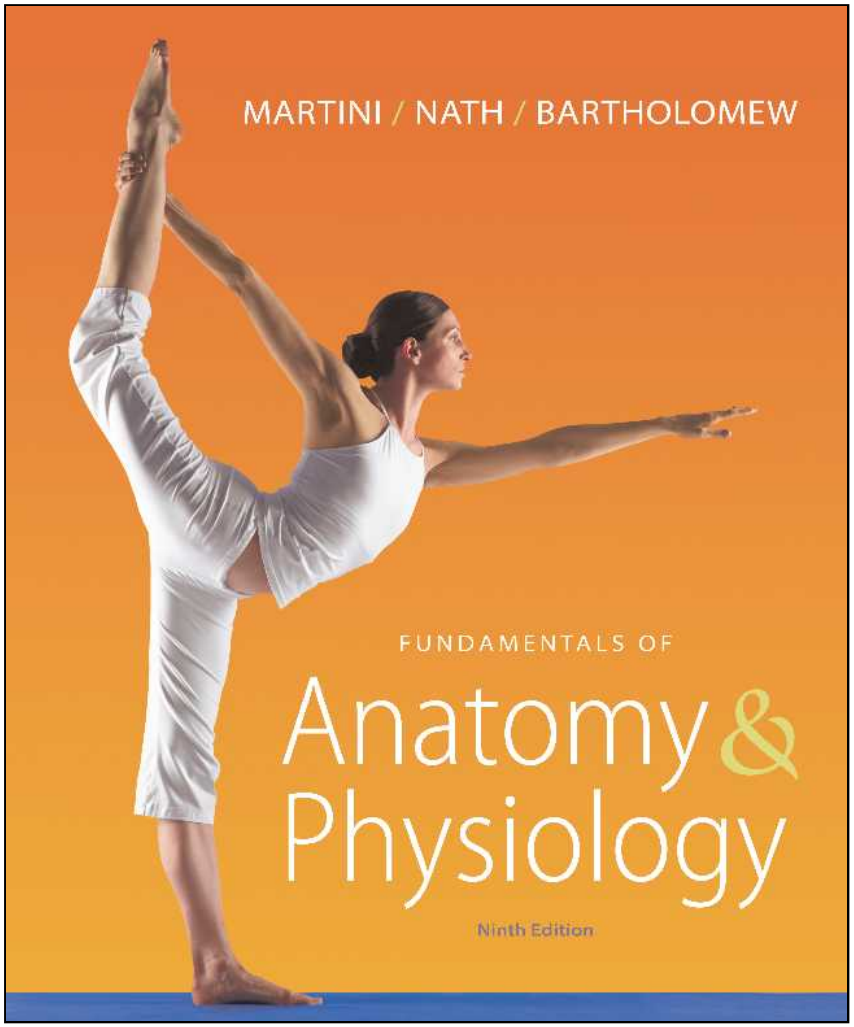


18

The Endocrine System

PowerPoint® Lecture Presentations prepared by Jason LaPres

Lone Star College—North Harris

An Introduction to the Endocrine System

- Learning Outcomes
  - **18-1** Explain the importance of intercellular communication, describe the mechanisms involved, and compare the modes of intercellular communication that occur in the endocrine and nervous systems.
  - **18-2** Compare the cellular components of the endocrine system with those of other systems, contrast the major structural classes of hormones, and explain the general mechanisms of hormonal action on target organs.

An Introduction to the Endocrine System

- Learning Outcomes
  - **18-3** Describe the location, hormones, and functions of the pituitary gland, and discuss the effects of abnormal pituitary hormone production.
  - **18-4** Describe the location, hormones, and functions of the thyroid gland, and discuss the effects of abnormal thyroid hormone production.
  - **18-5** Describe the location, hormone, and functions of the parathyroid glands, and discuss the effects of abnormal parathyroid hormone production.

An Introduction to the Endocrine System

- Learning Outcomes
  - **18-6** Describe the location, structure, hormones, and general functions of the adrenal glands, and discuss the effects of abnormal adrenal hormone production.
  - **18-7** Describe the location of the pineal gland, and discuss the functions of the hormone it produces.
  - **18-8** Describe the location, structure, hormones, and functions of the pancreas, and discuss the effects of abnormal pancreatic hormone production.

An Introduction to the Endocrine System

- Learning Outcomes
  - **18-9** Describe the functions of the hormones produced by the kidneys, heart, thymus, testes, ovaries, and adipose tissue.
  - **18-10** Explain how hormones interact to produce coordinated physiological responses and influence behavior, describe the role of hormones in the general adaptation syndrome, and discuss how aging affects hormone production and give examples of interactions between the endocrine system and other organ systems.

An Introduction to the Endocrine System

- The Endocrine System
  - Regulates long-term processes
    - Growth
    - Development
    - Reproduction
  - Uses chemical messengers to relay information and instructions between cells

Figure 18-1 Organs and Tissues of the Endocrine System

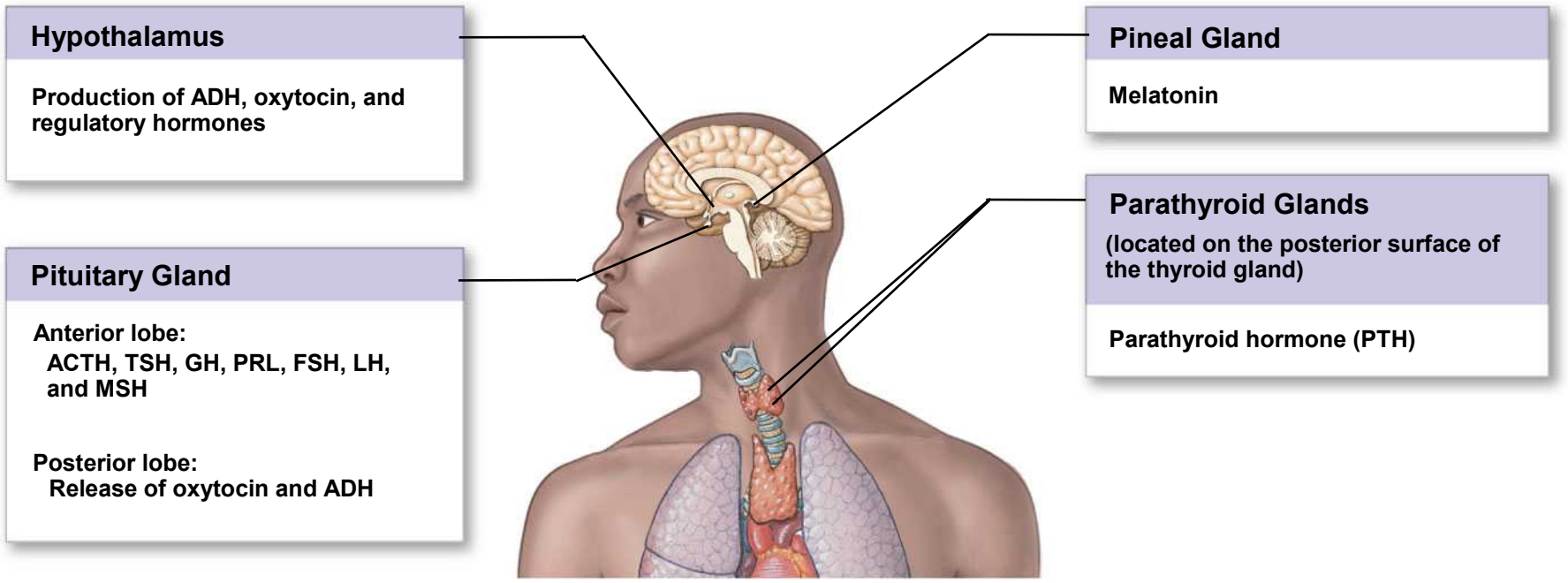
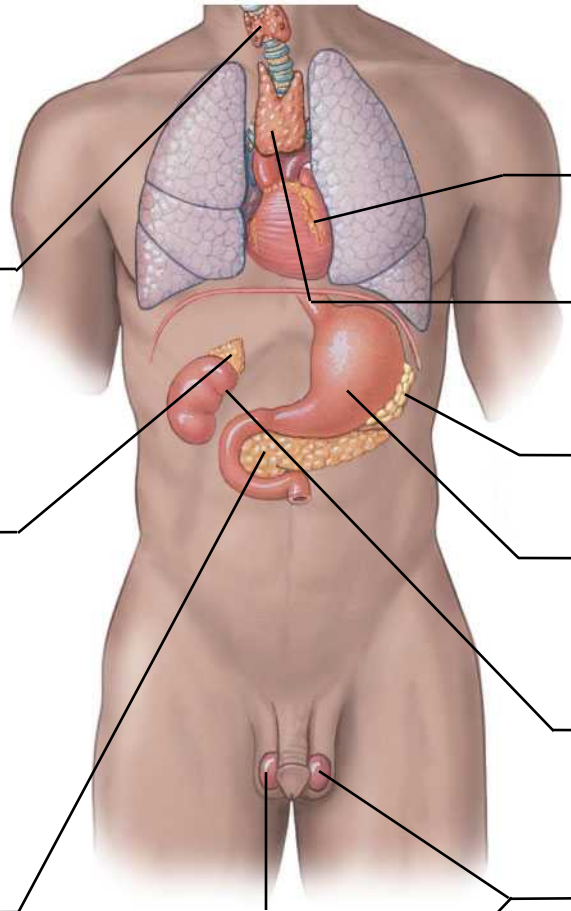


Figure 18-1 Organs and Tissues of the Endocrine System



Thyroid Gland

Thyroxine (T_4)
Triiodothyronine (T_3)
Calcitonin (CT)

Adrenal Glands

Adrenal medulla:
Epinephrine (E)
Norepinephrine (NE)

Adrenal cortex:
Cortisol, corticosterone, aldosterone, androgens

Pancreas (Pancreatic Islets)

Insulin
Glucagon

Organs with Secondary Endocrine Functions

Heart: Secretes natriuretic peptides. • Atrial natriuretic peptide (ANP) • Brain natriuretic peptide (BNP)	See Chapter 21
Thymus: (Undergoes atrophy during adulthood) Secretes thymosins	See Chapter 22
Adipose Tissue: Secretes • Leptin	
Digestive Tract: Secretes numerous hormones involved in the coordination of system functions, glucose metabolism, and appetite	See Chapter 25
Kidneys: Secrete • Erythropoietin (EPO) • Calcitriol	See Chapters 19 and 26
Gonads: Testes (male): Androgens (especially testosterone), inhibin Ovaries (female): Estrogens, progestins, inhibin	See Chapters 28 and 29

18-1 Homeostasis and Intercellular Communication

- **Direct Communication**
  - Exchange of ions and molecules between adjacent cells across gap junctions
  - Occurs between two cells of same type
  - Highly specialized and relatively rare
- **Paracrine Communication**
  - Uses chemical signals to transfer information from cell to cell within single tissue
  - Most common form of intercellular communication

18-1 Homeostasis and Intercellular Communication

- **Endocrine Communication**
  - Endocrine cells release chemicals (hormones) into bloodstream
  - Alters metabolic activities of many tissues and organs simultaneously

18-1 Homeostasis and Intercellular Communication

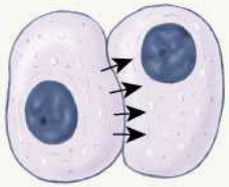
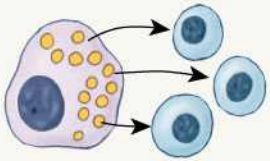
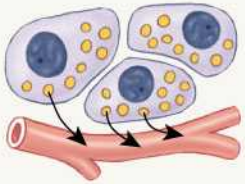
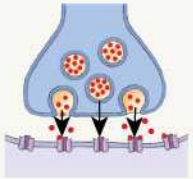
- **Target Cells**
  - Are specific cells that possess receptors needed to bind and “read” hormonal messages
- **Hormones**
  - Stimulate synthesis of enzymes or structural proteins
  - Increase or decrease rate of synthesis
  - Turn existing enzyme or membrane channel “on” or “off”

18-1 Homeostasis and Intercellular Communication

- **Synaptic Communication**
  - Ideal for crisis management
  - Occurs across synaptic clefts
  - Chemical message is “neurotransmitter”
  - Limited to a very specific area

Table 18-1 Mechanisms of Intercellular Communication

Table 18–1 Mechanisms of Intercellular Communication

Mechanism	Transmission	Chemical Mediators	Distribution of Effects
Direct communication 	Through gap junctions	Ions, small solutes, lipid-soluble materials	Usually limited to adjacent cells of the same type that are interconnected by connexons
Paracrine communication 	Through extracellular fluid	Paracrine factors	Primarily limited to a local area, where paracrine factor concentrations are relatively high Target cells must have appropriate receptors
Endocrine communication 	Through the bloodstream	Hormones	Target cells are primarily in other tissues and organs and must have appropriate receptors
Synaptic communication 	Across synaptic clefts	Neurotransmitters	Limited to very specific area; target cells must have appropriate receptors

18-2 Hormones

- Classes of Hormones
  - Hormones can be divided into three groups
    1. **Amino acid derivatives**
    2. **Peptide hormones**
    3. **Lipid derivatives**
- Secretion and Distribution of Hormones
  - Hormones circulate freely or travel bound to special carrier proteins

18-2 Hormones

- Amino Acid Derivatives
  - Are small molecules structurally related to amino acids
    - Derivatives of Tyrosine:
      - Thyroid hormones
      - Catecholamines
        - Epinephrine, norepinephrine
    - Derivatives of Tryptophan:
      - Dopamine, serotonin, melatonin

18-2 Hormones

- Peptide Hormones
  - Are chains of amino acids
  - Most are synthesized as prohormones
    - Inactive molecules converted to active hormones before or after they are secreted
  - Glycoproteins
    - Proteins are more than 200 amino acids long and have carbohydrate side chains
      - *Thyroid-stimulating hormone* (TSH)
      - *Luteinizing hormone (LH)*
      - *Follicle-stimulating hormone (FSH)*

18-2 Hormones

- Peptide Hormones
  - Short Polypeptides/Small Proteins
    - **Short chain polypeptides**
      - *Antidiuretic hormone (ADH)* and *oxytocin (OXT)* (each 9 amino acids long)
    - **Small proteins**
      - *Growth hormone (GH;* 191 amino acids) and *prolactin (PRL;* 198 amino acids)
    - Includes all hormones secreted by:
      - Hypothalamus, heart, thymus, digestive tract, pancreas, and posterior lobe of the pituitary gland, as well as several hormones produced in other organs

18-2 Hormones

- Lipid Derivatives
  - **Eicosanoids -** derived from arachidonic acid, a 20-carbon fatty acid
    - Paracrine factors that coordinate cellular activities and affect enzymatic processes (such as blood clotting) in extracellular fluids
    - Some eicosanoids (such as **leukotrienes**) have secondary roles as hormones
    - A second group of eicosanoids - **prostaglandins -** involved primarily in coordinating local cellular activities
    - In some tissues, prostaglandins are converted to **thromboxanes** and **prostacyclins,** which also have strong paracrine effects

18-2 Hormones

- Lipid Derivatives
  - **Steroid hormones -** derived from cholesterol
    - Released by:
      - The reproductive organs (androgens by the testes in males, estrogens and progestins by the ovaries in females)
      - The cortex of the adrenal glands (corticosteroids)
      - The kidneys (calcitriol)
    - Because circulating steroid hormones are bound to specific transport proteins in the plasma:
      - They remain in circulation longer than secreted peptide hormones

18-2 Hormones

- Secretion and Distribution of Hormones
  - Free Hormones
    - Remain functional for less than 1 hour
      1. Diffuse out of bloodstream and bind to receptors on target cells
      2. Are broken down and absorbed by cells of liver or kidneys
      3. Are broken down by enzymes in plasma or interstitial fluids

18-2 Hormones

- Secretion and Distribution of Hormones
  - Thyroid and Steroid Hormones
    - Remain in circulation much longer because most are “bound”
    - Enter bloodstream
      - More than 99% become attached to special transport proteins
      - Bloodstream contains substantial reserve of bound hormones

18-2 Hormones

- Mechanisms of Hormone Action
  - Hormone Receptor
    - Is a protein molecule to which a particular molecule binds strongly
    - Responds to several different hormones
    - Different tissues have different combinations of receptors
    - Presence or absence of specific receptor determines hormonal sensitivity

18-2 Hormones

- Hormones and Plasma Membrane Receptors
  - Catecholamines and Peptide Hormones
    - Are not lipid soluble
    - Unable to penetrate plasma membrane
    - Bind to receptor proteins at *outer* surface of plasma membrane (extracellular receptors)
  - Eicosanoids
    - Are lipid soluble
    - Diffuse across plasma membrane to reach receptor proteins on *inner* surface of plasma membrane (intracellular receptors)

18-2 Hormones

- Hormones and Plasma Membrane Receptors
  - **First** and **Second Messengers**
    - Bind to receptors in plasma membrane
    - Cannot have direct effect on activities inside target cell
    - Use intracellular intermediary to exert effects

18-2 Hormones

- **First Messenger**
  - Leads to **second messenger**
  - May act as enzyme activator, inhibitor, or cofactor
  - Results in change in rates of metabolic reactions

18-2 Hormones

- Important **Second Messengers**
  1. *Cyclic-AMP* (cAMP)
     - Derivative of ATP
  1. *Cyclic-GMP* (cGMP)
     - Derivative of GTP
  1. Calcium ions

18-2 Hormones

- The Process of *Amplification*
  - Is the binding of a small number of hormone molecules to membrane receptors
  - Leads to thousands of second messengers in cell
  - Magnifies effect of hormone on target cell

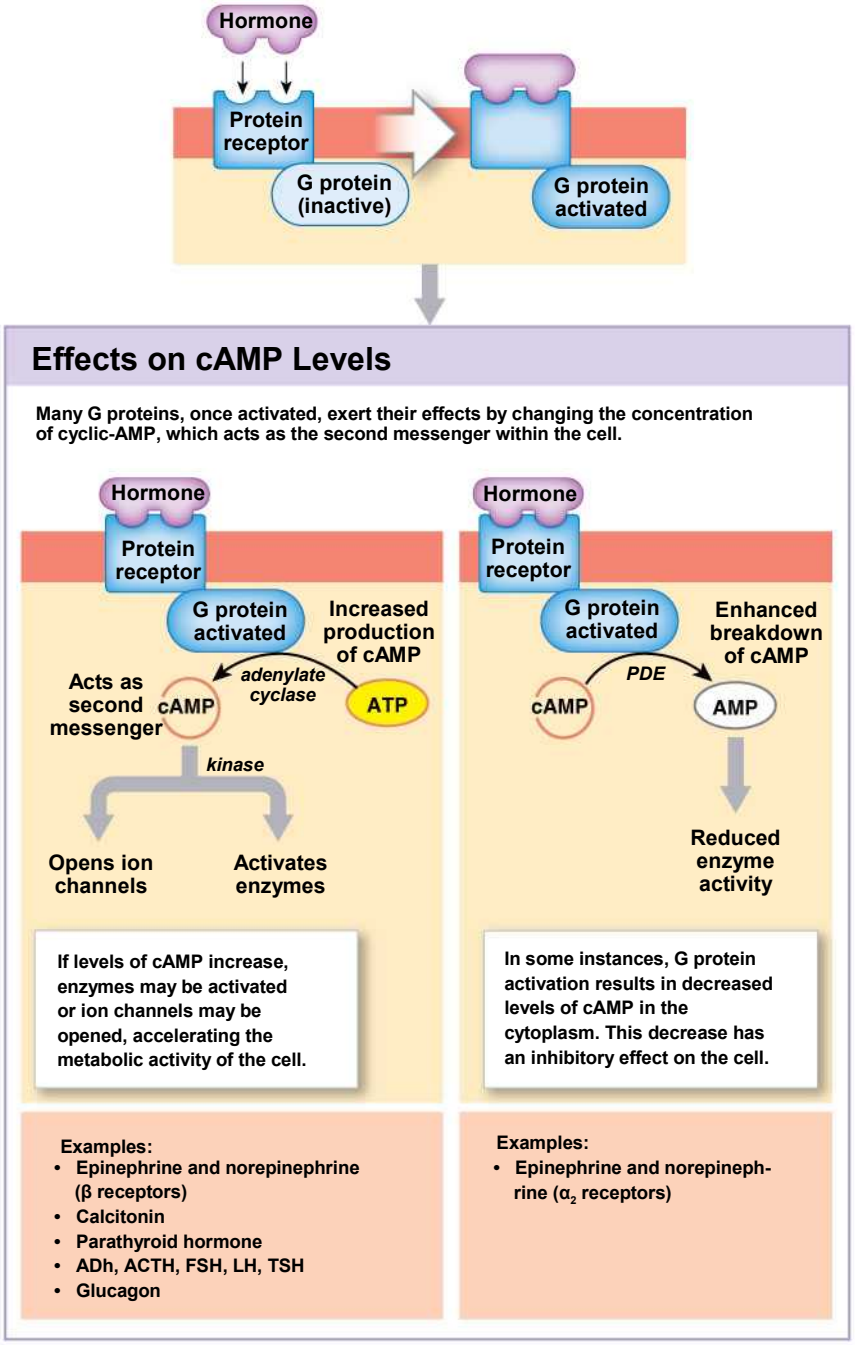
18-2 Hormones

- **Down-regulation**
  - Presence of a hormone triggers decrease in number of hormone receptors
  - When levels of particular hormone are high, cells become *less* sensitive to it
- **Up-regulation**
  - Absence of a hormone triggers increase in number of hormone receptors
  - When levels of particular hormone are low, cells become *more* sensitive to it

18-2 Hormones

- **G Protein**
  - Enzyme complex coupled to membrane receptor
  - Involved in link between first messenger and second messenger
- G Proteins and cAMP
  - **Adenylate cyclase** is activated when hormone binds to receptor at membrane surface and changes concentration of second messenger cyclic-AMP (cAMP) within cell
    - Increased cAMP level accelerates metabolic activity within cell

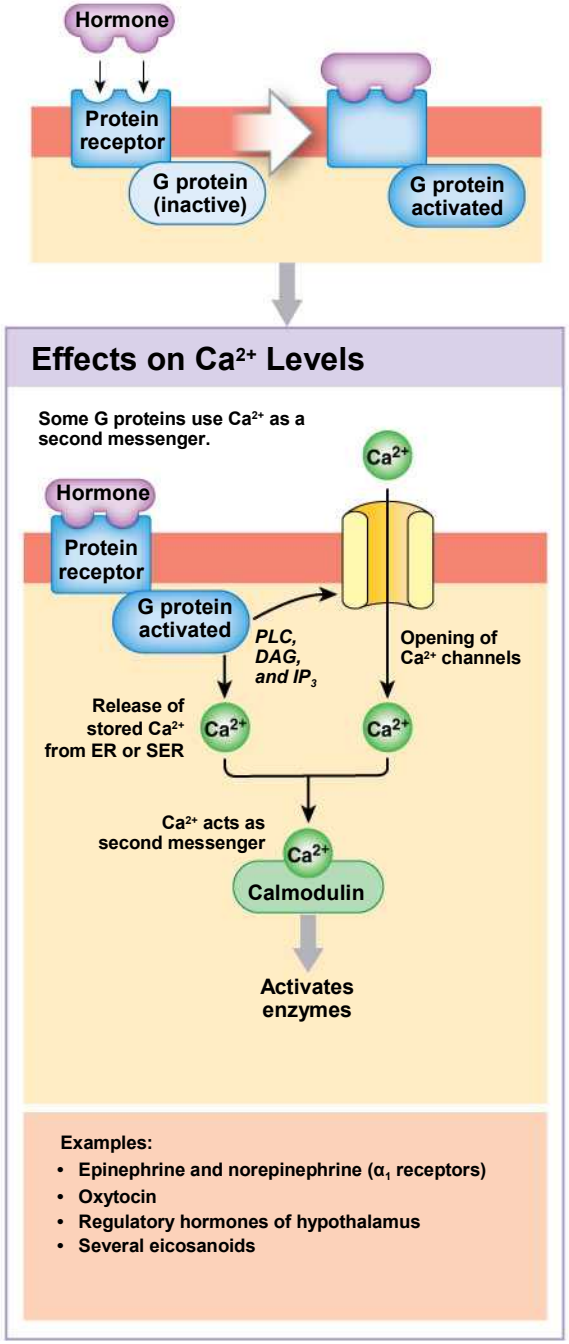
Figure 18-3 G Proteins and Hormone Activity



18-2 Hormones

- G Proteins and Calcium Ions
  - Activated G proteins trigger:
    - Opening of calcium ion channels in membrane
    - Release of calcium ions from intracellular stores
    - G protein activates enzyme *phospholipase C (PLC)*
    - Enzyme triggers receptor cascade
      - Production of **diacylglycerol (DAG)** and **inositol triphosphate (IP_3)** from membrane phospholipids
      - May further activate more calcium ion channels through **protein kinase C (PKC)**
      - Calcium ions may activate **calmodulin** which causes further cellular changes

Figure 18-3 G Proteins and Hormone Activity



18-2 Hormones

- Hormones and Intracellular Receptors
  - Alter rate of DNA transcription in nucleus
    - Change patterns of protein synthesis
  - Directly affect metabolic activity and structure of target cell
  - Include steroids and thyroid hormones

Figure 18-4a Effects of Intracellular Hormone Binding

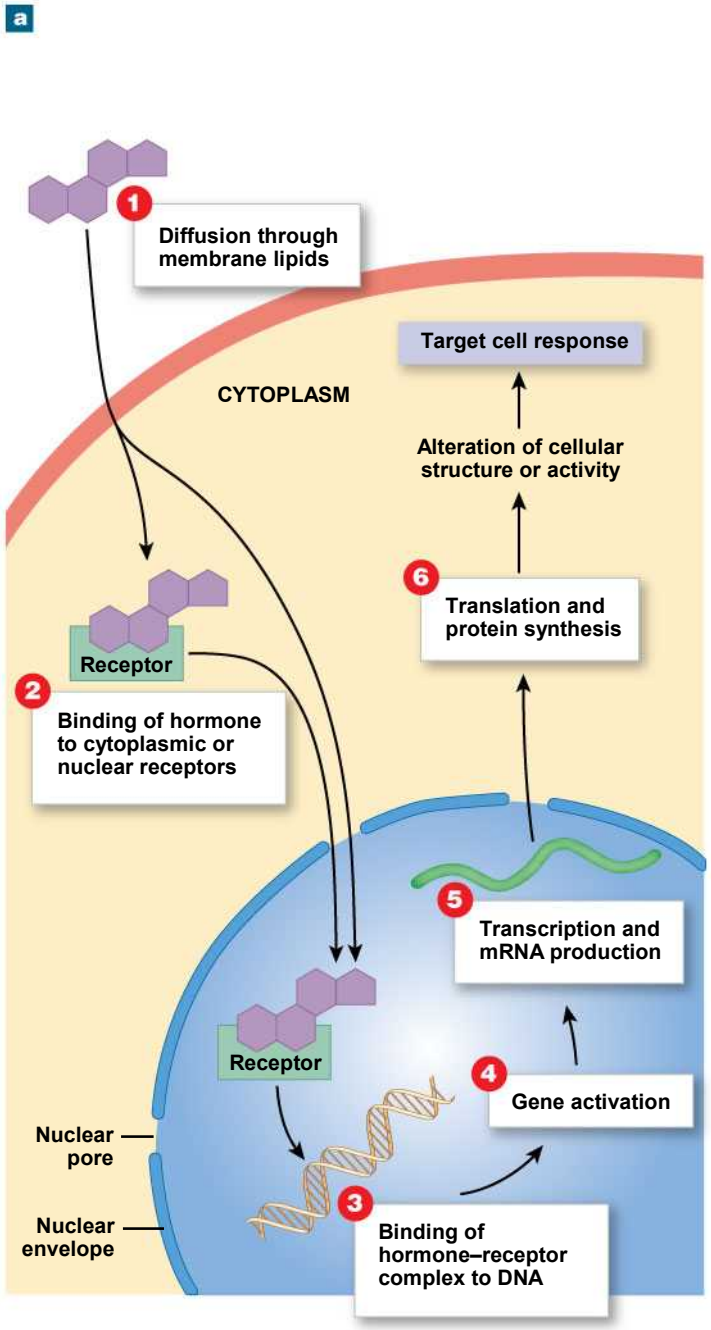
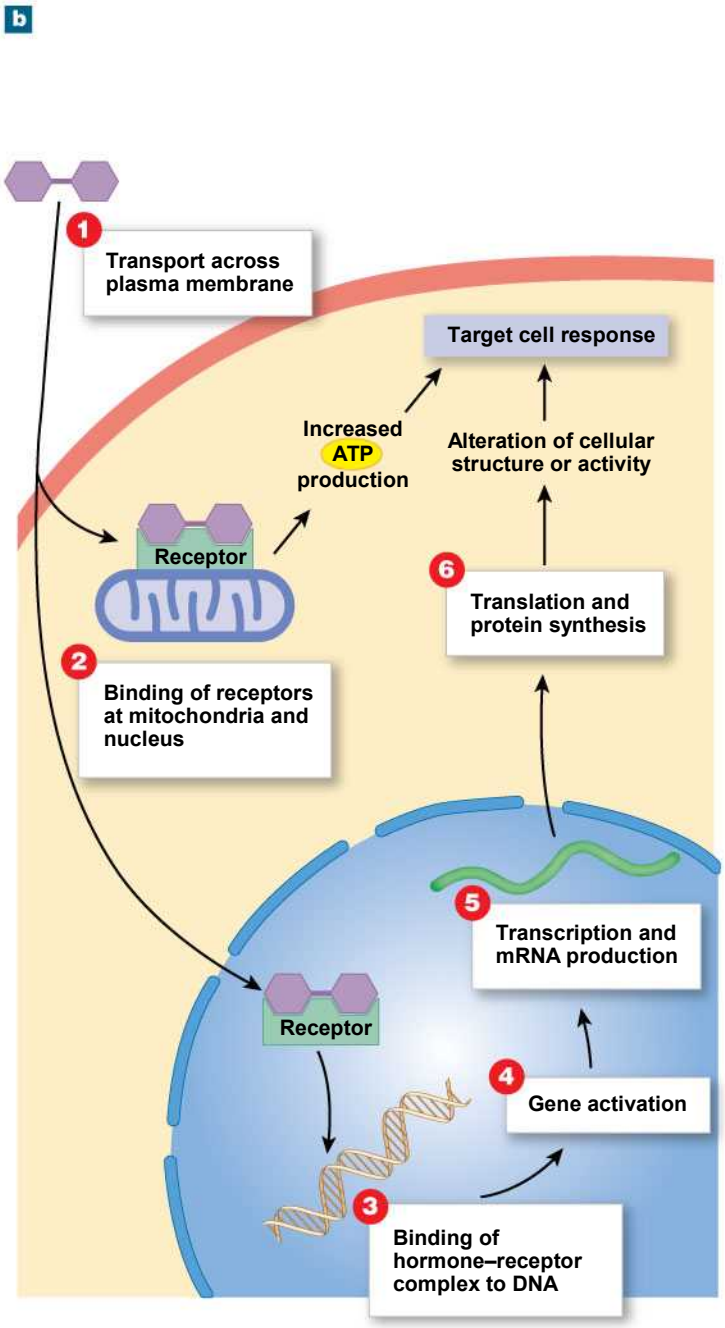


Figure 18-4b Effects of Intracellular Hormone Binding



18-2 Hormones

- Control of Endocrine Activity by Endocrine Reflexes
  - **Endocrine Reflexes**
    - Functional counterparts of neural reflexes
    - In most cases, controlled by negative feedback mechanisms
      - Stimulus triggers production of hormone, the direct or indirect effects of the hormone reduce intensity of the stimulus

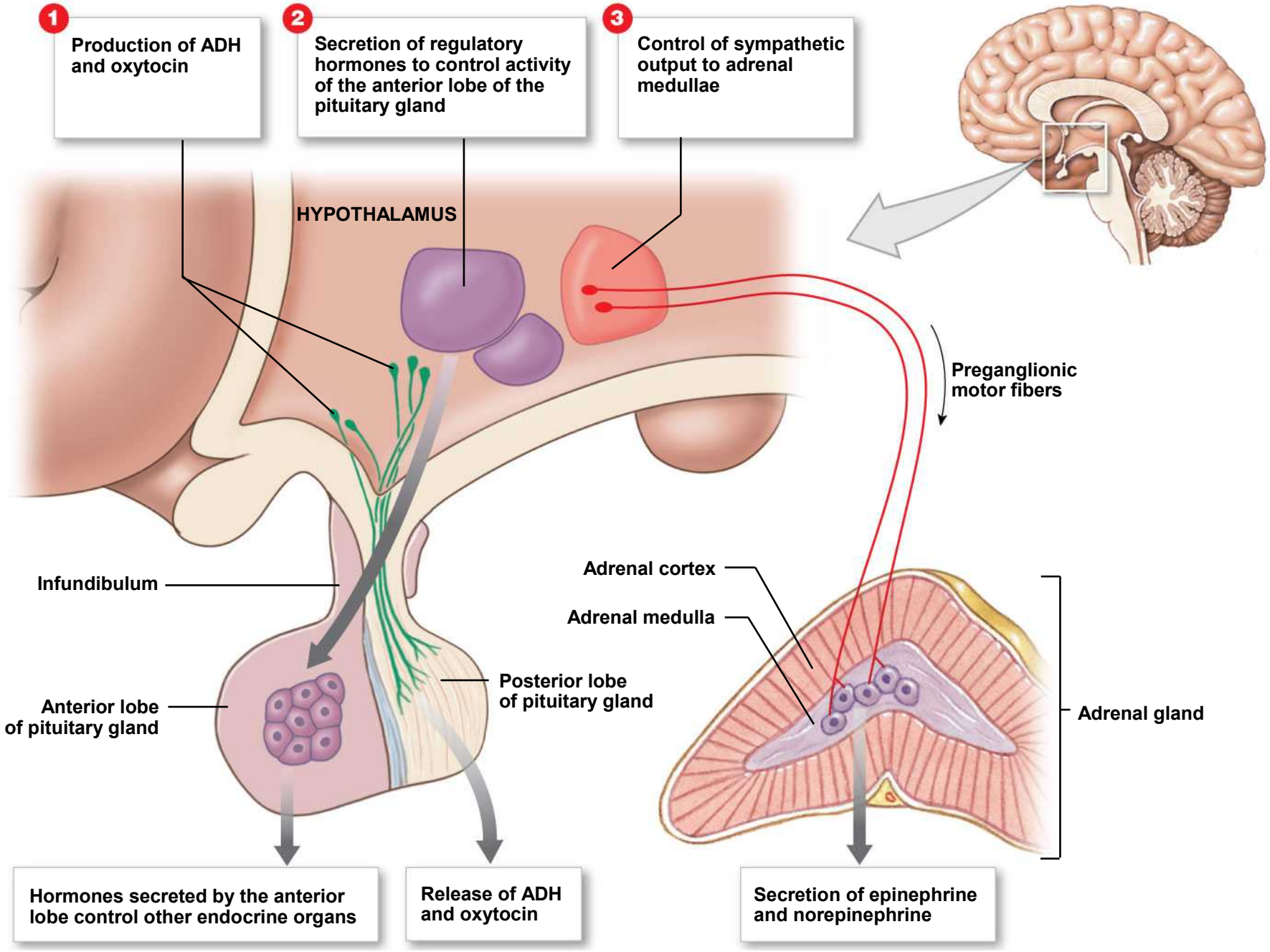
18-2 Hormones

- Endocrine Reflexes
  - Can be triggered by:
    1. *Humoral stimuli*
       - Changes in composition of extracellular fluid
    1. *Hormonal stimuli*
       - Arrival or removal of specific hormone
    1. *Neural stimuli*
       - Arrival of neurotransmitters at neuroglandular junctions

18-2 Hormones

- Endocrine Reflexes
  - Simple Endocrine Reflex
    - Involves only one hormone
    - Controls hormone secretion by the heart, pancreas, parathyroid gland, and digestive tract
  - Complex Endocrine Reflex
    - One or more intermediary steps
    - Two or more hormones
  - The hypothalamus provides highest level of endocrine control

Figure 18-5 Three Mechanisms of Hypothalamic Control over Endocrine Function



18-2 Hormones

- Neuroendocrine Reflexes
  - Pathways include both neural and endocrine components
- Complex Commands
  - Issued by changing:
    - Amount of hormone secreted
    - Pattern of hormone release
      - Hypothalamic and pituitary hormones released in sudden bursts
      - Frequency changes response of target cells

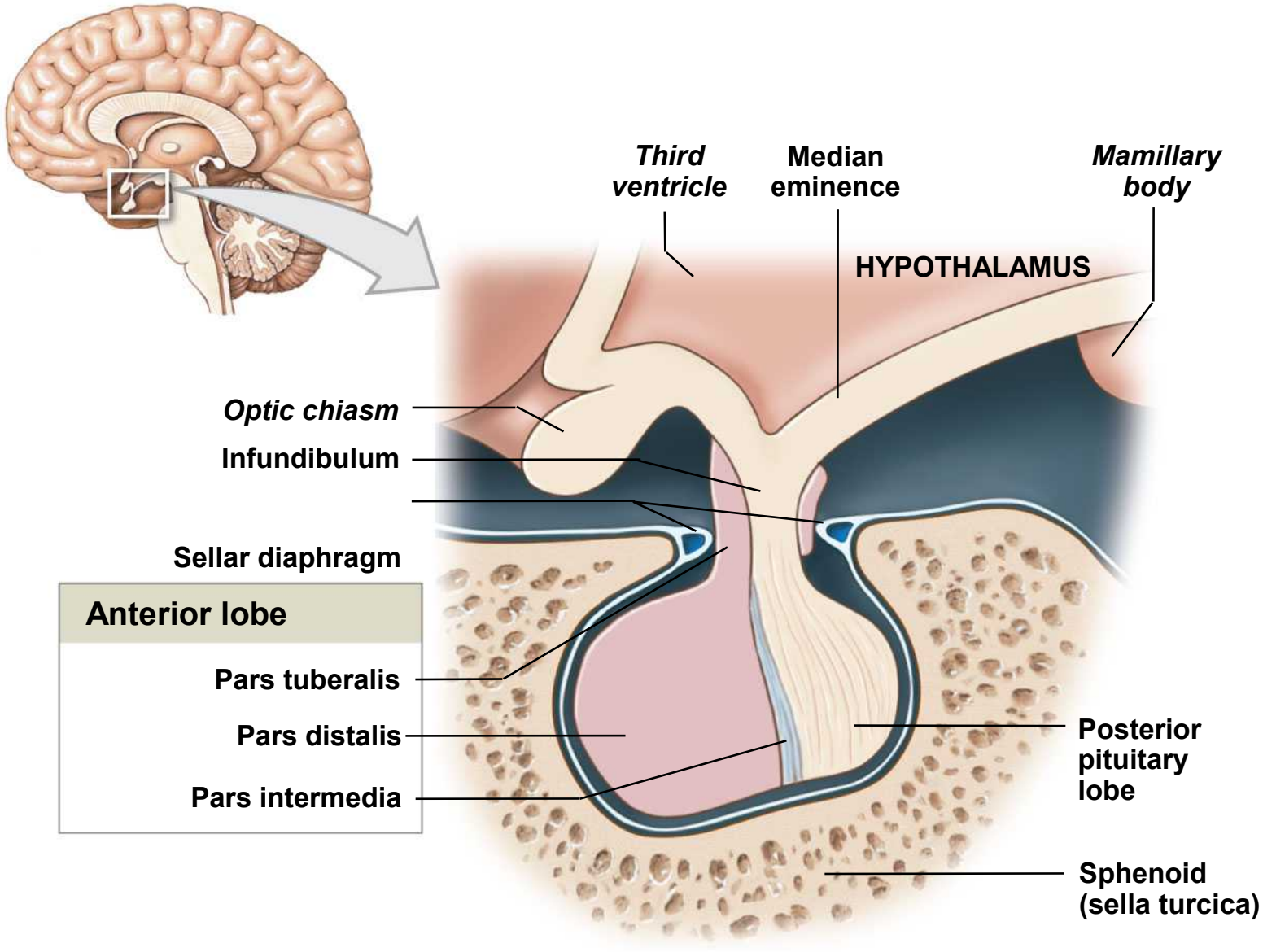
18-3 The Pituitary Gland

- The **Pituitary Gland**
  - Also called **hypophysis**
  - Lies within *sella turcica*
    - *Sellar diaphragm*
      - A dural sheet that locks pituitary in position
      - Isolates it from cranial cavity
  - Hangs inferior to hypothalamus
    - Connected by **infundibulum**

18-3 The Pituitary Gland

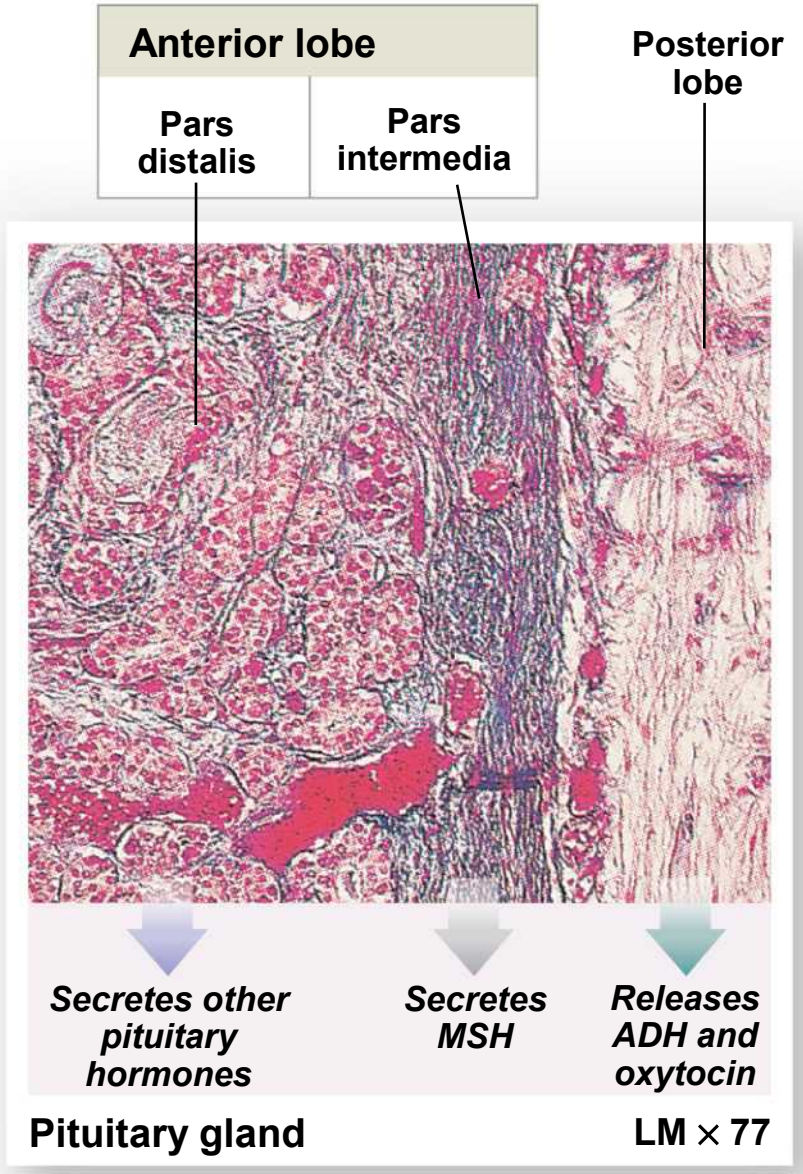
- The Pituitary Gland
  - Releases nine important peptide hormones
  - Hormones bind to membrane receptors
    - Use cAMP as second messenger

Figure 18-6a The Anatomy and Orientation of the Pituitary Gland



a Relationship of the pituitary gland to the hypothalamus

Figure 18-6b The Anatomy and Orientation of the Pituitary Gland



b **Histological organization of pituitary gland showing the anterior and posterior lobes of the pituitary gland**

18-3 The Pituitary Gland

- The **Anterior Lobe** of the Pituitary Gland
  - Also called **adenohypophysis**
    - Hormones "turn on" endocrine glands or support other organs
    - Has three regions
      1. **Pars distalis**
      2. **Pars tuberalis**
      3. **Pars intermedia**

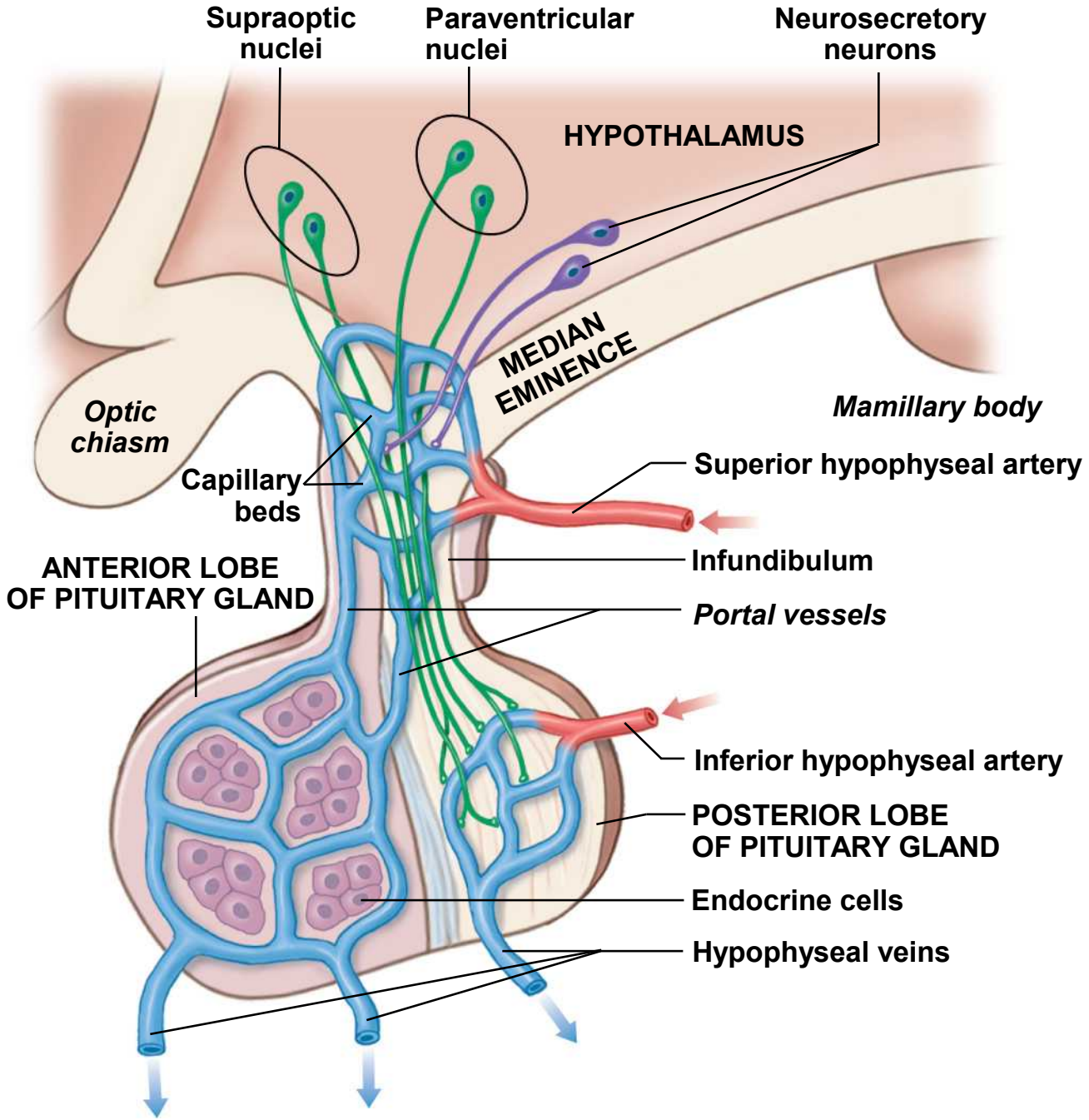
18-3 The Pituitary Gland

- The Hypophyseal Portal System
  - *Median eminence*
    - Swelling near attachment of infundibulum
    - Where hypothalamic neurons release regulatory factors
      - Into interstitial fluids
      - Through **fenestrated capillaries**

18-3 The Pituitary Gland

- **Portal Vessels**
  - Blood vessels link two capillary networks
  - Entire complex is **portal system**
    - Ensures that regulatory factors reach intended target cells before entering general circulation

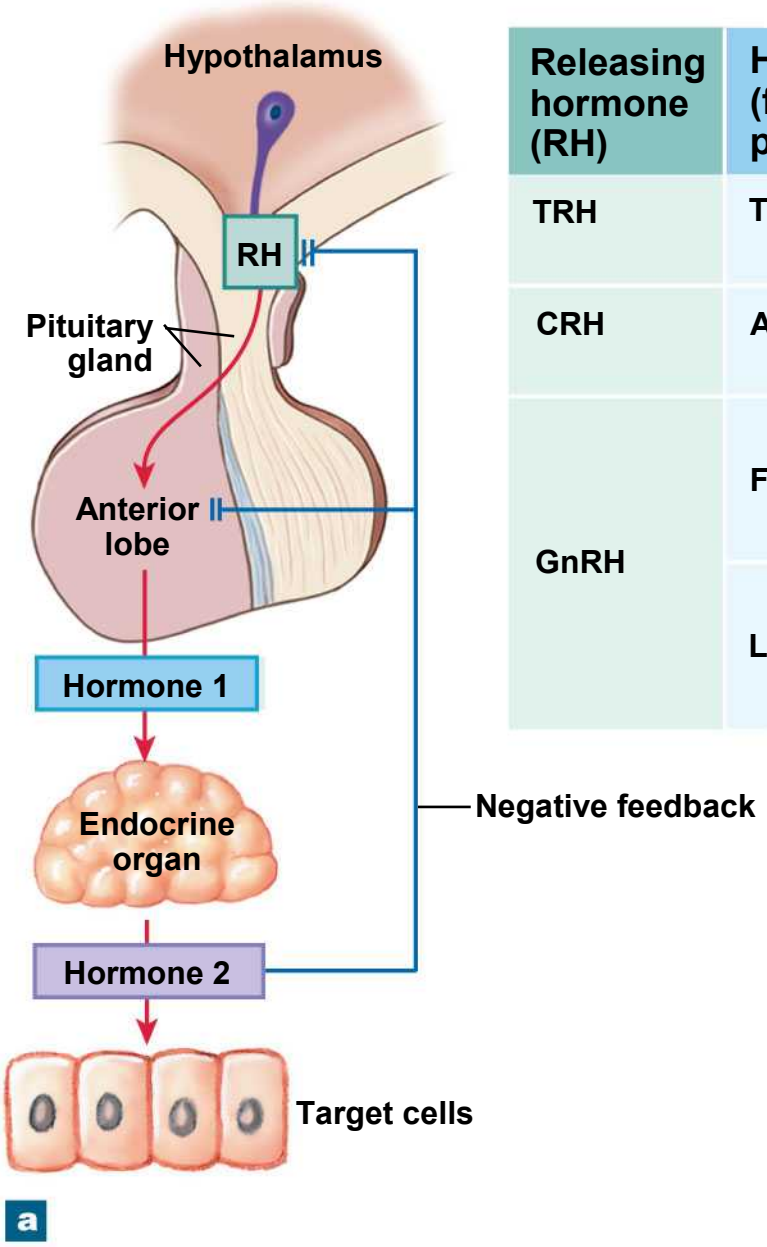
Figure 18-7 The Hypophyseal Portal System and the Blood Supply to the Pituitary Gland



18-3 The Pituitary Gland

- Hypothalamic Control of the Anterior Lobe
  - Two classes of hypothalamic regulatory hormones
    1. **Releasing hormones (RH)**
       - Stimulate synthesis and secretion of one or more hormones at anterior lobe
    1. **Inhibiting hormones (IH)**
       - Prevent synthesis and secretion of hormones from the anterior lobe
  - Rate of secretion is controlled by negative feedback

Figure 18-8a Feedback Control of Endocrine Secretion



Releasing hormone (RH)	Hormone 1 (from pituitary)	Endocrine target organ	Hormone 2 (from target organ)
TRH	TSH	Thyroid gland	Thyroid hormones
CRH	ACTH	Adrenal cortex	Gluco-corticoids
GnRH	FSH	Testes	Inhibin
		Ovaries	Inhibin Estrogens
	LH	Ovaries	Progestins Estrogens
		Testes	Androgens

KEY
Stimulation
Inhibition

Figure 18-8b Feedback Control of Endocrine Secretion

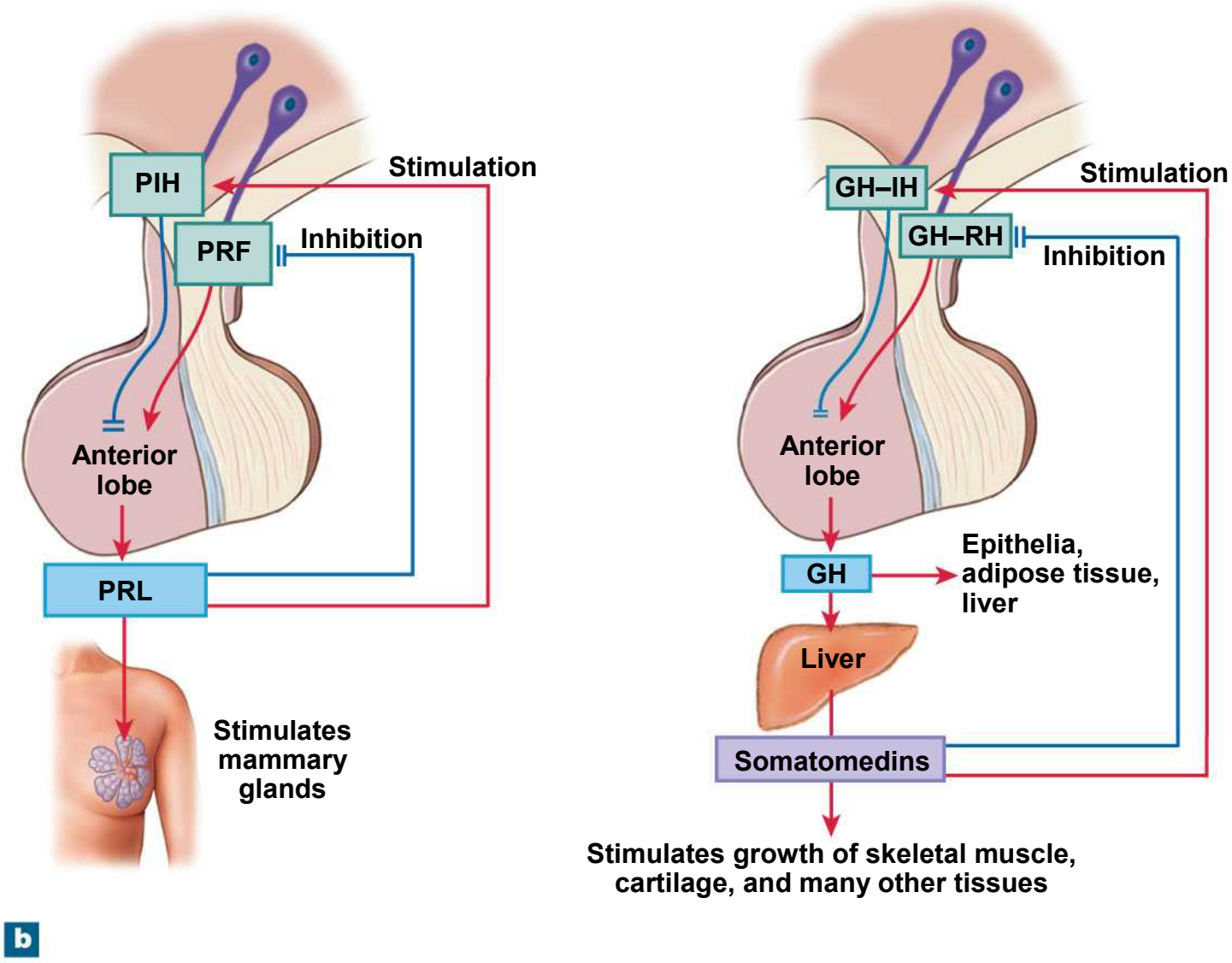


Figure 18-9 Pituitary Hormones and Their Targets

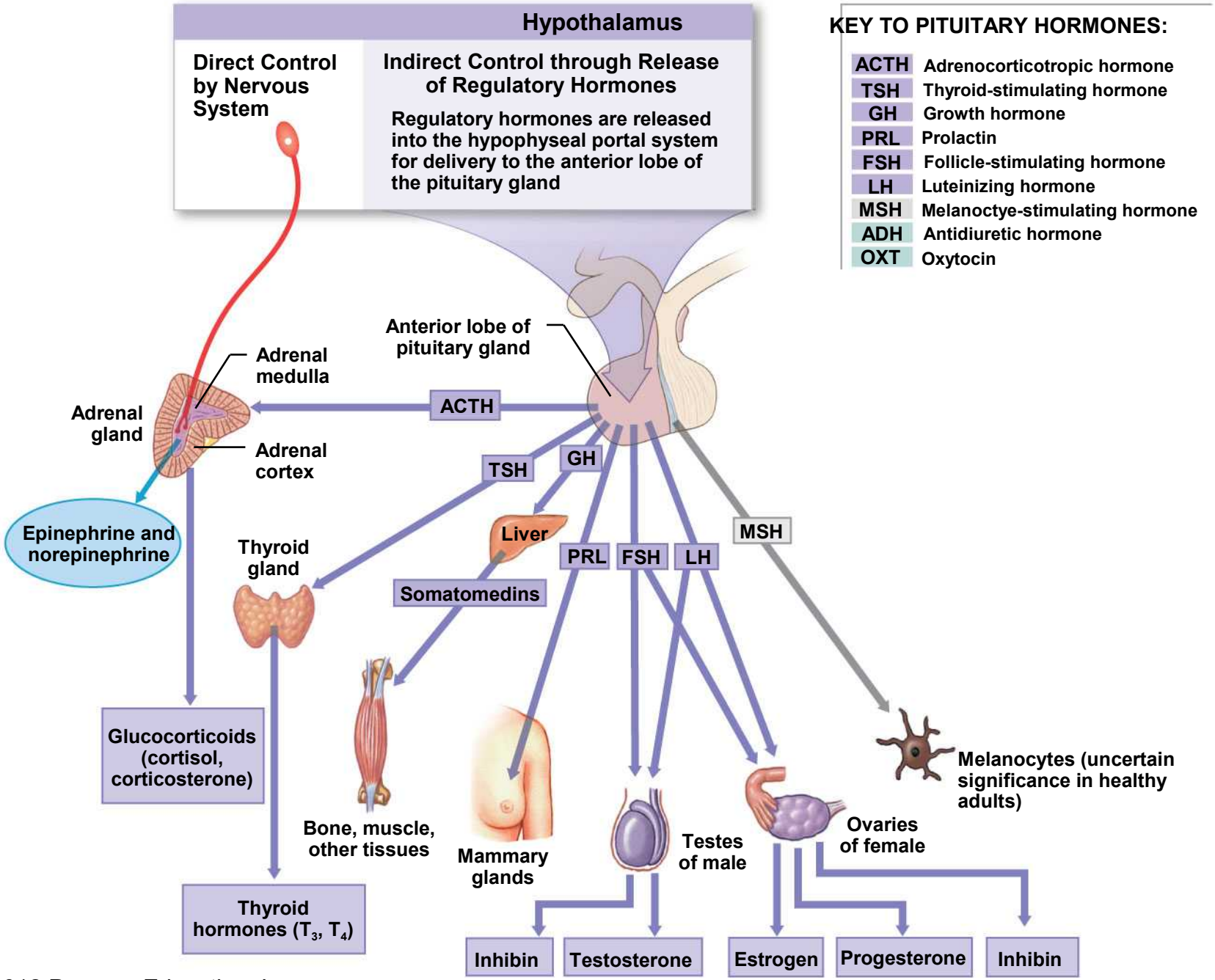


Table 18-2 The Pituitary Hormones

Table 18–2 The Pituitary Hormones

Region/Area	Hormone	Target	Hormonal Effect	Hypothalamic Regulatory Hormone
ANTERIOR LOBE				
Pars distalis	**Thyroid-stimulating hormone (TSH)**	Thyroid gland	Secretion of thyroid hormones	Thyrotropin-releasing hormone (TRH)
	Adrenocorticotropic hormone (ACTH)	Adrenal cortex (zona fasciculata)	Secretion of glucocorticoids (cortisol, corticosterone)	Corticotropin-releasing hormone (CRH)
	Gonadotropins:			
	Follicle-stimulating hormone (FSH)	Follicle cells of ovaries	Secretion of estrogen, follicle development	Gonadotropin-releasing hormone (GnRH)
		Nurse cells of testes	Stimulation of sperm maturation	Gonadotropin-releasing hormone (GnRH)
	Luteinizing hormone (LH)	Follicle cells of ovaries	Ovulation, formation of corpus luteum, secretion of progesterone	Gonadotropin-releasing hormone (GnRH)
		Interstitial cells of testes	Secretion of testosterone	Gonadotropin-releasing hormone (GnRH)
	Prolactin (PRL)	Mammary glands	Production of milk	Prolactin-releasing factor (PRF)
				Prolactin-inhibiting hormone (PIH)
	Growth hormone (GH)	All cells	Growth, protein synthesis, lipid mobilization and catabolism	Growth hormone–releasing hormone (GH–RH)
				Growth hormone–inhibiting hormone (GH–IH)
Pars intermedia (not active in normal adults)	**Melanocyte-stimulating hormone (MSH)**	Melanocytes	Increased melanin synthesis in epidermis	Melanocyte-stimulating hormone–inhibiting hormone (MSH–IH)

18-3 The Pituitary Gland

- The **Posterior Lobe** of the Pituitary Gland
  - Also called **neurohypophysis**
    - Contains unmyelinated axons of hypothalamic neurons
    - **Supraoptic** and **paraventricular nuclei** manufacture:
      - **Antidiuretic hormone** (ADH)
      - **Oxytocin** (OXT)

Figure 18-9 Pituitary Hormones and Their Targets

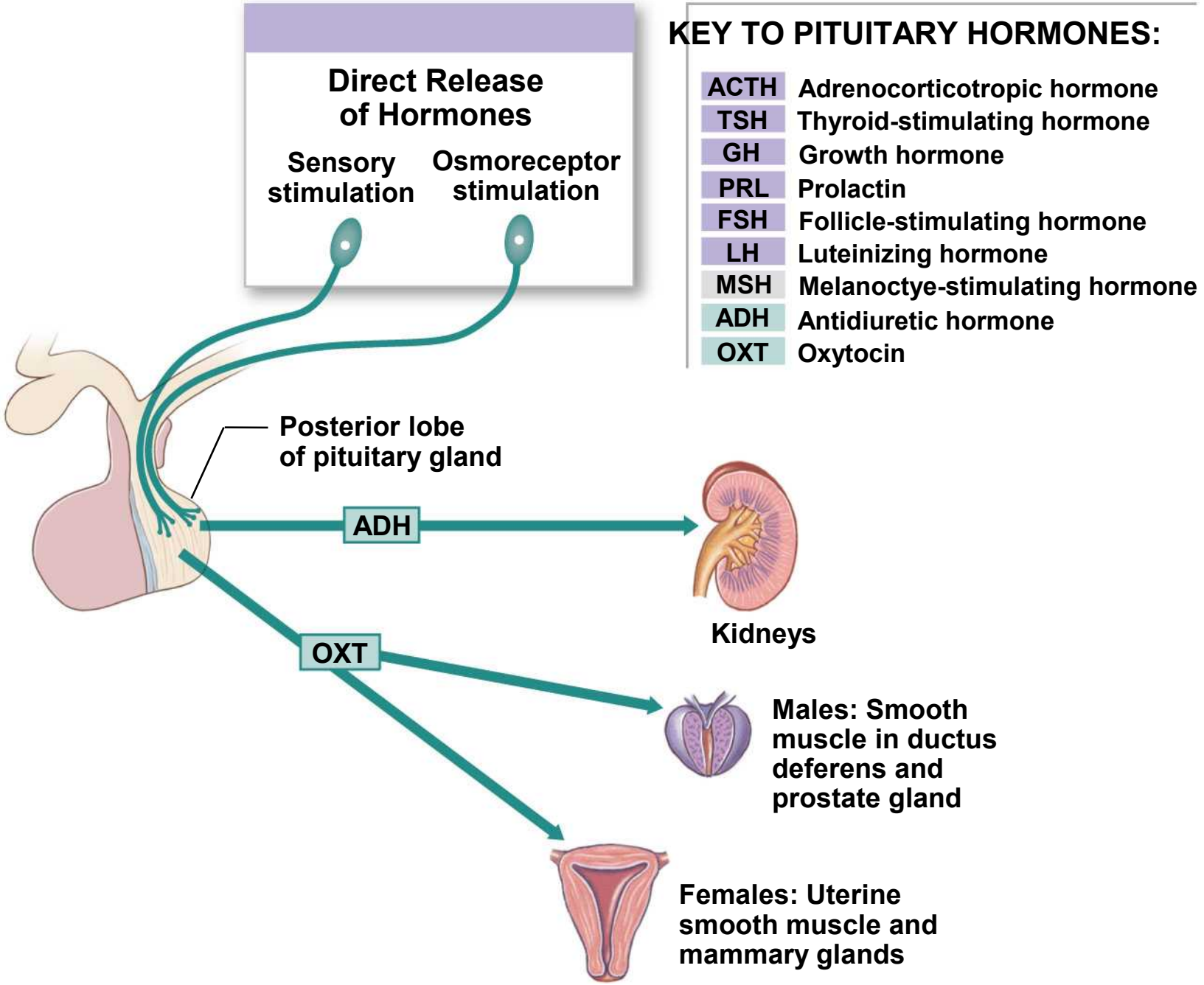


Table 18-2 The Pituitary Hormones

Table 18–2 The Pituitary Hormones

Region/Area	Hormone	Target	Hormonal Effect	Hypothalamic Regulatory Hormone
POSTERIOR LOBE				
	Antidiuretic hormone (ADH)	Kidneys	Reabsorption of water, elevation of blood volume and pressure	None: Transported along axons from supraoptic nucleus to the posterior lobe of the pituitary gland
	Oxytocin (OXT)	Uterus, mammary glands (females) Ductus deferens and prostate gland (males)	Labor contractions, milk ejection Contractions of ductus deferens and prostate gland	None: Transported along axons from paraventricular nucleus to the posterior lobe of the pituitary gland

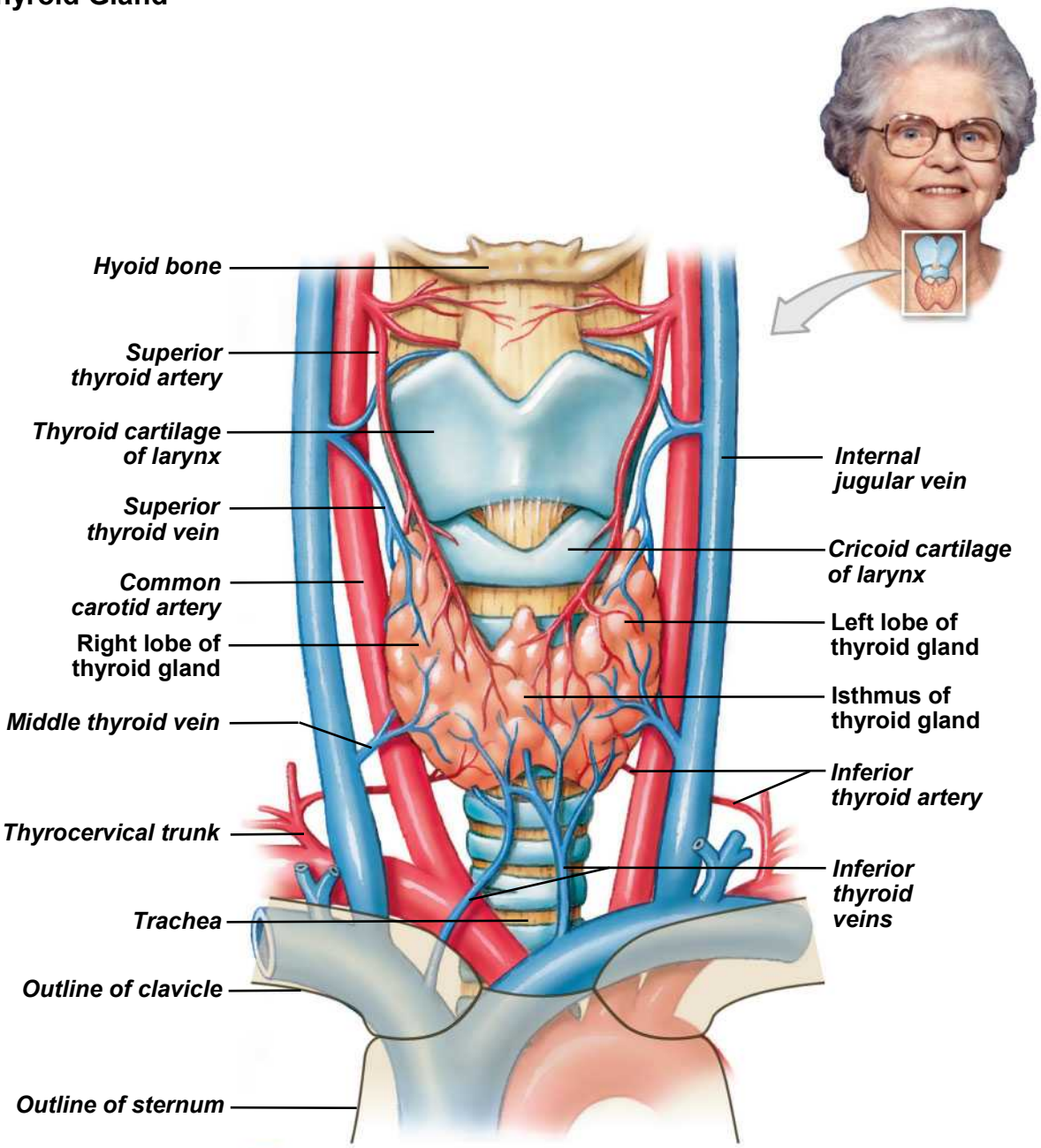
18-4 The Thyroid Gland

- The **Thyroid Gland**
  - Lies anterior to thyroid cartilage of larynx
  - Consists of two **lobes** connected by narrow **isthmus**
    - **Thyroid follicles**
      - Hollow spheres lined by cuboidal epithelium
      - Cells surround **follicle cavity** that contains viscous colloid
      - Surrounded by network of capillaries that:
        - Deliver nutrients and regulatory hormones
        - Accept secretory products and metabolic wastes

18-4 The Thyroid Gland

- **Thyroglobulin** (Globular Protein)
  - Synthesized by follicle cells
  - Secreted into colloid of thyroid follicles
  - Molecules contain the amino acid *tyrosine*
- **Thyroxine (T_4)**
  - Also called *tetraiodothyronine*
  - Contains four iodide ions
- **Triiodothyronine (T_3)**
  - Contains three iodide ions

Figure 18-10a The Thyroid Gland



a Location and anatomy of the thyroid gland

Figure 18-10b The Thyroid Gland

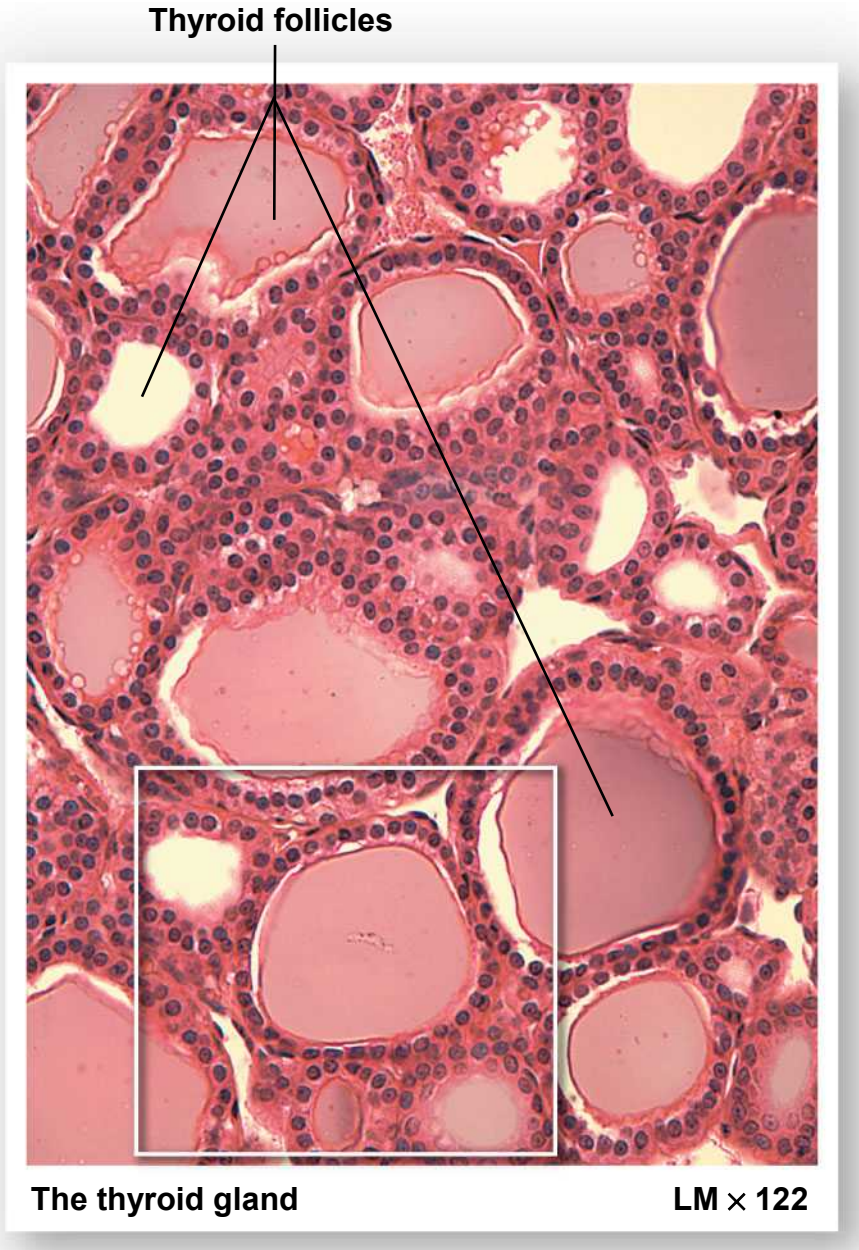
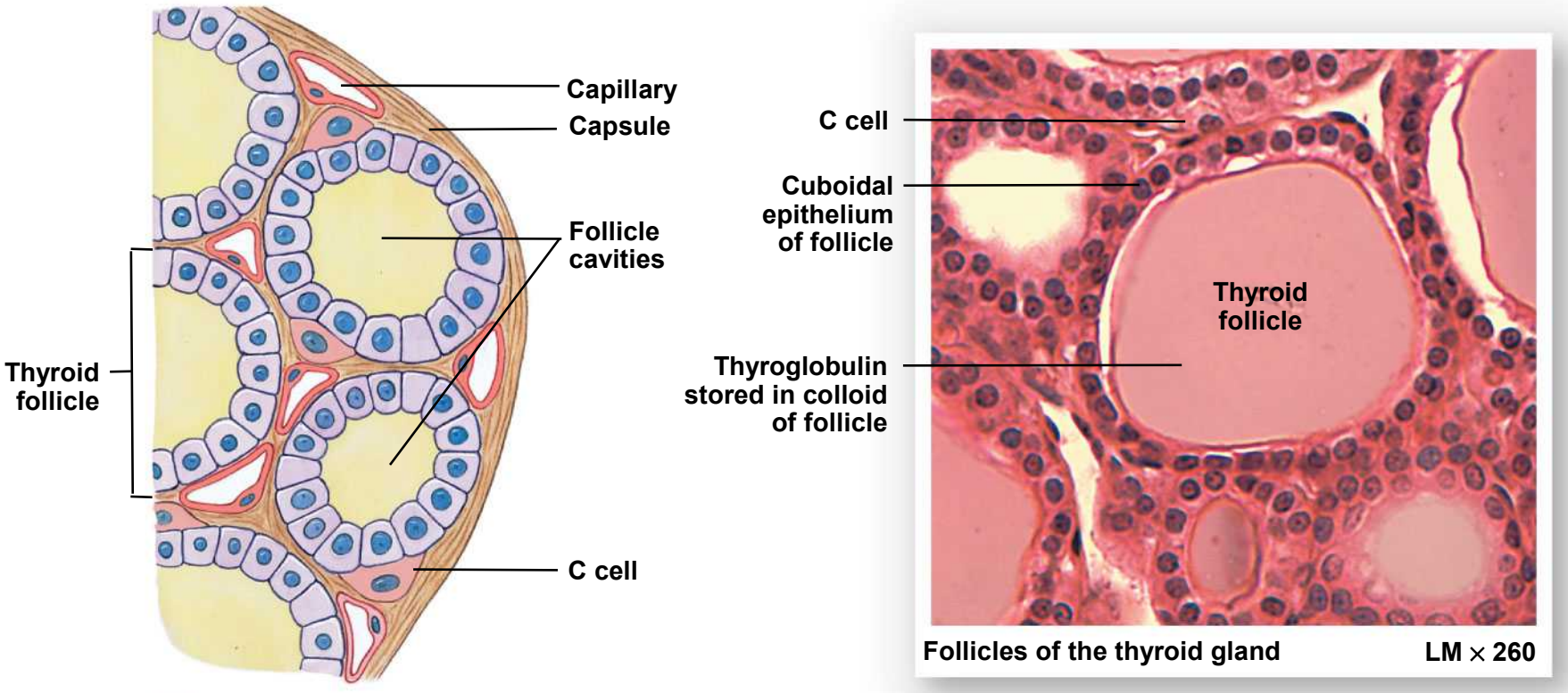
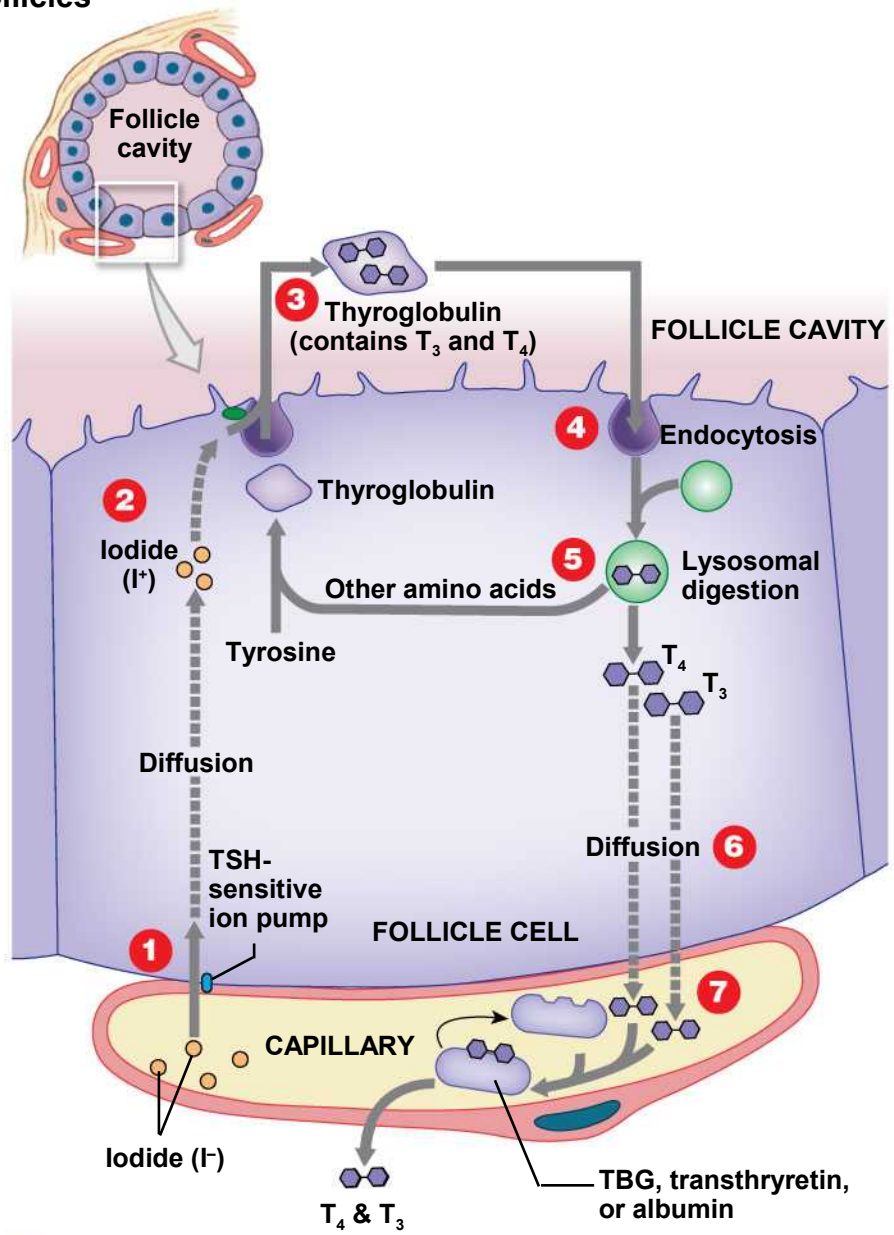


Figure 18-10c The Thyroid Gland



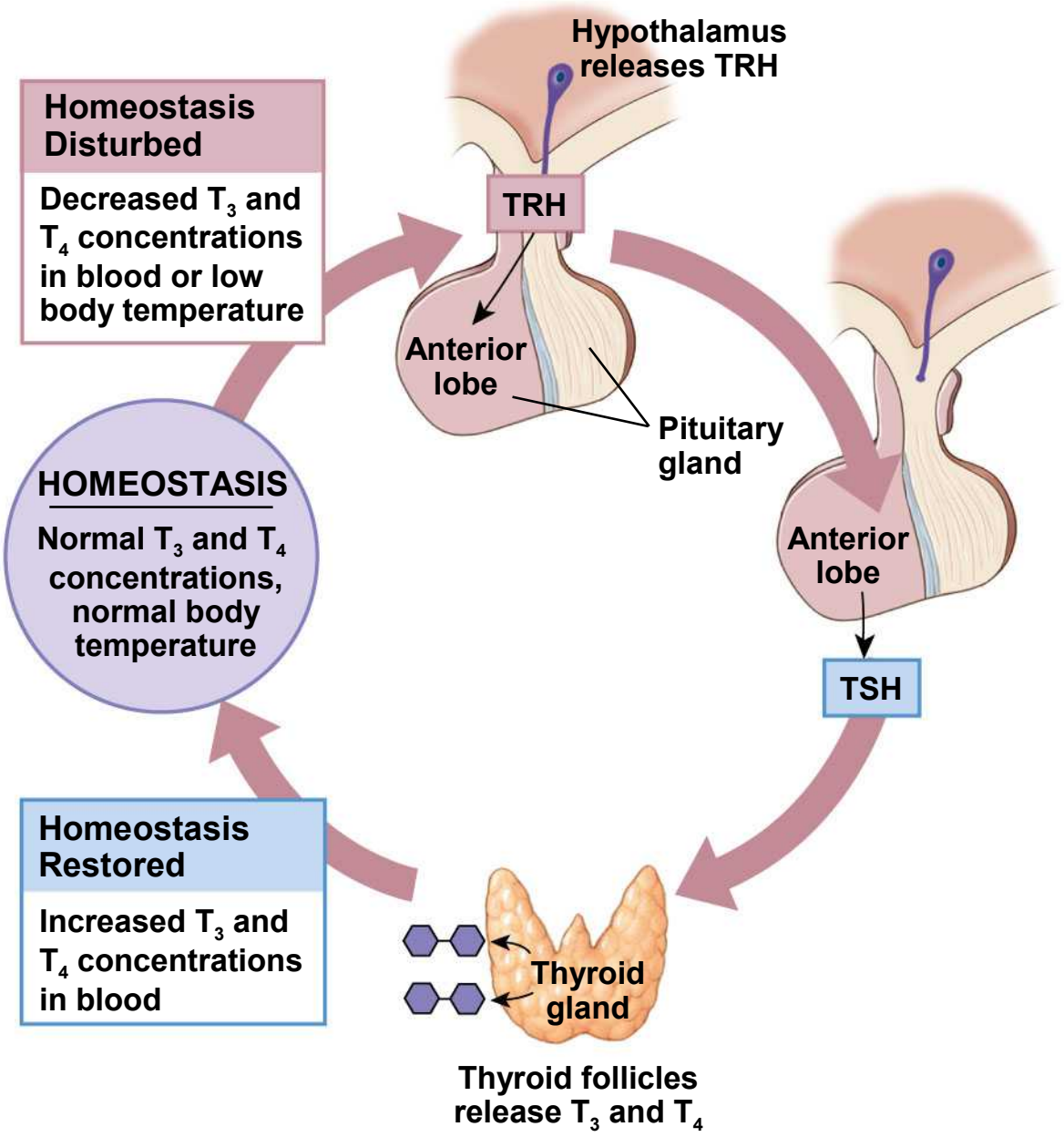
C Histological details of the thyroid gland showing thyroid follicles and both of the cell types in the follicular epithelium ATLAS: Plate 18c

Figure 18-11a The Thyroid Follicles



a The synthesis, storage, and secretion of thyroid hormones.

Figure 18-11b The Thyroid Follicles



b The regulation of thyroid secretion

18-4 The Thyroid Gland

- **Thyroid-binding Globulins (TBGs)**
  - Plasma proteins that bind about 75% of T_4 and 70% of T_3 entering the bloodstream
- **Transthyretin** (*thyroid-binding prealbumin – TBPA*) and *albumin*
  - Binds most of the remaining thyroid hormones
- About 0.3% of T_3 and 0.03% of T_4 are unbound

18-4 The Thyroid Gland

- Thyroid-Stimulating Hormone (TSH)
  - Absence causes thyroid follicles to become inactive
    - Neither synthesis nor secretion occurs
  - Binds to membrane receptors
  - Activates key enzymes in thyroid hormone production

18-4 The Thyroid Gland

- Functions of Thyroid Hormones
  - Thyroid Hormones
    - Enter target cells by transport system
    - Affect most cells in body
    - Bind to receptors in:
      1. Cytoplasm
      2. Surfaces of mitochondria
      3. Nucleus
    - In children, essential to normal development of:
      - Skeletal, muscular, and nervous systems

18-4 The Thyroid Gland

- **Calorigenic Effect**
  - Cell consumes more energy resulting in increased heat generation
  - Is responsible for strong, immediate, and short-lived increase in rate of cellular metabolism

18-4 The Thyroid Gland

- Effects of Thyroid Hormones on Peripheral Tissues
  1. Elevates rates of oxygen consumption and energy consumption; in children, may cause a rise in body temperature
  2. Increases heart rate and force of contraction; generally results in a rise in blood pressure
  3. Increases sensitivity to sympathetic stimulation
  4. Maintains normal sensitivity of respiratory centers to changes in oxygen and carbon dioxide concentrations
  5. Stimulates red blood cell formation and thus enhances oxygen delivery
  6. Stimulates activity in other endocrine tissues
  7. Accelerates turnover of minerals in bone

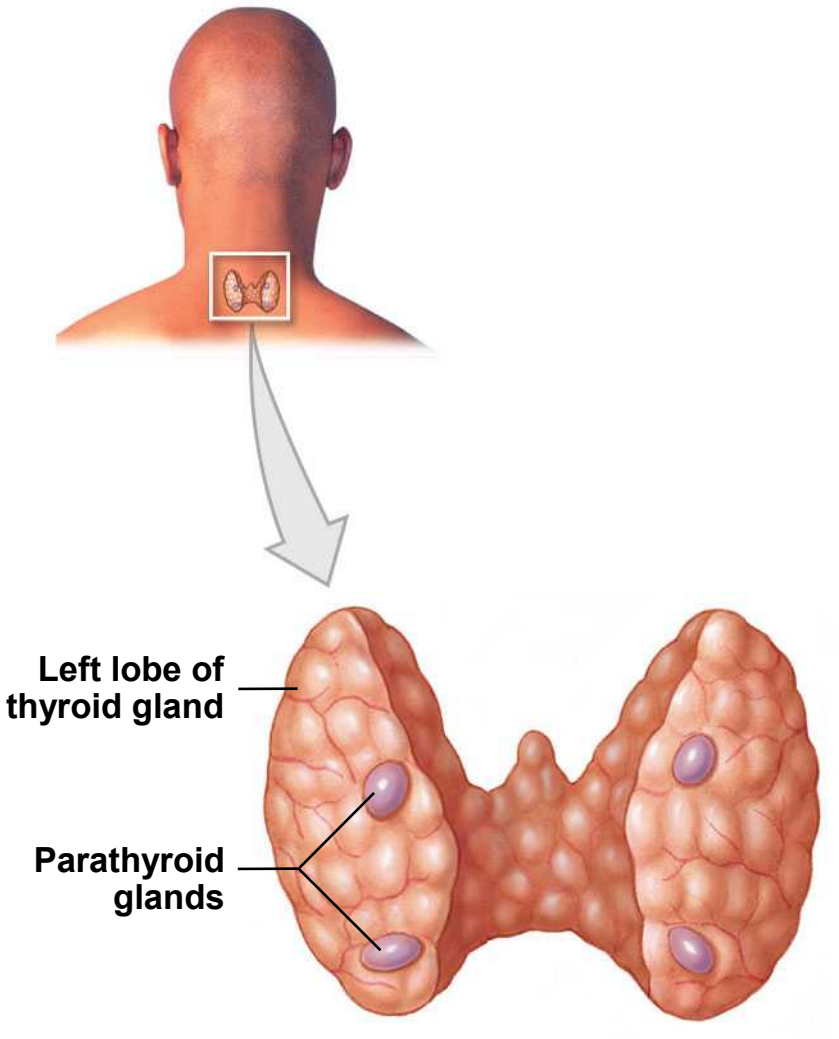
18-4 The Thyroid Gland

- The C Cells of the Thyroid Gland and Calcitonin
  - **C (clear) cells** also called *parafollicular cells*
  - Produce **calcitonin (CT)**
    - Helps regulate concentrations of Ca^{2+} in body fluids
      1. Inhibits osteoclasts, which slows the rate of Ca^{2+} release from bone
      2. Stimulates Ca^{2+} excretion by the kidneys

18-5 Parathyroid Glands

- Four Parathyroid Glands
  - Embedded in the posterior surface of the thyroid gland
  - Altogether, the four glands weigh 1.6 g
- **Parathyroid Hormone** (PTH) or *parathormone*
  - Produced by **parathyroid (chief) cells** in response to low concentrations of Ca^{2+}
  - Antagonist for calcitonin

Figure 18-12a The Parathyroid Glands

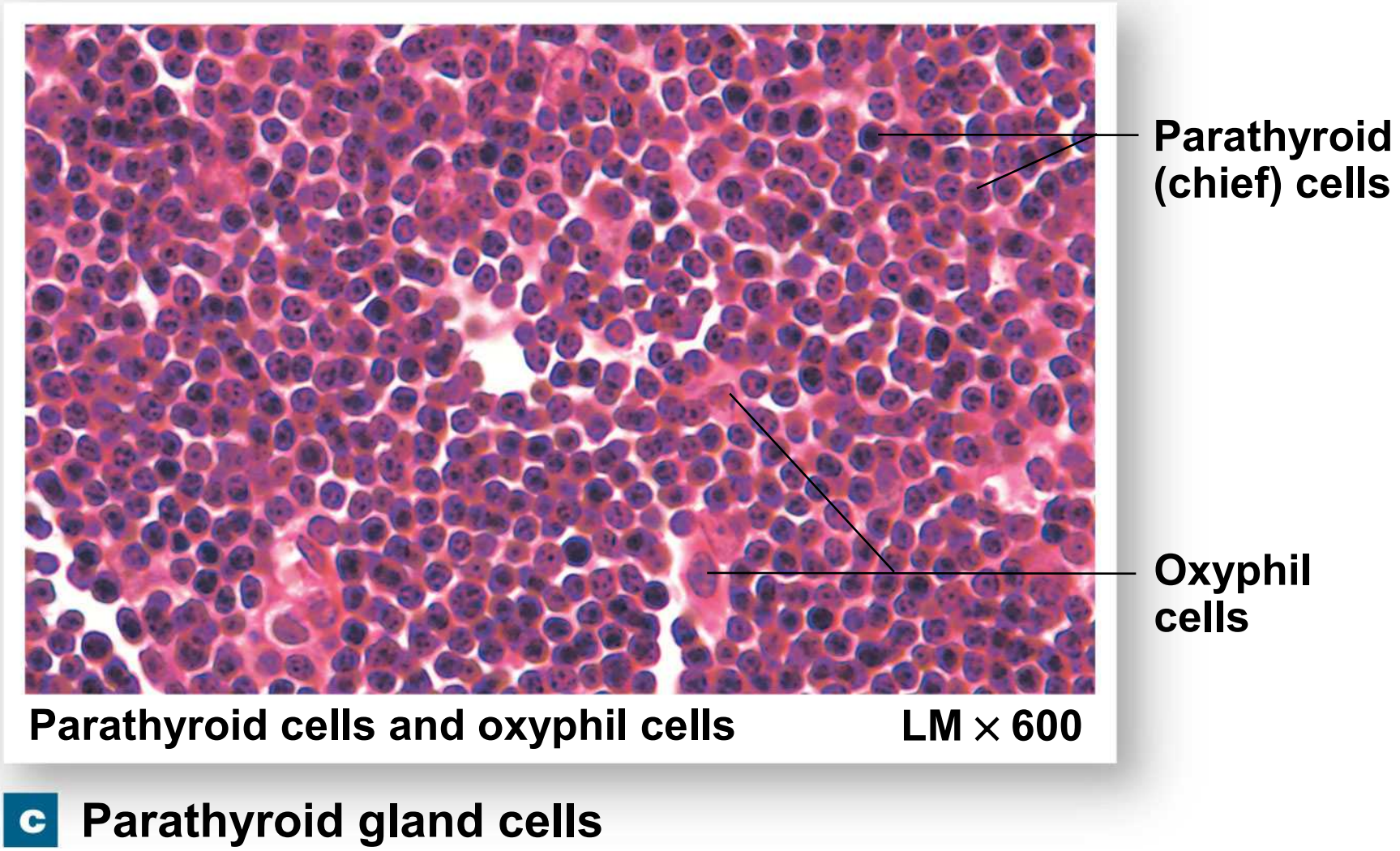


a Posterior view of the thyroid gland showing the parathyroid glands.

Figure 18-12b The Parathyroid Glands

b Both parathyroid and thyroid tissues

Figure 18-12c The Parathyroid Glands



18-5 Parathyroid Glands

- Three Effects of PTH
  1. It stimulates osteoclasts and inhibits osteoblasts
     - Accelerates mineral turnover and releases Ca^{2+} from bone
     - Reduces rate of calcium deposition in bone
  1. It enhances reabsorption of Ca^{2+} at kidneys, reducing urinary losses
  2. It stimulates formation and secretion of *calcitriol* by the kidneys
     - Effects complement or enhance PTH
     - Also enhances Ca^{2+}, PO_4^{3-} absorption by digestive tract

Figure 18-13 The Homeostatic Regulation of Calcium Ion Concentrations

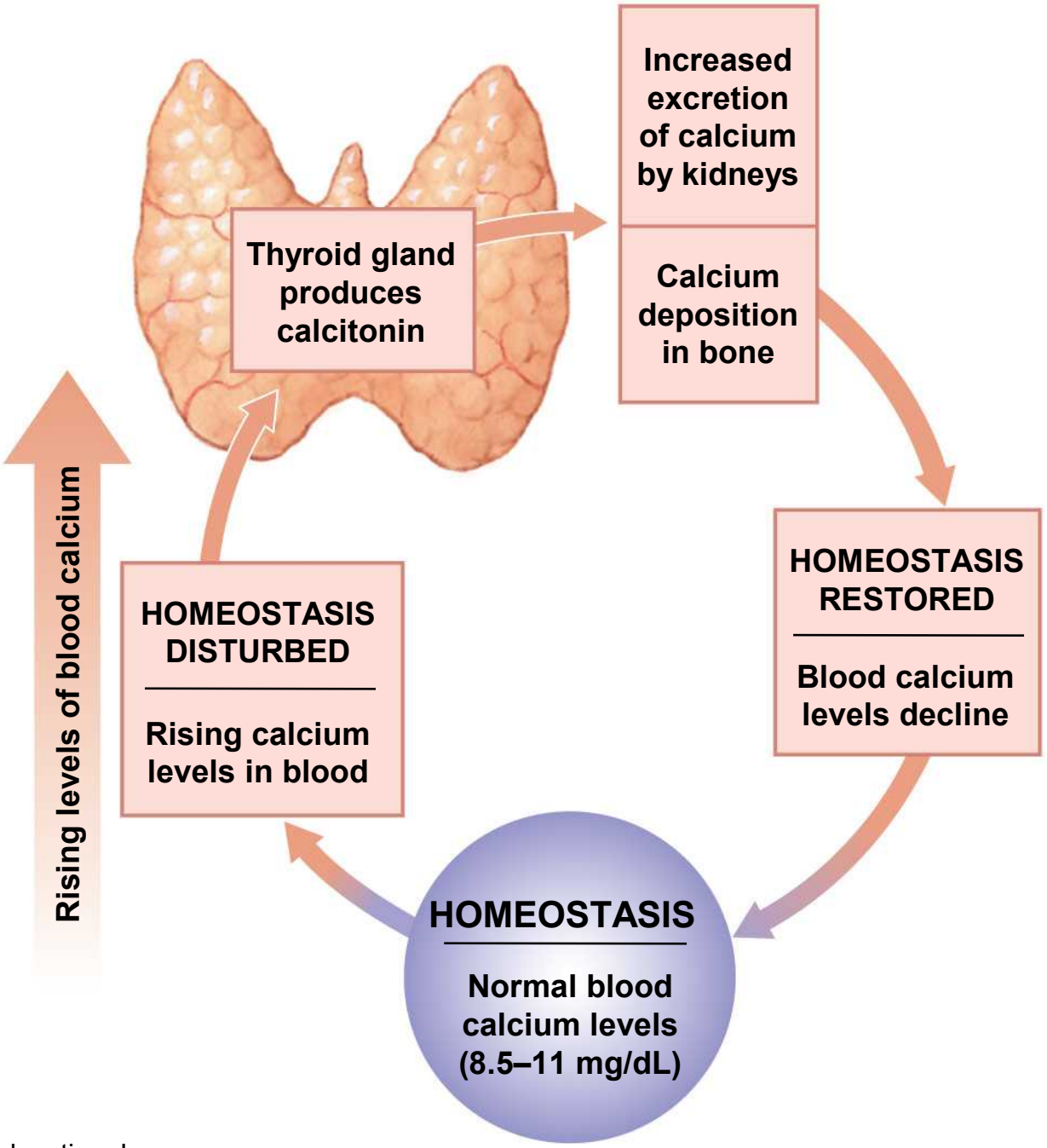


Figure 18-13 The Homeostatic Regulation of Calcium Ion Concentrations

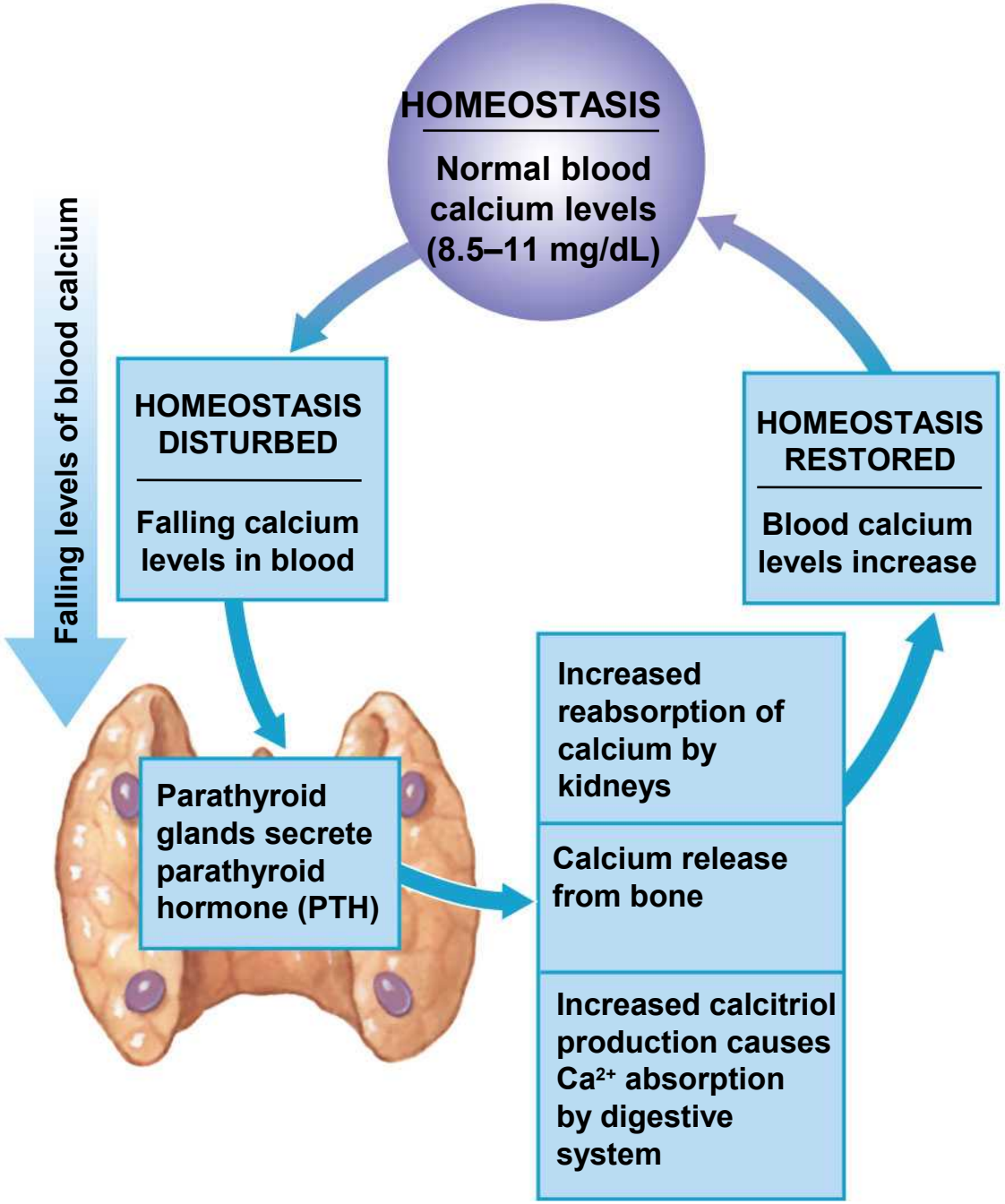


Table 18-4 Hormones of the Thyroid Gland and Parathyroid Glands

Table 18–4 Hormones of the Thyroid Gland and Parathyroid Glands

Gland/Cells	Hormone	Target	Hormonal Effect	Regulatory Control
THYROID GLAND				
Follicular epithelium	Thyroxine (T_4) Triiodothyronine (T_3)	Most cells	Increases energy utilization, oxygen consumption, growth, and development	Stimulated by TSH from the anterior lobe of the pituitary gland
C cells	Calcitonin (CT)	Bone, kidneys	Decreases Ca^{2+} concentrations in body fluids	Stimulated by elevated blood Ca^{2+} levels; actions opposed by PTH
PARATHYROID GLANDS				
Parathyroid (chief) cells	Parathyroid hormone (PTH)	Bone, kidneys	Increases Ca^{2+} concentrations in body fluids	Stimulated by low blood Ca^{2+} levels; PTH effects enhanced by calcitriol and opposed by calcitonin

18-6 Adrenal Glands

- The **Adrenal Glands**
  - Lie along superior border of each kidney
  - Subdivided into:
    - Superficial **adrenal cortex**
      - Stores lipids, especially cholesterol and fatty acids
      - Manufactures steroid hormones (**corticosteroids**)
    - Inner **adrenal medulla**
      - Secretory activities controlled by sympathetic division of ANS
      - Produces epinephrine (adrenaline) and norepinephrine
      - Metabolic changes persist for several minutes

18-6 Adrenal Glands

- Adrenal Cortex
  - Subdivided into three regions
    1. **Zona glomerulosa**
    2. **Zona fasciculata**
    3. **Zona reticularis**

18-6 Adrenal Glands

- **Zona Glomerulosa**
  - Outer region of adrenal cortex
  - Produces **mineralocorticoids**
    - For example, **aldosterone**

18-6 Adrenal Glands

- **Aldosterone**
  - Stimulates conservation of sodium ions and elimination of potassium ions
  - Increases sensitivity of salt receptors in taste buds
  - Secretion responds to:
    - Drop in blood Na^+, blood volume, or blood pressure
    - Rise in blood K^+ concentration

18-6 Adrenal Glands

- **Zona Fasciculata**
  - Produces **glucocorticoids**
  - For example, **cortisol** (hydrocortisone) with **corticosterone**
    - Liver converts cortisol to **cortisone**
  - Secretion regulated by negative feedback
  - Has inhibitory effect on production of:
    - Corticotropin-releasing hormone (CRH) in hypothalamus
    - ACTH in adenohypophysis

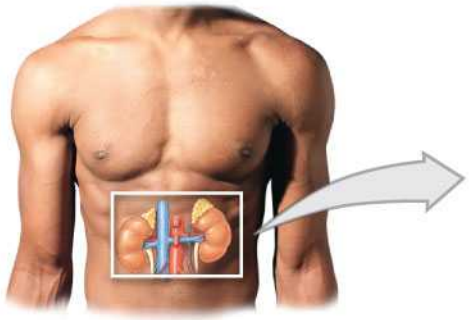
18-6 Adrenal Glands

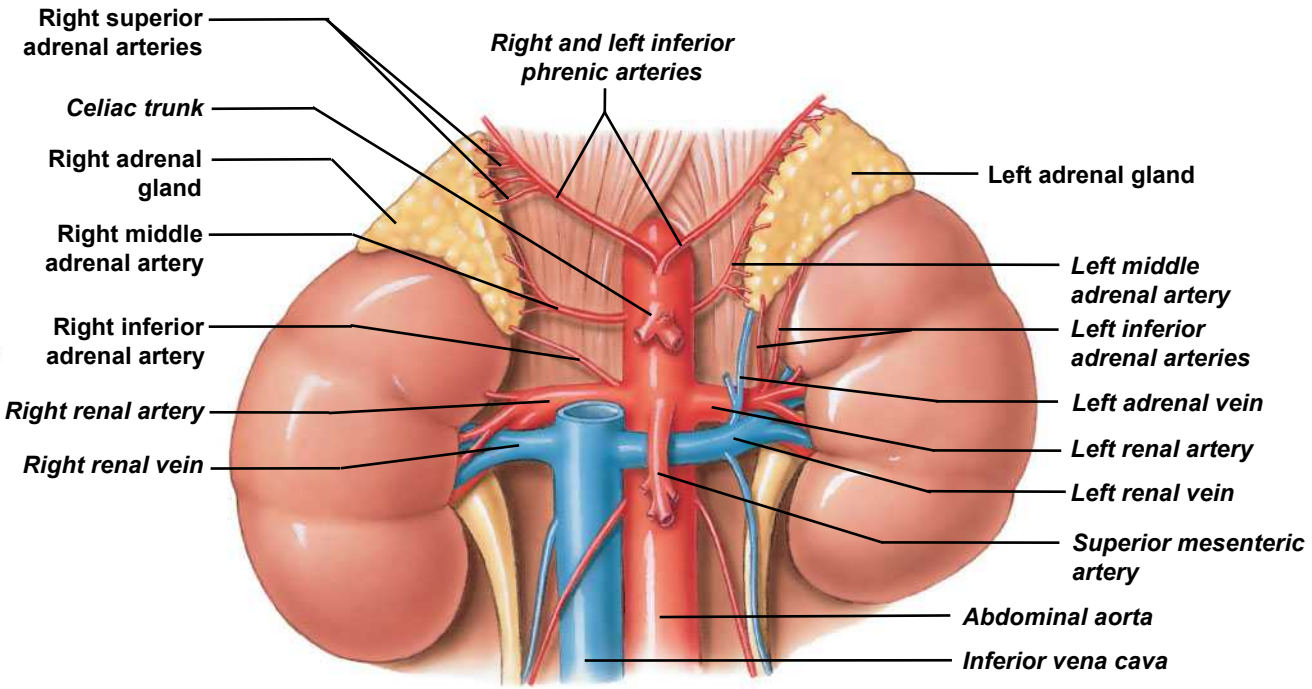
- **Glucocorticoids**
  - Accelerate glucose synthesis and glycogen formation
  - Show **anti-inflammatory** effects
    - Inhibit activities of white blood cells and other components of immune system

18-6 Adrenal Glands

- **Zona Reticularis**
  - Network of endocrine cells
  - Forms narrow band bordering each adrenal medulla
  - Produces androgens under stimulation by ACTH

Figure 18-14a The Adrenal Gland





a A superficial view of the left kidney and adrenal gland

Figure 18-14b The Adrenal Gland

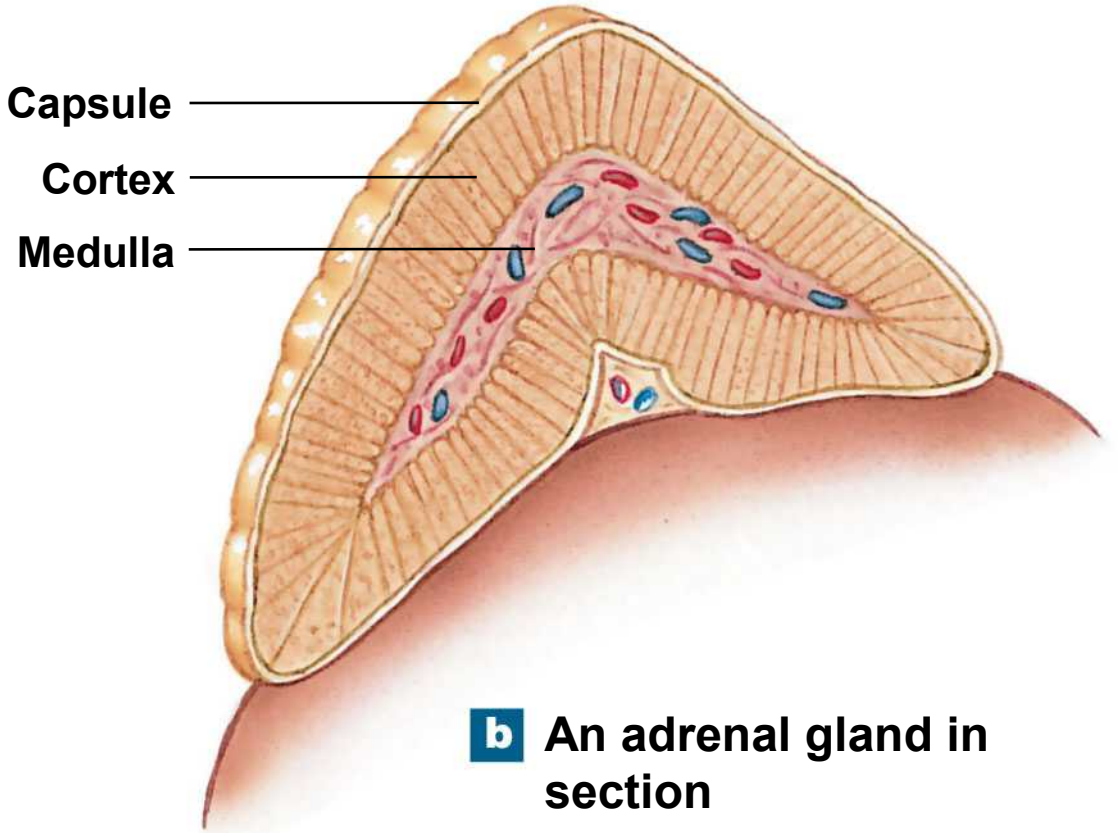
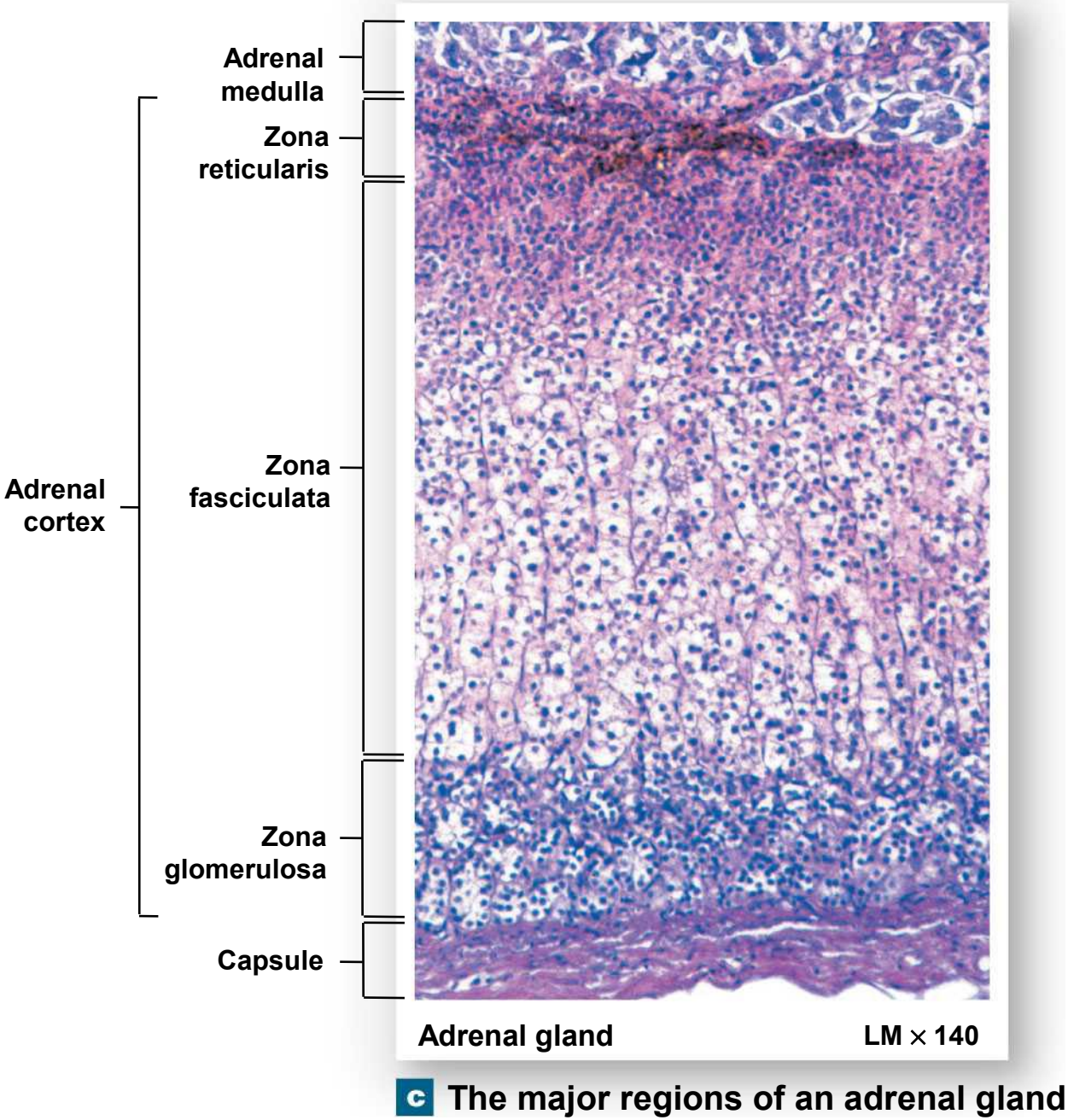


Figure 18-14c The Adrenal Gland



c The major regions of an adrenal gland

18-6 Adrenal Glands

- The Adrenal Medulla
  - Contains two types of secretory cells
    - One produces **epinephrine** (adrenaline)
      - 75% to 80% of medullary secretions
    - The other produces **norepinephrine** (noradrenaline)
      - 20% to 25% of medullary secretions

18-6 Adrenal Glands

- Epinephrine and Norepinephrine
  - Activation of the adrenal medullae has the following effects:
    - In skeletal muscles, epinephrine and norepinephrine trigger mobilization of glycogen reserves
    - And accelerate the breakdown of glucose to provide ATP
      - This combination increases both muscular strength and endurance
    - In adipose tissue, stored fats are broken down into fatty acids
      - Which are released into the bloodstream for other tissues to use for ATP production

18-6 Adrenal Glands

- Epinephrine and Norepinephrine
  - Activation of the adrenal medullae has the following effects:
    - In the liver, glycogen molecules are broken down
    - The resulting glucose molecules are released into the bloodstream
      - Primarily for use by neural tissue, which cannot shift to fatty acid metabolism
    - In the heart, the stimulation of beta 1 receptors triggers an increase in the rate and force of cardiac muscle contraction

Table 18-5 The Adrenal Hormones

Table 18–5 The Adrenal Hormones

Region/Zone	Hormone	Primary Target	Hormonal Effect	Regulatory Control
CORTEX				
Zona glomerulosa	Mineralocorticoids (primarily aldosterone)	Kidneys	Increase renal reabsorption of Na^+ and water (especially in the presence of ADH) and accelerate urinary loss of K^+	Stimulated by angiotensin II, elevated plasma K^+ or a fall in plasma Na^+; inhibited by ANP and BNP
Zona fasciculata	Glucocorticoids (cortisol [hydrocortisone], corticosterone)	Most cells	Release of amino acids from skeletal muscles and lipids from adipose tissues; promote liver formation of glucose and glycogen; promote peripheral utilization of lipids; anti-inflammatory effects	Stimulated by ACTH from the anterior lobe of the pituitary gland
Zona reticularis	Androgens	Most cells	Not important in adult men; encourages bone growth, muscle growth, and blood formation in children and women	Stimulated by ACTH from the anterior lobe of the pituitary gland
MEDULLA				
	Epinephrine, norepinephrine	Most cells	Increases cardiac activity, blood pressure, glycogen breakdown, blood glucose levels; releases lipids by adipose tissue	Stimulated during sympathetic activation by sympathetic preganglionic fiber

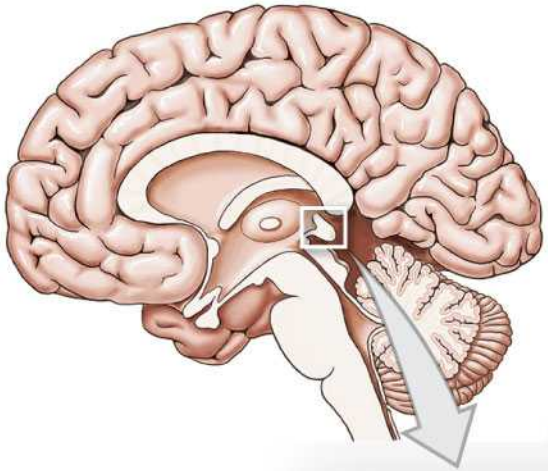
18-7 Pineal Gland

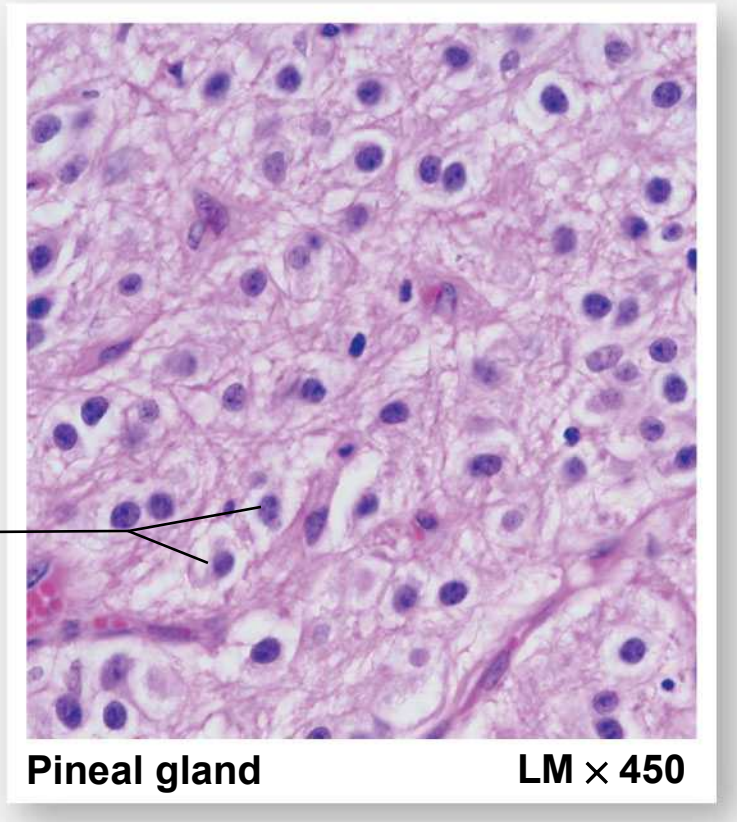
- The **Pineal Gland**
  - Lies in posterior portion of roof of third ventricle
  - Contains **pinealocytes**
    - Synthesize hormone **melatonin**

18-7 Pineal Gland

- Functions of Melatonin:
  - *Inhibits reproductive functions*
  - *Protects against damage by free radicals*
  - *Influences circadian rhythms*

Figure 18-15 The Pineal Gland





18-8 Pancreas

- The **Pancreas**
  - Lies between:
    - Inferior border of stomach
    - And proximal portion of small intestine
  - Contains exocrine and endocrine cells

18-8 Pancreas

- **Exocrine Pancreas**
  - Consists of clusters of gland cells called *pancreatic acini* and their attached ducts
  - Takes up roughly 99 percent of pancreatic volume
  - Gland and duct cells secrete alkaline, enzyme-rich fluid
    - That reaches the lumen of the digestive tract through a network of secretory ducts

18-8 Pancreas

- **Endocrine Pancreas**
  - Consists of cells that form clusters known as **pancreatic islets**, or *islets of Langerhans*
    1. **Alpha cells** produce glucagon
    2. **Beta cells** produce insulin
    3. **Delta cells** produce peptide hormone identical to GH–IH
    4. **F cells** secrete **pancreatic polypeptide (PP)**

Figure 18-16a The Endocrine Pancreas

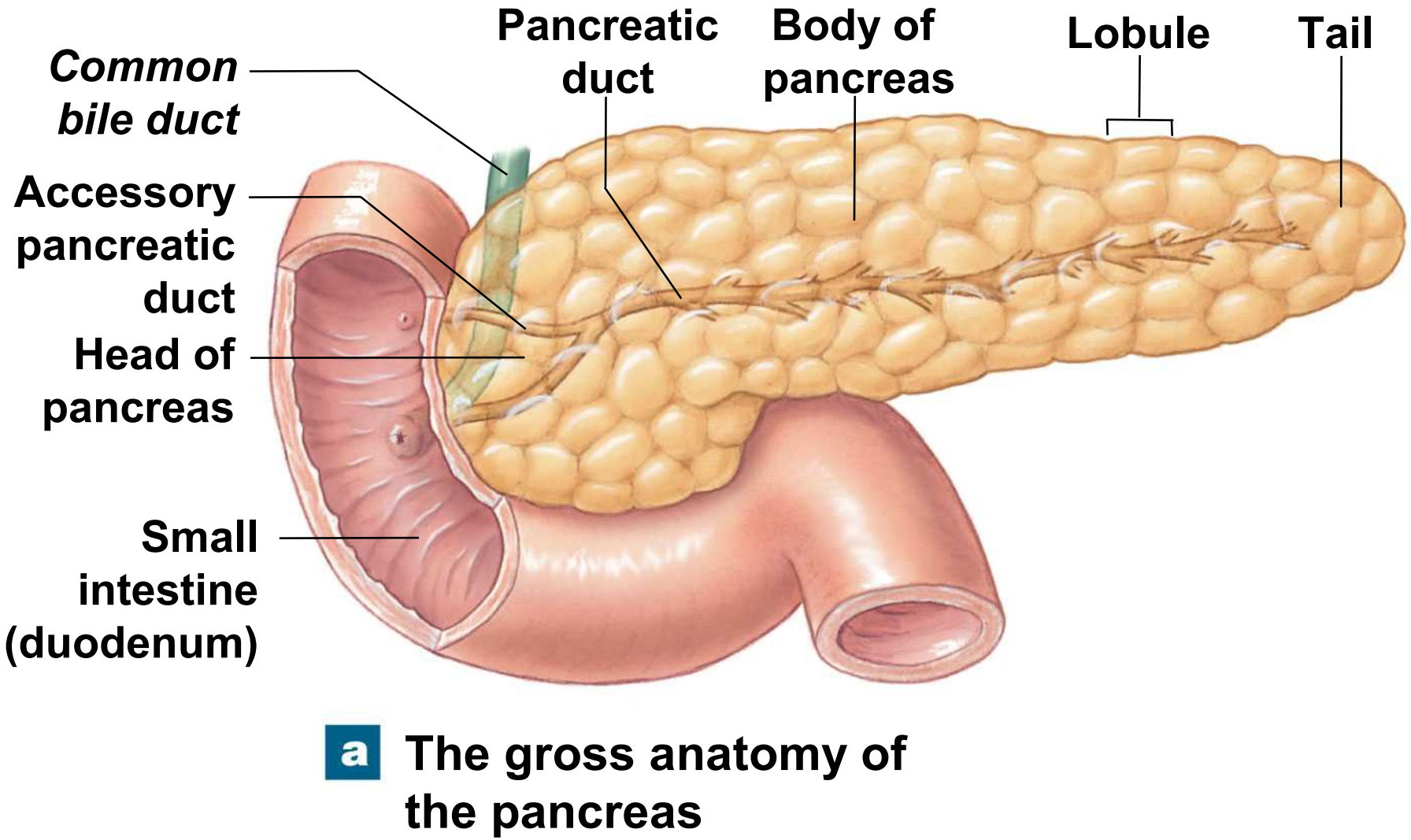
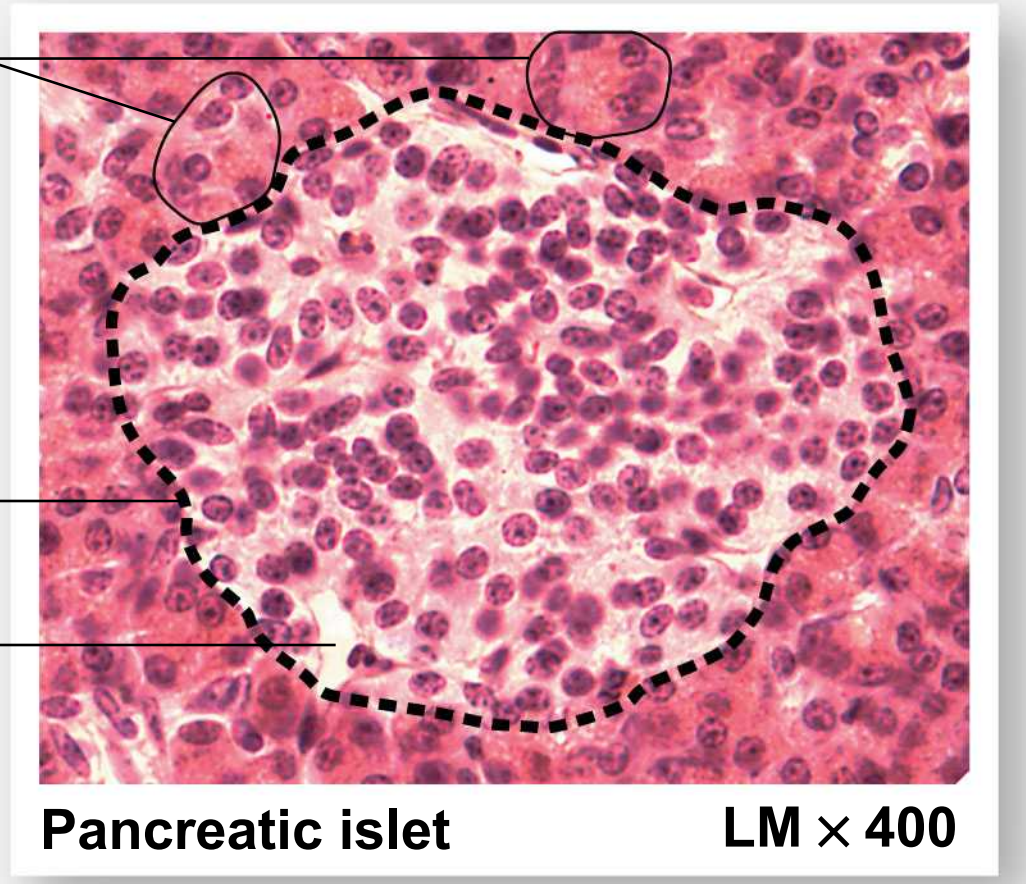


Figure 18-16b The Endocrine Pancreas



b A pancreatic islet surrounded by exocrine cells

18-8 Pancreas

- Blood Glucose Levels
  - When levels rise:
    - Beta cells secrete insulin, stimulating transport of glucose across plasma membranes
  - When levels decline:
    - Alpha cells release glucagon, stimulating glucose release by liver

Figure 18-17 The Regulation of Blood Glucose Concentrations

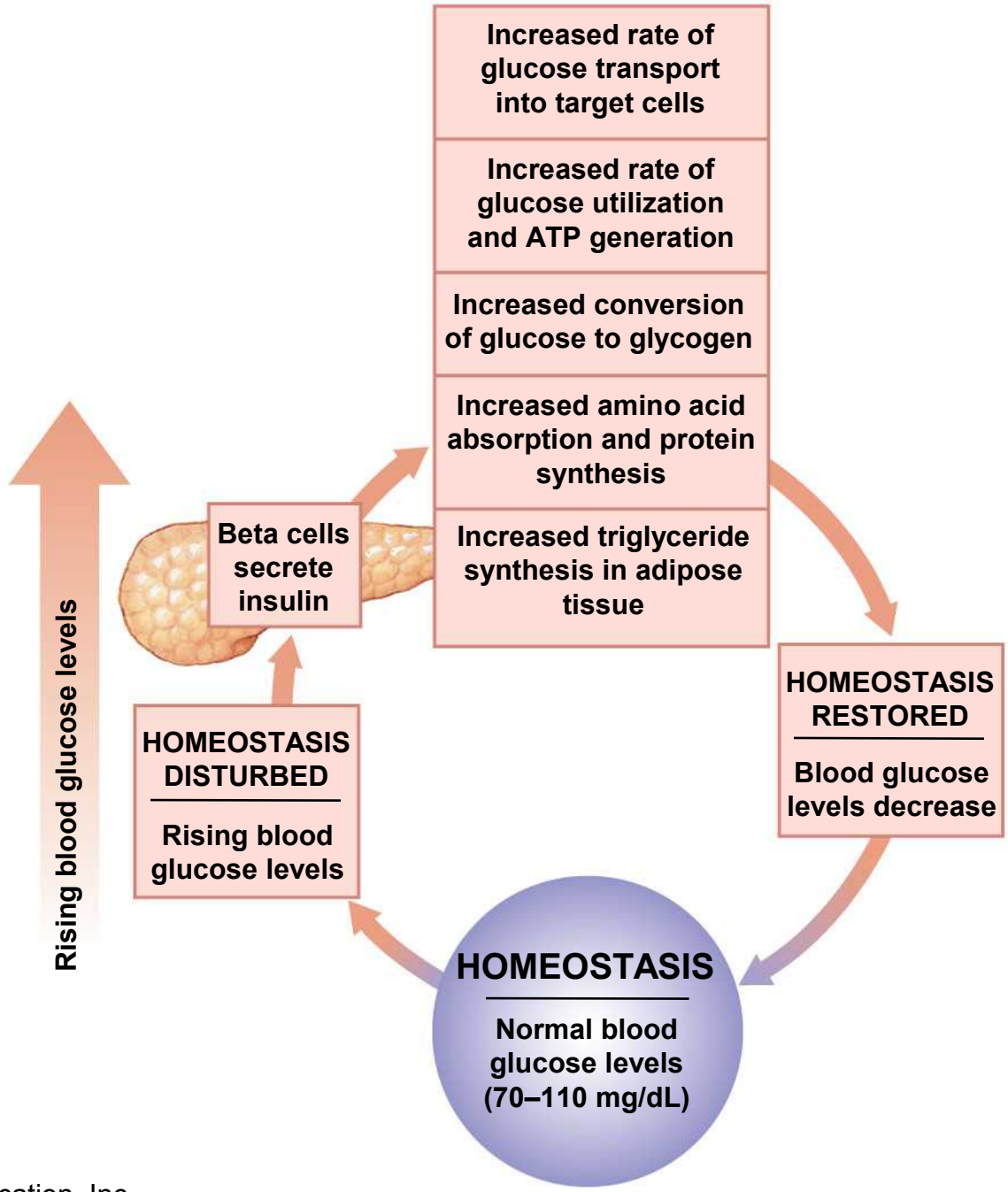
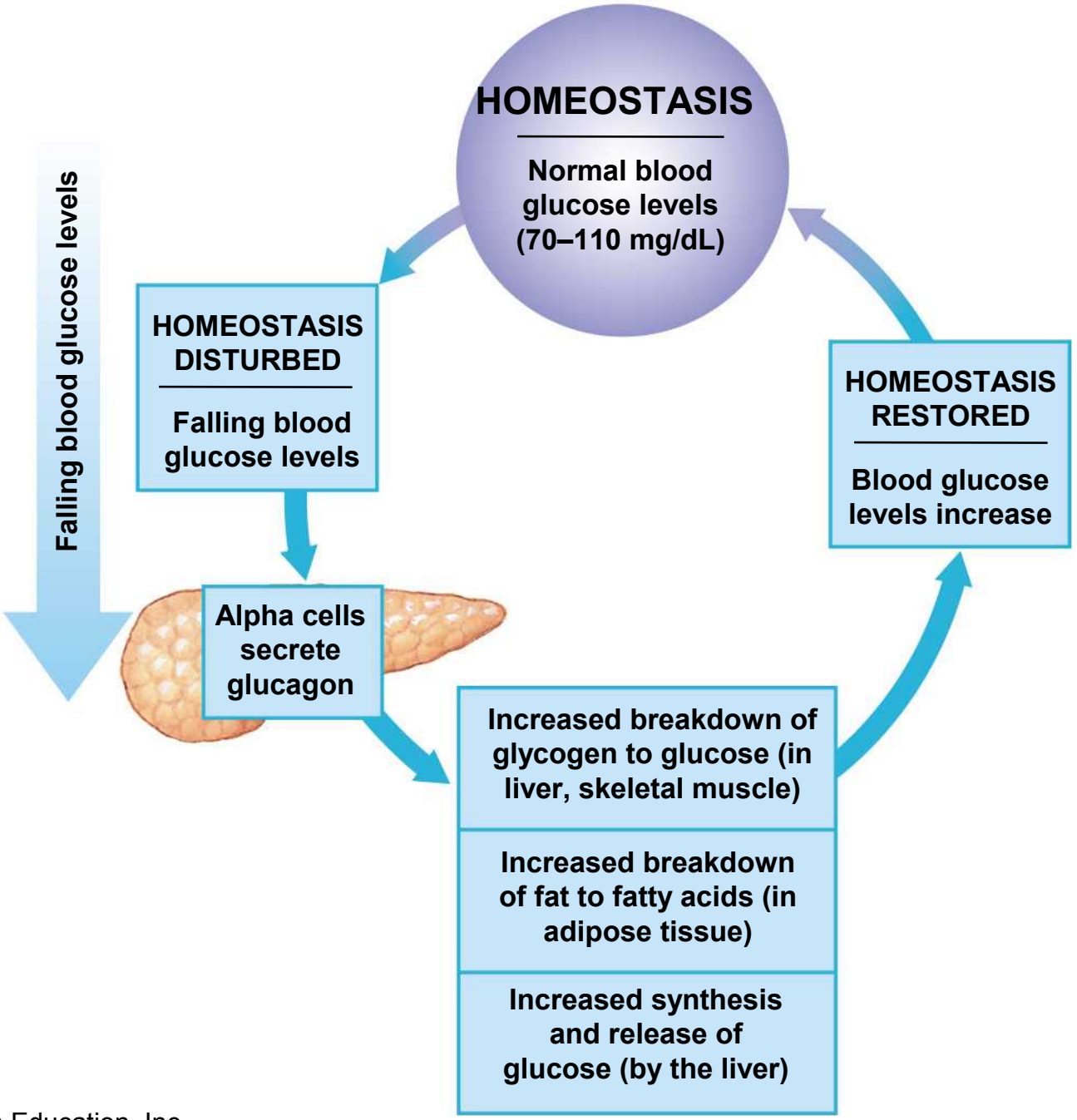


Figure 18-17 The Regulation of Blood Glucose Concentrations



18-8 Pancreas

- **Insulin**
  - Is a peptide hormone released by beta cells
  - Affects target cells
    - *Accelerates glucose uptake*
    - *Accelerates glucose utilization and enhances ATP production*
    - *Stimulates glycogen formation*
    - *Stimulates amino acid absorption and protein synthesis*
    - *Stimulates triglyceride formation in adipose tissue*

18-8 Pancreas

- Glucagon
  - Released by alpha cells
  - Mobilizes energy reserves
  - Affects target cells
    - *Stimulates breakdown of glycogen in skeletal muscle and liver cells*
    - *Stimulates breakdown of triglycerides in adipose tissue*
    - *Stimulates production of glucose in liver (gluconeogenesis)*

Table 18-6 Hormones Produced by the Pancreatic Islets

Table 18–6 Hormones Produced by the Pancreatic Islets

Structure/Cells	Hormone	Primary Targets	Hormonal Effect	Regulatory Control
PANCREATIC ISLETS				
Alpha cells	Glucagon	Liver, adipose tissue	Mobilizes lipid reserves; promotes glucose synthesis and glycogen breakdown in liver; elevates blood glucose concentrations	Stimulated by low blood glucose concentrations; inhibited by GH–IH from delta cells
Beta cells	Insulin	Most cells	Facilitates uptake of glucose by target cells; stimulates formation and storage of lipids and glycogen	Stimulated by high blood glucose concentrations, parasympathetic stimulation, and high levels of some amino acids; inhibited by GH–IH from delta cells and by sympathetic activation
Delta cells	GH–IH (somatostatin)	Other islet cells, digestive epithelium	Inhibits insulin and glucagon secretion; slows rates of nutrient absorption and enzyme secretion along digestive tract	Stimulated by protein-rich meal; mechanism unclear
F cells	Pancreatic polypeptide (PP)	Digestive organs	Inhibits gallbladder contraction; regulates production of pancreatic enzymes; influences rate of nutrient absorption by digestive tract	Stimulated by protein-rich meal and by parasympathetic stimulation

18-8 Pancreas

- **Diabetes Mellitus**
  - Is characterized by glucose concentrations high enough to overwhelm the reabsorption capabilities of the kidneys
    - **Hyperglycemia** = abnormally high glucose levels in the blood in general
    - **Glucose** appears in the urine, and urine volume generally becomes excessive **(polyuria)**

18-8 Pancreas

- Diabetes Mellitus
  - **Type 1 (insulin dependent) diabetes**
    - Is characterized by inadequate insulin production by the pancreatic beta cells
    - Persons with type 1 diabetes require insulin to live and usually require multiple injections daily, or continuous infusion through an insulin pump or other device
    - This form of diabetes accounts for only around 5% – 10% of cases; it often develops in childhood

18-8 Pancreas

- Diabetes Mellitus
  - **Type 2 (non-insulin dependent) diabetes**
    - Is the most common form of diabetes mellitus
    - Most people with this form of diabetes produce normal amounts of insulin, at least initially, but their tissues do not respond properly, a condition known as **insulin resistance**
    - Type 2 diabetes is associated with obesity
      - Weight loss through diet and exercise can be an effective treatment

18-8 Pancreas

- Diabetes Mellitus
  - Complications of untreated, or poorly managed diabetes mellitus include:
    - Kidney degeneration
    - Retinal damage
    - Early heart attacks
    - Peripheral nerve problems
    - Peripheral nerve damage

18-8 Pancreas

- Kidney Degeneration
  - **Diabetic nephropathy**
    - Degenerative changes in the kidneys, can lead to kidney failure
- Retinal Damage
  - **Diabetic retinopathy**
    - The proliferation of capillaries and hemorrhaging at the retina may cause partial or complete blindness

18-8 Pancreas

- Early Heart Attacks
  - Degenerative blockages in cardiac circulation can lead to early heart attacks
    - For a given age group, heart attacks are three to five times more likely in diabetic individuals than in nondiabetic people
- Peripheral Nerve Problems
  - Abnormal blood flow to neural tissues is probably responsible for a variety of neural problems with peripheral nerves, including abnormal autonomic function
    - These disorders are collectively termed **diabetic neuropathy**

18-8 Pancreas

- Peripheral Nerve Damage
  - Blood flow to the distal portions of the limbs is reduced, and peripheral tissues may suffer as a result
    - For example, a reduction in blood flow to the feet can lead to tissue death, ulceration, infection, and loss of toes or a major portion of one or both feet

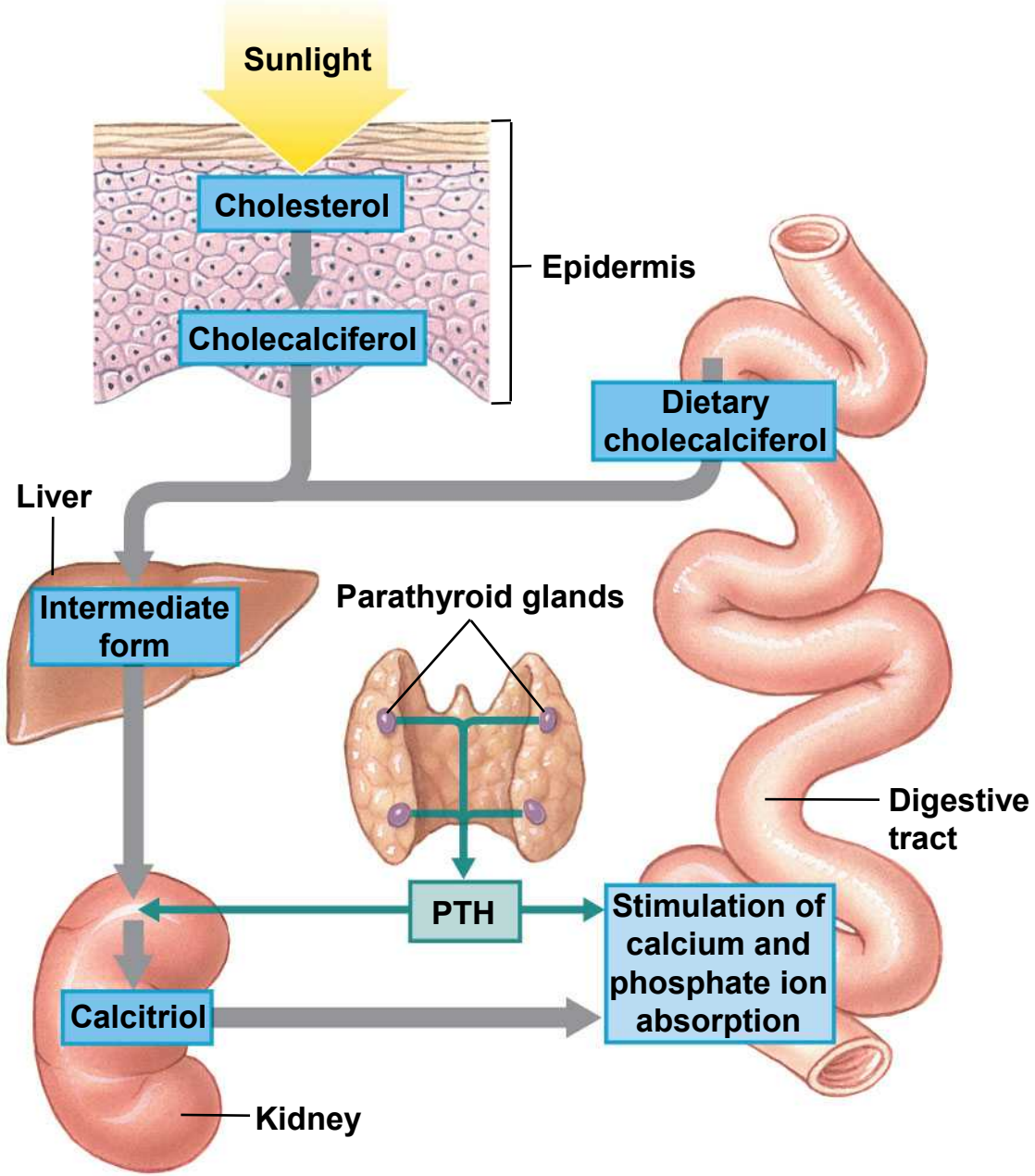
18-9 Endocrine Tissues of Other Systems

- Many Organs of Other Body Systems Have Secondary Endocrine Functions
  - Intestines (digestive system)
  - Kidneys (urinary system)
  - Heart (cardiovascular system)
  - Thymus (lymphatic system and immunity)
  - Gonads (reproductive system)

18-9 Endocrine Tissues of Other Systems

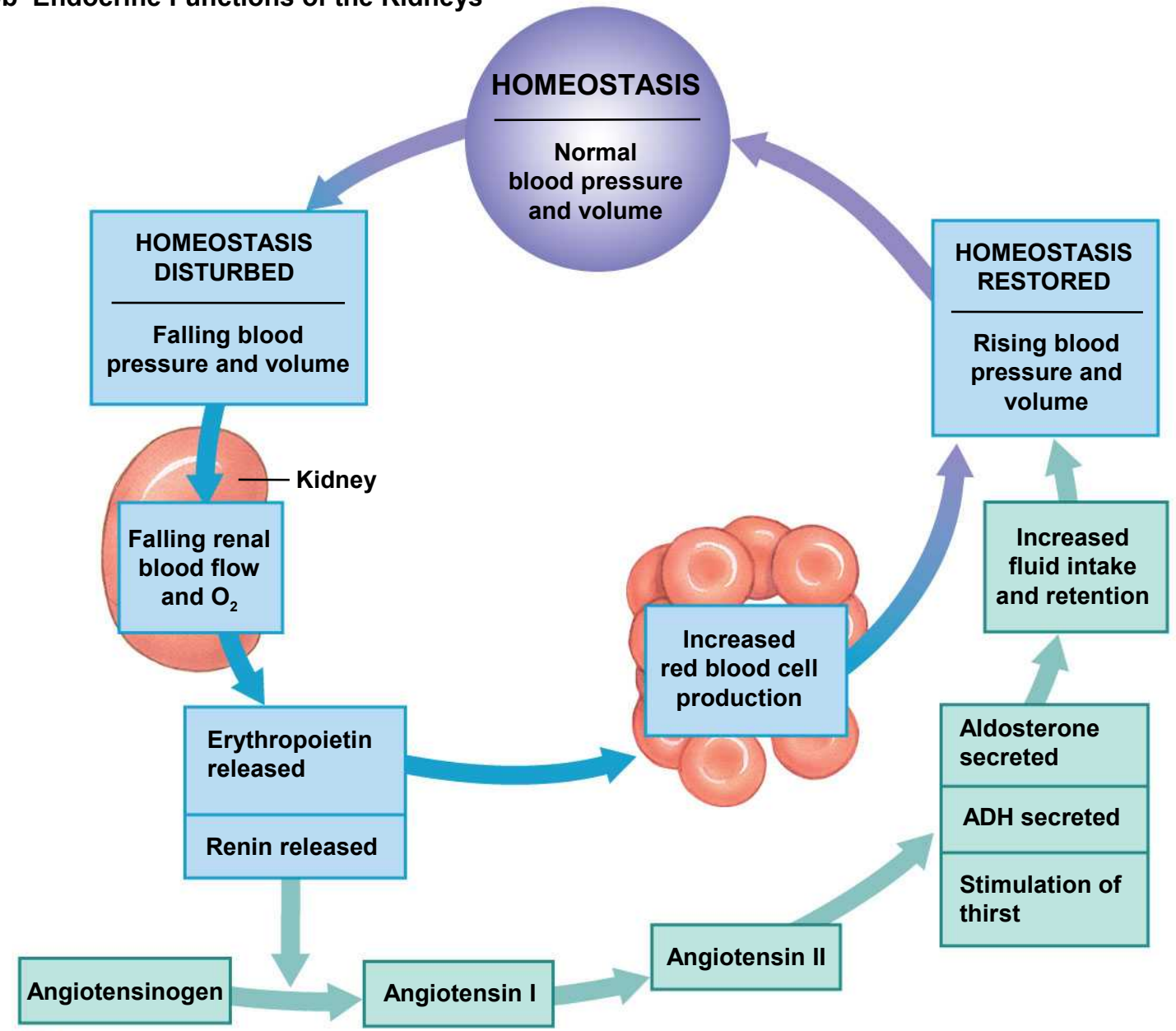
- The Intestines
  - Produce hormones important to coordination of digestive activities
- The Kidneys
  - Produce the hormones **calcitriol** and **erythropoietin (EPO)**
  - Produce the enzyme **renin**

Figure 18-19a Endocrine Functions of the Kidneys



a The production of calcitrol

Figure 18-19b Endocrine Functions of the Kidneys



b The release of renin and erythropoietin, and an overview of the renin–angiostensin system beginning with the activation of angiotensinogen by renin

18-9 Endocrine Tissues of Other Systems

- The Heart
  - Produces **natriuretic peptides** (*ANP* and *BNP*)
    - When blood volume becomes excessive
    - Action opposes angiotensin II
    - Resulting in reduction in blood volume and blood pressure

18-9 Endocrine Tissues of Other Systems

- The **Thymus**
  - Produces **thymosins** (blend of thymic hormones)
    - That help develop and maintain normal immune defenses

18-9 Endocrine Tissues of Other Systems

- The Gonads
  - Testes
    - Produce androgens in interstitial cells
      - **Testosterone** is the most important male hormone
    - Secrete **inhibin** in **nurse cells**
      - Support differentiation and physical maturation of sperm

18-9 Endocrine Tissues of Other Systems

- The Gonads
  - Ovaries
    - Produce **estrogens**
      - Principal estrogen is **estradiol**
    - After ovulation, follicle cells:
      - Reorganize into corpus luteum
      - Release estrogens and **progestins**, especially **progesterone**

Table 18-8 Hormones of the Reproductive System

Table 18–8	Hormones of the Reproductive System			
Structure/Cells	**Hormone**	**Primary Target**	**Hormonal Effect**	**Regulatory Control**
TESTES				
Interstitial cells	Androgens	Most cells	Support functional maturation of sperm, protein synthesis in skeletal muscles, male secondary sex characteristics, and associated behaviors	Stimulated by LH from the anterior lobe of the pituitary gland
Nurse cells	Inhibin	Pituitary gland	Inhibits secretion of FSH	Stimulated by FSH from the anterior lobe
OVARIES				
Follicular cells	Estrogens	Most cells	Support follicle maturation, female secondary sex characteristics, and associated behaviors	Stimulated by FSH and LH from the anterior lobe of the pituitary gland
	Inhibin	Pituitary gland	Inhibits secretion of FSH	Stimulated by FSH from anterior lobe
Corpus luteum	Progestins	Uterus, mammary glands	Prepare uterus for implantation; prepare mammary glands for secretory activity	Stimulated by LH from the anterior lobe of the pituitary gland

18-9 Endocrine Tissues of Other Systems

- Adipose Tissue Secretions
  - **Leptin**
    - Feedback control for appetite
    - Controls normal levels of GnRH, gonadotropin synthesis

Table 18-7 Representative Hormones Produced by Organs of Other Systems

Table 18–7 Representative Hormones Produced by Organs of Other Systems

Organ	Hormone	Primary Target	Hormonal Effect
Intestines	Many (secretin, gastrin, cholecystokinin, etc.)	Other regions and organs of the digestive system	Coordinate digestive activities
Kidneys	Erythropoietin (EPO) Calcitriol	Red bone marrow Intestinal lining, bone, kidneys	Stimulates red blood cell production Stimulates calcium and phosphate absorption; stimulates Ca^{+} release from bone; inhibits PTH secretion
Heart	Natriuretic peptides (ANP and BNP)	Kidneys, hypothalamus, adrenal gland	Increase water and salt loss at kidneys; decrease thirst; suppress secretion of ADH and aldosterone
Thymus	Thymosins (many)	Lymphocytes and other cells of the immune response	Coordinate and regulate immune response
Gonads	*See Table 18–8*		
Adipose tissues	Leptin	Hypothalamus	Suppression of appetite; permissive effects on GnRH and gonadotropin synthesis

18-10 Hormone Interactions

- Hormones Interact to Produce Coordinated Physiological Responses
  - When a cell receives instructions from two hormones at the same time, four outcomes are possible
    1. **Antagonistic effects -** opposing
    2. **Synergistic effects -** additive
    3. **Permissive effects -** one hormone is necessary for another to produce effect
    4. **Integrative effects -** hormones produce different and complementary results

18-10 Hormone Interactions

- Hormones Important to Growth
  - *Growth hormone (GH)*
  - *Thyroid hormones*
  - *Insulin*
  - *PTH and calcitriol*
  - *Reproductive hormones*

18-10 Hormone Interactions

- Growth Hormone (GH)
  - In children:
    - Supports muscular and skeletal development
  - In adults:
    - Maintains normal blood glucose concentrations
    - Mobilizes lipid reserves

18-10 Hormone Interactions

- Thyroid Hormones
  - If absent during fetal development or for first year:
    - Nervous system fails to develop normally
    - Mental retardation results
  - If T_4 concentrations decline before puberty:
    - Normal skeletal development will not continue

18-10 Hormone Interactions

- Insulin
  - Allows passage of glucose and amino acids across plasma membranes
- Parathyroid Hormone (PTH) and Calcitriol
  - Promote absorption of calcium salts for deposition in bone
  - Inadequate levels cause weak and flexible bones

18-10 Hormone Interactions

- Reproductive Hormones
  - Androgens in males, estrogens in females
  - Stimulate cell growth and differentiation in target tissues
  - Produce gender-related differences in:
    - Skeletal proportions
    - Secondary sex characteristics

Table 18-9 Clinical Implications of Endocrine Malfunctions

Table 18–9 Clinical Implications of Endocrine Malfunctions

Hormone	Underproduction or Tissue Insensitivity	Principal Signs and Symptoms	Overproduction or Tissue Hypersensitivity	Principal Signs and Symptoms
Growth hormone (GH)	Pituitary growth failure	Retarded growth, abnormal fat distribution, low blood glucose hours after a meal	Gigantism, acromegaly	Excessive growth
Antidiuretic hormone (ADH) or vasopressin (VP)	Diabetes insipidus	Polyuria, dehydration, thirst	SIADH (syndrome of inappropriate ADH secretion)	Increased body weight and water content
Thyroxine (T_4), triiodothyronine (T_3)	Myxedema, cretinism	Low metabolic rate; low body temperature; impaired physical and mental development	Hyperthyroidism, Graves disease	High metabolic rate and body temperature
Parathyroid hormone (PTH)	Hypoparathyroidism	Muscular weakness, neurological problems, formation of dense bones, tetany due to low blood Ca^{2+} concentrations	Hyperparathyroidism	Neurological, mental, muscular problems due to high blood Ca^{2+} concentrations; weak and brittle bones
Insulin	Diabetes mellitus (type 1)	High blood glucose, impaired glucose utilization, dependence on lipids for energy; glycosuria	Excess insulin production or administration	Low blood glucose levels, possibly causing coma

Table 18-9 Clinical Implications of Endocrine Malfunctions

Table 18–9 Clinical Implications of Endocrine Malfunctions

Hormone	Underproduction or Tissue Insensitivity	Principal Signs and Symptoms	Overproduction or Tissue Hypersensitivity	Principal Signs and Symptoms
Mineralocorticoids (MCs)	Hypoaldosteronism	Polyuria, low blood volume, high blood K^+, low blood Na^+ concentrations	Aldosteronism	Increased body weight due to Na^+ and water retention; low blood K^+ concentration
Glucocorticoids (GCs)	Addison's disease	Inability to tolerate stress, mobilize energy reserves, or maintain normal blood glucose concentrations	Cushing's disease	Excessive breakdown of tissue proteins and lipid reserves; impaired glucose metabolism
Epinephrine (E), norepinephrine (NE)	None identified		Pheochromocytoma	High metabolic rate, body temperature, and heart rate; elevated blood glucose levels
Estrogens (females)	Hypogonadism	Sterility, lack of secondary sex characteristics	Adrenogenital syndrome	Overproduction of androgens by zona reticularis of adrenal cortex leads to masculinization
			Precocious puberty	Premature sexual maturation and related behavioral changes
Androgens (males)	Hypogonadism	Sterility, lack of secondary sex characteristics	Adrenogenital syndrome (gynecomastia)	Abnormal production of estrogen, sometimes due to adrenal or interstitial cell tumors; leads to breast enlargement
			Precocious puberty	Premature sexual maturation and related behavioral changes

18-10 Hormone Interactions

- The Hormonal Responses to Stress
  - **General Adaptation Syndrome (GAS)**
    - Also called **stress response**
    - How body responds to stress-causing factors
    - Is divided into three phases
      1. *Alarm phase*
      2. *Resistance phase*
      3. *Exhaustion phase*

Figure 18-20 The General Adaptation Syndrome

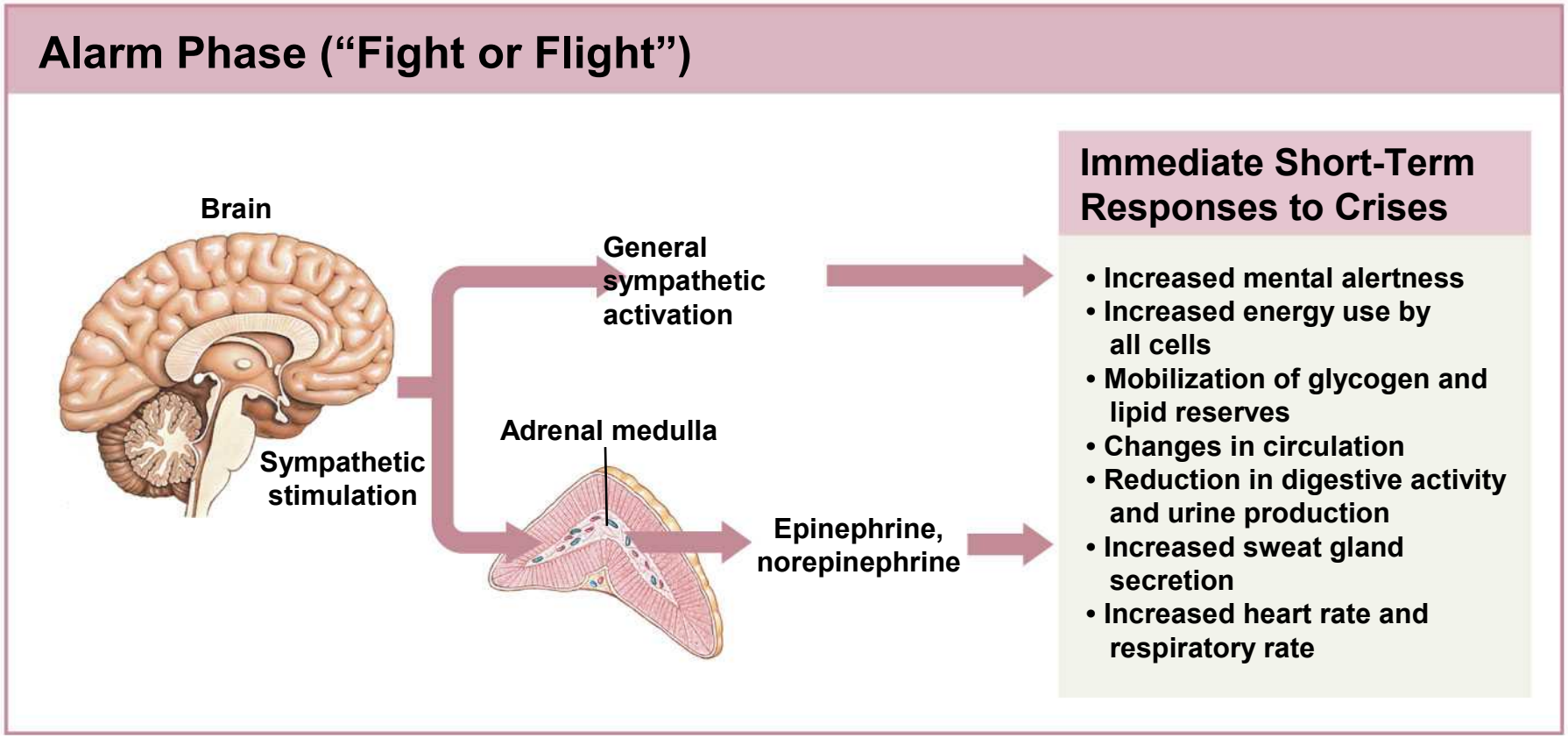


Figure 18-20 The General Adaptation Syndrome

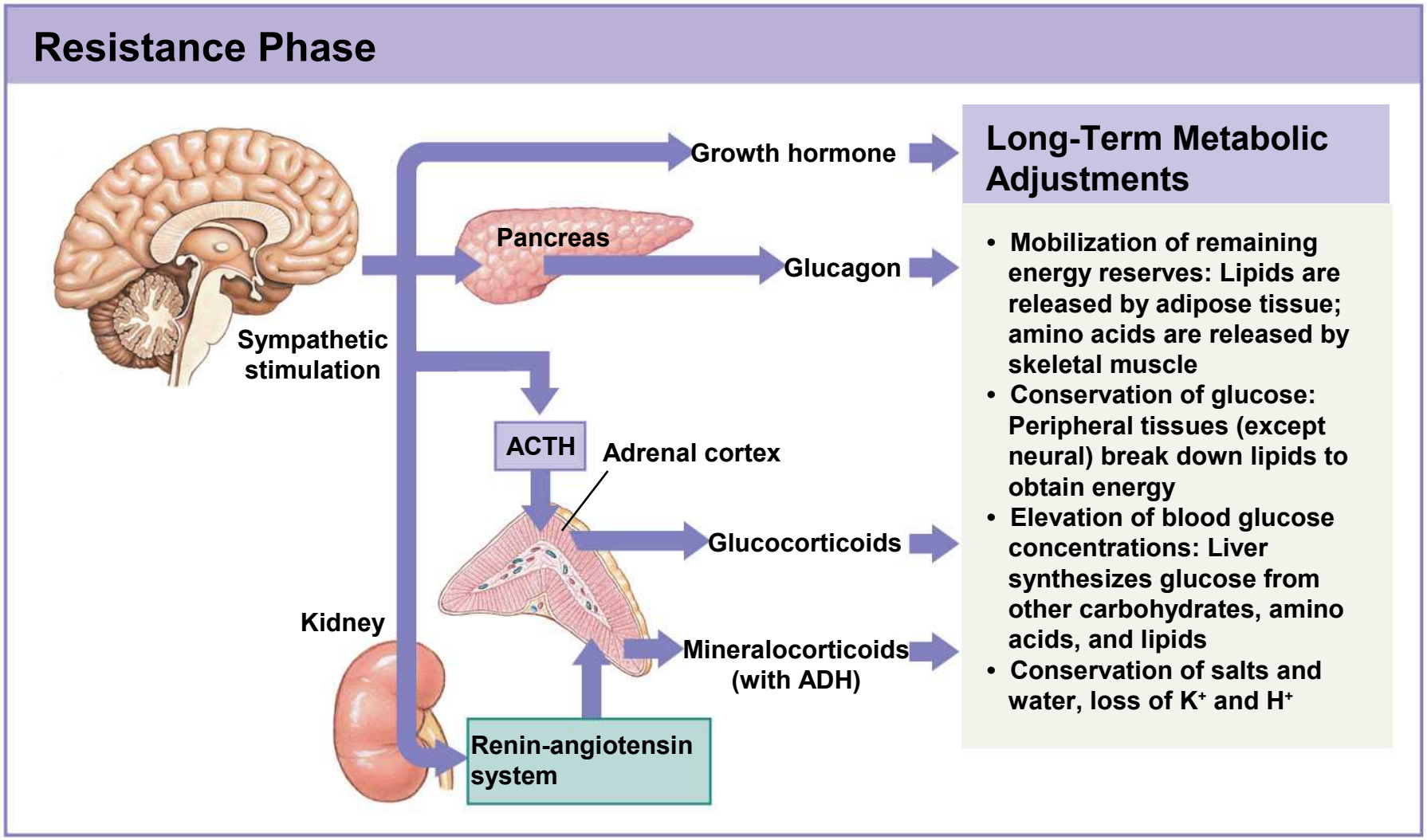


Figure 18-20 The General Adaptation Syndrome

Exhaustion Phase

Collapse of Vital Systems

- Exhaustion of lipid reserves
- Cumulative structural or functional damage to vital organs
- Inability to produce glucocorticoids
- Failure of electrolyte balance

18-10 Hormone Interactions

- The Effects of Hormones on Behavior
  - Hormone changes
    - Can alter intellectual capabilities, memory, learning, and emotional states
    - Affect behavior when endocrine glands are over-secreting or under-secreting

18-10 Hormone Interactions

- Aging and Hormone Production
  - Causes few functional changes
  - Decline in concentration of:
    - Growth hormone
    - Reproductive hormones

Figure 18-21 System Integrator: The Endocrine System