CHAPTER 20: URINARY SYSTEM

OBJECTIVES:

1. Name the major function of the urinary system, and name and locate (on a diagram) the organs that compose the system.

2. Explain what the term renal refers to.

3. Define the term retroperitoneal.

4. Using a cross-section diagram of a kidney, locate the renal capsule, renal cortex, renal medulla, renal pyramids, minor calyces, major calyces, renal sinus, renal pelvis, and ureter.

5. Discuss the many ways in which the kidney maintains the blood.

6. Name the functional unit of the kidney.

7. Distinguish between a renal corpuscle and renal tubule, and identify each component on a microscopic section of the kidney.

8. Trace a drop of blood from the heart through a nephron and back to the heart.

9. Explain what is meant by, the components of, and the significance of the juxtaglomerular apparatus.

10. List the three major steps involved in urine formation, name the portion of the nephron where each occurs, and discuss each process fully.

11. Explain why proteins are not filtered out of the blood in the glomerulus.

12. Name the force responsible for glomerular filtration.

13. Discuss the negative feedback mechanisms involved in the regulation of the glomerular filtration rate (GFR). Include the names of detection sites (cells), enzymes, hormones, target organs, and effects.

14. Explain the process by which most reabsorption occurs in the PCT, and list the substances that are reabsorbed here.
15. Explain the significance of anti-diuretic hormone (ADH) and which portion of the nephron it targets.
CHAPTER 20: URINARY SYSTEM

Objectives (continued)

16. List the wastes excreted in urine, and explain what metabolic processes these by-products result from.

17. Explain the structure, location, and function of the ureters, urinary bladder, and ureters.

18. Define the term *micturition*.

19. Discuss the differences between male and female urethras.

20. Trace a drop of urine from its initial collection point as the "glomerular filtrate".
 CHAPTER 20: URINARY SYSTEM

I. INTRODUCTION
The major function of the urinary system to remove metabolic wastes from blood, and direct them out of the body. The organs of the urinary system include the kidneys, ureters, urinary bladder, and urethra.
See Fig. 20.1 and Fig 20.2, page 780.

II. URINARY ORGANS

A. Kidney (Renal)

1. Location: Fig 20.1, page 780 and Fig 20.3, page 781.
   a. high on posterior abdominal wall;
   b. retroperitoneal;
   c. right kidney lies just below left. Why?

2. Structure: (Fig 20.4c, page 782)
   a. renal capsule = tough fibrous shell around kidney;
   b. renal cortex = outer portion of kidney;
   c. renal medulla = inner portion of kidney;
   d. renal pyramids = cone shaped masses of tissue in renal medulla;
   e. ureter = tube leading from kidney;
   f. renal pelvis = superior end of ureter which is expanded to form a funnel shape;
   g. major calyces = divisions of renal pelvis (2-3 tubes);
   h. minor calyces = divisions of major calyces.

3. Functions of Kidney:
   a. to remove metabolic wastes from blood & excrete them to outside (urine).
   b. Maintenance of blood:
      - regulation of RBC formation (hormone erythropoietin);
      - blood pressure (enzyme renin);
- blood volume (hormone ADH);
- blood composition;
- blood pH.
CHAPTER 20: URINARY SYSTEM

II. URINARY ORGANS

A. Kidney (Renal)

4. The functional unit of a kidney = the nephron.

   a. Structure: (Fig 20.4a, page 782)

      A nephron is composed of a renal corpuscle and a renal tubule.

      - Renal Corpuscle = glomerulus (filtration unit) within Bowman's capsule.
      - Renal Tubule =
        1. proximal convoluted tubule;
        2. descending loop of Henle
        3. ascending loop of Henle;
        4. distal convoluted tubule;
        5. collecting duct).

      Each collecting duct empties into a minor calyx which leads to a major calyx and into the renal pelvis.

      Refer to Fig 20.7 page 785 to see electron micrograph of glomeruli within the renal tubules.

5. Blood flow: Macroscopic = Fig 20.6, page 784;
     Microscopic = Fig 20.9. page 786;
     Summary Fig 20.14, page 790.

     Aorta -------------> Renal Artery (to each kidney) ----->
     Interlobar arteries (between each pyramid) --------------->
     Arciform arteries (between medulla & cortex) ----------->
     Interlobular arteries (within cortex) --------------------->
     Afferent arteriole (leading to glomerulus) --------------->
     Glomerular capillaries (site of filtration) ------------->
     Efferent arteriole (leading away from glom)------------->
     Peritubular capillaries (around renal tubule)----------->
Interlobular veins -------------> Arciform veins ------------->
Interlobar veins -------------> Renal vein --------------> IVC.

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CHAPTER 20: URINARY SYSTEM

II. URINARY ORGANS

A. Kidney (Renal)

6. **Juxtaglomerular Apparatus (JGA)** = point of contact between the afferent arteriole and distal convoluted tubule (DCT).

   See Fig. 20.11, page 788.

   a. **Macula Densa** = cells in DCT in contact with afferent arteriole.
   b. **Juxtaglomerular cells** = smooth muscle cells in afferent arteriole.
   c. The JGA is very important in the regulation of glomerular filtration (see below)!

7. **Urine Formation:**

   The nephrons function to remove wastes from blood and regulate water & electrolyte concentrations. Urine is the end-product of these functions. **Urine formation involves three major steps including glomerular filtration, tubular reabsorption, and tubular secretion.**

   a. **Glomerular Filtration** (Fig 20.15, page 791)

   - The fenestrated glomerular capillaries filter water & dissolved materials (remember plasma components) from blood. This "filtrate" is collected in Bowman's Capsule.

   - **Proteins are not filtered out of blood!**

   - Filtration is due to a force called **hydrostatic pressure** inside glomerular capillaries.

     1. 60 mmHg in glomerular capillaries;
     2. 15 mmHg in Bowman’s capsule

   - Kidneys produce 125 ml fluid per minute; (most of this is reabsorbed in tubule).
CHAPTER 20: URINARY SYSTEM

II. Urinary Organs (continued)

A. The kidney (continued)

7. Urine Formation (continued)

a. Glomerular Filtration (continued)

Regulation of Glomerular Filtration Rate (GFR)

1. involves juxtaglomerular apparatus (JGA);
2. directly affected by blood pressure:
CHAPTER 20: URINARY SYSTEM

II. URINARY ORGANS

A. Kidney (Renal)

7. Urine Formation (continued)

b. Tubular reabsorption: See Fig 20.19, page 794.

- Definition = the process by which substances are transported from the glomerular filtrate (through the walls of the renal tubule) to blood in the peritubular caps.

- Most occurs in the PCT through the process of active transport; Reabsorption of water = osmosis.

- Reabsorbed substances pass from the lumen of the renal tubule through the epithelial cells (PCT) and into the lumen of a peritubular capillary where they are returned to bloodstream.

- Reabsorbed substances include:
  1. glucose
  2. amino acids
  3. water
  4. ions (sodium, chloride, phosphate, sulfate, potassium)
  5. others (creatine, lactic acid, citric acid, urea, uric acid, ascorbic acid)

- Substances that remain in filtrate become concentrated as water is reabsorbed.

c. Tubular secretion: See Fig 20.25, page 800.

- Definition = the process by which substances are transported from the blood in the peritubular caps into the DCT.
Maintains ion concentrations in blood (i.e. if the blood is high in K⁺, K⁺ will be secreted into urine).
CHAPTER 20: URINARY SYSTEM

II. URINARY ORGANS

A. Kidney (Renal)

7. Urine Formation (continued)

   d. Regulation of urine concentration & volume

   - hormone anti-diuretic hormone (ADH) promotes the reabsorption of water through the DCT, when excessive amounts of water are being lost in the urine. This negative feedback mechanism prevents dehydration.

   See Table 20.2, page 799.

   e. Excretion of wastes (Urea & Uric Acid)

   - Wastes are by-products of metabolism:
     1. urea from amino acid metabolism;
     2. uric acid from nucleotide metabolism)

   - Wastes are reabsorbed by tubules, but are then secreted back into urine & excreted.

   f. Composition of Urine

   See Table 20.1, page 791.

   - 95% water;
   - other 5% includes:

     1. urea,
     2. uric acid,
     3. trace amino acids
     4. electrolytes.

7. Use Chart 20.1, page 791 to compare the levels of various

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substances present in plasma, the glomerular filtrate, and urine.
## CHAPTER 20: URINARY SYSTEM

### II. URINARY ORGANS

#### A. Kidney (Renal)

7. Urine Formation (continued)

<table>
<thead>
<tr>
<th>Major Step in Urine Formation</th>
<th>Location in Nephron</th>
<th>Substances Transported and Mode of Transport</th>
<th>From where to where? (i.e. from blood to glomerular filtrate)</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>

SUMMARY TABLE (Keyed on page of this outline 408)
CHAPTER 20: URINARY SYSTEM

II. Urinary Organs (continued)

B. Ureters are small tubes that carry urine from each to kidney to the urinary bladder through peristaltic movements.
   1. 25 - 39 cm in length;
   2. retroperitoneal;
   3. Three layers:
      a. Inner mucosa = transitional epithelium;
      b. Middle muscularis = inner circular layer of smooth muscle and outer longitudinal layer (peristalsis);
      c. Outer serosa = fibrous CT.

   See Fig 20.27, page 803.

C. Urinary Bladder (See Fig 20.28 and Fig 20.29, page 804).
   1. Location: within pelvic cavity, behind symphysis pubis;
   2. Structure:
      a. hollow, distensible, muscular organ;
      b. lined by transitional epithelium;
      c. detrusor muscle = 3 layers of smooth muscle;
      d. covered by fibrous CT.


* Micturition = the process by which urine is expelled from urinary bladder to outside.

D. The urethra is a tube that carries urine from the urinary bladder to the outside.

   See Figures on page 807.

   1. Length depends on sex:
      a. female = 4 cm;
b. male = 20 cm.

2. Histology depends of sex:
   a. female = 3 layers;
   b. males = 2 layers.

CHAPTER 20: URINARY SYSTEM

III. Elimination of Urine

Starts at glomerulus where glomerular filtrate is collected in
Bowman's capsule

| PCT
| loop of Henle
| DCT
| collecting duct (urine)
| minor calyx
| major calyx
| renal pelvis
| ureter
| (peristalsis)
| urinary bladder
| (micturition)
<p>| |</p>
<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>urethra</td>
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<tr>
<td></td>
</tr>
<tr>
<td>outside</td>
</tr>
</tbody>
</table>

Use this flow chart as a review by adding key points where they belong (i.e. reabsorption, reabsorption of water under influence of ADH, secretion, etc.)
CHAPTER 20: URINARY SYSTEM

IV. Homeostatic Imbalances/Disorder of the Urinary System

1. Hemolytic uremic anemia (See intro on page 779)

B. Inherited kidney abnormalities (see page 780)

C. Chronic Renal Failure (See CA 20.1, page 783)

D. Glomerulonephritis (See CA 20.2, page 787)

E. Nephrotic Syndrome (See CA 20.3, page 795)

6. Gout (page 799)

7. Cystitis/Ureteritis (page 803)

8. Kidney Stones (page 803)

9. Bladder Cancer (page 804)

V. Other Interesting Topics Concerning the Urinary System

A. Dialysis (page 781)

B. Renal Clearance (see CA 20.4, page 802)

C. Urinalysis (see CA 20.5, page 806)

VI. Innerconnections of the Urinary System: See page 808.
### Urine Formation SUMMARY TABLE (outline page 404)

<table>
<thead>
<tr>
<th>Major Step in Urine Formation</th>
<th>glomerular filtration</th>
<th>tubular reabsorption</th>
<th>tubular secretion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location in Nephron</td>
<td>glomerulus</td>
<td>primarily through proximal convoluted tubule (PCT)</td>
<td>primarily through distal convoluted tubule (DCT)</td>
</tr>
<tr>
<td>Substances Transported and Mode of Transport</td>
<td>All plasma constituents except proteins (i.e. glucose, amino acids, water, ions, creatine, lactic acid, urea, uric acid, ascorbic acid, etc)</td>
<td>glucose, amino acids, water, ions, creatine, lactic acid, urea, uric acid, ascorbic acid, etc</td>
<td>excess ions, urea, uric acid</td>
</tr>
<tr>
<td>From where to where? (i.e. from blood to glomerular filtrate)</td>
<td>from blood in glomerulus to “filtrate” in Bowman’s capsule</td>
<td>from “filtrate” in PCT to blood in peritubular capillaries</td>
<td>from blood in peritubular capillaries to “urine” in DCT</td>
</tr>
</tbody>
</table>