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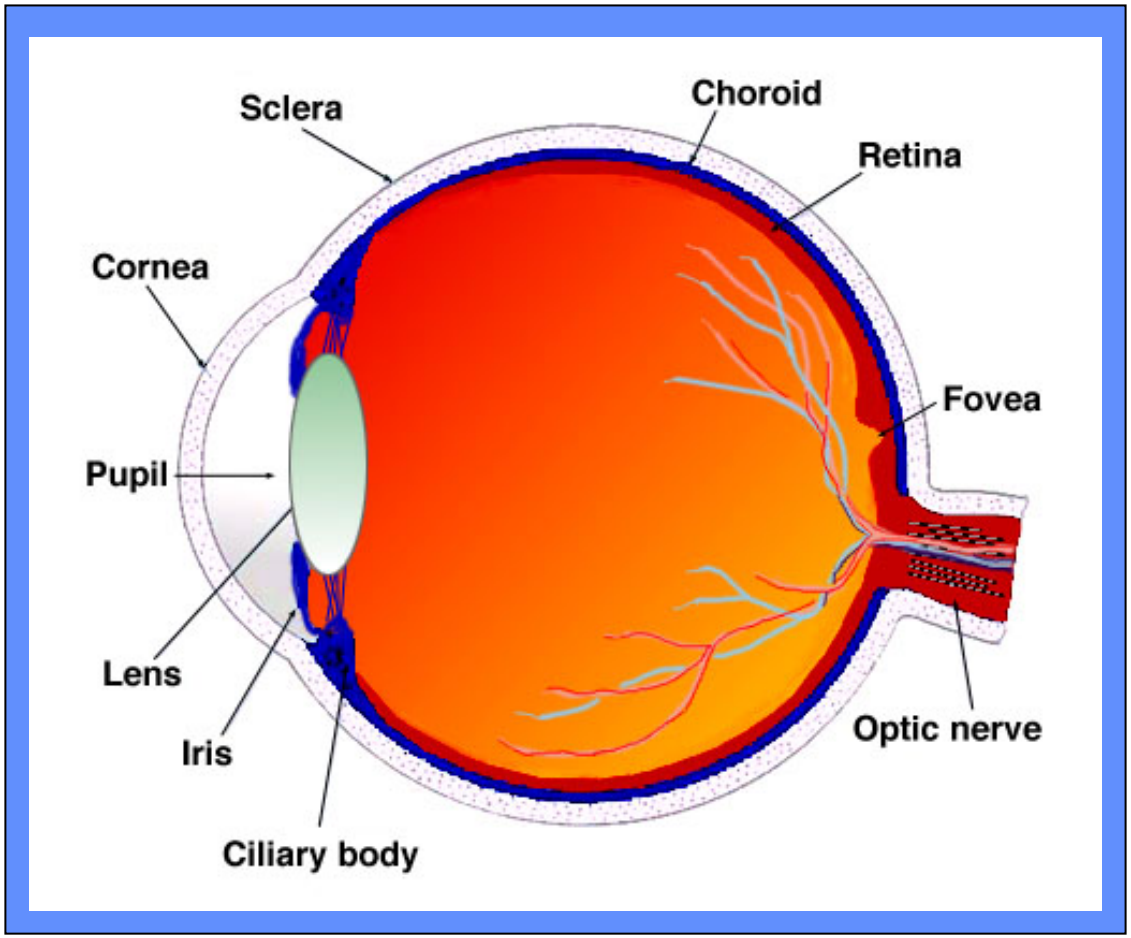
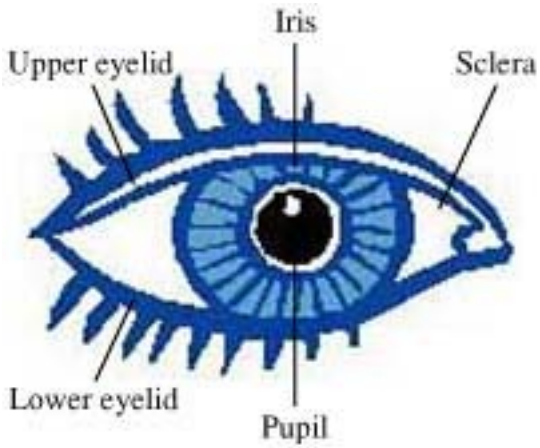
Principles of PHACOEMULSIFICATION

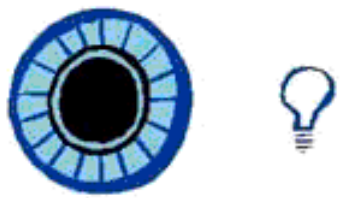
Health Care Technology Unit
ORBIS Flying Eye Hospital

Basic Eye Anatomy

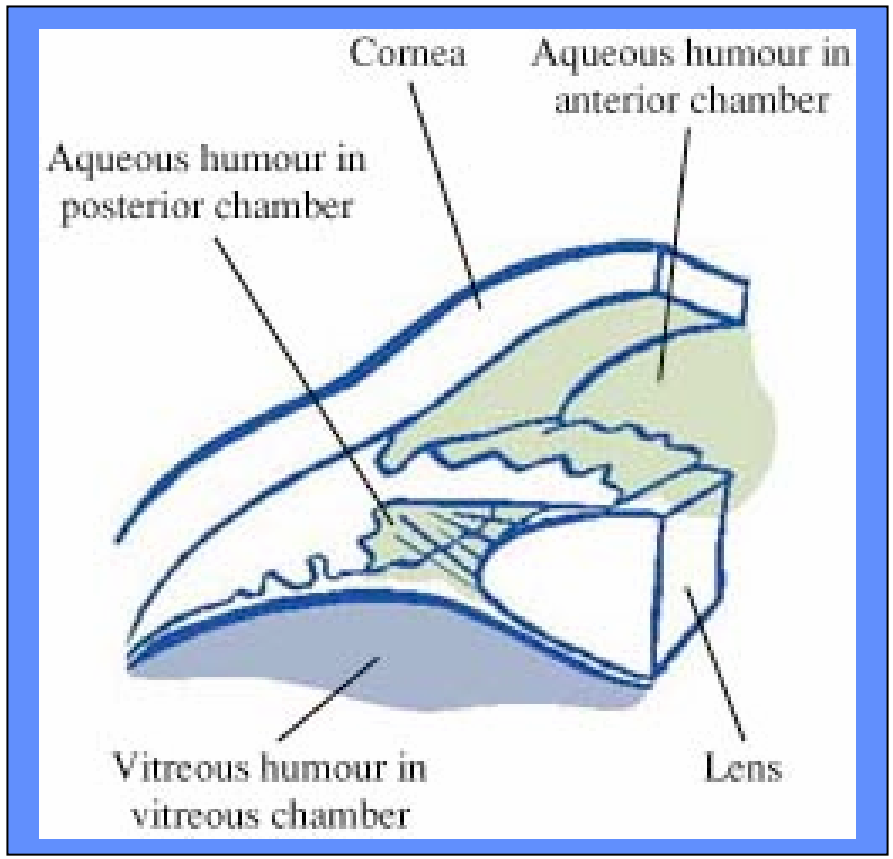


Basic Eye Anatomy

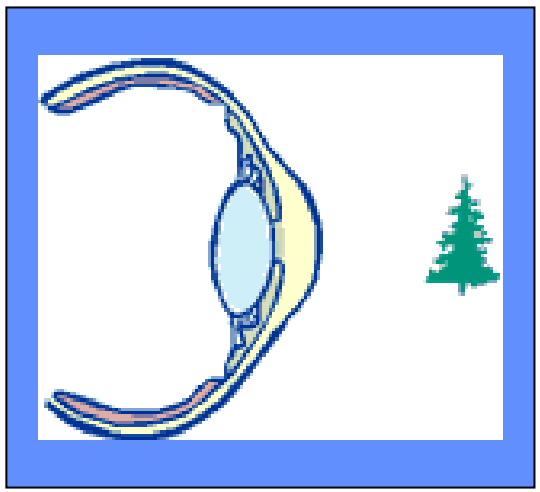




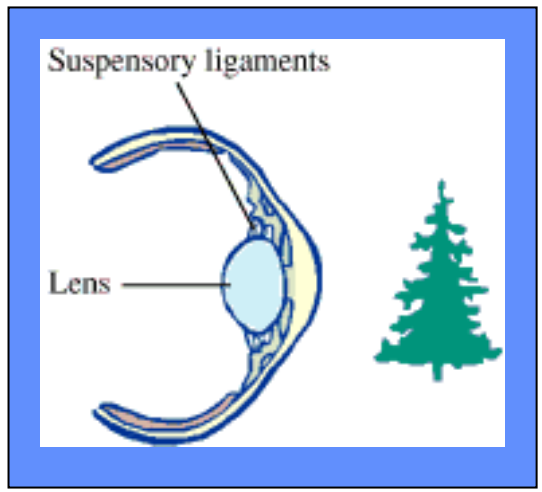
Basic Eye Anatomy



Basic Eye Anatomy



Distant objects require a long focal distance created by a thinner lens

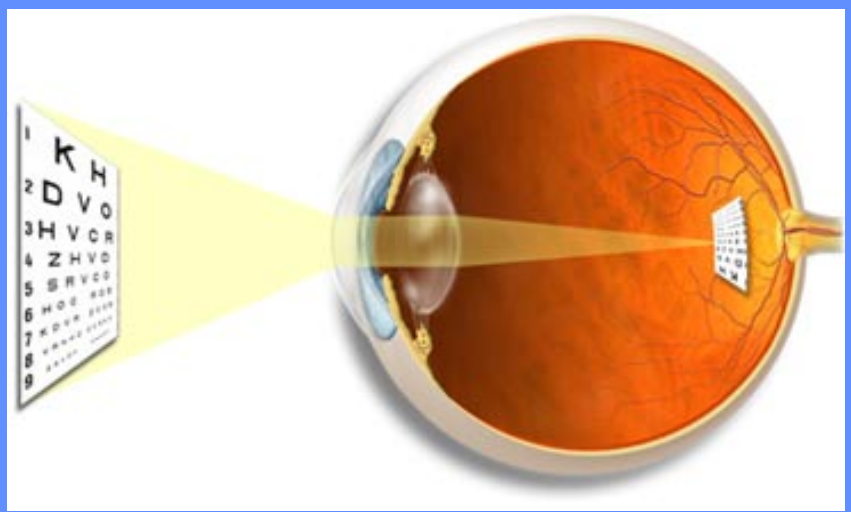


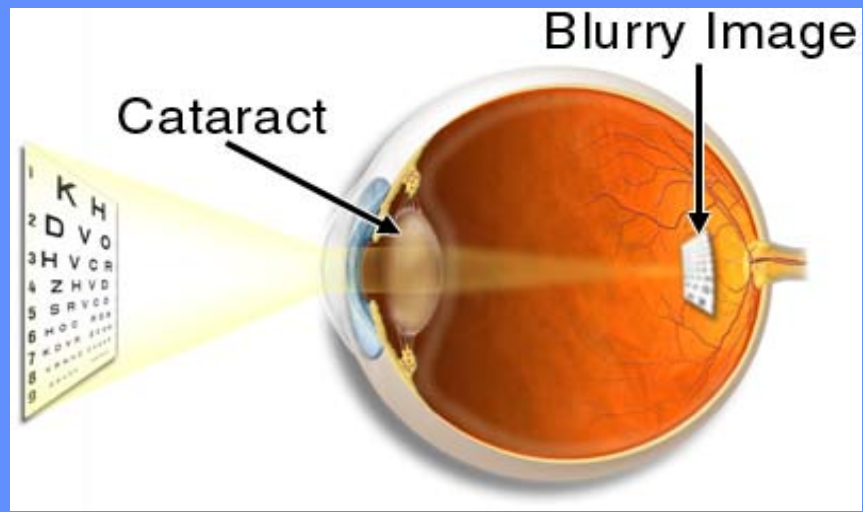
Closer objects require a short focal distance created by a thicker lens

CATARACT

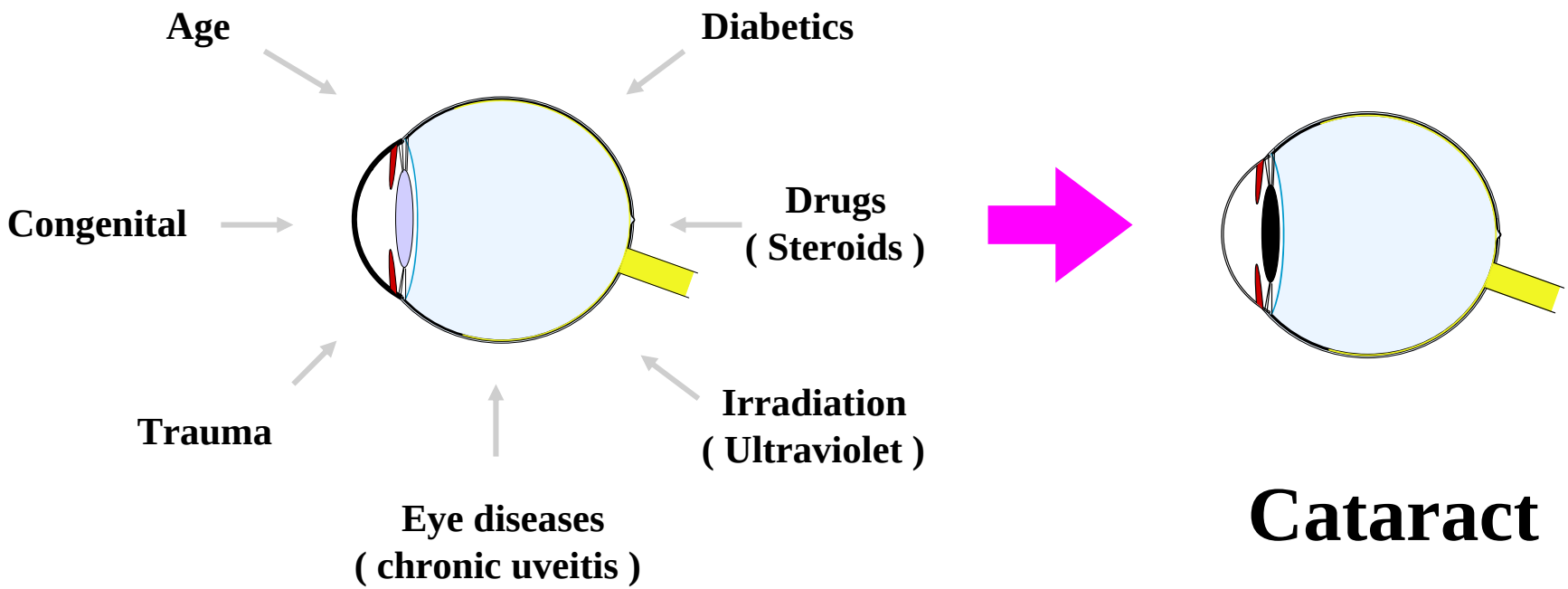
- *Cataract is an opacity of the lens*
- From the Greek word for “water fall”
- Estimated 20 million people suffering from Cataract
- Major cause of blindness

Lens and Cataract





Lens and Cataract



History of Cataract Surgery

- 5th Century BC: Couching
- 29AD: First written description of cataract and its treatment (De Medicinae)
- Mid 1700s: First actual removal of cataract
  - Jacques Daviel (Paris), Samuel Sharp (London)
  - Introduction of Intra Capsular Cataract Extraction (ICCE)
- Mid 1800s: Introduction of general anesthesia

Early Cataract Surgery

- 1867: Use of sutures for cataract surgery
- 1884: Introduction of local anesthesia (cocaine eye drops)
- Early 1900s: First use of Extra Capsular Cataract Extraction (ECCE)
- 1940s: Introduction of Intraocular Lenses (IOLs)
- 1960s: Development of a technique to emulsify the cataract using ultrasound (*Phacoemulsification*) by Charles Kelman (New York)

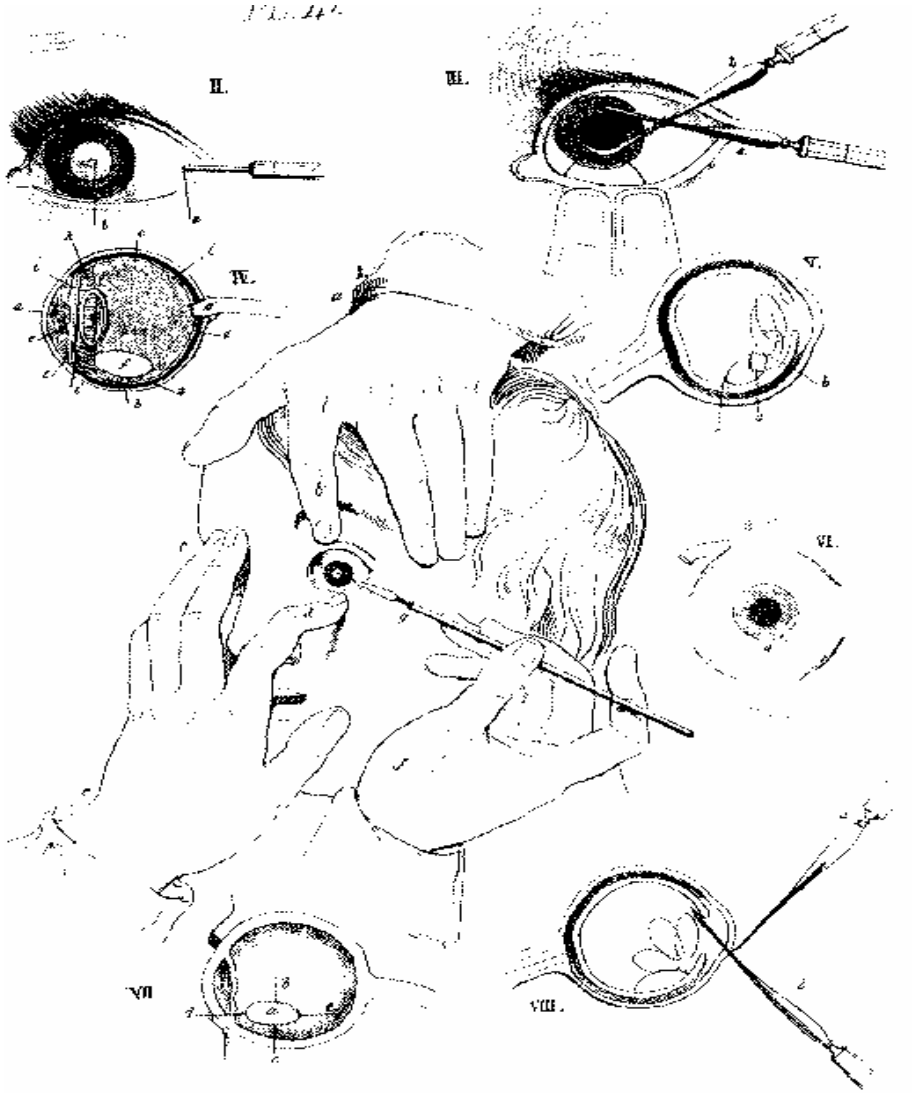
Couching

Reproduced from Duke-Elder S. Diseases of the Lens and Vitreous; Glaucoma and Hypotony. St. Louis: Mosby; 1969. In Basic Clinical Science Course, Foundation of the American Academy of Ophthalmology. 2003 - 2004.

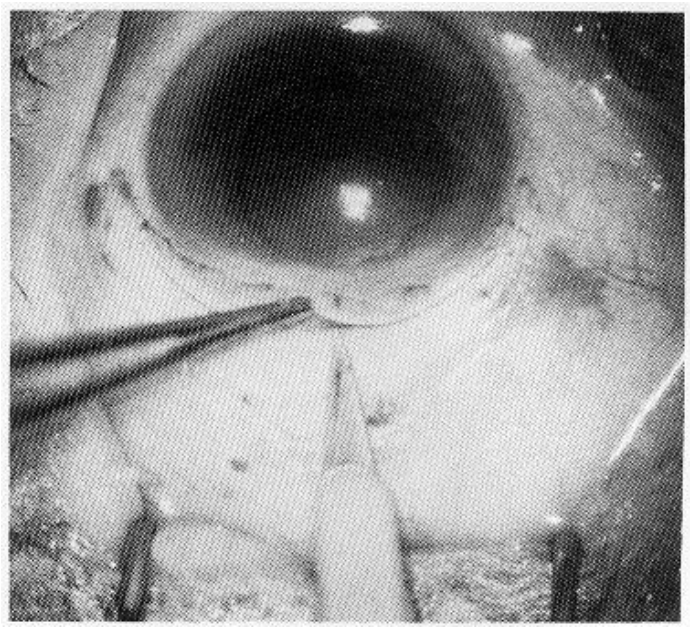
Couching

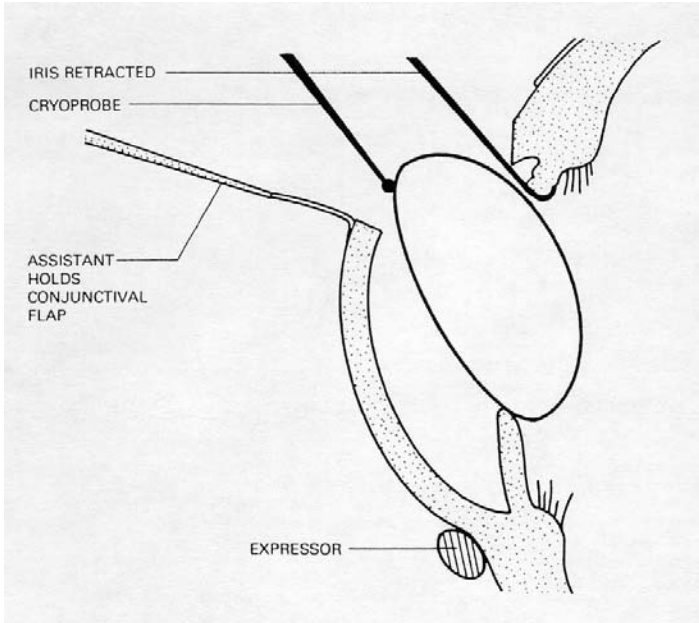
Reproduced from Wertenbaker L. The Eye: Window to the World. New York: Torstar Books 1984. In Basic Clinical Science Course, Foundation of the American Academy of Ophthalmology. 2003 - 2004.

Couching



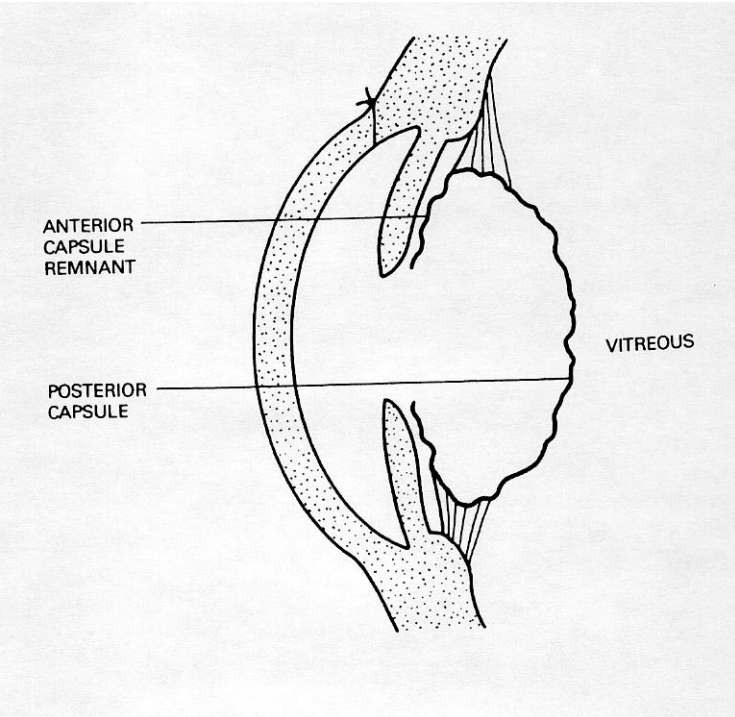
The Intracapsular Cataract Extraction (ICCE)





- **Requires a large incision (10-12mm)**
- **Can cause complications with retinal detachment and disturbances in the delicate structures**

The Improved Technique of ECCE



The Extracapsular Cataract Extraction (ECCE)

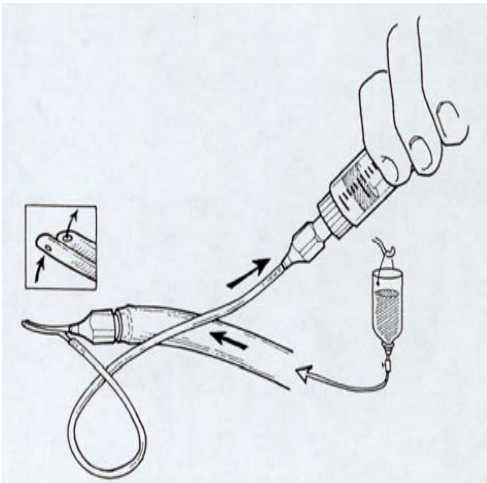
A technique of removing a portion of the anterior capsule, allowing extraction of the lens nucleus and cortex, and leaving the remainder of the capsule structure intact.

- **Still requires a large incision (10-12mm)**
- **Can cause clouding of the posterior membrane (secondary cataract)**

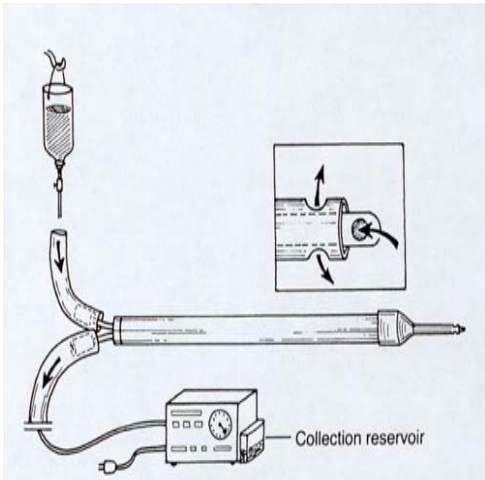
General Considerations of ECCE instrumentation

ECCE Requires:

- **Operating microscope and better illumination**
- **Microsurgical hand-held instruments**
- **Irrigation-aspiration systems**



A manual irrigation-aspiration system for removing lens cortex



An automated irrigation-aspiration System for cortex removal

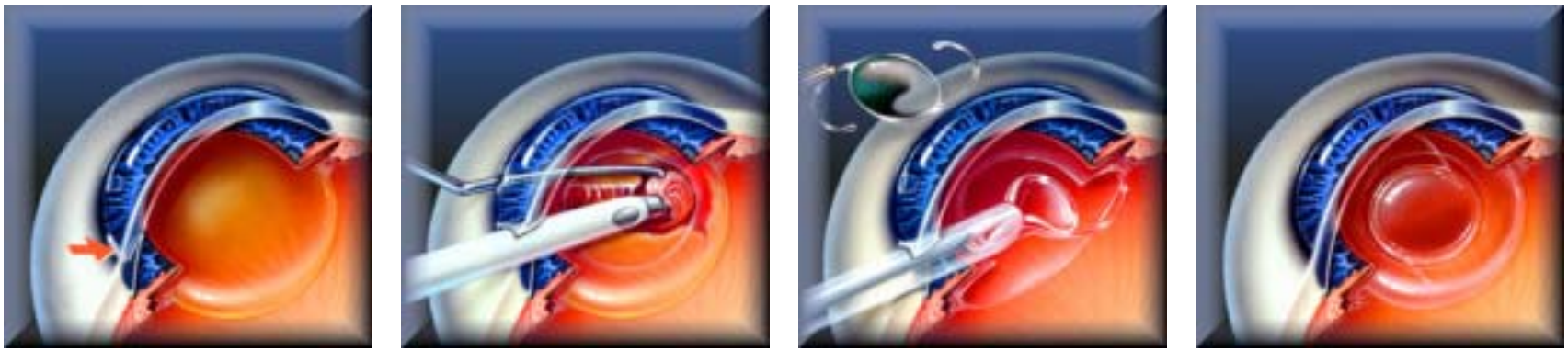
Phacoemulsification

- Phacoemulsification was invented and developed by Dr. Charles D Kelman in 1967.
  - His objective was to perform the ECCE through a small incision.
- Phacoemulsification is a technique which employs the ultrasound energy and fluid dynamics to facilitate the removal of nucleus and cortex of the lens in the cataract surgery.

The Principles of Phacoemulsification

- The fluid from an irrigation line enters the eye.
- Ultrasound tip break the lens in to fragment and emulsify the material.
- The emulsified material is subsequently aspirated by an aspiration line.

The Principles of Phacoemulsification



1. A very small "No Stitch" incision is made in the side of the cornea. Such an incision promotes fast and more comfortable recovery
2. The bag of the lens is opened and the ultrasonic probe (phacoemulsifier) removes the cloudy lens.
3. A small artificial lens is inserted through the small incision to replace the cataract lens (IOL)
4. In case of opacification of the capsule (secondary cataract), YAG laser can be used for treatment

Phaco Requires a Microscope

Surgical Ophthalmic Microscopes cost between $5,000 and $100,000

Intraocular Lenses (IOLs)

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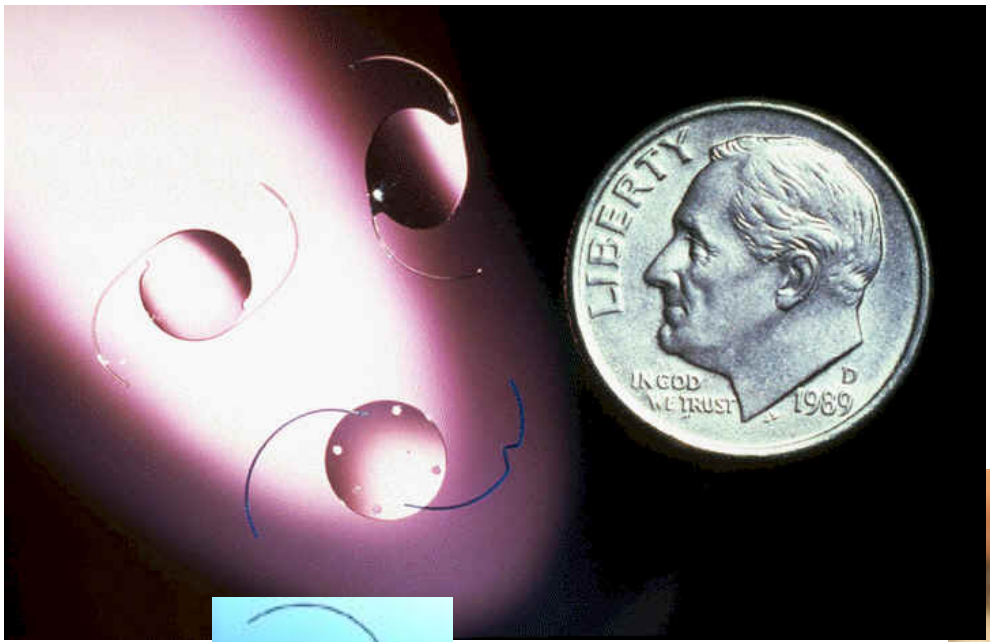

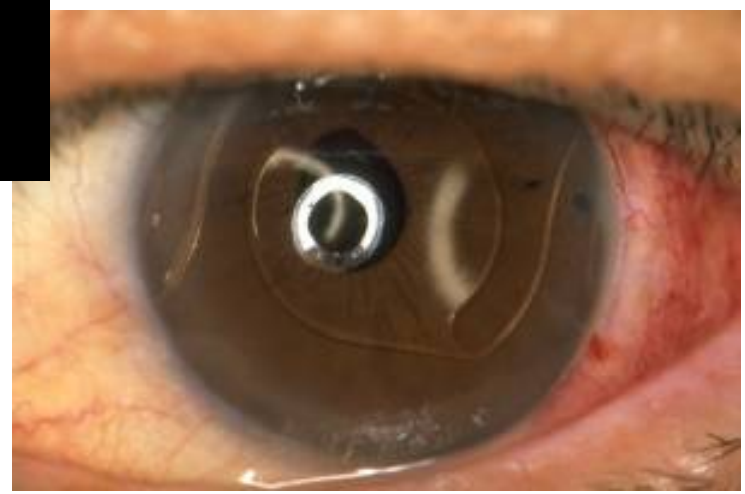

Treatment of Secondary Cataract using YAG Laser

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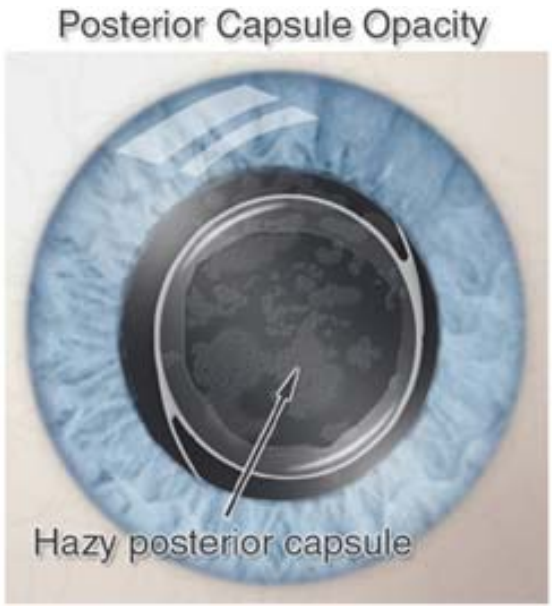

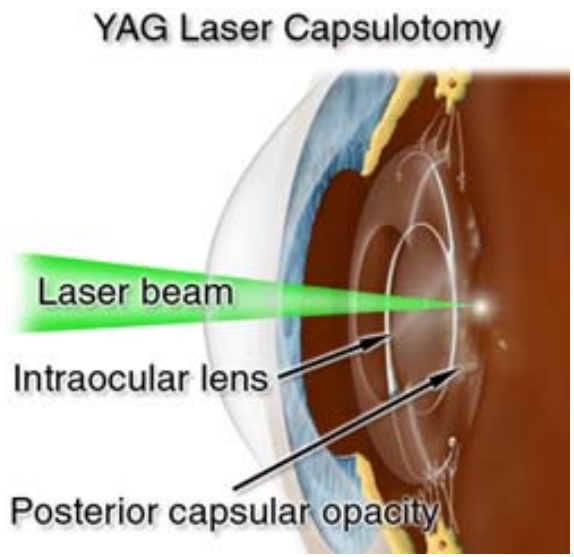

Secondary Cataract occurs in about 50% of the cases and it may occur a few months or even years after the surgery

Treatment of Secondary Cataract using YAG Laser

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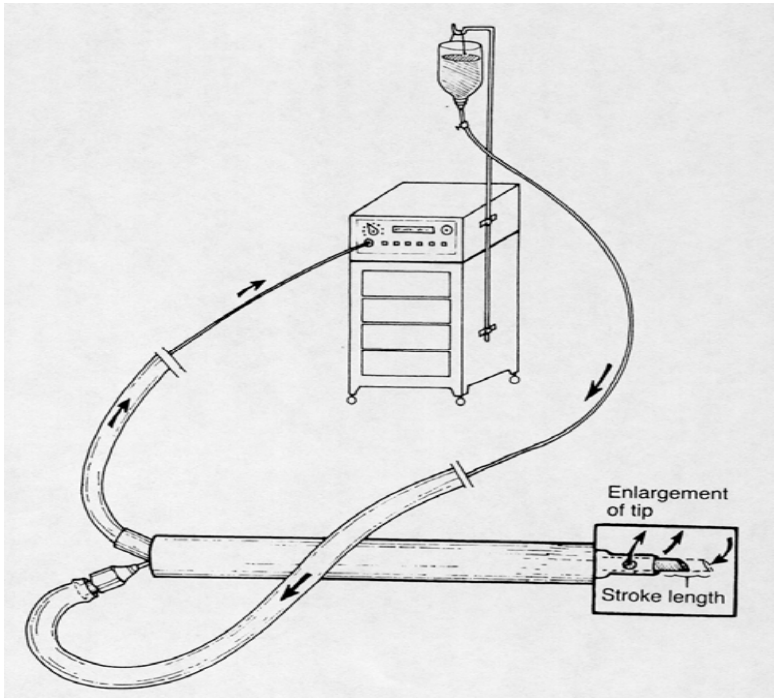
The Phacoemulsification Machine



The first phacoemulsification machine was patented in 1971.

Basic Components of a Phaco Machine

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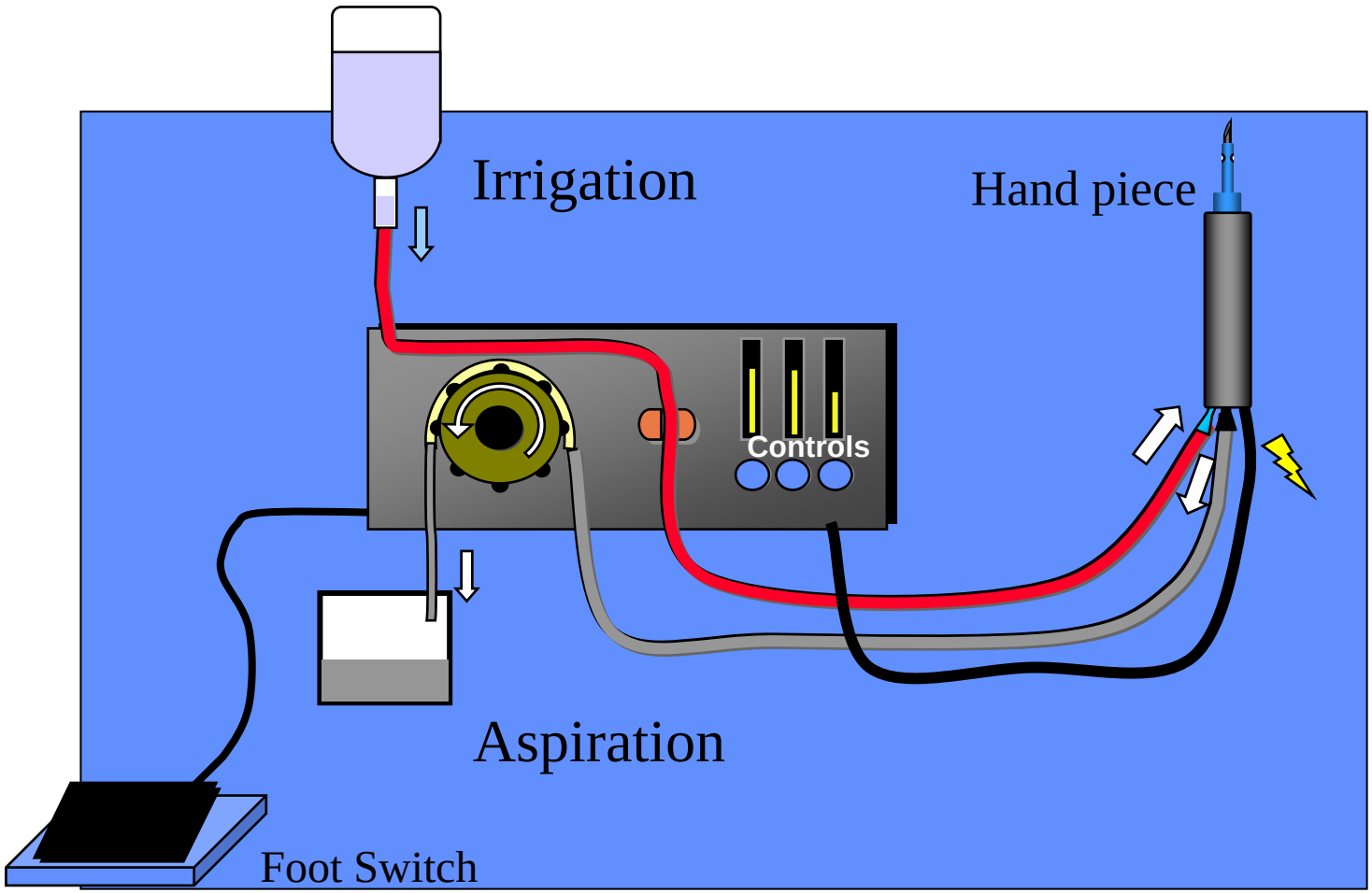
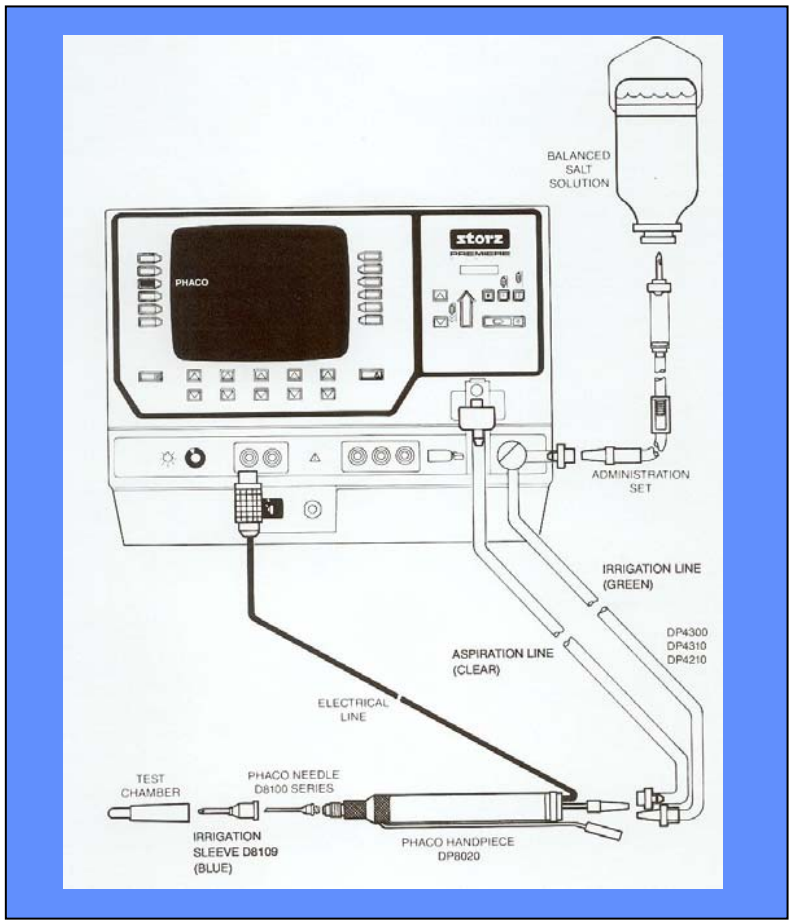
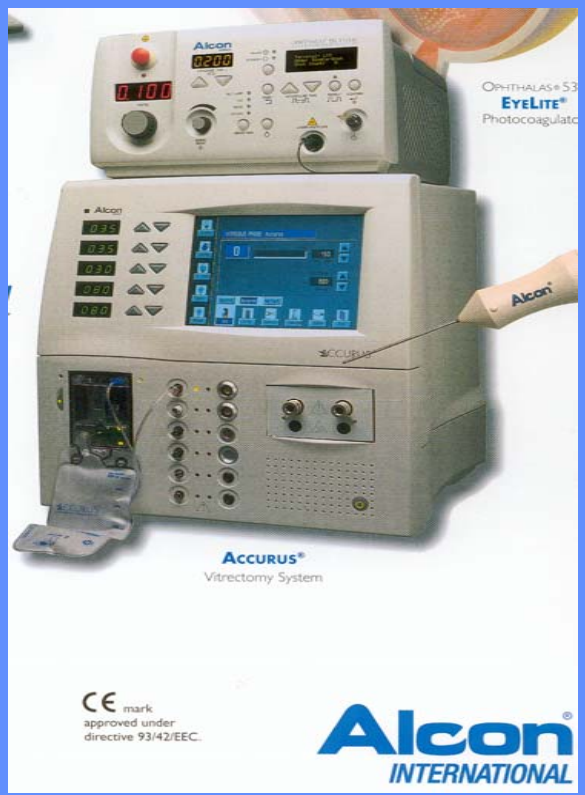


The Basic Elements of Phacoemulsification Machine



Storz Premier phacoemulsification machine

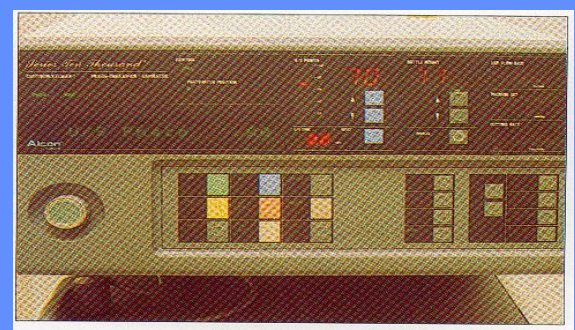
Phacoemulsification Machines



Alcon Accurus

Alcon Legacy

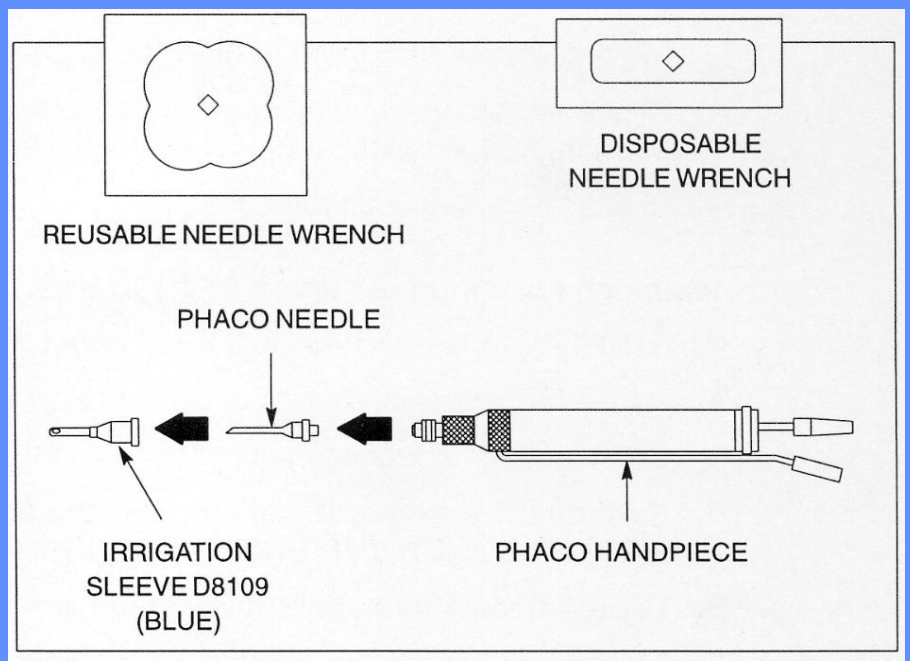
Storz Premier



Alcon 10000

Phaco machines cost between $25k and $100k

Phaco Handpieces



Phaco handpieces cost around $2000

Phaco Sets

Sets cost between $130 and $450 each

Comparison of Cataract Surgeries

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Procedure	Advantages	Disadvantages
ICCE	■**Inexpensive** ■**Less skill required** ■**Less equipment required**	■**Can cause retinal detachment** ■**Large incision-complications related to sutures and infection** ■**Can cause damage to delicate eye structures**
ECCE	■**Not much equipment required** ■**Less possibilities of damage to eye structures and retinal detachment**	■**Requires surgical microscope** ■**Large incision-complications related to sutures and infection** ■**Secondary Cataract**
PHACO	■**Excellent control of each phase of cataract removal** ■**Smaller incision-less suture and infection related complications**	■**Requires surgical microscope** ■**Expensive equipment** ■**Expensive consumable sets** ■**Secondary Cataract**

Considerations for Introducing Phaco Surgery

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- Must have Ophthalmic Surgical Microscope
- Must have Yag Laser for treatment of secondary cataract
- Ability to practice and perfect technique
- Ability to pay for sets
- Ability to properly sterilize handpieces and sets
- Ability to maintain equipment
- Availability of IOLs/Glasses
- There may be other surgical techniques that are more appropriate

Advantages of Phacoemulsification

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- **Smaller incision:** fewer suture and less suture related complications, more rapid anatomical healing.

- **Allows excellent control of each phase of the operation for cataract removal:** better and more complete removal and aspiration of the cortex.

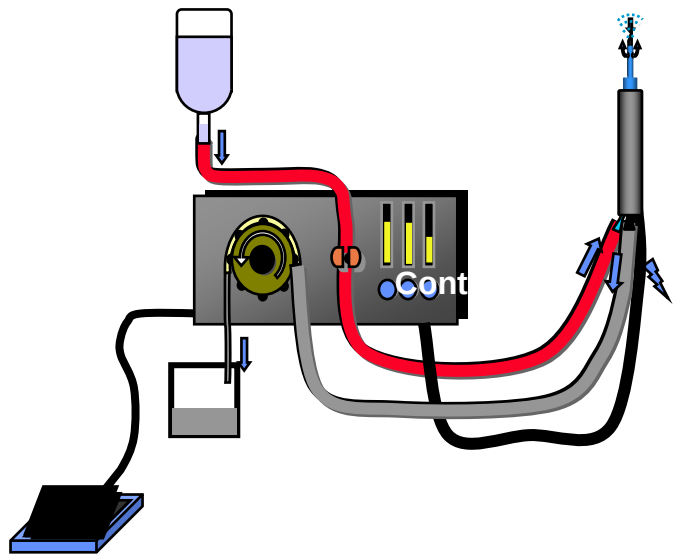
- **Stimulated the development of planned extracapsular surgery.**

The Basic Elements of Phacoemulsification Machine

- **Ultrasound hand-piece:**
  - **ultrasound transducer**
  - **titanium tip**

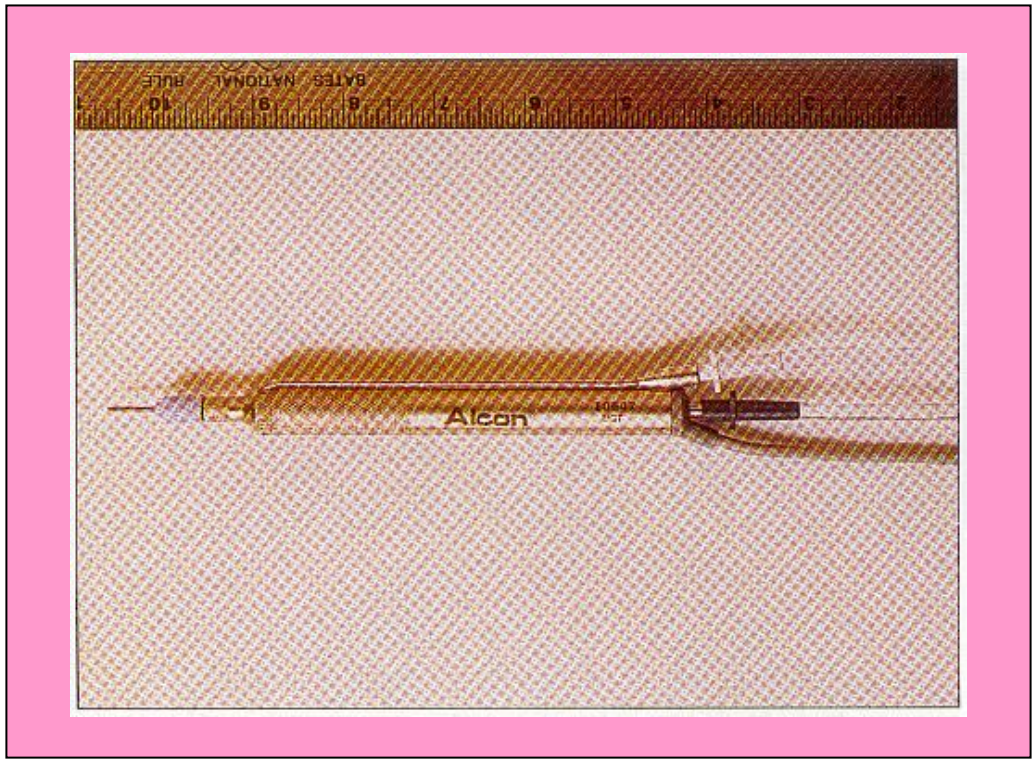
- **Irrigation-aspiration system:**
  - **irrigation liquid container**
  - **irrigation-aspiration lines**
  - **aspiration pump**
  - **waste container**

- **Electronic control system:**
  - **power supply**
  - **computer (or control circuits)**
  - **ultrasound generating circuits**
  - **electromagnetic valve controls**
  - **control panel and foot switch**



The Ultrasound Hand-piece

The ultrasound hand-piece consists of a probe containing a transducer connected to a titanium tip.



A piezoelectric transducer hand-piece

The Basic Concept of Ultrasound

The ultrasound refers to acoustical waves with frequency above 20kHz. (the frequency of ultrasound utilized in phacoemulsification ranges between 28k to 60kHz.)

Acoustical impedance* of different materials:

Material	Za (10^6 Rayls)
Air	0.0004
Water	1.48
Fat	1.38
Other soft tissue	1.63
Bone	7.80

* Acoustical impedance is a measure of its opposition to the propagation of ultrasound:

Za (acoustical impedance) = **r** (density of medium) x **V** (velocity of sound)

The Ultrasound Transducer

The ultrasound transducer is a device that converts alternative current oscillations into acoustical vibrations.

There are two type of devices:

Piezoelectric crystal

Piezoelectric crystal

Ac power supply

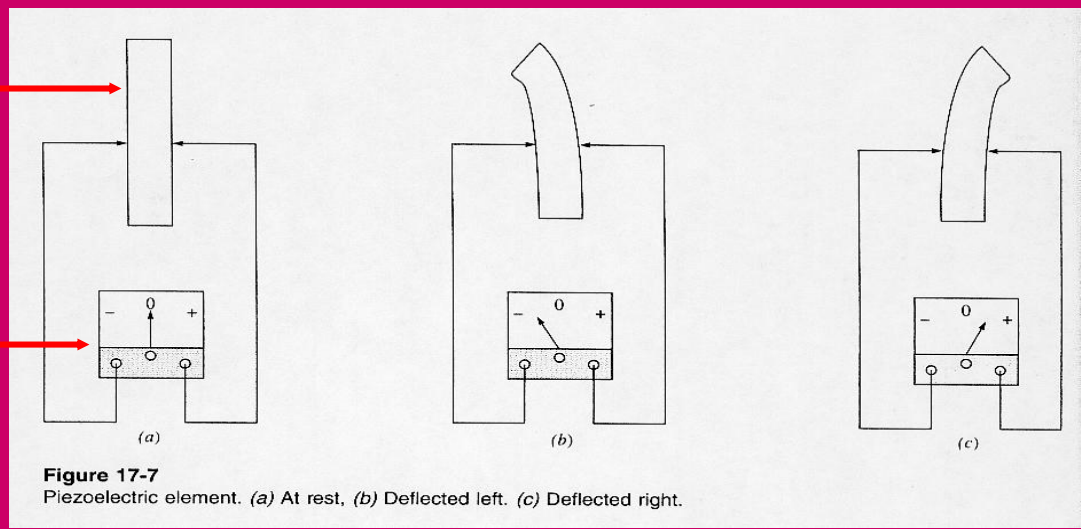


Figure 17-7
Piezoelectric element. *(a)* At rest, *(b)* Deflected left. *(c)* Deflected right.

The phenomenon of Piezoelectricity

Piezoelectricity

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- The piezoelectric effect is a phenomena resulting from a coupling between the electric and mechanical properties of a material. When mechanical stress is applied to a piezoelectric material, an electric potential will be produced. Likewise, when an electric potential is applied to the material a mechanical change will occur.
- Piezoelectric materials thus have numerous applications as electro-mechanical transducers - devices which can convert electrical signals into mechanical motion and vice-versa. Commercial applications of piezoelectric devices abound, for instance in speakers, spark generators inside electronic igniters, strain sensors pressure gages and as presice time-keepers in electronic clocks. A few types of basic piezoelectric devices include crystals, tubes, unimorphs, bimorphs and stacks.
- Piezoelectric crystals involve a non-uniform charge distribution within the unit cell of the crystal. When exposed to an electric field, this charge distribution shifts and the crystal will change its shape. The same polarization mechanism can cause a voltage to develop across the crystal in response to mechanical force.

Piezoelectricity

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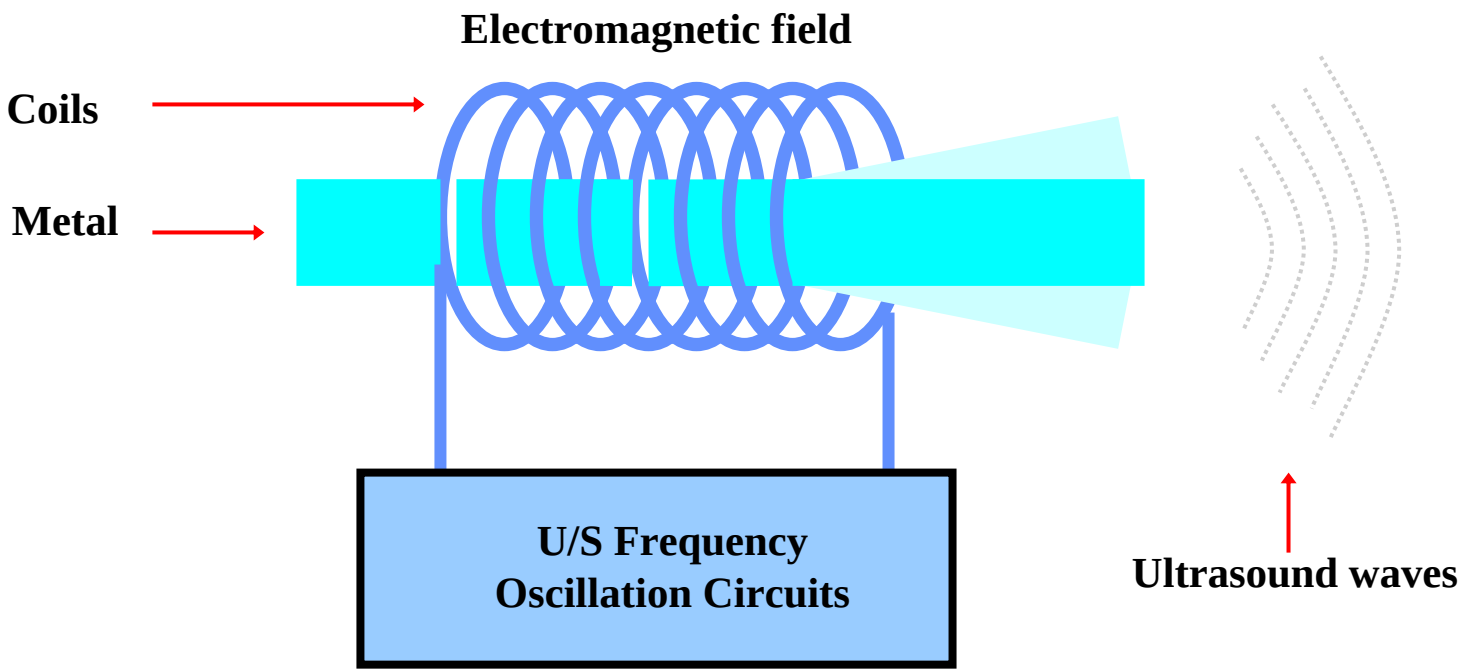
- Because the force and displacement created by a pure piezoelectric material is relatively small, methods have been developed to allow amplification of the piezoelectric effect. One approach (known as a unimorph) is to apply a thin layer of a piezoelectric material to a layer of inactive material. When the piezo expands or contracts, the device will then bend in response.
- By combining more than one piezo, it becomes possible to further increase the amount of transduction. For instance, an elongating, bending or twisting device can be created by placing two layers of piezoelectric material on top of one-another, and by controlling the polarization direction and the voltages such that when one layer contracts, the other will expand. Such a device is known as a bimorph.
- By stacking of piezo materials into layers, it becomes possible to combine their displacement to create what is known as a piezo stack. Such devices are capable of higher displacements and larger forces.

The Ultrasound Transducer

Magnetostrictive metal



Comparison of the Ultrasound Transducers

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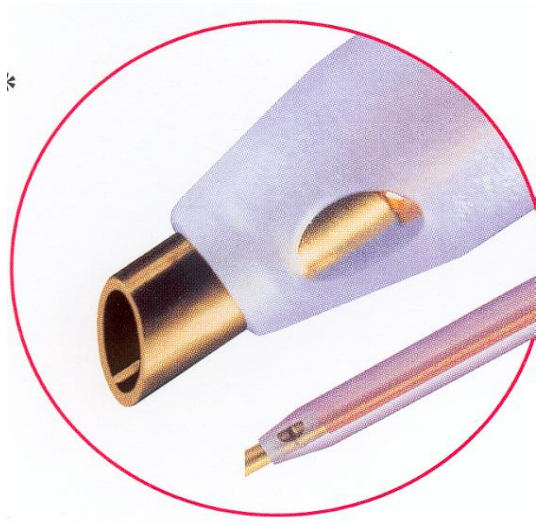
Piezoelectric transducer	Magnetostrictive transducer
light	heavier
easy to manage	bulky
easy to sterilize	difficult to sterilize
homogeneous U/S	depend
do not need cooling	need cooling
popular in new hand-piece	popular in old hand-piece
delicate and easy to break	last longer

The Ultrasound Tip of the Hand-pieces

U/S tips made up of titanium is suitable for the frequency of the ultrasound vibrations

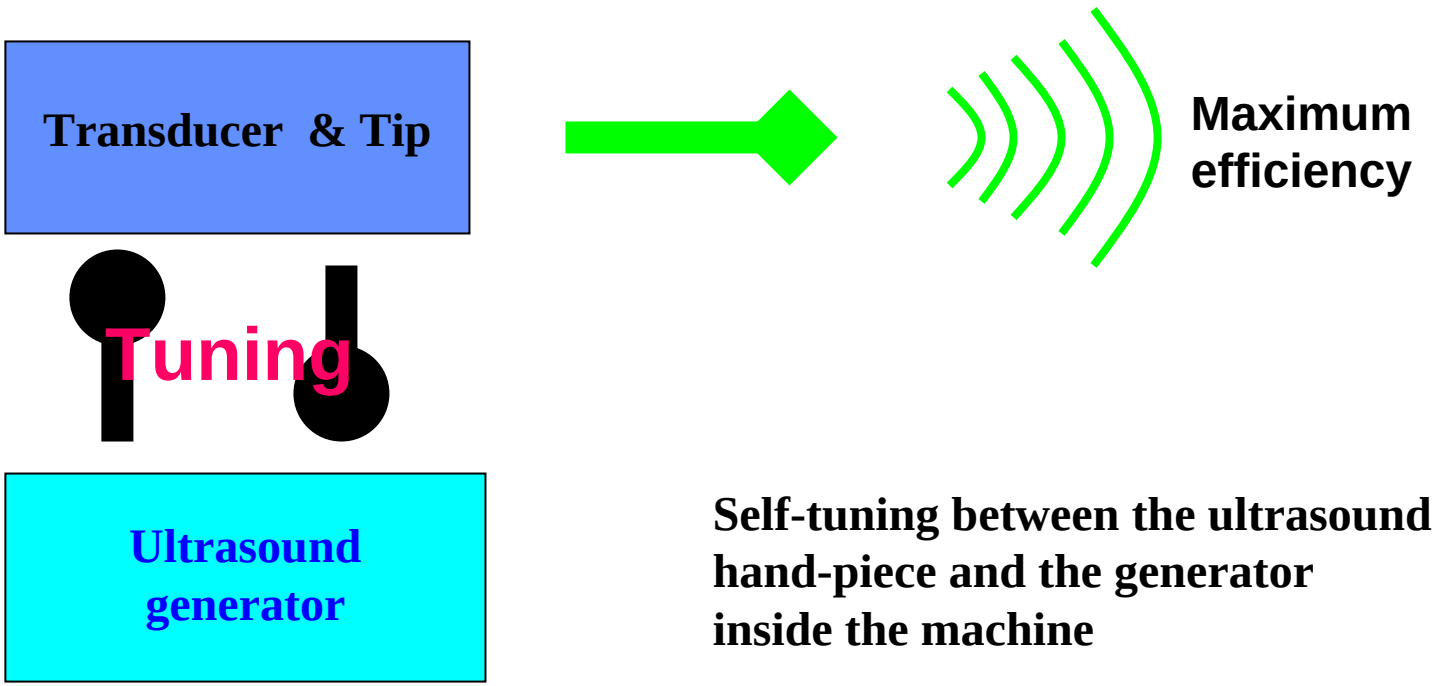
Different angles of U/S tips:

- **0º for Phaco chop**
- **15º tip has a greater occlusion capacity**
- **45º tip has a greater cutting capacity**
- **30º tip is an compromise between the two**



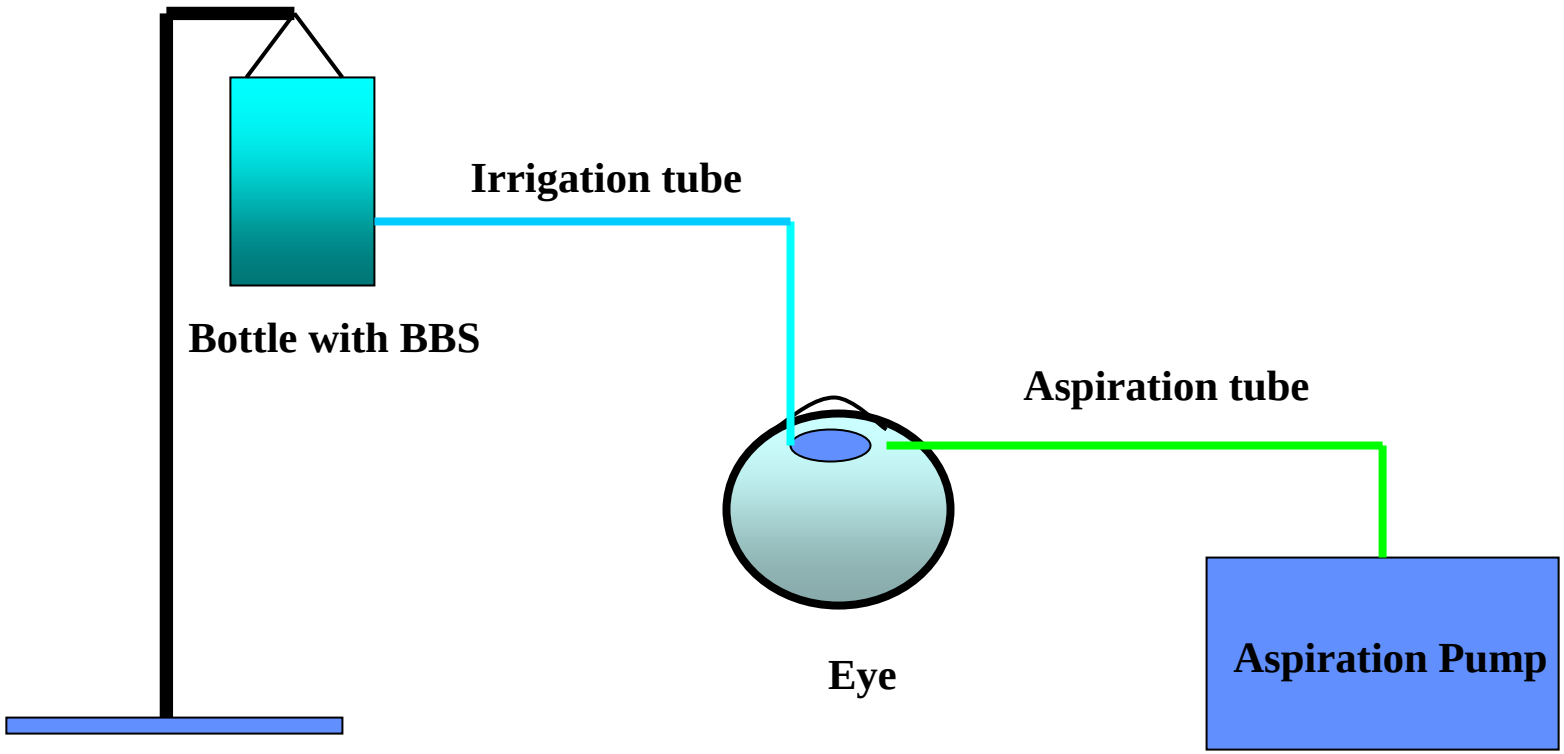
U/S tips is covered by a silicone sleeve, which allows BSS to flow into the anterior chamber through both the distal opening and the lateral opening. It is also important for cooling the U/S tip when functional.

The Importance of the Hand-piece Tuning



Self-tuning between the ultrasound hand-piece and the generator inside the machine

The Irrigation and Aspiration system



The Aspiration Pumps

Aspiration Pump creates the pressure difference that attracts the liquid and the materials toward the aspiration orifice.

Aspiration pump can be one of three types:

- **Peristaltic**
- **Venturi**
- **Membrane diaphragm**

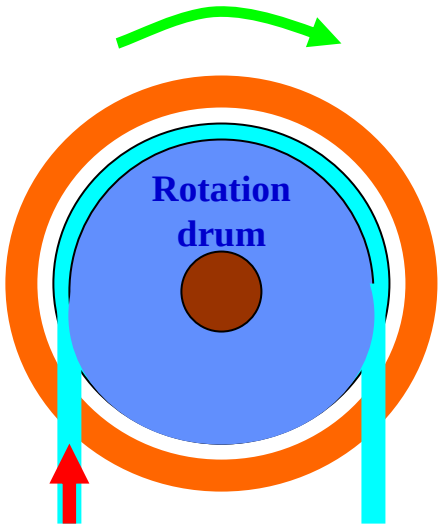
The hydrodynamic parameters related to the aspiration pump:

- **Flow rate**
- **Vacuum and rising time**
- **Occlusion**
- **Venting**
- **Reflux**

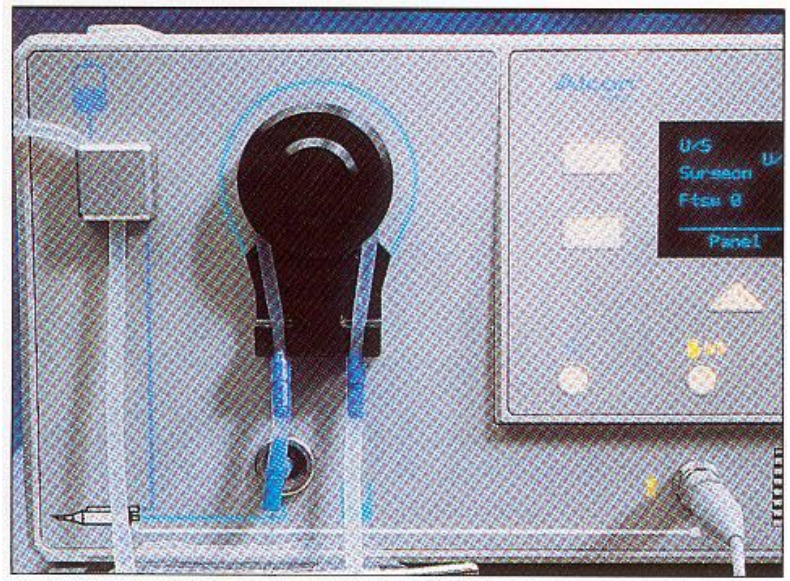
Peristaltic Pump

Peristaltic pump consists of a rotating drum fitted at regular intervals with cylinders that compress the aspiration tube wound around the rotating drum. The rotation of the drum will produce the peristaltic wave that will draw the liquid in the direction of rotation.

The direction of rotation and the peristaltic wave



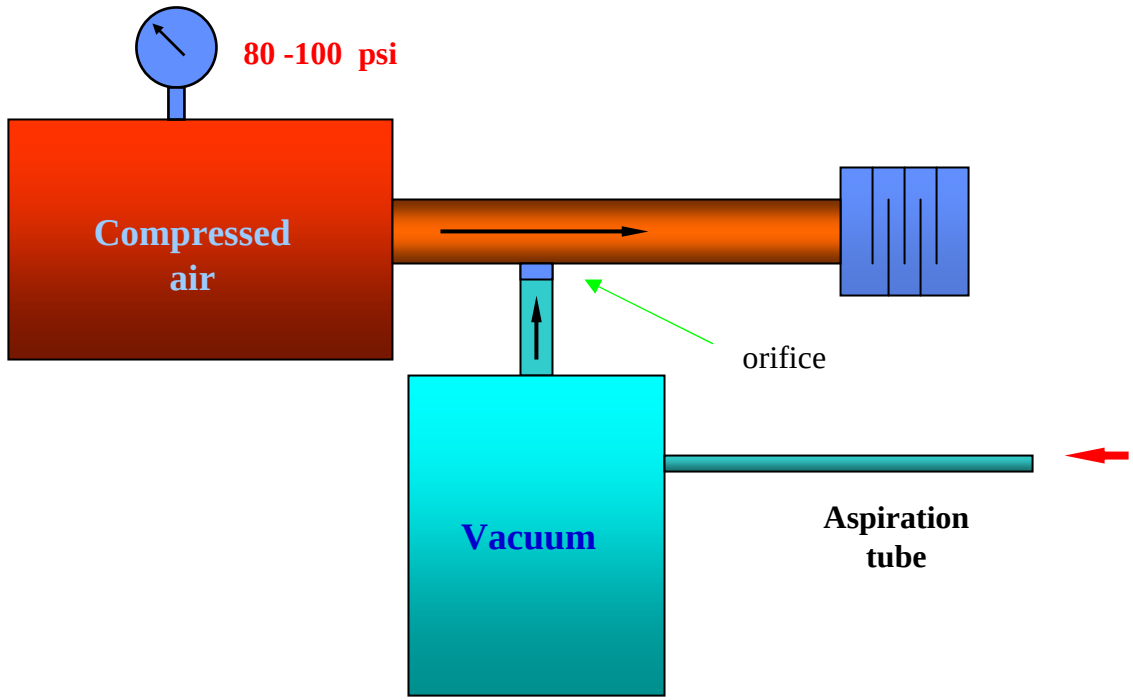
Aspiration tube



Peristaltic pump on Alcon Universal II

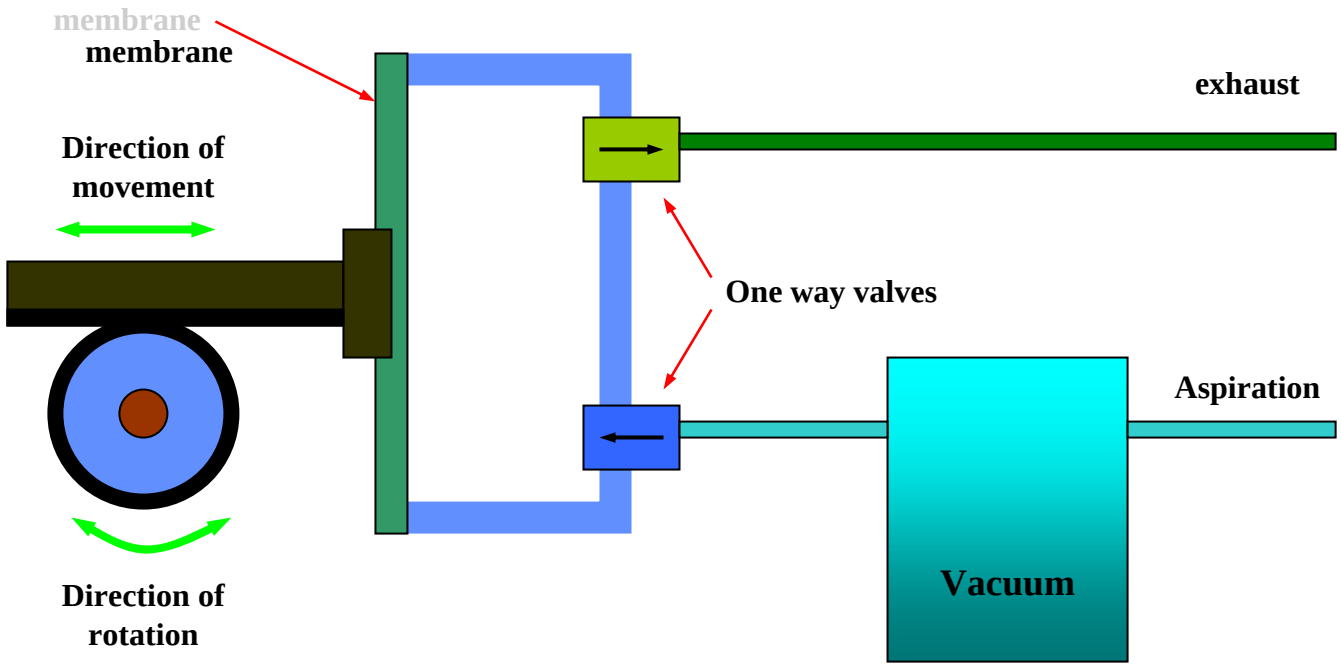
The Venturi Pump

The Venturi pump consists of a compensation chamber connected on one side to the aspiration tube and on the other to a chamber containing compressed air.



The Membrane Pump

The membrane pump consists of a compensation chamber connected on one side to the aspiration tube and on the other to a chamber containing compressed air.

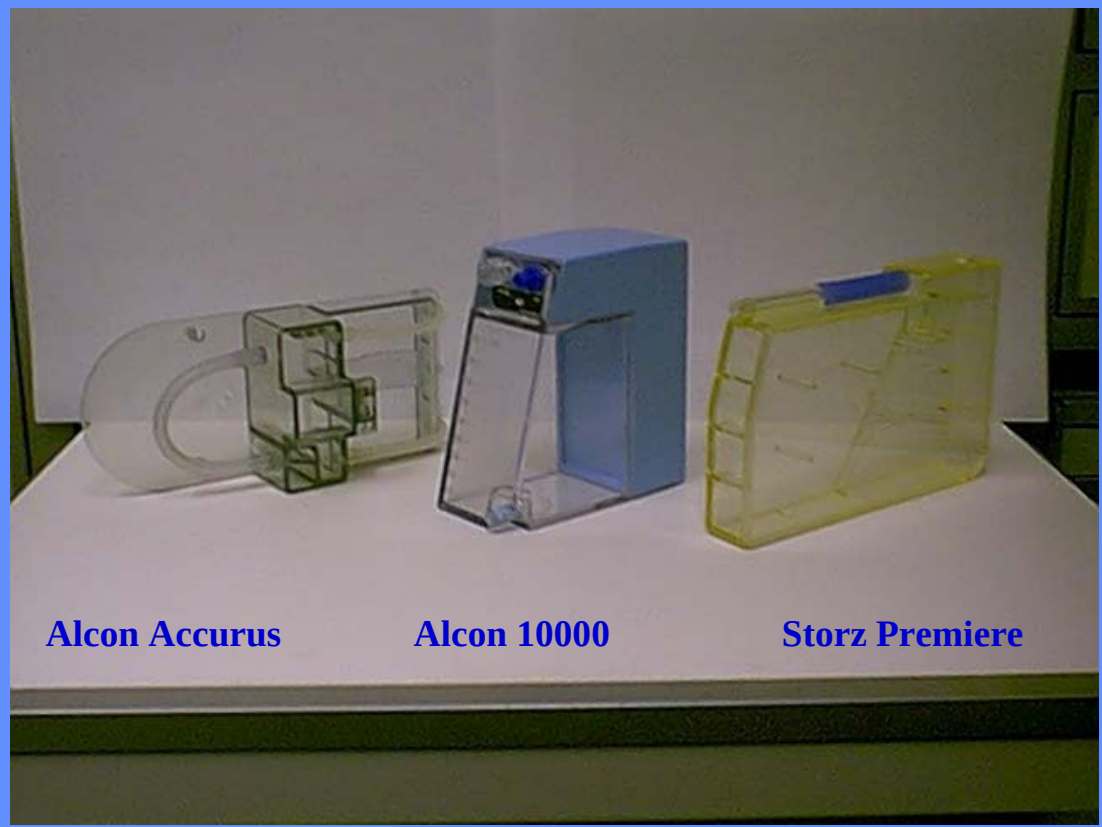


The hydrodynamic parameters

The hydrodynamic parameters related to the aspiration pump:

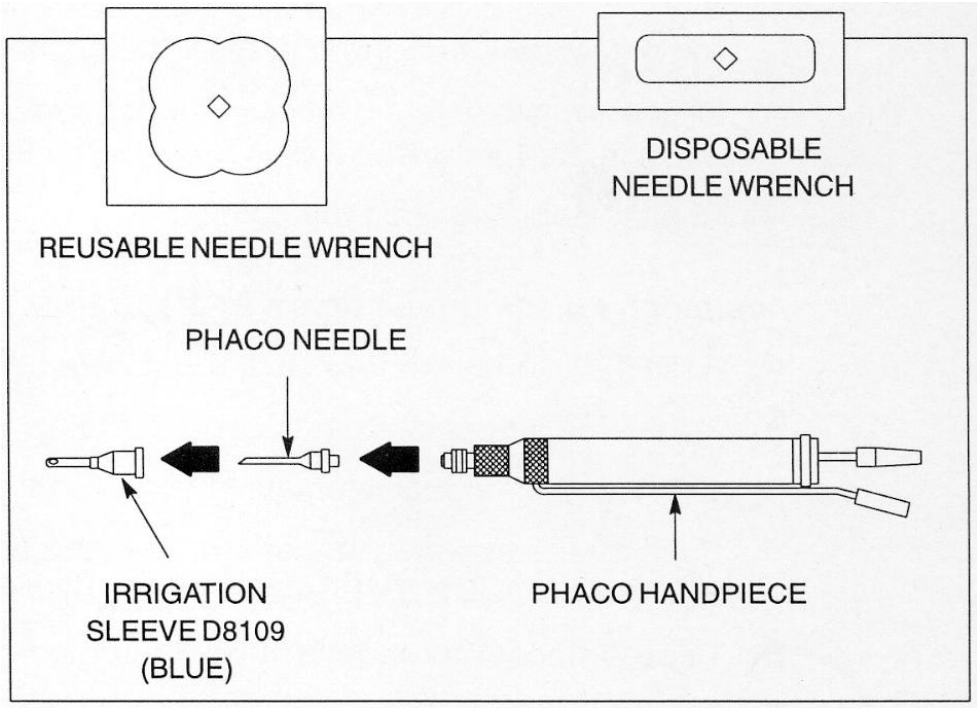
- **Flow rate indicates the quantity of liquid that is aspirated through the tube over the time unit. (cc/min)**
- **Vacuum indicate the negative pressure in the aspiration line.**
- **Occlusion occurs with the obstruction of U/S tip or aspiration line. The occlusion activates the increase in vacuum along the aspiration line and therefore increases the capacity of the pump for aspirating.**
- **Venting is designed for interrupting the aspiration, when the wrong material (e.g. the iris and capsule) is aspirated during the surgery.**
- **Reflux is to create a positive pressure inside the aspiration line. It can avoid tearing the tissue that has occluded the aspiration orifice.**

The Cartridges for Different Brand of Phaco Machines

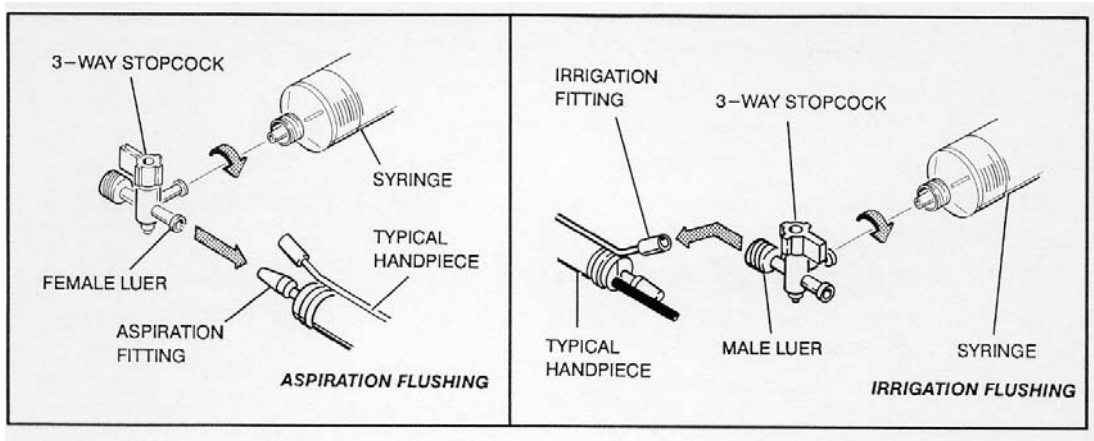


The Aspiration Pumps

Aspiration Pump creates the pressure difference that attracts the liquid and the materials toward the aspiration orifice.



Handpiece Flushing and Sterilization



Flushing

- **Use warm distilled water**
- **Do not use chemical agents to flush the hand-piece.**
- **Do not draw flushing fluid back through the hand-piece.**

Sterilization

- **Standard steam sterilization (121 ^{0}C, 103 kPa, 20 min)**
- **Flash sterilization (132 ^{0}C, 206 kPa, 5 min)**
- **High vacuum (132 ^{0}C, -64 cm Hg, 4min)**

Acknowledgements

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