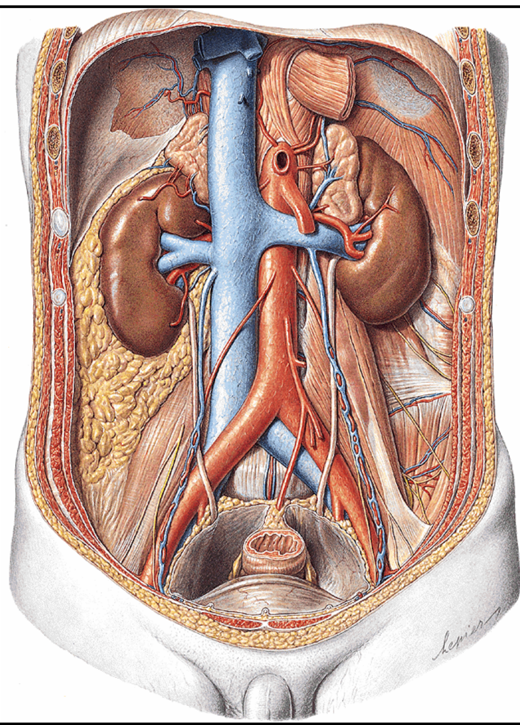
# Renal Physiology

- Functional Anatomy of the Kidneys
- Glomerular Filtration



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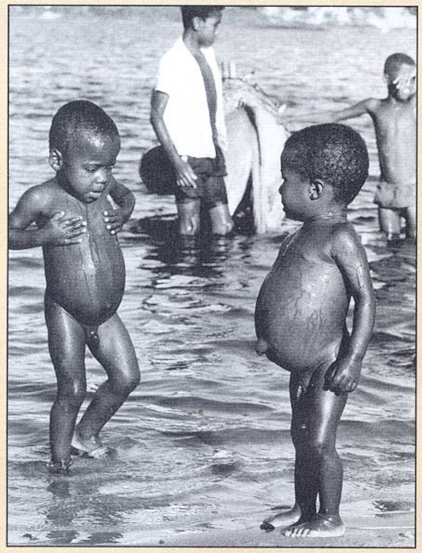

Children suffering from kwashiorkor, San Salvador, Brazil. (© Richard Frieman/Photo Researchers, Inc.)

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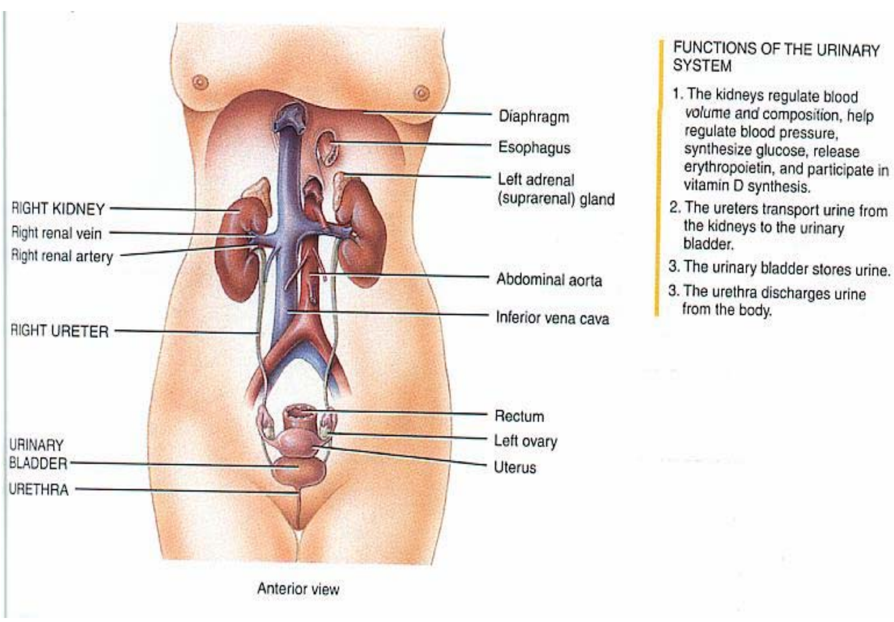
Diaphragm
Esophagus
Left adrenal (suprarenal) gland
RIGHT KIDNEY
Right renal vein
Right renal artery
Abdominal aorta
Inferior vena cava
RIGHT URETER
Rectum
Left ovary
Uterus
URINARY BLADDER
URETHRA
Anterior view
FUNCTIONS OF THE URINARY SYSTEM
1. The kidneys regulate blood volume and composition, help regulate blood pressure, synthesize glucose, release erythropoietin, and participate in vitamin D synthesis.
2. The ureters transport urine from the kidneys to the urinary bladder.
3. The urinary bladder stores urine.
3. The urethra discharges urine from the body.

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# ANATOMICAL CONSIDERATION

- General
- Nephron
- The Blood Supply
- Nerve Supply

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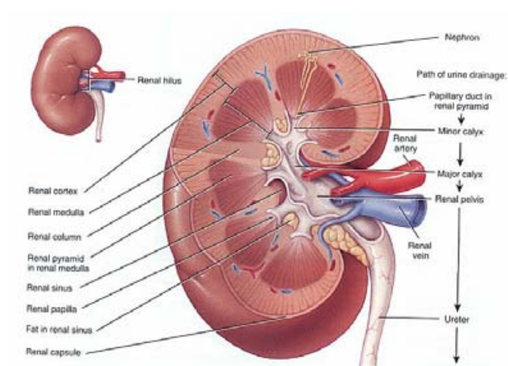
# General Consideration

- bean-shaped organs
- 170 grams
- cortex and medulla



(a) Frontal section of right kidney

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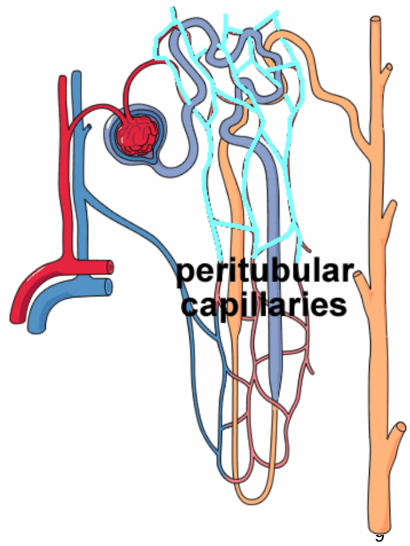
# Nephron

- functional unit
- 1 million
- glomerulus (bowmans capsule or *Malphigian corpuscle*), renal tubule (proximal, loop, distal→ collecting duct)
- Proximal tubule
  - convoluted (pars convoluta)
  - straight ( pars recta, thick Loop of Henle)

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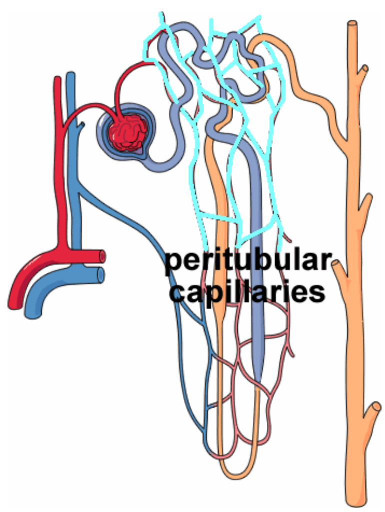
- Proximal Tubule (pars convoluta, pars recta)→thin Loop of Henle→ distal tubule(straight, convoluted)→ collecting ducts

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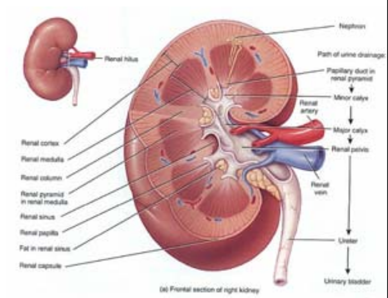
# Two Types of Nephrons

- Cortical Nephron
  - cortex
  - short thin Loop of Henle
- Juxtamedullary Nephron
  - g, pct, dct→ cortex
  - Loop of Henle, cd→ medulla
  - long thin Loop of Henle



- 7:1

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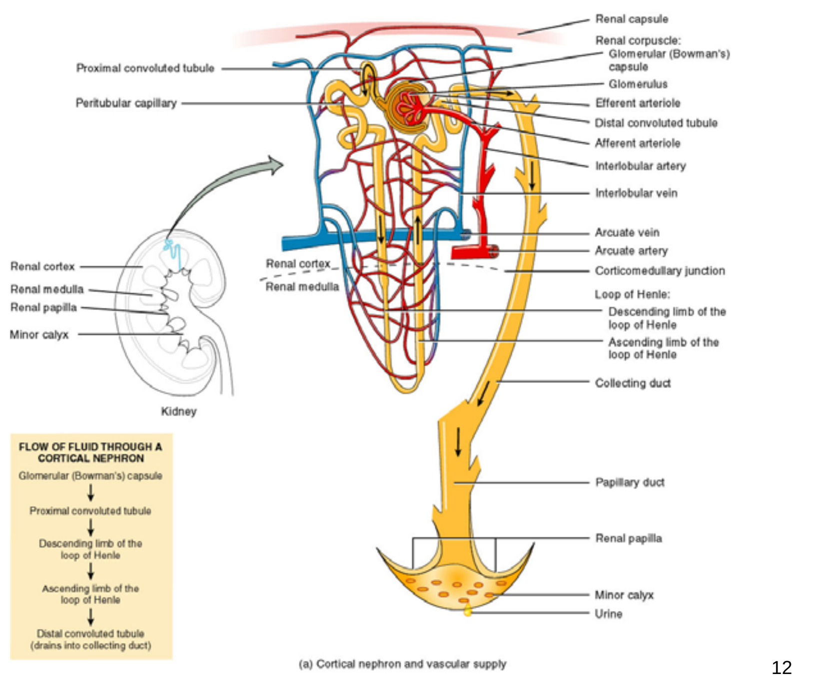
Fig. 26.05a




(a) Cortical nephron and vascular supply

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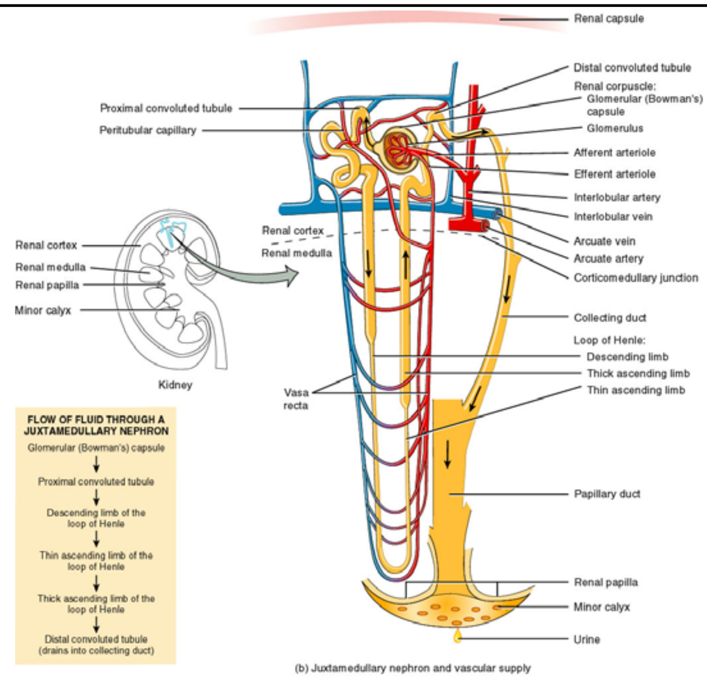
26.05a

Fig. 26.05b




(b) Juxtamedullary nephron and vascular supply

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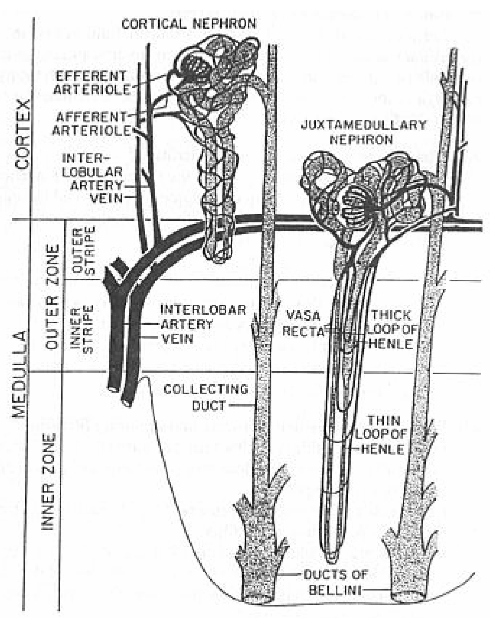
26.05b

Anatomy and vasculature of cortical (superficial) and juxtamedullary (deep) nephrons. (Reproduced with permission from Pitts RF: Physiology of the Kidneys and Body Fluids, 3rd ed. St. Louis, Mosby, 1974.)

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## The Blood Supply

- Describe the path blood travels as it passes from the renal artery to the renal vein..

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## The Blood Supply

- Renal artery → interlobar artery→ arcuate artery→ interlobular artery→Afferent arterioles → glomerular capillaries→ Efferent arterioles → Peritubular capillary → interlobular veins→ arcuate veins→ interlobar veins→Renal vein

- Juxtamedullary nephrons
  - different
    - cortical nephrons- peritubular network
    - juxtamedullary glomeruli- follow the tubule deep into the medulla, form hairpin loops (vasa recta)

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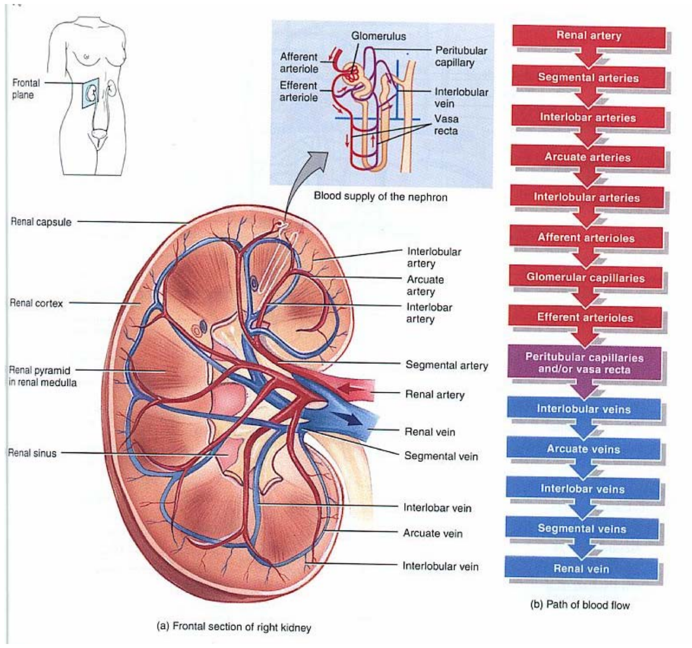

Frontal plane
Glomerulus
Afferent arteriole
Efferent arteriole
Peritubular capillary
Interlobular vein
Vasa recta
Blood supply of the nephron
Renal capsule
Renal cortex
Renal pyramid in renal medulla
Renal sinus
Interlobular artery
Arcuate artery
Interlobar artery
Segmental artery
Renal artery
Renal vein
Segmental vein
Interlobar vein
Arcuate vein
Interlobular vein
Renal artery
Segmental arteries
Interlobar arteries
Arcuate arteries
Interlobular arteries
Afferent arterioles
Glomerular capillaries
Efferent arterioles
Peritubular capillaries and/or vasa recta
Interlobular veins
Arcuate veins
Interlobar veins
Segmental veins
Renal vein
(b) Path of blood flow
(a) Frontal section of right kidney


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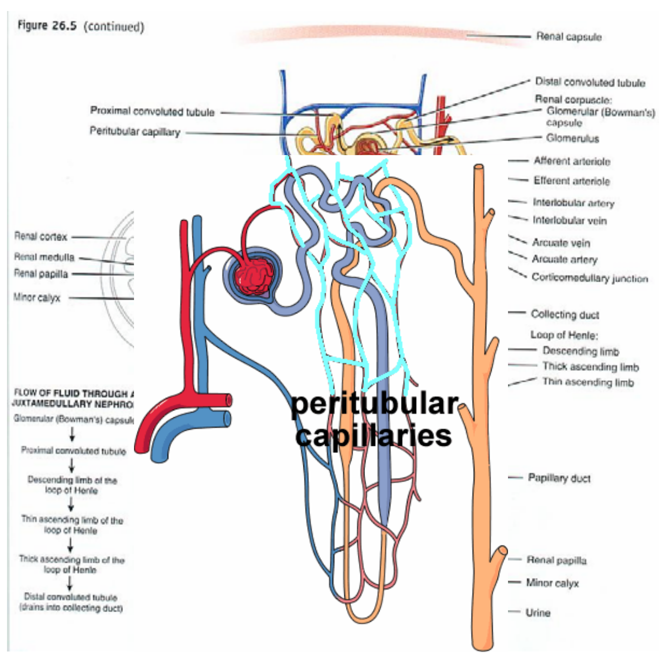
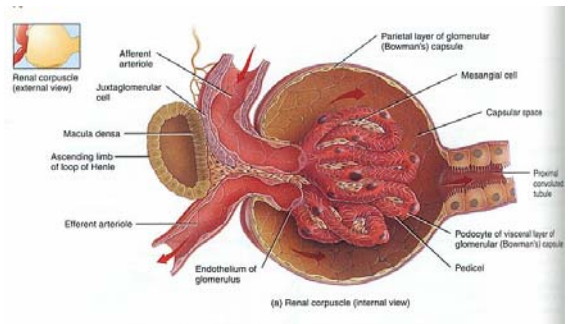


Figure 26.5 (continued)
Renal capsule
Distal convoluted tubule
Renal corpuscle:
Glomerular (Bowman's) capsule
Glomerulus
Proximal convoluted tubule
Peritubular capillary
Afferent arteriole
Efferent arteriole
Interlobular artery
Interlobular vein
Arcuate vein
Arcuate artery
Corticomedullary junction
Renal cortex
Renal medulla
Renal papilla
Minor calyx
Collecting duct
Loop of Henle:
Descending limb
Thick ascending limb
Thin ascending limb
peritubular capillaries
Papillary duct
Renal papilla
Minor calyx
Urine
Glomerular (Bowman's) capsule
Proximal convoluted tubule
Descending limb of the loop of Henle
Thin ascending limb of the loop of Henle
Thick ascending limb of the loop of Henle
Distal convoluted tubule (drains into collecting duct)

# Afferent Arteriole

- wall- endothelial cell, smooth muscle
- 30-50 microns distance
- JG cells elaborate renin, and erythropoetic factor

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# The Efferent Arteriole

- typical with smooth muscle layer
- breaks up
  - peritubular capillaries
  - vasa recta

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# The Nerve Supply

- sympathetic fibers terminating in arterial walls
  - vasoconstrictor
  - not tonically active
  - not essential for urine formation

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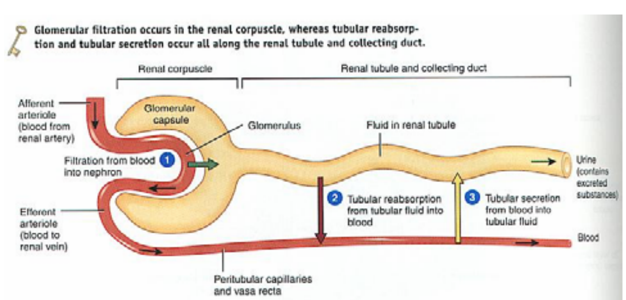
# The Elimination of Metabolic Waste Products and Toxic Substances through the Formation of Urine

- Glomerular Filtration
- Tubular Reabsorption
- Tubular Secretion
- Excretion

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## Glomerular Filtration

- Nature of Glomerular Ultrafiltration
- Structure of the Filter
- Nature of Filtrate
- Dynamics of Glomerular Filtration
- Evidences of Glomerular Filtration
- Estimation of Glomerular Ultrafiltration
- Factors Affecting the GFR
- Filtration Fraction

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## Nature of Glomerular Ultrafiltration

- glomerular membrane
  - not just an ordinary filter
  - more than a millipore filter
  - separates colloidal material
  - allow solutes of smaller molecular dimension
- passage of fluids
  - physical process
    - hydrostatic pressure

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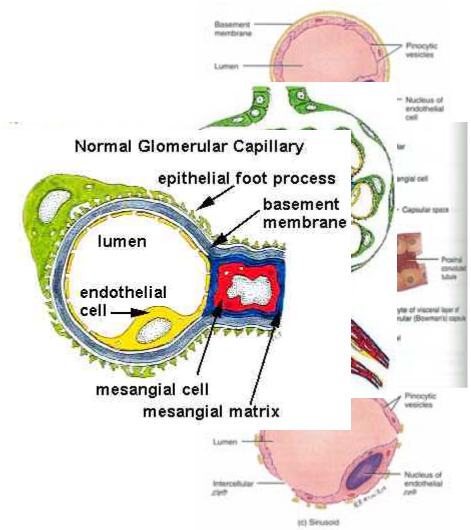
# Structure of the Filter

- Three Major Layers
  - endothelial layer
  - basement membrane
  - epithelial cells
- (Endothelium layers and epithelial membrane) very large opening between their cells
- basement membrane- filtration membrane act as a *sieve*
- molecules with a weight over 68,000 are not filtered
- permeability 100 times more than of the capillaries in skeletal muscle

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# Nature of Filtrate

The fluid entering the Bowman's capsule

- ultrafiltrate of plasma
  - except plasma proteins
  - the same concentration, pH, osmotic pressure
- slight difference in ionic concentration (Gibbs- Donnan effect)

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## Dynamics of Glomerular Filtration

1. Force inducing filtration
2. Forces Opposing Filtration (tends to keep fluid in the glomerulus)
3. Effective Filtration Pressure

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## Dynamics of Glomerular Filtration

- Force inducing filtration
  - glomerular capillary hydrostatic pressure (60mmHg)
  - CP is higher because
    - afferent arteriole is short and broad
    - renal artery is a direct branch of the abdominal aorta
    - resistance to outflow is higher

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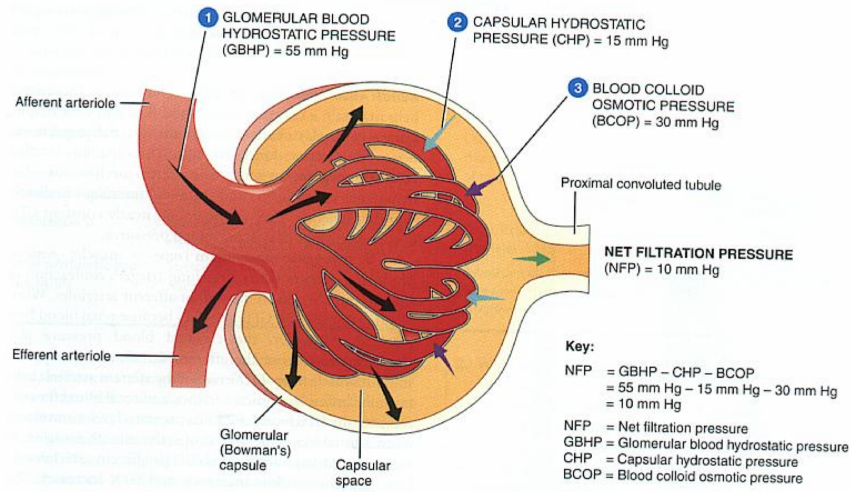
**Figure 26.9** The pressures that drive glomerular filtration. Taken together, these pressures determine net filtration pressure (NFP).

**Glomerular blood hydrostatic pressure promotes filtration, whereas capsular hydrostatic pressure and blood colloid osmotic pressure oppose filtration.**

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# Dynamics of Glomerular Filtration

- Forces Opposing Filtration (tends to keep fluid in the glomerulus)
  - tubular pressure
    - 18mmHg back pressure
  - osmotic pressure of plasma proteins (OPPP)
    - 32mmHg
    - higher than systemic
    - concentration of plasma proteins

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## Dynamics of Glomerular Filtration

- Effective Filtration Pressure

  *EFP= CP – (OPPP + Tubular Pressure)*

  10mmHg= 60 – (32 +18)

  – driving force that pushes fluid

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## Evidences of Glomerular Filtration

- utrafiltrate is protein free as evidence by the micropuncture technique of Richard and Wearn
- contains all crystalloids
- hydrostatic pressure is sufficient force to separate this protein-free portion from the plasma

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# Estimation of Glomerular Ultrafiltration

- How much of plasma that courses the two kidneys is filtered/minute?
- Characteristics of Substance
  - freely filtered
  - neither secreted into nor reabsorbed from the filtrate
  - neither synthesized nor altered by the kidney
  - easy to detect or analyze in both plasma and urine

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***Inulin* is such a substance, thus we can measure what we call the clearance of inulin, $C_{in}$, and for this "special" substance**

$$C_{in} = GFR = \frac{[U]_{in} \times V}{[P]_{in}} \quad \text{(units are ml/min)}$$

**We now have a standard in inulin clearance. If we measure the clearance of any substance, x, and compare it to $C_{in}$, if**

**$C_x > C_{in}$, substance must be added to the tubule (i.e., secreted)**

**$C_x < C_{in}$, substance must be removed from tubule (i.e., absorbed)**

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$$GFR = \frac{5mg/ml \times 5ml/\min}{0.2mg/ml}$$

**125 ml/min**

- If the amount excreted is less than the filtered amount= filtered and reabsorbed
- If in excess of what has been filtered= filtration and secretion

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# Factors Affecting the GFR

- Changes in glomerular capillary hydrostatic pressure
  - systemic blood pressure
  - afferent or efferent arteriolar constriction
- Changes in hydrostatic pressure in bowmans capsule
  - ureteral obstruction
  - edema of kidney inside tight renal capsule
- Changes in oncotic pressure of plasma proteins
  - dehydration
  - hypoproteinemia
- Increased permeability of glomerular filter
  - various disease
- Decrease in total area of glomerular capillary bed
  - disease which destroy glomeruli with or without destruction of tubules
  - partial nephrectomy

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# Filtration Fraction

- measure of the fluid loss from the plasma and the extent to which the plasma proteins are concentrated in the process.

[redacted]

  - Normal value: 0.16 - 0.20 in man

- A much higher filtration fraction- peritubular capillary oncotic pressure is high

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**PAH Clearance** = $\frac{\textbf{5.85mg/ml x 1 ml/min}}{0.01\text{mg/ml}}$

= **585ml/min**

= $\frac{\textbf{585ml/min}}{0.9}$

= **650ml/min**

**FF** = GFR/RPF **125/650 = 0.19**

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## Filtration Fraction

- measure of the fluid loss from the plasma and the extent to which the plasma proteins are concentrated in the process.

$$\text{Filtration Fraction} = \frac{\text{GFR}}{\text{RPF}}$$

  - Normal value: 0.16 - 0.20 in man

- A much higher filtration fraction- peritubular capillary oncotic pressure is high

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THANK YOU!