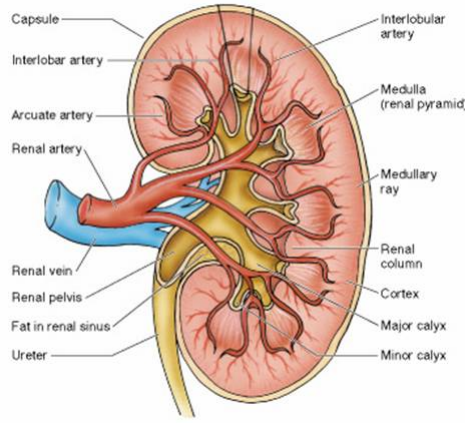
Kidney Structure



Capsule

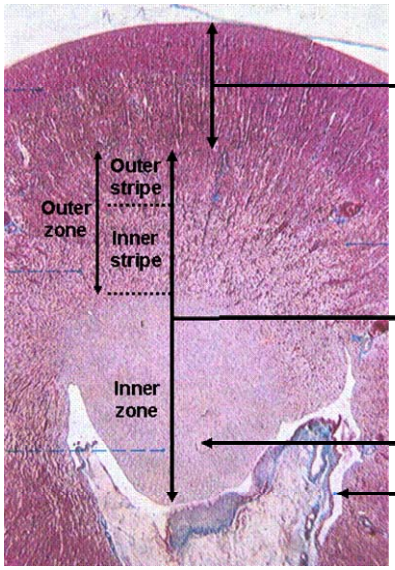
Hilum
- **ureter → renal pelvis → major and minor calyxes**
- **renal artery and vein → segmental arteries → interlobar arteries → arcuate arteries → interlobular arteries**

Medulla
- **renal pyramids**
- **cortical/renal columns**

Cortex
- **renal corpuscles**
- **cortical labryinth of tubules**
- **medullary rays**

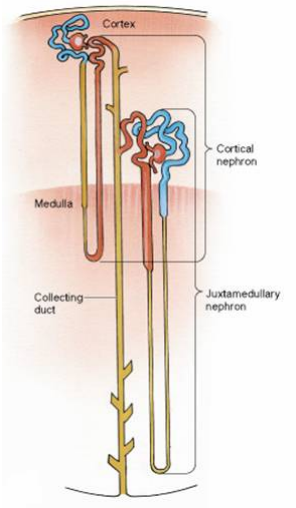
Renal Lobe

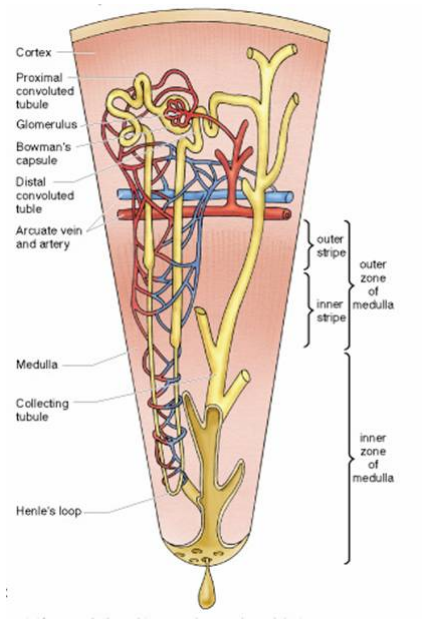
= renal pyramid & overlying cortex



Renal Lobule

= medullary ray & surrounding cortical labryinth





Uriniferous Tubule

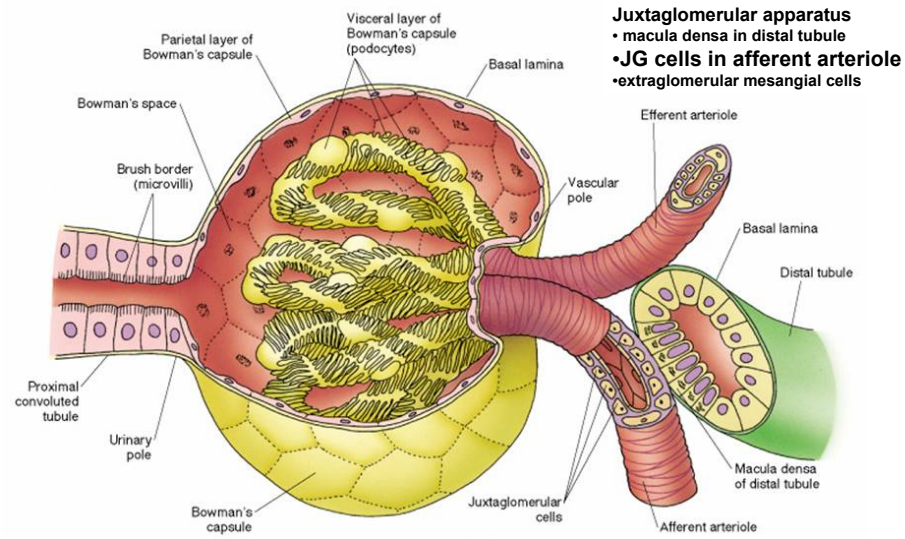
Nephron + Collecting tubule

Nephron

Renal corpuscle produces glomerular ultrafiltrate from blood

Ultrafiltrate is concentrated

- **Proximal tubule**
  - **convoluted**
  - **straight**
- **Henle's loop**
  - **thick descending**
  - **thin**
  - **thick ascending**
- **Distal tubule**
- **Collecting tubule**

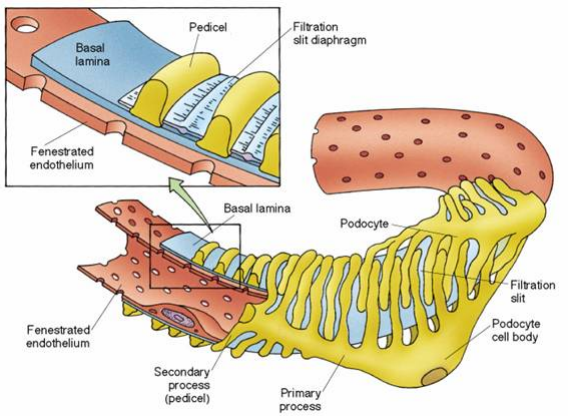


Juxtaglomerular apparatus

- **macula densa in distal tubule**
- **JG cells in afferent arteriole**
- **extraglomerular mesangial cells**

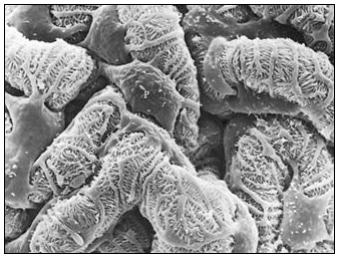
Glomerulus

- **fenestrated capillaries**
- **podocytes**
- **intraglomerular mesangial cells**

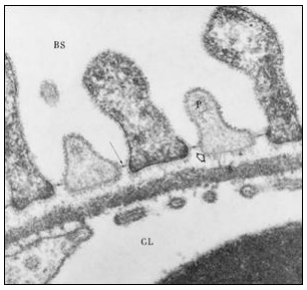


Urinary Filtration Membrane

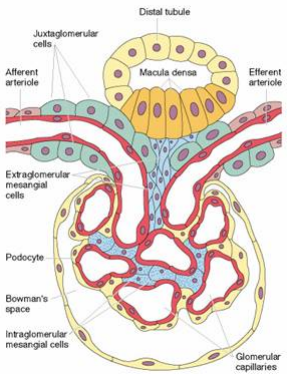
Podocytes

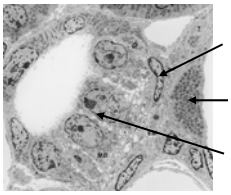


Urinary Membrane



- **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

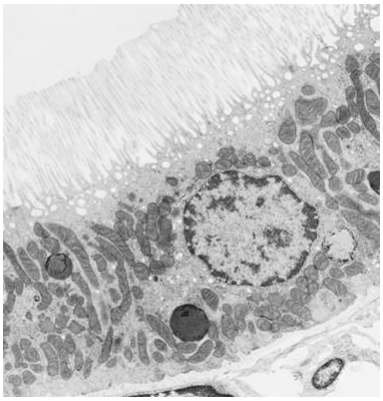
- secrete renin into circulation
  - renin converts angiotensinogen → angiotensin I
- contain angiotensin converting enzyme (ACE)
  - lung is principal site of ACE activity
  - ACE converts angiotensin I → II
- contain angiotensin I & II
  - angiotensin II constricts vasculature and stimulates secretion 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

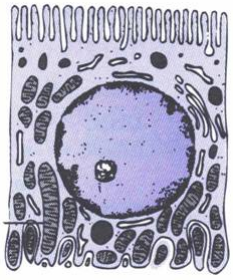
TABLE 19–3 Structure and Function of the Uriniferous Tubule

REGION OF URINIFEROUS TUBULE	MAJOR FUNCTIONS	MISCELLANEOUS COMMENTS
Renal Corpuscle: Simple squamous epithelium, fused basal laminae, podocytes	Filtration	Filtration barrier: endothelial cell, fused basal laminae, filtration slits
Proximal Tubule: Simple cuboidal epithelium	Resorption of 67%–80% of water, sodium, and chloride (reducing volume of ultrafiltrate); resorption of 100% of protein, amino acids, glucose, and bicarbonate	Sodium pump in basolateral membrane; ultrafiltrate is isotonic with blood
Descending Thin Limb of Henle's Loop: Simple squamous epithelium	Completely permeable to water and salts (reducing volume of ultrafiltrate)	Ultrafiltrate is hypertonic with respect to blood; urea enters lumen of tubule
Ascending Thin Limb of Henle's Loop: Simple squamous epithelium	Impermeable to water, permeable to salts; sodium and chloride leave tubule to enter renal interstitium	Ultrafiltrate is hypertonic with respect to blood; urea leaves renal interstitium and enters the lumen of tubule
Ascending Thick Limb of Henle's Loop: Simple cuboidal epithelium	Impermeable to water; chloride and sodium leave tubule to enter renal interstitium	Ultrafiltrate becomes hypotonic with respect to blood; chloride pump in basolateral cell membrane is responsible for the establishment of osmotic gradient in interstitium of outer medulla
Macula Densa: Simple columnar cells	Monitors sodium level and volume of ultrafiltrate in lumen of distal tubule	Contacts and communicates with juxtaglomerular cells
Juxtaglomerular Cells: Modified smooth muscle cells	Synthesize and release renin into bloodstream	Renin initiates the reaction for the eventual formation of angiotensin II (see Table 19–2)
Distal Convoluted Tubule: Simple cuboidal epithelium	Responds to aldosterone by resorbing sodium and chloride for lumen	Ultrafiltrate becomes more hypotonic (in the presence of aldosterone); sodium pump in basolateral membrane; potassium is secreted into the lumen
Collecting Tubule: Simple cuboidal epithelium	In the presence of ADH, water and urea leave the lumen to enter the renal interstitium	Urine becomes hypertonic in the presence of ADH; urea in interstitium is responsible for gradient of concentration in interstitium of the inner medulla



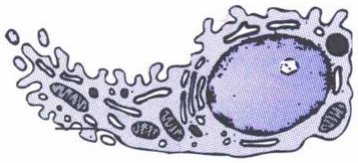
Proximal Convoluted Tubule

- 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

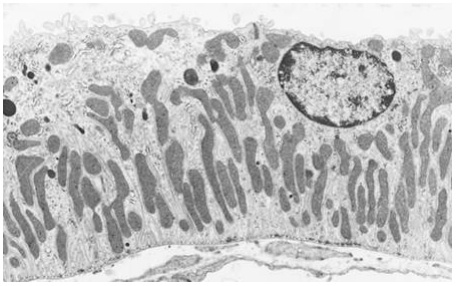
Henle's Loop (thin segments)



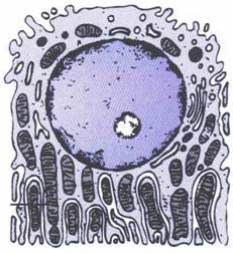
- Squamous cells
  - slightly thicker than endothelial cells
- Few short microvilli
- Lateral interdigitations

- 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)

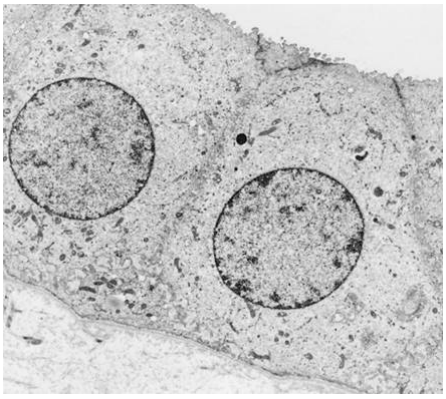


- Low cuboidal cells
- Clear pale cytoplasm
- Apical nuclei (DCT)
- Central nuclei (Henle's loop)
- Numerous mitochondria
- Absent (or few short) microvilli
- Basal interdigitations
- Numerous zonula occludens

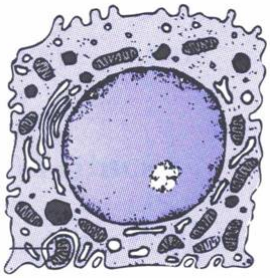


- Not permeable to water or urea
- Active Na^+/K^+ pumps (DCT)
  - aldosterone stimulates salt resorption
  - H^+ and K^+ transported into lumen
- Active Cl^- pumps (Henle's thick)
  - Cl^- enters interstitium (Na^+ follows)

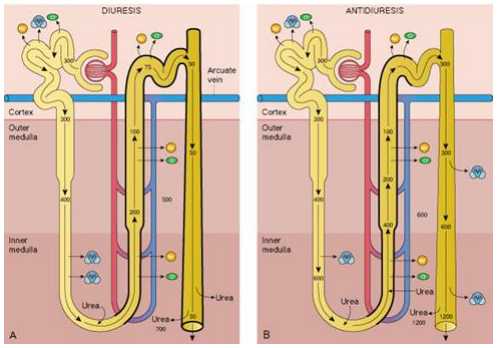
Collecting Tubule & Duct



- Cuboidal to columnar cells
- Clear cytoplasm
- Central nuclei



- Permeable to urea
- In response to ADH, becomes permeable to water which enter the interstitium



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**

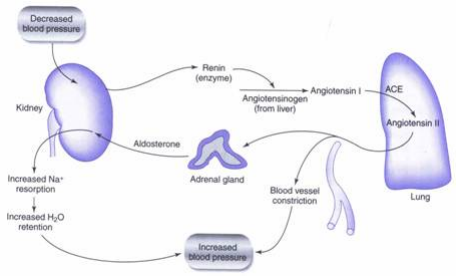
- **Descending thin limb of Henle is freely permeable to water and salt**
  - **Due to increasing osmolarity of interstitium: lumenal volume decreases and osmolarity increases**
- **Ascending (thin and thick) limb of Henle and DCT are <u>not</u> permeable to water**
  - **Lumenal volume does not change**
  - **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**

Angiotensin II Regulation of Blood Pressure

TABLE 19–2 Effects of Angiotensin II

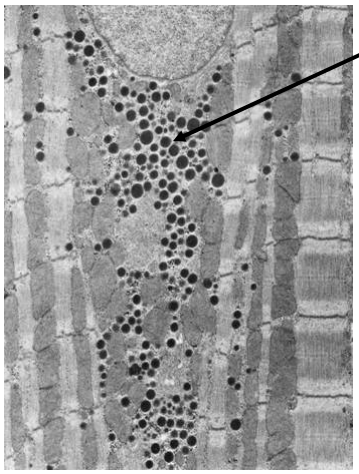
FUNCTION	RESULT
Acts as a potent vasoconstrictor	Increased blood pressure
Facilitates synthesis and release of aldosterone	Resorption of sodium and chloride from lumen of distal convoluted tubule
Facilitates release of ADH	Resorption of water from lumen of collecting tubule
Increases thirst	Increased tissue fluid volume
Inhibits renin release	Feedback inhibition
Facilitates release of prostaglandins	Vasodilation of afferent glomerular arteriole, thus maintaining glomerular filtration rate

Gartner & Hiatt



Burns & Cave

Additional Regulators of Kidney Function



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

Vasculature of Kidney