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MATRIC NO: 18/MHS02/103
DEPT: NURSING SCIENCE
COURSE : PHS 212

QUESTION

Explain the process of urine formation and concentration

ANSWER

Glomerular Filtration

Glomerular filtration occurs as blood passes into the glomerulus producing a plasma-like filtrate (minus proteins) that gets captured by the Bowman's (glomerular) capsule and funneled into the renal tubule. This filtrate produced then becomes highly modified along its route through the nephron by the following processes, finally producing urine at the end of the collecting duct.

Tubular Reabsorption

As the filtrate travels along the length of the nephron, the cells lining the tubule selectively, and often actively, take substances from the filtrate and move them out of the tubule into the blood. Recall that the glomerulus is simply a filter and anything suspended in the plasma that can fit through the holes in the filtration membrane can end up in the filtrate. This includes very physiologically important molecules such as water, sodium, chloride, and bicarbonate (along with many others) as well as molecules that the digestive system used a lot of energy to absorb, such as glucose and amino acids. These molecules would be lost in the urine if not reclaimed by the tubule cells. These cells are so efficient that they can reclaim all of the glucose and amino acids and up to 99% of the water and important ions lost due to glomerular filtration. The filtrate that is not reasbsorbed becomes urine at the base of the collecting duct.

Tubular Secretion

Tubular secretion occurs mostly in the PCT and DCT where unfiltered substances are moved from the peritubular capillary into the lumen of the tubule. Secretion usually removes substances from the blood that are too large to be filtered (ex: antibiotics, toxins) or those that are in excess in the blood (ex: H+, K+). These substances secreted into the tubule are destined to leave the body as components of urine.

Substances Secreted or Reabsorbed in the Nephron and Their Locations (Table

Substance	PCT	Loop of Henle	DCT	Collecting ducts
Glucose	Almost 100 percent reabsorbed; secondary active transport with Na+			
Oligopeptides, proteins, amino acids	Almost 100 percent reabsorbed; symport with Na+			
Vitamins	Reabsorbed			
Lactate	Reabsorbed			
Creatinine	Secreted			
Urea	50 percent reabsorbed by diffusion; also secreted	Secretion, diffusion in descending limb		Reabsorption in medullary collecting ducts; diffusion
Sodium	65 percent actively reabsorbed	25 percent reabsorbed in thick ascending limb; active transport	5 percent reabsorbed; active	5 percent reabsorbed, stimulated by aldosterone; active
Chloride	Reabsorbed, symport with Na+, diffusion	Reabsorbed in thin and thick ascending		

limb; diffusion in ascending limb Reabsorbed; diffusion Reabsorbed; symport
Water 67 percent reabsorbed osmotically with solutes 15 percent reabsorbed in descending limb; osmosis 8 percent reabsorbed if ADH; osmosis Variable amounts reabsorbed, controlled by ADH, osmosis
Bicarbonate 80–90 percent symport reabsorption with Na+ Reabsorbed, symport with Na+ and antiport with Cl–; in ascending limb Reabsorbed antiport with Cl–
H+ Secreted; diffusion Secreted; active Secreted; active
NH4+ Secreted; diffusion Secreted; diffusion Secreted; diffusion
HCO3– Reabsorbed; diffusion Reabsorbed; diffusion in ascending limb Reabsorbed; diffusion Reabsorbed; antiport with Na+
Some drugs Secreted Secreted; active Secreted; active
Potassium 65 percent reabsorbed; diffusion 20 percent reabsorbed in thick ascending limb; symport Secreted; active Secretion controlled by aldosterone; active
Calcium Reabsorbed; diffusion Reabsorbed in thick ascending limb; diffusion Reabsorbed if parathyroid hormone present; active
Magnesium Reabsorbed; diffusion Reabsorbed in thick ascending limb; diffusion Reabsorbed
Phosphate 85 percent reabsorbed, inhibited by parathyroid hormone, diffusion Reabsorbed; diffusion

The concentration of urine

As already indicated, 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 countercurrent 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 countercurrent 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 (ADH), which is secreted by the hypothalamus and stored in the posterior 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 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.