LECTURE OUTLINES & REVIEW QUESTIONS

LECTURE OUTLINE: URINARY SYSTEM

OVERVIEW

COMPONENTS:
Right & Left Kidneys, Right & Left Ureters, Urinary bladder, Urethra
Adrenal or suprarenal (above the kidney) glands sit atop kidneys, but belong to endocrine system, not urinary.

FUNCTIONS:
(1) Fluid & Electrolyte Balance / Metabolic Waste Removal:
a. About 20% of total blood volume flows through kidneys per minute: Abdominal aorta → renal aa. → glomeruli (fenestrated capillaries) → renal vv. → IVC.

b. Blood is filtered: glomerular filtration pressure → filtrate, a selective sample of blood plasma: water, electrolytes (acids, bases, salts), nutrients (amino acids, glucose), metabolic wastes (urea, uric acid, creatinine).

c. Filtrate → renal tubules (nephrons). Must pass through filtration membrane: capillary endothelium + basal lamina + basal lamina + tubular epithelium.

d. Tubular reabsorption (resorption): Conservation of needed materials. Actively or passively moved out of tubules and returned to circulatory system. Filtrate → renal tubules (nephrons) → interstitial tissues → peritubular capillaries → renal veins → IVC.

e. Excretion: Remaining materials (urine) → ureters → urinary bladder → urethra → exterior

f. Tubular Secretion (reverse of resorption): materials leave peritubular capillaries → interstitial tissues → renal tubules → ureter → urinary bladder → urethra

(2) Erythropoietin:
Kidneys produce erythropoietin → bone marrow → increased rbc production.

(3) Renin:
Decreased blood pressure: Kidneys release renin → circulation: angiotensinogen converted to angiotensin → vasoconstriction → increased blood pressure

(4) Vitamin D3:
Vitamin D3 precursor → kidneys: converted to active vitamin D3. D3: calcium & phosphate regulation

(5) Gluconeogenesis:
Prolonged fasting: Kidneys produce glucose → circulation

THE KIDNEYS

LOCATION & RELATIONS
Posterior abdominal wall. Retroperitoneal (outside the parietal peritoneum lining the abdominal cavity).

On either side of vertebral column, IVC, and abdominal aorta.

Adrenal glands sit on superior poles.

Posterior relations. Above: Ribs 11, 12, diaphragm. Below (medial to lateral): psoas major, quadratus lumborum, transversus abdominis.
Anterior relations. Right Kidney (superior to inferior): adrenal gland (bare contact); liver (separated by peritoneum); colon & duodenum; jejunum. Left Kidney: adrenal (bare); stomach & spleen (peritoneum); pancreas & colon; jejunum (peritoneum)

Connective tissue envelopes:
Renal fascia (ct); perirenal (perinephric) fat (between fascia and kidney); pararenal (paranephric) fat (outside fascia).
Help hold kidneys loosely in place.

Vascular connections:
Abdominal aorta → renal aa. Left artery shorter; right longer.
Renal vv. → IVC Right vein shorter; left longer and “clamped” by superior mesenteric a.

GROSS ANATOMY
Poles (ends): superior & inferior
Surfaces: anterior and posterior
Margins: lateral and medial.

Renal hilum (hilus): Indentation on medial margin.
Entrance / Exit for:
Renal pelvis (upper end of ureter)
Renal vein
Renal artery
Nerves, lymphatics

Longitudinal section of kidney:
Renal sinus: cavity just inside hilum. Not empty in life (see below).

Renal medulla (core):
Renal pyramids (average around 14, but varies)
Each pyramid has a base + papilla (little nipple)
Papilla projects into renal sinus.

Renal cortex (bark): surrounds pyramids.
Renal or cortical columns: cortex between adjacent pyramids.

Renal capsule: ct. envelope of kidney

Renal corpuscles (little bodies):
Small red dots in cortex of fresh kidney

Corticomедullary junction:
Contact area between cortex & base of pyramid

Renal lobe: pyramid + overlying cortex (~ 14).
Lobation obvious in fetal kidney.

Contents of renal sinus:
Minor calyces (singular calyx = wine cup).
Usually 14 arranged in 7 anterior – posterior pairs.
Each minor calyx encloses a renal papilla.

Major calyces.
Usually two, sometimes three.
Formed by merging of minor calyces.

Renal pelvis (basin).
Expanded upper end of ureter.
Leaves hilum and narrows down to tubelike part of ureter.

Renal artery. Enters hilum; branches into segmental arteries (~ 5) → lobar aa.

Lobar veins → renal vein. Leaves hilum.

Autonomic nerves & lymphatics.

Connective tissue. Fills spaces.
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RENAI CIRCULATION

Cortex:
Renal a. → segmental arteries (~5) → lobar aa. →
interlobar aa. (run in cortical columns) → arcuate or
arched aa. (arch along bases of pyramids) →
interlobular aa. (radiate through cortex towards
capsule; flanked by renal corpuscles) → afferent
(carrying toward) arterioles → glomeruli (looped
fenestrated capillaries) → efferent (carrying away)
arterioles → peritubular capillary plexus (network) →
interlobular vv. → arcuate or arched vv. → interlobar
vv. → lobar vv. → renal v. → IVC

Medulla:
Some efferent arterioles → vasa recta + peritubular
capillary plexus → arcuate veins → interlobar vv. →
lobar vv. → renal v. → IVC

RENAI TUBULES or NEPHRONS:

ORGANIZATION & TERMINOLOGY

Uriniferous Tubules = Renal tubules (nephrons) + collecting
tubules

Renal Tubule or Nephron (Gk = kidney): Structural &
functional unit of the kidney.

Divided into:
1. Bowman’s Capsule (glomerular capsule)
2. Proximal Tubule:
   Convoluted part (L. = pars convoluta = twisted part)
   (PCT)
   Straight part (L. = pars recta = straight part)

3. Thin segment of Loop of Henle (loop of the nephron)
4. Distal Tubule:
   Straight part (pars recta)
   Convoluted part (pars convoluta) (DCT)

   Loop of Henle (Henle’s loop) (loop of the nephron)
   Descending limb + Thin Segment + Ascending limb
   Descending limb: thick segment = straight part of
   proximal tubule
   Ascending limb: thick segment = straight part of distal
tubule

ORIENTATION IN THE KIDNEY:

Cortex:
Renal Tubules: Bowman’s capsules + proximal convoluted
tubules + distal convoluted tubules + variable parts of loops of
Henle
Blood Vessels: afferent arterioles + efferent arterioles +
interlobular aa. and vv. + peritubular capillary plexus.

Medulla:
Renal Tubules: variable parts of Loops of Henle
Blood Vessels: vasa recta + peritubular capillary plexus

Juxtamedullary Nephrons (~ 15% of human nephrons or 1 out 7)
Located closer to juxtamedullary junction.
Loop: longer, extends well into pyramid; thin segment longer.

Cortical Nephrons (~85% of human nephrons)
Located farther out in cortex.
Loop: shorter, may or may not extend into pyramid; thin
segment shorter.
MICROSCOPIC ANATOMY

Bowman’s Capsule (glomerular capsule)
Bowman’s capsule encloses glomerulus = renal corpuscle

Analogy: Fist pushing into a balloon.
Fist = glomerulus (looped capillary)
Balloon wall covering fist = visceral layer of Bowman’s capsule
Outer balloon wall = parietal layers of Bowman’s capsule
Space in balloon = capsular or filtration space
Wrist = vascular pole, point at which afferent arteriole enters and efferent arteriole exits

Parietal layer = simple squamous epithelium
Visceral layer = a sheet of podocytes (foot cells)
Cover most – but not all - surfaces of the glomerulus.

Filtration Membrane:
“Barrier” between blood n the glomerulus and the capsular space:
capillary endothelium (fenestrated)
capillary basal lamina { laminae
podocyte basal lamina { fuse
filtration slits between podocyte processes

Mesangial cells cover capillary surfaces not covered by podocytes.

Proximal Tubule
simple cuboidal epithelium with brush border (microvilli)
basal infoldings with numerous mitochondria

Thin segment of Henle’s Loop
simple squamous epithelium

Distal tubule:
simple cuboidal epithelium
compared to proximal tubule:
reduced numbers of microvilli
reduced basal infolding & mitochondria

FUNCTION
Bowman’s Capsule
Glomerular filtration:
Arteriole calibers: afferent usually greater than efferent
Produces glomerular filtration pressure
Forces plasma filtrate across filtration membrane & into capsular space.
Filtration is selective.
Not everything can cross the membrane.
Endothelium (fenestrated) + two fused basal laminae + filtration slits between podocyte processes
Basal laminae seem to be responsible for most of the selectivity of the filtration membrane.

Proximal tubule
Fluid pressure moves filtrate from capsular space into proximal tubule.

Tubular reabsorption (resorption):
Conserves needed materials
Water, sodium, chloride, calcium, phosphate, bicarbonate, glucose, amino acids, small proteins, etc. out of tubule \( \rightarrow \) interstitial tissues (ct) \( \rightarrow \) peritubular capillaries \( \rightarrow \rightarrow \) returned to circulation.
Active and passive transport.
Large surface area: microvilli, apical invaginations, basal infoldings
Large energy supply: numerous mitochondria.
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Tubular secretion:
- Metabolic end products, bile salts, urate, some drugs and toxins, etc.: peritubular capillaries → interstitial tissues → proximal tubules.

Loop of Henle: Thin Segment. Descending limb: water out; ascending limb: sodium, potassium, chloride, bicarbonate out; no water. (Check details again) Significance discussed later.

Distal Tubule
*Fluid pressure moves filtrate from thin segment into distal tubule.*
- Straight part + first part of convoluted:
  - Tubular reabsorption:
    - Sodium, potassium, chloride, bicarbonate
    - Impermeable to water & urea.
- Last part of convoluted:
  - Tubular reabsorption:
    - Principal cells: sodium & water.
    - Intercalated cells: potassium.
  - Tubular secretion:
    - Principal cells: potassium.
    - Intercalated cells: hydrogen ions.

*End of the distal convoluted tubule = end of the renal tubule.*
- Contents after filtration, resorption, and secretion = urine.

JUXTAGLOMERULAR APPARATUS
- Parts of the distal convoluted tubule and the afferent arteriole contact each other at the vascular pole of Bowman's capsule.
  - Specialized cells form the juxtaglomerular apparatus.
  - Distal convoluted tubule: macula densa (*dense spot*) cells

URINARY SYSTEM

Afferent arteriole: juxtaglomerular cells.
- Function:
  - Decreased BP → kidneys jg apparatus → renin → circulation
  - angiotensinogen converted to angiotensin → vasoconstriction → increased BP

MESANGIAL CELL FUNCTIONS
- glomerular support
- extracellular matrix maintenance
- phagocytosis: immunological + basal lamina clearance
- secretion: cytokines and prostaglandins
- angiotensin II → contraction → decreased glomerular blood flow
- naturietic factor → relaxation → increased glomerular blood flow.

QUICK REVIEW
- Tubular Resorption: glomerulus → plasma filtrate → nephron → peritubular capillaries → returned to circulation
- Tubular Secretion: peritubular capillaries → interstitial tissues → nephron
- Urine: Plasma filtrate – tubular reabsorption + tubular secretion
  - Leaves distal convoluted tubule
  - Enters system of collecting tubules

COLLECTING TUBULES
- DCT → arched collecting ducts → collecting tubules → papillary ducts → renal papilla
- Run through cortex and pyramids.
- Epithelium: simple cuboidal → simple columnar
- Smooth muscle
URINARY CONCENTRATION
Urine in last part of DCT is normally dilute.
Urine exiting papillary duct is normally concentrated.
Last part of DCT and collecting tubules are permeable to water.
There is a net diffusion of water out of the tubules.

Osmosis: Diffusion of water down a concentration gradient.

If water concentration inside the tubules = water concentration outside, then there is no net diffusion of water out of the tubules and no urine concentration.

If concentration inside the tubules is greater than the concentration outside, then there is a net diffusion of water out of the tubules and urine concentration.

Lower water concentration outside the tubules is achieved by taking up space with sodium (Na+) and urea.

Problem: As urine in tubules becomes more concentrated, more Na+ and urea is needed to maintain a lower water concentration outside the tubules.

Therefore: sodium and urea concentration increases from base of pyramid to papilla.

Loop of nephron: establishes sodium concentration.
Vasa recta: maintain concentration gradient.
Collecting tubules passively contribute ~50% of urea.

In pyramids, vasa recta, loops of Henle, and collecting tubules run parallel to each other. All surrounded by peritubular capillaries

ADH (antidiuretic hormone) (vasopressin)
Hypothalamic neurons → neurohypophysis (posterior pituitary) → circulation → kidneys

Increases water permeability of late DCT & collecting tubule system

Increased water permeability → increased water resorption → increased urine concentration.

CALYCES & URETERS

OVERVIEW
In each renal pyramid, papillary ducts empty urine into minor calyx surrounding its renal papilla.
Minor calyces merge to form major calyces.
Major calyces merge to form renal pelvis, expanded upper end of ureter.
Renal pelvis leaves renal hilum of kidney; narrows down to tubular portion of the ureter.
Ureters convey the urine to the urinary bladder.

URETERS: LOCATION & RELATIONS

Retroperitoneal.
Leave hilum on medial margin of kidneys.
Run down posterior abdominal wall on Psoas major muscles.
At pelvic brim, cross over external iliac a. & v. to enter pelvis minor.
Curve medially to empty into posterolateral angles of urinary bladder.
LECTURE OUTLINES & REVIEW QUESTIONS

MICROSCOPIC ANATOMY: CALYCES & URETERS

Ureter (x-sectioned):
- Mucosa:
  - Epithelium: transitional
  - Lamina propria: connective tissue (loose to dense)
  - Thrown into 4 or 5 longitudinal folds in tubular part of ureter.
- Muscularis:
  - Smooth muscle
  - Interlacing layers: longitudinal + circular + longitudinal (lower third)
  - Peristaltic contractions propel urine towards bladder
- Adventitia: connective tissue

Calyces: similar to ureters.
- Mucosa:
  - Epithelium: transitional
  - Lamina propria: connective tissue (loose to dense)
- Muscularis:
  - Smooth muscle
  - Interlacing layers: longitudinal + circular
  - In minor calyces, contractions of circular fibers appear to aid flow of urine out of papillary ducts.
- Adventitia: connective tissue

URINARY BLADDER

Receives urine from ureters; expels urine through urethra

LOCATION & RELATIONS

Pelvis minor (true pelvis)

Male:
- Anterior: pubic symphysis
- Posterior: seminal vesicle, end of ductus deferens, rectum
- Inferior: Prostate
- Ureters empty into posterolateral angles

Female:
- Anterior: pubic symphysis
- Posterior: vagina, lower part of uterus, rectum
  - Uterus is usually anteverted (tilted forward over the bladder).
- Ureters empty into posterolateral angles
- Upper surface covered with parietal peritoneum

Parietal peritoneal reflexions over urinary bladder, uterus, rectum create:
- Vesicouterine recess or pouch
- Rectouterine recess or pouch (of Douglas)
  - Lowest cavitation in reclining female body.

GROSS ANATOMY

Urinary bladder (coronal section).

Wall (internal to external):
- Transitional epithelium (uroepithelium) + connective tissue
- Smooth muscle
- Connective tissue
  - Superior surface: connective tissue + parietal peritoneum

Urinary Trigone (three corners)

Smooth area in posterior wall of bladder

Resembles inverted triangle
- Upper two angles: openings of ureters
  - Slit-like. Prevents reflux of urine when bladder contracts during micturition (urination).
  - Lower angle: Internal urethral meatus → urethra
- Rest of internal surface thrown into ridges.
MICROSCOPIC ANATOMY
Similar to lower third of ureter.
- Mucosa:
  - Epithelium: transitional (uroepithelium)
  - Lamina propria: connective tissue
- Muscularis:
  - Interlacing longitudinal, circular, and longitudinal layers
  - Circular fibers around internal urethral meatus = internal urethral sphincter
- Advenitia: connective tissue.
  - Serosa: peritoneum + ct over superior surface.

URETHRA

MALE
Internal urethral meatus & sphincter → urethra
- First part: Prostatic. Runs through prostate gland.
  - Colliculus (little hill): elevation in posterior wall
  - Utricle (uriculus = little uterus):
    - Small invagination. Embryological remnant.
    - Male homolog of uterus.
  - Ejaculatory duct openings (right & left)
    - Convey semen to urethra.
  - Multiple prostate gland duct openings

- Second part: Membranous.
  - Passes through urogenital (U-G) diaphragm, thin sheet of skeletal muscle and connective tissue.

- Third part: Penile.
  - Penis: three columns of tissue
    - Two corpora cavernosa (sing. = corpus cavernosum).
    - One corpus spongiosum.
      - Lies in groove on underside of corpora cavernosa.
      - Begins at bulb and ends at glans.
      - Contains urethra.
      - Enters corpus spongiosum at bulb.

FEMALE
Compared to male, short: 1.5 – 2 inches.
Internal urethral meatus & sphincter → U-G diaphragm → external urethral meatus
Runs more or less parallel and anterior to lower vagina.
Empty's at external urethral meatus in vestibule, the space between labia minora (sing. = labium minus). Usually a small elevation.
  - Anterior: glans clitoridis
  - Posterior: vaginal introitus
Urethral or skene’s glands.

REVIEW QUESTIONS

Resources: Text: Urinary System Chapter
Lab Manual Part 2: Urinary System Lab Exercises

1. Which of the following is not a component of the urinary system? (a) ureters (b) kidneys (c) urethra (d) urinary bladder (e) prostate gland
2. The kidneys __?__ (a) clear metabolic wastes from the blood (b) maintain the body’s water and electrolyte balance (c) secrete renin and erythropoietin (e) all of these
3. The kidneys __?__ (a) are retroperitoneal (b) are partly protected by the rib cage (c) are capped by the adrenal glands (d) all of these (e) none of these
4. Which of the following is closest to the surface of the kidney? (a) pararenal fat (b) perirenal fat (c) renal fascia (d) peritoneum (e) renal capsule
5. The renal hilus is located on the __?__ of the kidney. (a) medial margin (b) lateral margin (c) superior pole (d) inferior pole (e) anterior surface

6. Which of the following would not be found at the renal hilus? (a) renal artery (b) renal vein (c) urinary trigone (d) renal pelvis (e) upper part of the ureter

7. Which of the following occupy the renal sinus? (a) minor calyces (b) major calyces (c) segmental arteries and veins (d) all of these (e) none of these

8. Collectively, the renal pyramids are referred to as the renal __?__. (a) cortex (b) columns (c) medulla (d) corpuscles (e) juxtaglomerular apparatus

9. Renal pyramids are separated from each other by the __?__. (a) renal cortex (b) renal columns (c) renal sinus (d) calyces (e) renal capsule

10. The base of a renal pyramid lies next to the __?__. (a) renal capsule (b) renal cortex (c) renal fascia (d) renal sinus (e) perirenal fat

11. The apex of a renal pyramid projects into __?__. (a) a major calyx (b) the renal pelvis (c) a minor calyx (d) a renal corpuscle (e) the ureter

12. A renal lobe consists of __?__. (a) all the renal pyramids (b) all the renal pyramids and renal columns (c) a renal pyramid plus the cortex overlying it (d) all the renal columns (e) none of these

13. If you traced the flow of blood into the kidney, through which of the listed vessels would it pass secondly? (a) segmental artery (b) interlobular artery (c) interlobar artery (d) arcuate artery (e) afferent arteriole

14. If you traced the flow of blood into the kidney, through which of the following listed vessels would it pass fourthly? (a) segmental artery (b) interlobular artery (c) interlobar artery (d) arcuate artery (e) afferent arteriole

15. If you traced the flow of blood through the kidney, through which of the following listed vessels would it pass firstly? (a) afferent arteriole (b) efferent arteriole (c) glomerulus (d) peritubular capillaries (e) interlobar artery

16. Which blood vessel - location match is not correct? (a) segmental a. - renal sinus (b) interlobar a. - renal column (c) arcuate a. - corticomedullary junction (d) interlobular a. - cortex (e) afferent arteriole - pyramid

17. Which blood vessel - location match is not correct? (a) efferent arteriole - cortex (b) glomerulus - pyramid (c) afferent arteriole - cortex (d) peritubular capillary network - cortex (e) vasa recta - pyramid

18. Glomeruli are __?__. (a) fed by afferent arterioles (b) looped fenestrated capillaries (c) drained by efferent arterioles (d) all of these (e) none of these

19. The renal tubules __?__. (a) are the structural and functional units of the kidney (b) are also called nephrons (= nephroi) (c) are basically microscopic tubes of epithelium (d) all of these (e) none of these

20. A renal tubule "begins" as the __?__ and "ends" as the __?__. (a) glomerular capsule, loop (b) proximal tubule, distal tubule (c) glomerular capsule, distal convoluted tubule (d) proximal convoluted tubule, distal convoluted tubule (e) loop, glomerular capsule

21. The loop of a nephron is formed by the __?__. (a) proximal tubule: straight part (b) distal tubule: straight part (c) thin segment (d) all of these (e) none of these

22. A renal corpuscle is composed of a __?__. (a) glomerulus and glomerular capsule (b) glomerular capsule and proximal convoluted tubule (c) macula densa and juxtaglomerular cells (d) minor and major calyx (e) none of these

23. The __?__ is composed of podocytes? (a) glomerular endothelium (b) distal tubule (c) glomerular capsule; parietal layer (d) glomerular capsule; visceral layer (e) proximal tubule
24. To move from the glomerulus to the capsular space, filtered blood plasma must pass through __?___. (a) glomerular endothelium (b) two basal laminae (c) slits between podocyte processes (d) all of these (e) none of these

25. If you traced the flow of filtrate through a renal tubule, through which of the following structures would it pass fourthly? (a) distal convoluted tubule (b) glomerular capsule (c) proximal convoluted tubule (d) loop of the nephron: ascending limb (e) loop of the nephron: descending limb

26. Which of the following renal structures is composed of simple cuboidal epithelium and has the most microvilli? (a) distal tubule (b) proximal tubule (c) loop of the nephron: thin segment (d) glomerular capsule: parietal layer (e) collecting duct

27. Tubular reabsorption __?___. (a) is the movement of materials out of a nephron and into the renal interstitial tissue (b) may be an active or a passive process depending upon the materials involved (c) is the reverse of tubular secretion (d) all of these (e) none of these

28. Tubular secretion is the transport of materials from the renal interstitial tissue into the renal tubules. (a) true (b) false

29. Which part of the nephron is most active in tubular reabsorption? (a) glomerulus (b) glomerular capsule (c) proximal tubule (d) distal tubule (e) loop of the nephron: thin segment

30. In general, materials reabsorbed by the renal tubules __?___. (a) are stored in the kidney (b) are returned to the bloodstream (c) are excreted as urine (d) are metabolic wastes (e) none of these

31. Peritubular capillaries __?___. (a) are fed mostly by efferent arterioles (b) surround renal tubules (c) pick up materials reabsorbed by the nephrons (d) supply kidney cells (e) all of these

32. Which of the following is not composed of simple cuboidal epithelium? (a) loop of the nephron: thin segment (b) proximal convoluted tubule (c) distal convoluted tubule (d) descending limb of the loop of the nephron: thick segment (e) ascending limb of the loop of the nephron: thick segment

33. Which of the following is primarily responsible for establishing a sodium and urea concentration gradient within the renal pyramids? (a) proximal convoluted tubules (b) distal convoluted tubules (c) collecting tubules (d) loop of the nephron (e) papillary ducts

34. Renal tubules empty urine into __?___. (a) peritubular capillaries (b) arched collecting tubules (c) minor calyces (d) vasa recta (e) none of these

35. If you traced the flow of urine out of a renal tubule, through which of the listed structures would it pass fourthly? (a) straight collecting tubule (b) papillary duct (c) arched collecting tubule (d) major calyx (e) minor calyx

36. ADH or antidiuretic hormone __?___. (a) is produced by neurons in the hypothalamus (b) is released into capillaries in the neurohypophysis or posterior pituitary (c) increases the permeability of collecting tubule cells to water (d) all of these (e) none of these

37. Which of the following could not be found in the renal cortex? (a) renal corpuscles (b) proximal convoluted tubules (c) distal convoluted tubules (d) vasa recta (e) loops of nephrons

38. Which of the following could not be found in a renal pyramid? (a) vasa recta (b) loops of nephrons (c) collecting tubules (d) papillary ducts (e) renal corpuscles

39. Compared to juxtamedullary nephrons, cortical nephrons __?___. (a) are more numerous (b) have shorter loops of Henle (c) have shorter thin segments (d) are located more in the cortex than the medulla (e) all of these

40. Humans have about seven times more juxtamedullary nephrons than cortical nephrons. (a) true (b) false
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41. Vasa recta __?__. (a) are located in renal pyramids (b) run parallel to loops of Henle and collecting tubules (c) maintain the urea and sodium concentration gradients of the medulla (d) all of these (e) none of these

42. The juxtaglomerular apparatus __?__. (a) includes specialized muscle cells in the afferent arteriole (b) includes specialized distal convoluted tubule cells (c) secretes renin in response to falling arterial blood pressure (d) all of these (e) none of these

43. The macula densa is a group of specialized secretory cells in the __?__. (a) distal convoluted tubule (b) loop of the nephron (c) proximal convoluted tubule (d) glomerular capsule (e) efferent arteriole

44. The renal pelvis __?__. (a) is the dilated superior end of the ureter (b) is located in the renal hilus (c) is formed by the junction of the major calyces (d) all of these (e) none of these

45. As they run from kidneys to urinary bladder, the ureters __?__. (a) are retroperitoneal (b) lie anterior to the psoas major muscles (c) cross over the external iliac vessels (d) enter the pelvis minor (e) all of these

46. The ureters enter the __?__ of the urinary bladder. (a) urachus (b) neck (c) posterolateral borders (d) superior surface (e) inferior angle

47. Urine is moved through the ureters by peristaltic waves of smooth muscle contraction. (a) true (b) false

48. In the female, the urinary bladder is located __?__. (a) posterior to the pubic symphysis (b) anterior to the uterus and the upper vagina (c) inferior to the peritoneum lining the pelvis (d) all of these (e) none of these

49. Which of the following is lined with transitional epithelium? (a) urinary bladder (b) ureter (c) major calyces (d) minor calyces (e) all of these

50. The urinary trigone __?__. (a) is located in the posterior wall of the urinary bladder (b) is shaped like an upside-down triangle (c) has three corners marked by the openings of the ureters and the internal urethral meatus (d) all of these (e) none of these

51. If you traced the flow of urine through the male urethra, through which of the listed structures would it pass thirdly? (a) membranous urethra (b) prostatic urethra (c) internal urethral meatus (d) penile urethra (e) external urethral meatus

52. The female external urethral meatus is located __?__. (a) in the vestibule (b) posterior to the clitoris (c) anterior to the vaginal orifice (d) all of these (e) none of these