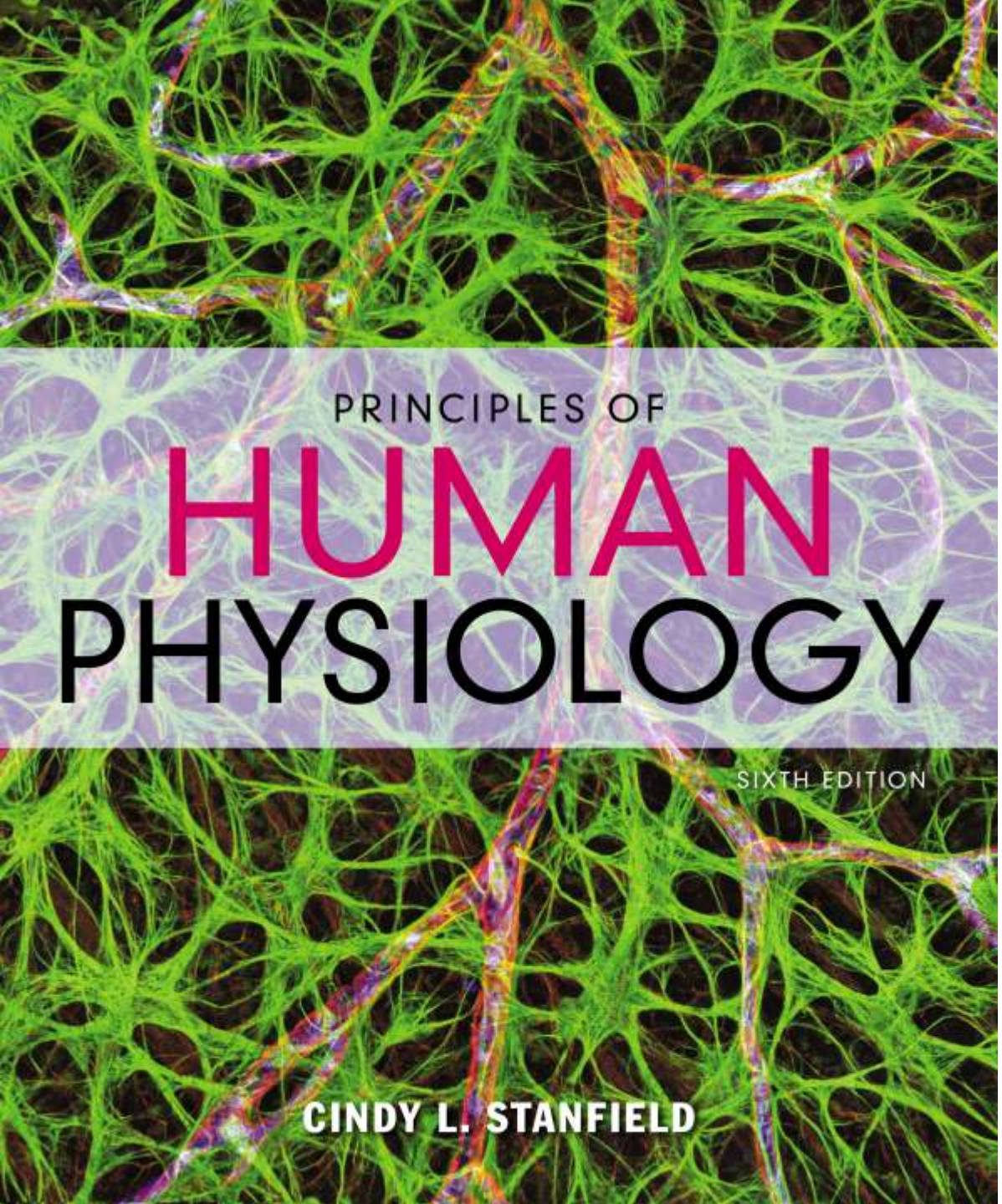


PowerPoint® Lecture Presentation

CHAPTER **19b**

The Urinary System: Fluid and Electrolyte Balance

Chapter Outline

19.1 The Concept of Balance
19.2 Water Balance
19.3 Sodium Balance
19.4 Potassium Balance
19.5 Calcium Balance
19.6 Interactions Between Fluid and Electrolyte Regulation
19.7 Acid-Base Balance

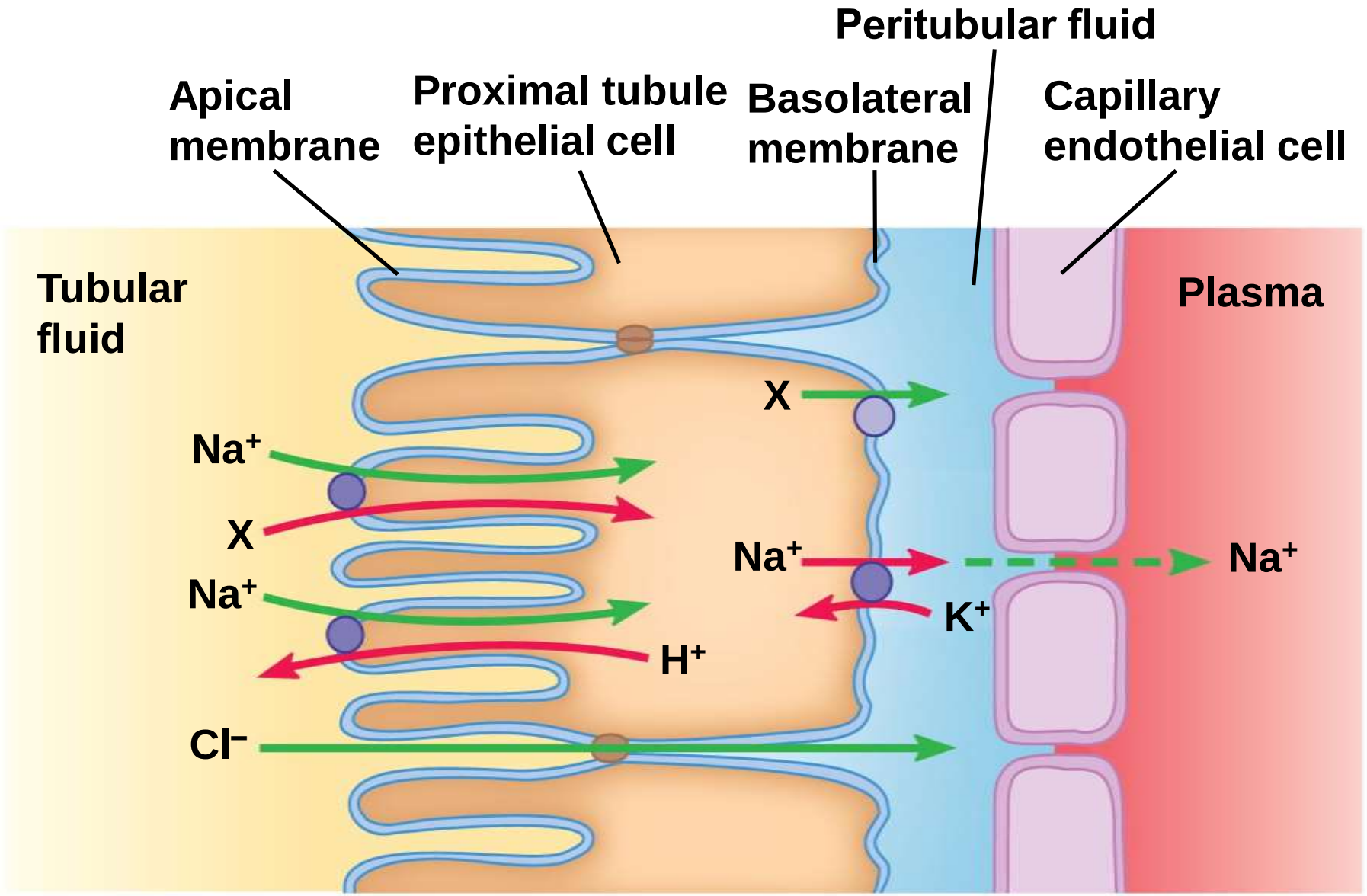
19.3 Sodium Balance

- Hypernatremia: high plasma sodium
- Hyponatremia: low plasma sodium
- Sodium: primary solute in ECF
  - Critical for normal osmotic pressure
  - Critical to function of excitable cells

Mechanisms of Sodium Reabsorption in the Renal Tubule

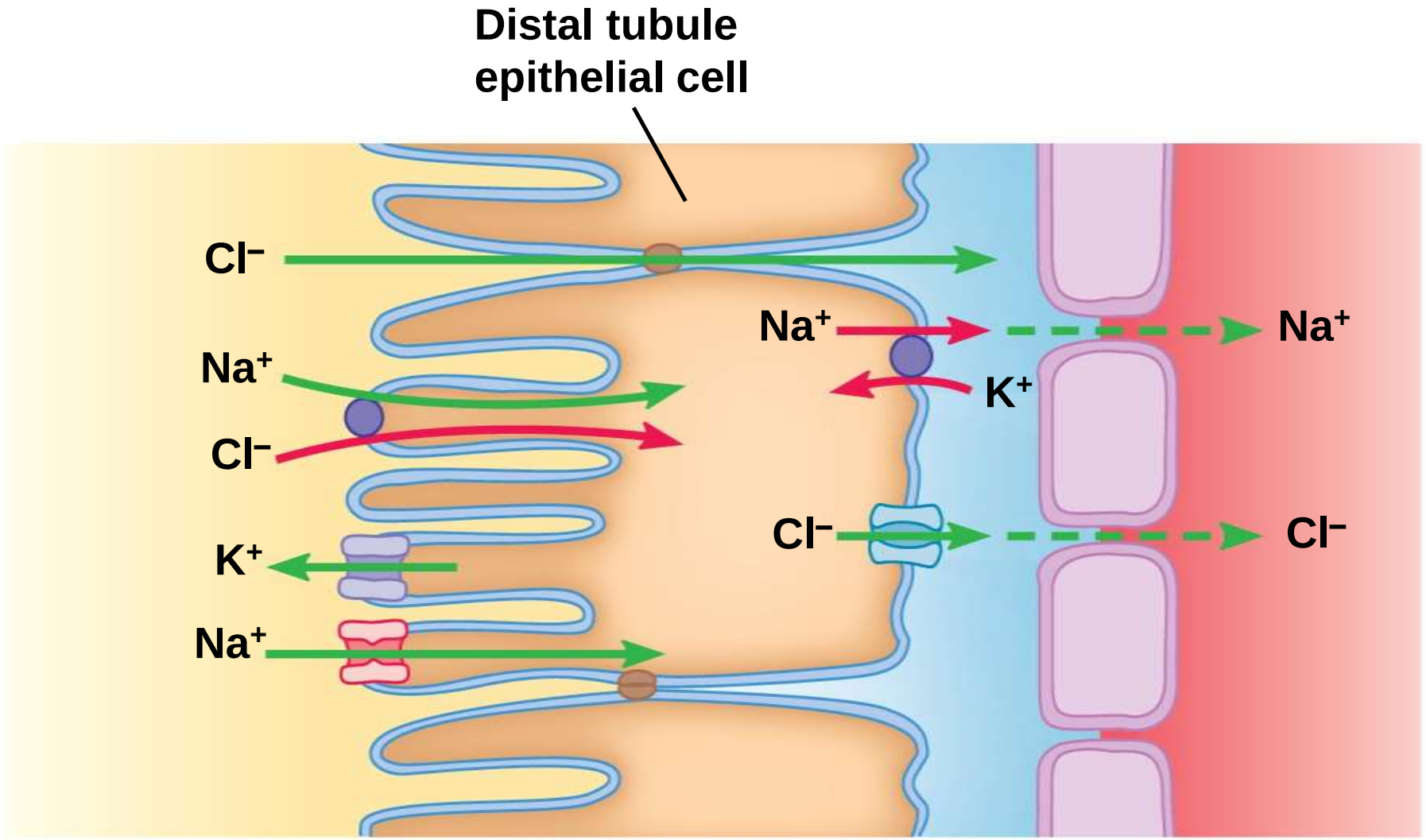
- Na^+
  - Freely filtered
  - Reabsorbed (70%) in proximal tubules, distal tubules, and collecting ducts
  - No secretion
  - Reabsorption regulated by aldosterone and ANP
  - Reabsorption regulated at principal cells of distal tubules and collecting ducts
  - Active reabsorption
  - Na^+/K^+ pump on basolateral membrane drives reabsorption

Figure 19.14a Mechanisms of sodium reabsorption in the proximal and distal tubules.



(a) Sodium reabsorption in the proximal tubule

Figure 19.14b Mechanisms of sodium reabsorption in the proximal and distal tubules.

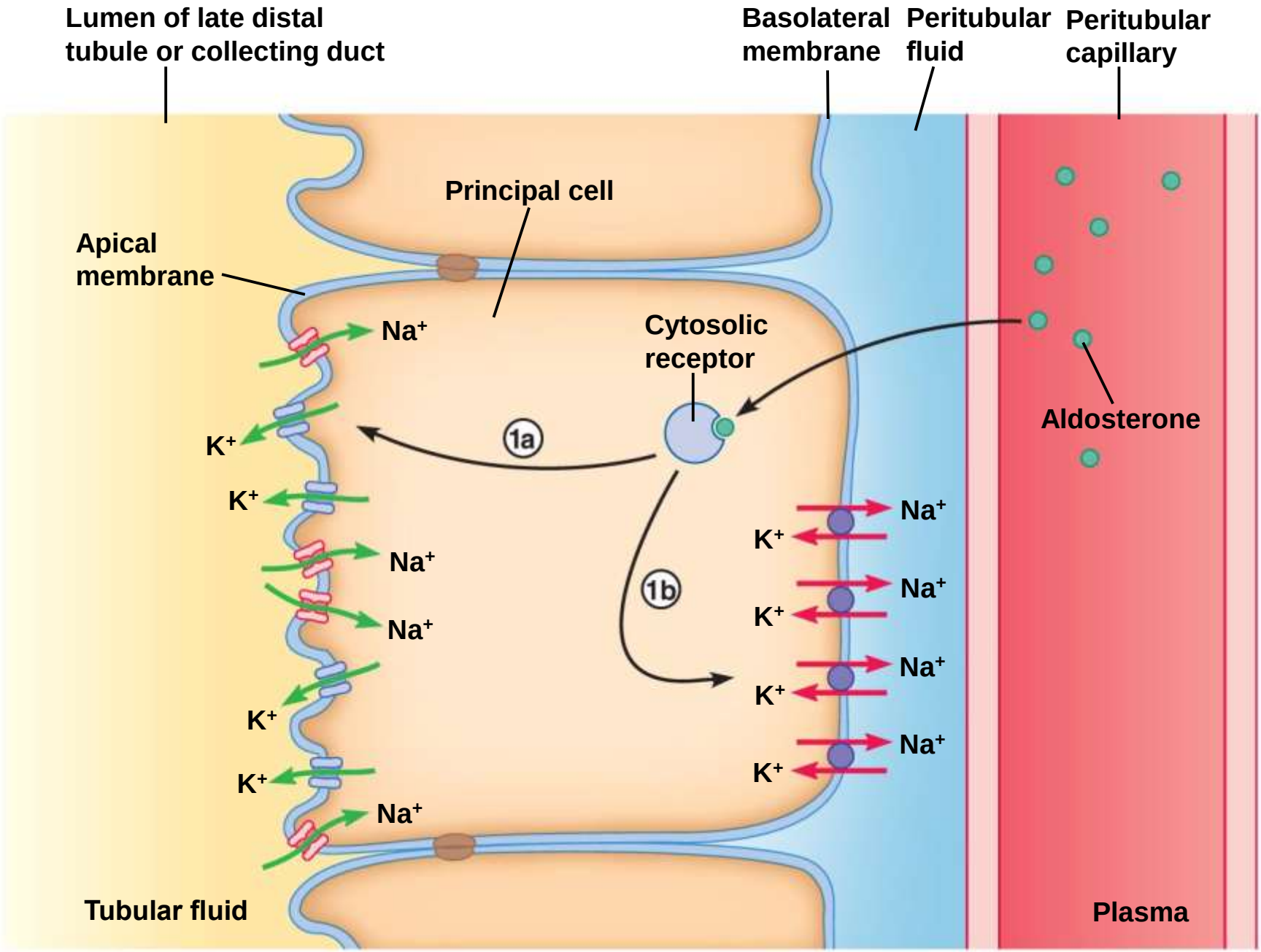


(b) Sodium reabsorption in the distal tubule

The Effects of Aldosterone

- Increases sodium reabsorption
- Steroid hormone secreted from adrenal cortex
- Acts on principal cells of distal tubules and collecting ducts
  - Increases number of Na^+/K^+ pumps on basolateral membrane
  - Increases number of open Na^+ and K^+ channels on apical membrane

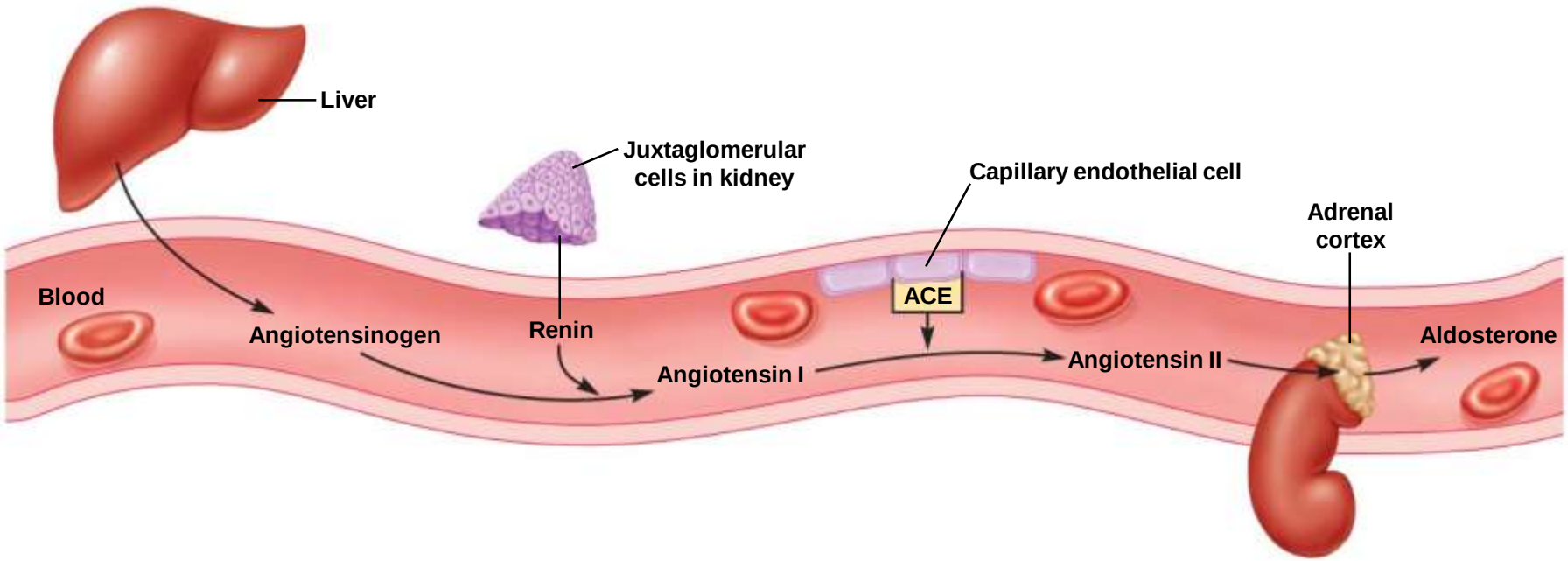
Figure 19.15 Effects of aldosterone on principal cells of the distal tubules and collecting ducts.



The Effects of Aldosterone

- Renin-angiotensin-aldosterone system (RAAS)
  - Granular cells of juxtaglomerular apparatus secrete renin
  - Capillary walls contain angiotensin-converting enzyme (ACE), especially in lungs
  - Liver secretes angiotensinogen
  - Angiotensinogen is converted by renin into angiotensin I
  - Angiotensin I is converted by ACE into angiotensin II
  - Angiotensin II stimulates aldosterone production

Figure 19.16 The renin-angiotensin-aldosterone system.



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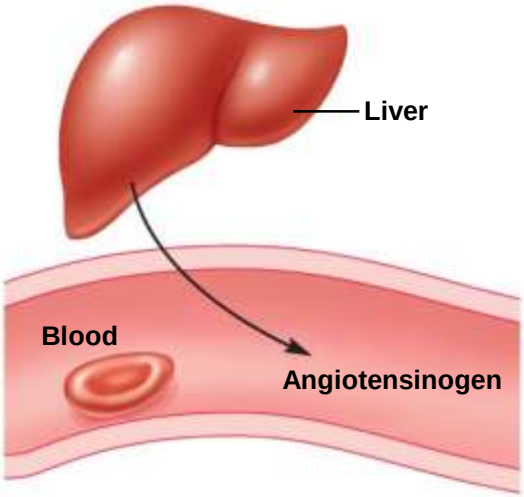

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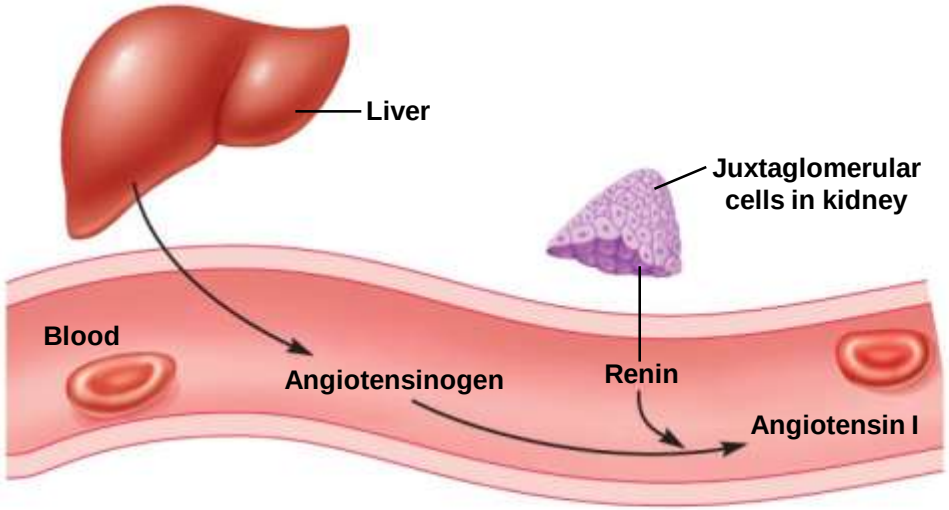
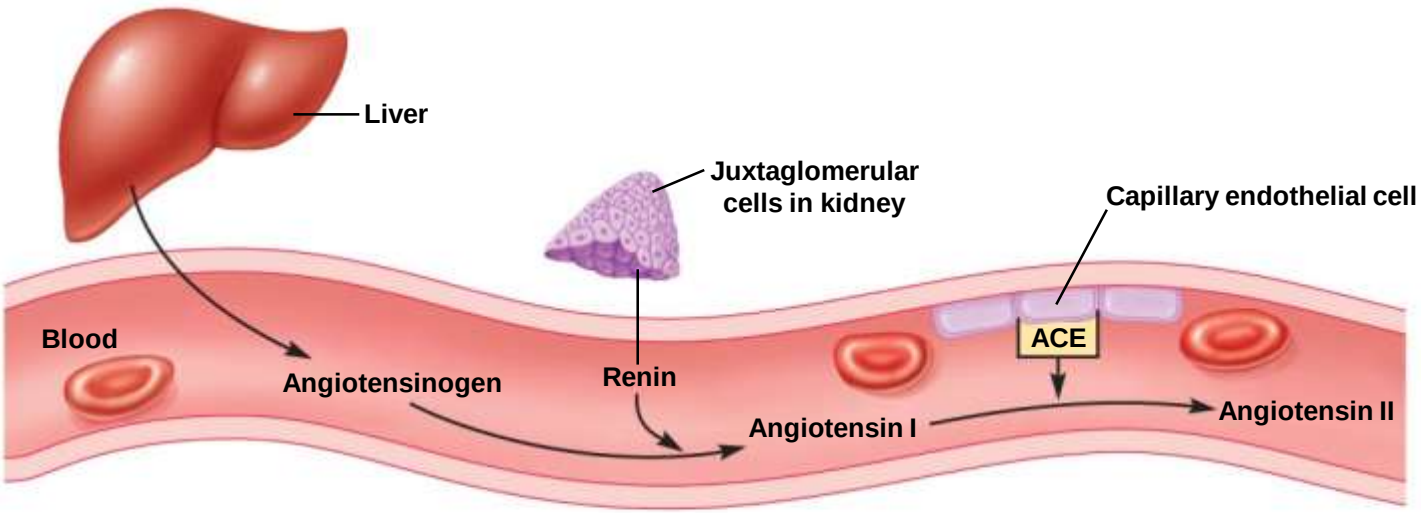


Figure 19.16 The renin-angiotensin-aldosterone system.



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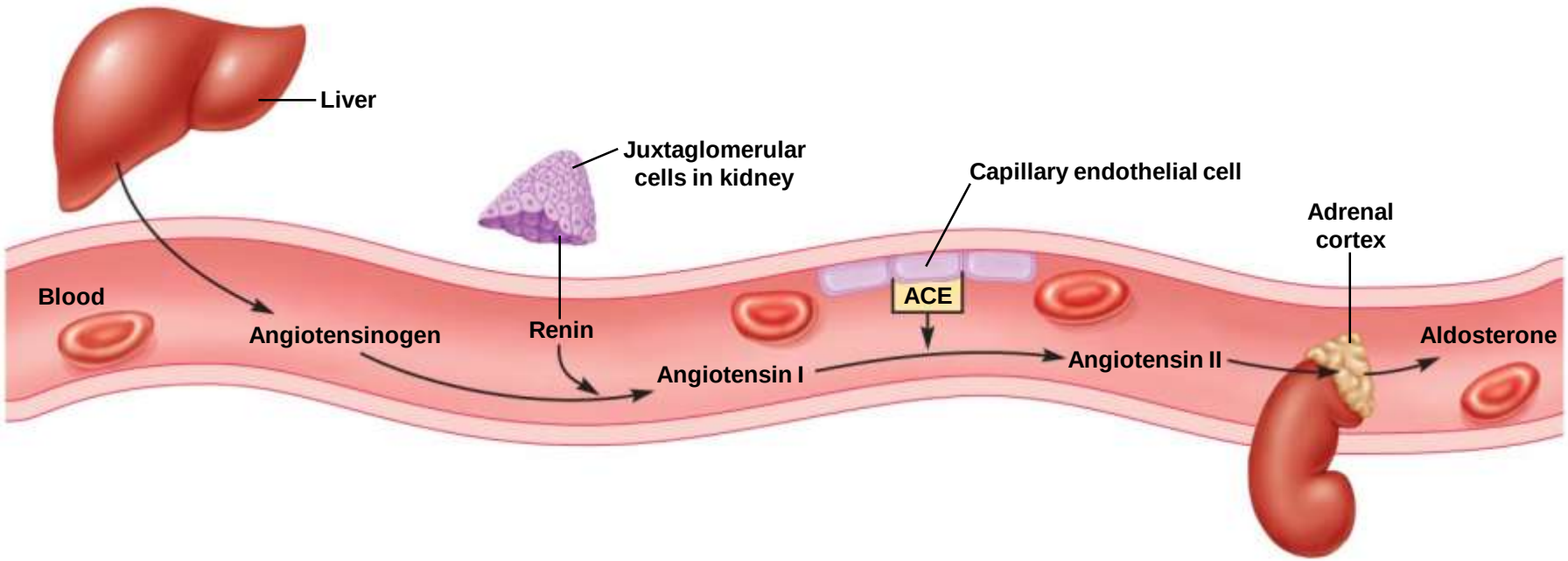


Figure 19.17 Mechanisms by which angiotensin II increases mean arterial pressure.

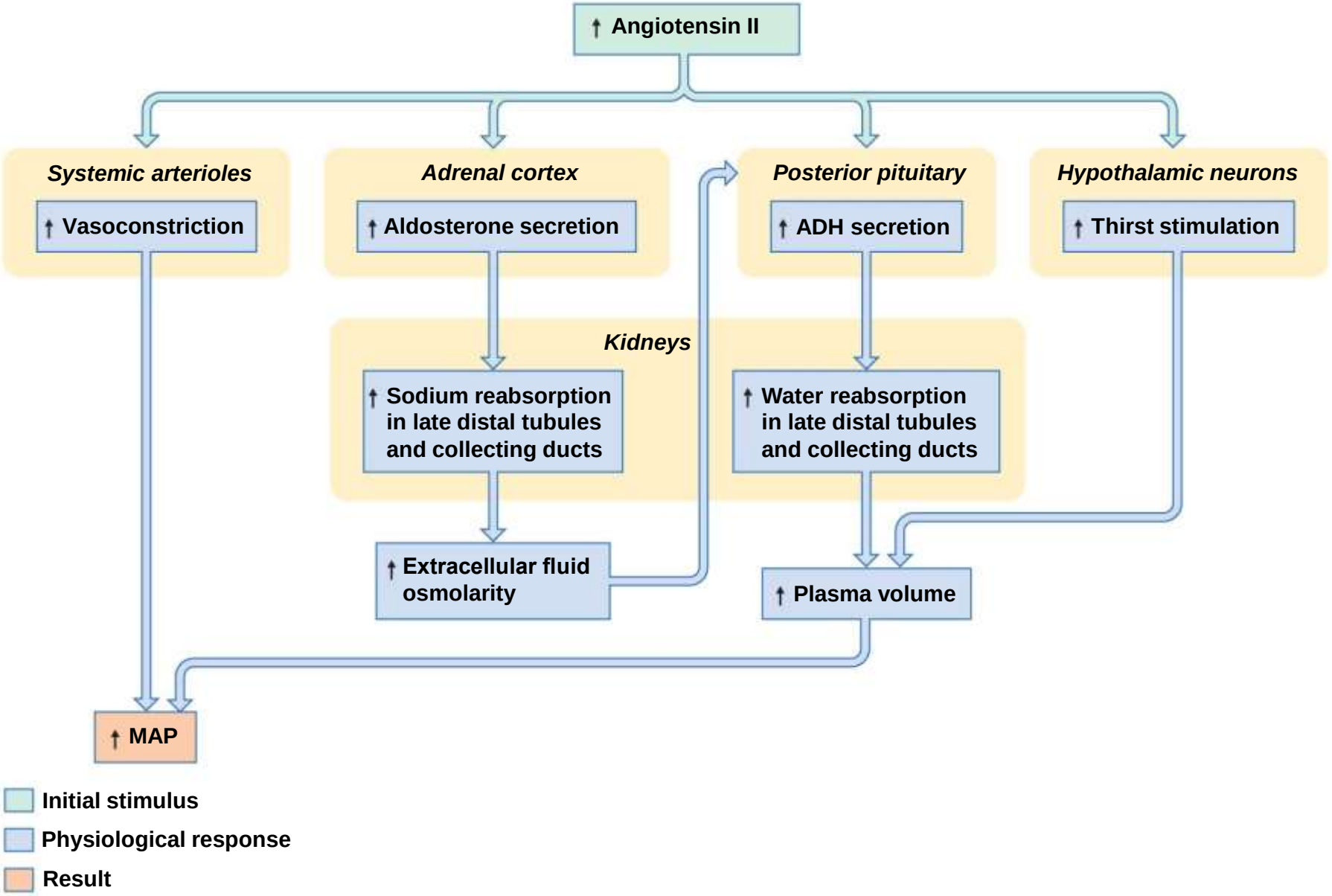


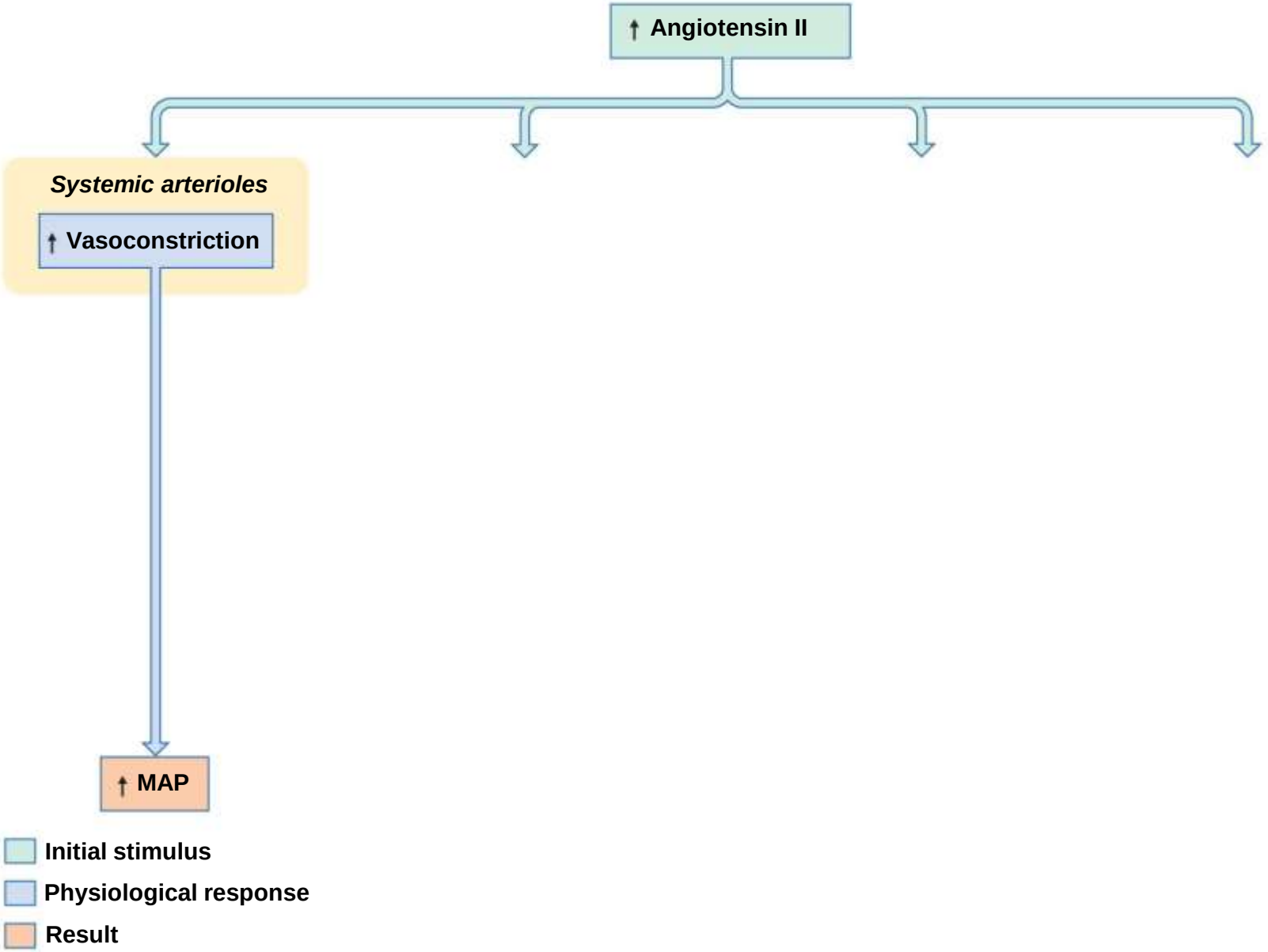
Figure 19.17 Mechanisms by which angiotensin II increases mean arterial pressure.

Initial stimulus

Physiological response

Result

Figure 19.17 Mechanisms by which angiotensin II increases mean arterial pressure.



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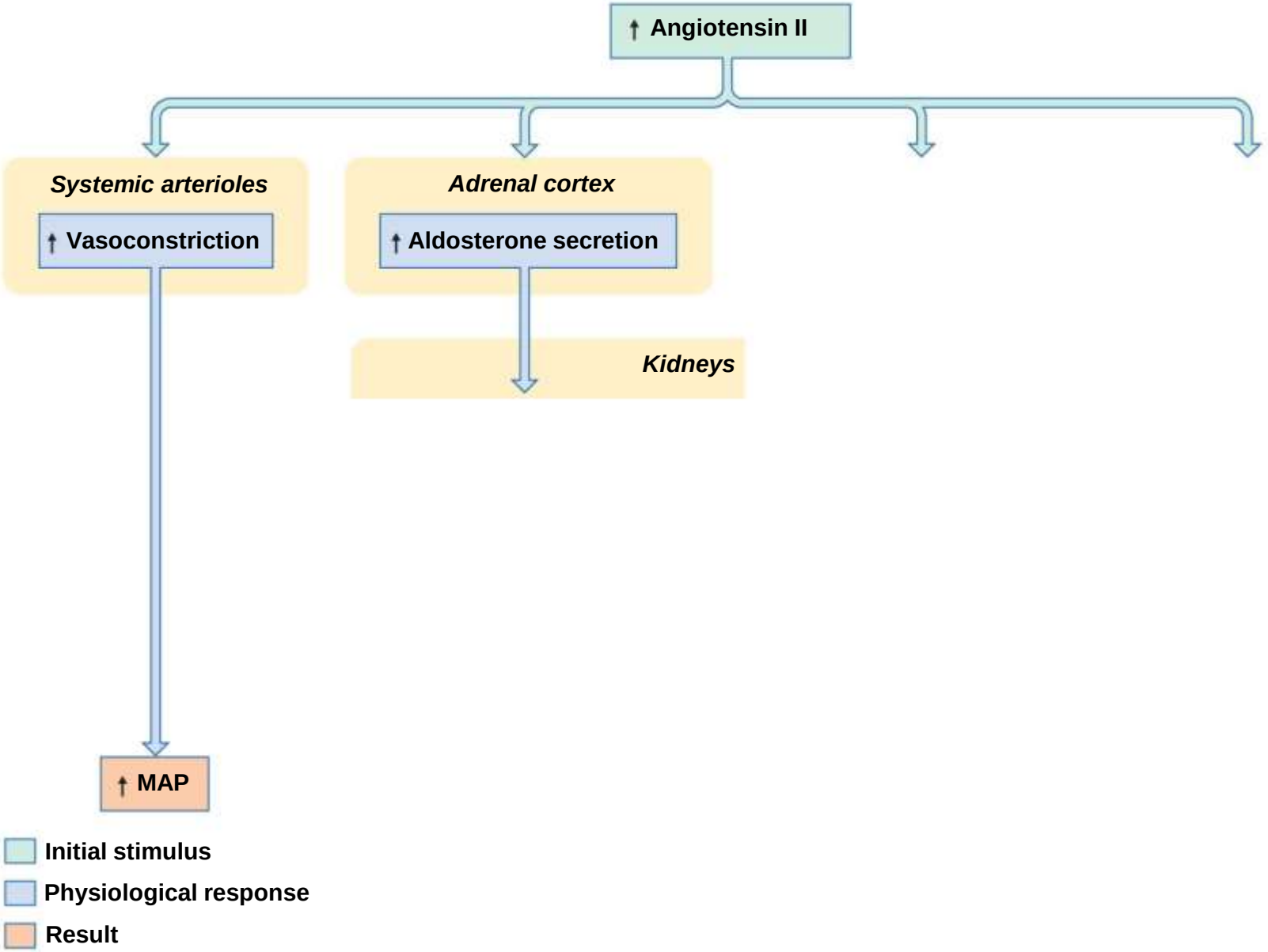

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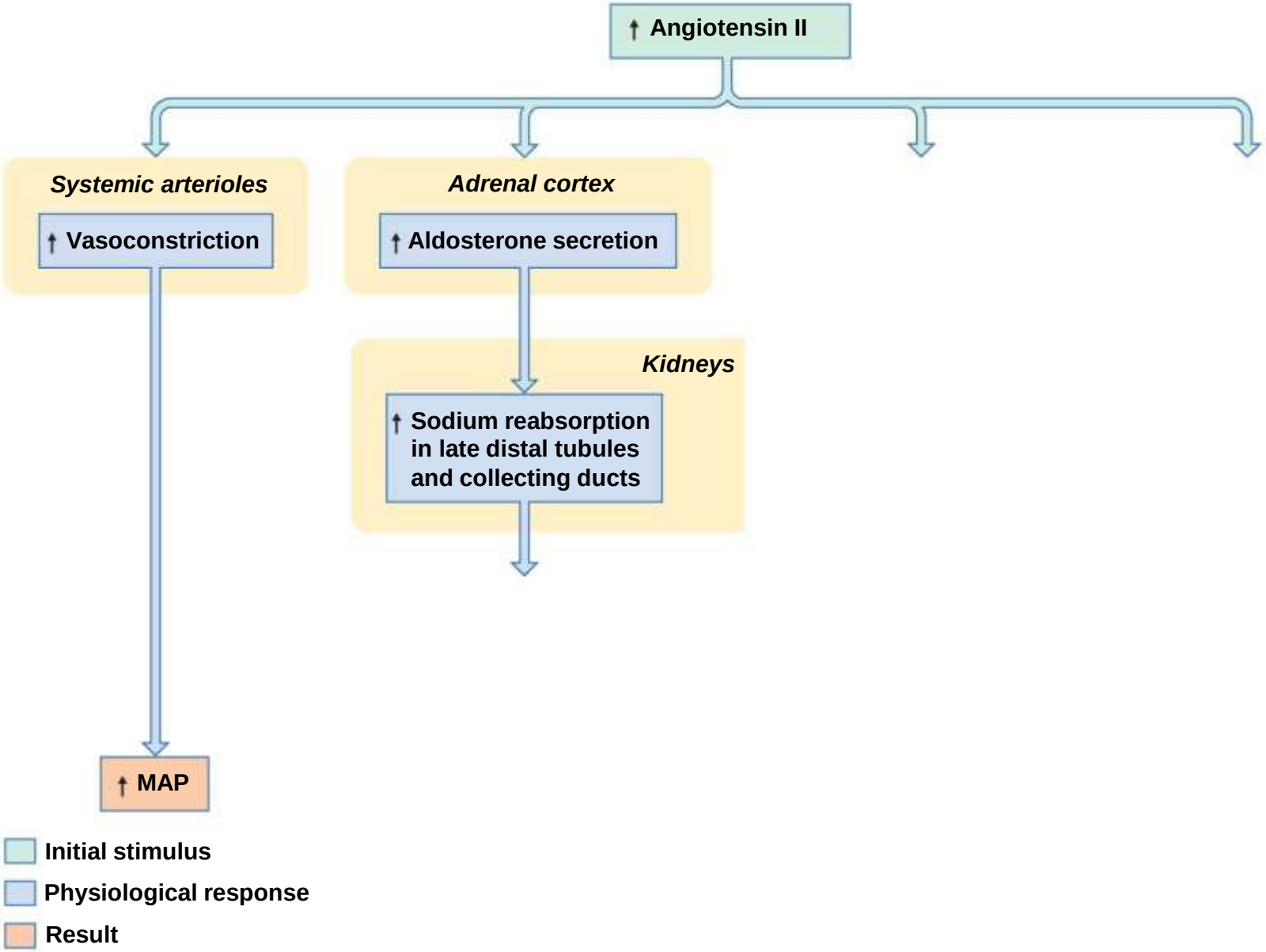

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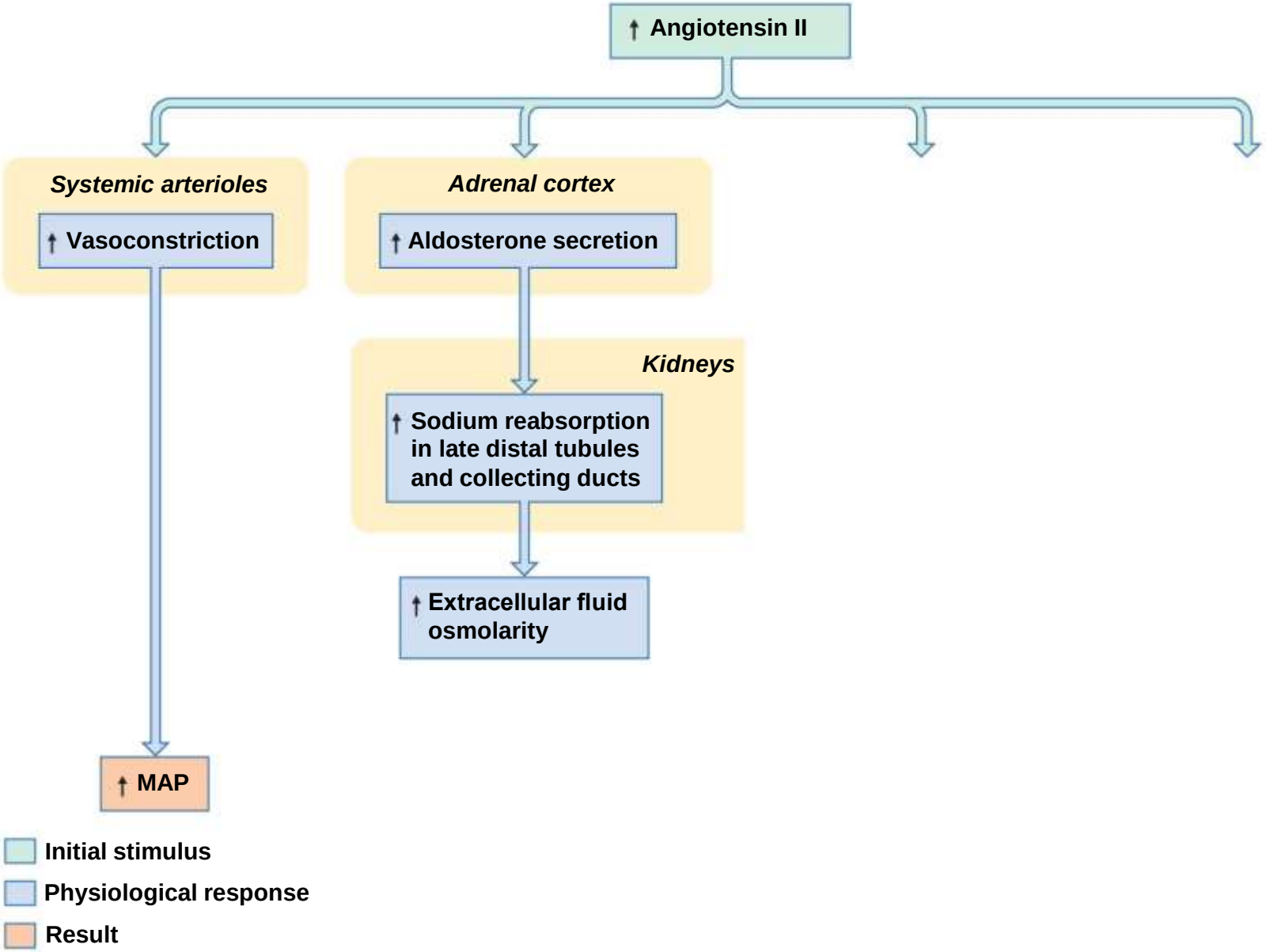

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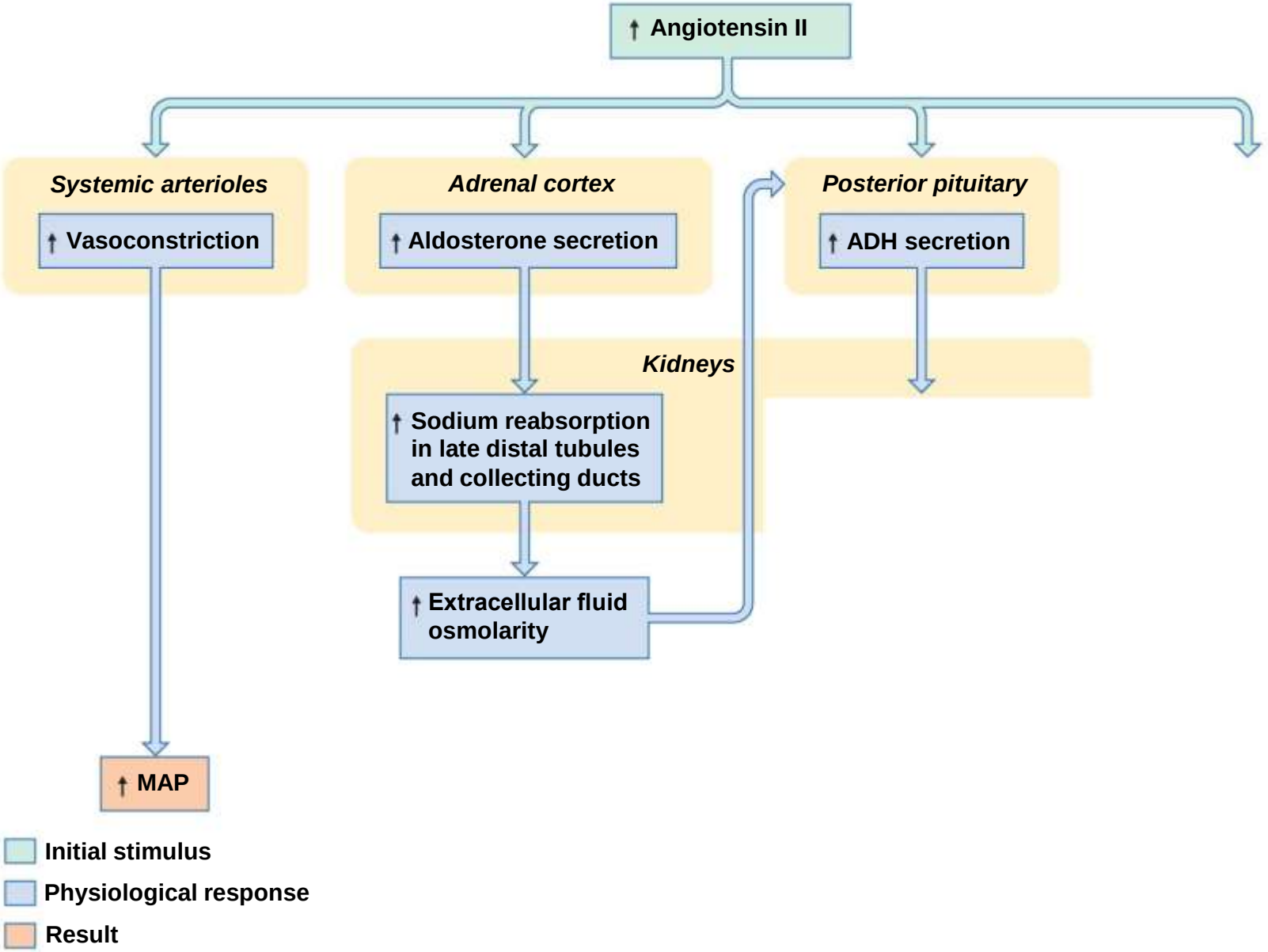

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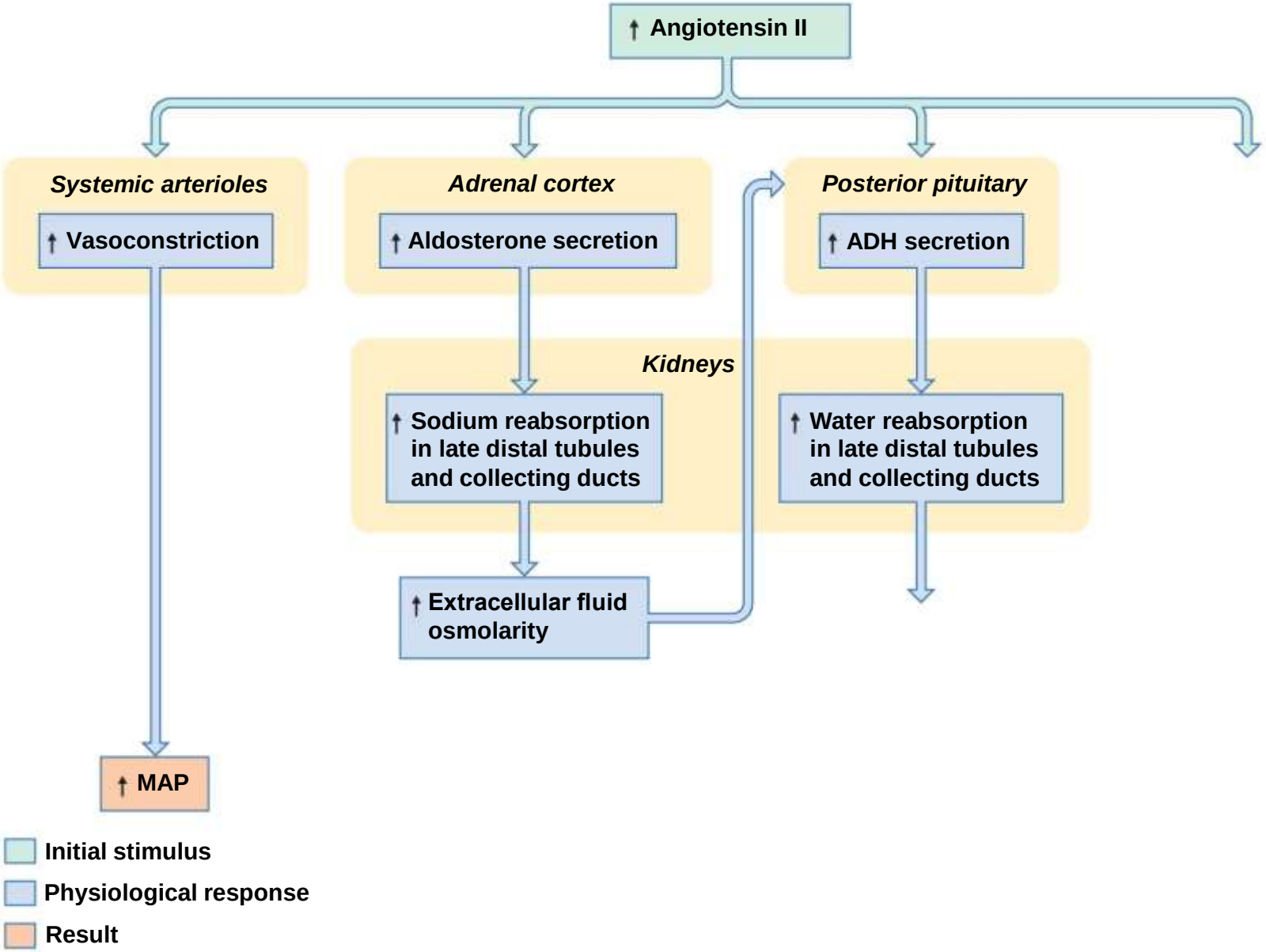

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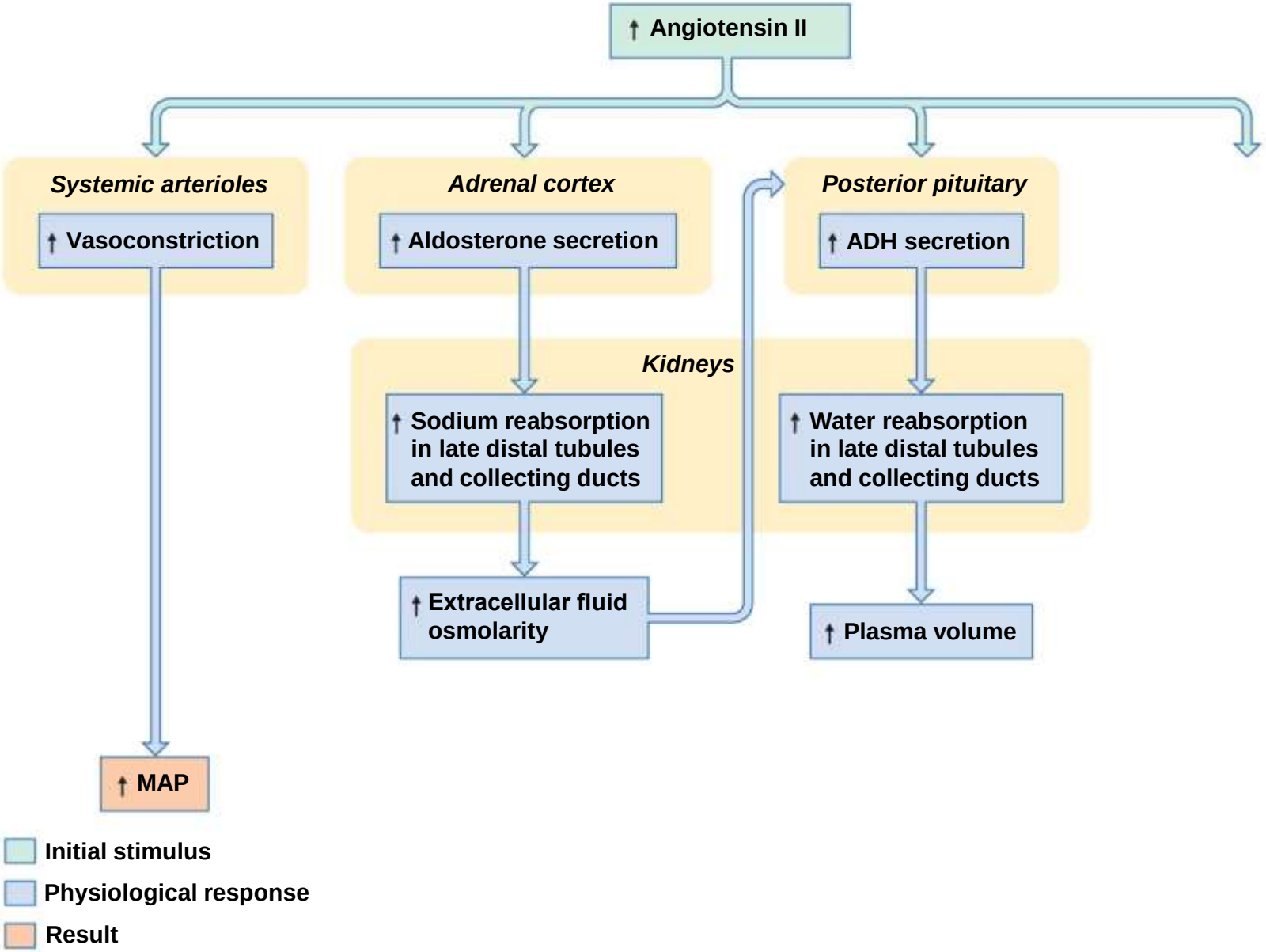

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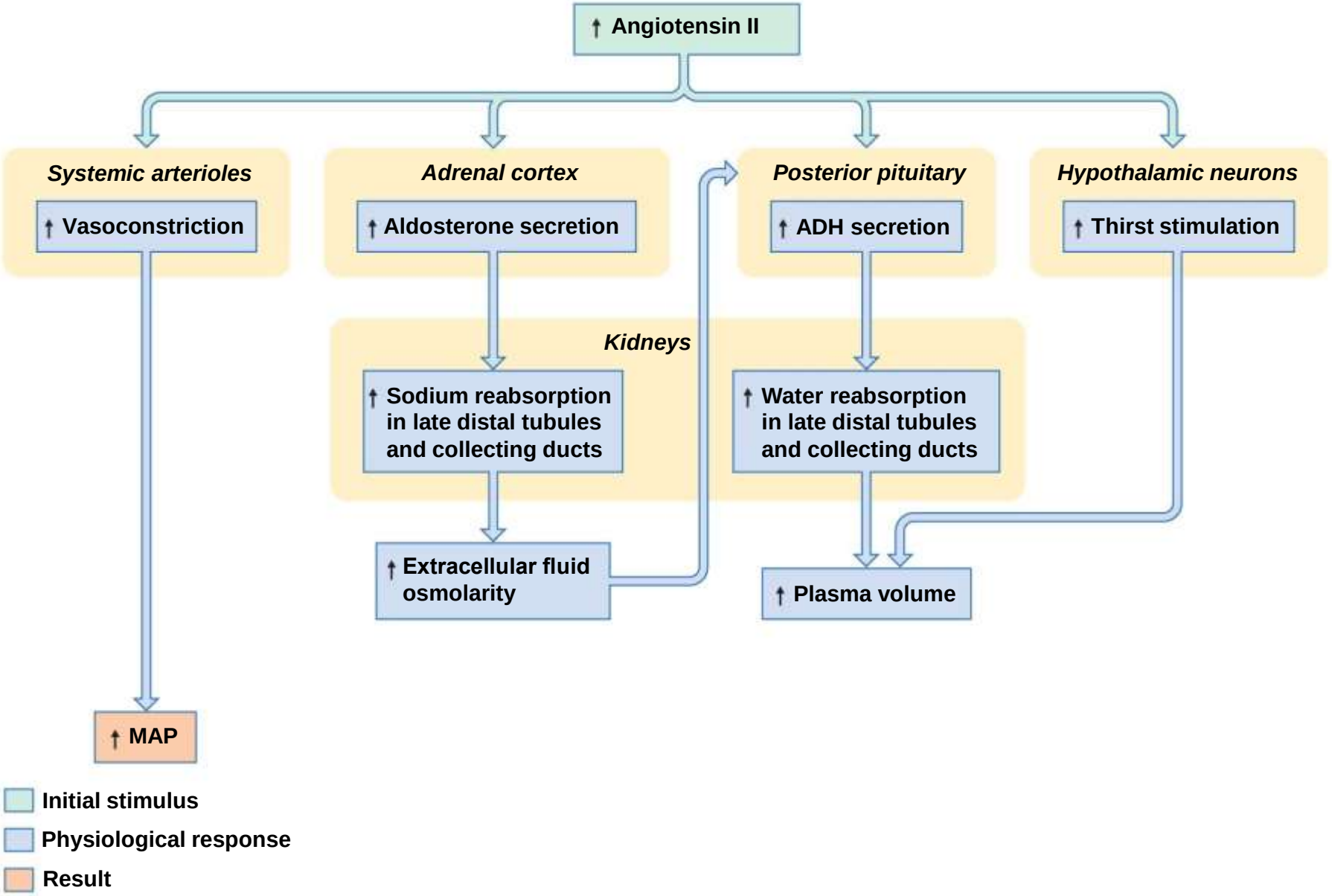

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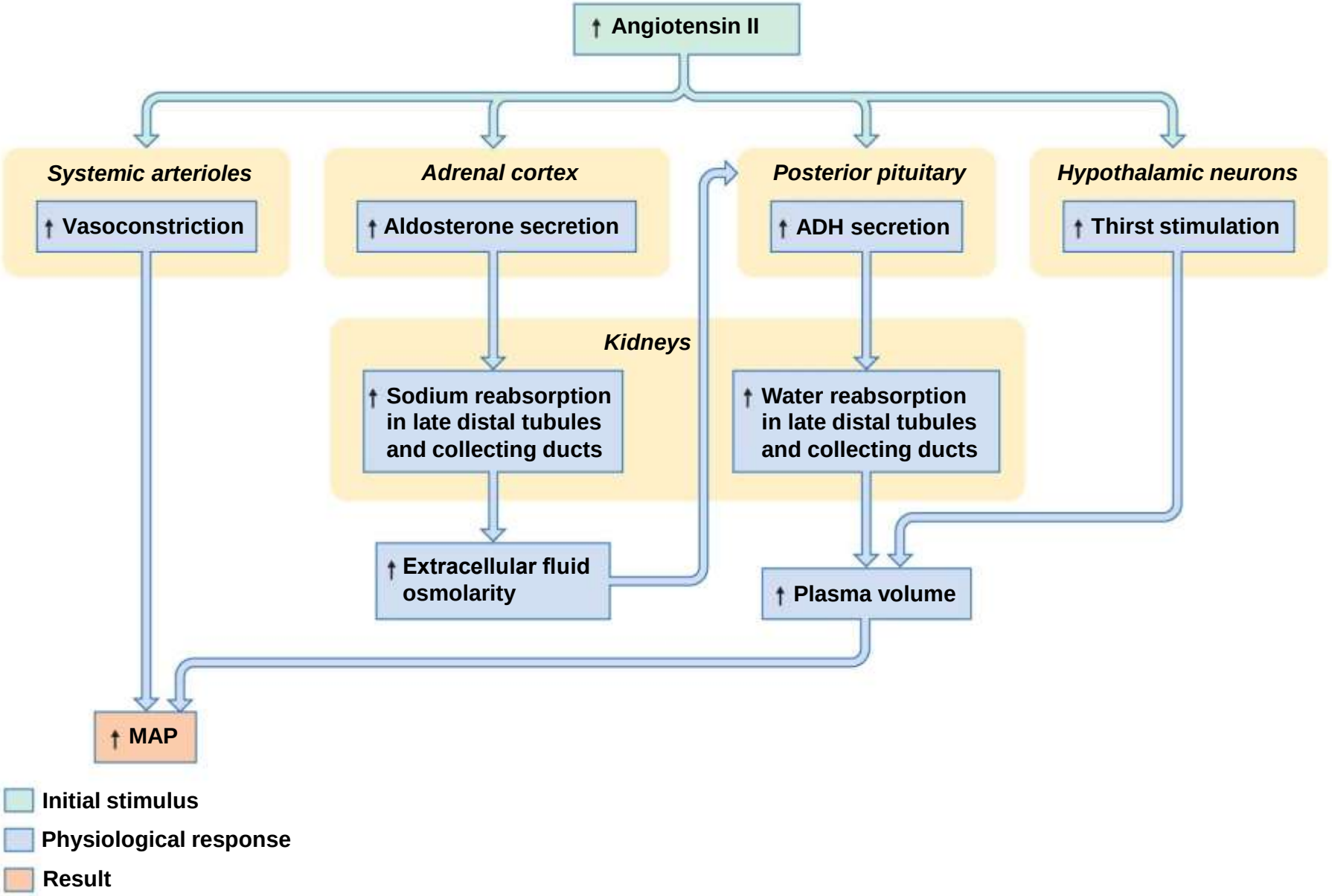
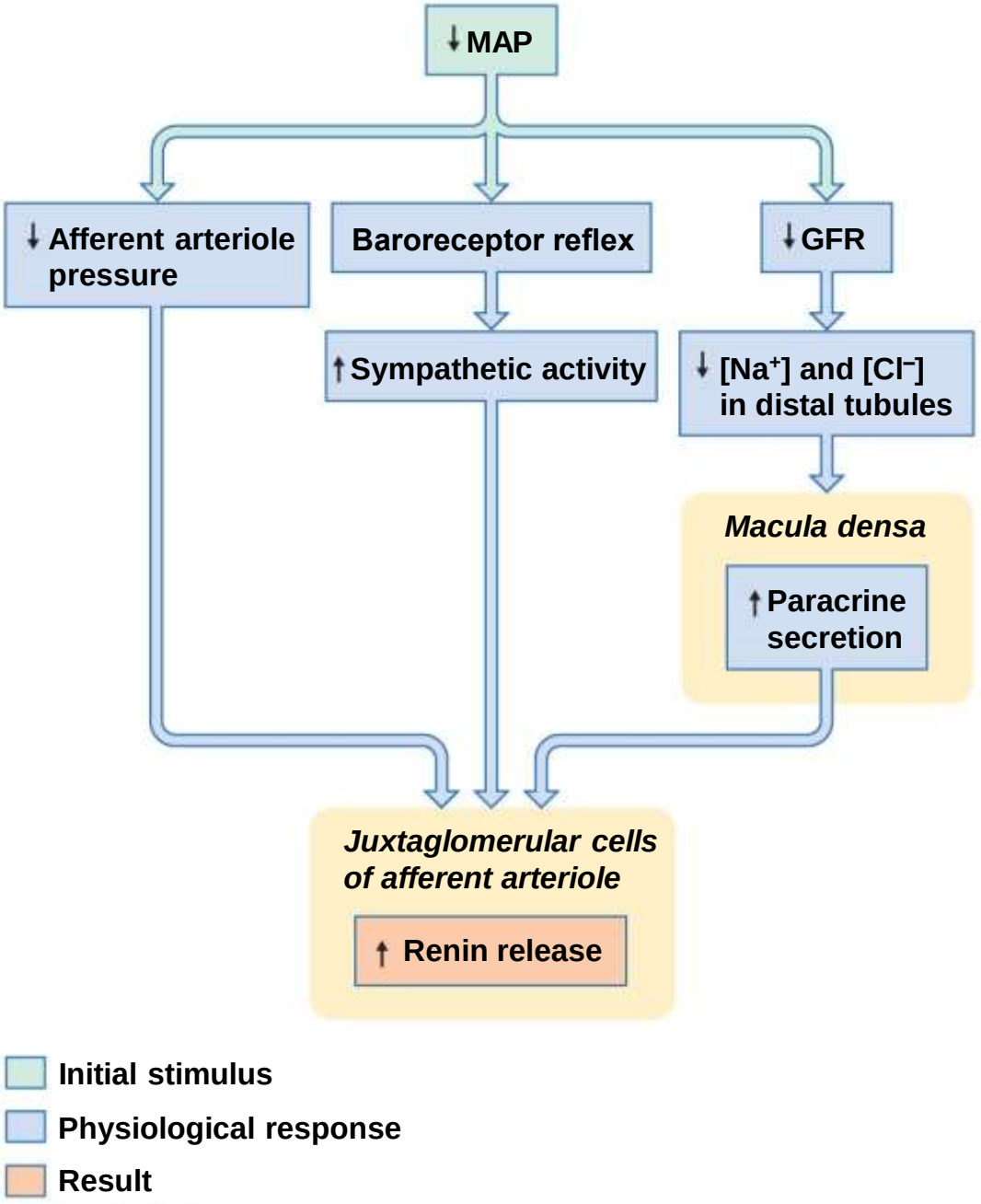


The Effects of Aldosterone

- Stimuli for renin release
  - Decreased pressure in afferent arteriole
  - Renal sympathetic nerve activity
  - Decreases in Na^+ and Cl^- in distal tubule filtrate

Figure 19.18 Mechanisms by which decreases in mean arterial pressure stimulate renin release.



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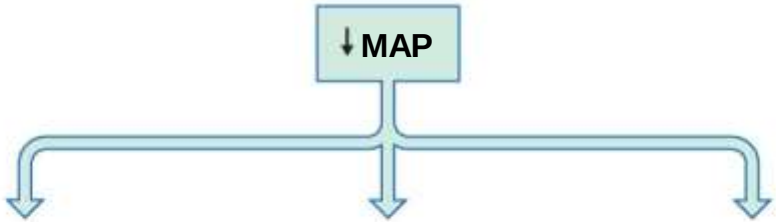
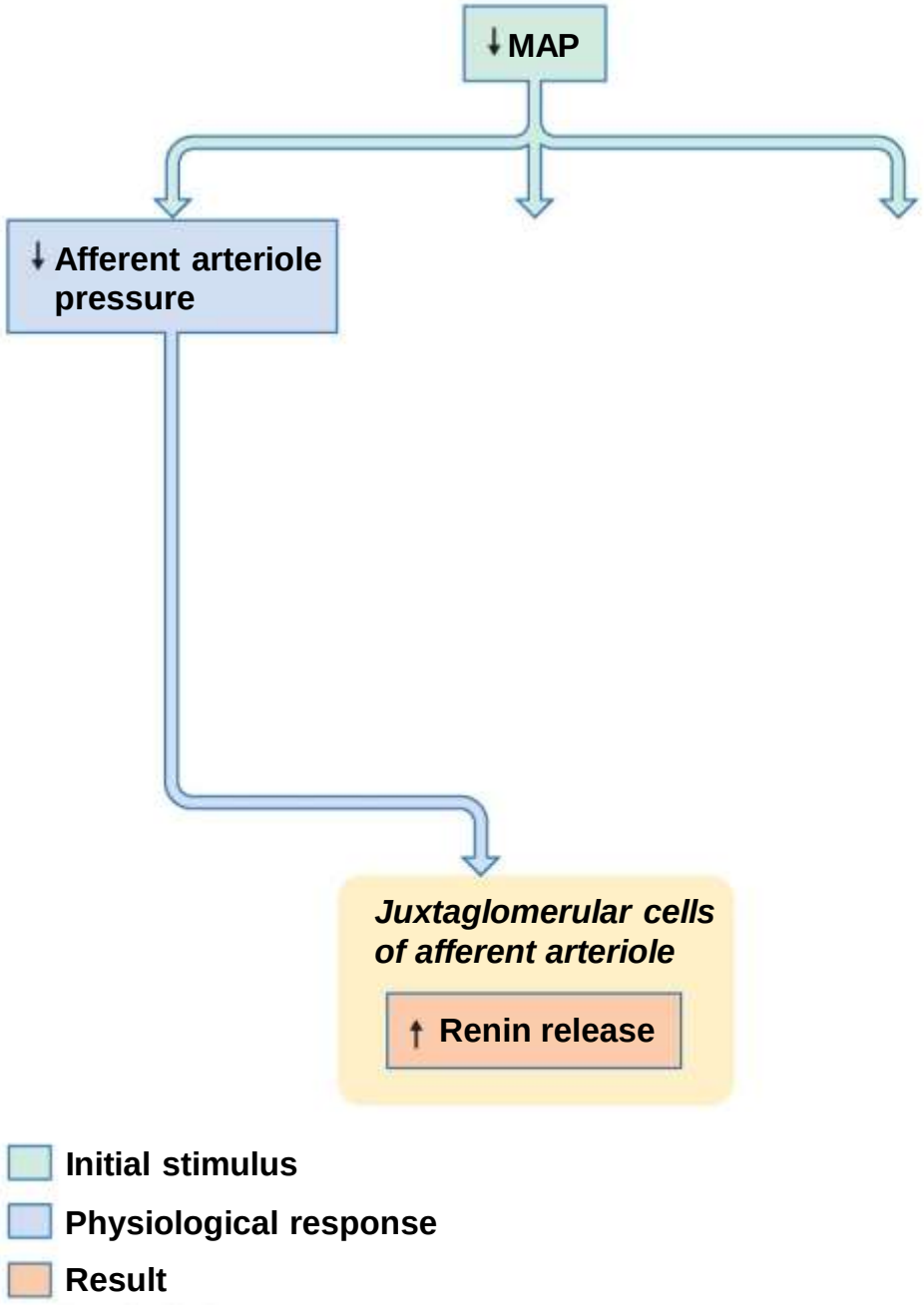


Initial stimulus

Physiological response

Result

Figure 19.18 Mechanisms by which decreases in mean arterial pressure stimulate renin release.



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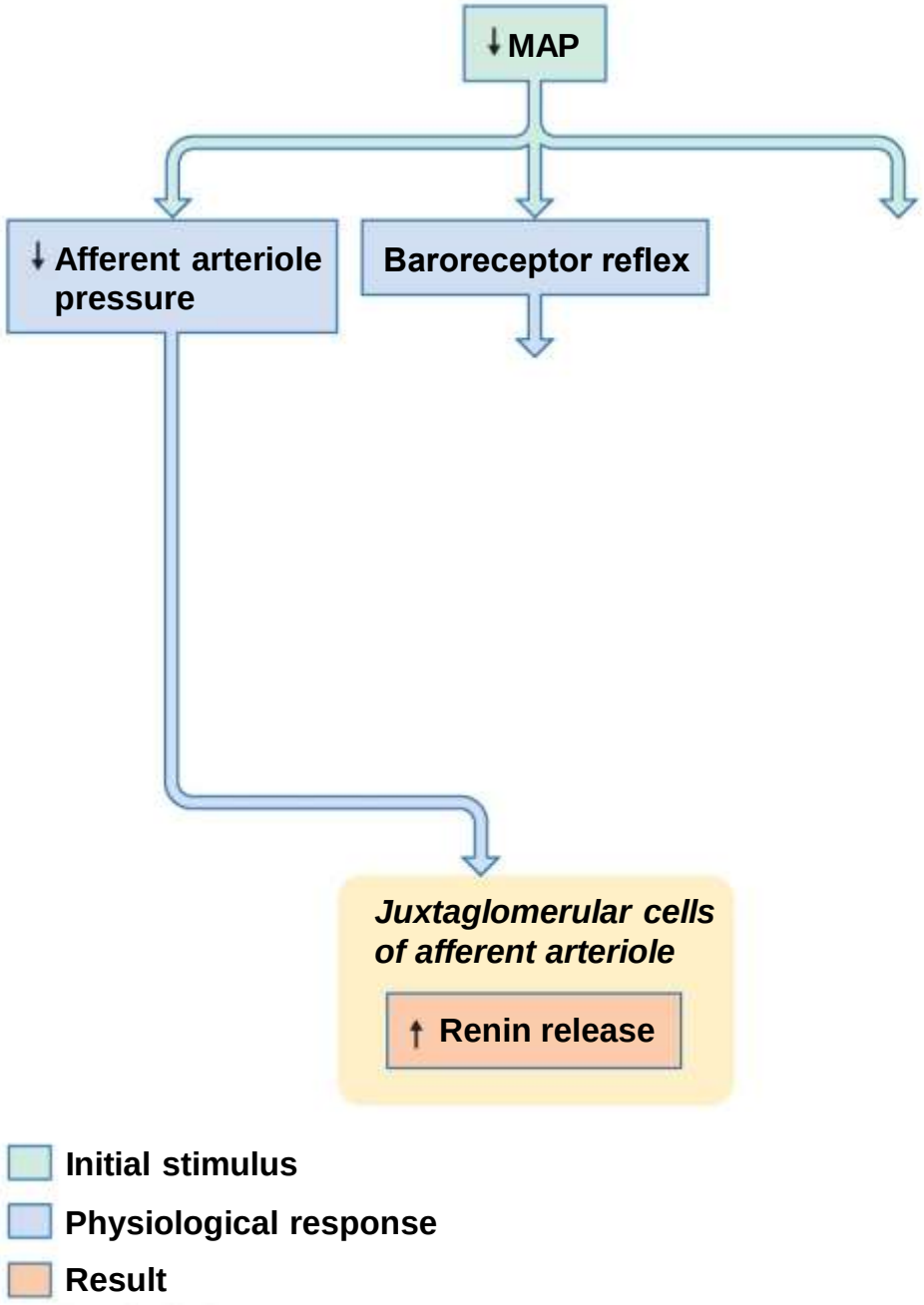

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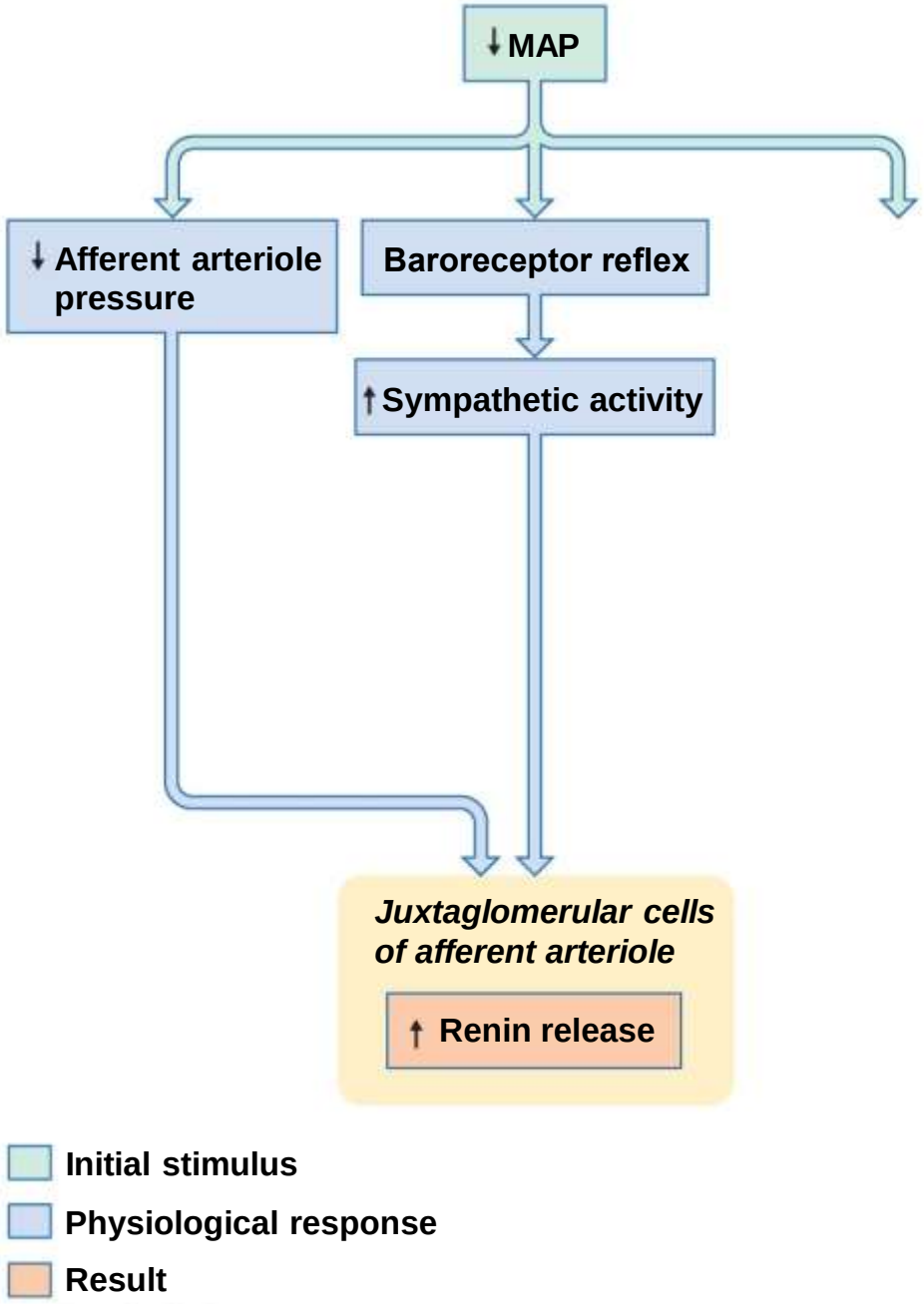

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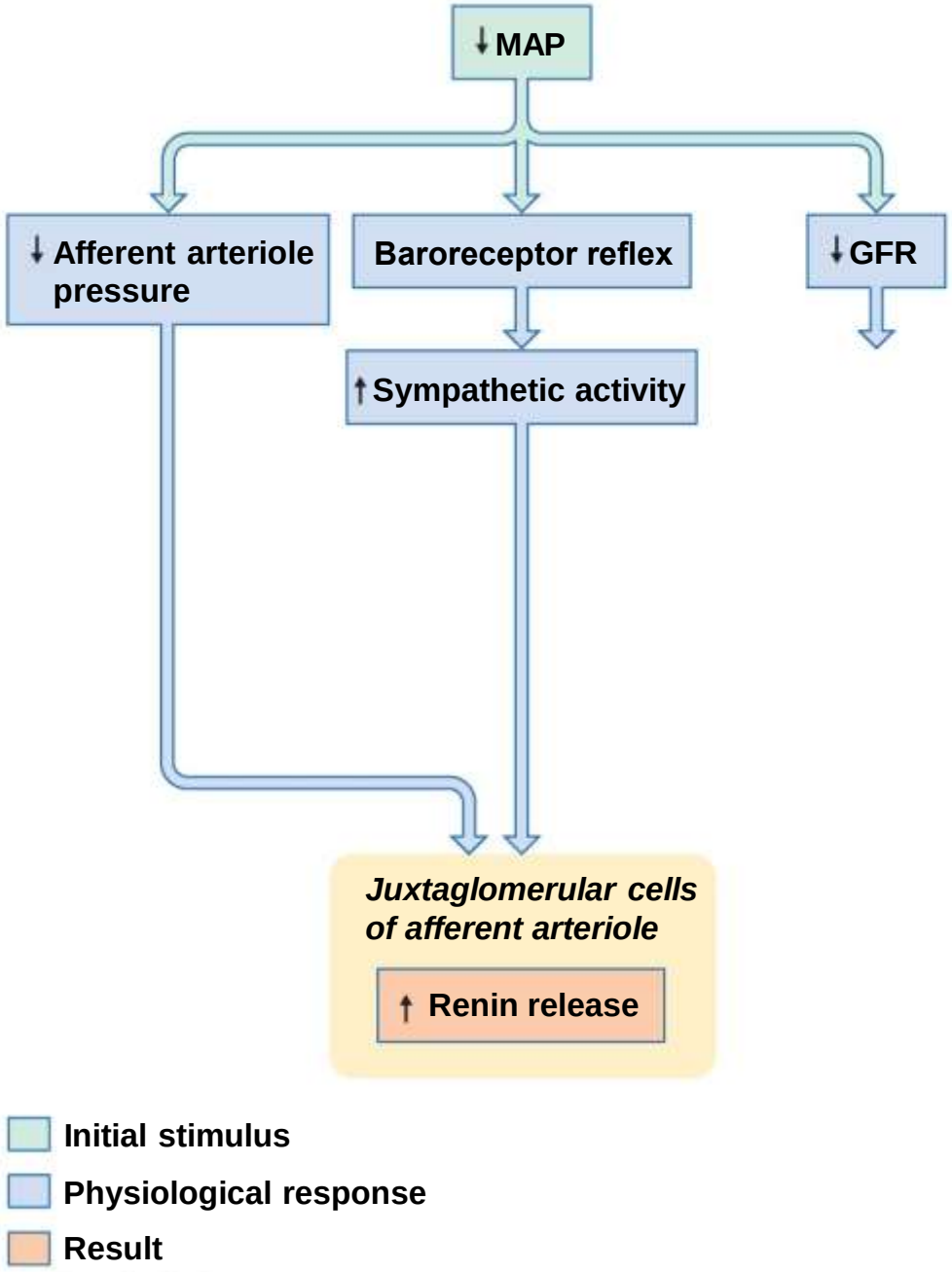

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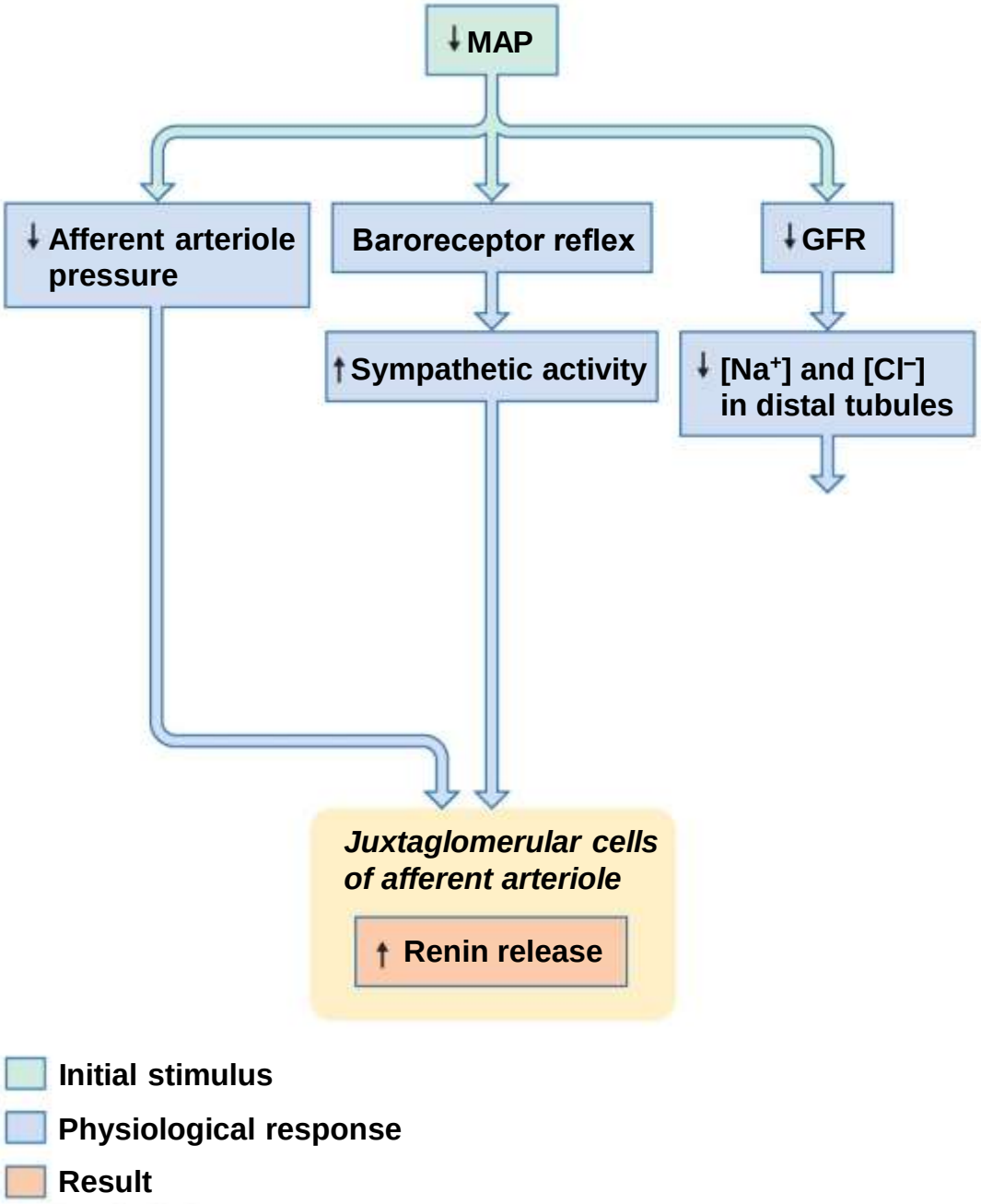

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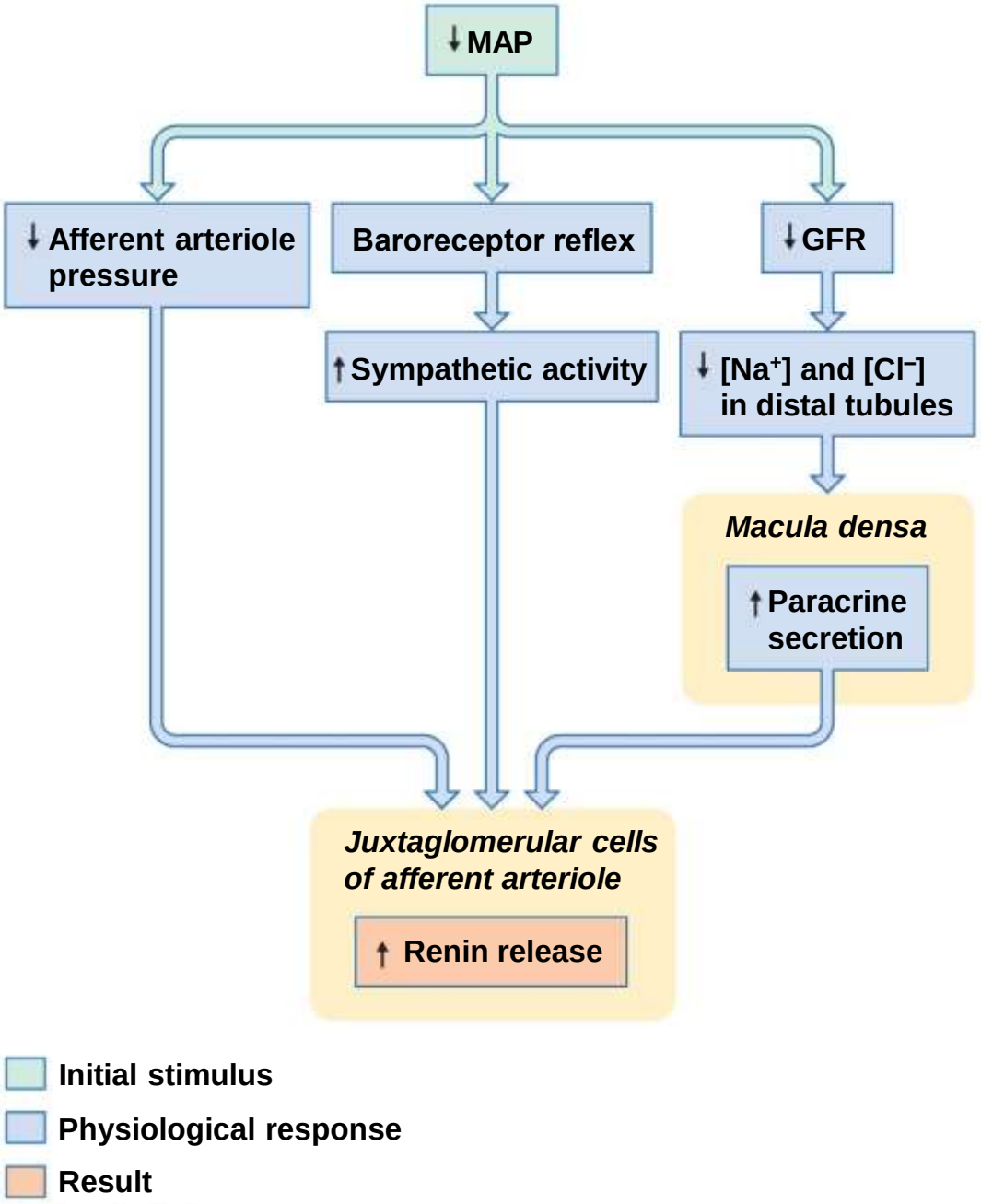
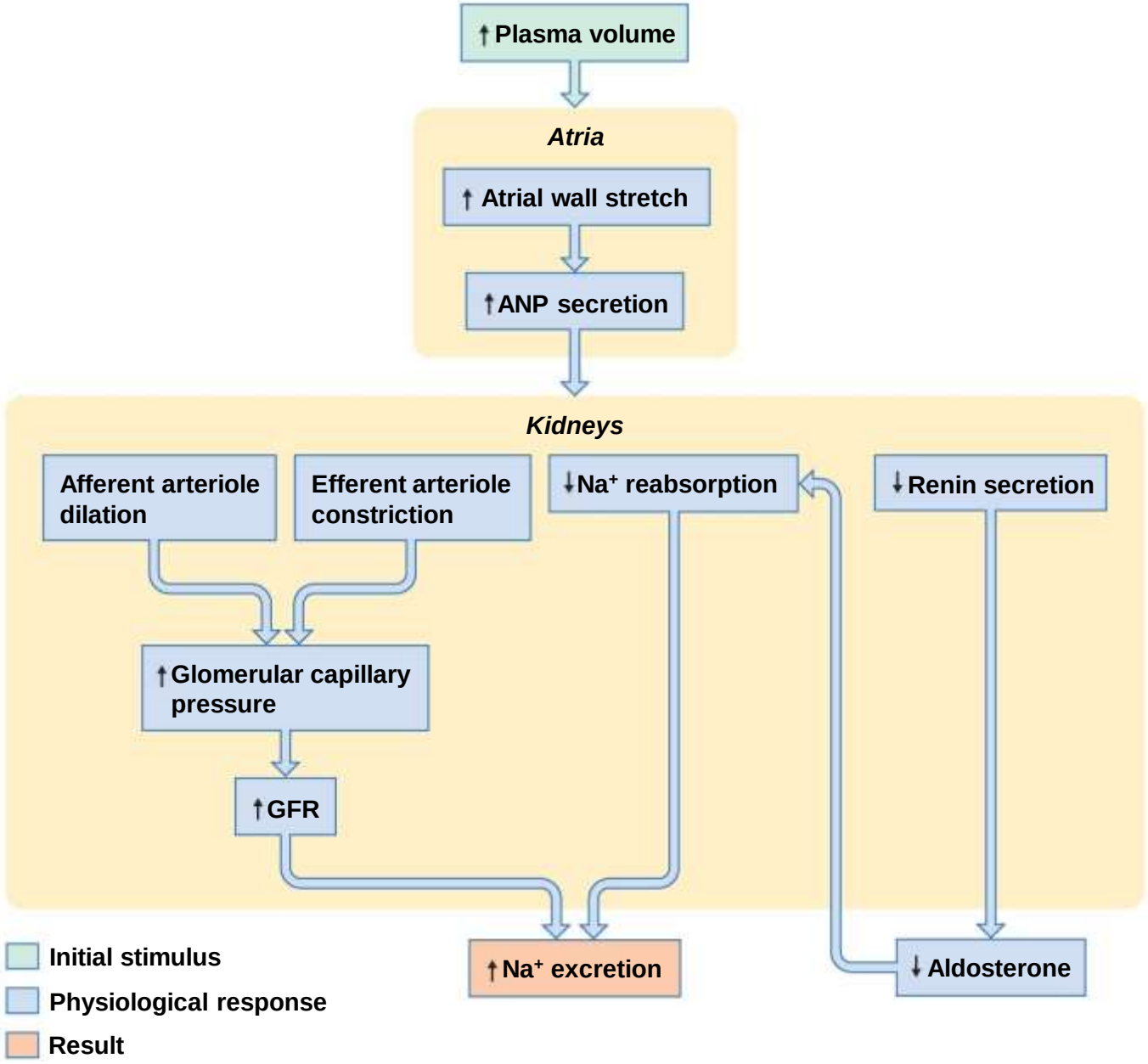


Atrial Natriuretic Peptide

- Secreted by atrial cells in response to distension of atrial wall
- Increases GFR
  - Dilation of afferent arteriole
  - Constriction of efferent arteriole
- Decreases Na^+ reabsorption by closing Na^+ channels in apical membrane
- Overall effect: increased Na^+ excretion

Figure 19.19 Mechanisms by which secretion of atrial natriuretic peptide increases sodium excretion in response to increased plasma volume.



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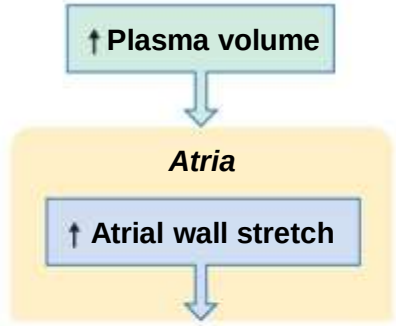
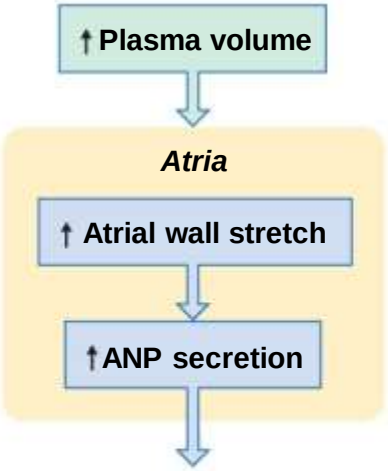


Initial stimulus
Physiological response
Result

Figure 19.19 Mechanisms by which secretion of atrial natriuretic peptide increases sodium excretion in response to increased plasma volume.



Initial stimulus
Physiological response
Result

Figure 19.19 Mechanisms by which secretion of atrial natriuretic peptide increases sodium excretion in response to increased plasma volume.

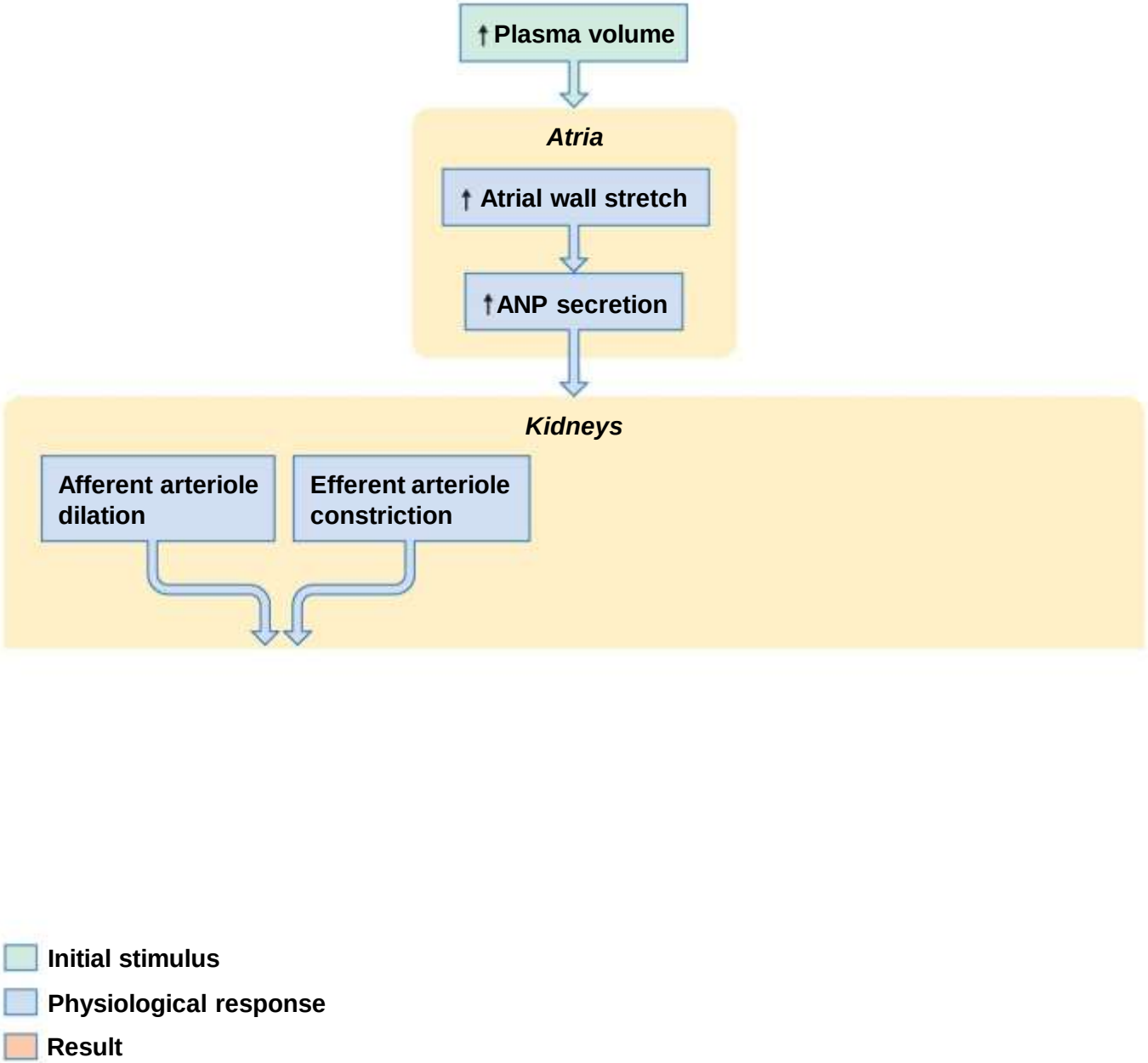
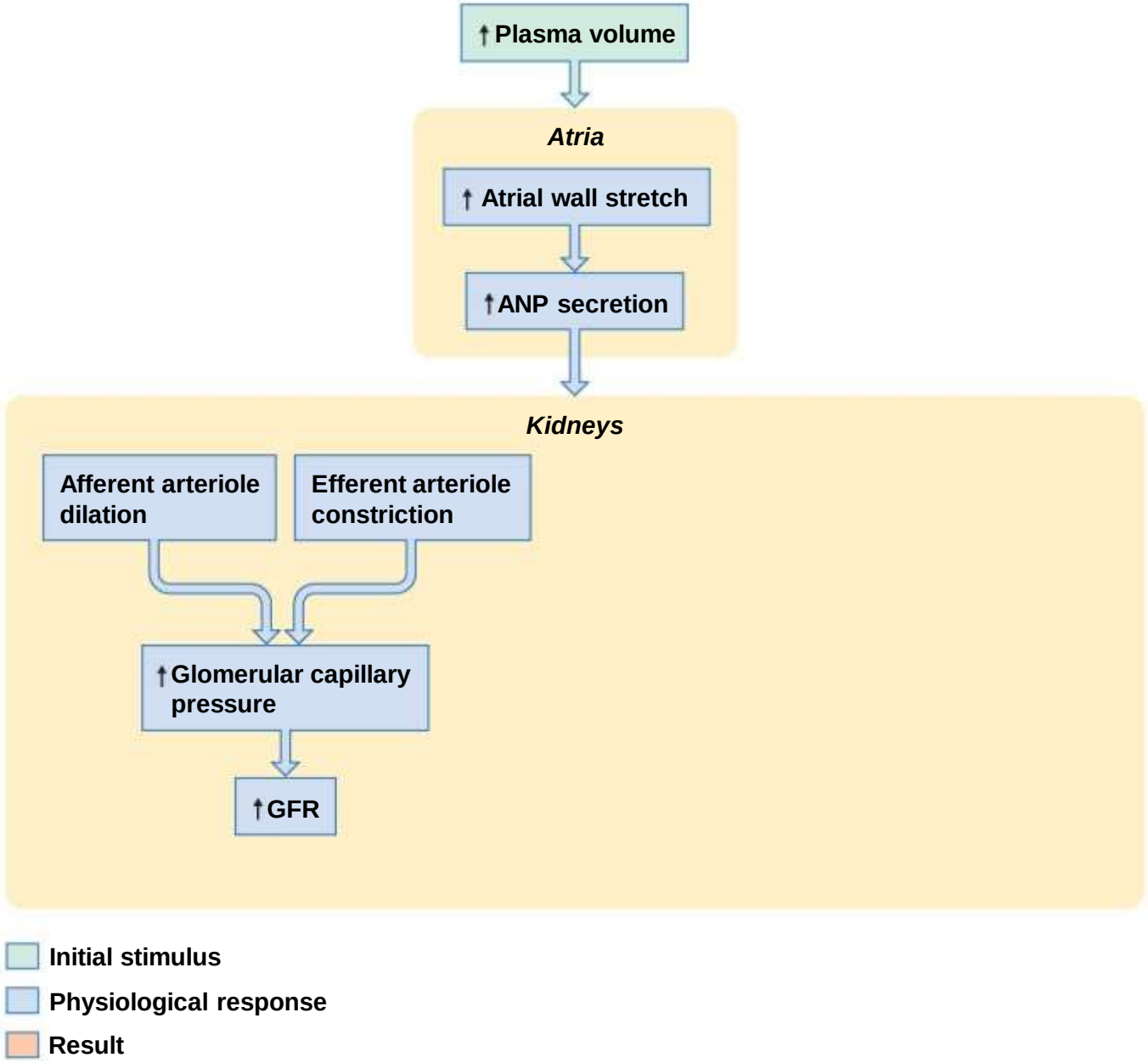


Figure 19.19 Mechanisms by which secretion of atrial natriuretic peptide increases sodium excretion in response to increased plasma volume.



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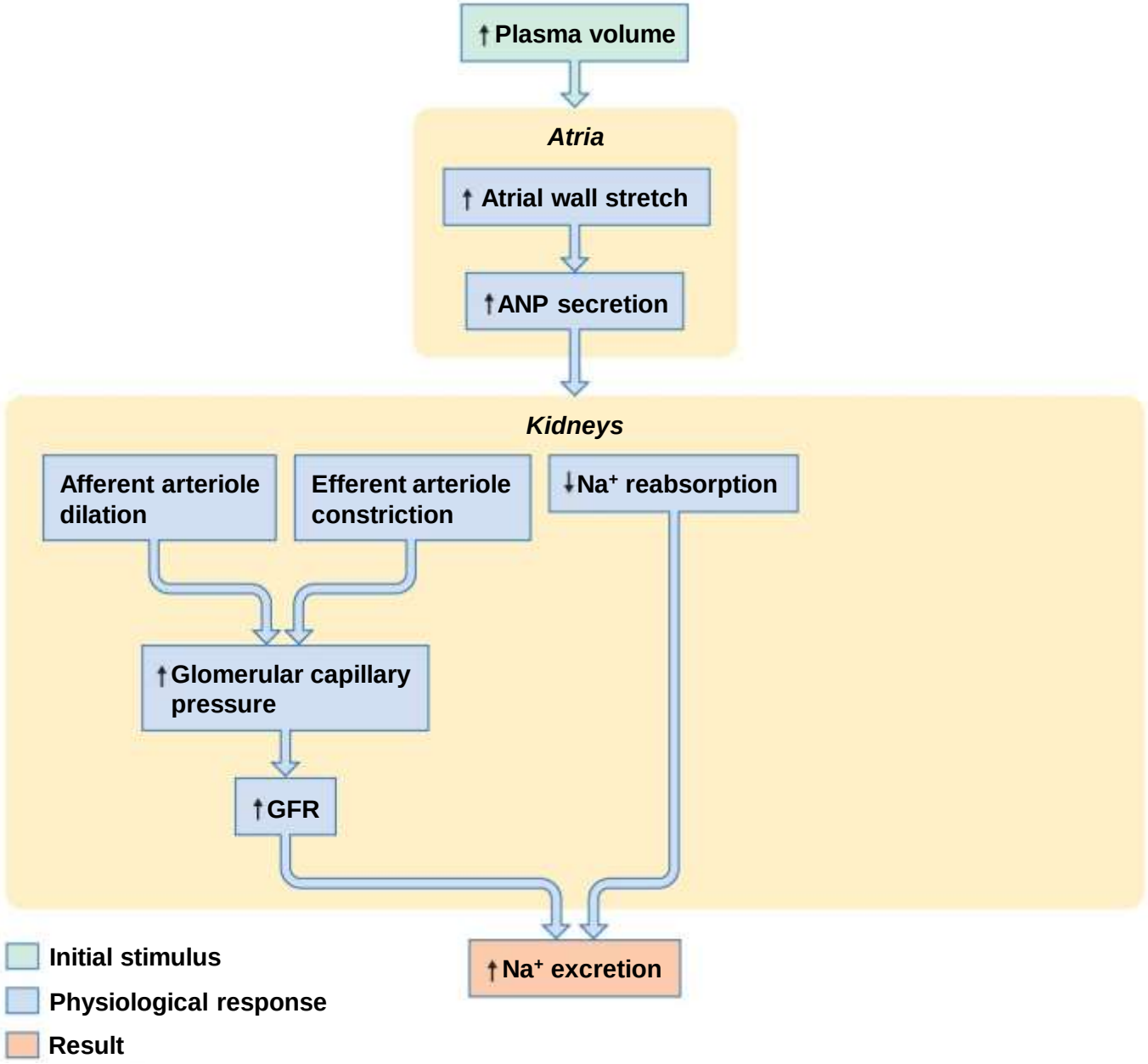
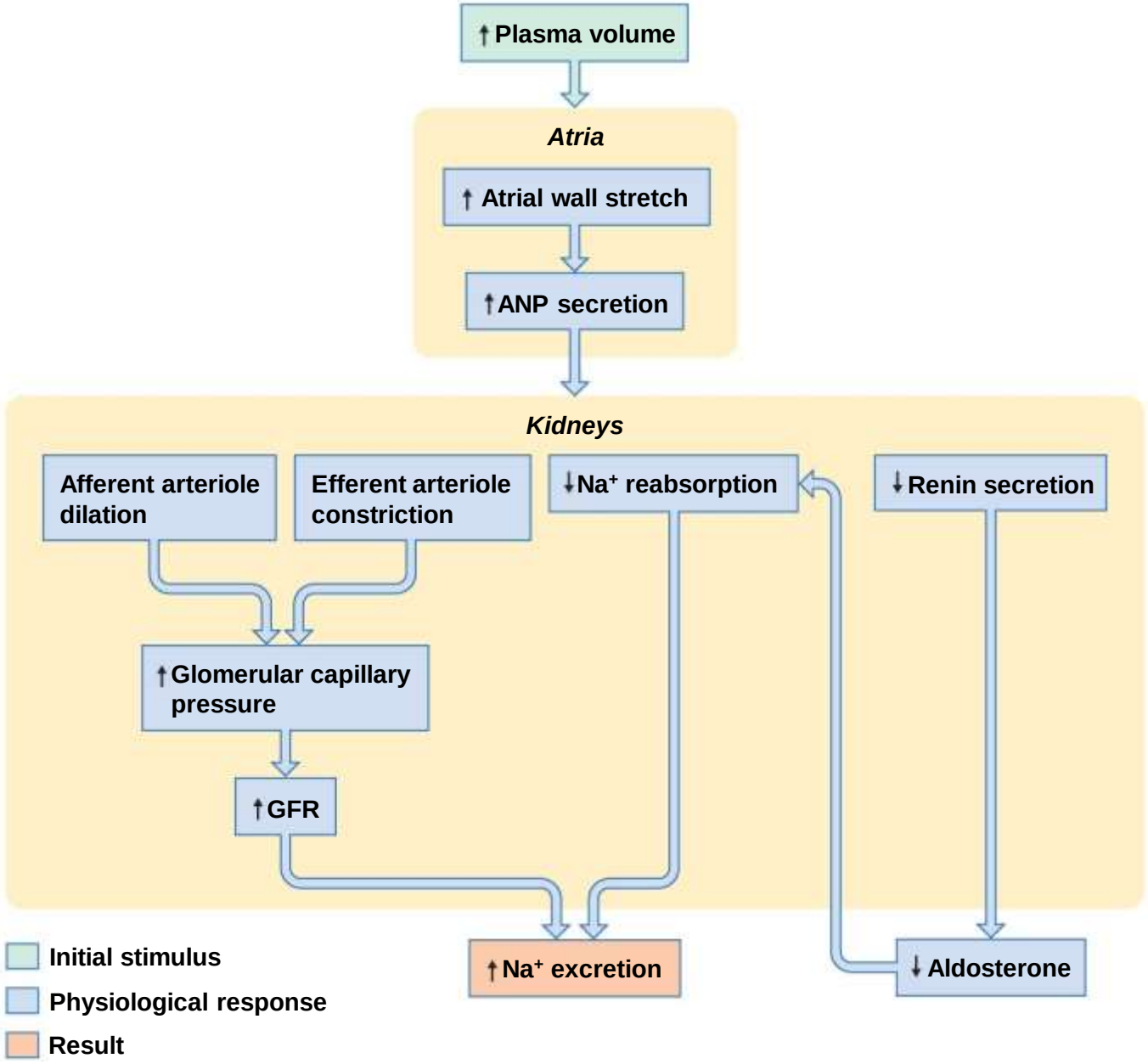


Figure 19.19 Mechanisms by which secretion of atrial natriuretic peptide increases sodium excretion in response to increased plasma volume.



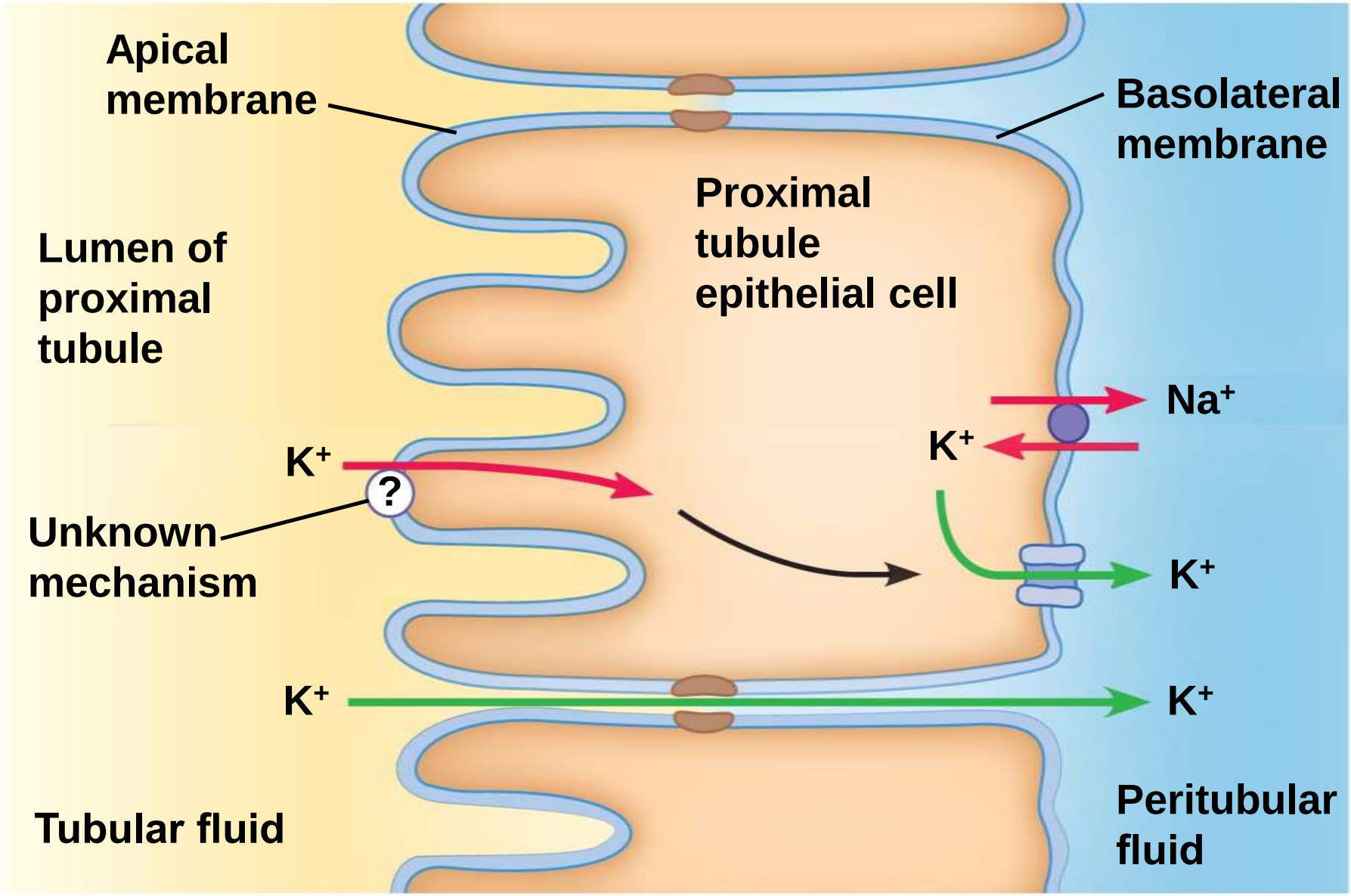
19.4 Potassium Balance

- Hyperkalemia: high plasma potassium
- Hypokalemia: low plasma potassium
- Potassium is crucial to function of excitable cells

Renal Handling of Potassium Ions

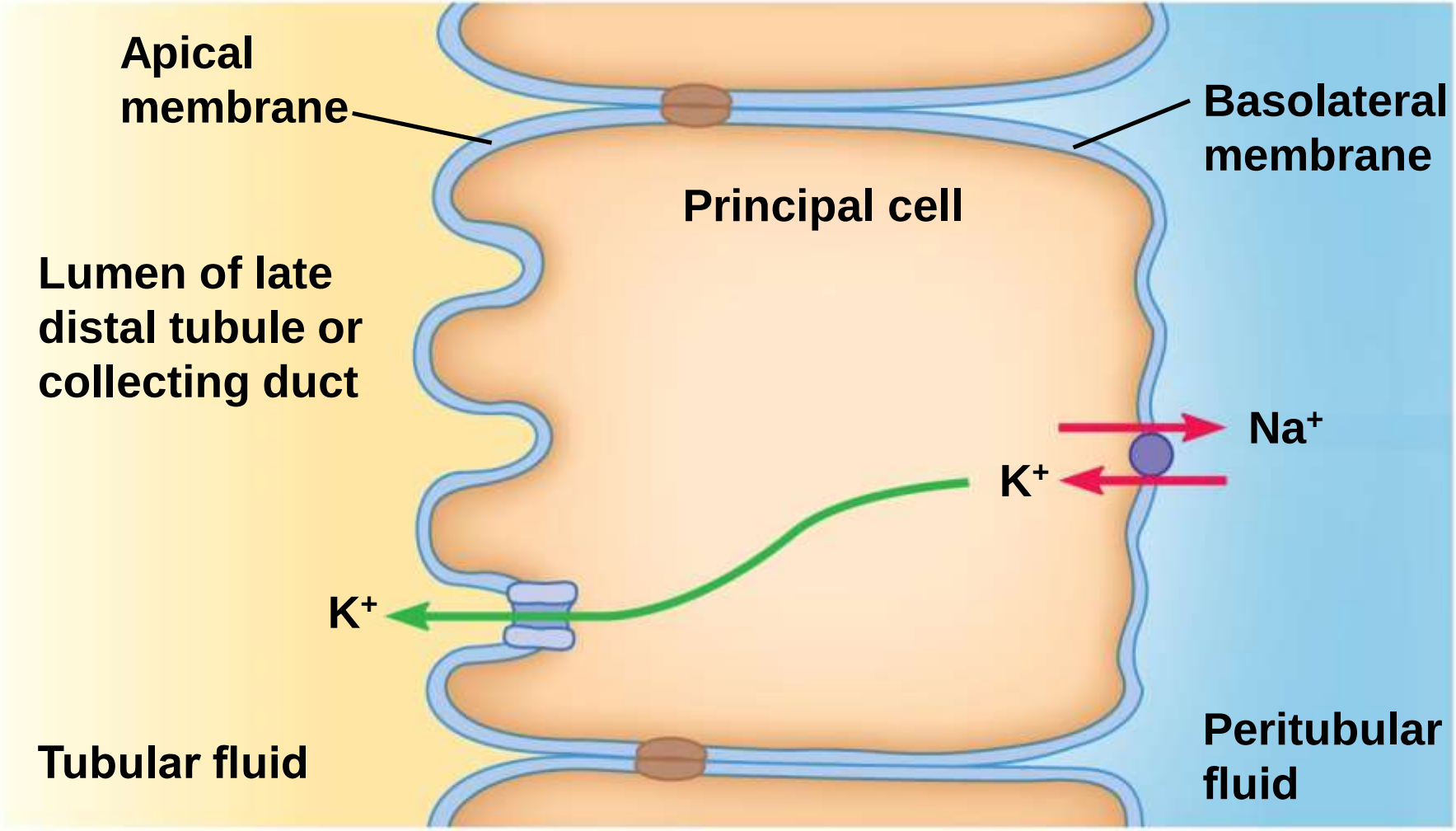
- Glomerulus: freely filtered
- Proximal tubules: reabsorbed
- Distal tubules and collecting ducts: reabsorbed and secreted
- K^+ secretion in distal tubules and collecting ducts is regulated
- Aldosterone regulates principal cells
- K^+ in plasma directly stimulates aldosterone release
  - As K^+ increases, more aldosterone is released

Figure 19.20a Potassium transport in renal tubules.



(a) Potassium reabsorption in the proximal tubule

Figure 19.20b Potassium transport in renal tubules.

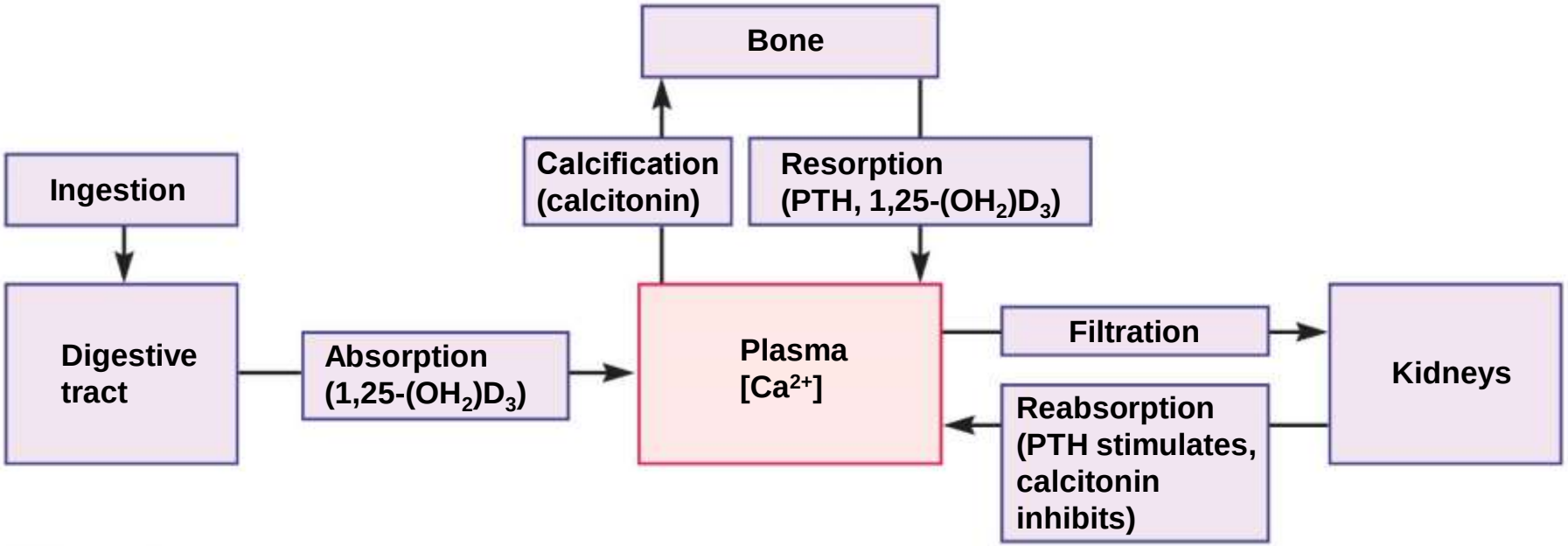


(b) Potassium secretion in the principal cells of the late distal tubule and collecting duct

19.5 Calcium Balance

- Hypercalcemia: high plasma calcium
- Hypocalcemia: low plasma calcium
- Calcium balance is critical
  - Triggers exocytosis
  - Triggers secretion
  - Triggers muscle contraction
  - Increases contractility of cardiac and smooth muscle

Figure 19.21 Routes of calcium exchange.



Renal Handling of Calcium

- Blood calcium
  - Bound to carrier proteins
  - Free in plasma
  - Ca^{2+} + protein $\rightleftharpoons$ Ca-protein
  - Free calcium: freely filtered at glomerulus

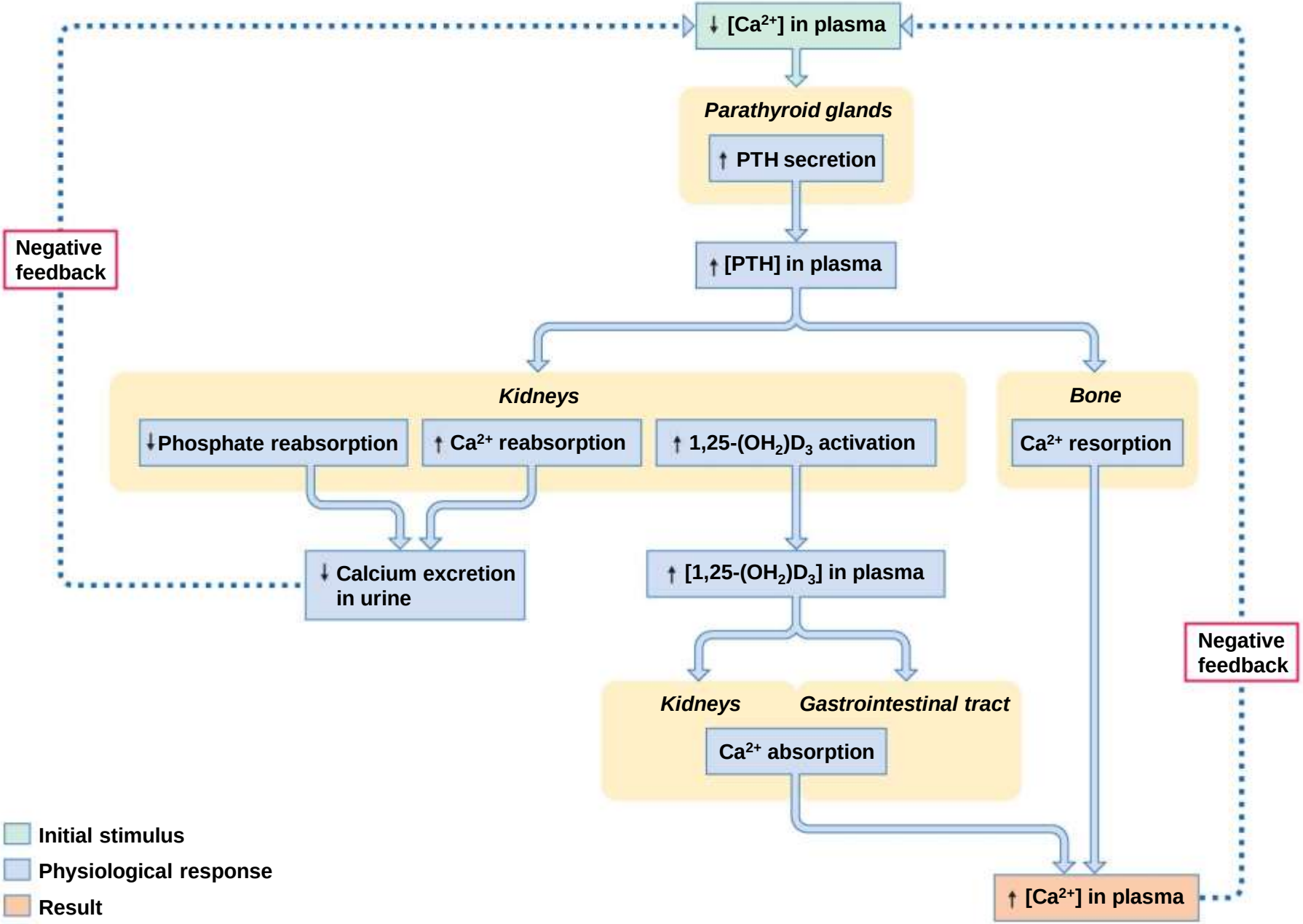
Renal Handling of Calcium

- 99% of filtered calcium is reabsorbed
  - 70% is reabsorbed in proximal tubules
  - 19–20% is reabsorbed in thick ascending limbs of the loops of Henle
  - 9–10% is reabsorbed in distal tubules
- Reabsorption in loops of Henle and distal tubules is regulated

Hormonal Control of Plasma Calcium Concentrations

- Parathyroid hormone (PTH): released from parathyroid glands
- Stimulus: decreased Ca^{2+} in plasma
- Actions
  - Increases Ca^{2+} reabsorption by kidneys
  - Stimulates activation of 1,25-dihydroxycholecalciferol in kidneys
  - Stimulates resorption of bone
  - Stimulates small increase in calcium absorption
  - Overall effect: increased blood calcium

Figure 19.22 Role of parathyroid hormone in calcium balance.



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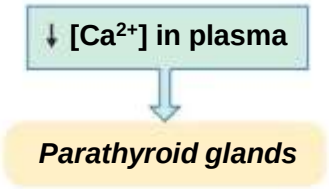
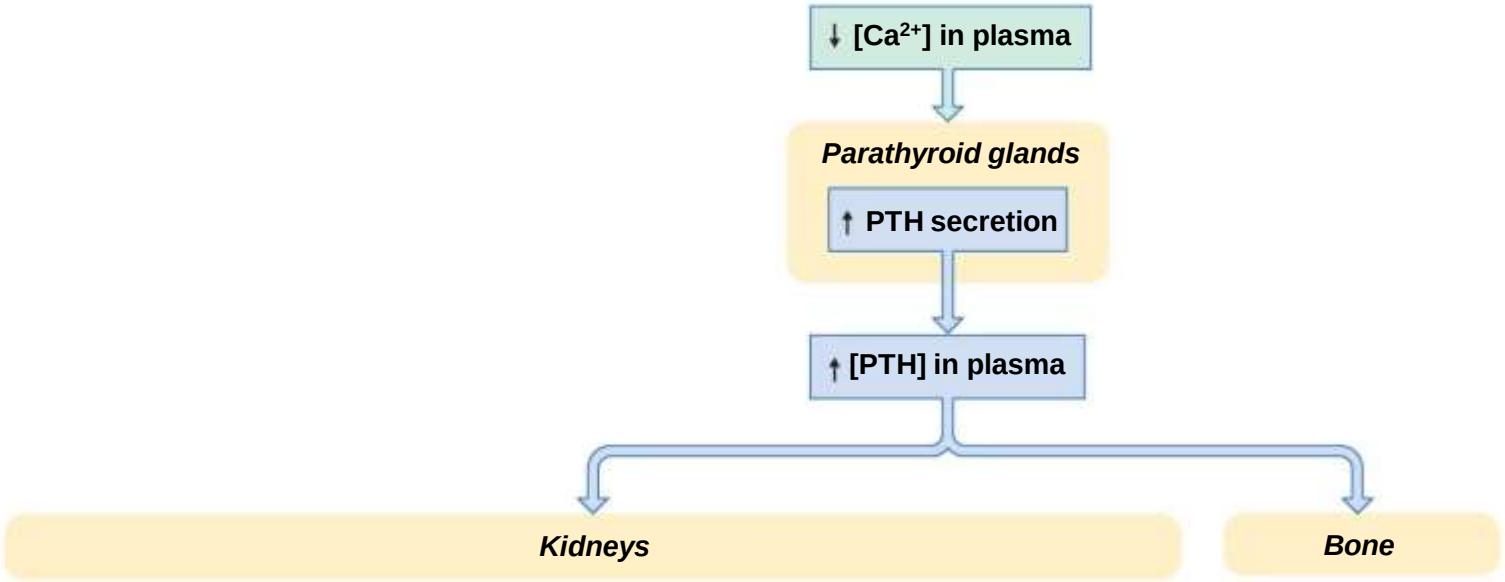


Initial stimulus
Physiological response
Result

Figure 19.22 Role of parathyroid hormone in calcium balance.



Initial stimulus
Physiological response
Result

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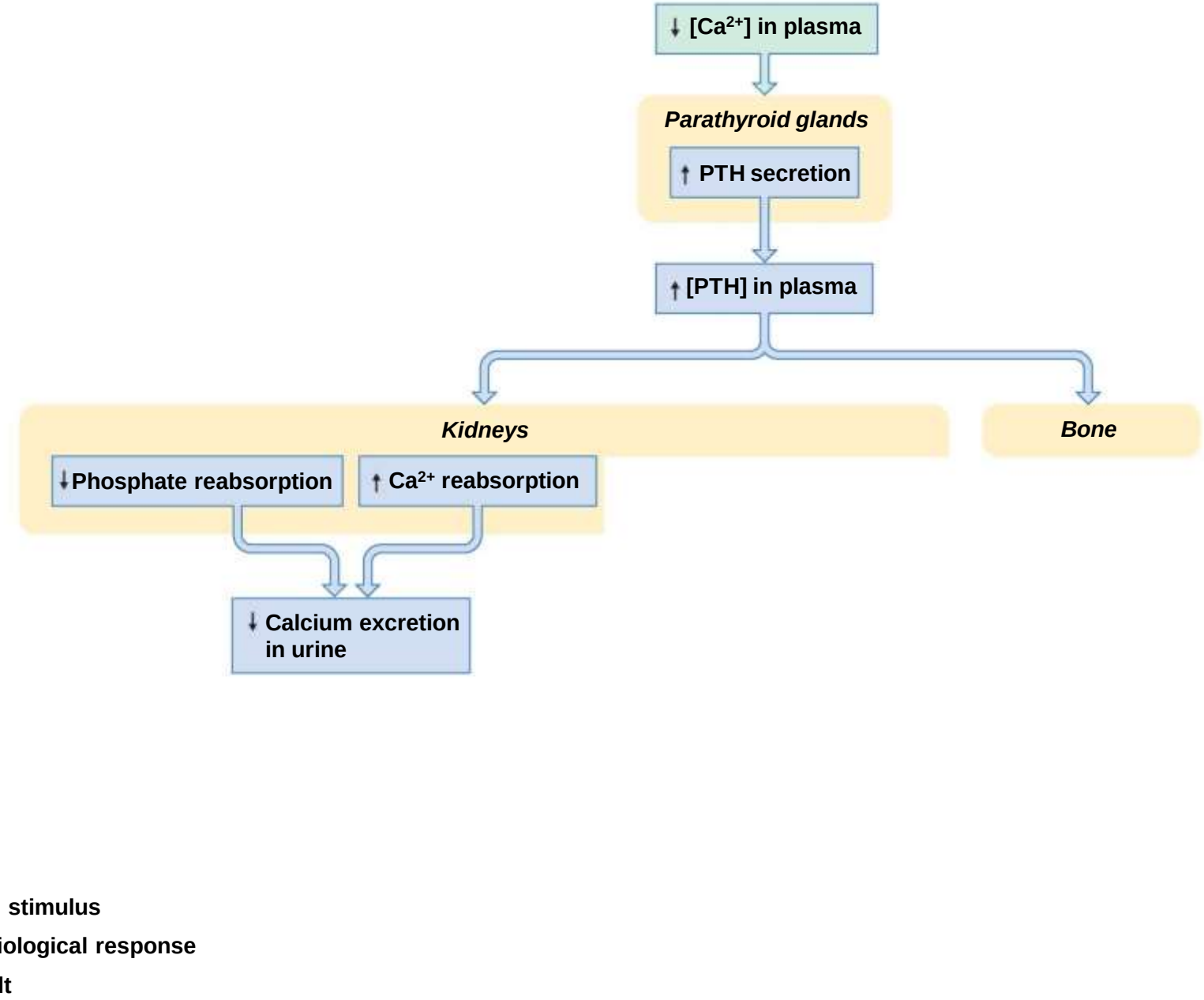

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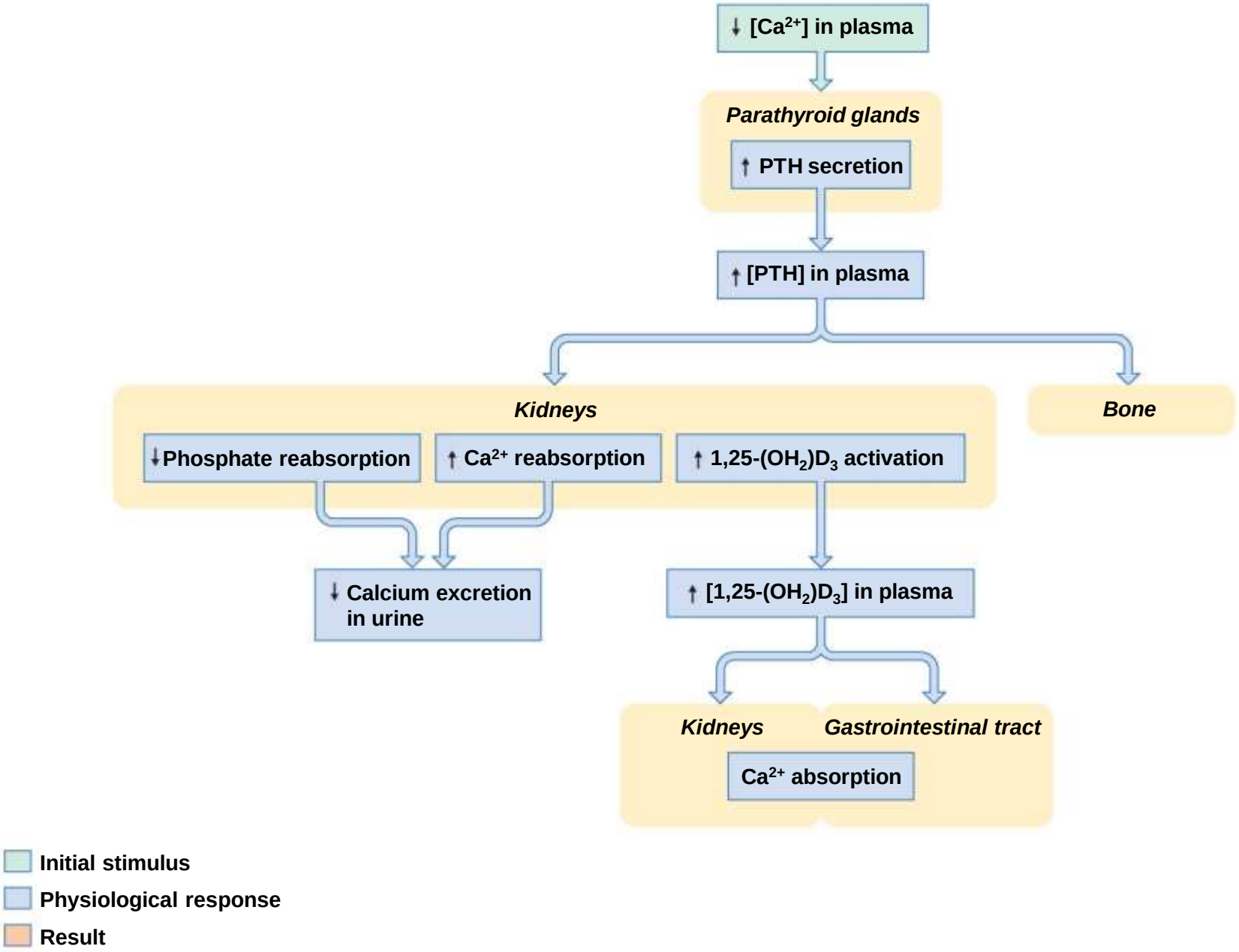

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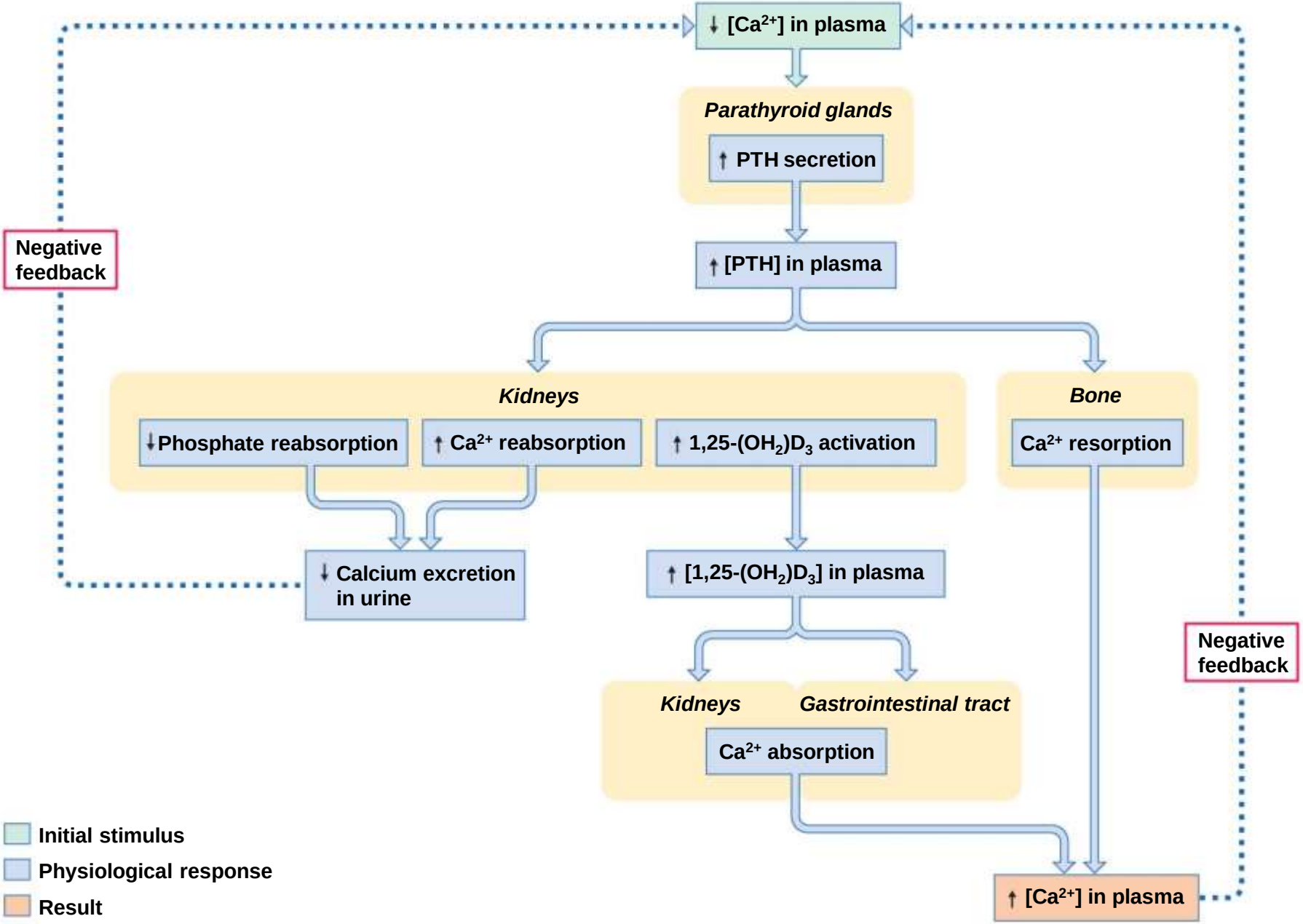


Hormonal Control of Plasma Calcium Concentrations

- 1,25-dihydroxycholecalciferol: steroid hormone derived from vitamin D_3

Figure 19.23 Activation of 1,25-$(OH_2)D_3$.

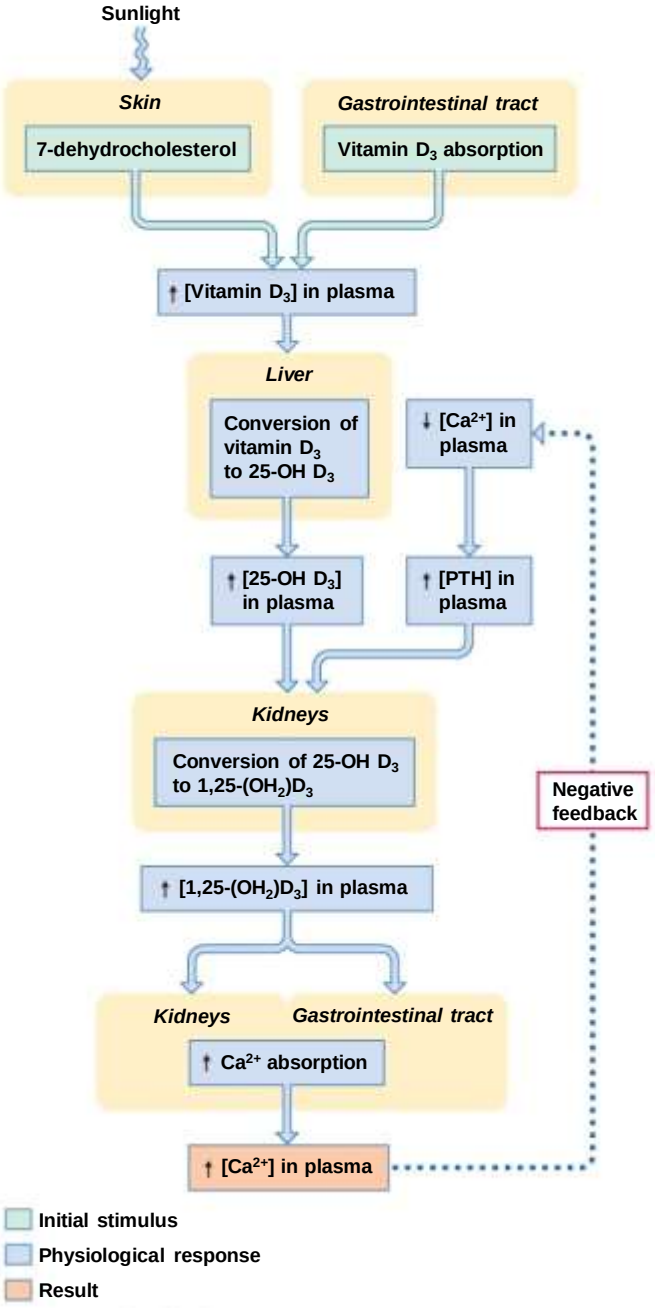
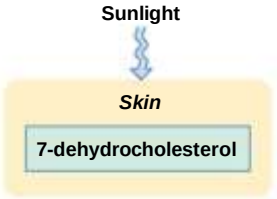


Figure 19.23 Activation of 1,25-$(OH_2)D_3$.

Initial stimulus
Physiological response
Result

Figure 19.23 Activation of 1,25-(OH_2)D_3.



Initial stimulus
Physiological response
Result

Figure 19.23 Activation of 1,25-$(OH_2)D_3$.

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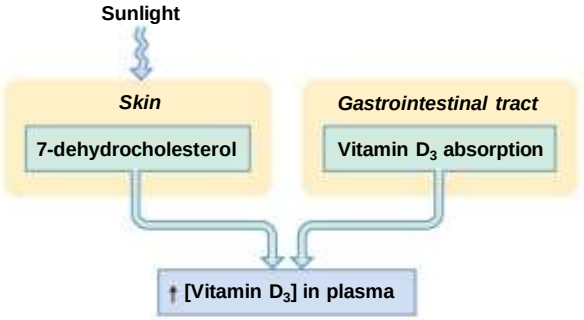


Figure 19.23 Activation of 1,25-$(OH_2)D_3$.

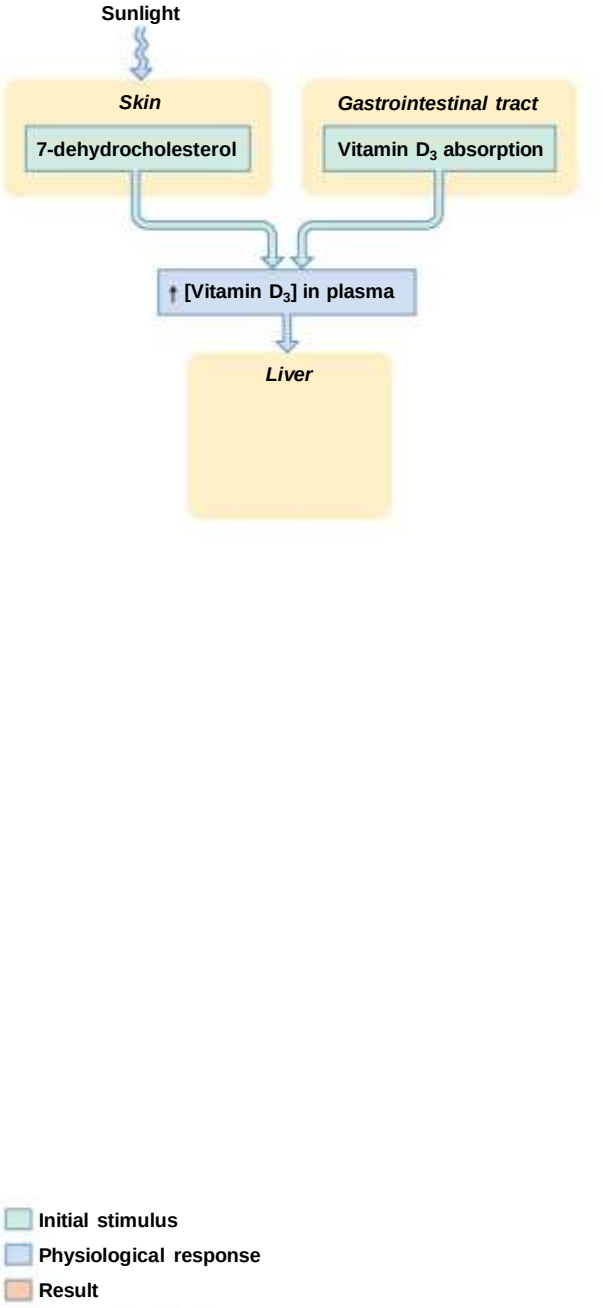
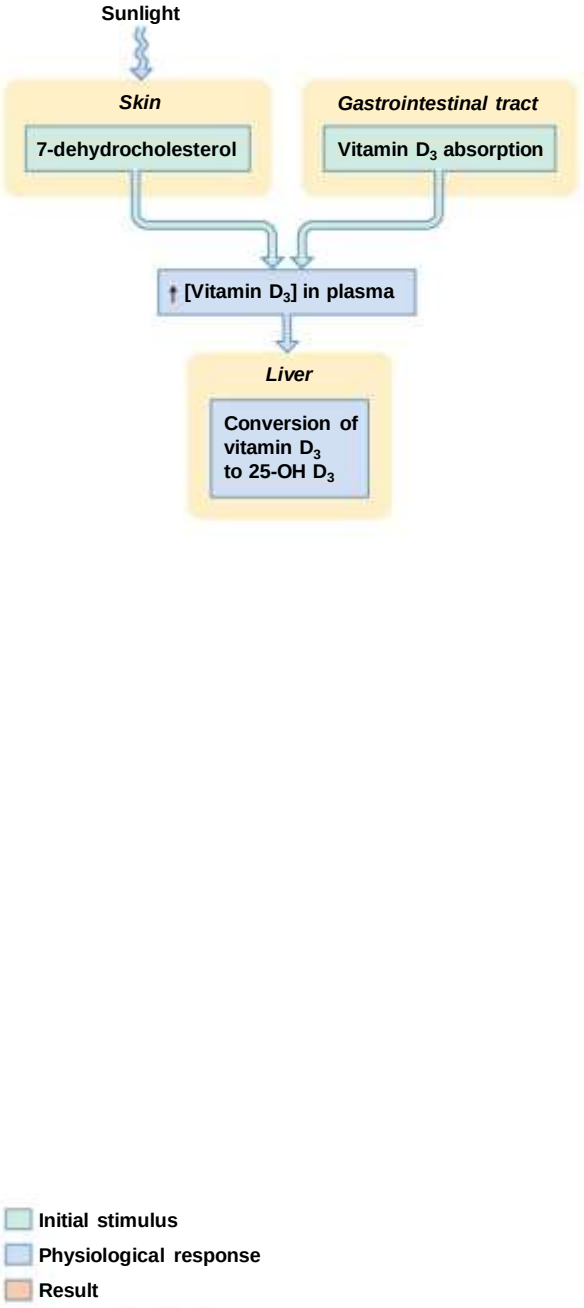


Figure 19.23 Activation of 1,25-$(OH_2)D_3$.



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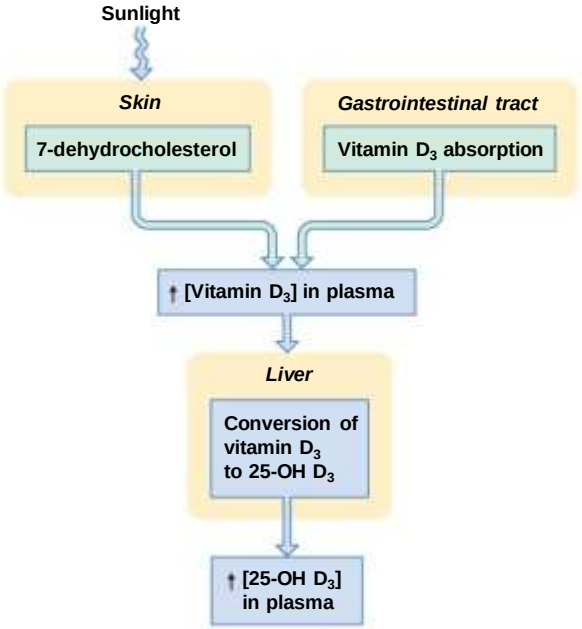

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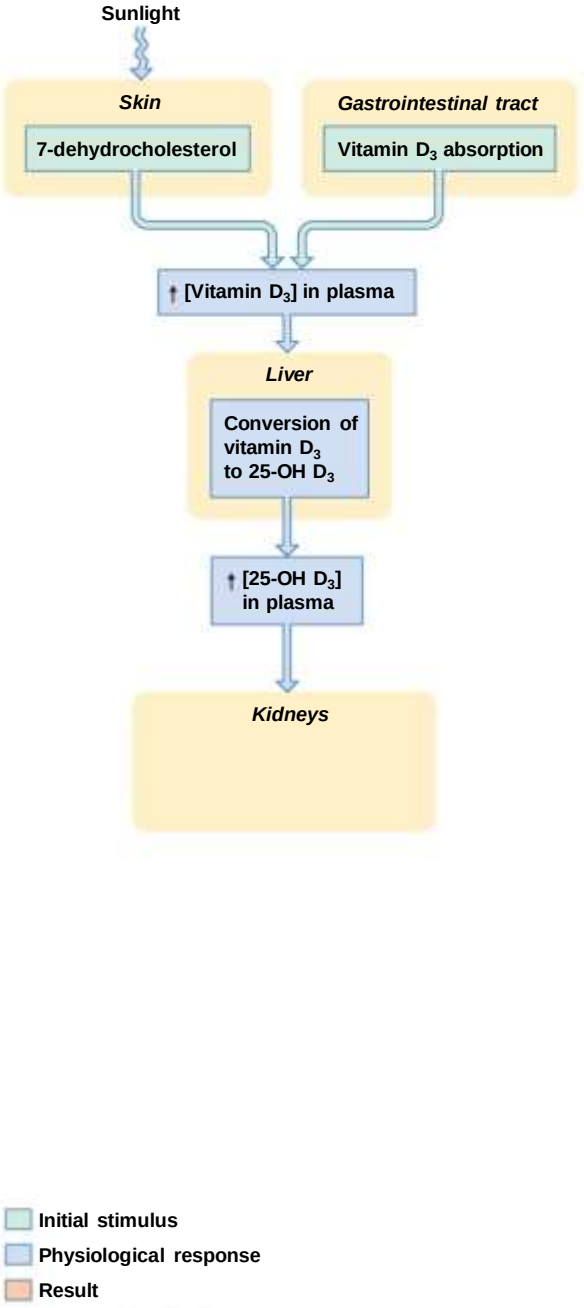

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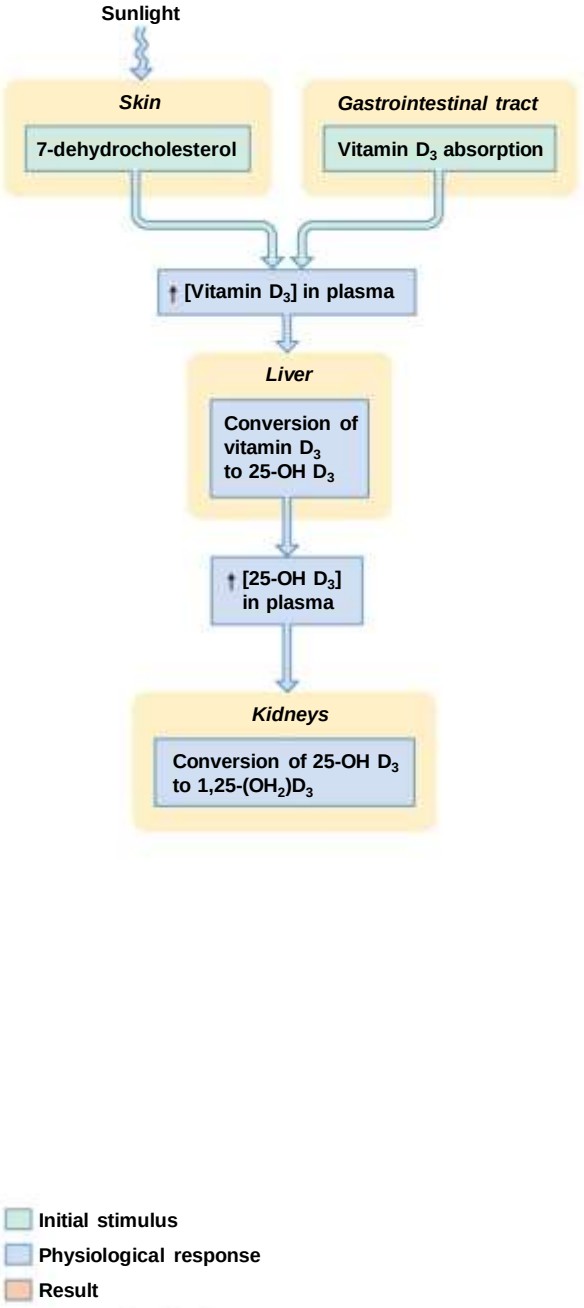

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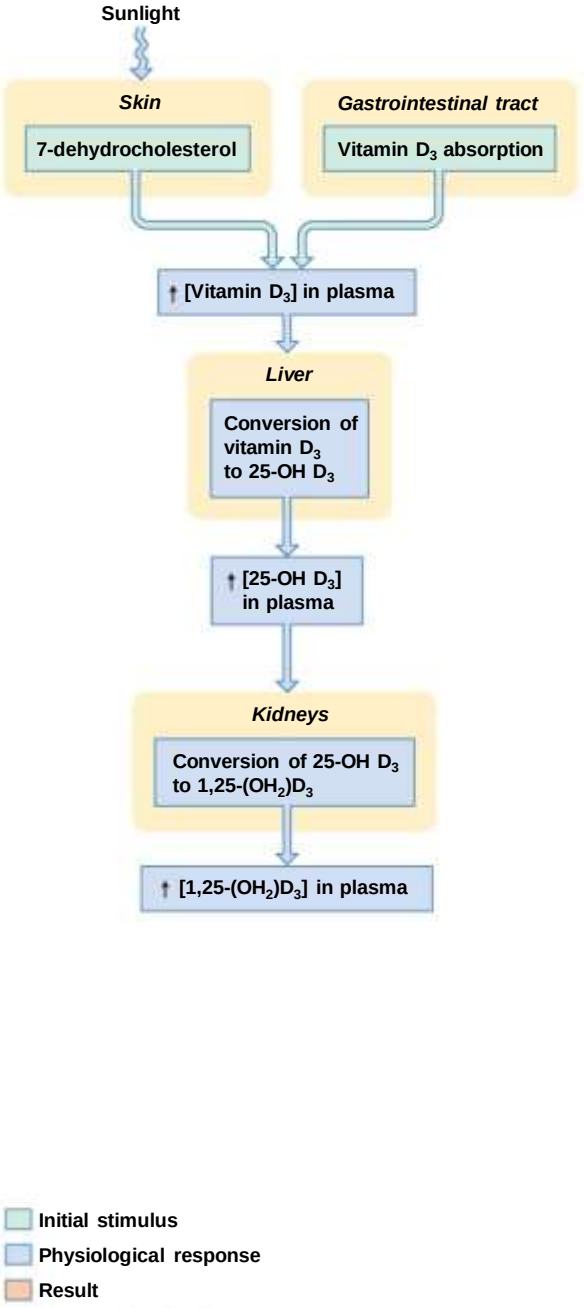


Figure 19.23 Activation of 1,25-$(OH_2)D_3$.

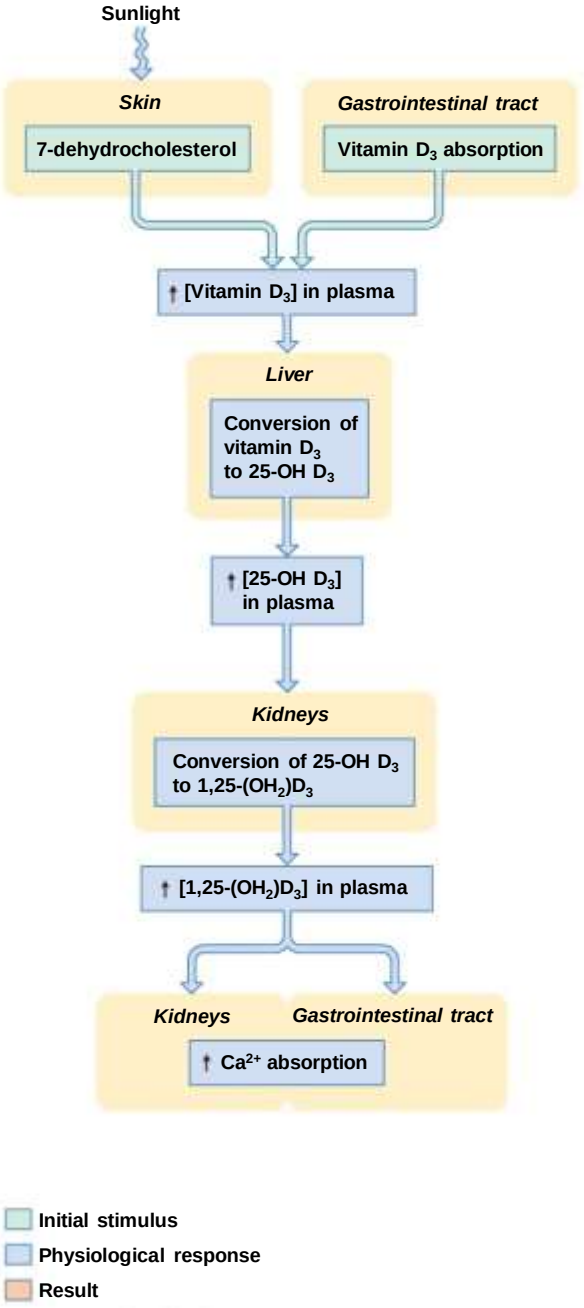


Figure 19.23 Activation of 1,25-$(OH_2)D_3$.

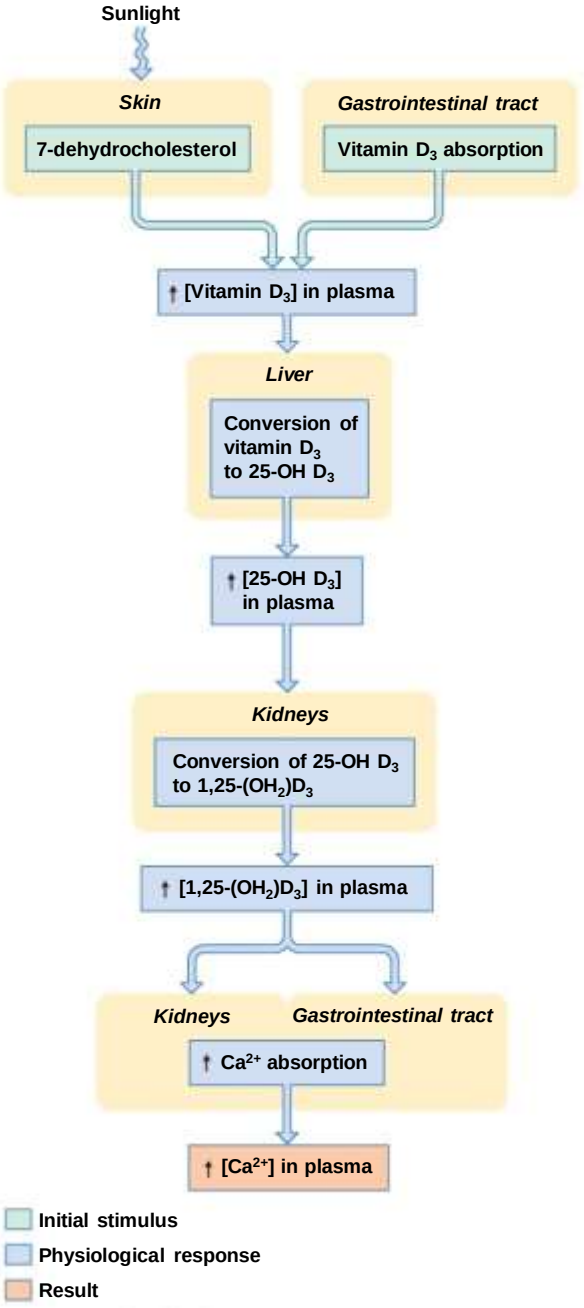


Figure 19.23 Activation of 1,25-$(OH_2)D_3$.

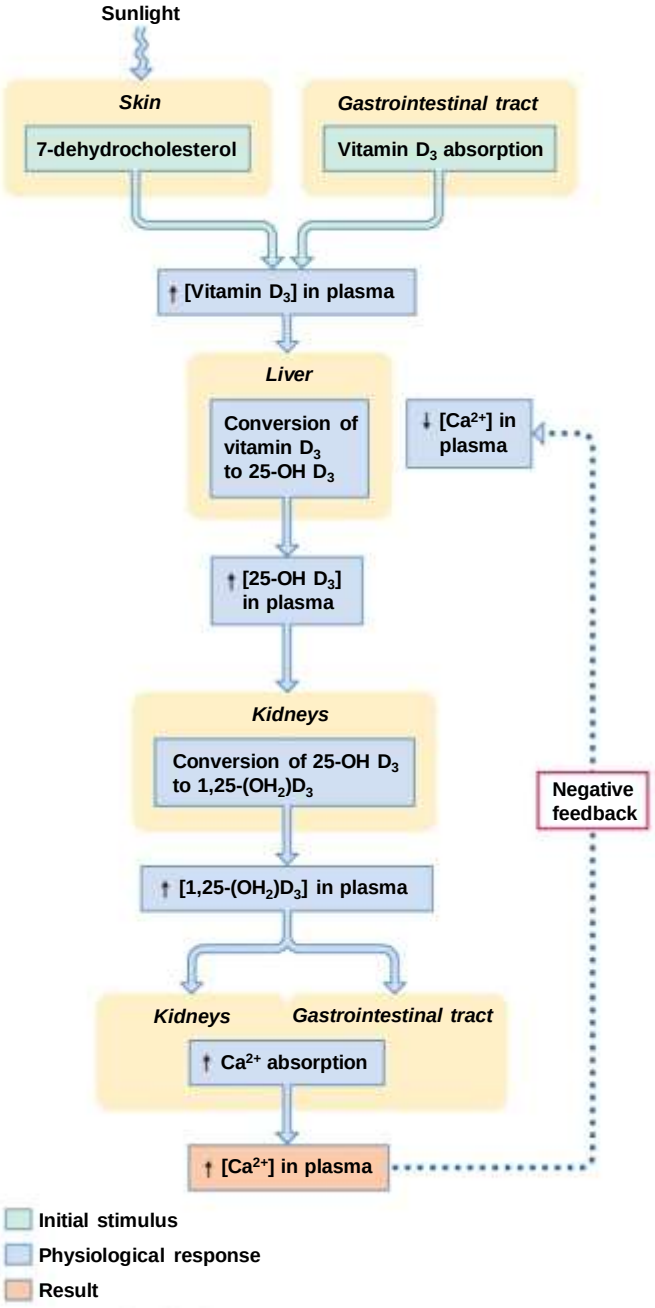
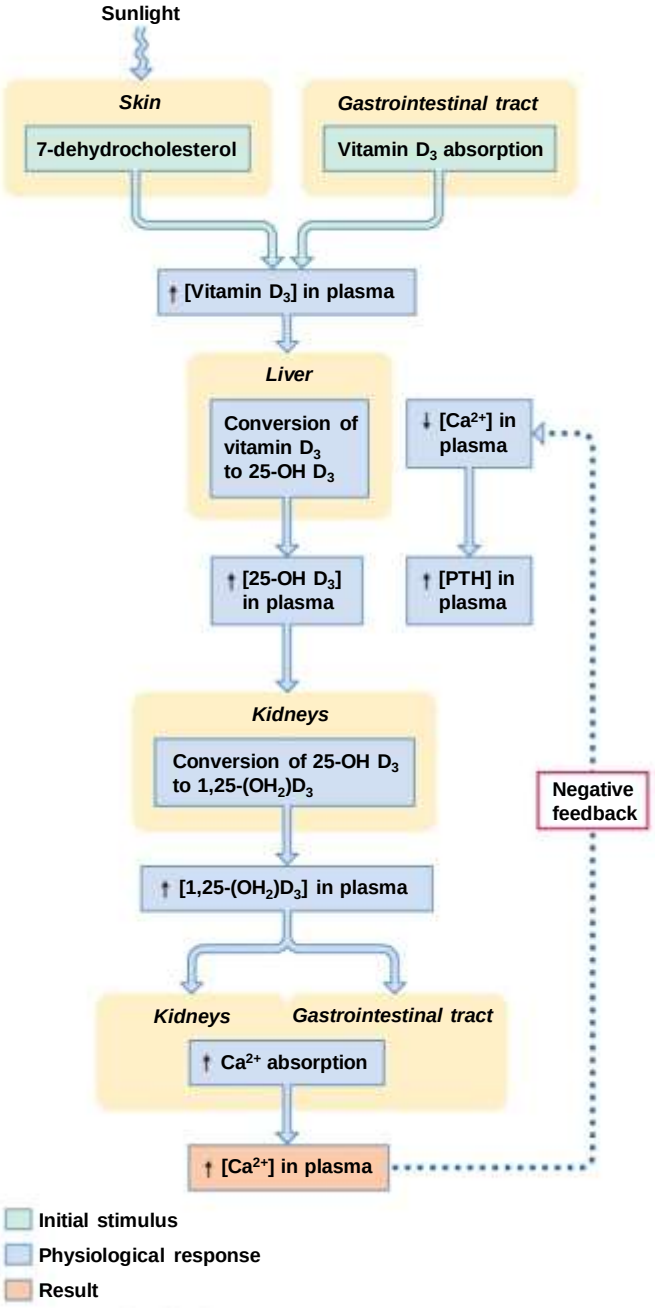


Figure 19.23 Activation of 1,25-$(OH_2)D_3$.



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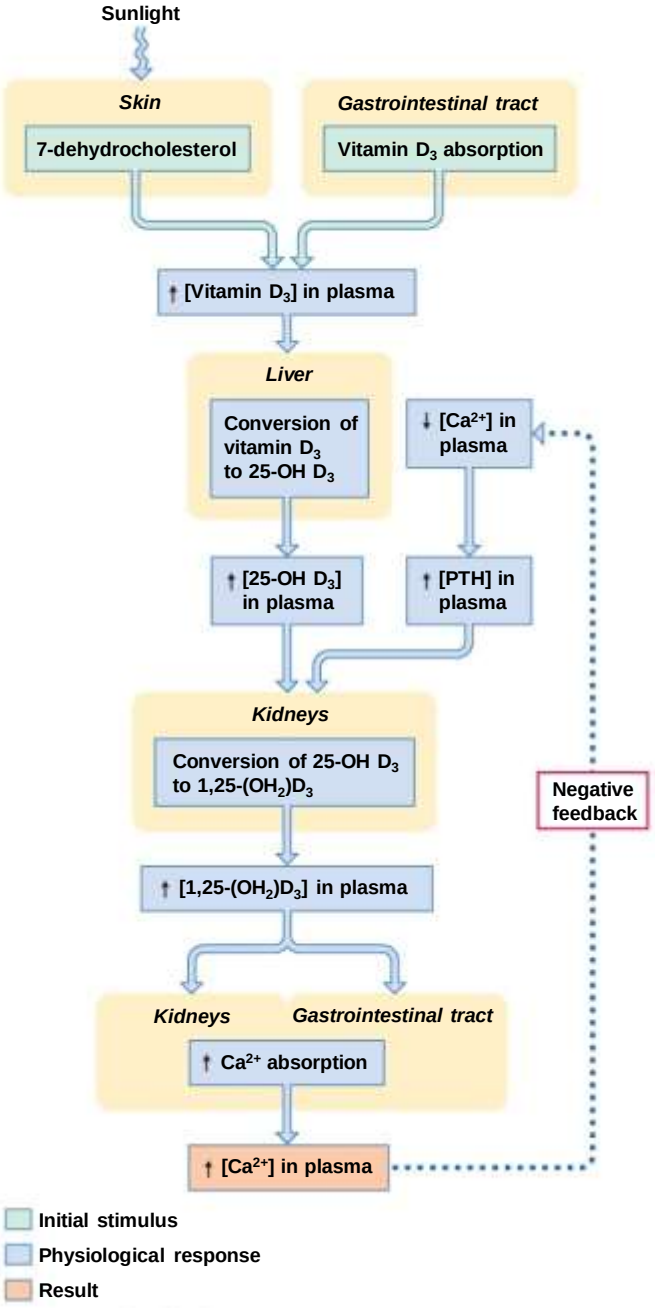

Hormonal Control of Plasma Calcium Concentrations

- Calcitonin
  - Secreted from C cells of thyroid gland
  - Release triggered by high plasma [Ca^{2+}]
  - Actions at target cells
    - Increases bone formation
    - Decreases calcium reabsorption by kidneys