Chapter 17: Urinary System

• Introduction
  • Organs of the Urinary System

  **REFERENCE FIGURE 17.1**
  - 2 kidneys—filters the blood
  - 2 ureters – transport urine from the kidneys to the urinary bladder
  - Urinary bladder – serves as a temporary urine storage
  - Urethra – conveys the urine from the urinary bladder to outside the body

• Kidneys

  **REFERENCE FIGURE 17.2 – 17.5**
  - Reddish-brown, bean-shaped organ, enclosed in a tough, fibrous capsule
  - Located at the back of the abdominal cavity, more or less behind the stomach, and up against the deep muscles of the back
  - Structure:
    - Renal sinus – “space” from the medial depression of the kidneys and into a hollow chamber into which nerves, ureter, and blood and lymphatic vessels enter and exit the kidneys
    - Renal pelvis – structure right inside the sinus and is subdivided into major and minor calyces. It carries the urine away from the kidneys. As the renal pelvis leaves the kidneys, it will taper and gradually connect to the ureters
    - 2 regions of the kidneys:
      - 1)-renal medulla – inner region composed of renal pyramids and their points or tips become renal papillae that extend into the minor calyx of the renal pelvis
      - 2)-renal cortex– outer region composed of the functional units of the kidneys, the nephron
  - Kidney Functions
    - To regulate the volume, composition, and pH of body fluids
    - To remove metabolic wastes from the blood especially nitrogen-carrying wastes
    - To help control the rate of erythrocyte formation by secreting erythropoietin
    - To regulate blood pressure by secreting the hormone, renin

• Renal Blood Vessels
  - Abdominal aorta gives rise to renal arteries leading to the kidneys
  - Renal arteries will diverge into smaller arteries which will diverge into afferent arterioles will carry unfiltered blood to the nephrons in the renal cortex. The efferent arterioles will carry filtered blood and will leave the nephron to give rise to capillaries called peritubular capillaries. The capillaries will lead to venules will converge to form larger veins and eventually renal veins will transport the filtered blood away from the kidneys.
  - Venous blood is returned through a series of vessels that run parallel to the arterial pathways

• Microscopic view of the kidneys: The Nephron

  **REFERENCE FIGURE 17.2- 17.7 AND TABLE 17.3**
  - 1 million nephrons per kidney
  - Nephron consists of renal corpuscle and renal tubule
• Renal corpuscle: the filtering portion of the nephron
  ▪ Glomerulus is made up of a ball of capillaries that filters the blood as the blood arrives through the afferent arteriole.
  ▪ Glomerular capsule is made up of simple squamous epithelium and collects the filtrate as the blood is being filtered by the glomerulus. The capsule connects to the renal tubule.
  ▪ Renal tubule is made up of simple cuboidal epithelium and collects the filtrate from the glomerulus. The composition of the filtrate is refined and modified as the filtrate travels through the renal tubule.
  • Leads from the glomerular capsule
  • First portion of the tubule: proximal convoluted tubule
    o The proximal convoluted tubule is highly coiled section of the renal tubule.
  • Middle portion: nephron loop
    o The nephron loop is the section of the renal tubule that descends down, curves upward, and ascends while the pertubular capillary “drapes” along its length. It is located in the renal medulla
  • End portion: distal convoluted tubule
    o The distal convoluted tubule is less coiled than the proximal convoluted tubule and transports the final product of urine out of the nephron and into collecting ducts to leave the kidneys
  • Several distal convoluted tubules join to become a collecting duct. The collecting ducts will connect to the minor calyx that will merge to form the major calyx of the renal pelvis. The renal pelvis will take the urine and transport it to the ureters.
• Blood Supply to the Nephron
  ▪ Glomerulus receives unfiltered blood from the afferent arteriole and passes the filtered blood into an efferent arteriole.
  ▪ The efferent arteriole gives rise to a peritubular capillary system that will surround the renal tubule to allow for the refinery process of the filtrate into urine.
• Juxtaglomerular Apparatus
  REFERENCE FIGURE 17.7
  • At the point of contact among the distal convoluted tubule, afferent arteriole, and efferent arteriole, the epithelial cells of the distal tubule form a modified structure called the macula densa. The macula densa is a set of modified epithelial cells that detect or monitor the composition of urine.
  • Near the macula densa, the smooth muscles of the afferent arteriole modify into large and vascular cells, juxtaglomerular cells. The juxtaglomerular cells will produce and secrete an enzyme, renin. Renin will regulate electrolyte imbalances.
  • Macula densa and the juxtaglomerular cells form the juxtaglomerular apparatus
  • Juxtaglomerular apparatus detects changes of certain ions that can cause blood pressure to drop and release renin to regulate and maintain normal levels.
• Urine Formation
  1. Glomerular filtration
     REFERENCE FIGURE 17.9
- Glomerular filtrate: fluid portion of the blood that is filtered by the glomerulus and enters the glomerular capsule
- Filtration pressure: the pressure that determines if the blood will be filtered by the glomerulus or not. Promotion of filtration will occur typically.

**REFERENCE FIGURE 17.10**

- Factors:
  - Hydrostatic pressure of plasma (blood)
  - Osmotic pressure of plasma (blood)
  - Hydrostatic pressure inside the glomerular capsule
    - Note: The outward hydrostatic pressure of the plasma or blood in the glomerulus SHOULD be GREATER than the combined forces of the inward pressures of the osmotic pressure of the blood and the hydrostatic pressure in the glomerular capsule. I.E. There should be filtration that will become urine.

- Filtration rate depends on filtration pressure. There is a direct relationship between filtration rate and filtration pressure. The greater the pressure, the faster the filtration rate.
- Examples: **If the afferent constricts, then blood flow and pressure decreases causing filtration rate to decrease.**
- **If the efferent constricts, then the blood flow and pressure increase causing the filtration rate to increase.**

**Regulation of Filtration Rate**

- Sympathetic impulses can signal the dilation or constriction of the arterioles.
- **Renin-angiotensin system**—regulates sodium secretion and in turn ensures that blood pressure is not too low.

**REFERENCE FIGURE 17.11**

- Macula densa detects fluctuations of sodium and other ions as urine leaves the nephron and enters the collecting ducts.
- Directed by the macula densa, the juxtaglomerular cells of the afferent arterioles adjust the amount of renin released into the bloodstream.
- Secretions of renin trigger a cascade of reactions leading to the activation and production of angiotensin II which acts as a vasoconstrictor to affect the filtration rate. Angiotensinogen from the liver will react with the renin to form angiotensin I. An enzyme from the lungs will react with angiotensin I to create angiotensin II.
- The presence of angiotensin II will trigger secretions of aldosterone from the adrenal gland to reabsorb sodium to maintain blood pressure in the optimal range.
- Antidiuretic hormone (ADH) is also released to conserve water and increase blood volume.
- The antagonistic hormone of the renin-angiotensin system is atrial natriuretic peptide (ANP). ANP is the antagonist of angiotensin II and will reduce blood pressure and volume.

2. **Tubular reabsorption**

**REFERENCE FIGURE 17.12 AND FIGURE 17.13**
Most reabsorption occurs in the proximal convoluted tubule
Cells contain carriers that have a maximum capacity of the molecules that can be carried back into the blood from the filtrate
Once the carriers reach maximal transport capacity, the excess substances are excreted as urine
Glucose and amino acids are reabsorbed by active transport
Water by osmosis
Proteins by pinocytosis
Sodium and water reabsorption:
Sodium ions (cations) are reabsorbed by active transport and anions follow passively
As the concentration of ions increase in the capillaries, the osmotic pressure within the blood increases and water is drawn inward.

3. Tubular secretion

**REFERENCE FIGURE 17.12 AND FIGURE 17.4**
- Transporting substances from the plasma into the renal tubule to be excreted in urine
- Active transport moves excessive hydrogen ions (in order to regulate body pH)
- Potassium ions (cations) are secreted both passively and actively into the distal convoluted tubule and collecting duct as sodium ions (cations) is conserved.

* Regulation of Urine Formation and Volume

**REFERENCE TABLE 17.2**
- Most of sodium are reabsorbed in the capillaries before urine is excreted
- The distal convoluted tubule and collecting ducts are usually impermeable to water so that water is conserved
- Increase of Antidiuretic hormone (ADH) can modify and regulate water balance and make the walls of the tubule and duct more impermeable so water is extremely conserved
- Increase in aldosterone will conserve sodium and release potassium into urine.
- Depending of water consumption, the concentration of urine will vary. If water is not consumed enough, then there will be an increase in ADH to conserve water. Urine will be concentrated and urine volume decreases.
- If plenty of water is consumed, then there will be a decrease in ADH and water will be filtered out. Urine will be diluted.

* Urea and Uric Acid Formation
- Urea is the byproduct of amino acid metabolism.
- Uric acid is the byproduct of nucleic acid metabolism.
- 20% of urea is excreted in urine while the remaining urea is reabsorbed through diffusion.
- Most of uric acid is reabsorbed by active transport. Very little uric acid is secreted into the renal tubule to be excreted.

* Urine Composition
- Composition varies from time to time due to the amounts of water and sodium that are eliminated to maintain homeostasis. Urine is slightly acidic.
- Components:

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- Water—95%
- Urea
- Uric acid
- Amino acids
- Electrolytes such as potassium, hydrogen ions, ammonia
- Very little or no glucose

- Ureters

**REFERENCE FIGURE 17.15**
- Muscular tubes that extend from kidneys (renal pelvis) to the base of urinary bladder
- Peristaltic waves moves urine down the ureters to the urinary bladder. The ureters possess flap like valves to prevent backflow of urine.
- Layers of the walls:
  - Mucous coat—to secrete the lumen as the slightly acidic urine flows down.
  - Muscular coat – consists of smooth muscles to propel the urine to the urinary bladder.
  - Outer fibrous coat—connective tissue layer

- Urinary Bladder

**REFERENCE FIGURE 17.16**
- Hollow, distensible, muscular organ in the pelvic cavity
- Internal floor: trigone- composed of 3 openings ( 2 opening for the ureter entrances and 1 opening for urethra)
- Wall of the bladder:
  - Inner mucous coat—made up of transitional epithelial cells that can stretch to hold more volume of urine.
  - Submucous coat – made up of connective tissue and elastic fibers
  - Muscular coat—made up of smooth muscles called detrusor muscles
    - The detrusor muscles at the neck of the urinary bladder forms the internal urethral sphincter. The sphincter stays contracted until pressure in the bladder forces the sphincter to open.
  - Outer serous coat – consists of parietal peritoneum and made up of connective tissue.

- Urethra

**REFERENCE FIGURE 17.17**
- Tube that conveys urine from the urinary bladder to the external environment
- Muscular tube with urethral glands that secrete mucus into the urethral canal
- Possesses skeletal muscles at the opening of the urethra to form the external urethral sphincter

- Micturation
  - Micturation is urination -- voiding of the urinary bladder
  - Steps (through a micturation reflex):
    - Stretching of the urinary bladder trigger the micturation reflex which is located in the sacral portion of the spinal cord
    - Parasympathetic impulses cause detrusor muscle to contract
    - Detrusor muscle contraction bring the need to micturate to conscious attention
- As contractions become stronger, the involuntary, internal urethral sphincter is forced open.
- The voluntary, external urethral sphincter, composed of skeletal muscles, must relax before urine is excreted.