

Chapter 26: Urinary System

I. Functions of the Urinary System

A. List and describe the six major functions of the kidneys:

1. _____

2. _____

3. _____

4. _____

5. _____

6. _____

II. Kidney Anatomy and Histology

A. Location and External Anatomy of the Kidneys

1. Describe the size and shape of the kidneys: _____

2. The kidneys lie _____ on the _____
_____ on either side of _____
near the _____
3. Why is the right kidney lower than the left? _____

4. What is the renal capsule? _____
5. What is perirenal fat? _____
 - a. Functionally the perirenal fat acts as _____
6. What is the structure of the renal fascia? _____
 - a. Functionally the renal fascia anchors _____
7. The hilum is a _____ that lies on _____
 - a. What structures enter here? _____
 - b. What structures exit here? _____
8. The hilum opens into the _____ that contains _____

B. Internal Anatomy and Histology of the Kidneys

1. The renal sinus is surrounded by an inner _____ and an outer _____
2. What are renal pyramids? _____
3. Medullary rays extend from the _____ into _____
4. What are renal columns? _____
5. The bases of the pyramids form the boundary between the _____ and the _____
6. The tips of the renal pyramids, called _____ point toward _____
7. What are minor calyces? _____
8. Minor calyces from several pyramids join together to form _____
9. The major calyces converge to form an enlarged chamber called the _____ which is surrounded by the _____
10. The renal pelvis narrows into a small-diameter tube the _____ which exits the kidney at the _____ and connects to _____
11. Nephron
 - a. The nephron is the _____ and _____ of the kidney
 - b. Each nephron is a tubelike structure with an:
 1. Enlarged terminal end called _____
 2. Proximal _____

3. Loop of _____ (_____) and a
 4. Distal _____
- c. The distal tubule empties into a _____, which carries urine toward the _____
 - d. Several collecting ducts merge to form a larger diameter tubule called a _____ which empties into a _____
 - e. Which structures are located in the renal cortex?
 1. _____
 2. _____
 3. _____
 - f. Which structures are located in the renal medulla?
 1. _____
 2. _____
 - g. Nephrons whose renal corpuscles lie near the medulla are called _____
 1. They have long _____ which extend deep into the _____
 2. These account for only about _____ of nephrons
 - h. The remainder of the nephrons are called _____
 1. Their loops of Henle do not _____
 - i. Each renal corpuscle consists of:
 1. Enlarged end of a nephron called _____
 2. Network of capillaries called _____
 3. The wall of the Bowman's capsule is indented to form a _____
 4. The glomerulus fills the _____ of the Bowman's capsule
 5. Fluid flows from the _____ to the _____ to the _____
 - j. Bowman's capsule has an:
 1. Outer layer called the _____
 2. Inner layer called the _____
 3. The parietal layer consists of _____ that

- becomes _____ at the beginning _____
4. The visceral layer is composed of specialized _____
that wrap around the _____
- k. What are fenestrae? _____
- l. What are filtration slits? _____
- m. There is a basement membrane sandwiched between the _____
_____ & the _____
- n. The kidney's filtration membrane consists of:
1. Capillary _____
 2. _____ membrane
 3. _____ of Bowman's capsule
- o. Urine formation begins when material moves from _____
across the _____ into the _____
- p. What supplies blood to the glomerulus? _____
- q. What drains blood from the glomerulus? _____
- r. Where the afferent arteriole enters the glomerulus the smooth muscle
cells form a cufflike arrangement called _____
- s. In the distal tubule adjacent to the afferent arteriole there are
specialized epithelial cells called the _____
- t. The juxtaglomerular cells and macula densa are collectively called the

- u. The proximal tubule is also called the _____
1. The wall of the tubule is made up of _____
 2. The luminal surface of the cells have many _____
- v. The loops of Henle are continuations of the _____
1. Each loop has two limbs, one _____ and one _____
 2. The first part of the descending is similar in structure to the

 3. The loops of Henle that extend into the medulla become _____
_____ near the end of the loop
- a. Lumen _____ in the thin part

- b. Abrupt transition from _____ to _____
4. The first part of the ascending limb is _____ and the wall consists of _____
5. Then it becomes _____ and _____
_____ is replaced by _____
6. The thick part of the ascending limb returns toward the _____
_____ and ends by giving rise to _____
- w. The distal tubules are also called _____
1. The wall is composed of _____
 - a. Cells are _____ than in the proximal tubule
 - b. Cells do not possess a large number of _____
 2. The distal tubules connect to _____
- x. The collecting ducts are composed of _____
1. Their diameter is _____
 2. They form much of the _____
 3. Extend through the _____ toward the tips of _____

C. Arteries and Veins of the Kidneys

1. The renal artery branches off the _____ and enters the kidney at the _____
2. The first branches of the renal artery are called _____
3. These diverge to form _____ which ascend within the renal column toward the cortex
4. These arteries branch at the base of the pyramids and arch over the pyramids forming the _____
5. Smaller branches off the arched arteries project into the cortex and are called _____
6. Derived from these small vessels are the _____ which supply blood to the glomerular capillaries of the _____

7. Blood is carried away from the glomerular capillaries in the _____
8. This vessel gives rise to a plexus of capillaries called the _____
_____ around the proximal and distal tubules
 - a. Specialized branches that follow the loop of Henle deep into the medulla and back are called _____
9. The plexus of capillaries drains into the _____
10. Which in turn drain into the _____
11. Which empty into the _____
12. Which drain into the _____ which exits the kidney and connects to the _____

III. Urine Production

A. General

1. Why are nephrons called the functional units of the kidney? _____

2. The three major processes critical to the formation of urine are:
 - a. _____
 - b. _____
 - c. _____
3. Describe the process of filtration: _____

 - a. The fluid entering the nephron is called the _____
4. Describe the process of reabsorption: _____

 - a. What is reabsorbed?
 - b. What is not reabsorbed?
5. Describe the process of secretion: _____

6. Urine produced by the nephrons consists of:
 - a. _____ and _____ filtered and _____ secreted
 - b. Minus _____ and _____ reabsorbed

B. Filtration

1. What is the renal fraction? _____
 - a. In a healthy resting adult it varies from _____
 - b. This results in an average renal blood flow rate of _____
2. Define "renal plasma flow rate": _____
 - a. It is equal to _____ multiplied by the portion of blood that is _____
3. What is the filtration fraction? _____

4. What is the glomerular filtration rate (GFR)? _____

 - a. This is approximately _____ each minute
 - b. With this GFR approximately how much filtrate is made a day? _____
 1. Approximately how much of this is reabsorbed? _____

C. Glomerular Filtration Rate (GFR)

1. List the four characteristics that a substance must have to estimate GFR:
 - a. _____
 - b. _____
 - c. _____
 - d. _____
2. What substance has these characteristics? _____
 - a. As filtrate is formed _____
 - b. As filtrate flows through the nephron _____

 1. Therefore, the entire volume of plasma that becomes filtrate is cleared _____
 2. The plasma clearance for inulin is equal to _____

3. Since GFR is reduced when the kidney fails using inulin to measure GFR indicates _____

4. Filtration Barrier

- a. The filtration membrane is a _____ and prevents:
 1. _____ and _____ from entering Bowman's capsule
 2. Allows other _____ to enter
- b. The filtration membrane is _____ permeable than a typical capillary
 1. _____ and solutes of a _____ readily pass through the filtration membrane from the glomerular capillaries
 2. _____ molecules do not pass through
- c. In general the membrane prevents molecules from passing that are
 1. Larger than _____
 2. Have a molecular mass of _____ or more
- d. What is the size of most plasma proteins? _____
 1. Do they pass through the filtration membrane? _____
- e. What is the diameter of an albumin molecule? _____
 1. This allows _____ amounts to enter the filtrate
- f. Do protein hormones pass through the filtration membrane? _____
- g. What happens in the proximal tubule to proteins in the filtrate?
 1. Actively reabsorbed by _____
 2. _____ by the cells
 - a. As a result _____ is normally found in the urine

5. Filtration Pressure

- a. Filtration pressure forces fluid from the _____ across the _____ into the _____
- b. Filtration pressure results from the sum of the forces that:
 1. Move fluid out of the glomerular capillary into _____
 2. Move fluid out of the lumen of Bowman's capsule into the _____
- c. The glomerular capillary pressure is _____ inside the capillary

1. It moves fluid _____ of the capillary _____ Bowman's capsule
 2. The glomerular capillary pressure averages _____
- d. Capsule pressure is caused by filtrate _____
1. It _____ the movement of fluid into Bowman's capsule
 2. The capsule pressure averages _____
- e. Colloid osmotic pressure within the glomerular capillary exists because _____
1. Proteins in the glomerular capillary produce an _____ of about _____ that favors fluid movement to the _____ from _____
- f. The high glomerular capillary pressure results from a:
1. Low resistance to blood flow in the _____ and _____
 2. Higher resistance to blood flow in the _____
 3. As the diameter of a vessel decreases:
 - a. Resistance to flow through the vessel _____
 - b. Pressure upstream from the decreased diameter is _____
 - c. Pressure downstream from the decreased diameter is lower
 4. Since the efferent arterioles have a small diameter:
 - a. Blood pressure in the glomerular capillaries is _____
 1. Results in filtrate being forced _____
 - b. Blood pressure in the peritubular capillaries is _____
 1. Allows fluid to _____ from the _____

D. Tubular Reabsorption

1. Tubular reabsorption results from processes such as:

a. _____	d. _____
b. _____	e. _____
c. _____	
2. Inorganic salts, organic molecules, and about 99% of the filtrate volume leave the nephron and enter _____

a. The material then enters the _____
and pass back into general circulation

3. Solutes reabsorbed from the lumen of the nephron to interstitial fluid include:

a. _____ e. _____

b. _____ f. _____

c. _____ g. _____

d. _____ h. _____

4. As solutes are reabsorbed from the nephron water follows by _____

5. The small volume of filtrate that forms urine contains a relatively high concentration of:

a. _____ c. _____

b. _____ d. _____

e. Other substances that are _____

6. Regulation of solute reabsorption and the permeability characteristics of portions of the nephron allow for production of:

a. Small volume of _____ OR

b. Large volume of _____

7. Reabsorption in the Proximal Tubule

a. The cells that form the wall of the nephron have:

1. Apical surface which makes _____

2. Basal surface which forms _____

3. Lateral surfaces which are bound _____

b. In the proximal tubule reabsorption of most solute is linked to the primary _____ of _____ across the

_____ of the epithelial cells from the _____ into the

_____ creating a low _____ inside the cells

c. At the basal cell membrane:

1. ATP provides the required energy to move out of the cell

in exchange for _____ by _____

2. Concentration of _____ is high in the lumen of the tubule so there is a large _____ between the lumen of the tubule and the _____ of the nephron cells
 1. This concentration gradient is the source of energy for the _____ of many solute molecules from the lumen of the nephron into the _____
- d. Carrier molecules that transport useful solutes like glucose and amino acids are located within the _____
 1. Each carrier molecule binds specifically to one _____ and to _____
 2. As the Na^+ moves down the concentration gradient from inside the lumen of the tubule to inside the epithelial cell:
 - a. Both the _____ and other _____ or _____ bound to the carrier molecule move
 - b. From the _____ into the _____
 3. Once the cotransported molecules are inside the cell they cross the _____ of the cell by _____
- e. Some solutes also _____ between the cells from the lumen of the _____ into the _____
- f. Reabsorption of solutes in the proximal tubule is _____ and the tubule is _____ to _____
 1. As solute molecules are reabsorbed water follows by _____
- g. About how much filtrate is reabsorbed in the proximal tubule? _____
8. Reabsorption in the Loop of Henle
 - a. The loop of Henle descends into the _____
 - b. In the medulla the concentration of solutes is _____
 - c. The thin segment of the loop of Henle (descending limb) is:
 1. _____ to water
 2. _____ to urea, sodium, and other ions
 3. Adapted to allow passive movements of _____ but _____ passes through more _____

4. As the filtrate passes through the thin segment of the loop of Henle:
 - a. Water moves _____
 - b. Some solutes move _____
5. By the time the filtrate reaches the end of the thin segment:
 - a. Volume of filtrate has been _____
 - b. Concentration of the filtrate _____
- d. In the ascending limb of Henle, both the thin and thick segments are _____ so no additional _____
 1. Surrounded by interstitial fluid that becomes _____ toward the cortex
 2. As the filtrate flows through the thin segment solutes _____ into the _____ making filtrate _____
 3. In the thick segment of the ascending limb of the loop of Henle:
 - a. Cotransport is responsible for the movement of _____, _____, & _____ across the apical membrane into the cell
 4. From the epithelial cells to the interstitial fluid:
 - a. Cl^- and K^+ move by _____
 - b. Na^+ moves by _____
 5. Because the ascending limb of the loop of Henle is:
 - a. Impermeable to _____ & ions _____
 1. The concentration of solutes in the filtrate is _____ by the time it reaches the distal tubule
9. Reabsorption in the Distal Tubule and Collecting Duct
 - a. In the distal tubules and collecting ducts:
 1. _____ is transported across the apical membrane with _____
 - a. The active transport of Na^+ across the _____ membrane creates the _____ gradient
 2. The collecting ducts extend from the _____ of the kidney through the _____ of the kidney where solute concentration is _____
 3. Water moves by _____ into the more concentrated interstitial fluid:

- a. When the distal tubule and collecting duct are _____
 - 1. Producing a _____ volume of _____ urine
- 4. Water does not move by _____ into the interstitial fluid:
 - a. When the distal tubule and collecting duct are _____
 - 1. Producing a _____ volume of _____ urine
- 5. Formation of dilute or concentrated urine is under _____
- 10. Changes in the Concentration of Solutes in the Nephron
 - a. Urea enters the glomerular filtrate and is in the _____ as in the plasma
 - b. As the volume of filtrate decreases in the nephron:
 - 1. Concentration of urea _____ because the renal tubules are more permeable to _____
 - a. How much water is reabsorbed? _____
 - b. How much urea is reabsorbed? _____
 - c. What other substances are not reabsorbed at the same rate as water?
 - 1. _____ 4. _____
 - 2. _____ 5. _____
 - 3. _____ 6. _____
 - d. They all become more _____ in the filtrate as the volume of the filtrate becomes _____
 - e. If these substances accumulate in the body they are _____
 - f. Their accumulation in the filtrate and _____ in urine help maintain _____
- E. Autoregulation
 - 1. What is autoregulation? _____
 - 2. Autoregulation involves changes in _____ in the _____
 - 3. As systemic blood pressure increases _____ & prevent _____
 - 4. A decrease in systemic blood pressure results in _____ preventing _____

5. If the macula densa detect an increased filtrate flow rate:
 - a. Sends a signal to _____
 - b. To constrict _____
 - c. The result is a _____

F. Effect of Sympathetic Stimulation on Kidney Function

1. Sympathetic stimulation of the kidneys constricts the _____ & _____
 - a. Decreasing _____ & _____
2. Intense sympathetic stimulation _____ the rate of filtrate formation to only _____
3. Small changes in sympathetic stimulation have _____
4. In response to severe stress or circulatory shock:
 - a. Renal blood flow can decrease _____
 - b. Kidney tissues can be _____ and unable to _____

G. Tubular Secretion

1. Tubular secretion involves the movement of substances such as:
 - a. By-products of _____
 - b. Drugs or molecules _____
 1. These substances are moved into _____
2. Tubular secretion can occur by either _____ or _____ processes
3. What substance diffuses into lumen of the nephron? _____
4. What substances are secreted by active transport or countertransport?

a. _____	c. _____
b. _____	d. _____
5. One example of a countertransport process moves H^+ into the filtrate:
 - a. The carrier molecule is on the apical surface of the nephron cell:
 1. H^+ bind to the carrier molecule on the _____
 2. Na^+ bind to the carrier molecule on the _____
 - a. As Na^+ move into the cell _____ cell
 - b. The H^+ are produced as a result of:

1. _____ and _____ reacting
2. To form _____ and _____
- c. _____ and _____ are cotransported across the _____
_____ of the cell and enter the _____

H. Urine Concentration Mechanism

1. When a large volume of water is consumed it is necessary to:
 - a. Eliminate _____ water without
 - b. Losing _____ homeostasis
 1. The response of the kidneys is to produce a _____ volume of _____ urine
 2. If water is not available this would lead to _____
2. When water intake is restricted the kidneys produce a _____ volume of _____ urine that contains _____ to prevent their accumulation
3. The kidneys can produce urine concentrations that vary between _____ and _____ while maintaining extracellular fluid close to _____
4. Conditions that are essential for the kidneys to control the volume and concentration of urine produced include:
 - a. Maintenance of _____
 - b. Countercurrent _____
 - c. Mechanism that _____
5. Medullary Concentration Gradient
 - a. What is the interstitial fluid concentration in the cortical region of the kidney? _____
 - b. Solutes become _____ in the medulla until they reach _____ near the _____
 - c. The major mechanisms that create and maintain the high solute concentrations in the medulla include:
 1. Active transport of _____ and the cotransport of ions out of _____ into the _____

2. Diffusion of smaller amounts of _____ than _____ from the _____ into _____
 3. The vasa recta remove water and solutes that enter the medulla without _____
 4. Active transport of ions from the _____ to the _____ of the medulla
 5. Passive diffusion of _____ to the _____ of the medulla
- d. The roles of each of these mechanisms in the maintenance of the high solute concentration in the medulla of the kidney includes:
1. Loops of Henle
 - a. Descending limbs of the loop of Henle:
 1. Are permeable to water so as filtrate flows through water _____ into the _____
 - b. Ascending limbs of the loop of Henle:
 1. Are _____ to water
 2. Solute _____ out of the thin segment as it passes through _____
 3. The thick segment actively transports _____, _____, and _____ into the _____
 - c. Water enters interstitial fluid from the _____
 - d. Solute enters interstitial fluid from the _____
 2. The Vasa Recta
 - a. What are countercurrent systems? _____

 - b. The vasa recta are a countercurrent system because:
 1. Blood flows through them to the _____
 2. After the vessels _____
 3. Blood is carried _____
 - c. Walls of the vasa recta are permeable to _____ & _____

- d. As blood flows toward the medulla:
1. Water _____
 2. Some solutes _____
- e. As blood flows back toward the cortex:
1. Water moves _____
 2. Some solutes _____
- f. The rates of diffusion are such that _____ and _____ are carried from the medulla by the vasa recta
- g. The composition of the blood at both ends of the vasa recta is
1. Nearly _____
 2. Volume and osmolality _____
- h. The loops of Henle and vasa recta are in:
1. Parallel _____ & their
 2. Functions _____
 - a. Water and solutes that leave the _____ enter the _____
 - b. Vasa recta carry the water and solutes away without _____
3. Urea
- a. Urea molecules are responsible for _____
 - b. Descending limbs are permeable to urea so urea diffuses from _____ into the _____
 - c. The ascending limbs and distal tubules are _____ to urea
 1. So there is no movement of urea in or out
 - d. The collecting ducts are permeable to urea:
 1. Some urea diffuses out of _____ and into the _____ of the medulla
 - e. Thus, urea flows in a _____
6. Summary of Changes in Filtrate Volume and Concentration
- a. In the average person how much filtrate is produced per day by glomerular filtration? _____

- b. As the filtrate flows through the proximal tubule:
1. Solutes such as glucose are moved by _____ from the lumens of the nephron into the _____
 2. Water moves by _____ from the lumen into _____
 3. Approximately how much of the filtrate is reabsorbed in the proximal tubule? _____

- c. As the filtrate passes through the descending limbs of the loops of Henle
1. Water _____ of the nephrons
 2. Solutes _____ the nephrons
 - a. Approximately how much filtrate is reabsorbed in the descending limbs of the loops of Henle? _____
 3. So total volume reabsorption at this point is _____

- d. As the filtrate passes through the ascending limbs of the loops of Henle:
1. Thick segments are _____ to water
 2. _____, _____, and _____ are transported from _____ into the _____
 - a. The reabsorption of ions but not water causes the osmolality of the filtrate to _____
 - b. Therefore the filtrate in the nephrons is _____

7. Formation of Concentrated Urine

- a. After leaving the loops of Henle filtrate passes into the _____ and then into the _____ ducts
- b. These tubes are effected by the hormone _____
 1. ADH _____ permeability of the membrane to water
 - a. Cyclic AMP increases the number of _____ in the _____
 2. When ADH is present _____ out of the _____ and _____
 - a. This water reabsorption accounts for another _____ of the filtrate being reabsorbed
 - b. The osmolality at the end of the collecting ducts is _____

8. Formation of Dilute Urine

- a. If ADH is not present the distal tubules and collecting ducts have a _____
- b. The amount of water reabsorbed by osmosis is _____
- c. Water remaining in the lumen of the nephron dilutes the solutes
- d. The resulting urine produced:
 - 1. Has a concentration less than _____
 - a. The osmolality may be close to the osmolality in the: _____
 - 2. The volume is _____
 - a. The volume may be much larger than _____ of the filtrate formed each day

IV. Regulation of Urine Concentration and Volume

A. General

- 1. Where is reabsorption obligatory and therefore relatively constant?
 - a. _____
 - b. _____
- 2. Where is reabsorption regulated and therefore changes dramatically?
 - a. _____
 - b. _____
- 3. If homeostasis requires the elimination of a large volume of dilute urine:
 - a. Large volume of _____
 - b. Dilute filtrate in the _____ and _____ passes through with little _____
- 4. If conservation of water is required to maintain homeostasis:
 - a. Slightly less _____
 - b. Water is reabsorbed as filtrate passes through _____ & _____
 - 1. Resulting in a _____ volume of _____ urine

B. Hormonal Mechanisms

- 1. Antidiuretic Hormone

- a. In the absence of ADH the _____ & _____ remain _____
- b. How much urine do people with a lack of ADH produce? _____
- c. Lack of ADH can lead to major problems such as:
 1. _____ &
 2. _____
- d. Insufficient ADH secretion results in a condition called diabetes insipidus:
 1. Diabetes implies _____
 2. Insipidus implies _____
- e. In contrast to diabetes mellitus, which implies: _____
 1. Mellitus means _____
- f. ADH is secreted from the _____
 1. Neurons with cell bodies in the _____ nuclei of the _____ have axons that terminate in the posterior pituitary
 - a. ADH is released into the _____ from these neuron terminals
- g. Where are the osmoreceptor cells? _____
- h. Osmoreceptor cells are very sensitive to _____
 1. If the osmolality increases these cells _____
 2. Action potentials in the ADH-secreting neurons are _____ to the posterior pituitary causing axons to _____
 3. Reduced osmolality within the supraoptic nuclei _____ from the _____
- i. Baroreceptors
 1. Baroreceptors that monitor blood _____ influence ADH secretion when the _____
 2. When baroreceptors detect decreases in blood pressure:
 - a. Decrease the _____ of nerve impulses to hypothalamus
 - b. Results in an _____ of ADH
- j. When blood osmolality increases or when blood pressure declines

significantly:

1. ADH secretion _____
2. ADH acts on the kidneys to _____
3. This decreases _____
4. Increases _____ which increases _____

k. When blood osmolality decreases or blood pressure increases:

1. ADH secretion _____
2. Causes the kidney to _____
3. Produce a _____ of _____ urine
4. Increases blood _____
5. Decreases _____

l. ADH is more important in _____ than _____

2. Renin-Angiotensin-Aldosterone

a. Renin is an enzyme secreted by cells of the _____

b. The rate of renin secretion increases in response to:

1. _____ in blood pressure in the afferent arteriole
2. _____ in Na^+ concentration of the filtrate as it passes by the macula densa cells

c. Renin enters the general circulation and acts on _____ converting it to _____

d. Then a proteolytic enzyme called _____ converts _____ to _____

e. Functionally angiotensin II:

1. Is a _____ that increases _____ causing _____ to _____
2. Increases the rate of _____
3. Increases the sensation of _____
4. Increases _____ appetite
5. Increases _____ secretion

f. The rate of renin secretion decreases:

1. If blood pressure _____

2. If the Na^+ concentration _____

g. Aldosterone

1. Aldosterone is a steroid hormone secreted by _____

2. In the distal tubules and collecting ducts aldosterone molecules:

a. Diffuse _____

b. Bind to _____

c. The combination of aldosterone molecules with receptor molecules increases _____

d. As a result the rate of Na^+ transport _____

3. Reduced secretion of aldosterone _____

a. Concentration of solutes in the distal tubules and collecting ducts remains _____

b. This diminishes the capacity of water to _____ from the tubules into the _____

c. Therefore, urine volume _____ and the urine has a greater concentration of _____

3. Other Hormones

a. Atrial natriuretic hormone is secreted by _____ when blood volume in the right atrium _____

b. Atrial natriuretic hormone:

1. Inhibits _____

2. Inhibits _____ reabsorption in the kidney

a. This leads to production of a _____ volume _____ urine

b. The resulting decrease in blood volume _____ blood pressure

c. Atrial natriuretic hormone also _____

1. Reduces _____ and lowers _____

V. Clearance and Tubular Maximum

A. Plasma Clearance

1. What is plasma clearance? _____

2. Plasma clearance can also be used to estimate _____

B. Renal Plasma Flow

1. Plasma clearance can also be used to calculate _____

2. What characteristics must the substance have?

a. _____

b. _____

3. What substance has these characteristics? _____

a. As blood flows through the kidney _____

1. The clearance calculation for PAH is therefore a good estimate for _____

2. If the hematocrit is known, one can easily calculate _____

C. Tubular Load and Tubular Maximum

1. What is the tubular load of a substance? _____

2. What is the tubular maximum? _____

3. Is the tubular maximum the same for all substances? _____

4. The tubular maximum for each substance is determined by:

a. Number of _____

b. Rate at which _____

5. In a person with diabetes mellitus:

a. The tubular load exceeds the _____

b. This allows _____ in the urine

c. Urine volume is _____ because the glucose _____

VI. Anatomy and Histology of the Ureters and Urinary Bladder

A. Anatomy

1. What are the ureters? _____

2. The ureters leave the renal pelvis of each kidney at the _____ and extend _____ & _____ to the urinary bladder
3. The urinary bladder is described as a _____ that lies _____
4. Where do the ureters enter the bladder? _____
5. The urinary bladder is positioned:
 - a. In the male _____
 - b. In the female _____
6. Functionally the urethra _____
7. Where does the urethra exit the bladder? _____
8. The triangular area marked by the two ureters and the urethra is called the _____

C. Histology

1. What kind of epithelium lines the ureters and bladder? _____
2. The rest of the walls consist of a:
 - a. _____
 - b. _____
 - c. _____
3. The wall of the urinary bladder is _____ than the ureters
 - a. This is caused by layers, composed primarily of _____ external to the epithelium
4. Transitional epithelium is specialized so that cells _____ and the number of cell layers _____ as the volume _____
 - a. How many cells thick when the urinary bladder is empty? _____
 - b. How many cells thick when the urinary bladder is full? _____
5. Where the urethra exits the urinary bladder _____ and _____ keeps urine from flowing out of the bladder until pressure _____
 - a. In males the _____ tissue and _____ muscle form an _____ which contracts to keep _____ from entering the bladder

6. The external urinary sphincter is composed of _____
 - a. It surrounds the urethra as it extends _____
 - b. The sphincter acts like a _____ that _____ the flow of urine through the urethra
7. The urethra opens to the outside:
 - a. In the male at _____
 - b. In the female into the _____ anterior to the _____

VII. Urine Movement

A. Urine Flow Through the Nephron and the Ureters

1. Hydrostatic pressure averages:
 - a. _____ in Bowman's capsule
 - b. _____ in the renal pelvis
1. This pressure gradient forces urine from _____ through _____ into the _____
2. No pressure gradient exists to force urine to flow to _____ through the _____
 - a. The circular smooth muscle in the walls of the ureters:
 1. Exhibits _____
 2. That forces _____
 - b. The peristaltic contractions of each ureter:
 1. Proceed at a velocity of _____
 2. Generate pressures _____
 - c. Where the ureters penetrate the _____ they course _____
 1. Pressure inside the urinary bladder:
 - a. Compresses _____
 - b. Prevents the _____
 - d. When no urine is present in the urinary bladder the internal pressure is _____
 1. When it contains 100 mL or urine pressure is elevated to _____

2. Between 400-500 mL of urine the pressure _____
3. With urine volumes over 500 mL the pressure _____

B. Micturition Reflex

1. What is micturition? _____
2. The micturition reflex is activated when _____
3. The micturition reflex is:
 - a. Integrated in _____
 - b. Modified by _____
4. Urine filling the urinary bladder:
 - a. Stimulates _____ which produce _____
 - b. Sensory neurons carry action potentials to the _____
_____ through the _____
5. In response:
 - a. Action potentials are carried to the urinary bladder through _____
 - b. This causes _____
 - c. Decreased somatic motor action potentials cause the _____
_____, composed of _____ to _____
 - d. Urine flows from the urinary bladder when the _____
to force _____ through the urethra while _____

 - e. The reflex normally produces a _____
6. Stretch receptors in the urinary bladder also send action potentials to micturition centers in the _____ and to the _____
 - a. Response from these areas modify the activity of the _____
_____ in the spinal cord
7. The micturition reflex, integrated in the spinal cord, predominates _____
8. The ability to voluntarily inhibit micturition develops at the age of _____
9. After this time the influence of the _____ & _____
on the spinal reflex predominates
 - a. The micturition reflex integrated in the spinal cord is _____
but it is either _____ or _____ by _____

- b. Higher brain centers prevent micturition by _____
 - 1. Inhibits parasympathetic stimulation of _____
 - 2. Stimulates somatic motor neurons that _____
- 10. When the contents of the urinary bladder exceed 400-500 mL:
 - a. Pressure _____
 - b. Frequency of action potentials _____
 - c. Increased stimulation of pons and cerebrum results in _____
- 11. Voluntary initiation of micturition involves:
 - a. _____ in action potentials from the _____ to:
 - 1. Facilitate _____
 - 2. Voluntarily _____
 - 3. Increased voluntary contraction of _____ which cause an increase in _____
 - a. Increases the pressure applied to the _____
- 12. The desire to urinate can also be initiated by:
 - a. Irritation of the _____ or _____ by _____ or other conditions

VIII. Effects of Aging on the Kidneys

A. Size of Kidneys

- 1. Aging causes a _____
 - a. Begins as early as _____
 - b. Obvious by _____
 - c. Continues _____
- 2. Loss of size appears to be related to changes _____

B. Blood Flow

- 1. The amount of blood flowing through the kidneys _____
 - a. Starting at age 20 there is _____ 10 years
- 2. Small arteries, including the afferent and efferent arteriole become _____ and _____
- 3. Functional glomeruli _____

4. Other glomeruli _____ and assume a structure similar to

C. Nephrons and Collecting Ducts

1. Some nephrons and collecting ducts become _____, _____, and more _____ in structure

2. The capacity to secrete and absorb _____

3. Whole nephrons _____

4. The ability of the kidney to concentrate urine _____

a. Increases the risk of _____

5. Decreased ability to eliminate:

a. _____ c. _____

b. _____ d. _____

6. Less responsive to _____ and _____

7. The reduced ability to _____

contributes to Ca^{2+} deficiency, osteoporosis, and bone fracture.