NAME: OLOFU JESSICA CHIOMA

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EXPLAIN URINE FORMATION AND CONCENTRATION.

Urine Formation

Urine is formed in the kidneys through a filtration of blood. The urine is then passed through the ureters to bladder, where it is stored. During urination, the urine is passed from the bladder through the urethra to the outside of the body.

Urine Formation – by filtering the blood the nephrons perform the following functions

(1) Regulate concentration of solutes in blood plasma; this also regulates pH

(2) Regulate water concentrations; this helps regulate blood pressure

(3) Removes metabolic wastes and excess substances

STEPS IN URINE FORMATION:

A. Glomerular Filtration
B. Reabsorption
C. Secretion

Glomerular Filtration – water and solutes are forced through the capillary walls of the glomerulus into the Bowman's capsule (glomerular capsule)

- Filtrate – the fluid that is filtered out into bowman's capsule

Glomerular Filtration Rate is regulated by mechanisms:

1. Autoregulation – the smooth muscle in the afferent arteriole responds to blood pressure changes by constricting and dilating to regulate filtration rate.
2. Sympathetic control – 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 – 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 II causes 3 changes:

- (1) Constriction of the arterioles – decreases urine formation and water loss
- (2) Stimulates the adrenal cortex to release aldosterone – promotes water reabsorption by causing the absorption of salt
- (3) Stimulates the posterior pituitary to release ADH – antidiuretic hormone – promotes water reabsorption
- (4) Stimulates the thirst and water intake (hypothalamus says we're thirsty so we get a drink)

Tubular Reabsorption – occurs both passive and actively; glucose, amino acids, and other needed ions (Na, K, Cl, Ca, HCO3) are transported out of the filtrate into the peritubular capillaries (they are reabsorbed back into the blood); about 65% of the filtrate is reabsorbed in the proximal convoluted tubule.

- As these substances are reabsorbed, the blood becomes hypertonic so water easily follows by osmosis
- Reabsorption in the distal convoluted tubule is under hormonal control…aldosterone causes more salt to be absorbed, ADH causes more water to be absorbed
- Around 99% of the filtrate obtained is reabsorbed by renal tubules. This is known as reabsorption. This is achieved by active and passive transport.

Secretion – waste products such as urea and uric acid, drugs and hydrogen and bicarbonate ions are move out of the peritubular capillaries into the filtrate; this removes unwanted wastes and helps regulate pH

- Urine – filtrate after it has passed through the nephron and undergone filtration, reabsorption, and secretion. The urine passes into the collecting duct, which joins with the minor calyx, major calyx, and eventually the renal pelvis. The renal pelvis joins with the ureter. The urine produced is 95% water and 5% nitrogenous wastes. Wastes such as urea, ammonia, creatinine are excreted in urine. Apart from rhese, the potassium, sodium and calcium ions are also excreted.

- Color – yellow color is due to urochrome – a pigment produced from the breakdown of bile pigments in the intestine
  - Deep yellow to orange – more concentrated, less water
  - Light yellow to clear – less concentrated, more water

Glomerular Filtration Rate (GFR)

The volume of filtrate formed by both kidneys per minute is termed the glomerular filtration rate (GFR). The heart pumps about 5 L blood per min under resting conditions. Approximately 20 percent or one liter enters the kidneys to be filtered. On average, this liter results in the production of about 125 mL/min filtrate produced in men (range of 90 to 140 mL/min) and 105 mL/min filtrate produced in women (range of 80 to 125 mL/min). This amount equates to a volume of about 180 L/day in men and 150 L/day in women. Ninety-nine percent of this filtrate is returned to the circulation by reabsorption so that only about 1–2 liters of urine are produced per day.

URINE CONCENTRATION

The final concentration of the urine is very dependent on the amount of liquid ingested, the losses through respiration, faeces and skin, including sweating. When the intake far exceeds the losses, then, in order to maintain homeostasis the rest of the liquid is eliminated through urine. If the fluid intake is low and the losses are high, then the kidney has to concentrate as much as possible the urine in order to maintain homeostasis. As a result the concentration can range from as diluted as 65 to as concentrated as 1200 mOsm/kg. Producing diluted urine is not as problematic as to concentrating it. To achieve the higher concentrations the kidney depends on the juxtaglomerular nephrons that reach deep into the medulla and in the architectural relationship with the vasa recta. As mentioned before the concentration of the interstitial fluid increases in the medulla towards the tip of the renal pyramid. The higher concentrations of the interstitial fluid in the tip of the renal pyramid are achieved because the nephron has the capability of recirculate urea. Urea in the filtrate is not completely reabsorbed and most of it goes into urine. A percentage of the urea in the filtrate diffuses out of the collecting duct into the interstitial fluid. Once in the interstitial fluid urea provides the increase in osmalality that makes the tip of the renal pyramid so concentrated.

The urea circulates between the collecting duct where it diffuses into the interstitial fluid and the thin descending segment of the loop of Henle which is also permeable to urea. At this point it diffuses into the tubule to reach again the collecting duct.

All the concentration capacity of the nephron can be attributed to the fact that the loop of Henle is in close association or apposition with the extension of the peritubular capillaries which deep in the medulla are called the vasa recta.

The association between these two structures is one that creates a counter current mechanism which permit the removal of all reabsorbed solutes and the water that follows by osmosis out of the medulla into the venous return of the kidney. Otherwise the interstitial fluid would be rapidly diluted or engorged with water and solutes.

Regulation of final urine volume and urine concentration.

The events taking place in the proximal convoluted tubule and the loop of Henle are standard and they account for the reabsorption of approximately 80 % of the filtrate volume. These events are endocrine independent in terms of regulating final volume and concentrations. There are endocrine influences at the level of the renal corpuscle that regulate the GFR but not the concentration of the urine.

The later section of the distal convoluted tubule and the collecting duct operates under direct endocrine influence to regulate the amount of fluid and electrolytes to be discarded in urine. This is not a locally made decision but it represent the needs of the entire organism as many baro and osmo receptors convey their information to the hypothalamus who in turn process it and organize the release of Anti Diuretic Hormone. The other hormonal system which contributes to the regulation of the concentration of the urine is the renin-angiotensin-aldosterone system. Although both system work in conjunction to maintain homeostasis ADH release is more in response to changes in osmolality in blood while the renin-angiotensin-aldosterone system is more sensible to changes in blood pressure.

ENDOCRINE CONTROL

- Anti Diuretic Hormone (ADH)
- Renin-Angiotensin-Aldosterone
- Atrial Natriuretic Hormone (ANH)
- Urodilatin