

- Disorders of electrolytes and water balance
 - **Water**
 - Osmolality
 - Electrolytes (ions)

• 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 of water intake)
- Reabsorption phase
 - ▶ Increased BP, CVP
 - ▶ Hyperhydration, risk of heart failure

- Water balance (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	> 2500 mL/24 hod
Normal amount of urine	500 - 2500 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⁻, HCO₃⁻), urea, glucose
- Effective osmolality
 - ▶ Osmolality by solutes, generating gradient in the cell (semipermeable) 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 - 3 mosm/hr.

•Hyperosmolality

- Causes

- ▶ Water deficit

- ★ Vomiting, diarrhea, fever, burns, uncontrolled DM

- ▶ Excess of solutes, retention/supply Na^+

- ★ Acute catabolism, DM decomp, alcohol

- Signs, 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 - 3 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

- Signs, symptoms

- ▶ Oedema, dyspnoea, mental status changes, cramps, cephalgia,..

- Labs

- ▶ Decreased HCT, TP, osmolality (serum, urine)

•Hypoosmolality

- Intervention
 - ▶ 1. Isotonic solution
 - ▶ 2. Hypertonic solution ?
- Osmolality changes during treatment
 - ▶ 1 - 3 mosm/hod.

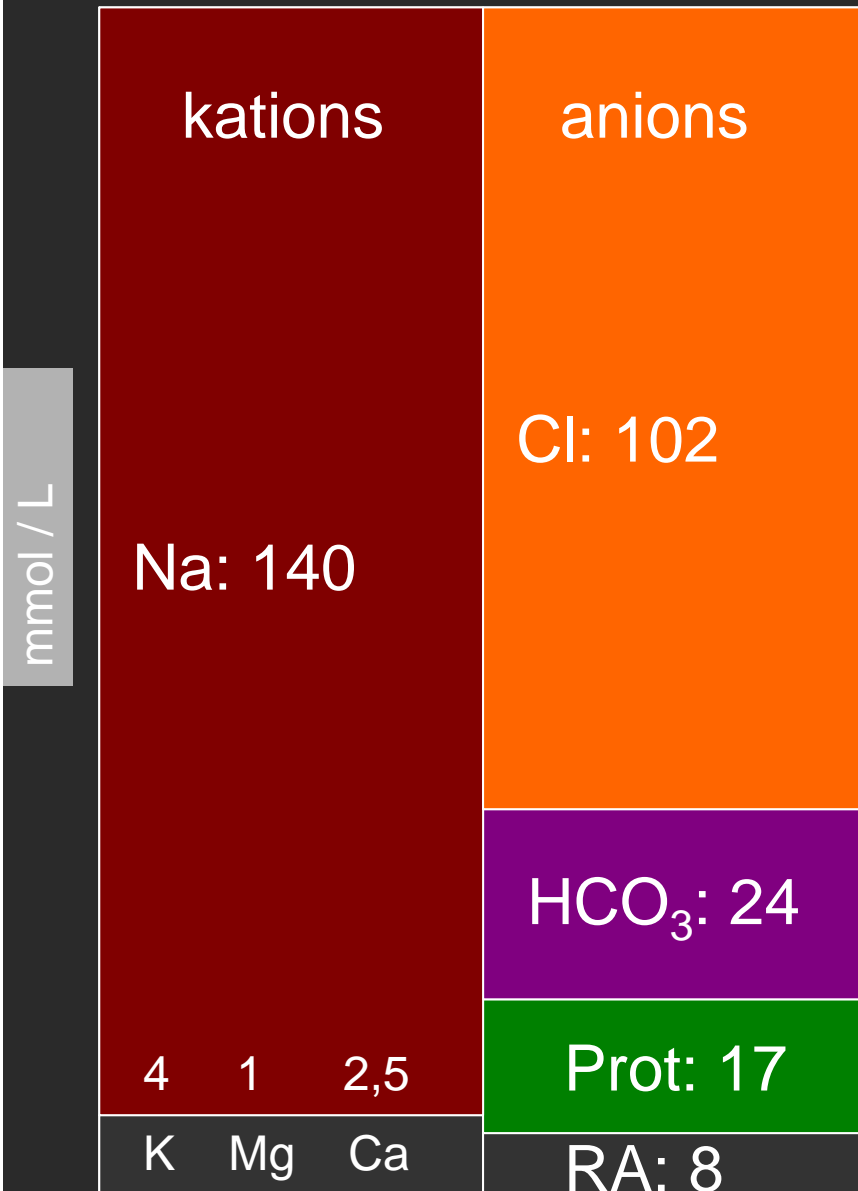
•Urine osmolality

- 50 - 1400 mosm/kg H₂O
 - ▶ In elderly: max. 800 mosm/kg H₂O
- 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

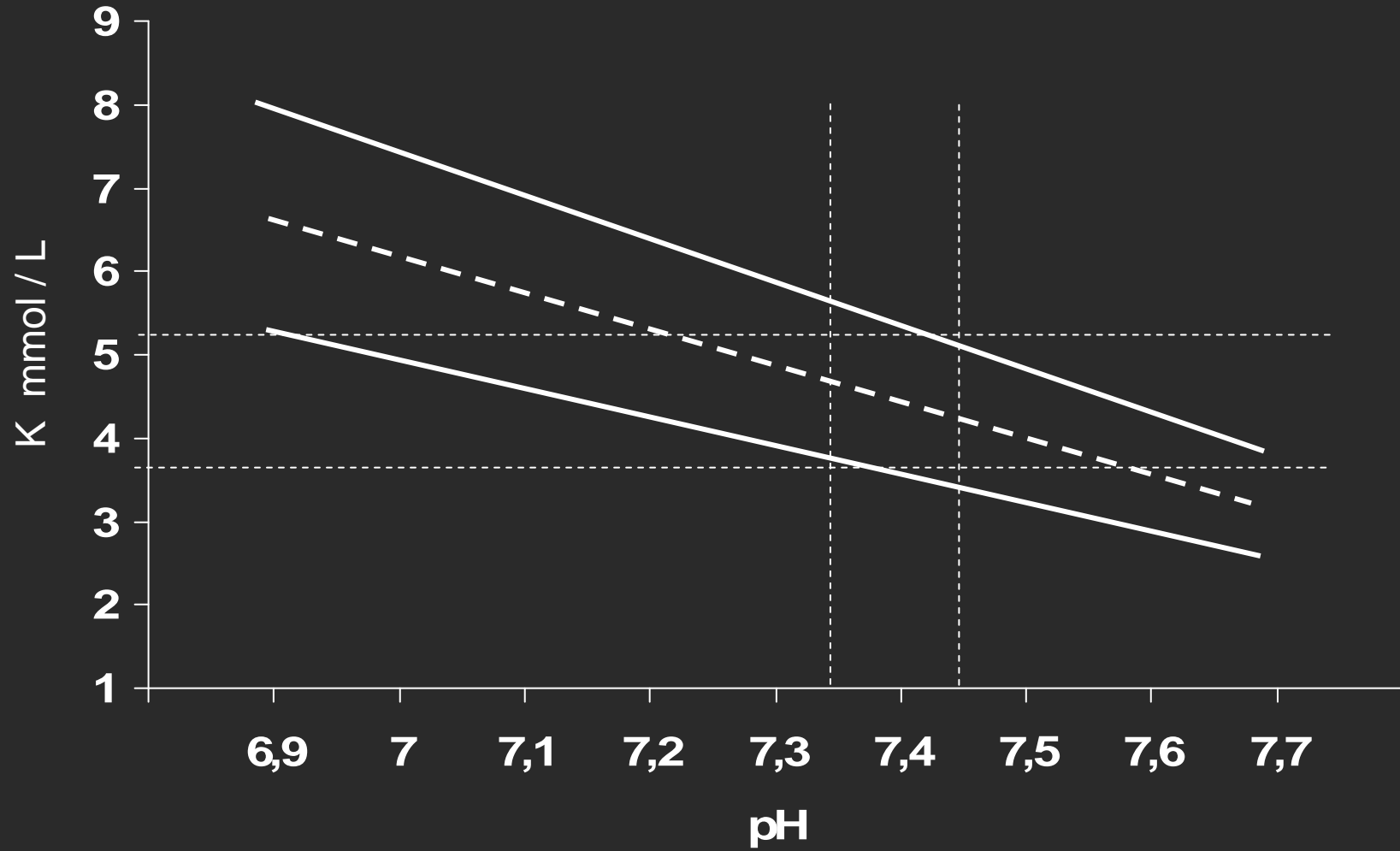
•Cations and anions in blood (el.charge)



•K⁺ - potassium

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

- Relationship between K_a and pH



•Hyperkalaemia - causes

- Shift K^+ (from ICF to ECF)
 - ▶ Acidosis, hypoxemia, haemolysis, catabolism
- Excessive K intake
 - ▶ In renal failure
- Insufficient excretion by kidney
 - ▶ Renal failure, lack of of adrenal corticoids, drugs (spironolacton)
- Critical values
 - ▶ $> 6,5$ mmol/L
- MAC is accompanied by hyperkalaemia

- Hyperkalaemia - signs, symptoms
- Signs, symptoms
 - ▶ Cardiac arrhythmias (bradycardia)
 - ▶ ECG
 - ★ Tall T, low P, a-v block, wide QRS complex
 - ▶ Muscle weakness, paralysis, paraesthesia of tongue, face, hands, and feet, cramping
- Therapy
 - ▶ Acidosis - causal treatment
 - ▶ 10 - 20% G + insulin
 - ▶ Diuretics, Ion exchanger (resonium)
 - ▶ Hemodialysis

- Hypokalaemia - causes
 - Shift K^+ (from ECF to ICF)
 - ▶ Alkalosis, 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 condition
- ▶ 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

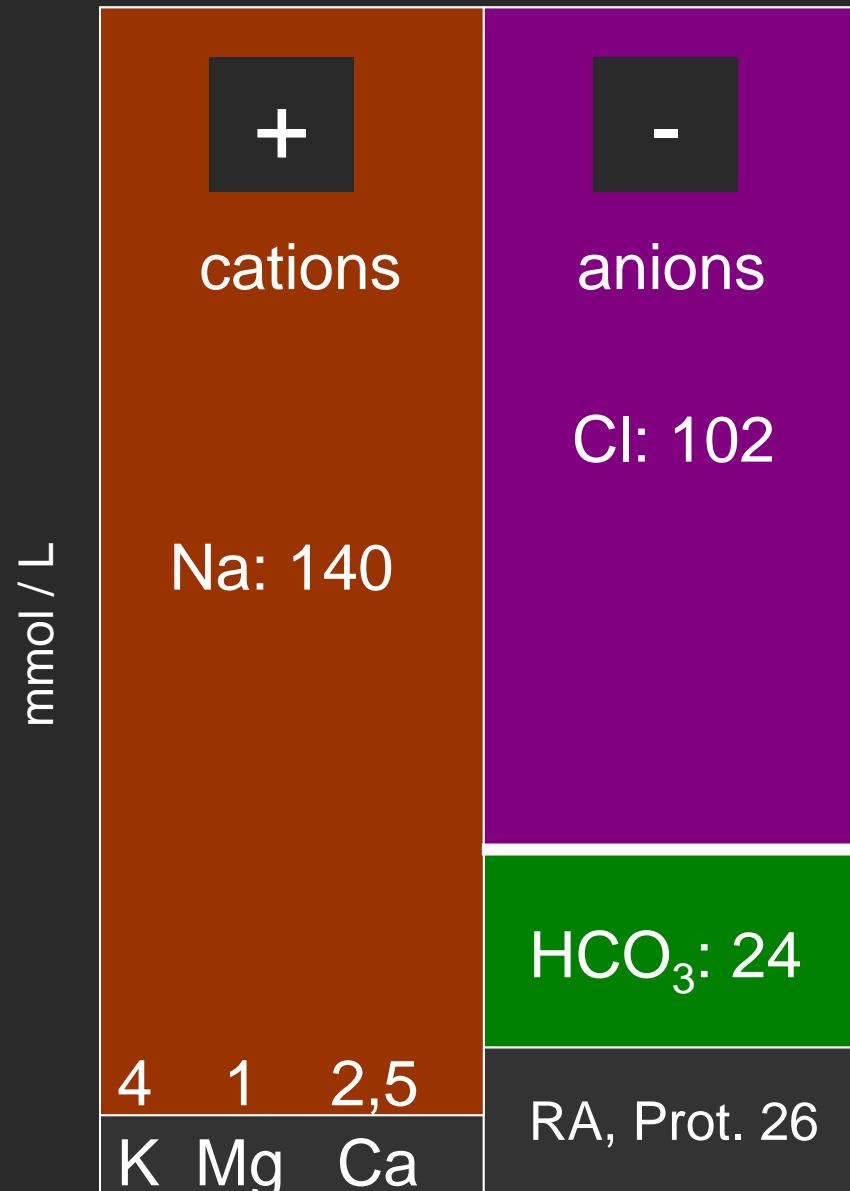
- Why examine Cl^- ?

- ▶ ABB

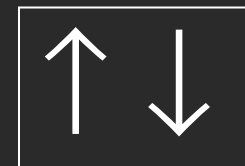
- ★ Acidosis, alkalosis

- ▶ Balance of fluid (hydration)

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



HCO₃ 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, NH₄Cl

- 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
- ▶ Haemolysis

- 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

- Calcium: 2,1-2,5 mmol/l

- Extracellular compartment

- ▶ Blood coagulation, neuromuscular contraction, enzymatic activity

- Distribution

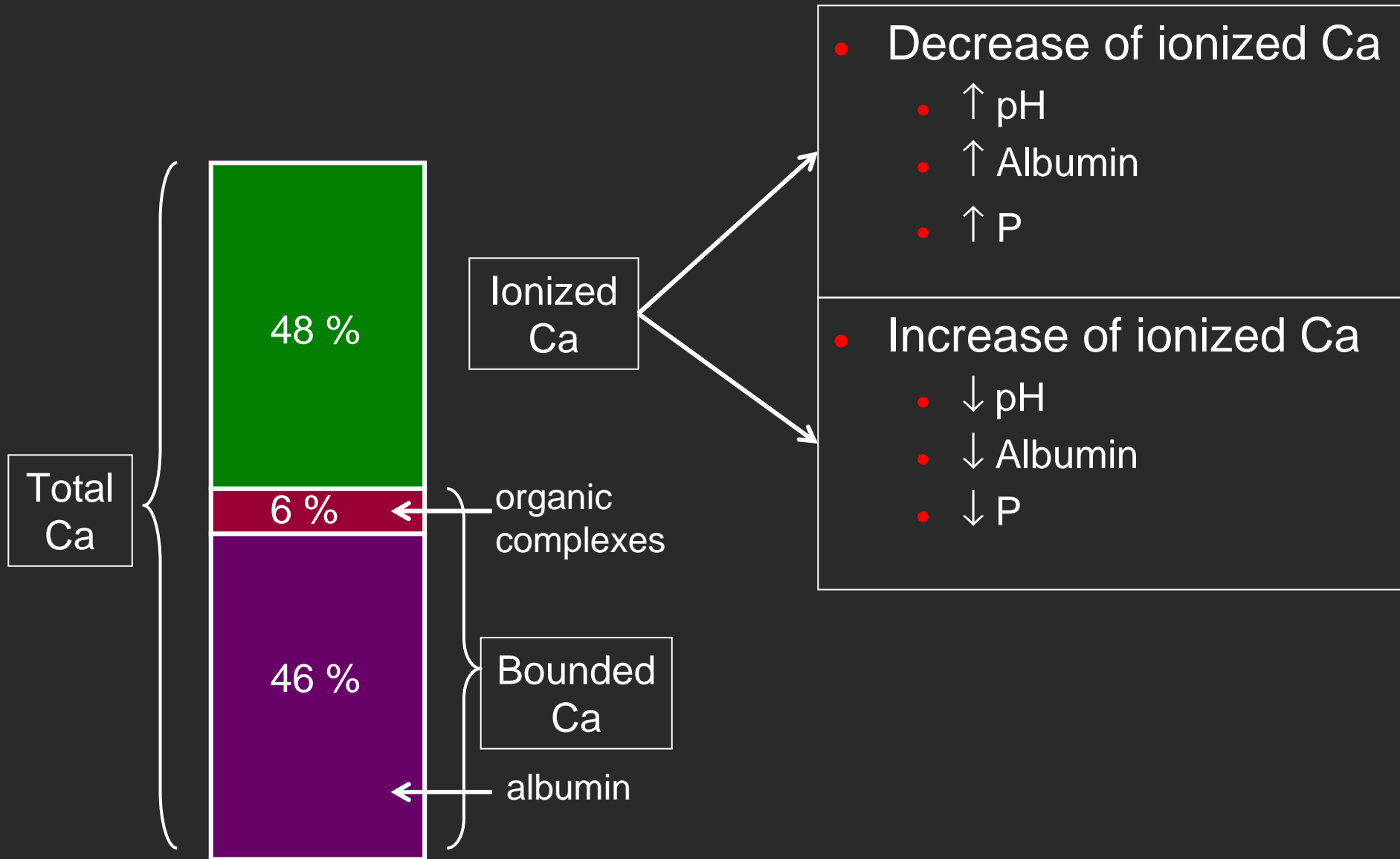
- ▶ Bone (99 %), ECF (1 %)

- ▶ ECF

- ★ Protein-bound

- ★ Complexes with anions

- ★ Ionized - neuromuscular activity



•Calcium homeostasis

- Parathyrin (PTH, parathyroid hormone)
- Calcitonin (thyreocalcitonin)
- Calcitriol

•Hypercalcaemia

- Causes

- ▶ Mobilization of Ca from bone

- ★ Malignancy, hyperparathyroidism, immobilization

- ▶ Thiazide diuretics, hyperfunction of thyroid gland

- ▶ Excessive ingestion of Ca and vit. D

•Hypercalcaemia

- Signs/Symptoms

- ▶ Anorexia, constipation
- ▶ Generalized muscle weakness, lethargy, ataxia
- ▶ Depression, fatigue, confusion, coma
- ▶ Rhythm disorders and heart block
- ▶ Polyuria & predisposes to renal calculi

- Hypercalcaemia

- Treatment

- ▶ Infusion of saline (0,9% NaCl)
 - ★ Loop diuretics (furosemid)
- ▶ Corticosteroids
- ▶ Bifosfonates and/or calcitonin
- ▶ Treatment of underlying diseases

•Hypocalcaemia

- Causes

- ▶ Depressed function of parathyroid gland
 - ★ Surgical removal of parathyroid gland
- ▶ Hypomagnesemia
- ▶ Hyperphosphatemia
- ▶ Administration of large quantities of stored blood (preserved with citrate)
- ▶ Renal insufficiency
- ▶ Lack of vitamin D

•Hypocalcaemia

- Signs/Symptoms

- ▶ Abdominal and/or extremity cramping
- ▶ Tetany; hyperactive reflexes
- ▶ Irritability, reduced cognitive ability, seizures
- ▶ Prolonged QT on ECG, hypotension, decreased myocardial contractility
- ▶ Abnormal clotting

• Hypocalcaemia

- Treatment

- ▶ Treatment of underlying diseases
- ▶ High calcium diet or oral calcium salts
- ▶ i.v. 10% calcium gluconate
- ▶ Vitamin D therapy

- Magnesium: 0,7-1,1 mmol/l

- Intracellular compartment

- ▶ Ensures K/Na transport across cell membrane
- ▶ Carbohydrate and protein metabolism
- ▶ Nerve cell conduction, neuromuscular activity
- ▶ Blood clotting, parathormone secretion
- ▶ Urine - defend concrements formation
- ▶

- Distribution

- ▶ Bone (60 %), ICF (38 %), ECF (2 %)
 - ★ ECF - protein-bound, ionized Mg^{2+}

•Hypermagnesaemia

- Causes
 - ▶ RF, muscle necrosis
- Signs and symptoms
 - ▶ Hypotension, weakness, respiratory depression
 - ▶ ECG - bradycardia, tall T waves, a-v block
 - ▶ > 6 mmol/l - cardiac arrest, apnoea
- Therapy
 - ▶ Calcium chloride or gluconate i.v. for acute symptoms
 - ▶ Diuretics, G + insulin
 - ▶ HD

• Hypomagnesaemia

- Causes

- ▶ Malabsorption, starvation, acute pancreatitis, alcoholism, diarrhea, diuretics therapy

- Signs and symptoms

- ▶ Tremor, tetany, paraesthesia of feet and legs, convulsions, personality changes with agitation
- ▶ ECG: ventricular tachycardia, fibrillation

- Th

- ▶ MgSO_4 i.m., slowly i.v.