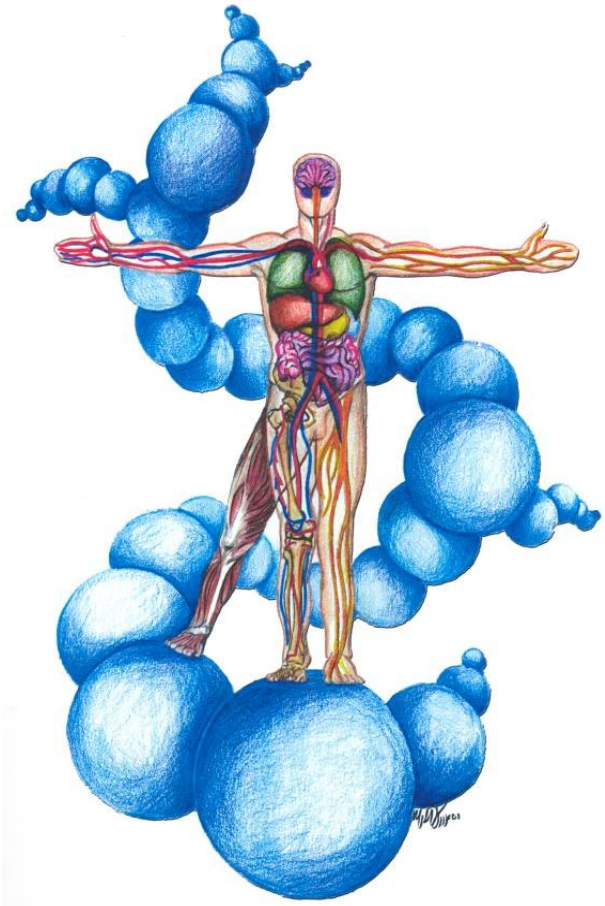
Body fluids and metabolism

Dr Vivek Nagaraja
FY2



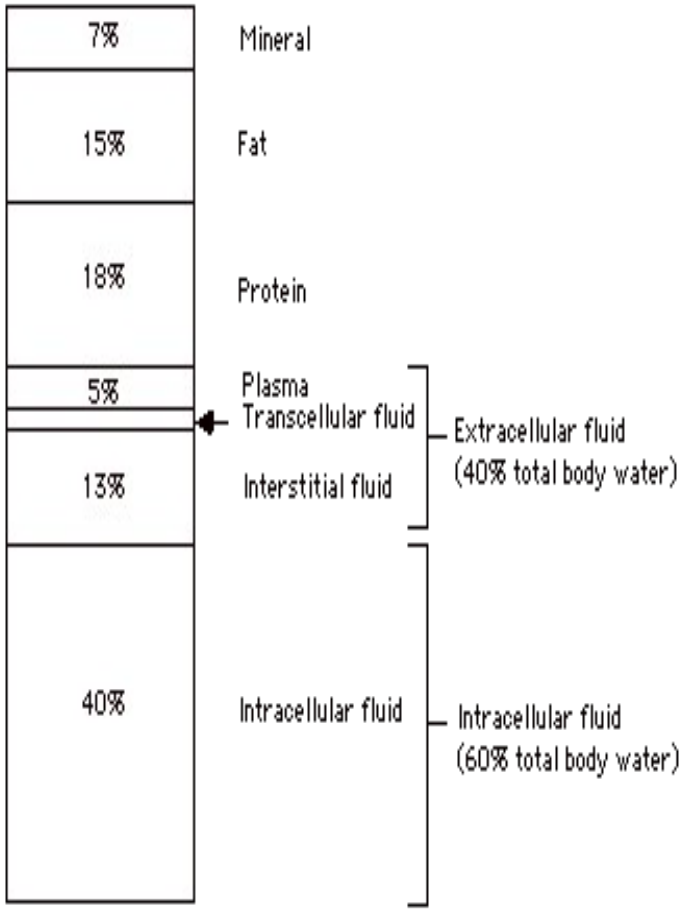
Overview

- Introduction
- Body fluid compartments
- Water balance
- Starling's hypothesis
- Control of water metabolism
- Disorders of Sodium and Potassium



Introduction

- Water- major constituent of body
- 60% of total body weight
- Variations in water content
  - Age
    - Neonates- 75-80%
    - Age 12- 60%
    - Age 60- 50%
  - Tissue
    - Plasma- 93%
    - Bone- 20%
    - Fat 15%
  - Individuals- Due to different amounts of adipose tissue



Body fluid compartments

- TBW- 60% of body weight
  - ICF- 40% (28 litres)
  - ECF- 20% (14 litres)
    - Interstitial-14% (10 litres)
    - Plasma- 5% (3.5 litres)
    - Transcellular- 1% (0.5- 1 litre)

- *ECF composition resembles that of primordial oceans in which, all life presumably originated*

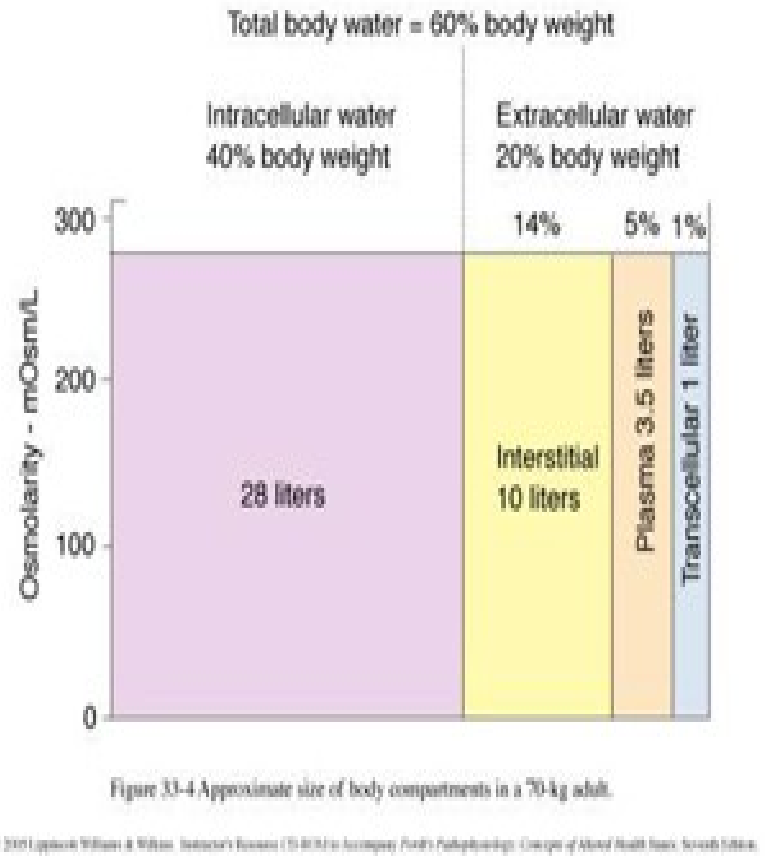
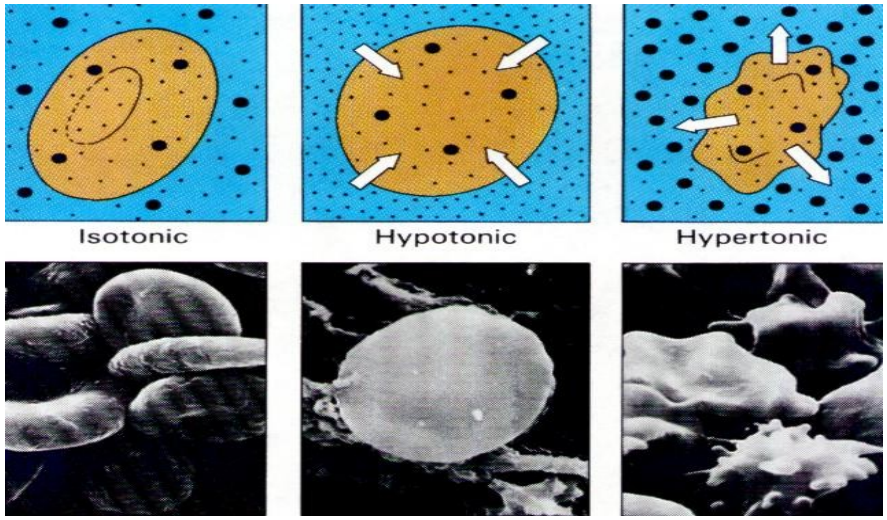


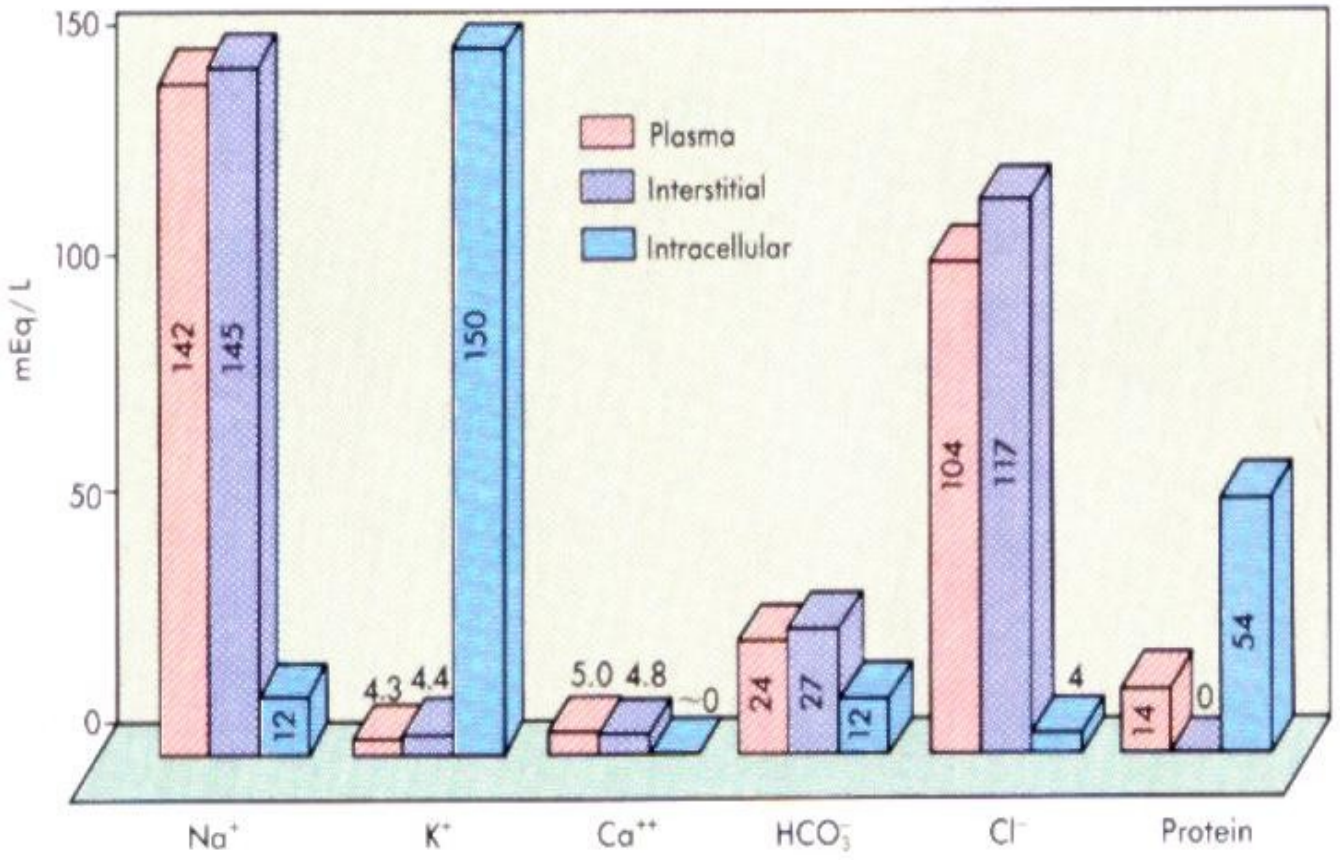
Figure 33-4 Approximate size of body compartments in a 70-kg adult.

Osmolality and Tonicity

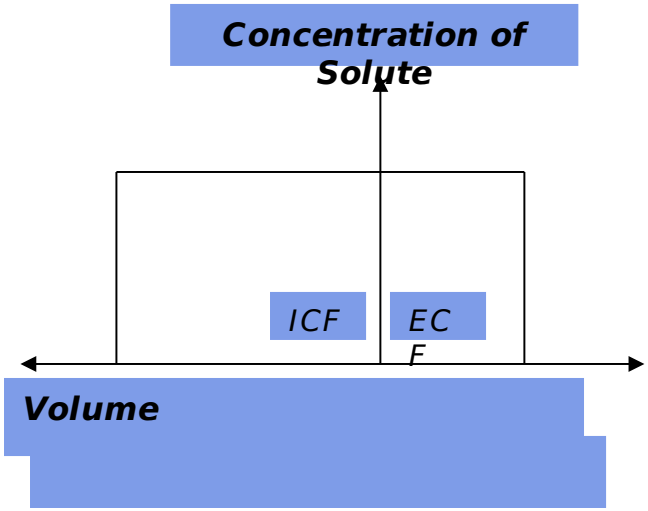


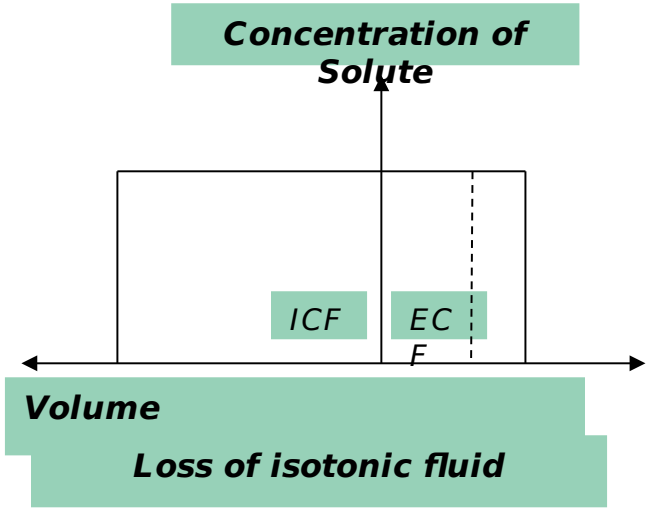
- **Osmolality**- Number of osmoles of solute per kilogram of solvent
  - mOsm- index of concentration of particles per litre of solution
  - mM - index of concentration of molecules dissolved per litre of solution
- **Tonicity** is the ***effective osmolality*** and is equal to the sum of the concentrations of the solutes which have the ***capacity to exert*** an osmotic force across the membrane
- ***Osmolality is a property of a particular solution and is independent of any membrane***
- ***Tonicity is a property of a solution in reference to a particular membrane***

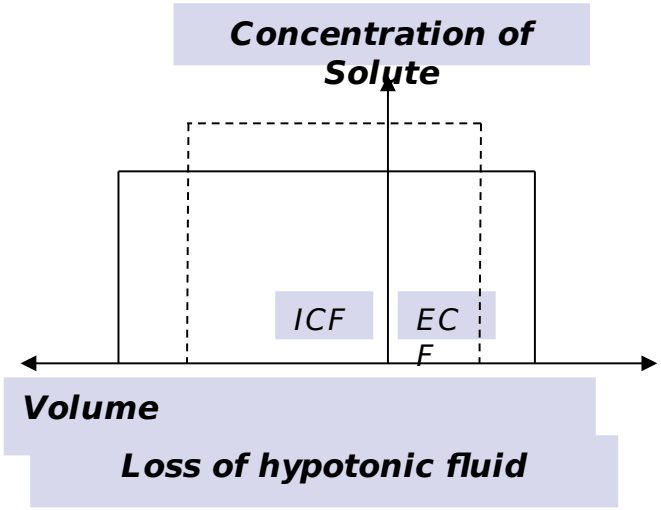
Difference in electrolyte concentrations of body fluids

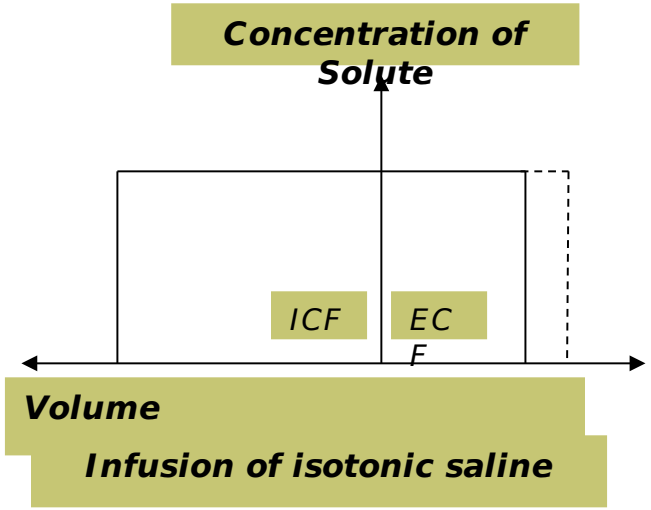


Darrow-Yannet diagram

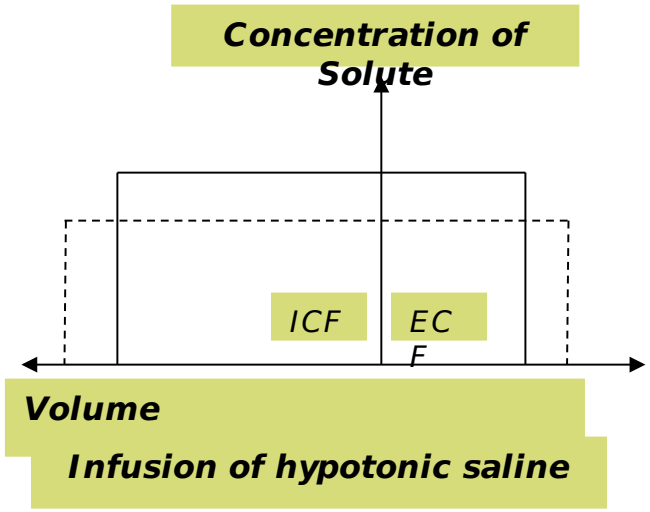


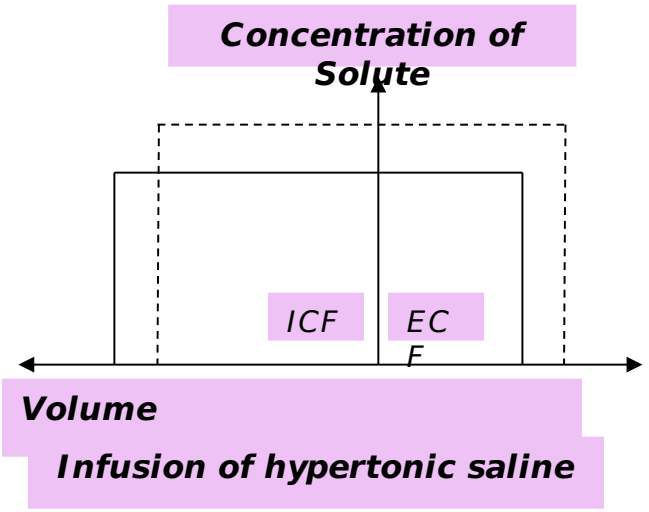






Darrow-Yannet diagram



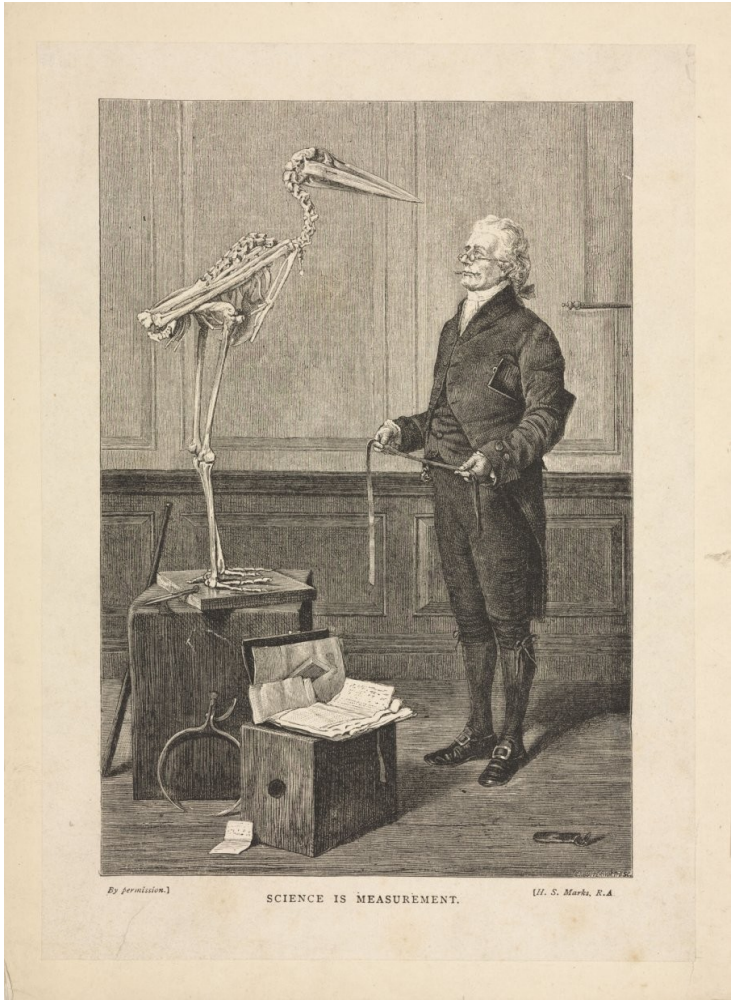


Measurement of compartment volumes

- Tracer substance
- **V** X **C** = **A**
- Required criteria
  - TBW- permeable to capillary and cell membranes

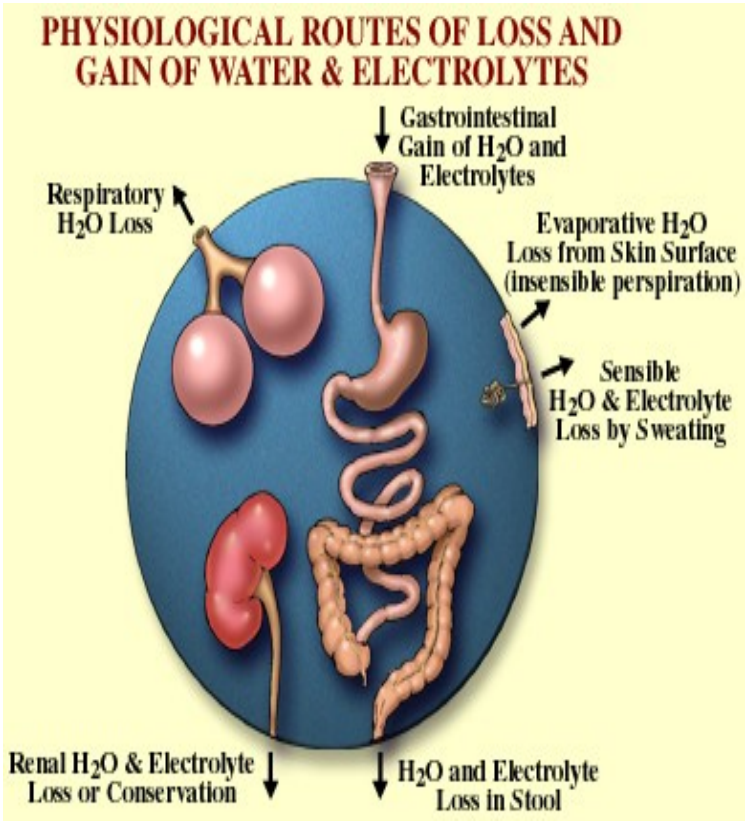
    Eg: Tritiated water, urea
  - ECF- permeable to capillary but not cell membranes Eg: Inulin, mannitol, sodium, sucrose
  - Plasma- not permeable to capillary membranes

    Eg: Albumin



Water balance

- **External balance**
  Comparison between the water input from and the water output to the external environment
- **Internal balance or flux**
  Movement of water across the capillaries of the body and movement of water between interstitial and intracellular fluids.



External balance

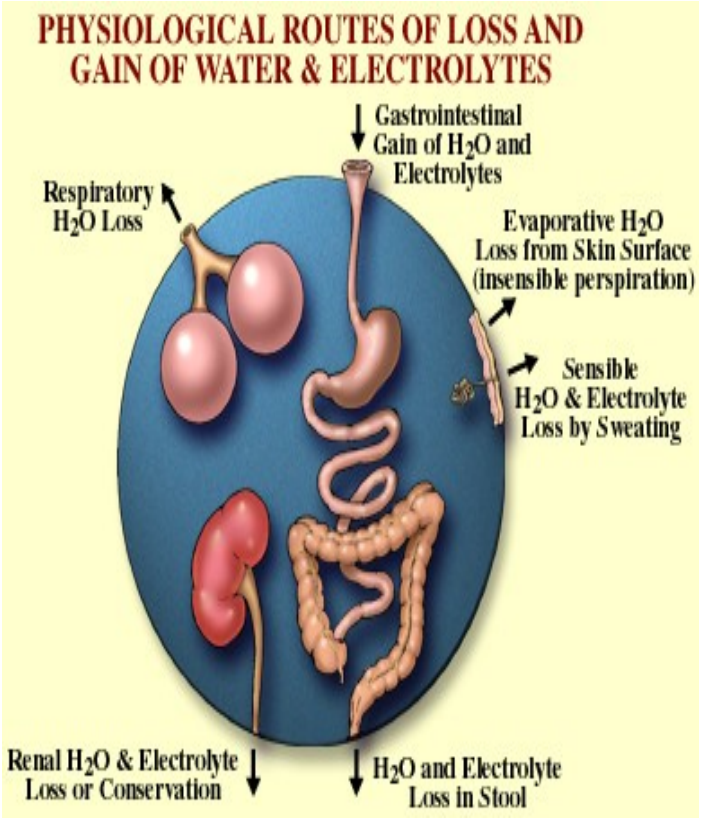


- **Estimation of Daily Water Requirements in Unstressed Healthy Adults**
  - Based on metabolic rate 80-110 mls/100kcals
  - Based on body surface area 1.5 l/m2/day
  - Based on weight 30-40 ml/kg/day

- The minimum water required for urine is dependent on the ***daily solute excretory load*** and the ***maximum urinary concentration*** achievable

External balance

- **Components of Daily Obligatory Water Loss**
  - Insensible loss: 800 mls
  - Minimal sweat loss: 100 mls
  - Faecal loss: 200 mls (turnover: 8-9 L/d)
  - Minimal urine volume to excrete solute load: 500 mls (GFR- 180 L/d)
  - **Total: 1,600 mls**
- **Fluid input**
  - **External**: Oral intake of fluids and food (and/or IV fluids)
  - **Internal**: Metabolic water production (oxidation of food 350-400 ml/day)



Bedside analysis of fluid balance

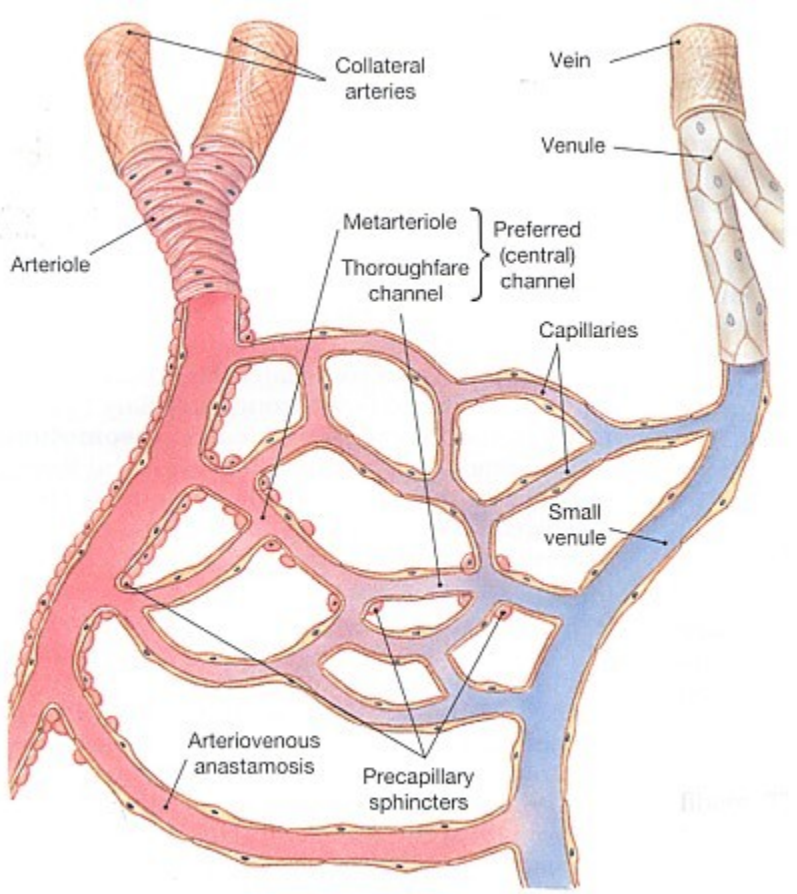


Calculate **water input** (oral + IV fluids) and **water loss** (urine + other measured losses) and make a **clinical estimate of the additional fluids required** (BP, pulse, CVP, urine flow rate, evidence of peripheral vasoconstriction, knowledge of pathophysiology of disease)

Internal balance *(at the level of microcirculation)*

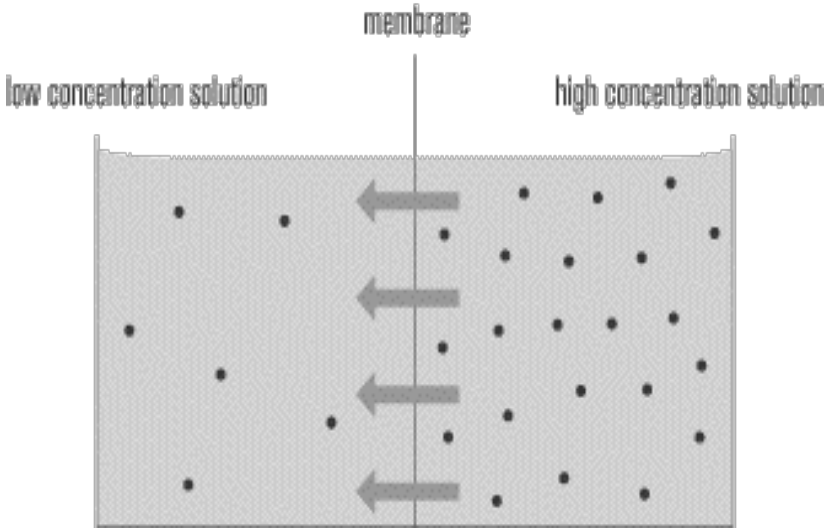
- **Microcirculation**
  - smallest arterioles
  - metarterioles
  - precapillary sphincters
  - capillaries
  - small venules
- **Principal function-**

  permit the transfer of substances between the tissues and the circulation (water, electrolytes, gases, nitrogenous wastes, glucose, lipids and drugs)



Diffusion

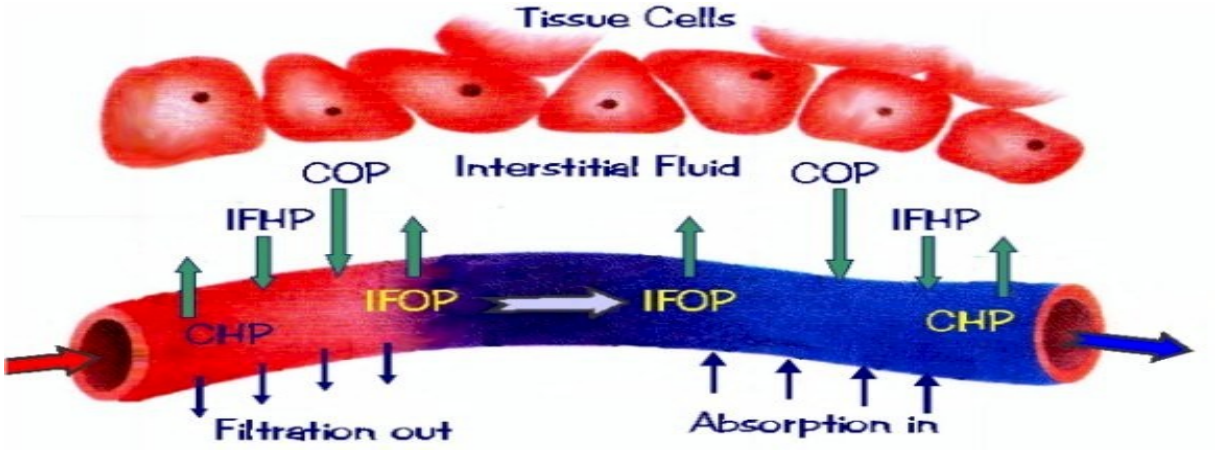
- Huge volumes of water are involved (turnover- 80,000 L/d)
- ***Bidirectional*** along the length of the capillary
- Net movement is governed by ***concentration gradient***
- Starling forces are not involved in diffusion
- Net movement of gases, nutrients and wastes by the same process
- There is no net movement of water across the capillary wall due to diffusion



Filtration

- Really ultrafiltration as proteins cannot easily cross most capillary membranes
- Volumes involved are much smaller then the diffusional flux
- ***Fluid movement can be either inwards (absorption) or outwards***, but not both at any particular position along the capillary
- Net movement is governed by the Starling forces
- This process is important for the net movement of water is important.

Starling's forces



- COP- Colloid Osmotic Pressure
- CHP- Capillary Hydrostatic Pressure
- IFOP- Interstitial Fluid Osmotic Pressure
- IFHP- Interstitial Fluid Hydrostatic Pressure

Oedema
(Alteration of Starling's forces)

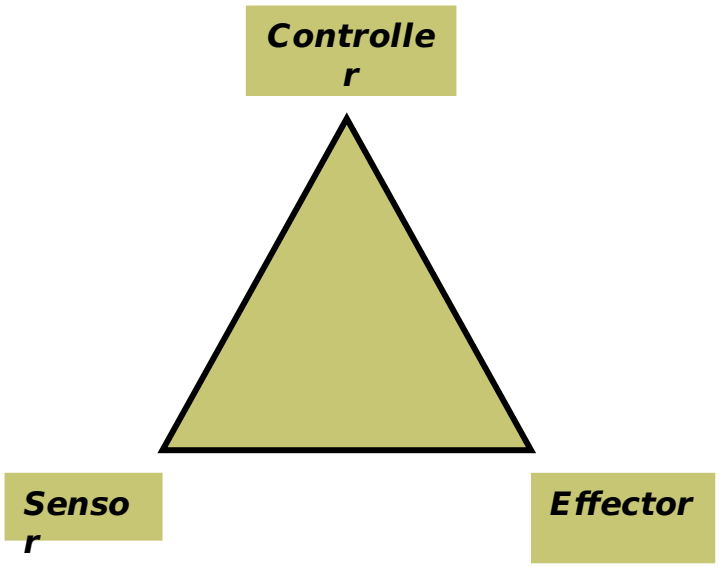
- Abnormal accumulation of fluid in interstitial space
- Causes-
  - Raised CHP- Venous thrombosis, CCF
  - Raised IOP- Lymphatic obstruction (radical surgeries, lymphoma, filariasis)
  - Low COP- Nephrotic syndrome, hypoalbuminemia
  - High capillary permeability- Anaphylaxis





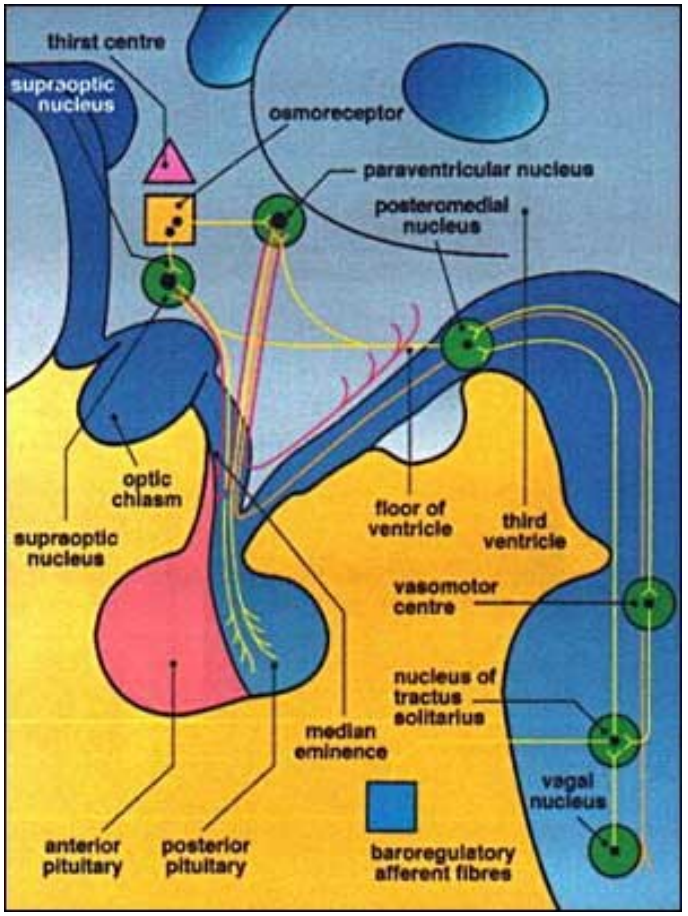
Regulation of water balance

- ***Servo-control system***
- Sensors
  - Osmoreceptors
  - Volume receptors (low pressure baroreceptors)
  - High pressure baroreceptors
- Controller
  - Hypothalamus
- Effectors
  - Kidney, ADH, thirst



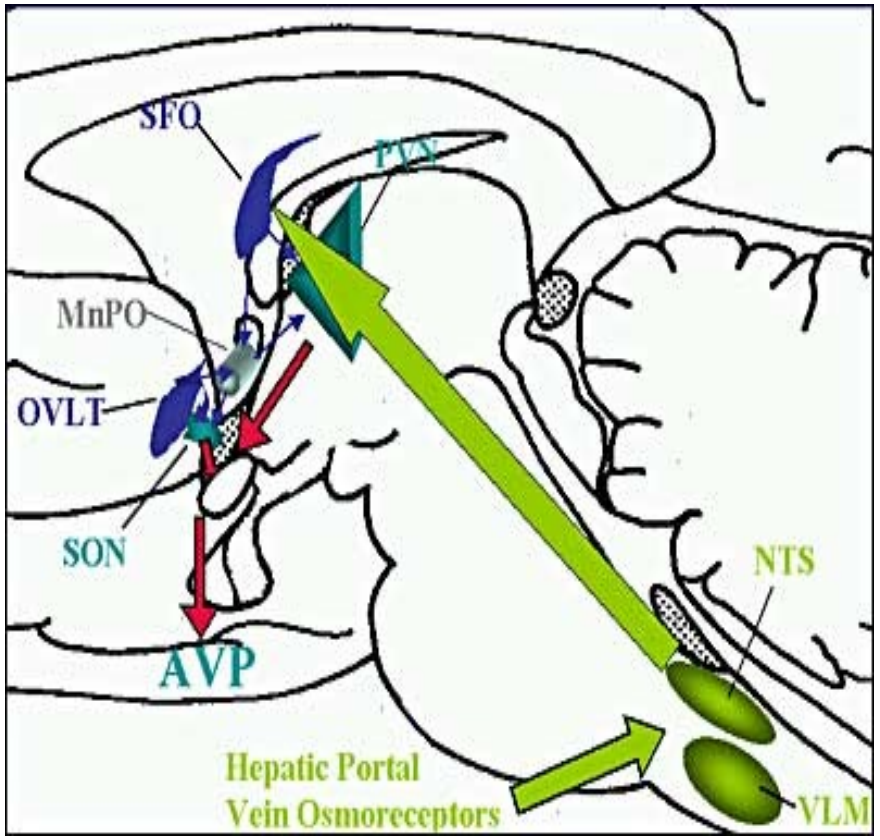
Sensors

- Osmoreceptors
  - Specialized cells in hypothalamus
  - Very sensitive to change in tonicity (1-2%)
- Baroreceptors
  - Less sensitive, more potent (threshold- 10% change in Body volume)
  - Low pressure baroreceptors- Right atrium, great veins (Transmural pressure)
  - High pressure baroreceptors- Carotid sinus (MAP)



Controller *(Hypothalamus)*

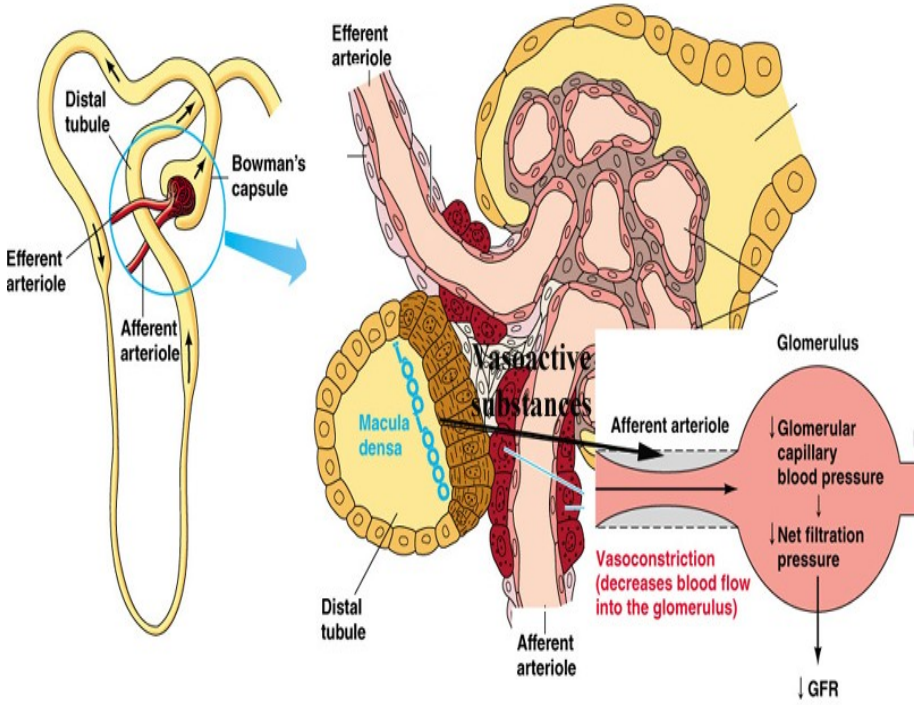
- Osmoreceptors
  (Antero-ventral third ventricle)
- Thirst centre
  (Lateral hypothalamus)
- OVLT & SFO
  (respond to angiotensin II)
- Supraoptic & paraventricular nuclei
  (for ADH synthesis)



Effector *(Kidneys)*

Three mechanisms

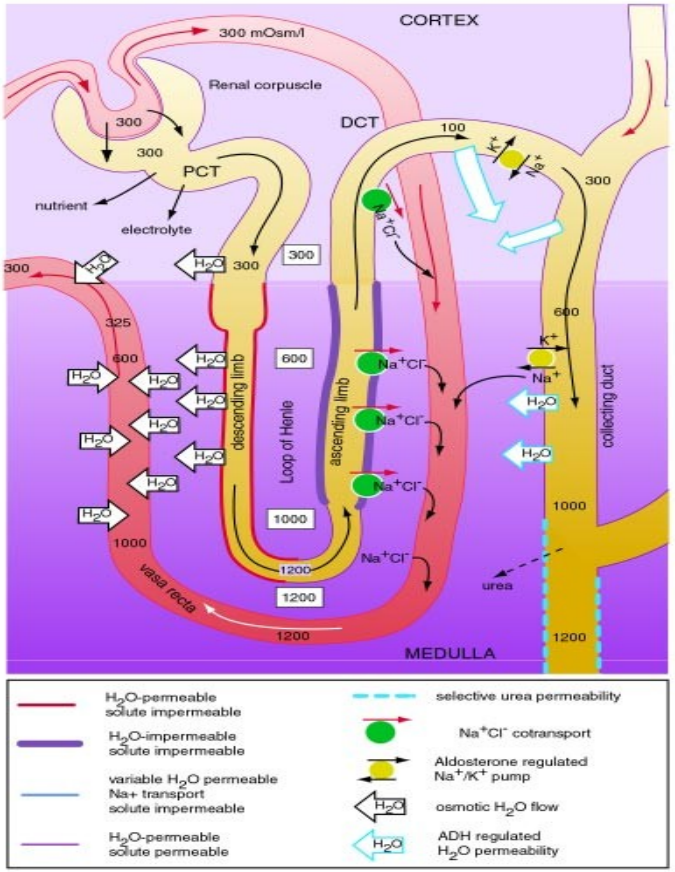
- Glomerulotubular balance
- Autoregulation of renal blood flow
- Natriuretic peptides



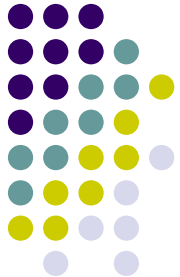
Role of kidneys

Quantitative summary of renal water handling

- GFR (180 l/day)
- 65% Reabsorbed Proximal Tubule
- 15% Reabsorbed Loop of Henle (thin descending limb)
- 20% of filtrate enters Distal Tubule
- In absence of ADH
  - 8% re-absorbed in CD
  - 12% of filtered water in urine
- With maximal ADH
  - >19% re-absorbed in CD
  - <1% of filtered water in urine



Hyponatremia



- Defined as a serum level of less than 135 mmol/L and is severe when the serum level is below 125 mmol/L
- Of clinical significance only when it reflects a drop in the ***serum osmolality= 2(Na) + serum glucose+ urea***
- Correction of hyponatremia must take into account the chronicity of the condition
- Acute can be safely corrected more quickly while in chronic correction should be gradual
- Acute drop in the serum osmolality causes ***neuronal cell swelling*** due to the water shift from the extra cellular space to the intracellular space

Causes of hyponatremia



- **With low plasma osmolality-** water gain or Na loss
  - **With ECF volume depletion**

    Renal or non renal causes of net Na loss.
  - **With ECF volume excess**

    Oedematous states (CHF, cirrhosis, nephrotic syndrome)
  - **Normal ECF volume**

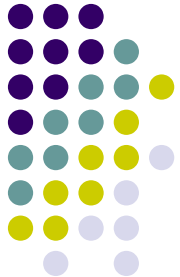
    SIADH, glucocorticoid deficiency, hypothyroidism, drugs (carbamazepine, TCA, chlorpropamide,NSAID), acute hypoxia or hypercapnia, psychogenic polydypsia, cerebral salt wasting

- **With normal or high osmolality**
  - hypertonic hypernatremia(hyperglycemia,mannitol infusion)

Management

- Underlying cause obtained with accurate history
- Lab tests
  - Plasma osmolality
  - Urine osmolality and volume
  - Urine Na
- Goals of therapy
  - Raise plasma Na (lowering ECF volume) by water restriction
  - Replace Na and K deficits
  - Correct the underlying disease

Hypernatremia



- Plasma Na >145mmol/L
- Primary water loss or Na gain
- Responses- increased thirst and maximally concentrated low volume urine output
- Causes
  - Impaired thirst
  - Diabetes mellitus and diabetes insipidus
  - Aggressive saline infusion
- Rapid correction dangerous, water deficit to be corrected over 24-48 hrs, plasma Na should be lowered by 0.5 mmol/L
- Safest route of water administration is oral
- Central DI-treat with DDAVP intranasal
- Nephrogenic DI-low Na diet and thiazide diuretics

Hypokalemia

- Symptoms seldom seen unless less than 3 mmol/L
- Profound depletion associated with arrhythmias and paralytic ileus
- ECG changes do not correlate well with plasma potassium
  - Early-T inversion wave, ST depression
  - Severe-prolonged PR, widening of QRS
- Hypokalemia enhances digoxin toxicity

- **Aetiology**
  - Poor intake
  - Trans-cellular shift: alkalosis, insulin therapy in DKA, beta agonists
  - Non-renal loss: vomiting, diarrhoea, excessive sweating
  - Renal loss: diuretic use,conn’s syndrome, malignant hypertension, Cushing's syndrome

Management



- Goals
  - Prevent life threatening complications
  - Correct the deficit
  - Minimize ongoing losses
  - Treat the cause
- IV replacement
  - For severe cases or unable to take orally
  - Should not exceed 40 mmol/L via peripheral line or 100 mmol/L via central line
  - Rate should not exceed 20mmol/hr
  - Mixed in N/saline and not dextrose fluids
  - Should be followed with close monitoring of the patient
- Oral- for mild to moderate deficit

Hyperkalemia

- Most serious consequence- ***cardiac toxicity***
- Early ECG changes-tall T waves
- Severe deficit-prolonged PR and QRS,AV delay, loss of P,VF and asystole
- **Treatment**
  - >6.5 mmol/L & ECG changes require urgent treatment
  - 10 ml of 10% calcium gluconate IV over 2 minutes
  - Insulin+glucose
  - Nebulised salbutamol(2.5mg)
  - Calcium resins
  - Dialysis if >7mmol/L, uraemia, pericarditis, encephalopathy

QUESTIONS

