Control of Blood Pressure and Volume: Hormonal Factors
Learning Objectives

1. Discuss the mechanism and various hormones involved in concentrating and diluting urine

2. Describe the roles of renin, angiotensin II, ADH, aldosterone and arterial natriuretic peptide (ANP)

3. Outline how the renin-angiotensin-aldosterone axis is stimulated when blood volume is reduced

4. Describe the stimuli for angiotensin II and aldosterone release and their actions in increasing blood volume

5. Discuss the release of ANP and its actions in reducing blood volume
Water balance is controlled by concentrating or diluting the urine
Countercurrent Multiplication

- \( \text{H}_2\text{O} \) moves into interstitium and vasa recta increasing osmolarity in the loop.
- Tubular fluid is very concentrated by the bottom of the loop.
- There are no water channels in the ascending limb.
- Some \( \text{Na}^+ \) and \( \text{Cl}^- \) leave the filtrate here by diffusion.
- In the thick portion of the ascending limb, \( \text{Na}^+ \) and \( \text{Cl}^- \) are actively removed.
- Tubule fluid is dilute.
- Some \( \text{NaCl} \) is absorbed by vasa recta; rest is trapped in interstitium contributing to the osmotic gradient of the medulla.
Osmolarity Changes in the Nephron

If plasma osmolarity (solute concentration) of blood increases, more water is needed in the blood → ADH is released → more water is reabsorbed → less urine.

If plasma osmolarity decreases, ADH is not released, less water is reabsorbed, urine is more dilute.
Renal Hormones
Anti-Diuretic Hormone (ADH) Secretion

- ADH is also called **Vasopressin**
- Involved in the regulation of body water content
- Secreted by posterior pituitary
- Allows formation of water channels in the late distal and collecting duct increasing reabsorption of water
  - Secretion stimulated by:
    1. Plasma osmolarity rises 1 mOsm/L
    2. Hypovolemia >8%
- **Actions:** Reabsorbs H₂O - Increases urine osmolarity and decreases urine flow volume
ADH Mechanism

- ADH is a peptide hormone that binds to the ADH receptor

- ADH receptors are a G-protein coupled receptors that when activated ultimately facilitates increases in principal cell cAMP

- Increases in cAMP cause the insertion of aquaporin H₂O channels in the principal cells facilitating active H₂O reabsorption
Regulation of Body Fluid Osmolarity

Variations in $\text{H}_2\text{O}$ reabsorption = Variations in urine osmolarity
Role of ADH

(a) With maximal vasopressin, the collecting duct is freely permeable to water. Water leaves by osmosis and is carried away by the vasa recta capillaries. Urine is concentrated.

(b) In the absence of vasopressin, the collecting duct is impermeable to water and the urine is dilute.
Role of ADH in Concentration and Dilution of Urine

High ADH

No ADH
Decreased Blood Volume/Pressure

[Diagram showing the effects of decreased blood volume/pressure on the body's response, including increased sympathetic activity, renin, angiotensin, aldosterone, and ADH, leading to changes in heart function, renal function, and renal excretion.]
Macula densa cells part of juxtaglomerular apparatus that sense tubular flow and GFR and send feedback signals to afferent or efferent arteriole to constrict/dilate to keep GFR at normal levels.
**Renin-Angiotensin-Aldosterone System**

**Renin**: Secreted by the *juxtaglomerular cells* (JG) of the afferent arterioles in response to low renal arteriole pressure; catalyzes conversion of plasma protein, angiotensinogen, to Angiotensin I eventually giving Angiotensin II; The macula densa cells located in the distal tubules stimulate the JG cells to release renin in response to decreased NaCl concentration in the tubules.

**Angiotensin II**: Potent arteriole vasoconstrictor, secretion stimulated by decreased arterial pressure and low Na⁺ intake; increases Na⁺ reabsorption in proximal tubule, stimulates thirst, stimulates aldosterone secretion from adrenal cortex.

**Aldosterone**: Increases Na⁺ reabsorption and K⁺ secretion by principal cell in late distal tubule and collecting duct; secreted in response to Angiotensin II, hyperkalemia (high blood [K⁺]), hyponatremia (low plasma [Na⁺]); Directs synthesis of proteins involved in Na⁺ reabsorption (increases number of Na⁺ channels, Na⁺/K⁺- ATPase pumps).
Renin-Angiotensin-Aldosterone System
Increased Blood Volume/Pressure

- Volume expansion
- ↓ Sympathetic activity
- ↓ Renin
- ↓ Angiotensin I
- ↓ Angiotensin II
- ↓ Aldosterone

1. ↑ Urodilatin
2. ↑ ANP and BNP
3. ↑ Na⁺, H₂O excretion

Heart

Brain

↓ ADH
Atrial Natriuretic Peptide (ANP)

High blood pressure stretches the heart chambers, and in response, atrial natriuretic hormone is secreted by the right atrium.

Actions:
• Increases Na⁺ & water excretion
• Inhibits Na⁺ reabsorption at collecting duct
• Vasodilation (renal arterioles - afferent)
• Inhibits renin secretion by juxtaglomerular cells in kidney → inhibits RAA system
• Inhibits aldosterone secretion by adrenal gland
• Inhibits ADH secretion
• Inhibits adenylate cyclase in target tissues

• Inhibits reabsorption of Na⁺ and water - stimulates Na⁺ and water excretion → blood volume is lowered and decreases blood pressure
Test Question

A man is lost in the Mojave desert for 3 days without food or water. Circulating levels of which one of the following hormones is most likely to be high?

1. ADH
2. Aldosterone
3. Angiotensin II
4. ANP
5. Erythropoietin
What actions does angiotensin II have that are not related to its ability to vasoconstrict? Angiotensin II:

a. Decreases blood pressure
b. Decreases ECF

✓ c. Increases Na\(^+\) reabsorption by proximal tubule

d. Inhibits the release of aldosterone from the adrenal cortex

e. Inhibits drive to drink H\(_2\)O
Hormone Summary

• **ADH** (post pituitary) allows formation of water channels in collecting ducts, increasing reabsorption of water. If Na\(^+\) concentration falls, osmolality drops, ADH is inhibited, more water is excreted. This will cause a decrease in blood volume and pressure, and an increase in osmolality. Conversely, if Na concentration increases, osmolality increases, ADH is released, water is reabsorbed. This increases blood volume and pressure and decreases osmolality.

• **Aldosterone** (adrenal cortex) stimulates reabsorption of Na\(^+\) by late distal tubules and collecting ducts.

• **Renin** is secreted by juxtaglomerular cells of the afferent arteriole in response to low renal pressure. Angiotensinogen \(\rightarrow\) angiotensin I \(\rightarrow\) angiotensin II. Angiotensin II causes vasoconstriction of arterioles, increasing blood pressure. The macula densa cells located in the distal tubules stimulate the JG cells to release renin in response to decreased Na concentration in the tubules. Angiotensin II also stimulates secretion of aldosterone, enhancing Na\(^+\) and water reabsorption.

• **Atrial natriuretic hormone:** high blood pressure stretches the heart chambers, stimulating release of atrial natriuretic hormone by the right atrium. This decreases aldosterone secretion. It will decrease reabsorption of Na\(^+\) and water from the urine, lowering blood volume.