The Urinary System

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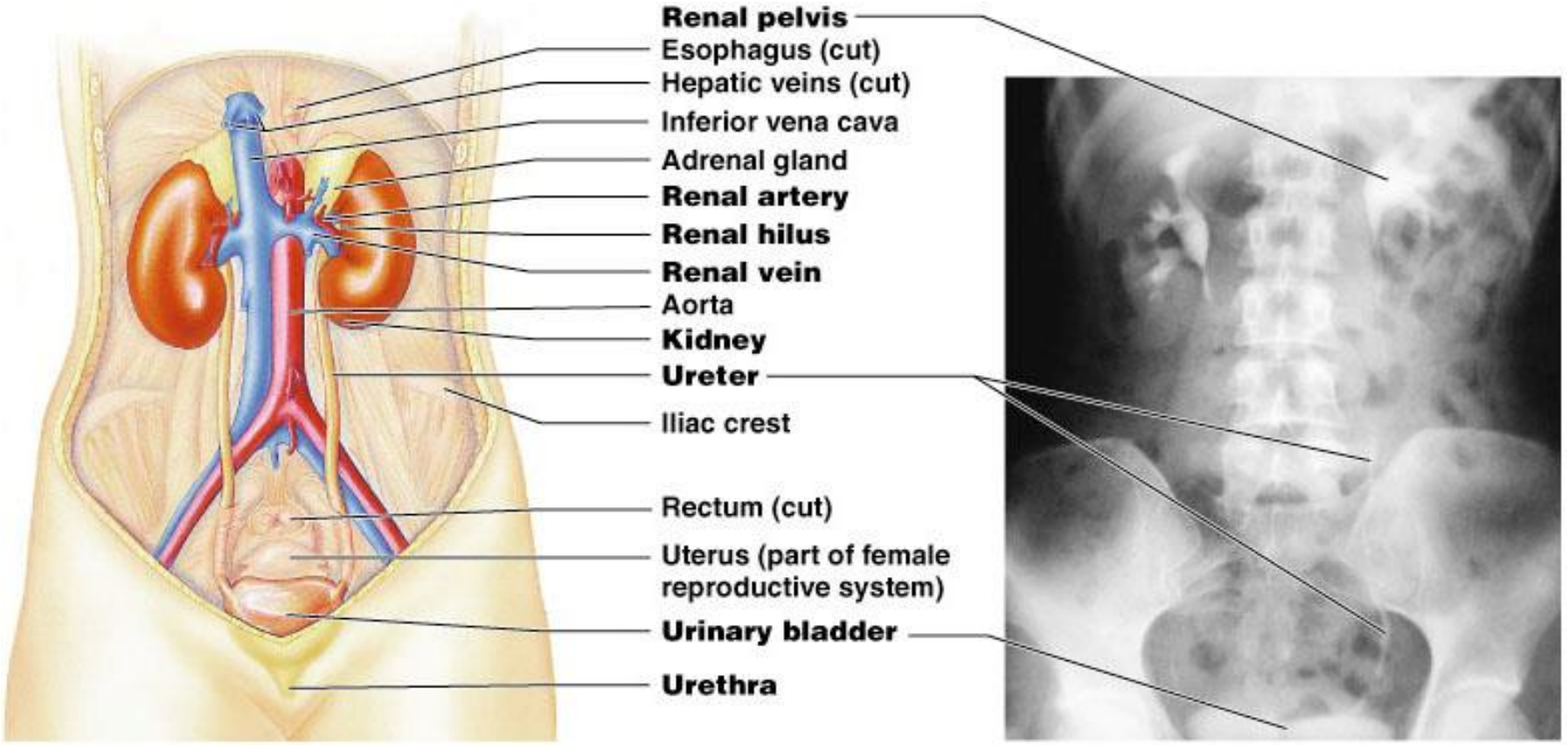
Urinary System

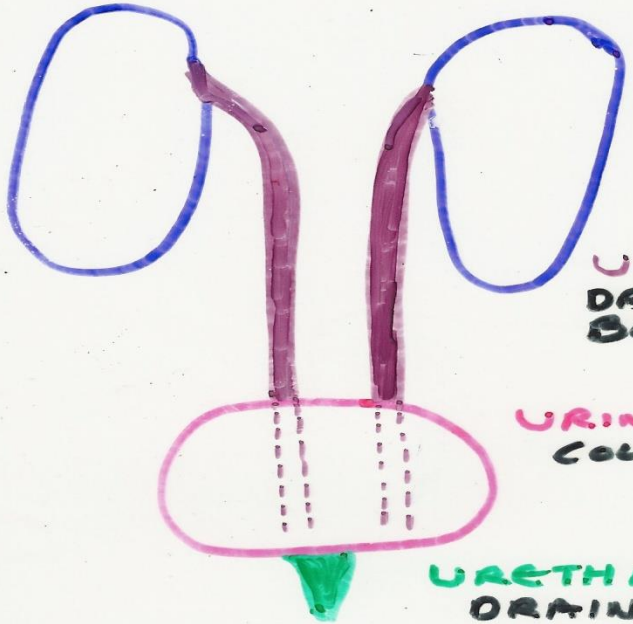


— RENAL SYSTEM —

THERE ARE TWO WAYS TO STUDY KIDNEYS

A) MACROSCOPIC - WHAT WE SEE

B) MICROSCOPIC - HOW THE KIDNEYS ACTUALLY WORK

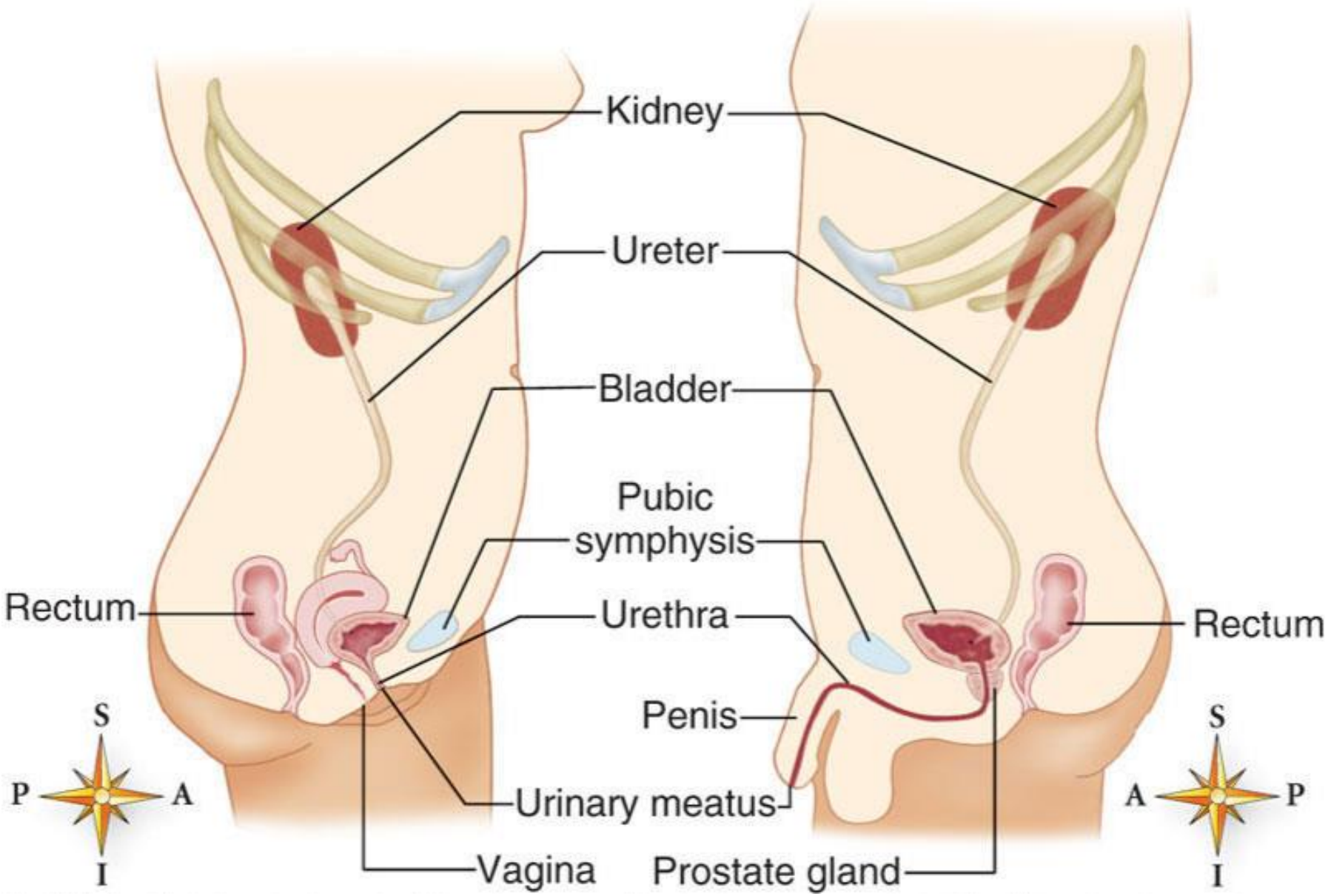


KIDNEYS
PRODUCES & FILTERS URINE

URETERS
DRAINS URINE INTO BLADDER

URINARY BLADDER
COLLECTS URINE

URETHRA
DRAINS URINE FROM BODY
♂ 19-20 CM
♀ 4 CM


Kidney
Ureter
Bladder
Pubic symphysis
Rectum
Urethra
Rectum
Penis
S
P
A
I
Urinary meatus
Vagina
Prostate gland
S
A
P
I

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
- 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

Kidney Location and External Anatomy

- The bean-shaped kidneys lie in a retroperitoneal position in the superior lumbar region and extend from the twelfth thoracic to the third lumbar vertebrae
- The right kidney is lower than the left because it is crowded by the liver
- The lateral surface is convex and the medial surface is concave, with a vertical cleft called the renal hilus leading to the renal sinus
- Ureters, renal blood vessels, lymphatics, and nerves enter and exit at the hilus

- Renal fasciae anchor the kidneys to surrounding structures
- Renal fat pad: heavy cushion of fat that surrounds each kidney
- Hilum: concave notch on medial surface where vessels and tubes enter kidney

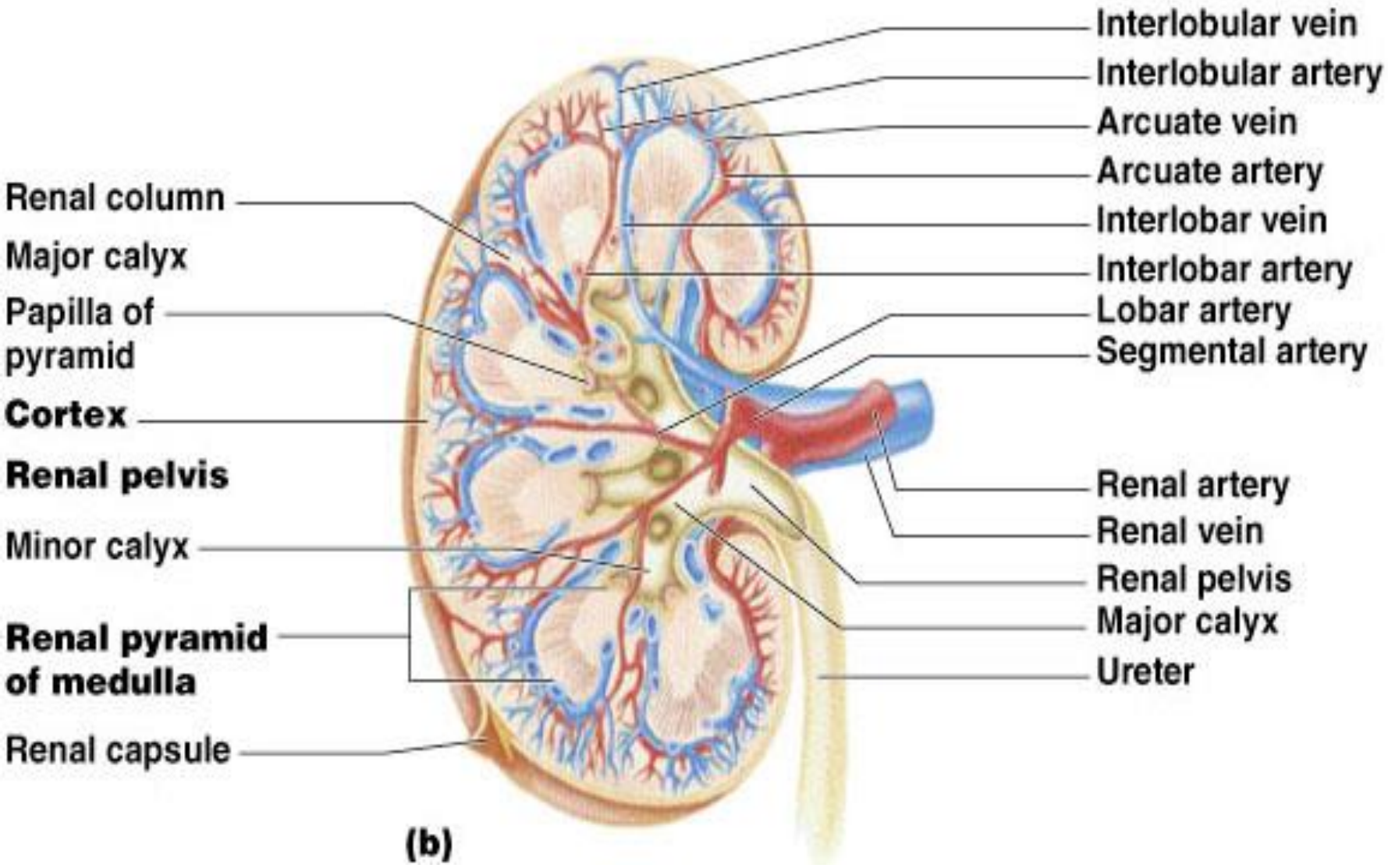
3 Layers of Tissue Around the Kidney

- Fibrous capsule that prevents kidney infection
- Peri-renal fat capsule is a fatty mass that cushions the kidney and helps attach it to the body wall
- Renal fascia is the outer layer of dense fibrous connective tissue that anchors the kidney

Internal Anatomy

- A frontal section shows three distinct regions
  - Cortex – the light colored, granular superficial region
  - Medulla – exhibits cone-shaped medullary (renal) pyramids
    - Pyramids are made up of parallel bundles of urine-collecting tubules
  - Renal pelvis – flat, funnel-shaped tube which is continuous with the ureter leaving the hilum
- Urine flows through the pelvis and ureters to the bladder

Internal Anatomy



Blood and Nerve Supply

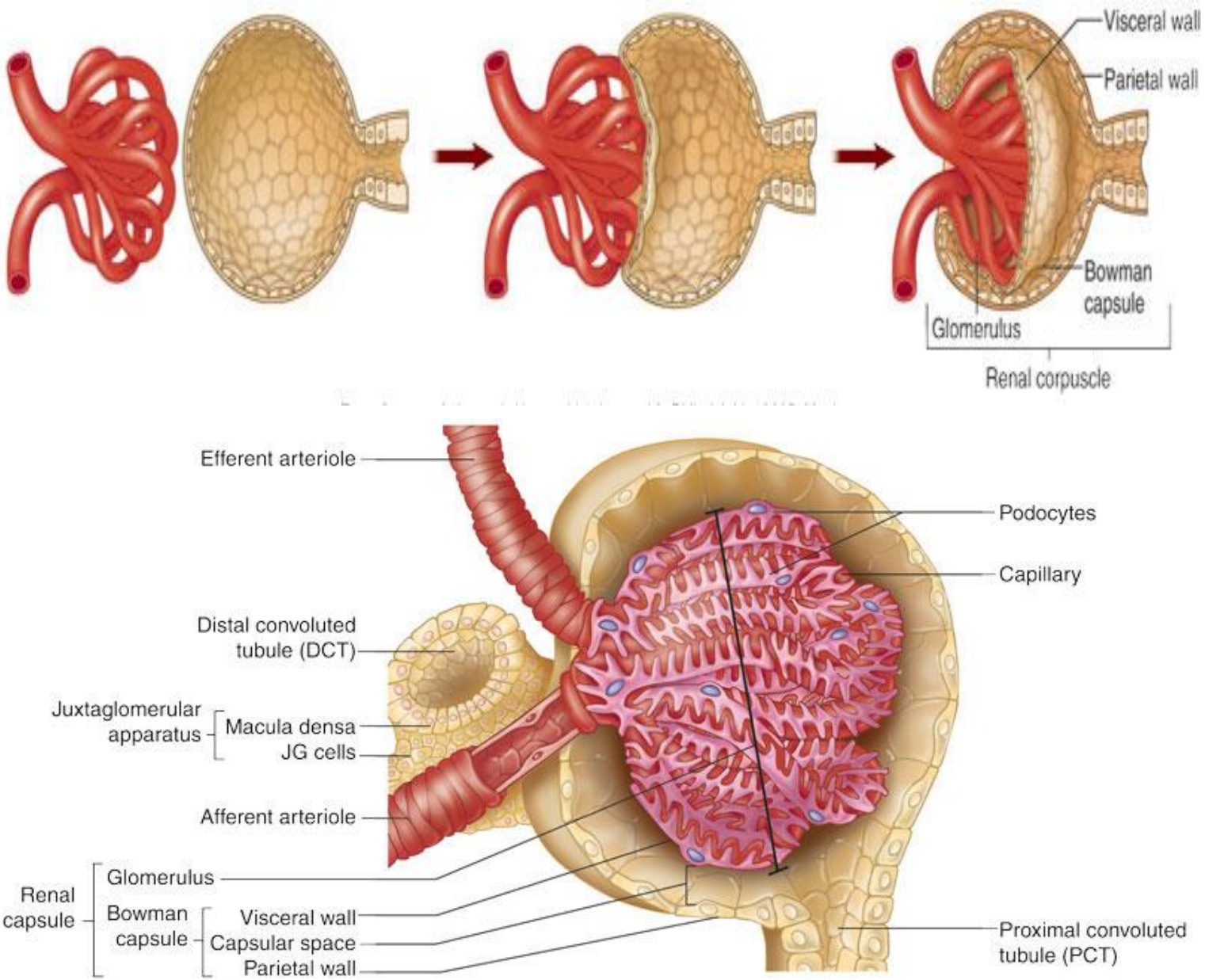
- Approximately one-fourth (1200 ml) of systemic cardiac output flows through the kidneys each minute
- The nerve supply is via the renal plexus

The Nephron

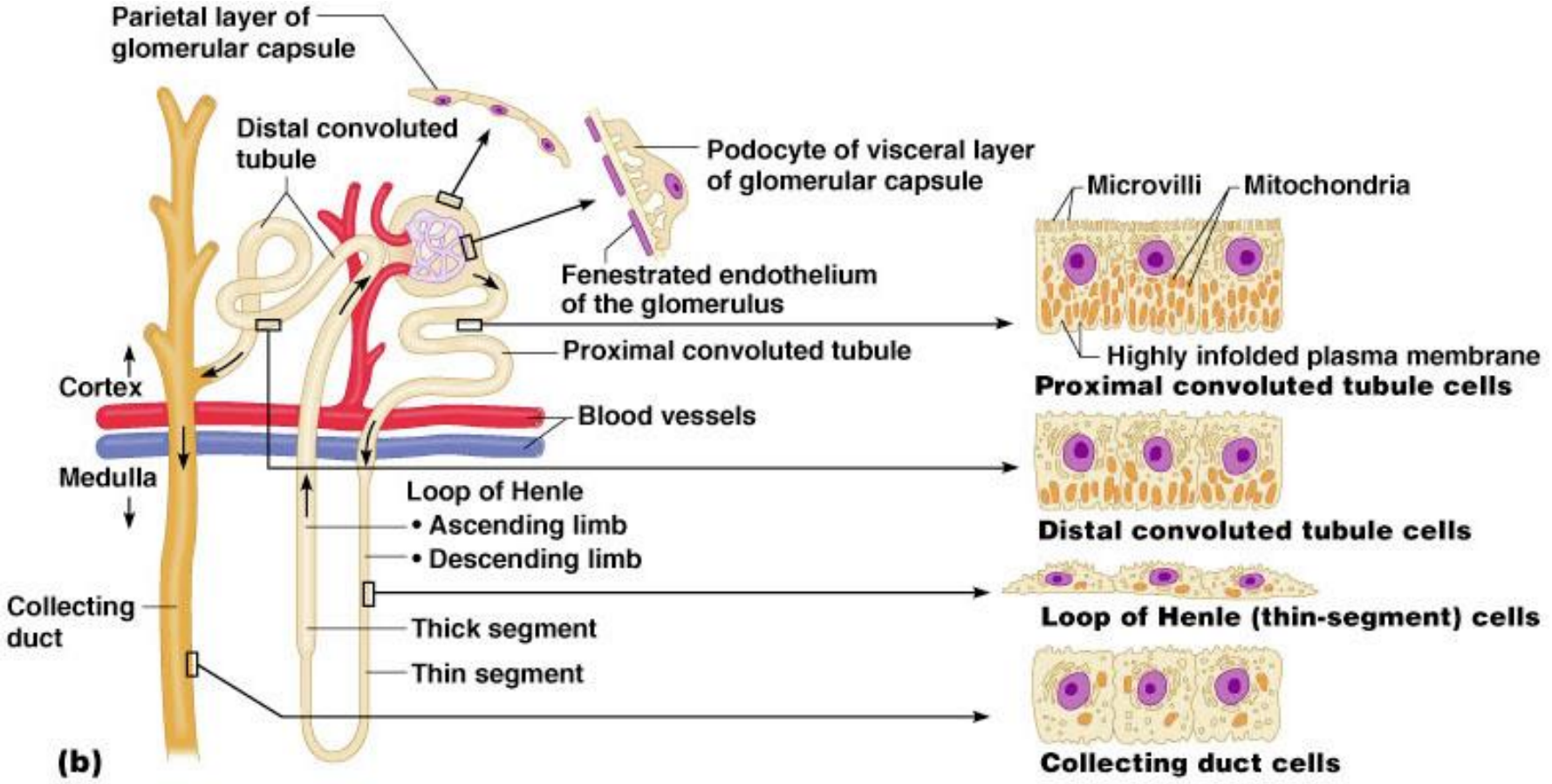
- Nephrons are the structural and functional units that form urine
- Each kidney contains over 1 million blood processing units, which carry out the processes that form urine
- In addition, there are thousands of collecting ducts, which collect fluid from the nephrons and conveys it to the renal pelvis

The Nephron

- Each nephron consists of:
  - Glomerulus – a tuft of capillaries associated with a renal tubule
    - Each glomerulus is:
      - Fed by an afferent arteriole
      - Drained by an efferent arteriole
  - Glomerular (Bowman's) capsule – blind, cup-shaped end of a renal tubule that completely surrounds the glomerulus
- Renal corpuscle – the glomerulus and its Bowman's capsule


Visceral wall
Parietal wall
Bowman capsule
Glomerulus
Renal corpuscle
Efferent arteriole
Podocytes
Capillary
Distal convoluted tubule (DCT)
Juxtaglomerular apparatus
Macula densa
JG cells
Afferent arteriole
Renal capsule
Glomerulus
Bowman capsule
Visceral wall
Capsular space
Parietal wall
Proximal convoluted tubule (PCT)

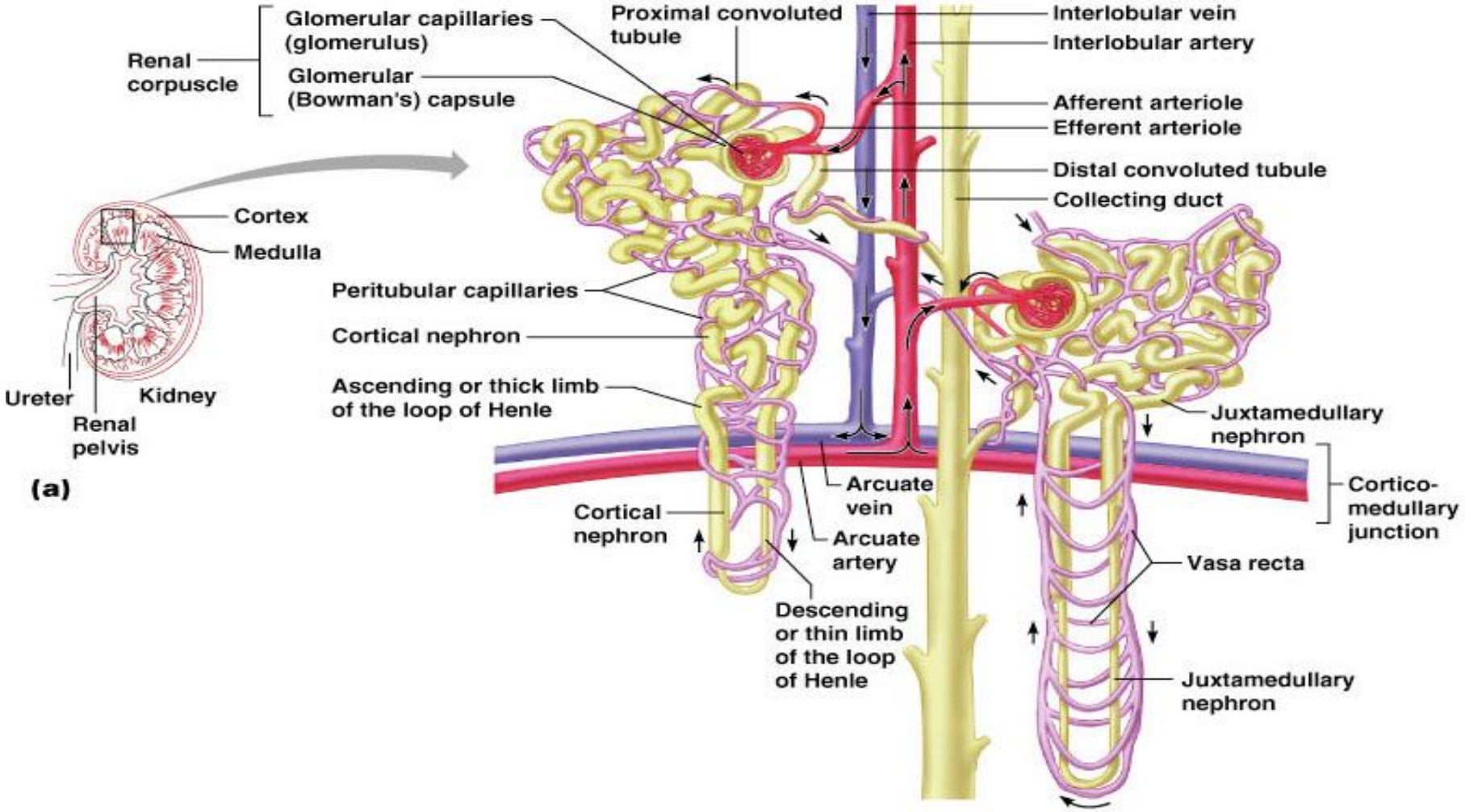
Location & Structure of Nephron



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
  - Are involved in the production of concentrated urine

Capillary Beds



Mechanisms of Urine Formation

- The kidneys filter the body's entire plasma volume 60 times each day
- Kidneys consume 20-25% of all oxygen used by the body at rest
- 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
  - Tubular secretion

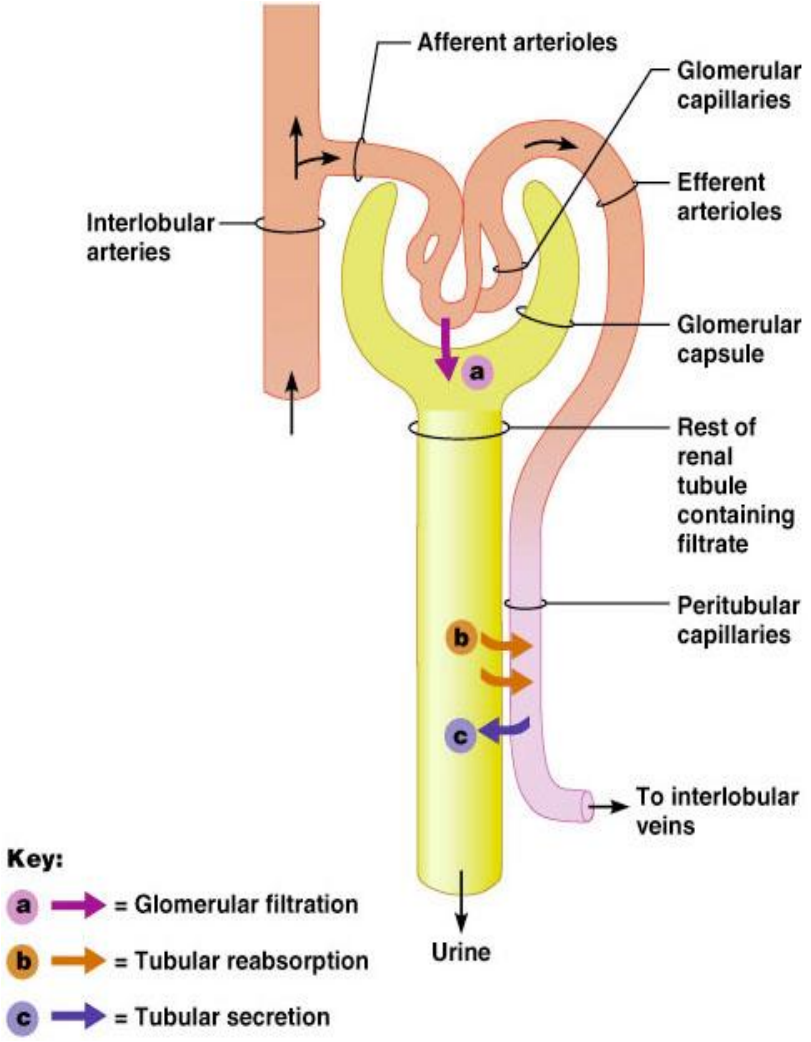


Figure 25.8

Glomerular Filtration

- The glomeruli function as filters
- Substances moving from the blood to the glomerular capsule
- The glomerular filtration rate is about

  125 ml/minute or 180 L/day

Regulation of Glomerular Filtration

- GFR is directly proportional to the net filration pressure
- If the GFR is too high (fast):
  - Needed substances cannot be reabsorbed quickly enough and are lost in the urine
- If the GFR is too low (slow):
  - Everything is reabsorbed, including wastes that are normally disposed of
- Three mechanisms control the GFR
  - Renal autoregulation (intrinsic)
  - Neural controls
  - Hormonal mechanism (extrinsic)

Regulation of Urine Concentration and Volume

- The ability of the kidneys to maintain the internal environment rests in a large part on their ability to concentrate urine by reabsorbing large volumes of water
- The distal convoluted tubule and the collecting duct are impermeable to water, so water may be excreted as dilute urine
- Osmolality
  - The number of solute particles dissolved in 1L of water
  - Reflects the solution's ability to cause osmosis
- This is accomplished by the countercurrent mechanism

Tubular Reabsorption

- During tubular reabsorption, needed substances are removed from the renal tubule into the interstitial fluid where they diffuse into the peritubular capilarries
- Certain substances (creatinine, drug metabolites) are not reabsorbed or are reabsorbed incompletely because of lack of carriers or their size
- Most of the nutrients, 70% water and sodium, are reabsorbed in the proximal convoluted tubules
- Reabsorption of additional sodium and water in the distal tubules and collecting ducts and is hormonally controlled

Tubular Secretion

- Essentially reabsorption in reverse, where substances move from peritubular capillaries or tubule cells into the fluid of the renal tubules
- Tubular secretion is important for:
  - Eliminating drugs
  - Eliminating wastes such as urea and uric acid
  - Ridding the body of excess ions
  - Controlling blood pH

Formation of Dilute Urine

- Dilute urine is created by allowing this filtrate to continue into the renal pelvis
- This will happen as long as antidiuretic hormone (ADH) is not being secreted
- Collecting ducts remain impermeable to water; no further water reabsorption occurs
- Sodium and selected ions can be removed by active and passive mechanisms

Formation of Concentrated Urine

- Antidiuretic hormone (ADH) inhibits diuresis
- In the presence of ADH, 99% of the water in filtrate is reabsorbed
- Water reabsorption that is dependant on ADH called facultative water reabsorption
- ADH is the signal to produce concentrated urine

Diuretics

- Chemicals that enhance the urinary output include:
  - Any substance not reabsorbed
  - Substances that exceed the ability of the renal tubules to reabsorb it
- Osmotic diuretics include:
  - High glucose levels – carries water out with the glucose
  - Alcohol – inhibits the release of ADH
  - Caffeine and most diuretic drugs – inhibit sodium ion reabsorption
  - Lasix and Diuril – inhibit Na^+-associated symporters

Physical Characteristics of Urine

- Color and transparency
  - Clear, pale to deep yellow
    - Due to urochrome – a pigment that results from the body's destruction of hemoglobin
  - Concentrated urine has a deeper yellow color
  - Drugs, vitamin supplements, and diet can change the color of urine
  - Cloudy urine may indicate infection of the urinary tract

Physical Characteristics of Urine

- Odor
  - Fresh urine is slightly aromatic
  - Standing urine develops an ammonia odor
    - As bacteria metabolizes the urea solutes
  - Some drugs, vegetables and diseases alter the odor
    - Uncontrolled diabetes urine smells fruity because of acetone content

Physical Characteristics of Urine

- pH
  - Slightly acidic (pH 6)
  - Diet or metabolism can alter pH (range of 4.5 to 8.0)
  - A acidic diet (protein and wheat products) creates acidic urine
  - An alkaline diet (vegetarian), prolonged vomiting, and UTI all cause alkaline urine

Chemical Composition of Urine

- Urine is 95% water and 5% solutes
- Nitrogenous wastes include urea, uric acid, and creatinine
- Other normal solutes include:
  - Sodium, potassium, phosphate, and sulfate ions
  - Calcium, magnesium, and bicarbonate ions
- Toxins: during disease, bacterial poisons leave the body in urine
- Pigments, especially urochromes
- Hormones: high hormone levels may spill into the filtrate
- Abnormally high concentrations of any urinary constituents may indicate pathology
  - Blood, glucose, albumin, casts, calculi

Ureters

- Slender tubes that convey urine from the kidneys to the bladder
- Ureter: tube running from each kidney to the urinary bladder; composed of three layers: mucous lining, muscular middle layer, and fibrous outer layer
- Ureters enter the base of the bladder through the posterior wall
  - This closes their distal ends as bladder pressure increases and prevents backflow of urine into the ureters
- Ureters actively propel urine to the bladder via response to smooth muscle stretch

Urinary Bladder

- Functions
  - Reservoir for urine before it leaves the body
  - Aided by the urethra, it expels urine from the body
- Smooth, collapsible, muscular sac that temporarily stores urine
- It lies retroperitoneally on the pelvic floor posterior to the pubic symphysis
  - Males – prostate gland surrounds the neck inferiorly
  - Females – anterior to the vagina and uterus
- Trigone – triangular area outlined by the openings for the ureters and the urethra
  - Clinically important because infections persist here

Urinary Bladder

- The bladder is distensible and collapses when empty
- As urine accumulates, the bladder expands without significant rise in internal pressure
- The muscular layer of the bladder is called the detrusor muscle (“to thrust out”)
- The bladder maximum capacity is 800-1000ml (quart)

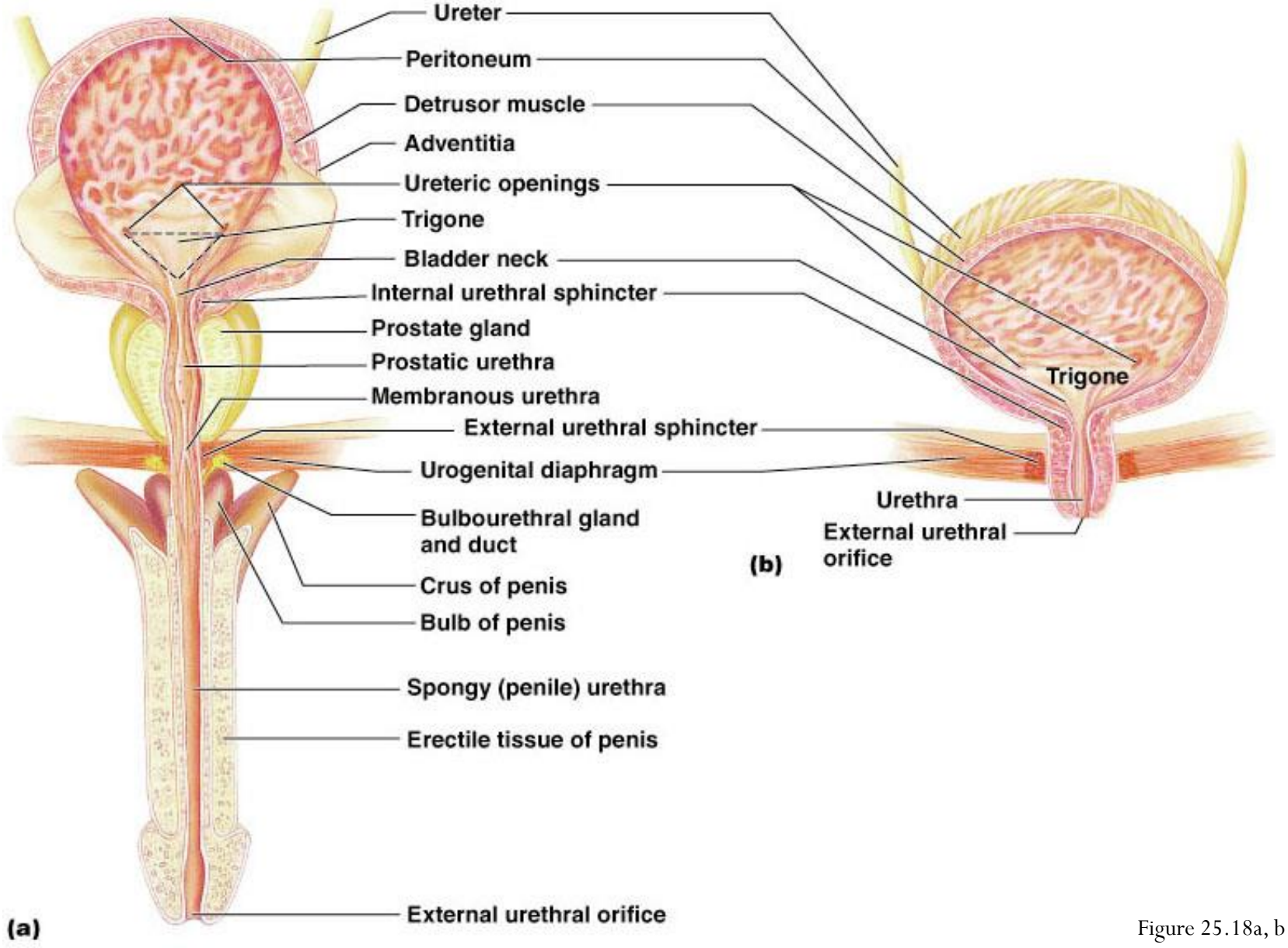


Figure 25.18a, b

Urethra

- Muscular tube that:
  - Drains urine from the bladder
  - Conveys it out of the body
- Sphincters keep the urethra closed when urine is not being passed
  - Internal urethral sphincter – involuntary sphincter at the bladder-urethra junction
  - External urethral sphincter – voluntary sphincter surrounding the urethra as it passes through the urogenital diaphragm
  - Levator ani muscle – voluntary urethral sphincter

Urethra

- The female urethra is tightly bound to the anterior vaginal wall
- Its external opening lies anterior to the vaginal opening
- The male urethra has three named regions
  - Prostatic urethra – runs within the prostate gland
  - Membranous urethra – runs through the urogenital diaphragm
  - Spongy (penile) urethra – passes through the penis and opens via the external urethral orifice

- Small mucous membrane–lined tube extending from the trigone to the exterior of the body
- In females, lies posterior to the pubic symphysis and anterior to the vagina; approximately 3 cm long
- In males, after leaving the bladder, passes through the prostate gland where it is joined by two ejaculatory ducts; from the prostate, it extends to the base of the penis, then through the center of the penis, ending as the urinary meatus; approximately 20 cm long; part of the urinary system as well as the reproductive system

Micturition (Voiding or Urination)

- The act of emptying the bladder
- Distension of bladder walls initiates spinal reflexes that:
  - Stimulate contraction of the external urethral sphincter
  - Inhibit the detrusor muscle and internal sphincter (temporarily)
- Voiding reflexes:
  - Stimulate the detrusor muscle to contract
  - Inhibit the internal and external sphincters

Developmental Aspects

- Infants have small bladders and the kidneys cannot concentrate urine, resulting in frequent micturition
- Control of the voluntary urethral sphincter develops with the nervous system
- *E. coli* bacteria account for 80% of all urinary tract infections
- Sexually transmitted diseases can also inflame the urinary tract
- Kidney function declines with age, with many elderly becoming incontinent

Lifespan Changes

- The urinary system is sufficiently redundant, in both structure and function, to mask age-related changes
- The kidneys become slower to remove nitrogenous wastes and toxins and to compensate for changes that maintain homeostasis
- Changes include:
  - The kidneys appear scarred and grainy
  - Kidney cells die
  - By age 80 the kidneys have lost a third of their mass
  - Kidney shrinkage is due to loss of glomeruli
  - Proteinuria may develop
  - The renal tubules thicken
  - It is harder for the kidneys to clear certain substances
  - The bladder, ureters, and urethra lose elasticity
  - The bladder holds less urine

Clinical Terms

- *Continent – ability to hold or retain urine*
- *Non continent – urine cannot be held and drains continually*
- *Incontinent – Involuntary discharge*
- *SUI – Stress Urinary Incontinence – involuntary discharge with coughing, sneezing or straining*