Physiology of Urinary system

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3rd Year/ Lecture 1

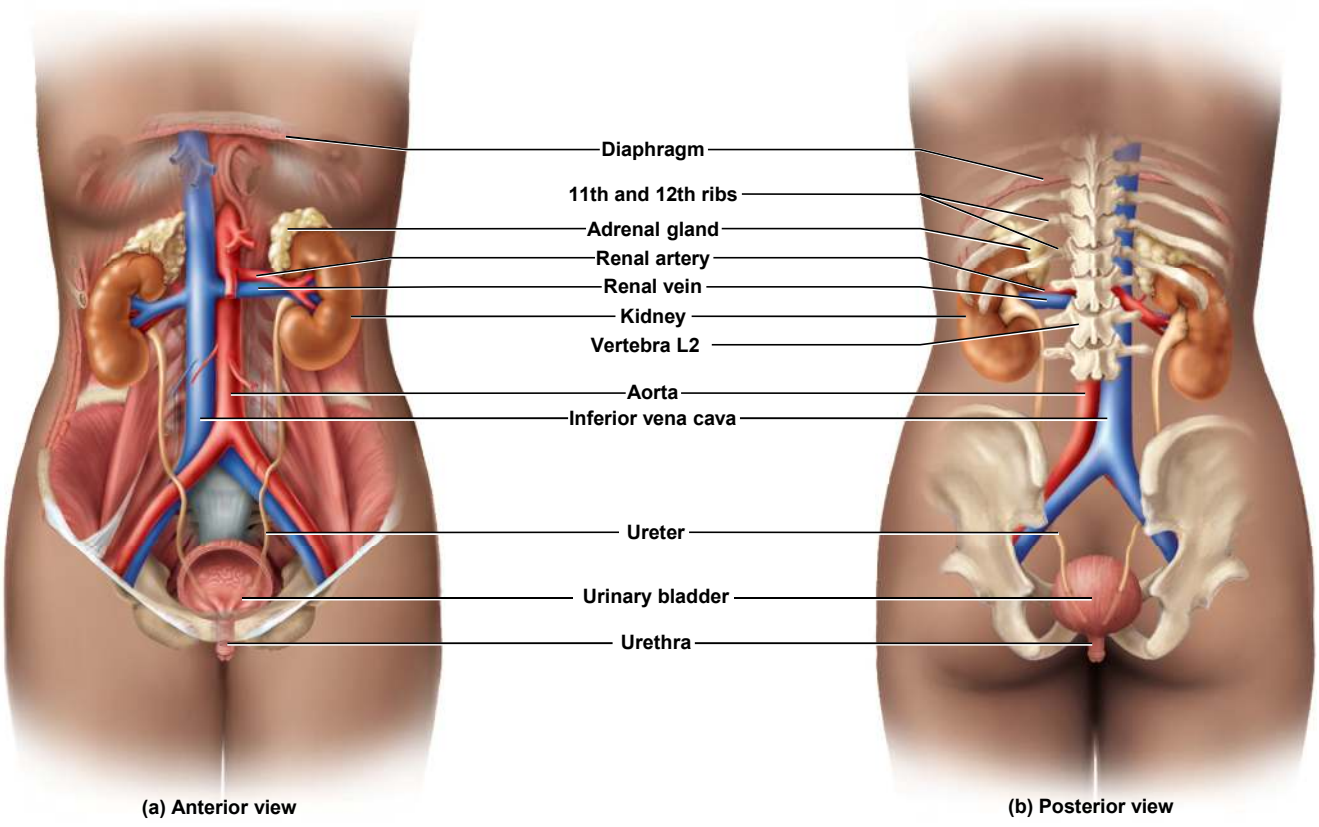
The Urinary System

- functions of urinary system
- anatomy of kidney
- urine formation
  - glomerular filtration
  - tubular reabsorption and secretion
  - water conservation
- urine and renal function tests
- urine storage and elimination

Waste Products & Kidney Function

- '*to live is to metabolize*', and metabolism creates a variety of toxic waste products
- removed from the body by various systems
  - respiratory, digestive, sweat glands and urinary
- **urinary system** – principal means of waste removal
- kidney functions
  - regulate blood volume and pressure, erythrocyte count, blood gases, blood pH, and electrolyte and acid base balance
- urinary system is closely associated with reproductive system
  - 'urogenital system'
  - share embryonic development
  - share adult anatomical relationship
  - male urethra serves as a common passage for urine and sperm
- **urologists** – treat both urinary and reproductive disorders

Urinary System



urinary system consists of 6 organs: Figure 23.1a-b
2 kidneys, 2 ureters, urinary bladder, and urethra

Functions of the Kidney

- filters blood plasma, separates waste from useful chemicals, returns useful substances to blood, **eliminates wastes**
- regulate **blood volume and pressure** by eliminating or conserving water
- regulate the **osmolarity** of the body fluids by controlling the relative amounts of water and solutes eliminated
- secretes enzyme, ***renin***, which activates hormonal mechanisms that control blood pressure and electrolyte balance
- secretes the hormone, ***erythropoietin***, which stimulates the production of red blood cells
- collaborate with the lungs to regulate the P_{CO_2} and **acid-base balance** of body fluids
- final step in synthesizing hormone, ***calcitriol***, which contributes to calcium homeostasis
- **gluconeogenesis** from amino acids in extreme starvation

- **waste** – any substance that is useless to the body or present in excess of the body's needs
- **metabolic waste** – waste substance produced by the body
- **urea formation**
  - proteins→ amino acids → NH_2 removed → forms **ammonia**, liver converts to urea
- **uric acid**
  - product of nucleic acid catabolism
- **creatinine**
  - product of creatine phosphate catabolism
- **blood urea nitrogen (BUN)** – expression of the level of nitrogenous waste in the blood
  - normal concentration of blood urea is 10 – 20 mg/dl
  - **azotemia** – elevated BUN
    - indicates renal insufficiency
  - **uremia** – syndrome of diarrhea, vomiting, dyspnea, and cardiac arrhythmia stemming from the toxicity of nitrogenous waste
    - treatment – hemodialysis or organ transplant

Nitrogenous Wastes

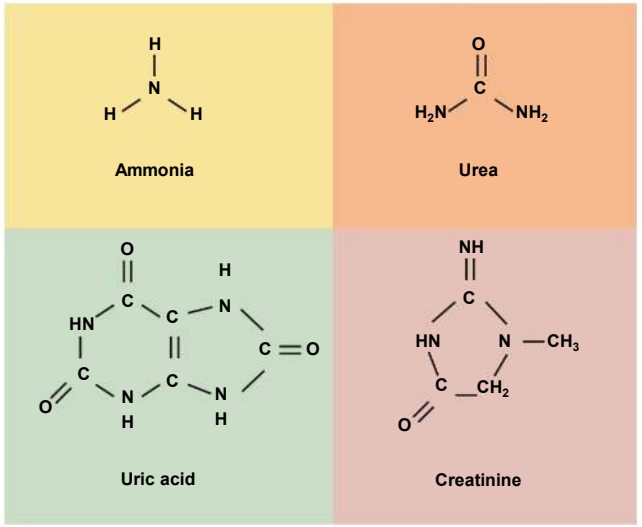
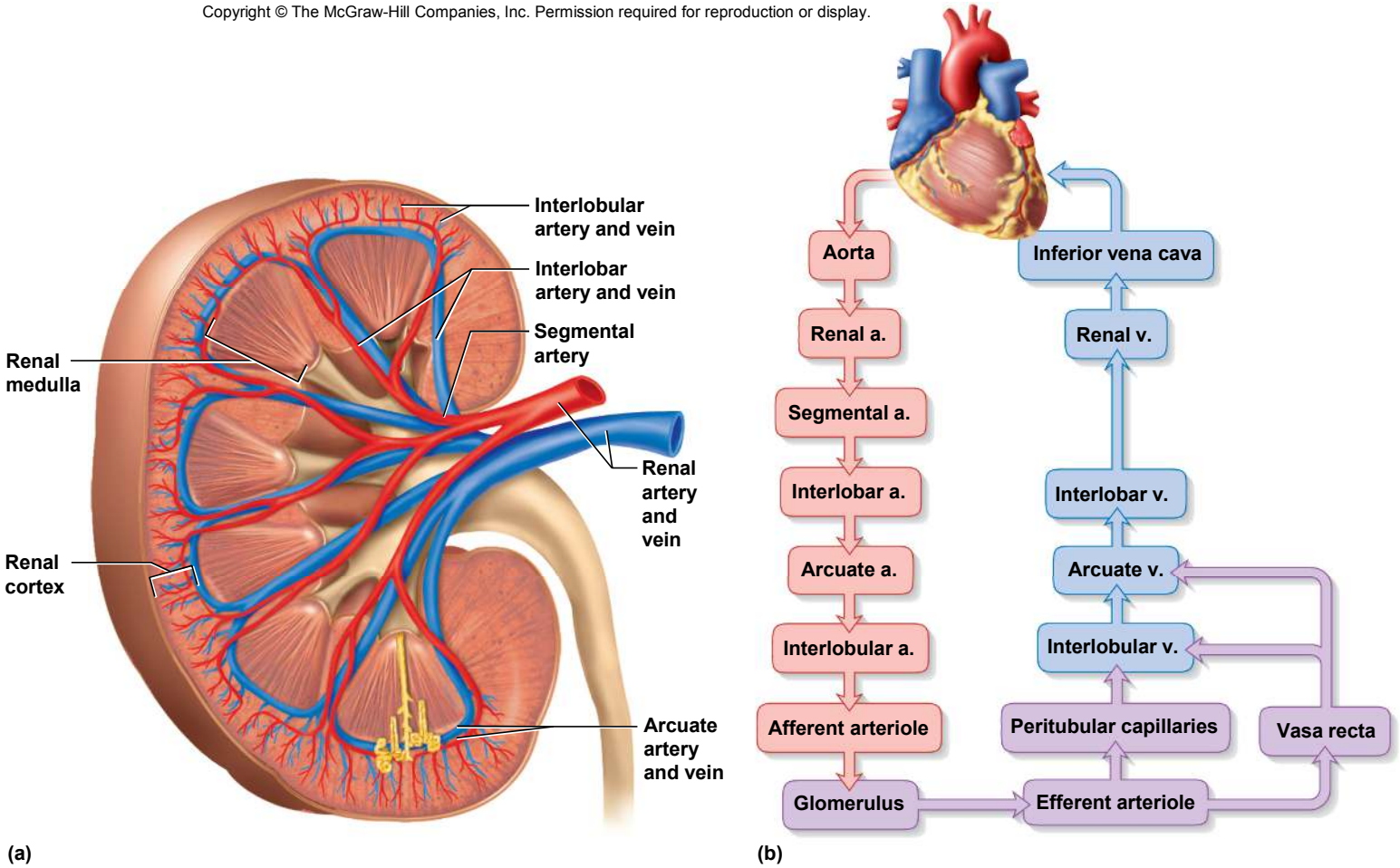


Figure 23.2

Excretion

- **excretion** - separation of wastes from body fluids and eliminating them
- **four body systems** carry out excretion
  - **respiratory system**
    - CO_2 , small amounts of other gases, and water
  - **integumentary system**
    - water, inorganic salts, lactic acid, urea in sweat
  - **digestive system**
    - water, salts, CO_2, lipids, bile pigments, cholesterol, other metabolic waste, and food residue
  - **urinary system**
    - many metabolic wastes, toxins, drugs, hormones, salts, H^+ and water

Blood Supply Diagram



kidneys receive 21% of cardiac output

Figure 23.5 a-b

Renal Circulation

- kidneys account for only 0.4% of body weight, they receive about 21% of the cardiac output (**renal fraction**)

- **renal artery** divides into **segmental arteries** that give rise to
  - **interlobar arteries** - up renal columns, between pyramids
  - **arcuate arteries** - over pyramids
  - **interlobular arteries** - up into cortex
  - branch into **afferent arterioles -** each supplying **one nephron**
    - leads to a ball of capillaries - **glomerulus**
  - blood is drained from the glomerulus by **efferent arterioles**
  - lead to either **peritubular capillaries** or **vasa recta** around portion of the renal tubule
  - **interlobular veins** or directly into **arcuate veins** - **interlobar veins**

- **renal vein** empties into **inferior vena cava**

Microcirculation of the Kidney

- in the cortex, **peritubular capillaries** branch off of the efferent arterioles supplying the tissue near the glomerulus, the proximal and distal convoluted tubules
- in medulla, the efferent arterioles give rise to the **vasa recta,** supplying the nephron loop portion of the nephron.

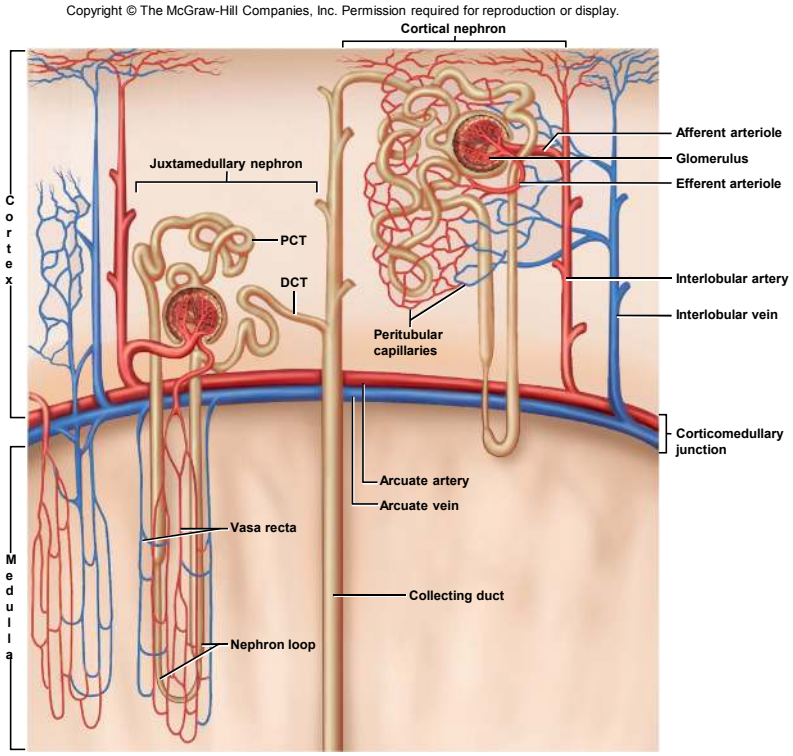


Figure 23.6

The Nephron

- each kidney has about 1.2 million nephrons
- each composed of two principal parts:
  - **renal corpuscle** – filters the blood plasma
  - **renal tubule** – long coiled tube that converts the filtrate into urine
- **renal corpuscle** consists of the **glomerulus** and a two-layered **glomerular (Bowman) capsule** that encloses glomerulus
  - **parietal (outer) layer of Bowman capsule** is simple squamous epithelium
  - **visceral (inner) layer of Bowman capsule** consists of elaborate cells called **podocytes** that wrap around the capillaries of the glomerulus
  - **capsular space** separates the two layers of Bowman capsule
- **vascular pole** – the side of the corpuscle where the afferent arterial enter the corpuscle and the efferent arteriole leaves
- **urinary pole** – the opposite side of the corpuscle where the renal tubule begins

Renal Corpuscle

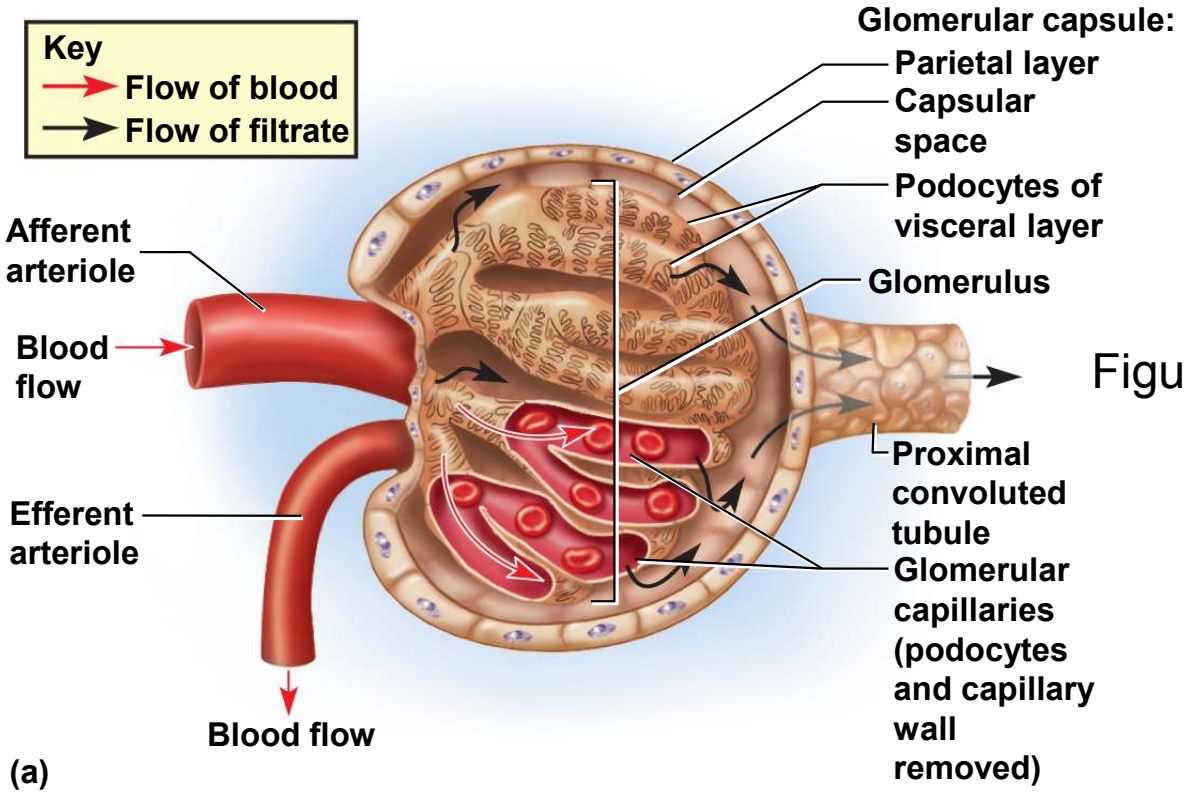


Figure 23.7a

- glomerular filtrate collects in capsular space, flows into proximal convoluted tubule. Note the vascular and urinary poles. Note the afferent arteriole is larger than the efferent arteriole.

Renal Tubule

- **renal (uriniferous) tubule** – a duct that leads away from the glomerular capsule and ends at the tip of the medullary pyramid
- **divided into four regions** –
  - ***proximal convoluted tubule***, ***nephron loop***, ***distal convoluted tubule*** – parts of one nephron
  - ***collecting duct*** receives fluid from many nephrons
- **proximal convoluted tubule** (PCT) – arises from glomerular capsule
  - longest and most coiled region
  - simple cuboidal epithelium with **prominent microvilli** for majority of absorption
- **nephron loop (loop of Henle)** – long U-shaped portion of renal tubule
  - descending limb and ascending limb
  - **thick segments** have simple cuboidal epithelium
    - initial part of descending limb and part or all of the ascending limb
    - heavily engaged in the active transport of salts and have many mitochondria
  - **thin segment** has simple squamous epithelium
    - forms lower part of descending limb
    - cells very permeable to water

Renal Tubule

- **distal convoluted tubule** (DCT) – begins shortly after the ascending limb reenters the cortex
  - shorter and less coiled that PCT
  - cuboidal epithelium without microvilli
  - DCT is the end of the nephron
- **collecting duct** – receives fluid from the DCTs of several nephrons as it passes back into the medulla
  - numerous collecting ducts converge toward the tip of the medullary pyramid
  - **papillary duct** – formed by merger of several collecting ducts
    - 30 papillary ducts end in the tip of each papilla
    - collecting and papillary ducts lined with simple cuboidal epithelium
- flow of fluid from the point where the glomerular filtrate is formed to the point where urine leaves the body:

  glomerular capsule → proximal convoluted tubule → nephron loop → distal convoluted tubule → collecting duct → papillary duct → minor calyx → major calyx → renal pelvis → ureter → urinary bladder → urethra

The Nephron

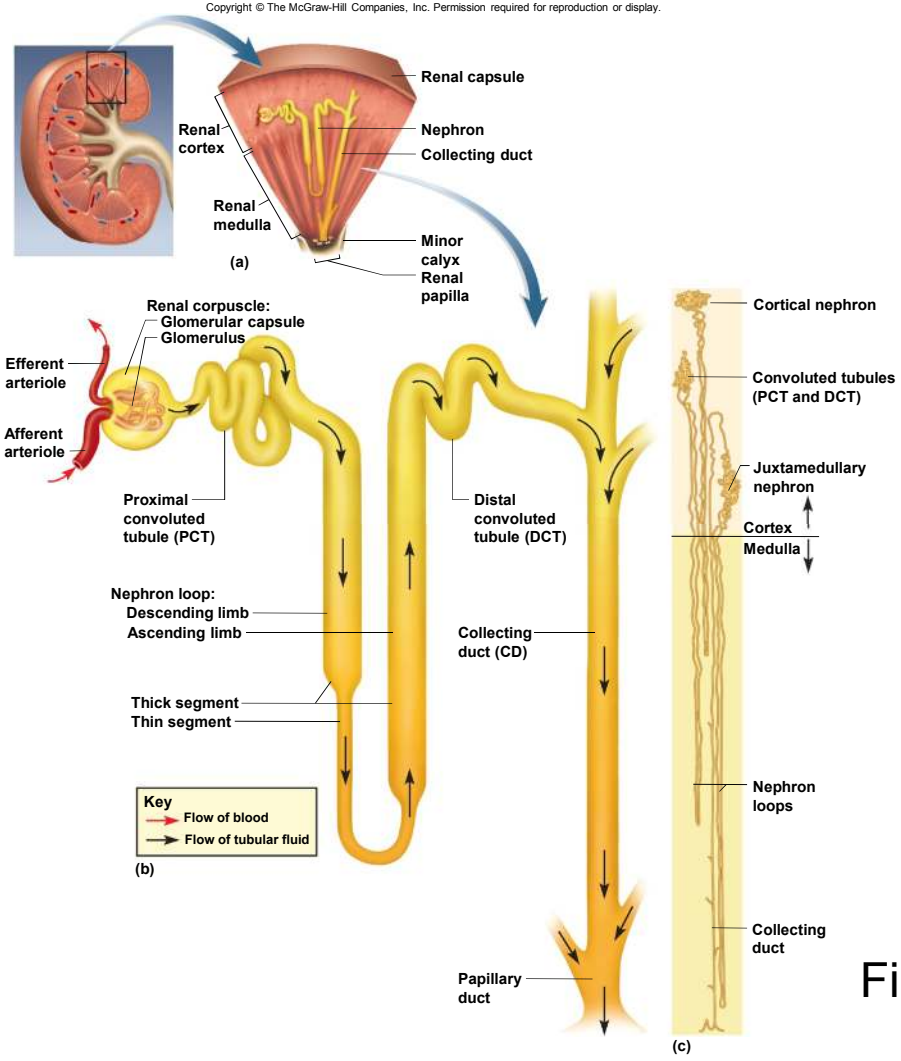


Figure 23.8

Cortical and Juxtamedullary Nephrons

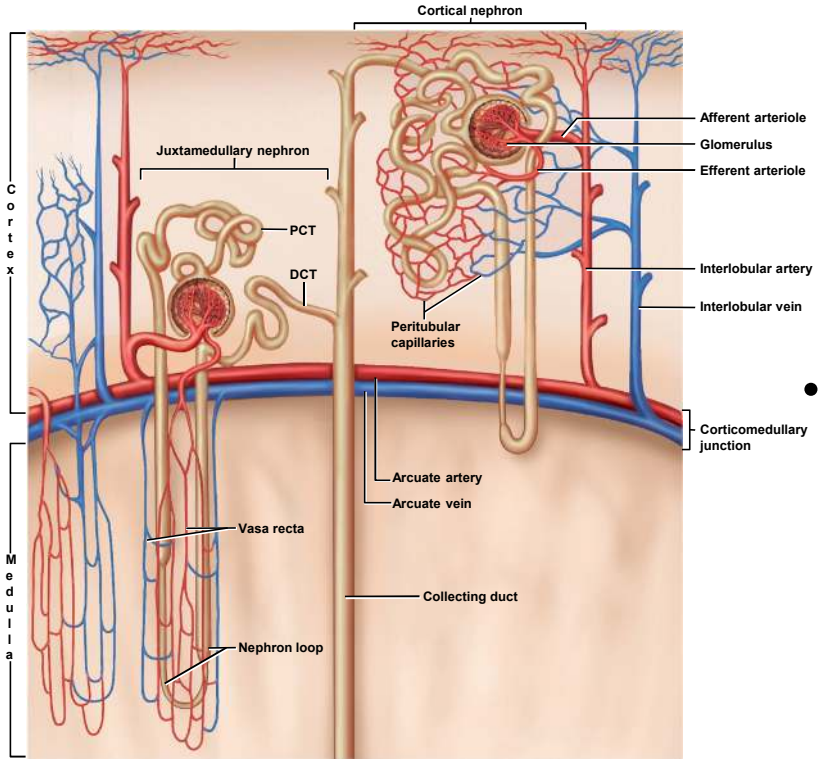


Figure 23.6

- **cortical nephrons**
  - 85% of all nephrons
  - short nephron loops
  - efferent arterioles branch into **peritubular capillaries** around PCT and DCT
- **juxtamedullary nephrons**
  - 15% of all nephrons
  - very long nephron loops, maintain salinity gradient in the medulla and helps conserve water
  - efferent arterioles branch into **vasa recta** around long nephron loop

Renal Innervation

- **renal plexus** – nerves and ganglia wrapped around each renal artery
  - follows branches of the renal artery into the parenchyma of the kidney
  - issues nerve fibers to the blood vessels and convoluted tubules of the nephron
  - carries **sympathetic** innervation from the abdominal aortic plexus
    - stimulation reduces glomerular blood flow and rate of urine production
    - respond to falling blood pressure by stimulating the kidneys to secrete ***renin***, an enzyme that activates hormonal mechanisms to restore blood pressure
  - carries **parasympathetic** innervation from the vagus nerve – increases rate of urine production

Overview of Urine Formation

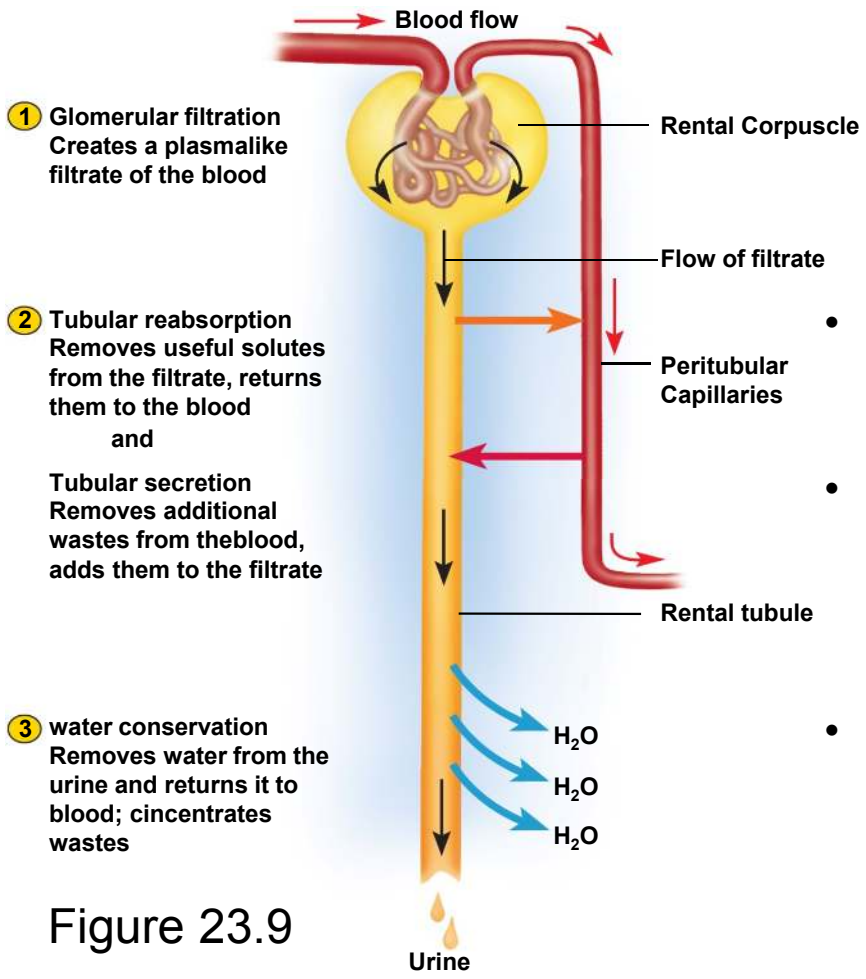


Figure 23.9

- kidneys convert blood plasma to urine in three stages
  - **glomerular filtration**
  - **tubular reabsorption and secretion**
  - **water conservation**
- **glomerular filtrate**
  - fluid in capsular space
  - blood plasma without protein
- **tubular fluid**
  - fluid in renal tubule
  - similar to above except tubular cells have removed and added substances
- **urine**
  - once it enters the collecting duct
  - only remaining change is water content