Renal Physiology

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III. Physiology
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   \[
   \text{renal clearance (ml/min)} = \frac{\text{urine concentration (mg/ml)} \times \text{urine flow (ml/min)}}{\text{plasma concentration (mg/ml)}}
   \]
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         b. Posterior Pituitary

      3. Aldosterone (renin-angiotensin-aldosterone system)
         a. Juxtaglomerular Apparatus
            - Juxtaglomerular Cells (afferent arteriole)
            - Macula Densa Cells (DCT)

      4. Atrial Natriuretic Factor

VII. Additional Key Terms / Topics (FYI)

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A. **Renal Corpuscle.** The glomerulus within the renal corpuscle is the site of filtration. About 1000 ml of blood passes through the capsule (called filtrate). Filtration is strictly a mechanical process as blood is filtered through minute pores formed by the fenestrated glomerular filtration is influenced by hydrostatic and osmotic pressure differentials between the glomerular capillaries and Bowman’s capsule. The rate of filtration is regulated in part by changes in the diameter of the afferent and efferent arterioles.

B. **Proximal Convoluted Tubule (PCT).** Filtrate entering the PCT has about the same osmolarity as plasma but does not contain any large proteins. As much as 80% of the filtrate will be reabsorbed within the PCT. Nearly all nutrients, such as glucose & amino acids are actively reabsorbed. Sodium (Na\(^+\)) is also actively reabsorbed while chloride (Cl\(^-\)) and water follow passively. Hydrogen ions (H\(^+\)) are actively secreted and bicarbonate (HCO\(_3^-\)) is reabsorbed.

C. **Descending Loop of Henle.** The descending limb is impermeable to salt but is freely permeable to water which diffuses out as the tubule descends into an increasingly hypertonic interstitial fluid of the medulla. Consequently the filtrate becomes concentrated within the descending limb.

D. **Ascend Loop of Henle.** The ascending limb is impermeable to water but salts (Na\(^+\) & Cl\(^-\)) are actively reabsorbed contributing to the hypertonicity of the interstitial fluid. The filtrate becomes more dilute as salt is removed but waste molecules remain concentrated within the filtrate.

E. **Distal Convoluted Tubule (DCT).** The DCT is essentially impermeable to water except when aldosterone is present. Under the influence of aldosterone Na\(^+\) is reabsorbed and K\(^+\) is secreted (water follows Na\(^+\) passively).

F. **Collecting Duct.** In the absence of ADH the collecting duct is impermeable to water. In the presence of ADH the collecting duct becomes permeable to water and water is reabsorbed by osmosis as the tubule descends into the increasingly hypertonic interstitial fluid of the medulla.
Renal Corpuscle (Glomerulus & Bowman’s Capsule)

Proximal Convoluted Tubule (PCT)

Loop of Henle (LH)

Distal Convoluted Tubule (DCT)

Collecting Duct (CD)

Efferent Arteriole

Afferent Arteriole

FILTRATION

1200ml blood (625 ml plasma)

RC: ALL filtration occurs here: 20% of plasma is filtered (producing ~125 ml of filtrate per minute)

REABSORPTION (and secretion)

PCT: The MAJORITY of reabsorption occurs here: 65-75% of filtrate is reabsorbed as a default

LH: Both water (passive) and salt (active) are reabsorbed. The counter-current-multiplier allows water to be carried away while salt is trapped producing an increasing osmotic concentration gradient in the medulla.

CONCENTRATION

1° REGULATED REABSORPTION (and secretion)

Reabsorption (and secretion) in the DCT and CD is regulated by ADH and Aldosterone (amount is variable).

ADH stimulates tubule epithelial cells (1° in CD) to insert aquaporins into their membranes resulting in increased water permeability and reabsorption (depending on the osmotic gradient)

Aldosterone stimulates increased sodium-potassium pump activity (1° in DCT) resulting in increased sodium (and water) reabsorption in exchange for increased potassium secretion

Salt (Na, K, Cl)

Urine: ~1 ml / min
ANTIDIURETIC HORMONE (ADH) and ATRIAL NATURIETIC HORMONE (stimulatory pathway for ADH, stimulatory pathway for ANH)

- **Baroreceptors**
- **Osmoreceptors** (hypothalamus)
- **Thirst**

**POSTERIOR PITUITARY**

**Antidiuretic Hormone (ADH)** (aka vasopressin)

**ADRENAL CORTEX**

**ANH decreases sodium (and water) reabsorption from the collecting ducts via inhibition of aldosterone and ADH secretion**

**ADH increases water reabsorption by increasing the permeability of the collecting ducts to water (through addition of water pores)**

RENNIN-ANGIOTENSIN-ALDOSTERONE SYSTEM (stimulatory pathway for aldosterone)

- **Plasma Sodium [Na+]**
- **Macula Densa (DCT)**
- **Juxtaglomerular (JG) Cells**
- **Angiotensinogen**
- **Renin (enzyme)**
- **Angiotensin I**
- **ACE (angiotensin converting enzyme)**
- **Angiotensin II**
- **Vasoconstriction**

**ADRENAL CORTEX**

**Aldosterone increases sodium reabsorption (and water) in exchange for potassium and hydrogen ions in the distal convoluted tubules and collecting ducts.**
Study Questions – Renal Physiology:

1. Define “interstitial fluid,” “plasma,” and “urine”.
2. Describe the fluid inputs and outputs associated with the kidneys.
3. Describe the distribution and composition of fluids in the body and the associations between each “compartment”.
4. Describe the different routes of water intake and water loss.
5. Describe the regulatory mechanisms regulating water intake.
6. Describe the anatomical association between the renal blood vessels and the renal tubules (nephron).
7. Name and describe the three nephron processes of urine production.
8. Describe the role of the renal corpuscle.
9. What is glomerular filtration? What filters? How is this determined? How much filters? How is the rate of filtration described?
10. How is glomerular filtration controlled?
11. Describe the role of the proximal convoluted tubule (PCT). How much filtrate enters and leaves the PCT?
12. Describe the mechanism associated with sodium, glucose, and water reabsorption in the PCT.
13. Define “renal threshold.” What characterizes molecules that exhibit a renal threshold?
14. Describe the two general functions of the loop of Henle. How much filtrate enters and leaves the loop of Henle?
15. Describe the function of the descending limb of the loop of Henle.
16. Describe the function of the ascending limb of the loop of Henle.
17. What single factor distinguishes the distal convoluted tubule (DCT) and collecting ducts from all other regions of the nephron?
18. Describe the regulatory mechanisms that control the DCT and collecting duct.
19. Describe the three general mechanisms for regulating blood pH.
20. Describe the mechanism and significance of intrinsic control over glomerular filtration.
21. Describe the role of the autonomic nervous system in regulating urine production.
22. Describe the source of antidiuretic hormone (ADH).
23. Describe the stimuli that trigger ADH secretion (or inhibit secretion).
24. Describe the target cells and effect of ADH.
25. Describe the source of aldosterone.
26. Describe the stimuli that trigger aldosterone secretion (or inhibit secretion).
27. Describe the structure and function of the juxtaglomerular apparatus.
28. Describe all of the steps in renin-angiotensin-aldosterone pathway.
29. Describe the target cells and effect of aldosterone.
30. Describe the source, stimuli, and effect of atrial natriuretic hormone.