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ANSWER

URINE FORMATION AND CONCENTRATION

Urine Formation

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, amino acids, 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.
- 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, amino acids, 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, amino acids, 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 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 Hyperkalaemia.
- 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.

Urine Concentration

The nephron loop of juxtamedullary nephrons is the apparatus that allows the nephron to concentrate urine. The loop is a counter-current multiplier system in which fluids move in opposite directions through

side-by-side, semi-permeable tubes. Substances are transported horizontally, by passive or active mechanisms, from one tube to the other. The movement of the transported substances up and down the tubes results in a higher concentration of substances at the bottom of the tubes than at the top of the tubes.

1. The descending limb of the nephron loop is permeable to H_2O, so H_2O diffuses out into the surrounding fluids. Because the loop is impermeable to Na^+ and Cl^- and because these ions are not pumped out by active transport, Na^+ and Cl^- remain inside the loop.

2. As the fluid continues to travel down the descending limb of the loop, it becomes more and more concentrated, as water continues to diffuse out. Maximum concentration occurs at the bottom of the loop.

3. The ascending limb of the nephron loop is impermeable to water, but Na^+ and Cl^- are pumped out into the surrounding fluids by active transport.

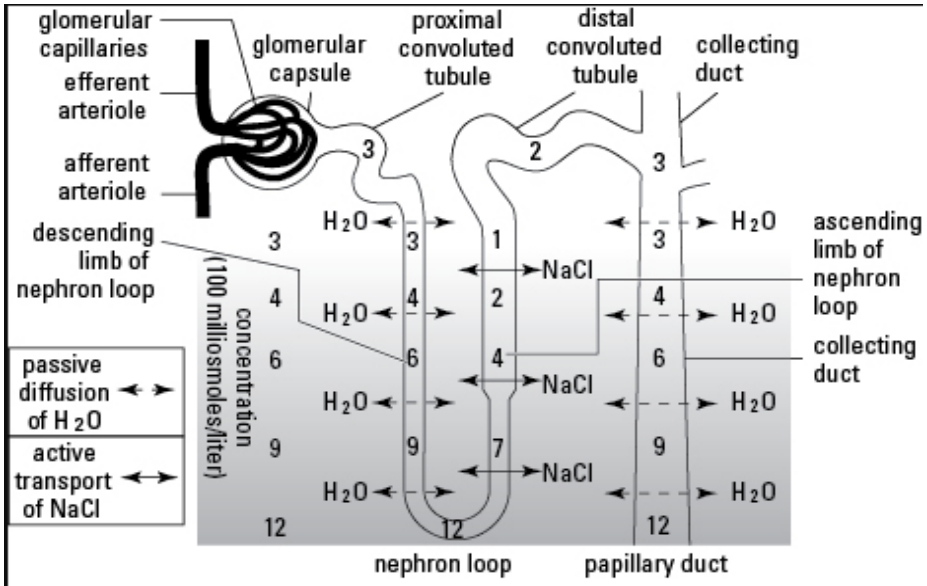
4. As fluid travels up the ascending limb, it becomes less and less concentrated because Na^+ and Cl^- are pumped out. At the top of the ascending limb, the fluid is only slightly less concentrated than at the top of the descending limb. In other words, there is little change in the concentration of the fluid in the tubule as a result of traversing the nephron loop.

5. In the fluid surrounding the nephron loop, however, a gradient of salt (Na^+, Cl^-) is established, increasing in concentration from the top to the bottom of the loop.

    - Fluid at the top of the collecting duct has a concentration of salts about equal to that at the beginning of the nephron loop (some water is reabsorbed in the DCT). As the fluid descends the collecting duct, the fluid is exposed to the surrounding salt gradient established by the nephron loop. Without ADH, the collecting duct is impermeable to H_2O. Two outcomes are possible :

        - If water conservation is necessary, ADH stimulates the opening of water channels in the collecting duct, allowing H_2O to diffuse out of the duct and into the surrounding fluids. The result is concentrated urine.

        - If water conservation is not necessary, ADH is not secreted and the duct remains impermeable to H_2O. The result is dilute urine.



Regulation of Urine Concentration