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? _____

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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_____

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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

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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

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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 _____

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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

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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. Glomeralar 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 _____

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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

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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 _____

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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 _____

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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:

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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 _____

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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:

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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 _____

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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. Solutes _____ 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. Solutes enter 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. Afterthe vessels _____
3. Blood is carried _____

c. Walls of the vasa recta are permeable to _____ & _____

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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? _____

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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 _____

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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

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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 _____

I. 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 _____

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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? _____

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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

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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 _____

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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 _____

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b. Higher brain centers prevent micturition by _____

1. Inhibits parasympathetic stimulation of _____

2. Simulates 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 _____

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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.

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