Outline – Renal System

I. Functions

II. Organs of the renal system

III. Kidneys
   1. Structure
   2. Function

IV. Nephron
   1. Structure
   2. Function

V. Hormonal control of urine production
Renal System

- Digestive system eliminates waste from the digestive tract.
  - We also need a way to eliminate waste from the rest of the body.

- Functions of renal system: excretion of metabolic wastes and maintenance of blood homeostasis.
1. **Kidneys** – main organs of the renal system; produce urine.

2. **Ureters** – conduct urine from the kidneys to the bladder by peristaltic contractions produced from contractions of smooth muscles in ureter wall.
Organs of the Renal System

3. **Urinary bladder** – stores urine until it is expelled from the body.

3. **Urethra** – small tube that extends from the urinary bladder to an external opening.
Renal System

Kidney
- Produces urine
- Conserves water
- Regulates pH
- Stimulates production of red blood cells
- Transforms vitamin D into active form

Ureter
- Transports urine from kidneys to bladder

Urinary bladder
- Stores urine

Urethra
- Transports urine from urinary bladder to outside the body
Regions of the Kidneys

- Each kidney has three regions:

1. **Renal cortex**: an outer granulated layer.
2. **Renal medulla**: consists of cone-shaped tissue masses called *renal pyramids*.
3. **Renal pelvis**: a central cavity that is continuous with the ureter.
Figure 16.3b Structure of the kidney

Renal cortex

Renal pyramid (of renal medulla)

Renal column (extension of renal cortex)

Renal pelvis

(b) Internal kidney structure
Functions of the Kidneys

1. Filter waste from blood.
3. Regulate blood pressure.
5. Secretion of hormones = renin and erythropoietin.
Nephrons

- The functional units of the kidneys.
- Over 1 million nephrons per kidney
- Nephrons extend from the renal cortex, into the renal medulla.
Parts of the Nephron

1. The renal corpuscle
   A. Glomerulus
   B. Glomerular capsule

2. The renal tubule
   A. Proximal convoluted tubule
   B. Loop of Henle
   C. Distal convoluted tubule

3. The collecting duct
(b) A nephron and its blood supply
The Nephron

(c) Simplified view of a nephron, showing the basic structural components but not the associated capillaries
The Nephron

- The nephron performs three functions:
  1. Glomerular filtration
  2. Tubular reabsorption
  3. Tubular secretion
Renal Corpuscle

- This is where fluid is filtered from blood.

- Contains:
  - **Glomerulus** – tuft of capillaries.
  - **Glomerular capsule** (Bowman’s capsule) – surrounds the glomerulus.
Glomerular Filtration

- Glomerular filtration occurs as blood pressure forces water, ions, and other small molecules in the blood through the pores in the glomerulus and into the glomerular capsule.

- The filtrate passes into the renal tubule.
(a) The renal corpuscle consists of the glomerular capsule and a ball of capillaries called the glomerulus.
Renal Tubule

1. Proximal convoluted tubule (PCT) – reabsorption of filtrate components occurs; tubular secretion can also occur here.

2. Loop of Henle – consists of a descending limb and an ascending limb that regulate osmotic balance.

3. Distal convoluted tubule (DCT) – further absorption of water and salts; leads to the renal pelvis.
Collecting Ducts

- Collecting ducts – carry urine to the renal pelvis.
Urine Formation

- **Tubular reabsorption** – many molecules are reabsorbed back into the capillaries.
  - Occurs mainly in the PCT (H$_2$O, nutrients, salts).

- **Tubular secretion** – substances are removed from the blood and added to the tubular fluid.
  - Occurs mainly in the DCT (H$^+$, creatinine, and drugs like penicillin).
Figure 16-8  Biology of Humans, 2/e
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Step 1: Glomerular filtration
Water, ions, amino acids, glucose, nitrogen-containing wastes, and other small molecules move from the glomerulus to the inside of the glomerular capsule to form glomerular filtrate.

Step 2: Tubular reabsorption
Water, essential ions, and nutrients are reabsorbed from the proximal convoluted tubule into the surrounding capillaries. Some reabsorption of water and ions occurs along other sections of the renal tubule and collecting duct.

Step 3: Tubular secretion
Wastes, excess ions, and drugs are actively secreted into the distal (and proximal) convoluted tubules from the surrounding capillaries. Some secretion also occurs along the collecting duct.
<table>
<thead>
<tr>
<th>Region of Nephron</th>
<th>Roles*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renal corpuscle (glomerular</td>
<td>Filters the blood, removing water, glucose, amino acids, ions,</td>
</tr>
<tr>
<td>capsule and glomerulus)</td>
<td>nitrogen-containing wastes, and other small molecules</td>
</tr>
<tr>
<td>Proximal convoluted tubule</td>
<td>Reabsorbs water, glucose, amino acids, some urea, Na(^+), Cl(^-),</td>
</tr>
<tr>
<td></td>
<td>and HCO(_3)(^-)</td>
</tr>
<tr>
<td></td>
<td>Secretes drugs, H(^+), NH(_4)(^+)</td>
</tr>
<tr>
<td>Loop of the nephron</td>
<td>Reabsorbs water, Na(^+), Cl(^-), and K(^+)</td>
</tr>
<tr>
<td>Distal convoluted tubule</td>
<td>Reabsorbs water, Na(^+), Cl(^-), and HCO(_3)(^-)</td>
</tr>
<tr>
<td></td>
<td>Secretes drugs, H(^+), K(^+), and NH(_4)(^+)</td>
</tr>
</tbody>
</table>

NOTE: *Major reabsorbed or secreted substances are listed here.
This structure conducts urine from the kidneys to the bladder:

1. Urethra
2. Ureters
What is the functional unit of the kidney?

1. Renal medulla
2. Nephron
3. Renal cortex
Hormonal Regulation of Urine

1. Antidiuretic hormone (ADH)
   - Makes more concentrated urine
   - Increases blood volume and pressure

2. Aldosterone
   - Makes more concentrated urine
   - Increases blood volume and pressure

3. Atrial Natriuretic Peptide (ANP)
   - Makes more dilute urine
   - Decrease blood volume and pressure
Hormonal Regulation of Urine – ADH

- **Antidiuretic hormone (ADH)**
  - Makes the collecting duct more permeable and increases water reabsorption in the collecting duct, making more concentrated urine.
  - Produced by the hypothalamus, stored in the posterior pituitary gland.
  - Site of action: collecting ducts.
Diabetes Insipidus

- Diabetes insipidus is caused by producing too little ADH!

- Symptoms: excrete large amounts of dilute urine.
Hormonal Regulation of Urine – Aldosterone

- **Aldosterone**
  - Hormone produced and released by the adrenal cortex in response to low blood pressure.
  - Increases sodium and water reabsorption in the DCT and the collecting duct.
  - Makes more concentrated urine.
Hormonal Regulation of Urine – ANP

- **Atrial Natriuretic Peptide (ANP)**
  - Hormone produced by the heart in response to increased blood volume and pressure.
  - Decreases sodium reabsorption in the distal convoluted tubule and the collecting duct, water stays in the filtrate.
  - Also inhibits production of aldosterone.
  - Makes more dilute urine.
### Table 16.3 Review of Some Hormones that Influence Kidney Function

<table>
<thead>
<tr>
<th>Hormone</th>
<th>Effect on Water and Solute Reabsorption in Nephron</th>
<th>Effect on Blood Volume and Pressure</th>
<th>Urine Produced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antidiuretic hormone (ADH)</td>
<td>Increases permeability to water of collecting ducts, resulting in more water moving from filtrate to blood</td>
<td>Increases</td>
<td>Concentrated</td>
</tr>
<tr>
<td>Aldosterone</td>
<td>Increases reabsorption of Na(^+) by distal convoluted tubules and collecting ducts, resulting in more water following Na(^+) as it moves from filtrate to blood</td>
<td>Increases</td>
<td>Concentrated</td>
</tr>
<tr>
<td>Atrial natriuretic peptide (ANP)</td>
<td>Decreases reabsorption of Na(^+) by distal convoluted tubules and collecting ducts, resulting in more Na(^+) and water remaining in filtrate</td>
<td>Decreases</td>
<td>Dilute</td>
</tr>
</tbody>
</table>
Hormones Produced by the Kidneys

1. Renin – increases blood pressure by triggering the release of aldosterone by the adrenal cortex.

2. Erythropoietin – speeds up the maturation process of RBCs by targeting stem cells in bone marrow.
Kidney’s Role in Acid-Base Balance

- $H^+$ is secreted into the tubules and bicarbonate is reabsorbed out of the tubules.
When $\text{H}^+$ is secreted into the tubules, this lowers the pH of the blood.

1. True
2. False
The kidneys reabsorb salt and water, maintaining osmotic balance in the blood, and this also affects blood pressure.
Urine

- Urine contains:
  - Water
  - $\text{HCO}_3^-$
  - Inorganic salts
  - $\text{H}^+$
  - Urea
  - Uric acid
  - Creatinine
The urine goes from the kidneys into the ureters, and then to the bladder where it is stored until it can be released through the urethra.

Urination is controlled by both voluntary and involuntary actions.

When the bladder fills to about 250 mL of urine, the motor nerve impulses cause the bladder to contract and the sphincters to relax so that urination is possible.
Which hormone is secreted by the kidneys to increase blood pressure?

1. ADH
2. Renin
3. Aldosterone
4. Erythropoietin

<table>
<thead>
<tr>
<th>Hormone</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADH</td>
<td>16%</td>
</tr>
<tr>
<td>Renin</td>
<td>58%</td>
</tr>
<tr>
<td>Aldosterone</td>
<td>16%</td>
</tr>
<tr>
<td>Erythropoietin</td>
<td>11%</td>
</tr>
</tbody>
</table>
Important Concepts

- Read Chapter 16
- What are the functions of the renal system?
- What are the organs of the renal system and their functions, including all the functions of the kidney?
- What are the three regions of the kidney?
Important Concepts

 What is the function of a nephron? What are the parts of the nephron and the functions of these parts?

 What are glomerular filtration, reabsorption, and secretion in the nephron?
   What is contained in the filtrate leaving the renal corpuscle?
   Which compounds are reabsorbed and which are secreted? Where in the nephron are the compounds reabsorbed or secreted?
Important Concepts

- How is urinary output regulated?
  - Which hormones decrease or increase urinary output?
  - What effect on blood pressure do these hormones have?
  - Where are these hormones produced?
  - What is their effect on the nephron?

- What is the cause of diabetes insipidus?

- What is the effect of renin on urine production and blood pressure?
Important Concepts

- What is the function of erythropoietin, what is its target, and where is it produced?

- How does the kidney regulate blood pH and maintain osmotic balance? How does the regulation of salt/water balance affect blood pressure?

- How does urination occur?
Definitions

- Excretion, renal pyramid, renal corpuscle, tubular reabsorption, tubular secretion, filtration, filtrate