# Water Homeostasis

## Introduction

Water is an essential body constituent, and homeostatic processes are important to ensure that the total water balance is maintained within narrow limits, and the distribution of water among the vascular, interstitial and intracellular compartments is maintained.

The body maintains a balance of water intake and output by a series of negative feedback loops involving the endocrine system and autonomic nervous system.

**Pretest:/ What is the cell membrane or plasma membrane made of?**

### Distribution of Water:

In a 70-kg man, the Total Body Water (TBW) is about 42 L and contributes about 60 per cent of the total body weight.

Two thirds of the water are in the Intra Cellular Fluid (ICF), and one third is in the Extra Cellular Fluid (ECF). Because the plasma membrane of most cells is highly permeable to water, ICF and ECF are in osmotic equilibrium.

The ECF is divided into a vascular compartment (plasma) and an interstitial fluid compartment. Expressed as percentages of body weight, the volumes of total body water, ICF, and ECF are:

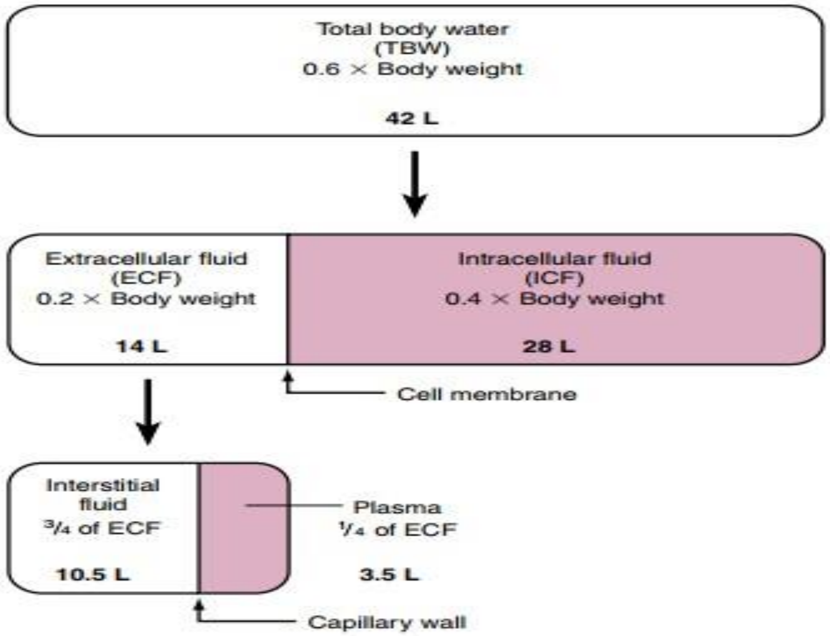
**TBW** (Total body water) **= 0.6 × (body weight)**

**ICF (**Intra Cellular Fluid) **= 0.4 × (body weight)**

**ECF (**Extra Cellular Fluid) **= 0.2 × (body weight)**

**Plasma = ¼ × ECF**

**Interstitial fluid= ¾ × ECF**




*Q/* In woman with 54 kg calculate all the following

**1. TBW 2. ECE 3. ICF 4. Plasma 5. Interstitial fluid**

***Water Intake—Water is supplied to the body by the following processes:***

- Dietary liquids
- Solid foods
- Oxidation of foodstuffs: It is obtained from the combustion of fats, proteins and carbohydrates. The oxidation of fats yields 107 ml/100 gm, proteins 41 ml/100 gm and carbohydrates 56 ml/100 gm.

***Water output: Water is lost from the body by the following routs:***

- Urine
- Respiration
- Lactation
- Faeces
- Evaporation from skin and lung
- Eyes (tears)

# FUNCTIONS OF WATER

**1. *Solvent:***

One of the most important properties of water is its capacity to dissolve different kinds of substances. It is therefore the most suitable solvent for cellular components. Water brings together various substances in contact when chemical reactions take place.

**2. *Catalytic action:***

Water accelerates a large number of chemical reactions in the body due to its ionizing power.

**3. *Lubricating actions:***

Water acts as a lubricant in the body and prevents friction in joints, pleura, conjunctiva, and peritoneum.

**4. *Heat regulation:***

By virtue of its high specific heat, water prevents any significant rise in the body temperature due to heat liberated from body reactions. The loss of heat from the body is also regulated by the evaporation of water from skin and lungs and its removal in urine.

***The balance sheet of water intake and loss is given as:***

| *Water intake* | | | *Water loss* | | |
|---|---|---|---|---|---|
| Drinks | 48 % | 1350 ml | Lungs | 12% | 500 ml |
| Solid | 40 % | 900 ml | Skin | 24% | 700 ml |
| Oxidation of food | 12% | 450 ml | Urine | 56% | 1400 ml |
| | | | Faeces | 08% | 100 ml |
| | 100% | 2700 ml | | 100% | 2700 ml |

## Disturbances of Water Homeostasis

- Gain or loss of extracellular fluid volume.
- Gain or loss of solute.

In many instances disturbances of water homeostasis involve imbalances of both volume and solutes.

## Four specific examples of water homeostasis:

**Hypervolemia:** occurs when too much water and solute at the same time. Although extracellular fluid volume increases, plasma osmolarity may remain normal.

**Overhydration:** occurs when too much water is taken by drinking without solute, volume increases, but because solute is not present, plasma osmolarity decreases.

**Hypovolemia:** occurs when water and solutes are lost at the same time. This condition primarily involves a loss of plasma volume. Plasma osmolarity usually remains normal even though volume is low.

Too much IV fluids can increase plasma volume dramatically, but with an isotonic solution the plasma osmolarity would remain normal and result in hypervolemia.

**Dehydration:** When water, but not solute, is lost, dehydration occurs. Dehydration involves a loss of volume but, because solutes are not lost in the same proportion, plasma osmolarity increases. Although sweating causes the loss of some solute through the skin, much more water is lost, and the person becomes dehydrated.

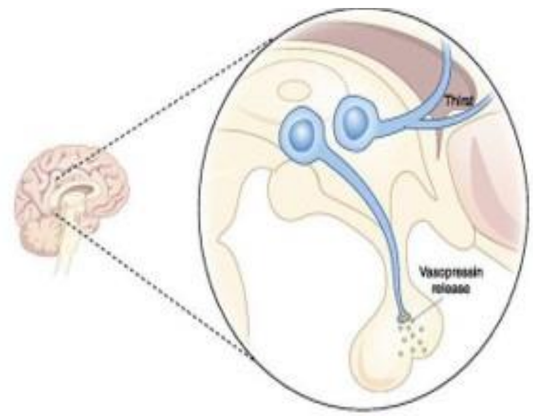
## Mechanisms of Fluid Balance

The body have mechanisms that regulate fluid levels within a narrow range, the body fluids remain within certain physiological limits, an important aspect of homeostasis, four primary mechanisms regulate fluid homeostasis:

- Antidiuretic hormone or ADH (Vasopressin)
- Thirst mechanism
- Aldosterone
- Sympathetic nervous system

Three of these mechanisms involve the kidneys.

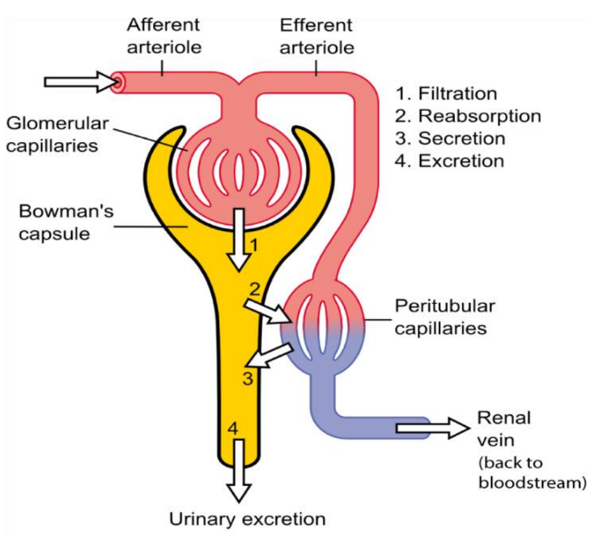
## Effect of ADH

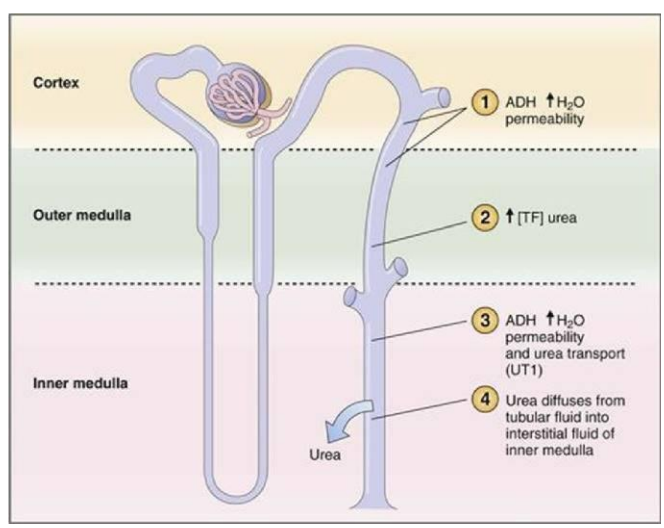



- When loses water by sweating, his plasma becomes more concentrated in solutes.
- Osmoreceptors in the hypothalamus detect the increased osmolarity or concentration of solutes in the plasma.
- In response to this increased concentration antidiuretic hormone is released into the blood at the posterior pituitary.
- The target tissue for ADH is the late distal convoluted tubule and collecting duct cells in the kidney.

### ADH in the Nephron

- These cells become permeable to water only in the presence of ADH.
- ADH promotes the addition of water channels into the cells of the late distal convoluted tubule and collecting duct, allowing water to move from the filtrate to the plasma by way of osmosis.
- ADH therefore increases the reabsorption of water.



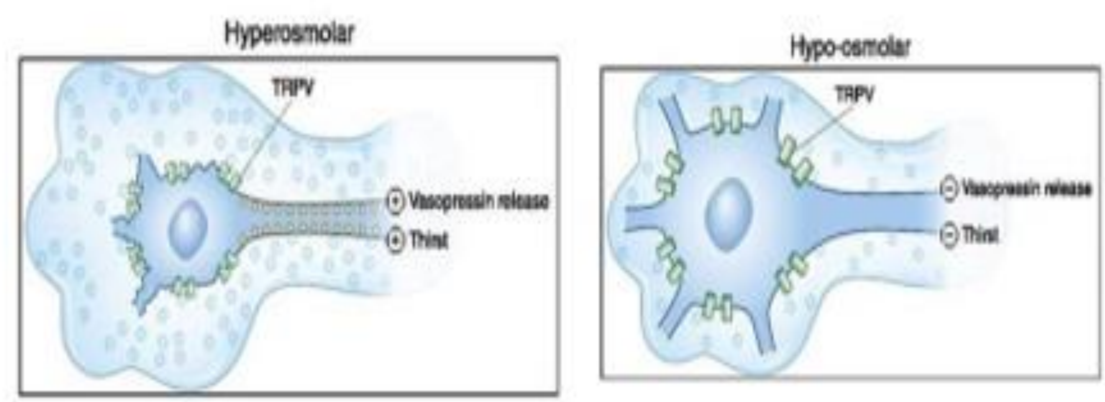
## Thirst Mechanism

The thirst mechanism is the primary regulator of water intake and involves hormonal and neural input as well as voluntary behaviors.
There are three major reasons why dehydration leads to thirst:

1. When saliva production decreases, the mouth and throat become dry. Impulses go from the dry mouth and throat to the thirst center in the hypothalamus, stimulating that area.
2. When you are dehydrated, blood osmotic pressure increases, stimulating osmoreceptors in the hypothalamus and the thirst center in the hypothalamus is now further activated.
3. Decreased blood volume causes a decrease in blood pressure that stimulates the release of renin from the kidney.

This causes the production of angiotensin II which stimulates the thirst center in the hypothalamus.

• Stimulation of the thirst center in the hypothalamus gives you the desire to drink.




### Results of Fluid Ingestion:

1. Relieves the dryness in the mouth and throat.
2. Fluid ingestion also stimulates stretch receptors in the stomach and intestine to send inhibitory signals to the thirst center.

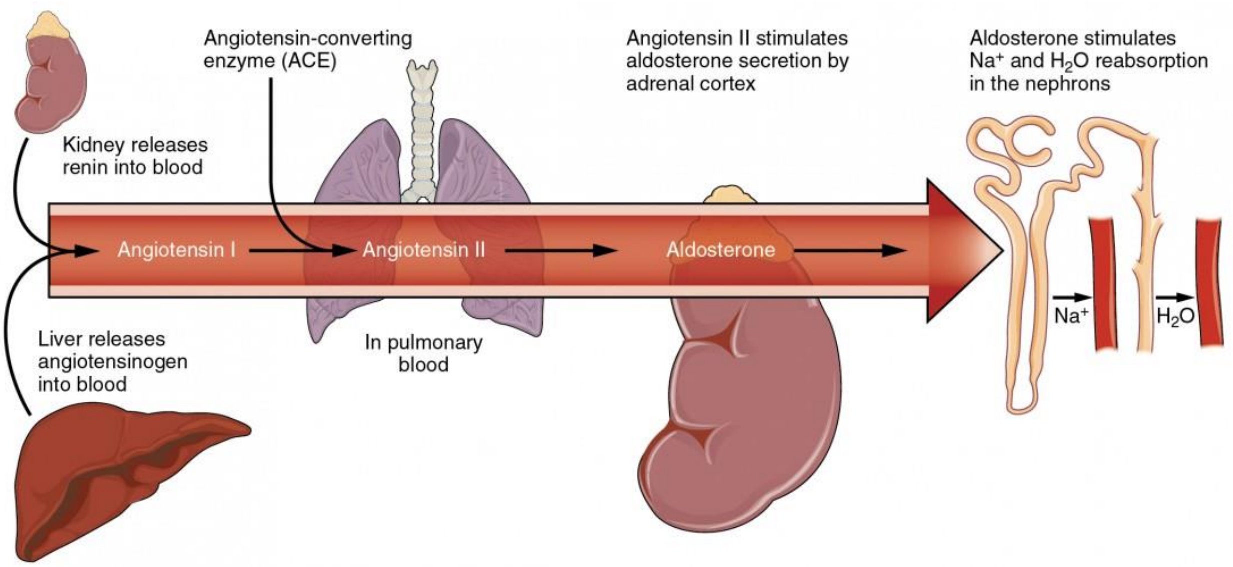
When normal fluid volume is restored, dehydration is relieved. Renin secretion from the kidney and angiotensin II now decreases to baseline levels.

## Effect of Aldosterone

1. When a person donates large amounts of blood, they lose salts as well as water. When electrolytes and water are lost at the same time, blood volume decreases, threatening hypovolemia.
2. When a person experiences blood loss, blood pressure decreases.
   Because a hypovolemic person experiences a decrease in blood pressure, juxtaglomerular cells in the arterioles of the kidney release renin.

## Renin to Aldosterone

1. As renin travels through the bloodstream, it binds to an inactive plasma protein, angiotensinogen, activating it into angiotensin I.
2. As angiotensin I passes through the lung and other capillaries, an enzyme called Angiotensin Converting Enzyme, or ACE, converts angiotensin I to angiotensin II.
3. Angiotensin II continues through the blood stream until it reaches the adrenal gland. Here it stimulates the cells of the adrenal cortex to release the hormone aldosterone.
4. Angiotensin II also has a vasoconstriction effect that helps to increase the blood pressure.
5. Aldosterone can also be released when potassium concentrations in the blood are high.




## Aldosterone in the Nephron

1. In the absence of aldosterone, the cells in the late distal convoluted tubule and collecting ducts allow little sodium and potassium ions to pass because there are few sodium and potassium channels in the cell membrane facing the kidney tubule. There are also few sodium/potassium ATPase pumps on the basal side of these cells.
2. Aldosterone exerts its effect by inserting additional channels in the late distal convoluted tubule and collecting duct of the kidney. This allows more sodium to move from the filtrate into the blood and potassium to move from the blood into the filtrate.

## Results of Aldosterone Action

1. The net result of aldosterone action is the reabsorption of sodium and the secretion of potassium.
2. If ADH is also present, water is reabsorbed into the blood at the kidney, preventing further water loss from the body. As a result, blood volume and blood pressure are stabilized until water is consumed.

## Sympathetic Stimulation

1. A decrease in blood volume and therefore blood pressure will further stimulate the sympathetic nervous system.
2. When blood pressure is low, baroreceptors in the heart, aortic arch, and carotid arteries send sensory information to the medulla.
3. The information sent from the baroreceptors to the medulla will cause an increase in the sympathetic impulses to the kidney.

## Sympathetic Stimulation in the Nephron

1. Release of neurotransmitters from the sympathetic nerves in the kidney stimulates smooth muscle cells in the afferent arteriole to constrict.
2. This process causes a decrease in blood flow into the glomerulus and a drop in glomerular filtration rate and results in less urine formation. Less water leaves the body.
3. Sympathetic stimulation also causes the release of renin which, by stimulating aldosterone secretion, will increase the reabsorption of sodium.
4. As a result, blood volume will stop decreasing and blood pressure may stabilize. However, because the blood pressure and blood volume have not yet returned to normal, the baroreceptors will continue to be stimulated to prevent further loss of blood volume.
5. In order to bring this person back into to homeostasis, we need to increase the blood volume by drinking fluids. In fact, after an individual has given blood, they are encouraged to drink juice to increase their plasma level.

**Posttest:/ What are the mechanisms of fluid balance?**