Chapter 10
Urinary System and Excretion

10.1 Urinary system
Overview of the urinary system

What are the organs of the urinary system

- Kidneys (2) – bean-shaped, fist-sized organ where urine is formed
- Ureters (2) – small, muscular tubes that carry urine from the kidneys to the bladder
- Bladder (1) – expandable organ that stores urine until it is expelled from the body
- Urethra (1) – tube (longer in men than women) that carries urine from the bladder to the outside of the body

What are the functions of the urinary system?

1. Excretion of metabolic wastes
2. Maintenance of water-salt balance
3. Maintenance of acid-base balance
4. Hormone secretion: renin and erythropoietin
1. Excretion

- Mostly of nitrogenous wastes:
  - Urea made by the breakdown of amino acids in the liver
  - Uric acid made by the breakdown of nucleotides
  - Creatinine made by muscle cells from the breakdown of creatine phosphate

2 & 3. Maintenance of water-salt and acid-base balance

- Both are homeostatic mechanisms
- Water-salt balance helps to maintain blood pressure
- The kidneys, by excreting hydrogen ions and reabsorbing the bicarbonate ions, maintains a blood pH of ~7.4

4. Hormone secretion

- Renin – secreted by the kidneys to allow the adrenal glands to secrete aldosterone to help regulate water-salt balance
- Erythropoietin – secreted by the kidneys to stimulate red blood cell production when blood oxygen is low
What are the 3 regions of the kidney?

• Renal cortex – an outer granulated layer
• Renal medulla – cone-shaped tissue masses called renal pyramids
• Renal pelvis – central cavity that is continuous with the ureter

What are nephrons?

• Microscopic functional unit of the kidney that produces urine
• > 1 million per kidney

How does the nephron form urine?

Anatomy of a nephron

• Glomerulus – a knot of capillaries inside the glomerular capsule where pores produce a blood filtrate
• Proximal convoluted tubule – epithelial layer with a brush border of microvilli to allow reabsorption of filtrate components
• Loop of nephron – U-shaped structure that has a descending limb to allow water to leave and an ascending limb that pushes out salt
• Distal convoluted tubule – made of epithelial cells rich in mitochondria and thus is important for movement of molecules from the blood to the tubule (tubular secretion)
• Collecting ducts – several nephrons share a collecting duct which serve to carry urine to the renal pelvis
10.3 Urine formation

**Glomerular filtration**

- Water and small molecules move from the glomerulus to the glomerular capsule while large molecules and formed elements remain in the glomerular blood

<table>
<thead>
<tr>
<th>Filtrable Blood Components</th>
<th>Non-Filtrable Blood Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>formed elements (blood cells and platelets)</td>
</tr>
<tr>
<td>Nitrigenous wastes</td>
<td>Plasma proteins</td>
</tr>
<tr>
<td>Urea</td>
<td></td>
</tr>
<tr>
<td>Salts</td>
<td></td>
</tr>
</tbody>
</table>

10.3 Urine formation

**Tubular reabsorption and secretion**

- Many molecules and ions are reabsorbed from the nephron into the blood

- A second way to remove substances such as drugs, H\(^+\) and creatinine from the blood

<table>
<thead>
<tr>
<th>Substances Absorbed</th>
<th>Urine Produced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluid loss</td>
<td>Some loss</td>
</tr>
<tr>
<td>Nitrigenous wastes</td>
<td>None</td>
</tr>
<tr>
<td>Other losses</td>
<td>Some loss</td>
</tr>
</tbody>
</table>

10.4 Regulatory functions of the kidneys

**How is blood volume and pressure maintained by the kidneys?**

- Reabsorption of salt – increases the blood volume
  - Aldosterone: promotes the excretion of K\(^+\) and the reabsorption of Na\(^+\)
  - Atrial natriuretic hormone (ANH) – secreted by the heart when blood volume increases and inhibits the secretion of aldosterone which promotes the excretion of Na\(^+\)
- Establishment of solute gradient – a greater concentration is towards the inner medulla
- Reabsorption of water – due to the solute gradient water leaves the descending limb of the loop of the nephron then antidiuretic hormone (ADH) from the pituitary plays a role in water reabsorption at the collecting duct

10.4 Regulatory functions of the kidneys

**Water reabsorption in nephrons**
What role does alcohol play in this process?

- Alcohol inhibits ADH secretion and thus increases the amount of urine and dehydration

How is the acid-base balance maintained?

- Buffers are a chemical or a combination of chemicals that can take up excess H⁺ or excess OH⁻
  When H⁺ are added to blood:
  \[ \text{H}^+ + \text{HCO}_3^- \rightarrow \text{H}_2\text{CO}_3 \]
  When OH⁻ are added to blood:
  \[ \text{OH}^- + \text{H}_2\text{CO}_3 \rightarrow \text{HCO}_3^- + \text{H}_2\text{O} \]
- The respiratory center in the brain can increase breathing rate if the buffers cannot maintain the pH
- Ultimately, the kidneys are responsible for maintaining blood pH

How do the kidneys maintain homeostasis?

- Excrete wastes
  - Urea, creatinine and uric acid
- Water-salt balance of blood
  - Helps regulate blood volume and pressure
- Acid-base balance of blood
  - Helps regulate pH
- Assistance to other systems
  - Endocrine, cardiovascular, skeletal, muscular nervous and digestive