Biophysics

Lecture 3

Edema

Formerly known as dropsy or hydropsy - is an abnormal accumulation of fluid beneath the skin, or in one or more cavities of the body.

Generally, the amount of interstitial fluid is determined by the balance of fluid homeostasis, and increased secretion of fluid into the interstitium or impaired removal of this fluid may cause edema.

Five factors can contribute to the formation of edema:

- It may be facilitated by increased capillary hydrostatic pressure or,
- reduced oncotic pressure within blood vessels;
- by increased blood vessel wall permeability as in inflammation;
- by obstruction of fluid clearance via the lymphatic; or,
- by changes in the water retaining properties of the tissues themselves. Raised hydrostatic pressure often reflects retention of water and sodium by the kidney.

Edema

Generation of interstitial fluid is regulated by the forces of the Starling equation.

The Starling equation is an equation that illustrates the role of hydrostatic and oncotic forces (the so-called Starling forces) in the movement of fluid across capillary membranes.

Capillary fluid movement may occur as a result of two processes:

- diffusion
- filtration

Starling's equation only refers to fluid movement across the capillary membrane that occurs as a result of filtration.

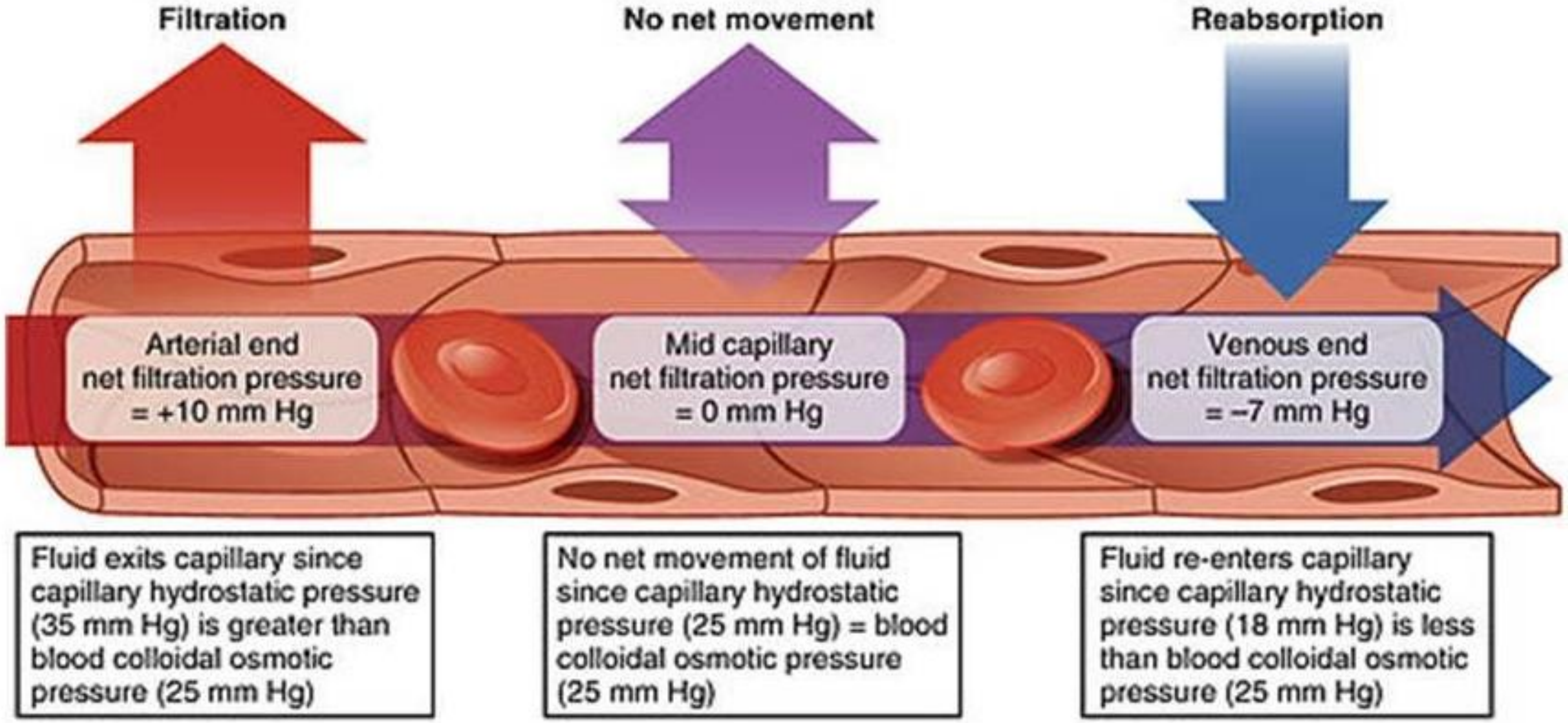
In the glomerular capillaries, there is a net fluid filtration of 125 ml/min (about 180 litres/day). In the rest of the body's capillaries, there is a total net transcapillary fluid movement of 20 ml/min (about 28.8 litres/day) as a result of filtration.

Edema

According to Starling's equation, the movement of fluid depends on six variables:

- Capillary hydrostatic pressure
- Interstitial hydrostatic pressure
- Capillary oncotic pressure
- Interstitial oncotic pressure
- Filtration coefficient
- Reflection coefficient

Edema



Filtration
No net movement
Reabsorption
Arterial end net filtration pressure = +10 mm Hg
Mid capillary net filtration pressure = 0 mm Hg
Venous end net filtration pressure = –7 mm Hg
Fluid exits capillary since capillary hydrostatic pressure (35 mm Hg) is greater than blood colloidal osmotic pressure (25 mm Hg)
No net movement of fluid since capillary hydrostatic pressure (25 mm Hg) = blood colloidal osmotic pressure (25 mm Hg)
Fluid re-enters capillary since capillary hydrostatic pressure (18 mm Hg) is less than blood colloidal osmotic pressure (25 mm Hg)

Glomerular filtration rate (GFR)

- is the volume of fluid filtered from the renal (kidney) glomerular capillaries into the Bowman's capsule per unit time.
- Glomerular filtration rate (GFR) can be calculated by measuring any chemical that has a steady level in the blood, and is freely filtered but neither reabsorbed nor secreted by the kidneys.
- The rate therefore measured is the quantity of the substance in the urine that originated from a calculable volume of blood. The GFR is typically recorded in units of volume per time, e.g. milliliters per minute ml/min. Compare to filtration fraction.
- There are several different techniques used to calculate or estimate the glomerular filtration rate . It is also theoretically possible to calculate GFR using the Starling equation.

$$GFR = \frac{Urine\ concentration \times Urine\ flow}{Plasma\ concentration}$$

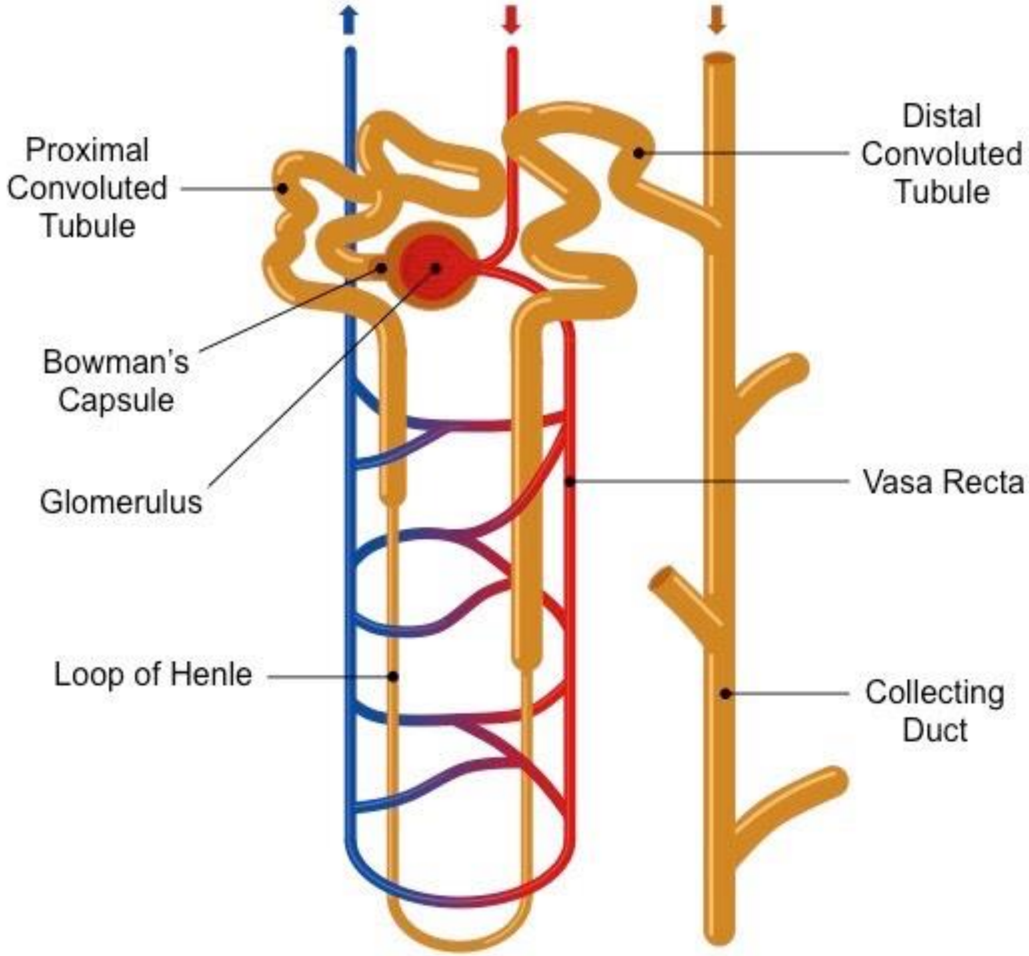
Glomerular filtration rate

Example:

A person has a plasma creatinine concentration of 0.01 mg/ml and in 1 hour produces 60ml of urine with a creatinine concentration of 1.25 mg/mL (Creatinine clearance).

$$C_{cr} = \frac{1.25mg/ml \times \frac{60ml}{60\ min}}{0.01\ mg/ml} = \frac{\frac{1.25mg}{ml} \times 1ml/min}{0.01\ mg/ml} = \frac{1.25\ mg/min}{0.01\ mg/ml} = 125ml/min$$

Glomerular filtration rate



3- Facilitated Diffusion

Use transport proteins, such as uniporters & channel proteins

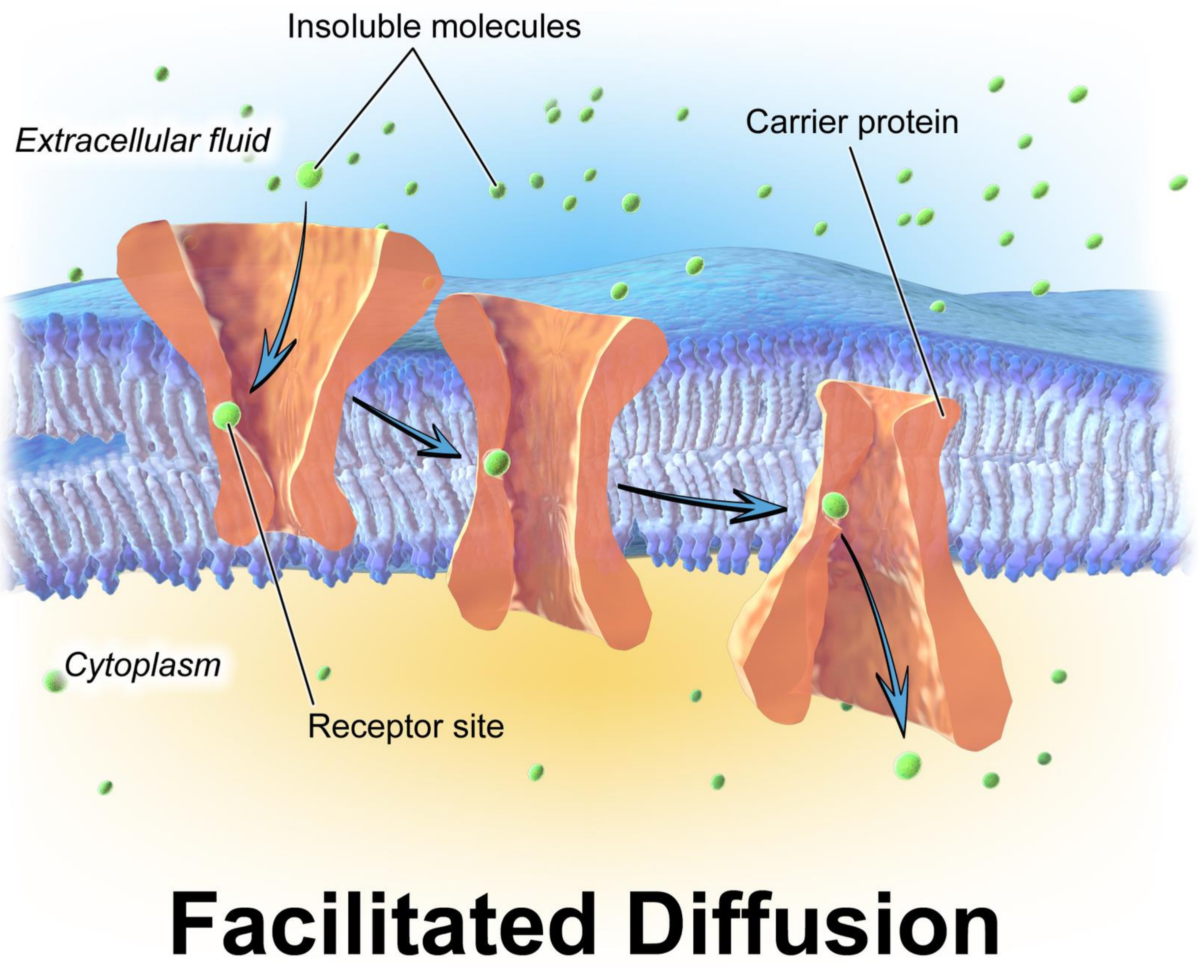
From an area of higher concentration to lower concentration.

It is powered by the potential energy of a concentration gradient.

Does not require metabolic energy.

- Uniporter: transport Amino acid & sugars & nucleosides
- Channel proteins: as aquaporins for water

3- Facilitated Diffusion



Ionophores

- An ionophore is a chemical species that reversibly binds ions. Many ionophores are lipid-soluble entities that transport ions across a cell membrane. "Ionophore" means "ion carrier" as these compounds catalyze ion transport across hydrophobic membranes such as liquid polymeric membranes or lipid bilayers found in the living cells.

- Some ionophores are synthesized by microorganisms to import ions into their cells. Synthetic ion carriers have also been prepared.

The two broad classifications of ionophores synthesized by microorganisms are:

- **Carrier ionophores** that bind to a particular ion and shield its charge from the surrounding environment. This makes it easier for the ion to pass through the hydrophobic interior of the lipid membrane. An example of a carrier ionophore is **valinomycin**, a molecule that transports a single potassium cation. Carrier ionophores may be proteins or other molecules.
- **Channel formers** that introduce a hydrophilic pore into the membrane, allowing ions to pass through without coming into contact with the membrane's hydrophobic interior. An example of a channel former is **gramicidin A**. Channel forming ionophores are usually large proteins.

Ionophores