

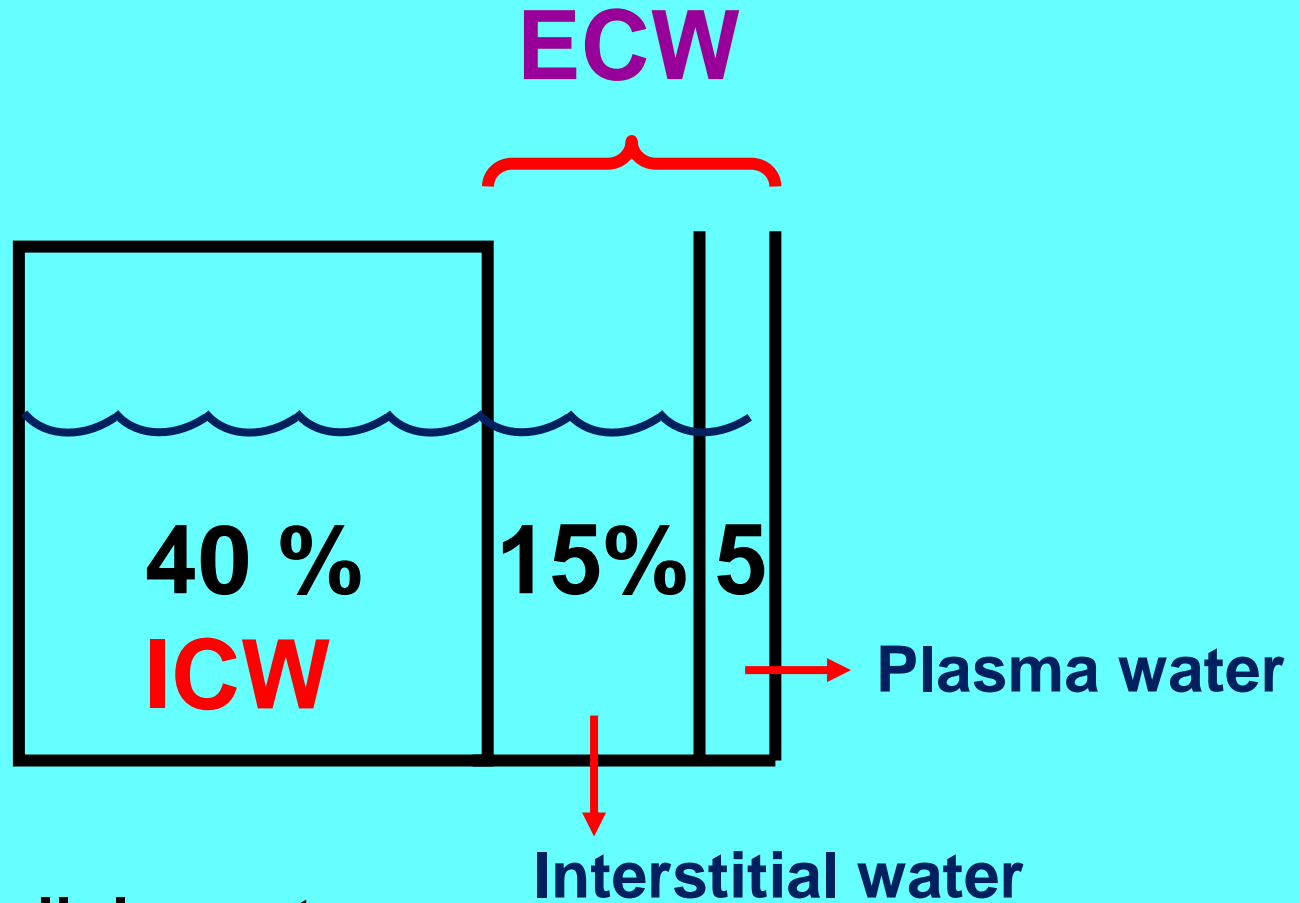
**Kuliah**

**KESEIMBANGAN  
AIR & ELEKTROLIT**

**Oleh :  
dr. Diah Hermayanti, SpPK**

# Total body water : **60 %** Body Wt

ADULT

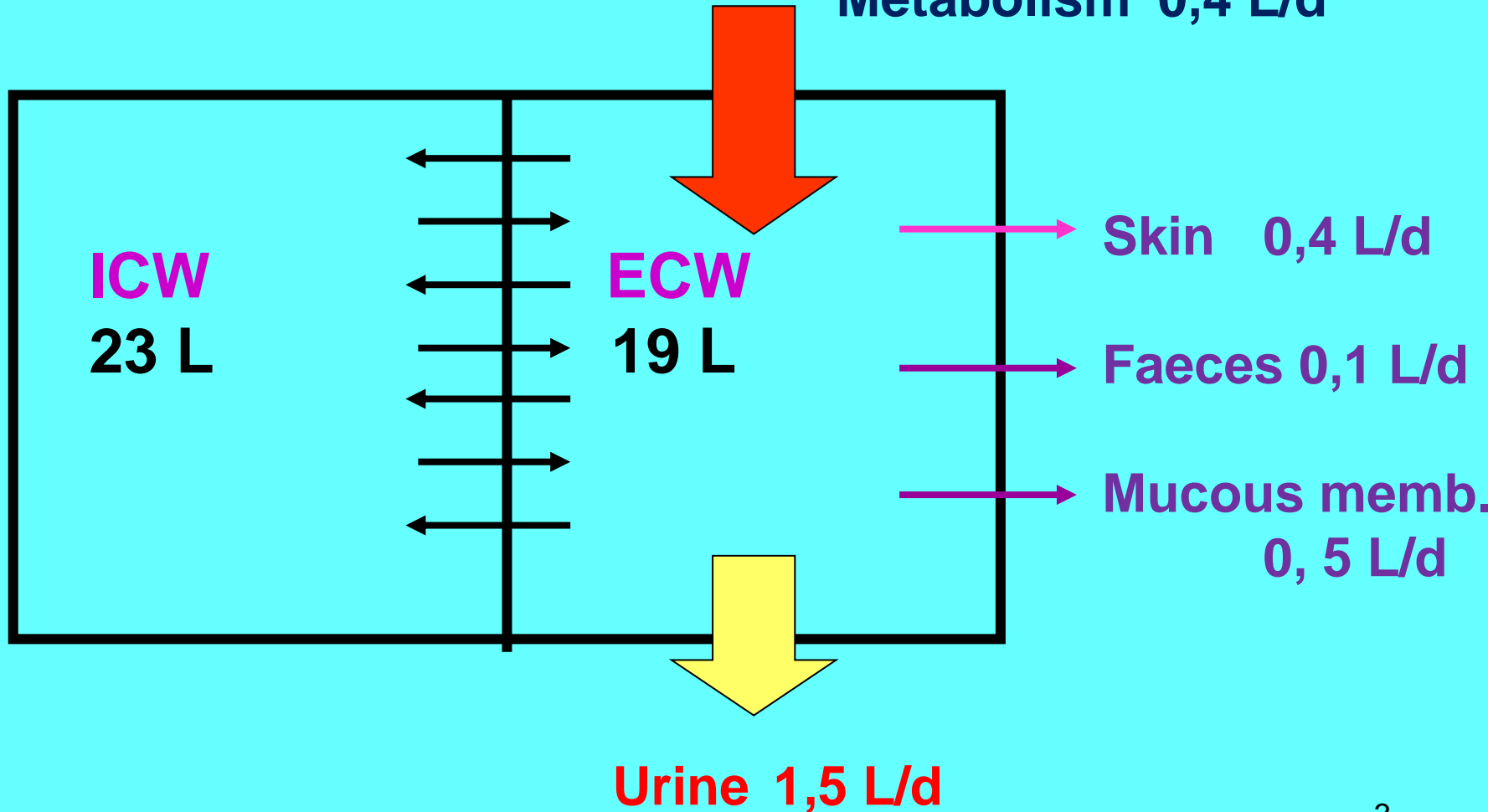


ICW : intracellular water

ECW : extracellular water

# WATER BALANCE

Fluid 1,4 L/d  
Food 0,7 L/d  
Metabolism 0,4 L/d



# ELEKTROLIT TUBUH

## ANION (ion negatif )

Cl<sup>-</sup>                      HPO<sub>4</sub><sup>2-</sup>  
HPO<sub>4</sub><sup>2-</sup>                SO<sub>4</sub><sup>-</sup>  
HCO<sub>3</sub><sup>-</sup>  
Laktat



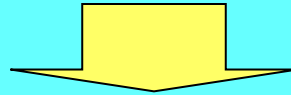
## KATION (ion positif)

Na<sup>+</sup>                      K<sup>+</sup>  
Ca<sup>++</sup>                    Mg<sup>++</sup>  
Trace element

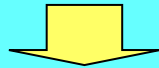
Elektrolit utama / Profil elektrolit :

Na<sup>+</sup> , K<sup>+</sup> , Cl<sup>-</sup> , HCO<sub>3</sub><sup>-</sup>

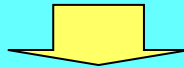
# **Pengaturan Volume ECW & Osmolalitasnya :**



**Mekanisme pengaturan**



**VOLUME AIR &  
KANDUNGAN ELEKTROLIT:**



## **1. Pengaturan Osmotik :**

**Pusat haus (hipotalamus anterior)**

**Antidiuretic hormone (ADH)**

## **2. Pengaturan Volume (Aldosteron)**

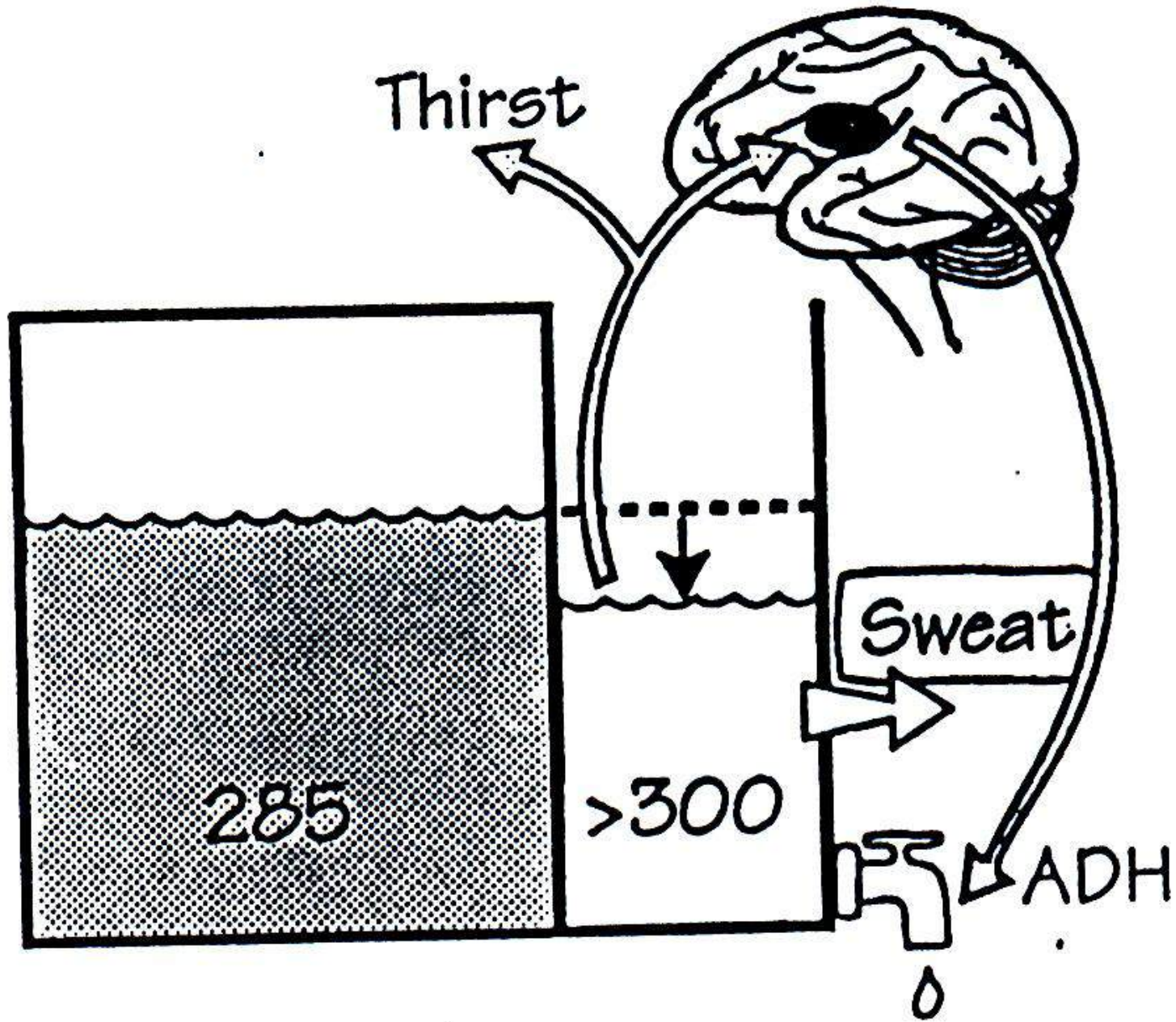
# FAKTOR-FAKTOR YG MEMPENGARUHI KESEIMBANGAN AIR

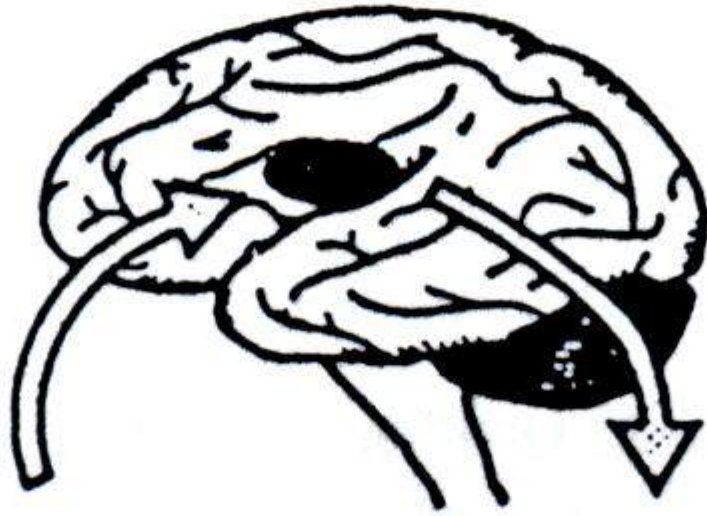
**INPUT**

**KESEIMBANGAN AIR**  
Osmolalitas ECW  
 $\approx 285 - 298 \text{ mOsm/L}$

**OUTPUT**

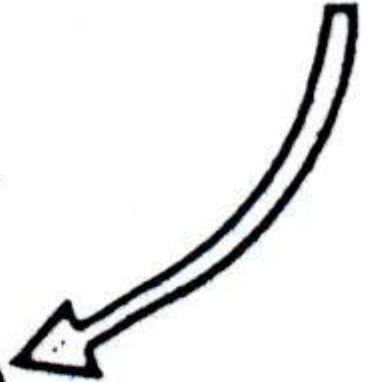
**Hipotalamus : ADH**  
**Aldosteron**  
**Renin-angiotensin**  
**Atrial natriuretik ginjal**





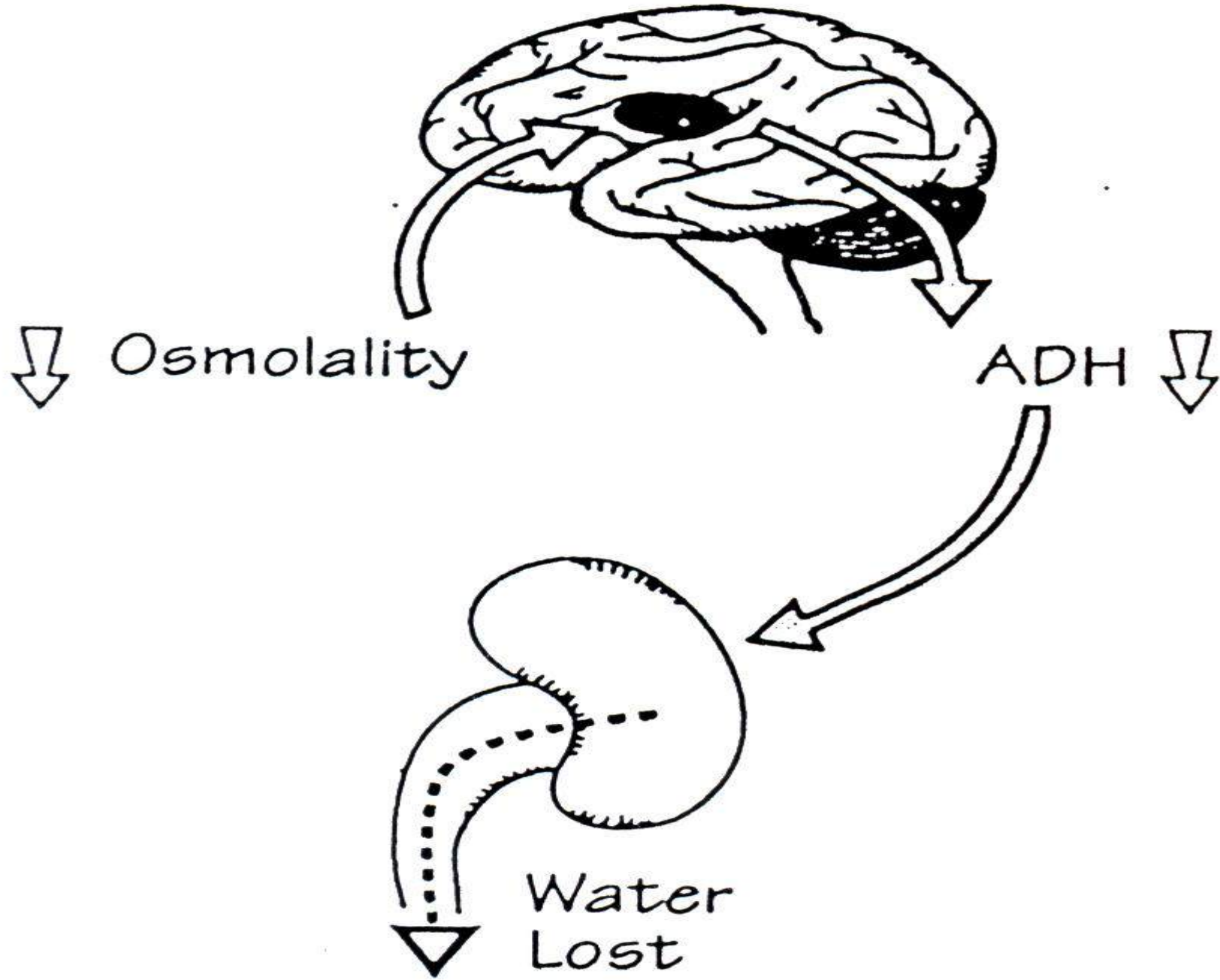
↑ Osmolality

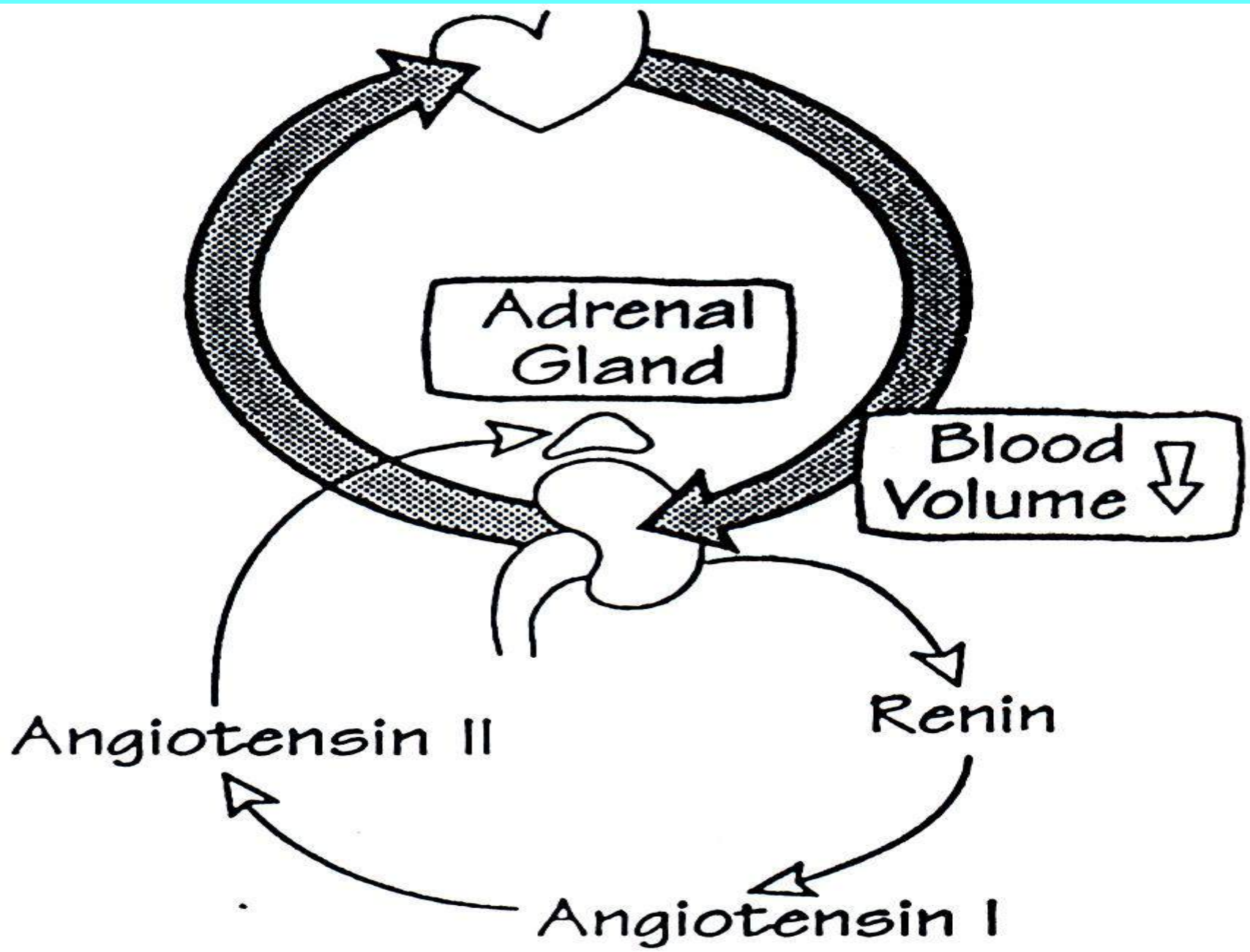
ADH ↑

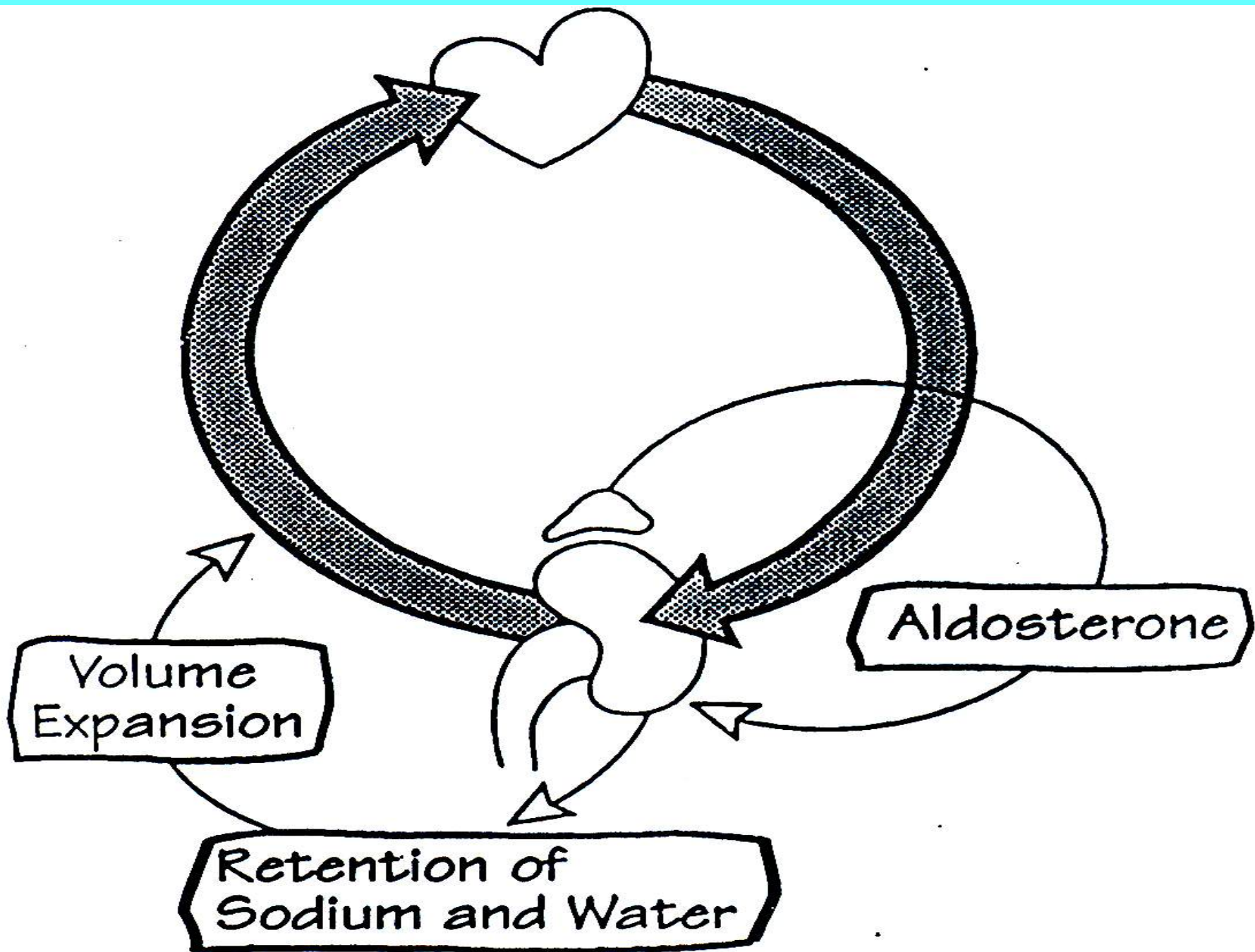


Water Retained

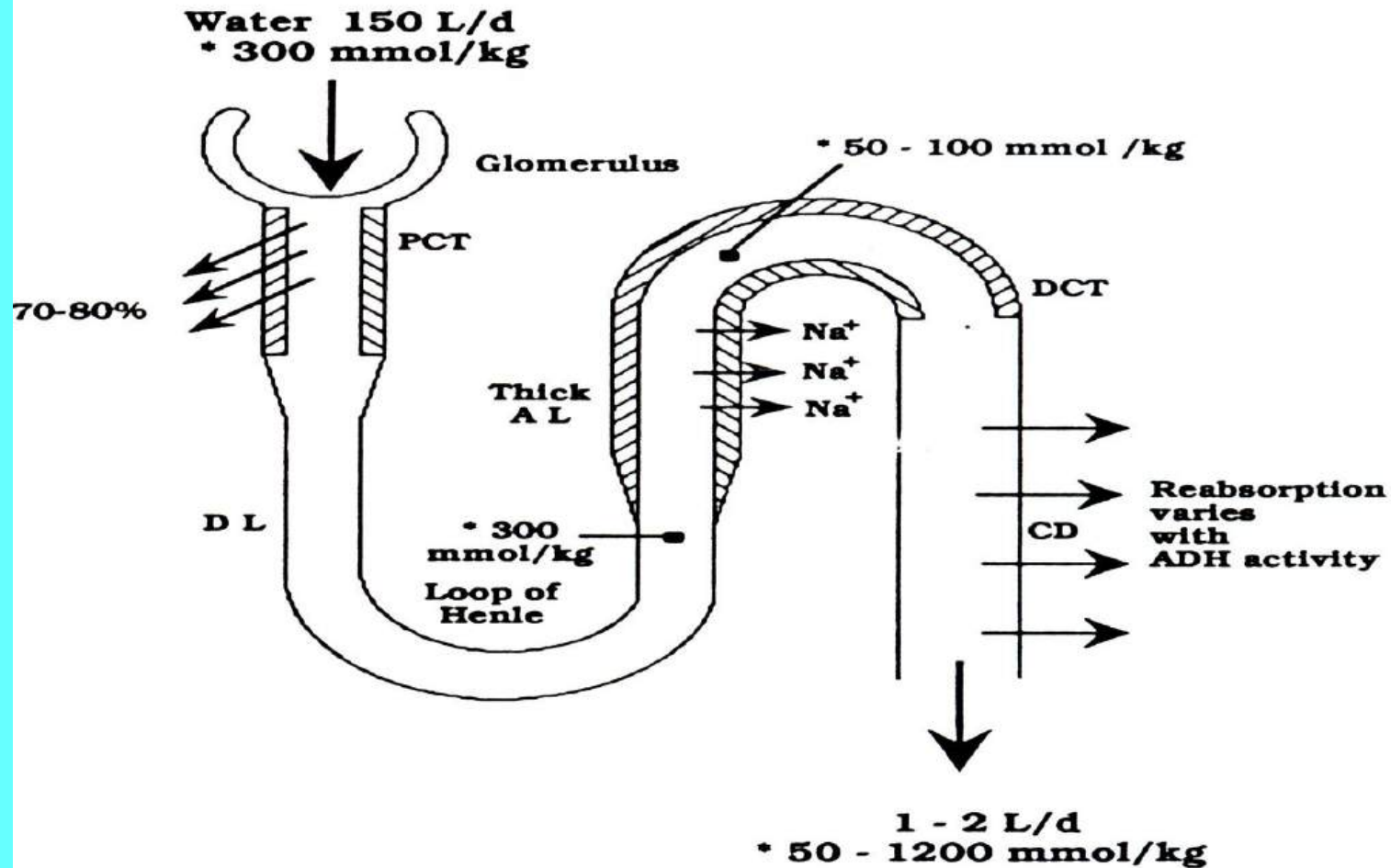








# RENAL WATER EXCRETION



\* refers to osmolality

**Figure 1.2** Renal water excretion

*PCT, proximal convoluted tubule; DCT, distal convoluted tubule; CD, collecting duct; DL, descending limb; AL, ascending limb*

# RENAL SODIUM EXCRETION ( $\text{Na}^+$ )

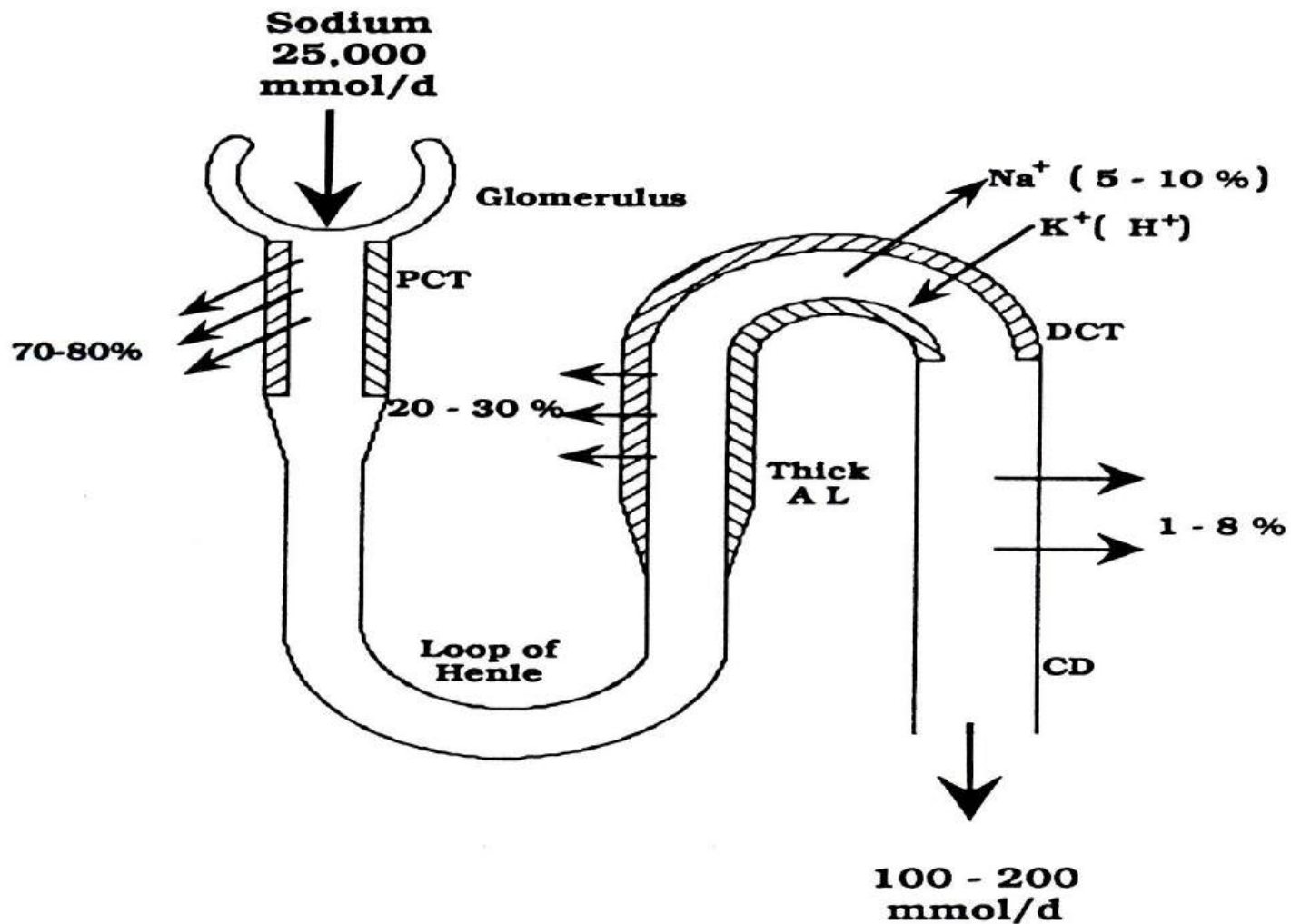


Figure 1.3 Renal sodium excretion

PCT, proximal convoluted tubule; DCT, distal convoluted tubule; CD, collecting duct; AL, ascending limb

# **GANGGUAN KESEIMBANGAN AIR & NATRIUM (SODIUM)**

**Gangguan homeostasis air & natrium saling berkaitan erat, shg dibicarakan bersama-sama**

## **1. Dehidrasi**

- \* Dehidrasi hipernatremi**
- \* Dehidrasi hiponatremi**
- \* Dehidrasi normonatremi**

## **2. Overhidrasi**

## **Gejala dehidrasi :**

- rasa haus**
- membran mukosa kering**
- turgor kulit turun**
- out put urin turun**
- osmolaritas urin meningkat**
- urea darah meningkat**
- hematokrit meningkat**

## **Lebih berat lagi :**

- lemah, letargi, hipotensi, syok**

## **PENYEBAB DEHIDRASI HIPER- Na :**

- kurang makan & minum
- keringat >>
- osmotik diuresis
- pengobatan diuresis

## **PENYEBAB DEHIDRASI HIPO- Na :**

- pengobatan diuretik
- keringat >>
- penyakit ginjal
- insufisiensi adrenokortikal

## **PENYEBAB DEHIDRASI NORMO – Na :**

- muntah – diare
- penggantian cairan dg larutan rendah natrium



# **OVER – HIDRASI** **(TBW ↑, Na<sup>+</sup> normal)**

- Polidipsia (intake air berlebihan)**
- SIADH (Syndrome inappropriate ADH)**
- Gagal ginjal dg oliguria**
- Sindroma nefrotik**
- Sirosis**
- Gagal jantung kongestif**
- Hiperaldosteronisme**

## **GEJALA :**

**nausea, vomiting, seizures, koma**

# NATRIUM / SODIUM

-Kation mayor di ECW (mempertahankan distribusi air & tekanan osmotik ECW)

-Kandungan normal

\* tubuh total : 55 mmol/kgBB

\* plasma : 135 – 145 mmol/L

**INTAKE**  
Natrium  
250-200  
Mmol/hr

**KESEIMBANGAN**  
Natrium  
\*plasma  
\*sel/jaringan

**OUTPUT :**  
\*Kulit/keringat  
50 mmol/hr  
\*gastrointestin  
1-2 mmol/hr  
\*ginjal : utama

# **HIPONATREMI**

**(Plasma natrium < 130 mmol/l)**

## **Classification :**

- 1. Euvolaemic : retention of water**
- 2. Hypovolaemic : water & salt depletion which is replaced with pure water & evidence of volume depletion**
- 3. Hypervolaemic : water & salt excess with water excess greater than sodium excess**

# CAUSES OF HYPONATREMIA

## **EUVOLAEMIC:**

- \* **Pseudohyponatremia : hyperlipidemia, hyperproteinemia**
- \* **Excess intracellular solute (hypertonic hyponatremia) :  
hyperglycemia**
- \* **Acute water overload (hypotonic hyponatremia) :  
drugs : chlorpromazine, barbiturat, diuretic,ect  
stress : post-surgery, psychogenic  
endokrin disorders : hypothyroidism  
renal insufficiency**
- \* **Chronic water overload :  
SIADH (syndrome of inappropriate secretion  
of ADH )  
drugs  
chronic renal failure  
endocrine disorders : hypothyroidism, cortisol  
deficiency**

## **HYPOVOLAEMIA :**

- \* Extrarenal causes :**

  - gastrointestinal : vomiting, diarrhea**

  - skin : burns, severe sweating**

- \* Renal causes :**

  - diuretic therapy**

  - Addison's disease**

  - salt-losing nephritis**

## **HYPERVOLEMIA :**

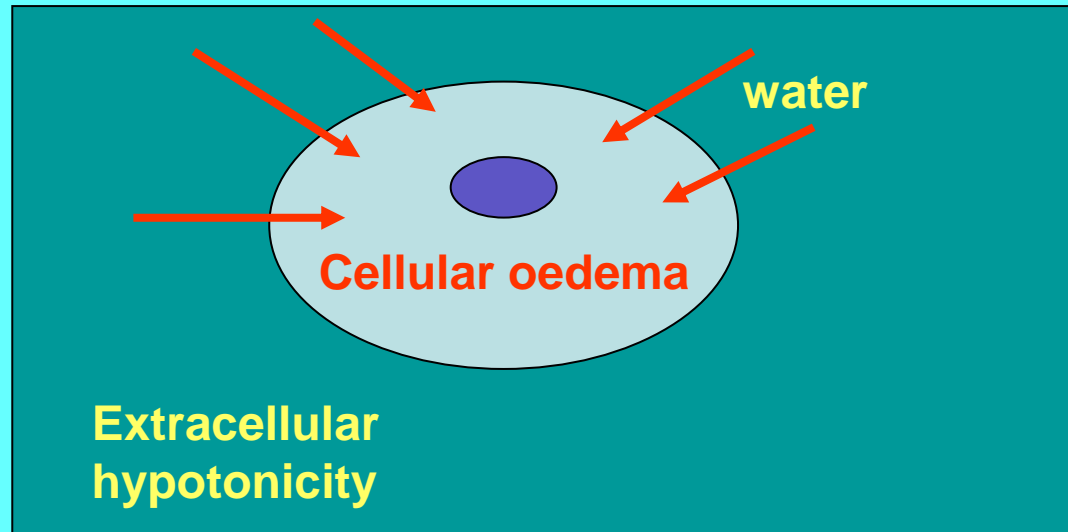
- \* Oedematous condition :**

  - congestive cardiac failure**

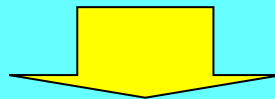
  - nephrotic syndrome**

  - liver cirrhosis**

## AKIBAT DARI HIPONATREMIA



- **Sel otak** : **oedem** selular sel otak (cerebral oedema) (tulang tengkorak yg rigid)

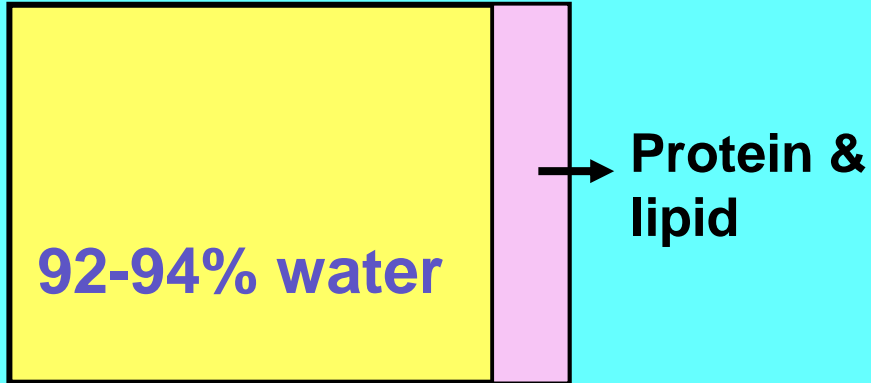


**INTRACRANIAL PRESSURE ↑**

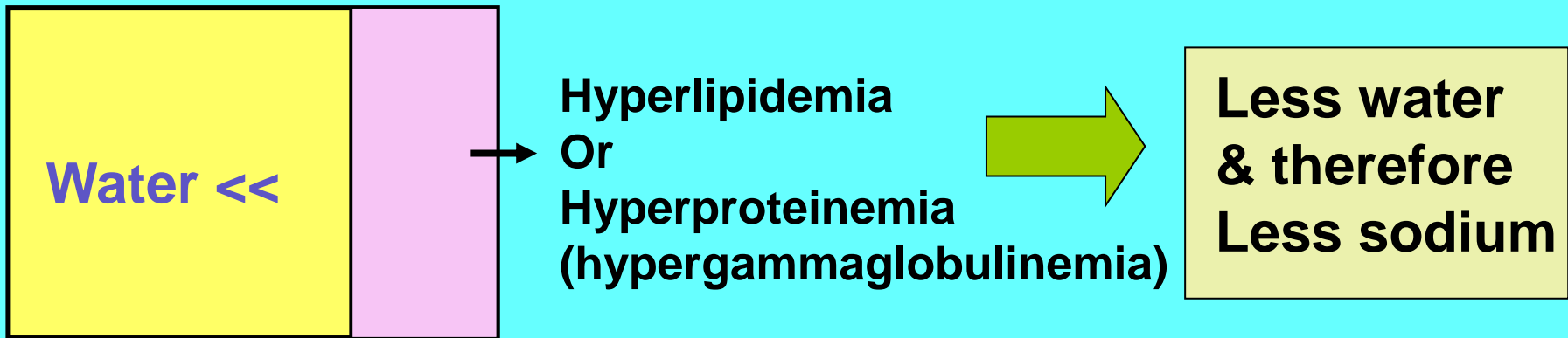
- **Sel organ lain** : tidak begitu berpengaruh

# PSEUDOHYPONATREMIA

Plasma normal



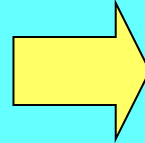
Pseudohyponatremia



# SYNDROME OF INAPPROPRIATE OF ADH (SIADH)

Inappropriate increase of ADH activity, because :

\* hypo-osmolality  
\* extracellular volume



Both of which should  
Suppress  
ADH secretion

## Features :

1. Hyponatremia
2. Hypo-osmolality of the plasma
3. Increased urinary osmolality
4. High random urine  $(\text{Na}^+)$   $> 20 \text{ mmol/l}$

To differentiate SIADH from the other causes of hypo-Na :

- No dehydration
- no drug therapy
- No cardiac, adrenal, pituitary, or thyroid dysfunction
- Respond to a restricted fluid intake ( $< 500 \text{ ml/day}$ )



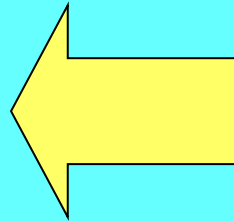
# HIPERNATREMIA

(Plasma Na<sup>+</sup> : > 145 mmol/l)

(Jarang, selama pusat haus tidak terganggu)

Penyebab : keseimbangan air yang negatif, disertai :

- \* normal
- \* menurun
- \* meningkat



**KANDUNGAN NATRIUM  
TUBUH TOTAL**

## KLASIFIKASI :

1. Normal body sodium :  
pure water depletion
2. Decreased body sodium :  
sodium & water depletion  
(water depletion > salt depletion)
3. Increased body sodium :  
salt gain

## **PURE WATER DEPLETION :**

- \* **Extrarenal causes**
  - too old, too young, too sick
  - access to water denied
  - oesophageal obstructions
  - thirst centre lesions
- \* **Renal causes : Diabetes insipidus**

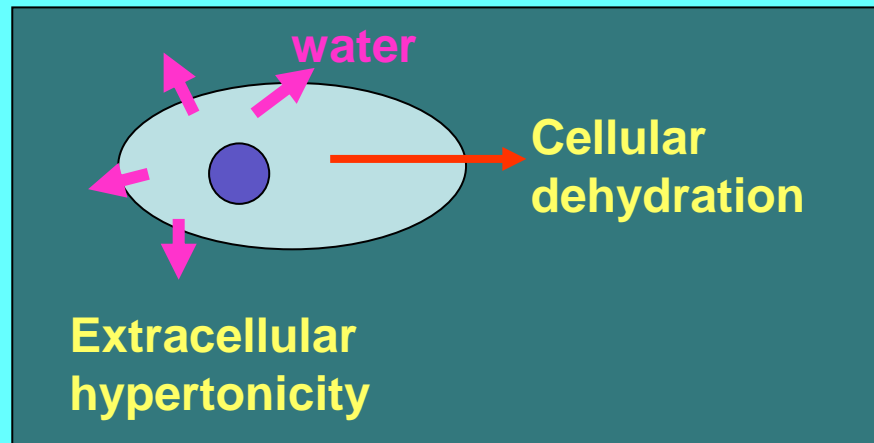
## **SODIUM & WATER DEPLETION :**

- \* **Gastrointestinal**
  - vomiting, diarrhoea
- \* **Skin : excessive sweating**
- \* **Osmotic diuresis : glucose, urea manitol**

## **SODIUM GAIN :**

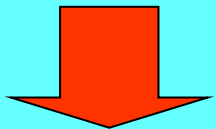
- \* **Iatrogenic : IV hypertonic saline or sodium bicarbonat**
- \* **Salt ingestion : intentional, accidental (sea water)**

# AKIBAT DARI HIPERNATREMI



**OTAK** → shrinkage

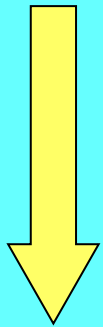
**HATI2** → PENURUNAN tonisitas harus **pelan-pelan**



Hindari aliran air kembali ke sel → **Oedema cerebral**

# KALIUM / POTASSIUM

Distribusi :

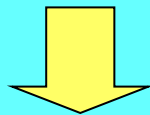


- intrasel (ICW)
- ECW (yang diukur)

98% : 150-160 mmol/l  
2% : 3,5 – 5,0 mmol/l

**Na<sup>+</sup> - K<sup>+</sup> - ATP PUMP**

mempertahankan ionic gradient



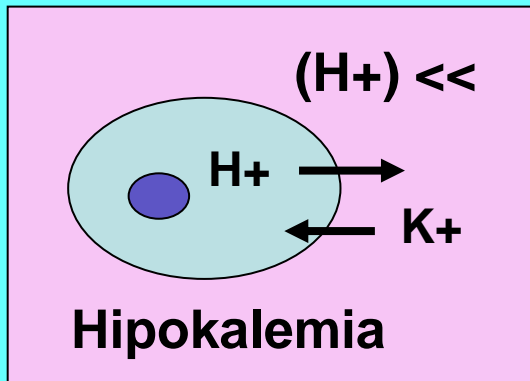
aktivitas neuromuscular

# FAKTOR YG MEMPENGARUHI TRANSFER KALIUM MELEWATI MEMBRAN SEL :

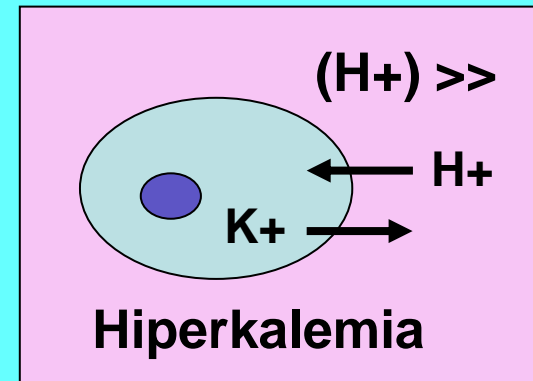
**1. K LOAD** : 50 % K dari luar (oral/IV)      **MASUK SEL**  
40 %      dibuang oleh ginjal

## 2. pH

### Alkalosis



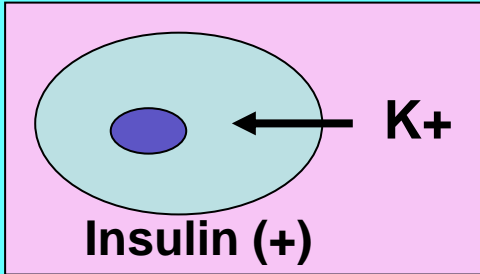
### Asidosis



**3. Aldosteron** :  $\uparrow$  up take extracellular  $K^+$   
by the distal renal tub. Cells

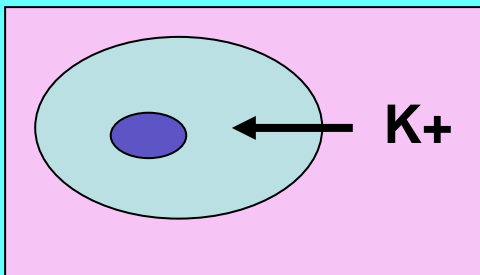
## 4. INSULIN

Insulin (+) → cellular K<sup>+</sup> uptake ↑



## 5. KATEKOLAMIN

Adrenalin & beta receptor agonist (salbutamol)



# **HYPERKALAEMIA**

## **(PLASMA (K<sup>+</sup>) > 4,8 mmol/l)**

### **CAUSES of HYPERKALAEMIA :**

- **Pseudohyperkalaemia : haemolysis, leucosytosis, thrombocytosis**
- **K-intake >> : - exogenous : oral / IV therapy**
  - **endogenous : tissue necrosis (crush injury, burns)**
- **Disturbed intracellular/extracellular distribution :**
  - **acidaemia**
  - **drugs : digoxin toxicity**
  - **insulin deficiency**
  - **hyperkalaemic periodic paralysis, etc**
- \* **Decreased renal K-excretion :**
  - **renal failure : acute / chronic**
  - **drugs : \* potassium-sparing diuretics : spironolactone**
    - \* **prostaglandin inhibitors : indometacin, ibuprofen**
    - \* **etc**
  - **mineralocorticoid deficiency synd**
  - **mineralocorticoid resistance synd**

## **AKIBAT HIPERKALEMIA**

- **Hiperkalemia ringan (<6 mmol/l) :**  
**gejala : symptomless**
- **Hiperkalemia berat (> 6 mmol/l) :**  
**gejala :**
  - gelisah, mental confusion**
  - kelemahan otot**
  - mual, muntah**
  - ileus paralitik**
  - parastesia**
  - cardiac arrhythmia, cardiac arrest**
  - perubahan ECG :**
    - ( T wave tinggi, QRS complex lebar,**
    - PR interval lebar)**



# **HYPOKALAEMIA**

**(Plasma (K+) < 3,5 mmol/l)**

## **CAUSES of HYPOKALAEMIA :**

### **Intake ↓**

- inappropriate IV therapy**
- anorexia nervosa**
- chronic alcoholism**

**•Transcellular shift : therapy insulin, salbutamol, vit B12**

### **•Extra renal loss :**

- vomiting**
- diarrhoeae : acute/chronic**
- laxative abuse**
- villous adenoma of colon, etc**

### **•Renal loss :**

- metabolic alkalosis**
- diuretic therapy**
- renal tubular acidosis**
- mineralocorticoid excess**
- Bartter's syndrome**
- miscellaneous : osmotic diuresis**

# Hypokalaemia periodic paralysis

- Paralisis otot periodik yg berhubungan dg hipokalemi
- Cellular potassium uptake >>  
Diinduksi oleh :
  - stress fisik
  - makan karbohidrat >>
  - kedinginan, dll
- Mekanisme : ??

## **AKIBAT HIPOKALEMIA**

- Kelemahan otot
- Fatigue & apathy
- reflek tendon <<
- takikardia, cardiac arrhythmia, cardiac arrest
- Hipotensi, postural hipotensi
- Sensitifitas thdp digitalis >>
- Perubahan ECG :
  - T wave deplesi / inversi
  - ST depletion
  - muncul gelombang U (pada kasus berat)
  - QT & QRS complex melebar

# **KLORIDA (Cl<sup>-</sup>)**

**-Kadar serum / plasma : 98-107 mmol/l**

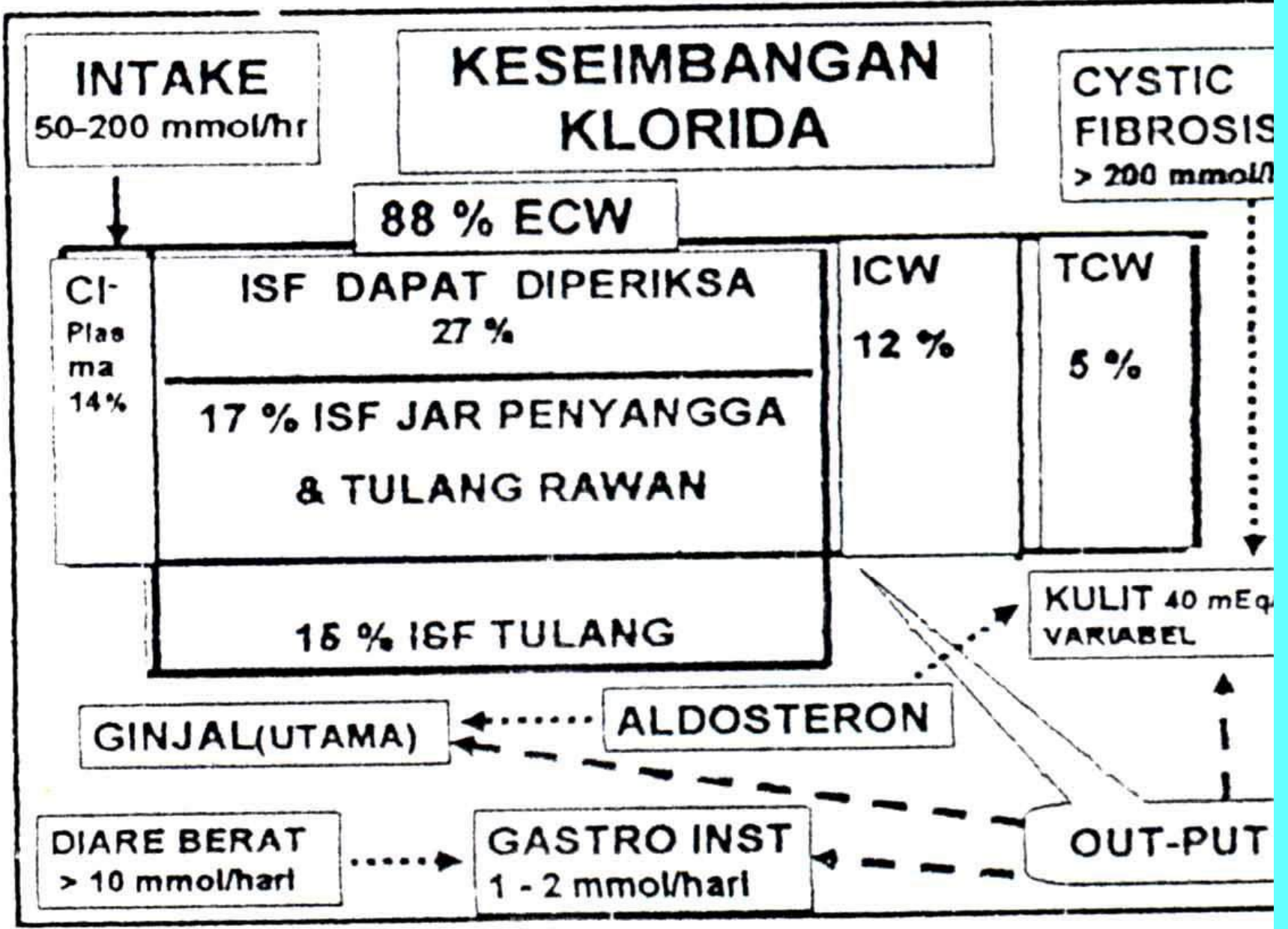
**-Penyebab kelainan Cl sesuai dg kelainan Natrium  
Namun : simptom lebih mengarah pd kelainan Na  
kecuali pada :**

**Asidosis metabolik kronik :**

**hiperkloremi tanpa hipernatremia**

**Alkalosis metabolik kronik :**

**hipoklorida tanpa hiponatremia**



## METODA ANALISA KLORIDA

- Kolorimetri
- Koulometri titrasi
- Ion selective electrode (ISE)

### SAMPEL :

- Serum / plasma :  
normal 98 – 107 mmol/l
- Urine :  
normal 110-250 mmol/l

## METODA ANALISA Na<sup>+</sup> & K<sup>+</sup>

- ISE
- FAES
- Kolorimetri

### SAMPEL :

- Serum / plasma heparin
- Urine
- Cairan tubuh

Sampel hemolisis → / → K<sup>+</sup>

# KALSIUM

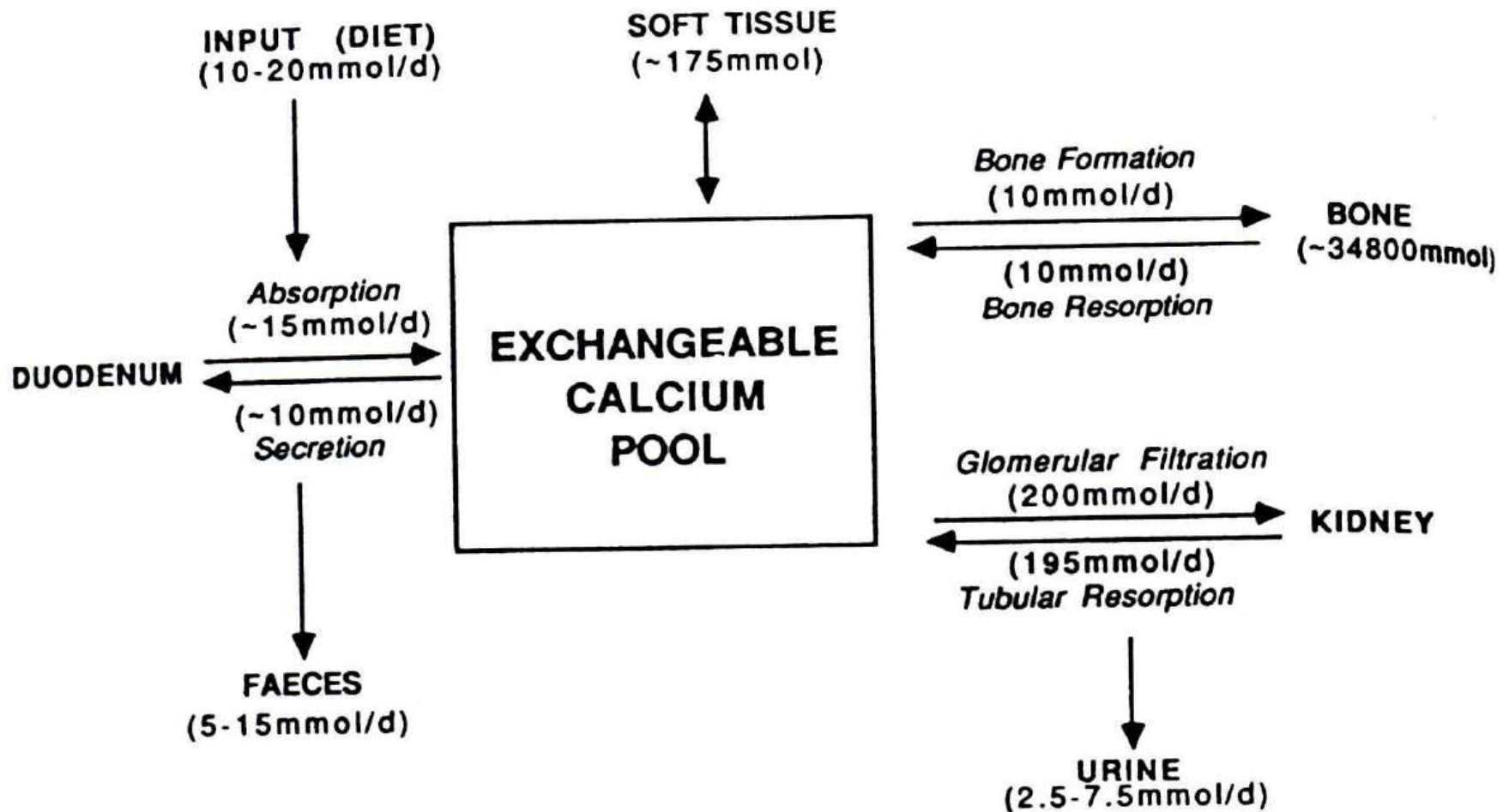
## FUNGSI :

- Mineralisasi
- Eksitabilitas neuromuskular
- Pembekuan darah
- Kontrol signal intra sel

## DISTRIBUSI :

Kalsium tubuh total 25 – 35 mol

- \* >99 % di tulang
- \* 0,5 % di jaringan lunak
- \* 0,1 % di ECW



**Figure 6.1** Distribution of body calcium



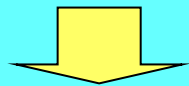
**Kalsium serum /plasma : 2,10 – 2,60 mmol/l**

- \* 40-45 % terikat protein ( tu. Albumin 80%)**
- \* 45-50 % ionised (ion aktif)**
- \* 5-10 % berikatan dg substansi lain (sitrat, fosfat, dll)**

**1 gr albumin  $\approx$  0,02 mmol ion  $\text{Ca}^{2+}$**



**penurunan 10 gr/l albumin**



**total kalsium serum  $\downarrow$  0,2-0,25 mmol/l**

# KONTROL KALSIUM

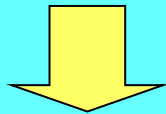
- **PARATHYROID HORMONE (PTH)**
- **VIT. D**

- **Kalsitonin**
- **Hormon thyroid**
- **Adrenocortical steroid**
- **Prostaglandins**
- **Osteoclast activity factor**

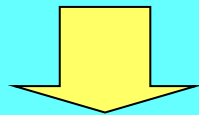
## PEMERIKSAAN KALSIUM :

- Kimiawi : total kalsium
- ISE : ION kalsium (langsung) (sampel anaerob)
- Atomic absorption spectrophotometry : total kalsium

Bila yg diukur adalah kalsium total



**ION KALSIUM BEBAS** masih harus diperhitungkan



$$\%Ca \text{ terikat protein} = 0,8 \times ALb(g/l) + 0,2 \text{ Glob} (g/l) + 3$$

## KOREKSI KALSIMUM

\* **Hiperalbuminemia :**

**[Ca<sup>2+</sup>] terkoreksi =**

$$\text{Total kalsium terukur (mmol/l)} - \{\text{Alb (g/l)} - 40\} \times 0,02$$

• **Hipoalbuminemia :**

**[Ca<sup>2+</sup>] terkoreksi =**

$$\text{Total kalsium terukur (mmol/l)} + \{40 - \text{Alb (G/L)}\} \times 0,02$$

# HIPERKALSEMIA

**Hiperkalsemia (Ca<sup>2+</sup>) plasma > normal  
(tidak spesifik) :**

**> 3 mmol/l : anorexia, nausea, vomiting, konstipasi,  
muscle weakness**

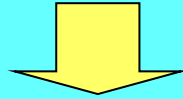
**> 4 mmol/l : stupor, koma**

**Deposit garam kalsium pada jaringan :**

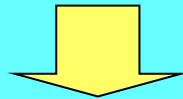
- deposit di konjunktiva**
- keratopathy band**
- nephrocalcinosis**
- renal calculi**

# HIPOKALSEMIA

**Hipokalsemia akut**



**Gangguan aktivitas neuromuscular**



- Muscle cramps**
- Perioral praesthesiae**
- Carpopedal spasms (tetany)**
- Convulsion (in infants)**