Renal Physiology 2
Guyton

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Renal Handling of Water and Solutes

	Filtration	reabsorption	excretion
L/day Water	180	179	1
Na+ mmol/day	25,560	25,410	150
Glucose gm/day	180	180	0
Creatinine gm/day	1.8	0	1.8

Renal Handling
of
Different Substances

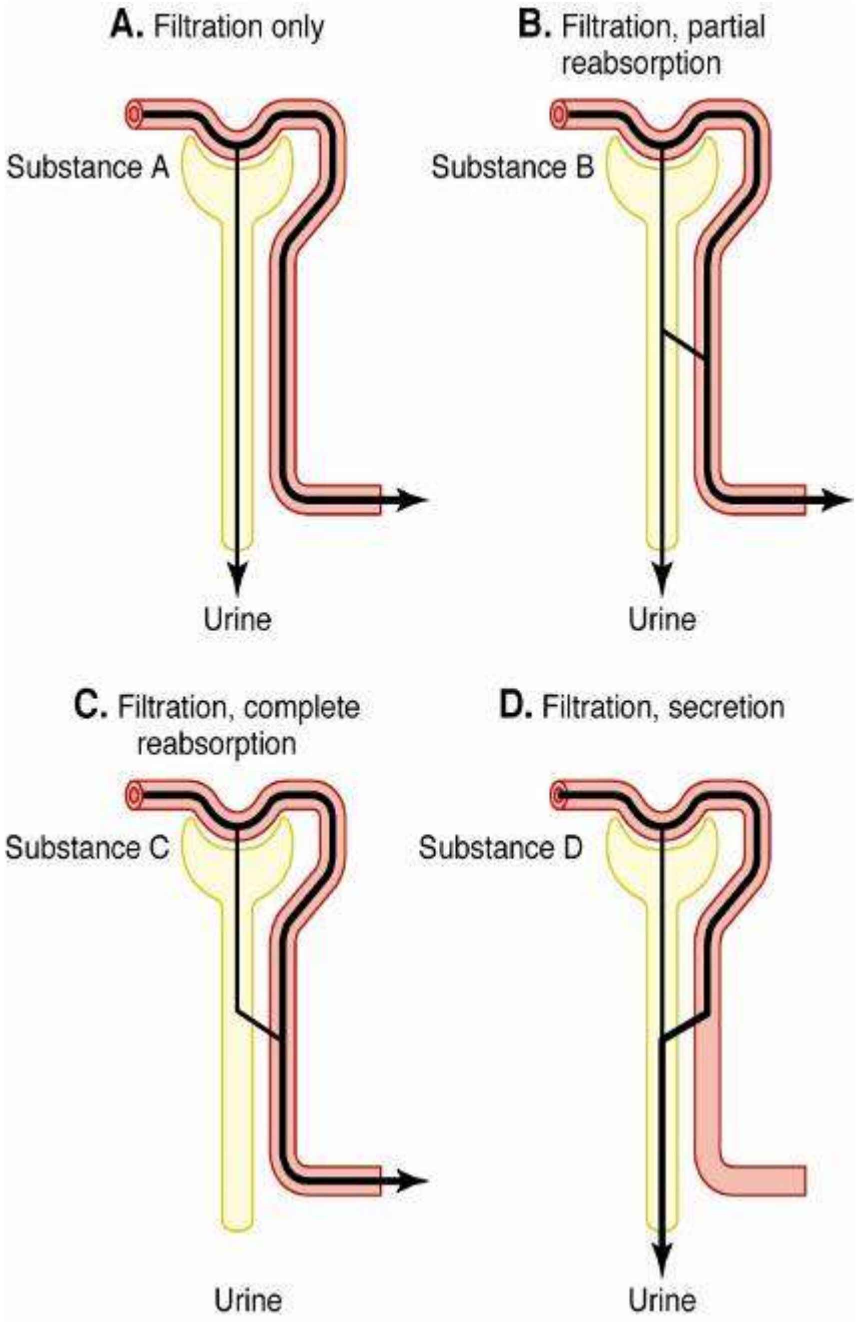


Figure 26-10

Effects of size and electrical charge of dextran on filterability by glomerular capillaries.

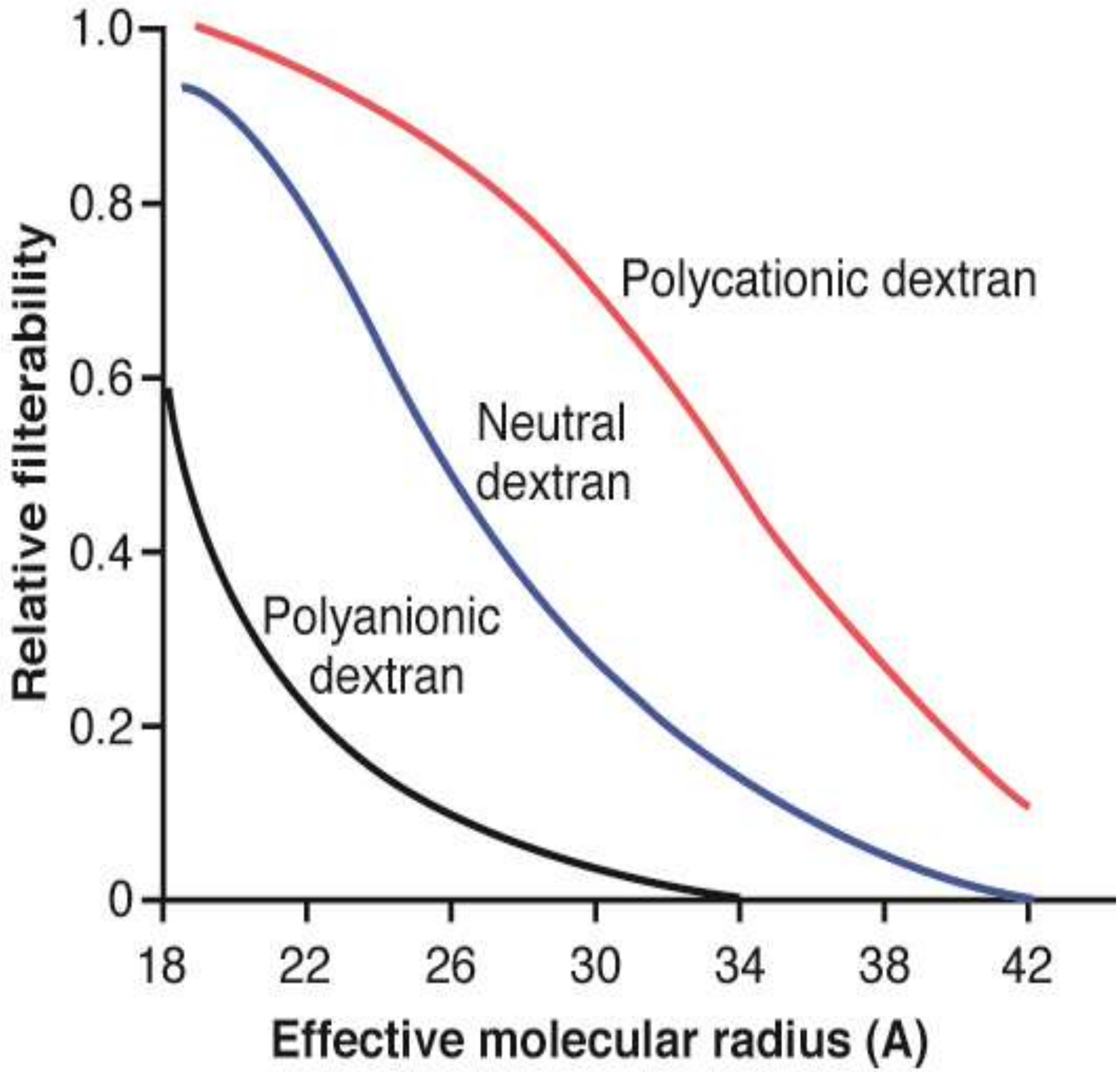


Figure 26-12

Glomerular Filtration

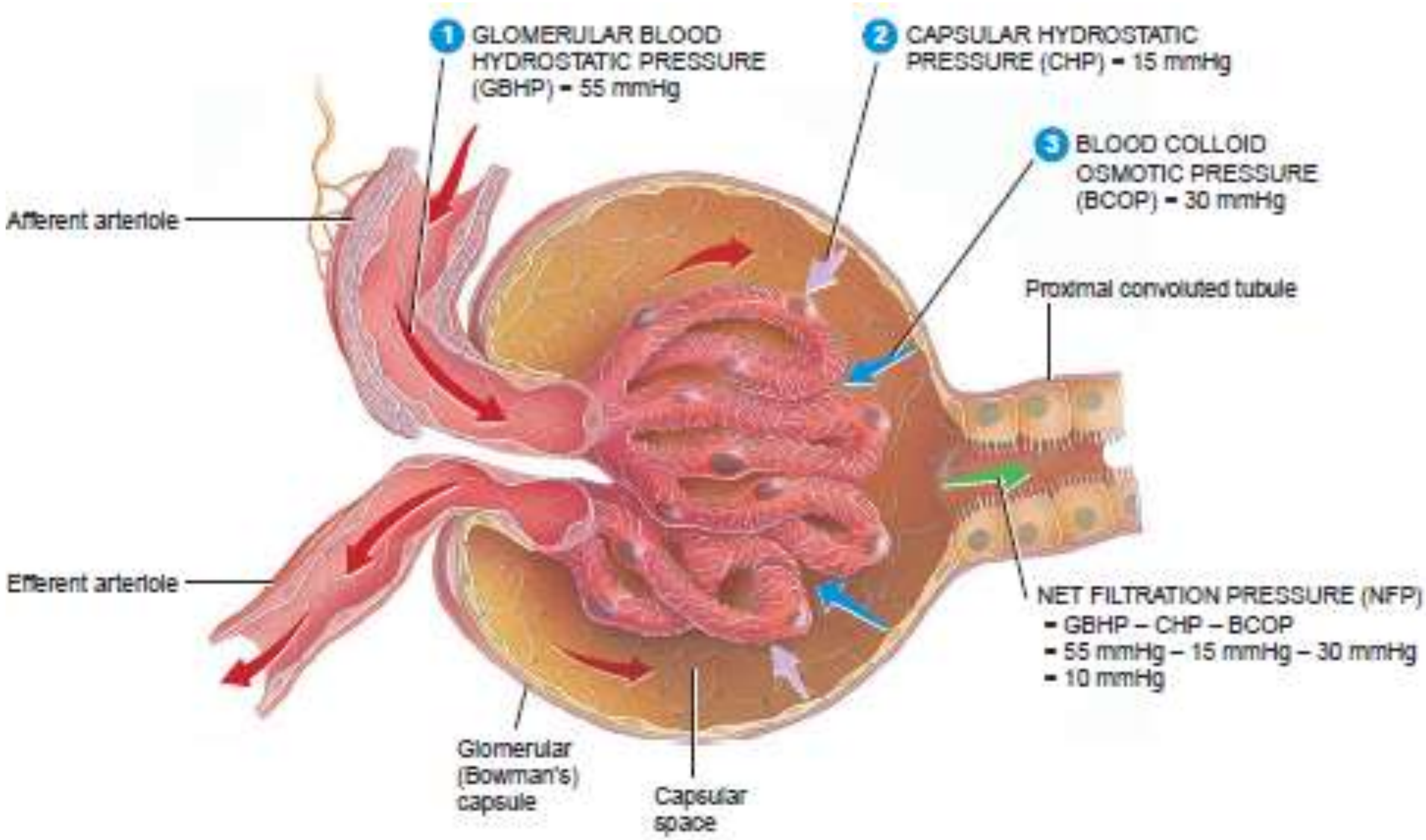
GFR = 125 ml/min = 180 liters/day

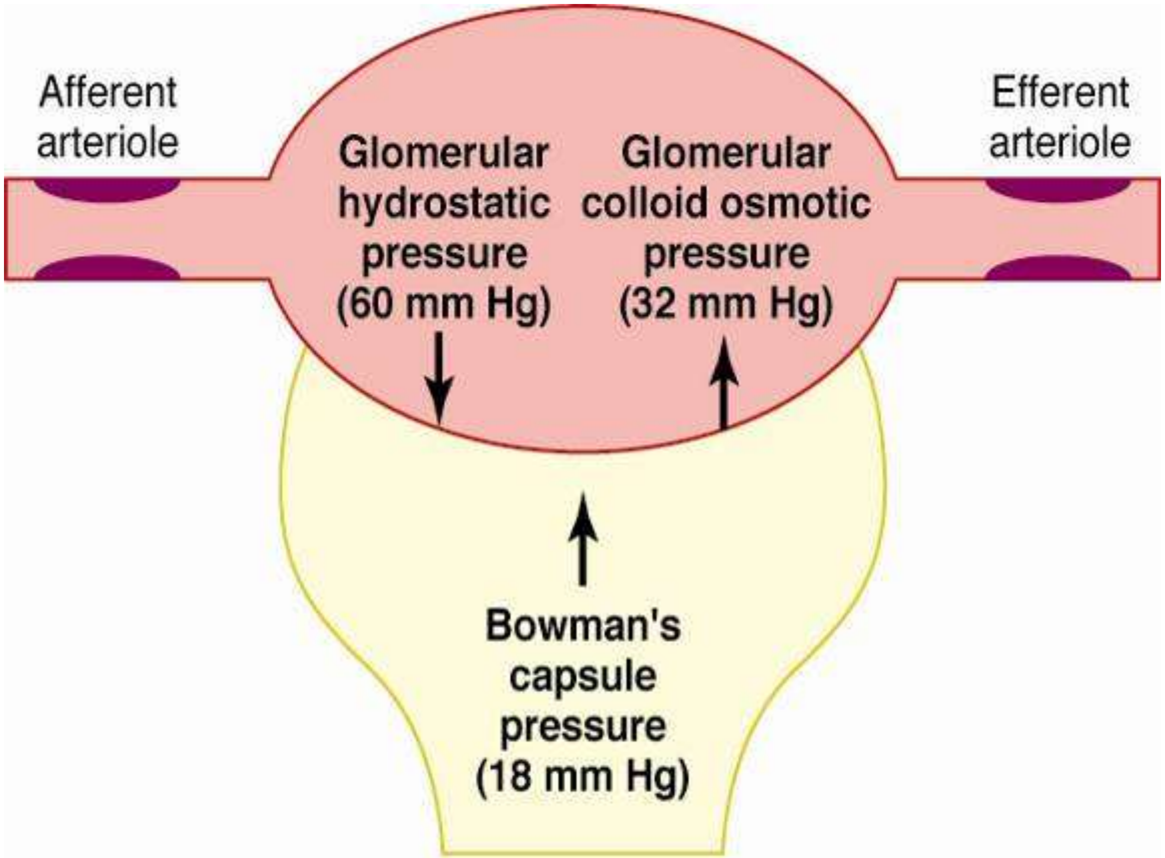
- Plasma volume is filtered 60 times per day
- Glomerular filtrate composition is about the same as plasma, except for large proteins
- Filtration fraction (GFR / Renal Plasma Flow) = 0.2 (i.e. 20% of plasma is filtered)

Clinical Significance of Proteinuria

- Early detection of renal disease in at-risk patients
  - hypertension: hypertensive renal disease
  - diabetes: diabetic nephropathy
  - pregnancy: gestational proteinuric hypertension (pre-eclampsia)
  - annual "check-up": renal disease can be silent
- Assessment and monitoring of known renal disease

Glomerular Filtration





Net filtration pressure (10 mm Hg) = Glomerular hydrostatic pressure (60 mm Hg) – Bowman's capsule pressure (18 mm Hg) – Glomerular oncotic pressure (32 mm Hg)

+ colloid capsular pressure (0)

Figure 26-13

Glomerular Filtration Rate (GFR)

- **Filtration Fraction (FF)= Fraction** of blood plasma in the afferent arterioles that becomes filtrate= 16-20%.
- **GFR** =The volume (ml) of fluid filtered through all the corpuscles of both kidneys per minute.
- The volume of fluid filtered daily through all the corpuscles of both kidneys per day = 180 L
- **Hence, GFR**= 180 L/24hours * (1000 ml/ L)*(1hour/60 min)= **125 ml/min (Males)**
- For 125ml/min; renal plasma flow = 625ml/min

  FF * PF=GFR, PF= 125/(20%)=625 ml/min
- 55% of blood is plasma, so blood flow = 1140ml/min

  55% * BF= PF; BF= 625ml/min/ (55%)=1140 ml/min
- Renal Blood Flow of 1140 ml/min = (22.8 % of 5 liters) is required to have GFR of 125ml/min.

Clinical Application

- ***Edema***
- Some kidney diseases result in a damage of the glomerular Capillaries leading to an increase in their permeability to large proteins .
- Hence, Bowman's capsule colloid pressure will increase significantly leading to drawing more water from plasma to the capsule (i.e more filtered fluid).
- Proteins will be lost in the urine causing deficiency in the blood colloid pressure which worsens the situation, blood volume decreases and interstitial fluids increases causing ***edema***.

Regulation of Glomerular Filtration

- Homeostasis of body fluids requires constant GFR by kidneys.
- If the GFR is too high, needed substances cannot be reabsorbed quickly enough and are lost in the urine.
- If the GFR is too low -everything is reabsorbed, including wastes that are normally disposed of.

Determinants of Glomerular Filtration Rate

Normal Values:

GFR = 125 ml/min

Net Filt. Press = 10 mmHg

K_f = 12.5 ml/min per mmHg, or 4.2 ml/min per mmHg/ 100gm

(400 x greater than in many tissues)

Glomerular Capillary Filtration Coefficient (K_f)

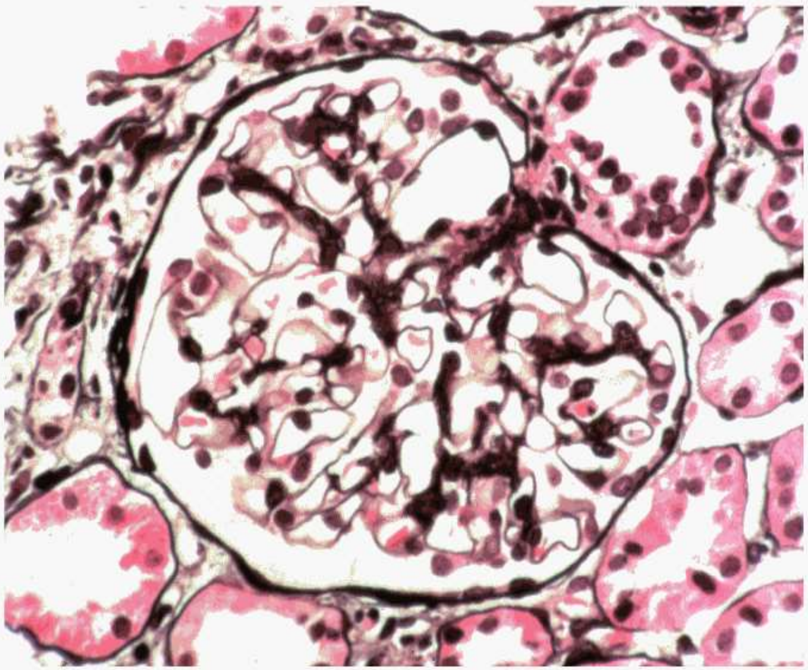
- K_f = hydraulic conductivity x surface area

K_f = GFR/net filt pressure

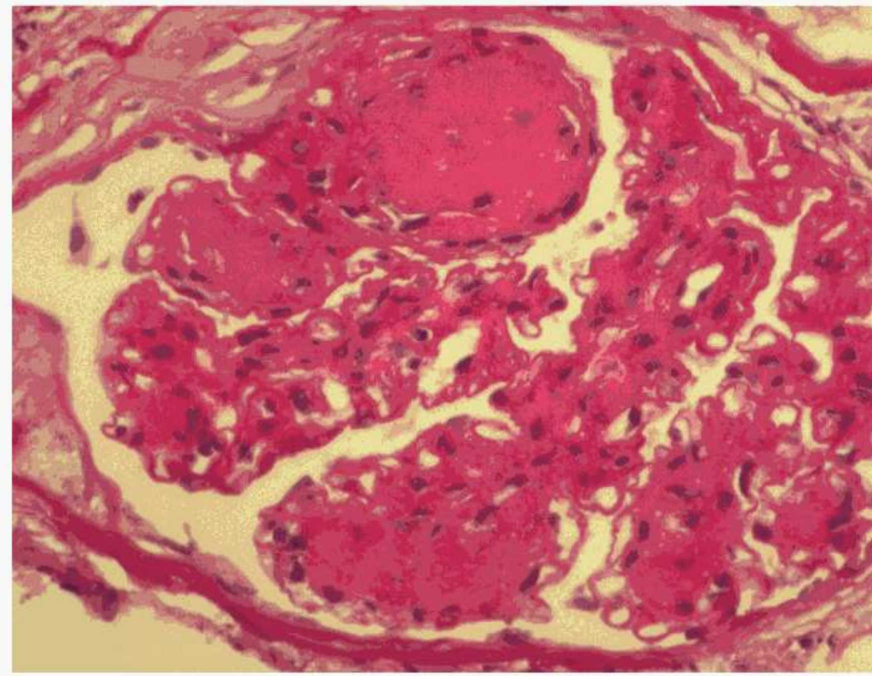
  - Normally <u>not</u> highly variable
- Disease that can reduce K_f and GFR
- damage of capillaries, BM thickens,
  - chronic hypertension
  - obesity / diabetes mellitus
  - glomerulonephritis

Glomerular Injury in Chronic Diabetes

Normal glomerulus



Diabetic nephropathy



Bowman's Capsule hydrostatic Pressure (P_B)

- Normally changes as a function of GFR, not a physiological regulator of GFR
- Increases with Tubular Obstruction
  - kidney stones
  - tubular necrosis

Reducing GFR

- Urinary tract obstruction

Prostate hypertrophy/cancer

Factors Influencing Glomerular Capillary Oncotic Pressure (Π_G)

- Arterial Plasma Oncotic Pressure (π_A)

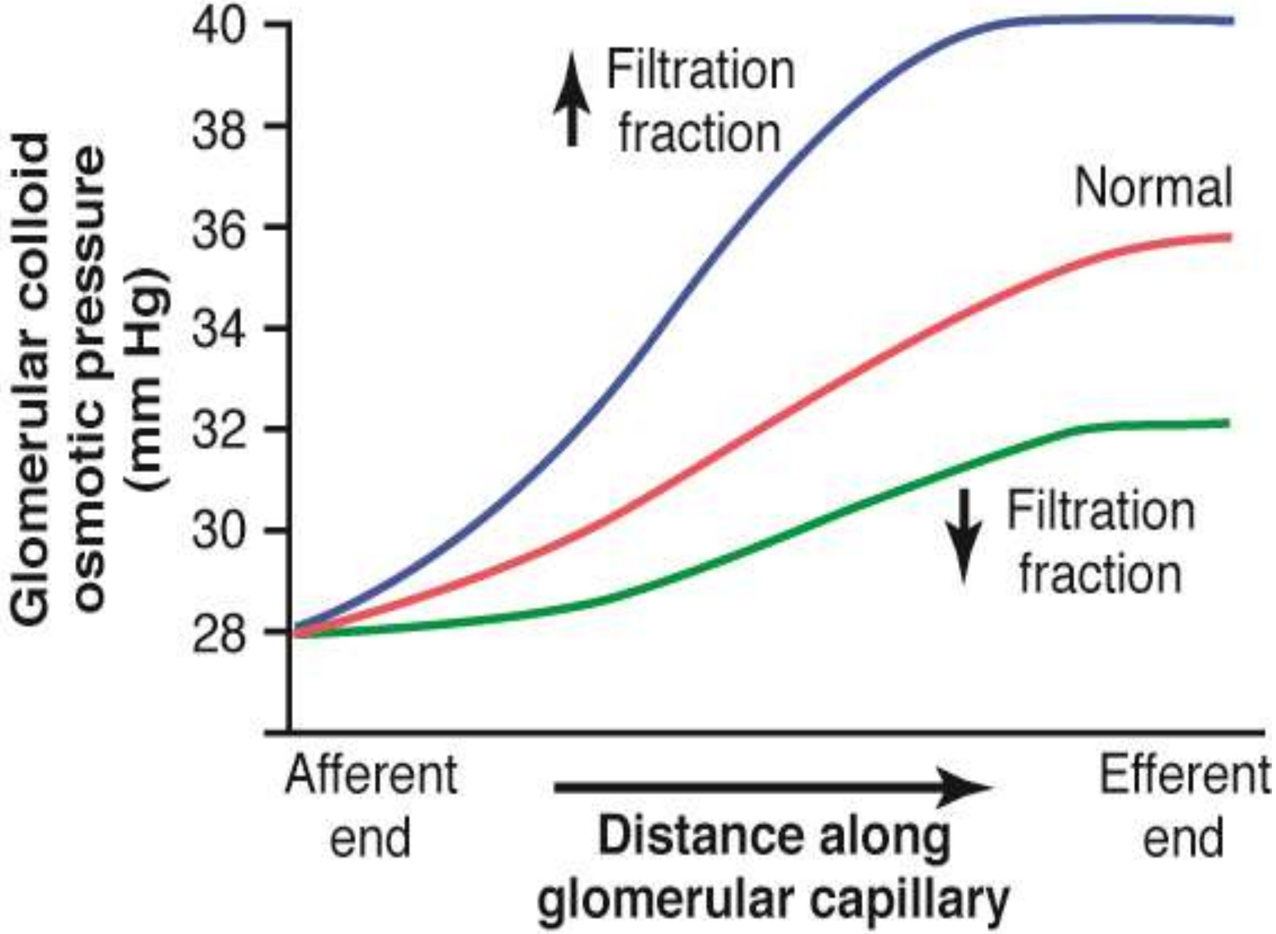
$$\uparrow \pi_A \longrightarrow \uparrow \pi_G$$

- Filtration Fraction (FF)

$$\uparrow FF \longrightarrow \uparrow \pi_G$$

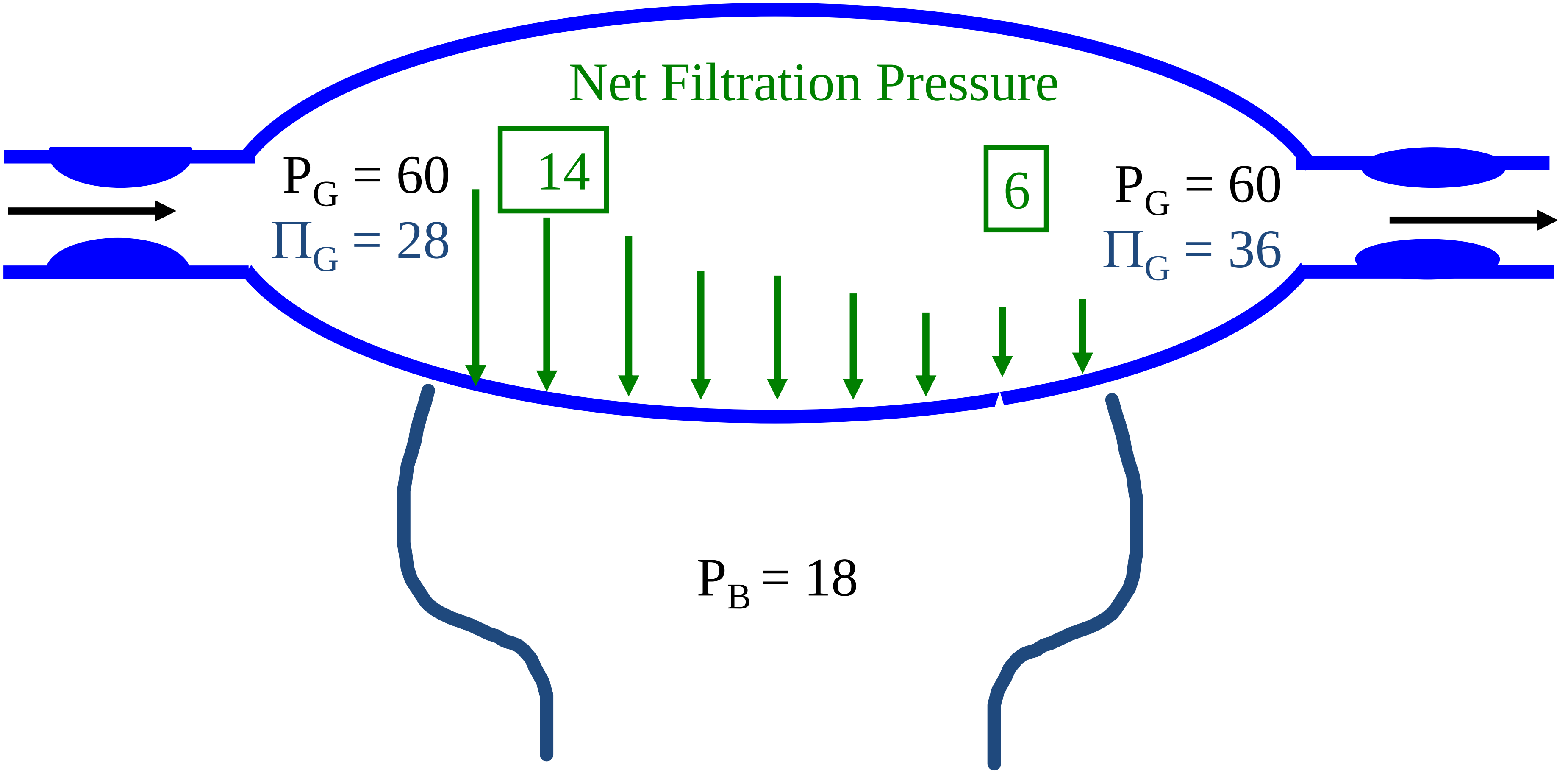
FF = GFR / Renal plasma flow

= 125 / 650 ~ 0.2 (or 20%)



Glomerular colloid osmotic pressure (mm Hg)
40
38
36
34
32
30
28
↑ Filtration fraction
Normal
↓ Filtration fraction
Afferent end
Distance along glomerular capillary
Efferent end

Figure 26-14


Net Filtration Pressure
14
6
$P_G = 60$
$\Pi_G = 28$
$P_G = 60$
$\Pi_G = 36$
$P_B = 18$

Microalbuminuria

- Definition: urine excretion of > 30 but < 150 mg albumin per day

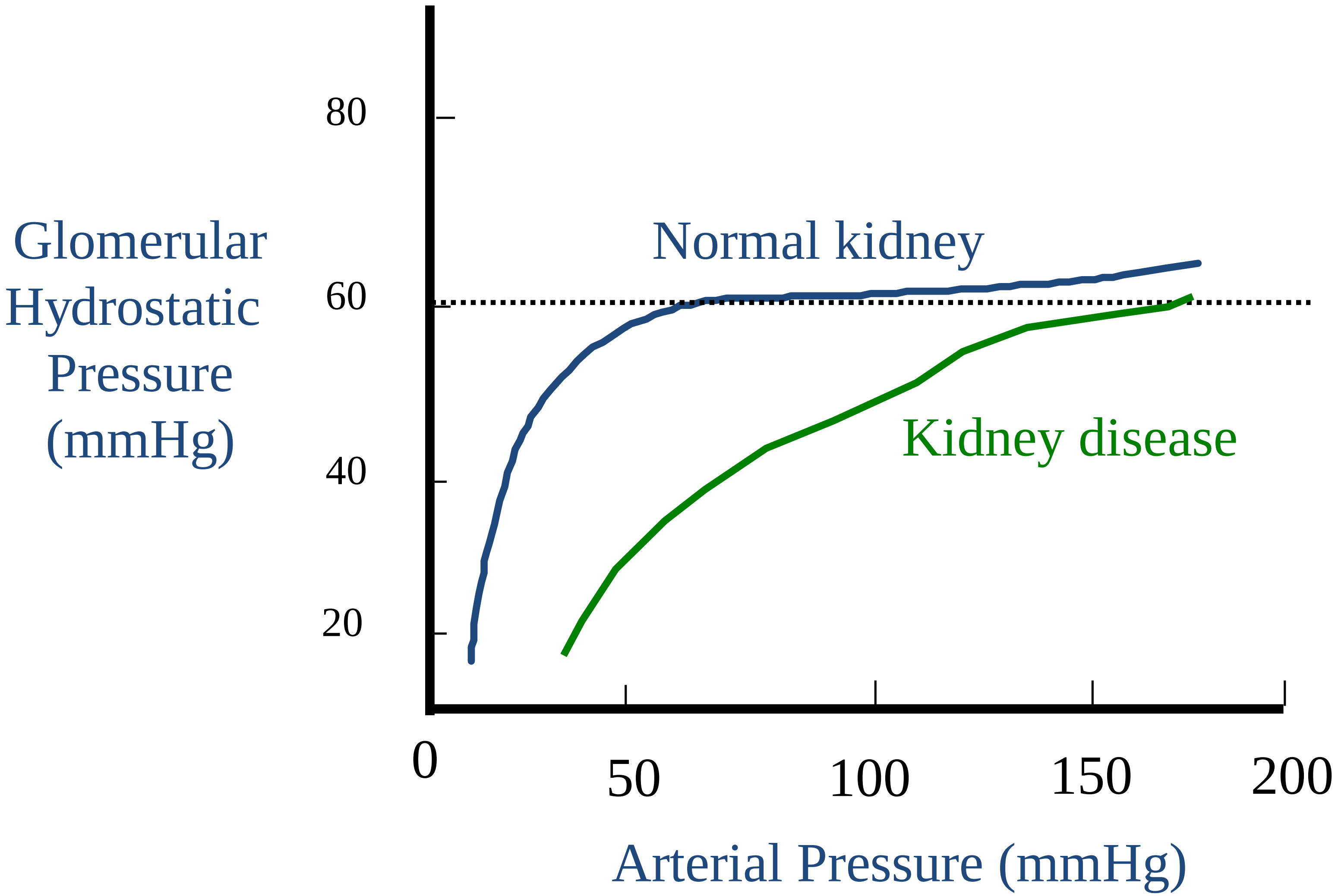
- Causes: early diabetes, hypertension, glomerular hyperfiltration

Prognostic Value: diabetic patients with microalbuminuria are 10-20 fold more likely to develop persistent proteinuria

Glomerular Hydrostatic Pressure (P_G)

- Is the determinant of GFR most subject to physiological control

- Factors that influence P_G
  - arterial pressure (effect is buffered by autoregulation)
  - afferent arteriolar resistance
  - efferent arteriolar resistance



Glomerular Hydrostatic Pressure (mmHg)
80
60
40
20
Normal kidney
Kidney disease
0
50
100
150
200
Arterial Pressure (mmHg)

Autoregulation of renal blood flow and GFR but not urine flow

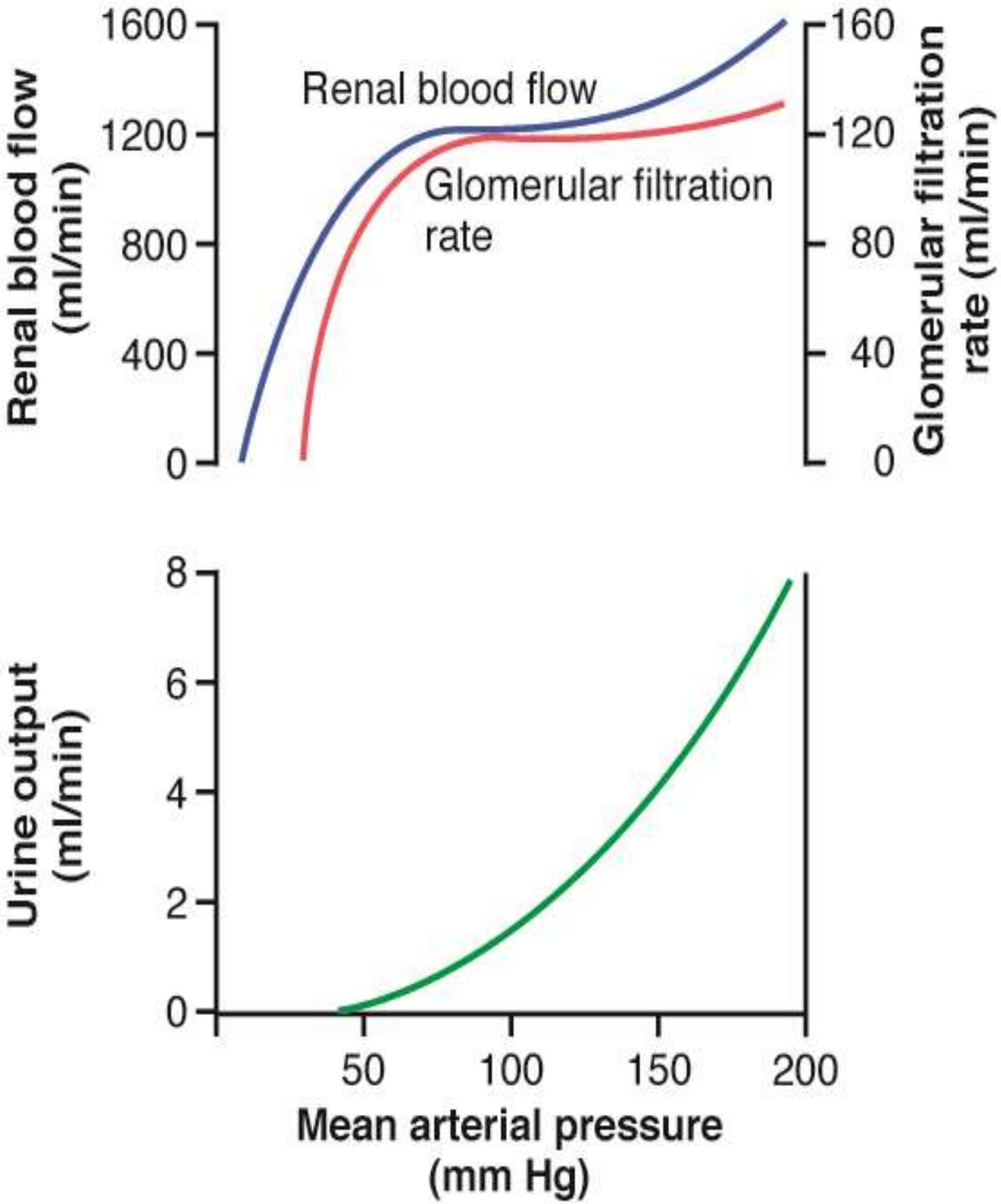
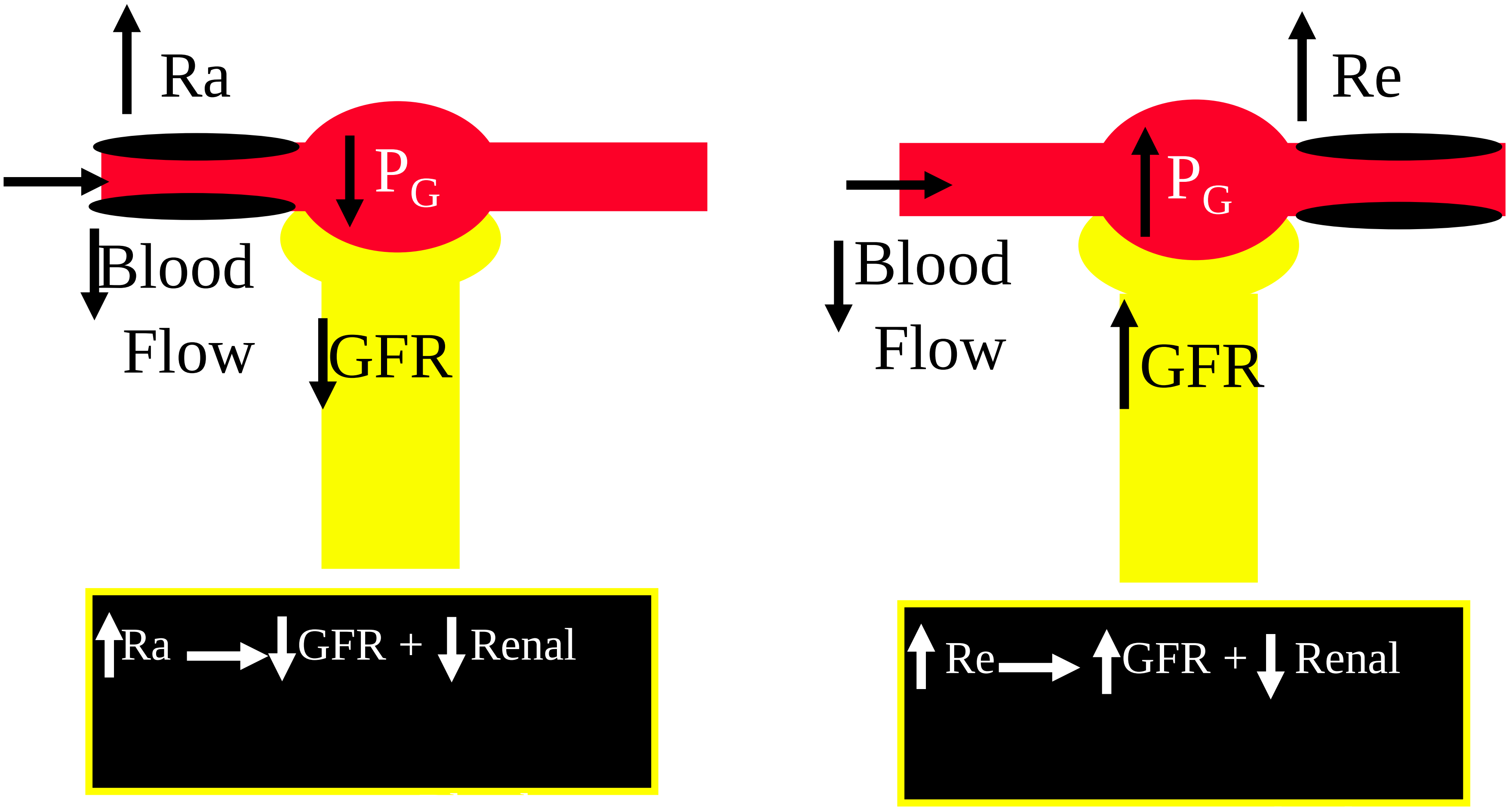


Figure 26-16

Effect of afferent and efferent arteriolar constriction on glomerular pressure



Effect of changes in afferent arteriolar or efferent arteriolar resistance

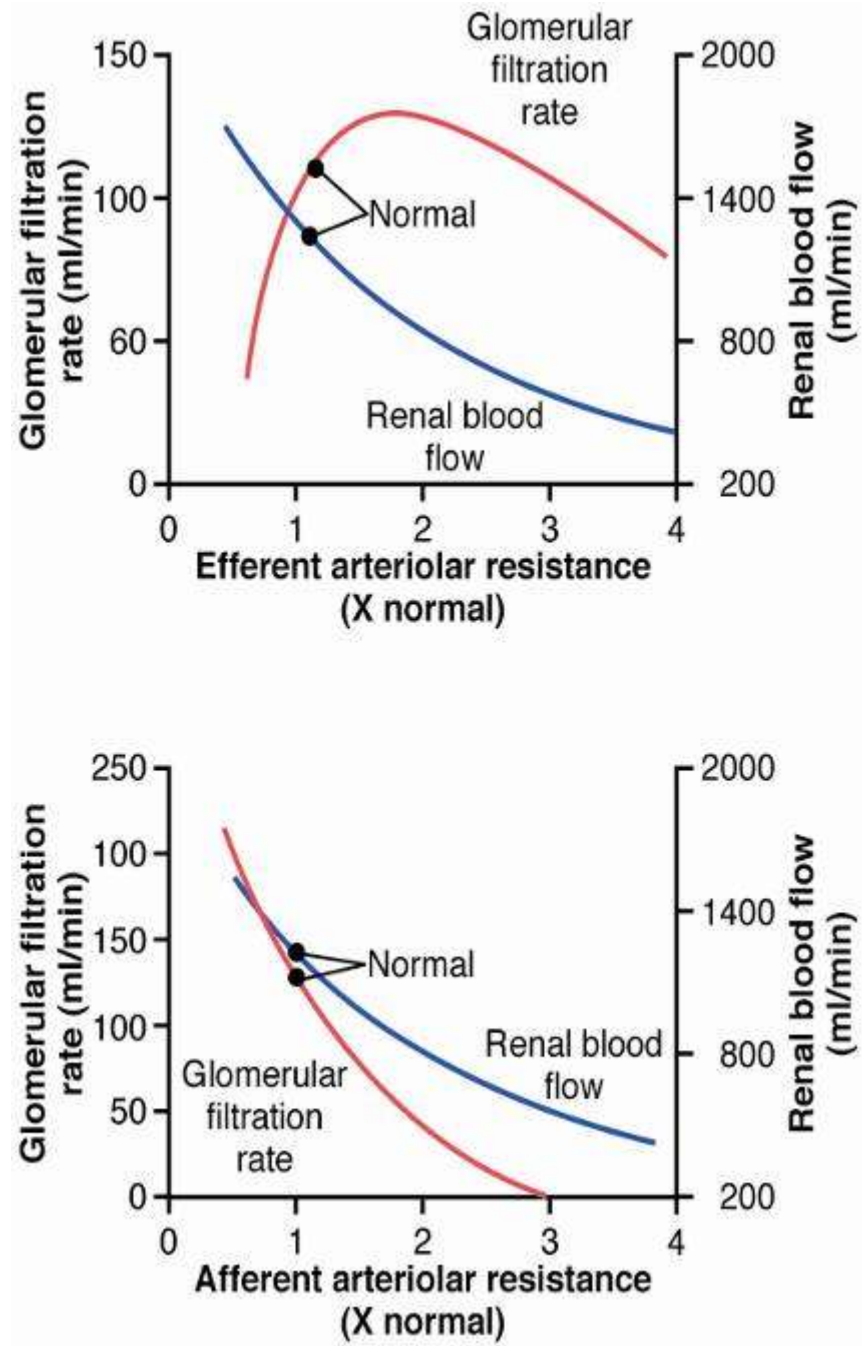
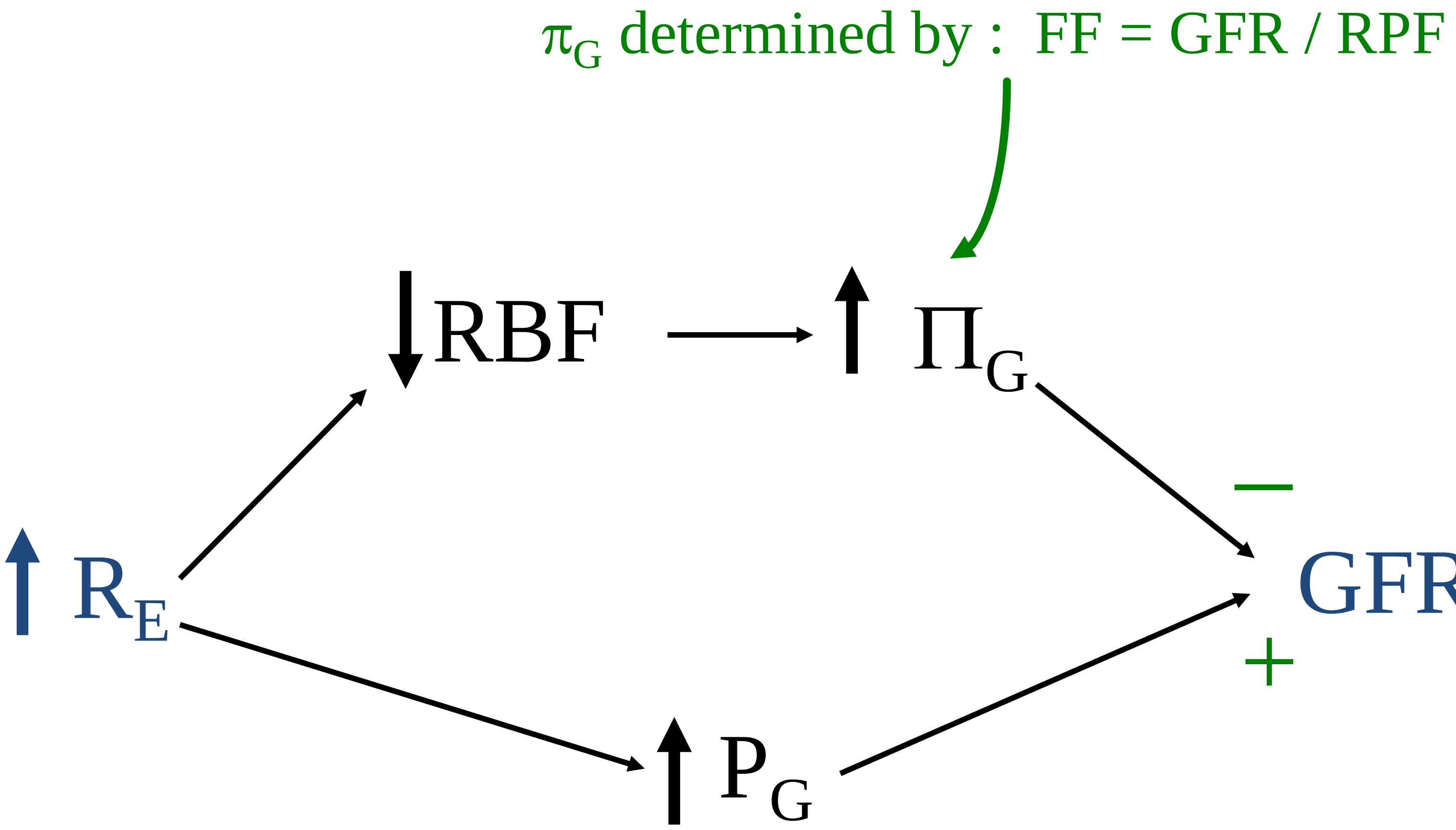


Figure 26-15



πG determined by : FF = GFR / RPF
RBF
ΠG
RE
PG
GFR
−
+

Summary of Determinants of GFR

$\uparrow$GFR If $\longrightarrow$ $\uparrow$ K_f

$\uparrow$GFR If $\longrightarrow$ $\downarrow$ P_B

$\uparrow$GFR If $\longrightarrow$ $\downarrow$ Π_G

$\uparrow \Pi_G$ If $\longrightarrow$ $\uparrow \Pi_A$ $\longrightarrow$ $\downarrow$GFR

$\uparrow \Pi_G$ If $\longrightarrow$ $\uparrow$FF

$\uparrow$GFR If $\longrightarrow$ $\uparrow$ P_G

$\uparrow P_G$ If $\longrightarrow$ $\downarrow R_A$ $\longrightarrow$ $\uparrow$ GFR

$\uparrow P_G$ If $\longrightarrow$ $\uparrow R_E$ $\longrightarrow$ $\uparrow$ GFR

(as long as $\uparrow R_E$ < 3-4 x normal)

Determinants of Renal Blood Flow (RBF)

$$RBF = \Delta P / R$$

ΔP = difference between renal artery pressure and renal vein pressure

R = total renal vascular resistance

= Ra + Re + Rv

= sum of all resistances in kidney vasculature

Renal blood flow

- High blood flow (~22 % of cardiac output)
- High blood flow needed for high GFR
- Oxygen and nutrients delivered to kidneys normally greatly exceeds their metabolic needs
- A large fraction of renal oxygen consumption is related to renal tubular sodium reabsorption

Renal oxygen consumption and sodium reabsorption

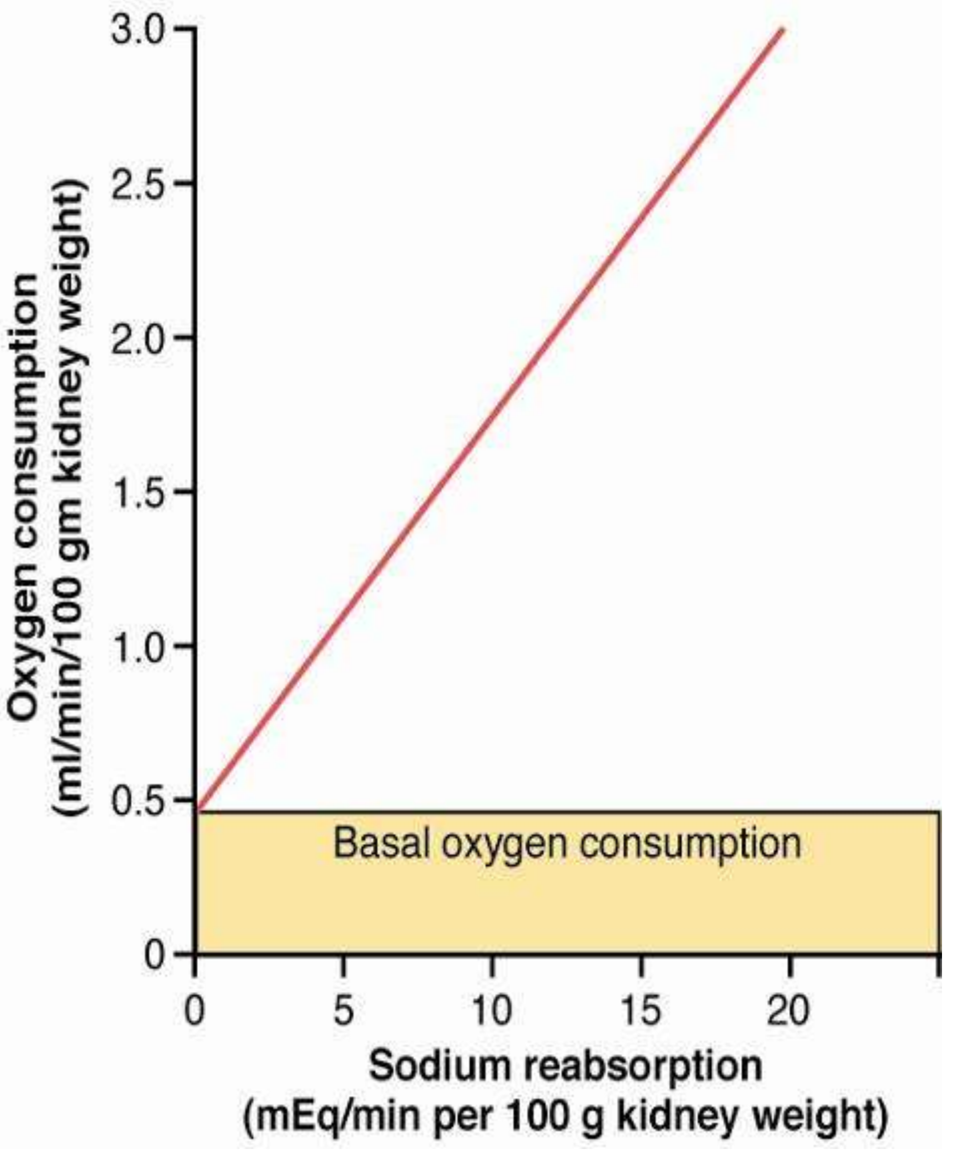


Figure 26-16