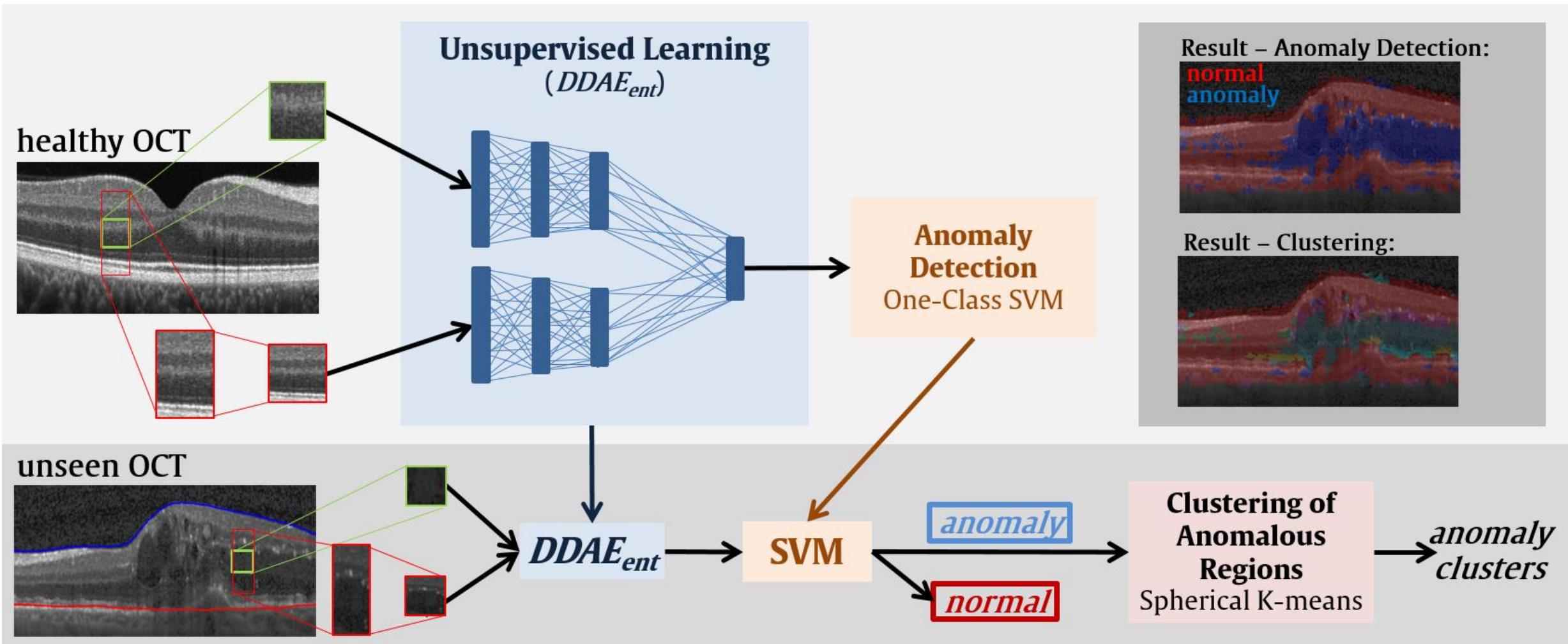
(b)

(c)

AnoGAN



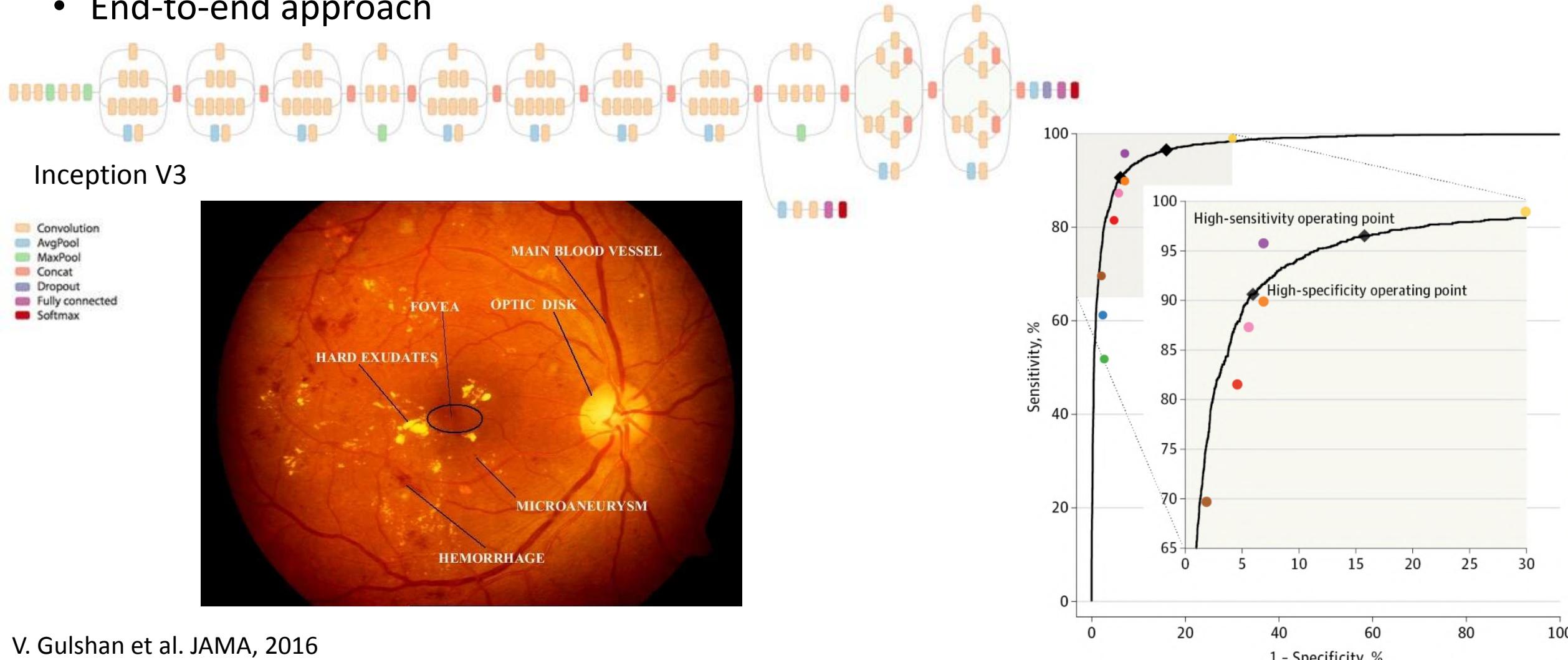
Anomaly detection + biomarker discovery



DL for Ophthalmic Image Classification

DR screening/diagnosis: Google

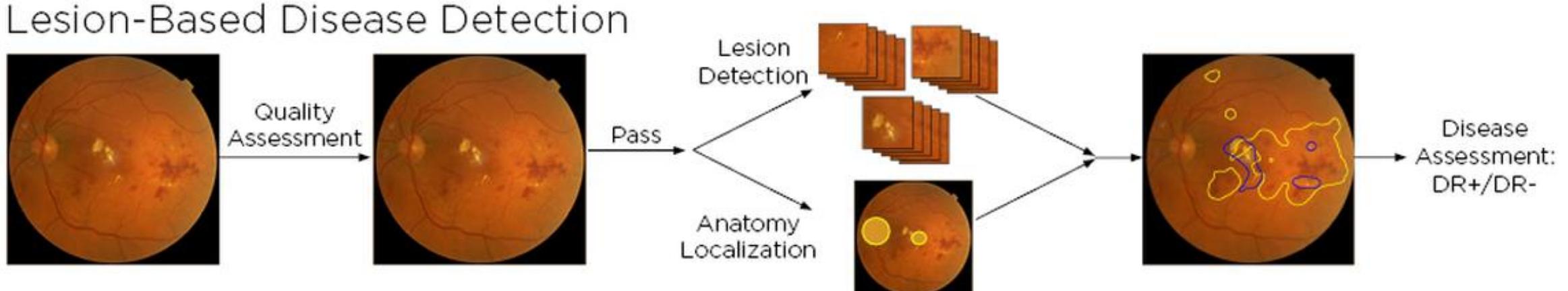
- End-to-end approach



DR screening: IDx-DR

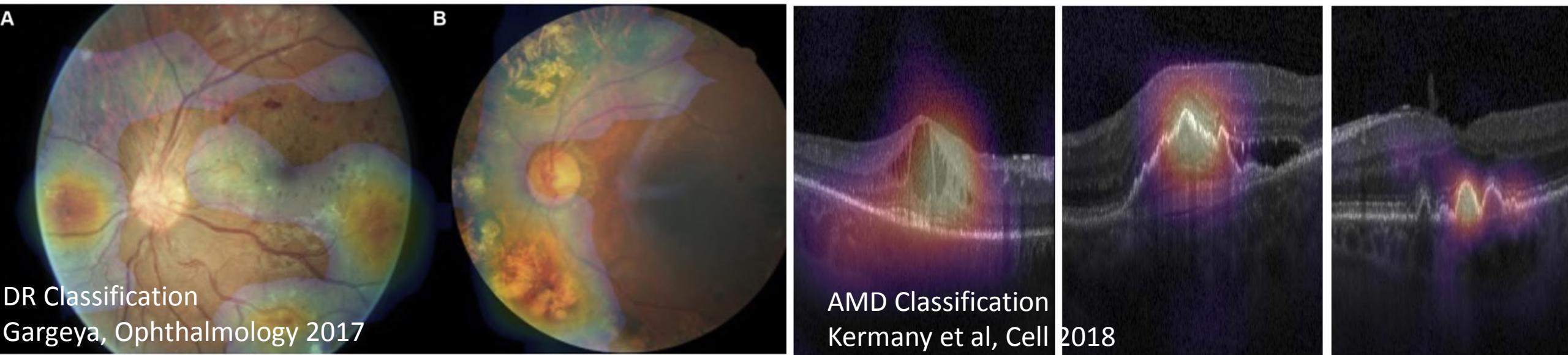
- Millions of individuals with diabetes
- Uses a series of deep learning detectors to search for lesions specific to diabetic retinopathy
 - Mimics how clinician assesses the disease as opposed to image classification
- Each image is run through a series of filters that evaluate for disease, exam protocol, and image quality.

Lesion-Based Disease Detection

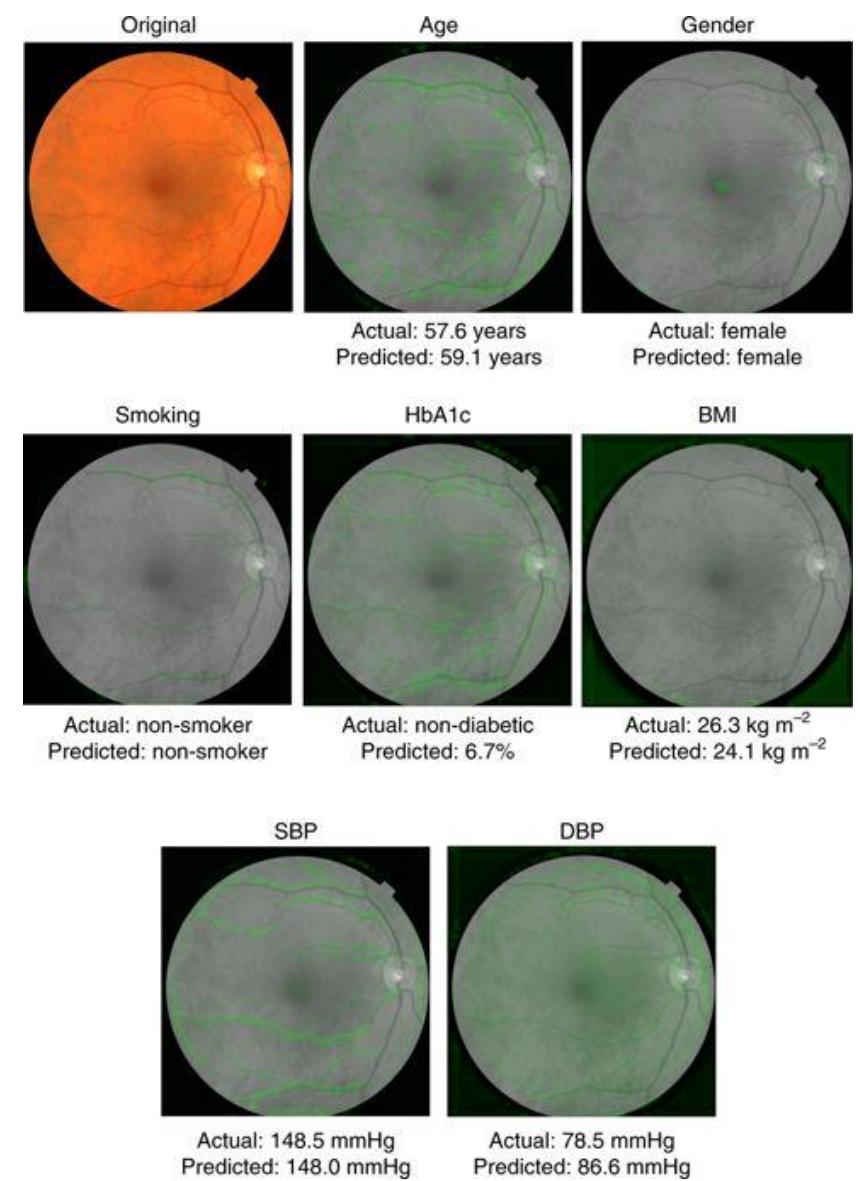
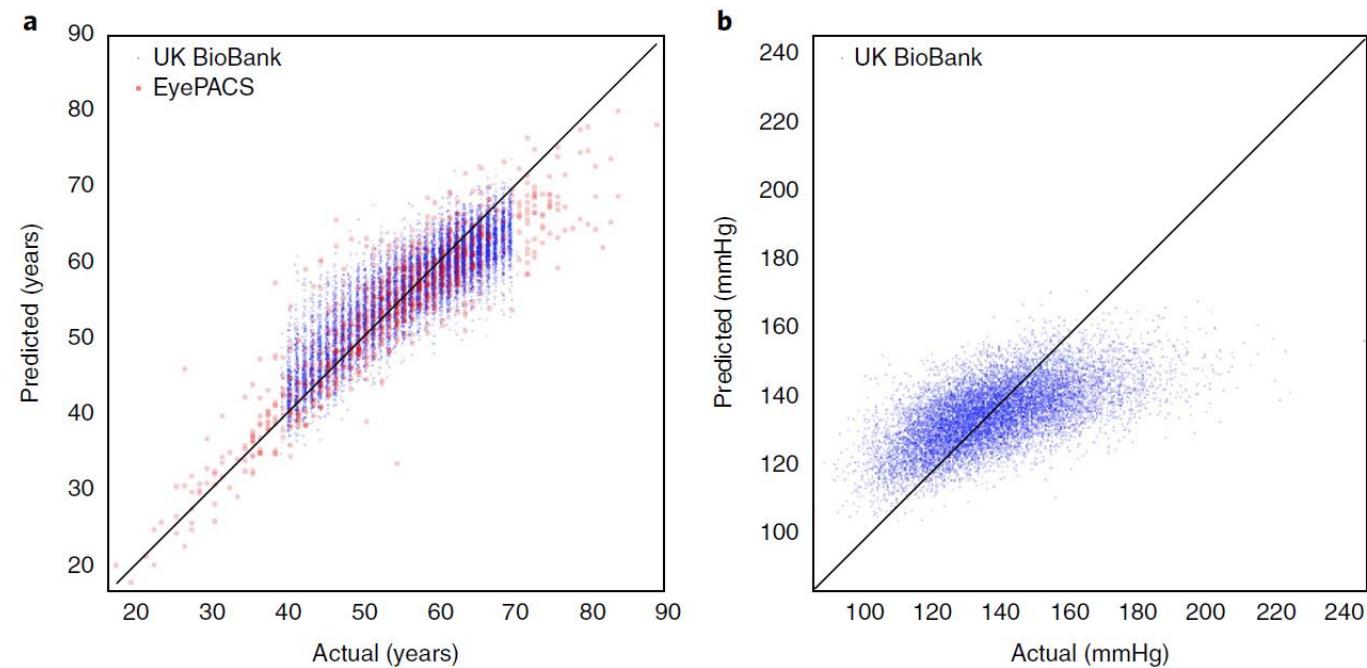


Interpretability of deep learning

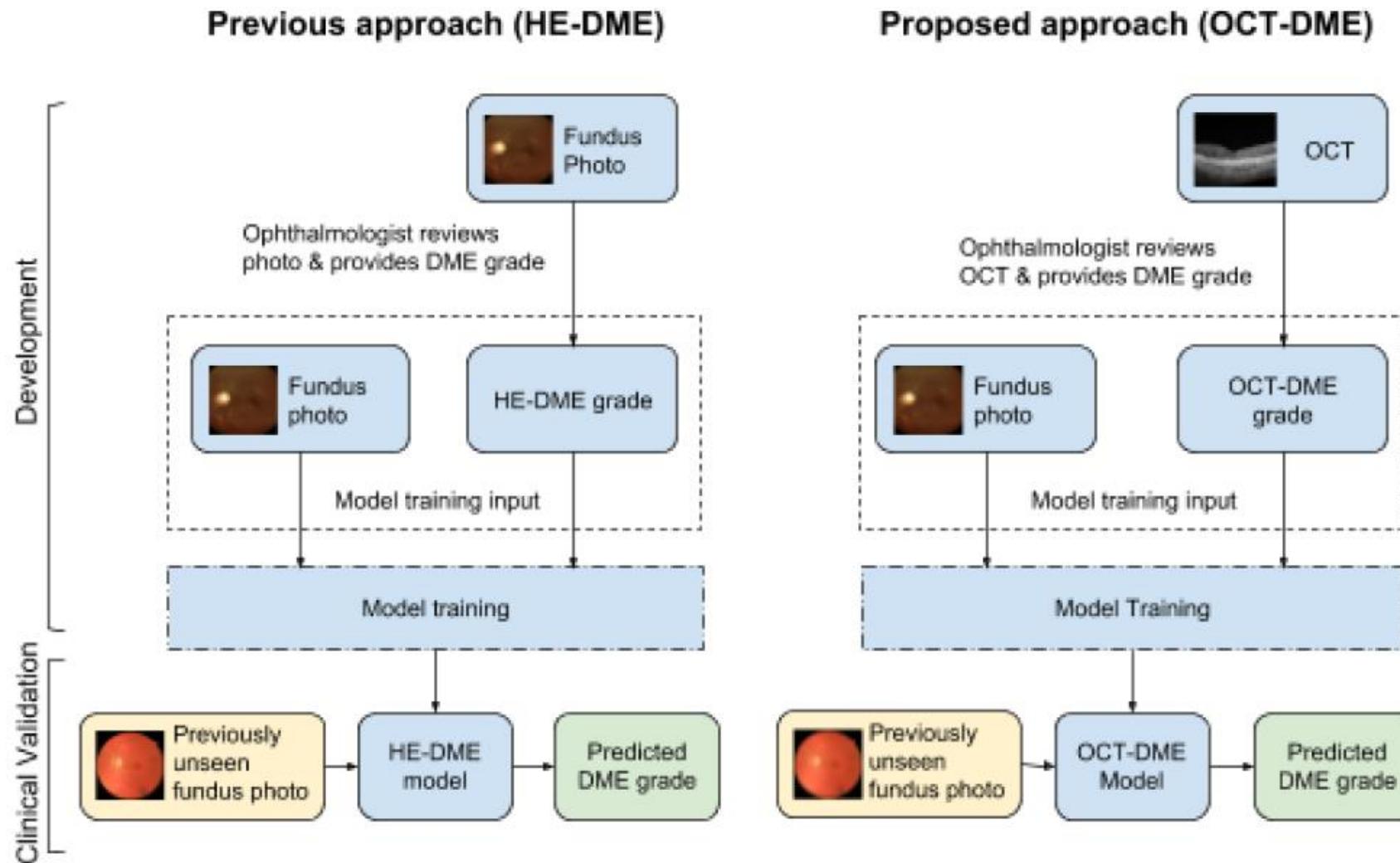
- Weight is assigned to each pixel of the image (heatmap)
 - What part of an example image is responsible for the network activating in a particular way. Which local changes would modify the network predictions
- Occlusion test: move a blank box is moved across the image and measure how much the classification score changes



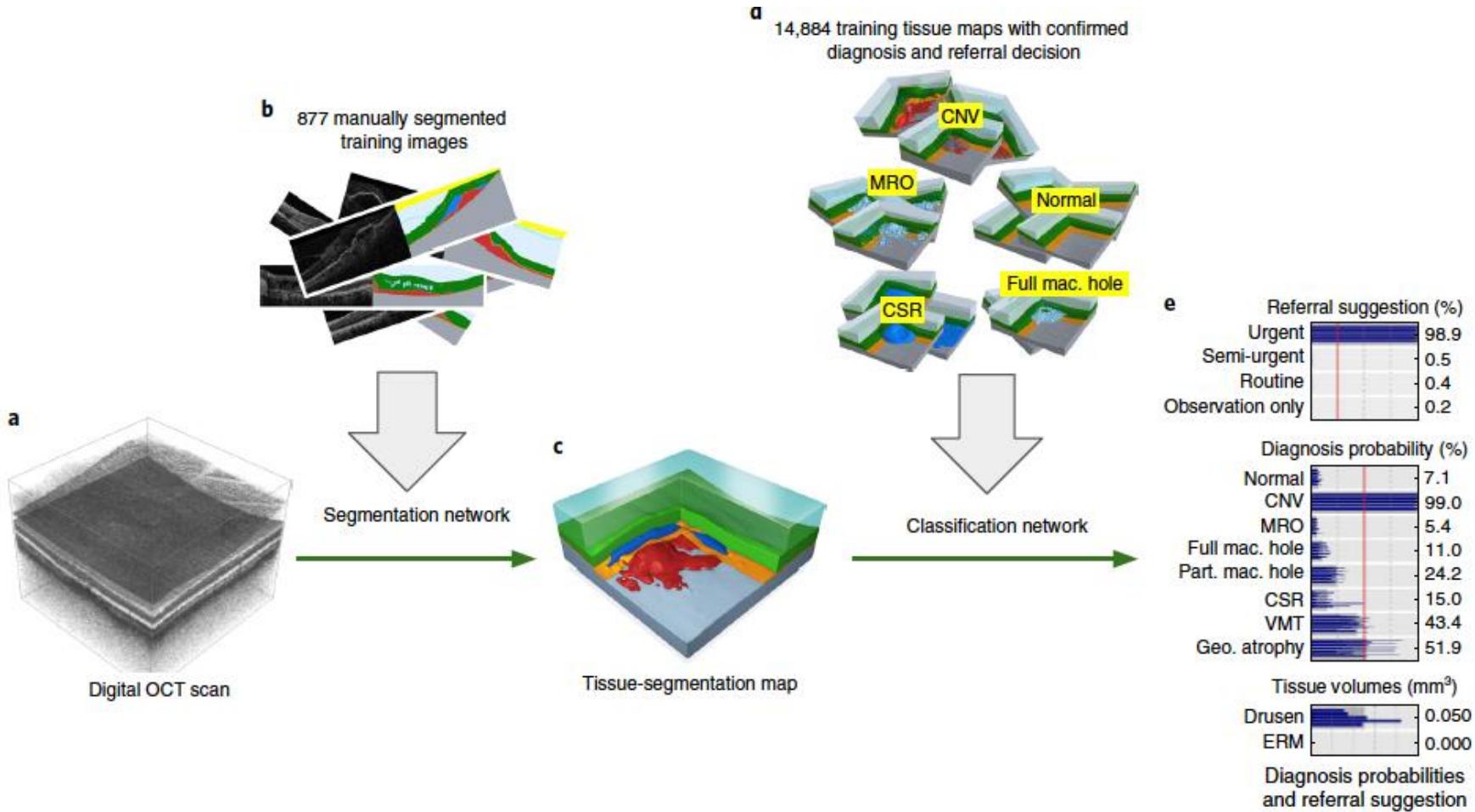
Eye as a Window-to-the-Body



OCT-derived diabetic macular edema grades from fundus photographs

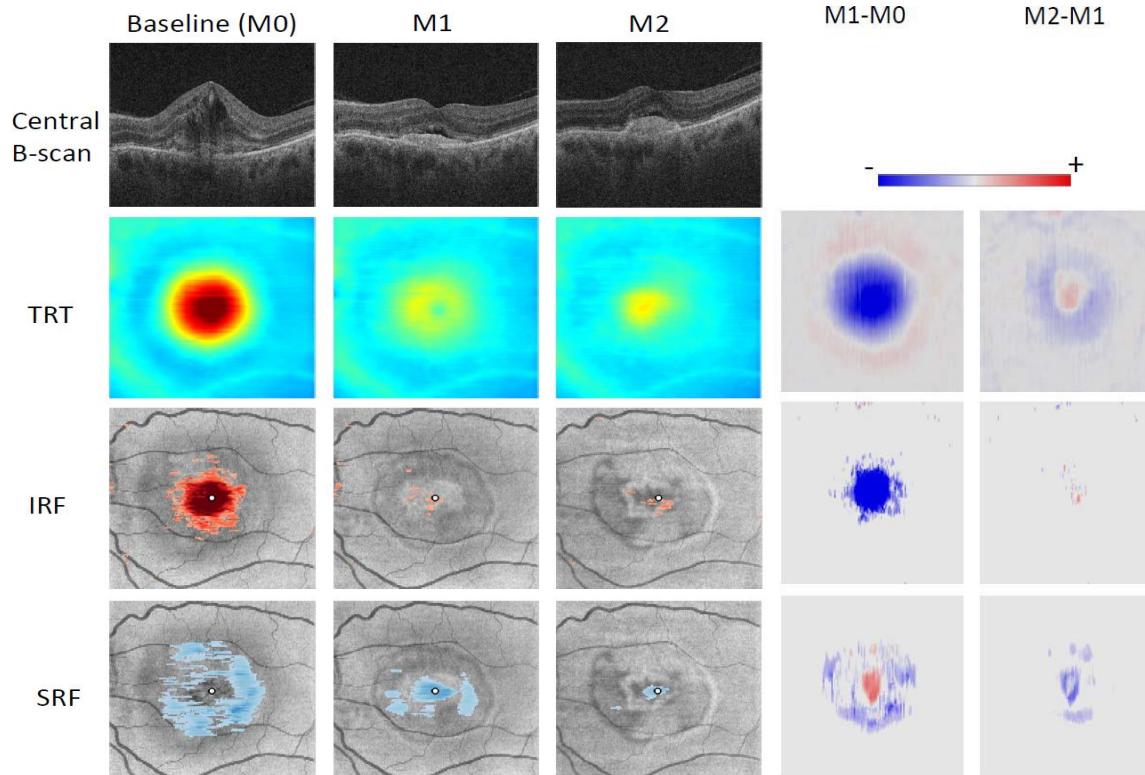


Retinal disease diagnosis with OCT

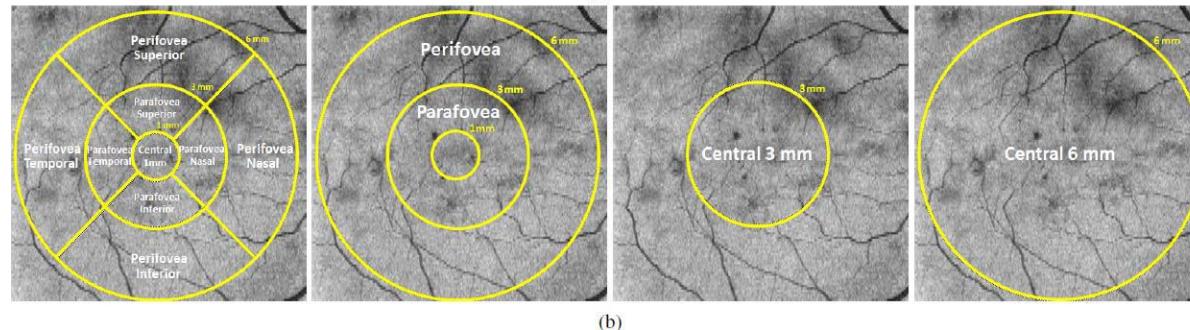


DL for Prognosis/Prediction

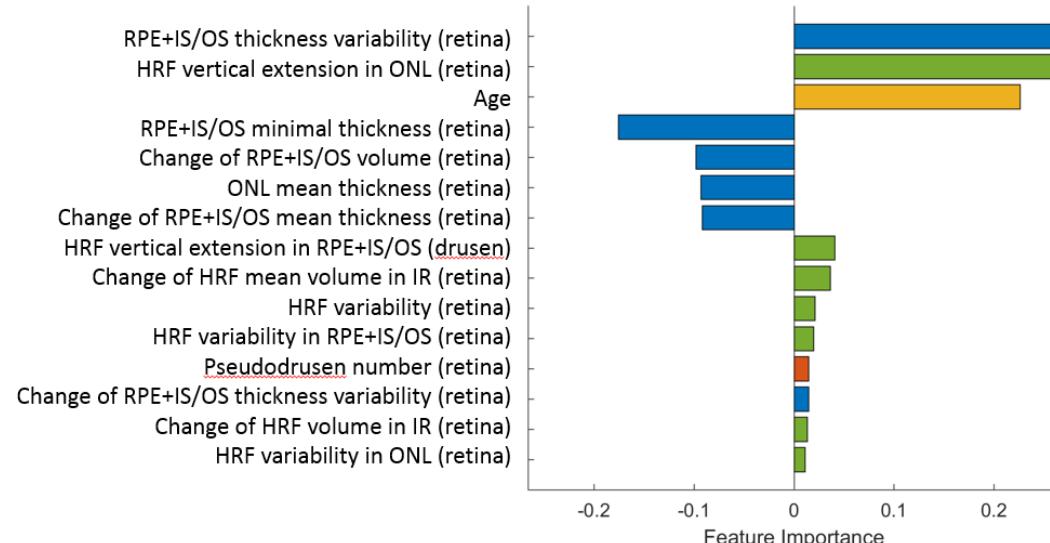
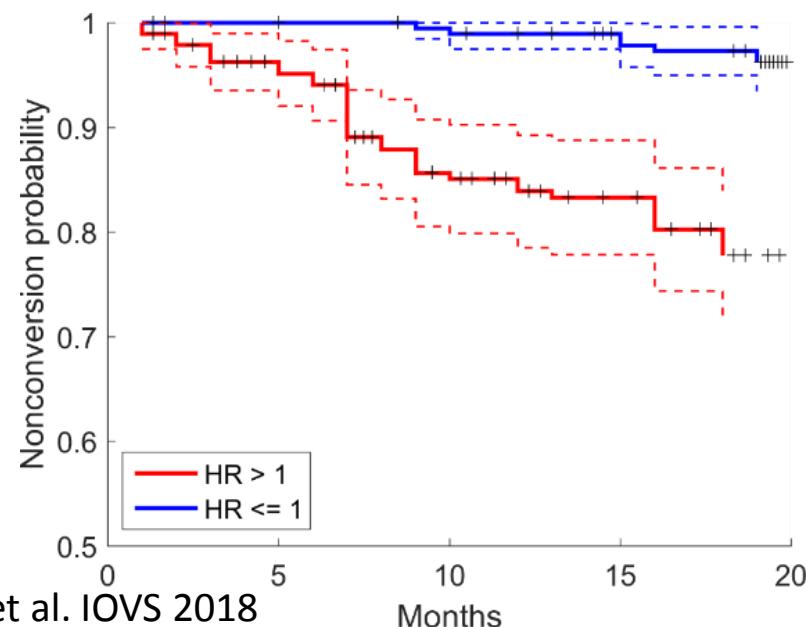
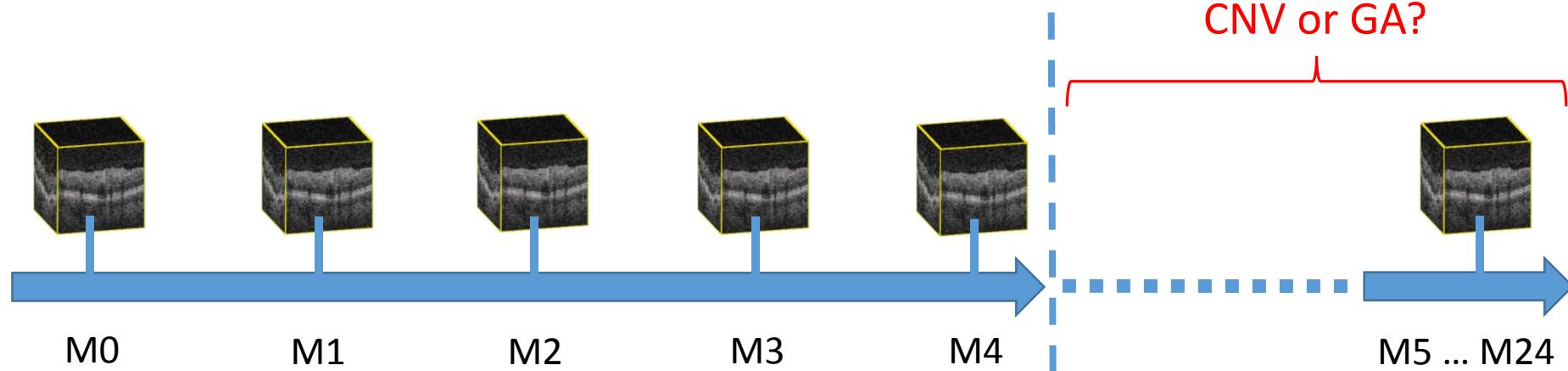
Prognostic spatio-temporal features



≈ 300 spatio-temporal OCT features
+ BCVA at baseline and M1,M2
+ Age and Gender

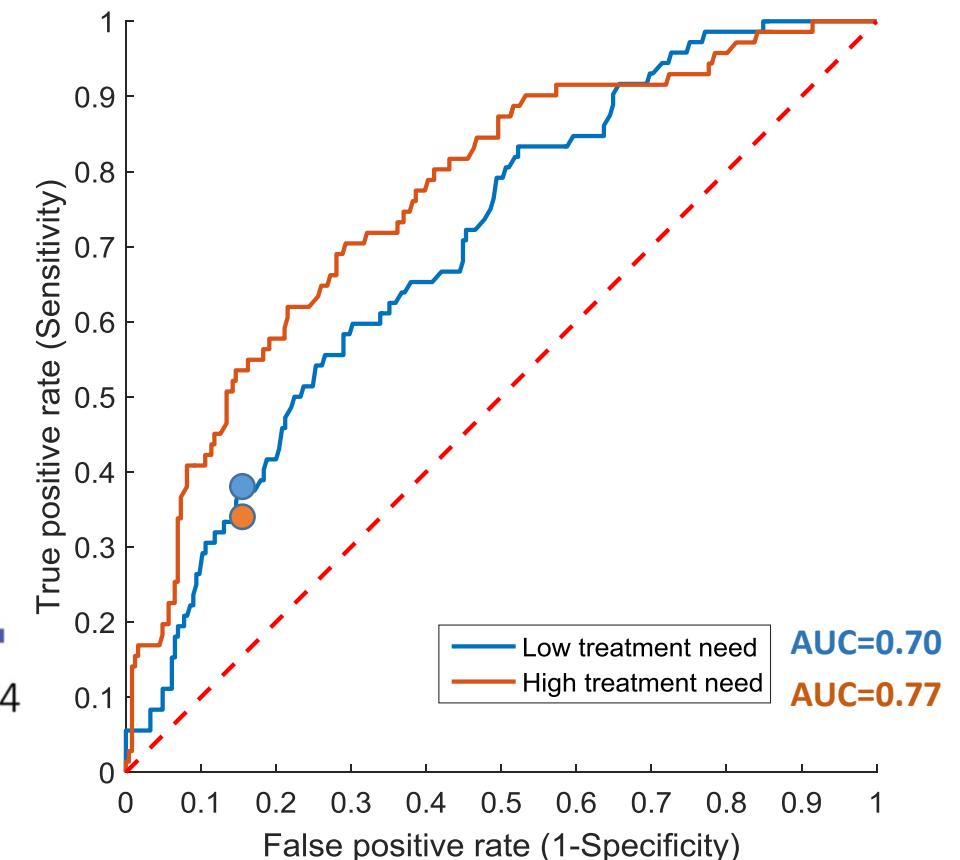
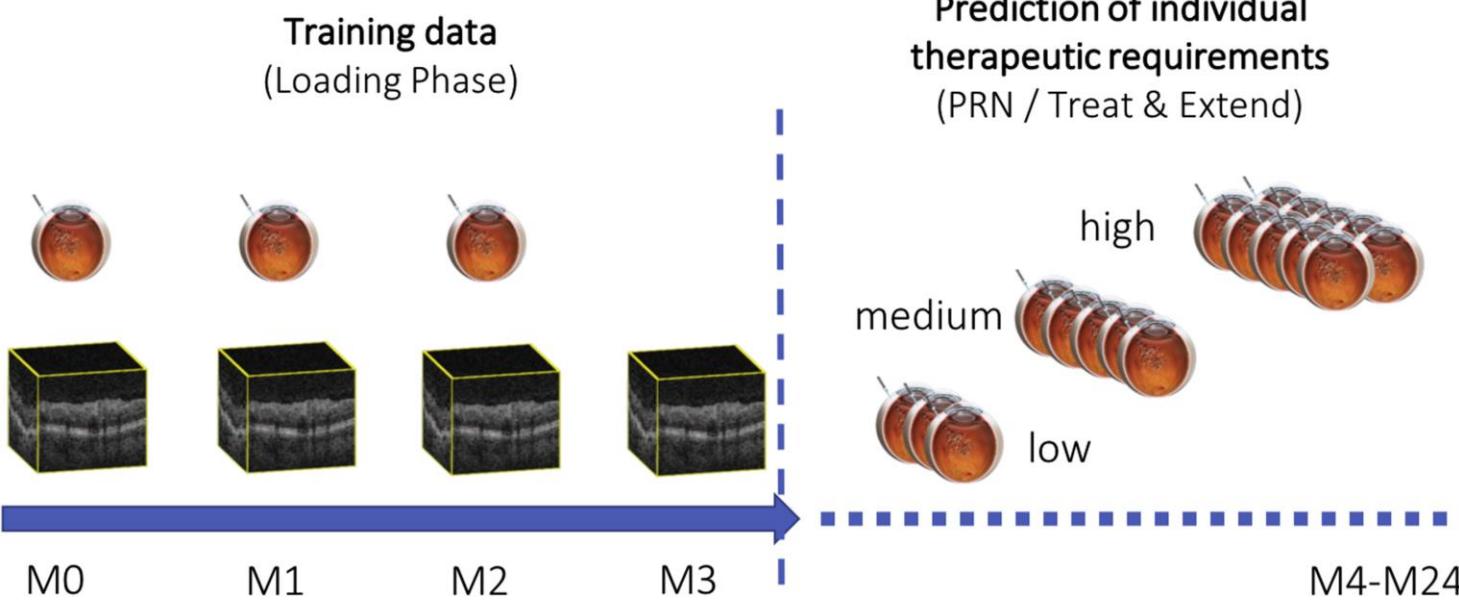


Prediction of disease conversion



Prediction of treatment requirements

- Anti-VEGF retreatment needs over 2 years



Industry Solutions

- Timing of catching the disease early is crucial for outcomes
- Population based, performed outside a hospital
 - Typically at a primary care clinic
- The binary decision between healthy and diseased
 - Immediate referral to a specialist needed or not
- Special need in developing countries



Grand-Challenges - <https://grand-challenge.org/>

Filters

Host

Modality

Task type

Structure

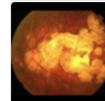
Displaying 171 of 171

All Challenges

Here is an overview of all challenges that have been organized within the area of medical image analysis that we are aware of. If you know any study that would fit in this overview, or want to advertise your challenge, please send an email to support@grand-challenge.org and we will add the challenge to the list on this page.

Active filters: 0

2019



PALM

The Pathologic Myopia Challenge (PALM) focuses on the investigation and development of algorithms associated with the diagnosis of Pathological Myopia (PM) and segmentation of lesions in fundus photos from PM patients.

Participants: 209
Workshop: April 8, 2019
Associated with: ISBI 2019
Hosted on: grand-challenge.org



ACDC-LungHP

Automatic Cancer Detection and Classification in Whole-slide Lung Histopathology

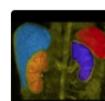
Participants: 306
Workshop: April 8, 2019
Associated with: ISBI 2019
Hosted on: grand-challenge.org



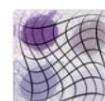
EAD2019

Endoscopic Artefact Detection (EAD) is a core problem and needed for realising robust computer-assisted tools. The EAD challenge has 3 tasks: 1) Multi-class artefact detection, 2) Region segmentation, 3) Detection generalisation.

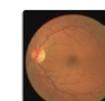
Participants: 398
Workshop: April 8, 2019
Associated with: ISBI2019
Hosted on: grand-challenge.org



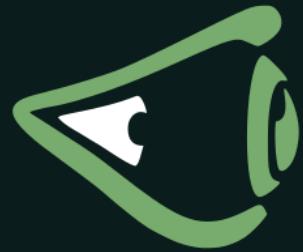
CHAOS



ANHIR

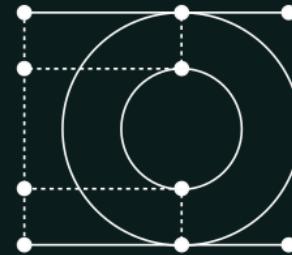


DRIVE



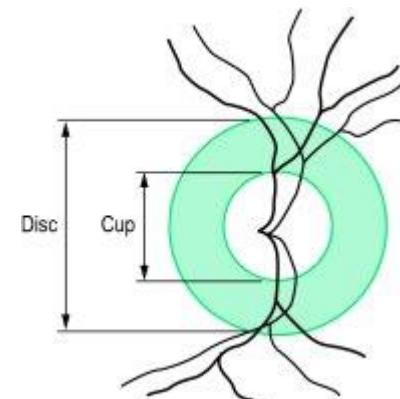
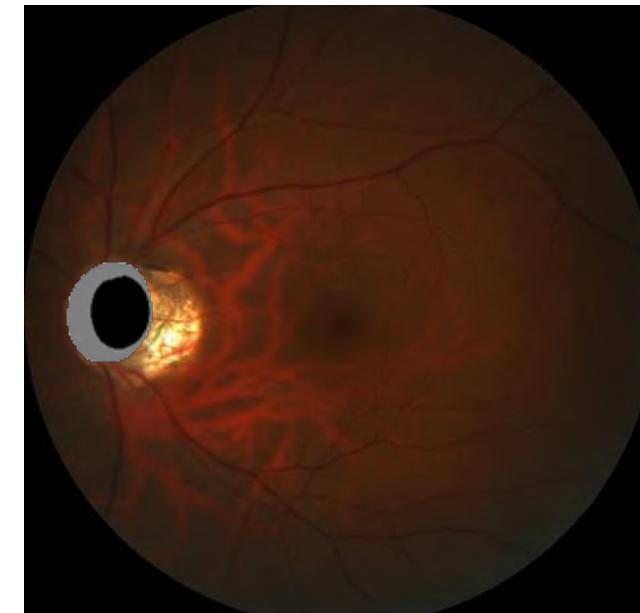
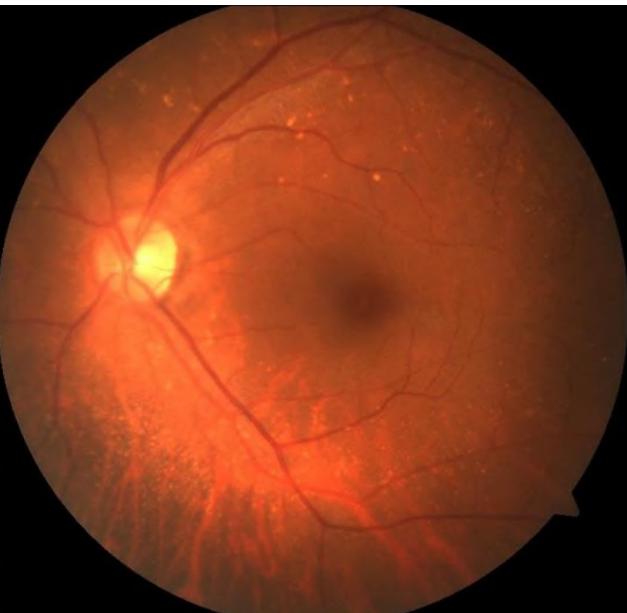
REFUGE

Retinal Fundus Glaucoma Challenge



refuge.grand-challenge.org

- 1200 color fundus image (400 Train, 400 Validation, 400 Test) with labels from the clinical records
- Classification and Segmentation (optic disc and cup) tasks

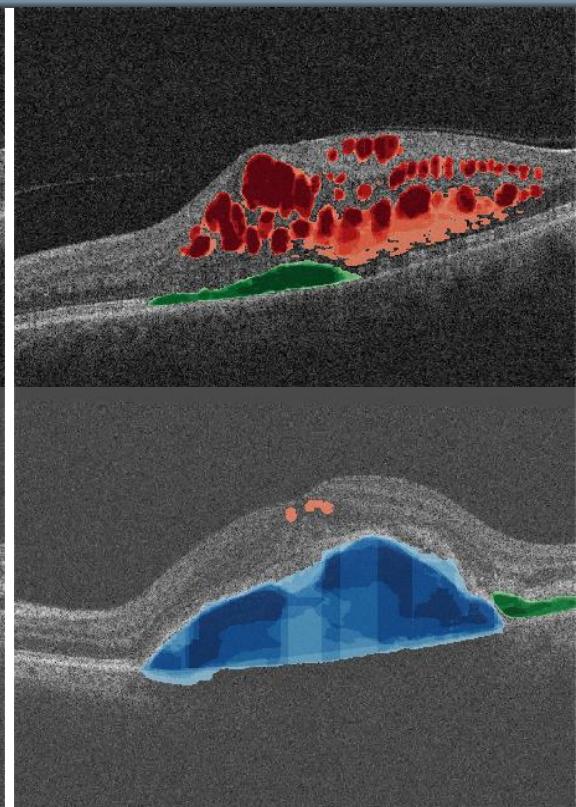
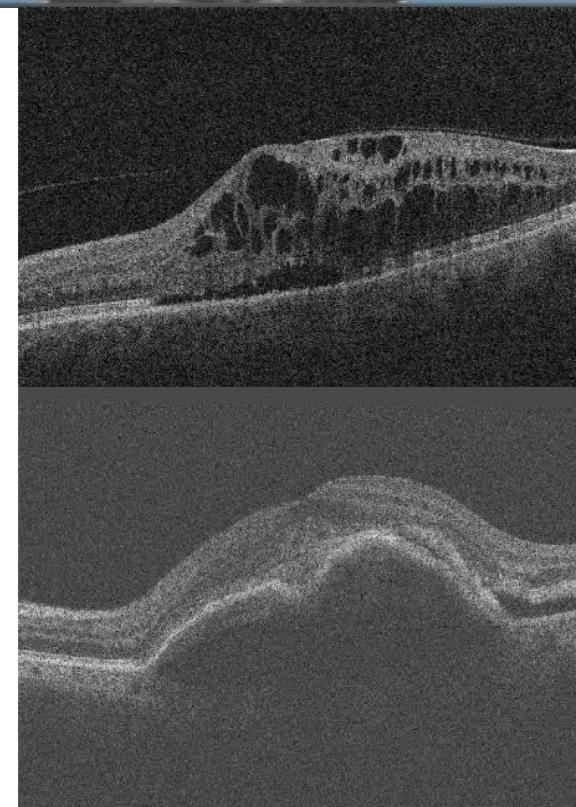
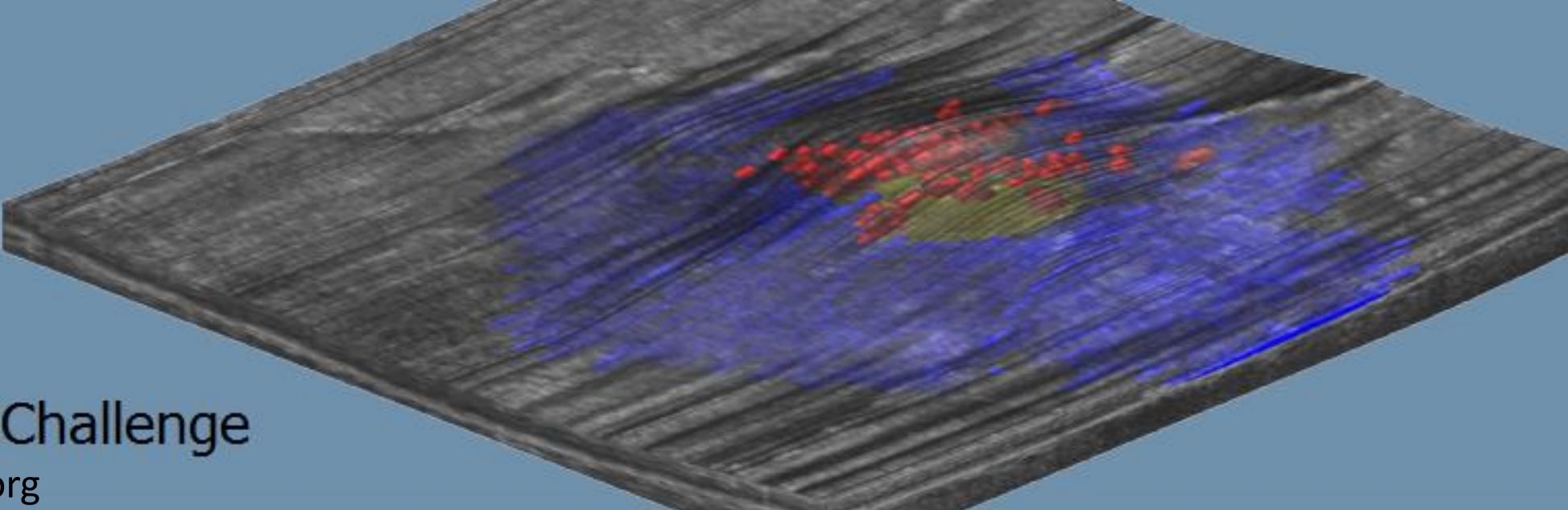
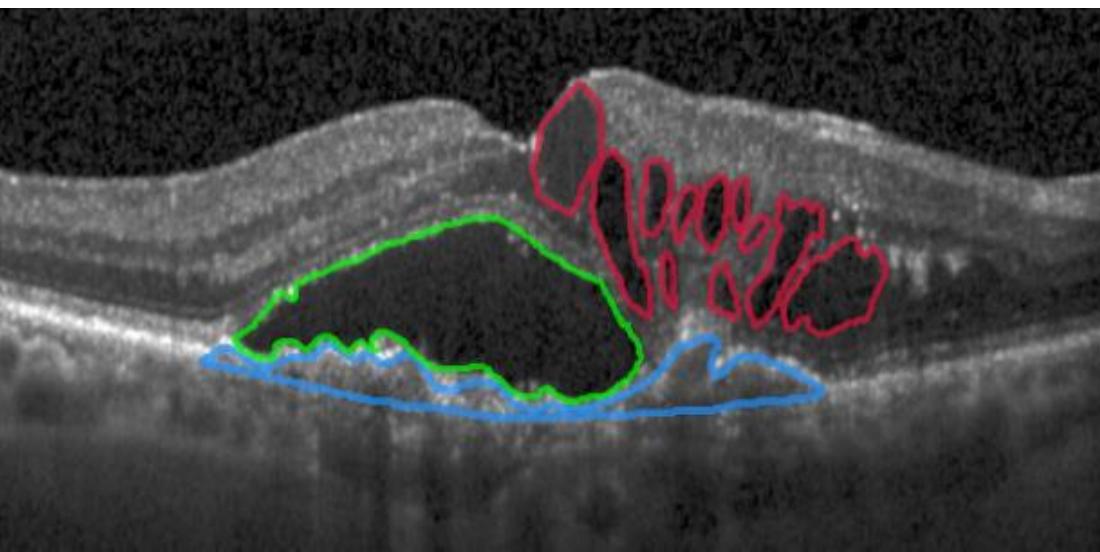


RETOUCH

Retinal OCT Fluid Challenge

retoch.grand-challenge.org

- 110 OCT scans (70 Train, 40 Test) with double annotations
- OCTs from three different devices
- Classification and Segmentation tasks



PATHOLOGIC MYOPIA CHALLENGE

palm.grand-challenge.org

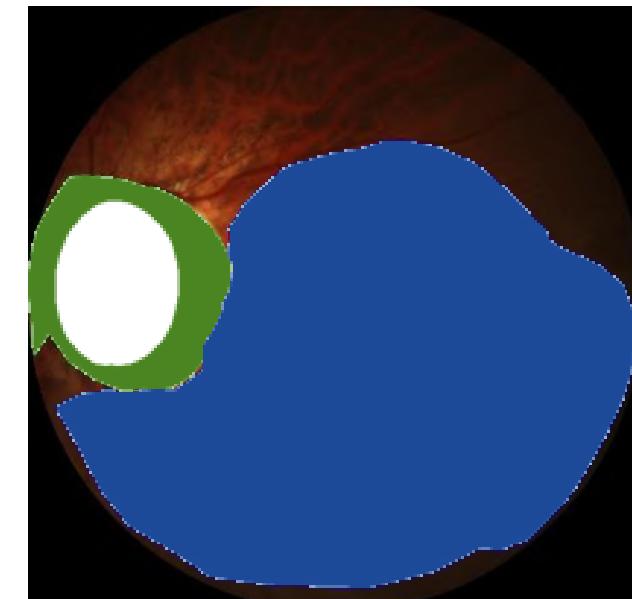


- 1200 color fundus image (400 Train, 400 Validation, 400 Test)
- Classification task: PM vs non-PM (including High myopia)
- Segmentation task: retinal lesions (atrophy and detachment).
- In association with ISBI 2019 (April 8th, Venice, IT)



High myopia

Pathologic myopia



Atrophy Detachment