Kuliah ANFISMAN
Program S1-FFUP

Sistem Urinaria

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Outline

- **Anatomi** sistem urinaria: nefron, glomerulus & tubulus
- **Suplai darah** ke ginjal dan persyarafan
- **Fisiologi ginjal**: proses pembentukkan urin, filtrasi, reabsorpsi, sekresi
- **Proses berkemih**

Sistim urinaria ~ ekskresi

- **Urinaria** → pembentukan urin, melibatkan organ-organ sistem ekskresi & organ genitalia
  - **Ekskresi** → pengeluaran; sisa –sisa metabolisme;
- Sistim urinaria terdiri atas: **ginjal** (2), **ureter** (2), **kandung kemih** dan **uretra**
- ***Nephrology*** → ilmu yang mempelajari tentang anatomi, fisiologi dan patologi dari **ginjal**
- ***Urology*** → cabang ilmu kedokteran yang mempelajari tentang **sistem urinaria** pria dan wanita **dan sistem reproduksi**

Sistem urinari & homeostasis

- Mengatur **komposisi darah**, **pH**, **volume cairan tubuh**, **osmolalitas** darah
- **Membuang** sisa metabolisme/ substansi asing
- Memproduksi **hormon**

Fungsi Utama Ginjal*

Ekskresi

1. Mempertahankan **osmolitas** plasma ~ 285 mOsm → mengubah ekskresi air
2. Mempertahankan konsentrasi **elektrolit** dalam plasma
3. Mempertahankan **pH** plasma ~7,4 → membuang H^+ dan membentuk HCO_3^-
4. Mengekskresikan **hasil akhir metabolisme protein** yang mengandung **nitrogen**; urea, asam urat dan kreatinin

Non Ekskresi

1. Menghasilkan **renin** → penting untuk pengaturan tekanan darah
2. Menghasilkan **eritropoietin** → stimulasi pembentukkan sel darah merah dalam sumsum tulang
3. Metabolisme **vitamin D** menjadi bentuk aktif
4. Degradasi **insulin**
5. Membentuk **prostaglandin**

* Anderson S. 1985. Patofisiologi, konsep klinik penyakit Bagian 2, hal. 27

Kenapa posisi ginjal kanan lebih rendah dari ginjal kiri ???

Posisi ginjal = posterior peritoneum di rongga abdominal → **retroperionea**l

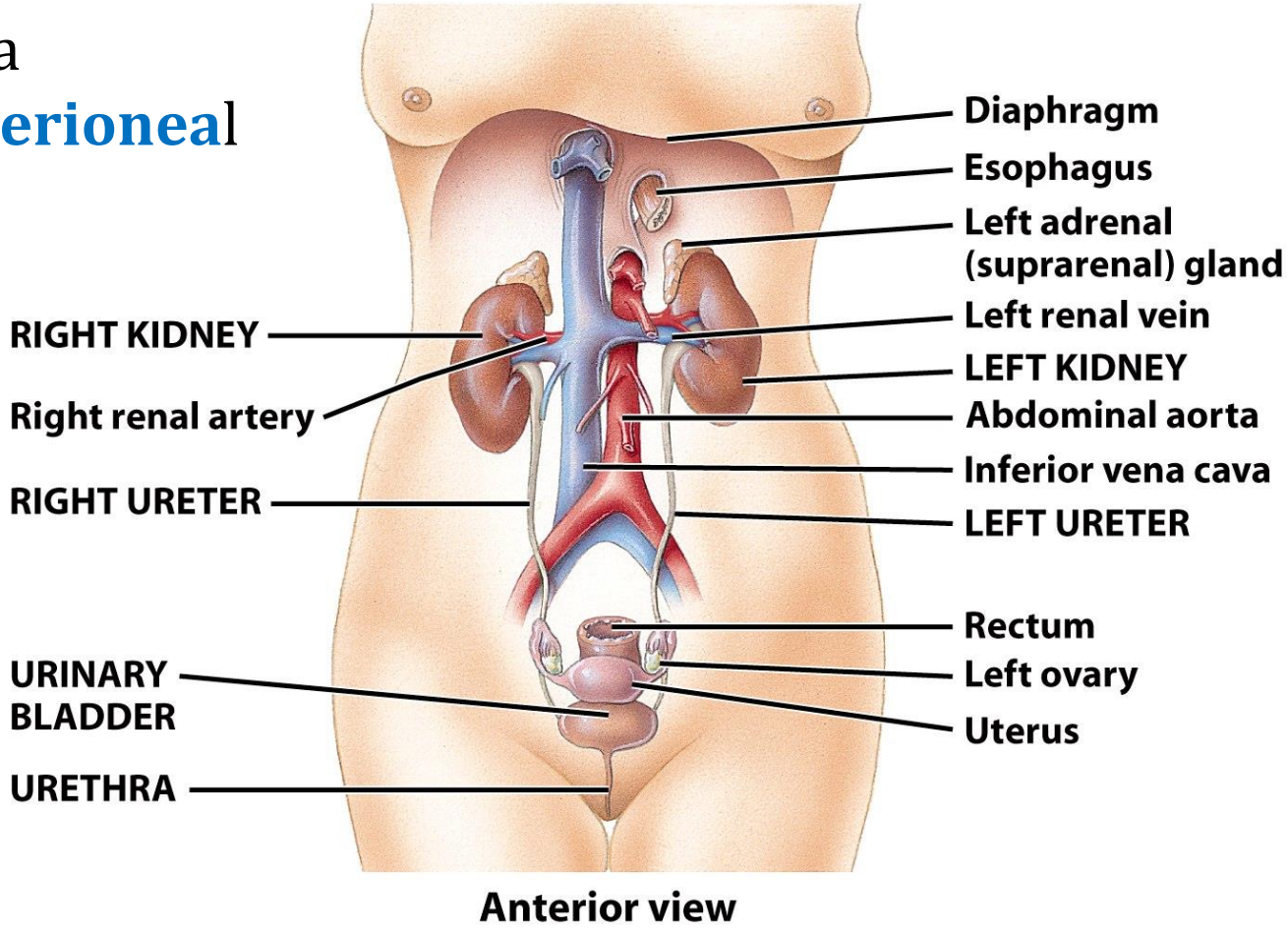


Figure 26-1 Principles of Anatomy and Physiology, 11/e

Anatomi eksternal

- **Ukuran ginjal** (dewasa); panjang 10-12 cm dan lebar 5-7 cm dengan tebal 3 cm.; berat 135 – 150 gram.
- **Bentuk medial ginjal** (= bagian tengah) = **hilum** ; tempat bergabung pembuluh darah, limfatik dan saraf.
- Terdiri atas 3 lapisan:
  a. *Deep layer* → renal kapsul (ren=kidney): jaringan konektif
  b. *Middle layer* → kapsul adipose terdiri dari jaringan lemak
  c. *Superficial layer* → renal fascia

Anatomi internal

Frontal section

- Superfisial → renal cortex
- *Inner portion* → renal medulla ; *cone-shaped* = pyramid
- The base (*wider end*)

Pyramid

- The base (*wider end*) → renal cortex
- The apexs (*narrower end*) → renal papilla = renal hilum

Parenchym; bagian fungsional dari renal medula (bagian cortex dan piramid) → unit fungsional = **Nefron**

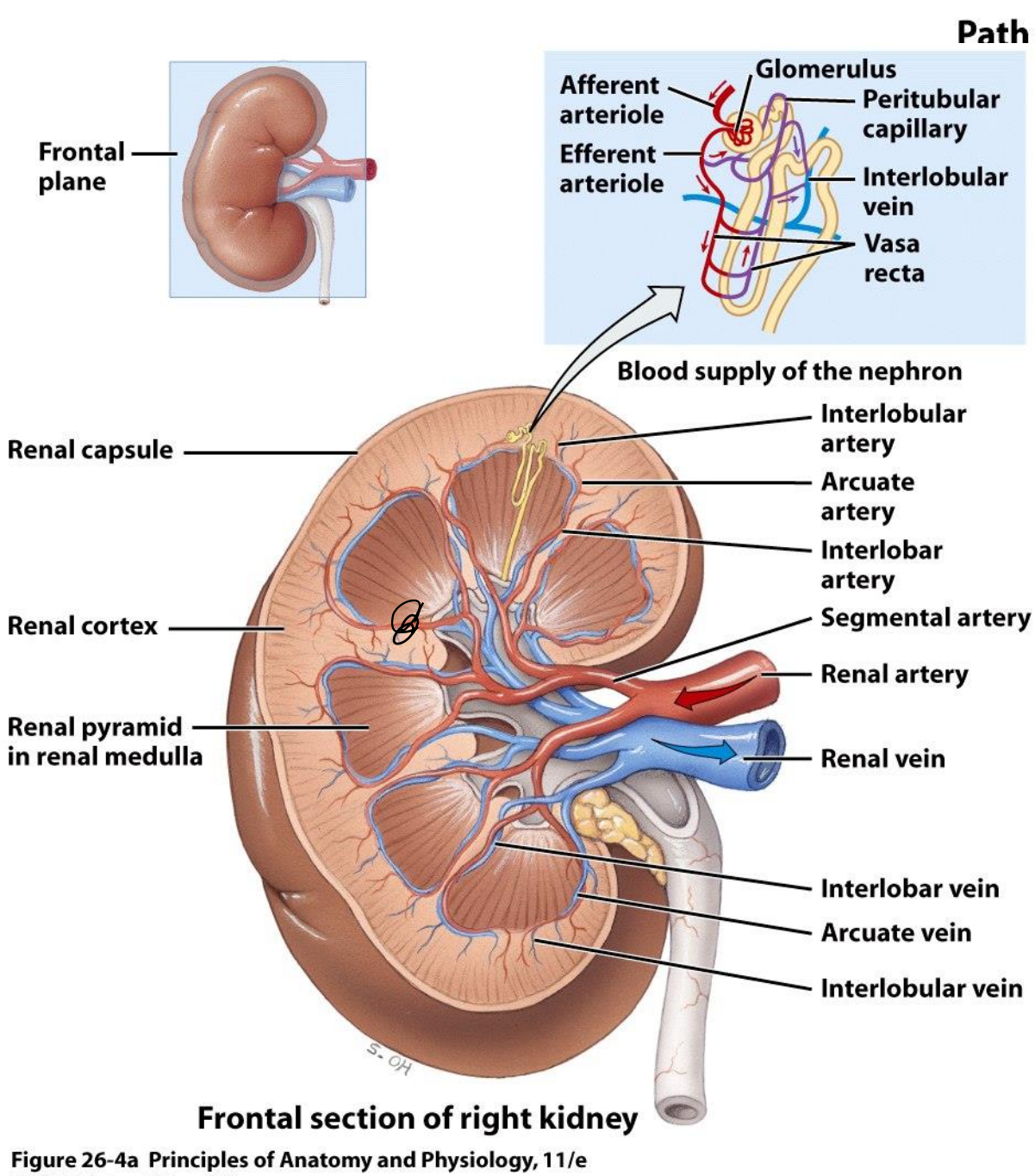


Figure 26-4a Principles of Anatomy and Physiology, 11/e

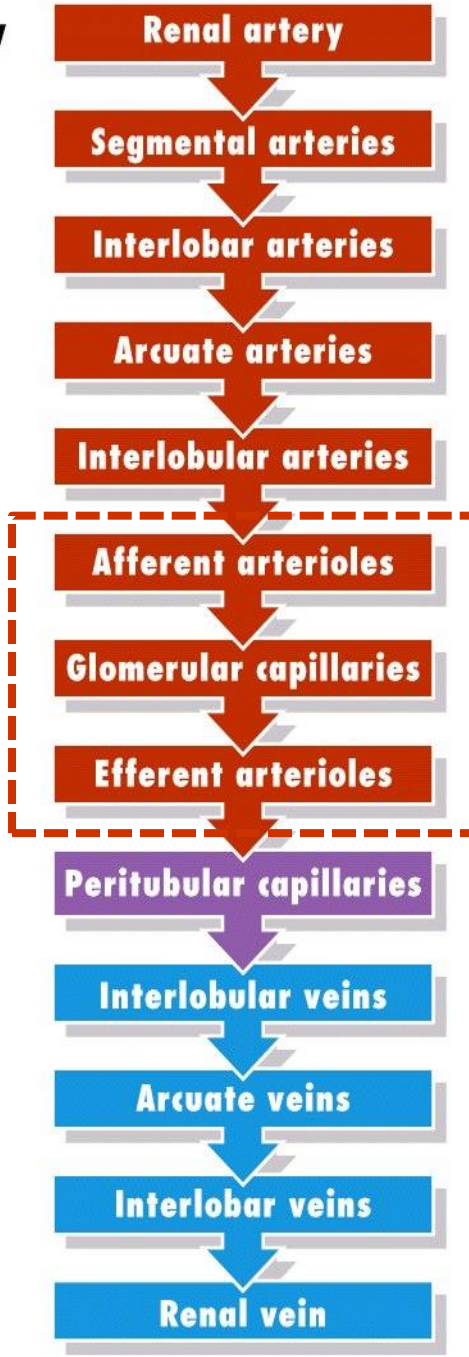


Figure 26-4b Principles of Anatomy and Physiology, 11/e

Suplai darah

- Massa ginjal ≤0,5 % dari *Body Weight*
- Aliran darah ke ginjal = **20-25%**
- *Renal Blood Flow* = **1,2 L/menit**

- ***Afferent arterioles*** (af- = toward; ferrent=to carry)
- ***Efferent arterioles*** (ef-=out) → that carries blood out of the glomerulus.
  - The ***efferent arteriole*** divide to form the **peritubular capilaries** (peri-=around), which surround tubular parts of the nephron in the renal cortex.
  - Extending from some efferent arterioles are long loop shaped capillaries called **vasa recta** (vasa=vessel; recta=straight) that supply tubular portions of the nephron in the renal medulla

NEFRON

Unit struktural dan fungsional ginjal

- Tiap ginjal mengandung **± 1 juta nefron**
- Tiap nefron terdiri dari:

a. **Komponen vaskular** (kapiler glomerulus)

yi: bagian penyaring; air & zat terlarut dari darah difiltrasi masuk ke dalam komponen tubular dan kapsul Bowman

b. **Komponen tubular** terdiri atas :

- Proximal Convoluted Tubule (**PCT**),
- Loop of Henle (**vasa recta**)
- Distal Convoluted Tubule (**DCT**)

80-85% nefron → cortical nefron

10-15% nefron → juxta medullary nefron

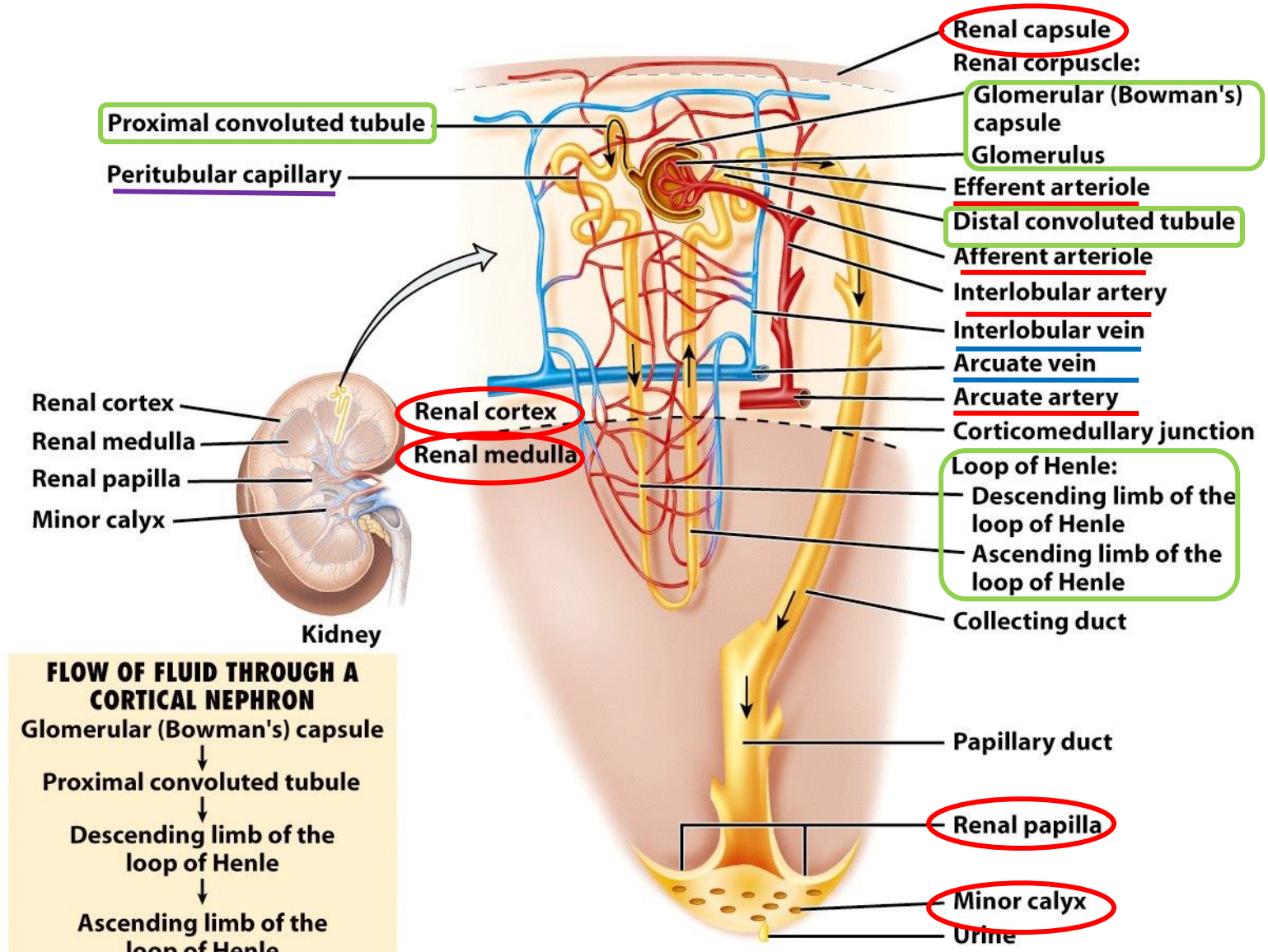


Figure 26-5a Principles of Anatomy and Physiology, 11/e

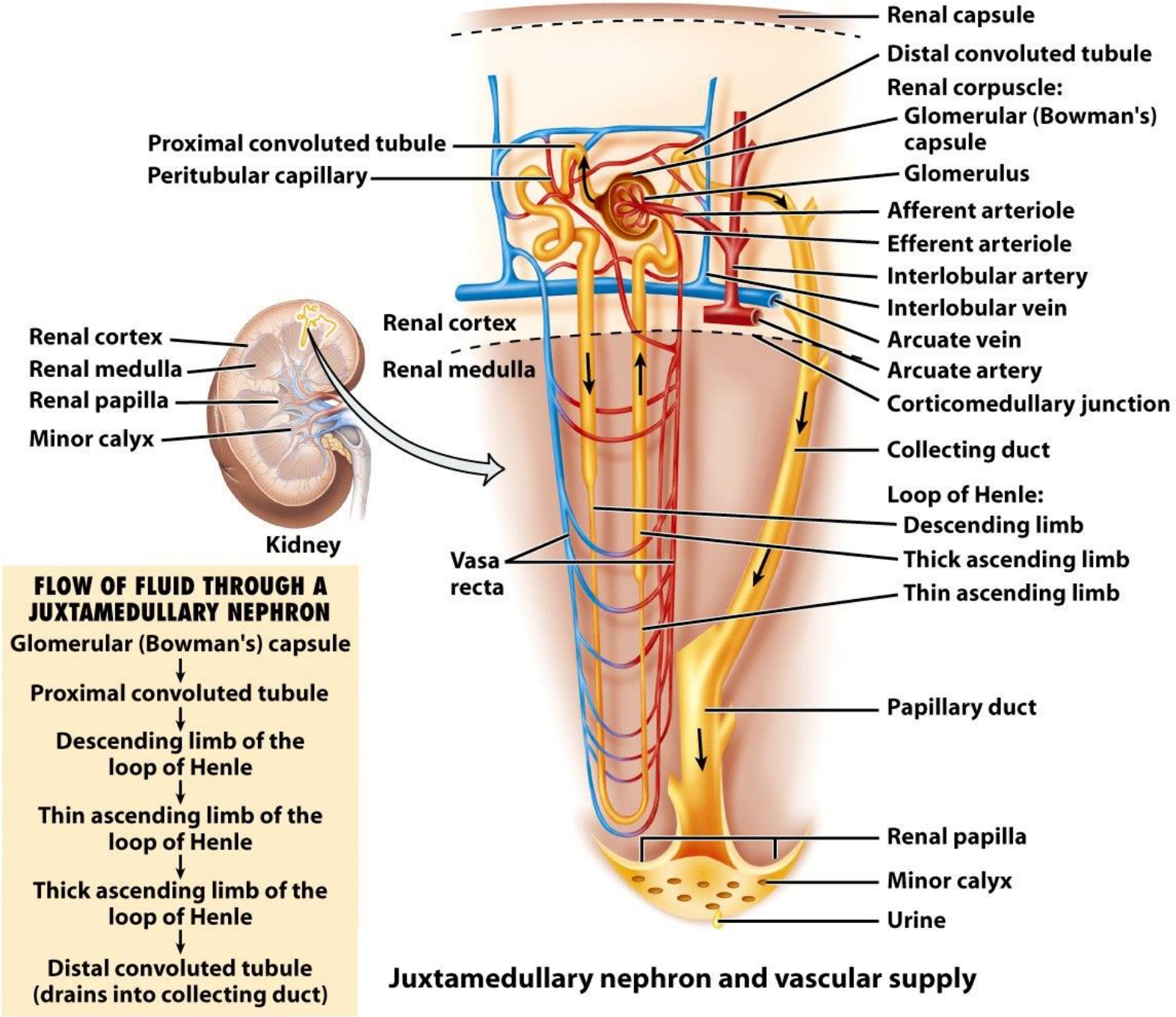


Figure 26-5b Principles of Anatomy and Physiology, 11/e

Glomerular Filtration Rate (GFR)

- **Jumlah pembentukan filtrat di *renal corpuscle* setiap menit**
- **Dewasa = 125 mL/menit (pria) dan 105 mL/menit (wanita)**
- Bila GFR terlalu tinggi, substansi yang difiltrasi cepat , tidak cukup waktu untuk reabsorpsi→ banyak kehilangan substansi dalam urin
- GFR ~ konstan bila tekanan arteri darah 80 dan 180 mmHg

Regulasi GFR

1. Penyesuaian **aliran darah** keluar glomerulus
2. Perubahan **luas permukaan kapiler** untuk filtrasi.
   Kontriksi *arteriole afferent* → mengurangi aliran darah ke glomerulus.

   Dilatasi → meningkatkan aliran darah

Pengontrolan GFR

1. ***Renal autoregulation***; myogenic mechanism dan tubuloglomerular feedback
2. ***Neural regulation*** → saraf simpatis/reseptor α1
3. ***Hormonal***; angiotensin II→ vasokonstriktor dan
   Atrial natriuretic peptide (ANP)→ meningkatkan GFR

Filtrasi glomerulus

- Cairan yang telah disaring oleh kapsul Bowman = **filtrat glomerulus**
- Fraksi plasma darah dari arteriol aferen yang disaring = **fraksi filtrasi = 16-20%**, bervariasi tergantung kesehatan individu
- Setiap hari **volume filtrat glomerulus = 150 L (wanita) dan 180 L (pria)**;
- **99% reabsorpsi via tubular** dan **1-2 L diekskresi dalam urin**

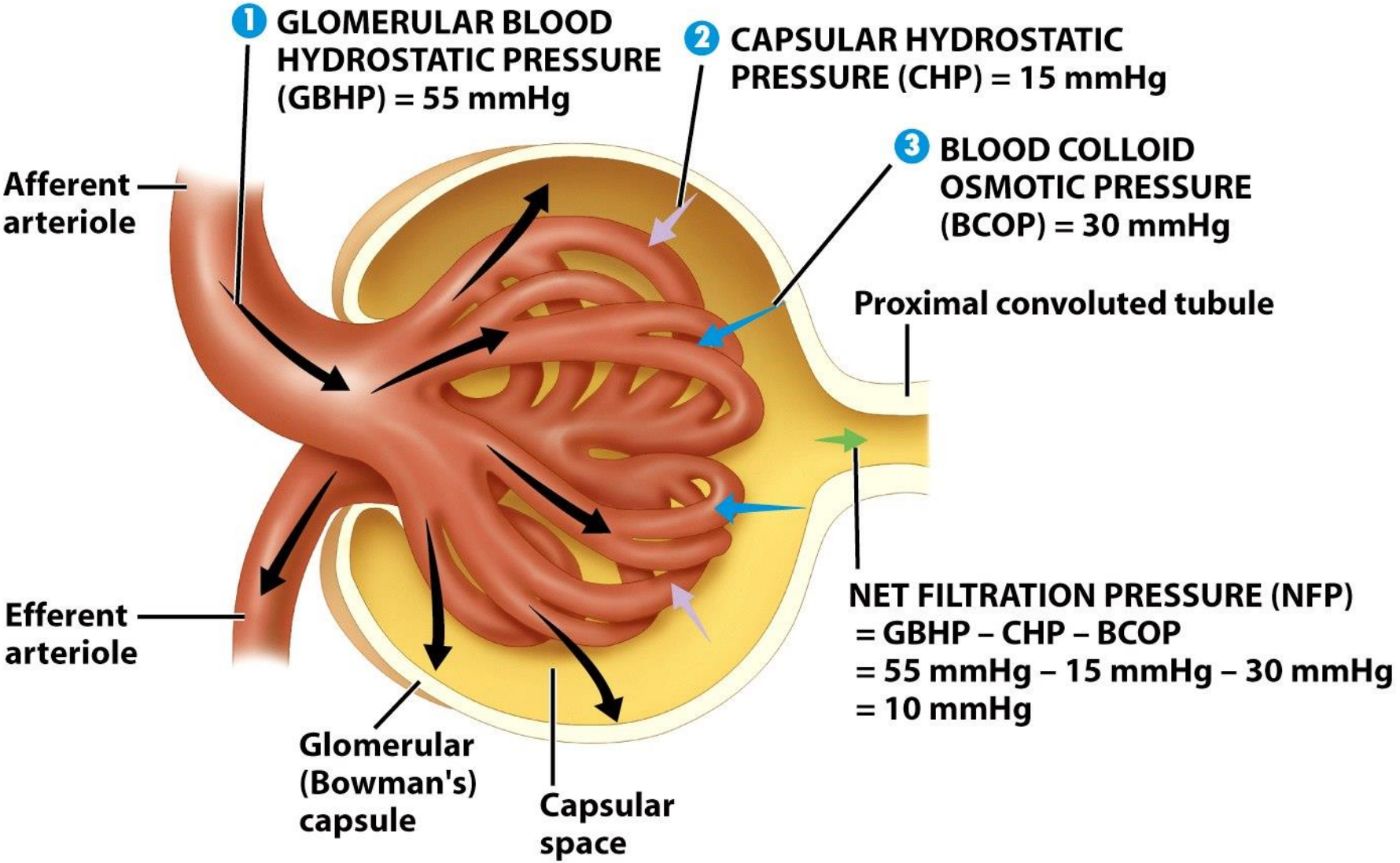


Figure 26-9 Principles of Anatomy and Physiology, 11/e

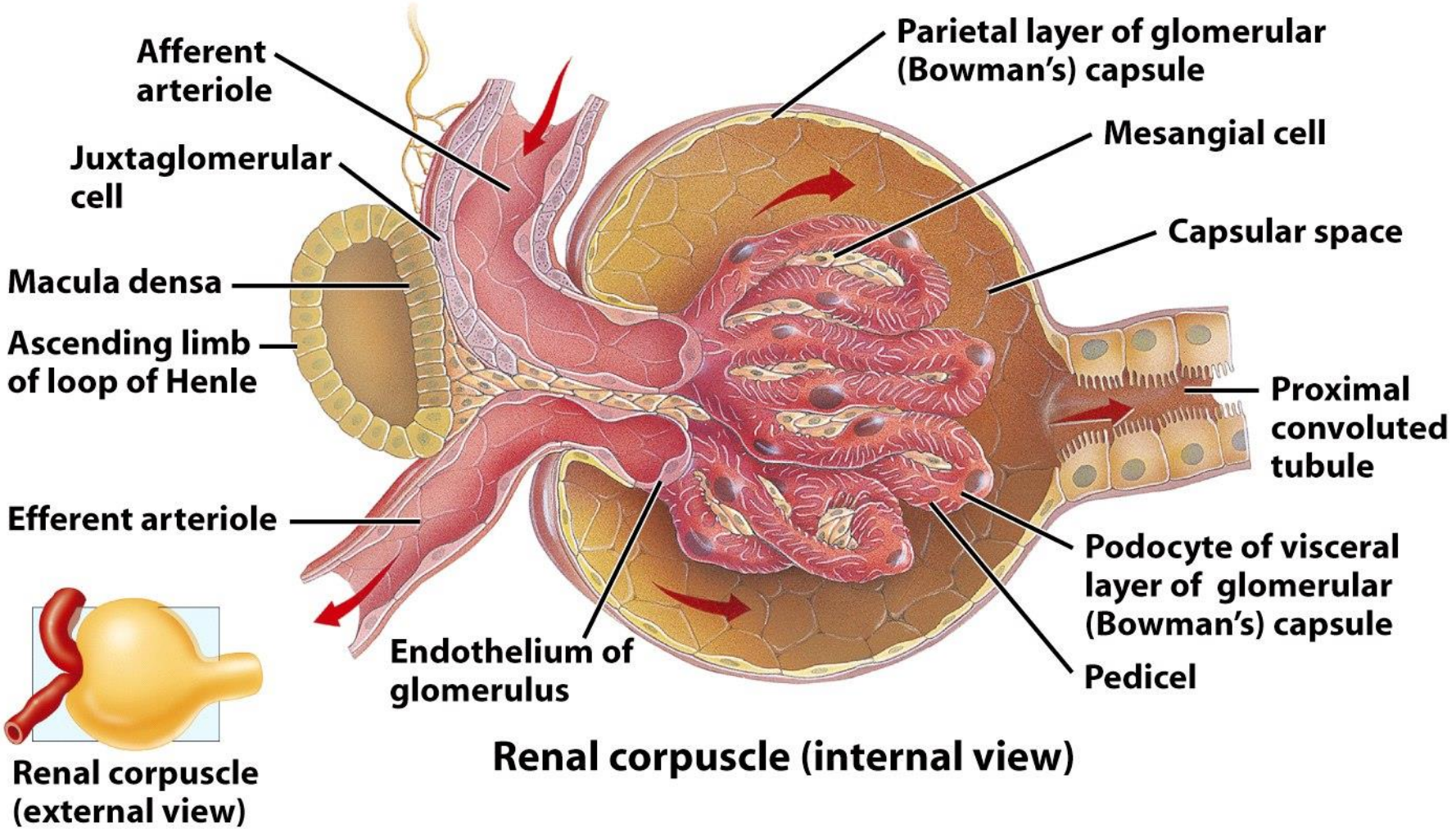


Figure 26-6a Principles of Anatomy and Physiology, 11/e

Juxtaglomerular cell: mensekresikan renin dan eritropoietin

Sel macula densa: kemoreseptor untuk mendeteksi ion Na^+

Membran filtrasi

- Terdiri atas **sel endotel** kapiler glomerulus dan **podocytes**
- Menyaring **molekul kecil** dan **air**, **tidak menyaring plasma protein, sel darah dan platelet**

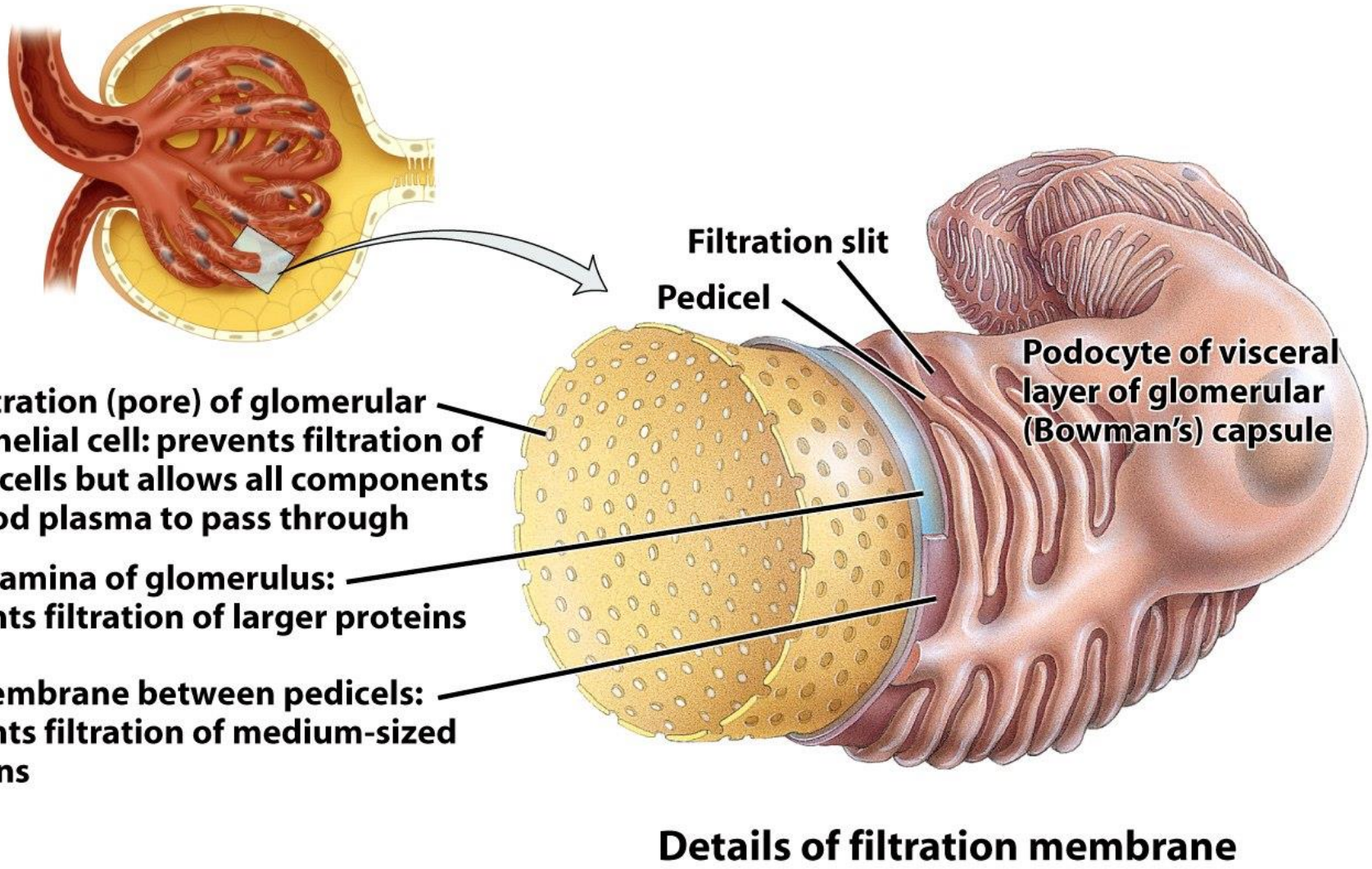


Figure 26-8a Principles of Anatomy and Physiology, 11/e

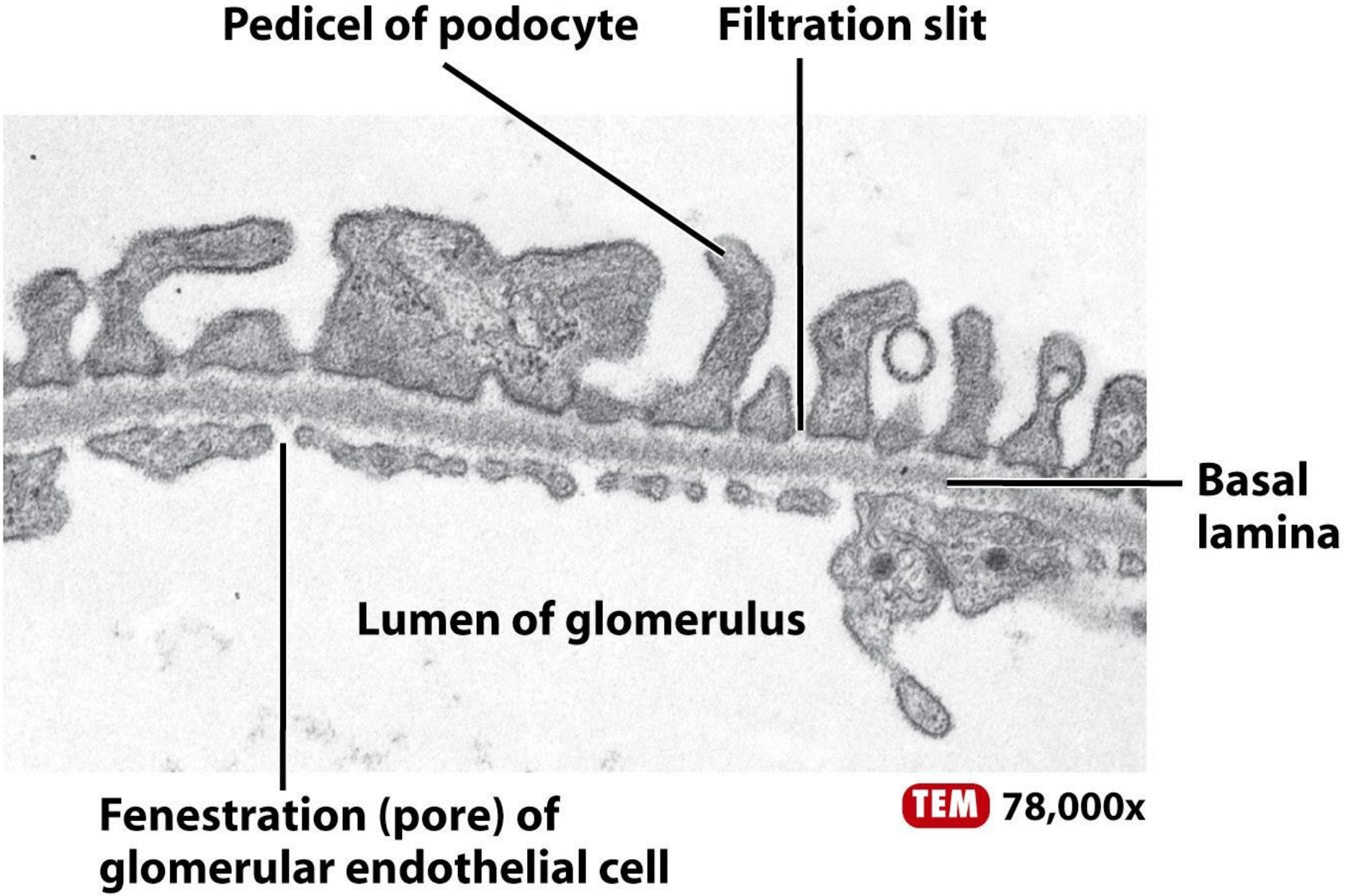


Figure 26-8b Principles of Anatomy and Physiology, 11/e

Proximal convoluted tubule (PCT)

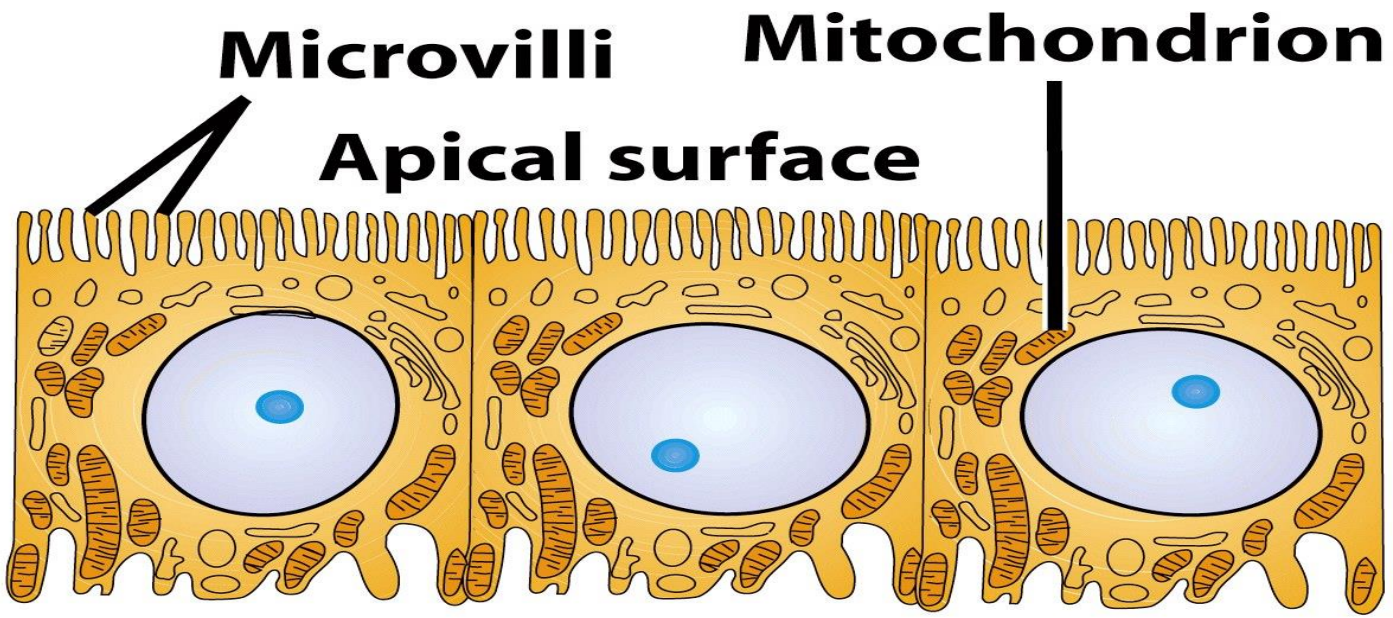


Table 26-1 figure 1 Principles of Anatomy and Physiology, 11/e

Deskripsi

Simple **cuboidal** epithelium cells with prominent brush borders of **microvilli**

Loop of Henle: descending limband thin ascending limb

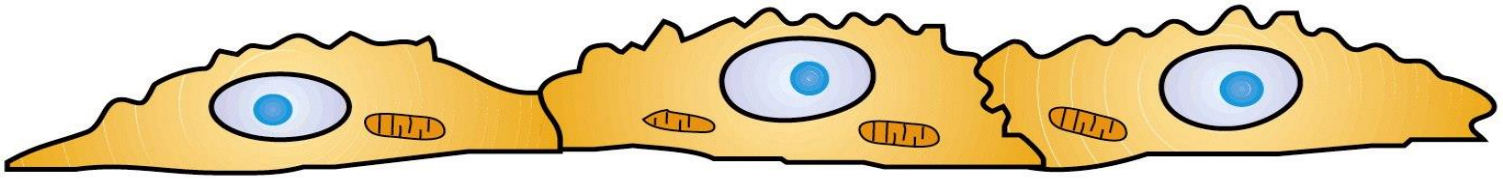


Table 26-1 figure 2 Principles of Anatomy and Physiology, 11/e

Deskripsi:

Simple **squamous** epithelial cells

Loop of Henle: thick ascending limb

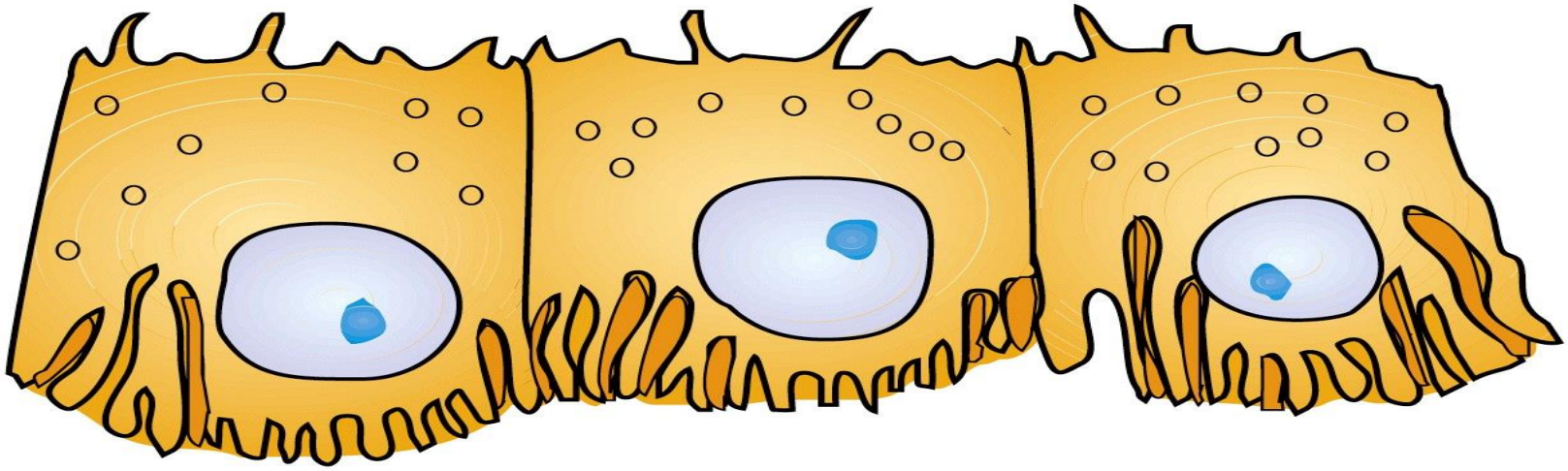


Table 26-1 figure 3 Principles of Anatomy and Physiology, 11/e

Deskripsi

Simple **cuboidal to low columnar** epithelial cells

Most of distal convoluted tubule (DCT)

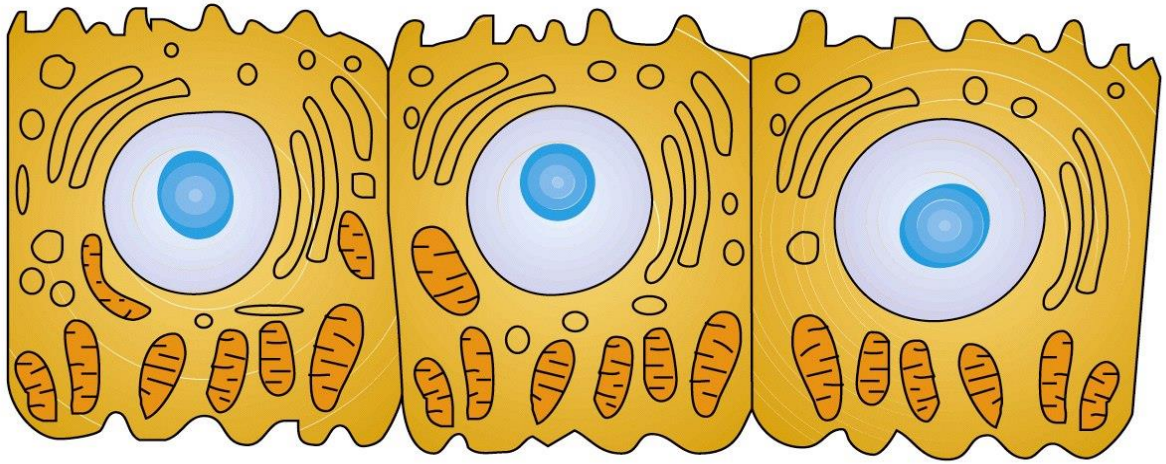
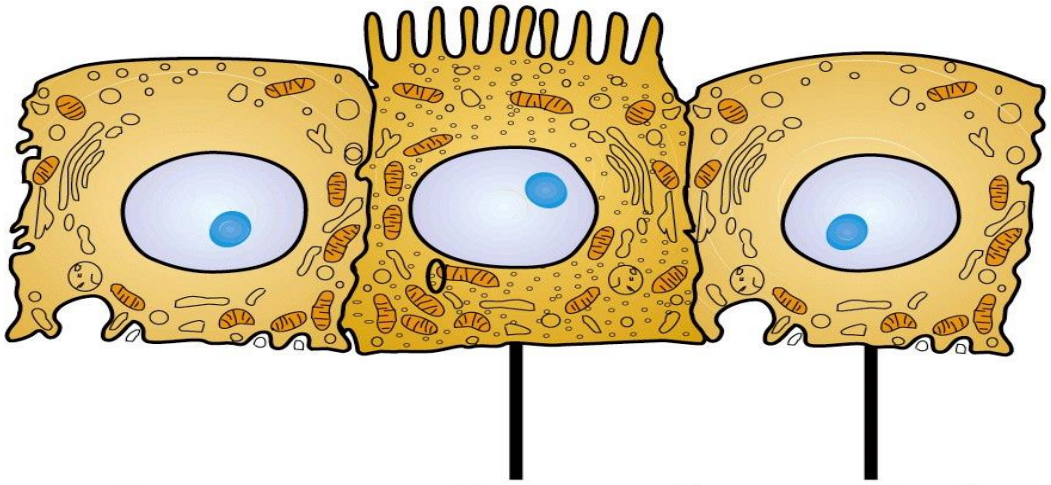


Table 26-1 figure 4 Principles of Anatomy and Physiology, 11/e

Deskripsi

Simple **cuboidal** epithelial cells

Last part of DCT and all of collecting duct (CD)



Intercalated cell

Principal cell

Table 26-1 figure 5 Principles of Anatomy and Physiology, 11/e

Deskripsi

Simple **cuboidal** epithelium consisting of **principlal cells** and **intercalated cells**

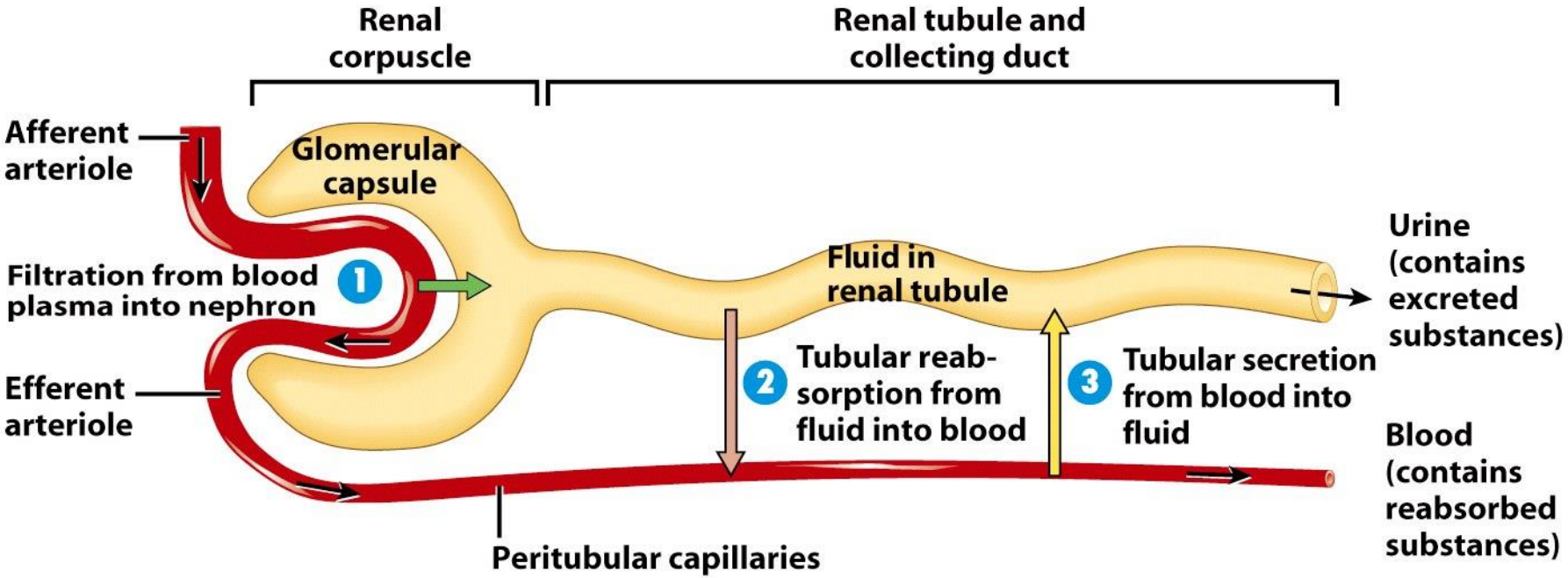


Figure 26.7. Relation of a nephron's structure to its three basic functions: **glomerular filtration**, **tubular reabsorption** and **tubular secretion**. Excreted substances remain in the urine and subsequently leave the body.

For any substance S;

Excretion rate = filtration rate – reabsortion rate + secretion rate

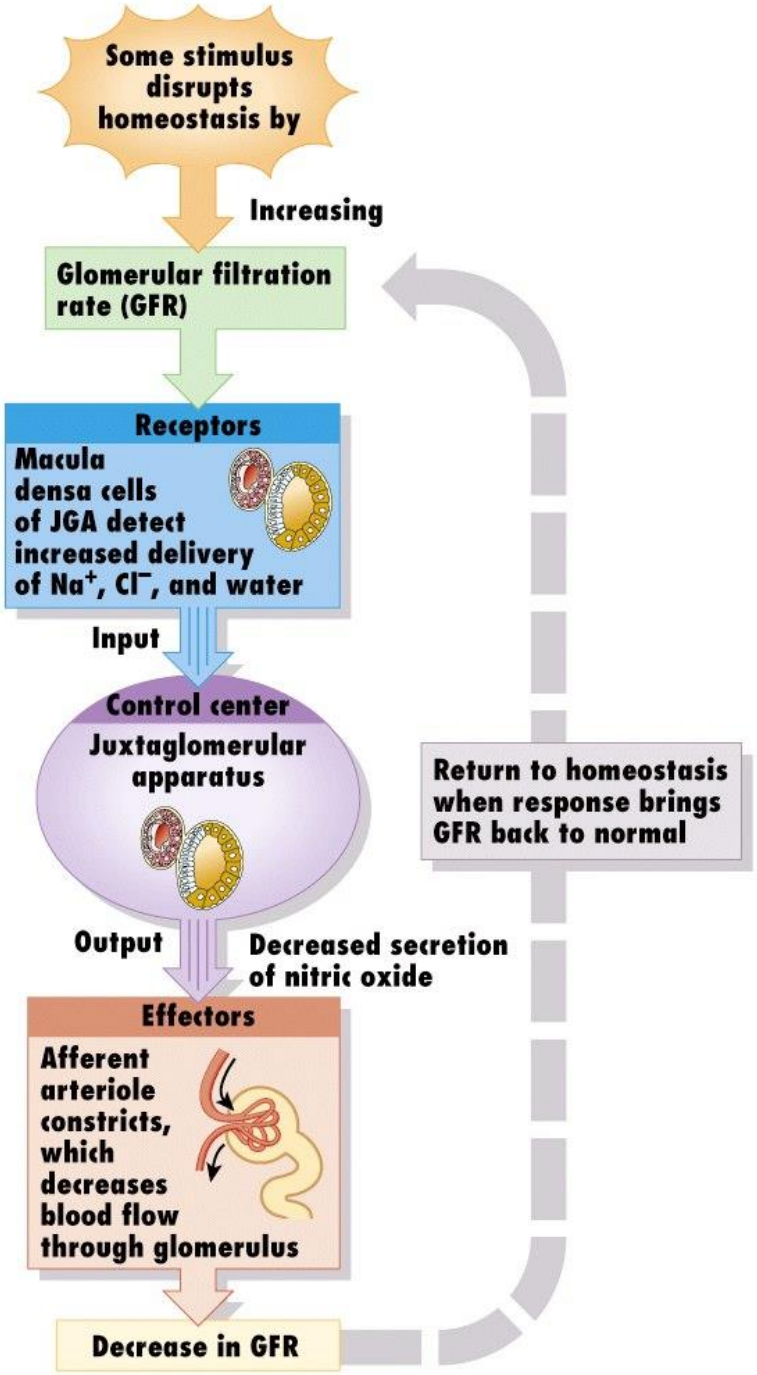


Figure 26-10 Principles of Anatomy and Physiology, 11/e

Figure 26.11. Paracellular Reabsorption and transcellular reabsorption

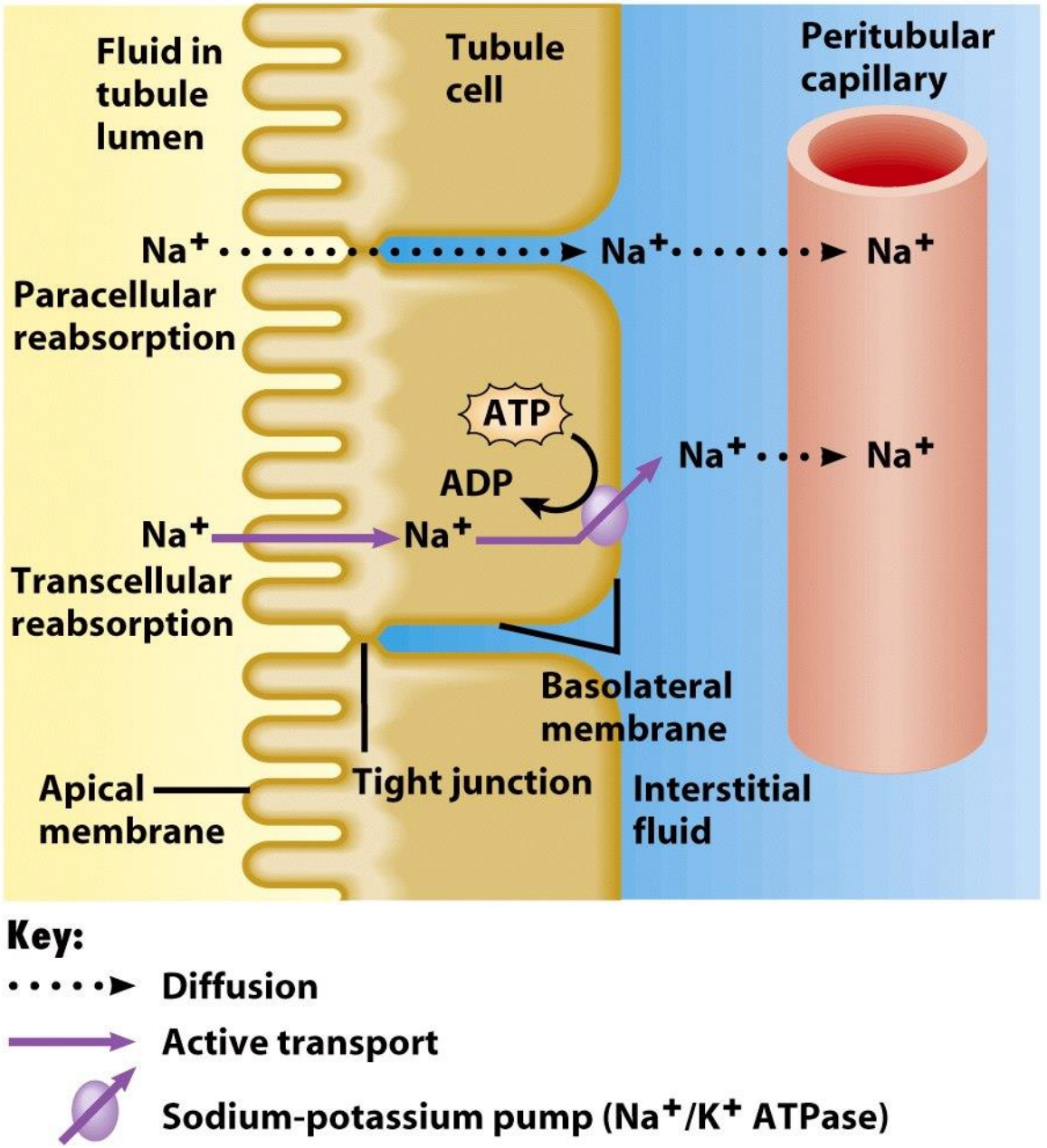


Figure 26-11 Principles of Anatomy and Physiology, 11/e

Figure 26.12.
Reaborpsion of glucose by Na $^{+}$ glucose symporters in cells of the proximal convoluted tubule (PCT)

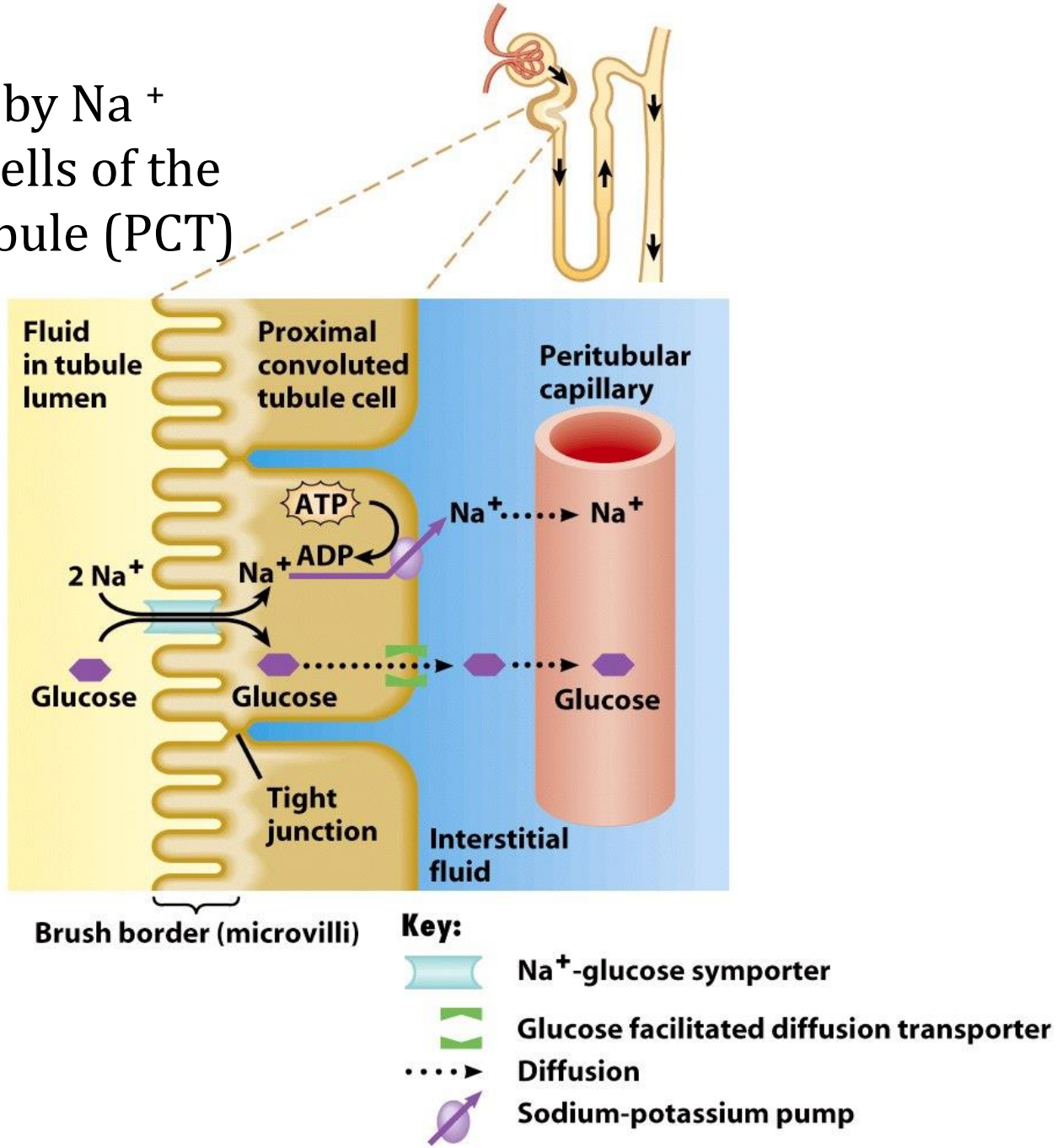


Figure 26-12 Principles of Anatomy and Physiology, 11/e

Figure 26.13. Actions of Na^+/H^+ antiporters in PCT cells

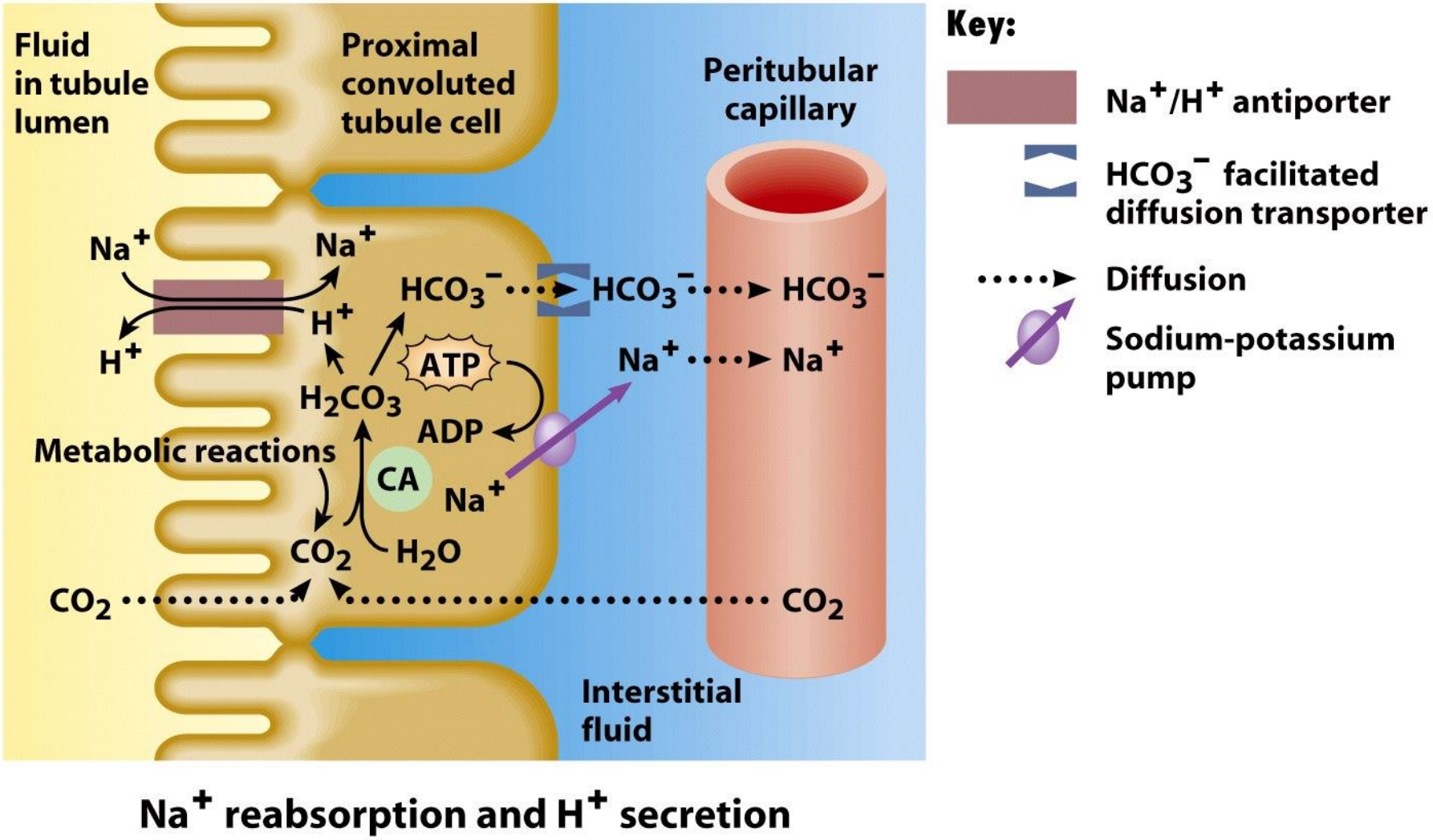


Figure 26-13a Principles of Anatomy and Physiology, 11/e

Figure 26.15. Na, K, Cl symporter in the thick assending limb of the loop of Henle

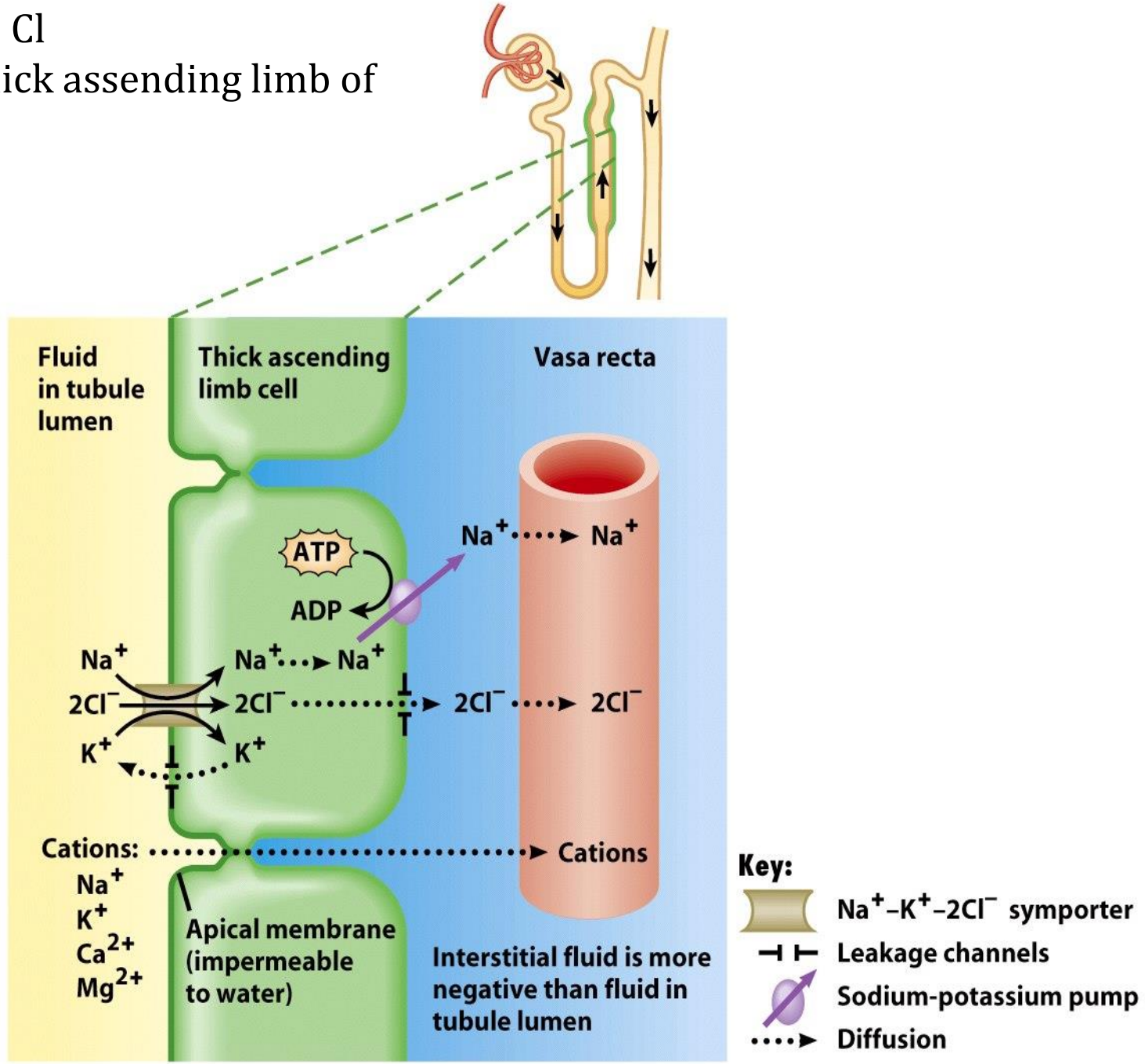


Figure 26-15 Principles of Anatomy and Physiology, 11/e

Figure 26.16. Reabsorption of Na and secretion of K by principal cells in the last part of the distal convoluted tubule and in the collecting ductus

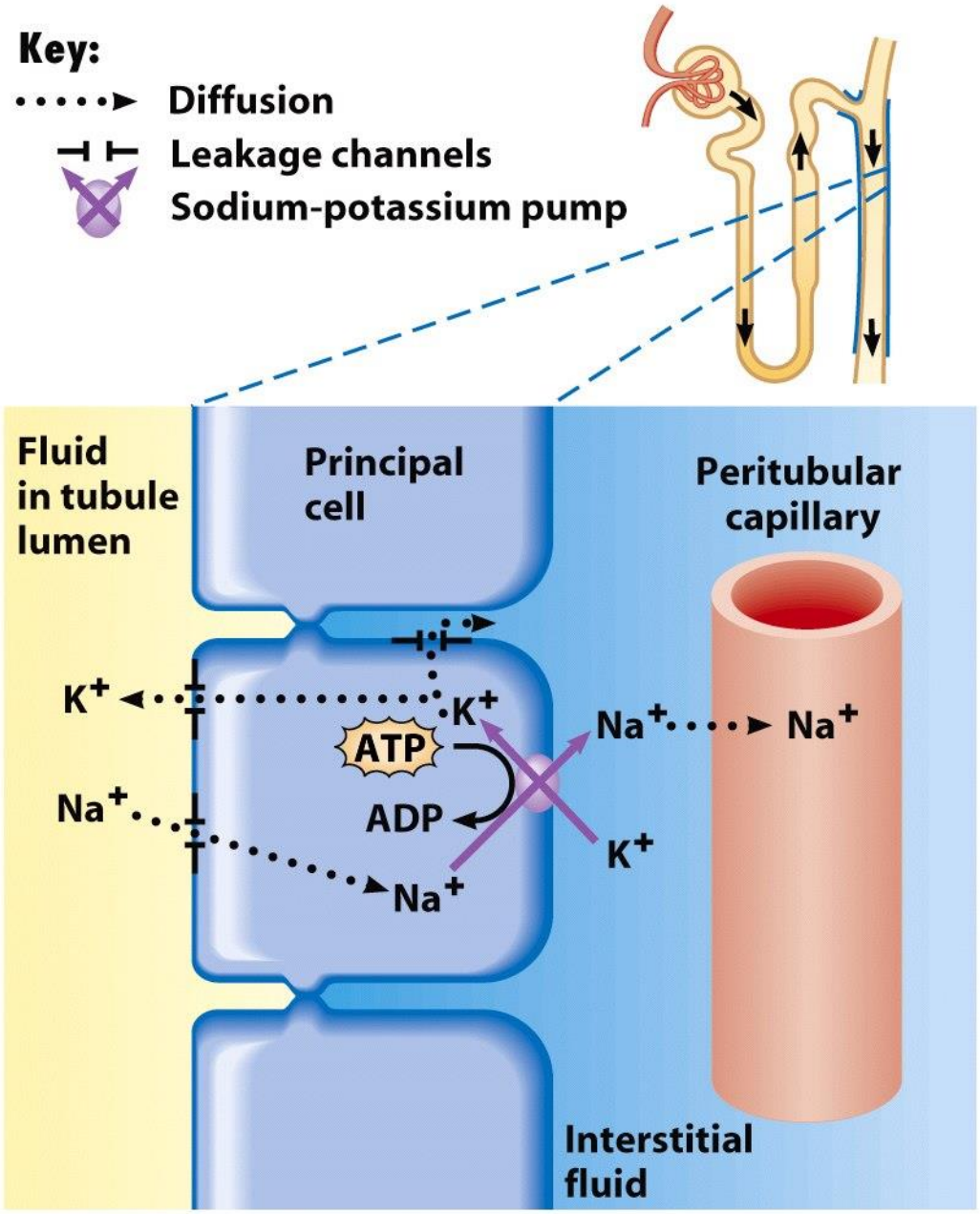


Figure 26-16 Principles of Anatomy and Physiology, 11/e

PROXIMAL CONVOLUTED TUBULE

Reabsorption (into blood) of filtered:

Water	65% (osmosis)
Na^+	65% (sodium-potassium pumps, symporters, antiporters)
K^+	65% (diffusion)
Glucose	100% (symporters and facilitated diffusion)
Amino acids	100% (symporters and facilitated diffusion)
Cl^-	50% (diffusion)
HCO_3^-	80–90% (facilitated diffusion)
Urea	50% (diffusion)
Ca^{2+}, Mg^{2+}	variable (diffusion)

Secretion (into urine) of:

H^+	variable (antiporters)
NH_4^+	variable, increases in acidosis (antiporters)
Urea	variable (diffusion)
Creatinine	small amount

At end of PCT, tubular fluid is still isotonic to blood (300 mOsm/liter).

LOOP OF HENLE

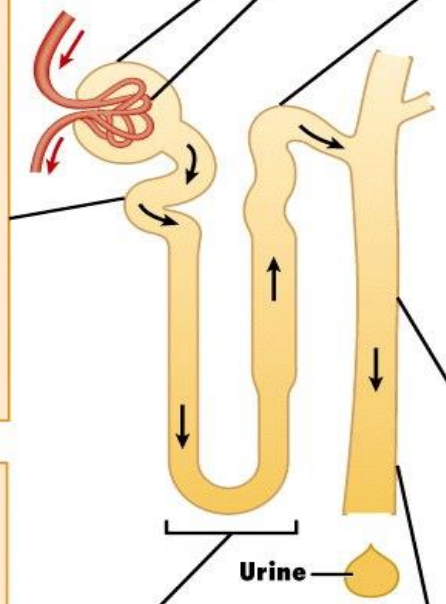
Reabsorption (into blood) of:

Water	15% (osmosis in descending limb)
Na^+	20–30% (symporters in ascending limb)
K^+	20–30% (symporters in ascending limb)
Cl^-	35% (symporters in ascending limb)
HCO_3^-	10–20% (facilitated diffusion)
Ca^{2+}, Mg^{2+}	variable (diffusion)

Secretion (into urine) of:

Urea	variable (recycling from collecting duct)

At end of loop of Henle, tubular fluid is hypotonic (100–150 mOsm/liter).



RENAL CORPUSCLE

Glomerular filtration rate:
105–125 mL/min of fluid that is isotonic to blood

Filtered substances: water and all solutes present in blood (except proteins) including ions, glucose, amino acids, creatinine, uric acid

DISTAL CONVOLUTED TUBULE

Reabsorption (into blood) of:

Water	10–15% (osmosis)
Na^+	5% (symporters)
Cl^-	5% (symporters)
Ca^{2+}	variable (stimulated by parathyroid hormone)

PRINCIPAL CELLS IN LATE DISTAL TUBULE AND COLLECTING DUCT

Reabsorption (into blood) of:

Water	5–9% (insertion of water channels stimulated by ADH)
Na^+	1–4% (sodium-potassium pumps)
Urea	variable (recycling to loop of Henle)

Secretion (into urine) of:

K^+	variable amount to adjust for dietary intake (leakage channels)

Tubular fluid leaving the collecting duct is dilute when ADH level is low and concentrated when ADH level is high.

INTERCALATED CELLS IN LATE DISTAL TUBULE AND COLLECTING DUCT

Reabsorption (into blood) of:

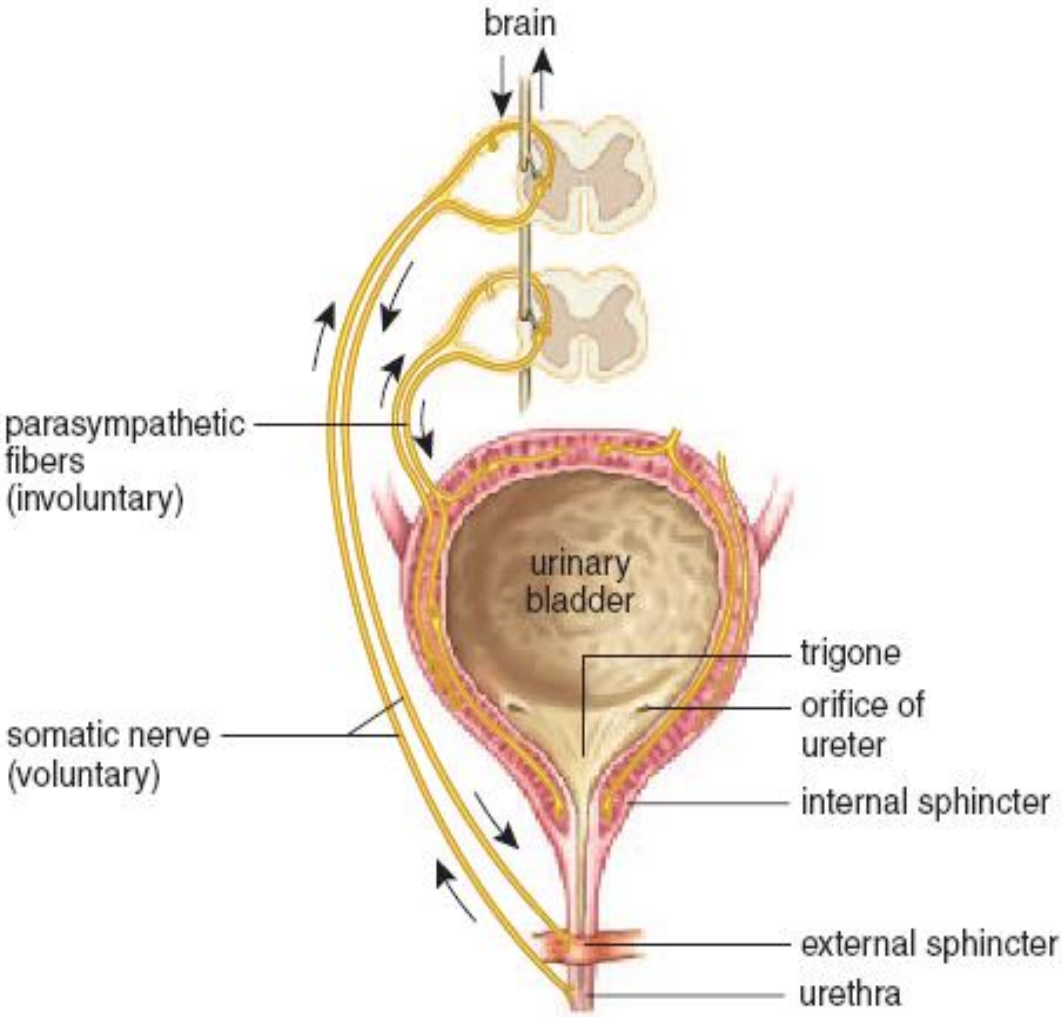
HCO_3^- (new)	varible amount, depends on H^+ secretion (antiporters)
Urea	variable (recycling to loop of Henle)

Secretion (into urine) of:

H^+	variable amounts to maintain acid-base homeostasis (H^+ pumps)

Figure 26-20 Principles of Anatomy and Physiology, 11/e

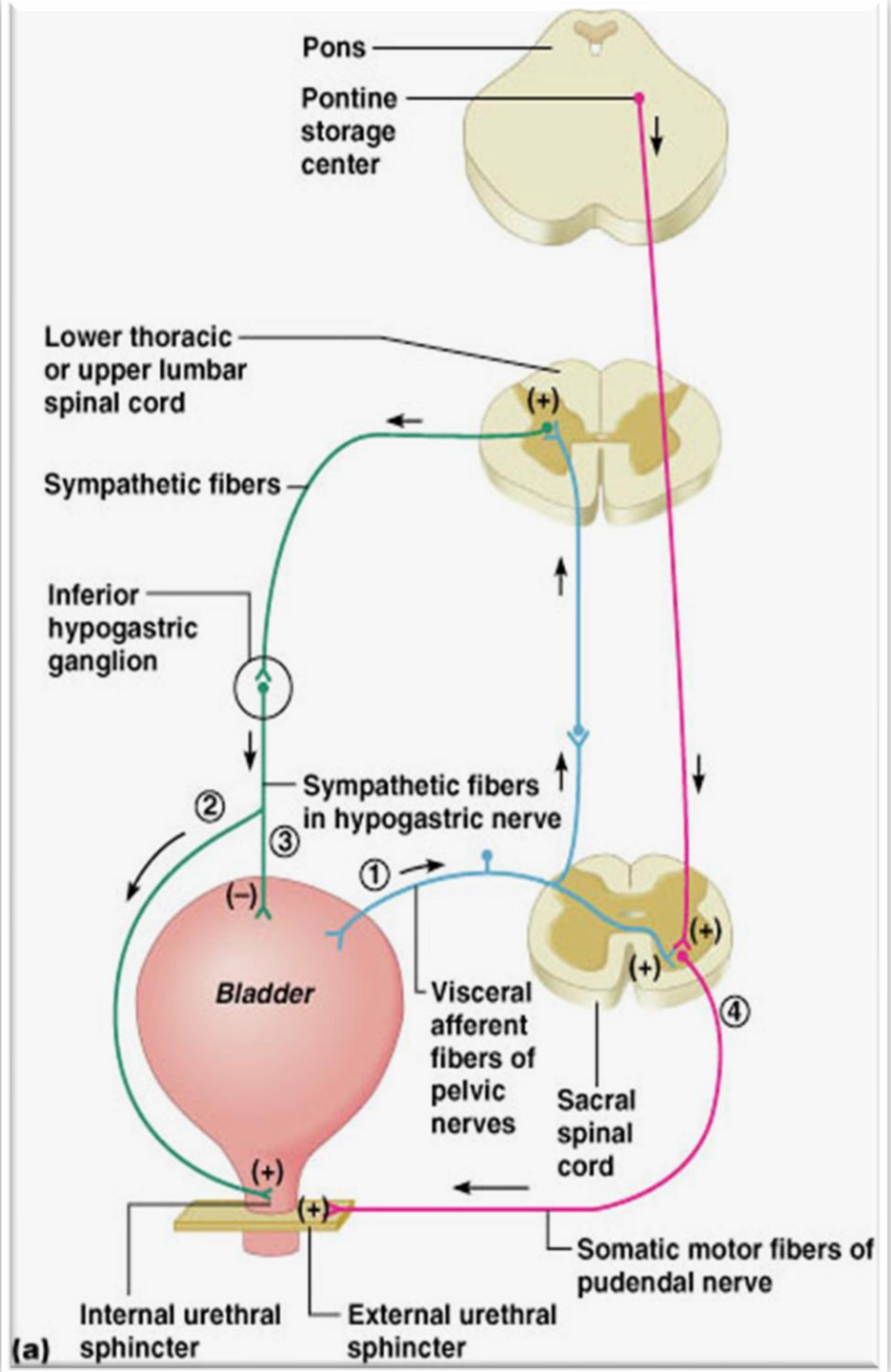
Figure 16.2 Urination. As the bladder fills with urine, sensory impulses go to the spinal cord and then to the brain. The brain can override the urge to urinate. When urination occurs, motor nerve impulses cause the bladder to contract and an internal sphincter to open. Nerve impulses also cause an external sphincter to open.



URINASI

- Volume urin dipengaruhi oleh tekanan darah, konsentrasi darah (tekanan osmotik darah), suhu, diuretik, dan emosi.
- Karakteristik urin :
  Mengandung 95% air dan 5% zat terlarut (urea, kreatinin, asam urat, asam hipurat, indichan, badan keton, garam-garam dan ion.
- Karakteristik urin dievaluasi pd urinalisis : warna, bau, kekeruhan, pH, dan berat jenis.
- Kandungan abnormal pd urinalisis:
  Albumin, glukosa, eritrosit, leukosit, badan keton, bilirubin, urobilinogen, adanya serpihan/padatan, renal calculi, dan mikroba.

SELESAI



Pengisian urine ke dalam vesica urinaria

↓

Reseptor regang (mekanoreseptor)

↓

Otak — Nervus pelvikus (saraf sensoris)

↓

Medula spinalis (pada segmen sakral) — Medula spinalis (pada segmen lumbal)

↓

Nervus pudendus (parasimpatis) — Nervus hipogastrikus (simpatis)

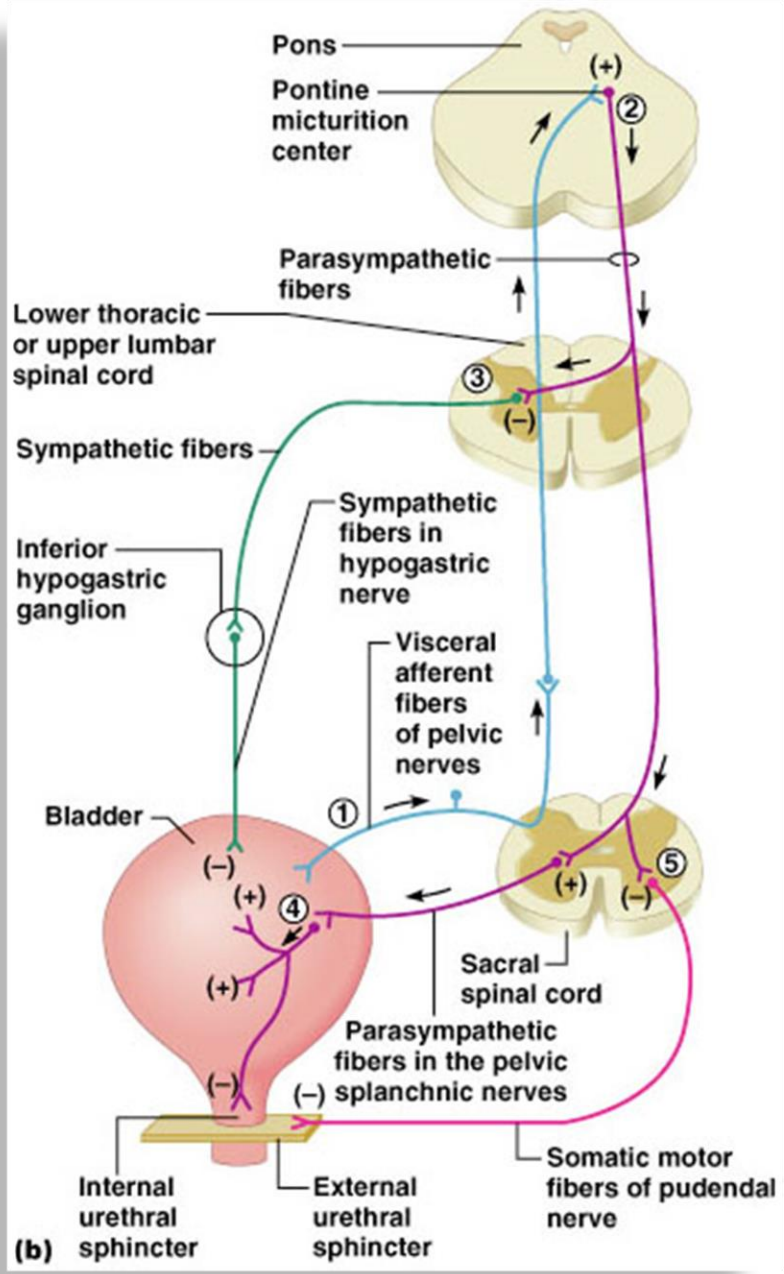
↓

Kontraksi Sfingter — Relaksasi VU

↓

Hambatan mikturisi dan pengisian urine kembali

Pengisian lanjut urine ke dalam vesica urinaria → Proses semakin kuat



Reseptor regang (mekanoreseptor)

Nervus pelvikus (saraf sensoris)

Otak (pons) — inhibisi → Medula spinalis (pada segmen lumbal) → Nervus hipogastrikus (simpatis)

Medula spinalis (pada segmen sakral)

inhibisi

Nervus pudendus (parasimpatis) → Relaksasi sfingter

Nervus pelvikus (motoris) → Kontraksi VU

Relaksasi sfingter + Kontraksi VU → Berkemih