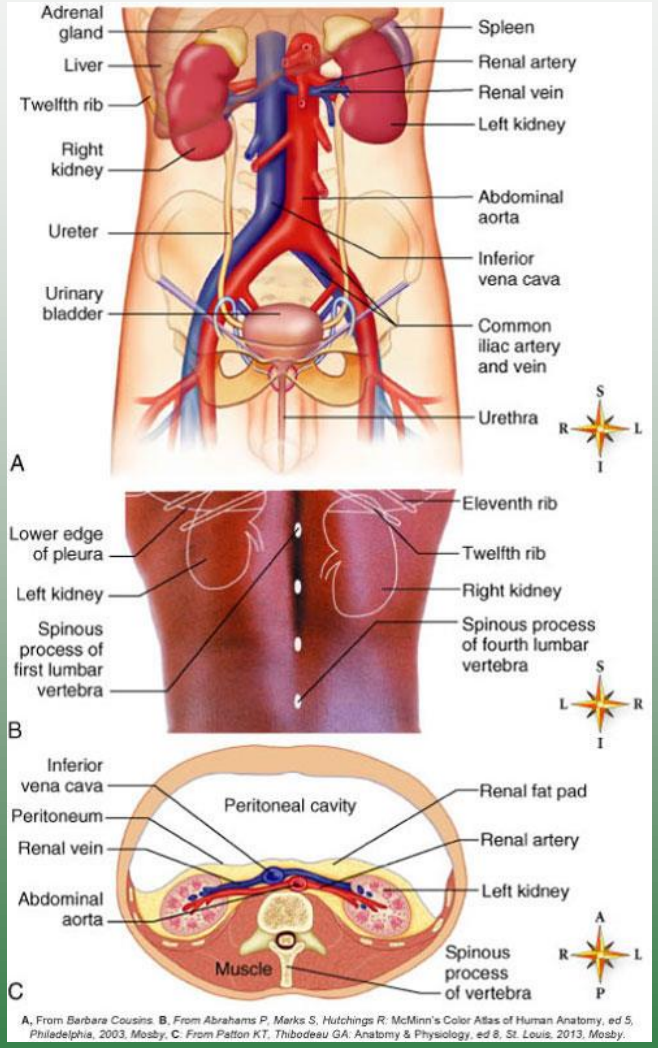
Chapter 18

Urinary System Disorders

Urinary System

- Anatomy
  - Kidneys
  - ↓
  - Ureters
  - ↓
  - Urinary bladder
  - ↓
  - Urethra



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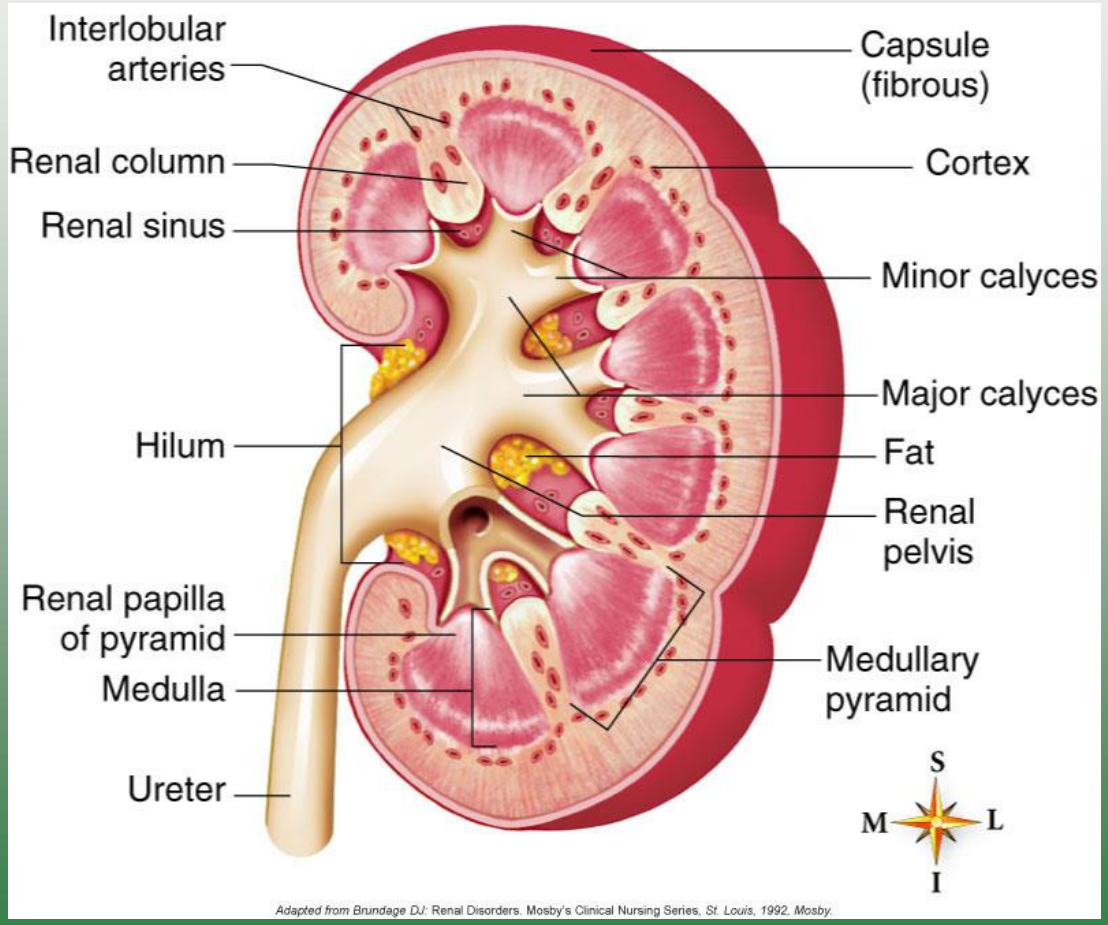
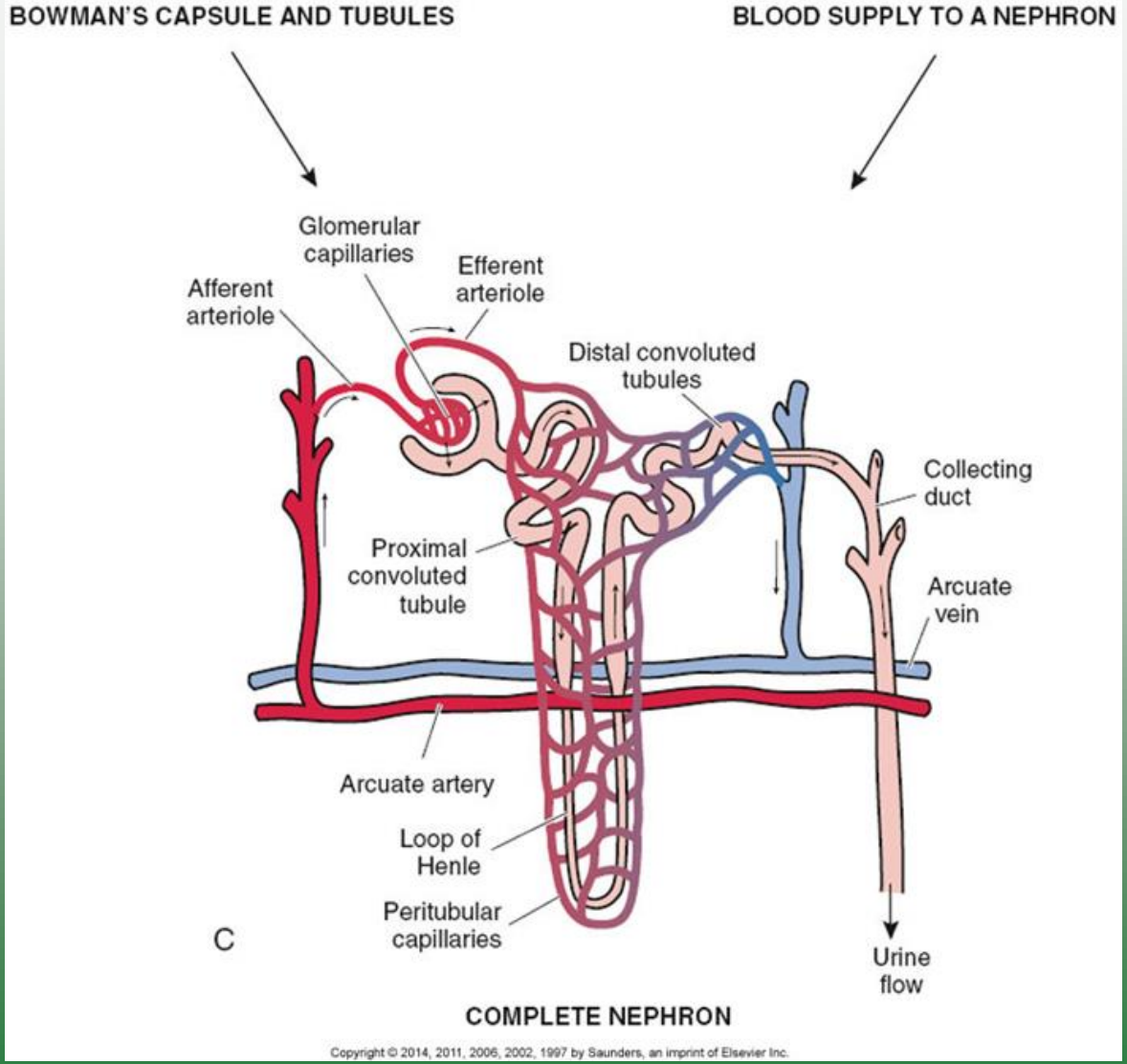
Urinary System: Review

- Removes metabolic wastes
- Removes hormones from the body
- Removes drugs other foreign material from body
- Regulates water, electrolyte, acid-base balance
- Secretes erythropoietin
- Activates vitamin D
- Regulate blood pressure through the renin-angiotensin-aldosterone system

Anatomy of the Kidney

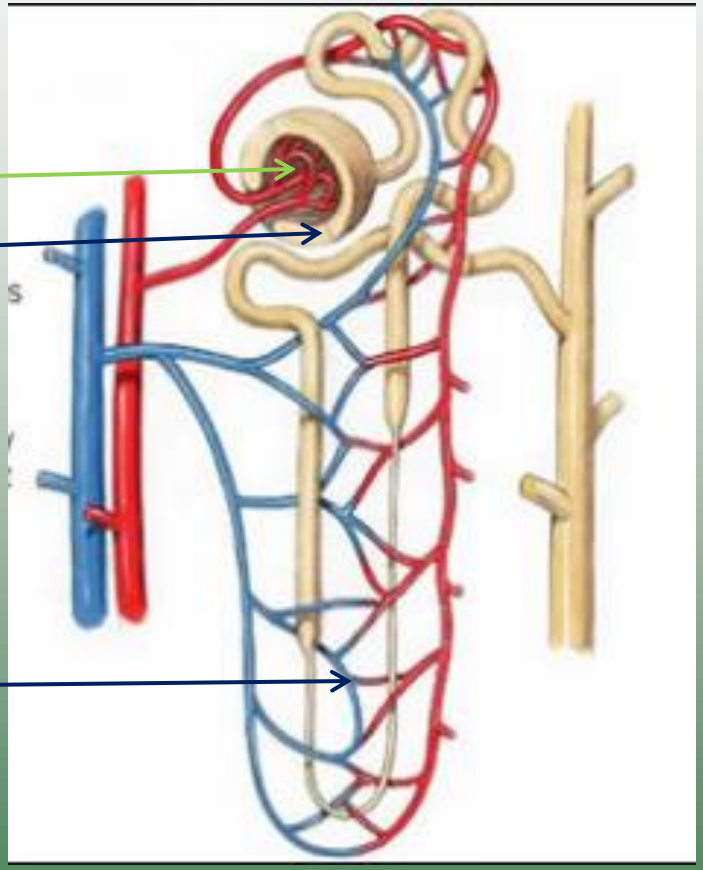


Nephrons: functional units of the kidneys



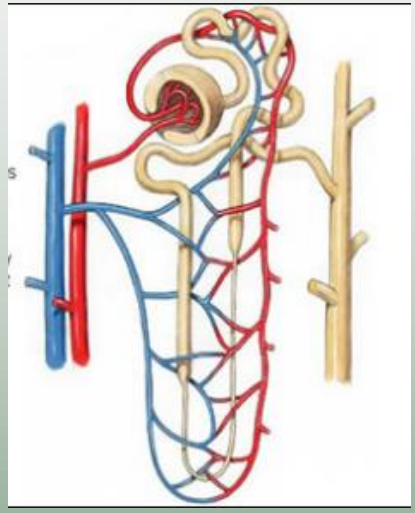
Formation of Urine

- Filtration
  - In renal corpuscles
  - Large volume of fluid passes from glomerular capillaries
  - into the tubule (Bowman capsule)
    - Wastes, nutrients, electrolytes, other dissolved substances
    - Cells and protein remain in the blood.
- Reabsorption
  - Reabsorption of essential nutrients, water, and electrolytes into the peritubular capillaries
  - Control of pH and electrolytes

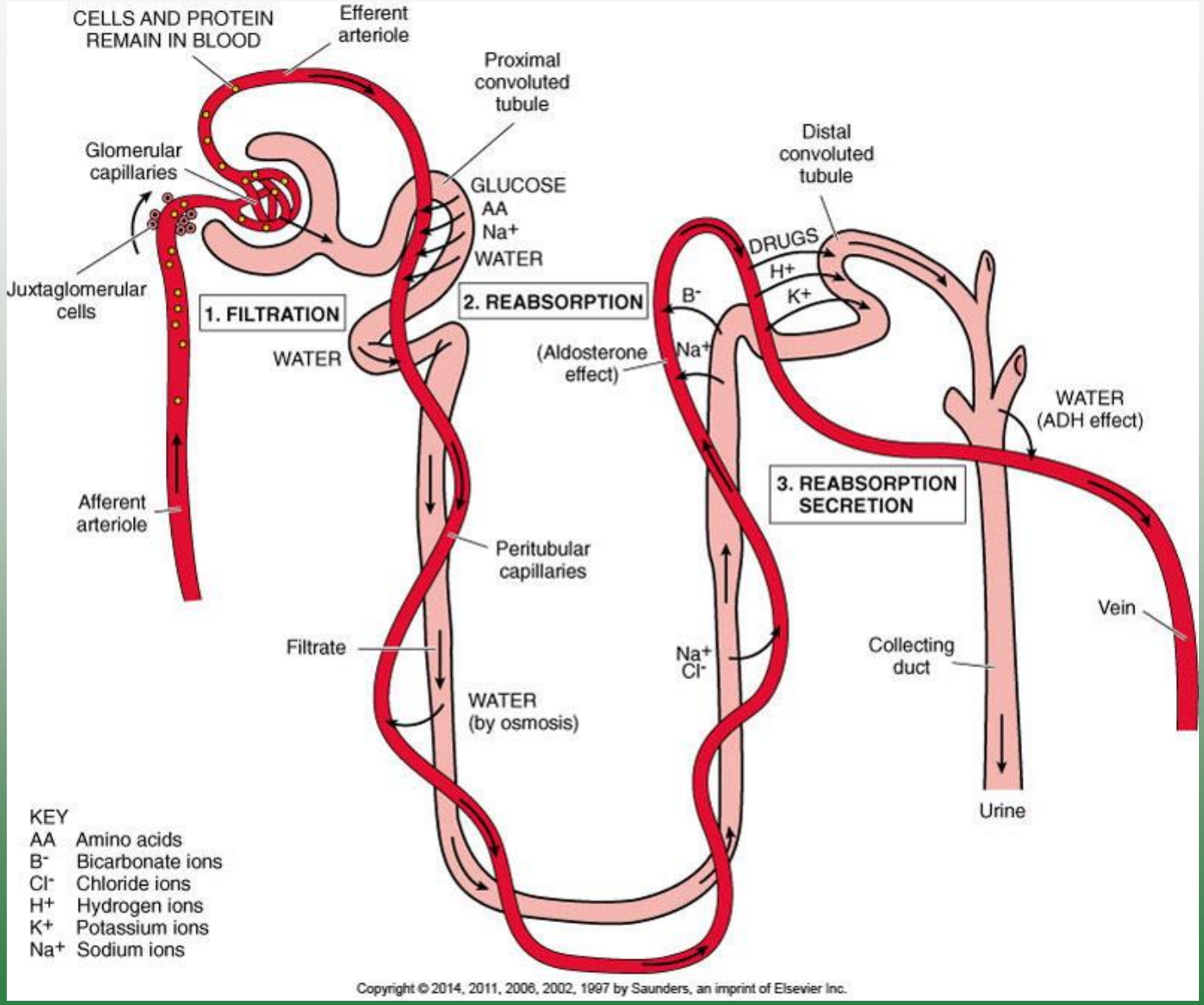


Reabsorption

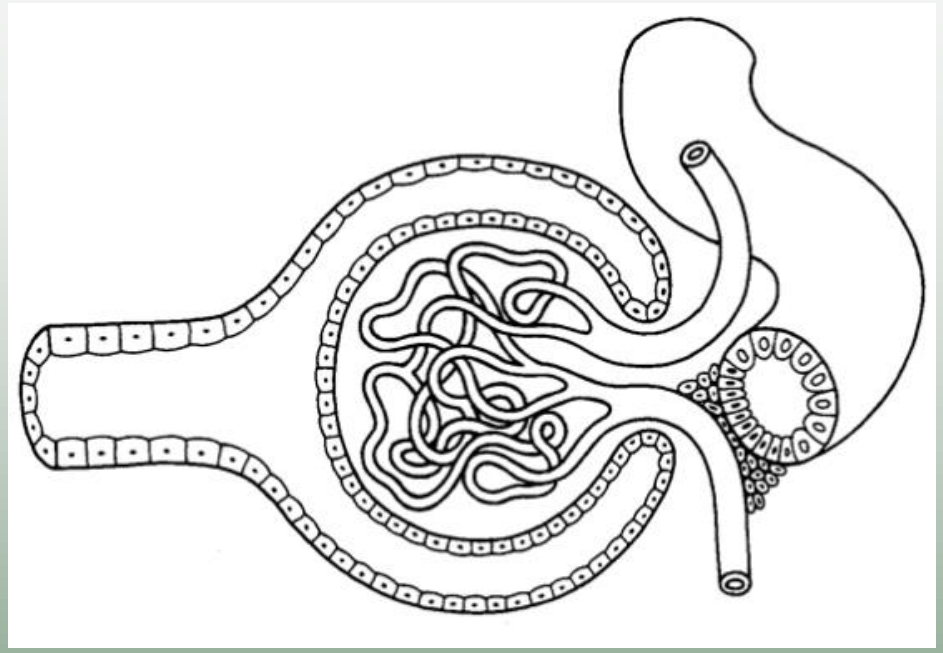
- Transport mechanisms for reabsorption
  - Active transport
  - Co-transport
  - Osmosis—water
- Proximal convoluted tubules
  - Most of water reabsorption
  - Glucose reabsorption
  - Nutrients and electrolytes to maintain homeostasis



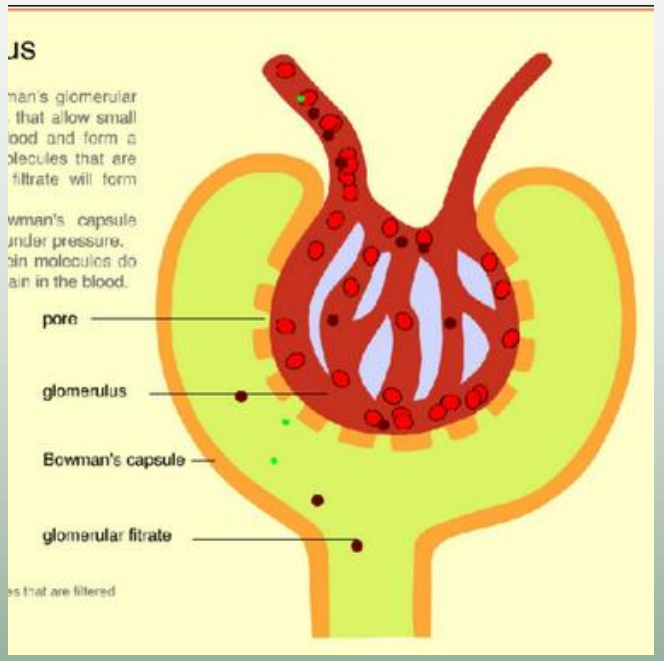
Schematic Illustration of Urine Formation



Additional views of glomerulus:



This figure shows how Bowman's capsule forms with a visceral and parietal layer (like pleura does in lungs).



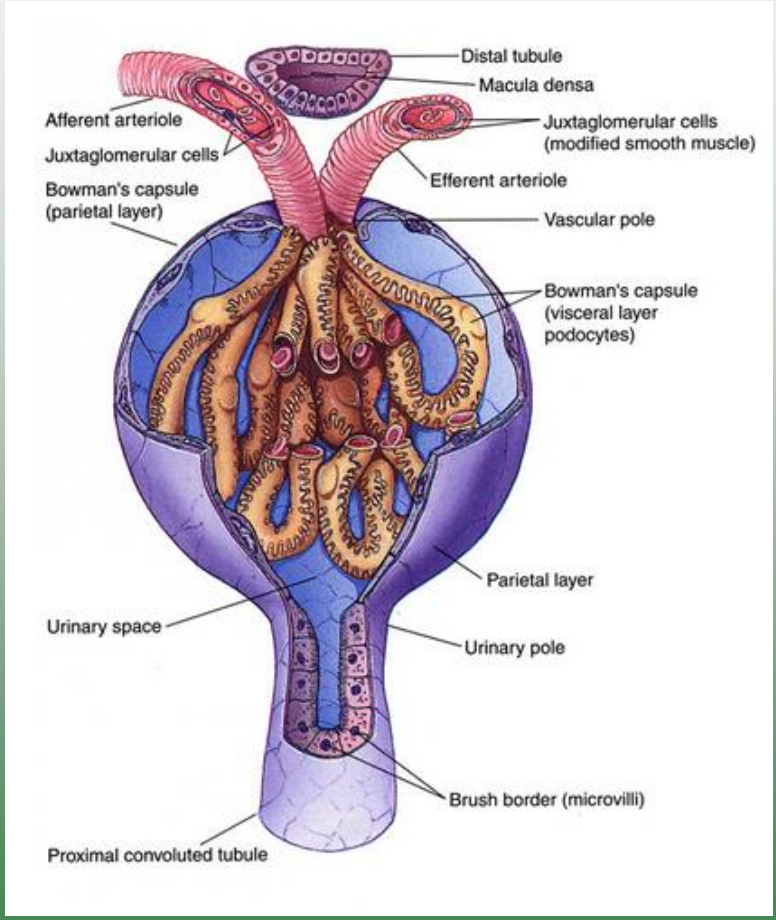
This figure shows how the visceral layer has pores to allow filtrate into the space leading to the tubule lumen.

Hormones Involved in Reabsorption

- **Antidiuretic hormone (ADH)**
  - Secreted by the **posterior pituitary**
  - Reabsorption of water in **distal convoluted tubules** and collecting ducts
- **Aldosterone**
  - Secreted by **adrenal cortex**
  - Sodium reabsorption in exchange for potassium or hydrogen
- **Atrial natriuretic hormone**
  - Hormone from the **heart**
  - Reduces sodium and fluid reabsorption
  - Natri (sodium) – Uretic (into the urine).

Glomerular Filtration Rate

- Afferent and efferent arterioles of the glomerulus
  - Autoregulation and hormones control pressure in the glomerular capillaries by:
  - Vasoconstriction of afferent arteriole
    - Decreased glomerular pressure—decreased filtrate
  - Dilation of afferent arteriole
    - Increased pressure in glomerulus—increased filtrate
  - Vasoconstriction of efferent arteriole
    - Increased pressure in glomerulus—increased filtrate



Glomerular Filtration Rate (Cont.)

Control of arteriolar constriction by three factors:

- Autoregulation
  - Local adjustment in diameter of arterioles
    - Made in response to changes in blood flow in kidneys
- Sympathetic nervous system
  - Increases vasoconstriction in both arterioles
- Renin
  - Secreted by juxtaglomerular cells when blood flow to afferent arteriole is reduced
  - Renin-angiotensin mechanism

Composition of Blood, Filtrate,and Urine

TABLE 18-1 Composition of Blood, Filtrate, and Urine

Substance	Blood	Filtrate	Urine
Water (L)	180	180	1.4
Cells	Yes	No	No
Glucose (mg/L)	1000	1000	0
Protein (mg/L)	40,000	0-trace	0-trace
Urea (mg/L)	260	260	18,000
Na^+ (mEq/L)	142	142	128
K^+ (mEq/L)	5	5	60
HCO_3^- (mEq/L)	28	28	14

Note the differences in the urine vs filtrate due to resorption and secretion in the tubules.

Incontinence and Retention

- Incontinence
  - Loss of voluntary control of the bladder
- Enuresis
  - Involuntary urination by child age older than 4 years
    - Often related to developmental delay, sleep pattern, psychosocial aspect (**bed wetting**).
- Stress incontinence (more common in women)
  - Increased intra-abdominal pressure forces urine through sphincter.
    - Coughing, lifting, laughing
    - Multiple pregnancies

Incontinence and Retention (Cont.)

- Overflow incontinence
  - Incompetent bladder sphincter
  - Older adults
    - Weakened detrusor muscle may prevent complete emptying of bladder—frequency and incontinence
  - Spinal cord injuries or brain damage
    - Neurogenic bladder—may be spastic or flaccid
    - Interference with CNS and ANS voluntary controls of the bladder

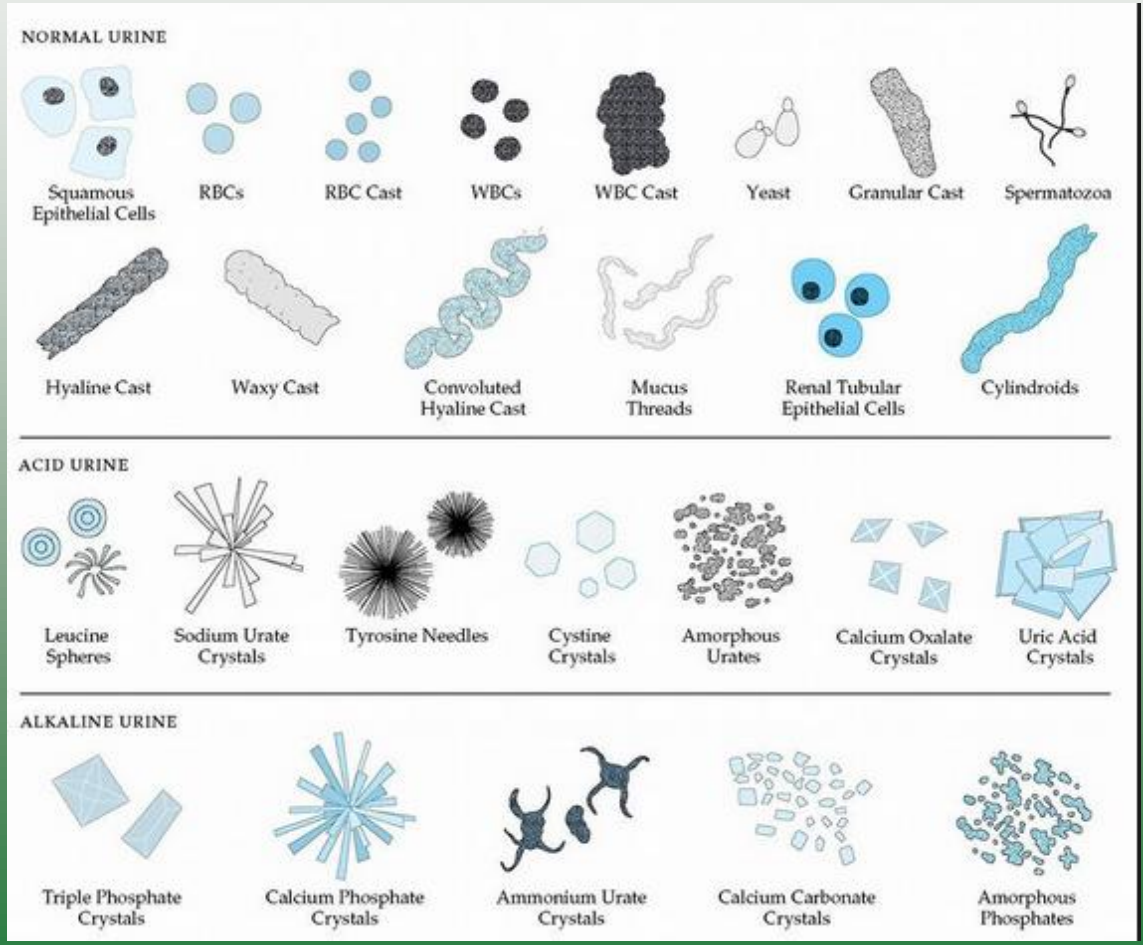
Incontinence and Retention (Cont.)

- Retention
  - Inability to empty bladder
  - May be accompanied by overflow incontinence
  - Spinal cord injury at sacral level blocks micturition reflex
  - May follow anesthesia (general or spinal)

Diagnostic Tests

Urinalysis

A test strip and a microscopic examination that assesses: urine color, pH, specific gravity, osmolarity, protein, glucose,ketones, bilirubin, inflammatory cells, red blood cells, bacteria, and crystals.

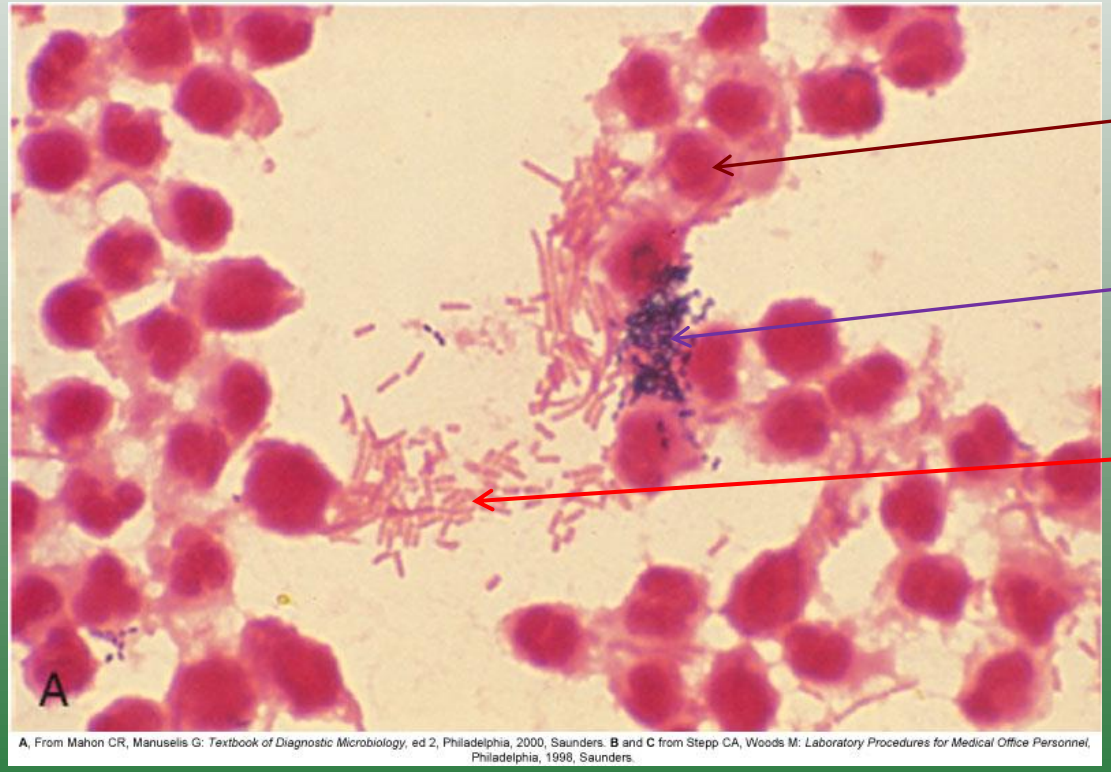


Urinalysis: Appearance of Urine

- Straw colored with mild odor
  - Normal urine, specific gravity 1.010 to 1.050
- Cloudy
  - May indicate the presence of large amounts of protein, blood, bacteria, and pus
- Dark color
  - May indicate hematuria, excessive bilirubin, or highly concentrated urine
- Unpleasant or unusual odor
  - Infection or result from certain dietary components or medication (asparagus is good example – makes some people's urine smell bad from the amino acid asparagine – an amine)

Urinalysis: Urinary Infection

- Heavy purulence and presence of gram-negative and gram-positive organisms



A, From Mahon CR, Manuselis G: *Textbook of Diagnostic Microbiology*, ed 2, Philadelphia, 2000, Saunders. **B** and **C** from Stepp CA, Woods M: *Laboratory Procedures for Medical Office Personnel*, Philadelphia, 1998, Saunders.

Urinalysis: Abnormal Constituents of Urine

- Blood (hematuria)
  - Small amounts
    - Infection, inflammation, or tumors in urinary tract
  - Large amounts
    - Increased glomerular permeability or hemorrhage
- Elevated protein level (proteinuria, albuminuria)
  - Leakage of albumin or mixed plasma proteins into filtrate
- Bacteria (bacteriuria)
  - Infection in urinary tract

Urinalysis: Abnormal

- Urinary casts *(picture on next slide)*
  - Indicate inflammation of kidney tubules
- Specific gravity
  - Indicates ability of tubules to concentrate urine
  - Low specific gravity—dilute urine (with normal hydration)
  - High specific gravity—concentrated urine (with normal hydration)
    - Related to renal failure
- Glucose and ketones
  - Found when diabetes mellitus is not well controlled

Urinalysis: Red Blood Cell Casts in Urine

A, From Mahon CR, Manuselis G: *Textbook of Diagnostic Microbiology*, ed 2, Philadelphia, 2000, Saunders. **B** and **C** from Stepp CA, Woods M: *Laboratory Procedures for Medical Office Personnel*, Philadelphia, 1998, Saunders.

Blood Tests

- Elevated serum urea (blood urea nitrogen, BUN) and serum creatinine levels
  - Indicate failure to excrete nitrogen wastes
    - Caused by decreased GFR
- Metabolic acidosis*
  - Indicates decreased GFR
  - Failure of tubules to control acid-base balance
- Anemia*
  - Indicates decreased erythropoietin secretion and/or bone marrow depression

*In the absence of other problems.

Blood Tests (Cont.)

- Electrolytes
  - The kidney can retain or loose electrolytes.
- Antibody level
  - Antistreptolysin O or antistreptokinase titers
    - Used for diagnosis of poststreptococcal glomerulonephritis
- Elevated renin levels
  - Indicate kidney as a cause of hypertension
  - **Renin > Aldosterone > Na retention > elevation in blood pressure.**

Other Tests

- Culture and sensitivity studies on urine specimens
  - Identification of causative organism of infection
  - Help select appropriate drug treatment
- Radiologic tests
  - Radionuclide imaging, angiography, ultrasound, CT, MRI, intravenous pyelography
  - Used to visualize structures and possible abnormalities, flow patterns, and filtration rates

Other Tests (Cont.)

- Clearance tests
  - Examples: creatinine or inulin clearance
  - Used to assess GFR
- Cystoscopy
  - Visualizes lower urinary tract
  - May be used to perform biopsy or remove kidney stones
- Biopsy
  - Used to acquire tissue specimens

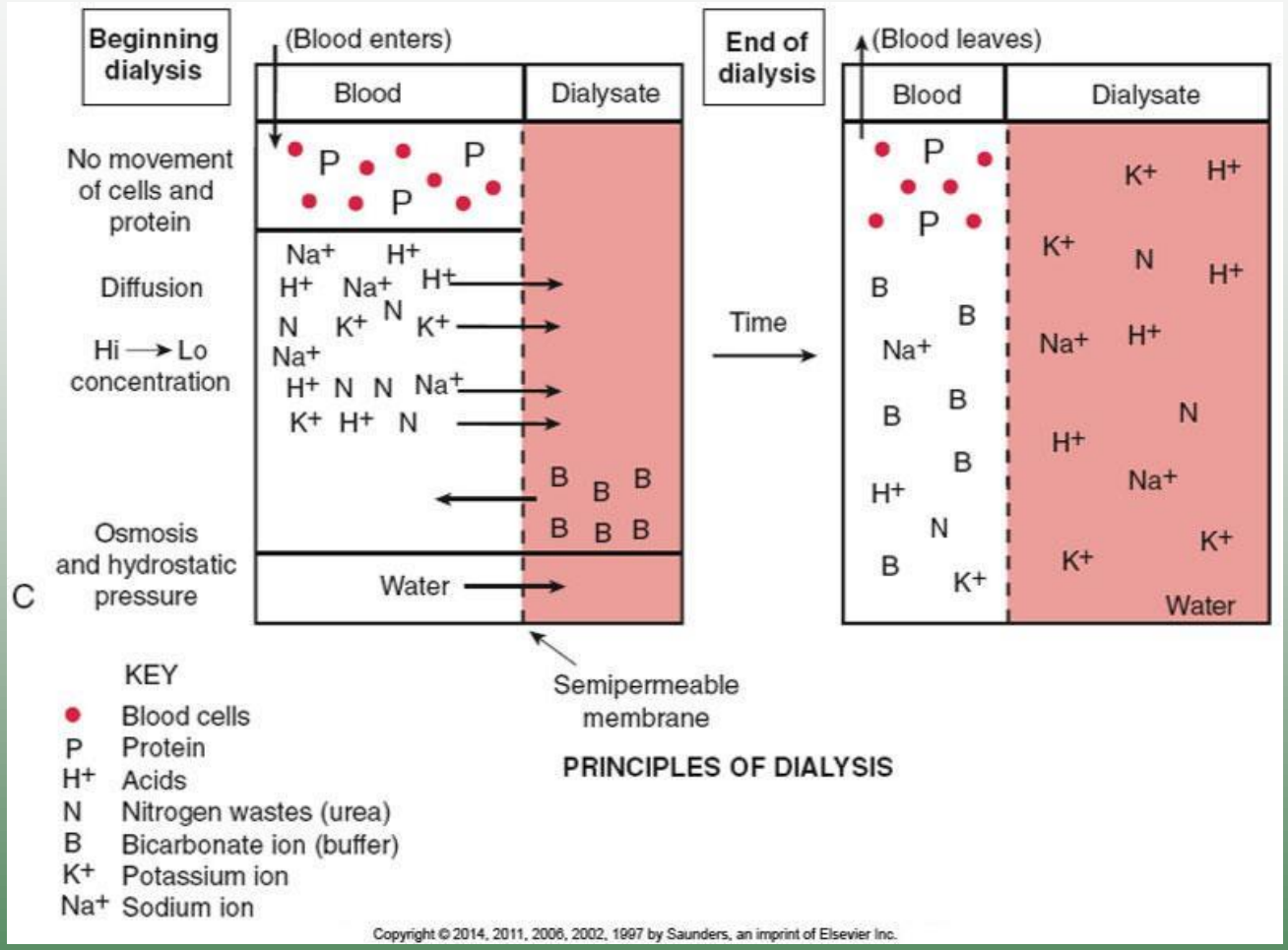
Diuretic Drugs

- Used to remove excess sodium ions and water from the body
  - Increased excretion of water though the kidneys
  - Reduces fluid volume in tissues and blood
  - Prescribed for many disorders
    - Renal disease, hypertension, edema, congestive heart failure, liver disease, pulmonary edema
  - Several different mechanisms to increase urine volume based on specific drug
  - Some drugs are potassium-wasting and some are potassium-sparing.

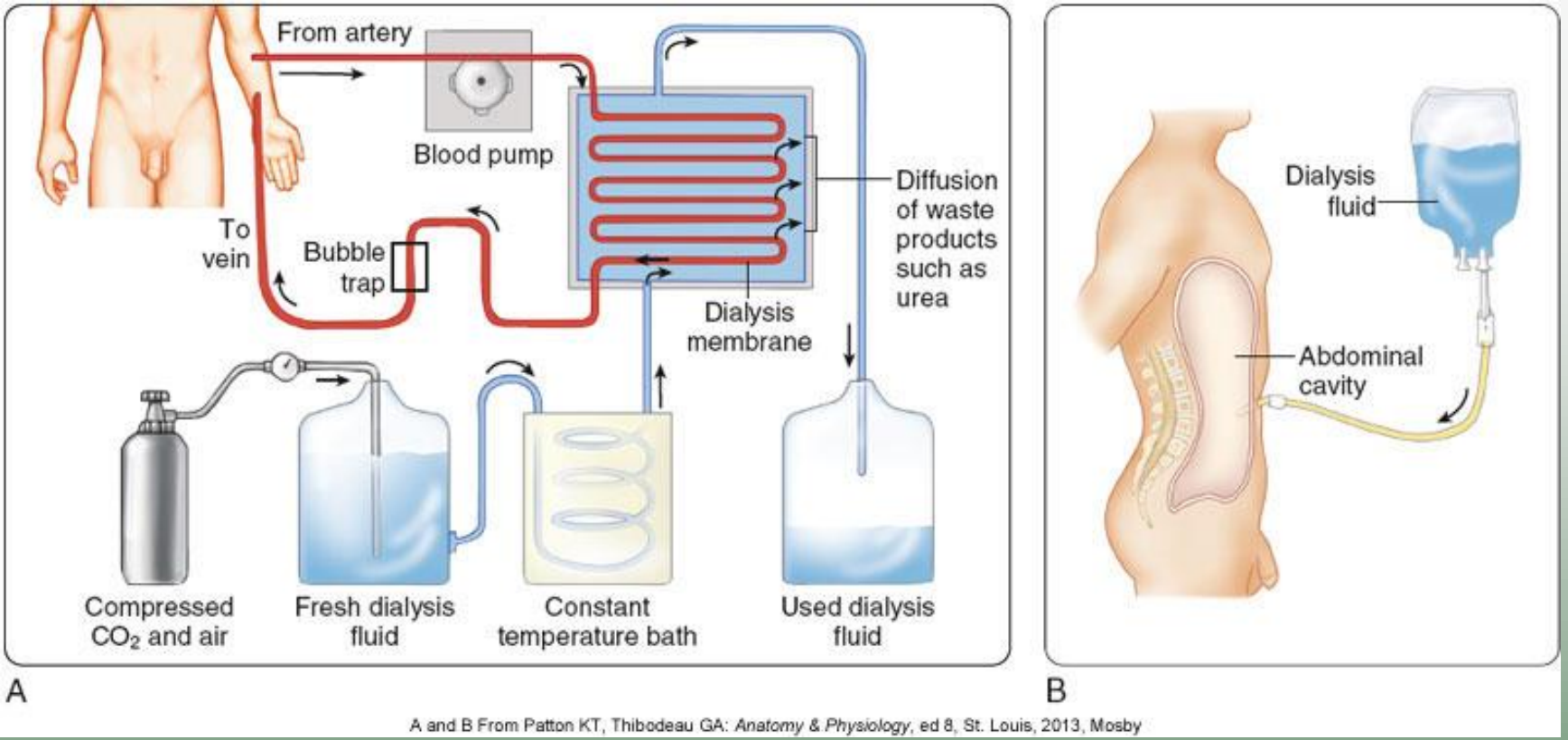
Dialysis – an artificial way to filter the blood to provide renal function

- Provides filtration and reabsorption
- Two forms
  - Hemodialysis
  - Peritoneal dialysis
- Sustains life during kidney failure
- Used to treat patients with acute kidney failure
  - Until primary problem reversed
- For patients in end-stage renal failure
  - Until kidney transplant becomes available and is successful

Principles of Dialysis



Ions and fluid move back and forth across the membrane to balance ion concentrations.



A and B From Patton KT, Thibodeau GA: *Anatomy & Physiology*, ed 8, St. Louis, 2013, Mosby

A. Hemodialysis: blood is pumped through dialysis membrane tubing. Dialysis fluid is circulated in the space around the tubing.

B. Peritoneal dialysis: Dialysis fluid is put into peritoneal cavity. Ions and urea are drawn into the fluid that is then removed.

Hemodialysis

- In hospital, dialysis center, or home with special equipment and training
- Patient's blood moves from an implanted shunt or catheter in an artery to machine
  - Exchange of wastes, fluids, and electrolytes
  - Semipermeable membrane between blood and dialysis fluid (dialysate)
    - Blood cells and proteins remain in blood.
  - After exchange is completed, blood returned to patient's vein

Hemodialysis (Cont.)

- Usually required three times a week
  - Each lasts about 3 to 4 hours.
- Potential complications
  - Shunt may become infected.
  - Blood clots may form.
  - Blood vessels involved in shunt may become sclerosed or damaged.
  - Patient has an increased risk of infection with hepatitis B, hepatitis C, or HIV if Standard Precautions are not followed.

Peritoneal Dialysis

- Usually done on outpatient basis
- May be done at night (during sleep) or while patient is ambulatory
- **Peritoneal membrane serves as the semipermeable membrane.**
- Catheter with entry and exit points is implanted into the peritoneal cavity
- Dialyzing fluid is instilled into cavity
- Dialysate is drained from cavity via gravity into container

Peritoneal Dialysis (Cont.)

- Takes more time than hemodialysis
- Requires loose clothing to accommodate bag of fluid
- Major complication
  - Infection resulting in peritonitis
- With both types of dialysis
  - Prophylactic antibiotics with either form of dialysis
  - Any additional problem occurring in patient such as infection may alter dialysis requirements
  - Caution is required with many drugs because toxic level buildup can occur.

Disorders of the Urinary System

Urinary Tract Infections (UTIs)

- Very common infections
- Urine is an excellent growth medium.
- Lower urinary tract infections
  - Cystitis
  - Urethritis
- Upper urinary tract infections
  - Pyelonephritis
- Common causative organism
  - *Escherichia coli*

Urinary Tract Infections (UTIs)

- Other species of organisms associated with UTIs *(fyi – do not have to memorize)*
  - *Klebsiella*
  - *Proteus*
  - *Enterobacter*
  - *Citrobacter*
  - *Serratia*
  - *Pseudomonas*
  - *Enterococcus*
  - Coagulase-negative *Staphyloccus*
  - *Chlamydia*
  - *Mycoplasma*

Urinary Tract Infections (UTIs)

- More common in women because of:
  - Shortness of urethra
  - Proximity to anus
- Older men
  - Prostatic hypertrophy
  - Urine retention
- Congenital abnormalities in children
- Other common predisposing factors
  - Incontinence
  - Retention of urine
  - Direct contamination with fecal material

Cystitis and Urethritis

- Bladder wall (cystitis) and urethra (urethritis) are inflamed.
  - Hyperactive bladder and reduced capacity
- Pain is common in pelvic area
- Dysuria, urgency, frequency, and nocturia
- Systemic signs may be present.
  - Fever, malaise, nausea, leukocytosis
- Urine often cloudy, with unusual odor
- Urinalysis indicates bacteriuria, pyuria, microscopic hematuria

Pyelonephritis

- One or both kidneys involved
- From ureter into kidney
- Purulent exudate fills pelvis and calyces
- Recurrent or chronic infection can lead to scar tissue formation.
  - Loss of tubule function
  - Obstruction and collection of filtrate → hydronephrosis
  - Eventual chronic renal failure if untreated

Pyelonephritis (Cont.)

- Signs of cystitis plus pain associated with renal disease
  - Dull, aching pain in lower back or flank area
- Systemic signs include high temperature
- Urinalysis
  - Similar to cystitis
  - Urinary casts are present.
    - Reflection of renal tubule involvement
- Treatment with antibacterials

Inflammatory Disorders: Glomerulonephritis (GN)

- Many types with a variety of etiologies.
- Example: Post Steptococcal GN occurs after a streptococcal infection.
- Blood test shows antistreptococcal (ASO) antibodies
  - Formation of an antigen-antibody complex that deposits in glomerulus
  - Activates complement system and damages glomerulus.
  - Inflammatory response in glomeruli
    - Increased capillary permeability—leakage of some protein and large numbers of erythrocytes
    - Can lead to decreased urinary output and hypertension.

Inflammatory Disorders: Glomerulonephritis (Cont.)

- Blood tests
  - Elevated BUN and creatinine levels
  - Elevation of anti-DNase B, streptococcal antibodies, antistreptolysin, antistreptokinase
  - Complement levels decreased (use in renal inflammation)
- Metabolic acidosis
- Urinalysis
  - Proteinuria, hematuria, erythrocyte casts
  - No evidence of infection

Inflammatory Disorders: Glomerulonephritis (Cont.)

- Treatment
  - Sodium restriction possible (to treat hypertension).
  - Protein and fluid intake decreased in severe cases
  - Drug treatment
    - Glucocorticoids to reduce inflammation
    - Antihypertensives

Inflammatory Disorders: Nephrotic Syndrome

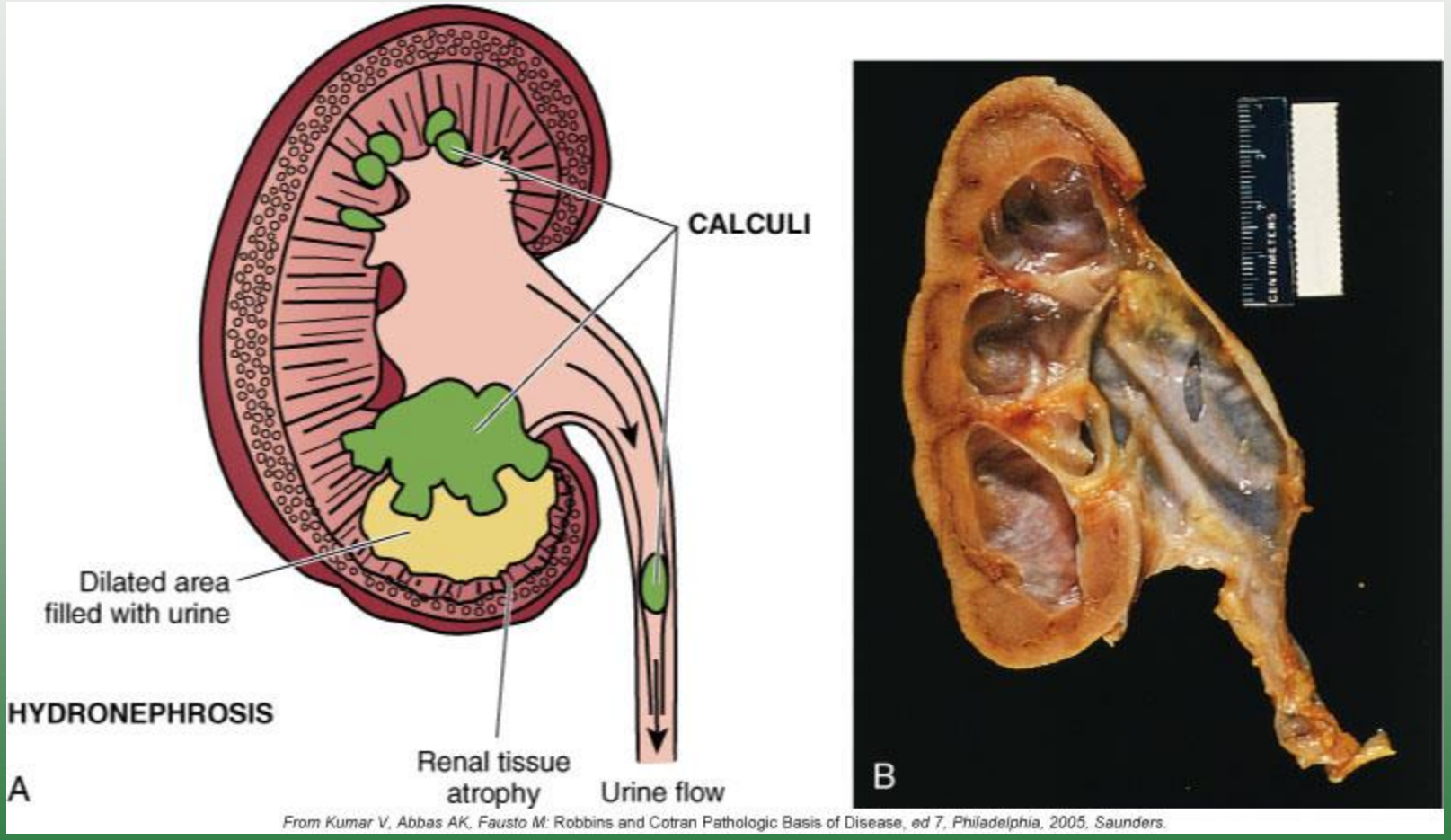
- Abnormality in glomerular capillaries, increased permeability, **large amounts of plasma proteins escape into filtrate**
- **Low serum protein leads to edema and low blood pressure.**
- May be idiopathic, autoimmune (like lupus), from exposure to nephrotoxins or drugs.

Urinary Tract Obstructions

Urolithiasis (Stones, aka Calculi)

- Can develop anywhere in urinary tract
- Stones may be small or very large.
- Tend to form with:
  - Excessive amounts of solutes in filtrate
  - Insufficient fluid intake—major factor for calculi formation
  - Urinary tract infection
- Manifestations only occur with obstruction of urine flow.
  - May lead to infection
  - Hydronephrosis with dilation of calyces
  - If located in kidney or ureter and atrophy of renal tissue

Hydronephrosis



From Kumar V, Abbas AK, Fausto M: Robbins and Cotran Pathologic Basis of Disease, *ed 7, Philadelphia, 2005, Saunders.*

Urolithiasis

- Stones are examined by mineral analysis. The composition of the stone indicates what imbalance is operative.

- Stone may be composed of a wide variety of minerals and metabolites:
  - Calcium oxalate
  - Calcium phoshate
  - Uric acid
  - Struvite (ammonium magnesium phosphate)
  - Cystine

- May be caused by an excess of mineral in the urine, is affected by urine pH, some casued by infections.

Urolithiasis (Calculi) (Cont.)

- Stones in kidney or bladder often asymptomatic
  - Frequent infections may lead to investigation.
  - Flank pain possible caused by distention of renal capsule

- Renal colic caused by obstruction of the ureter
  - **Intense spasms of pain in flank area**
    - Radiating into groin area
    - **Lasts until stone passes or is removed**
  - Possible nausea and vomiting, cool moist skin, rapid pulse
  - **Radiological examination confirms location of calculi.**

Urolithiasis (Calculi) (Cont.)

- Treatment
  - Small stones will be passed eventually.
  - Extracorporeal shock wave lithotripsy (ESWL)
  - Laser lithotripsy
  - Drugs may be used to dissolve stones partially.
  - Surgery
- Prevention
  - Treatment of underlying condition
  - Adjustment of urine pH through dietary modifications
  - Consistent increased fluid intake

Cancer: Renal Cell Carcinoma

- Primary tumor arising from the tubule epithelium

- Tends to be symptomatic in early stages
- Often has metastasized to liver, lung, bone, or central nervous system at time of diagnosis

- Occurs more frequently in men and smokers

- Treatment is removal of kidney.
- Immunotherapy may be used in some cases.
- Tumor is radioresistant, and chemotherapy is not used in most cases.

Renal Cell Carcinoma

- Manifestations
  - Painless hematuria initially
    - Gross or microscopic
  - Dull, aching flank pain
  - Palpable mass
  - Unexplained weight loss
  - Anemia or erythrocytosis
  - Paraneoplastic syndromes
    - Hypercalcemia or Cushing's syndrome

Wilms' Tumor

- Most common renal tumor in children
- Defects in tumor suppressor genes on chromosome 11
  - May occur in conjunction with other congenital disorders
- Usually unilateral
  - Large encapsulated mass
- Pulmonary metastases may be present at diagnosis.

Bladder Cancer

- Most bladder tumors are malignant and commonly arise from transitional epithelium of the bladder.
- Often develops as multiple tumors
- Diagnosed by urine cytology and biopsy
- Early signs
  - Hematuria, dysuria
  - Infection common
- Tumor is invasive through wall to adjacent structures.
  - Metastasizes to pelvic lymph nodes, liver, and bone

Tumors: Bladder Cancer (Cont.)

- Predisposing factors
  - Working with chemicals in laboratories and industry
    - Particularly aniline dyes, rubber, aluminum
  - Cigarette smoking
  - Recurrent infections
  - Heavy intake of analgesics
- Treatment
  - Surgical resection of tumor
  - Chemotherapy and radiation
  - Photoradiation successful in some early cases

Vascular Disorders: Nephrosclerosis

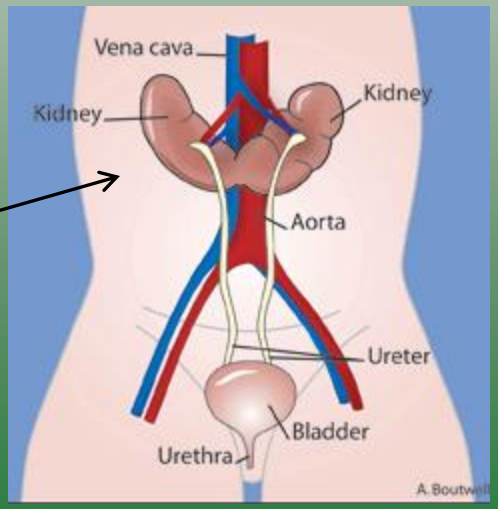
- Involves vascular changes in the kidney
  - Some occur normally with aging.
- Thickening and hardening of the walls of arterioles and small arteries
- Narrowing of the blood vessel lumen
  - Reduction of blood supply to kidney
  - Stimulation of renin
    - Increased blood pressure
  - Continued ischemia
    - Destruction of renal tissue
    - Chronic renal failure

Nephrosclerosis

- Nephro (kidney) – sclerosis (scarring).
- Can be primary lesion developed in kidney
- May be secondary to essential hypertension
- Treatment
  - Antihypertensive agents
  - Diuretics
  - Beta blockers
  - Sodium intake should be reduced.

Congenital Disorders

- Vesicoureteral reflux (urine in bladder backs up into ureters).
- Agenesis
  - Failure of one kidney to develop
- Hypoplasia
  - Failure to develop to normal size
- Ectopic kidney
  - Kidney and ureter displaced out of normal position
- “Horseshoe” kidney
  - Fusion of the two kidneys



Adult Polycystic Kidney

- Autosomal dominant gene on chromosome 16
- No indications in child and young adults
- **First manifestations usually around age 40 years**
- Multiple cysts develop in both kidneys.
  - Enlargement of kidneys
  - **Compression and destruction of kidney tissue**
  - **Chronic renal failure**
- Diagnosis by CT or MRI

From Kumar V, Abbas AK, Fausto M: Robbins and Cotran Pathologic Basis of Disease, ed 7, Philadelphia, 2005, Saunders.

Renal Failure

Acute Renal Failure

- Causes
  - Acute bilateral kidney diseases
  - Severe, prolonged circulatory shock or heart failure
  - Nephrotoxins
    - Drugs, chemicals, or toxins
  - Mechanical obstruction (occasionally)
    - Calculi, blood clots, tumors
      - Block urine flow beyond kidneys

Acute Renal Failure (Cont.)

- Sudden onset
- Blood tests
  - Elevated BUN and creatinine levels
  - Metabolic acidosis and hyperkalemia
- Treatment
  - Identify and remove or treat primary problem.
    - To minimize risk of necrosis and permanent kidney damage
  - Dialysis
    - To normalize body fluids and maintain homeostasis

Chronic Renal Failure

- Gradual irreversible destruction of the kidneys over a long period of time
- Asymptomatic in early stages
- May result from
  - Chronic kidney disease
  - Congenital polycystic kidney disease
  - Systemic disorders
  - Low-level exposure to nephrotoxins over sustained period of time

Final stage of Renal Failure

- End-stage renal failure
  - Negligible GFR
  - Fluid, electrolytes, and wastes retained in body
  - ***A*zotemia, *a*nemia, and *a*cidosis (three As)**
    - Azotemia is high BUN and creatinine.
    - Anemia from decreased erythropoietin.
    - Acidosis from inability to dump acid (H^+).
  - **Marked oliguria or anuria**
  - Regular dialysis or kidney transplantation
    - To maintain patient's life