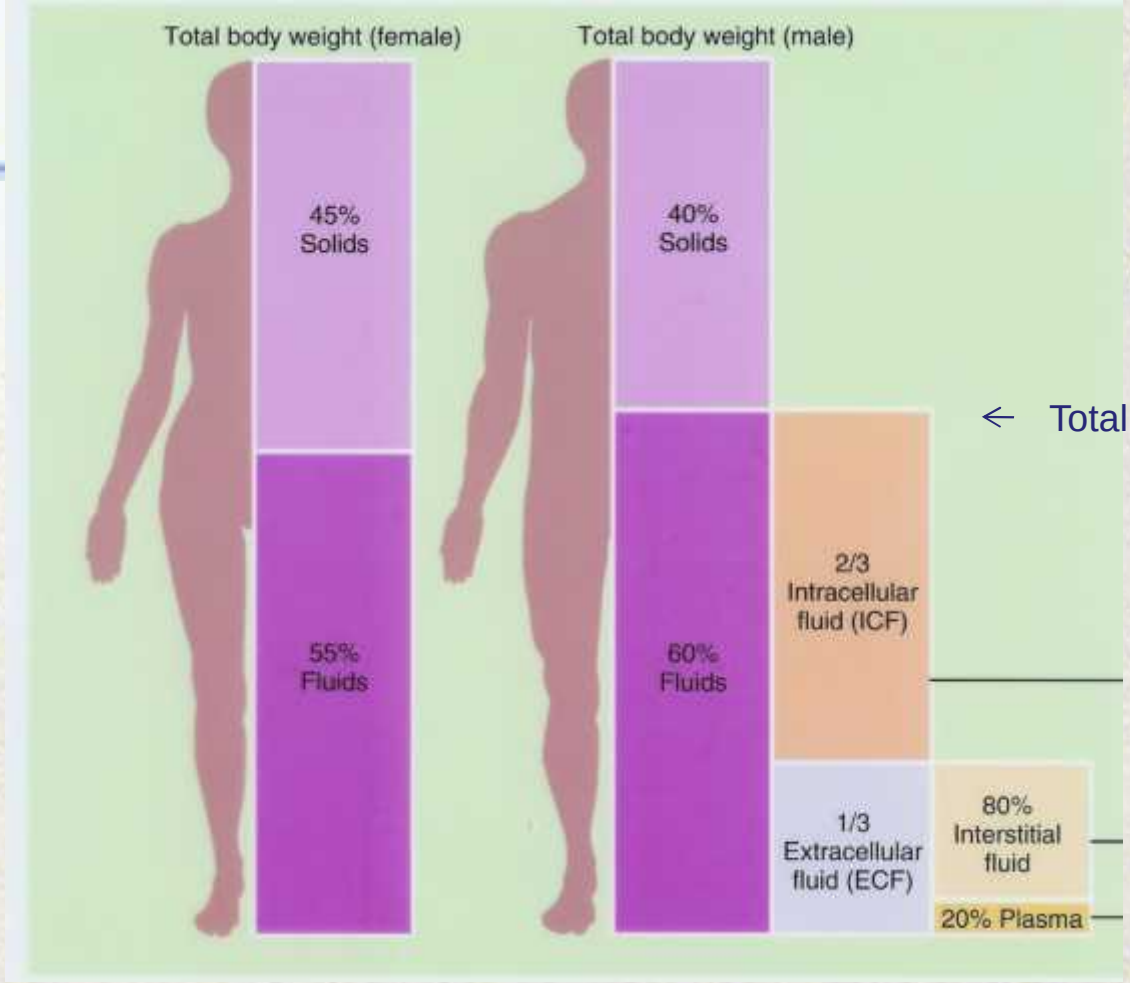
Fluids and Electrolytes

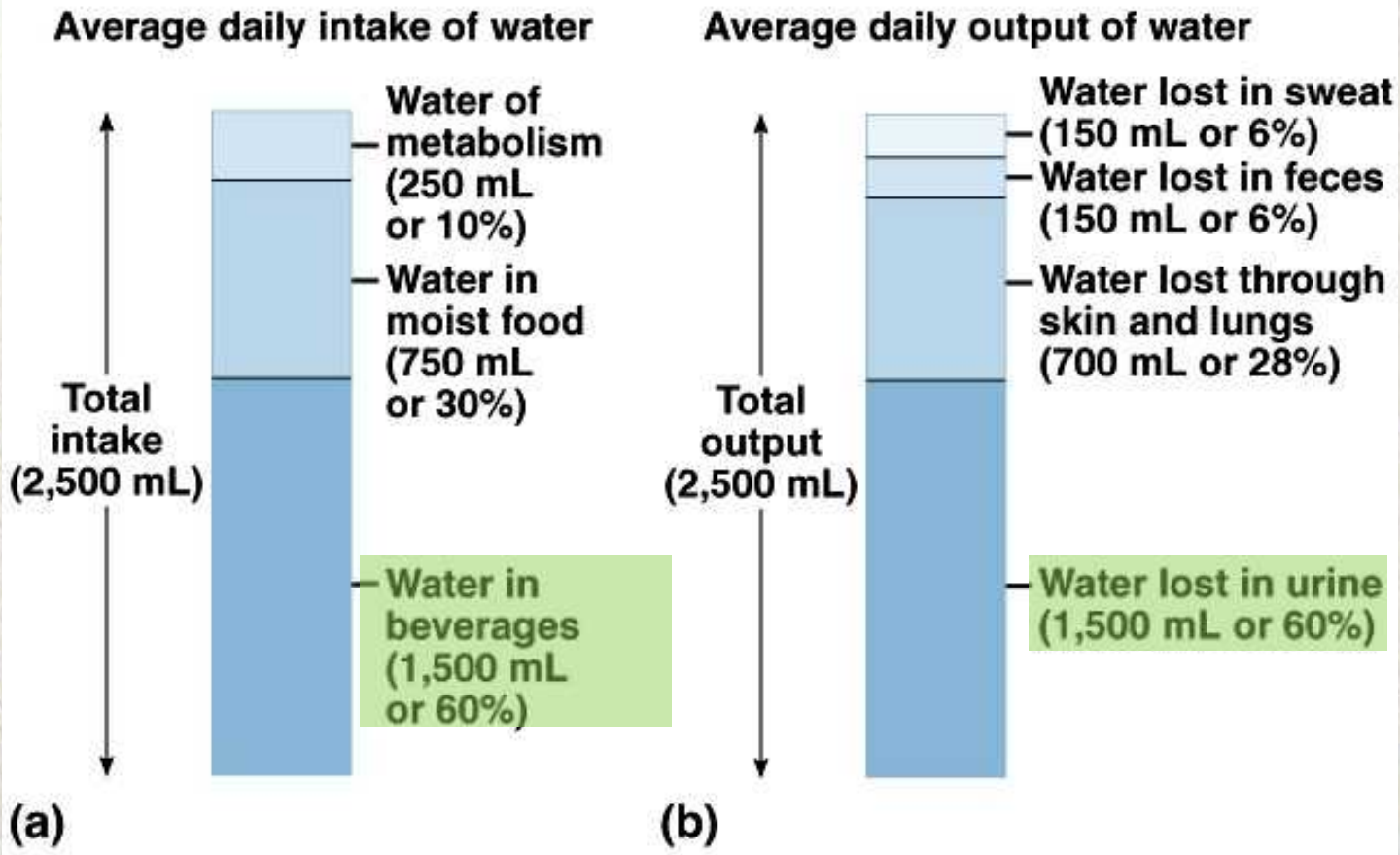


← Total body water (TBW)

- Fluid compartments are separated by membranes that are freely permeable to water – but **impermeable** to **solutes**.

- Movement of **fluids** is due to:
  - **hydrostatic pressure differentials**
  - **osmotic pressure differentials**

Fluid Balance



Fluid Balance

The body tries to maintain **homeostasis** of fluids and electrolytes by regulating:

- **Volumes**
- **Solute charge** and **osmotic load**

Solute Homeostasis

- **Electrolytes** – charged particles
  - – Cations – positively charged ions
    - • Na^+, K^+ , Ca^{++}, H^+
  - – Anions – negatively charged ions
    - • Cl^-, HCO_3^- , PO_4^{3-}
- **Non-electrolytes** - Uncharged particles
    - • Proteins, urea, glucose, O_2, CO_2

Solute Homeostasis

Maintained by:

- Ion transport
- Water movement
- Kidney function

These functions act to keep body fluids:

- **Electrically** neutral
- **Osmotically** stable (specified number of particles per volume of fluid)

Solute Homeostasis

Where sodium goes, water follows.

Diffusion – movement of particles down a concentration gradient.

Osmosis – diffusion of water across a selectively permeable membrane

Active transport – movement of particles up a concentration gradient; requires energy

Regulation of body water

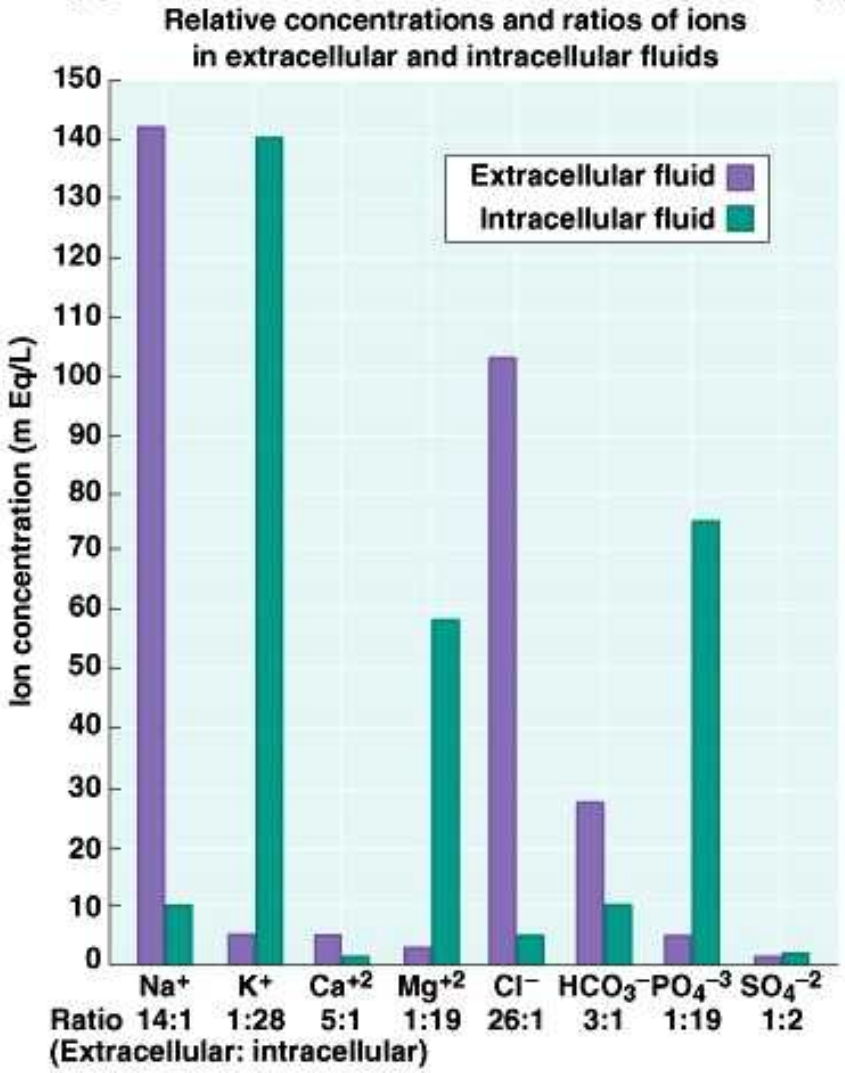
The default is **get rid of it**

The control processes include:

Release of ADH (antidiuretic hormone)

Thirst

Electrolytes



Electrolyte balance

- **Na^+ (Sodium)**
  - Predominant extracellular cation
  - 136 -145 mEq / L
  - Pairs with Cl^- , HCO_3^- to neutralize charge
  - Most important ion in water balance
  - Important in nerve and muscle function
- **Reabsorption in renal tubule regulated by:**
  - Aldosterone
  - Renin/angiotensin
  - Atrial Natriuretic Peptide (ANP)

Electrolyte balance

- **K^+ (Potassium)**
  - Major intracellular cation
  - 150- 160 mEq/ L
  - Regulates resting membrane potential
  - Regulates fluid, ion balance inside cell
- **Regulation in kidney through:**
  - Aldosterone
  - Insulin

Electrolyte balance

- **Cl^- (Chloride)**
  - Major extracellular anion
  - 105 mEq/ L
  - Regulates tonicity
  - Reabsorbed in the kidney with sodium
- **Regulation in kidney through:**
  - Reabsorption with sodium
  - Reciprocal relationship with bicarbonate

Hypernatremia

- Plasma Na+ > 145 mEq / L
- Due to ↑ Na + or ↓ water
- Water moves from ICF → ECF
- Cells dehydrate

Due to:

- Excess Na intake (hypertonic IV solution)
- Excess Na retention (oversecretion of aldosterone)
- Loss of pure water
  - Long term sweating with chronic fever
  - Respiratory infection → water vapor loss
  - Diabetes (mellitus or insipidus) – polyuria
- Insufficient intake of water (hypodipsia)

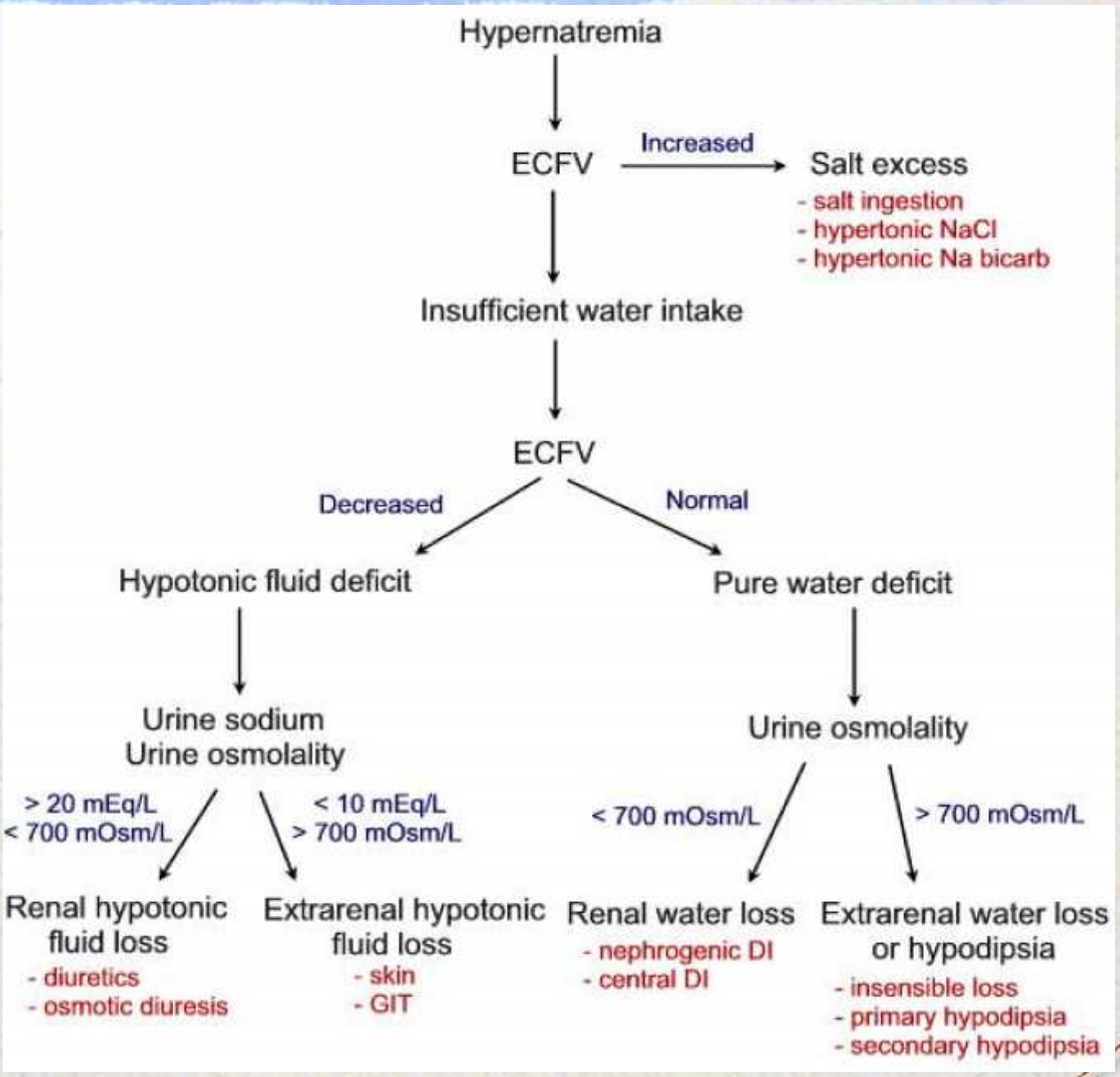
Clinical manifestations of Hypernatremia

- Thirst
- Lethargy
- Irritability
- Seizures
- Fever
- Oliguria

Hypernatremia

Evaluation

- Volume
- Serum sodium, osmolality, BUN/Creatinine
- Urine sodium, osmolality


Hypernatremia
ECFV
Increased
Salt excess
- salt ingestion
- hypertonic NaCl
- hypertonic Na bicarb
Insufficient water intake
ECFV
Decreased
Normal
Hypotonic fluid deficit
Pure water deficit
Urine sodium
Urine osmolality
> 20 mEq/L
< 700 mOsm/L
< 10 mEq/L
> 700 mOsm/L
Urine osmolality
< 700 mOsm/L
> 700 mOsm/L
Renal hypotonic fluid loss
- diuretics
- osmotic diuresis
Extrarenal hypotonic fluid loss
- skin
- GIT
Renal water loss
- nephrogenic DI
- central DI
Extrarenal water loss or hypodipsia
- insensible loss
- primary hypodipsia
- secondary hypodipsia

Hyponatremia

Symptoms

- Anorexia
- Headache
- Nausea
- Emesis
- Impaired response to verbal stimuli
- Impaired response to painful stimuli
- Bizarre behavior
- Hallucinations
- Obtundation
- Incontinence
- Respiratory insufficiency
- Decorticate or decerebrate posturing
- Bradycardia
- Hypertension or hypotension
- Altered temperature regulation
- Dilated pupils
- Seizure activity
- Respiratory arrest
- Coma
- Hypotension
- Renal failure as consequence of hypotension
- Tachycardia
- Weakness
- Muscular cramps

Hyponatremia

Evaluation

- Volume
- Serum sodium, osmolality, BUN/Creatinine
- Urine sodium, osmolality

Hyponatremia

- Hypovolemic hyponatremia
  - Renal losses caused by diuretic excess, osmotic diuresis, salt-wasting nephropathy, adrenal insufficiency, proximal renal tubular acidosis, metabolic alkalosis, and pseudohypoaldosteronism result in a urine sodium concentration greater than 20 mEq/L
  - Extrarenal losses caused by vomiting, diarrhea, sweat, and third spacing result in a urine sodium concentration less than 20 mEq/L
- Rx: Volume resuscitation with NS

Hyponatremia

- Normovolemic hyponatremia
  - When hyponatremia is caused by SIADH, reset osmostat, glucocorticoid deficiency, hypothyroidism, or water intoxication, urine sodium concentration is greater than 20 mEq/L
- Rx:
  - Fluid restriction
  - Correct endocrine abnormality

Hyponatremia

- Hypervolemic hyponatremia
  - If hyponatremia is caused by an edema-forming state (eg, congestive heart failure, cirrhosis, nephrotic syndrome), urine sodium concentration is less than 20 mEq/L
  - If hyponatremia is caused by acute or chronic renal failure, urine sodium concentration is greater than 40 mEq/L
- Rx: Correct underlying state

Acute Hyponatremia

- Na < 120 and duration < 48 hrs
- Etiology:
  - Postoperative
  - Exercise with hypotonic fluid replacement
  - Drugs - Ecstasy
- Treat aggressively using 3% saline to raise Na by 5mm/L in one hour
- Beware rapid drop in vasopressin levels

Hypochloremia

- Most commonly from gastric losses
  - Emesis, gastric suctioning, EC fistula
- Often presents as a contraction alkalosis with paradoxical aciduria (Na+ retained and H+ wasted in the kidney)
- Rx: resuscitation with normal saline

Hyperchloremia

- Most commonly from over-resuscitation with normal saline
- Often presents as a hyperchloremic acidemia with paradoxical alkaluria (H+ retained and Na+ wasted in the kidney)
- Rx: stop normal saline and replace with hypotonic crystalloid

Hypokalemia

- Serum K^+ < 3.5 mEq /L
- Beware if diabetic
  - Insulin pushes K^+ into cells
  - Ketoacidosis – H^+ replaces K^+, which is lost in urine
- β – adrenergic drugs or epinephrine

Causes of Hypokalemia

- Decreased intake of K^+
- Increased K^+ loss
  - Chronic diuretics
  - Severe vomiting/diarrhea
  - Acid/base imbalance
  - Trauma and stress
  - Increased aldosterone
  - Redistribution between ICF and ECF

Clinical manifestations of Hypokalemia

- Neuromuscular disorders
  - Weakness, flaccid paralysis, respiratory arrest, constipation
- Dysrhythmias, appearance of U wave
- Postural hypotension
- Cardiac arrest
- **Rx-** Increase K^+ intake, but slowly, preferably by foods

Hyperkalemia

- Serum K+ > 5.5 mEq / L
- Check for renal disease
- Massive cellular trauma
- Insulin deficiency
- Addison's disease
- Potassium sparing diuretics
- Decreased blood pH
- Exercise pushes K+ out of cells

Clinical manifestations of hyperkalemia

- Early – hyperactive muscles , paresthesia
- Late - muscle weakness, flaccid paralysis
- Peaked T-waves
- Dysrhythmias
  - Bradycardia, heart block, cardiac arrest

Hyperkalemia

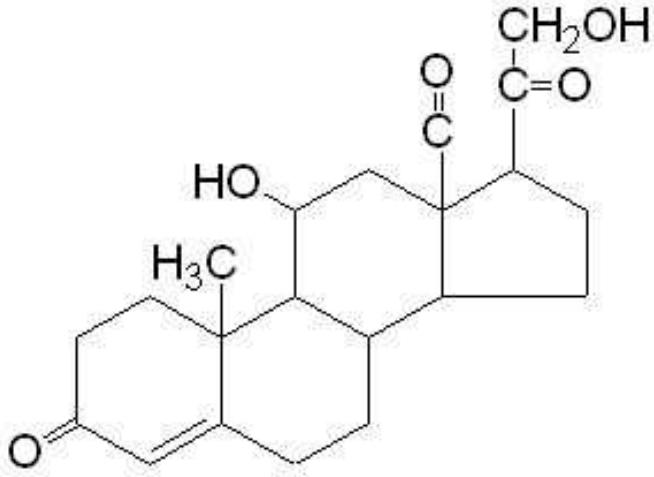
Management

- 10% Calcium Gluconate or Calcium Chloride
- Insulin (0.1U/kg/hr) and IV Glucose
- Lasix 1mg/kg (if renal function is normal)
- Metabolic alkalosis (if the patient is acidemic)
  - 1 L H20 with 150meq of $NaHCO_3$
- Kayexelate
- Hemodialysis

Regulation of electrolyte balance

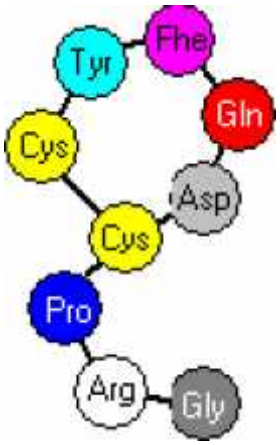
- **Electrolytes and water balance are regulated together and the *kidney* play a critical role.**
- **The regulation is mostly achieved through the hormones *aldosterone, ADH (Antidiuretic hormone) and renin-angiotensin*.**

Aldosterone

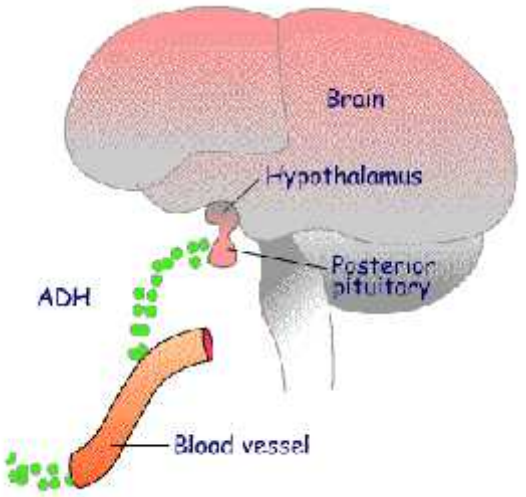


- **mineralocorticoid, steroid hormone.**
- **produced by adrenal cortex, increase Na^+ reabsorption at the expense of K^+ and H^+.**
  - **retain Na^+, lose K^+**

Antidiuretic hormone (ADH)



- **or vasopressin**
- **a 9-amino acid peptide hormone**
- **produced by specialized nerve cells in the hypothalamus and transported in the bloodstream to the posterior pituitary gland.**
- **mainly released when the body is low on water, increases water reabsorption by renal tubules.**

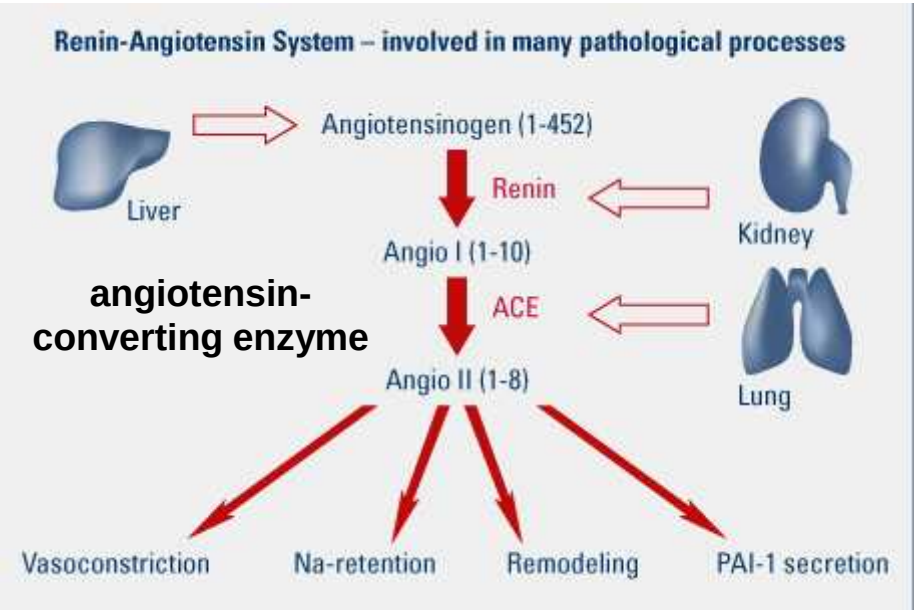


Renin-angiotensin system(RAS)

- **Renin: peptide hormone (340 aa), secreted by the kidney.**
- **Angiotensinogen: α2-globulin, produced constitutively and released into the circulation mainly by the liver.**
- **Angiotensinogen**

  → Angiotensin Ⅰ

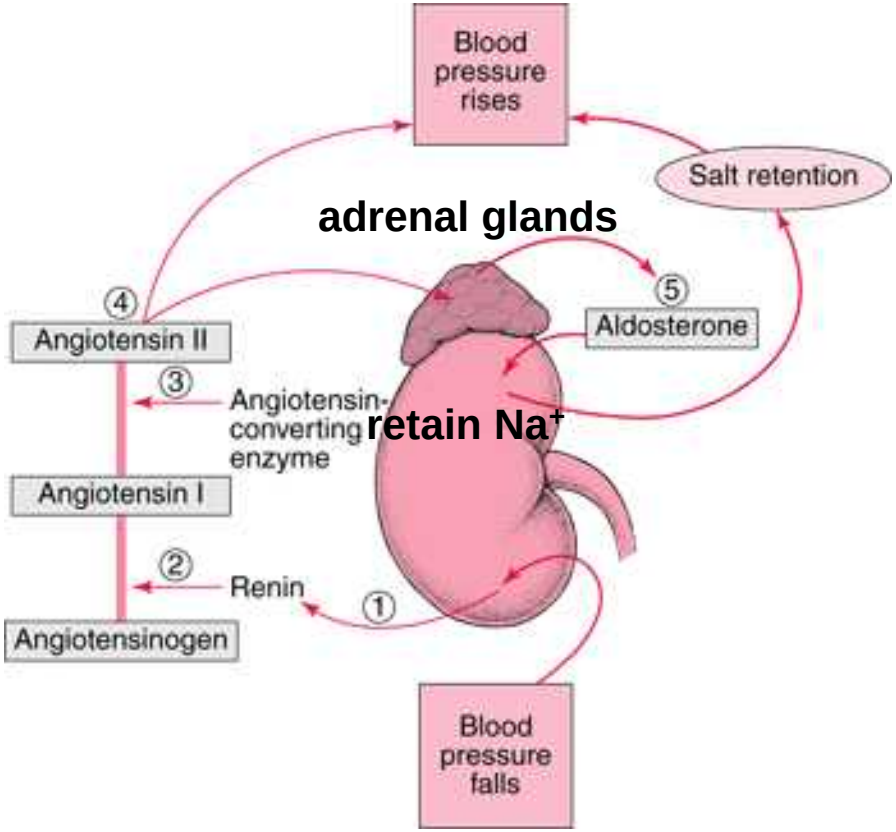
  → Angiotensin Ⅱ



PAI-1: Plasminogen activator inhibitor-1, inhibits fibrinolysis

Renin-angiotensin system (RAS)

- **Angiotensin Ⅱ can stimulate the release of aldosterone.**
- ***Renin-angiotensin system*** **regulates blood pressure and water (fluid) balance.**

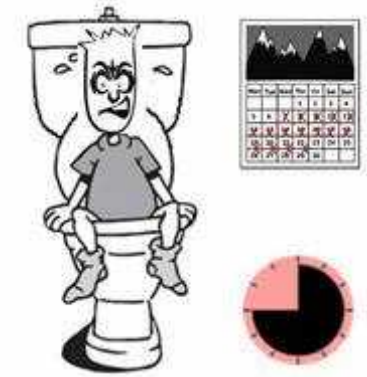


Dehydration

- **Dehydration** is condition characterized by water depletion in body. It may be due to insufficient intake or excessive water loss or both.

- Two types:

1. due to loss of water alone.
2. Due to deprivation of water and electrolytes.



- **Causes of dehydration:**

1. Diarrhea
2. Vomiting
3. Excessive sweating
4. Adrenocortical dysfunction
5. Kidney disease
6. Deficiency of ADH

Characteristic feature of dehydration

•Features of dehydration

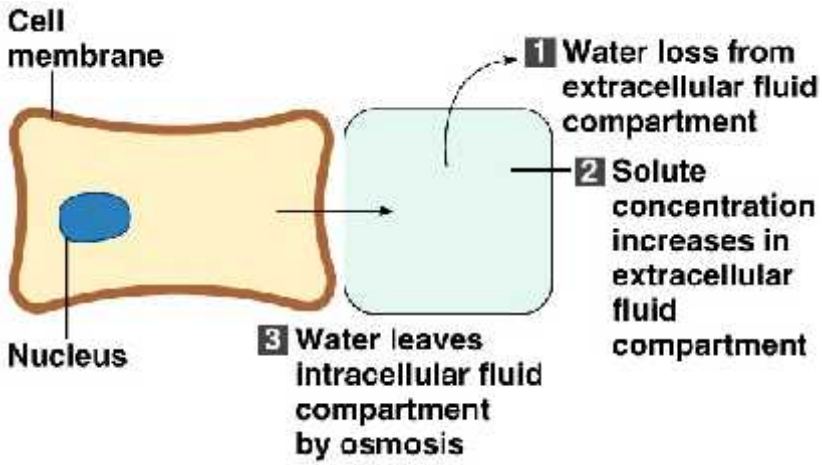
a) The volume of ECF decrease, electrolytes concentration and osmotic pressure increase.

b) Water is drawn from the ICF, shrunken cells and disturbed metabolism.

c) ADH secretion is increased.

d) Plasma protein and blood urea concentration increased.

e) Loss of electrolytes from the body (Na^+, K^+, etc.).



Clinical symptoms of sever dehydration

•Increased pulse rate, Low blood pressure, Sunken eyeballs, Decreased skin turgor, Lethargy, Confusion and coma

•**Treatment:** intake plenty of water, 5% glucose solution.

Overhydration

Overhydration or water intoxication is caused by excessive retention of water in the body. It may be due to excess intake or large volumes of salt free fluids, renal failure, overproduction of ADH.

Clinical syndromes: headache, lethargy and convulsions.

Treatment: stop water intake, administration of hypertonic saline.

Points

- **Function of water**
- Distribution of water: ICF and ECF
- **Electrolyte composition of body fluids**
- **Regulation of electrolyte balance**
  - ***aldosterone, ADH (Antidiuretic hormone) and renin-angiotensin***
- **Dehydration and Overhydration**