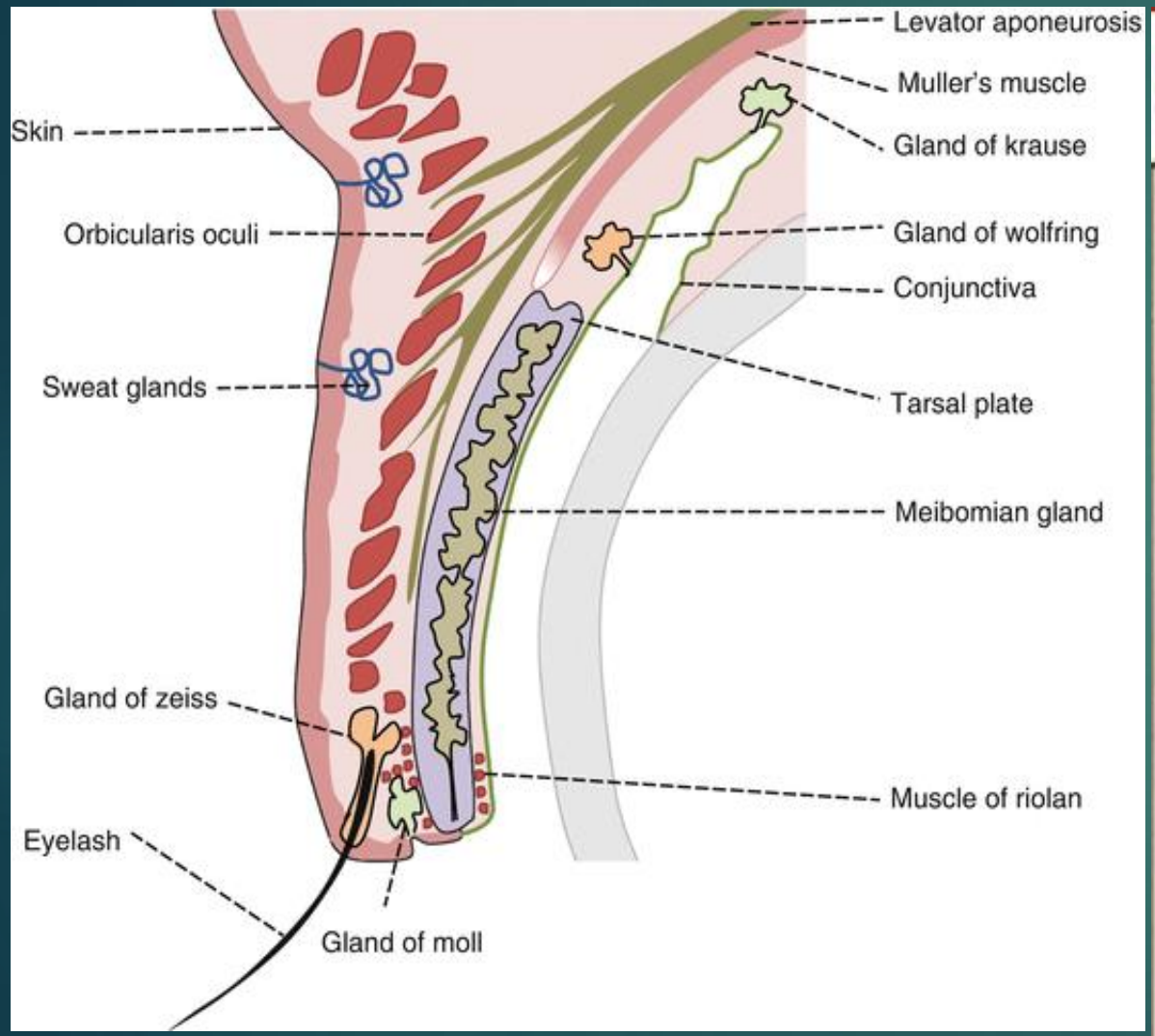
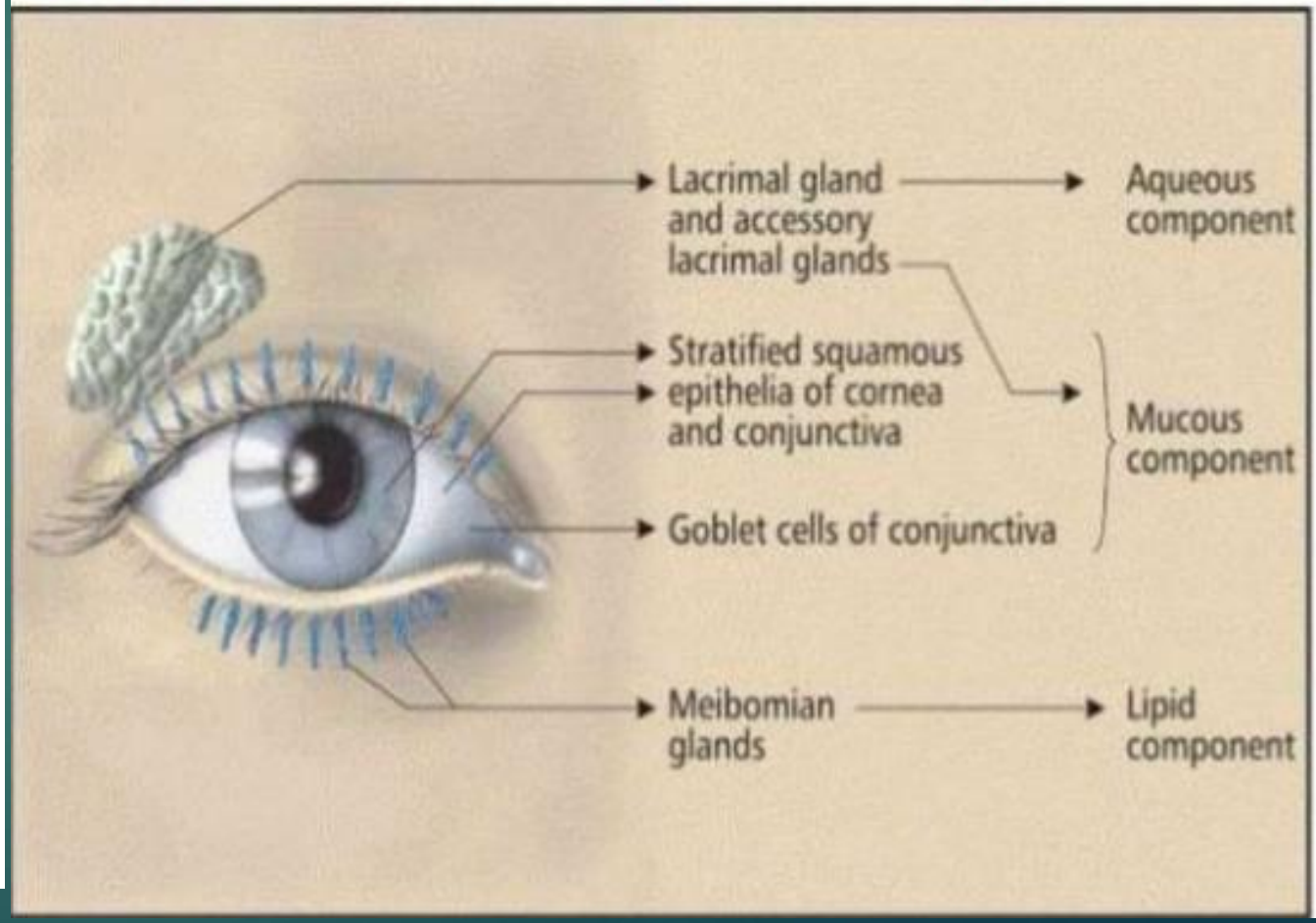
# Tear Film

# Introduction

- The tear film is a complex mixture of substances secreted from multiple sources on the ocular surface, including the lacirmal gland, the accessory lacrimal glands, the meibomian glands and the goblet cells.
- The tear film overlays the ocular surface, which is comprised of the corneal and conjunctival epithelia, and provides the interface between these epithelia and the external environment.
- The tear film is essential for the health and protection of the ocular surface and for clear vision as the tear film is the first refractive surface of the eye

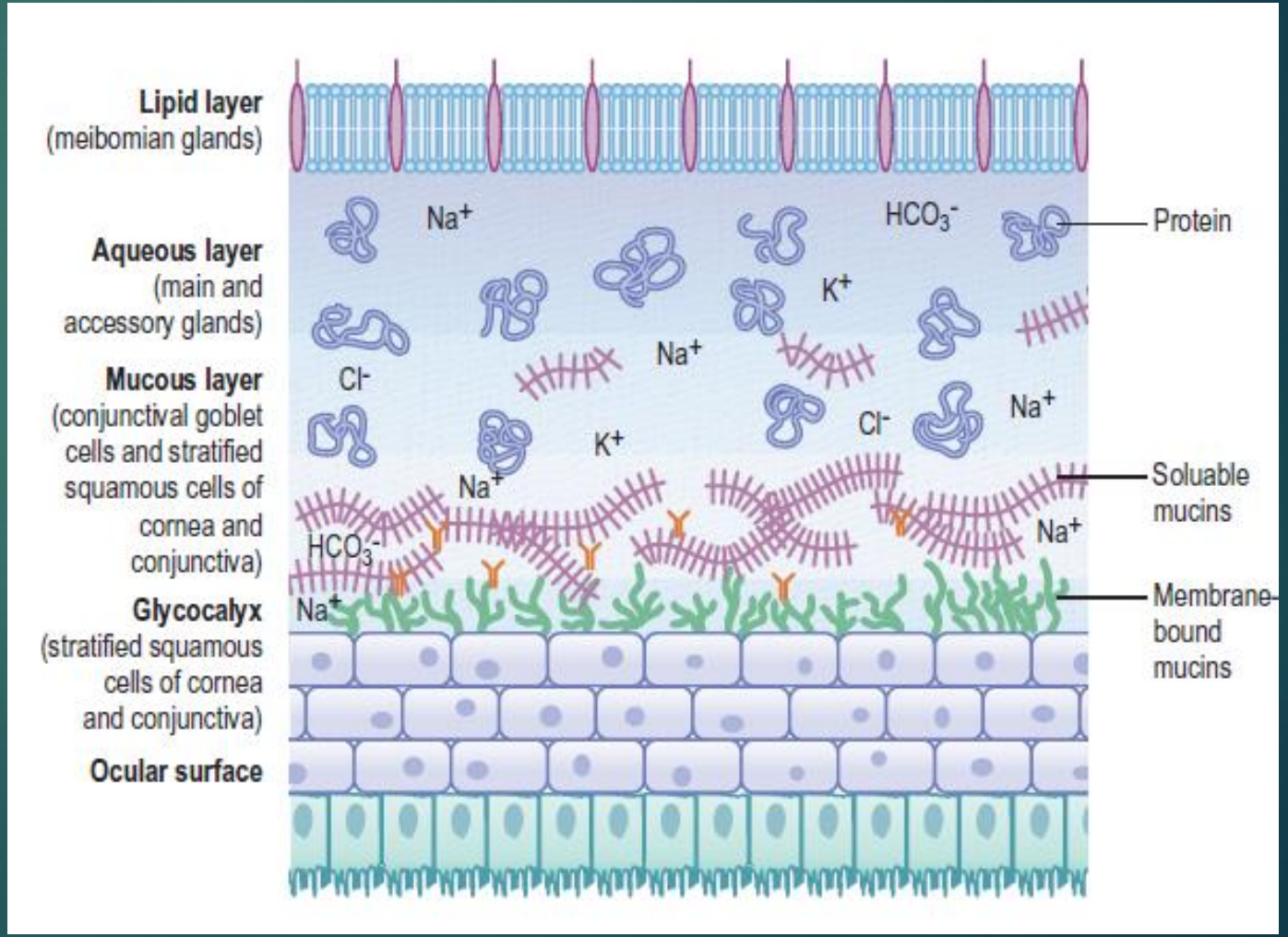



# Components Of Eye Forming Tear Film



# Structure of tear film

- The tear film is composed of three layers :
  1. Lipid layer
  2. Aqueous layer
  3. Mucin layer



1. **Lipid Layer:**

- It is the outermost superficial oily layer derived from the secretion of meibomian, zeiss and Moll glands.
- Contains lipids with low polarity such as wax and cholesterol esters. High polarity lipids such as triglycerides, free fatty acids, and phospholipids are present is negligible amount.
- Its thickness is about 0.1 µm.
- Functions:
  - Prevents overflow of tears and retards evaporation
  - Prevents migration of skin lipids onto the tear film
  - Aids in lubrication of eyelids during blinking

## 2. Aqueous layer:

- Middle layer and is secreted by the lacrimal gland and the accessory glands of Krause and wolfring.
- It has uniform thickness of 10 µm. *Previous estimates suggested thickness of aqueous layer comprised more than 95%, but has been reduced to 60% with a larger component being provide by mucin layer based on recent confocal corneal microscope*.
- This layer is an aqueous solution of low viscosity, containing ions of inorganic salts, glucose, urea, and various biopolymers such as enzymes, proteins and glycoproteins. Lysozyme, lactoferrin, tear specific prealbumin and secretory immunoglobulin-A are main constitute of protein fraction.
- Functions:
  - Provides atmospheric oxygen to the epithelium
  - Contains antibacterial enzymes like lysozyme and betalysin
  - Reflex secretion of the aqueous layers helps to wash away debris and noxious substances
  - Bicarbonate and protein present gives buffering capacity which protect against pH changes

3) Mucin layer:

- It is the deepest layer of pre-corneal tear film which acts a interference that facilitates adhesion of the aqueous layer of the tears to the ocular surface.
- This layer was thought to be thin 0.02-0.05 µm. * *However, measurements using laser interferometry suggest that the full thickness of the mucous layer was not recognized using conventional measuring methods and showed that mucin layer is considerably thick (30 µm)* and that the precorneal tear film is mucin dominated gel hydrated by aqueous fluid.
- We can find two kind of mucin: cell surface associated and secreted.
- Cell surface associated is composed of the glycocalyx secretion from the surface epithelia and Secreted mucin are secreted by the conjunctival goblet cells, crypts of Henle and glands of Manz.
- Corneal epithelium is relatively hydrophobic surface. In order for tears to completely cover the surface must be converted to a hydrophilic surface. Glycocalyx migrate out from the surface of the corneal microvilli to form hydrophilic network that holds mucin on the ocular surface

- Function :
  - Plays major role in tear film stability
  - Acts as wetting agents that keeps ocular surface hydrated
  - Provides a slippery coating over foreign bodies, thereby protecting cornea and conjunctiva against abrasive effects of the particles as they move about with blinking.
  - contribute to resistance of the eye to infection by providing protection against microorganisms

# Functions of Tear Film

I. Forms an almost perfectly smooth optical surface on the cornea by filling in and smoothening out small surface irregularities in corneal epithelium.

II. It serves to keep the surface of cornea and conjunctiva moist.

III. It serves as a lubricant between globe and eyelids thereby decreasing the frictional forces that are generated during constant blinking and rotational movement of the eyeball.

IV. It is the primary source of atmospheric oxygen for the cornea

V. It helps to maintain corneal hydration by changes in tonicity that occur with evaporation

VI. contains antibacterial substances (lysozyme, beta-lysin, lactoferrin, immunoglobulins) to help protect against infection

VII. It washes away debris and noxious irritants.

VIII. It contains various growth factors and peptides that can regulate ocular surface wound repair

# Physical properties of tear film

| property | |
|---|---|
| Thickness | 4-8 µm (*recent confocal microscopy shows tear film thickness as 40 µm) |
| Volume | 4-13 µl |
| Rate of secretion | 1-2µl per minute |
| Turn over rate | 18% per min |
| Refractive index | 1.357 |
| pH of tears | 7.3-7.7 |
| Osmotic pressure | 0.90-0.95% |
| Temperature | 30'c at cornea and 35'c at limbus |
| Oxygen tension | 40-160 mmHg |

# Chemical composition of tears

1. Water:
   - Major component, 98.2%
   - With salts dissolved $Na^{+}$, $K^{+}$, $CL^{-}$, $HCO^{3-}$, $Ca^{2+}$

2. Proteins:
   - 0.6 – 2 gm /100ml (in mixture of stimulated and unstimulated tears)

Group A : similar to serum protein. IgG, Albumin, Transferrin, Alpha-1 antitrypsin, Alpha-1 antichymotrypsin, beta 2- microglobulins

Group B: Synthesized by tear gland also known as "rapid migrating proteins".

Lysozyme, Lactoferrin, IgA

# Chemical composition of tears

- **Immunoglobulins**: IgA is more prominent (14-24 mg/100ml) followed by IgG (17mg/100ml). Defence against viral and bacterial antigens.
- Other enzymes: Lactate dehydrogenase, Betalysin
- Mucopolysachharides, glycoprotein, Amino acids(17 in human tear) are also found

3. Lipids:
   - Present in very small amount
   - Hydrocarbon, wax ester, cholesterol ester, triglycerides.
4. Metabolites:
   - Glucose, lactate, pyruvate, Urea
5. Electrolytes:
   - $Na^{+}$, $K^{+}$ Common positively charged and $CL^{-}$, $HCO^{3-}$ are common negatively charged electrolytes

# Tear film Dynamics

- Tear film accomplishes its function by highly specialized and well organized dynamic activities which from starting to end are includes:
  1. Secretion of tears
  2. Formation of tear film
  3. Retention and redistribution of tear film
  4. Displacement phenomenon
  5. Evaporation of tear film
  6. Drying and break up of tear film
  7. Dynamic events during blinking
  8. Elimination of tears

# 1. Secretion of tears

I. Basal secretion:

- Secreted by accessory lacrimal gland
- Cornea is continually kept moist and nourished by basal tears
- They lubricate the eye and help to keep it clear of dust

II. Reflex secretion:

- Secreted by main lacrimal gland
- It result from irritation of the eye by foreign particles, bright light, hot and peppery stimuli to the tongue
- These reflex tear attempt to wash out the irritants that may have come in contact with eye

# 1. Secretion of tears

- For mucous and aqueous layers: secretion is regulated by neural reflexes. Sensory nerves in cornea and conjunctiva are activated by mechanical, chemical, and thermal stimuli that in turn activate the efferent parasympathetic and sympathetic nerves, which innervate the lacrimal gland and the conjunctival goblet cells, and cause mucous and fluid secretion.
- For the lipid layer: the blink itself regulates release of pre-secreted meibomian gland lipids stored in the meibomian gland duct. When the eyelids retract a thin film of lipid overspreads the underlying aqueous and mucous layers.

# 2. Formation of tear film

- Lacrimal fluids which flows over the ocular surface and a continuous preocular tear film is formed

Lids surface the cornea with thin layer of mucus

On the new surface, the aqueous component of the tear spreads spontaneously

As the aqueous layer spreads, the superficial lipid layer spreads over the aqueous film, probably contributing to its stability and retarding evaporation between blinks

# 3. Retention and redistribution of tear film

- Tear film is retained at uniform thickness over the corneal surface against a gravitational force.
- The outermost layer of corneal epithelium , along with mucopolysaccharides play important role in retaining the fluid layer on the corneal surface.
- Tear film remain stagnant until blink or eye movement.
- Redistribution occurs in form of new tear film by marginal tear strip.

# 4. Displacement Phenomenon

- Tear film possess certain stability, compressibility and elasticity and that is more or less unaffected by gravity.
- It is possible due to thin monomolecular layer on the surface of cornea that is displaced as an integral whole and not the whole of the precorneal tear film

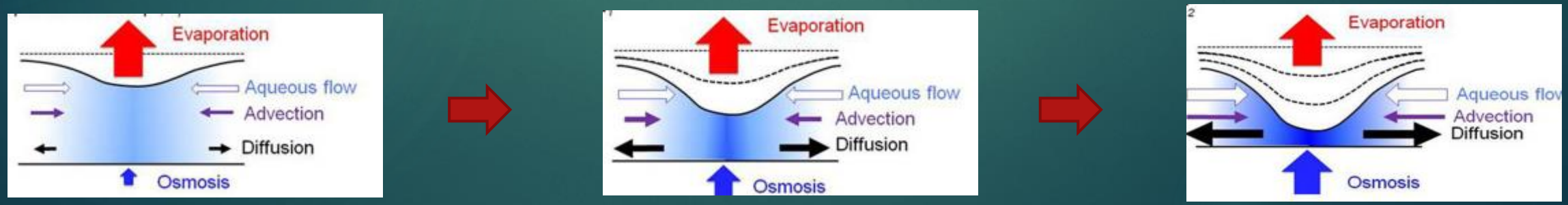
# 5. Evaporation of tear film

- Evaporation of tear film is expected to be about 10% of the production rate. i.e 0.12 µl/ min since the tear production rate is 1.2 µl/ min.
- There is little effect of air motion on the evaporation rate because most of the resistance to evaporation is given by oily layer ( lipid layer) on the tea film.

# 6. Drying, and break up of tear film

- When blinking is prevented, after a brief time interval of 15-40 seconds, the tear film ruptures and dry spots appear on various parts of cornea. The drying of corneal surface is not a result of evaporation alone.
- Mechanism :

  1. Tear film thins uniformly by evaporation → 2. tear film thinned out to critical thickness → 3. significant number of lipid molecule migrate down to mucin layer → 4. mucin layer contaminated by lipid making mucin hydrophobic → 5. tear film rupture



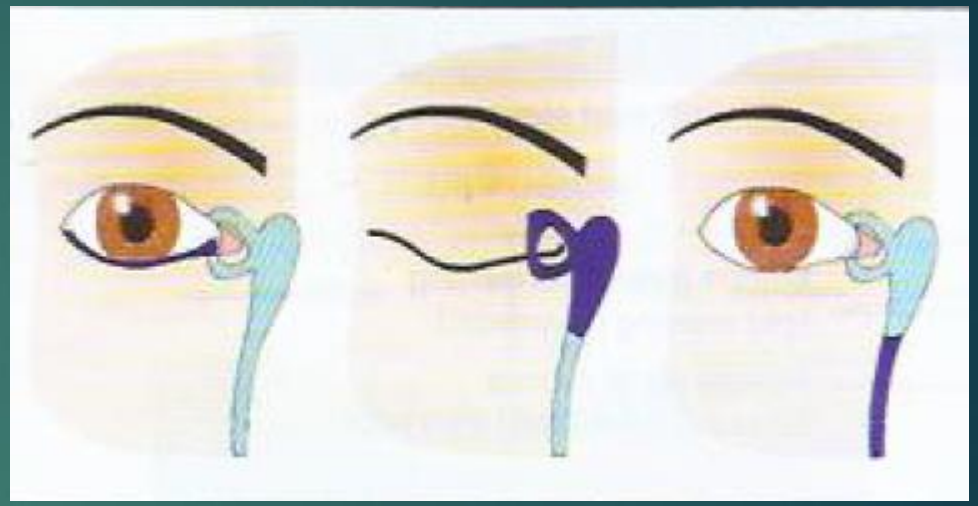
# 7.Dynamic events during blinking

- Closing :
  - As upper lid moves downwards, the superficial layer is compressed.
  - Whole lipid Layer together with the associated biopolymers is compressed between the lid edges.
- Closed:
  - Lipid epiphora never occurs as the compresses lipid layer between closed eyelids has a thickness only of 0.1 um.
- Opening:
  - Lipids in form of monolayer → spreading of excess lipids follows→ multimolecular lipid layer forms in 1 sec → spreading drags some aqueous with it thereby thickening tear film

# 8. Elimination of tears

**Active Pump Mechanism**

Tear
↓
Marginal tear strip
↓
Lacus lacrimalis in inner canthus
↓
Lacrimal passage
↓
Nasal cavity



Drainage of lacrimal fluid from nasolacrimal duct to nasal cavity is influenced by :

1. Gravity
2. Air current movement within the nose
3. Hasner's valve: present at the lower end of the NLD remains open as long as pressure within the nose is less than NLD. When intranasal pressure increase the Hasner's valve close thereby preventing reflux upward.

# Tear Film abnormalities

I. **Aqueous deficiency:**
   - Decresed secretion or obstruction of lacrimal ducts
   - e.g keratoconjunctivitis sicca

II. **Mucin deficiency :**
   - Any disease or disorder which destroys normal conjunctival architecture
   - eg vitamin A deficiency, stevens-Johnson syndrome

III. **Lipid abnormality:**
   - Obstruction in meibomian gland opening.
   - Eg : meibomian glad dysfunction, chronic blepheritis

IV. **Lid surface abnormalities:**
   - Any condition which interfere with normal blinking function of eyelids
   - Eg: ectropion, eyelid coloboma, Lagophthalmos

# Test for Tear film adequacy

## Invasive

* TBUT
* Schirmer test
* Phenol red thread test
* Rose bengal staining

## Noninvasive

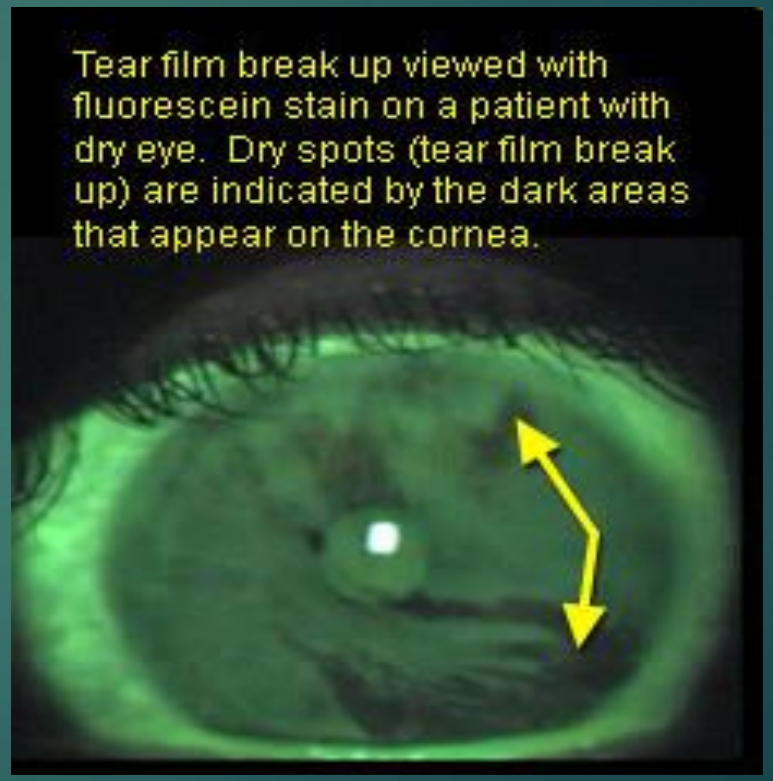
* NIBUT
* Tear prism height
* Lipid layer evaluation

# Invasive

## 1. Invasive TBUT :

* Interval between complete blink & appearance of 1st randomly distributed dry spot on cornea
* Qualitative assessment
* Fluorescein instilled into lower fornix
* Blink several times & then stop
* Diffuse illumination
* Monitored under cobalt blue light of slight lamp.

* Normal : 15 – 35 sec
* Abnormal : < 10 sec

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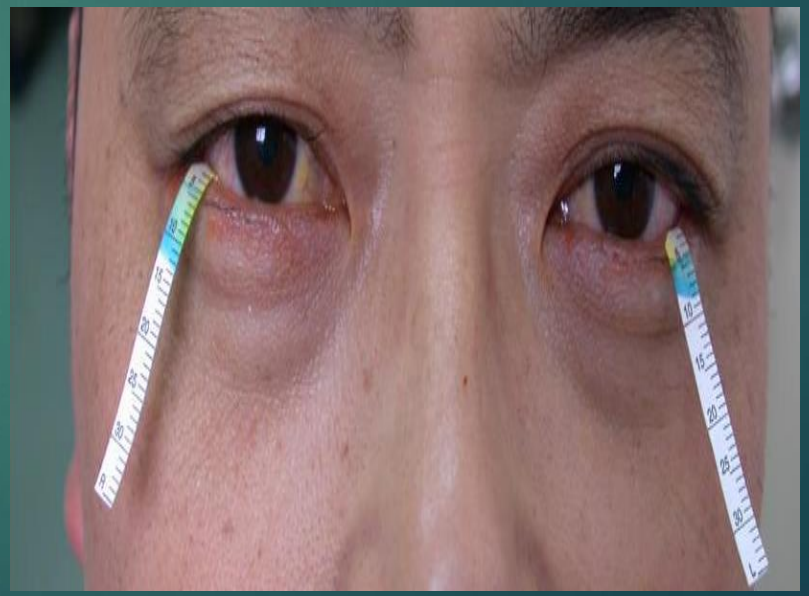
# 2. Schirmer test :

* Determines tear Quantity

* 2 types:
  - Schirmer test 1
  - Schirmer test 2



# Schirmer test 1 :

* Measure basic & reflex secretion
* 5 x 35 mm strip of Whatman filter paper no 41
* Folded 5 mm from one end
* Lower fornix at junction of lateral 1/3$^{rd}$ & medial 2/3$^{rd}$
* Keep eyes open & blink normally
* After 5 min strip is removed
* Amount of wetting is measured

  * Normal :> 15 mm
  * Moderate : 6 – 10 mm
  * Severe : < 6 mm

## Shirmer test2

* Measure basic secretion
* Use of tropical anesthetic
* Procedure is same

# 3. Phenol red thread test :

*Assess the tear volume

* More comfortable

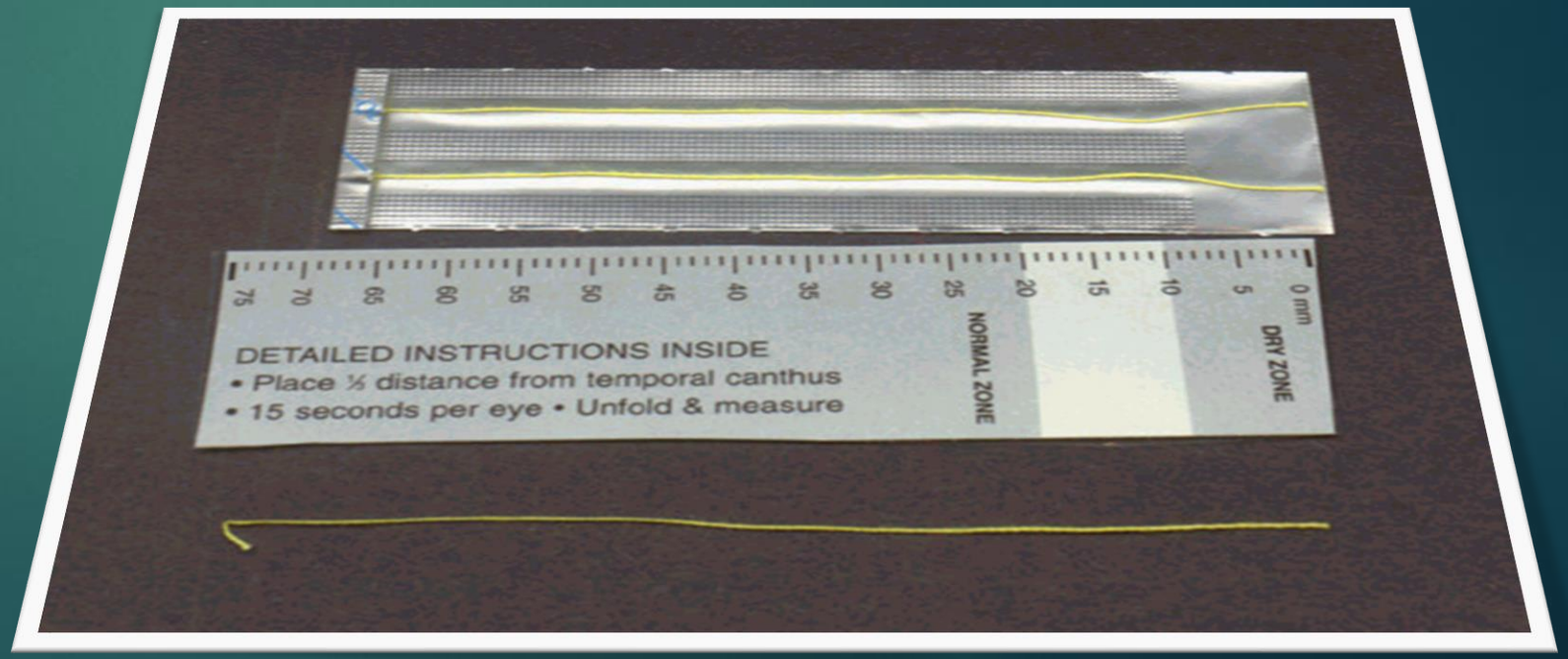
* 70 mm length of phenol red impregnated cotton thread

* Inserted into lower fornix for 15 sec

* Wet length & color changes noted

* Yellow to red

* Normal : 15 mm



# 4.Rose bengal staining :

* Detecting mild cases of KCS
* Stains dead cells & mucus
* Irritating in tear deficiency eye
* Depending on severity staining patterns are :
* C Pattern :
    - Mild
    - Punctate stain in interpalpebral area

B Pattern

- Moderate
- Extensive staining

A Pattern

- Severe
- Confluent staining of conjunctiva & cornea

# Noninvasive

## 1. NIBUT :

* Keratometer
* 1st blurring of mires from last complete blink

# 2. Tear prism height :

- Tear prism formed in inferior cul-de-sac
- Eyepiece graticule
- Seen with fluorescein
- Calculated- changing slit of slit lamp

Normal height:

0.1 – 0.3 mm

Dry eye:

< 0.1 mm