•Disorders of electrolytes and water balance

- **Water**
- Osmolality
- Electrolytes (ionts)

• Fluids

- Total body water volume: 60 % body weight, 40 L
- Body fluids/weight of adult
  - Male 55-60 %
  - Female 50-55 %
  - Newborn 75-80 %
  - Elderly - decreases to 45-50% of body weight
  - Water content varies greatly from fat to muscle
- Loss of 20 % BF - fatal

•Compartments

- Intracellular (ICF)
  - 2/3 of body fluid
    - ★Located primarily in skeletal muscle mass
- Extracellular (ECF)
  - 1/3 of body fluid
  - Comprised of 3 major components
    - ★Intravascular (plasma X serum)
    - ★Interstitial (fluid in and around tissues)
    - ★Transcellular

•Transcellular component

- < 1 % of BF
- Physiologically located in
  - Body cavities (CSF, synovial fluid), gastrointestinal tract, bones, ..
- Potential to increase significantly in abnormal conditions
  - Hydrothorax, ascites, haematoma (massive bleeding into joint or cavity), ileus (bowel obstruction)

• Assessment of transcellular-spacing

- Signs/Symptoms
  - Decreased urine output with adequate intake
  - Tachycardia
  - Decreased BP, CVP
  - Increased weight (in case od water intake)

- Reabsorption phase
  - Increased BP, CVP
  - Hyperhydration, risk of heart failure

•Water bilance (water exchanges)

Intake (mL)		Losses (mL)	
Beverages	1000-1500	Urine	1000-1500
Food	700	Insensible perspiration	400
Metabolic water	300	Respiratory	400
		Sweating	100
		Stool	100
		Drains, ..	??
	2,0 - 2,5 L		2,0 - 2,5 L

- Diuresis

Polyuria	> 3000 mL/24 hod
Normal amount of urine	500 - 3000 mL/24 hod
Oliguria	50 - 500 mL/24 hod
Anuria	< 50 mL/24 hod

•Serum osmolality: 275-295 mosm/kg

< 240 or > 320 is critically abnormal

- The ratio of the amount of solute (particles) dissolved in a given weight of water
- The principal contribution to osmolality
  - Na^+ (Cl^-, HCO_3^-), urea, glucose
- Effective osmolality
  - Osmolality by solutes, generating gradient in the cell (semipermeabile) membrane
- Calculation (= osmolality)
  - (2 x Na) + K + glucose + urea)

•Osmolal gap

- Osmolar gap
  - Difference between the measured osmolality and the calculated osmolality
    - ★Measured osmolality is higher than calculated o.
  - Difference > 10 mmol/kg

•Absolute value x change of osmolality

- Osmotic difference between ICF and ECF
  - Osmosis (transfer of water, not ions)
- Rapid changes of effective osmolality
    - ★Rapid transfer of the water to (from) the cells

- Optimal osmolality changes during treatment of hyper (hypo) osmolality
  - 1 - 4 mosm/hr.

•Hyperosmolality

- Causes
  - Water deficit
    - ★Vomiting, diarrhea, fever, burns, uncontrolled DM
  - Excess of solutes, retention/supply Na^+
    - ★Acute catabolism, DM decomp, alkohol
- Sings, symptoms (volume deficit)
  - Acute weight loss, decreased skin turgor, oliguria, concentrated urine, rapid pulse, decreased BP, sensations of thirst
- Labs
  - Increased HCT, TP, osmolality (serum, urine), decreased urine volume

•Hyperosmolality

- Intervention = hydration
  - 1. Isotonic solution
  - 2. *Hypotonic solution ?*

- Osmolality changes during treatment should be gradual
  - 1 - 4 mosm/hod.
- Risk of rapid changes (rapid treatment of hyperosmolality)
  - Brain oedema !

•Hypoosmolality

- Causes
  - Excess of water (water retention)
    - ★Hypersecretion ADH (brain injury)
  - Loss of Na^+, chronic catabolism, protein malnutrition
- Sings, symptoms
  - Oedema, dyspnoea, mental status changes, cramps, cephalea,..
- Labs
  - Decreased HCT, TP, osmolality (serum, urine)

•Hypoosmolality

- Intervention
  - 1. Isotonic solution
  - 2. Hypertonic solution ?
- Osmolality changes during treatment
  - 1 - 4 mosm/hod.

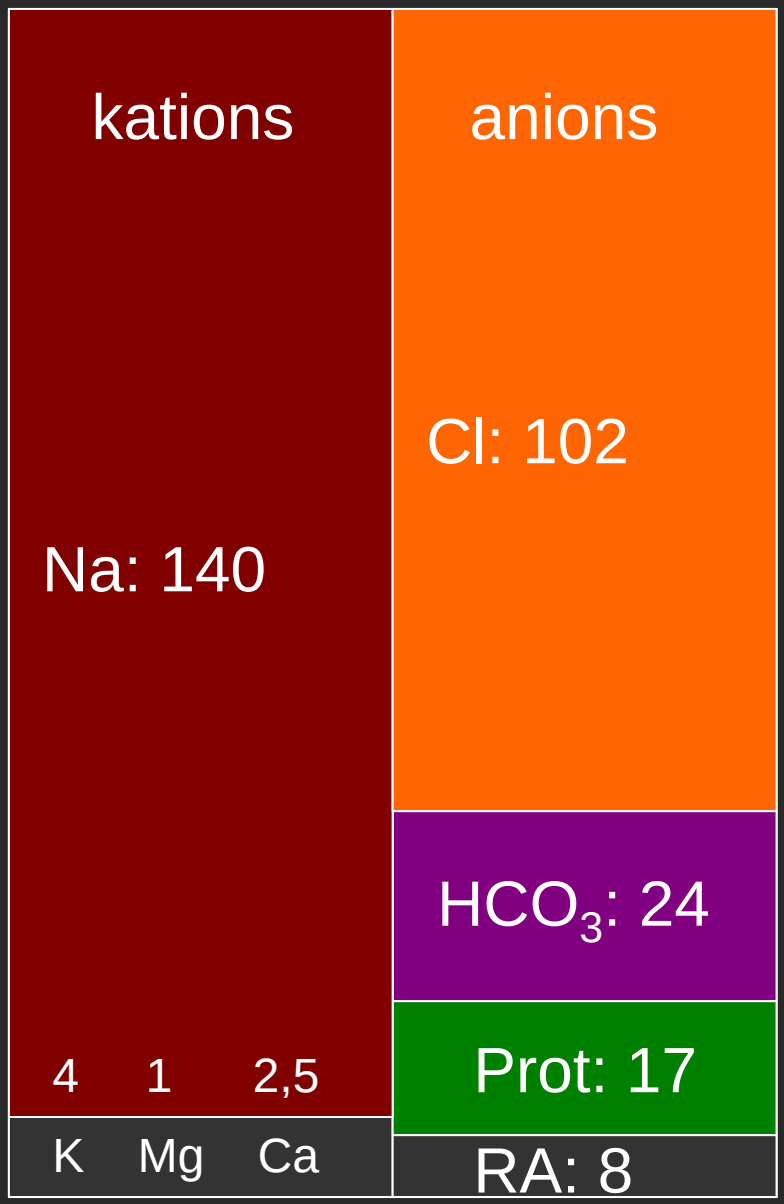
•Urine osmolality

- 50 - 1400 mosm/kg H_2O
  - In elderly: max. 800 mosm/kg H_20
- Depends on secretion of ADH

•Ions in ECF and ICF

	ECF (blood) mmol/L	ICF (cells) mmol/L
Na	**140**	10
Cl	**102**	8
K	**4,0**	155
Ca	**2,2**	0,001
Mg	**1,0**	15
P	**1,0**	65

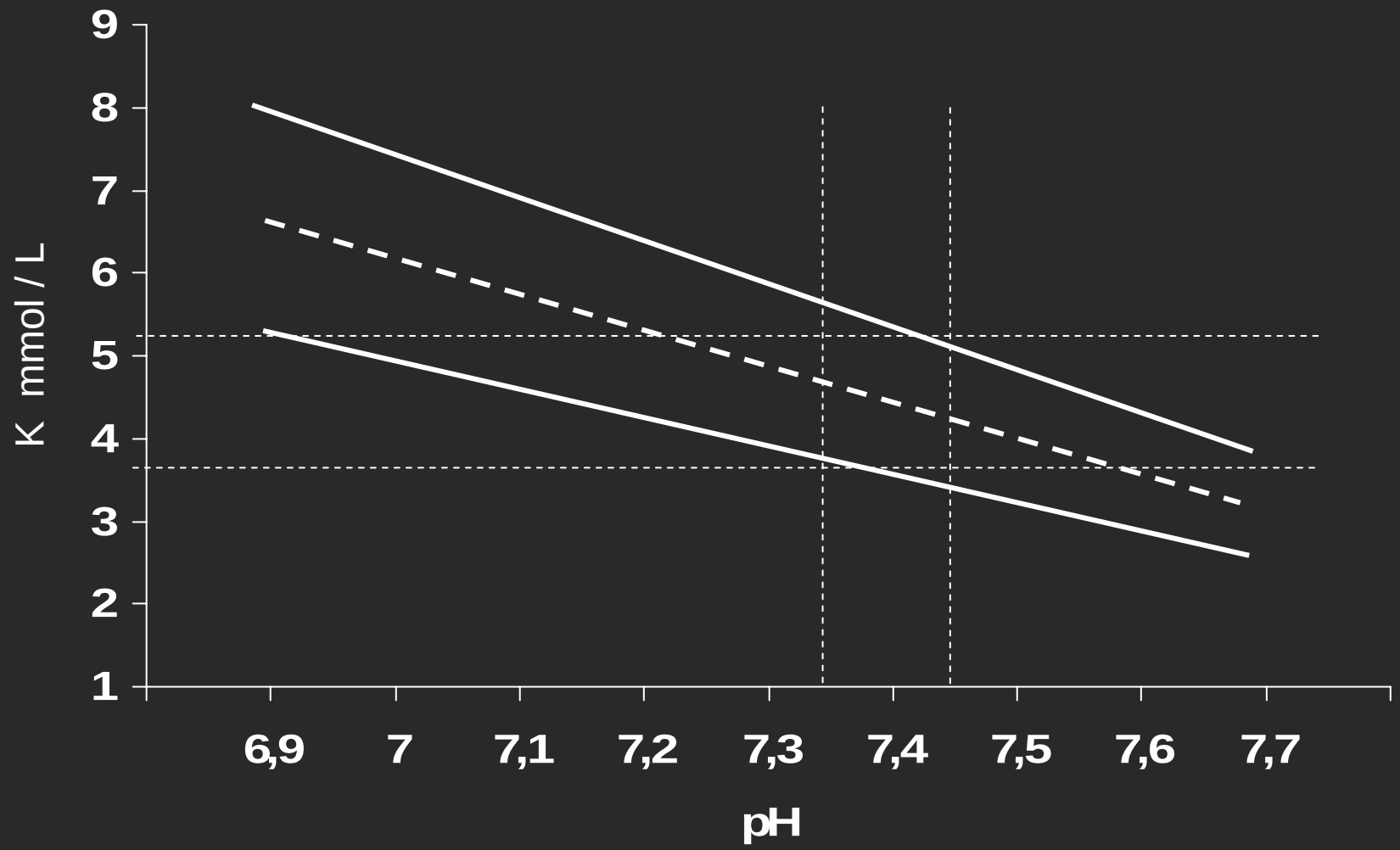
•Cations and anions in blood (el.charge)



•K^+ - potassium

- Physiological concentration
  - 3,5 - 5,1 mmol/L
  - Major cation in ICF
- Why examinate K^+ ?
  - ABB
  - Neuromuscular excitation
    - ★Cardiac and neuromuscular function
    - ★Influences nerve impulse conduction
- ***E***valuation of the kalemia
  - Connection to pH !

•Relationship between K a pH



•Hyperkalaemia - causes

- Shift K^+ (from ICF to ECF)
  - Acidosis, hypoxemia, haem**o**lysis, c**a**tabolism
- Excessive K intake
  - In renal failure
- Insufficient excretion by kidney
  - Renal failure, lack of of adrenal cortic**o**ids, drugs (spironolacton)
- Critical values
  - > 6,5 mmol/L
- MAC is accompanied by hyperkalaemia

• Hyperkalaemia - signs, symptoms

- Signs, symptoms
  - Cardiac arrhythmias (bradyc**a**rdia)
  - ECG
    - ★Tall T, low P, a-v block, wide QRS complex
  - Muscle weakness, par**a**lysis, paraesthaesia of tongue, face, hands, and feet, cramping
- Therapy
  - Acidosis - causal treatment
  - 10 - 20% G + insulin
  - Diuretics, Ion exchanger (resonium)
  - Hemod**ia**lysis

• Hypokalaemia - causes

- Shift K^+ (from ECF to ICF)
  - Alcalosis, anabolism
- Excessive K loss
  - Renal - diuretics
  - Gastrointestinal - diarrhea
  - Drugs - large doses of adrenal corticoids

- MAL is accompanied by hypokalemia

• Hypokalaemia - signs, symptoms

- Signs, symptoms
  - Muscle weakness, paralytic ileus
  - Cardiovascular: ↓ BP, possible cardiac arrest
  - EKG changes: decrease T wave, U wave
  - Mental depression and confusion

- Therapy:
  - Therapy of alkalosis
  - Replacement of K
    - ★Oral, Parenteral (KCl 7,5 % = hypertonic solution !)

•Na^+ (sodium): 135-145 mmol/L

- Significance
  - Major cation in ECF
  - One of main factors in determining ECF volume
  - Helps maintain acid-base balance
  - Regulates voltage of action potential

- Normal concentration of Na
  - Physiological conditon
  - Loss of isotonic fluid
  - Excess of isotonic fluid

•Hypernatraemia

- Causes
  - Excess of Na gain or loss of water
  - Use of large doses of adrenal corticoids
- Critical value: > 155 mmol/l
- Risk
  - If hypovolemia present - prerenal failure
  - If hyperhydration - heart failure

•Hypernatraemia - symptoms

- Early
  - Generalized muscle weakness
- Moderate
  - Confusion, thirst
- Late
  - oedema, restlessness, thirst, hyperreflexia, muscle twitching, irritability, possible coma
- Severe
  - Brain damage, hypertension, tachycardia

•Hypernatraemia - therapy

- Therapy should be gradual
  - Changes osmolality
  - Fast therapy = risk of brain oedema !!

- When Na > 155 mmol/l - start with isotonic saline
- Gradual lowering with hypotonic solution of NaCl
- Decrease of natraemia: no more than 2 mmol/L/hr !

•Hyponatraemia - causes, risks

- Excess Na loss or water gain
- Hepatic cirrhosis, congestive heart failure, deficit of suprarenal corticoids
- The major risks
  - Oedema (lungs)
  - Hyponatraemic encephalopathy !
    - ★Intracerebral osmotic fluid shifts
    - ★Intracerebral vasoconstriction

•Hyponatraemia - therapy

- Therapy
  - 0.9% solution NaCl (*3% solution NaCl ?*)
- Hyponatraemia must be corrected slowly (risk of the development of central pontine myelinolysis).
- Rapid correction of hypoNa is the most common cause of that potentially devastating disorder.
- Serum sodium should not be allowed to rise by more than 8 mmol/l over 24 hours (i.e. 0.33 mmol/l/h

• Chronic hyponatraemia

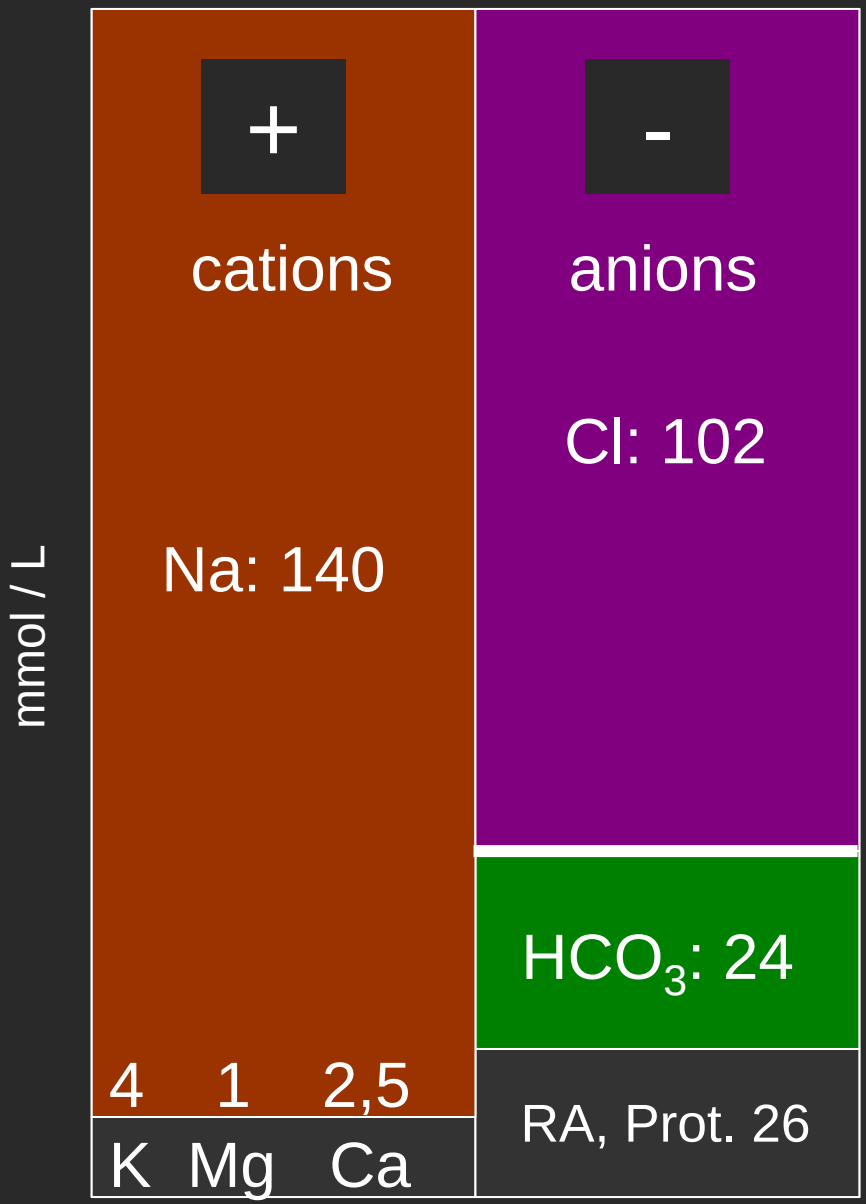
- Chronic ill
  - Hypoproteinaemia, katabolism
  - Shift sensitivity of osmoreceptors
  - Na^+ levels drop gradually over months
  - Chronic hypoNa is often called „asymptomatic hypoNa“
- Therapy?
  - Try to increase albumin level
  - Try to induce anabolism

•Chloride: 98 - 107 mmol/L

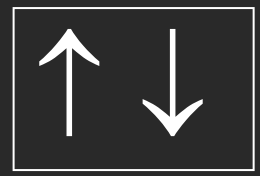
- Major anion in ECF

- Why examinate Cl^- ?
  - ABB
    - ★Acidosis, alkalosis
  - Balance of fluid (hydration)

- The law of electroneutrality: the sum of positive and negative charges must be equal



HCO_3 is anion, which can adapt its concentration rapidly to the changing conditions



•Hyperchloraemia

- Causes
  - Diarrhea, kidney diseases (CRF)
  - Excessive intake Cl
- Hyperchloraemia is accompanied by acidosis
- Therapy
  - Correcting the underlying diseases
  - Loop diuretics

•Hypochloraemia

- Causes
  - Heavy vomiting, (sweating)
  - Adrenal gland insufficiency
  - Loop diuretics
- Hypochloraemia is accompanied by alkalosis
- Therapy
  - NaCl, KCl, Arginin-Cl, NH_4Cl

- Saline („0,9 % solution NaCl, 300 mOsm/l)
- Saline acidify body fluids !

•Phosphorus - P: 0,9 – 1,5 mmol/L

- Intracellular mineral
- Inverse relationship to Ca
- Significance
  - Tissue oxygenation, normal CNS function
  - Movement of glucose into cells
  - Maintenance of acid-base balance
  - Enzymes, storage of energy (ATP - ADP),….
  - Bone mass

- Supply P in bone: > 20 000 mmol

•Hypophosphataemia

- Causes
  - Malnutrition
  - Hyperparathyroidism
  - Disorders causing hypercalcemia
- Signs/Symptoms
  - Muscle fatigue, weakness, paresis
  - Disorientation, seizures, coma
  - Haem**o**lysis
- Therapy
  - Supplementation of P

•Hyperphosphataemia

- Causes
  - Chronic renal failure (most common)
  - Hypoparathyroidism
  - Severe catabolic states
  - Conditions causing hypocalcemia
- Signs/Symptoms
  - Muscle cramping and weakness
  - ↑ HR, diarrhea, nausea
  - Calcifications

•Hyperphosphataemia

- Treatment
  - Treat cause (if possible)
  - Restrict phosphate-containing foods
  - Administer phosphate-binding agents
    - ★CRF - $CaCO_3$
  - Diuretics