EXCRETION

Components of the Human Urinary System

The '**Urinary System**' is also called the '**Renal System**' because this group of inter-connected body parts process a liquid substance called **urine** via specialist organs called the **kidneys**. The word '**renal**' means '**pertaining to the kidneys**'

They are also called '**Genito-urinary System**' because the organs of the urinary system are located in close proximity to those of the reproductive system.

The Urinary (or "Renal") System consists of :

1. **Pair of kidneys**
2. **Pair of ureters**
3. **Bladder**
4. **Urethra**

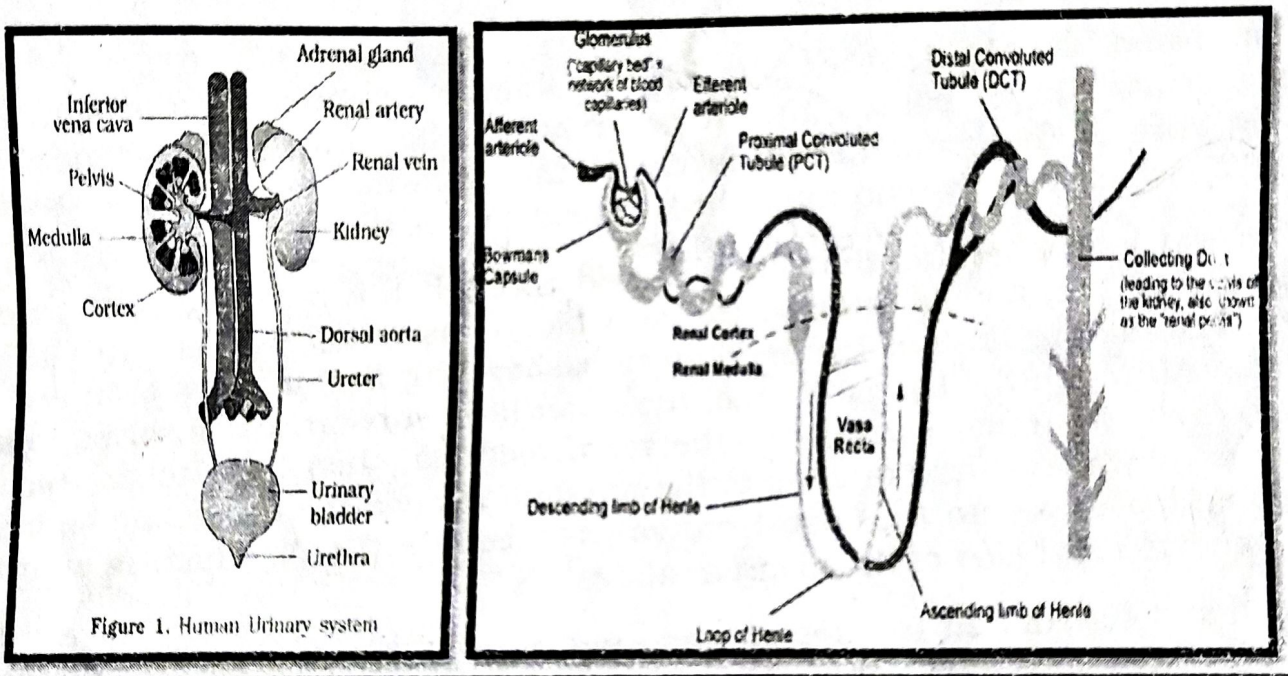


Figure 1. Human Urinary system

The Structure of a Kidney Nephron: Kidney nephrons are the functional units of the kidneys. There are normally approx. one million (0.8 - 1.5 million) kidney nephrons in each of the two kidneys in the body.

Anatomy: Descriptions of the Parts of a Kidney Nephron:

There are two parts of a kidney nephron: the **renal corpuscle**, and the **renal tubule**.

(1) Renal Corpuscle

The **renal corpuscle** is the part of the kidney nephron in which blood plasma is filtered.

The word "corpuscle" means "tiny" or "small" body. The renal corpuscle of each kidney nephron has two parts - they are the **Glomerulus**, which is a network of small blood vessels called capillaries, and the **Bowman's Capsule**

(also known as the **Glomerular Capsule**), which is the double-walled epithelial cup within which the glomerulus is contained.

Within the glomerulus are **glomerular capillaries** that are located between the **afferent arteriole** bringing blood into the glomerulus and the **efferent arteriole** draining blood away from the glomerulus. The (outgoing) efferent arteriole has a smaller diameter than the (incoming) afferent arteriole. This difference in arteriole diameters helps to raise the blood pressure in the glomerulus.

The area between the double-walls of the Bowman's Capsule is called the **capsular space**. The cells that form the outer edges of the glomerulus form close attachments to the cells of the inner surface of the Bowman's Capsule. This combination of cells adhered to each other forms a **filtration membrane** that enables water and solutes (substances that are dissolved in the water / blood) to pass through the first wall of the Bowman's Capsule into the capsular space. This filtration process is helped by the raised blood pressure in the glomerulus - due to the difference in diameter of the afferent and efferent arterioles.

(2) Renal Tubule

The **renal tubule** is the part of the kidney nephron into which the glomerular filtrate passes after it has reached the Bowman's capsule. The first part of the renal tubule is called the **proximal convoluted tubule (PCT)**, which is shown on the right-hand side of the diagram above.

The water and solutes that have passed through the proximal convoluted tubule (PCT) enter the **Loop of Henle**, which consists of two portions - first the **descending limb of Henle**, then the **ascending limb of Henle**. In order to pass through the Loop of Henle, the water (and substances dissolved in it) pass from the renal cortex into the renal medulla, then back to the renal cortex. When this fluid returns to the renal cortex (via the ascending limb of Henle) it passes into the **distal convoluted tubule (DCT)**, which is shown on the left-hand side of the diagram above.

The distal convoluted tubules of many individual kidney nephrons converge onto a single **collecting duct**. The fluid that has passed through the distal convoluted tubules is drained into the collecting duct (far left-hand-side of the diagram above). Many collecting ducts join together to form several hundred **papillary ducts**. There are typically about 30 papillary ducts per **renal papilla** (the renal papillae being the tips of the renal pyramids - which point towards the centre of the kidney). At each renal papilla the contents of the papillary ducts drain into the **minor calces** - the channels through which the fluid passes, via the **major calyx**, into the centre of the kidney - called the renal pelvis.

PROCESS OF URINE FORMATION

Excretion is an process in which nitrogenous waste products get eliminated from blood by the formation of urine.

This takes place in three steps

formation of urine.

urine is a waste product, product from excess H_2O and metabolic waste molecules during the process of renal system filteration.

urine formation occurs in 3 stages.

1. Filtration 2. Reabsorption 3. secretion

Filtration- involves the transfer of soluble components such as H_2O and waste, from the blood into glomerulus.

Reabsorption- involves absorption of molecules, ions & H_2O that are necessary for the body to maintain homeostasis from glomerular filtrate back into the blood.

Secretion- involves the transfer of H^+, creatinine, K^+ drugs and urea from the blood into the collecting duct, and is made up of H_2O.

Step 1: GLOMERULAR FILTRATION

→ The process by which glomerular filtration occurs is called renal ultrafiltration.

→ The force of hydrostatic pressure in the glomerulus (force of pressure exerted from the pressure of blood vessel) is the main force that helps in the filtration. (60mm Hg).

→ glomerular oncotic pressure (pressure exerted by proteins) opposes the filteration and is equal to 32 mm Hg

→ Pressure in the Bowman's capsule also opposes the filtration and is equal to 16mm of Hg

So the net filtration pressure = Glomerular filtration hydrostatic pressure − Bowman's

net filtration pressure = Glomerular hydrostatic pressure − Bowman's capsule Pressure − glomerular oncotic pressure

= 60 mm Hg − 18 mm Hg − 32 mm Hg

nF_R = 10 mm Hg (This is the effective pressure of glomerulus which facilitates filtration)

* Glomerular filtration rate (GFR) is the total amount of filtrate formed by all the renal capsules of both kidneys per minute and ~~then~~ 125 ml/~~do~~ minute" 180L/day

→ Blood enters the glomerulus through afferent arteriole the blood is filtered in Bowman's capsule which surrounds the glomerulus.

→ The ~~base~~ capsule is made of special type of epithelial cells known as podocytes which have fenestrations (slits) in which the fluid passes through into nephron.

→ The size of the slits restricts the passage of larage molecules (albumin) & cells, that are the non filtrable components of blood. The fluid filtrate and has same composition of plasma excluding proteins and cells.

Factors affecting GFR formed is known as ultra

Factors affecting GFR. → Rate of filtration α GFR

→ Increased blood volume and increased blood pressure will increase GFR.

→ constriction in the afferent arteriole ↓ GFR

→ Dialation of efferent arteriole ↓ GFR

→ Low GFR activates renin-angiotensin system which acts to increase GFR by ↑ blood volume.

Step-2 : Tubular reabsorption.

→ Reabsorption is a finely tuned process which is altered to maintain homeostasis of blood volume, Blood pressure, plasma osmolarity and blood pH.

→ Reabsorbed ions, molecules are returned to blood stream and ~~dare not form~~ are not excreted as urine.

→ Reabsorption in nephron may be by passive diffusion, active transport (Eg Na^+/K^+ ATPase) and by co-transport.

→ The filtrate which enters PCT has an osmolarity of 300 mosm/L (same as blood plasma), in PCT all glucose along with equal amounts of H_2O is reabsorbed through co-transport. The solution that leaves PCT has an osmolarity of 300 mOsm/L

→ In the descending loop of henle's, H_2O is lost and as it is ~~im~~permeable to H_2O, the solution becomes hypertonic (1200 mOsm/L). In ascending loop, which is impermeable to H_2O and permeable to solute, osmolarity falls to 100-200 mOsm/L

→ In DCT and collecting ducts, a variable amount of H_2O and ions are reabsorbed depending on hormone stimulus.

Reabsorption of Na^+

→ 1. In Proximal convoluted tubule - sodium is reabsorbed along with chloride (passive chloride absorption)

→ 2. Na^+/H^+ exchanger - Sodium is actively counter transported with H^+ ions. and Cl^- is absorbed with Na^+.

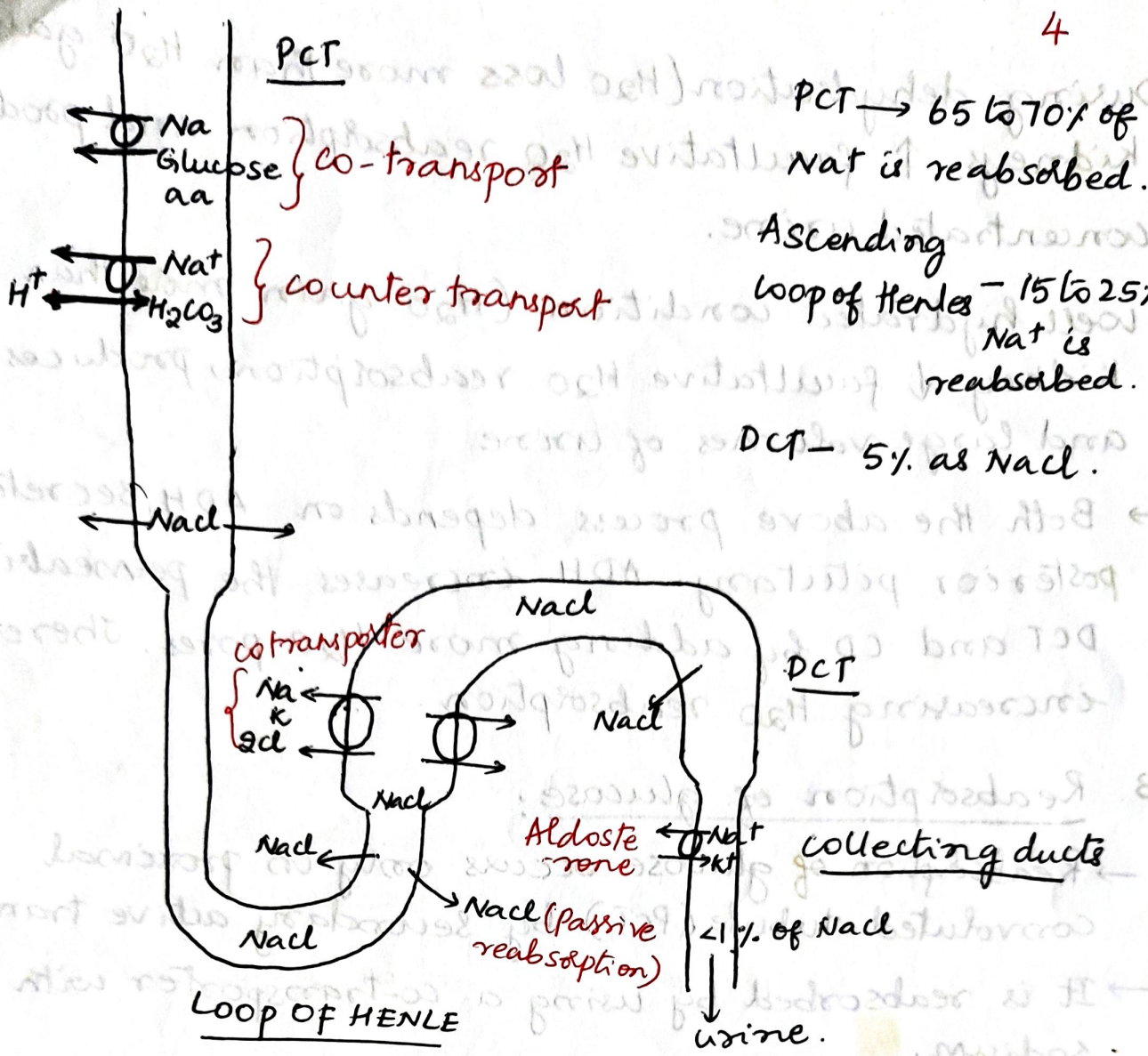
→ Sodium is actively transported across the basolateral membrane by the Na^+/K^+ pumps.

→ Sodium moves across the membrane by co-transport along with organic molecules (glucose or an amino acid).

→ In distal convoluted tubules. Sodium reabsorbtion is coupled with potassium secretion.

→ Effects of aldosterone, ad it is a steroid hormone released from adrenal cortex, and regulates the reabsorption of Na^+ and secretion of K^+ in the principal cells.

→ Binding of aldosterone to its receptors on the principal cells of DCT, ↑ the opening of Na^+ channels and K^+ channels. It also increases the synthesis and insertion of more Na^+/K^+ pumps on basolateral membrane.



PCT → 65 to 70% of Nat is reabsorbed.

Ascending loop of Henles – 15 to 25% Na^+ is reabsorbed.

DCT – 5% as Nacl.

Reabsorption of water :

→ water reabsorption occurs through osmosis in PCT reabsorption of Nat and other solutes in PCT creates an osmotic gradient and ∴ H_2O follows the solutes.

→ 65% of H_2O is reabsorbed in PCT, 15% in Descending limb of henle, 10 – 15% in DCT and remainder in collecting ducts.

→ The reabsorption of H_2O in PCT and DLOH is ~~known as~~ obligatory water absorption

→ while the reabsorption of H_2O from DCT and collecting tubules is known as facultative H_2O absorption and is under hormonal control and H_2O intake. depen (ADH) = anti diuretic Hormone

→ During dehydration (H_2O loss more than H_2O gain) kidneys ↑ facultative H_2O reabsorption and produces concentrated urine.

→ Well hydrated condition (H_2O gain more than H_2O loss) kidney ↓ facultative H_2O reabsorption, produces dilute and large volumes of urine

→ Both the above process depends on ADH secreted by posterior pituitary. ADH increases the permeability of DCT and CD by adding more H_2O pores. There by increasing H_2O reabsorption.

3. Reabsorption of glucose:

→ Reabsorption of glucose occurs only in proximal convoluted tubule (PCT) by secondary active transport.

→ It is reabsorbed by using a co-transporter with sodium.

→ Glucose the energy for the uptake reabsorption of glucose is derived from the movement of Na^+ from higher concentration to lower concentration.

→ Glucose is moved from membrane to epithelial cells and passively transported out of epithelial cells across the basolateral membrane.

→ concentrations of double the normal levels are required for glucose to appear in urine. and the concentration where glucose can be first detected is termed as renal threshold of glucose.

Reabsorption of Urea:

→ Urea is also passively reabsorbed from the tubule. The absorption of H_2O in PCT increases urea concentration in the tubular lumen. This creates a concentration gradient favourable for urea reabsorption.

→ Around 50% of urea is reabsorbed in PCT. The remainder of urea is excreted in urine.

→ The reabsorption of urea is facilitated by specific urea transporters in collecting duct.

Step-3 - Secretion/Tubular secretion

→ Hydrogen, creatinine, K^+, NH_4^+ and drugs are removed from the blood and into collecting duct. through peritubular capillaries.

→ occurs in distal convoluted tubules and collecting ducts.

→ Excess H^+ ions are secreted into the distal tubule to maintain pH of the blood.

→ K^+ ions are also secreted into the distal tubule.

Urine composition:

Urine is an aqueous solution of greater than 95% of H_2O, Urea - 9.3g/L, chloride 1.87g/L, Sodium 1.17g/L, Potassium-0.75g/L, creatinine 0.67g/L

Around 1 to 2 L of urine is secreted /day by a healthy adult.

What are the physical characteristics of normal urine ?

Volume (as mentioned above) is one of the physical characteristics of urine. Other physical characteristics that can apply to urine include colour, turbidity (transparency), smell (odour), pH (acidity - alkalinity), and density.

- **Colour**: Typically yellow-amber but varies according to recent diet and the concentration of the urine. Drinking more water generally tends to reduce the concentration of urine, and therefore cause it to have a lighter colour. (The converse is also true.)
- **Smell:** The smell of urine may provide health information. For example, urine of diabetics may have a sweet or fruity odour due to the presence of ketones (organicmolecules of a particular structure). Generally fresh urine has a mild smell but aged urine has a stronger odour, similar to that of ammonia.
- **Acidity**: The pH of normal urine is generally in the range 4.6 - 8, a typical average being around 6.0. Much of the variation is due to diet. For example, high protein diets result in more acidic urine, but vegetarian diets generally result in more alkaline urine (both within the typical range 4.6 - 8).
- **Density**: *Density is also known as "specific gravity". This is the ratio of the weight of a volume of a substance compared with the weight of the same volume of distilled water.*
  Given that urine is mostly water, but also contains some other substances dissolved in the "water", its density is expected to be close to, but slightly greater than, 1.0. This is true - the density of normal urine is in the range 0.001 to 0.035.

What is contained in normal urine ?

- Approx. 95% of the volume of normal urine is **water**.
- The other 5% consists of solutes (chemicals that are dissolved in the water).

Some of these solutes are the results of normal biochemical activity within the cells of the body. Other solutes may be due to chemicals that originated outside of the body, such as pharmaceutical drugs.

Solutes found in urine may be classified as **ions** or **organic molecules**