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QUESTION**Explain urine formation and concentration

**ANSWERS**

**URINE FORMATION**

The urine which is one of the waste products in the body is formed by the Nephrons of the kidneys. The process of the urine formation involves three phases which include:

1. Simple filtration
2. Selective reabsorption
3. Secretion

**Simple Filtration**: This is the process by which the blood constituents having a molecular weight of less than 68000 are forced out through the semi-permeable walls of the glomerulus and the Bowman’s capsule into the renal tubules. Simple filtration is made possible because of the difference in the size of the lumen of the efferent Arteriole being smaller than that of the Afferent Arteriole. This difference creates a capillary hydrostatic blood pressure of about 70 millimetres of mercury (70mm.Hg) within the glomerulus. This pressure is opposed by the osmotic pressure (onchotic pressure) of the plasma protein being 30mm Hg as well as the filtrate hydrostatic pressure of 5mm.Hg in the glomerular capsule (Bowman’s capsule). This gives a net filtration pressure of 35mm. Hg. (i.e. 70mm.Hg - (30 + 5 mm Hg = 35mm.Hg). The Net filtration pressure then forces the glomerular filtrates having molecular weight of less than 68000 into the renal tubules. Those filtrates include water, glucose, amino acid, fatty acid, inorganic salts, urea, uric acid, creatinine, hormones, toxins and even haemoglobin. The constituents of the blood with a higher molecular weight of 68000 or more which are not filtered into the renal tubules include red blood cells, white blood cells, platelets and plasma proteins. As much as 180 litres of the glomerular filtrates may be produced per day out of which 1.5 litres of urine is formed and excreted per day. It then becomes obvious and imperative that the remaining 178.5 litres of the filtrates must be reabsorbed into the blood stream. This then necessitates the involvement of the second phase of urine formation which is called the selective reabsorption.

**Selective Reabsorbtion**: This is the process by which some constituents of the glomerular filtrates which are still essential to the body tissue re-enter the blood stream by passing through the semi-permeable walls of the renal tubules and the surrounding capillary walls to maintain the fluid and electrolyte balance of the body, as well as the maintenance of Acid-Base balance of the blood. This second phase implies that the renal tubules are selectively porous to substances of value to the body and impermeable to the unwanted ones. The selective reabsorption takes place in the walls of renal tubules by active and passive transport. The passive process of diffusion depends upon the pressure gradient which is of immense use in this phase in which the blood pressure is lower in the capillaries surrounding the renal tubules than in the glomerular capillaries and renal tubules.

**Secretion**: This is the last phase in the urine formation. It is a process by which non-threshold substances which have escaped filtration from the glomeruli are cleared from the blood by active transport into the renal tubules to be excreted in the urine. These substances include drugs (e.g. penicillin, steroids), foreign materials, Para-Aminohippuric acid, Hydrogen ions, Hydroxyl ions, Urea, Uric acid, Phosphates, creatinine etc. The secretion of phosphate is influenced by the parathyroid hormone. The urine which is now fully formed in the collecting tubules passes through the calyces into the renal pelvis and thereafter down the ureters into the urinary bladder, where it is temporarily stored.

**URINE CONCENTRATION**

The Loop of Henle is critical to the ability of the kidney to concentrate urine. The high concentration of salt in the medullary fluid is believed to be achieved in the loop by a process known as counter current exchange multiplication. The principle of this process is analogous to the physical principle applied in the conduction of hot exhaust gases past cold incoming gas so as to warm it and conserve heat. That exchange is a passive one, but in the kidney the counter current multiplier system uses energy to “pump” sodium and chloride out of the ascending limb of the loop into the medullary fluid. From there it enters (by diffusion) the filtrate (isotonic with plasma) that is entering the descending limb from the proximal tubule, thus raising its concentration a little above that of plasma. As this luminal fluid in turn reaches the ascending limb, and subsequently the distal tubule, it in turn provides more sodium to be pumped out into the surrounding fluid or blood, if necessary, and transported (by diffusion) back into the descending limb; this concentrating process continues until the osmotic pressure of the fluid is sufficient to balance the resorptive power of the collecting ducts in the medulla, through which all of the final urine must pass. This resorptive capacity in the ducts is regulated by [antidiuretic hormone](https://www.britannica.com/science/vasopressin) (ADH), which is secreted by the hypothalamus and stored in the posterior [pituitary gland](https://www.britannica.com/science/pituitary-gland) at the base of the brain. In the presence of ADH, the medullary collecting ducts become freely permeable to solute and water.   
 As a consequence, the fluid entering the ducts (en route to the [renal pelvis](https://www.britannica.com/science/renal-pelvis) and subsequent elimination) acquires the concentration of the interstitial fluid of the medulla; i.e., the urine becomes concentrated. On the other hand, in the absence of ADH, the collecting ducts are impermeable to solute and water, and, thus, the fluid in the lumen, from which some solute has been removed, remains less concentrated than plasma; i.e., the urine is dilute.The secretion of ADH by the hypothalamus and its release from the posterior pituitary is part of a feedback mechanism responsive to the tonicity of plasma. This interrelation between plasma osmotic pressure and ADH output is mediated by specific and sensitive receptors at the base of the brain. These receptors are particularly sensitive to sodium and chloride ions. At normal blood tonicity there is a steady receptor discharge and a steady secretion of ADH. If the plasma becomes hypertonic (i.e., has a greater osmotic pressure than normal), either from the ingestion of crystalloids such as [common salt](https://www.britannica.com/science/salt), or from shortage of water, receptor discharge increases, triggering increased ADH output, and more water leaves the collecting ducts to be absorbed into the blood. If the osmotic pressure of plasma becomes low, the reverse is the case. Thus water ingestion dilutes body fluids and reduces or stops ADH secretion; the urine becomes hypotonic, and the extra water is excreted in the urine.   
 The situation is complex because there are also receptors sensitive to changes in blood volume that reflexively [inhibit](https://www.merriam-webster.com/dictionary/inhibit) ADH output if there is any tendency to excessive blood volume. Exercise increases ADH output and reduces urinary flow. The same result may follow emotional disturbance, fainting, pain, and injury, or the use of certain drugs such as morphine or nicotine. Diuresis is an increased flow of urine produced as the result of increased fluid intake, absence of hormonal activity, or the taking of certain drugs that reduce sodium and water reabsorption from the tubules. If ADH secretion is [inhibited](https://www.merriam-webster.com/dictionary/inhibited) by the drinking of excess water, or by disease or the presence of a tumour affecting the base of the brain, water diuresis results; and the rate of urine formation will approach the rate of 16 millilitres per minute filtered at the glomeruli. In certain disorders of the pituitary in which ADH secretion is diminished or absent—e.g., diabetes insipidus—there may be a fixed and irreversible output of a large quantity of dilute urine.