Lec. 5

Fluids and electrolyte balance

Dr. Muthana A. Al-Shemeri

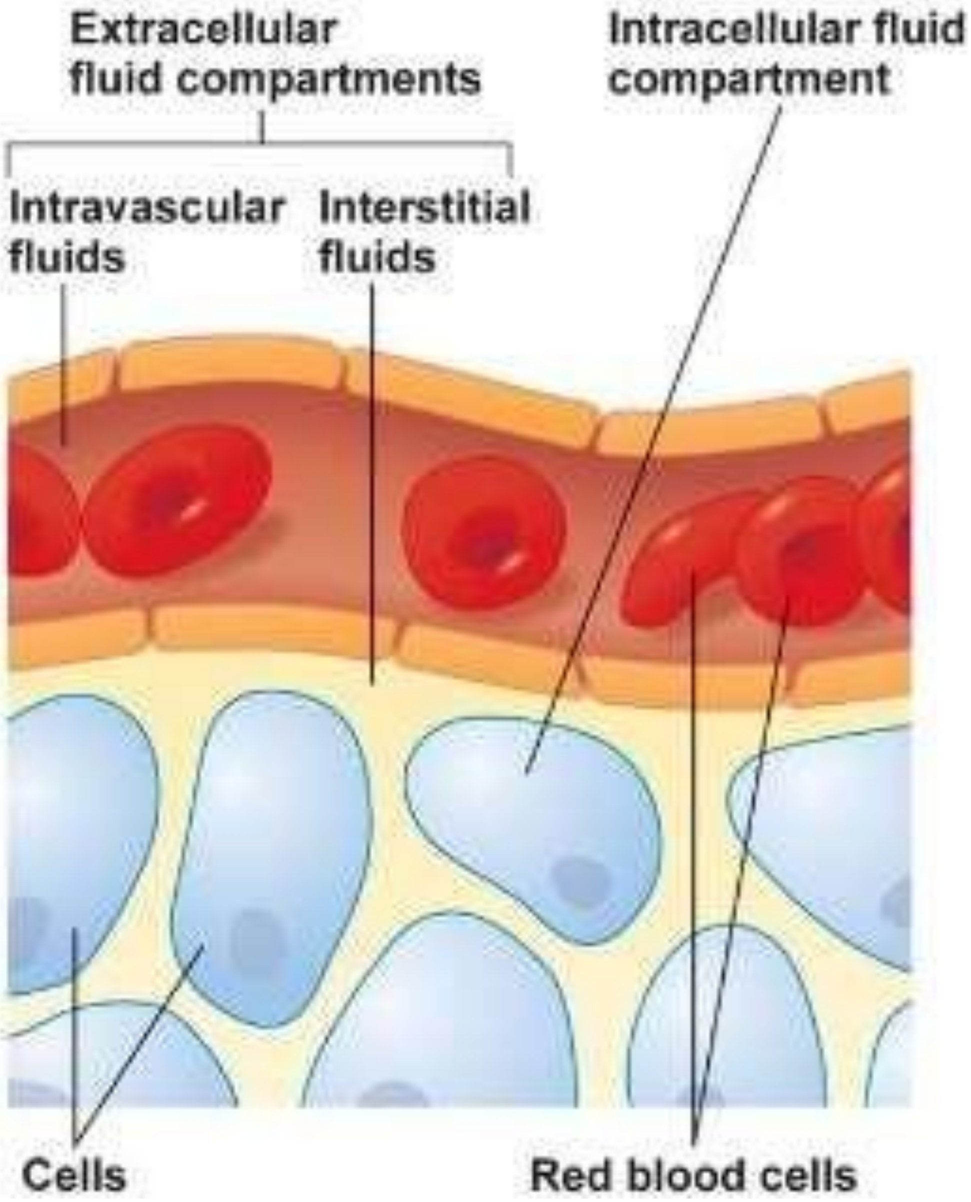
Body fluid compartments

- The major body constituents is water. An average person weighing 70 kg, contains about 42 liters of water in total. Two- thirds (28L) of this is intracellular fluid (ICF) and one third (14L) is extracellular fluid (ECF). The ECF can be further subdivided into plasma (3.5 L) and interstitial fluid (10.5 L).

Water Balance between Fluid Compartments

Body fluid is located

- Intracellular – within the cells
- Extracellular – outside the cells



Electrolytes:

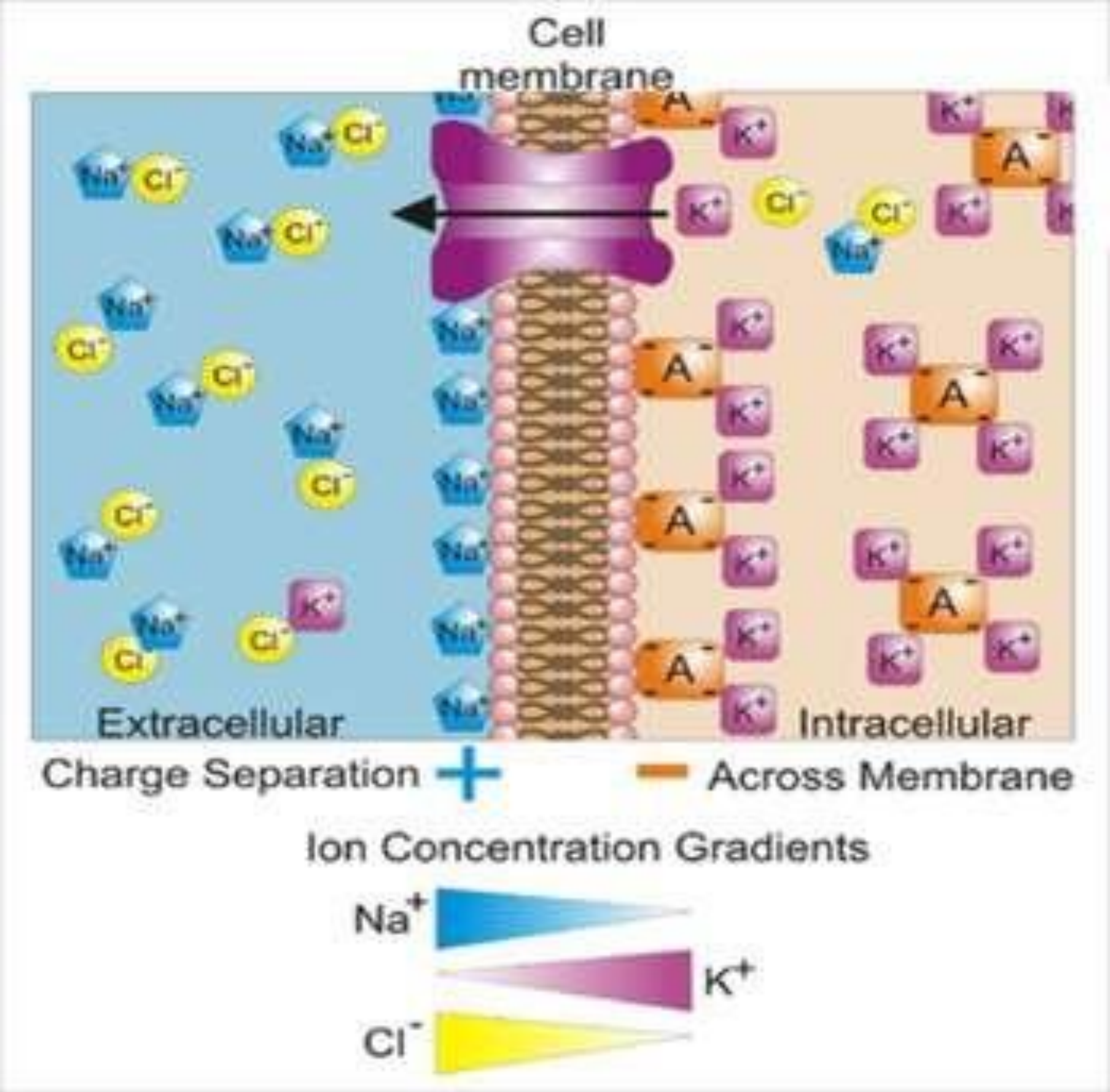
- Compounds, which dissociate readily in solution into their constituents ions or radicals are defined as electrolytes. To cite two common examples, NaCl (sodium chloride) does not exist in the body fluids as a compound but as a mixture of positively charged Na^+ ions (cations) and negatively charged Cl^- ions (anions).

Ions in body fluid

- Sodium (Na^+) is the principal extracellular cation, and potassium (K^+) the principal intracellular cation. Inside cells the main anions are phosphate and protein, whereas in ECF chloride (Cl^-) and bicarbonate (HCO_3^-) predominant.

Extracellular fluid				Intracellular fluid			
Cations		Anions		Cations		Anions	
Na^+	142	Cl^-	105	K^+	155	PO^-	90
K^+	5	HCO_3^-	27	Na^+	12	$Protein^{--}$	60
Ca^{++}	5	HPO_4^-	2	Mg^{++}	15	HCO_3^-	8
Mg^{++}	2	Org.	4	Ca^{++}	2	Cl^-	8
		Acids Proteins	16			Others	18
Total	154		154		184		184

All values are in milliequivalents per litre.


Cell membrane
Extracellular
Intracellular
Charge Separation + − Across Membrane
Ion Concentration Gradients
Na+
K+
Cl-

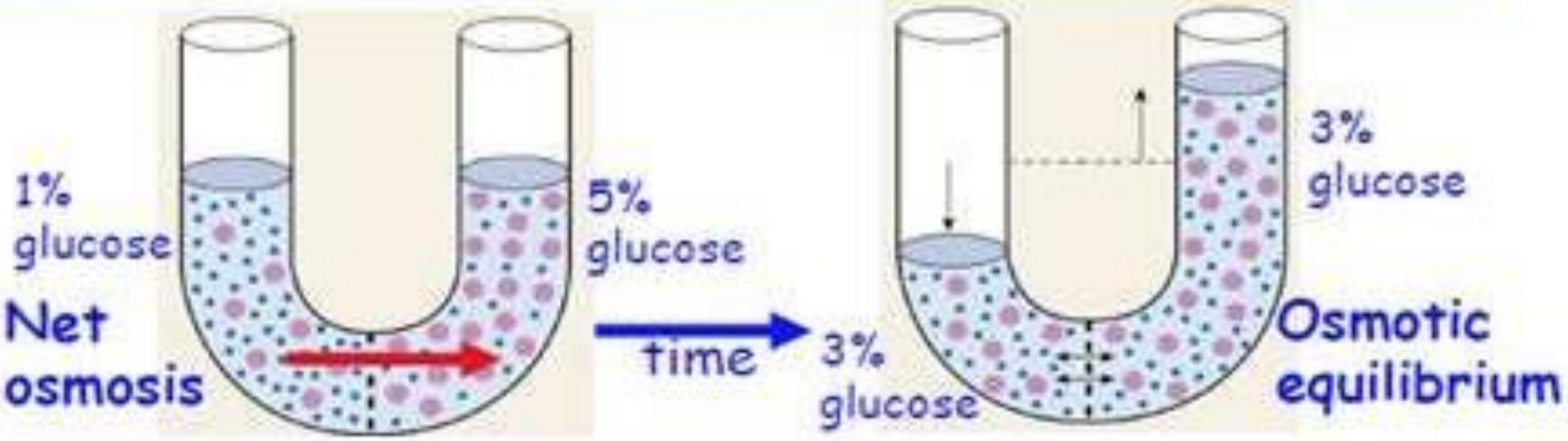
Osmolality:

- Body compartments are separated by semipermeable membranes through which water moves freely. Osmotic
-

pressure must always be the same on both sides of a cell membrane, and water moves to keep the osmolality the same, even if this water movement causes cells to shrink or expand in volume. The osmolality of the ICF is normally the same as the ECF. The two compartments contain isotonic solutions.

OSMOTIC PRESSURE

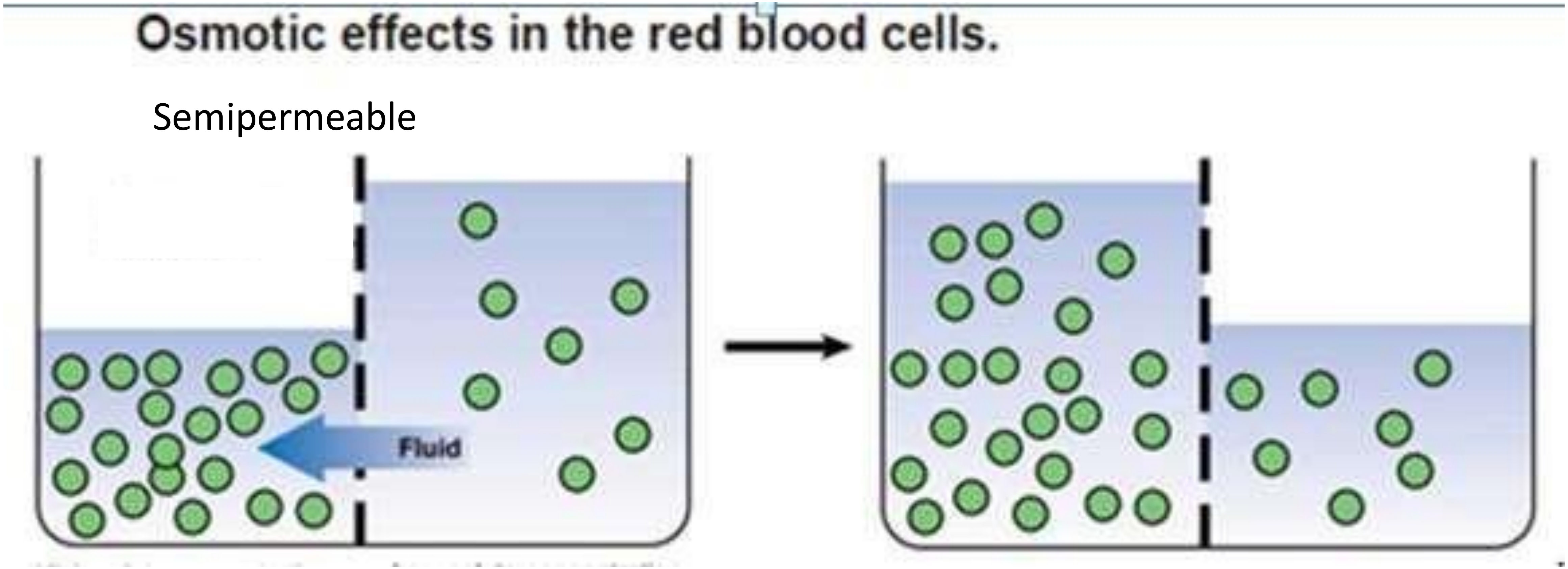
- **OSMOTIC PRESSURE** (=osmotic potential) is a measure of the ability of a given solution to attract H_2O molecules by net osmosis.
- Therefore **NET OSMOSIS** will occur from a solution of lower osmotic pressure into a solution of higher osmotic pressure until an **OSMOTIC EQUILIBRIUM** is reached.



1% glucose solution	net osmosis →	5% glucose solution
HIGH H_2O concentration		LOW H_2O concentration
LOW SOLUTE concentration		HIGH SOLUTE concentration
LOW OSMOTIC PRESSURE		HIGH OSMOTIC PRESSURE

- Water intake largely depends on social habits and is very variable. Some people drink less than half a liter each day, and others may intake more than 5L in 24 hours without harm. Water losses are equally variable and are normally seen as changes in the volume of urine produced. The kidneys can respond quickly to meet the body’s need to get rid of water. The urine flow rate can vary widely in a very short time. However, even when there is need to conserve water, man cannot completely shut down urine production. Total body water remains remarkably constant in health despite massive fluctuations in intake.

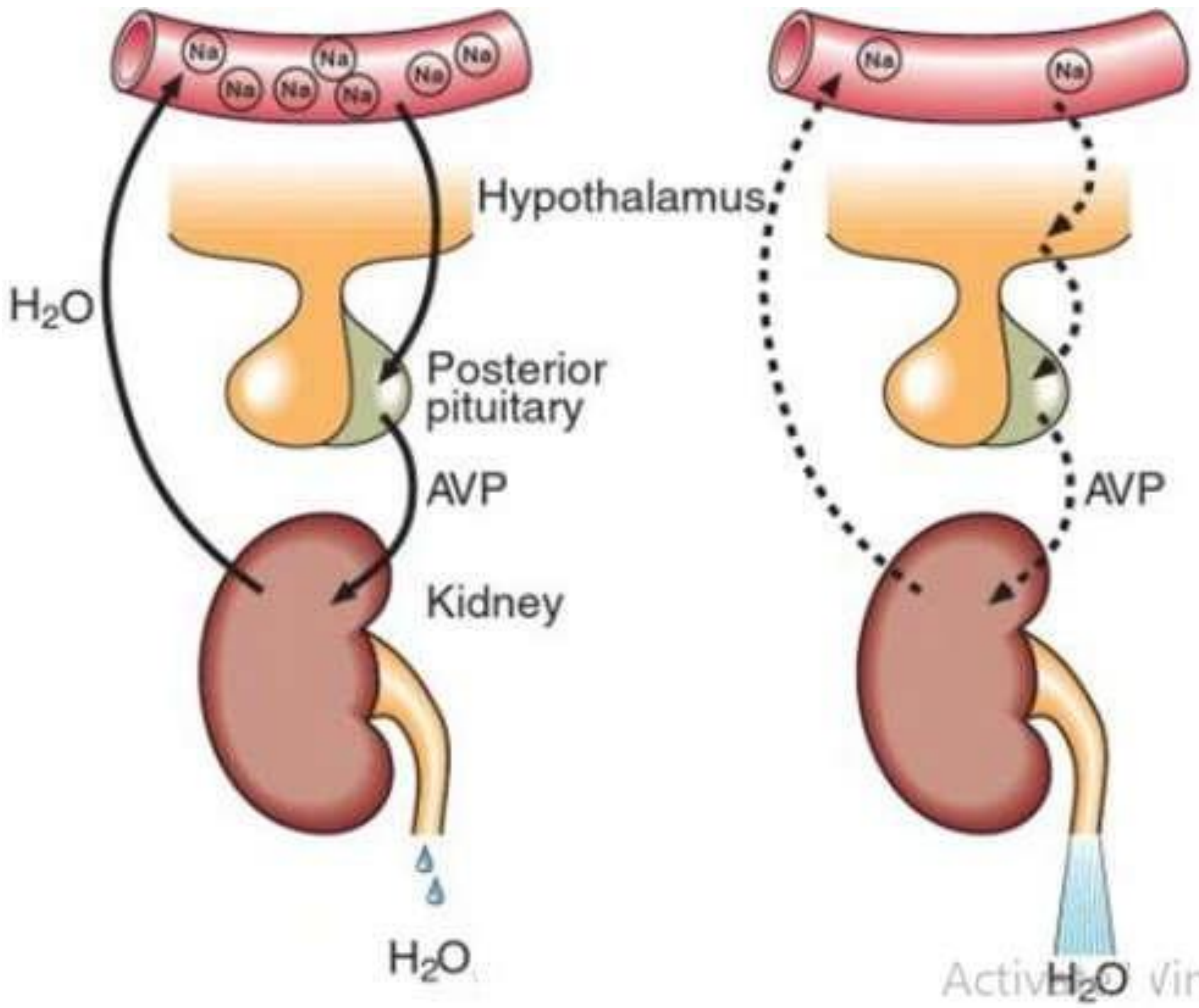
- Water excretion by the kidney is very tightly controlled by arginine vasopressin (AVP), is also called
- antidiuretic hormone (ADH). The body is also continually losing water through the skin as perspiration and from the lungs during respiration. This is called the "insensible loss. This water loss amounts to between 500 and 850 mL/day. Water may also be lost in disease from diarrhoea or because of prolonged vomiting.
- Semipermeable membrane



- **High solute conc. Low solute conc.**
- **High osmotic pressure Low osmotic pressure**

AVP and the regulation of osmolality

- Specialized cells in the hypothalamus sense differences between their intracellular osmolality and that of the extracellular fluid, and adjust the secretion of AVP from the posterior pituitary gland. AVP causes water to be retained by the kidneys. Fluid deprivation results in the stimulation of endogenous AVP secretion, which reduces the urine flow rate in order to conserve body water.
-



The regulation of water balance by AVP and osmolality.

Sodium

- The total body sodium of the average 70\kg man is approximately 3700 mmol, of which approximately 75% is exchangeable. A quarter of the body sodium is termed non exchangeable, which means it is incorporated into tissues such as bone and has a slow turnover rate. Most of the exchangeable sodium is in the extracellular fluid.

- In the ECF, which comprises both the plasma and the interstitial fluid, the sodium concentration is tightly regulated at around 140 mmol/L.

- Sodium intake is variable, a range of less than 100 mmol/day to more than 300 mmol/day. In health, total body sodium does not change. Sodium losses are just as variable. In practical terms, urinary sodium excretion matches sodium intake. Most sodium excretion is via the kidneys. Some sodium is lost in sweat (approximately 5 mmol/day) and in the faces (approximately 5 mmol/day). In disease the gastrointestinal tract is often the major route of sodium loss. This is a very important clinical point, especially in paediatric practice, as infantile diarrhoea may result in death from salt and water depletion.

Regulation of volume

- It is important to realize that water will only remain in the extracellular compartment if it is held there by the osmotic effect of ions. As sodium (and accompanying anions, mainly chloride) are largely restricted to the extracellular compartment, the amount of sodium in the ECF determines what the volume of the compartment will be. This is an important concept.

Urinary sodium output is regulated by two hormones:

1- Aldosterone

- Aldosterone decreases urinary sodium excretion by increasing sodium reabsorption in the renal tubules at the expense of potassium and hydrogen ions. Aldosterone also stimulates sodium conservation by the sweat glands and the mucosal cells of the colon, but in normal circumstances these effects are trivial. A major stimulus to aldosterone secretion is the volume of the ECF.

2- Natriuretic hormone:

- It is a polypeptide hormone that increases urinary sodium excretion and play important role in the regulation of ECF volume and sodium balance.

- Aldosterone and AVP interact to maintain normal volume and concentration of the ECF. Consider a patient who has been vomiting and has diarrhoea from a gastrointestinal infection. With no intake the patient becomes fluid depleted. Water and sodium have been lost. Because the ECF volume is low, aldosterone secretion is high. Thus, as the patient begins to take fluids orally, any salt ingested is maximally retained. As this raises the ECF osmolality, AVP action then ensures that water is retained too. Thus, aldosterone and AVP interaction continues until ECF fluid volume and composition return to normal.

Hyponatraemia:

- Is defined as a serum sodium concentration below the reference interval of 135-145 mmol/L. the serum concentration of sodium is simply a ratio, of sodium (in millimoles) to water (in litres), and hyponatraemia can arise either because of loss of sodium ions or retention of water.

Water retention:

- Water retention usually results from impaired water excretion and rarely from increased intake. Most patients who are hyponatraemic due to water retention have the so called (SIAD). The (SIAD) is encountered in many conditions, e.g. infections, chest disease and trauma. (SIAD) results from the inappropriate secretion of AVP.

Sodium loss

- Sodium depletion is extremely rare and effectively occurs only when there is pathological sodium loss, either from the gastrointestinal tract or in urine. Gastrointestinal losses commonly include those from vomiting and diarrhoea.

Potassium

- Normal serum concentration of potassium is 3.5-5 mmol/L. because its intracellular concentration is much higher than concentration in plasma, a relatively minor shift of potassium between the ECF and ICF may result in major changes in its serum concentration. Both high and low concentrations of potassium (hyperkalemia and hypokalemia respectively) affect the cardiac muscle and can be life-threatening.

- Serum potassium concentration below 2.5 mmol/L or above 6 mmol/L is dangerous. The most common cause of severe hyperkalemia is renal failure: in this condition potassium cannot be adequately exerted in the urine. On the other hand, low serum potassium usually results from excessive losses, either in urine or through the gastrointestinal tract. Kidneys account for more than 90% of the body potassium loss, and diuretic thearpy can induce both hypokalemia and hypercalemia.

Factors affect body fluids

- Changes in temperature and humidity affect body fluids. Acute heat will cause tissue fluids to move into the vascular system, increasing volume and diluting components of the blood. Excessive sweating will also cause hemoconcentration if fluid replacement is not provided. Alcohol affects body fluids regulation; it inhibits secretion of ADH, increase urine output, leads to dehydration

Thank you