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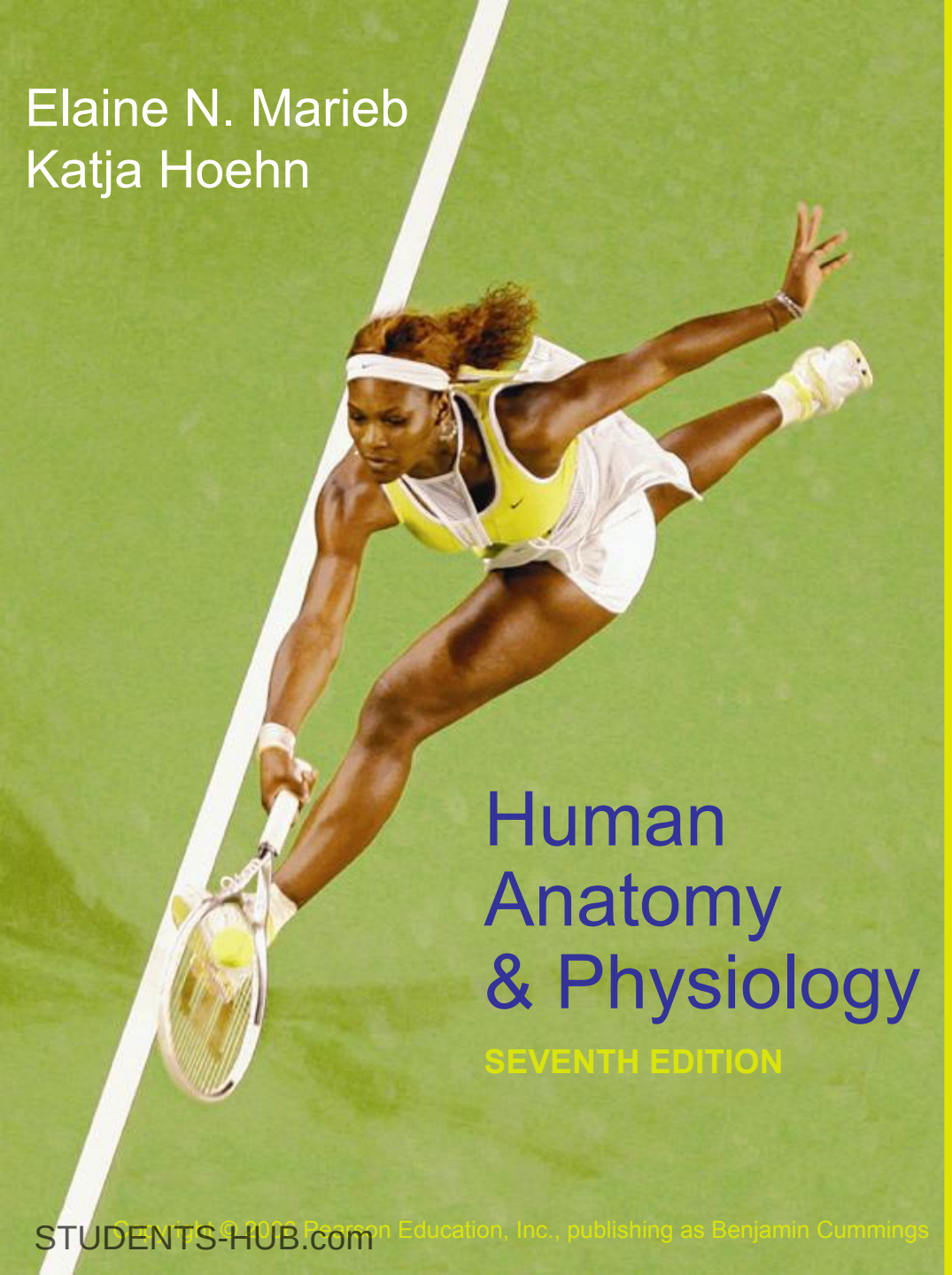

Human Anatomy & Physiology

SEVENTH EDITION

PowerPoint® Lecture Slides
prepared by Vince Austin,
Bluegrass Technical
and Community College

CHAPTER 25 PART A

The Urinary System

Kidney Functions

- Filter 200 liters of blood daily, allowing toxins, metabolic wastes, and excess ions to leave the body in urine
- Regulate volume and chemical makeup of the blood
- Maintain the proper balance between water and salts, and acids and bases

Other Renal Functions

- Gluconeogenesis during prolonged fasting
- Production of rennin to help regulate blood pressure and erythropoietin to stimulate RBC production
- Activation of vitamin D

Other Urinary System Organs

- Urinary bladder – provides a temporary storage reservoir for urine
- Paired ureters – transport urine from the kidneys to the bladder
- Urethra – transports urine from the bladder out of the body

Urinary System Organs

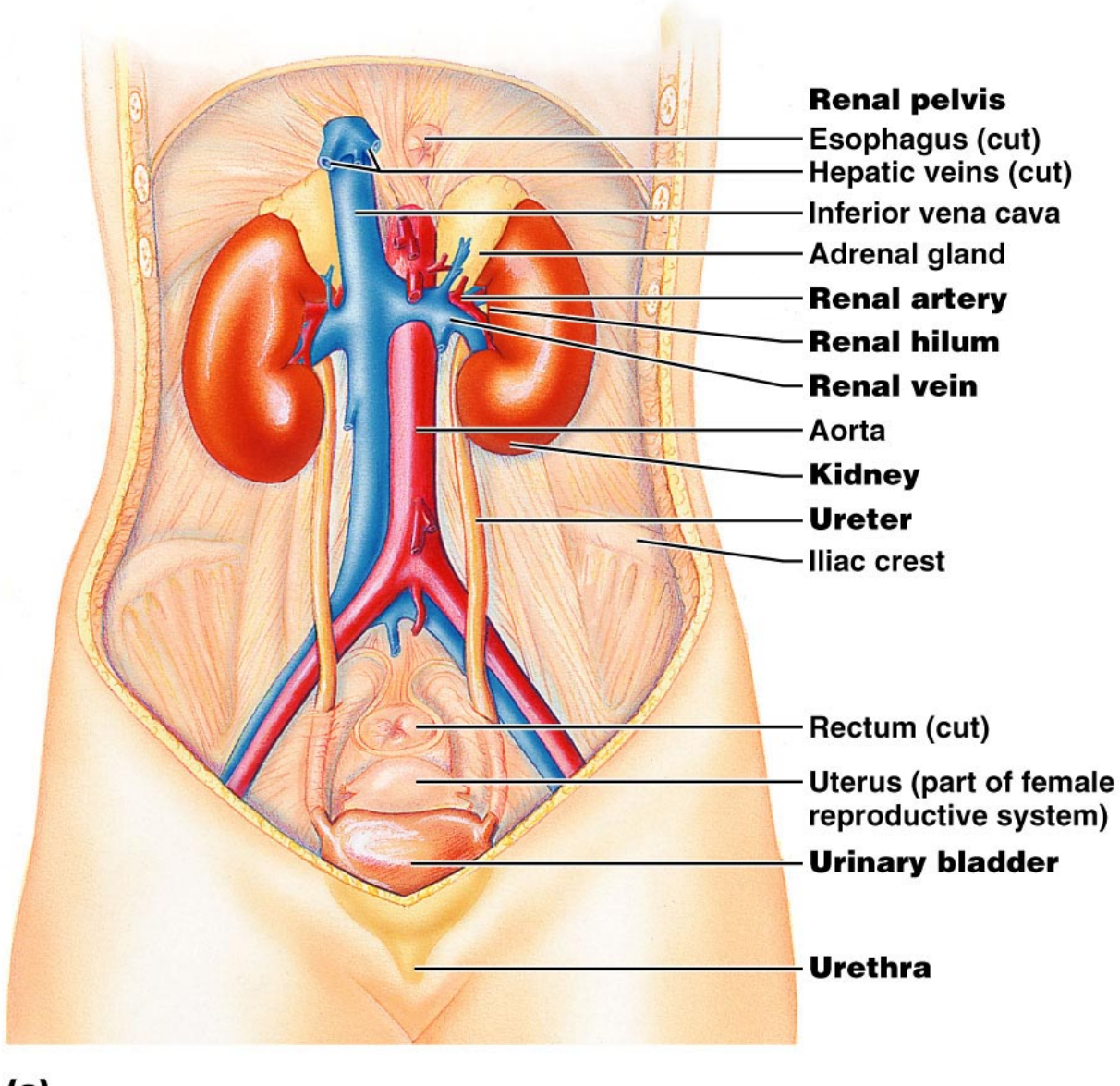

Figure 25.1a

Kidney Location and External Anatomy

- The kidneys lie in a retroperitoneal position in the superior lumbar region
- The right kidney is lower than the left because it is crowded by the liver
- The lateral surface is convex; the medial surface is concave
- The renal hilus leads to the renal sinus
- Ureters, renal blood vessels, lymphatics, and nerves enter and exit at the hilus

Layers of Tissue Supporting the Kidney

- Renal capsule – fibrous capsule that prevents kidney infection
- Adipose capsule – fatty mass that cushions the kidney and helps attach it to the body wall
- Renal fascia – outer layer of dense fibrous connective tissue that anchors the kidney

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Anatomy Review, page 4

Kidney Location and External Anatomy

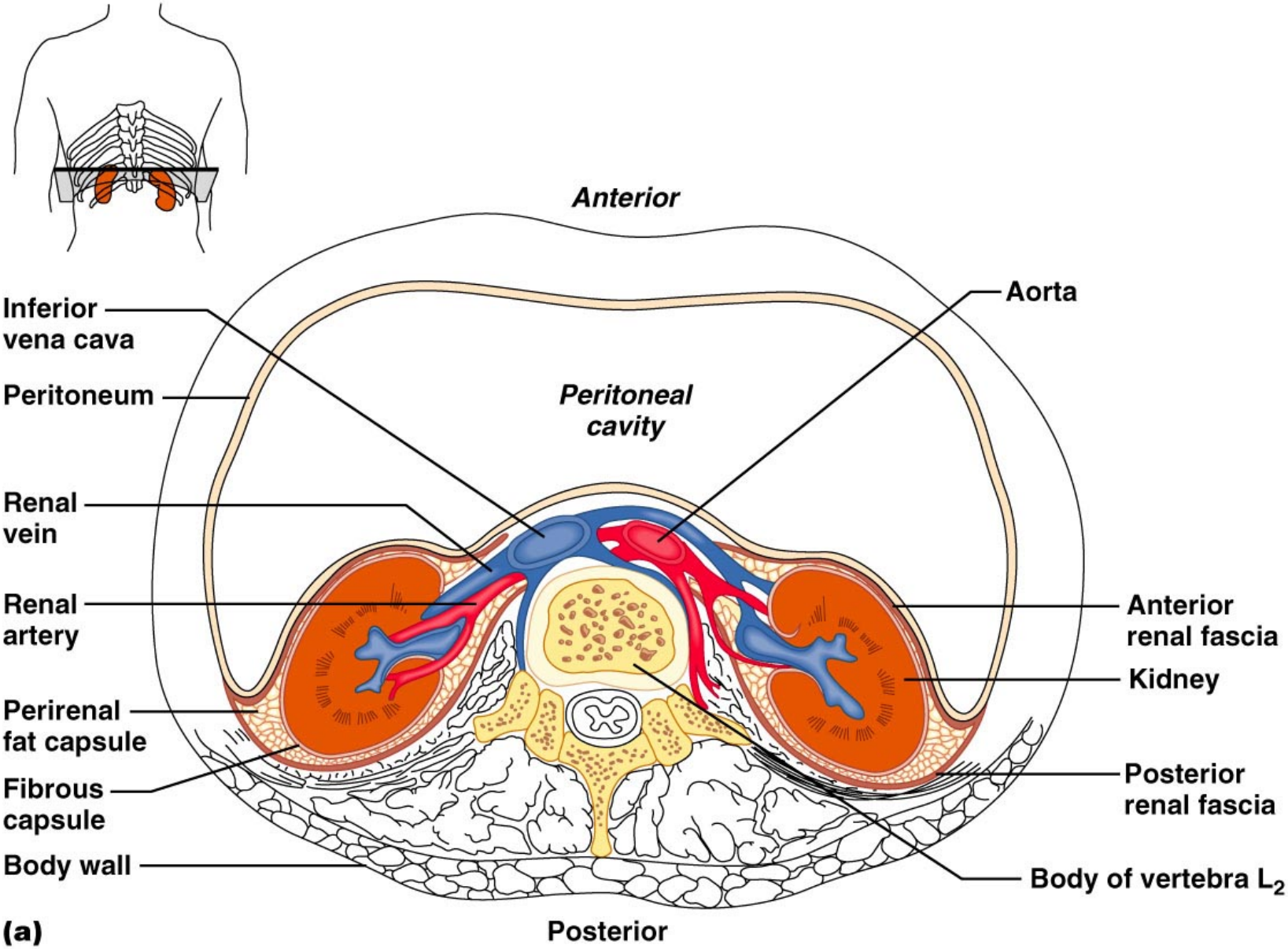

Figure 25.2a

Internal Anatomy (Frontal Section)

- Cortex – the light colored, granular superficial region
- Medulla – exhibits cone-shaped medullary (renal) pyramids separated by columns
  - The medullary pyramid and its surrounding capsule constitute a lobe
- Renal pelvis – flat funnel shaped tube lateral to the hilus within the renal sinus

Internal Anatomy

- Major calyces – large branches of the renal pelvis
  - Collect urine draining from papillae
  - Empty urine into the pelvis
- Urine flows through the pelvis and ureters to the bladder

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Internal Anatomy

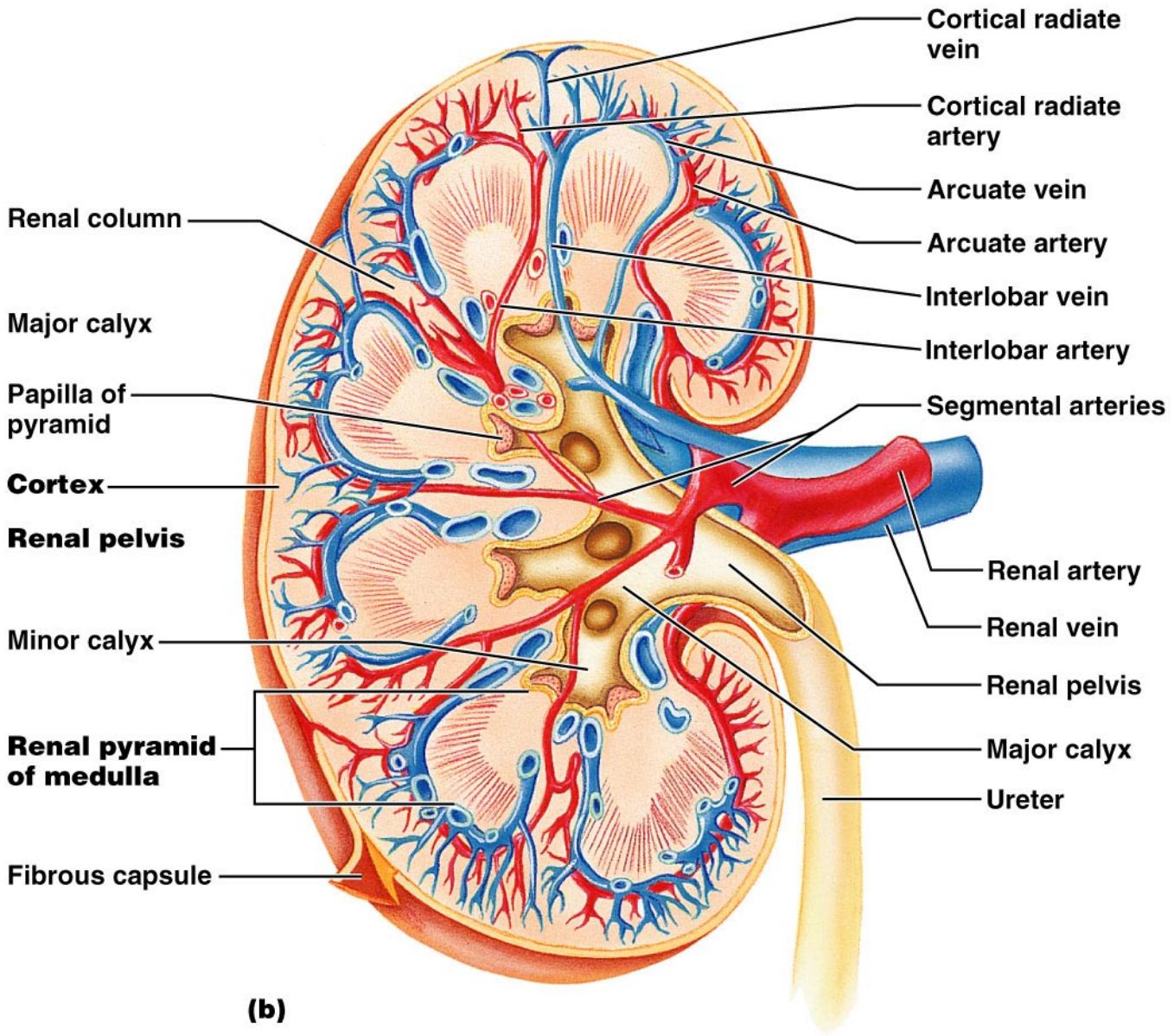

Figure 25.3b

Blood and Nerve Supply

- Approximately one-fourth (1200 ml) of systemic cardiac output flows through the kidneys each minute
- Arterial flow into and venous flow out of the kidneys follow similar paths
- The nerve supply is via the renal plexus

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Renal Vascular Pathway

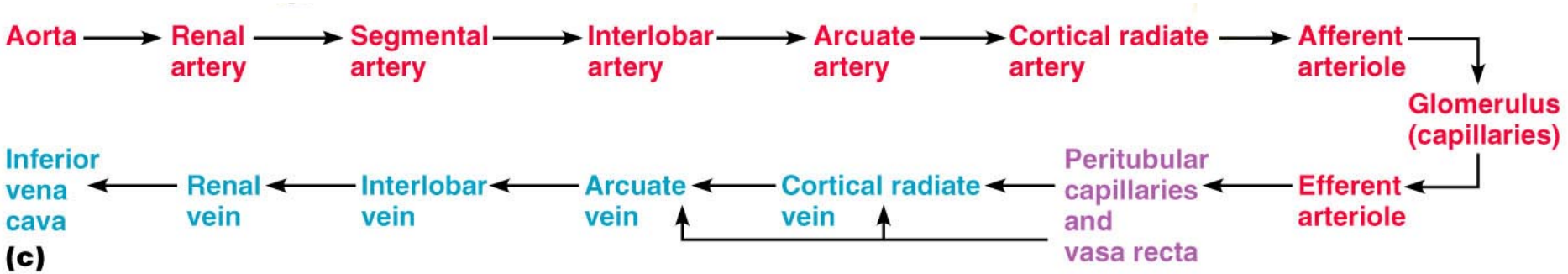

Figure 25.3c

The Nephron

- Nephrons are the structural and functional units that form urine, consisting of:
  - Glomerulus – a tuft of capillaries associated with a renal tubule
  - Glomerular (Bowman's) capsule – blind, cup-shaped end of a renal tubule that completely surrounds the glomerulus

The Nephron

- Renal corpuscle – the glomerulus and its Bowman's capsule
- Glomerular endothelium – fenestrated epithelium that allows solute-rich, virtually protein-free filtrate to pass from the blood into the glomerular capsule

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Urinary: Anatomy Review, pages 7-9

The Nephron

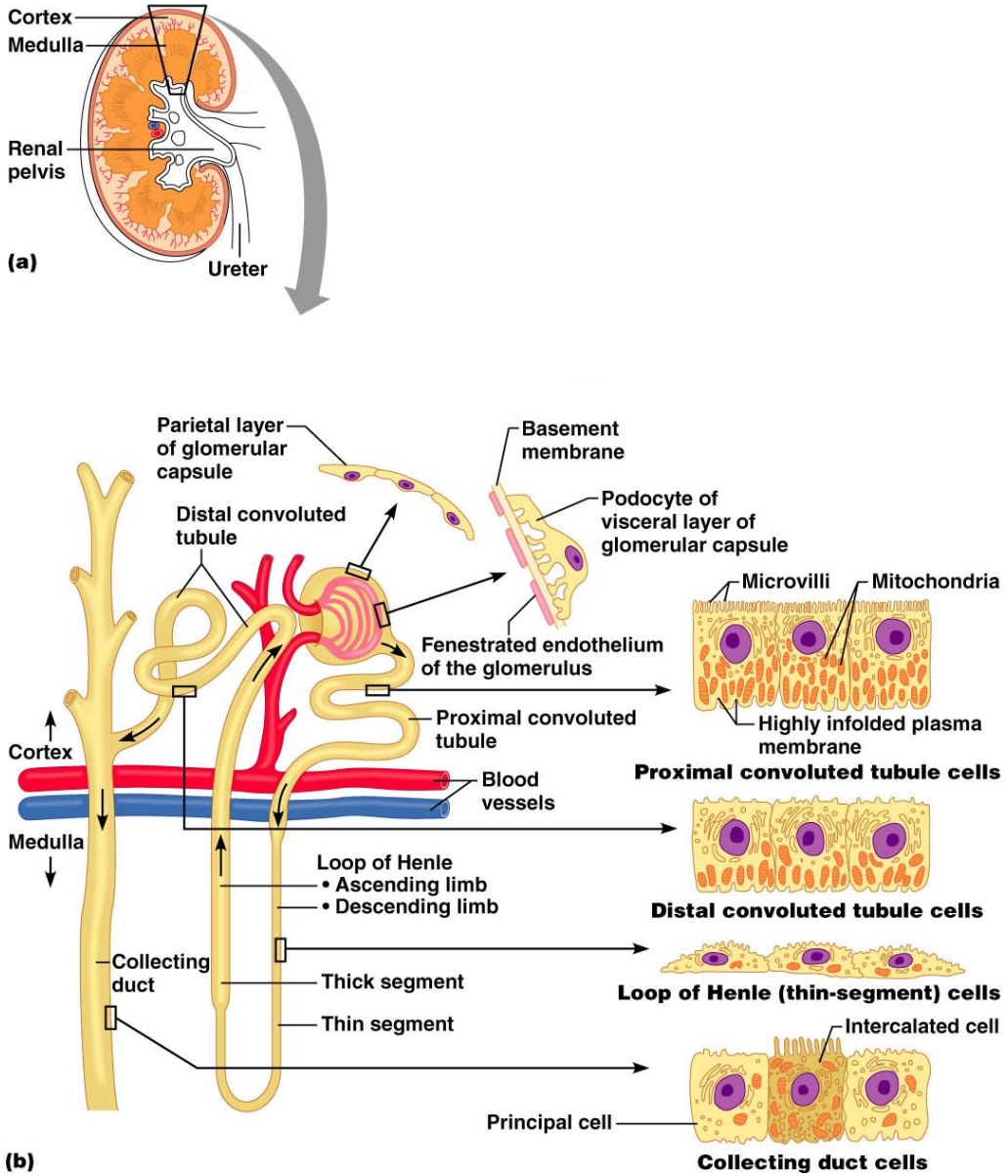

Figure 25.4a, b

Anatomy of the Glomerular Capsule

- The external parietal layer is a structural layer
- The visceral layer consists of modified, branching epithelial podocytes
- Extensions of the octopus-like podocytes terminate in foot processes
- Filtration slits – openings between the foot processes that allow filtrate to pass into the capsular space

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Renal Tubule

- Proximal convoluted tubule (PCT) – composed of cuboidal cells with numerous microvilli and mitochondria
  - Reabsorbs water and solutes from filtrate and secretes substances into it

Renal Tubule

- Loop of Henle – a hairpin-shaped loop of the renal tubule
  - Proximal part is similar to the proximal convoluted tubule
  - Proximal part is followed by the thin segment (simple squamous cells) and the thick segment (cuboidal to columnar cells)
- Distal convoluted tubule (DCT) – cuboidal cells without microvilli that function more in secretion than reabsorption

Renal Tubule

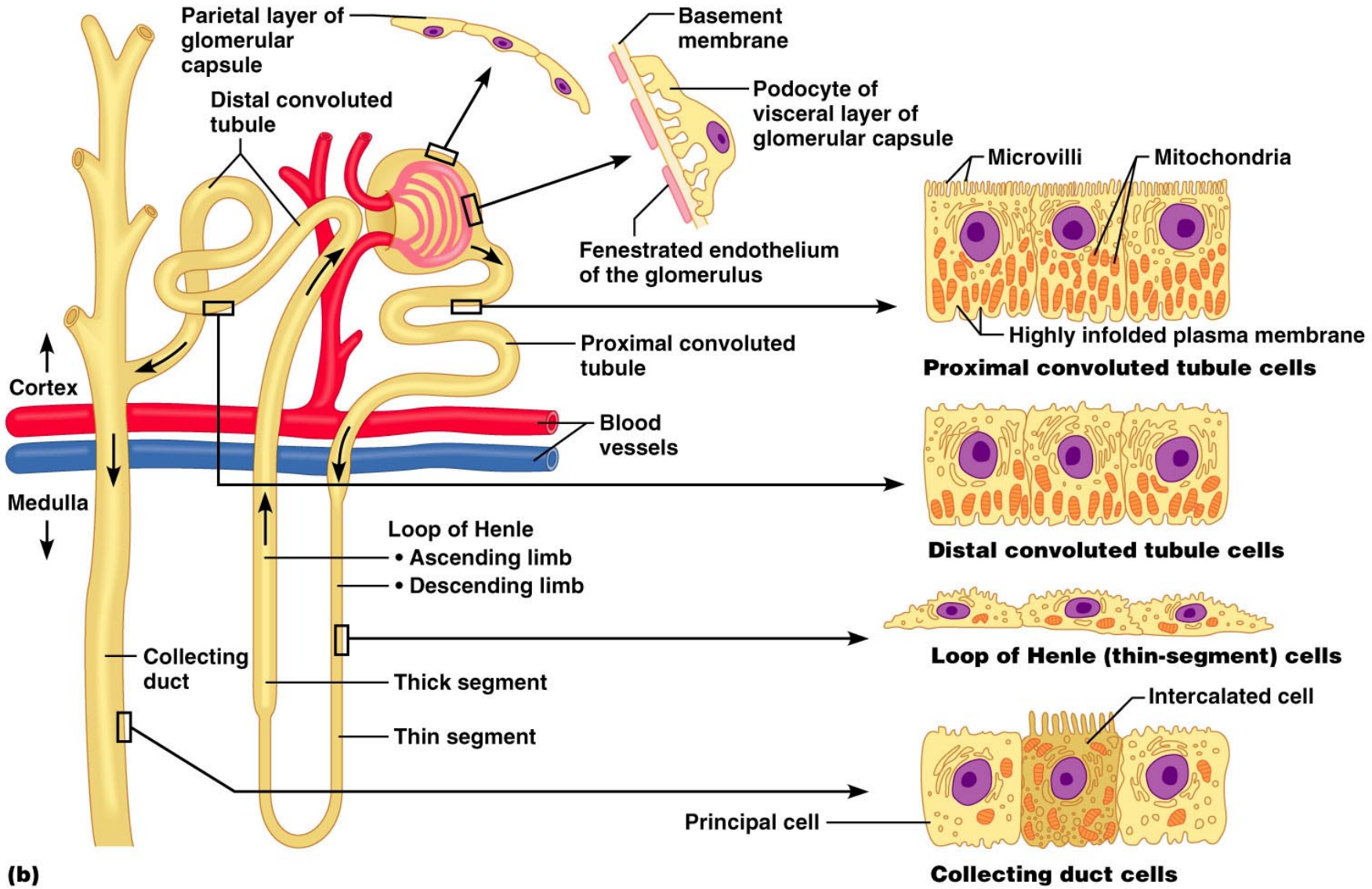

Figure 25.4b

Connecting Tubules

- The distal portion of the distal convoluted tubule nearer to the collecting ducts

Connecting Tubules

- Two important cell types are found here
  - Intercalated cells
    - Cuboidal cells with microvilli
    - Function in maintaining the acid-base balance of the body
  - Principal cells
    - Cuboidal cells without microvilli
    - Help maintain the body's water and salt balance

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Anatomy Review, pages 12–15, 17–19

Nephrons

- Cortical nephrons – 85% of nephrons; located in the cortex
- Juxtamedullary nephrons:
  - Are located at the cortex-medulla junction
  - Have loops of Henle that deeply invade the medulla
  - Have extensive thin segments
  - Are involved in the production of concentrated urine

Nephron Anatomy

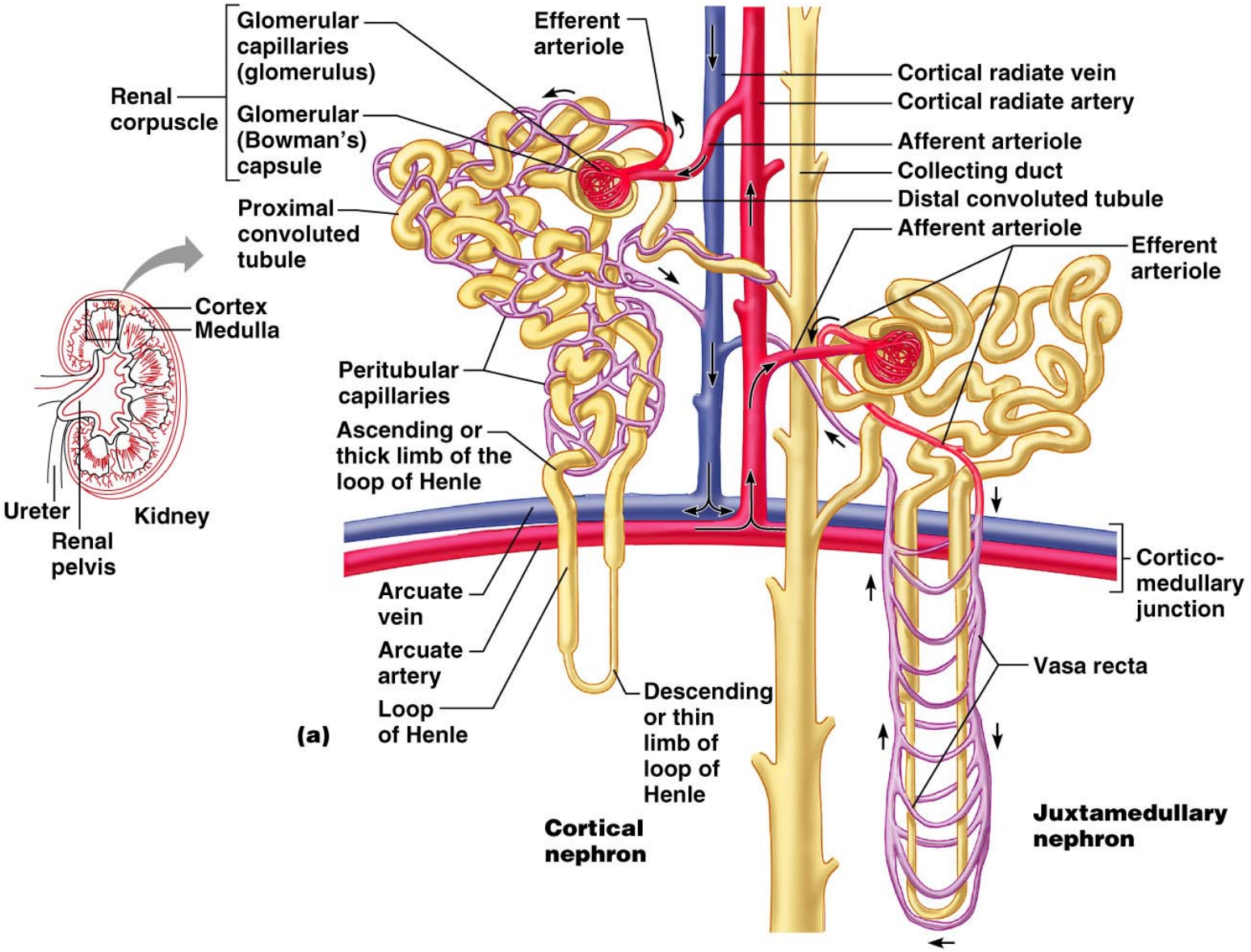

Figure 25.5a

Capillary Beds of the Nephron

- Every nephron has two capillary beds
  - Glomerulus
  - Peritubular capillaries
- Each glomerulus is:
  - Fed by an afferent arteriole
  - Drained by an efferent arteriole

Capillary Beds of the Nephron

- Blood pressure in the glomerulus is high because:
  - Arterioles are high-resistance vessels
  - Afferent arterioles have larger diameters than efferent arterioles
- Fluids and solutes are forced out of the blood throughout the entire length of the glomerulus

Capillary Beds

- Peritubular beds are low-pressure, porous capillaries adapted for absorption that:
  - Arise from efferent arterioles
  - Cling to adjacent renal tubules
  - Empty into the renal venous system
- Vasa recta – long, straight efferent arterioles of juxtamedullary nephrons

Capillary Beds

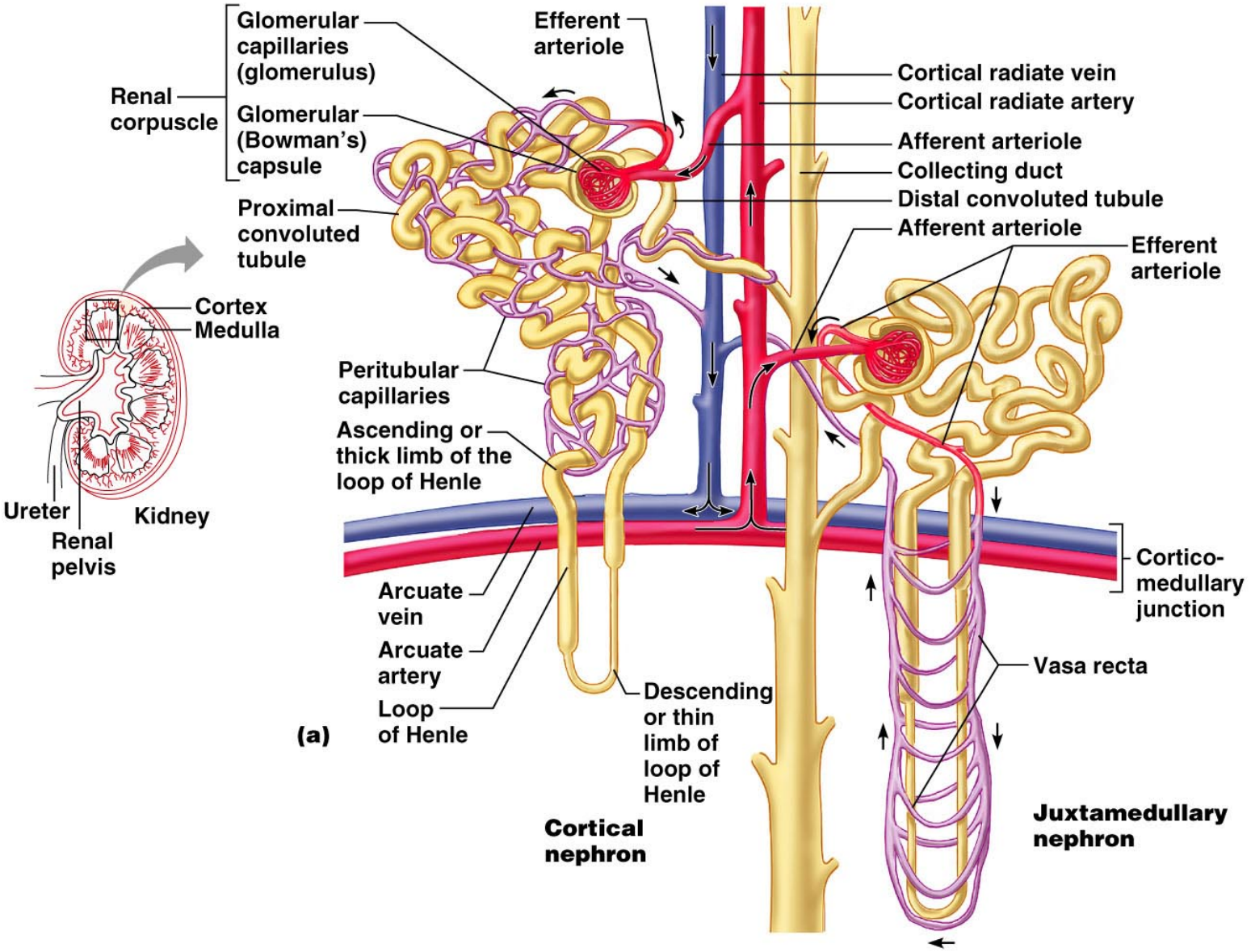

Figure 25.5a

Vascular Resistance in Microcirculation

- Afferent and efferent arterioles offer high resistance to blood flow
- Blood pressure declines from 95mm Hg in renal arteries to 8 mm Hg in renal veins

Vascular Resistance in Microcirculation

- Resistance in afferent arterioles:
  - Protects glomeruli from fluctuations in systemic blood pressure
- Resistance in efferent arterioles:
  - Reinforces high glomerular pressure
  - Reduces hydrostatic pressure in peritubular capillaries

Juxtaglomerular Apparatus (JGA)

- Where the distal tubule lies against the afferent (sometimes efferent) arteriole
- Arteriole walls have juxtaglomerular (JG) cells
  - Enlarged, smooth muscle cells
  - Have secretory granules containing renin
  - Act as mechanoreceptors

Juxtaglomerular Apparatus (JGA)

- Macula densa
  - Tall, closely packed distal tubule cells
  - Lie adjacent to JG cells
  - Function as chemoreceptors or osmoreceptors
- Mesanglial cells:
  - Have phagocytic and contractile properties
  - Influence capillary filtration

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Anatomy Review: page 16

Juxtaglomerular Apparatus (JGA)

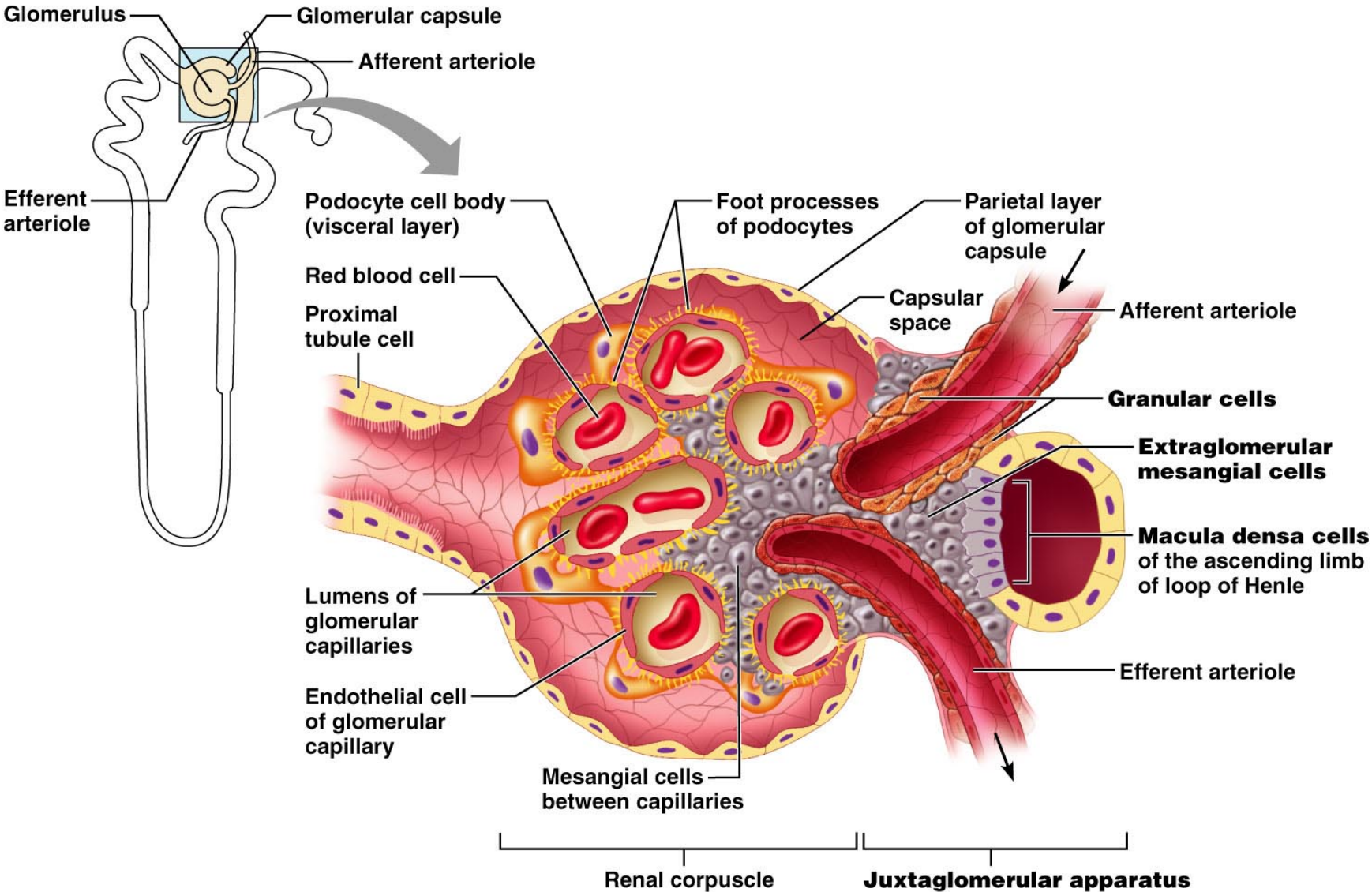

Figure 25.6

Filtration Membrane

- Filter that lies between the blood and the interior of the glomerular capsule
- It is composed of three layers
  - Fenestrated endothelium of the glomerular capillaries
  - Visceral membrane of the glomerular capsule (podocytes)
  - Basement membrane composed of fused basal laminae of the other layers

Filtration Membrane

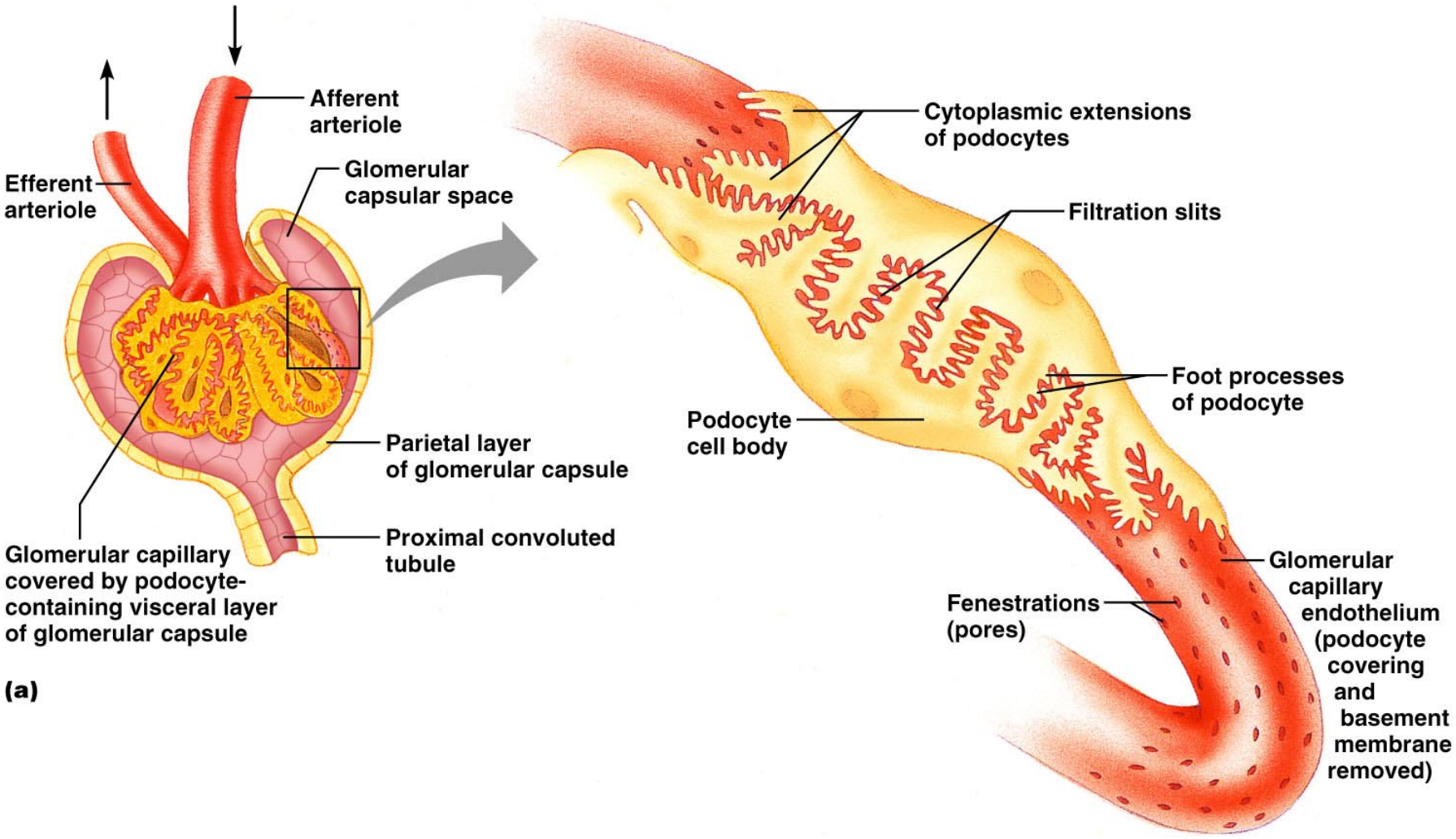

Figure 25.7a

Filtration Membrane

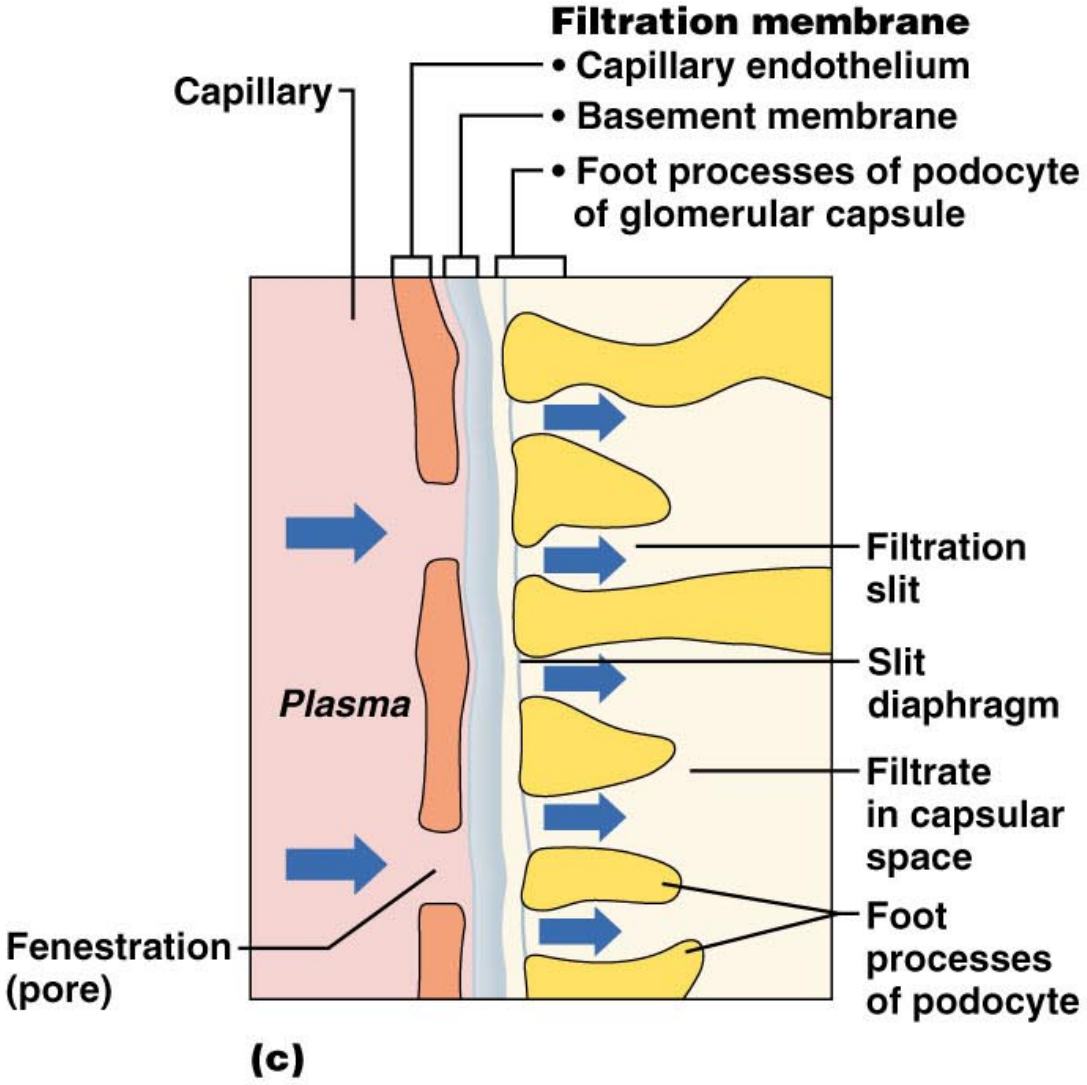

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Figure 25.7c

Mechanisms of Urine Formation

- The kidneys filter the body's entire plasma volume 60 times each day
- The filtrate:
  - Contains all plasma components except protein
  - Loses water, nutrients, and essential ions to become urine
- The urine contains metabolic wastes and unneeded substances

Mechanisms of Urine Formation

- Urine formation and adjustment of blood composition involves three major processes
  - Glomerular filtration
  - Tubular reabsorption
  - Secretion

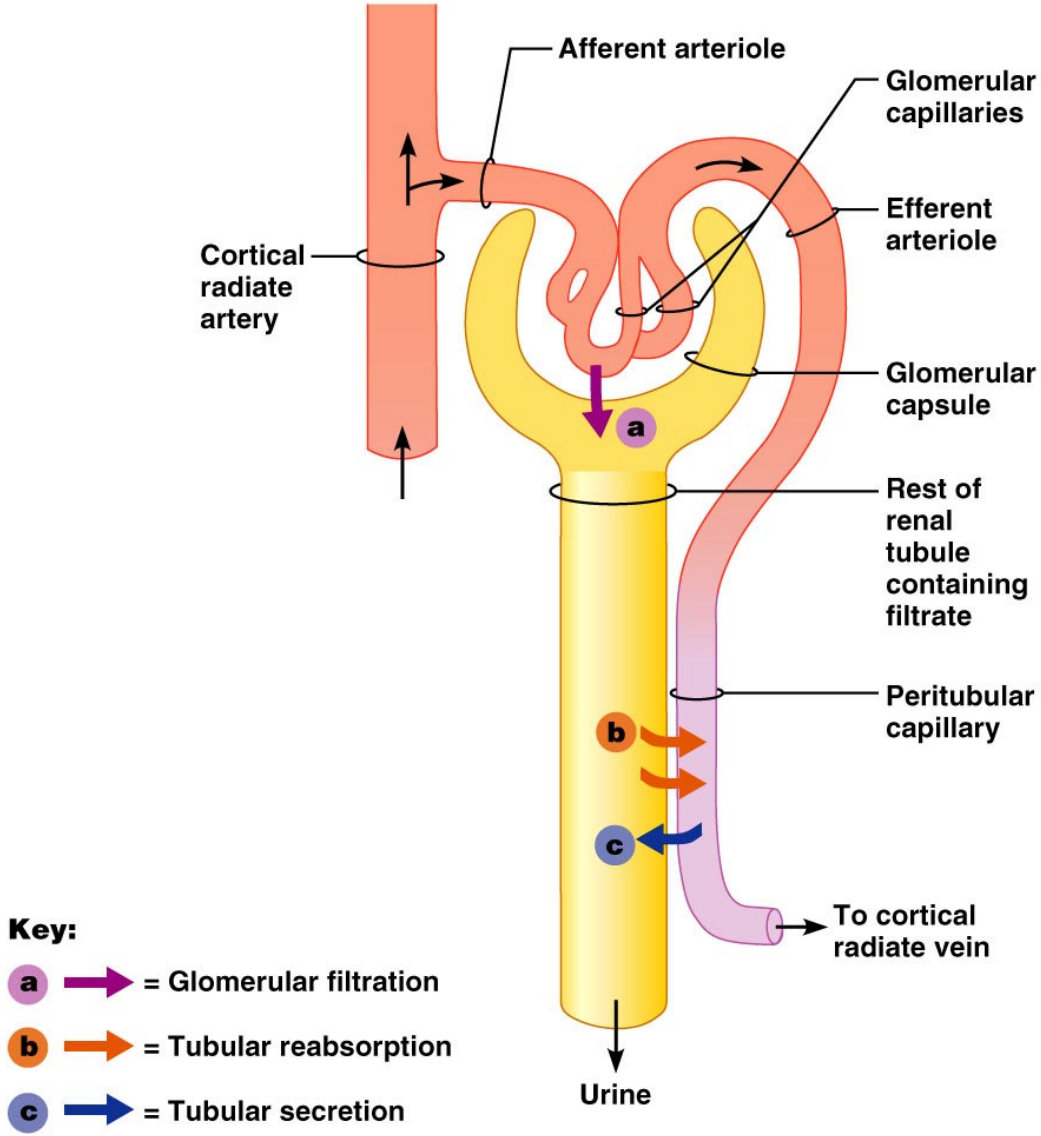

Figure 25.8

Glomerular Filtration

- Principles of fluid dynamics that account for tissue fluid in all capillary beds apply to the glomerulus as well
- The glomerulus is more efficient than other capillary beds because:
  - Its filtration membrane is more permeable
  - Glomerular blood pressure is higher
  - It has a higher net filtration pressure
- Plasma proteins are not filtered and are used to maintain oncotic pressure of the blood

Net Filtration Pressure (NFP)

- The pressure responsible for filtrate formation
- NFP equals the glomerular hydrostatic pressure (HP_g) minus the oncotic pressure of glomerular blood (OP_g) combined with the capsular hydrostatic pressure (HP_c)

$$NFP = HP_g - (OP_g + HP_c)$$

Glomerular Filtration Rate (GFR)

- The total amount of filtrate formed per minute by the kidneys
- Factors governing filtration rate at the capillary bed are:
  - Total surface area available for filtration
  - Filtration membrane permeability
  - Net filtration pressure

Glomerular Filtration Rate (GFR)

- GFR is directly proportional to the NFP
- Changes in GFR normally result from changes in glomerular blood pressure

Glomerular Filtration Rate (GFR)

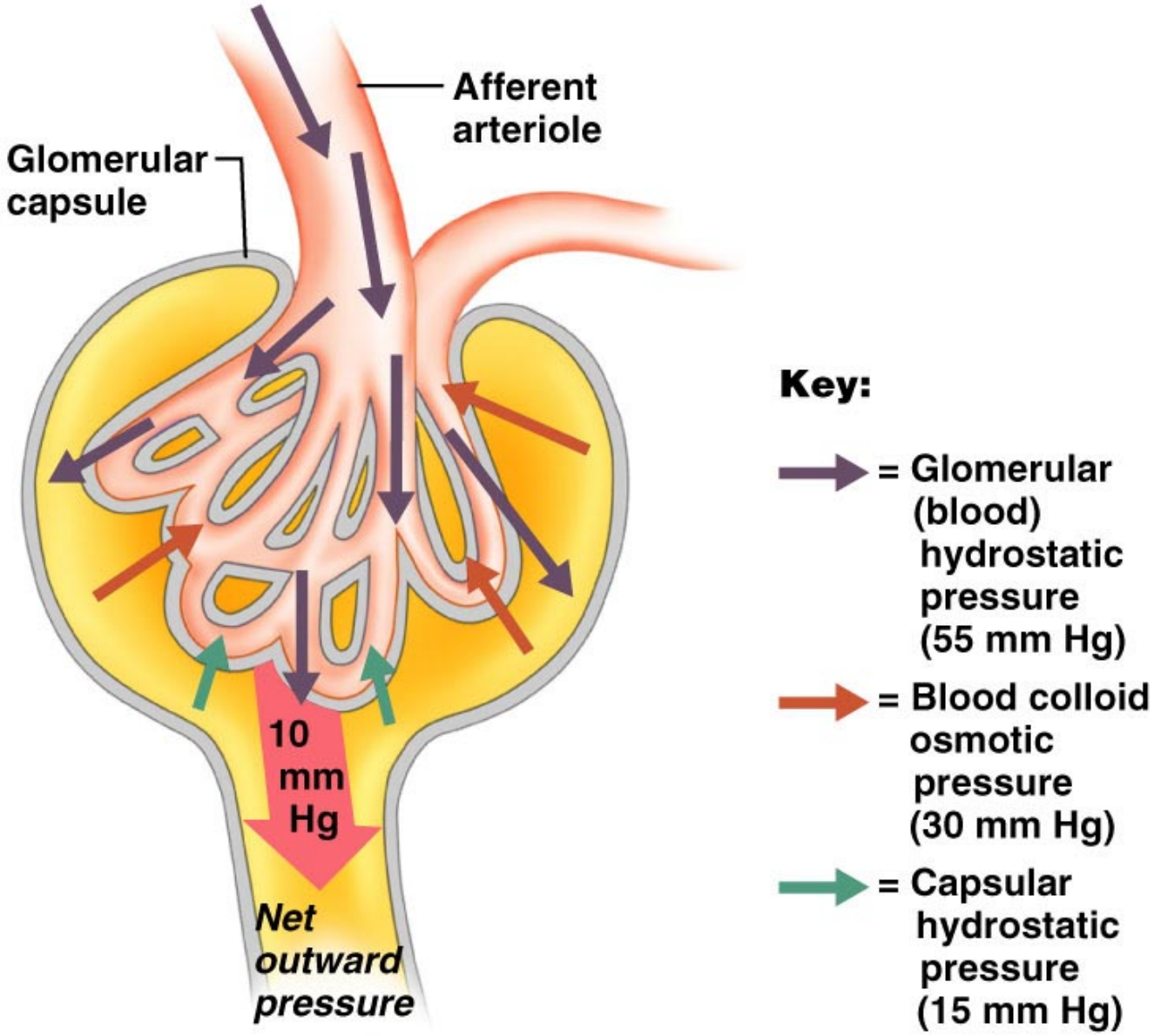

Figure 25.9

Regulation of Glomerular Filtration

- If the GFR is too high:
  - Needed substances cannot be reabsorbed quickly enough and are lost in the urine
- If the GFR is too low:
  - Everything is reabsorbed, including wastes that are normally disposed of

Regulation of Glomerular Filtration

- Three mechanisms control the GFR
  - Renal autoregulation (intrinsic system)
  - Neural controls
  - Hormonal mechanism (the renin-angiotensin system)

Intrinsic Controls

- Under normal conditions, renal autoregulation maintains a nearly constant glomerular filtration rate
- Autoregulation entails two types of control
  - Myogenic – responds to changes in pressure in the renal blood vessels
  - Flow-dependent tubuloglomerular feedback – senses changes in the juxtaglomerular apparatus

Extrinsic Controls

- When the sympathetic nervous system is at rest:
  - Renal blood vessels are maximally dilated
  - Autoregulation mechanisms prevail

Extrinsic Controls

- Under stress:
  - Norepinephrine is released by the sympathetic nervous system
  - Epinephrine is released by the adrenal medulla
  - Afferent arterioles constrict and filtration is inhibited
- The sympathetic nervous system also stimulates the renin-angiotensin mechanism

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Glomerular Filtration, pages 3–14

Renin-Angiotensin Mechanism

- Is triggered when the JG cells release renin
- Renin acts on angiotensinogen to release angiotensin I
- Angiotensin I is converted to angiotensin II
- Angiotensin II:
  - Causes mean arterial pressure to rise
  - Stimulates the adrenal cortex to release aldosterone
- As a result, both systemic and glomerular hydrostatic pressure rise

Renin Release

- Renin release is triggered by:
  - Reduced stretch of the granular JG cells
  - Stimulation of the JG cells by activated macula densa cells
  - Direct stimulation of the JG cells via β_1-adrenergic receptors by renal nerves
  - Angiotensin II

Renin Release

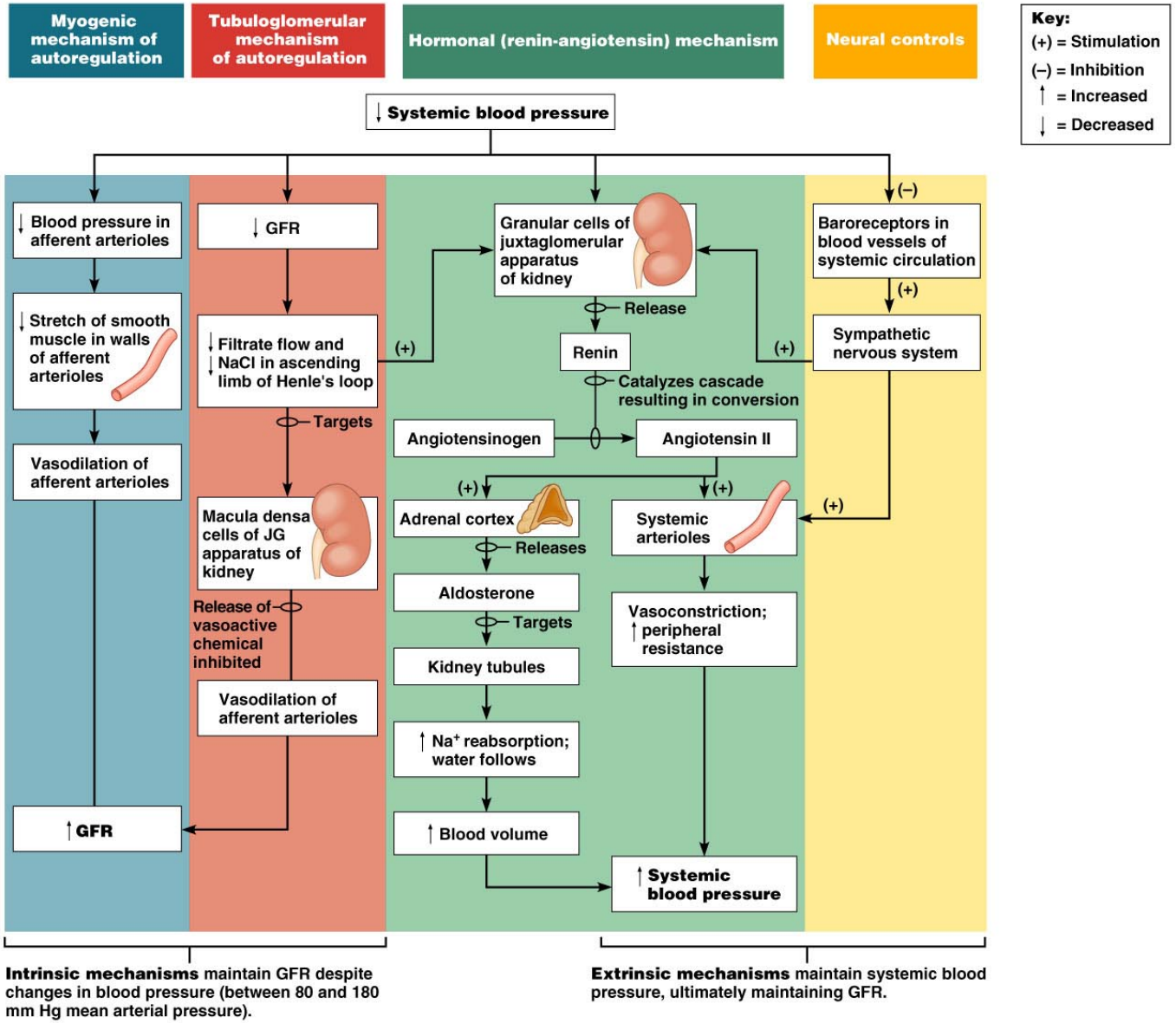

Figure 25.10