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URINE FORMATION AND CONCENTRATION

Urine is a waste by-product formed from excess water and metabolic waste molecules during the process of renal system filtration. The primary function of the renal system is to regulate blood volume and plasma osmolarity, and waste removal via urine is essentially a convenient way that the body performs many functions using one process. Urine formation occurs during three processes:

* Filtration
* Reabsorption
* Secretion

FILTRATION

During filtration, blood enters the afferent arteriole and flows into the glomerulus where filterable blood components, such as water and nitrogenous wastes, will move towards the inside of the glomerulus, and the non-filterable components, such as cells and serum albumins, will exit via the efferent arteriole. These filterable components accumulate in the glomerulus to form the glomerular filtrate. Normally, about 20% of the total blood pumped by the heart each minute will enter the kidneys to undergo filtration; this is called the filtration fraction. The remaining 80% of the blood flows through the rest of the body to facilitate tissue perfusion and gas exchange. By glomerular filtration, water and solutes are forced through the capillary walls of the glomerulus into the Bowman’s capsule (glomerular capsule). The fluid that is filtered out into the Bowman’s capsule is the filtrate. Glomerular Filtration Rate is regulated by some mechanisms:

1. Auto regulation: The smooth muscle in the afferent arteriole responds to blood pressure changes by constricting and dilating to regulate filtration rate.
2. Sympathetic control: This causes afferent arterioles to constrict or dilate when activated by a nerve impulse (fight or flight response to keep blood pressure up).

Renin-angiotensin mechanism is triggered by the juxtaglomerular apparatus; when filtration rate decreases, the enzyme renin is released. Renin converts a plasma protein called angiotensinogen into angiotensin I. Angiotensin I is quickly converted into angiotensin II by another enzyme. Angiotensin causes some changes:

* Constriction of the arterioles- decreases urine formation and water loss
* Stimulates the adrenal cortex to release aldosterone- promotes water reabsorption by causing the absorption of salt.
* Stimulates the posterior pituitary to release ADH which promotes water reabsorption
* Stimulates the thirst and water intake

REABSORPTION

The next step is reabsorption, during which molecules and ions will be reabsorbed into the circulatory system. The fluid passes through the components of the nephron (the proximal/distal convoluted tubules, loop of Henle, the collecting duct) as water and ions are removed as the fluid osmolarity (ion concentration) changes. In the collecting duct, secretion will occur before the fluid leaves the ureter in the form of urine.

SECRETION

During secretion, some substances such as hydrogen ions, creatinine, and drugs will be removed from the blood through the peritubular capillary network into the collecting duct. The end product of all these processes is urine, which is essentially a collection of substances that has not been reabsorbed during glomerular filtration or tubular reabsorption. Urine is mainly composed of water that has not been reabsorbed, which is the way in which the body lowers blood volume, by increasing the amount of water that becomes urine instead of instead of becoming reabsorbed. The other main component of urine is urea, a highly soluble molecule composed of ammonia and carbon dioxide, and provides a way for nitrogen (found in ammonia) to be removed from the body. Urine also contains many salts and other waste components. Red blood cells and sugar are not normally found in urine but may indicate glomerulus injury and diabetes mellitus respectively.

URINE CONCENTRATION

Urine concentration test determines how well your kidneys are functioning. The test may be used to test may be used to your kidney’s response to:

* Too much fluid intake (water loading)
* Too little fluid intake (dehydration)
* A hormone that should concentrate the urine, anti-diuretic hormone (ADH)

A urine concentration test can also be used to evaluate:

* Dehydration
* Kidney failure
* Heart failure
* Other hormone problems
* Complications of a urinary tract infection

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 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 fluid is sufficient to balance the resorptive power of the collecting ducts in the medulla, through which all of the final urine must pass.

COUNTER CURRENT MULTIPLICATION

Counter current multiplication refers to the process by which a small osmolality difference, at each level of the outer medulla, between fluid flows in ascending and descending limbs of the loops of Henle, is multiplied by the counter current flow configuration to establish a large axial osmolality difference. This axial difference is frequently referred to as the cortico-medullary osmolality gradient, as it is disturbed along the cortico-medullary axis.