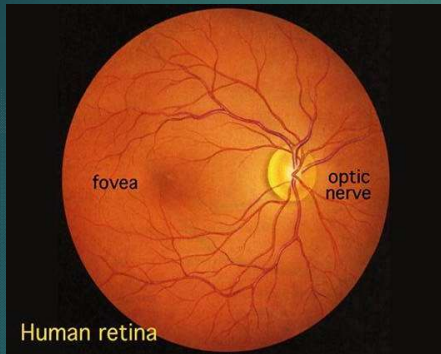


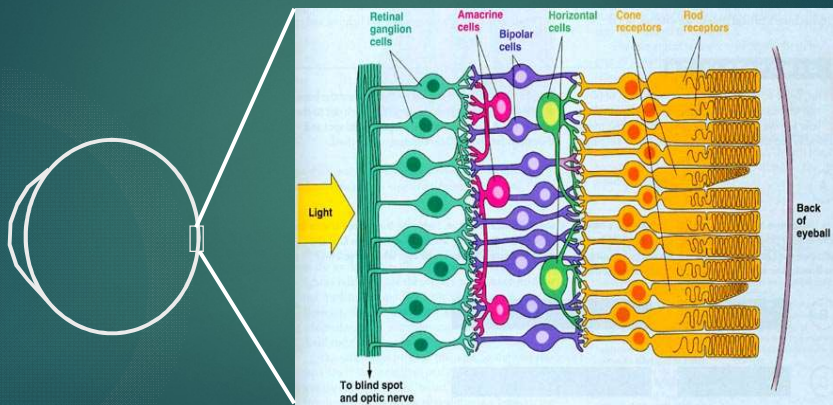
Retinal Imaging



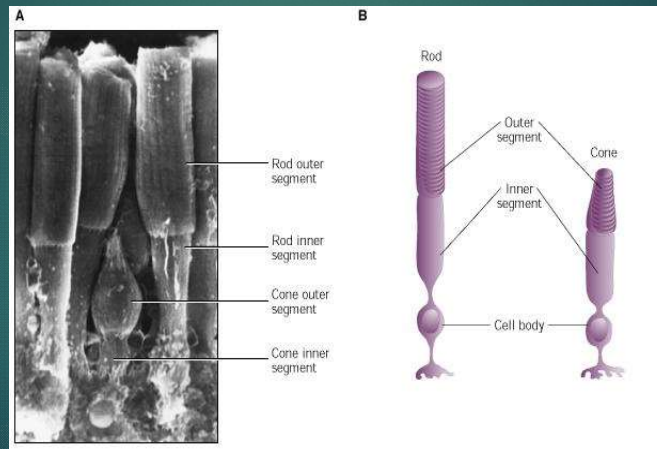
“The eyes are the window to the soul”
16th century proverb

The retina gives an unobstructed view of the human vascular. Also, retinal imaging is important for diagnosing retina diseases.

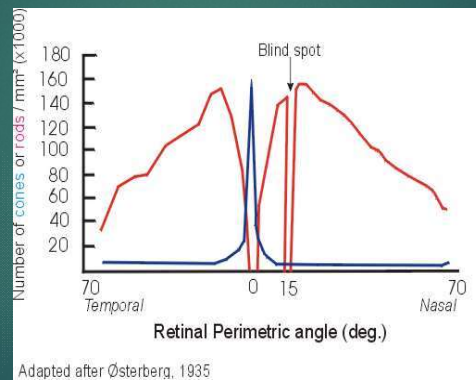
Retinal Physiology



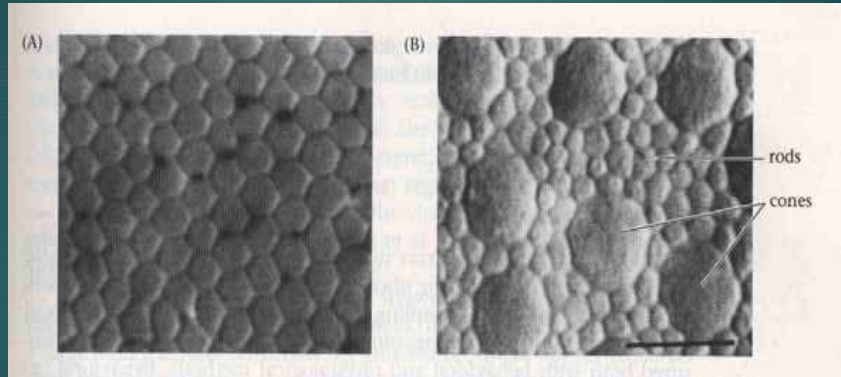
Rods and Cones



Rod and Cone Density



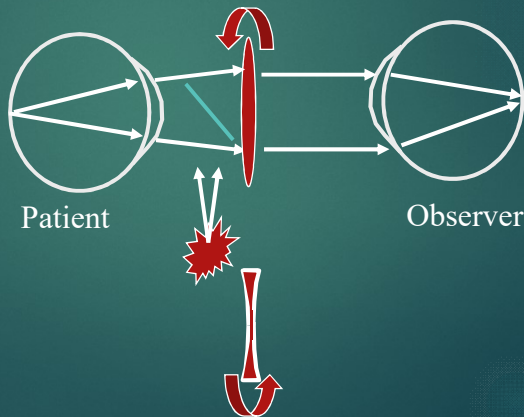
Rod and Cone Mosaic



Direct Ophthalmoscopy



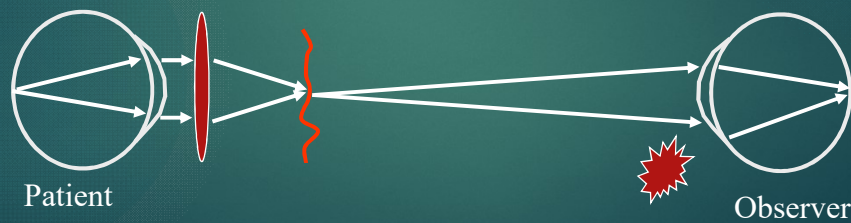
Observer adjusts power of lens wheel so that the patient's far point is imaged to the Observer's far point.



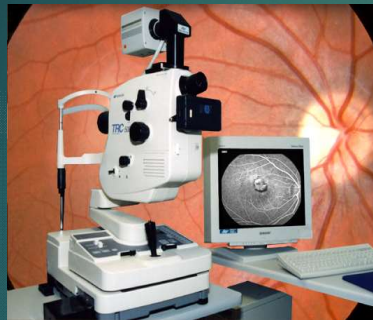
Indirect Ophthalmoscopy



The Observer holds a high power lens in front of the Patient and views the intermediate image formed by the lens. The system is binocular, so a 3-D feel for structures with the eye is obtained.

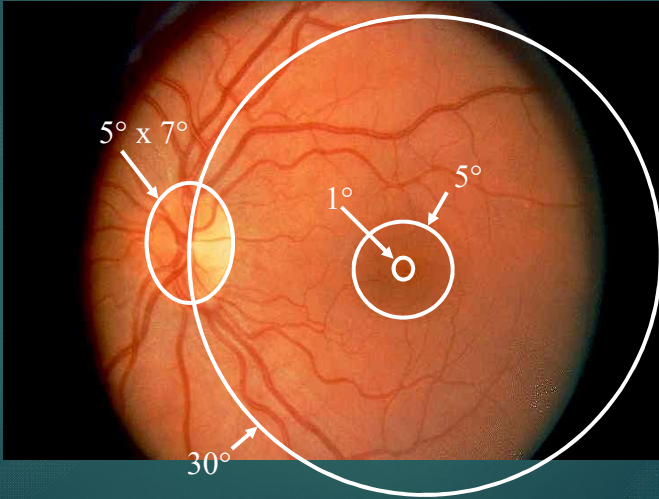


Fundus Camera

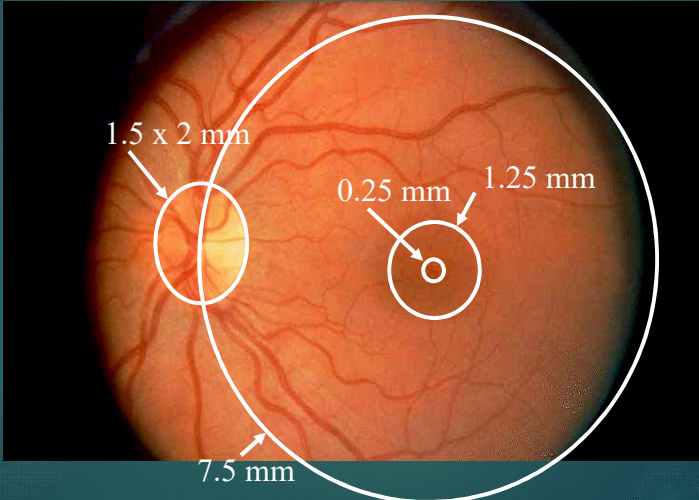


A fundus camera is a device for photographing the retina. It is based on the indirect ophthalmoscopy principle, where the Observer's eye is replaced with a camera.

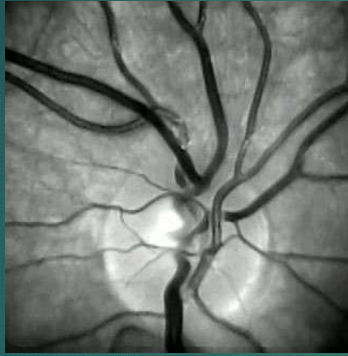
Angular Size



Dimensions

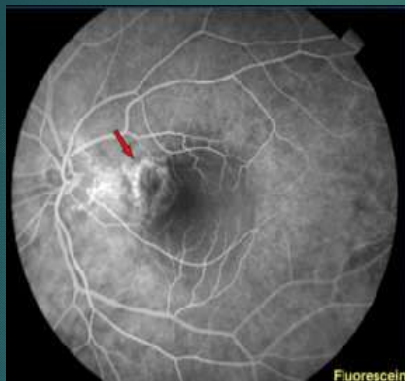


Red-Free Images



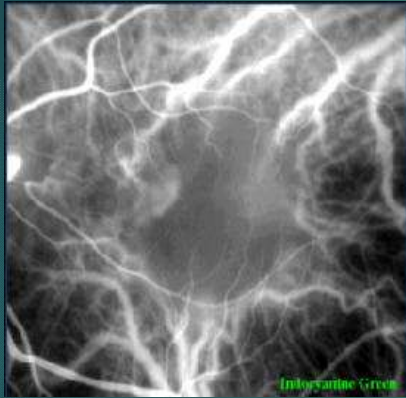
Fundus images are sometimes taken with a green filter to enhance the contrast of the blood vessels.

Fluorescein Angiography



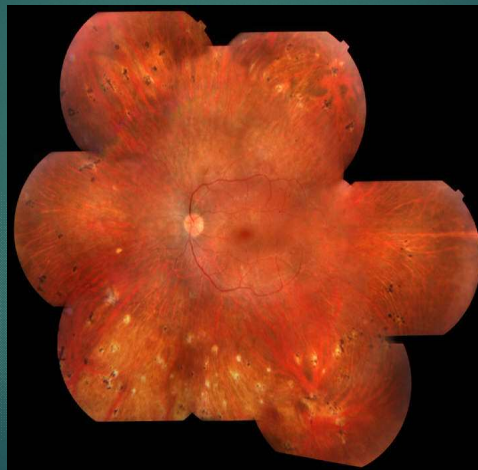
Sodium Fluorescein dye is injected into a vein in the patient. As the dye circulates, it passes through the vessels of the retina. Blue light is used to illuminate the retina and fundus photographs are taken to capture the green fluorescence of the dye. This technique aids in visualizing the vessels of the retina.

Indocyanine Green (ICG) Angiography



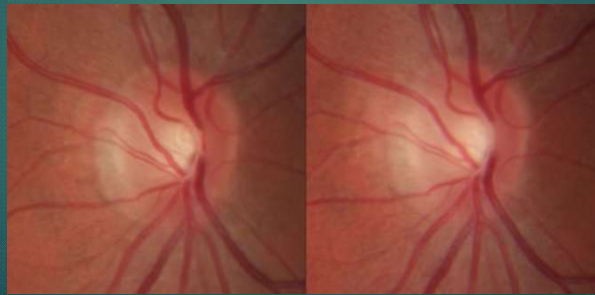
Indocyanine Green dye is injected into a vein in the patient. As the dye circulates, it passes through the vessels of the retina. Digital fundus photographs are taken to capture the infrared fluorescence of the dye. This technique aids in visualizing the vessels of the choroid.

Retinal Mosaic



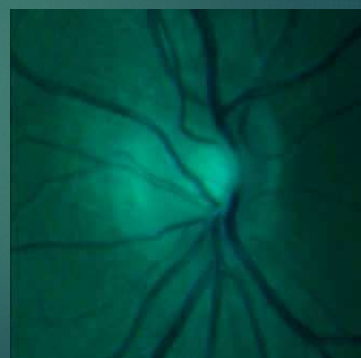
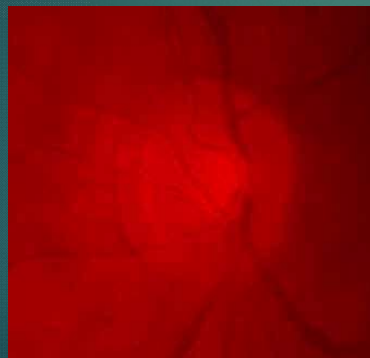
Stereo Pairs

- ▶ Two images of the retina can be taken from slightly different angles to form a stereo pair.
- ▶ Useful for visualize cupping of the optic nerve head in glaucoma and edema (swelling) that occurs from some pathologies.



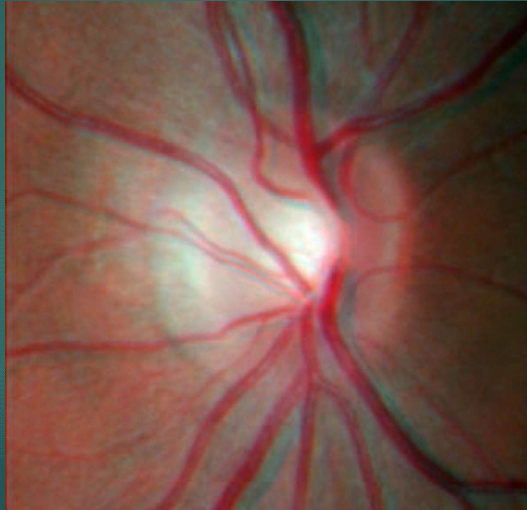
Red/Blue Anaglyphs

Take the red channel from the left hand image and the blue and green channels from the right hand image.



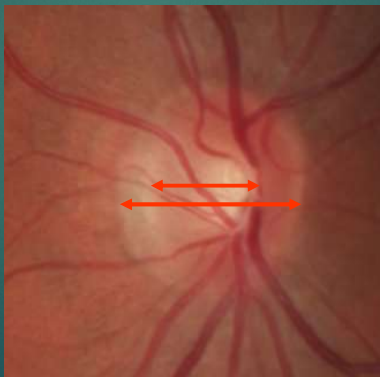
Red/Blue Anaglyphs

Merge images to create
and anaglyph



Cup to Disk Ratio

- ▶ Diameter of the cupped region of the optic nerve head divided by the diameter of the optic nerve head.
- ▶ Normal is ~0.3-0.5.
- ▶ Abnormal values are higher and are associated with glaucoma

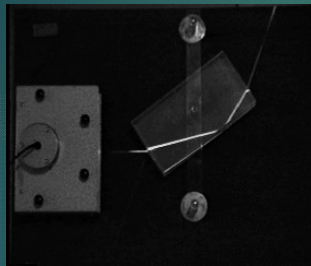


$C/D = 0.6$

Glaucoma



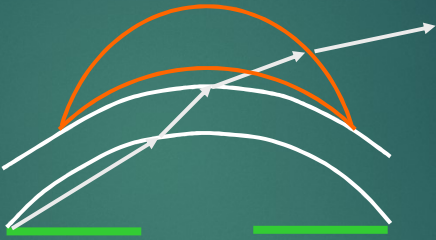
Total Internal Reflection



When going from a high index material to a low index material, if the angle of incidence is too great, then 100% of the light is reflected from the surface. This phenomenon prevents the light from the angle from exiting the eye.



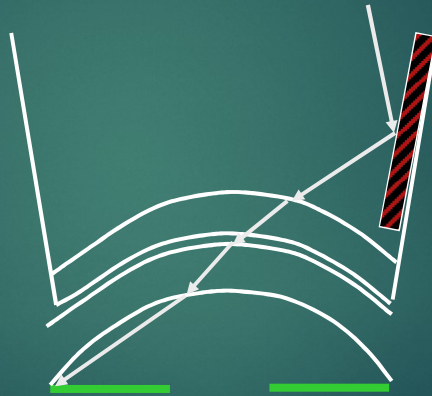
Direct Gonioscopy



Direct Gonioscopy



Indirect Goniscopy



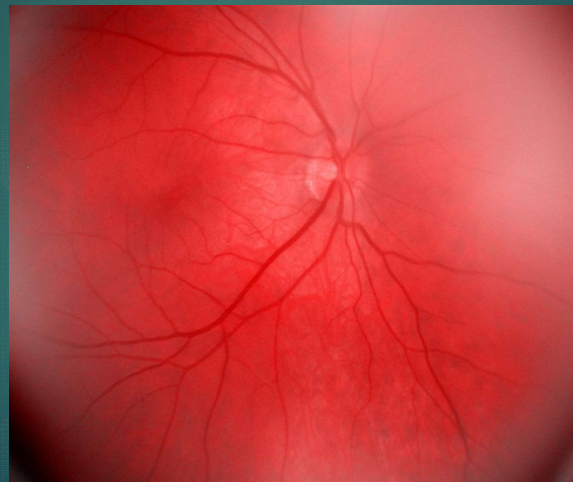
Portable Fundus Camera



Portable Fundus Camera



Normal Retina



Shaken Baby Syndrome

- ▶ Severe head injury of baby from being shaken.
- ▶ Cause is usually child abuse.
- ▶ Poor prognosis, typically severe disabilities in survivors.
- ▶ Injuries and symptoms may include:
 - ▶ Bruising, swelling and bleeding in the brain.
 - ▶ Lethargy, loss of consciousness, convulsions.
 - ▶ Hemorrhages in the retina.
 - ▶ Possible broken or dislocated bones.

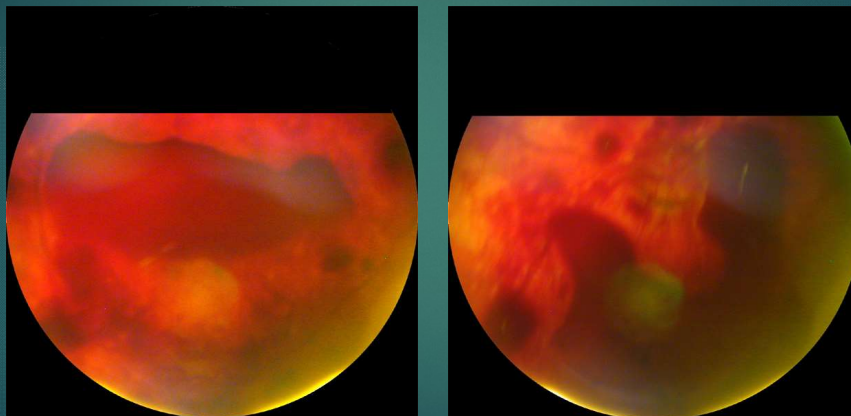
Shaken Baby Syndrome

- ▶ SBS and Retinal Hemorrhages
 - ▶ 50-80% of SBS have retinal hemorrhages
 - ▶ 60-90% are bilateral
 - ▶ Retinal Hemorrhages is strong confirmatory evidence of abuse.

Shaken Baby Syndrome

- ▶ Victims are usually in a pediatric intensive care unit and cannot be easily moved to ophthalmology departments for conventional fundus photographs.
- ▶ Victims usually cannot sit upright, so conventional fundus cameras cannot be used.
- ▶ Emergency room and intensive care personnel may not be well versed in traditional retinal examination, so an easy to use camera may aid in identifying retinal hemorrhages.
- ▶ Inexpensive cameras can be placed in multiple hospitals.
- ▶ Digital photographs can easily be transmitted for consultation by off-site ophthalmologists.
- ▶ Child Protective Services and the Police can use the photographs as evidence against abusers, instead of solely relying on the expert verbal testimony of an ophthalmologist.

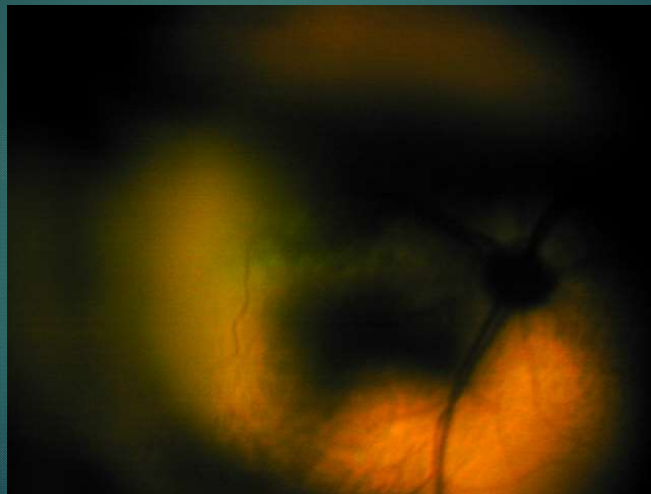
Shaken Baby Syndrome



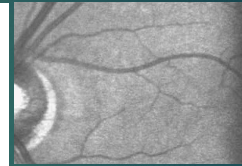
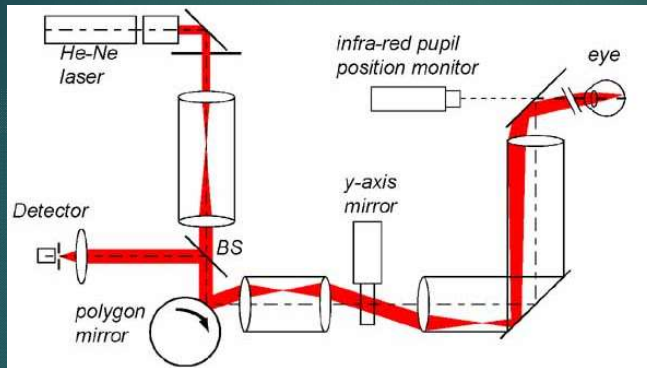
Child Abuse



Veterinary Use

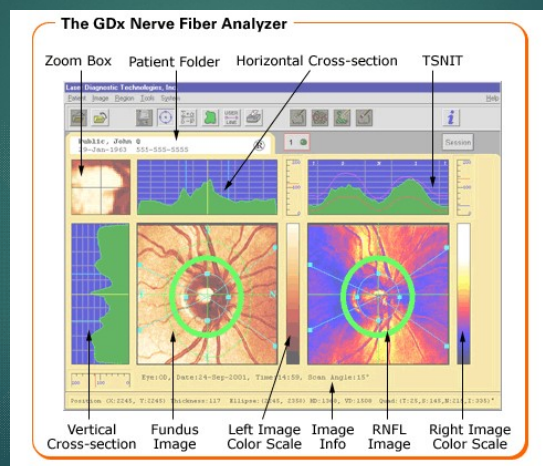


Scanning Laser Ophthalmoscopy

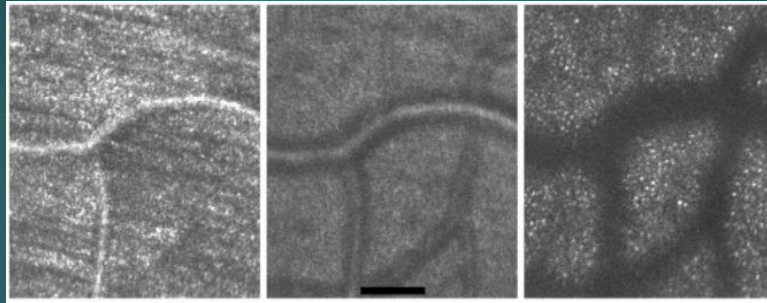


Scanning confocal microscope

Scanning Laser Polarimeter



Adaptive Optics



Nerve Fibers

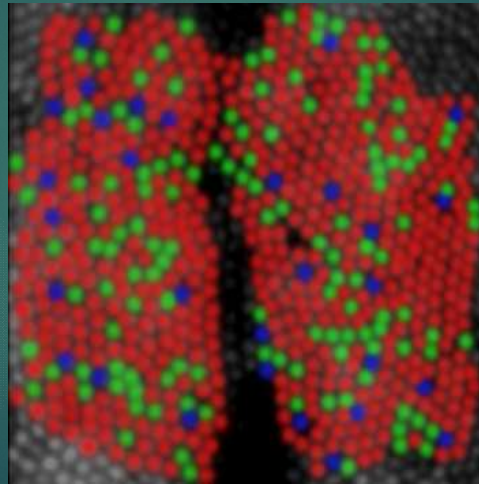
Blood Vessels

Photoreceptors

Adaptive Optics



Retinal Densitometry



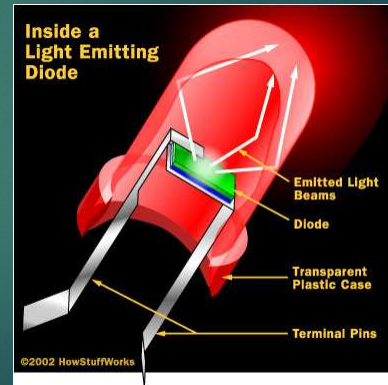
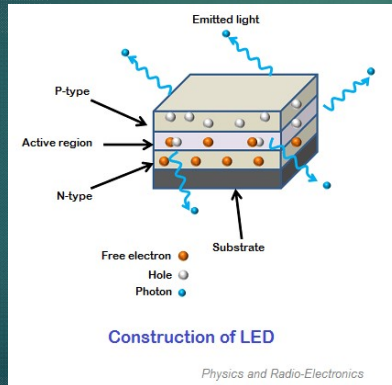
Lasers

- ▶ Nearly monochromatic
- ▶ Coherent
- ▶ Highly directional
- ▶ High power
- ▶ Pulsed and continuous



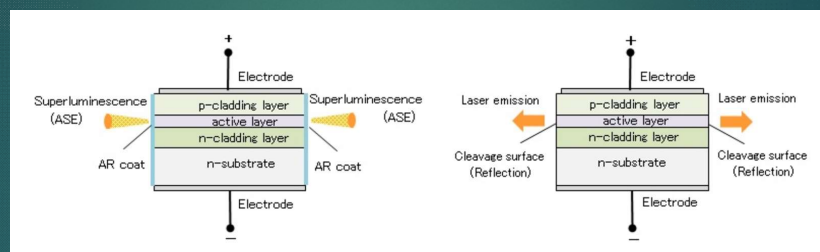
LEDs

Light Emitting Diodes (LEDs) are sandwiched semi-conductors that emit light in a broad range of directions when voltage is applied. The light has a broader bandwidth than a laser. Packaging is used to direct the light.



SLD vs. LD

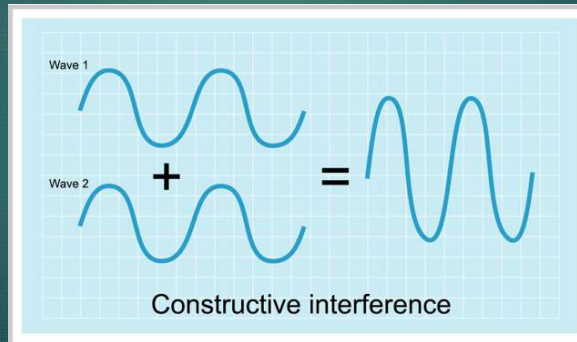
Superluminescent diodes (SLDs) are like Laser Diodes (LDs) except the end faces are AR coated or cut at an angle to eliminate feedback.



SLDs are bright sources, but have a broader spectrum than LDs and reduced coherence.

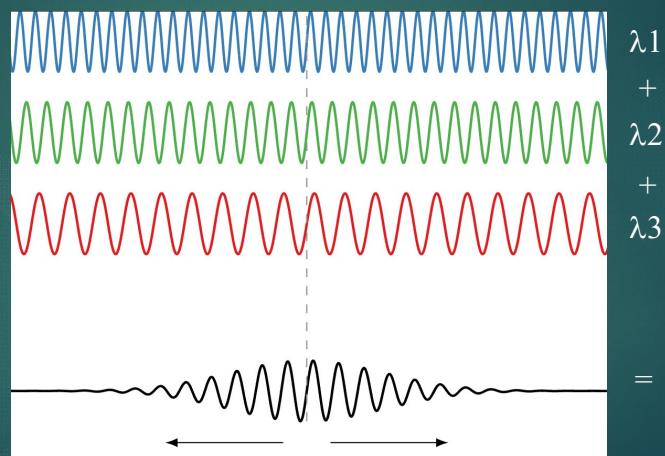
Interference and Coherence

- ▶ Interference is when two waves of light from the same source are combined. The electric fields from each wave can constructively or destructively combine.



ASTROLab of Mont-Mégantic National Park

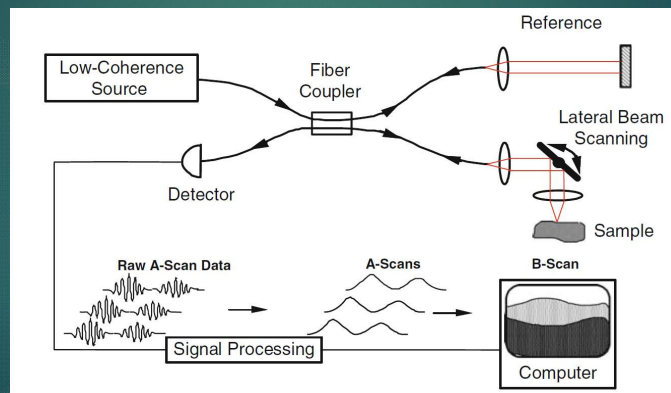
Spectral Coherence



By Glosser.ca - Own work, CC BY-SA 4.0,
<https://commons.wikimedia.org/w/index.php?curid=42502787>

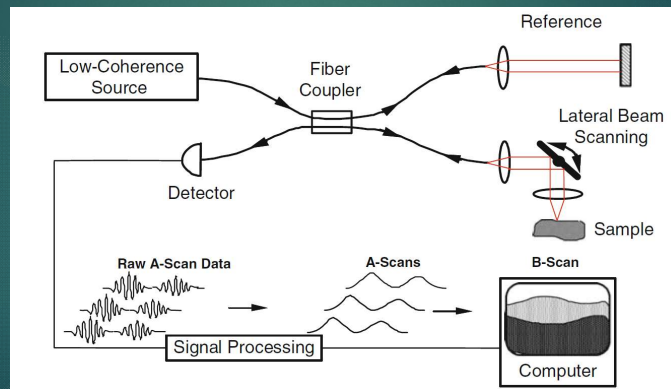
Optical Coherence Tomography (OCT)

A low coherence light source is used



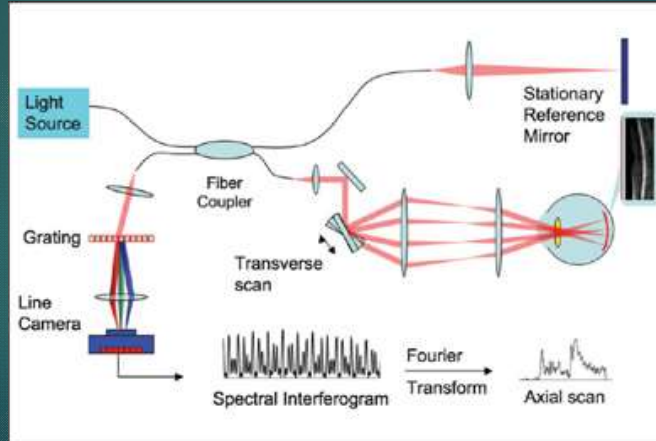
TD-OCT

Time-Domain OCT moves reference mirror back and forth and fringes are formed for planes at the same optical distance.



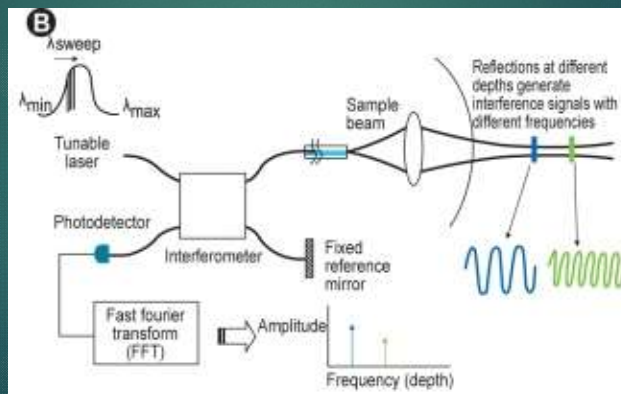
SD-OCT

Spectral-Domain OCT fixes reference mirror and light is detected with a spectrometer. Each wavelength corresponds to a planes at the same optical distance.

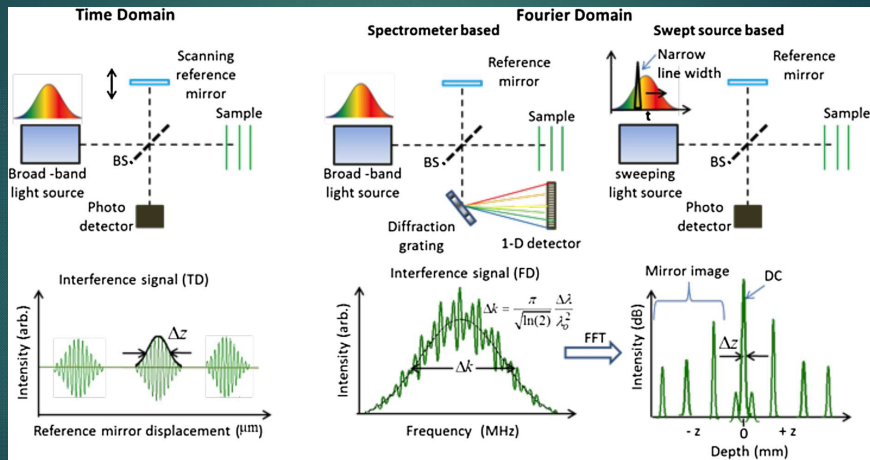


SS-OCT

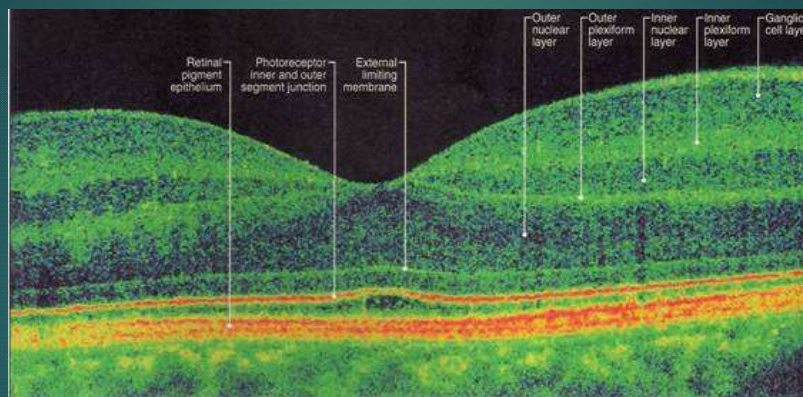
Swept-Source OCT fixes reference mirror and light is detected with a photodetector. The source is rapidly swept through a range of wavelengths. Each wavelength corresponds to a planes at the same optical distance.



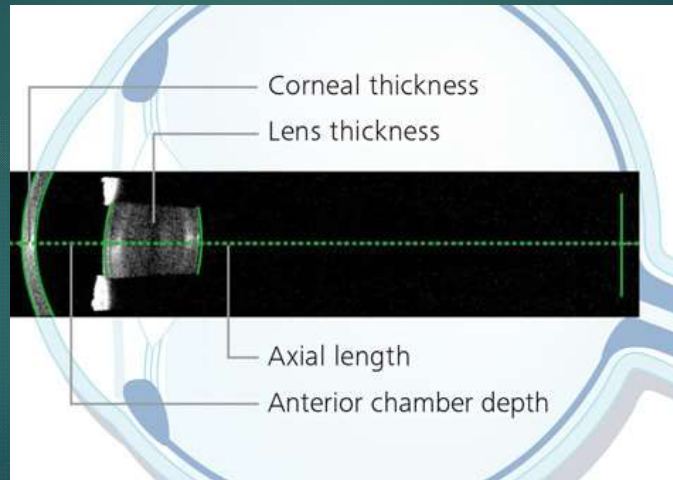
OCT



Optical Coherence Tomography

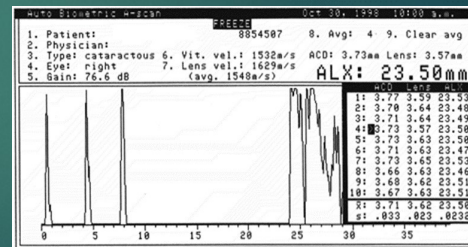
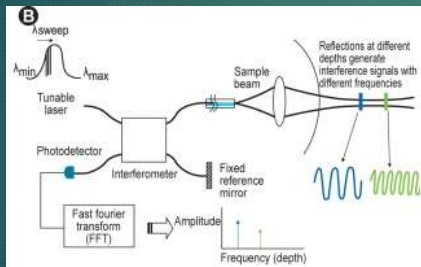


IOLMaster 700



SS-OCT vs. Ultrasound

Axial length measurement with a Swept-Source OCT is accurate to $\sim 10\mu\text{m}$. Axial length measurement with traditional ultrasound units are accurate to $\sim 100\mu\text{m}$.



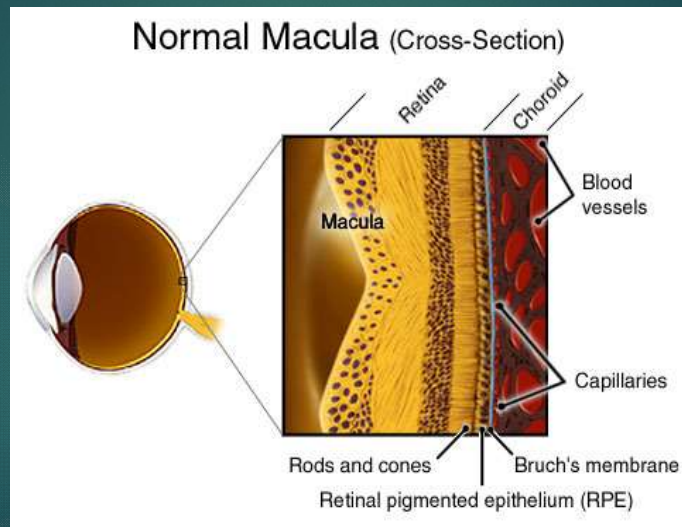
Macular Degeneration

- ▶ An age-related degenerative disease of the retina that causes loss of the rods and cones.
- ▶ Vision is lost in the center of the visual field, which makes reading especially difficult.
- ▶ Peripheral vision is spared.
- ▶ 30% of People over 80 years of age suffer from this disease.

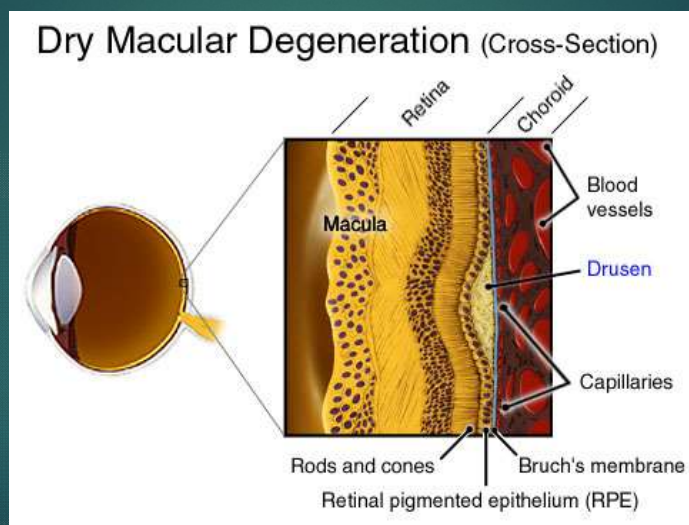
Macular Degeneration



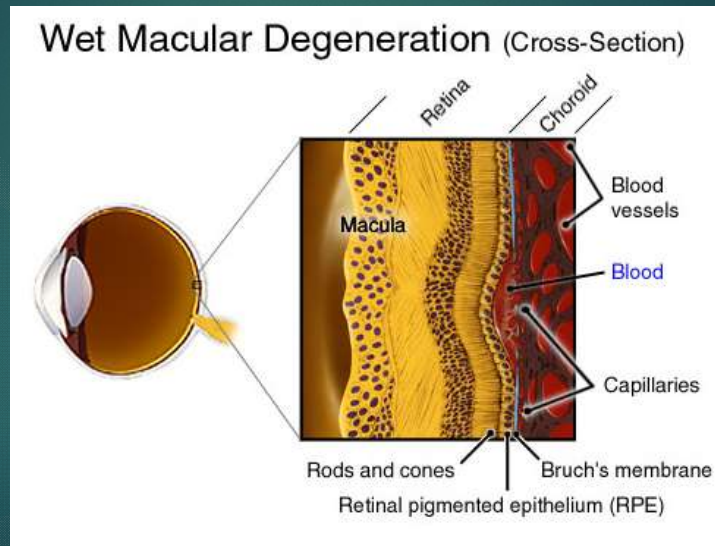
Macular Degeneration



Macular Degeneration



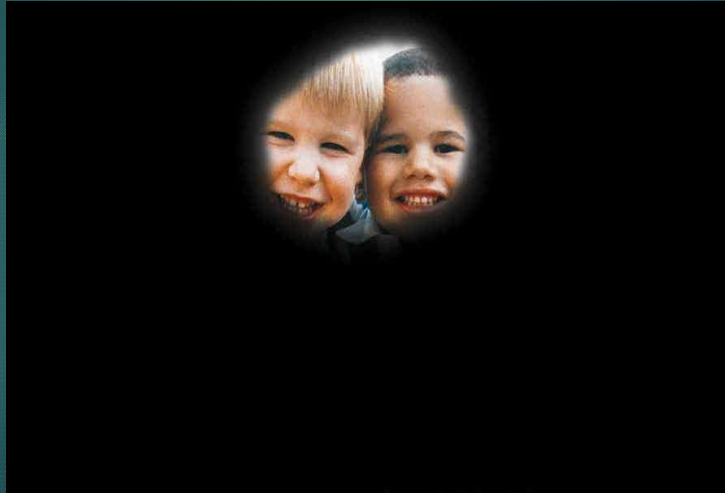
Macular Degeneration



Retinitis Pigmentosa

- ▶ Hereditary Disease
- ▶ Slowly destroys photoreceptors
- ▶ Usually progresses earlier in life
- ▶ Starts in mid-periphery and works towards central and peripheral vision.

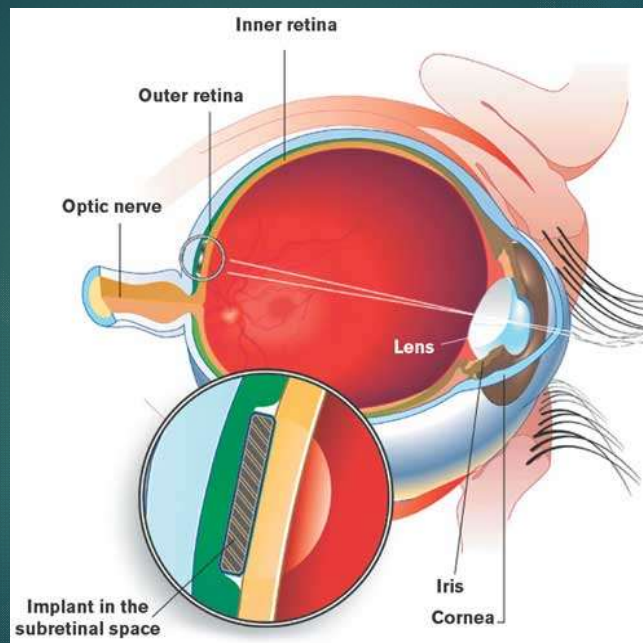
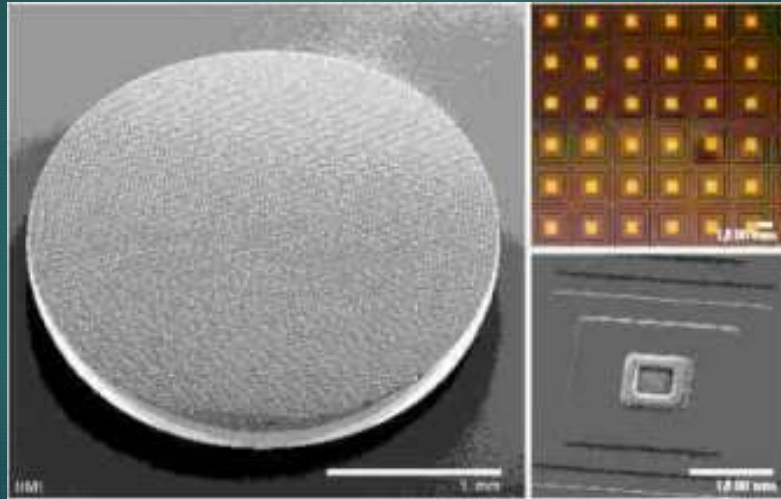
Retinitis Pigmentosa



Background

- ▶ In 1967 GS Brindley applied an electrical stimulation to the retina of a completely blind nurse.
- ▶ The nurse reported seeing some very distorted images and light.
- ▶ This means the wiring is ok, but the sensors are bad.

Subretinal Implant



FDA Trials



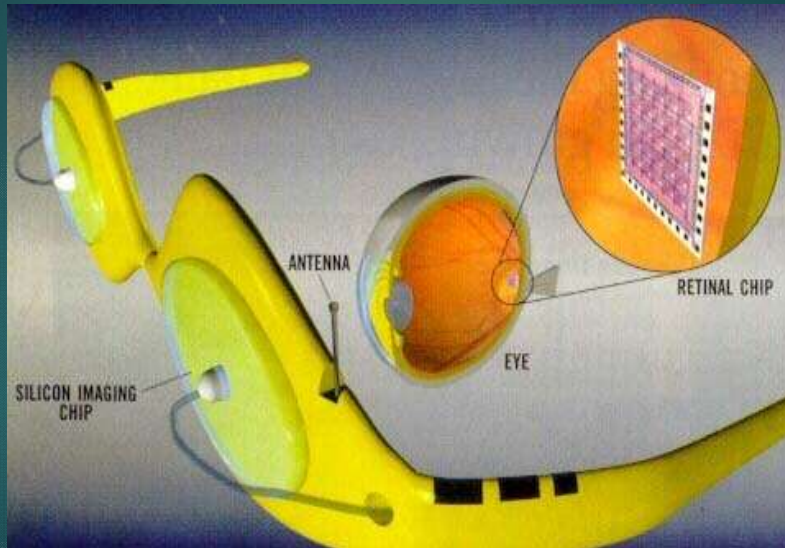
- ▶ Implant surgery was performed in the first three recipients in June 2000, and three others received the implant in July 2001.
- ▶ The patients range in age from 46 to 76 years and baseline vision ranged from count fingers to almost no light perception.
- ▶ Surgery was performed unilaterally with the fellow eye serving as a control

FDA Trials



- ▶ All patients have noted varying degrees of improvement in their vision, with some gaining perception of light and shapes.
- ▶ Two patients showed dramatic improvements in visual acuity following treatment: one from none at baseline to 20 to 25 letters and another from 20 at baseline to 40 letters.

Epiretinal Implant



Hurdles For Retinal Implants

- ▶ Materials – Body must not reject the sensor – Silicone, Platinum & Iridium
- ▶ Lifetime – Sensor must function for years or decades
- ▶ Power – Energy must be indirectly supplied to the implant – Solar powered batteries.

Argus Retinal Prosthesis

- ▶ Approved in 2011 in Europe and 2013 in US.
- ▶ http://youtu.be/Bi_HpbFKnSw