Urinary System
kidneys, ureters, bladder & urethra

Kidney Function
Filters blood
• removes waste products
• conserves salts, glucose, proteins, nutrients and water

Produces urine
Endocrine functions
• regulates blood pressure
• produces
  • renin
  • erythropoietin
  • prostaglandins
• converts vitamin D to active form

Kidney Structure

Capsule

Hilum
• ureter → renal pelvis
  → major and minor calyxes
• renal artery and vein
  → segmental arteries
  → interlobar arteries
  → arcuate arteries
  → interlobular arteries

Medulla
• renal pyramids
• cortical/renal columns

Cortex
• renal corpuscles
• cortical labryinth of tubules
• medullary rays
Renal Lobe
= renal pyramid & overlying cortex

Renal Lobule
= medullary ray & surrounding cortical labyrinth

Uriniferous Tubule
Nephron + Collecting tubule

Nephron
Renal corpuscle produces glomerular ultrafiltrate (180 L per day) from blood

Ultrafiltrate is concentrated
- Proximal tubule
  - convoluted
  - straight
- Henle’s loop
  - thick descending
  - thin
  - thick ascending
- Distal tubule
- Collecting tubule

Urine (1-2 L per day) secreted from collecting ducts into calyces
Renal Cortex

Glomerulus surrounded by cortical labyrinth

Medullary rays (cross section)

Renal corpuscle = glomerulus + Bowman’s capsule

Cortical labyrinth of tubules

Medullary ray = collecting tubules
Renal Corpuscle

- Urinary / Bowman’s space
- Bowman’s capsule
- Glomerulus
  - fenestrated capillaries
  - podocytes
  - intraglomerular mesangial cells
  - Juxtaglomerular apparatus
    - macula densa in distal tubule
    - JG cells in afferent arteriole
    - extraglomerular mesangial cells
Renal Corpuscle

- Vascular pole
- Urinary pole

Intraglomerular Mesangial Cells
- Support capillaries
- Phagocytose basal lamina
- Vasoconstrict in response to angiotensin II
Urinary Filtration Membrane

- **Endothelial cell**
  - 70-90 nm fenestra restrict proteins > 70kd

- **Basal lamina**
  - heparan sulfate is negatively charged
  - produced by endothelial cells & podocytes
  - phagocytosed by mesangial cells

- **Podocytes**
  - pedicels 20-40 nm apart
  - diaphragm 6 nm thick with 3-5 nm slits
  - podocalyxin in glycocalyx is negatively charged
Juxtaglomerular Apparatus

Macula densa in distal tubule
- monitor Na⁺ content and volume in DT
- low Na⁺:
  - stimulates JG cells to secrete renin
  - stimulates JG cells to dilate afferent arteriole
- tall, narrow columnar cells
- numerous microvilli

JG cells
- secrete renin into circulation
  - renin converts angiotensinogen → angiotensin I
- contain angiotensin converting enzyme (ACE)
  - lung is principal site of ACE activity
- ACE converts angiotensin I → II
- contain angiotensin I & II
  - angiotensin II constricts vasculature and stimulates secretion of aldosterone and ADH
- primarily in afferent arteriole
- specialized smooth muscle cells
- no basal lamina between JG cells & macula densa

Extraglomerular mesangial cells
- also known as Polkissen or lacis cells

Proximal tubule
- proximal convoluted tubule
- thick descending limb Henle’s loop

Henle’s loop
- thin descending & ascending limbs

Distal tubule
- thick ascending limb Henle’s loop
- distal convoluted tubule
- macula densa in DCT

Collecting tubule & duct
Proximal Convoluted Tubule

- Cuboidal (low to high) cells
- Eosinophilic granular cytoplasm
- Basal nuclei
- Elaborate brush/striated border
- Lateral interdigitations

- Resorbs 100% protein, amino acids, glucose, creatinine, and bicarbonate ions
- Resorbs 70-80% of Na⁺, Cl⁻, and water
  - Na⁺/K⁺ pumps in basolateral membrane
  - Na⁺ pumped into interstitium
  - Cl⁻ and water follow
- Secretes waste products into lumen

Henle’s Loop (thin segments)

- Squamous cells
  - Slightly thicker than endothelial cells
- Few short microvilli
- Lateral interdigitations

- Descending limb
  - Highly permeable to water, salt, and urea
- Ascending limb
  - Impermeable to water
  - Permeable to salt which enters interstitium
Distal Tubule
(DCT & thick ascending limb of Henle’s loop)

- Low cuboidal cells
- Clear pale cytoplasm
- Apical nuclei (DCT)
- Central nuclei (Henle’s loop)
- Numerous mitochondria
- Absent (or few short) microvilli
- Basal interdigitations
- Numerous zonula occludens

- Not permeable to water or urea
- Active Na⁺/K⁺ pumps (DCT)
  - Aldosterone stimulates salt resorption
  - H⁺ and K⁺ transported into lumen
- Active Cl⁻ pumps (Henle’s thick)
  - Cl⁻ enters interstitium (Na⁺ follows)

Renal Medulla

- Collecting tubules/ducts
- Henle’s loop (thin segments)
- Capillaries of vasa recta
Collecting Tubule & Duct

- Cuboidal to columnar cells
- Clear cytoplasm
- Central nuclei
- Permeable to urea
- In response to ADH, becomes permeable to water which enter the interstitium

Renal Cortex

Sobotta & Hammersen: Histology
Formation of Urine

Countercurrent Multiplier System

Increasing osmolarity gradient exists from corticomedullary junction to deep in medulla

** due to high urea and salt content deep in medulla

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**TABLE 19-3** Structure and Function of the Uriferous Tubule

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- **Descending thin limb of Henle is freely permeable to water and salt**
  - Due to increasing osmolarity of interstitium: lumenal volume decreases and osmolarity increases
- **Ascending (thin and thick) limb of Henle and DCT are not permeable to water**
  - Lumenal volume does not change
  - Urea enters lumen
  - Cl− pumped into interstitium (Na+ follows)
  → increases salt deep in medulla
  → ultrafiltrate becomes hypotonic as it ascends
- **Without ADH: collecting tubule/duct impermeable to water**
  - ADH (pars nervosa of pituitary) makes collecting tubule/duct freely permeable to water and urea
  → increases water resorption, decreases urine volume, and increases urine tonicity
  → increases urea content deep in medulla to maintain interstitial osmolarity gradient

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**Formation of Urine**

**Countercurrent Multiplier System**

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Angiotensin II Regulation of Blood Pressure

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<td>Acts as a potent vasoconstrictor</td>
<td>Increased blood pressure</td>
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<td>Facilitates synthesis and release of aldosterone</td>
<td>Resorption of sodium and chloride from lumen of distal convoluted tubule</td>
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<td>Facilitates release of ADH</td>
<td>Resorption of water from lumen of collecting tubule</td>
</tr>
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<td>Increases thirst</td>
<td>Increased tissue fluid volume</td>
</tr>
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<td>Inhibits renin release</td>
<td>Feedback inhibition</td>
</tr>
<tr>
<td>Facilitates release of prostaglandins</td>
<td>Vasodilation of afferent glomerular arteriole, thus maintaining glomerular filtration rate</td>
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Burns & Cave: Histology & Cell Biology
Atrial Natriuretic Peptide (ANP)

- Secreted by atrial cardiac myocytes
- Function
  - decreases renin release
  - decreases aldosterone release
  - blocks resorption salt and water
  - decreases blood pressure

Alcohol

- decreases ADH release

Caffeine

- increases salt resorption in DCT

Vasa Rectae

- Peritubular capillary system in medulla
- Freely permeable to water and salts
- Counter current exchange system: equilibrates contents of medullary interstitium and vasculature
Vasculature of Kidney

Renal artery → Segmental artery → Interlobar artery → Arcuate artery → Interlobular artery → Afferent glomerular arteriole → Glomerular capillaries → Efferent glomerular arteriole

Cortex
- Interlobular vein
- Stellate vein
- Peritubular capillary network
- Cortical nephrons
- Arcuate vein
- Interlobar vein
- Renal vein

Medulla
- Vasa rectae
- Juxtamedullary & deep cortical nephrons

Urine is excreted through
- Calyces and renal pelvis
- Ureters
- Urinary bladder (storage)
- Urethra

Netter: Atlas of Human Anatomy
**Ureter**

- **Mucosa - transitional epithelium**
- **Lamina propria**
- **Muscularis – smooth muscle**
  - Inner longitudinal
  - Middle circular
  - Outer longitudinal (lower 1/3)

**Urinary Bladder**

- **Mucosa - transitional epithelium**
  - provides osmotic barrier
- **Lamina propria**
- **Muscularis – smooth muscle**
  - inner longitudinal
  - middle circular
  - (internal urethral sphincter)
  - outer longitudinal
Urethra

• Mucosa
  • varies from transitional to stratified columnar to pseudostratified columnar to stratified squamous in different regions

• Lamina propria
  • contains glands of Littre
  • highly vascularized

• External urethral sphincter of skeletal muscle

• In the male, 3 regions:
  • prostatic
  • membranous
  • penile or spongy