WATER AND ELECTROLYTE BALANCE

Role of water

- Water is a medium for a vast number of biochemical reactions that occur each moment, which form the basis of life
- Water solubilises various biomolecules such as proteins, nucleic acid and carbohydrates by forming hydrogen bond with them
- Apart from providing an aqueous medium, water act as strong nucleophile,directly participates as reactant in various metabolic reaction
- Water plays an important role in regulating body temperature

TABLE 35-2 Electrolyte and Water Composition of Body Fluid Compartments*

Component	Plasma	Fluid	
		Interstitial	Intracellular†
Volume, H_2O	~3.5 L	10.5 L	28 L
Na^+	142	145	12
K^+	~4	~4	156
Ca^{2+}	~6	2-3	~3
Mg^{2+}	~2	1-2	26
Trace elements	~1		
Total cations	155		
Cl^-	103	114	~4
HCO_3^-	27	31	12
$Protein^-$	16	—	55
$Organic\ acids^-$	~5	—	—
HPO_4^{2-}	~2		
SO_4^{2-}	~1		
Total anions	154		

TBW, *Total body water* = 42 L.

**All electrolyte values are expressed in mEq/L of fluid. Because the H_2O content of plasma is ~90% by volume, the corresponding electrolyte concentrations in plasma water are ~10% higher. Note that the molar concentration of divalent ions is one-half the depicted value.*

†*These values are derived from skeletal muscle.*

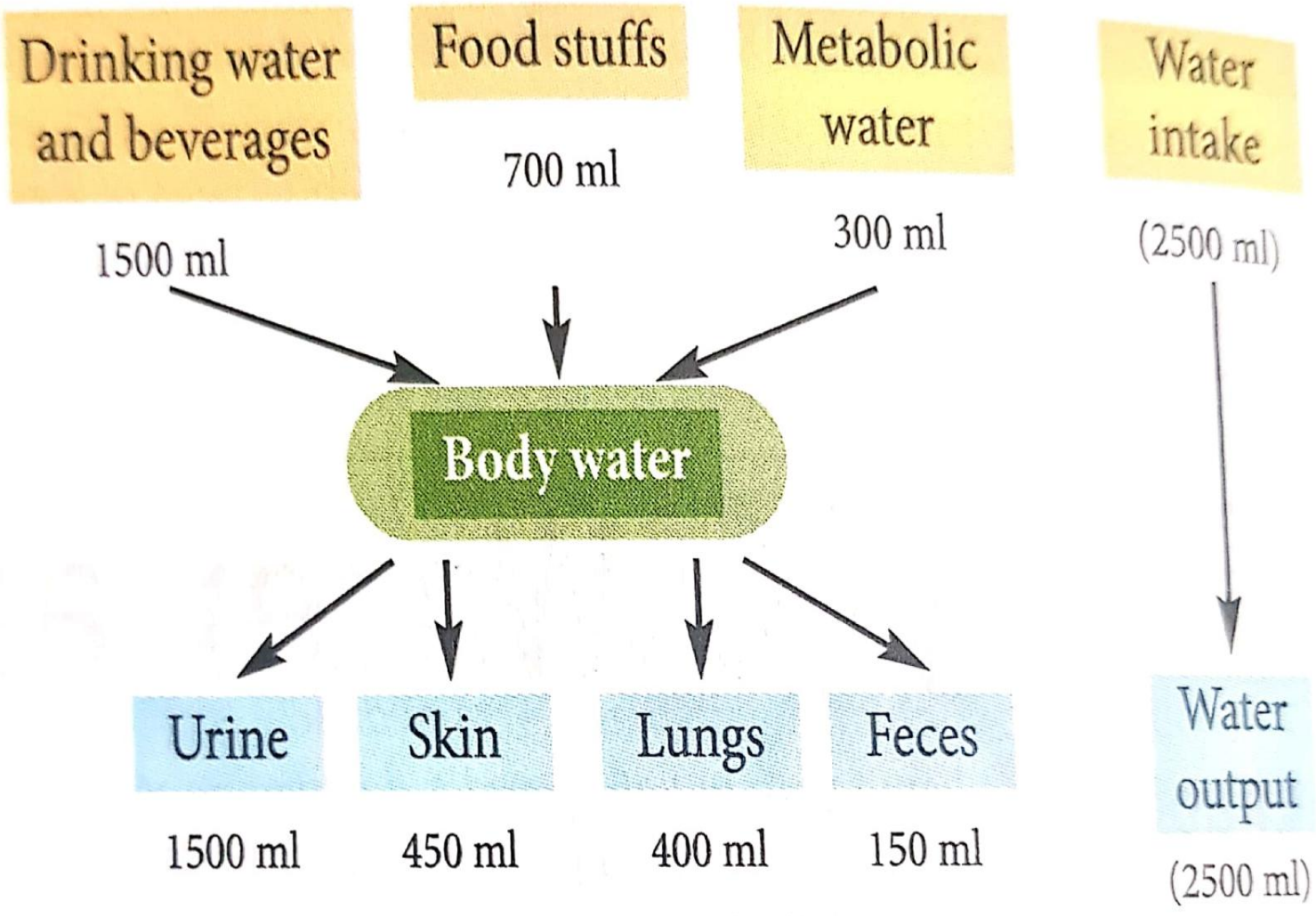


Fig. 23.1 *Water balance in humans.*

ELECTROLYTE – DISTRIBUTION AND BALANCE

- Electrolytes are the substances which readily dissociate in solution and exist in ionic form i.e. positively and negatively charged ions
- Electrolytes are well distributed in body fluids to maintain osmotic equilibrium and water balance
- Sodium is the principal cation of ECF,while potassium is the chief cation of ICF
- Chloride and bicarbonate are the principal anion of ECF,while phosphate is the chief anion of ICF

- The total concentration of cations and anions in each body compartment is equal in order to maintain electrical neutrality
- The concentration of molecules in body fluids are mainly expressed in terms of osmolality and osmolarity
- Osmolality : osmotic pressure exerted by number of moles per kg of solvent
- Osmolarity :osmotic pressure exerted by number of moles per litre of solution
- The osmolality of plasma is in the range of 280-300mosmo/kg

Table 23.2 *Constituents contributing to plasma osmolality*

Name of the constituent	Osmolality (mosm/kg)
Sodium	135
Associated anions	135
Potassium	3.5
Associated anions	3.5
Calcium	1.5
Associated anions	1.5
Magnesium	1.0
Associated anions	1.0
Glucose	5.0
Urea	5.0
Protein	1.0
Total	**293**

- Sodium and its associated anions makes the largest contribution to plasma osmolality
- It is measured by osmometer
- osmolality = $2(Na^+)+2(K^+)+(glucose)+(urea)$

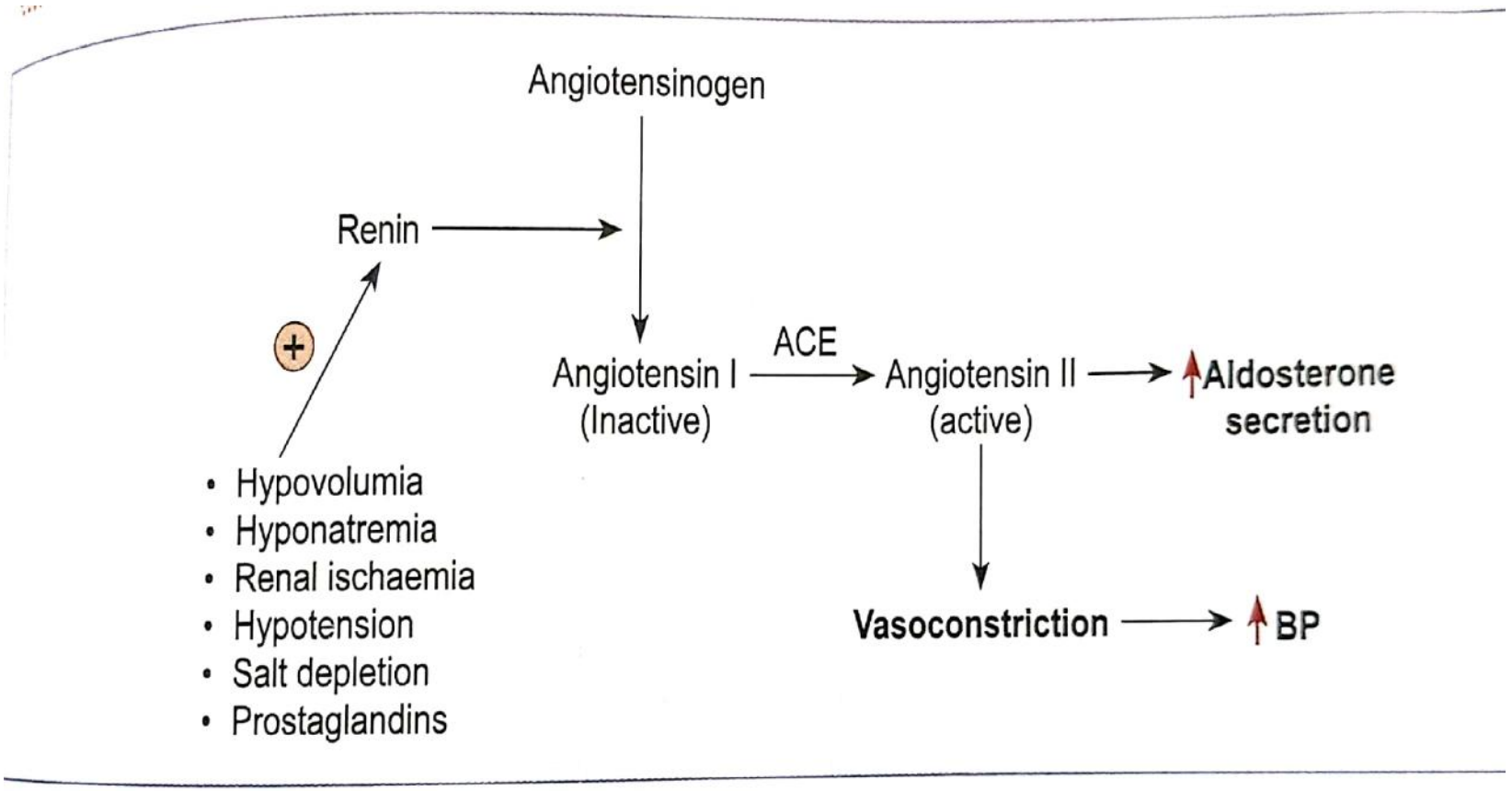
Regulation of water and electrolyte balance

- Kidney play a major role in the regulation of electrolyte and water balance
- The regulation is maintained by the hormones aldosterone,ADH and renin-angiotensin
- Aldosterone is a mineralcorticoid produced by the zona glomerulosa of the adrenal cortex in response to angiotensin II derived by the action of renin

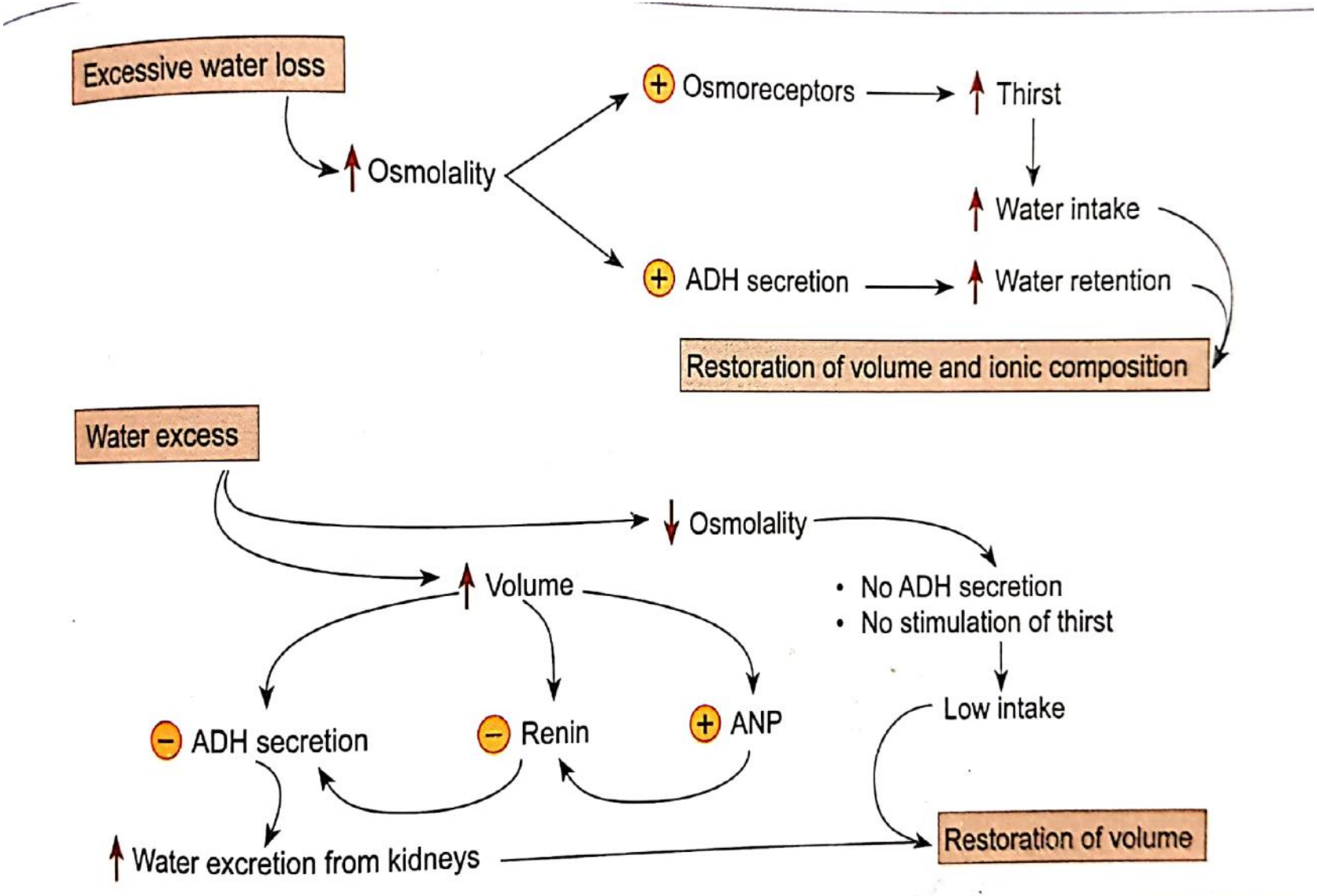
Renin-Angiotensin system

- The secretion of aldosterone is regulated by the renin-angiotensin system

- When there is fall in ECF volume, renal plasma flow decreases and this would be sensed by the juxtaglomerular apparatus of the nephron which secrete renin



IG. 48.2: Renin-angiotensin system



IG. 48.3: Regulation of water balance

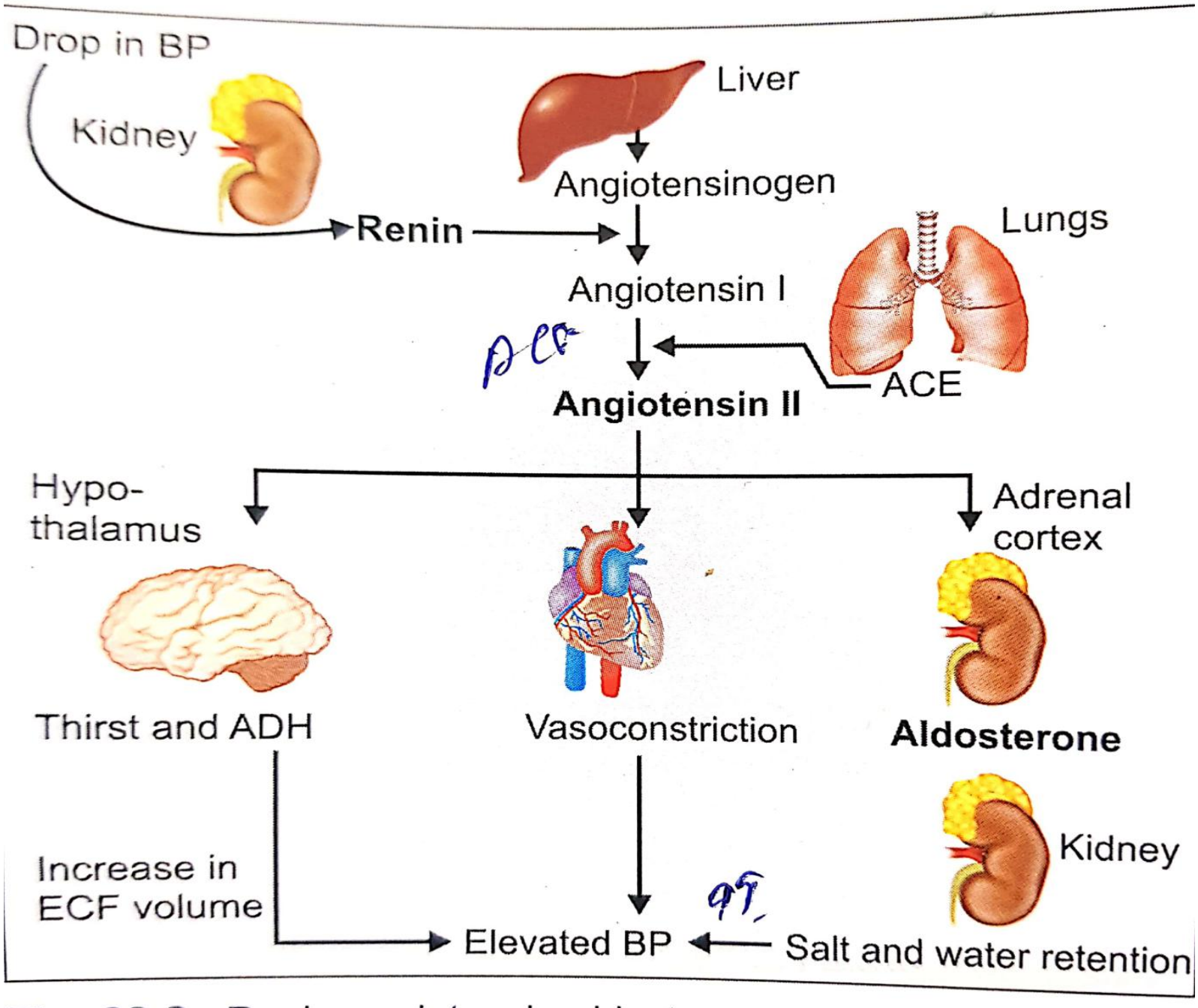


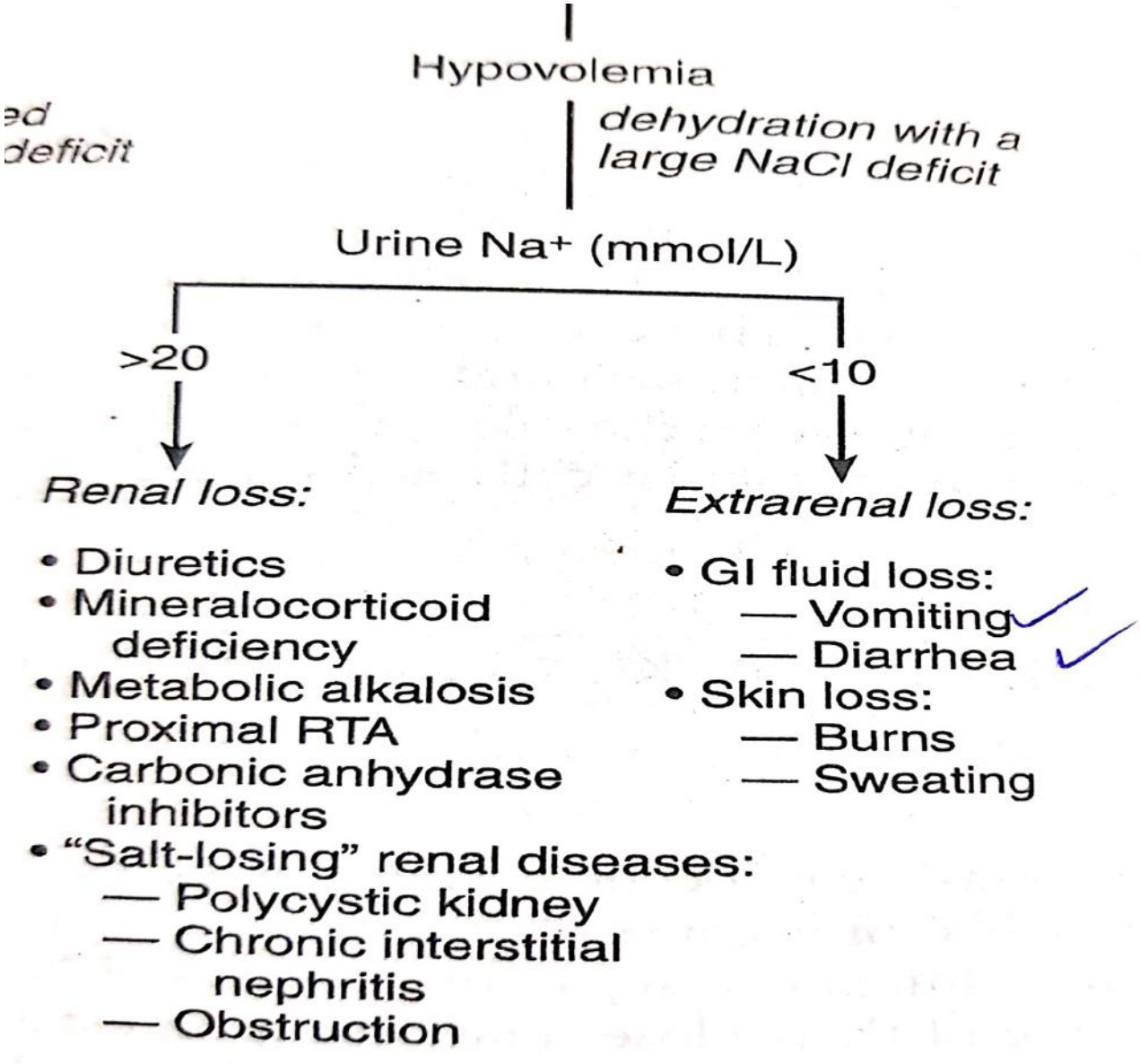
Fig. 28.2: Renin-angiotensin-aldosterone

Hyponatremia

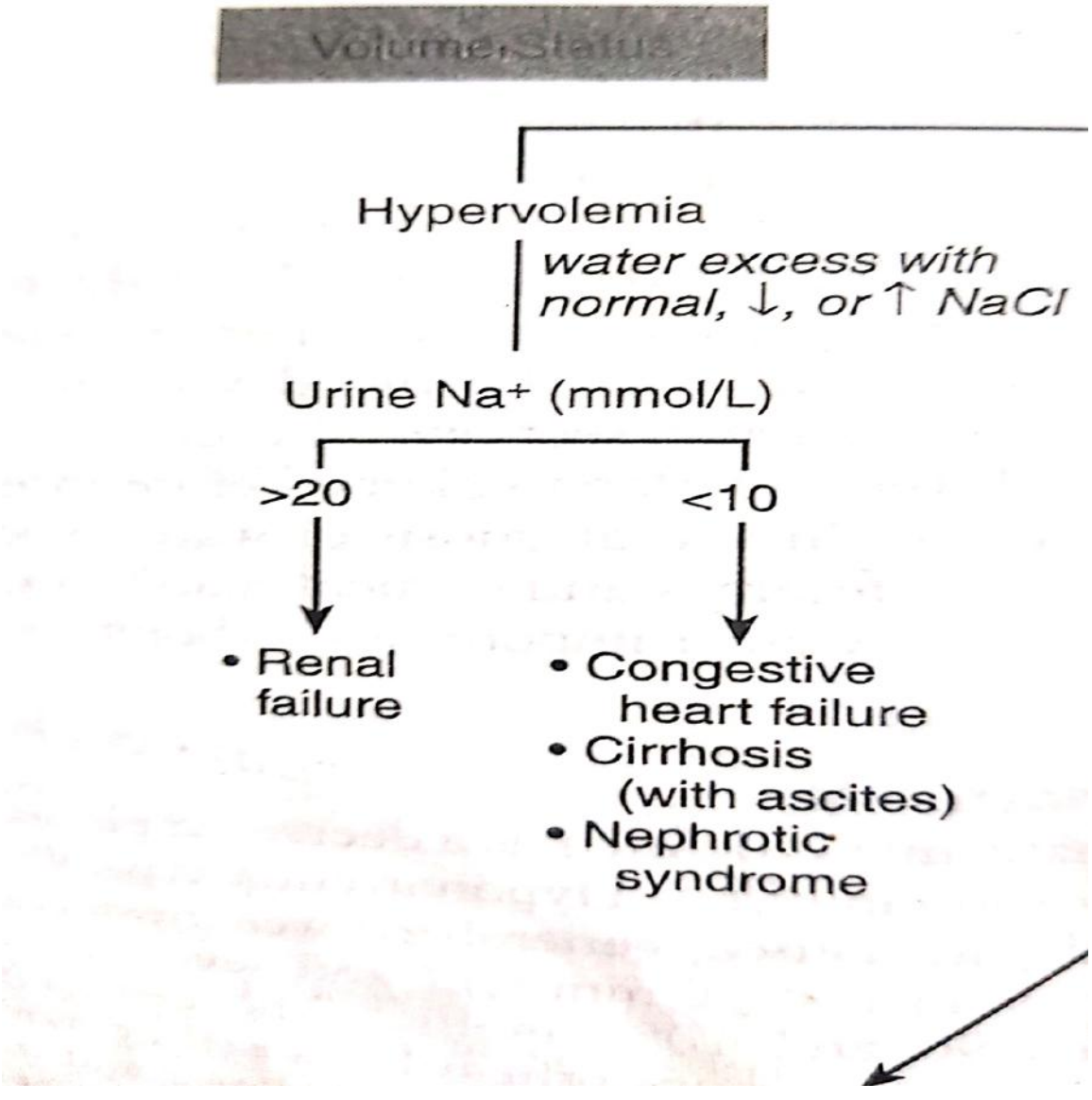
- Hyponatremia is defined as decrease plasma sodium concentration below 136 meq/l
- Hyponatremia typically manifests itself clinically as nausea,genarlized weakness and mental confusion at value below 120 meq/l
- The central nervous system symptoms are primarily caused by movement of water in to cells to maintain osomotic balance and thus swelling of CNS cells
- Hyposmotic Hyponatremia
- Hyperosmotic Hyponatremia
- Isosmotic Hyponatremia

Hyposmotic Hyponatremia

- This type of hyponatremia can be result of either excess loss of sodium (depletional hyponatremia) or increased ECF volume (dilutional hyponatremia)
- Differentiating these initially requires a clinical assessment of TBW and ECF volume
- Depletional hyponatremia is almost accompanied by a loss of ECF water, but to a lesser extent than sodium loss



- Dilutional hyponatremia is a result of excess water retention and can often be detected during physical examination as presence of weight gain or edema



Hyperosmotic Hyponatremia

- Hyponatremia occurs with an increased amount of other solutes in the ECF,causing an extracellular shift of water or intracellular shift of sodium to maintain osmotic balance between ECF and ICF
- The most common cause of this type of hyponatremia is severe hyperglycemia
- As a general rule,the Na+decreases by 1.6 mmoles/l for every 100 mg/dl increase of glucose above 100 mg/dl
- The clinical use of mannitol for osmotic diuresis can have similar effect

Isosmotic Hyponatremia

- If the measured sodium concentration in plasma is decreased,but measured plasma osmolality,glucose,urea are normal ,the only explanation is pseudohyponatremia

- This occurs when sodium is measured by an indirect ion selective electrode in patient with severe hyperlipidemia or in state of hyperproteinemia caused due to multiple myeloma

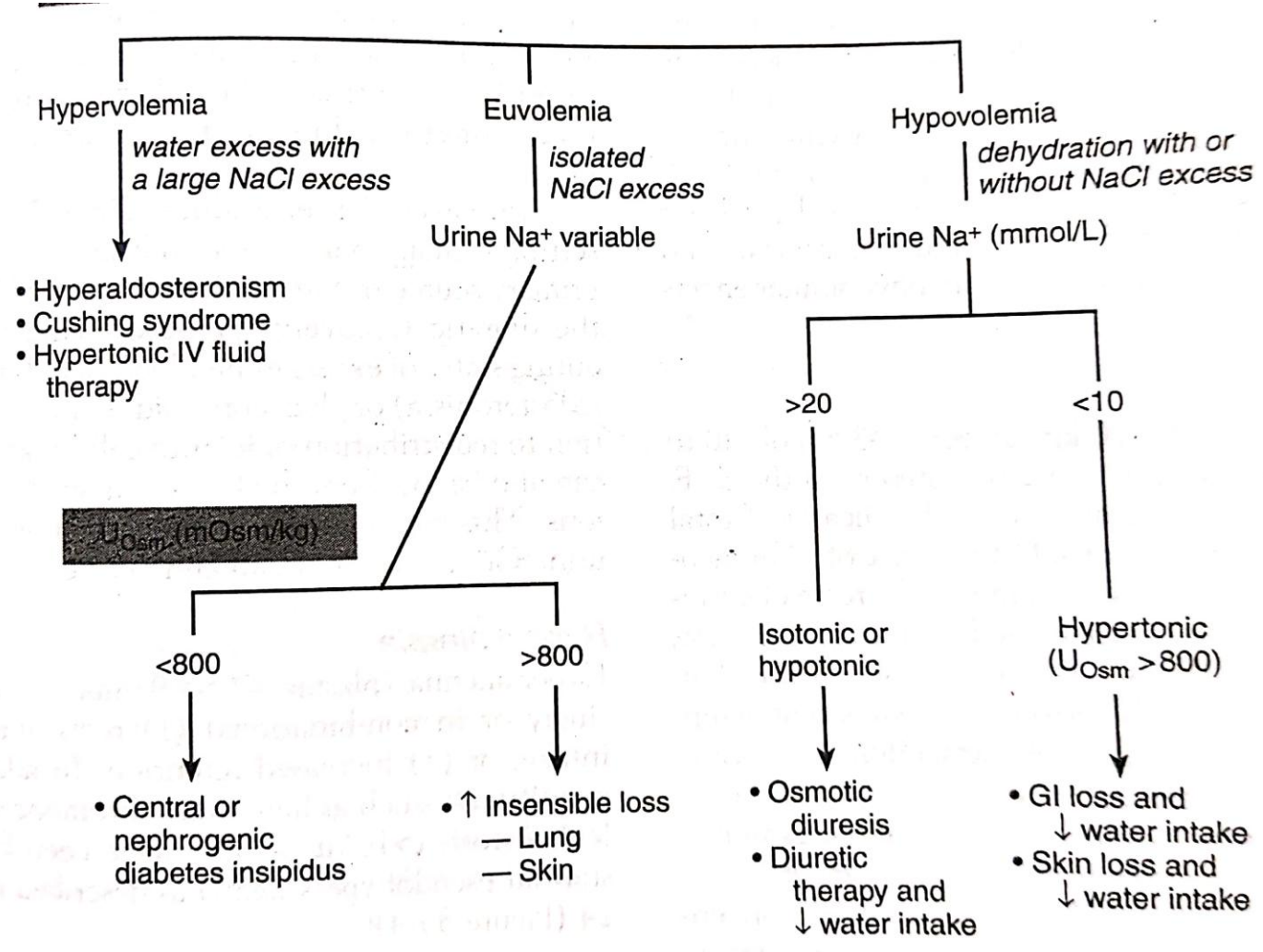
Hypernatremia

- Hypernatremia (plasma Na^+>150mmol/l) is always hyperosmolar
- Symptoms of hypernatremia is primarly neurological and include tremors,irratibility,ataxia,confusion and coma
- Most cases of hypernatremia occurs in patients with altered mental status or infants,both of whom may have difficulty in rehydrating themselves despite a normal thirst reflex

Hypovolemic Hypernatremia

Normovolemic Hypernatremia

Hypervolemic Hypernatremia



gure 35-2 Algorithm for the differential diagnosis of hypernatremia. (Modified from Kirkpatric , Kreisberg R. Acid-base and electrolyte disorders. In: Liu P, ed. Blue book of diagnostic tests. iladelphia: WB Saunders Co, 1986:239-54.)

Hypokalemia

- Plasma potassium level less than 3.5 meq/l is called hypokalemia
- Characterized by muscle weakness,irratibility and paralysis
- Plasma potassium less than 3 meq/l are associated with serious neuromuscular symptoms
- Tachycardia along with flattened T waves is seen in ECG
- Caused due to redistribution of ECF k^+ in to ICF or due to true k^+ deficit(loss of potassium rich body fluid or decreased intake of k^+)

Redistribution

- Insulin therapy for diabetic hyperglycemia
- Metabolic alkalosis
- Acute leukemia

True potassium deficit

- Extrarenal loss in diarrhea or excessive sweating
- Renal loss in acute tubular necrosis
- Mineralcorticoid excess
- Cushing syndrome

Hyperkalemia

- Plasma potassium greater than 5 mmoles/l is called hyperkalemia
- Characterized by mental confusion,weakness,tingling,flaccid paralysis of the extremities
- Cardiac effects of hyperkalemia including bradycardia and conduction defect evident on ECG by prolonged PR and QRS interval and peaked T waves
- Level above 7 mmoles/l leads to cardiac arrest

Pseudohyperkalemia

- Hemolysis
- Thrombocytosis(>10^6/µl)
- Leukocytosis(>10^5/µl)

Redistribution

- Metabolic acidosis
- Dehydration
- Massive tissue hypoxia
- Insulin deficiency

Potassium retention

- Acute renal disease and end stage renal failure
- Addison disease
- ACE inhibitors
- Potassiun sparing diuretics (spironolactone,Amiloride)