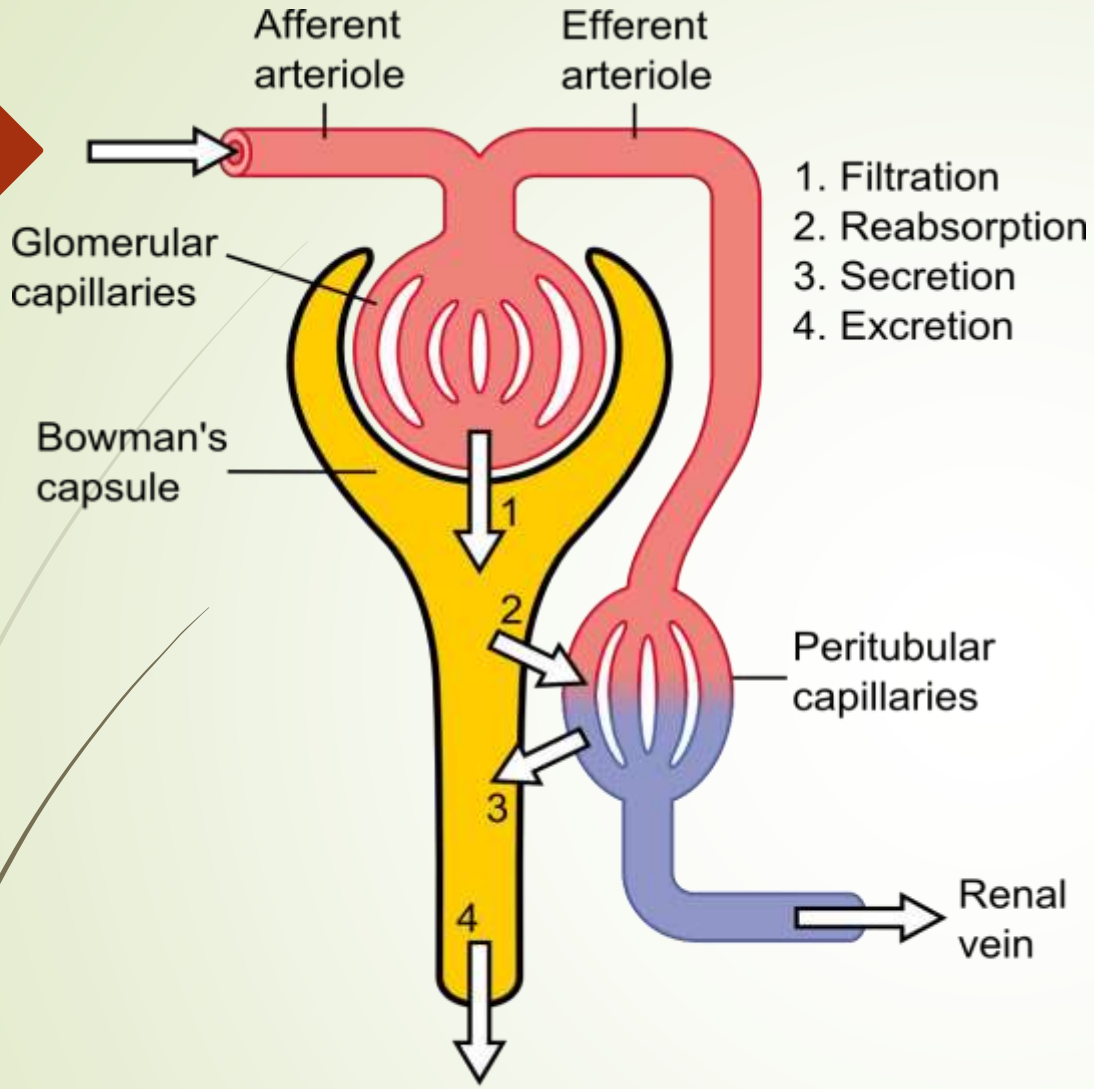
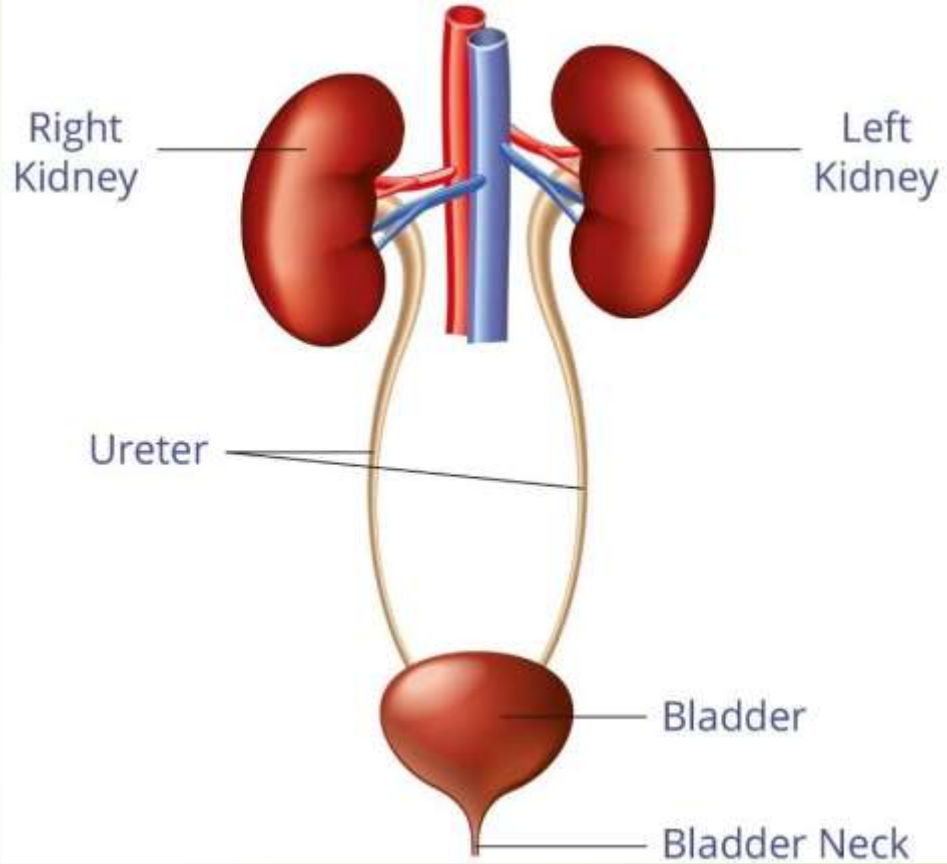
Renal Function

By Dr. Safa Ammer

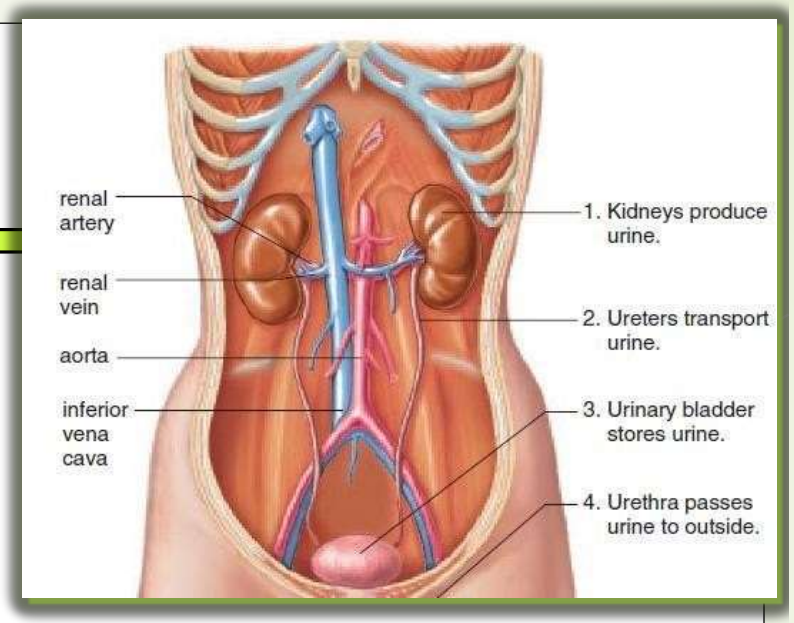


Excretion = Filtration – Reabsorption + Secretion



Anatomy

- The kidneys are a pair of fist-sized organs that are located on either side of the spinal column.
- A kidney consists of an outer layer (renal cortex) and an inner region (renal medulla).
- The functional unit of the kidney is the nephron.



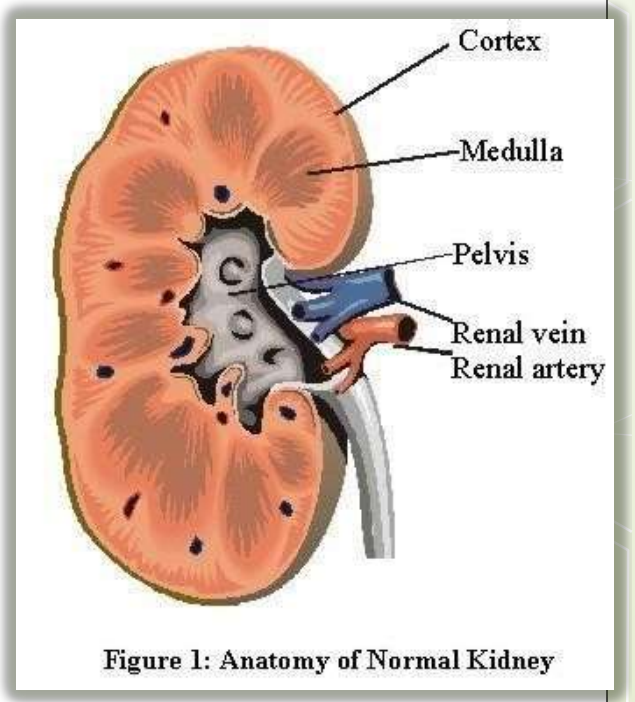


Figure 1: Anatomy of Normal Kidney

Nephron

Structural and functional unit of the kidney

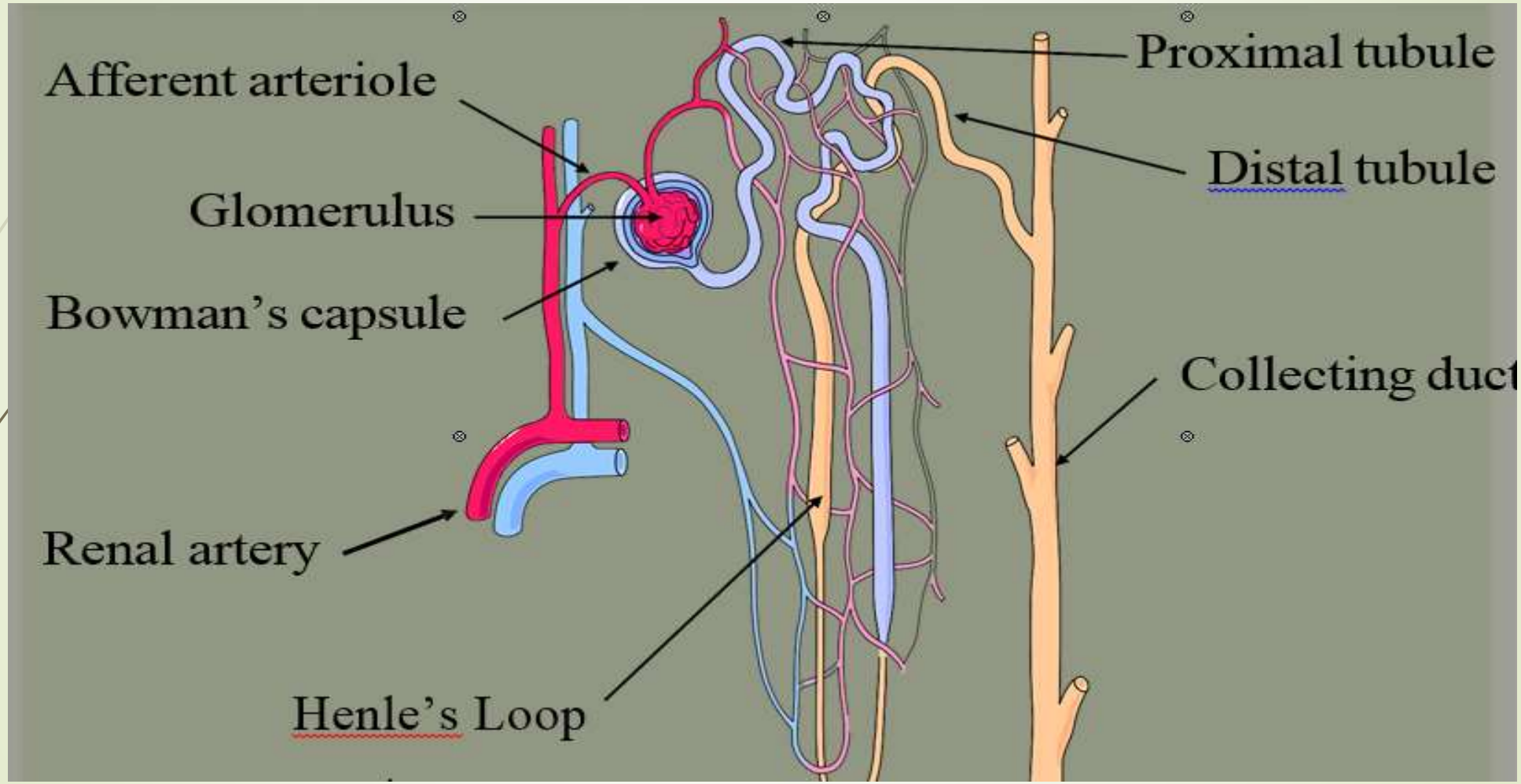
- **1 million nephrons per kidney**
- Consists of 2 parts

1. Glomerulus (filtering system)

- tuft of capillaries surrounded by Bowman's capsule

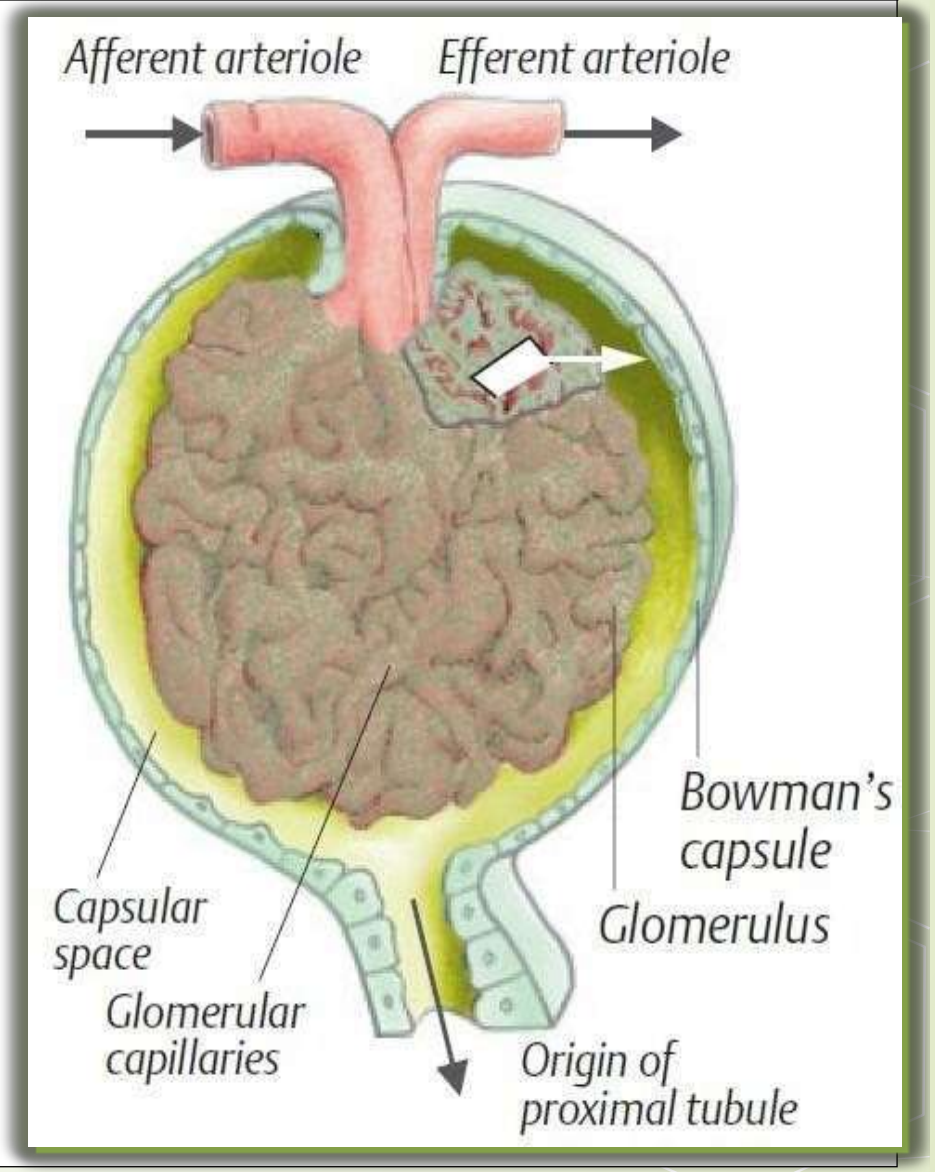
2. Tubules

Nephron


Afferent arteriole
Glomerulus
Bowman's capsule
Renal artery
Henle's Loop
Proximal tubule
Distal tubule
Collecting duct

Nephron - Bowman's capsule

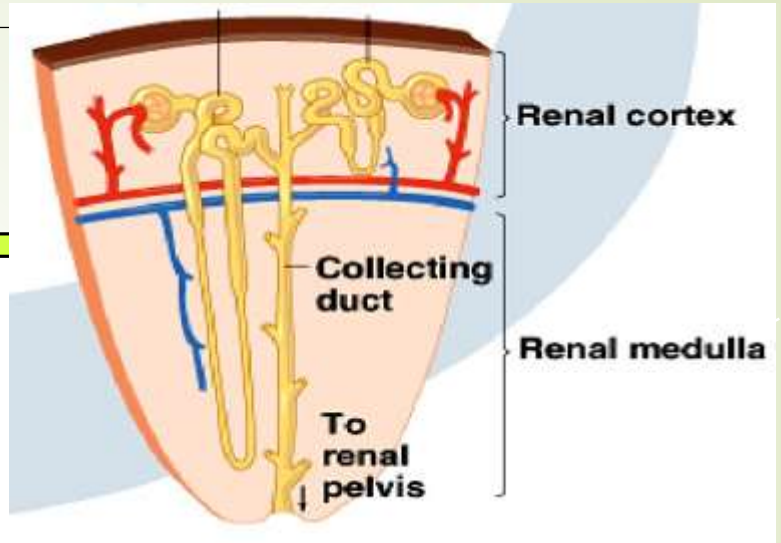
- Bowman's capsule: funnel with tubules as stem
- Blood carried to glomerulus by afferent arteriole
- Afferent arteriole divides to form capillary network.
- These capillaries reunite to form efferent arteriole, which carries blood out of the glomerulus



Nephron - Bowman’s capsule

- **Blood filtered in glomerulus; some water and small molecules removed**
  - Size cutoff value of approximately 66,000 Da, about the molecular size of albumin.
- **Glomerular filtrate collected in Bowman’s capsule and enters tubules.**
- Specific reabsorption occurs in tubules.
  - Most water and soluble nutrients reabsorbed.

Tubule System



Proximal convoluted tubule

- located in the cortex
- Reabsorption of Glucose, water, amino acids, Na, Cl & others

Loop of Henle

- composed of the thin descending limb, which spans the medulla, and the ascending limb, which is located in both the medulla and the cortex,
- More water reabsorbed

Distal convoluted tubule

- located in the cortex
- Sodium and hydrogen ion reabsorption

Tubule System

- **The collecting duct**
  - formed by two or more distal convoluted tubules as they pass back down through the cortex and the medulla to collect the urine thatdrains from each nephron.
- **collecting tubules, then ureters → bladder** → urethra
- **1000 liter of blood through glomerulus per day; 100 liters of glomerular filtrate formed; 1 liter of urine produced**

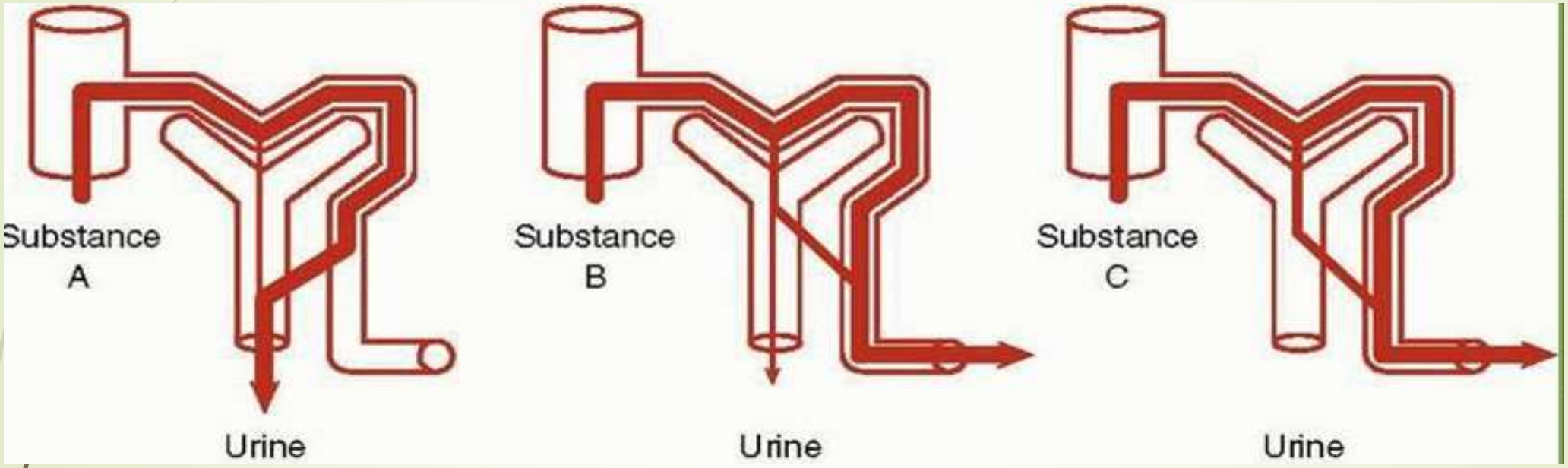
Functions of Kidney

- Urine formation
- Regulate body fluid, osmolality and volume
- Regulate electrolyte balance
- Regulate acid-base balance
- Excrete waste products and foreign substances
- Produce and excrete hormones

1. Urine Formation

Removal of potentially toxic waste products

- 3 processes involved:
  - **Filtration, Reabsorption, Secretion**



- Substance A is filtered and secreted, but notreabsorbed;
- Substance B is filtered and a portion reabsorbed
- Substance C is filtered and completely reabsorbed

2. Glomerular Filtration

Glomerular filtration rate (GFR) is approximately 130 mL/min

- Cells and large plasma proteins unable to pass through the semipermeable membrane
- **Glomerular filtrate is essentially plasma without proteins.**
  - water, electrolytes, glucose, amino acids, low-molecular-weight proteins, urea, and creatinine, pass freely throughthe basement membrane and enter the proximal convoluted tubule

Proximal Convoluted Tubules

The next part of the nephron to receive filtrate

- This filtrate contains
  - waste products,
  - and substances that are valuable to the body.
- One function of the PCT is to return the bulk of each valuable substance back to the blood circulation.
  - Glucose, water, amino acids, Na, Cl & others
- Organic acids and bases, hydrogen ions and ammonia may be secreted into the tubular fluid

Proximal Convoluted Tubules

- **Reabsorption may be active or passive**
  - **Active — against a concentration gradient (glucose, amino acids, low mw proteins, sodium, etc.) —**
    - regulated by kidney according to levels of these substances in the blood
  - Passive — no energy involved — water and urea
- **Tubular secretion may also be passive or active**

Loop of Henle

- **Descending limb is highly permeable to water**
- Passive reabsorption of water in descending loop
- **Ascending loop is impermeable to water but actively reabsorbs sodiumand chloride**
- it lowers the salt concentration

Distal Convoluted tubule

The function is to effect small adjustments to achieve electrolyte and acid-base homeostasis

- Small amount of sodium, chloride, waterare reabsorbed
- **Under influence of AVP (ADH) increase water permeability of tubule (reabsorbs water)**
- Potassium also reabsorbed or secreted
  - Aldosterone - sodium reabsorption and potassium secretion

3. Regulation of Fluid and ElectrolyteBalance

Water:

- body water (weight) remains constant day to day — ability of kidney to excrete or conservewater
- Water balance is controlled by voluntary intake (thirst) and urinary loss

- **Sodium:**
  - freely filtered through the glomerulus and reabsorbed by tubules
  - Active reabsorption of Na+ results in passive transport of Cl- and bicarbonate and passive reabsorption of water.

Regulation of Fluid and Electrolyte Balance

Potassium:

- Both the distal convoluted tubule and the collecting ducts can reabsorb and excrete potassium, and this excretion is controlled by aldosterone

Chloride:

- parallels sodium
- but reabsorption is passive in proximal tubules
- and active in distal tubules and collecting duct

4. Acid-Base Balance

Secretion of hydrogen ions from tubular cells

- Hydrogen ions generated in proximal and distal tubules as a result of carbonic acid

- React with bicarbonate ions
- React with buffers — phosphate ions
- React with ammonia (deamination of gluatamine) to form ammonium ion
- Excretion as free hydrogen ions

5. Nitrogenous Waste Excretion

When low GFR, levels of nitrogenous wastes increase in blood — NPN's

- Urea
- Creatinine
- Uric Acid

6. Primary Endocrine Functions

Kidneys synthesize renin, prostaglandins and erythropoietin

- **Renin:**
  - **Renin is the initial member of the renin-angiotensin-aldosterone system**
  - help regulate sodium and potassium in the blood, fluid levels in the body, andblood pressure.

Prostaglandins

- **A group of potent cyclic fatty acids**
- Behave like hormones
- **Prostaglandins produced by the kidney increase renal blood flow, sodium & water excretion**
- They oppose renal vasoconstriction due to angiotensin

Erythropoietin

- It is a single chain polypeptide.
- It is produced by cells close to the proximaltubules.
- Its production is regulated by blood oxygen levels "hypoxia increases its production".
- Erythropoietin acts on the erythroid progenitor cells in the bone marrow, causing their maturation and increasing the number of RBCs.
- In chronic renal insufficiency, erythropoietin production is significantly reduced causinganemia.

Secondary Endocrine Functions

- The kidneys are the target locus for the action of aldosterone
- For the catabolism of insulin, glucagonand aldosterone
- The point of activation for vitamin D.

Renal Disorders

- **Acute Glomerulonephritis**
- Nephrotic Syndrome
- **Tubular Diseases**
- Urinary Tract Infection
- **Acute Renal Failure**

1. Acute inflammation of the glomeruli

- Results in oliguria, hematuria, increased BUN and serum creatinine, decreased GFR and hypertension
- Red cell cast finding are of great importance
- Proteinuria also present

2. Nephrotic Syndrome

- Massive proteinuria, edema, hypoalbuminemia, hyperlipidemia,and lipiduria
- Has many cuases
- Characterized by increased glomerular membrane permeability —loss of protein (greater than 2-3 grams per day)

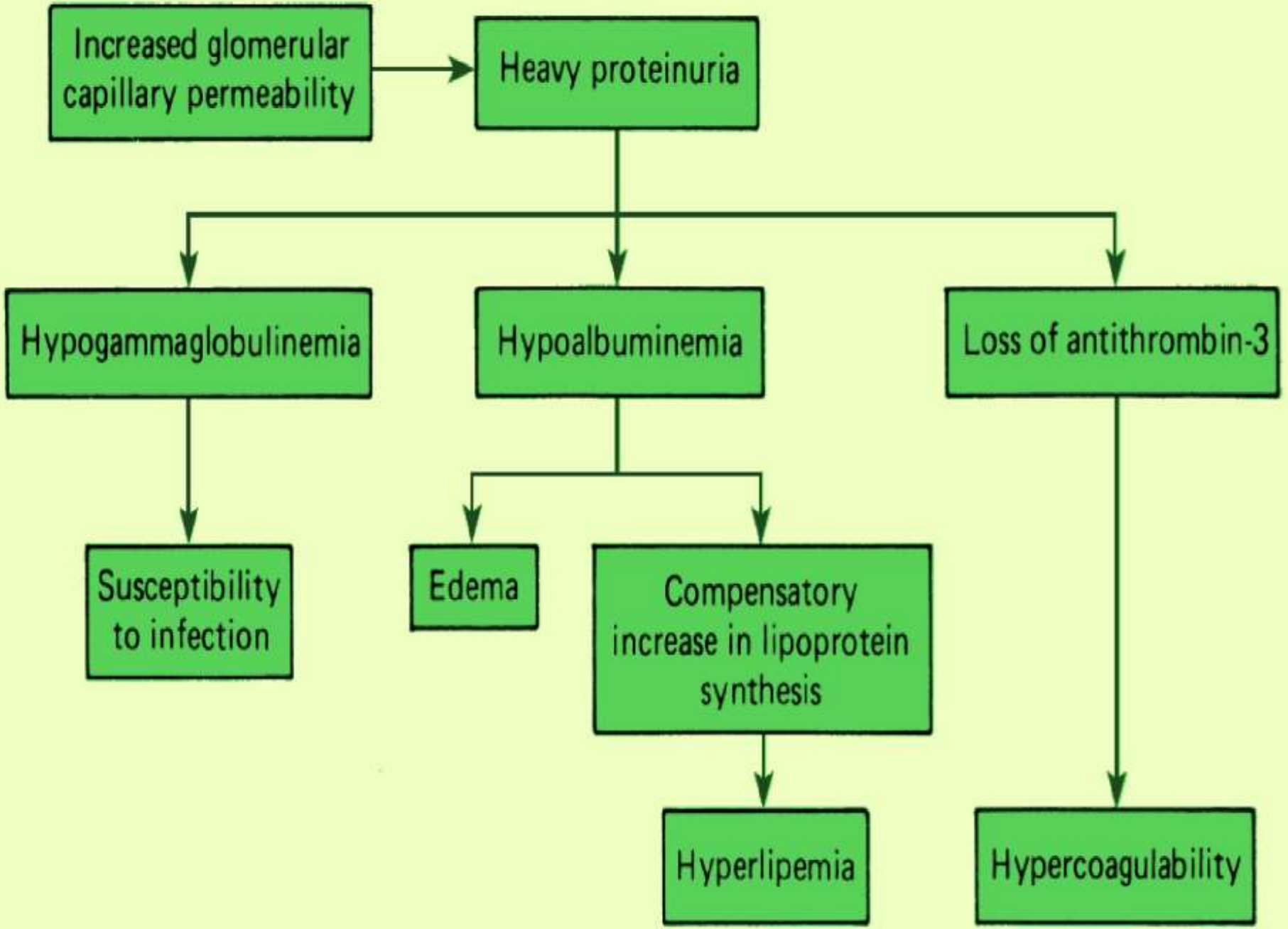


FIGURE 26-6. Pathophysiology of nephrotic syndrome.

3. Tubular Diseases

- Depressed secretion or reabsorptionof specific biochemicals
- Or Impairment of urine dilution and concentration mechanisms
- Renal Tubular Acidosis — most important
- Low values of phosphorus in serum, and presence of glucose and aminoacids in urine

4. Urinary Tract Infection

- Bladder — cystitis
- Kidneys — pyelonephritis
- Bacterial concentrations >100,000 colonies/mL is considered diagnostic for infection
- Increased number of white blood cells
- Increased number of red blood cells may be present
- White blood cell casts is considered diagnostic of pyelonephritis

5. Acute Renal Failure

- **Defined as occurring when the GFR is reduced to less than 10 mL/minute.**
- Prerenal — before blood reaches the kidney
  - Hypovolemia
  - Cardiovascular failure
- **Renal — occurring in kidney**
  - Acute tubular necrosis
  - Glomerulonephritis
- **Post renal — after urine leaves kidney**
  - Obstruction

5- Acute Renal Failure -continued

- **Usually accompanied by**
- oliguria
- **varying degrees of proteinuria,**
- hematuria, and presence of red cell casts and other casts
- **BUN and creatinine increase rapidly**
- Can progress to chronic renal insufficiency or failure

Renal Function Tests

- Tests of Glomerular Function
  - Creatinine Clearance
  - Most sensitive method of assessing renal function
- Tests of Tubular Function
  - Concentration — Dilution Studies
- Non-protein nitrogen compounds
  - Urea nitrogen
  - Creatinine
  - Uric acid
- Urinalysis and Microscopy
  - pH, Chemical Analyses (glucose, protein, bilirubin/urobilinogen & others)