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

Compartments

- Intracellular (ICF)
  - 2/3 of body fluid
  - Located primarily in .....
  - High in K, PO_4
- Extracellular (ECF)
  - 1/3 of body fluid
  - Comprised of 3 major components
    - Intravascular (plasma X serum)
    - Interstitial
    - Transcellular

• Transcellular component

- 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)

Water bilance (water exchanges)/24 hours

Intake (mL)		Losses (mL)	
Beverages	1000-1500	Urine	1000-1500
Food	700	Skin	400
Metabolic water	300	Respiratory	400
		Sweating	100
		Stool	100
		Drains, ..	??

Can be measured | Can be estimated | Weigh the patient

- Diuresis/24 hours

Polyuria	> 2500 ml/24 hours
Physiologic volume of urine	500 - 2500 ml/24 hours
Oliguria	50 - 500 ml/24 hours
Anuria	< 50 ml/24 hours

- Lab. analysis of urine
  - Density (osmolality)
  - Losses of ions (Na, K, Cl, Mg, P, Ca)
  - pH of the urine: fresh urine

- 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
  - Number of particles, regardless of their size/properties

Osmolality: measurement x calculation

- Osmolality can be measured on an analytical instrument called an osmometer. It works on the method of depression of freezing point

- Calculation

$$(2 \times Na) + K + \text{glucose} + \text{urea}$$

- Serum osmolality: 275-295 mosm/kg

- Particles which contribute most to the osmolality
  - Na^+ (Cl^-, HCO_3^-), urea, glucose

- Effective osmolality
  - Osmolality by solutes, generating gradient in the cell (semipermeabile) membrane
    - Na^+ (Cl^-, HCO_3^-), glucose

Osmolal gap

- Results of measured (cryoscopic method) and calculated osmolality
  - Approximately equal (negligible difference)
- Osmolal gap
  - Difference between the measured osmolality and the calculated osmolality
    - Measured osmolality is higher than calculated o.
  - Difference > 10 mmol/kg ???

  - Ethanol: 1g/L = 1 ppt = 23 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

- The optimal osmolality changes during treatment of hyper (hypo) osmolality
  - 1 - 3 mosm/hr.

• Hyperosmolality

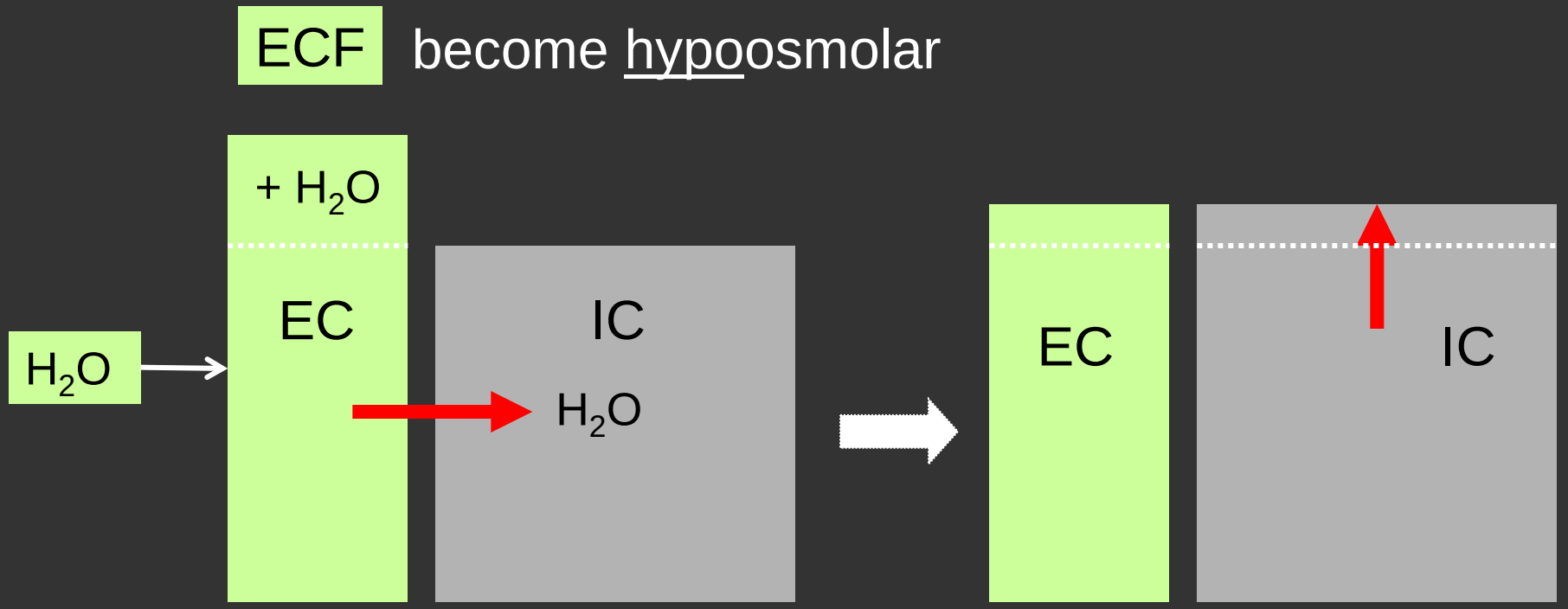
- Causes
  - Water deficit
    - Vomiting, diarrhea, fever, uncontrolled DM
  - Excess of solutes, retention/supply Na^+
    - Uncontrolled DM, alkohol
- Sings, symptoms .....
  - Water deficit
    - Weight loss, ↓ skin turgor, rapid pulse, ↓ BP, oliguria and ↑ urine osmolality
  - Sensations of thirst
- Labs
  - Increased HCT, TP, osmolality

Hyperosmolality

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

- Osmolality changes during treatment should be gradual
  - 1 - 3 mosm/hr.
- Risk of rapid changes (rapid treatment of hyperosmolality)
  - Brain oedema !!

Treatment of hyperosmolality by hypotonic solutions



- Leak of water into ICF → ↑ intracranial pressure in CNS (expansion of CNS)

• 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,..
- Lab:
  - Decreased HCT, TP, osmolality (serum, urine)

• Hypoosmolality

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

Urine osmolality

- Reference interval:...
  - 50 - 1400 mosm/kg H2O
  - In elderly: max. 800 mosm/kg H20
- Depends on secretion of ADH

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

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

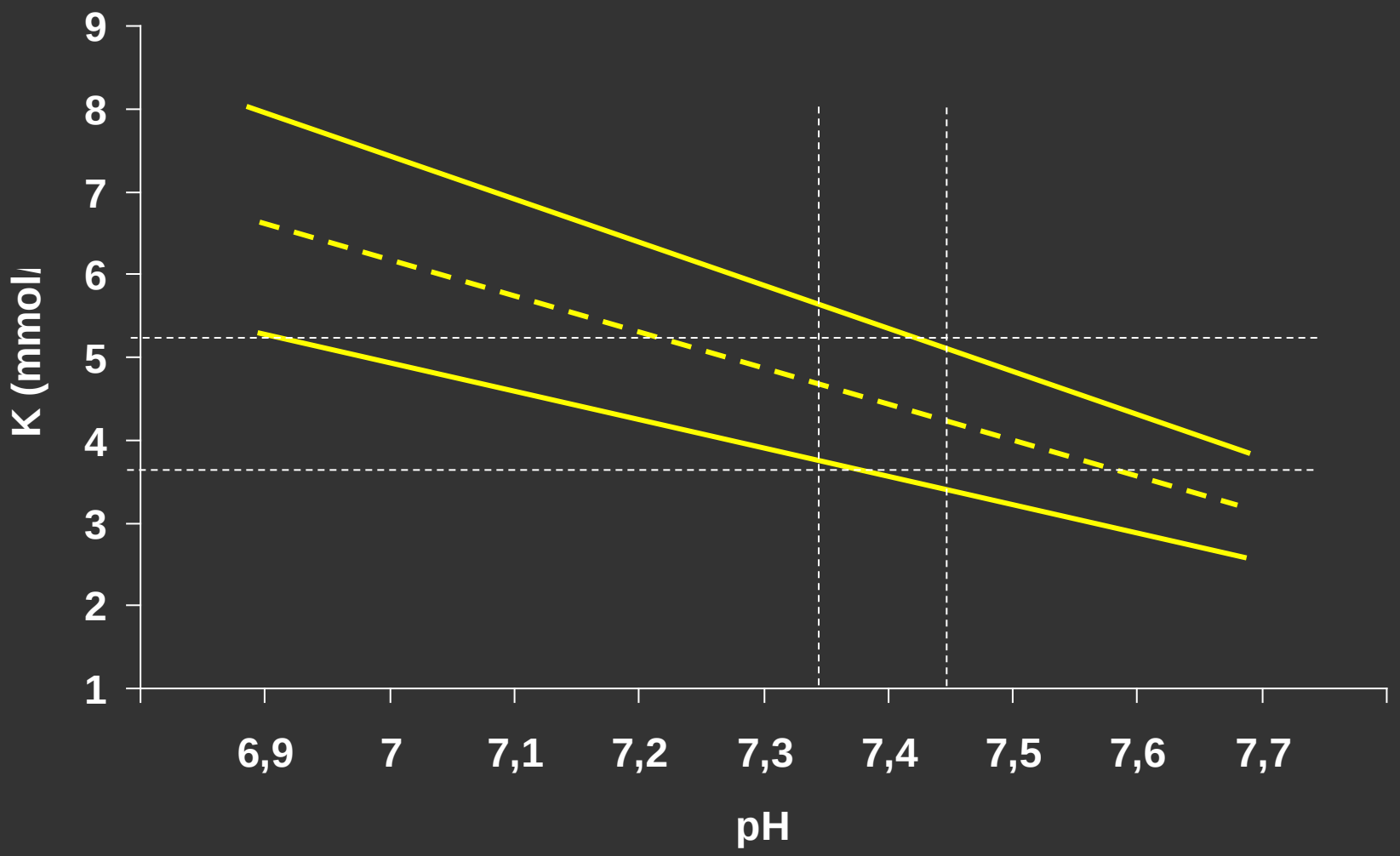
• K^+ - potassium

- Physiological concentration
  - 3,5 - 5,1 mmol/L
  - Major cation in ICF

- Why examinate K^+ ?
  - ABB
  - Neuromuscular excitation

- ***E***valuation of the kalemia
  - Connection to pH !

Relationship between K a pH



Hyperkalaemia - causes

- Shift K^+ (from ICF to ECF)
  - Acidosis, hypoxemia, haemolysis, catabolism
- Insufficient excretion by kidney
  - Renal failure, lack of of adrenal corticoids, drugs (spironolacton)

- Critical concentration .....
  - > 6,5 mmol/L

- MAC is accompanied by hyperkalaemia

Hyperkalaemia - signs, symptoms

- Signs, symptoms
  - Muscle parestesia, cramps
  - Cardiac arrhythmias (bradyc**a**rdia)
  - ECG
    - Tall and tented T waves, low P, a-v block, wide QRS complex
  - Muscle weakness, par**a**lysis, paresthesia

Hyperkalaemia - therapy

- Therapy ...
  - Acidosis - causal treatment
  - 10 - 20% G + insulin
  - Diuretics
  - Ion exchanger (resonium)
  - Haemodialysis

  - Avoid K in food (fruit)

Hypokalaemia - causes

- Shift K^+ (from ECF to ICF)
  - Alkalosis
  - Transition from catabolism to 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, paralysis, ↓ smooth muscle function (paralytic ileus)
  - Cardiovascular: ↓ BP, possible cardiac arrest
  - EKG changes
    - U wave, ↓ T wave, mental depression and confusion

Hypokalaemia - therapy

- If alkalosis is present
  - Therapy of alkalosis

- Replacement of K
  - Oral
  - Parenteral
    - KCl 7,5 % (hypertonic solution !)
      - Dilution in saline
      - No more than 10 mmol/hr

K - comments

- Lab. examination of K
- Careful blood collection
  - Haemolysis !
  - Storage of the blood - releasing K from ery. to collection tube
    - Time
    - Temperature

- 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

- Why examinate Na^+ ?
  - Hydration (ECF volume)
  - Osmolality

- Normal concentration of Na

- Physiological conditon
- Loss of isotonic fluid
- Excess of isotonic fluid

- How to distinguish loss x excess isotonic fluid
  - Lab: TP, Hb, Htk
  - Clinical examination
    - BP, filling of jugular veins

Hyper and hyponatraemia

- Na = the main ion contributing to the osmolality in the extracellular fluid
- Changes of Na concentration = changes of osmolality in the extracellular fluid
- Changes of osmolality = shift of water to/from the cells

Hypernatraemia - causes, risks

- Causes
  - Excess of Na gain or loss of water

- Hyperatraemia
  - Moderate: 150 - 155 mmol/L
  - Serious: < 156 - 160 mmol/L
  - Critical: > 160 mmol/l

- Risk
  - Hypovolemia - prerenal failure
  - 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 - water from ECF to ICF
  - Fast therapy = risk of brain oedema !!
- When Na > 155 mmol/l - start th. with isotonic saline
- Gradual lowering with hypotonic solution of NaCl
- ↓ natraemia: no faster than 2 mmol/L/hr !

Hyponatraemia - causes, risks

- Excess Na loss or water gain
  - Diuretic therapy, unregulated production of ADH
  - Congestive heart failure, deficit of suprarenal corticoids

- Moderate: < 135 mmol/L
- Serious: < 130 mmol/L
- Critical: < 125 mmol/l

- The major risks
  - Oedema (lungs)
  - Hyponatraemic encephalopathy !

Hyponatraemic encephalopathy

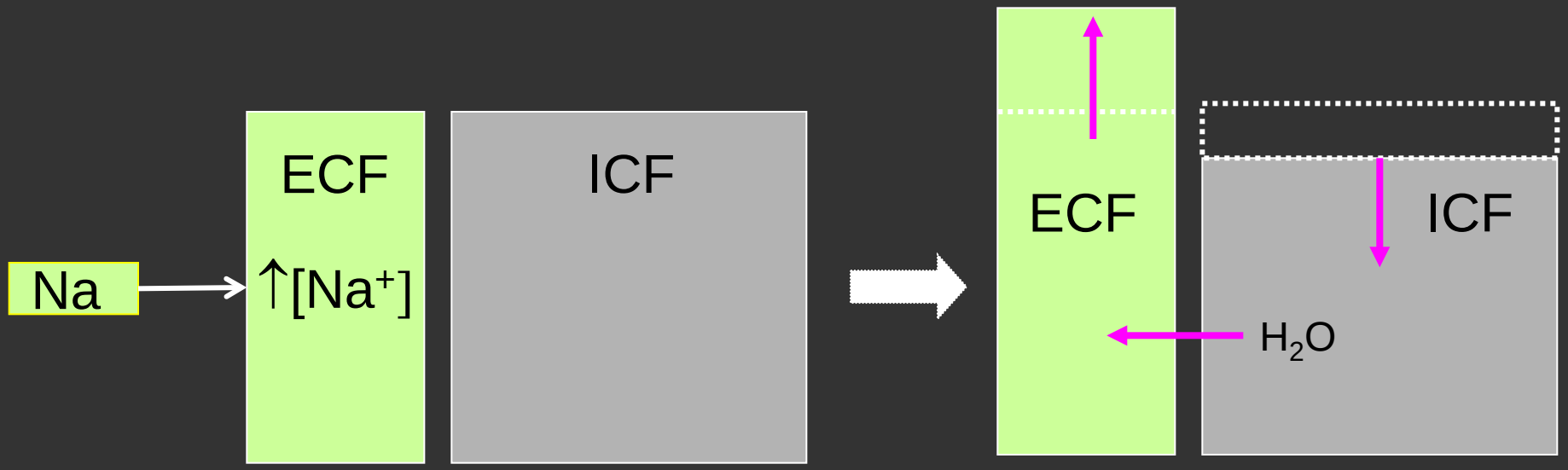
- Intracerebral osmotic fluid shifts
  - Brain oedema developed, brain compression
- Intracerebral vasoconstriction
  - Decrease of blood flow and O_2 saturation
- Risk of respiratory arrest, resulting in death
- Hyponatraemic encephalopathy
  - 5 times more frequent in women than in men
    - Na < 128 mmol/l
    - Estrogens - influence Na/K pump

Hyponatraemia - therapy

- Therapy
  - 0.9% solution NaCl (3% solution NaCl ?)

- Hyponatraemia must be corrected very slowly

- Treatment of hyponatraemia with hypertonic solution (supply of Na^+)



- Water from ICF to the ECF - expansion of ECF
- Deficit of water in ICF disturbances of CNS - central pontine myelinolysis
  - Separation of nerve cells from the myelin sheaths (cells shrink)

• Hyponatraemia - therapy

- Therapy
  - 0.9% solution NaCl (3% solution NaCl ?)
- Hyponatraemia must be corrected slowly (risk of the development of central pontine myelinolysis).
  - Separation of nerve cells from the myelin sheaths (cells shrink)
- 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

- Chloride: 98 - 107 mmol/L

- Major anion in ECF

- Why examinate Cl^- ?
  - ABB
    - Acidosis, alkalosis

  - Balance of fluid (hydration)

• Hyperchloraemia

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

• Hypochloraemia

- Causes
  - Vomiting, (sweating)
  - Loop diuretics

- Hypochloraemia is accompanied by alkalosis

- Therapy
  - NaCl, KCl, Arginin-Cl, NH4Cl

- Saline („0,9 % solution NaCl, 300 mOsm/l)
  - pH = neutral (pH = 7,0)

- Saline acidify body fluids !

- Ratio Na : Cl

Na : Cl

- Saline: 150 mmol/l : 150 mmol/l = 1,0 : 1,0
- ECF: 140 mmol/l : 100 mmol/l = 1,4 : 1,0

- Phosphorus - P: 0,9 – 1,5 mmol/L

- Intracellular mineral
- Inverse relationship to Ca concentration in blood

- Supply P in bone: > 20 000 mmol

Hypophosphataemia

- Causes
  - Malnutrition
  - Hyperparathyroidism
  - Disorders causing hypercalcemia
- Signs/Symptoms
  - Muscle fatigue, weakness, paresis
  - Disorientation, 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