Outline – Urinary System

I. Function

II. Organs of the urinary system
   A. Kidneys
      1. Function
      2. Structure

III. Disorders of the urinary system

IV. Metabolism
Urinary System

- The digestive system eliminated waste from the digestive tract. But we also need a way to **eliminate** waste from the rest of the body.

- Function of urinary system is: Excretion of metabolic wastes and to maintain homeostasis of blood.
Which of the following system does not function to excrete waste?

1. Digestive
2. Urinary
3. Integumentary
4. Circulatory
Urine contains:
- Water
- $\text{HCO}_3^-$
- Inorganic salts
- $\text{H}^+$
- Urea
- Uric acid
- Creatinine
Excretion

- Excretion - the majority of the metabolic wastes removed from the body is mainly due to the action of the kidneys.
Organs of the Urinary System

1. **Kidneys** – main organ in the urinary system, produces urine.

2. **Ureters** - conduct urine from the kidneys to the bladder by peristaltic contractions produced from contractions of smooth muscles in ureter wall.
3. **Urinary bladder** - stores urine until it is expelled from the body.

4. **Urethra** - small tube that extends from the urinary bladder to an external opening. In males the urethra also functions as a reproductive tract organ.
Functions of the Kidneys

1. Filter waste from blood
3. Regulates blood pressure
5. Secretion of hormones = renin and erythropoietin.
Urinary 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
The kidneys are located in this cavity:

1. Cranial
2. Thoracic
3. Abdominopelvic
4. Pleural
Vascularization

- Aorta
- Renal artery
- Arterioles
- Capillaries
- Venules
- Renal Vein
- Vena Cava
The Kidneys

(a) Blood vessels and protective layers around kidneys
The Regions of the Kidneys

- Each kidney has three regions:
  1. Renal cortex
  2. Renal medulla
  3. Renal pelvis
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
Regions of the Kidney

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.
Nephrons

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

Renal cortex
Renal medulla
Renal pyramid (of renal medulla)
Renal column (extension of renal cortex)
Renal pelvis

(b) Internal kidney structure

Nephron
Collecting duct

(c) Nephrons

Figure 16.3b–c
Figure 16.4b

The Nephron

(b) A nephron and its blood supply
Parts of the Nephron

1. The renal corpuscle
   A. The glomerulus
   B. The glomerular capsule

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

3. The collecting Duct
(c) Simplified view of a nephron, showing the basic structural components but not the associated capillaries.
The renal corpuscle

- The renal corpuscle is where fluid is filtered from blood

- Consists of
  - The glomerulus - The network of capillaries
  - The glomerular capsule (Bowman’s capsule) - Surrounds the glomerulus
The Nephron

- The nephron performs three functions

1. Glomerular filtration
2. Tubular reabsorption
3. Tubular secretion
The Nephron - 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.
The renal corpuscle, where blood is filtered

Afferent arteriole entering glomerulus

Efferent arteriole leaving glomerulus

Glomerular capillaries

Glomerular capsule

Renal corpuscle
The Nephron

(a) The renal corpuscle consists of the glomerular capsule and a ball of capillaries called the glomerulus.
(b) Diagram of the glomerular filter showing how water and small solutes in the blood move first through the pores in the endothelium of the capillary, then through the basement membrane, and finally through slits in the inner lining of the glomerular capsule.
1. Proximal convoluted tubule (PCT) - where reabsorption of filtrate components occurs, tubular secretion can also occur here.

2. Loop of the Nephron (Loop of Henle) - consists of a descending limb and an ascending limb that regulates 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.
The Nephron

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.
Urine Formation

- **Tubular reabsorption** - many molecules are reabsorbed – transported from the lumen into the tissues then into capillaries. Occurs mainly in the PCT\((H_2O, \text{nutrients, salts})\)

- **Tubular secretion** - substances are removed from the blood and added to the tubular fluid, mainly in the DCT. \((H^+, \text{creatinine, and drugs like penicillin})\)
<table>
<thead>
<tr>
<th>Region of Nephron</th>
<th>Roles*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renal corpuscle (glomerular capsule and glomerulus)</td>
<td>Filters the blood, removing water, glucose, amino acids, ions, nitrogen-containing wastes, and other small molecules</td>
</tr>
</tbody>
</table>
| Proximal convoluted tubule        | Reabsorbs water, glucose, amino acids, some urea, $\text{Na}^+$, $\text{Cl}^-$, and $\text{HCO}_3^-$  
|                                   | Secretes drugs, $\text{H}^+$, $\text{NH}_4^+$                        |
| Loop of the nephron               | Reabsorbs water, $\text{Na}^+$, $\text{Cl}^-$, and $\text{K}^+$      |
| Distal convoluted tubule          | Reabsorbs water, $\text{Na}^+$, $\text{Cl}^-$, and $\text{HCO}_3^-$  
|                                   | Secretes drugs, $\text{H}^+$, $\text{K}^+$, and $\text{NH}_4^+$      |

NOTE: *Major reabsorbed or secreted substances are listed here.
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.

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Figure 16-8 Biology of Humans, 2/e
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Figure 16-9 Biology of Humans, 2/e
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**Step 1: Descending limb of the loop**
Solute concentration of the filtrate increases as water leaves.

**Step 2: Ascending limb of the loop**
Solute concentration of the filtrate decreases as NaCl leaves (water cannot follow because this section of the tubule is not permeable to it).

**Step 3: Collecting duct**
Antidiuretic hormone (ADH) causes the collecting duct to become permeable to water. Water leaves the filtrate due to high NaCl and urea in the medulla. This results in concentrated urine and the conservation of water.
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
A. Renal Cortex
B. Renal Medulla

C. Glomerular capsule, contains glomerulus
D. Proximal Convoluted Tubule
E. Loop of Henle
F. Distal Convoluted Tubule
G. Collecting Duct
Regulation of Urine

- **Diuretics** increase urinary output, making more dilute urine

- Examples:
  - Caffeine
  - Lasix
  - Alcohol
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
<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>
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</table>
**Antidiuretic hormone (ADH)**

- Makes the collecting duct more permeable to water therefore, increases the 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
Kidney Function and ADH

Decrease in concentration of water in blood is detected by the hypothalamus.

Hypothalamus

Nerve cells produce antidiuretic hormone (ADH)

Anterior lobe of pituitary gland

Posterior lobe of pituitary gland

Antidiuretic hormone (ADH) is produced by the hypothalamus and released by the posterior lobe of the pituitary gland.

An increase in the concentration of water in the blood causes:
- Increase in blood volume
- Increase in blood pressure
- Decrease in urine volume

More water moves from the filtrate back into the blood.

ADH prompts an increase in the permeability to water of distal convoluted tubules and collecting ducts of nephrons.
Hormonal Regulation of Urine - Aldosterone

- **Aldosterone**
  - Hormone produced and released by the adrenal cortex
  - Increases sodium reabsorption in the distal convoluted tubule and the collecting duct, water follows
  - Making more concentrated urine.
Aldosterone is released in response to blood pressure monitored by the juxtaglomerular apparatus.

The cells in the juxtaglomerular apparatus release the hormone renin.

Renin is converted to an active form that stimulates the adrenal cortex to release aldosterone.
Kidney Function and Hormones

(a) The juxtaglomerular apparatus (within the square) is a section of the nephron where the distal convoluted tubule contacts the afferent arteriole. The nearby renal corpuscle is shown in ghosted view to reveal its components, the glomerular capsule and the glomerulus.

(b) Close-up view of the juxtaglomerular apparatus

Juxtaglomerular cells in the afferent arteriole secrete renin in response to reduced volume of filtrate within the nephron.
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 and renin
- Making more dilute urine. Lowers blood pressure and blood volume
<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>
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<tr>
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<td>Increases reabsorption of $\text{Na}^+$ by distal convoluted tubules and collecting ducts, resulting in more water following $\text{Na}^+$ as it moves from filtrate to blood</td>
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<td>Dilute</td>
</tr>
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Table 16.2  Review of Some Hormones that Influence Kidney Function
Hormones secreted 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, target = stem cells in bone marrow
The Kidney’s role in Vit D

- Vitamin D is produced in the skin in response to sunlight, and provided by certain foods in diet.

- The kidneys and liver transform Vitamin D into the active form, calcitrol.

- Calcitrol promotes the absorption of calcium into the small intestine and re-absorption of calcium in the kidneys.
Kidney’s role in Acid-Base Balance

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

1. True
2. False
Kidney’s role in Salt-Water Balance

- The kidneys reabsorb salt and water, maintaining osmotic balance in the blood, this also affects blood pressure
The urine goes from the kidneys into the bladder where it is stored until it can be released through the urethra.
Urination is a reflex action controlled by the brain.

When the bladder fills to about 250ml of urine then the motor nerve impulses cause the bladder to contract and the sphincters to relax so that urination is possible.
Urinary Function Disorders

- **Urethritis**—infection confined to the urethra.
- **Cystitis**—infection of the urethra and bladder.
- **Pyelonephritis**—infection reaches the kidneys.
What hormone is secreted by the kidneys to increase blood pressure:

1. ADH
2. Renin
3. Aldersterone
4. Erythropoietin
Important Points

- Read Chapter 17 for next lecture
- Know the functions of the urinary system
- Know the organs of the urinary system and their functions, including all the functions of the kidney
- Know the structure of the kidney (see “kidney structure slide and preceding illustrations)
- Know what a nephron is, what are the five parts of the nephron and the function of
Important Points

- Understand the re-absorption and secretion of compounds in the nephron, what is re-absorbed and secreted and where in the nephron are the compounds re-absorbed or secreted.

- How is urinary output regulated, what are examples of diuretics. What hormones decrease or increase urinary output. What effect on blood pressure do these hormones have. Where are these hormones produced, stored and released from. What specific parts of the nephron do these hormones effect.
Important Points

- What is diabetes insipidus
- Know what renin is, what its function is, where it is produced.
- Know what erythropoietin is, what its function is, where it is produced.
- Know what the role the kidney has in calcium absorption

Definitions: diuretic, tubular reabsorption, tubular secretion, filtration, filtrate