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Explain urine formation and concentration

Urine Formation

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

- **Urine Formation:**

1. **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. **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** – 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.

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.

- **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

<u>Concentration Of Urine</u>

The mammalian kidney maintains nearly constant blood plasma osmolality and nearly constant blood plasma sodium concentration by means of mechanisms that independently regulate water and sodium excretion. Because many mammals do not have continuous access to water, the ability to vary water excretion can be essential for survival.

Because sodium and its anions are the principal osmotic constituents of blood plasma, and stable electrolyte concentrations are also essential, water excretion must be regulated by mechanisms that decouple it from sodium excretion. The urine concentrating mechanism plays a fundamental role in regulating water and sodium excretion. When water intake is large enough to dilute blood plasma, a urine more dilute than blood plasma is produced; when water intake is so small that blood plasma is concentrated, a urine more concentrated than blood plasma is produced. In both cases, the total urinary solute excretion rate and the urinary sodium excretion rate are small and normally vary within narrow bounds.

Most physiologic studies relevant to the urine concentrating mechanism have been conducted in species (rodents, rabbits) that can achieve higher maximum urine osmolalities than humans. For example, rabbits can concentrate to ~ 1,400 mOsm/kg H_2O, rats to ~ 3,000 mOsm/kg H_2O, mice and hamsters to ~ 4,000 mOsm/kg H_2O, and chinchillas to ~ 7,600 mOsm/kg H_2O.

The mechanisms for the independent control of water and sodium excretion are mostly contained within the renal medulla. The medullary nephron segments and vasa recta are arranged in complex but specific anatomic relationships, both in terms of three-dimensional configuration and in terms of which segments connect to which segments. The

production of concentrated urine involves complex interactions among the medullary nephron segments and vasculature. In outer medulla, the thick ascending limbs of the loops of Henle actively reabsorb NaCl. This serves two vital functions: it dilutes the luminal fluid; and it provides NaCl to increase the osmolality of the medullary interstitium, pars recta, descending limbs, vasculature, and collecting ducts. Both the nephron segments and vessels are arranged in a countercurrent configuration, thereby facilitating the generation of a medullary osmolality gradient along the cortico-medullary axis. In inner medulla, osmolality continues to increase, although the source of the concentrating effect remains controversial. The most widely accepted mechanism remains the passive reabsorption of NaCl, in excess of solute secretion, from the thin ascending limbs of the loops of Henle.