NOTES: CH 44
– Regulating the Internal Environment (Homeostasis & The Urinary System)
**HOMEOSTASIS**

**Recall…**

**HOMEOSTASIS** is the steady-state physiological condition of the body.

It includes:

1) **Thermoregulation**: maintaining internal temperature;

2) **Osmoregulation**: regulating solute balance and gain / loss of water;

3) **Excretion**: getting rid of waste products of metabolism
Evolutionary perspective on H$_2$O balance

Problems faced by...

a) **freshwater fish**: always taking in H$_2$O; excrete lots of urine

b) **saltwater fish**: losing H$_2$O; drinks a lot; salt glands

c) **terrestrial animals**: need to get rid of N-wastes without losing much H$_2$O; NH$_3$ is very toxic; urea is less toxic
Toxic waste products of metabolism include ammonia (NH$_3$):

proteins $\rightarrow$ NH$_3$ $\rightarrow$ urea $\rightarrow$ excreted amino acids
Functions of the Urinary System:

1) remove salts and nitrogenous wastes (e.g. NH$_3$) from the blood
2) maintain normal water and electrolyte concentrations within body fluids
3) regulates pH and volume of body fluids
4) helps control red blood cell production and blood pressure
The main organs in this system include the **KIDNEYS** & associated “plumbing”:

Ureters  
Bladder  
Urethra

(also skin & lungs play minor roles)
ORGANS OF THE URINARY SYSTEM

1) **KIDNEYS**: remove substances from the blood; **form urine**

2) **URETERS**: transport urine from the kidneys

3) **URINARY BLADDER**: stores urine

4) **URETHRA**: conveys urine to the outside of the body
• **KIDNEYS**

- located high on the posterior abdominal wall

- each kidney is divided into the:
  * **CORTEX**: outer region
  * **MEDULLA**: inner region
  * **PELVIS**: funnel-shaped region where superior end of ureters expands

[Image of urinary tract]
KIDNEY FUNCTIONS:

1) remove metabolic wastes from the blood & combine them with water ➔ **formation of urine**

2) secrete hormone erythropoietin ➔ control of red blood cell formation

3) help to maintain blood pressure
KIDNEY BLOOD SUPPLY:

- **RENAL ARTERIES**: arise from **abdominal aorta**; supply blood to kidney
  - branches into smaller arteries & eventually into the **AFFERENT ARTERIOLES**

- blood returns to the **inferior vena cava** through the **RENAL VEINS**
• URETERS

→ each ureter is about **25 cm** long

→ begin at the renal pelvis; extend downward and join the **URINARY BLADDER** from underneath
Kidney stones may form in the renal pelvis and be passed through a ureter.
• URINARY BLADDER

- a hollow, distensible ("stretchable"), muscular organ
- stores urine and forces it into the URETHRA
● **URETHRA**

- convey urine from the urinary bladder to the outside
- in females, urethra opens just anterior to the vaginal opening
- in males, urethra is enclosed in the penis
**URETHRA**

*female urethral pathway is shorter than in males; as a result, females are more prone to urinary tract infections*

(“**CYSTITIS**” = inflammation of the urinary bladder)
Urinary System – PROCESSES!

- Kidney
- Ureter
- Urinary Bladder
- Urethra
*Recall: the primary function of the urinary system is to filter the blood of ions and nitrogenous wastes; when combined with water, these wastes make up URINE.
NEPHRONS

- **NEPHRONS**: the functional units of the kidneys
  - each kidney contains about a million nephrons!
Parts of a NEPHRON:

• **GLOMERULUS**: tangled cluster of blood capillaries

• **GLOMERULAR CAPSULE** (a.k.a. Bowman’s capsule): thin-walled structure surrounding glomerulus
Parts of a NEPHRON:

- PROXIMAL CONVOLUTED TUBULE
- LOOP OF HENLE
  - descending limb
  - ascending limb
- DISTAL CONVOLUTED TUBULE
Parts of a NEPHRON:

• **COLLECTING DUCT** (where distal tubules from several nephrons converge and drain into; from here, urine empties into the RENAL PELVIS)
Blood Supply of a Nephron:

-blood is brought to a nephron (glomerulus) via an afferent arteriole;
-from here, it is passed to an efferent arteriole;
-this gives rise to a system of peritubular capillaries that surround the renal tubules.
URINE FORMATION

*nephrons remove wastes from blood and regulate water and electrolyte concentrations.

URINE IS THE END PRODUCT!
Three Steps of Urine Formation:

1) **FILTRATION** – in the glomerulus
2) **REABSORPTION** – “good stuff” is reabsorbed into the bloodstream; occurs in the tubular portion of the nephron
3) **SECRETION** – substances the body needs to get rid of at a faster rate are secreted; occurs in the tubular portion of the nephron

**followed by EXCRETION** (urine is excreted from the body).
1) GLOMERULAR FILTRATION:

• water and dissolved materials filter out of glomerular capillaries
• the composition of the filtrate is similar to that of tissue fluid (water, salts, amino acids, etc.)
1) GLOMERULAR FILTRATION:

• occurs due to pressure pushing the fluid into the capillaries

*FILTRATION RATE varies with FILTRATION PRESSURE
2) TUBULAR REABSORPTION:

- substances are selectively reabsorbed from the glomerular filtrate
- the capillaries around the nephron have increased permeability
- most reabsorption occurs in the PROXIMAL TUBULE
2) TUBULAR REABSORPTION:

- substances may be reabsorbed via:
  - **ACTIVE TRANSPORT**: glucose, amino acids, sodium ions (Na\(^+\))
  - **OSMOSIS**: water

- substances that remain in the filtrate become more concentrated as water is reabsorbed
3) TUBULAR SECRETION:

- transports substances from the plasma to the tubular fluid to be excreted with the urine
- substances secreted actively and passively along the tubule:

  - hydrogen ions (H\(^+\)): important in regulating pH
  - potassium ions (K\(^+\))
URINE COMPOSITION:

- about 95% water
- usually contains urea and uric acid (byproducts of nitrogen metabolism)
- electrolytes, amino acids, glucose (only if in excess)
In summary…

You begin with a liquid a lot like blood plasma; by the time it travels through the nephron, your body has taken out the good stuff and put it back into the veins (e.g. water, electrolytes); what you do not reclaim goes out as urine.

*for every 100 mL of filtrate you start with, 99 mL are reabsorbed & only 1 mL urine is made
Control of Water Content / Urination:

1) ADH (antidiuretic hormone):
   - made in hypothalamus;
   - helps you conserve water (& prevent dehydration);
   - acts on distal tubules and collecting ducts to **increase water reabsorption**
   - released in response to increased osmolarity of blood OR a decrease in blood volume.
Release of antidiuretic hormone

Permeability of renal tubules

Water reabsorption

\[ \downarrow \text{Serum osmolality} \]

\[ \downarrow \text{Urine volume} \]

\[ \uparrow \text{Urine osmolality} \]
\[ \begin{align*}
\uparrow \text{Plasma osmolality} \\
\text{or} \\
\downarrow \text{Effective circulating volume}
\end{align*} \]

\[ \begin{align*}
\downarrow \text{Thirst} \\
\uparrow \text{Water ingestion}
\end{align*} \quad \begin{align*}
\uparrow \text{ADH release} \\
\downarrow \text{Water excretion}
\end{align*} \]

\begin{center}
ADH feedback loop
\end{center}

\[ \begin{align*}
\text{Water retention}
\end{align*} \]

\[ \begin{align*}
\downarrow \text{Plasma osmolality} \\
\text{and} \\
\uparrow \text{Effective circulating volume}
\end{align*} \]

\[ \begin{align*}
\downarrow \text{ADH release} \\
\text{and} \\
\downarrow \text{Thirst}
\end{align*} \]
2. high osmotic pressure of blood stimulates hypothalamus
3. hypothalamus
4. posterior lobe of pituitary

5. ADH secretion
6. water retention
7. drink of water
8. inhibits release

1. water loss

osmotic pressure decreases
What if there is no ADH? Or it is inhibited?

- alcohol can disturb water balance by inhibiting the release of ADH;
- this causes excessive urinary water loss and dehydration
Control of Water Content / Urination:

2) **RENIN / ANGIOTENSIN**: work together to increase blood pressure and blood volume

→ **RENIN**: reacts with angiotensinogen to form angiotensin I

→ **ANGIOTENSIN II**: formed from angiotensin I (by an enzyme: ACE); stimulates secretion of **ALDOSTERONE**
Control of Water Content / Urination:

3) ALDOSTERONE:

⇒ made in adrenal gland;
⇒ release of this hormone is stimulated by angiotensin II;
⇒ it stimulates distal tubule to increase reabsorption of sodium (Na\(^+\)), which helps you conserve water;
⇒ result is: an increase in blood volume and blood pressure
Renin-angiotensin-aldosterone system

- Angiotensinogen → Angiotensin I → Angiotensin II
- Renin

Decrease in renal perfusion (juxtaglomerular apparatus)

- Lungs
- Kidney
- Surface of pulmonary and renal endothelium: ACE

Sympathetic activity

Tubular Na⁺ Cl⁻ reabsorption and K⁺ excretion. H₂O retention

Adrenal gland: cortex

Aldosterone secretion

Arteriolar vasoconstriction. Increase in blood pressure

ADH secretion

Pituitary gland: posterior lobe

Collecting duct: H₂O absorption

Legend:
- +: Secretion from an organ
- +: Stimulatory signal
- -: Inhibitory signal
- Reaction
- Active transport
- Passive transport

Water and salt retention. Effective circulating volume increases. Perfusion of the juxtaglomerular apparatus increases.
What if B.P. is too high?

Atrial Natriuretic Hormone (ANH)

● opposes the RAAS
● released by the walls of the atria
● triggered by an **increase in blood volume** and/or **increase in blood pressure**
Atrial Natriuretic Hormone (ANH)

- **inhibits** the release of renin
- **inhibits** NaCl reabsorption by the collecting ducts
- **reduces** aldosterone release from the adrenal glands
- these actions lower blood volume and pressure
**thus, ADH, the RAAS, and ANH provide an elaborate system of checks and balances that regulate the kidney’s ability to control the osmolarity, salt concentration, volume, and pressure of blood.**