Nephron Definition

"Nephron is the basic functional unit of kidneys that consists of a glomerulus and its associated tubules through which the glomerular filtrate passes before it emerges as urine"

A nephron is the basic structural and functional unit of the kidney. They are the microscopic structure composed of a renal corpuscle and a renal tubule. The word nephron is derived from the Greek word – nephros, meaning kidney. There are about millions of nephrons in each human kidney.

Structure of Nephron

The mammalian nephron is a long tube-like structure, its length varying from 35–55 mm long. At one end, the tube is closed, folded and expanded, into a double-walled, a cuplike structure called the Bowman's capsule or renal corpuscular capsule, which encloses a cluster of microscopic blood vessels called the glomerulus. This capsule and glomerulus together constitute the renal corpuscle.

The structure of nephron comprises two major portions:

1. Renal Tubule
2. Renal Corpuscle

Renal Tubule

The renal tubule is a long and convoluted structure that emerges from the glomerulus and can be divided into three parts based on function.

- The first part is called the proximal convoluted tubule (PCT) due to its proximity to the glomerulus; it stays in the renal cortex.
- The second part is called the loop of Henle, or nephritic loop because it forms a loop (with descending and ascending limbs) that goes through the renal medulla.
- The third part of the renal tubule is called the distal convoluted tubule (DCT) and this part is also restricted to the renal cortex.

The capillaries of the glomerulus are enclosed by a cup-like structure called Bowman's capsule. This structure extends to form highly coiled tubules called PCT. PCT continues to form the loop of Henle which ascends to DCT, which in turn opens into the collecting duct.

The major function of tubules is reabsorption and the process can either be through **active transport** or passive transport. In addition, secretions by tubules help in the urine formation without affecting the electrolyte balance of the body.

- **Proximal Convoluted Tubule (PCT)**

The blood brought by the renal artery is filtered by the glomerulus and then passed to the PCT. Maximum reabsorption takes place in PCT of the nephron.PCT is the region of renal tubule where reabsorption of essential substances like glucose, proteins, amino acids, a major portion of electrolytes and water takes place. The surface area for reabsorption is facilitated by the lining of the simple cuboidal epithelium in them. Reabsorption takes place at the expense of energy, i.e., the process is active.PCT selectively secretes ions such as hydrogen, ammonia, and potassium into the filtrate and absorbs $HCO_3^-$from it. Thus, PCT maintains the electrolyte and acid-base balance of the body fluids.

- **Henle's Loop**

Henle's loop has a descending and an ascending limb. Being parts of the same loop, both the descending and ascending limbs show different permeability. The descending limb is permeable to water but impermeable to an electrolyte, while the ascending limb is permeable to electrolytes but impermeable to water. Since the electrolytes get reabsorbed at the ascending loop of Henle, the filtrate gets diluted as it moves towards the ascending limb. But reabsorption is limited in this segment.

- **Distal Convoluted Tubule (DCT)**

The DCT, which is the last part of the nephron, connects and empties its contents into collecting ducts that line the medullary pyramids. The collecting ducts amass contents from multiple nephrons and fuse together as they enter the papillae of the renal medulla.

Similar to PCT, DCT also secretes ions such as hydrogen, potassium, and NH_3 into the filtrate while reabsorbing the $HCO_3^-$from the filtrate. Conditional reabsorption of sodium ions and water takes place in DCT. Thus, it maintains the pH and sodium-potassium level in the blood cells.

Collecting Duct

Collecting duct is a long, straight tube where H+ and K+ ions are secreted to maintain the electrolyte balance of the blood. This is also the region where the maximum reabsorption of water takes place to produce concentrated urine.

Renal Corpuscle

The renal corpuscle consists of a glomerulus surrounded by a Bowman's capsule. The glomerulus arises from an afferent arteriole and empties into an efferent arteriole. The smaller diameter of an efferent arteriole helps to maintain high blood pressure in the glomerulus.

The Bowman's capsule is divided into three layers:

1. **Outer Parietal layer:** It is made up of epithelial cells with minute pores of diameter 12nm.
2. **Middle Basement membrane:** This layer is selectively permeable.
3. **Inner Visceral Layer:** It consists of large nucleated cells called podocytes which bear finger-like projections called podocel.

Types of Nephron

There are two types of nephron:

- **Cortical nephron**

These are the nephrons present within the cortex. These are short and comprise about 80% of the total nephrons.

- **Juxtamedullary nephron**

These have long loops of Henle and extend into the medulla. These are about 20%.

Functions of Nephron

The primary function of nephron is removing all waste products including the solid wastes, and other excess water from the blood, converting blood into the urine, reabsorption, secretion, and excretion of numerous substances.

As the blood passes through the glomerulus with high pressure, the small molecules are moved into the glomerular capsules and travel through a winding series of tubules.

The cell present in each tube absorbs different molecules excluding the glucose, water, and other beneficial molecules which are called as the ultrafiltrate. As the ultrafiltrate molecules travel down the tubules they become more and more hypertonic, which results in more amount of water to be extracted from the ultrafiltrate before it exits the nephrons.

The blood surrounding the nephron travels back into the body through the renal blood vessels, which are free of toxins and other excess substances. The obtained ultrafiltrate is urine, which travels down via the collecting duct to the bladder, where it will be stored and released through the urethra.

The major functions of the kidneys are to:

1. Maintains the body's pH

2. Reabsorption of nutrients
3. Regulates blood pressure
4. Excretion of wastes from the body
5. Removal of excess fluid from the body
6. Secret hormones that help in the production of red blood cell, acid regulation, etc.

The functional unit of the kidney is the nephron. Each kidney consists of millions of nephron which plays a significant role in the filtration and purification of blood. The nephron is divided into two portions, namely, the glomerulus and the renal tubule and helps in the removal of excess waste from the body.

Urine

The urine is a straw-colored, watery fluid, slightly acidic with a characteristic ammonium smell formed by nephrons and excreted from the body. It is mainly composed of water, organic and inorganic wastes.

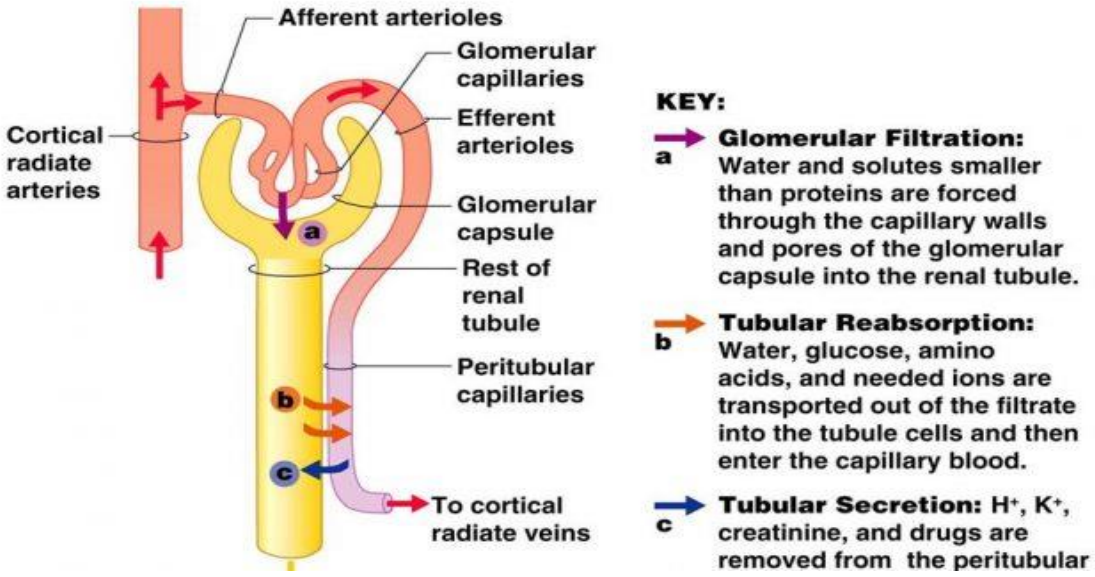
Mechanism of Urine formation in humans

Urine in humans is formed by nephrons, the structural and functional unit of the kidneys. There are three stages involved in the process of urine formation. They are-

1. Glomerular filtration or ultra-filtration

2. Selective reabsorption

3. Tubular secretion



Glomerular filtration

- This takes place through the semipermeable walls of the glomerular capillaries and Bowman's capsule.
- The afferent arterioles supplying blood to glomerular capsule carries useful as well as harmful substances. The useful substances are glucose, aminoacids, vitamins, hormones, electrolytes, ions etc and the harmful substances are metabolic wastes such as urea, uric acids, creatinine, ions, etc.
- The diameter of efferent arterioles is narrower than afferent arterioles. Due to this difference in diameter of arteries, blood leaving the glomerulus creates the pressure known as hydrostatic pressure.
- The **glomerular hydrostatic pressure** forces the blood to leaves the glomerulus resulting in filtration of blood. A capillary hydrostatic pressure of about 7.3 kPa (55 mmHg) builds up in the glomerulus. However this pressure is opposed by the **osmotic pressure** of the blood, provided mainly by plasma proteins, about 4 kPa (30 mmHg), and by **filtrate hydrostatic pressure** of about 2 kPa (15 mmHg in the glomerular capsule.
- The **net filtration pressure** is,

Therefore: 55-(30 +15) = 10mmHg.

- By the net filtration pressure of 10mmHg, blood is filtered in the glomerular capsule.
- Water and other small molecules readily pass through the filtration slits but Blood cells, plasma proteins and other large molecules are too large to filter through and therefore remain in the capillaries.
- The filtrate containing large amount of water, glucose, aminoacids, uric acid, urea, electrolytes etc in the glomerular capsule is known as nephric filtrate of glomerular filtrate.
- The volume of filtrate formed by both kidneys each minute is called the **glomerular filtration rate (GFR).** In a healthy adult the GFR is about 125 mL/min, i.e. 180 litres of filtrate are formed each day by the two kidneys

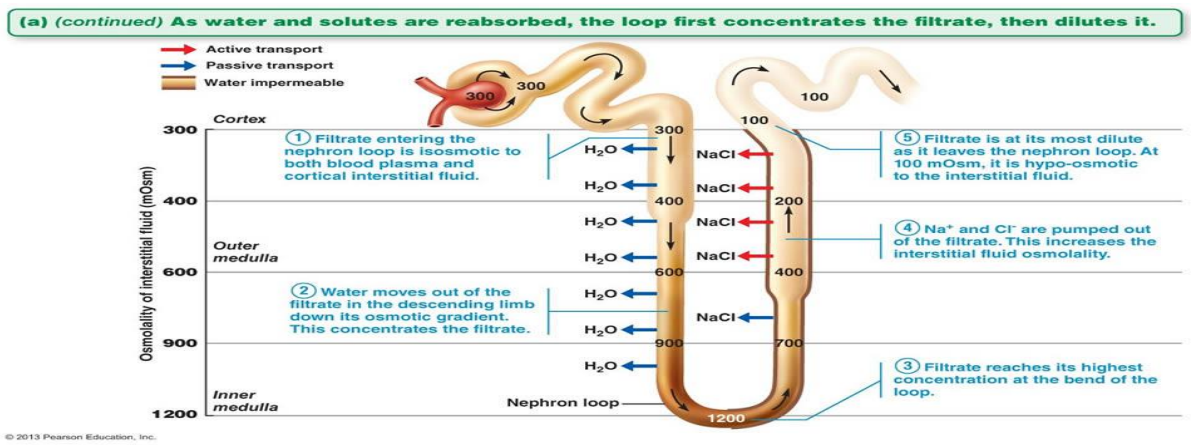
Selective reabsorption

- As the filtrate passes to the renal tubules, useful substances including some water, electrolytes and organic nutrients such as glucose, aminoacids, vitamins hormones etc are selectively reabsorbed from the filtrate back into the blood in the proximal convoluted tubule.

- Reabsorption of some substance is passive, while some substances are actively transported. Major portion of water is reabsorbed by Osmosis.
- Only 60–70% of filtrate reaches the Henle loop. Much of this, especially water, sodium and chloride, is reabsorbed in the loop, so that only 15–20% of the original filtrate reaches the distal convoluted tubule, More electrolytes are reabsorbed here, especially sodium, so the filtrate entering the collecting ducts is actually quite dilute.
- The main function of the collecting ducts is to reabsorb as much water as the body needs.
- Nutrients such as glucose, amino acids, and vitamins are reabsorbed by active transport. Positive charged ions ions are also reabsorbed by active transport while negative charged ions are reabsorbed most often by passive transport. Water is reabsorbed by osmosis, and small proteins are reabsorbed by pinocytosis.

Tubular secretion

- Tubular secretion takes place from the blood in the peritubular capillaries to the filtrate in the renal tubules and can ensure that wastes such as creatinine or excess H+ or excess K+ ions are actively secreted into the filtrate to be excreted.
- Excess K+ ion is secreted in the tubules and in exchange Na+ ion is reabsorbed otherwise it causes a clinical condition called Hyperkalemia.
- Tubular secretion of hydrogen ions (H+) is very important in maintaining normal blood pH.
- Substances such as , e.g. drugs including penicillin and aspirin, may not be entirely filtered out of the blood because of the short time it remains in the glomerulus. Such substances are cleared by secretion from the peritubular capillaries into the filtrate within the convoluted tubules.
- The tubular filtrate is finally known as urine. Human urine is usually hypertonic.



Composition of human urine

Water – 96%

Urea – 2%

Uric acids, creatinine, pigments- 0.3%

Inorganic salts – 2%

Bad smell is due to Urinoid

Pale yellow color due to urochrome or urobillin (which is a breakdown product of haemoglobin)

Micturation:

- The process of time to time collection and removal of urine from urinary bladder is known as micturition. Collection of more than 300ml of urine in urinary bladder creates pressure on the wall. The pressure stimulates the desire for urination.