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 _____
   7. Blood is carried away from the glomerular capillaries in the _____

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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. 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. _____

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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 _____

IV. 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: _____

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_____

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? _____
5. Filtration Barrier
   a. The filtration membrane is a _____ and prevents:
      1. _____ and _____ from entering Bowman's capsule
      2. Allows other _____ to enter

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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

6. 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 _____

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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 _____

C. 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

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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

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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 _____

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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

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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 _____

D. 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. _____

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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 _____

E. 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

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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. 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? _____ _____

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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:

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1. Some urea diffuses out of _____ 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

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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

V. 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 _____

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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 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 _____

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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 _____

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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 _____

C. 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 _____

D. 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 _____

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VI. Clearance and Tubular Maximum

A. Plasma Clearance

1. What is plasma clearance? _____

   _____

2. Plasma clearance can also be used to estimate _____

B. 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 _____

C. 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 _____

      _____

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1. The clearance calculation for PAH is therefore a good estimate for _____
2. If the hematocrit is known, one can easily calculate _____ _____

D. 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 _____

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 _____

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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 _____

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_____

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. 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

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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.

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