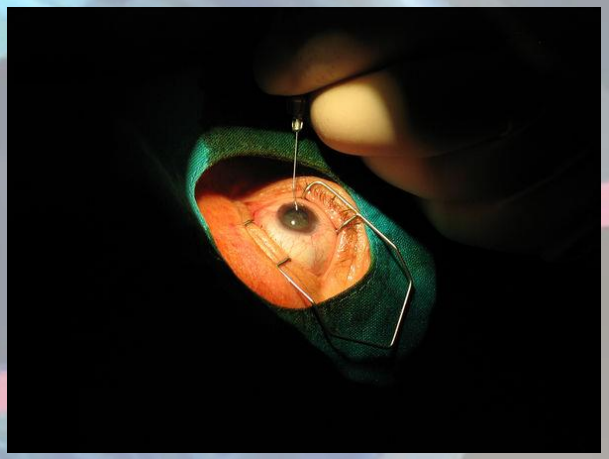
LASER Applications in Dermatology, Dentistry and LASIK Eye Surgery

http://www.medispainstitute.com/menu_laser_tattoo.html

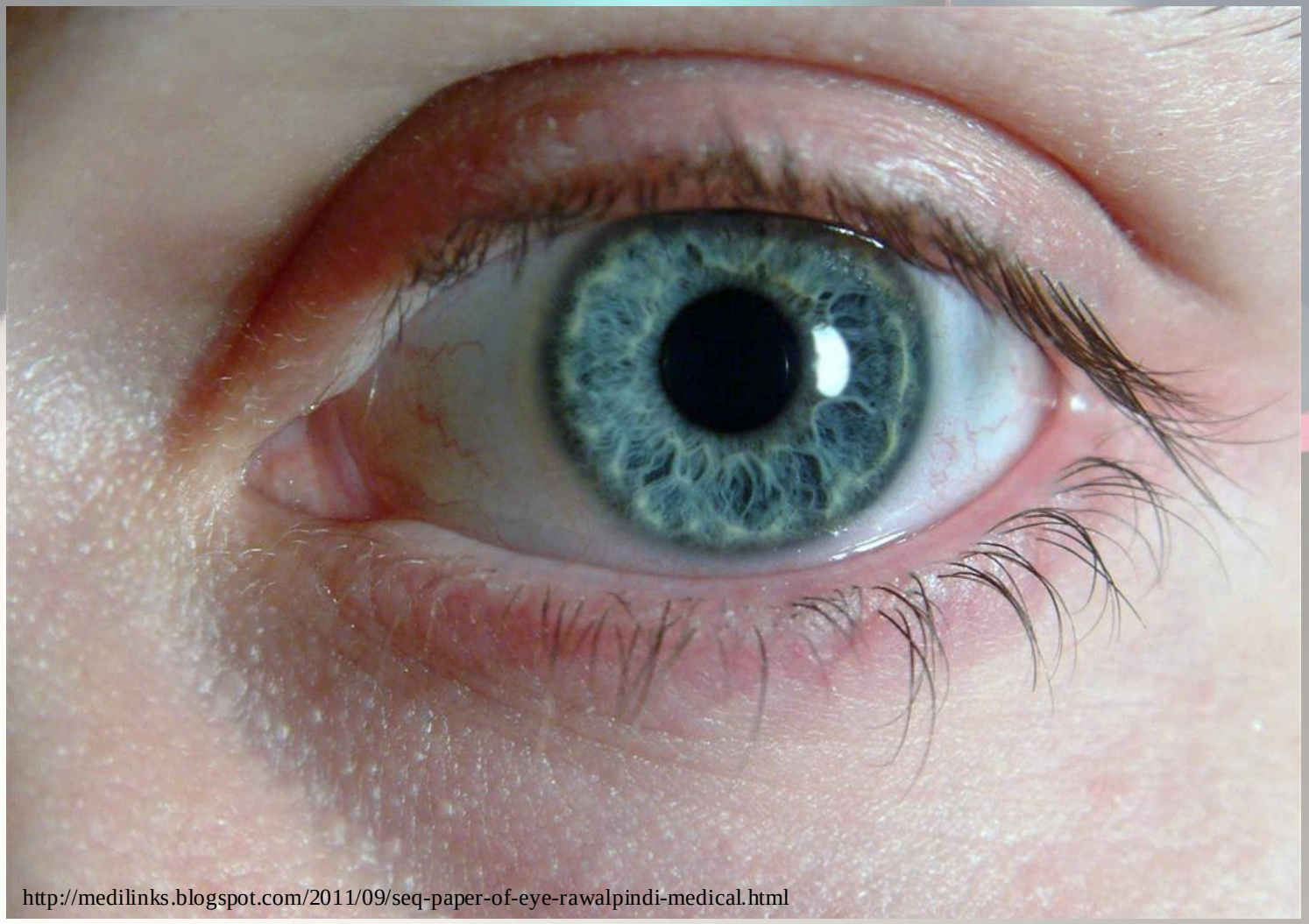
http://www.ny1.com/content/ny1_living/health/89972/doctor-uses-laser-procedure-to-eliminate-gum-disease/Default.aspx



http://www.life123.com/bm.pix/bigstockphoto_close_up_of_eye_surgery_catar_2264267.s600x600.jpg

Background Image: http://www.theeyepractice.com.au/optometrist-sydney/behind-laser-eye-surgery-excimer-laser

The Human Eye



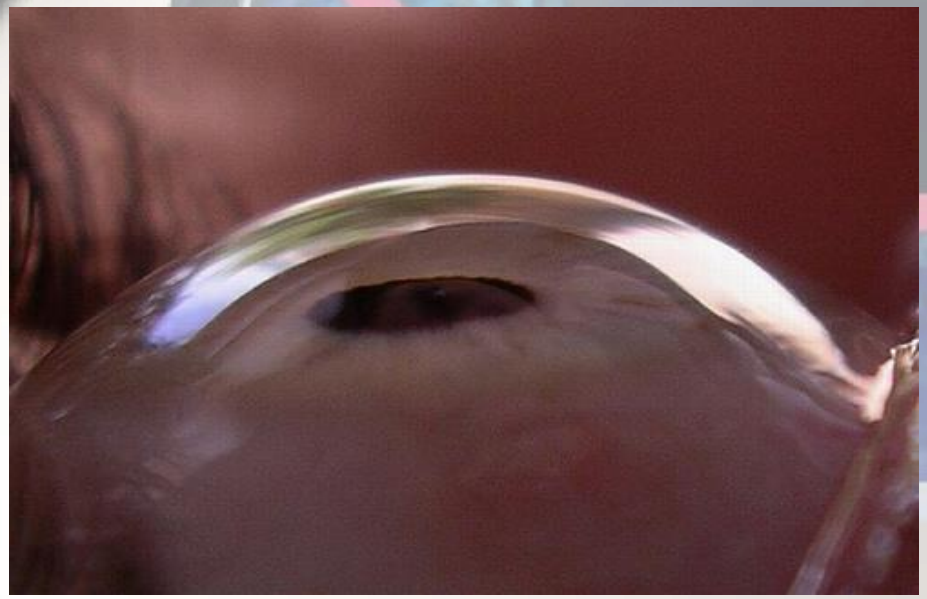
http://medilinks.blogspot.com/2011/09/seq-paper-of-eye-rawalpindi-medical.html

The Human Eye

- Anatomy of the anterior portion of the human eye

1. Epithelium (cornea)
2. Stroma (cornea)
3. Descemet's membrane and endothelium (cornea)
4. Anterior chamber
5. Iris
6. Lens
7. Ciliary body
8. Sclera

The Human Eye - Cornea

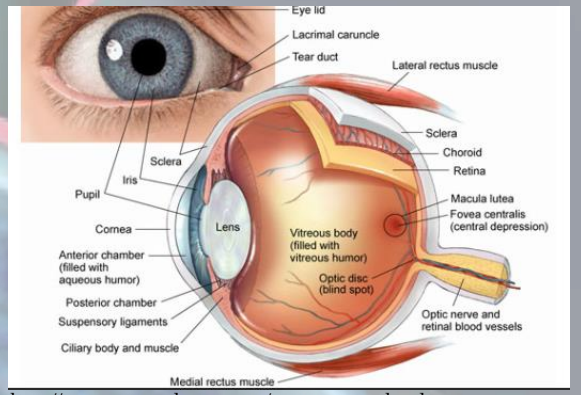


http://www.shorelinevision.com/visiondata/db/UPLOADEDIMAGES/comea2-20071103-164958.jpg

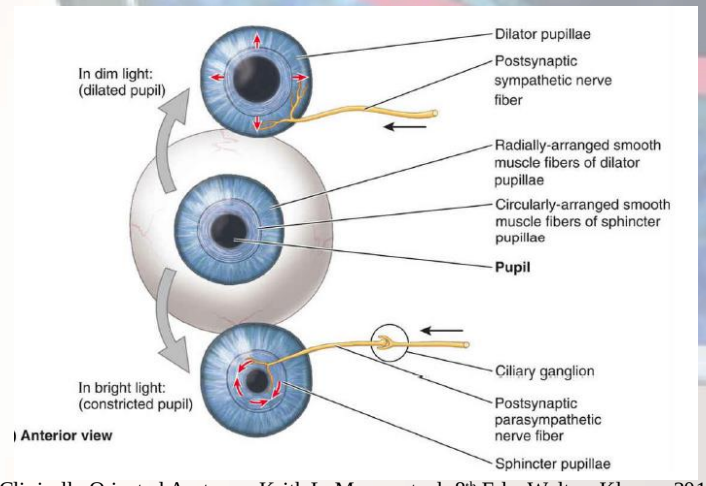
- The cornea is the transparent, dome-shaped window covering the front of the eye. It is a powerful refracting surface, providing 2/3 of the eye's focusing power. Like the crystal on a watch, it gives us a clear window to look through.
- There are no blood vessels in the cornea (avascular), and it is normally clear with a shiny surface. The cornea is extremely sensitive - there are more nerve endings in the cornea than anywhere else in the body.
- The adult cornea is between $\frac{1}{2}-1$ millimeter thick. The epithelial and endothelial cornea $50-90\mu m$ $(0.05-0.09mm)$ and the stroma $0.5-0.9mm$.

The Human Eye – Iris

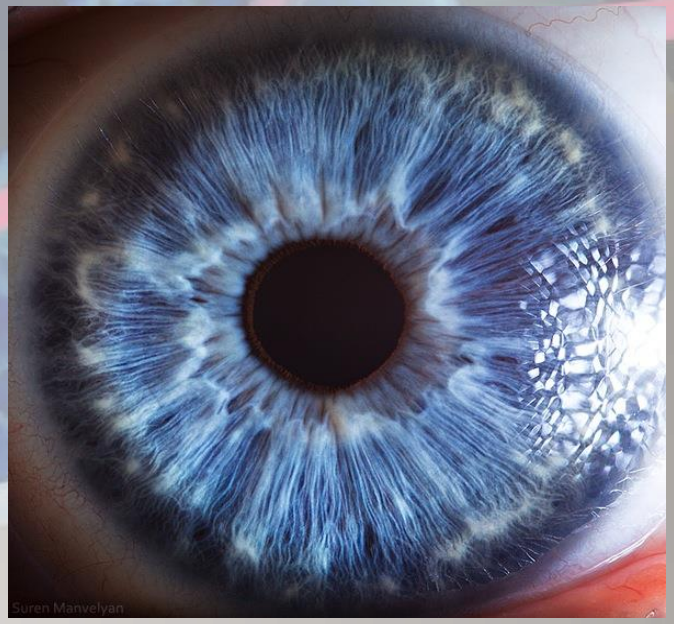
- The colored part of the eye which helps regulate the amount of light entering the eye through the pupil (black hole).
- In bright light, the sphincter contracts, causing the pupil to constrict. The dilator muscle runs radially through the iris, like spokes on a wheel. This muscle dilates the eye in dim lighting.
- The iris is flat and divides the front of the eye (anterior chamber) from the back of the eye (posterior chamber). Its color comes from microscopic pigment cells called melanin. The color, texture, and patterns of each person's iris are as unique as a fingerprint.



http://www.pceyeglasses.com/eye-anatomy.html



Clinically Oriented Anatomy, Keith L. Moore, et. al, 8th Ed., Wolters Kluwer, 2018/



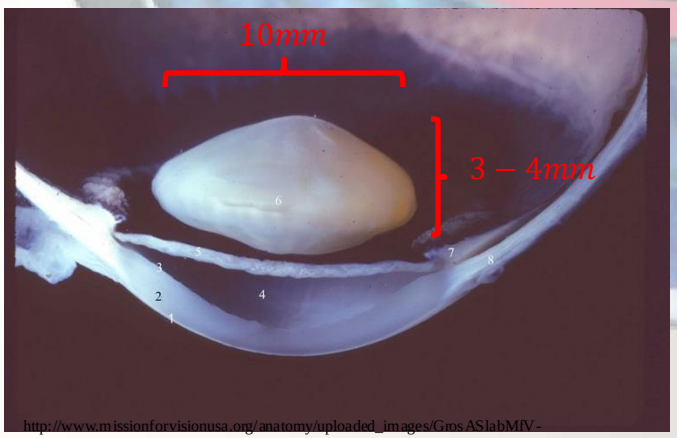
https://www.smithsonianmag.com/smart-news/the-science-behind-these-amazing-photographs-of-the-human-eye-118697490/

The Human Eye – Lens

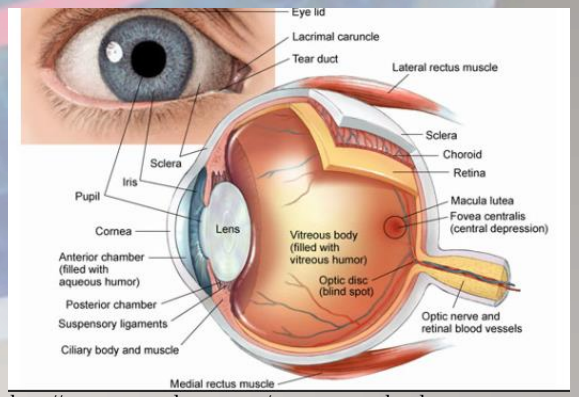
- The crystalline lens is located just behind the iris. Its purpose is to focus light onto the retina. The nucleus, the innermost part of the lens, is surrounded by softer material called the cortex. The lens is encased in a capsular-like bag and suspended within the eye by tiny delicate fibers called *zonules*.

- In young people, the lens changes shape to adjust for close or distance vision. This is called *accommodation*. With age, the lens gradually hardens, diminishing the ability to accommodate.

http://www.med.mun.ca/getdoc/bb1b99b8-ccf3-4468-a4f7-330eb74a1317/Example-6.aspx



http://www.missionforvisionusa.org/anatomy/uploaded_images/GrosASlabMfV-702936.jpg



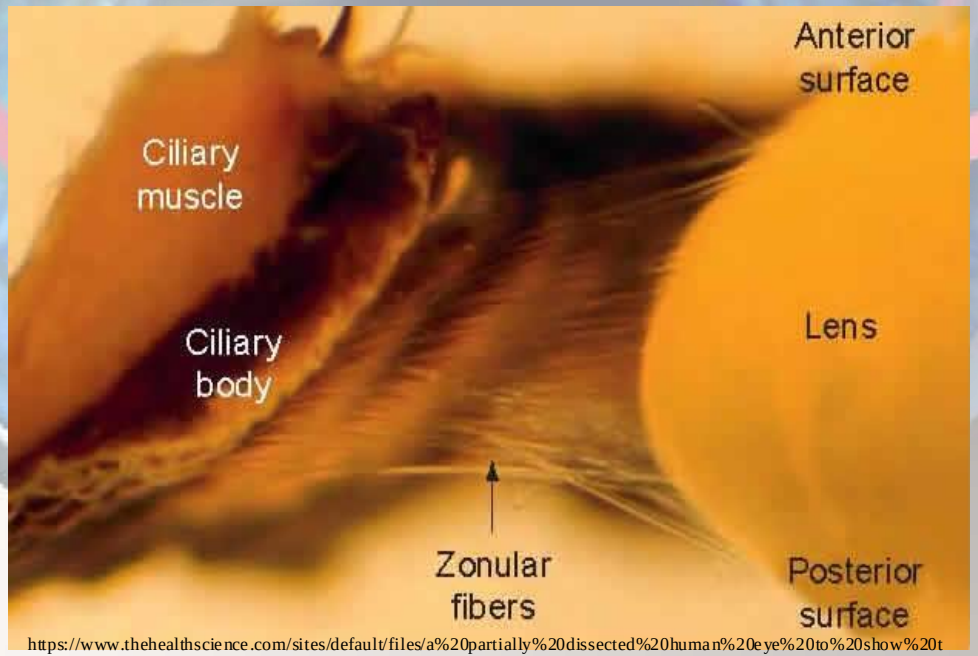
http://www.pceyeglasses.com/eye-anatomy.html

The Human Eye – Lens

- An actual photograph of a human eye that has been bisected in the coronal plane to show the view of the anterior segment from a posterior perspective (as though you are looking from the retina).

- The crystalline lens is suspended by delicate fibers called the zonule. The ciliary body (CB) is composed of about 72 processes that make up the pars plicata and a flat area called the pars plana.

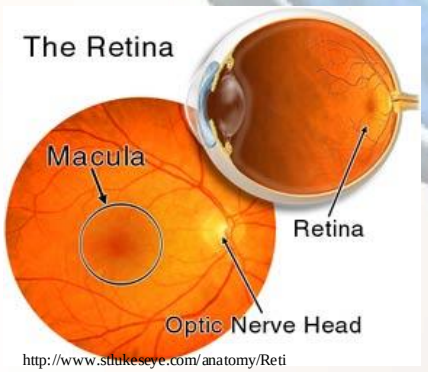
- The ora serrata (ora) is the place where the retina joins the ciliary body.



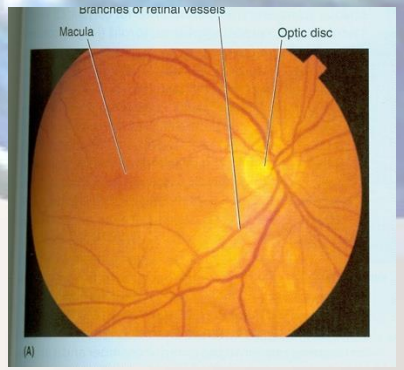
https://www.thehealthscience.com/sites/default/files/a%20partially%20dissected%20human%20eye%20to%20show%20the%20accommodative%20structures.jpg

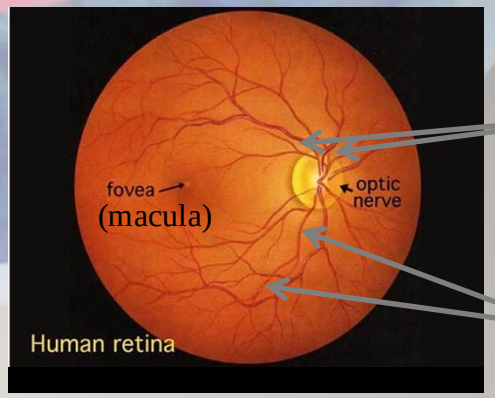
The Human Eye – Retina

- The retina is a multi-layered sensory tissue that lines the back of the eye. It contains millions of photoreceptors that capture light rays and converts the light into electrical impulses. These impulses travel along the optic nerve to the brain where they are turned into images.
- There are two types of photoreceptors in the retina: *rods* and *cones*.
- The retina contains approximately 6 million cones, and they are contained in the macula, the portion of the retina responsible for central vision. They are most densely packed within the fovea, the very center portion of the macula. Cones function best in bright light and allow us to appreciate color.
- There are approximately 125 million rods. They are spread throughout the peripheral retina and function best in dim lighting. The rods are responsible for peripheral and night vision.
- Rods and cones work by total internal reflection.



http://www.stlukeseye.com/anatomy/Retina.asp





https://webvision.med.utah.edu/book/part-i-foundations/simple-anatomy-of-the-retina/

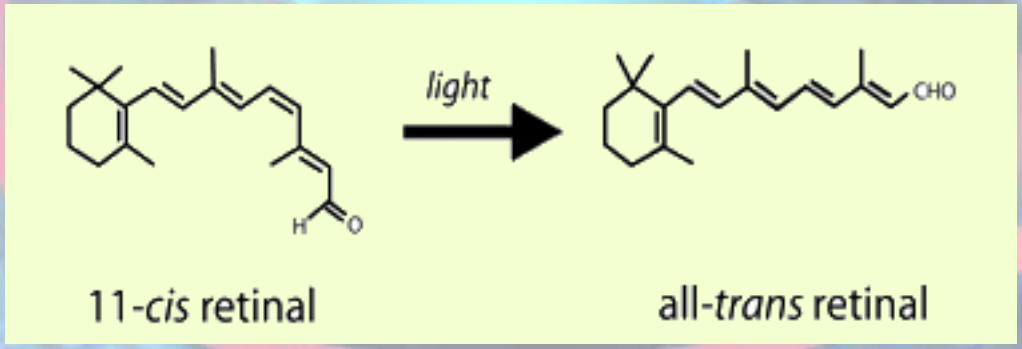
Superior retinal arteries

Inferior retinal arteries

The Human Eye – Retina

- The eye contains a molecule called *11-cis-retinal* (a photosensitive derivative of vitamin A) that changes shape when struck by light of sufficient energy.

- The change in shape triggers a series of events that result in an electrical signal being sent to the brain that results in vision.

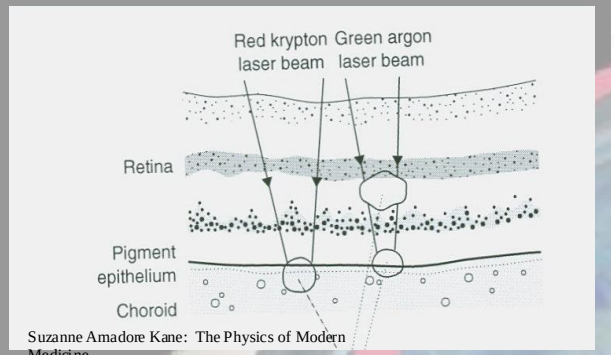


http://photobiology.info/Crouch.html

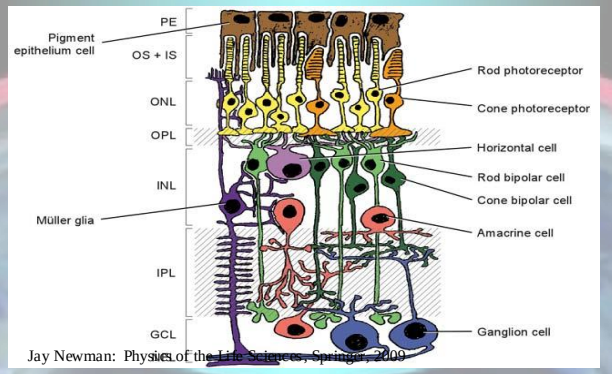
- The minimum energy need to change the structure of *11-cis-retinal* to *all-trans-retinal* is about $164 \frac{kJ}{mole\ of\ photons}$. What's the longest wavelength visible to the human eye?

LASIK Eye Surgery

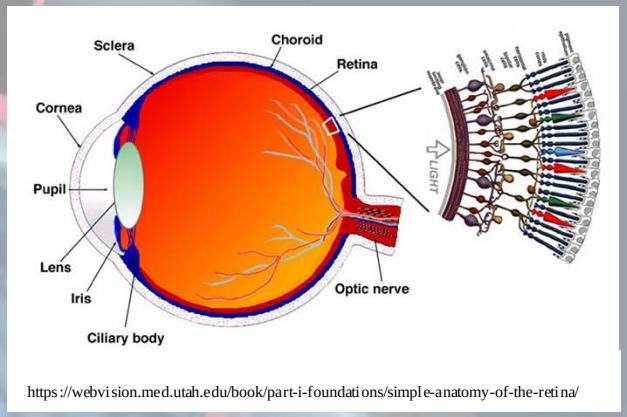
- *Anatomy of the eye: a closer look at rods & cones*



Suzanne Amadore Kane: The Physics of Modern Medicine

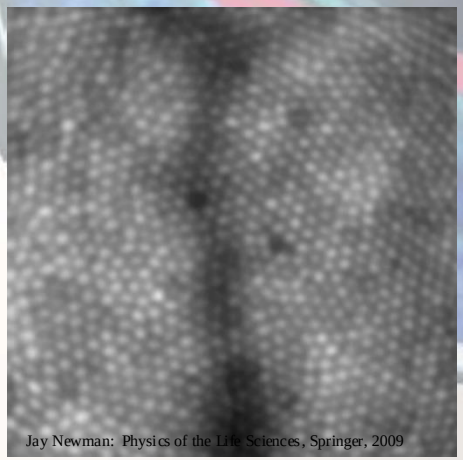


Jay Newman: Physics of the Life Sciences, Springer, 2009



https://webvision.med.utah.edu/book/part-i-foundations/simple-anatomy-of-the-retina/

Clockwise from the upper left: A sketch of the retina showing its structure, The pigment epithelium showing the rods and cones and the relation to the retina. Two SEM pictures of the cone cells.



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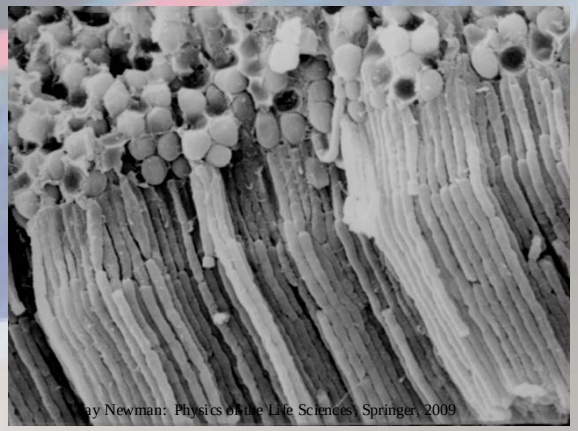


Jay Newman: Physics of the Life Sciences, Springer, 2009

Laser Eye Surgery

- *Refractive Errors of the Eye*

- In a nutshell, the cornea aids in the focusing of light to create an image on the retina by means of refraction.

- Often, the shape of the cornea and the eye are not perfect and the image on the retina is out-of-focus.

- There are three primary types of refractive errors (or imperfections in the focusing power of the eye.)

Myopia – or nearsightedness

Persons with myopia, or nearsightedness, have more difficulty seeing distant objects as clearly as near objects.

Hyperopia/Presbyopia - or farsightedness

Persons with farsightedness have more difficulty seeing near objects as clearly as distant objects. *Hyperopia* can happen at any age, whereas the *natural decline* in being able to see up close as you age is *presbyopia*.

Astigmatism – which is a distortion of the image on the retina caused by irregularities in the cornea or lens of the eye (usually due to the cornea not being spherical, but oval.)

LASIK Eye Surgery

- *What for?*

- Nearsightedness, or myopic vision, the image forms in front of the retina while in the case of farsightedness, or hyperopic vision, the image forms behind the retina because the lens of the eye can't accommodate (or change its focal length) to form a clear image.

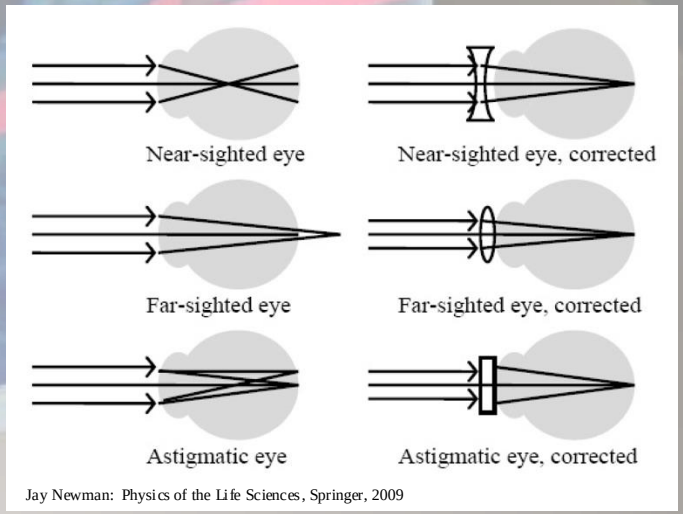
- Combinations of myopia and astigmatism or hyperopia and astigmatism are common and can be corrected with glasses or contact lenses that are designed to compensate for the eye's imperfections.

- Surgical procedures aimed at improving the focusing power of the eye are called refractive surgeries.

- In a *LASIK* surgery, precise and controlled removal of corneal tissue by a special laser reshapes the cornea changing the focusing power and aids in the eyes ability to focus the light.

- For myopia, micro thin layers of cornea are eliminated to flatten its shape.

- For hyperopia, a doughnut-shaped hole is made to create a more conical shape.



Jay Newman: Physics of the Life Sciences, Springer, 2009

Laser Eye Surgery

- *LASIK* is an acronym of ***L***aser ***A***ssisted ***I***n-***S***itu ***K***eratomileusis or the subsequent use of a laser (usually an eximer laser or UV laser) to reshape and flatten the cornea after an incision has been made in the cornea by using a microkeratome (a thin knife) or a laser keratome.

- Compared to *PRK* (*Photorefractive Keratectomy*) which is the direct removal of the epithelium cornea to flatten the cornea.

- A keratectomy is the surgical removal of part of the cornea and the desired outcome of either *LASIK* or *PRK* is to correct the refractive errors of the eye.

- Generally, this means correcting for farsightedness or nearsightedness.

- For *LASIK* eye surgery the Epithelium of the Cornea is incised and folded back revealing the Stroma.

- The stroma is then laser vaporized to reshape the cornea and the epithelium is then replaced.

LASIK Eye Surgery

- *The procedure*

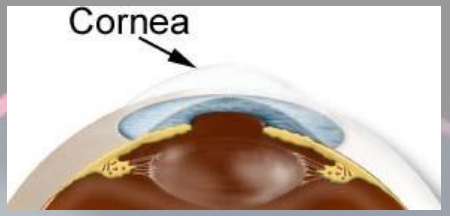
- A laser *keratome* or a *microkeratome* is used to cut a flap in the *epithelium* (*cornea*). The epithelium is only a few cell layers thick. A hinge is left at one end of this *epithelium layer*. The flap is folded back revealing the *stroma*, and laser pulses are used to vaporize a portion (a few to 10's of microns of tissue) of the *stroma* and the *epithelium layer* is then replaced.

- The epithelium cornea seals itself in about 24 hours.

- In cases of myopia, micro thin layers of cornea are eliminated to flatten its shape.

- For hyperopia, a doughnut-shaped hole is made to create a more conical shape.

- An Eximer laser – A low power (1 – 20W) UV (~ 250nm) laser which is absorbed by the cornea and not transmitted into the eye.



http://www.stlukeseye.com/anatomy/Cornea.asp

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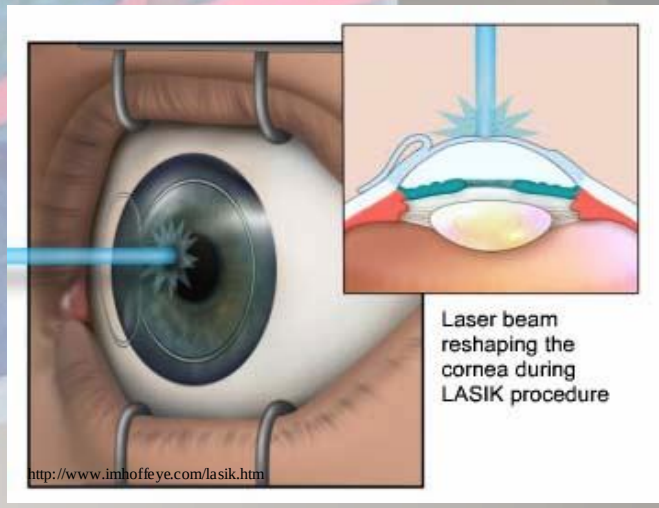
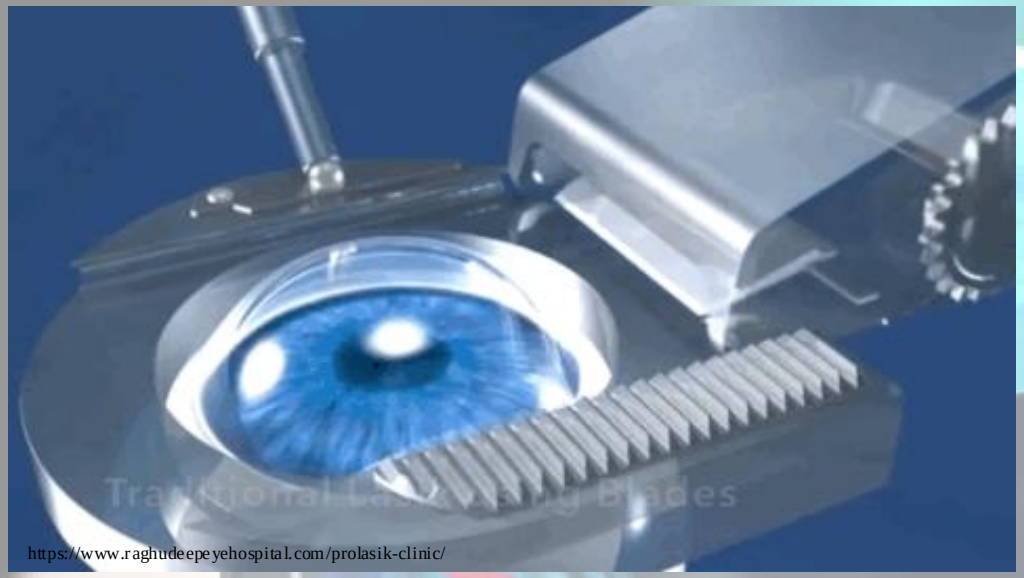
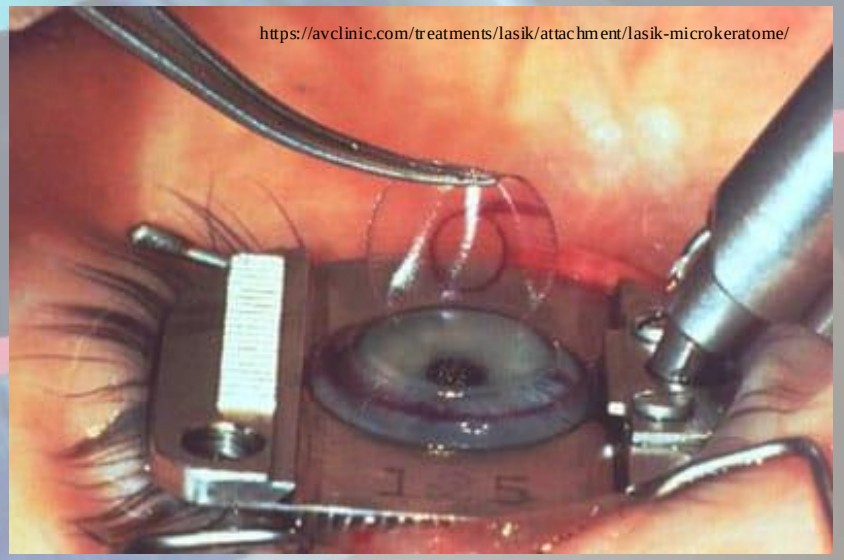


LASIK Eye Surgery

- *The procedure*



https://www.raghudeepeyehospital.com/prolasik-clinic/

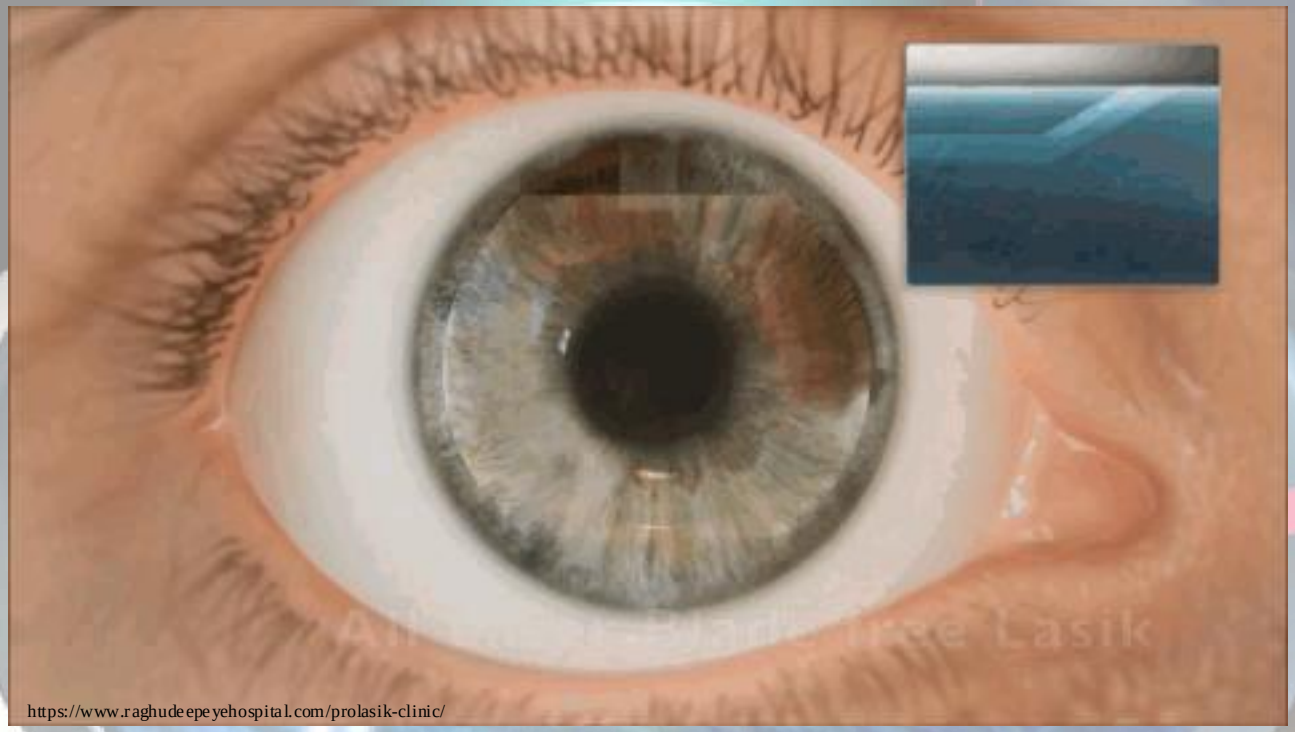


https://avclinic.com/treatments/lasik/attachment/lasik-microkeratome/

The upper image is an animation of a blade microkeratome. The blade slides under the epithelium cornea and above the stroma. The upper right image shows the actual microkeratome

LASIK Eye Surgery

- *The procedure*



An alternate procedure is to use a laser to cut the corneal flap.

LASIK Eye Surgery

- *Eximer Laser for Surgery*

Eximer Laser: A low power ($1 - 20W$) UV ($\sim 250nm$) laser which is absorbed by the cornea and not transmitted into the eye. Types of Eximer Lasers:

1. Slit Scanning Laser

- The slit scanning laser utilizes small beams that are connected to an apparatus outfitted with slit holes that can enlarge. During the laser eye surgery, the beams are scanned across these slits. This results in an ablation zone that will slowly grow. Ablations are smooth, especially when compared to the old broad beam lasers.

2. Spot Scanning Laser

- Spot scanning lasers are also known as the flying spot laser. During laser eye surgery, laser beams that are small in diameter are scanned across the cornea to create the ablation zone. Spot scanning lasers have the capability to produce the smoothest ablations. It is also more flexible in terms of customizing an ablation, and it is also best used in repairing irregular astigmatism.

3. Wavefront Guided Lasers

- The Wavefront device is an apparatus used in laser eye surgery that helps steer the way through the cornea until it is reshaped according to the surgeon's specifications. A customized LASIK ablation is therefore achieved using this device. The two above mentioned types, namely the slit scanning laser and the spot scanning laser, can both be utilized for treatments using the Wavefront device.

LASIK Eye Surgery

- *Eximer Laser for Surgery*

- How do you know how much cornea you need to ablate during a Lasik procedure?
- The theoretical ablation depth is given by the *Munnerlyn formula*:

$$d_{ablation\ (\mu m)} = \Delta D \times \frac{(optical\ zone\ diameter\ (mm))^2}{3}$$

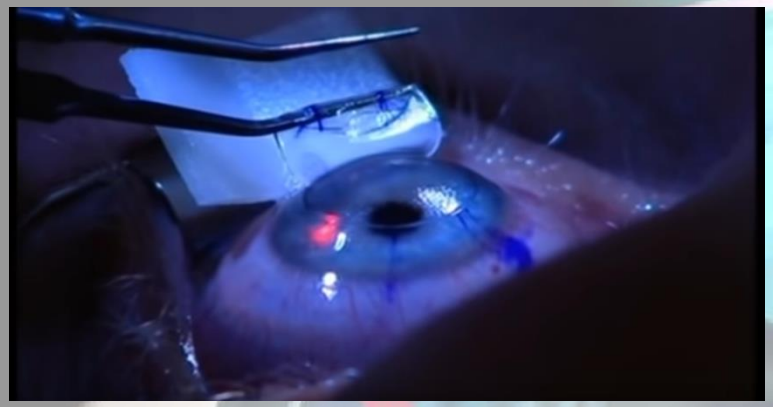
- $d_{ablation}$ is the ablation depth in μm needed to be achieved by the laser.
- ΔD is the change in the prescription to be achieved in Diopters. This is usually the prescription of your glasses (that you'd like to get rid of).
- $Optical\ zone\ diameter$ is the size of the ablation zone in mm.
- Suppose that you have reading glasses with a power of $+2.5D$. If the optical zone diameter is $3mm$, what ablation depth is needed?
- How many laser pulses would be needed to achieve this depth is the ablation rate is $0.3\frac{\mu m}{pulse}$?

Huebscher HJ, Genth U, Seiler T. Determination of excimer laser ablation rate of the human cornea using in vivo Scheimpflug videography. Invest Ophthalmol Vis Sci. 1996 Jan;37(1):42-6.

"Corneal tipulsessue alation depth and the Munnerlyn formula", Chang, A.W., Journal of Cataract and Refractive Surgery, 29, Issue 6, 1204-1210, 2003.

LASIK Eye Surgery

- *LASIK eye surgery video*



https://www.youtube.com/watch?v=6Q_EKXN3EMg

It it worth it?

Cost: As little as $200 per eye.

Benefits:

- improved vision
- fast recovery time
- lower risk of infections than other eye surgeries
- less pain than regular corneal surgery
- no more glasses or contacts (hmm?)
- recreational and job opportunities

Drawbacks:

- light sensitivity
- some pain
- swelling of the cornea
- wrinkling of the epithelium flap
- poor night vision – halos and glare
- hard to measure how much tissue was removed
- can't stop the aging process – might still need reading glasses (*presbyopia*)