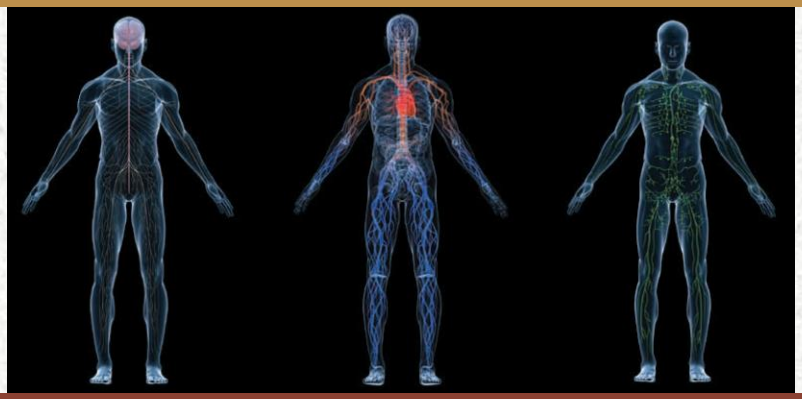
UNIT V

GUYTON AND HALL *Textbook of*

Medical Physiology

TWELFTH EDITION



Chapter 29:

Renal Regulation of Potassium, Calcium, Phosphate, and Magnesium; Integration of Renal Mechanisms for Control of Blood Volume and Extracellular Fluid Volume

Normal potassium intake, distribution, and output from the body.

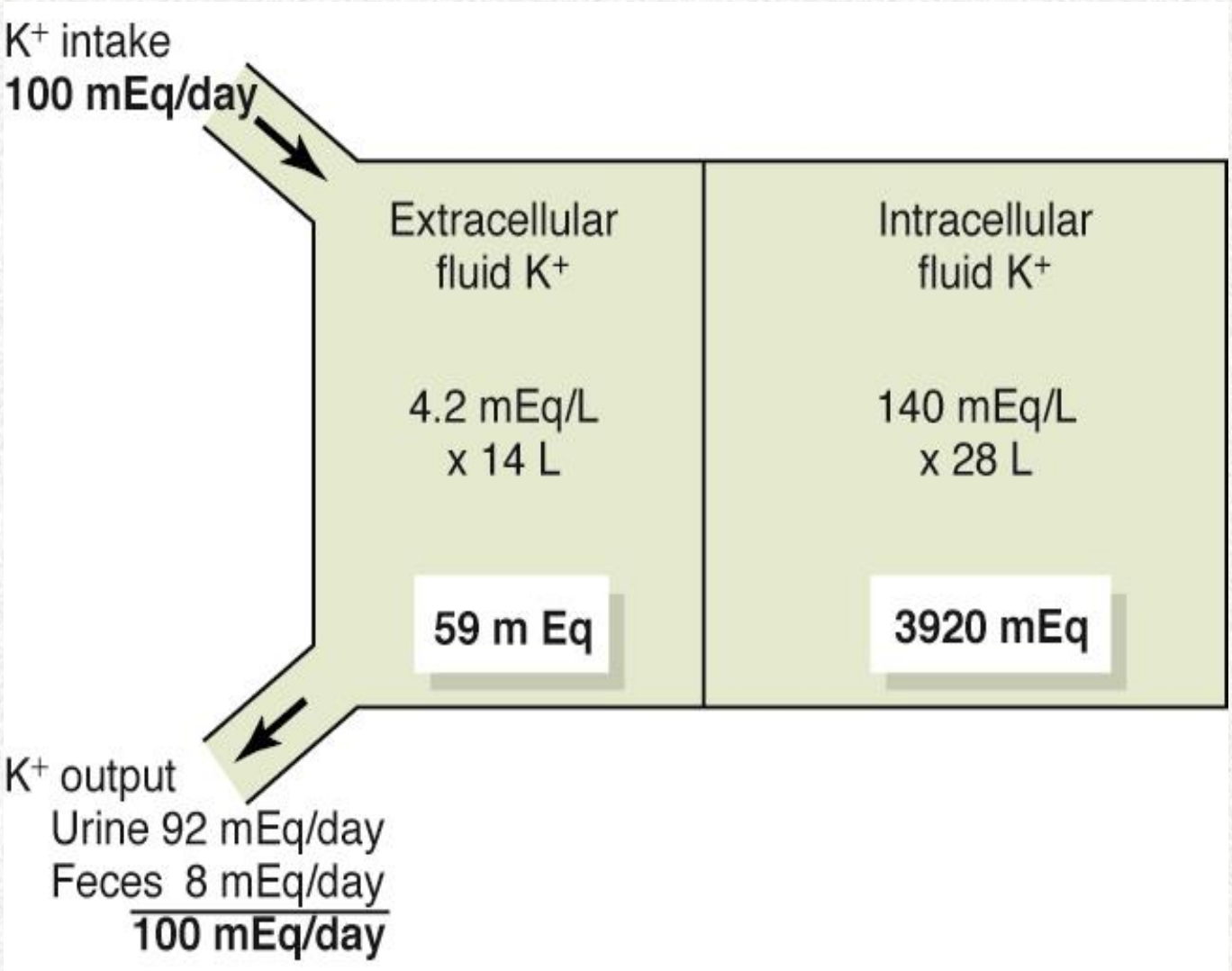
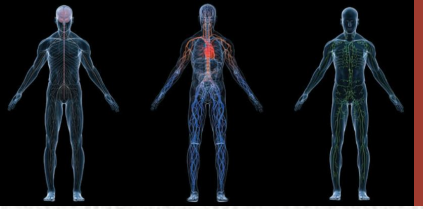


Figure 29-1

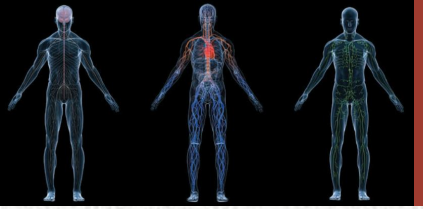


Effects of severe hyperkalemia

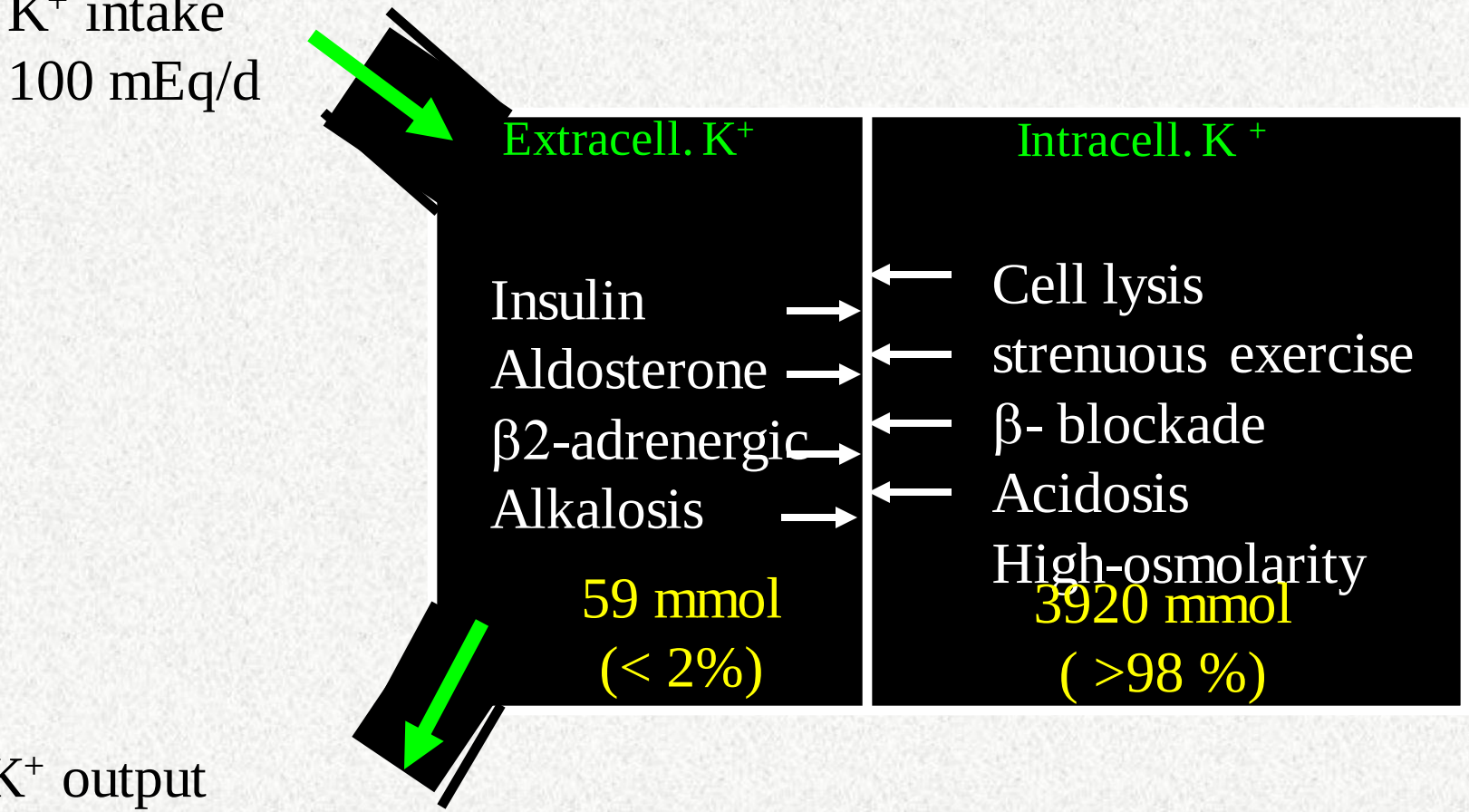
- Partial depolarization of cell membranes
- Cardiac toxicity
  ventricular fibrillation or asystole

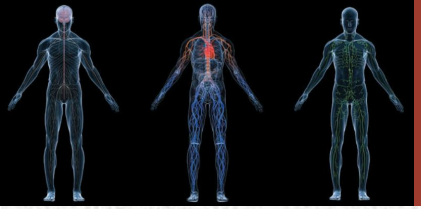
Effects of severe hypokalemia

- Hyperpolarization of cell membranes
- Fatigue, muscle weakness
- hypoventilation
- delayed ventricular repolarization

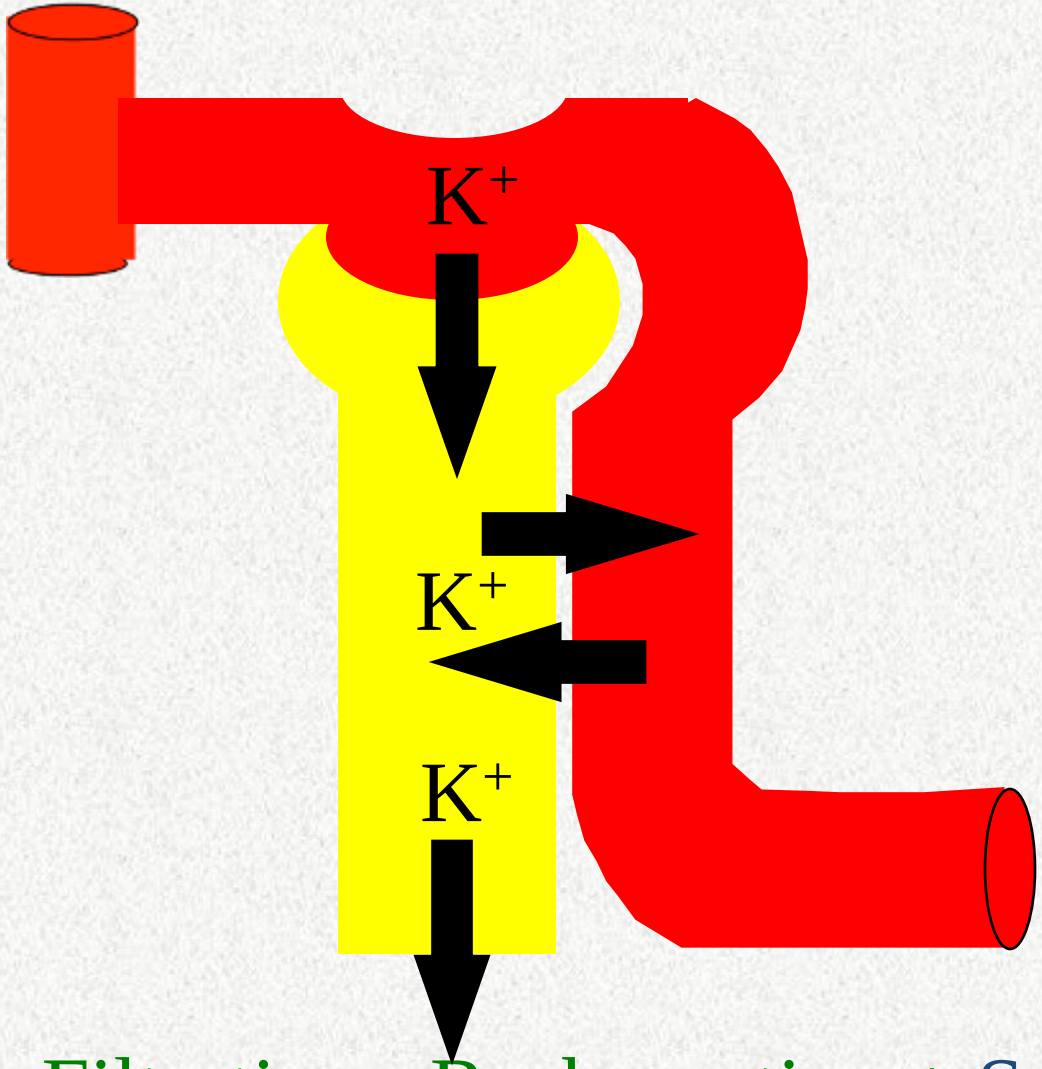


Potassium Regulation: Internal and External

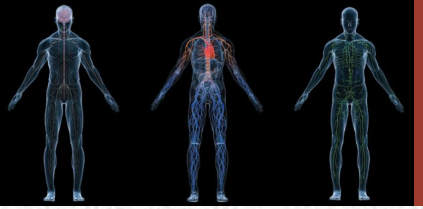




Control of Potassium Excretion



Excretion = Filtration - Reabsorption + Secretion



Renal tubular sites of potassium reabsorption and secretion.

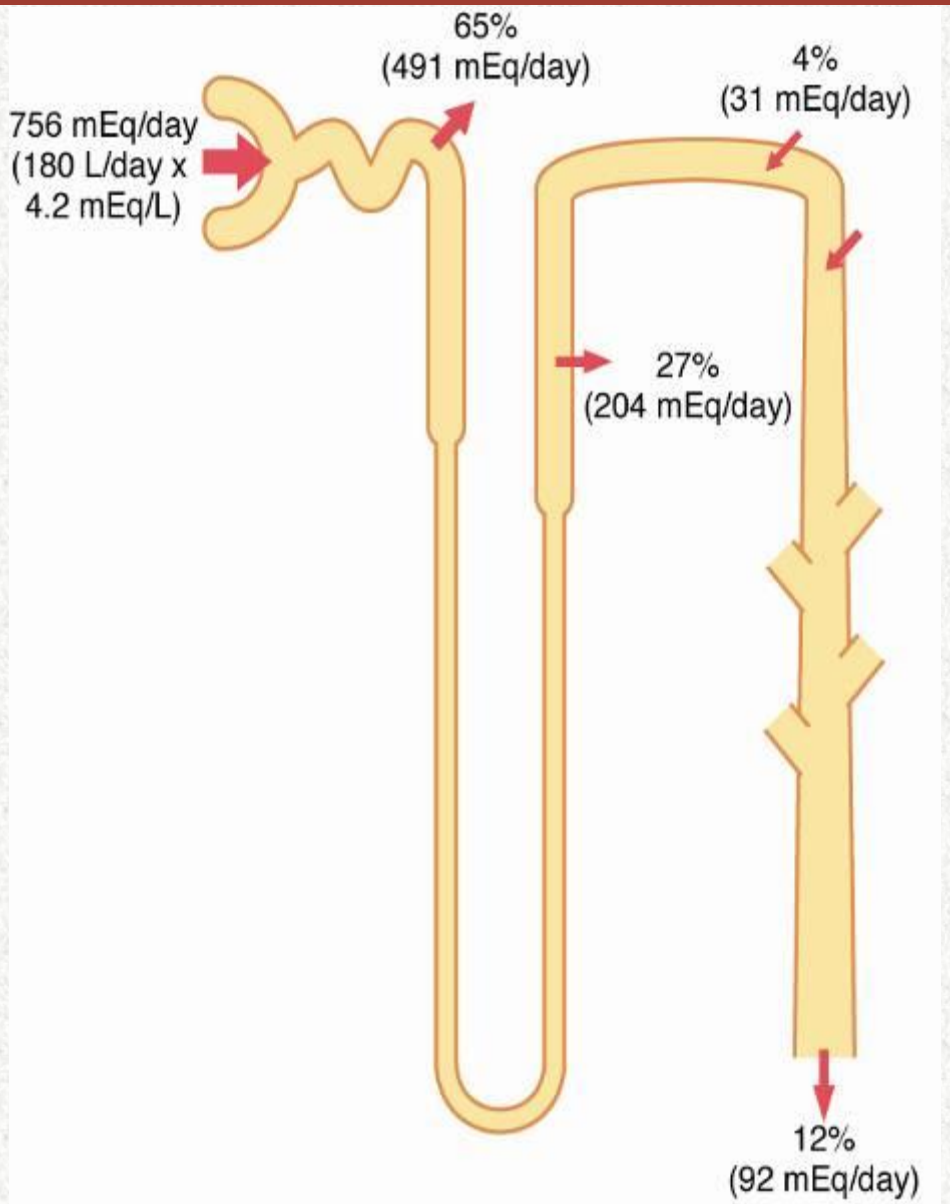
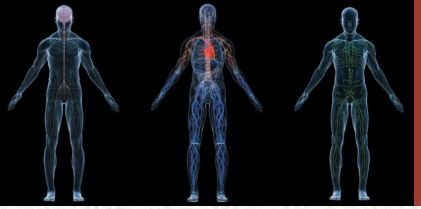
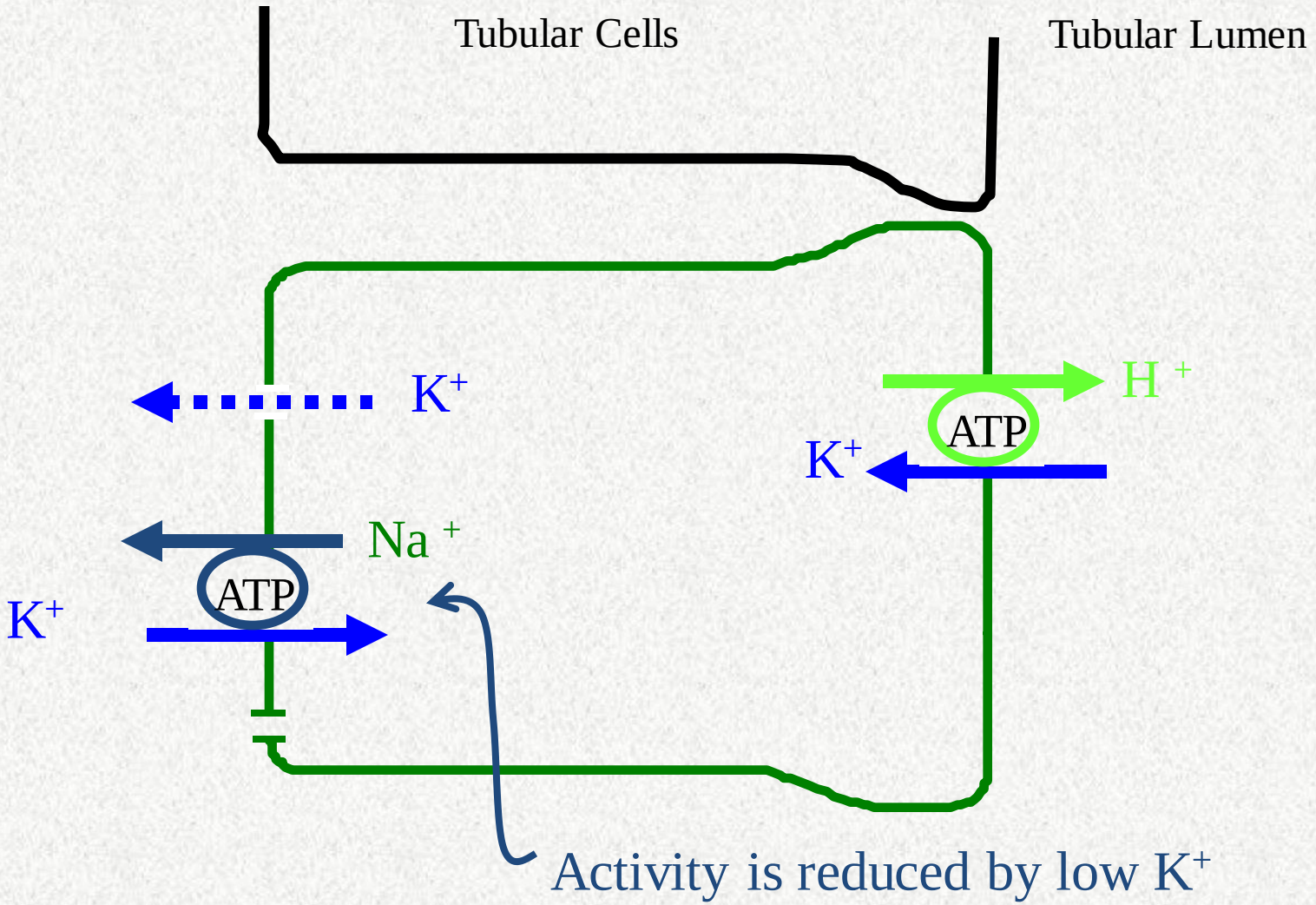
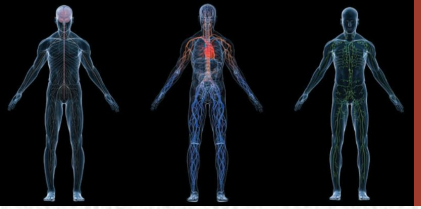


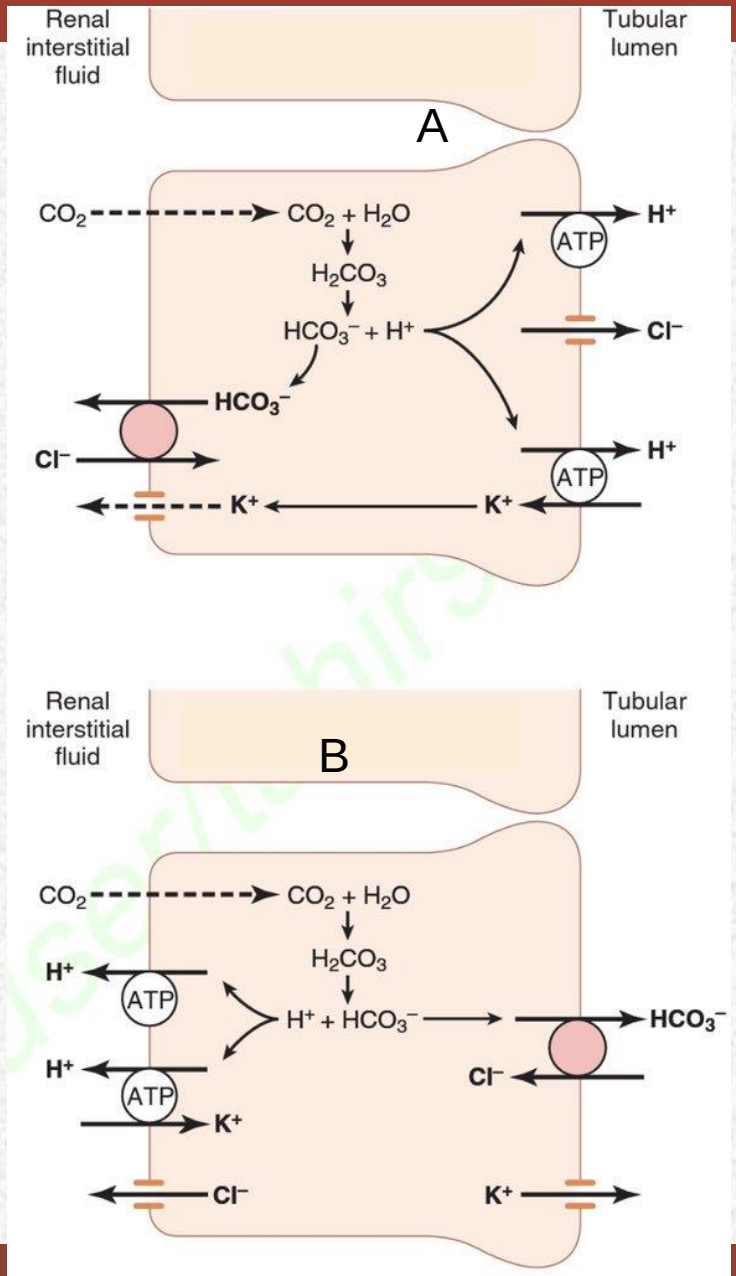
Figure 29-2



Late Distal and Cortical Collecting Tubules
Intercalated Cells –Reabsorb K^+







Potassium Secretion by Principal Cells

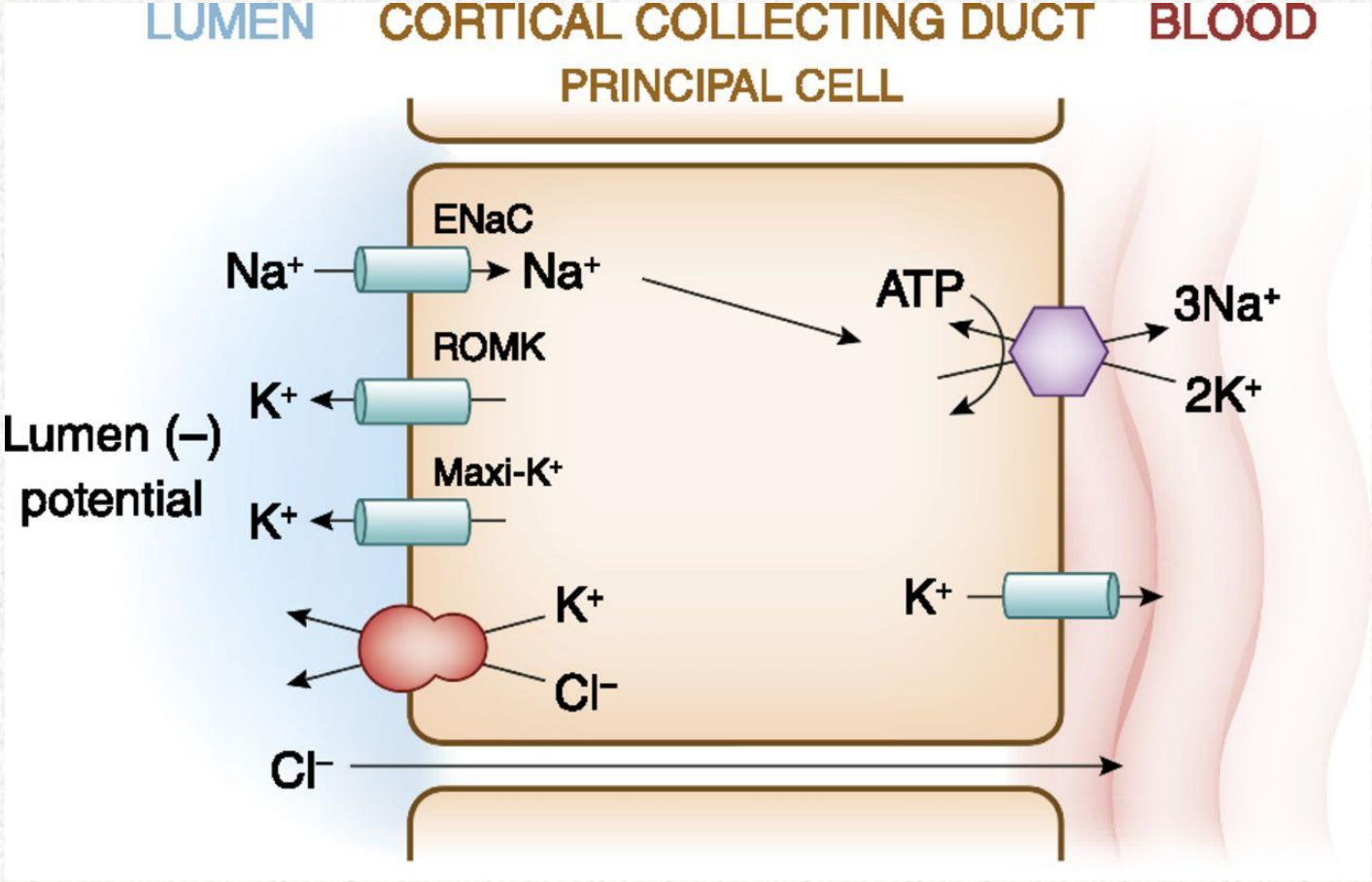
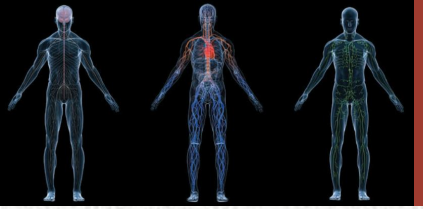
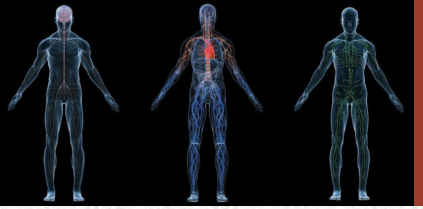


Figure 29-3

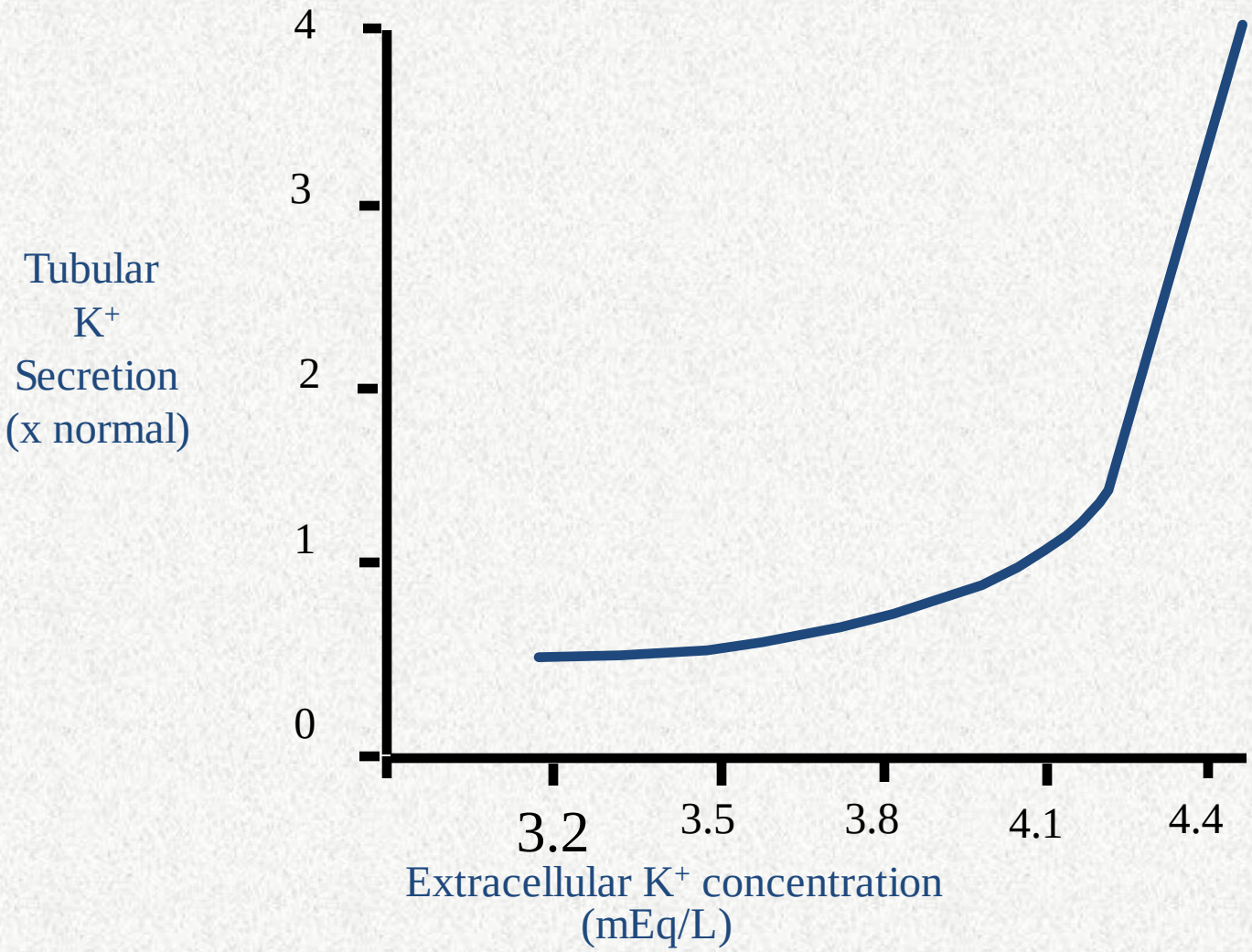


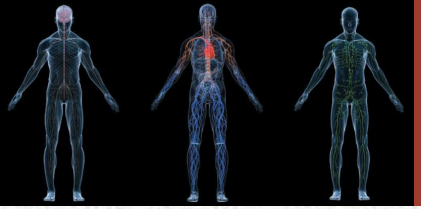
Control of Cortical Collecting Tubule (Principal Cells) K^+ Secretion

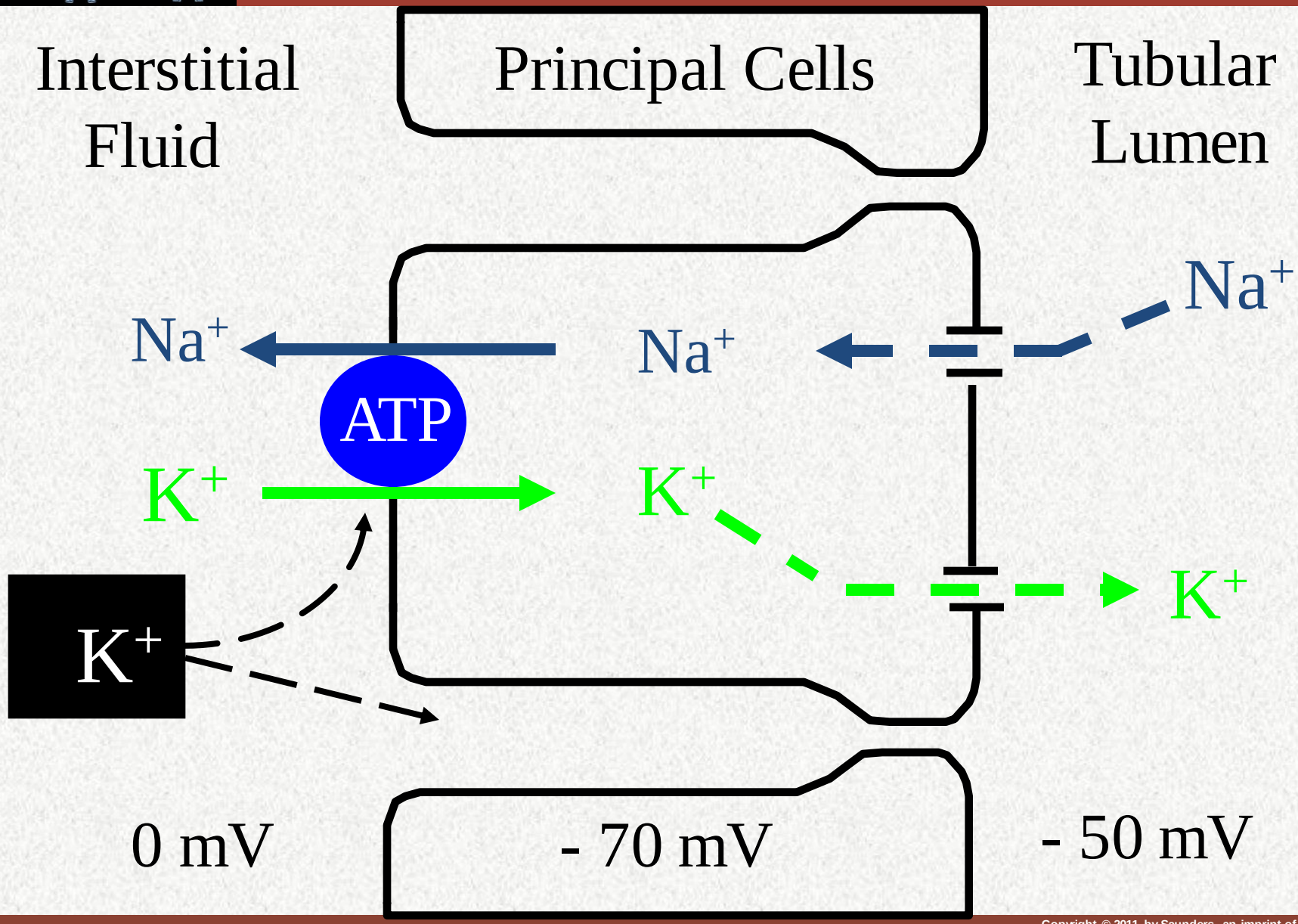
- Extracellular K^+ concentration :
  - Increases K^+ secretion: pump, gradient, aldo
- Aldosterone : increases K^+ secretion (pump+perm)
- Sodium (volume) delivery : increases K^+ secretion
- Acid - base status:
  - acidosis : decreases K^+ secretion
  - alkalosis : increases K^+ secretion

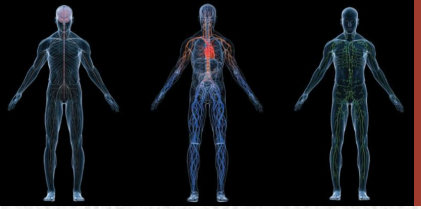


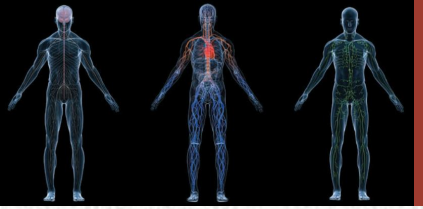
Effect of Extracellular K^+ on Excretion of K^+











Increased serum K^+ stimulates aldosterone secretion

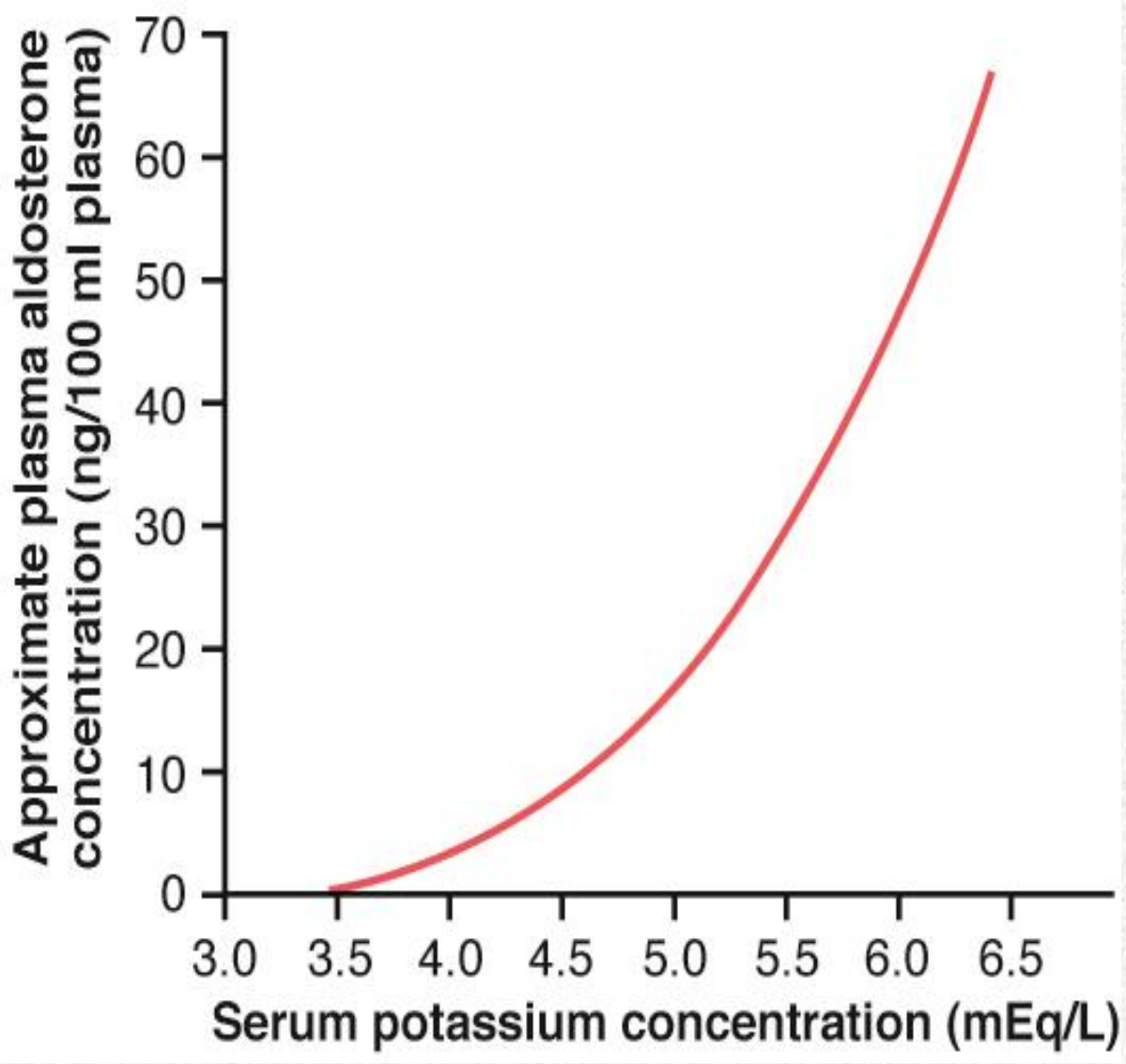
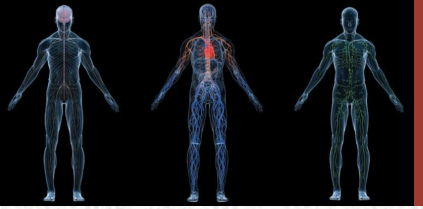
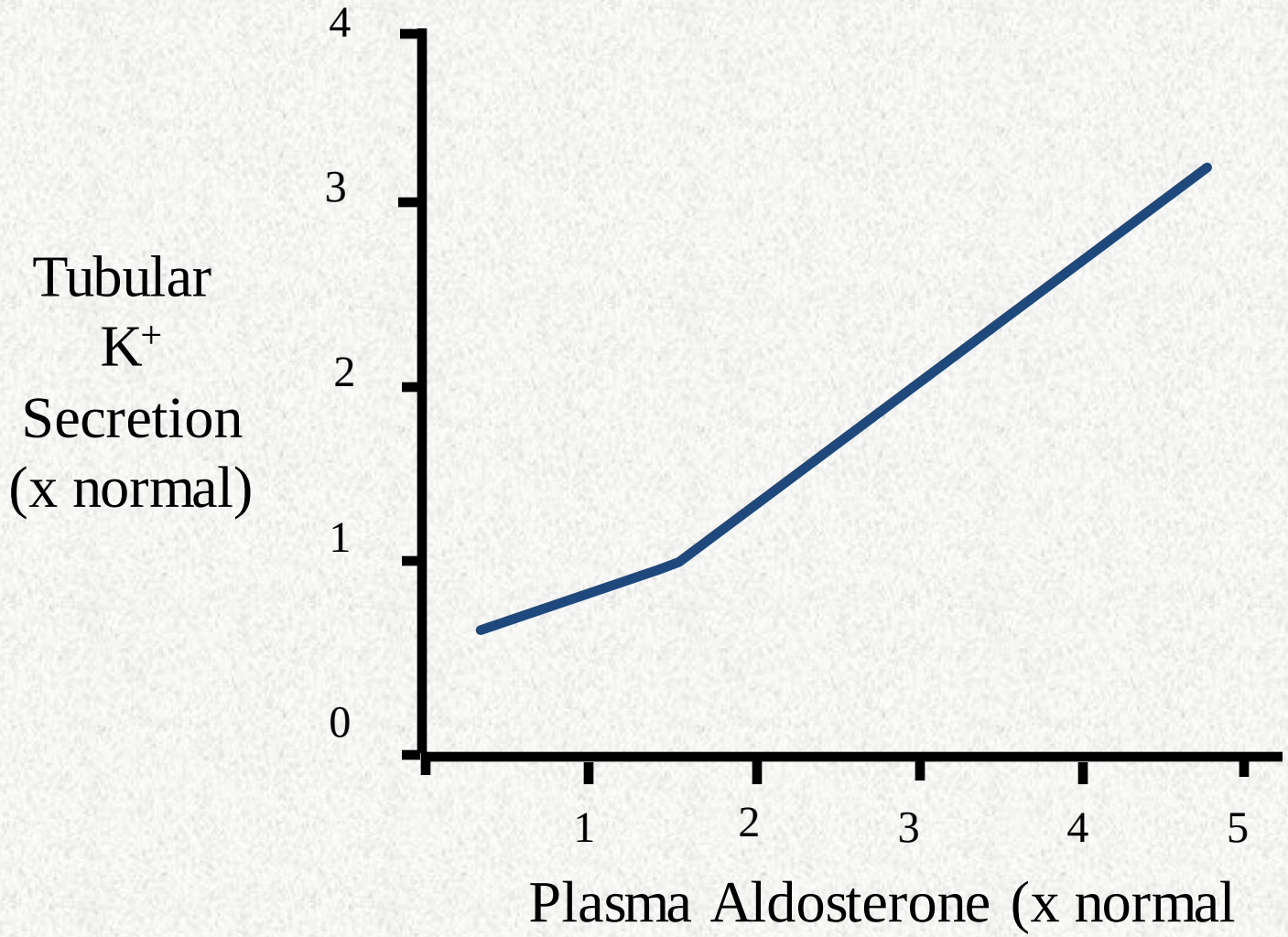
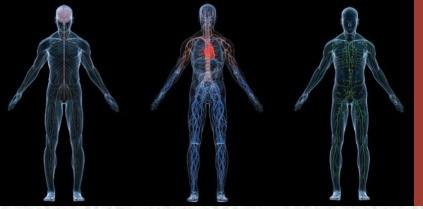


Figure 29-5

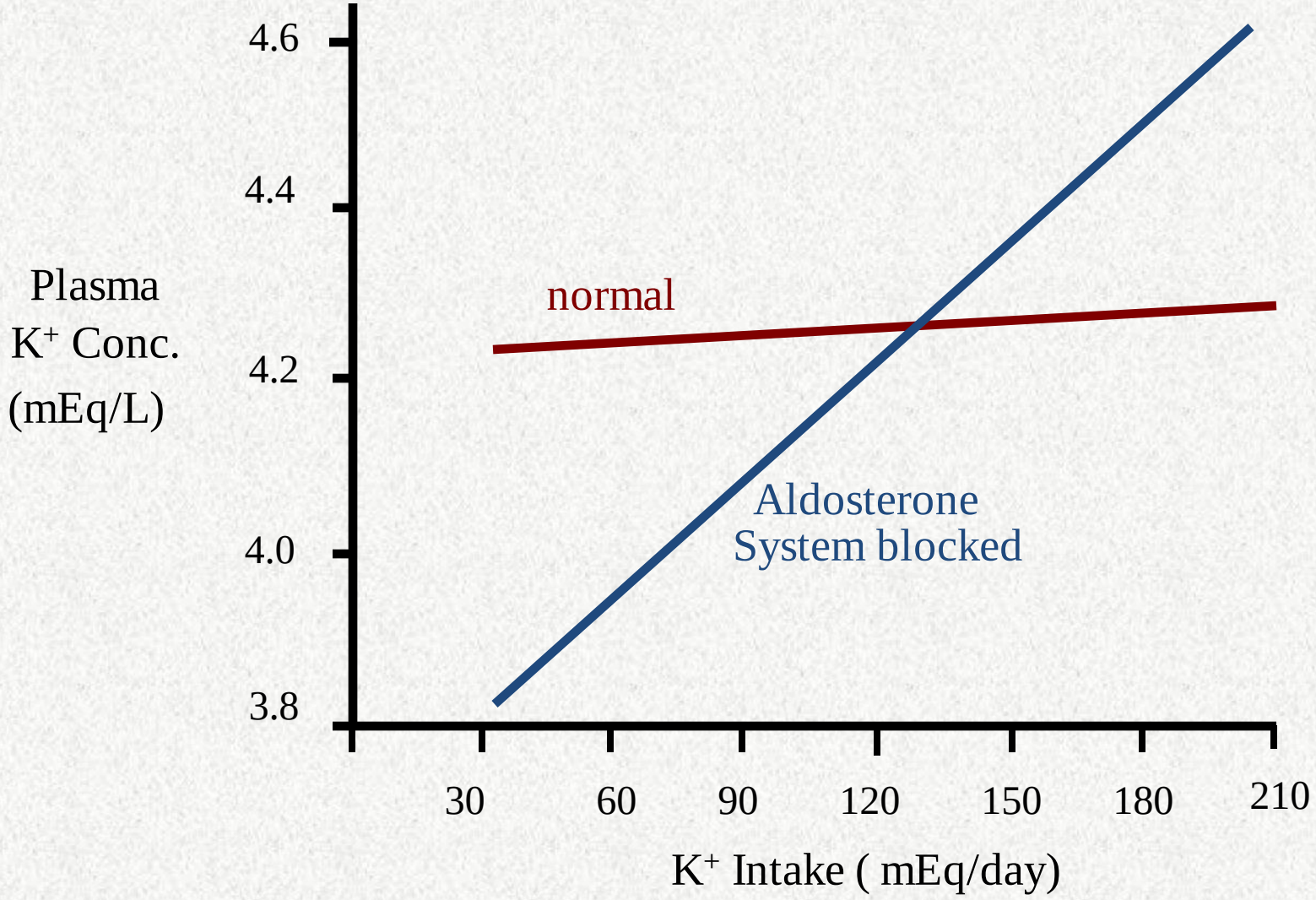


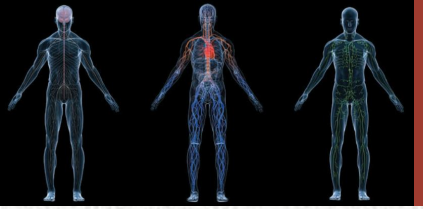
Effect of Aldosterone on K^+ Excretion





Effect of Changes in K^+ Intake on Plasma K^+ After Blocking Aldosterone System





Effect of collecting tubule flow rate on K^+ secretion

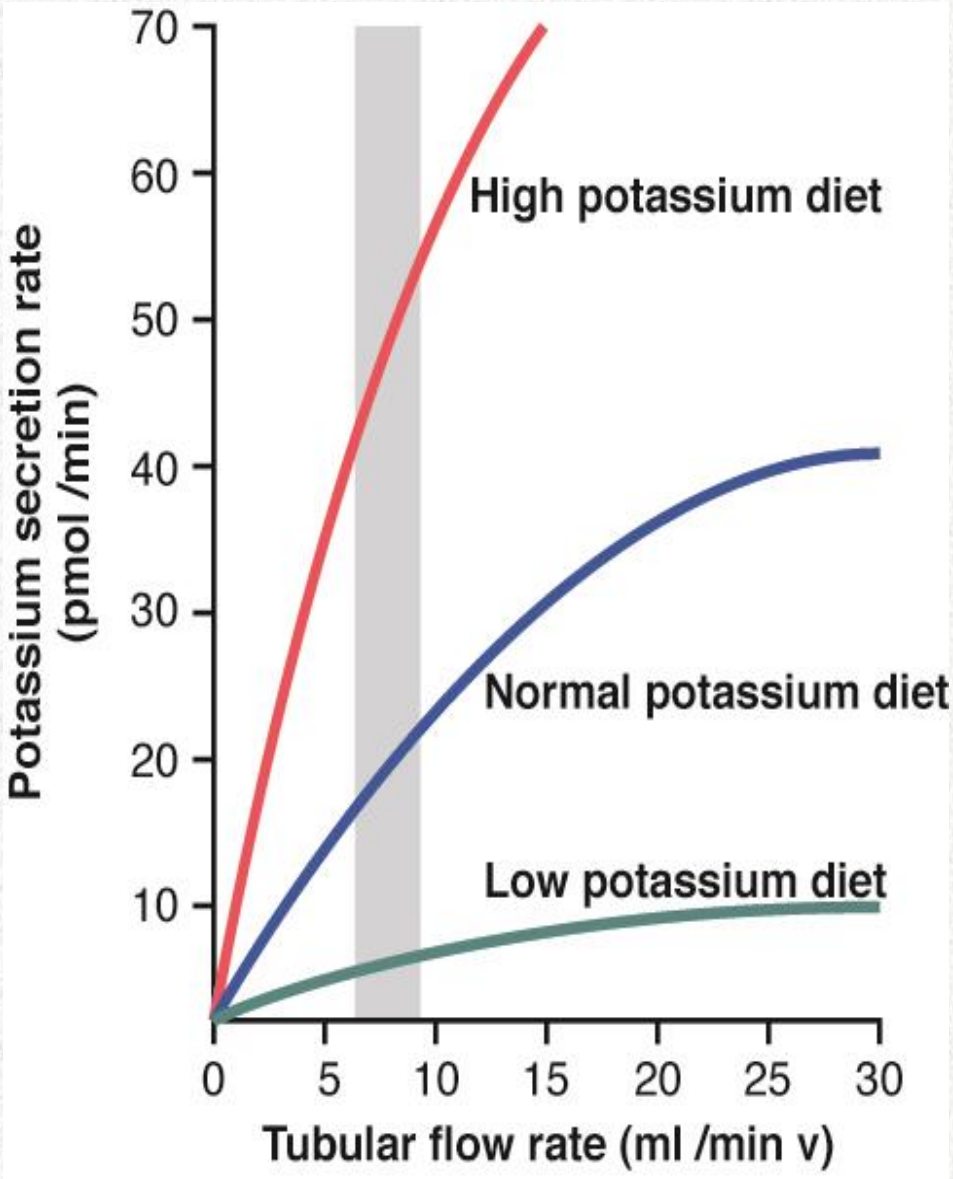
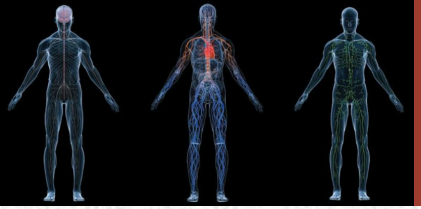


Figure 29-9



Diuretics that ↓ Prox. or ↓ Loop Na^+ Reabsorption

↓ Water Reabsorption

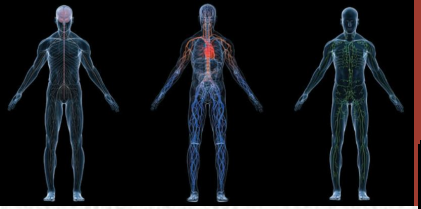
↓ Volume Delivery to Cort. Collect. Tub.

↑ Cell : Lumen Gradient for K^+ Diffusion

↑ K^+ Secretion

K^+ Depletion

↓ K^+ Reabsorption



↑ Na^+ Intake

↓ Aldosterone

↑ GFR

↓ Proximal Tubular Na^+ Reabsorption

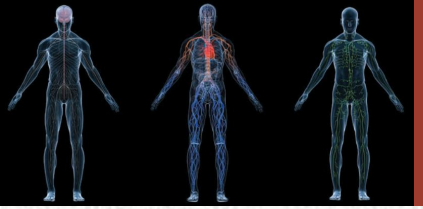
⊖

↑ K^+ Secretion Cort. Collect.Ducts

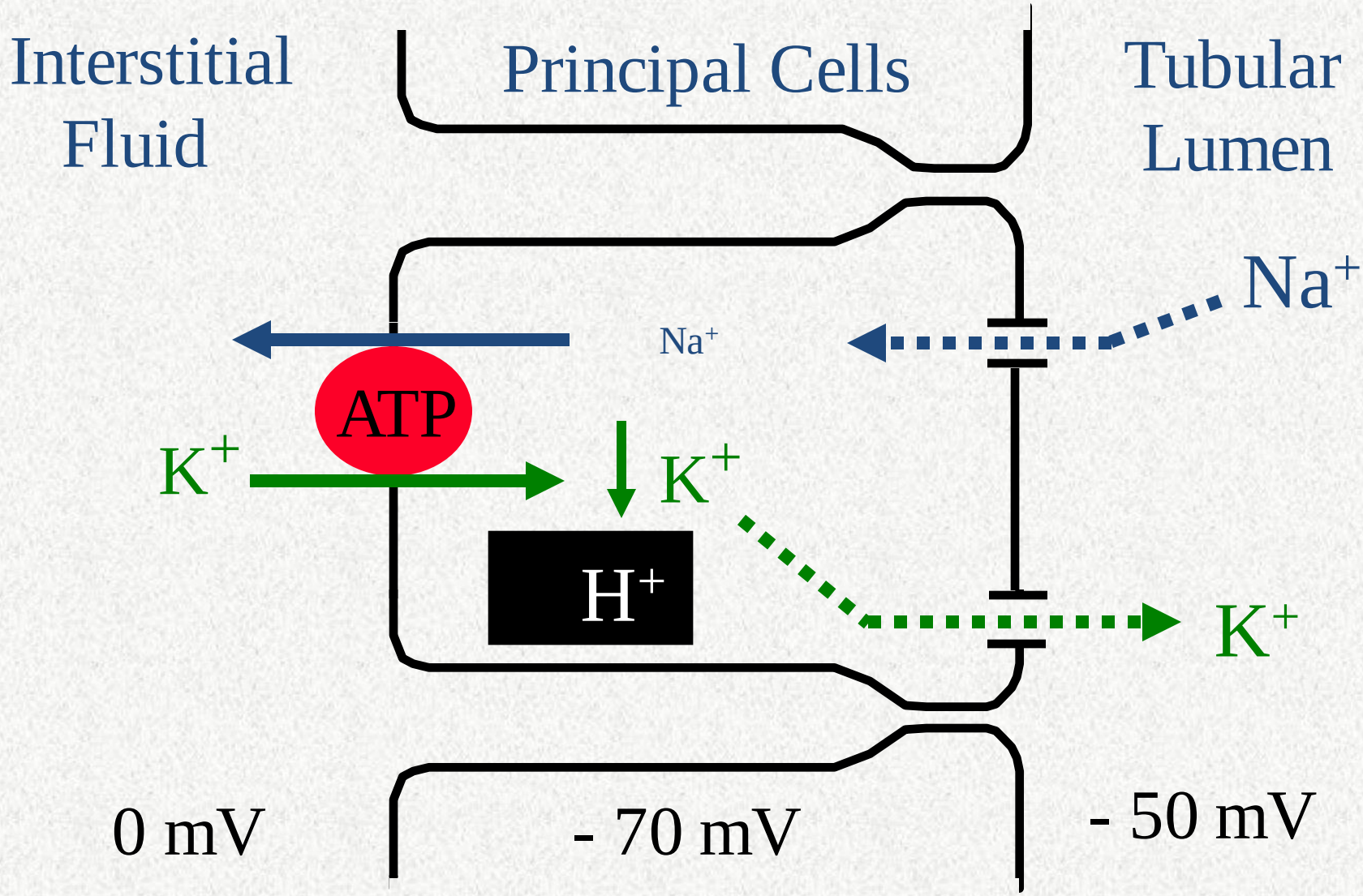
⊖

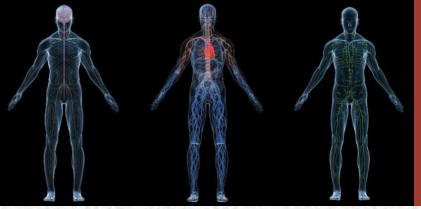
↑ Distal Tubular Flow Rate

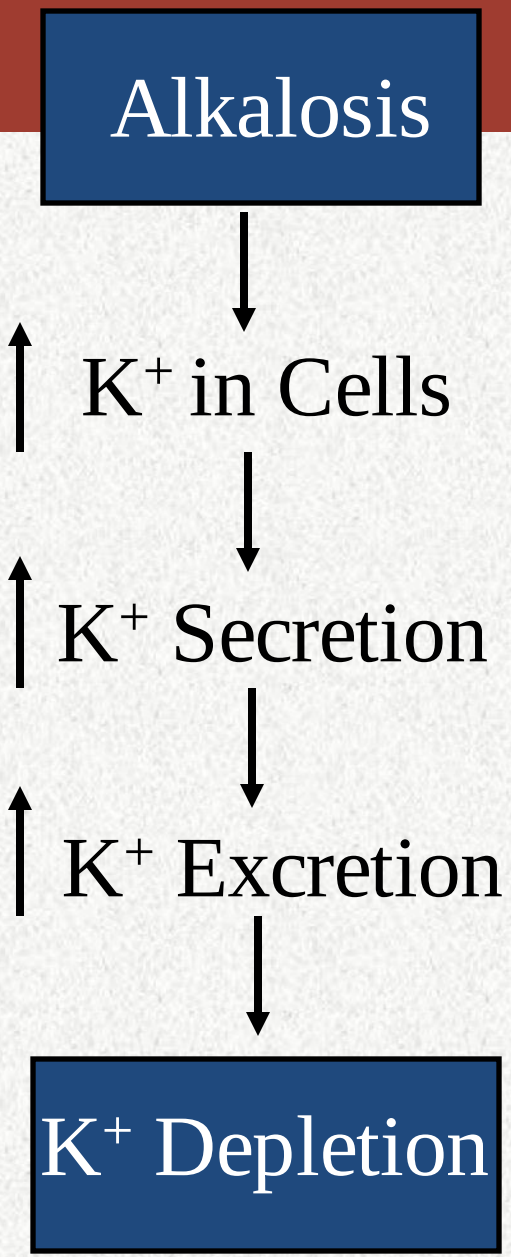
Unchanged K^+ Excretion

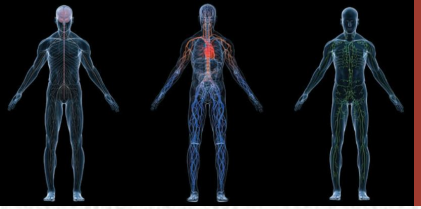


Acute Acidosis Decreases Cell K^+



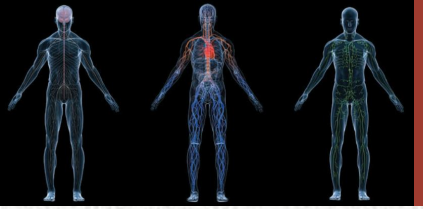






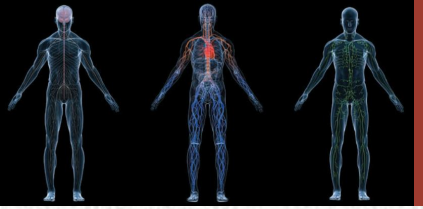
Causes of Hyperkalemia

- Renal failure
- Decreased distal nephron flow (heart failure, severe volume depletion, NSAID, etc)
- Decreased aldosterone or decreased effect of aldosterone
  - adrenal insufficiency
  - K^+ sparing diuretics (spironolactone, eplerenone)
- Metabolic acidosis (hyperkalemia is mild)
- Diabetes (kidney disease, acidosis ↓ insulin)



Causes of Hypokalemia

- Very low intake of K^+
- GI loss of K^+ - diarrhea
- Metabolic alkalosis
- Excess insulin
- Increased distal tubular flow /
  - salt wasting nephropathies
  - osmotic diuretcs
  - loop diuretics
- Excess aldosterone or other mineralocorticoids



Compensatory responses to decreased plasma ionized calcium

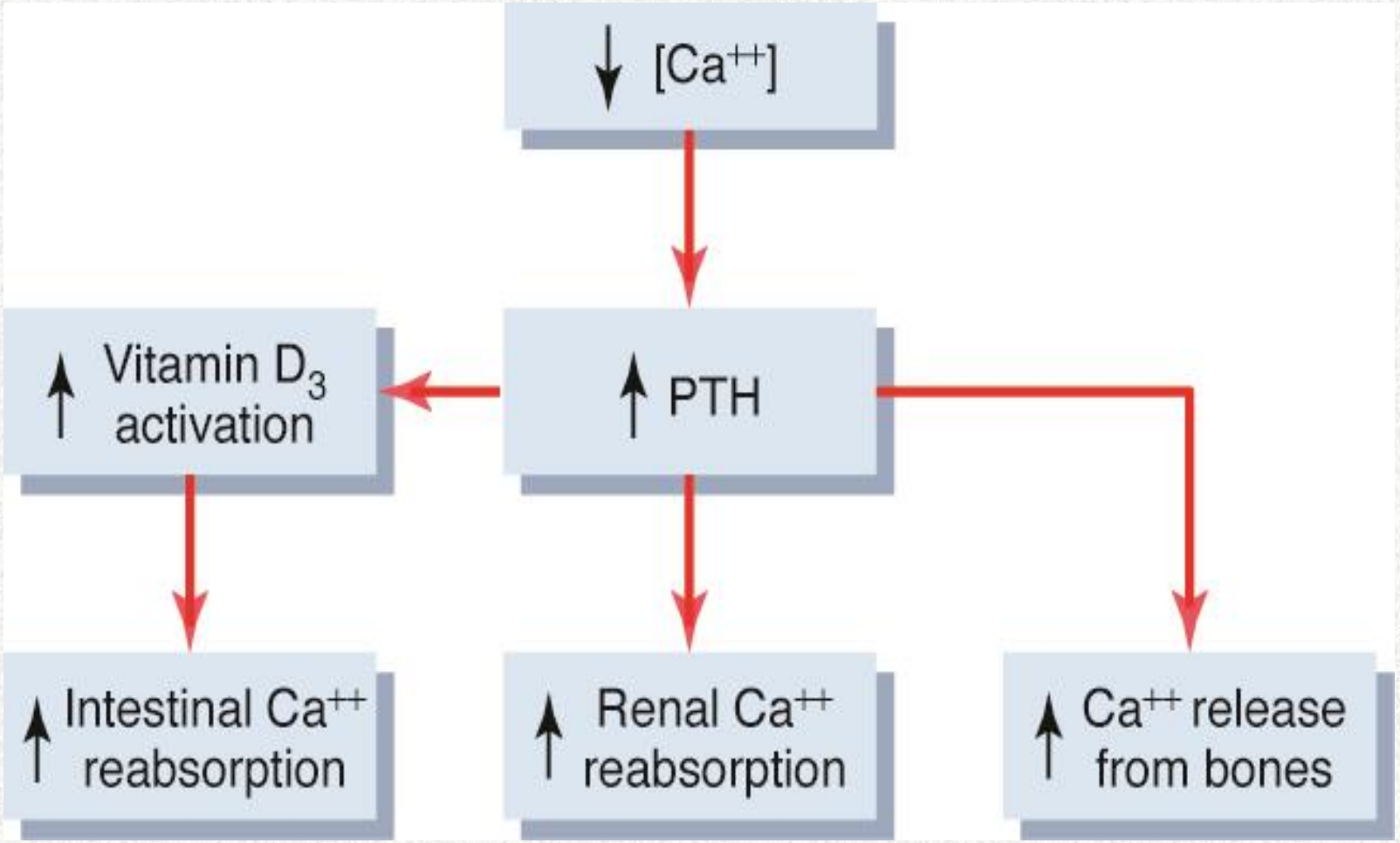


Figure 29-11

Proximal tubular calcium reabsorption

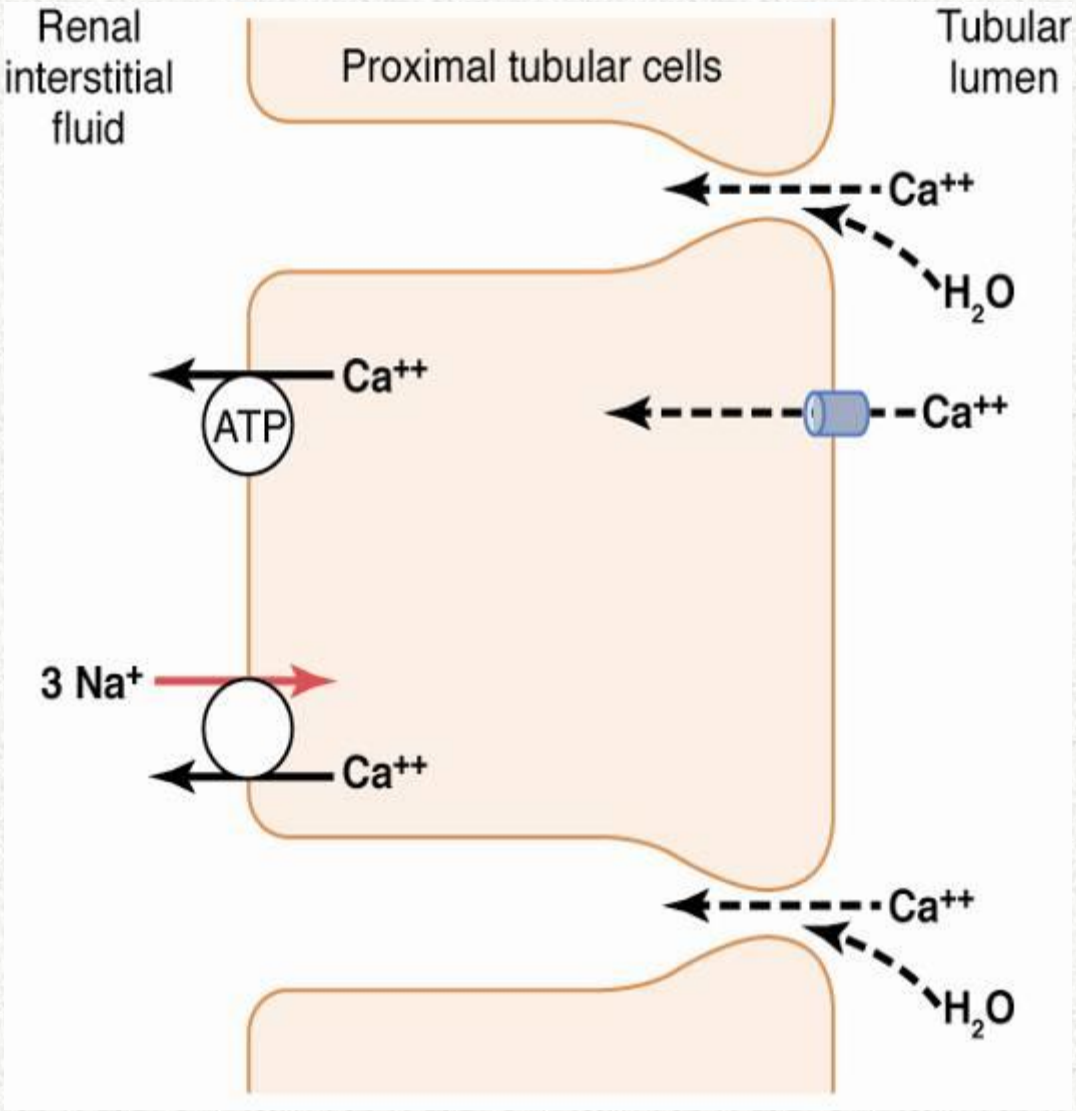
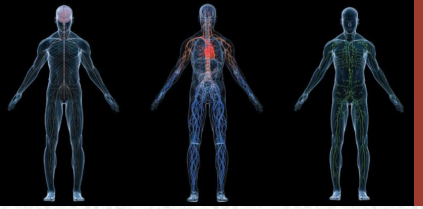


Figure 29-12



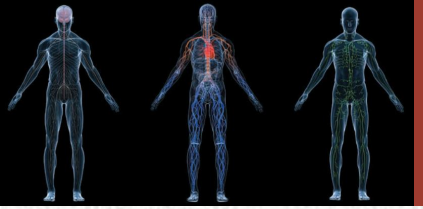
Integration of Renal Mechanisms for Regulation of Body Fluids

Excretion = Filtration - Reabsorption + Secretion

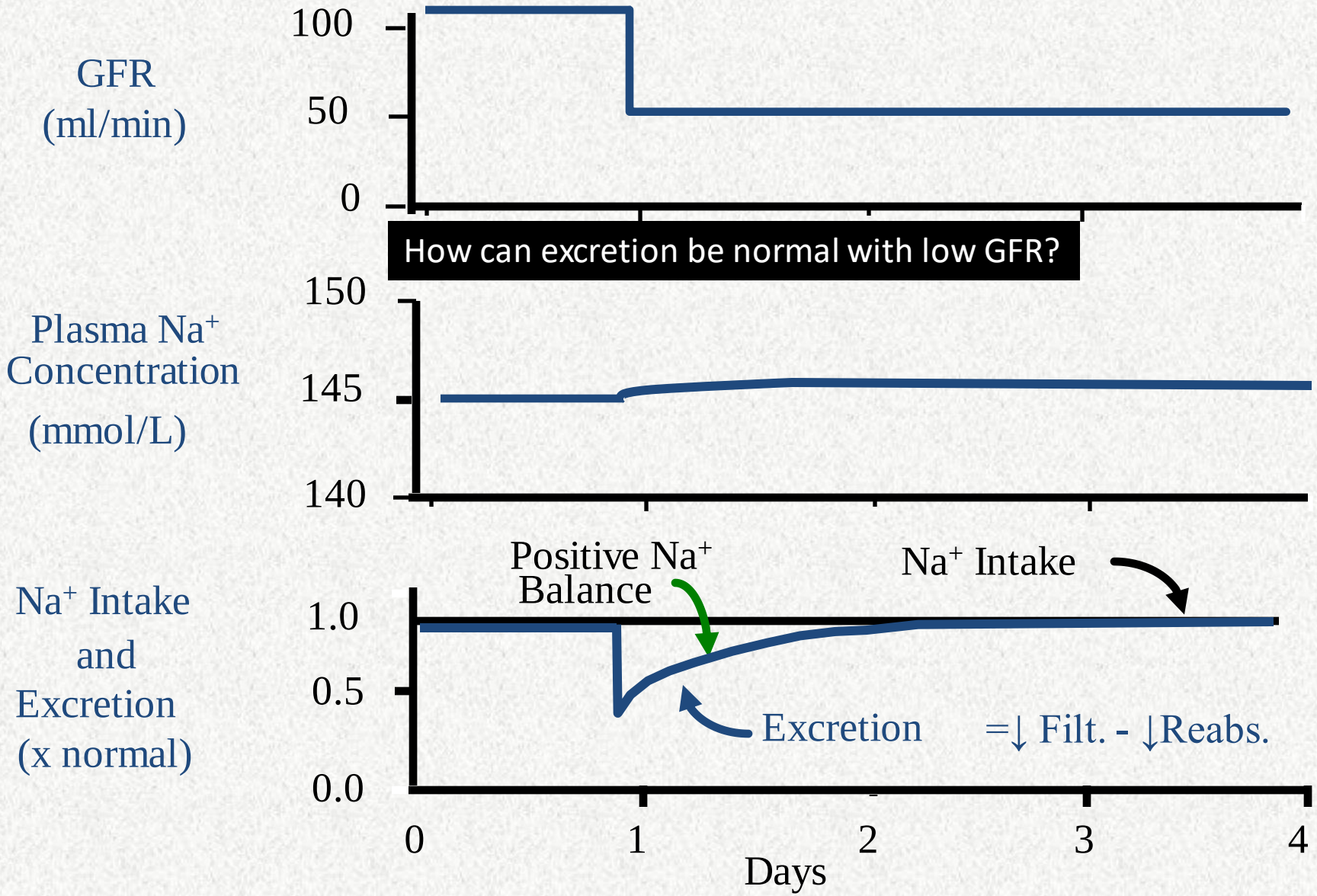
If there is a steady - state :

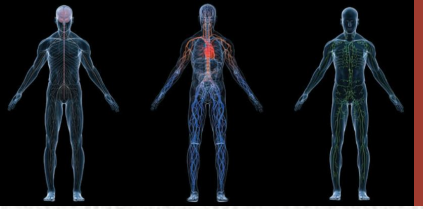
Fluid Excretion = Fluid Intake

Electrolyte Excretion = Electrolyte intake

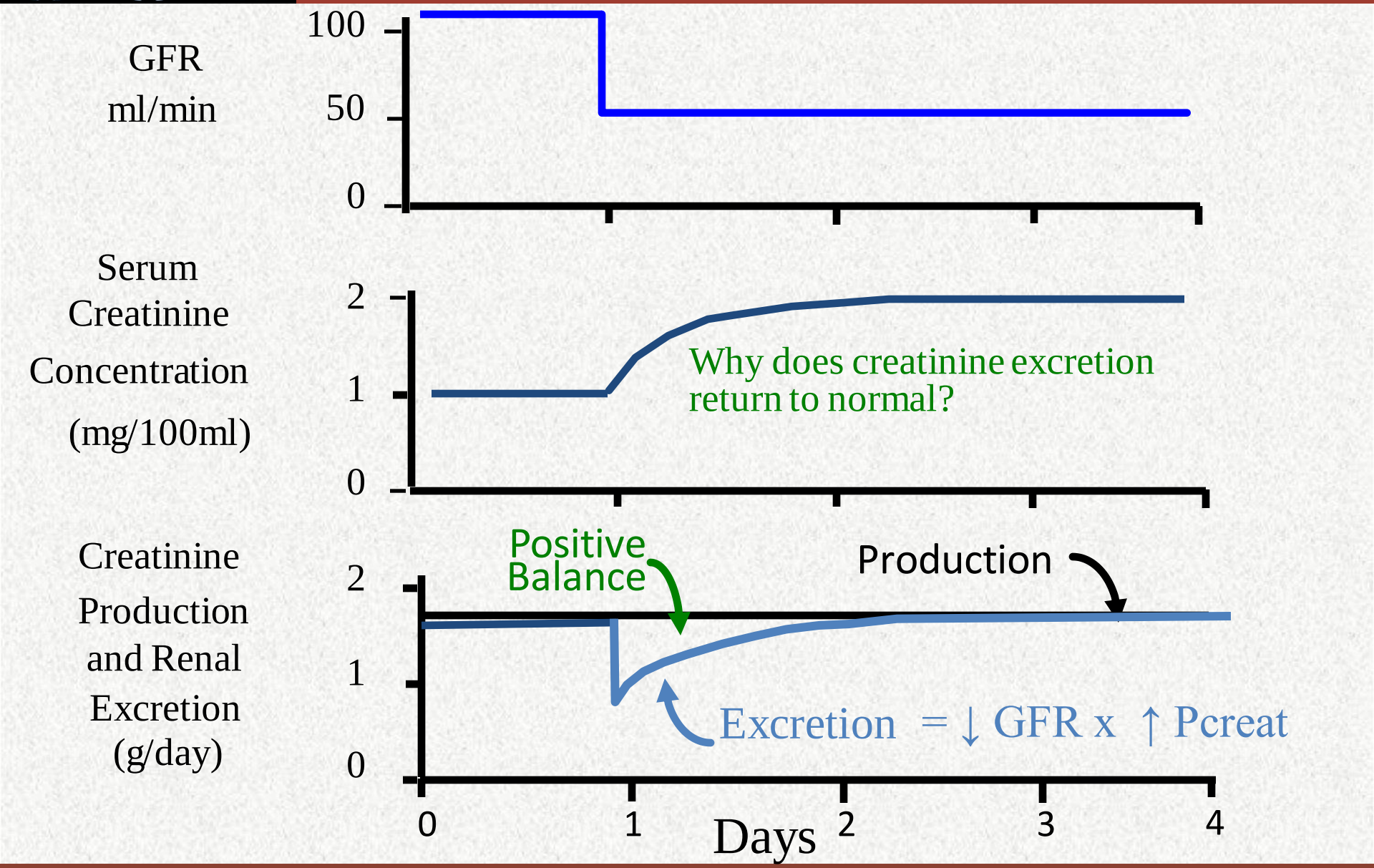


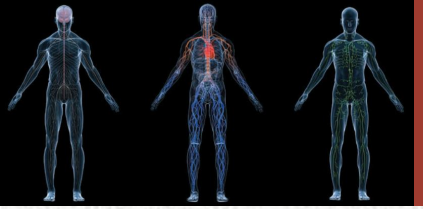
Effect of Decreased GFR on Sodium





Effect of Decreased GFR on Creatinine





Plasma concentrations of solutes in chronic renal failure

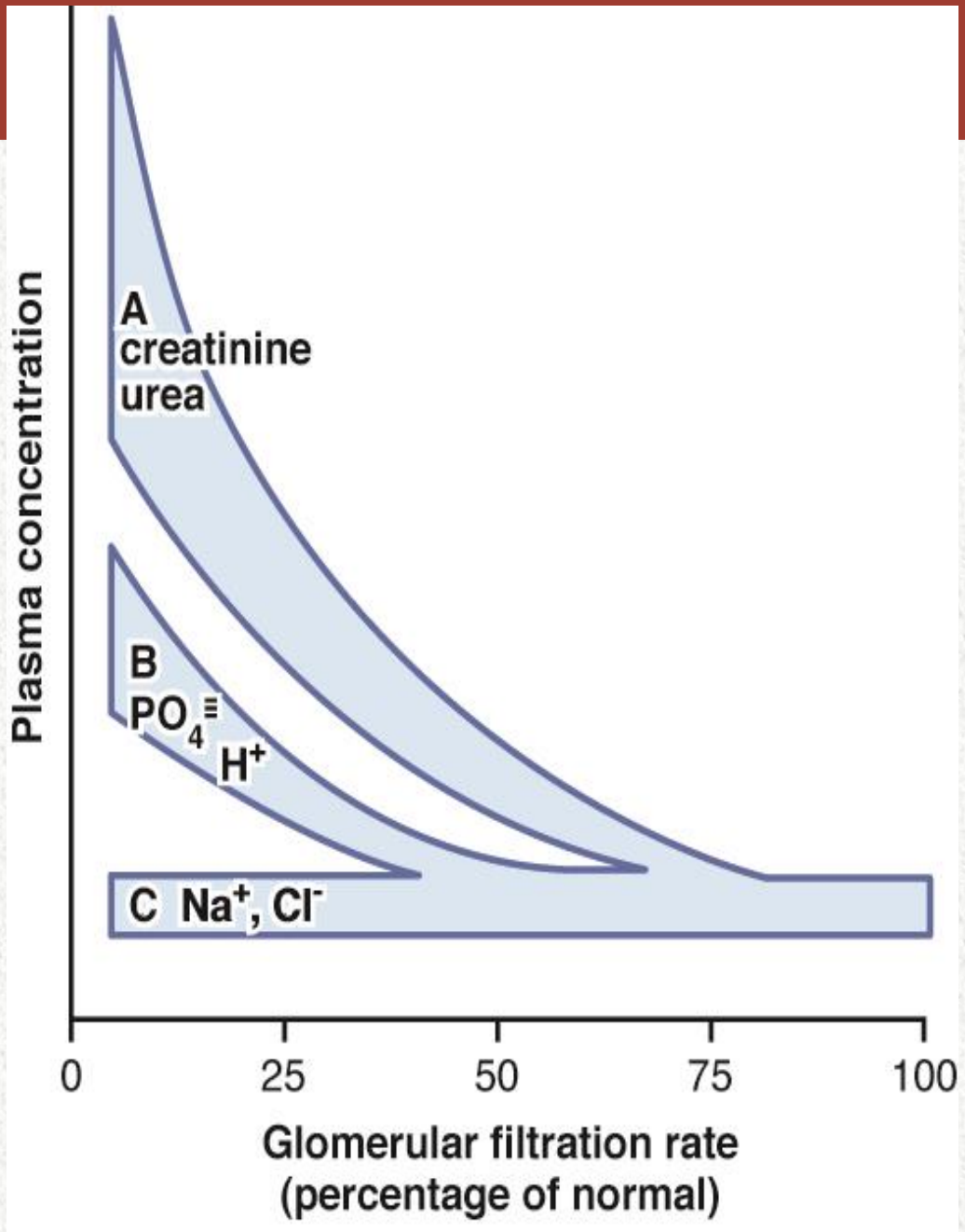
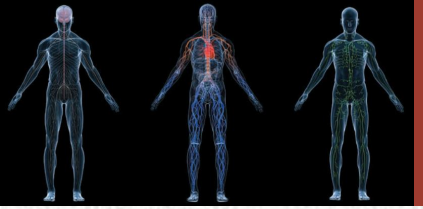
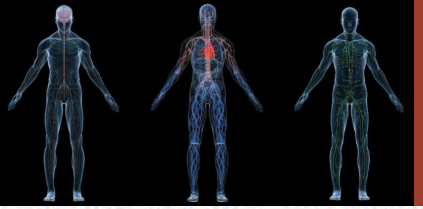


Figure 31-5



Hierarchy of Responses to Disturbances of Body Fluid Regulation

1. Local renal mechanisms
   - changes in GFR
   - changes in tubular reabsorption
   - changes in tubular secretion
2. Systemic mechanisms (which can affect the whole body)
   - changes in hormones
   - changes in sympathetic activity
   - changes in blood pressure
   - changes in blood composition



GFR

Proximal Delivery.

Tubulo-glomerular feedback

Reabsorption

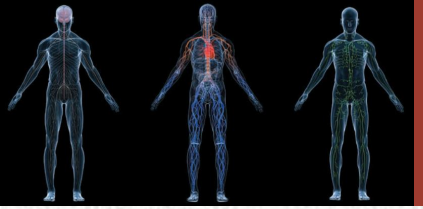
Loop NaCl Delivery

Glomerulo-tubular balance

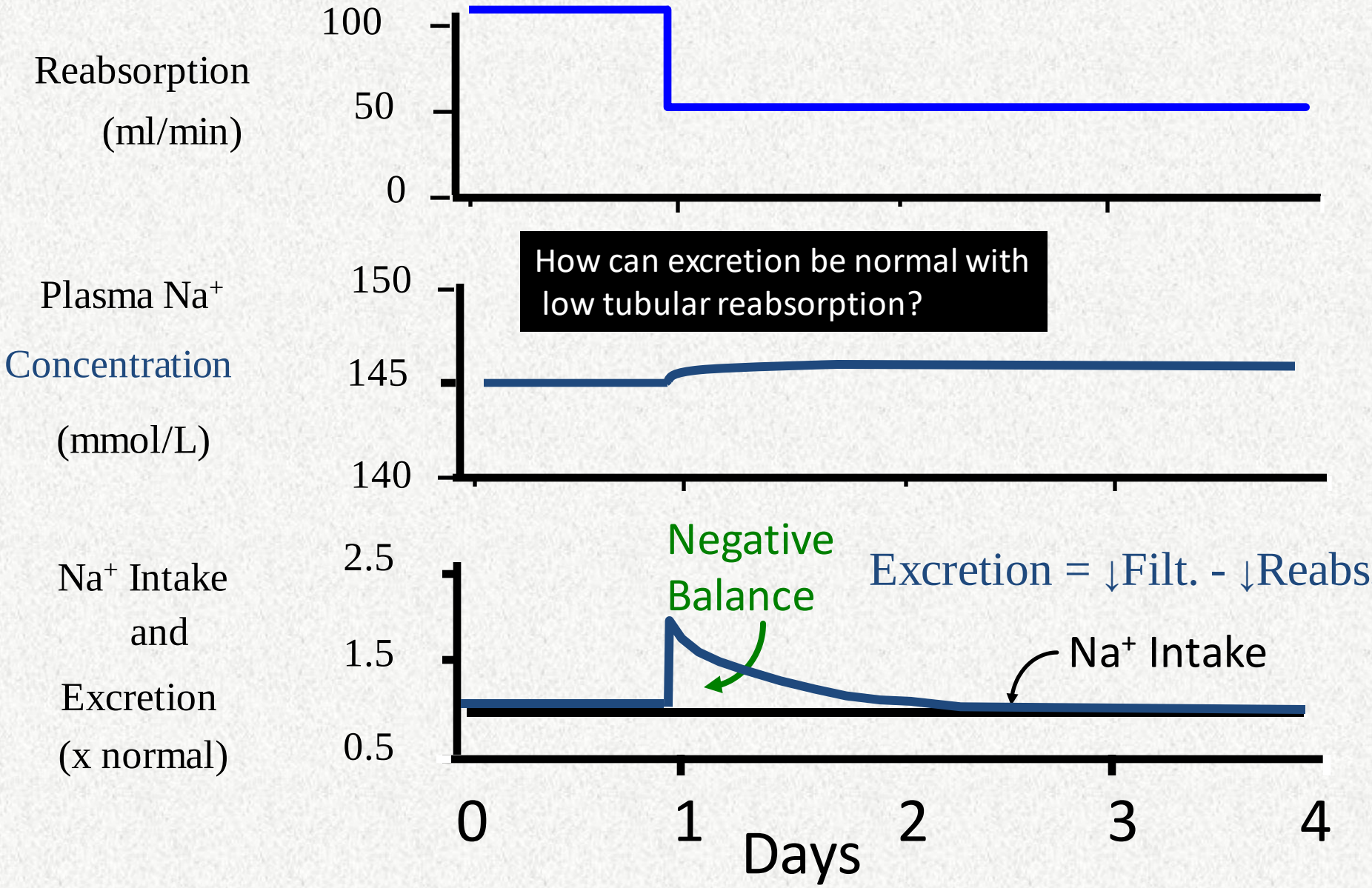
Macula Densa NaCl Delivery

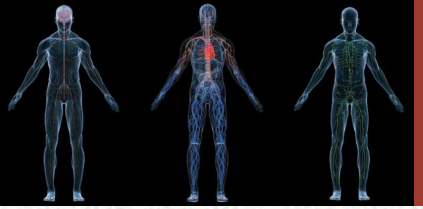
Distal NaCl Delivery

Urine Excretion
Na^+ *Minimized*

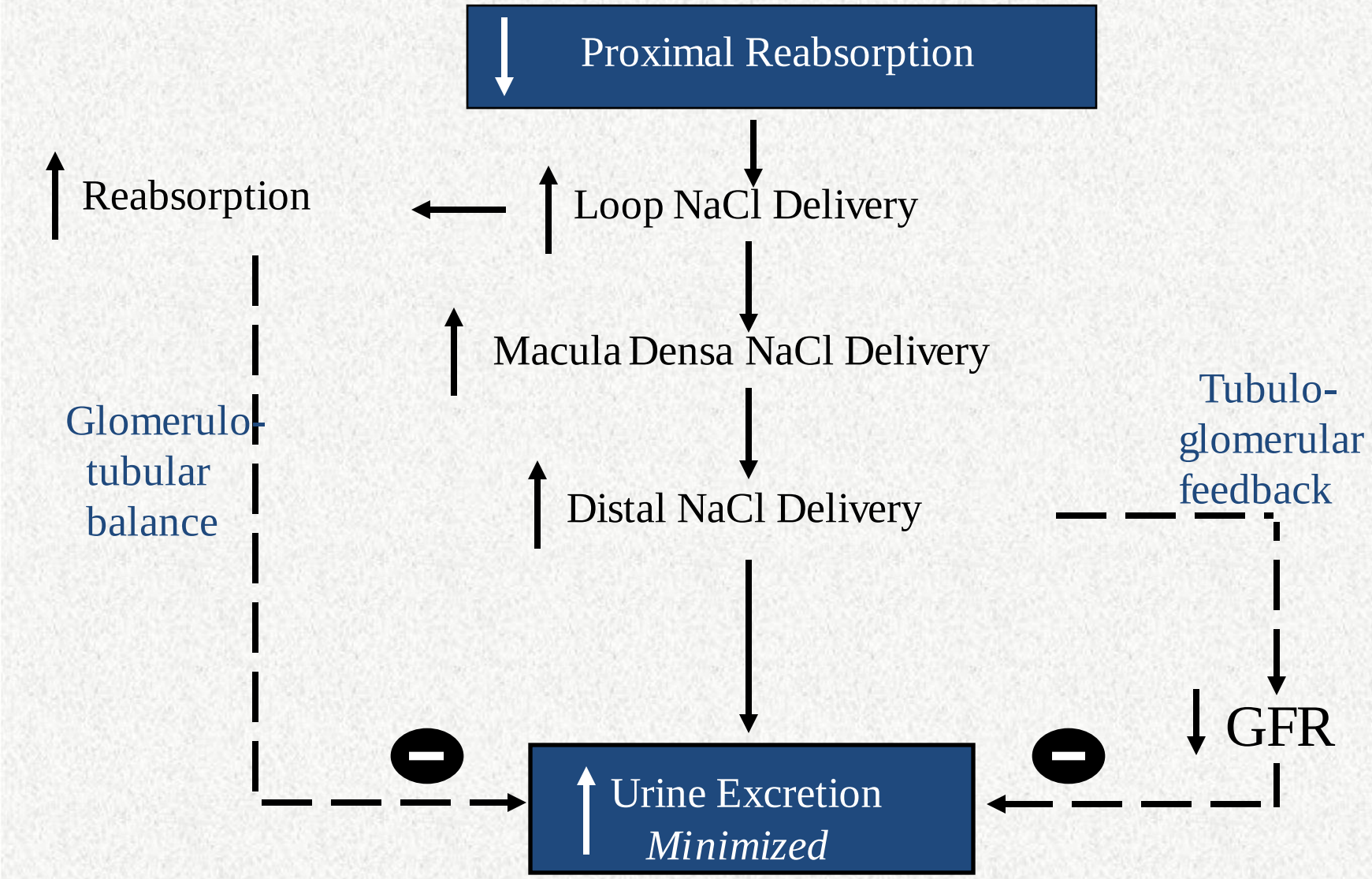


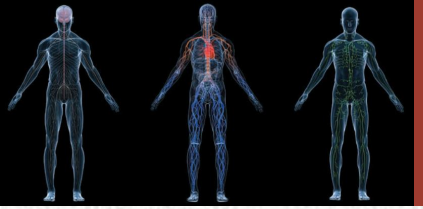
Effect of Decreased Reabsorption on Sodium Balance





Maintenance of Sodium Balance After Decreased Proximal Reabsorption



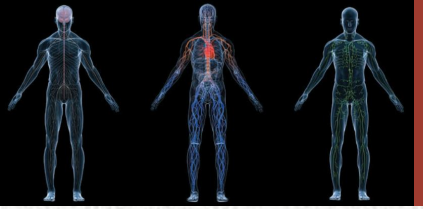


Hierarchy of Responses to Disturbances of Body Fluid Regulation

In steady-state, Intake = Output

1. Local renal responses
   - changes in GFR
   - changes in tubular reabsorption
   - changes in tubular secretion

2. Systemic mechanisms (which can affect the whole body)
   - changes in hormones
   - changes in sympathetic activity
   - changes in blood pressure
   - changes in blood composition



Sodium excretion and extracellular fluid volume during diuretic administration.

Compensations that Permit Na^+ balance:

- ↓ blood pressure
- ↑ renin, angiotensin II
- ↑ aldosterone

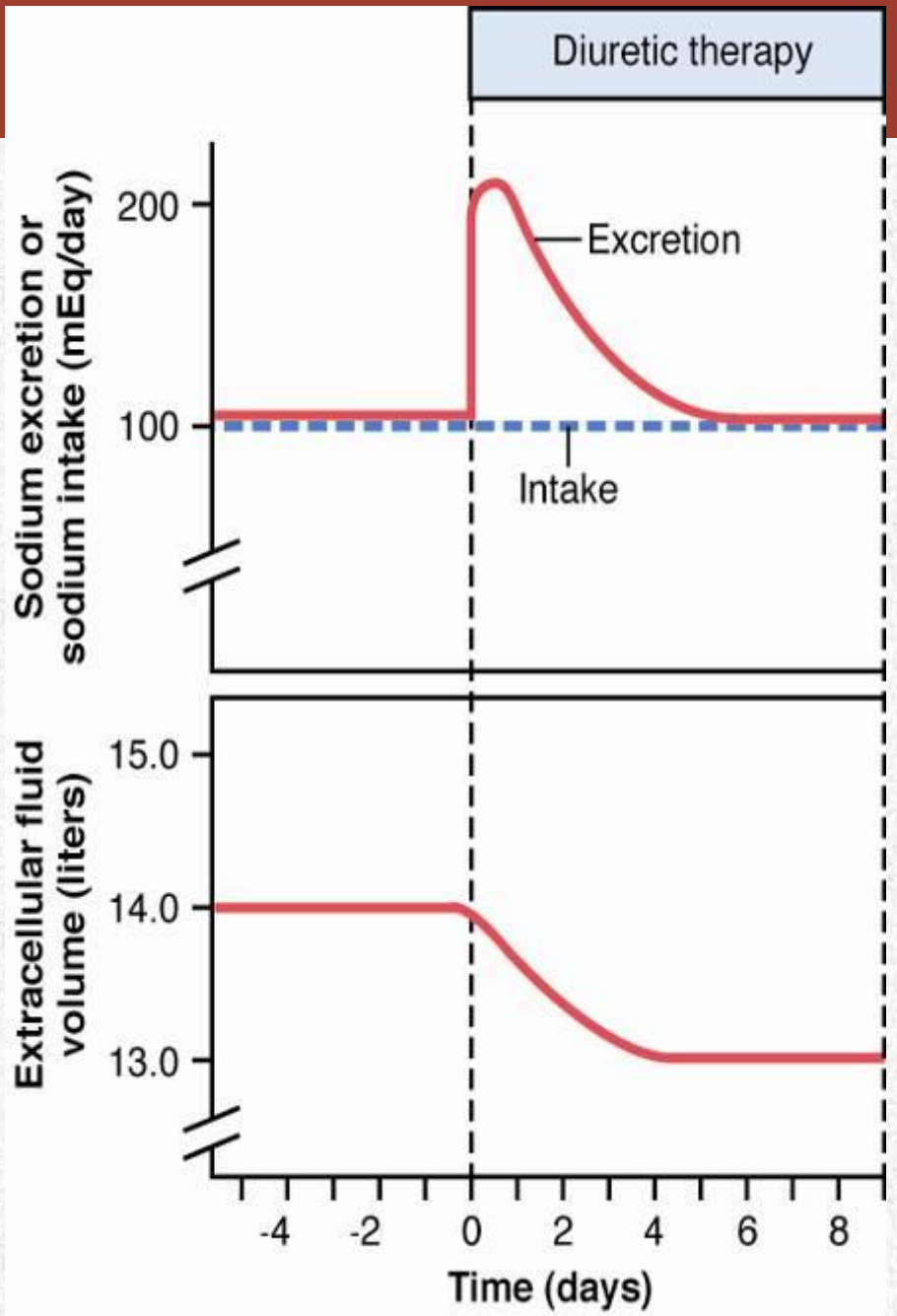
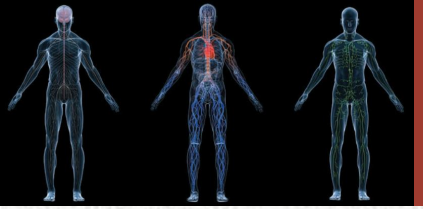
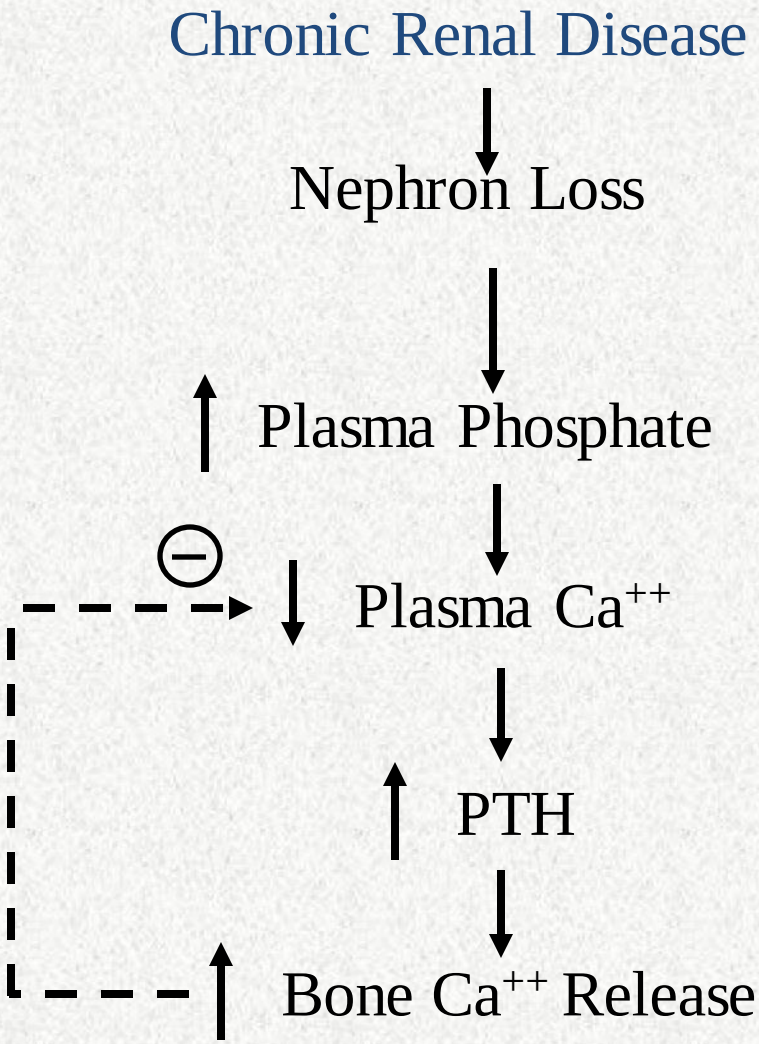


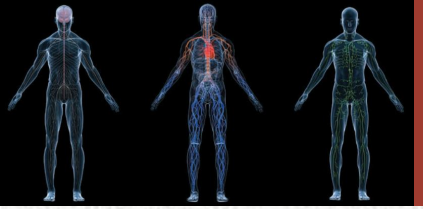
Figure 31-1



Hormonal Response to Chronic Renal Disease - PTH



(osteoporosis - brittle bones)



Hierarchy of Responses to Disturbances of Body Fluid Regulation

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   - changes in sympathetic activity
   - changes in blood pressure
   - changes in blood composition

Renal-Body Fluid Feedback- Increased Fluid (Na^+) Intake

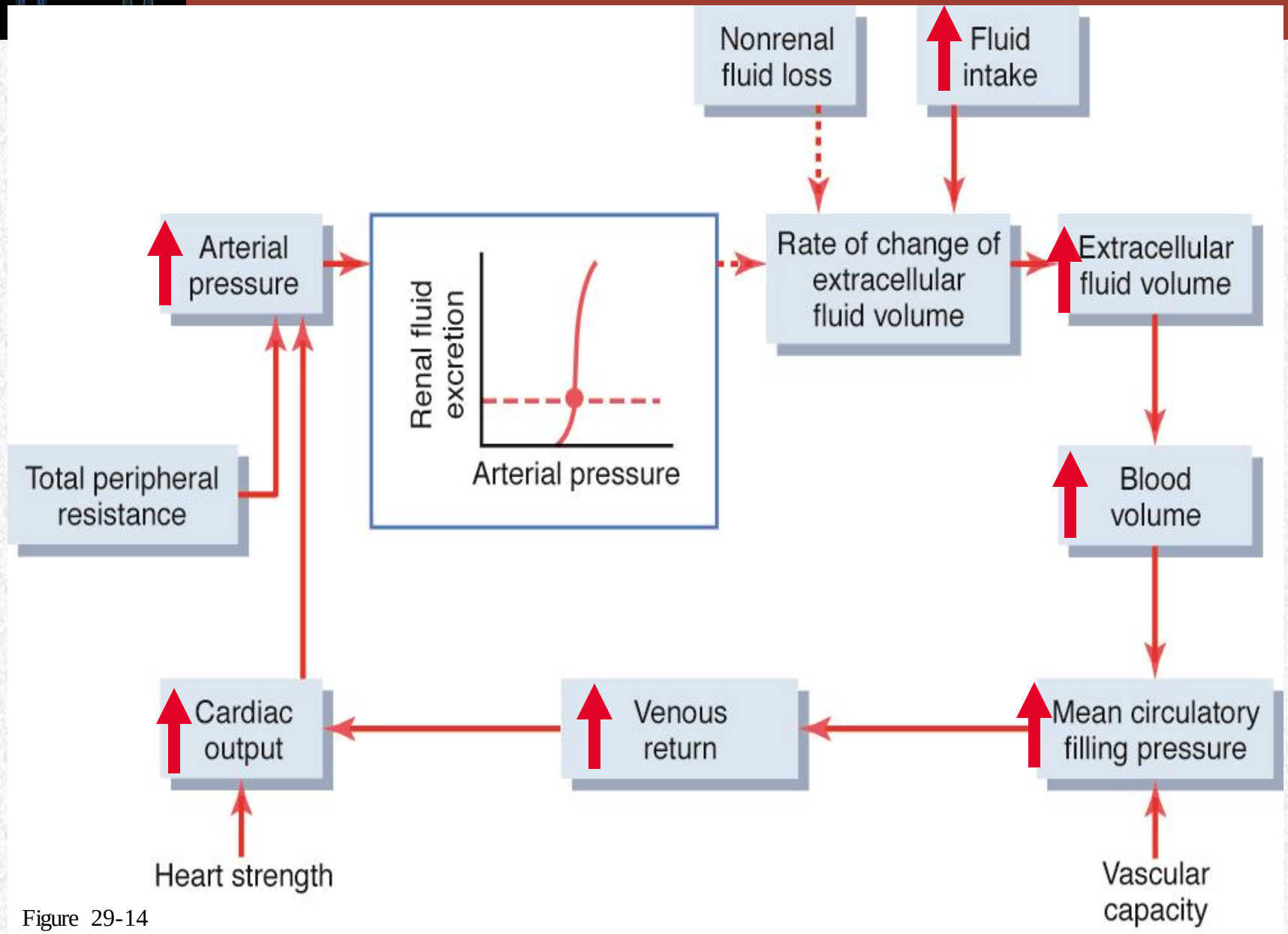
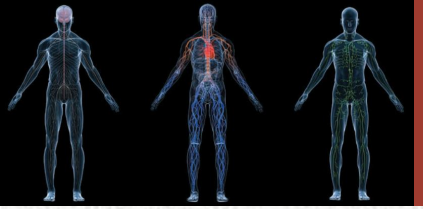


Figure 29-14



Integrated Responses to High Na^+ Intake

Excretion Na^+ = Filtration Na^+ - Reabsorption Na^+

1. Small increase in GFR
2. Decreased Na^+ Reabsorption is caused by:
   - small increase in blood pressure
   - increased peritubular capillary pressure
   - decreased angiotensin II
   - decreased aldosterone
   - Increased natriuretic hormones (e.g. ANP)

Net effect = increased Na^+ excretion