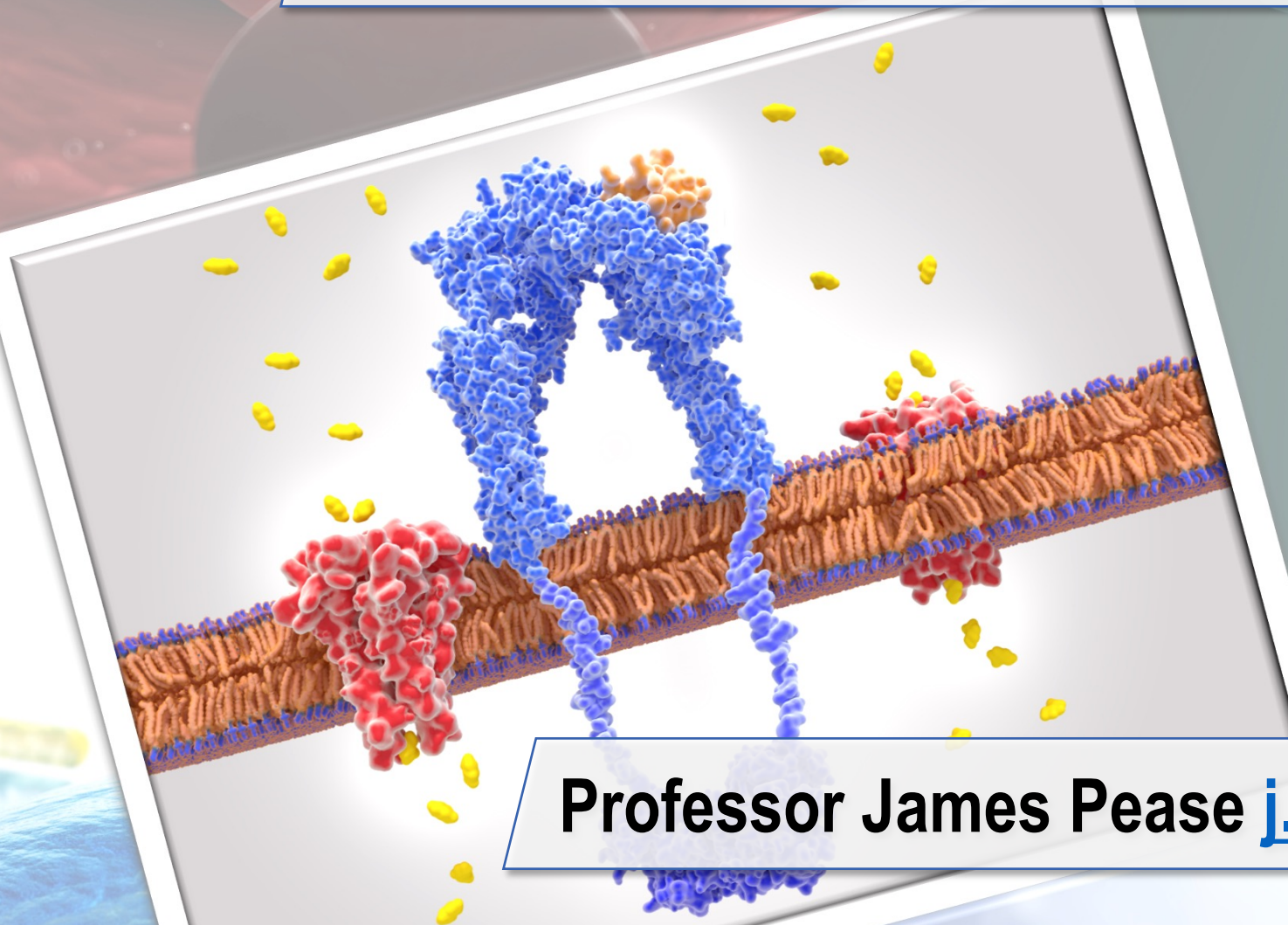
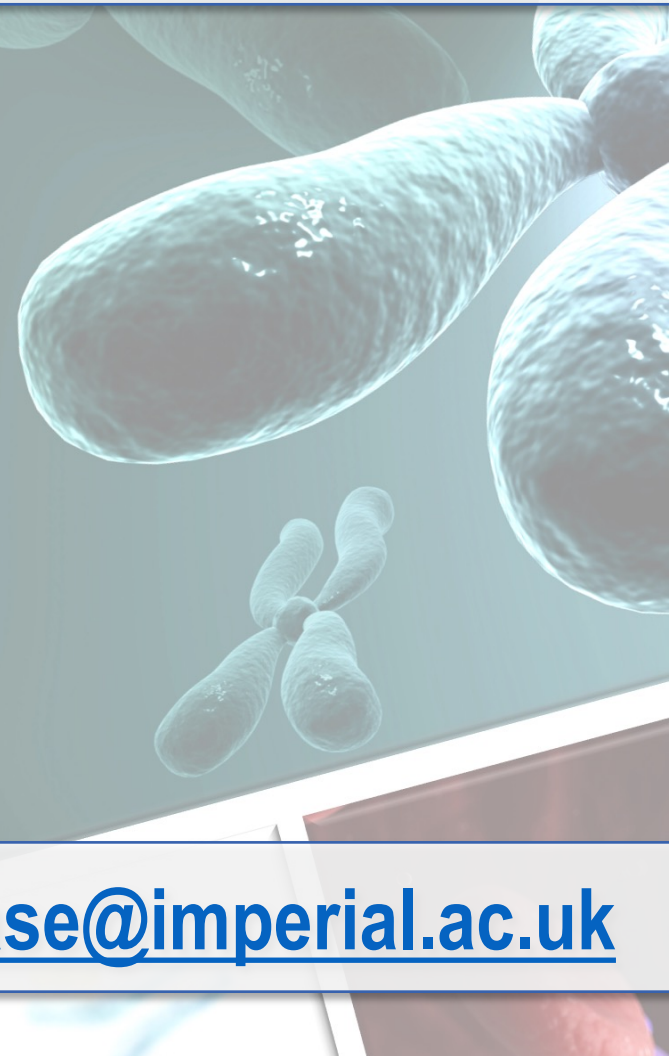
Imperial College London

Fluid compartments & solutes





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Session Plan

Part 1

- Ionic constituents
- Diffusion
- Osmosis
- Solute and water molecule movement across cell membranes

  Impact on cell volume

Part 2

- Tonicity

  Hypertonic, hypotonic & Isotonic
- Active transport of ions
- Tissue preservation solutions
- Solute exchange across blood vessels and oedema

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Composition of the main fluid compartments

	in plasma*** (mmol/l)	in muscle (mmol/l)
Na^+	150	10
K^+	5	150
Free Ca^{2+}	2	10^{-4}
Cl^-	110	5
Organic phosphates^{1-}	5	130
Protein^{17-}	1	2
pH	7.4	7.1

***

Plasma is like interstitial fluid (IF) except plasma has **more** protein

1-POM-2-4: Blood plasma: Recall the major components of plasma, summarise their functions, and explain the main types of exchange between plasma and body fluids across the capillary wall.

Osmolarity

Osmolarity is defined as a measure of the concentration of **all** solute particles in a solution.

	Concentration (mol/L)	Osmoles/L
NaCl	1	2 (Na^+, Cl^-)
$CaCl_2$	1	3 (Ca^{2+}, $2Cl^-$)
Glucose	2	2 (glucose)
Osmolarity		**7**

Biological ion concentrations are usually in the order of mM concentrations so the resulting units are milliosmoles/L

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osmolarity	285 mosm/l	285 mosmol/l

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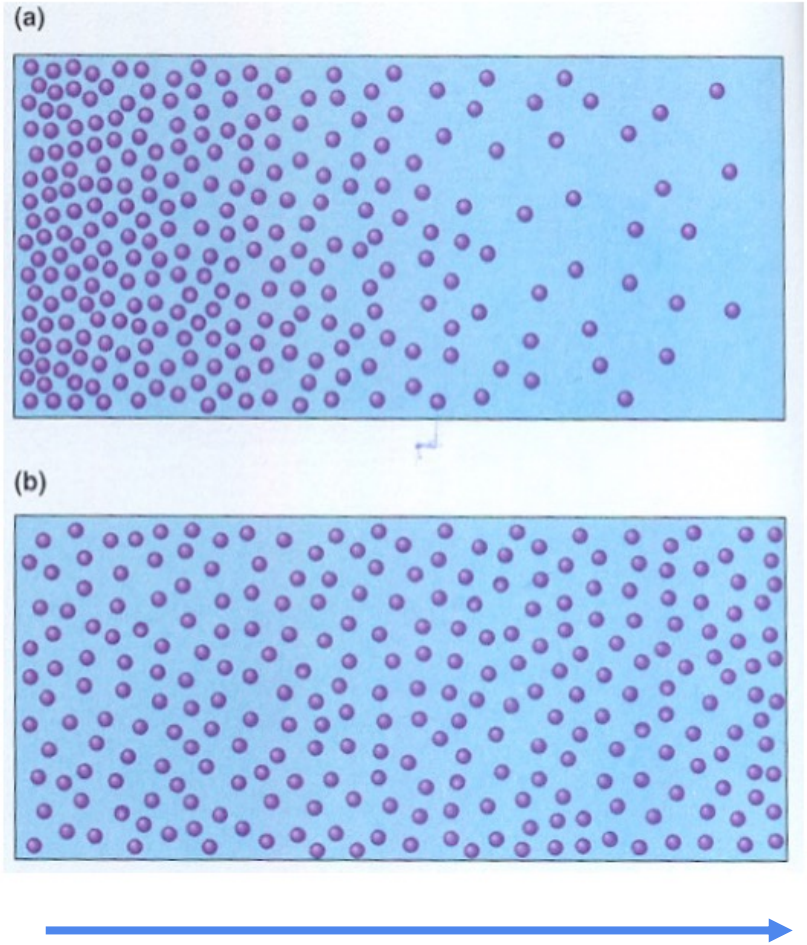
Diffusion

Diffusion:

the spontaneous movement of a solute down a concentration gradient until the solute molecules reach an equilibrium.



Down its concentration gradient

Diffusion equilibrium

Osmosis

The movement of water down its own concentration gradient.

Osmosis moves water toward an area of higher osmolarity.

It can therefore change cell volume with consequences for cell function and survival.

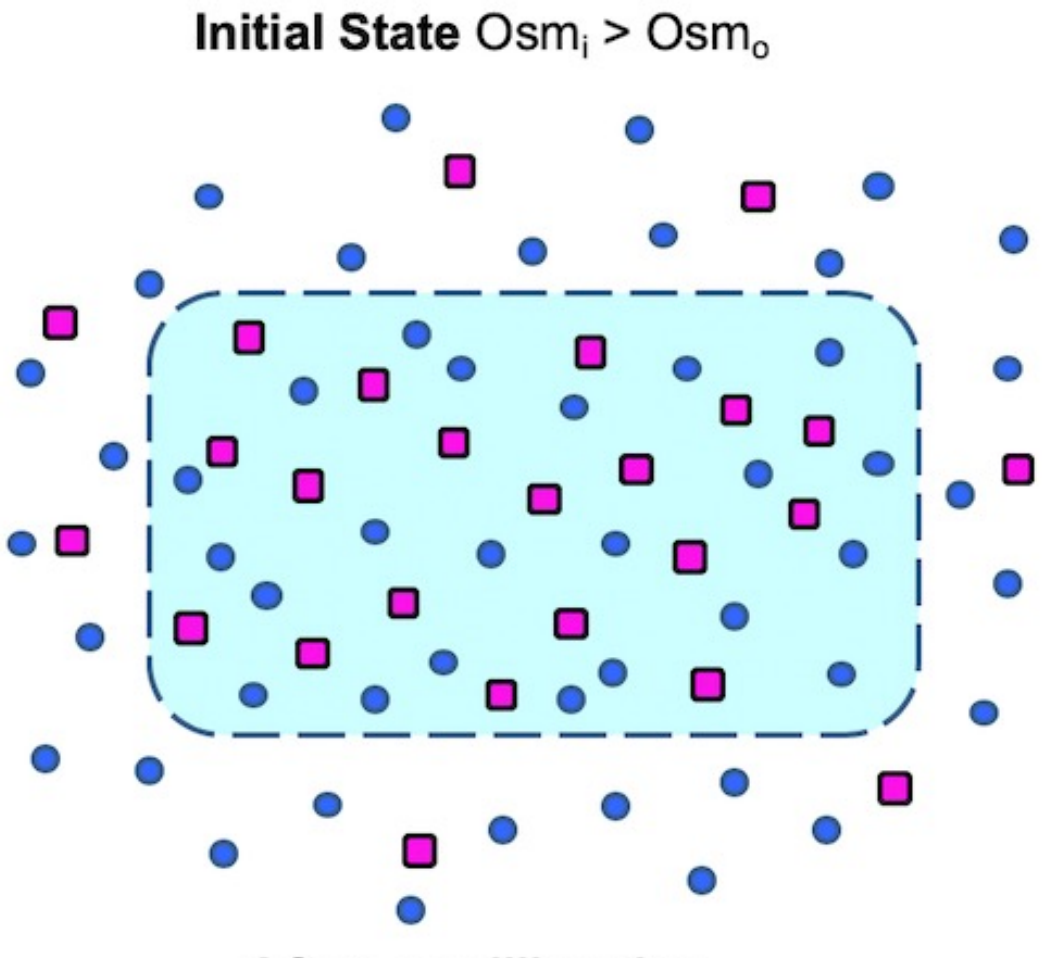
Osmoles:

the number of **moles** of solute that contribute to the osmotic pressure of a solution

	Conc (mmol/l)	Osmolarity (mosmol/l)
NaCl	150	300
$CaCl_2$	1	3
Glucose	2	2
TOTAL		305

Osmolarity as a function of solute concentration.

1. Membrane permeable to both H_20 and solute



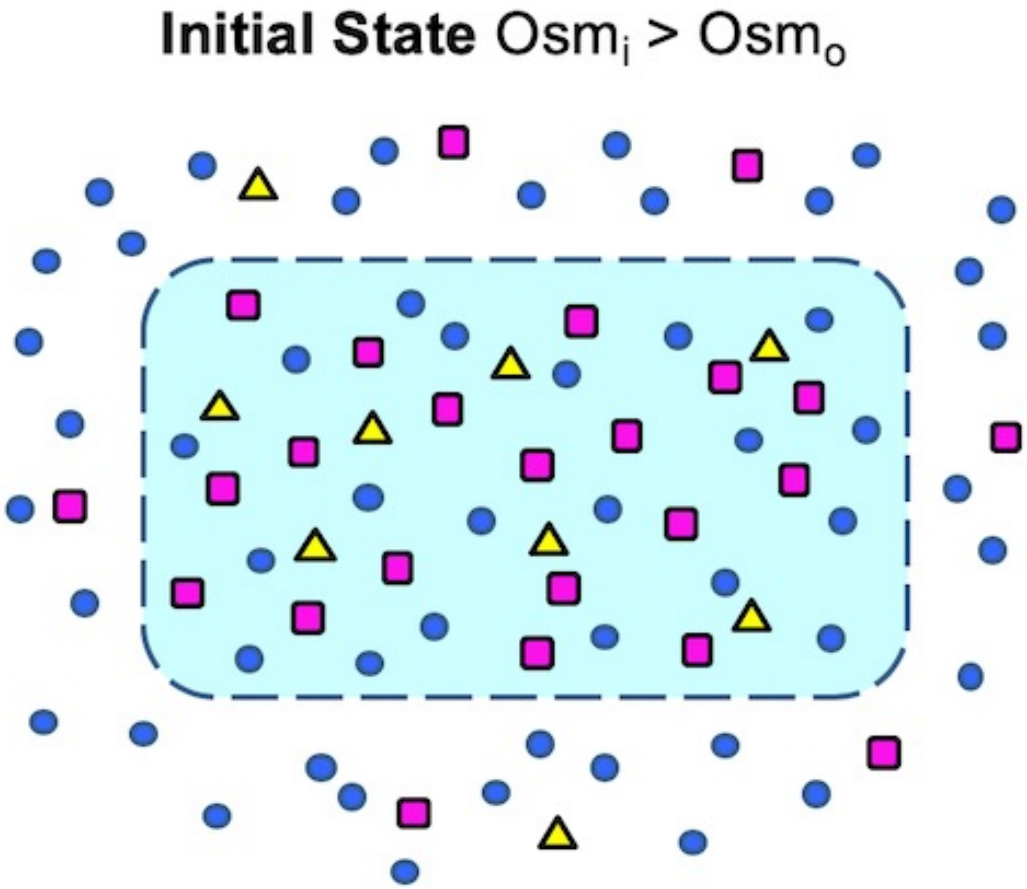
H_2O

solute

After equilibrium:

No net volume change of cell

2. Membrane permeable to both H_20 and solute ■ but not solute ▲



● H_2O

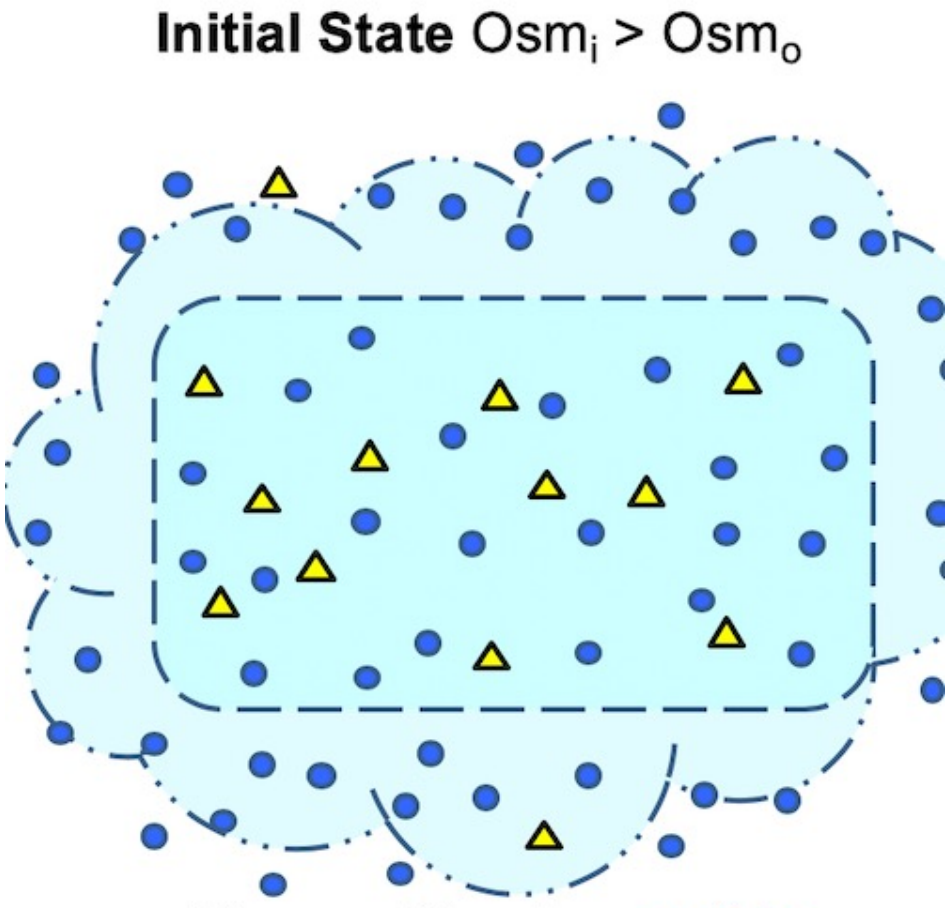
■ solute

▲ solute

After equilibrium:

The cell is swollen.

3. Membrane permeable to H_20 but impermeable to solute



H_2O

solute

After equilibrium:

The cell is swollen and may rupture

Osmolarity – an unreliable guide?

Initial state		Δcell vol =
1.	$Osm_o < Osm_i$	no change
2.	$Osm_o < Osm_i$	increase
3.	$Osm_o < Osm_i$	bursts

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Tonicity

Hypertonic solutions

Osmolarity of **impermeant** solutes outside> inside, so cell shrinks.

Hypotonic solutions

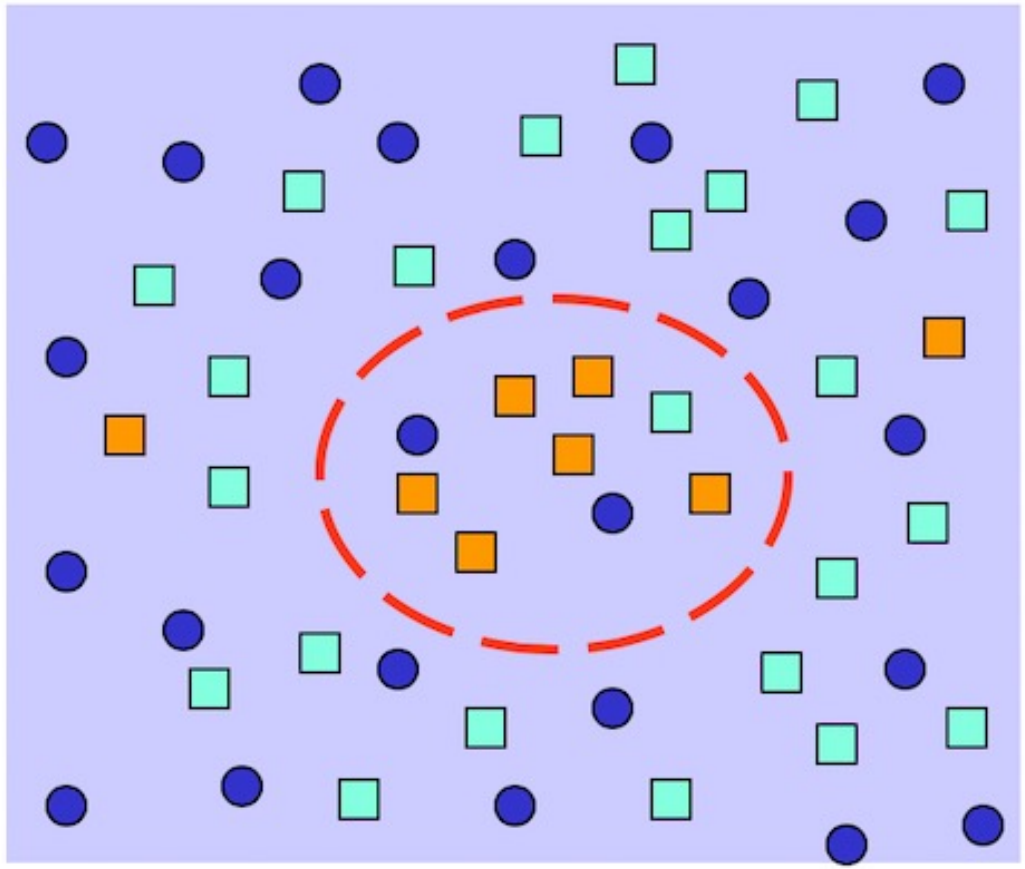
Osmolarity of **impermeant** solutes outside < inside, so cell swells.

Tonicity

Isotonic solutions

Osmolarity of **impermeant** solutes outside = inside, so cell volume is unchanged.

Cell volumes are maintained by actively pumping ions



Na^+ proteins

H_2O cell membrane

So why don't cells burst?

Na^+K^+ ATPase

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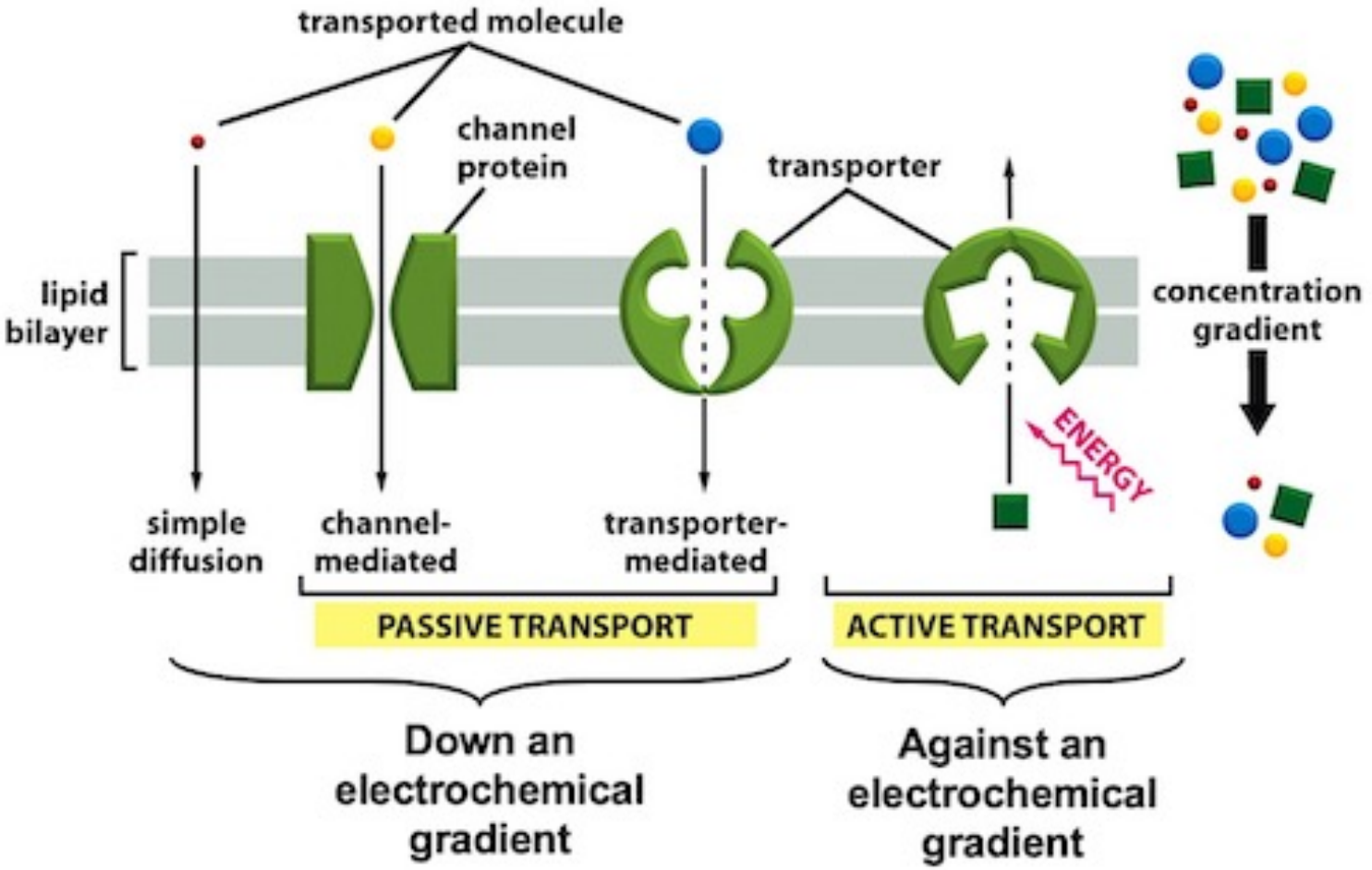
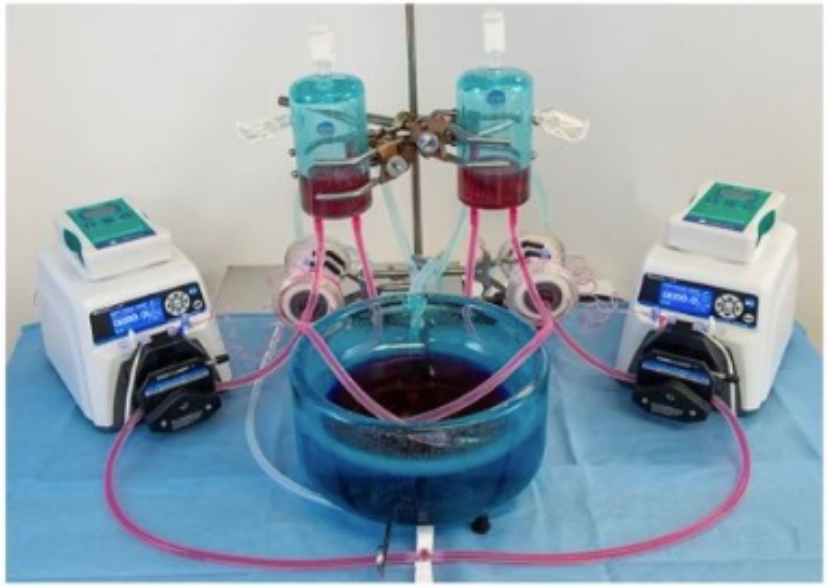
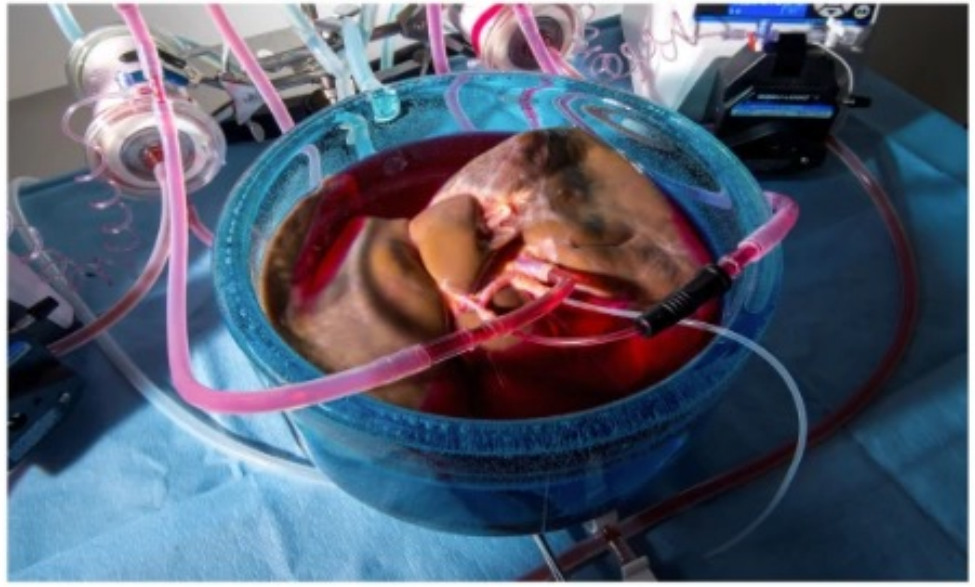
Methods used by solutes to cross membranes



- Gases (e.g. O_2, N_2, CO_2) and hydrophobic molecules (e.g. steroids) can diffuse across the lipid bilayer.
- Most molecules require particular proteins for transportation across a biological membrane.
- This uses ATP hydrolysis in the case of **active transport** against an electrochemical gradient (e.g. Na^+K^+-ATPase) or is **passive**, facilitating the flow of molecules down an electrochemical gradient.

Fluid composition in action: tissue preservation solutions





Machine perfusion of livers with UW solution prior to transplantation. system.

Nature Biotechnology **37**:1131–1136 (2019)

1-POM-2-4: Blood plasma: Recall the major components of plasma, summarise their functions, and explain the main types of exchange between plasma and body fluids across the capillary wall.

University of Wisconsin (UW) solution

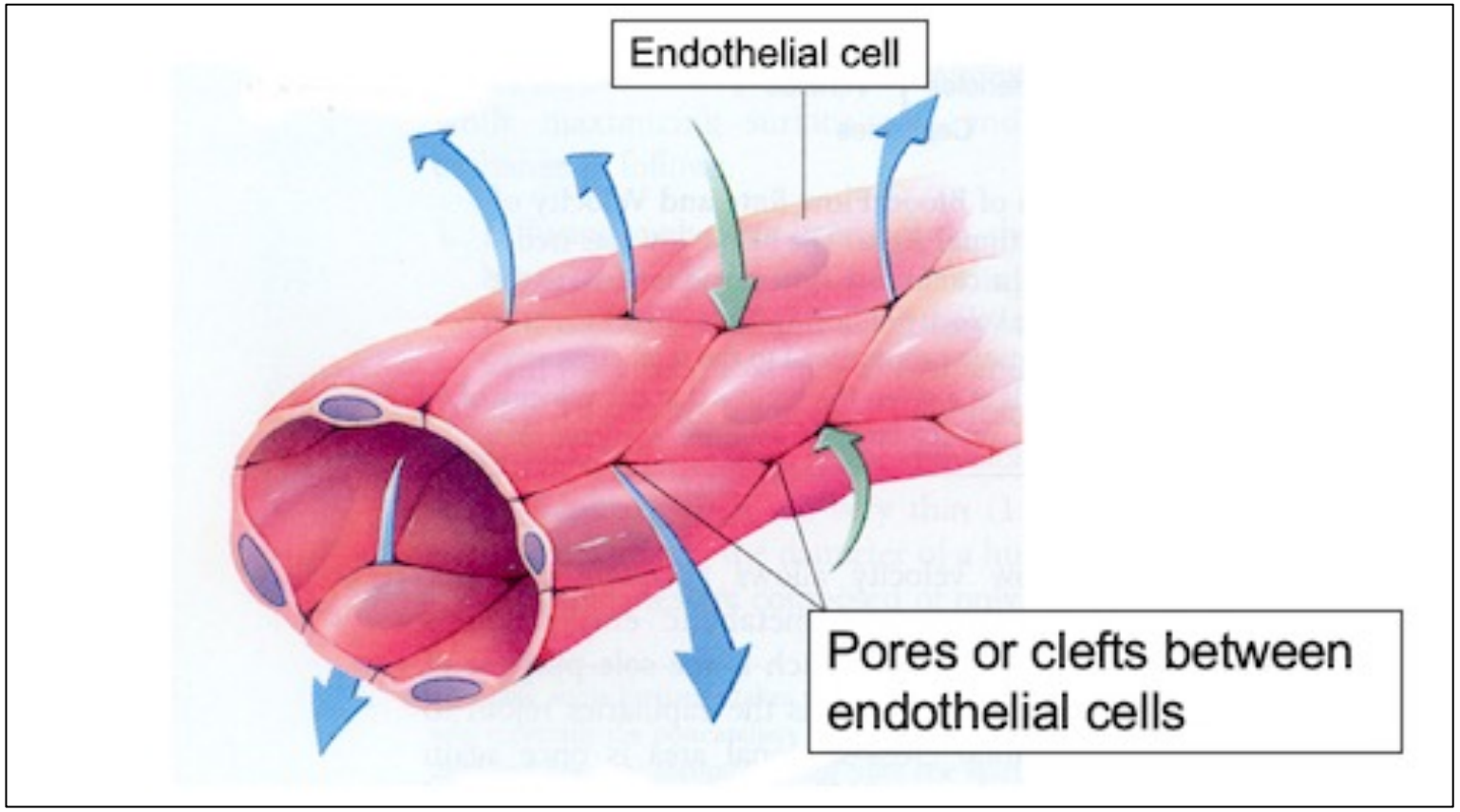
Potassium lactobionate:	100 mM
KH_2PO_4:	25 mM
$MgSO_4$:	5 mM
Raffinose:	30 mM
Adenosine:	5 mM
Glutathione:	3 mM
Allopurinol:	1 mM
Hydroxyethyl starch:	50 g/L

Three main factors serve to reduce cell swelling in UW-infused tissues:

- Lack of Na^+ or Cl^-
- Presence of extracellular impermeant solutes
- Presence of a macromolecular colloid (starch)

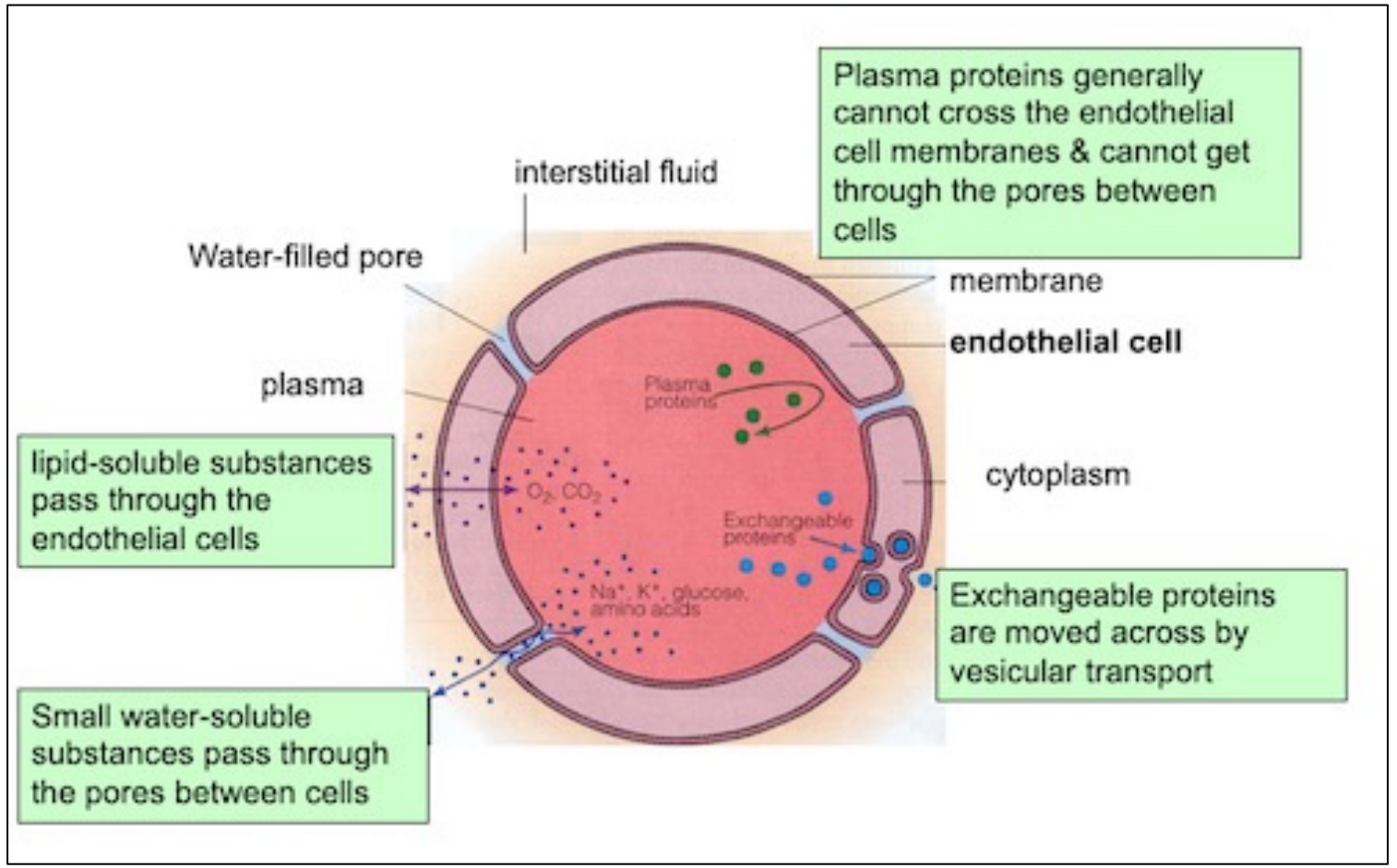
Allopurinol and glutathione also present as antioxidants

Solute exchange across blood vessels and oedema



N.B. The **blood-brain barrier** (**BBB**) which separates the circulating blood from the brain is tightly sealed (to be discussed in the BRS module).

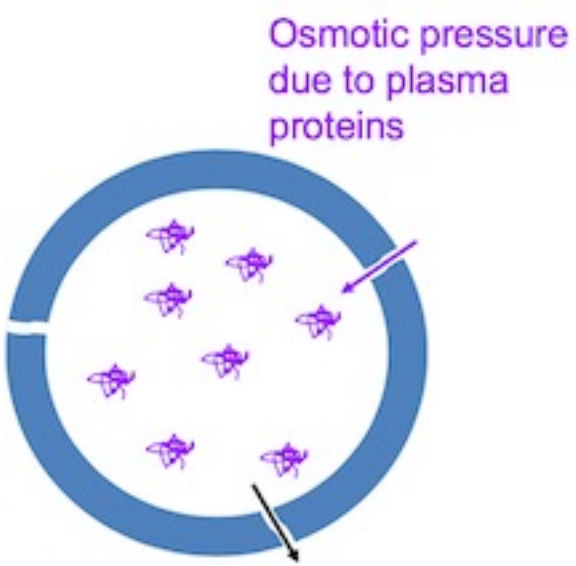
COP vs Hydrostatic pressure



- Colloid osmotic pressure (COP) due to higher concentrations of plasma proteins inside the capillary than outside.
- Hydrostatic pressure inside the vessel due to blood flow through the tissue.

COP vs Hydrostatic pressure

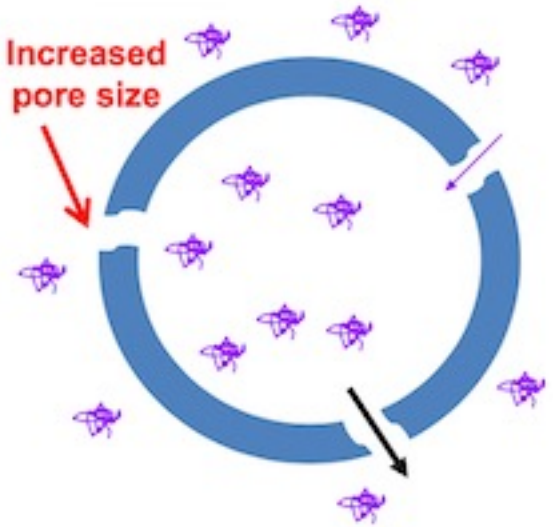
Normal capillary



Hydrostatic pressure ~osmotic pressures

Leaky capillary

Excess fluid loss from capillary to intersitital space: **oedema**



Hydrostatic pressure>>osmotic pressures

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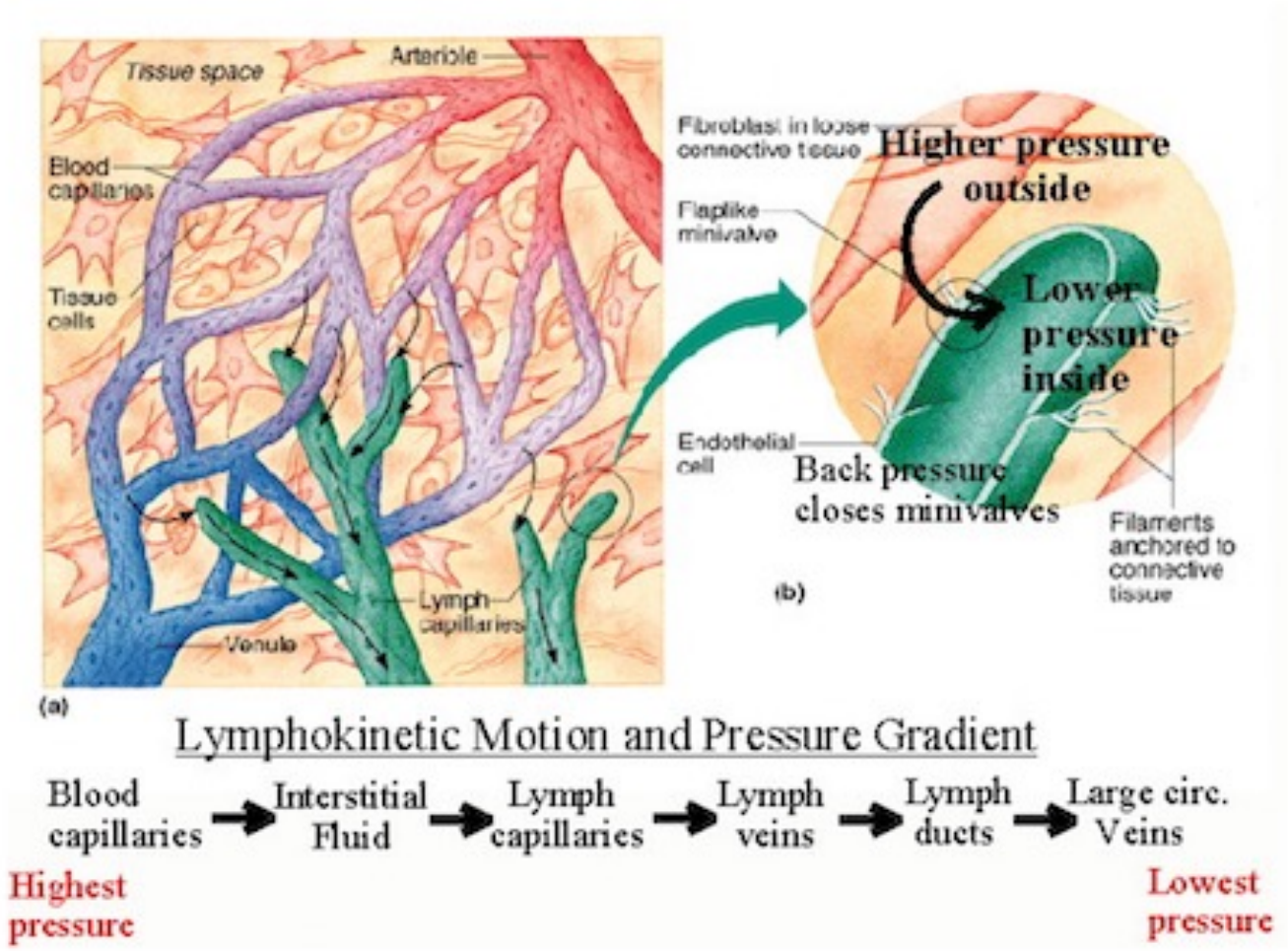
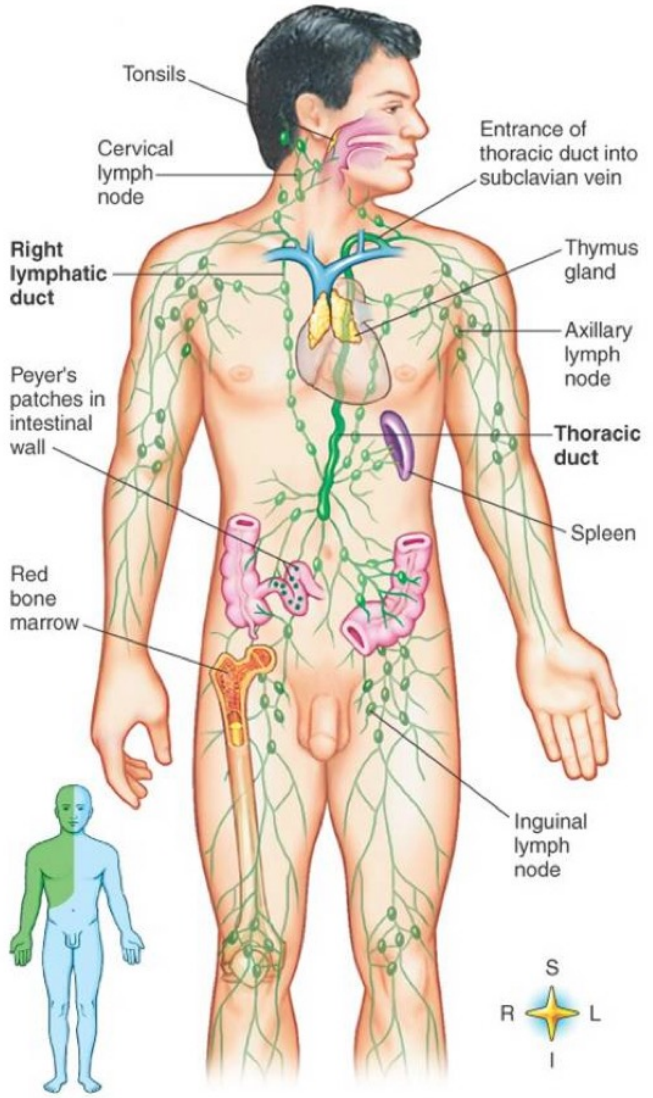
Lymphatic capillaries collect interstitial fluid for redistribution





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Inflammatory and hydrostatic oedema

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Oedema due to compromised lymphatic function

Breast cancer survivor

Elephantiasis

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