

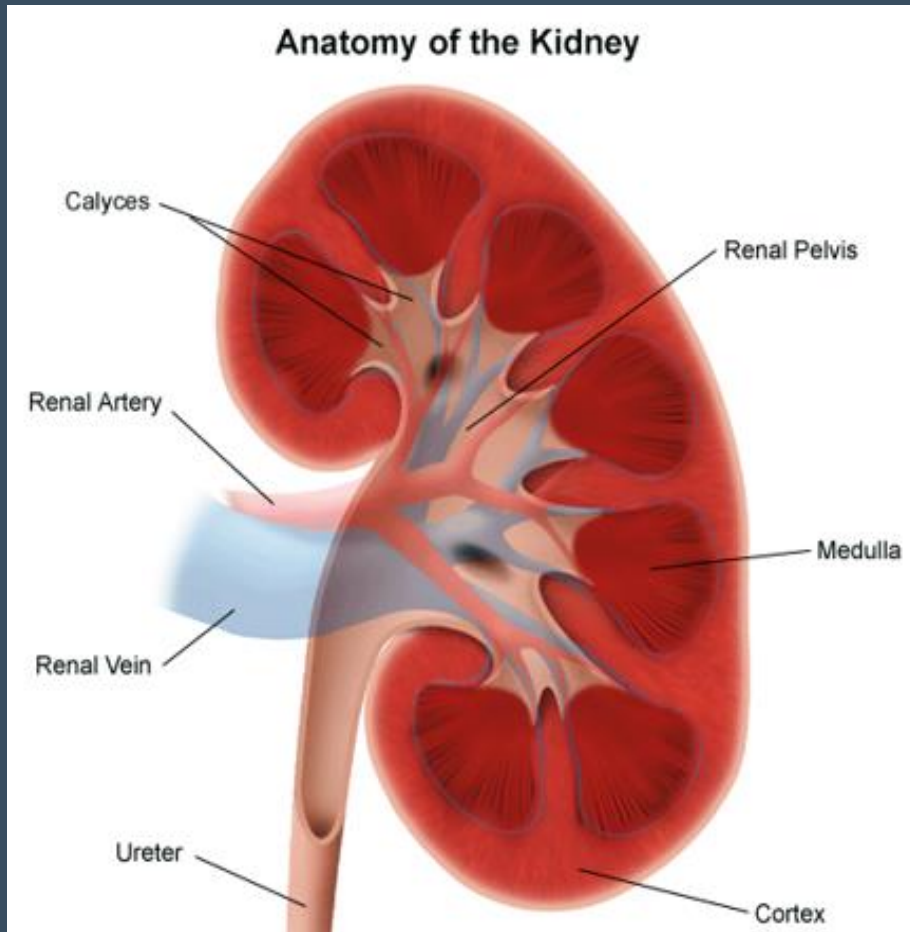
Renal Physiology and Function

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Nephron



Basic structural and functional unit of kidney

- 1-1.5 million per kidney
- Cortical nephrons (85%)
 - Waste removal
 - Nutrient reabsorption
- Juxtamedullary nephrons
 - Urine concentration

Renal physiology

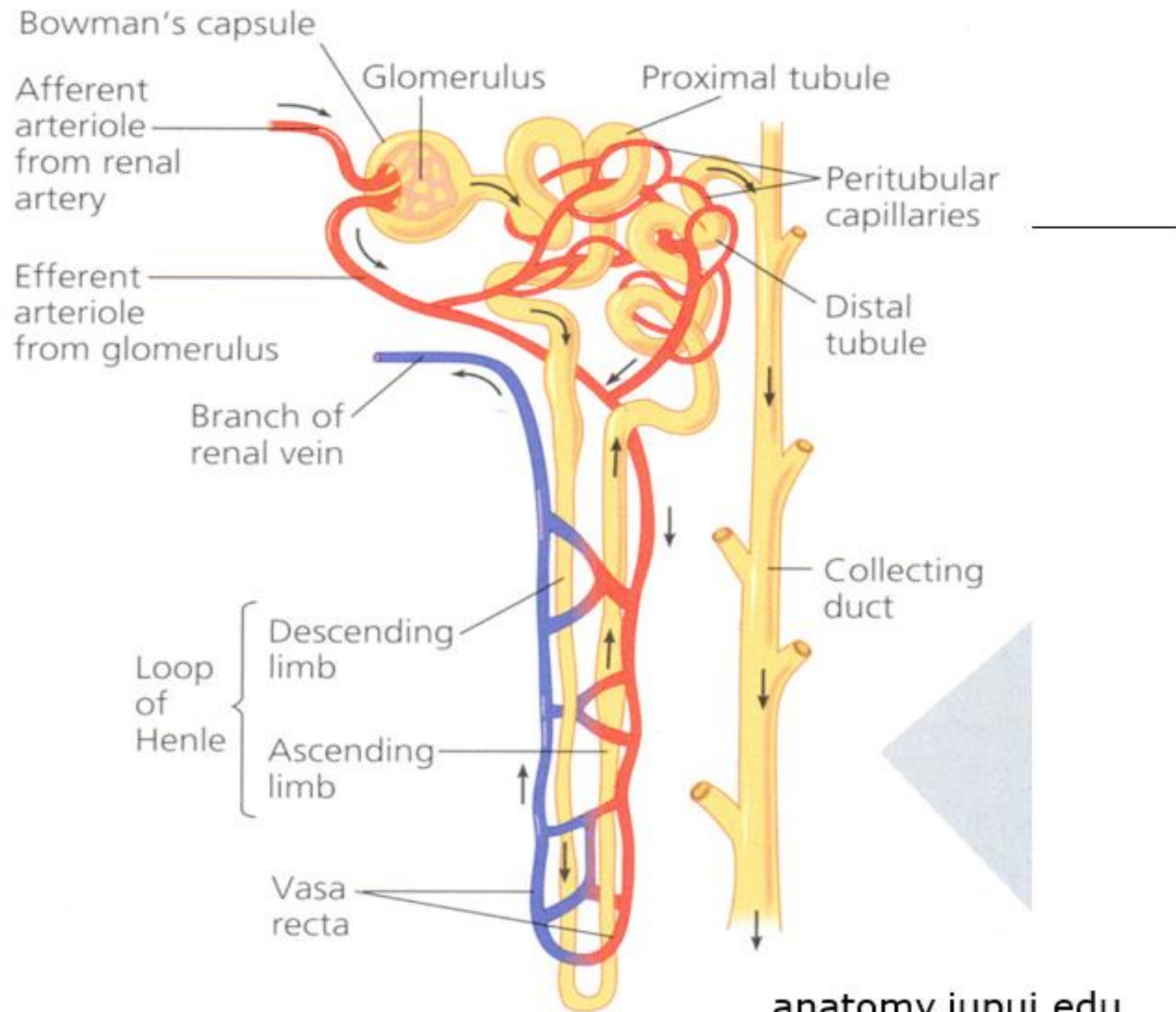
- Three primary functions
 - Glomerular filtration
 - Tubular reabsorption
 - Tubular secretion



Renal blood flow

- Kidneys receive 25% of cardiac output
 - Blood - 1200 mL/minute
 - Plasma - 600 to 700 mL/minute
- Afferent and efferent arterioles
 - Glomerular capillary pressure
- Peritubular capillaries
 - Reabsorption and secretion
- Vasa recta
 - Osmotic gradient (Na^+)





Glomerular filtration

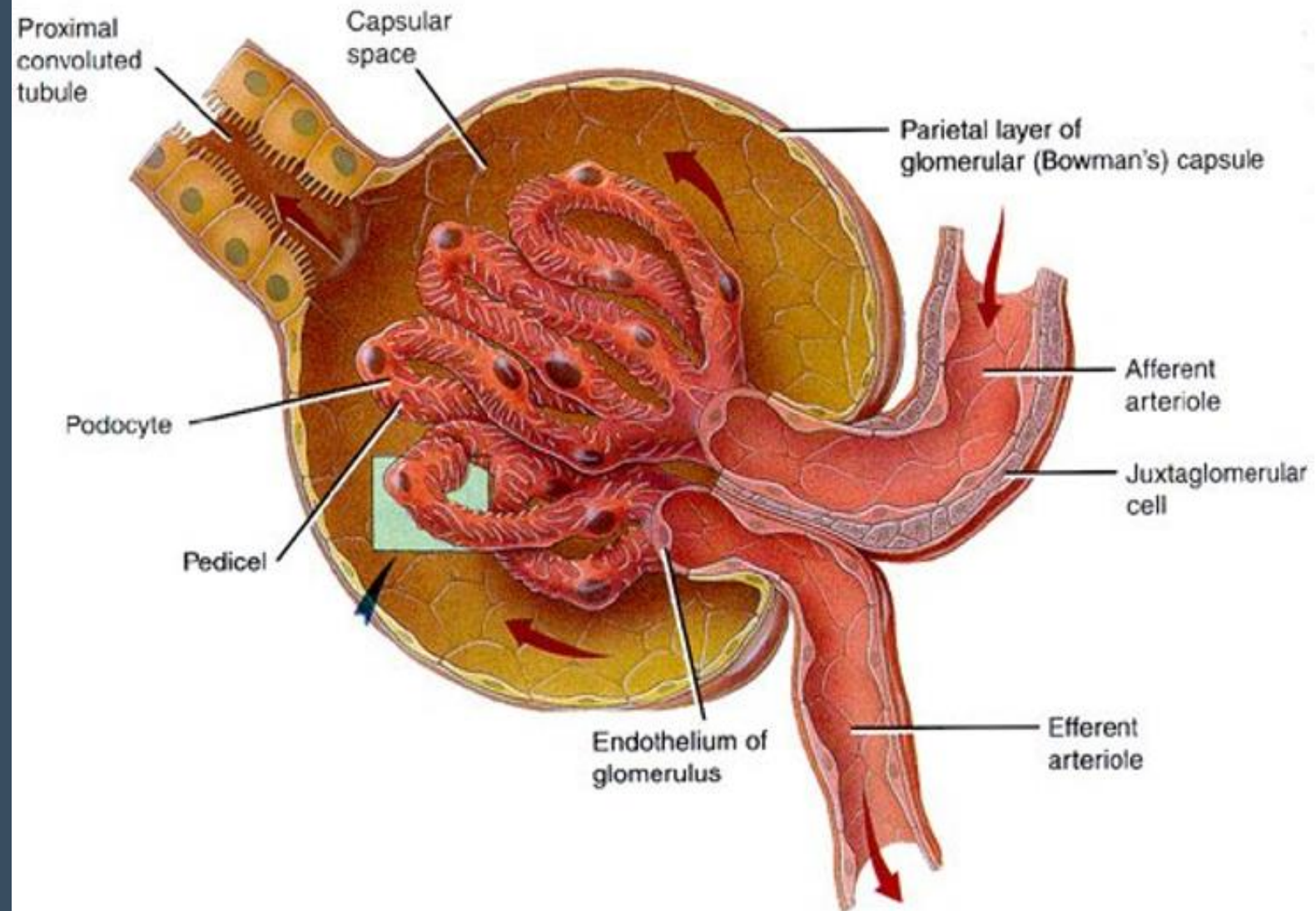
- Cellular structure of glomerulus
- Hydrostatic and oncotic pressure
- Renin-angiotensin-aldosterone system (RAAS)



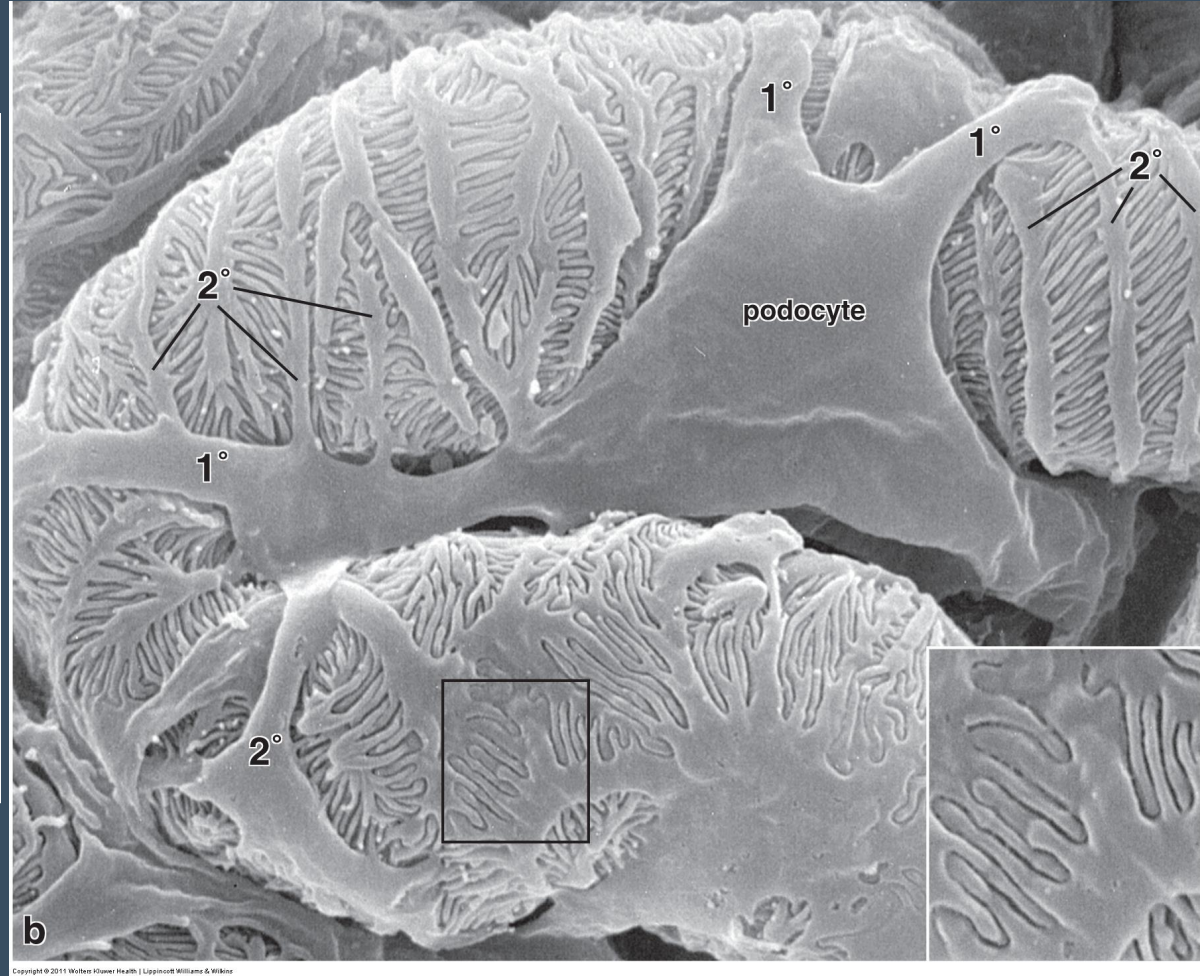
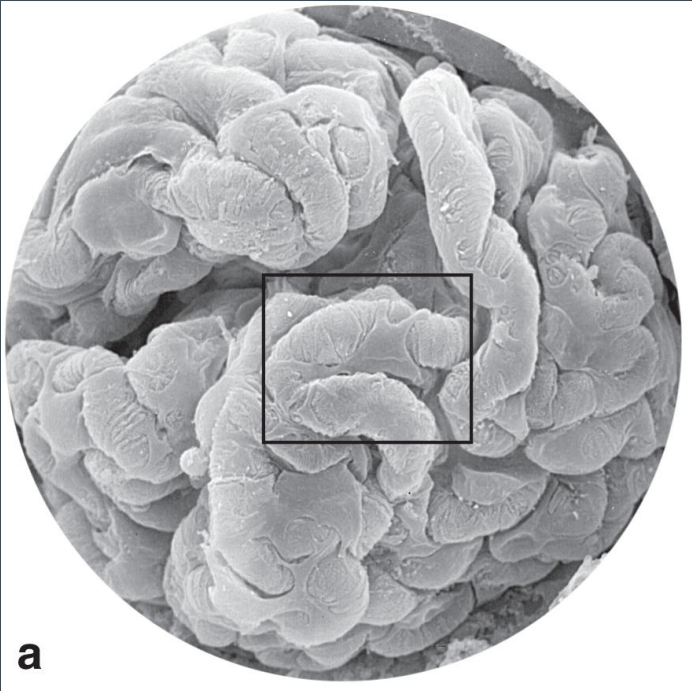
Cellular structure

- Blocks passage of large molecules and blood cells
- Three cell layers
 - Endothelial cells
 - Fenestrated (porous) surface
 - Glomerular Basement membrane
 - Podocytes
 - Interdigitating foot processes (pedicels)
 - Slit diaphragms with negative charge





Podocytes – scanning electron microscopy



Pressure

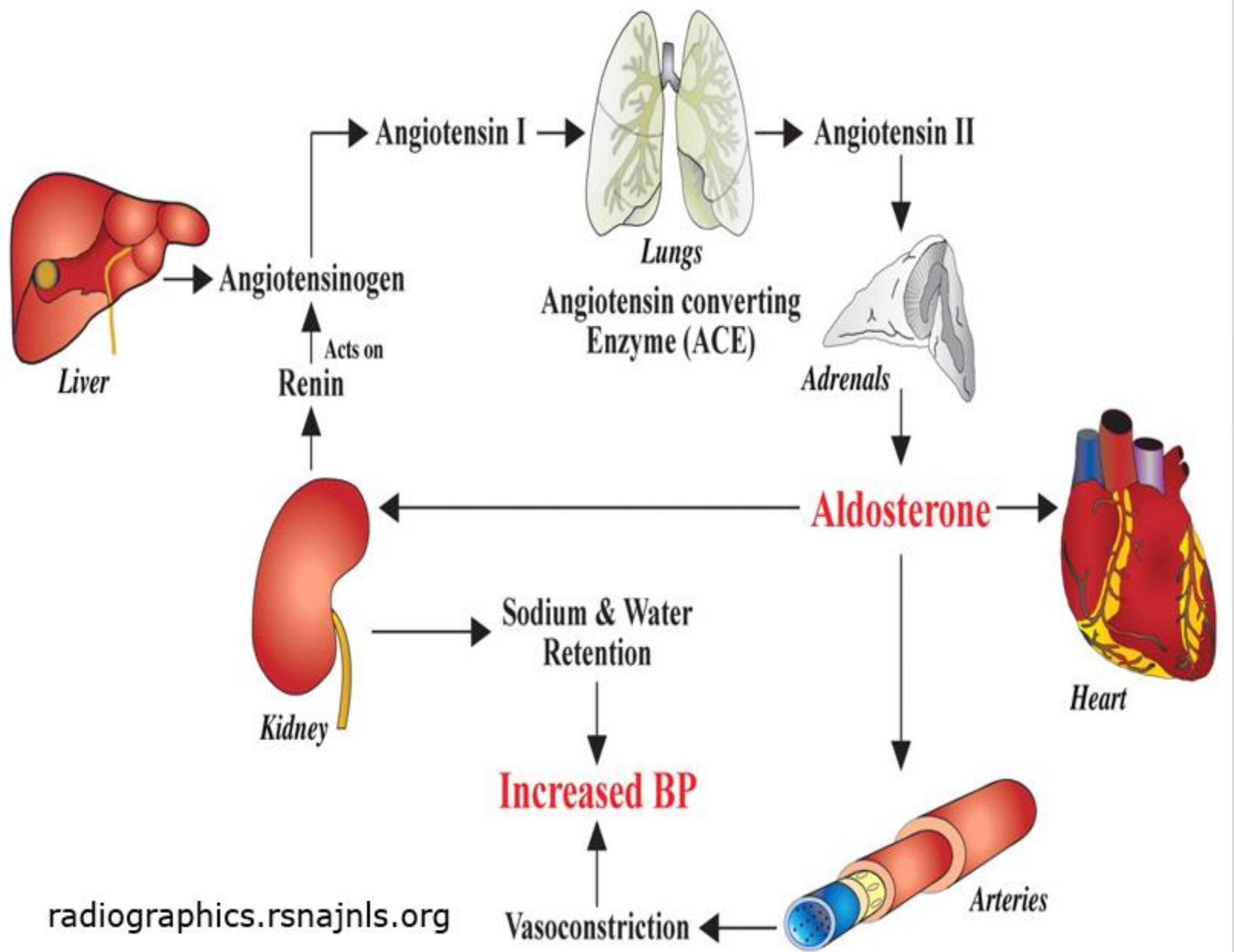
- Hydrostatic
 - Smaller size of glomerular capillaries and efferent arteriole
- Oncotic
 - Unfiltered plasma proteins



RAAS

- Autoregulatory mechanism
 - Low blood pressure
 - Low Na^+ concentration
- Juxtaglomerular apparatus
 - Afferent arteriole
 - Juxtaglomerular cells
 - Distal convoluted tubule
 - Macula densa





Tubular reabsorption

- Urine → blood
- Active transport
 - Proximal convoluted tubule
 - Glucose
 - Amino acids and proteins
 - Sodium and other salts
 - Ascending loop of Henle
 - Chloride
 - Distal convoluted tubule
 - Sodium
 - Calcium (regulated by PTH)



Tubular reabsorption

- Passive transport
 - Proximal convoluted tubule
 - Water
 - Urea
 - Descending loop of Henle
 - Water
 - Ascending loop of Henle
 - Urea
 - Sodium
 - Collecting duct
 - Water



Tubular reabsorption

- Maximal reabsorptive capacity
 - Highest rate at which tubules can transport a substance from the tubules
 - When exceeded, substance appears in urine
- Renal threshold
 - Plasma concentration at which active transport stops
 - Glucose – 160 to 180 mg/dL

Urine concentration

- Loop of Henle (countercurrent mechanism)
 - Descending loop
 - Passive transport of water
 - Ascending loop
 - Impermeable to water
 - Active transport of Na^+ , Cl^-
- Distal convoluted tubule
 - Active transport of Na^+
 - Regulated by aldosterone



Urine concentration

- Collecting duct
 - Final determinant of concentration
 - Reabsorption of water regulated by antidiuretic hormone (ADH)
 - Produced in hypothalamus
 - Production primarily based on state of hydration
 - Dehydrated → more ADH → less urine
 - Hydrated → less ADH → more urine



Tubular secretion

- Blood → Urine
- Two major functions
 - Elimination of waste not filtered by glomerulus
 - Regulation of acid-base balance



Waste elimination

- Primarily through proximal convoluted tubule
 - Protein-bound waste within peritubular capillaries
 - Waste develops stronger affinity with renal tubule cells
 - Disassociation into urine



Acid-base balance

- Blood must buffer and eliminate acid to maintain pH
 - Normal blood pH is 7.4
- Reabsorption of bicarbonate (HCO_3^-)
- Excretion of acid (H^+)
 - Titratable acid (H_2PO_4^-)
 - Ammonium ion (NH_4^+)

Acid-base balance

- All three processes occur simultaneously
- Disruption can result in acidosis
 - Metabolic acidosis
 - Acidemia (can be fatal)
 - Renal tubule acidosis
 - Inability to produce acidic urine
 - Can lead to metabolic acidosis



Renal function tests

- Glomerular filtration tests (GFR)
 - Clearance tests
 - Creatinine clearance
 - Inulin clearance
 - Calculated glomerular filtration estimates
 - Multivariable formulas based on serum creatinine
 - Beta₂microglobulin
 - Cystatin C

Renal function tests

- Tubular reabsorption tests
 - Osmolality / osmolarity
 - Measure of total number of particulates in solution
 - Does not factor in density (SG)
 - More representative of true renal concentrating ability
 - Freezing point
 - Vapor pressure
 - Free water clearance
 - Measures ability to maintain hydration

Renal function tests

- Tubular secretion and renal blood flow tests
 - p-aminohippuric acid (PAH) test
 - Clearance test (peritubular capillaries)
 - Titratable acidity
 - Urinary ammonia



References

Urinalysis and Body Fluids, Susan King Strasinger, Marjorie Schaub Di Lorenzo. Seventh Edition

Leal Herlitz, MD Director of Medical Kidney Pathology, Cleveland Clinic

