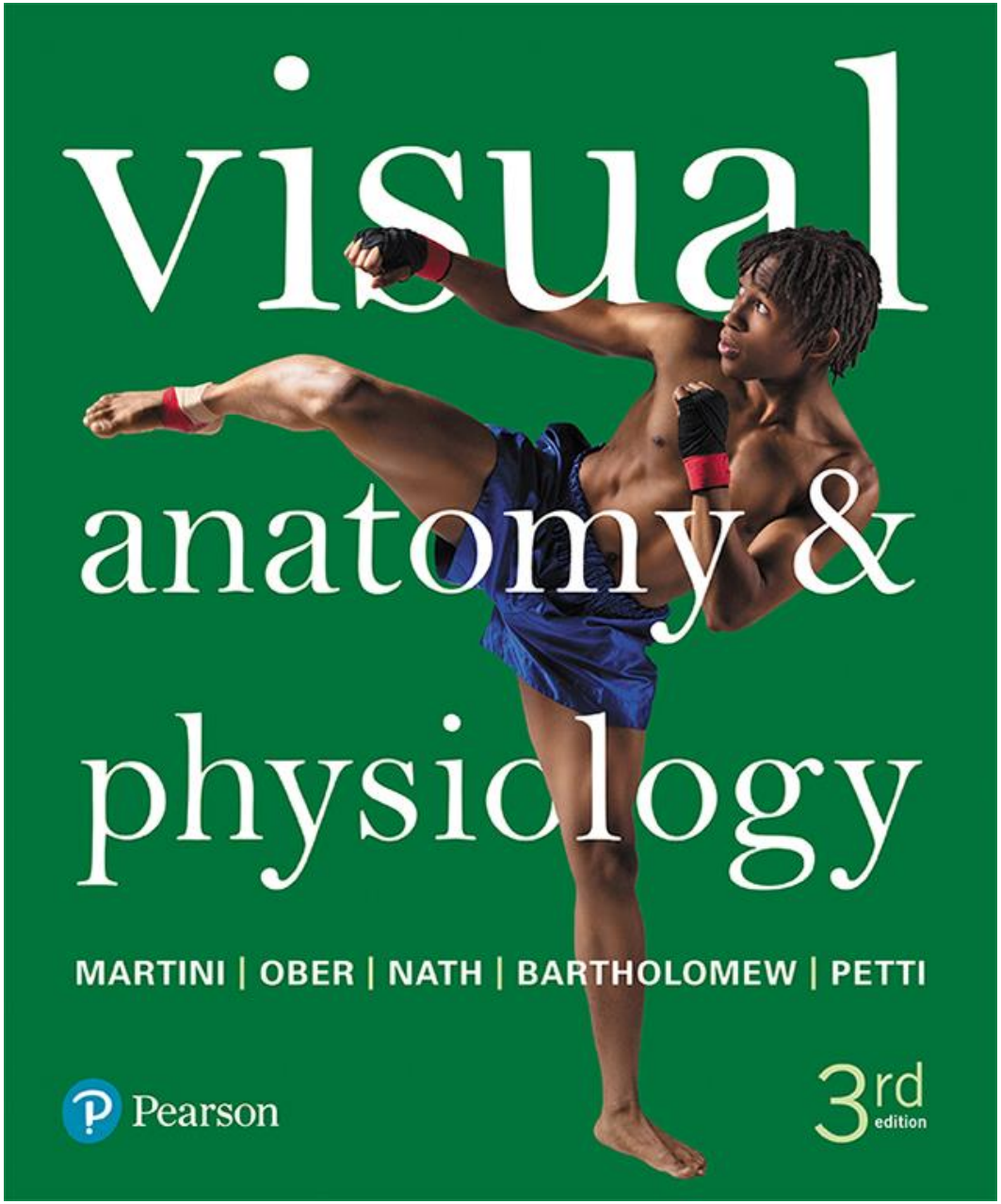


16

The Endocrine System

Lecture Presentation by
Lori Garrett

Section 1: Hormones and Intercellular Communication

Learning Outcomes

16.1 Describe the similarities between the endocrine and nervous systems and their specific modes of intercellular communication.

16.2 Explain the chemical classification of hormones.

16.3 Identify the organs and tissues of the endocrine system and the key functions of the hormones they secrete.

16.4 Explain the general mechanisms of hormonal action.

Section 1: Hormones and Intercellular Communication

Learning Outcomes (continued)

16.5 Describe how the hypothalamus controls endocrine organs.

16.6 Describe the location and structure of the pituitary gland, and identify pituitary hormones and their functions.

16.7 Describe the role of negative feedback in the functional relationship between the hypothalamus and the pituitary gland.

Section 1: Hormones and Intercellular Communication

Learning Outcomes (continued)

16.8 Describe the location and structure of the thyroid gland, identify the hormones it produces, and specify the functions of those hormones.

16.9 Describe the location of the parathyroid glands, and identify the functions of the hormone they produce.

16.10 Describe the location, structure, and functions of the adrenal glands, identify the hormones produced, and specify the functions of each hormone.

Section 1: Hormones and Intercellular Communication

Learning Outcomes (continued)

16.11 Describe the location and structure of the pancreas, identify the hormones it produces, and specify the functions of those hormones.

16.12 Describe the location of the pineal gland, and identify the functions of the hormone that it produces.

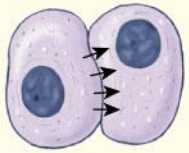
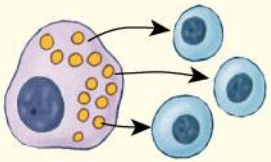
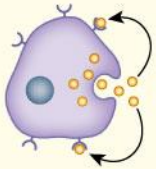
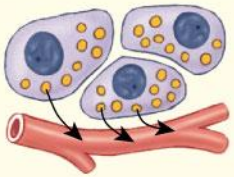
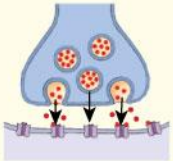
16.13 **Clinical Module**: Explain diabetes mellitus: its types, clinical manifestations, and treatments.

Module 16.1: The nervous and endocrine systems release chemical messengers that bind to target cells

Similarities

- Both systems rely on the release of chemicals that bind to specific receptors on their target cells
- They share many chemical messengers
  - Called neurotransmitters in the nervous system
  - Called **hormones** in the endocrine system
- Both regulated primarily by negative feedback mechanisms
- Common goal of both is to preserve homeostasis by coordinating and regulating other cells, tissues, organs, and systems

Mechanisms of Intercellular Communication

Mechanisms of Intercellular Communication			
Mechanism	**Transmission**	**Chemical Signals**	**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	Paracrines	Primarily limited to the local area, where paracrine concentrations are relatively high; target cells must have appropriate receptors (see Modules 3.3, 11.8)
Autocrine communication 	Through extracellular fluid	Autocrines	Limited to the cell that secretes the chemical signal
Endocrine communication 	Through the bloodstream	Hormones	Target cells are mainly in other distant tissues and organs and must have appropriate receptors
Synaptic communication 	Across synapses	Neurotransmitters	Limited to very specific area; target cells must have appropriate receptors

Similarities between the Nervous and Endocrine Systems

Similarities between the Nervous and Endocrine Systems

- Both systems rely on the release of chemicals that bind to specific receptors on their target cells.
- The two systems share many chemical messengers; for example, norepinephrine and epinephrine are called hormones when released into the bloodstream, but they are called neurotransmitters when released across synapses.
- Both systems are regulated primarily by negative feedback control mechanisms.
- The two systems share a common goal: to preserve homeostasis by coordinating and regulating the activities of other cells, tissues, organs, and systems.

Module 16.1: Review

A. What is the common goal of the nervous and endocrine systems?

Learning Outcome: Describe the similarities between the endocrine and nervous systems and their specific modes of intercellular communication.

Module 16.2: Hormones may be amino acid derivatives, peptides, or lipid derivatives

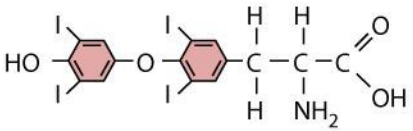
Groups based on chemical structure

1. **Amino acid derivatives**
   1) Thyroid hormones
      - Produced by the thyroid gland
   2) **Catecholamines**
      - Includes epinephrine, norepinephrine, and dopamine
   3) Tryptophan derivatives
      - Melatonin
        - Secreted by the pineal gland

Hormone classes

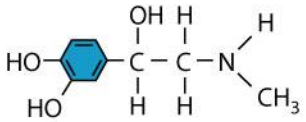
Amino Acid Derivatives

Thyroid Hormones



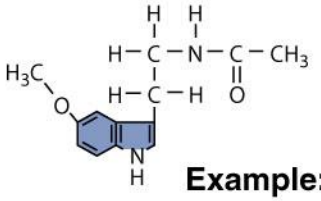
Example: Thyroxine (T_4)

Catecholamines



Example: Epinephrine

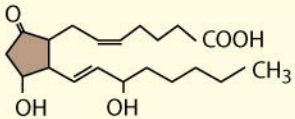
Tryptophan Derivatives



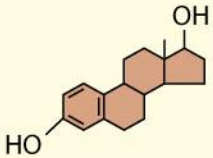
Example: Melatonin

Peptide Hormones

Lipid Derivatives



Eicosanoids Example: Prostaglandin E



Steroid Hormones Example: Estrogen

Module 16.2: Hormone classes

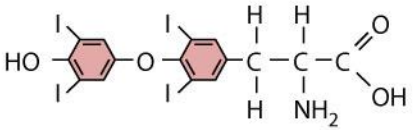
Groups based on chemical structure (continued)

2. **Peptide hormones**
   - Include most hormones of body
   - Synthesized as **prohormones**
     - Inactive precursor molecules that are converted to active form
   - Range from short polypeptide chains of amino acids (such as ADH and oxytocin) to small proteins (such as insulin, GH, and prolactin)
   - Glycoproteins may also function as hormones
     - Polypeptides with carbohydrate side chains
     - *Examples:* TSH, LH, FSH

Hormone classes

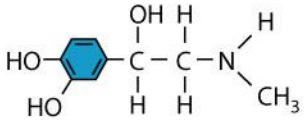
Amino Acid Derivatives

Thyroid Hormones



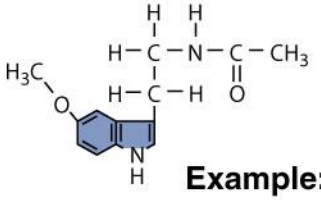
Example: Thyroxine (T_4)

Catecholamines



Example: Epinephrine

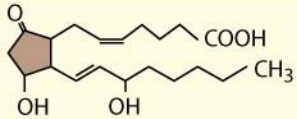
Tryptophan Derivatives



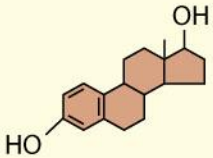
Example: Melatonin

Peptide Hormones

Lipid Derivatives



Eicosanoids Example: Prostaglandin E



Steroid Hormones Example: Estrogen

Module 16.2: Hormone classes

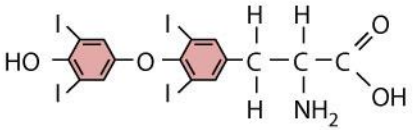
Groups based on chemical structure (continued)

3. **Lipid derivatives**
   - Consist of carbon rings and side chains built from either fatty acids (eicosanoids) or cholesterol (steroid molecules)
   - **Eicosanoids**
     - Important paracrine factors that coordinate cellular activities and enzymatic processes (such as blood clotting) in extracellular fluids
       - **Leukotrienes** (secondary roles as hormones)
       - **Prostaglandins** (involved primarily in coordinating local cellular activities)

Hormone classes

Amino Acid Derivatives

Thyroid Hormones



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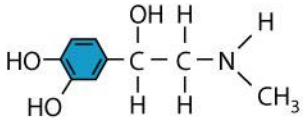
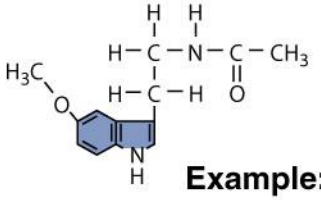
Catecholamines



Example: Epinephrine

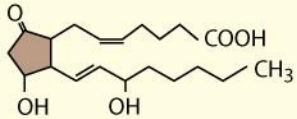
Tryptophan Derivatives



Example: Melatonin

Peptide Hormones

Lipid Derivatives



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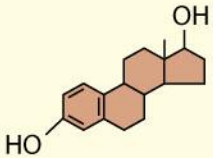


Steroid Hormones Example: Estrogen

Module 16.2: Hormone classes

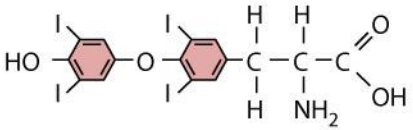
Groups based on chemical structure (continued)

3. **Lipid derivatives** (continued)
   - **Steroid hormones**
     - Released by:
       - Reproductive organs (androgens by testes in males; estrogen and progesterone by ovariesin females)
       - Adrenal gland (corticosteroids)
       - Kidneys (calcitriol)
     - Bound to specific transport proteins in blood
       - Remain in circulation longer than peptide hormones

Hormone classes

Amino Acid Derivatives

Thyroid Hormones



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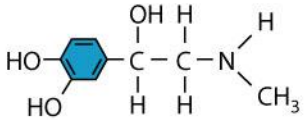
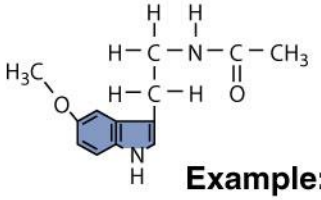


Example: Epinephrine

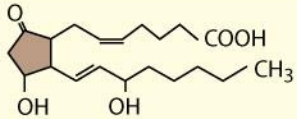
Tryptophan Derivatives



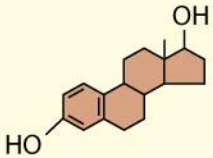
Example: Melatonin

Peptide Hormones

Lipid Derivatives



Eicosanoids Example: Prostaglandin E



Steroid Hormones Example: Estrogen

Module 16.2: Review

A. Describe the structural classification of hormones.

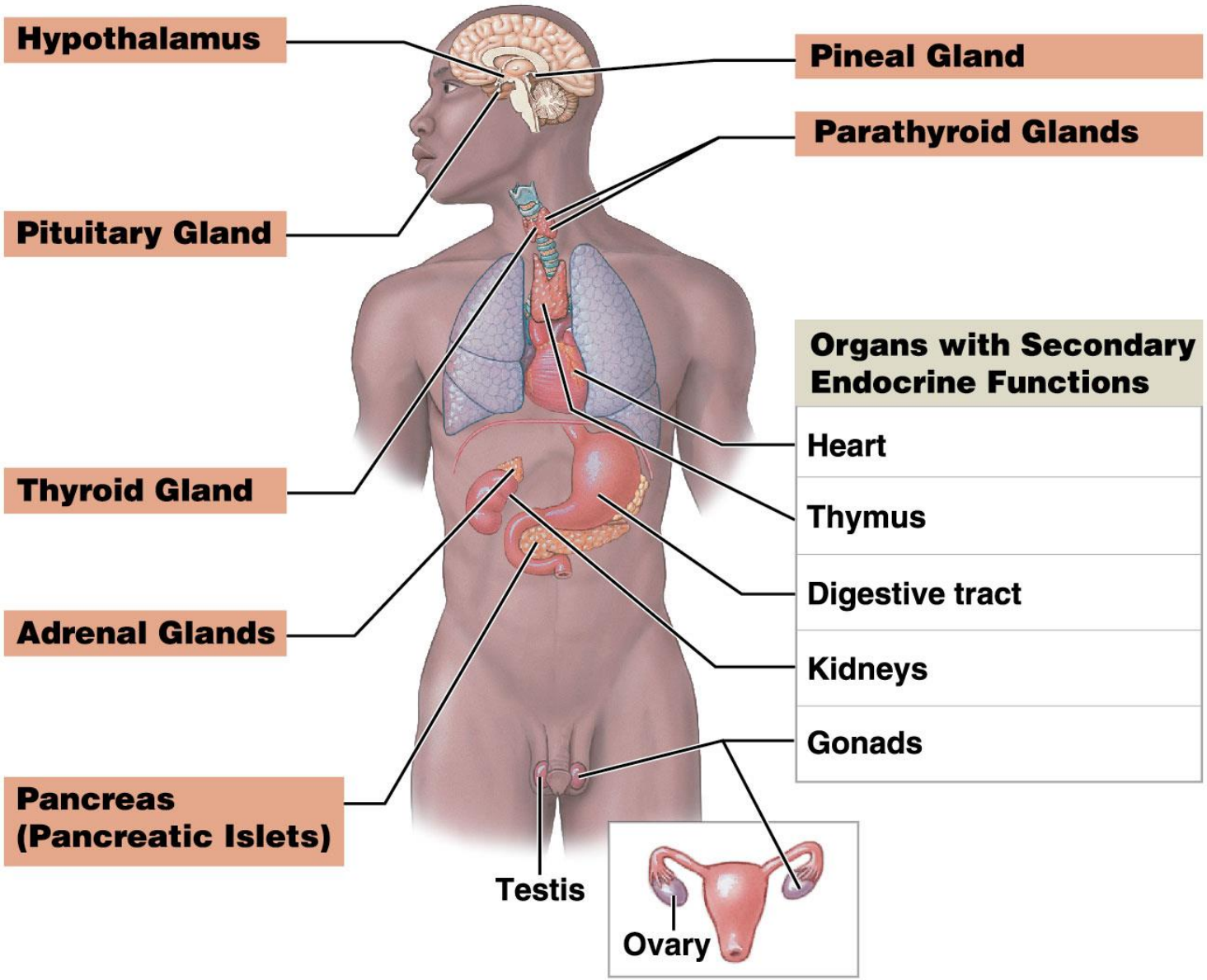
Learning Outcome: Explain the chemical classification of hormones.

Module 16.3: The endocrine system includes organs and tissues with primary and secondary hormone-secreting roles

Endocrine system overview

- Includes those organs whose primary function is the production of hormones or paracrines
  - Hypothalamus, pituitary gland, thyroid gland, adrenal gland, pancreas (pancreatic islets), pineal gland, parathyroid glands
- Many other organs contain tissues that secrete hormones, but endocrine function is secondary
  - Heart, thymus, digestive tract, kidneys, and gonads

The endocrine system

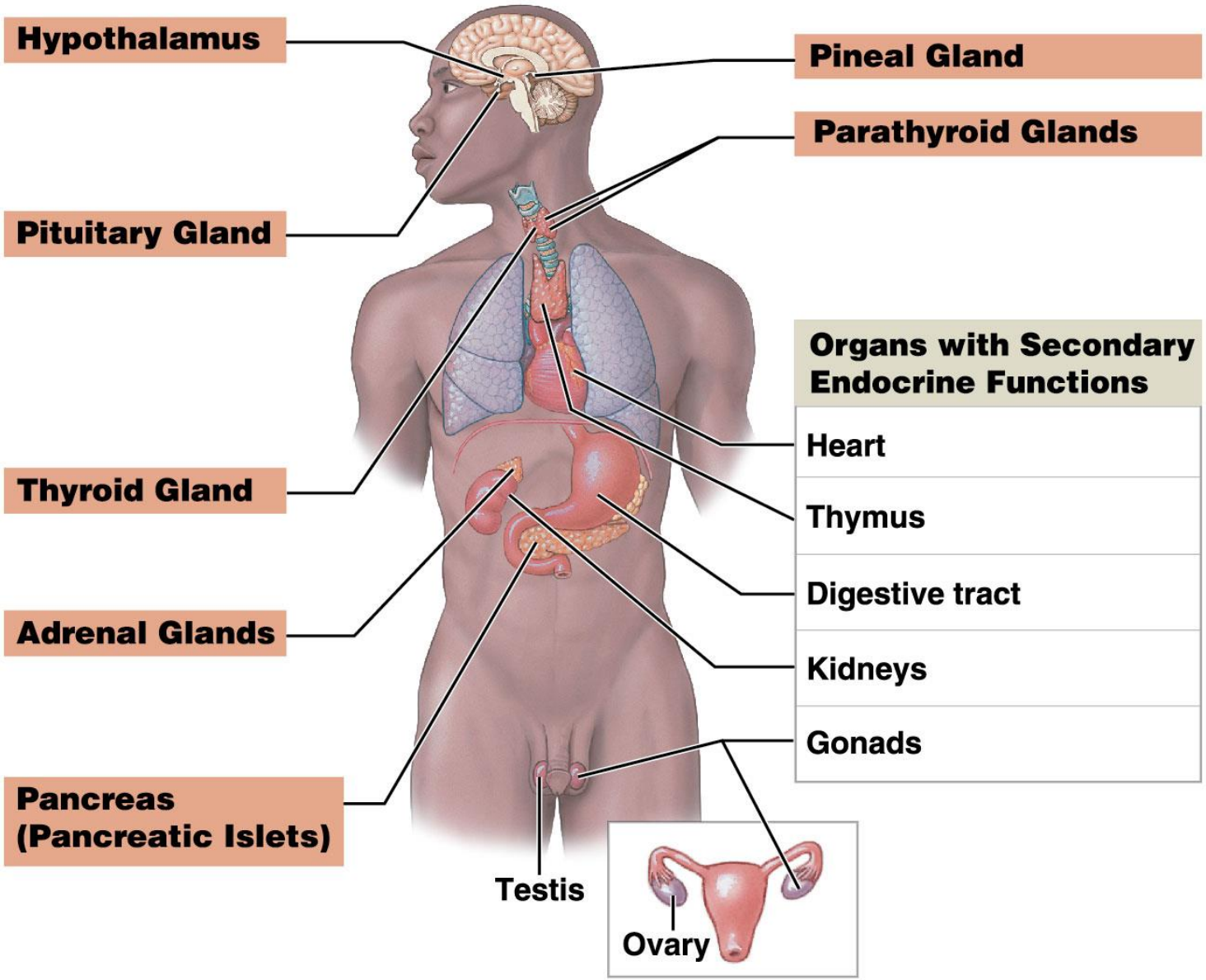


Module 16.3: The endocrine system

Endocrine system overview (continued)

- **Hypothalamus**
  - Secretes hormones involved in fluid balance, smooth muscle contraction, control of hormone secretion by anterior pituitary gland
- **Pituitary gland**
  - Secretes multiple hormones that regulate the endocrine activities of the adrenal cortex, thyroid gland, and reproductive organs, and a hormone that stimulates melanin production

The endocrine system

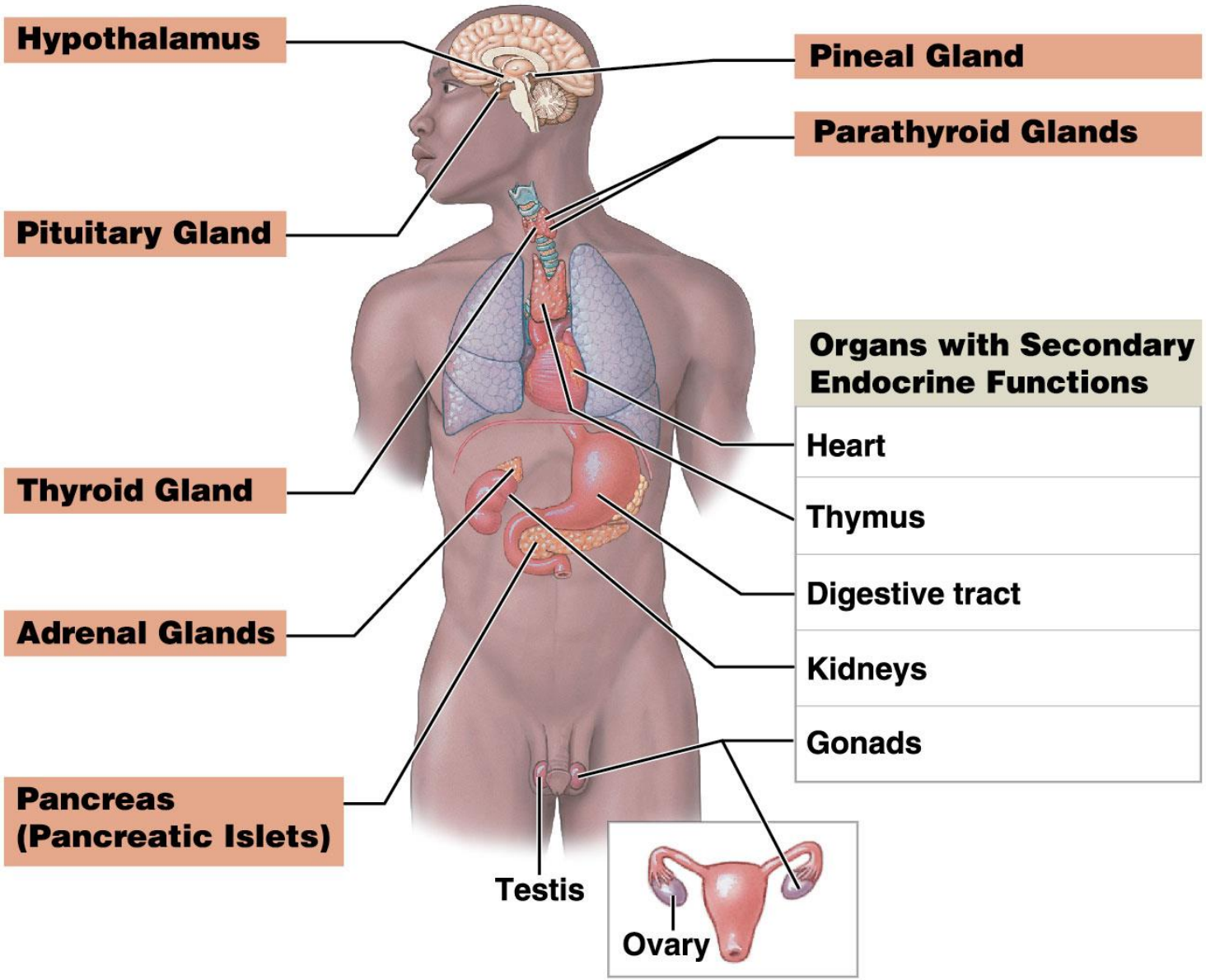


Module 16.3: The endocrine system

Endocrine system overview (continued)

- **Thyroid gland**
  - Secretes hormones affecting metabolic rate and calcium ion levels in body fluids
- **Adrenal glands**
  - The two adrenal glands secrete hormones involved with mineral balance, metabolic control, and resistance to stress
  - They also release epinephrine and norepinephrine during sympathetic activation

The endocrine system



Module 16.3: The endocrine system

Endocrine system overview (continued)

- **Pancreas (pancreatic islets)**
  - Secretes hormones regulating rate of glucose uptake and utilization by body tissues
- **Pineal gland**
  - Secretes melatonin, which affects reproductive function and circadian (day/night) rhythms
- **Parathyroid glands**
  - Secrete hormone important to regulation of calcium ion levels in body fluids

Module 16.3: The endocrine system

Endocrine system overview (continued)

- Other organs with endocrine function and what their hormones regulate
  - Heart—blood volume
  - Thymus—immune response
  - Digestive tract—digestive function coordination, glucose metabolism, appetite
  - Kidneys—blood cell production, rate of calcium and phosphorus absorption by digestive tract, and an enzyme involved in regulating blood pressure
  - Gonads—growth, metabolism, sexual characteristics as well as activities of organs in reproductive system

Module 16.3: Review

A. Define *endocrine system.*
B. Name the organs of the endocrine system.

Learning Outcome: Identify the organs and tissues of the endocrine system and the key functions of the hormones they secrete.

Module 16.4: Hormones affect target cells after binding to receptors in the plasma membrane, cytoplasm, or nucleus

Hormones and receptors

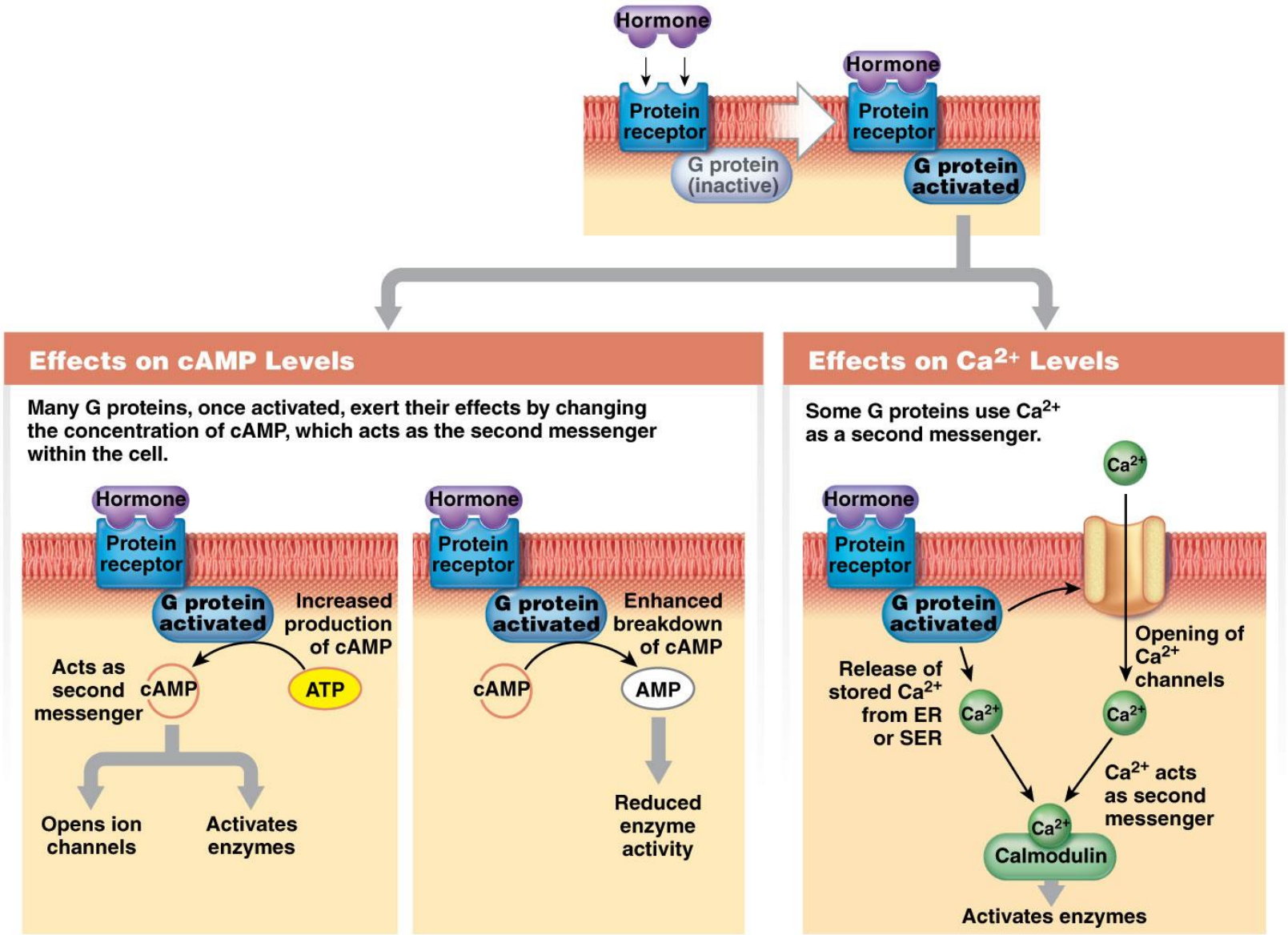
- To respond to a hormone, a target cell must have the appropriate protein *receptor*
  - Without the receptor, the circulating hormone has no effect
- Cells have receptors for many different hormones
  - Different combinations of receptors produce differential effects on specific tissues

Module 16.4: Hormone binding

Two possible receptor locations on target cells

1. Receptor in plasma membrane (extracellular receptors)
   - Receptors for catecholamines and peptide hormones, and most eicosanoids
   - Act as **first messenger**, relaying message to an intracellular intermediary (**second messenger**)
   - **Second messenger** then affects enzyme activity and changes cellular metabolic reactions, exerting hormone's effects in the cell
   - Generally involves a **G protein** (enzyme complex coupled to receptor)

G protein–coupled receptors

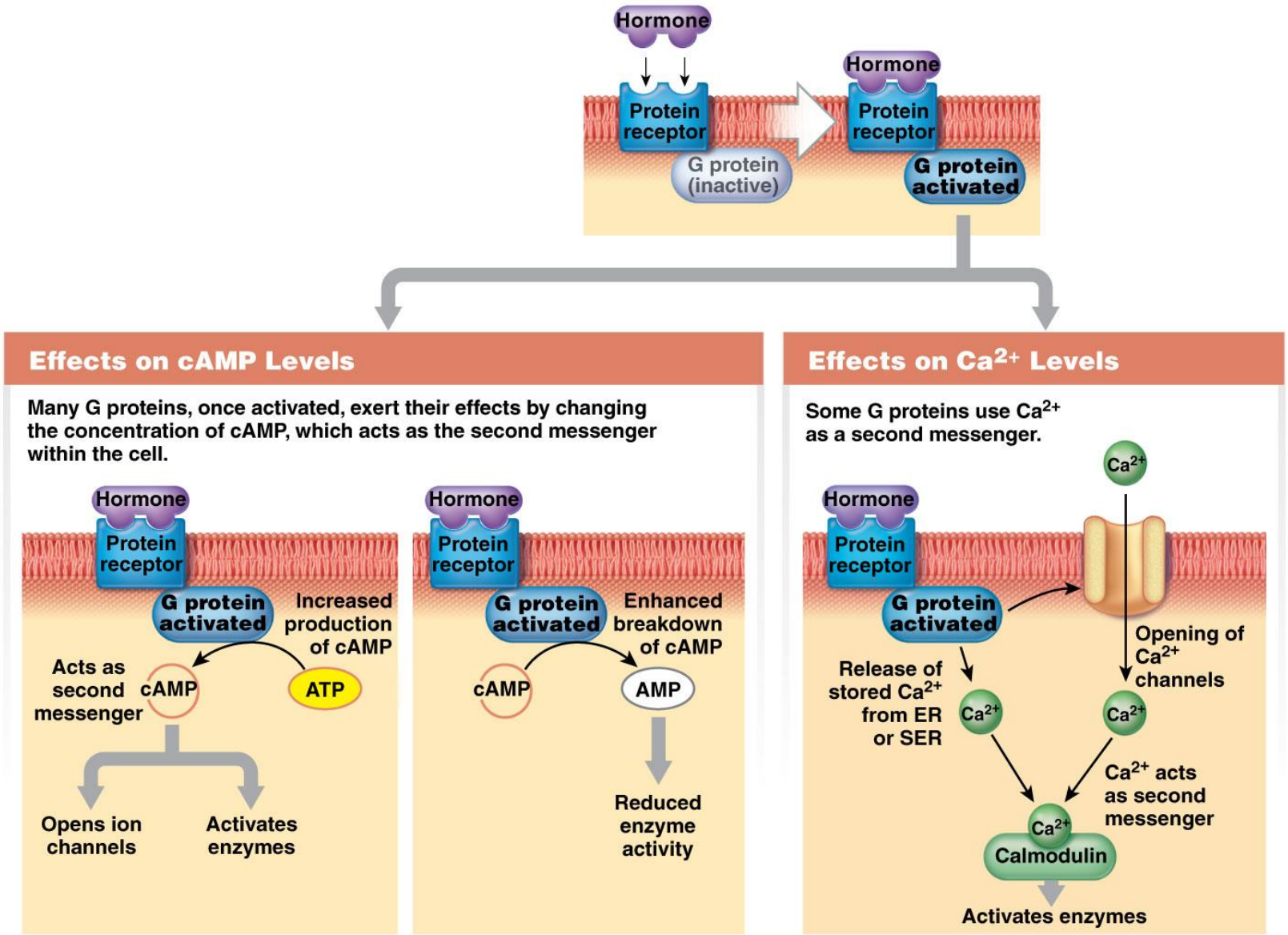


Module 16.4: Hormone binding

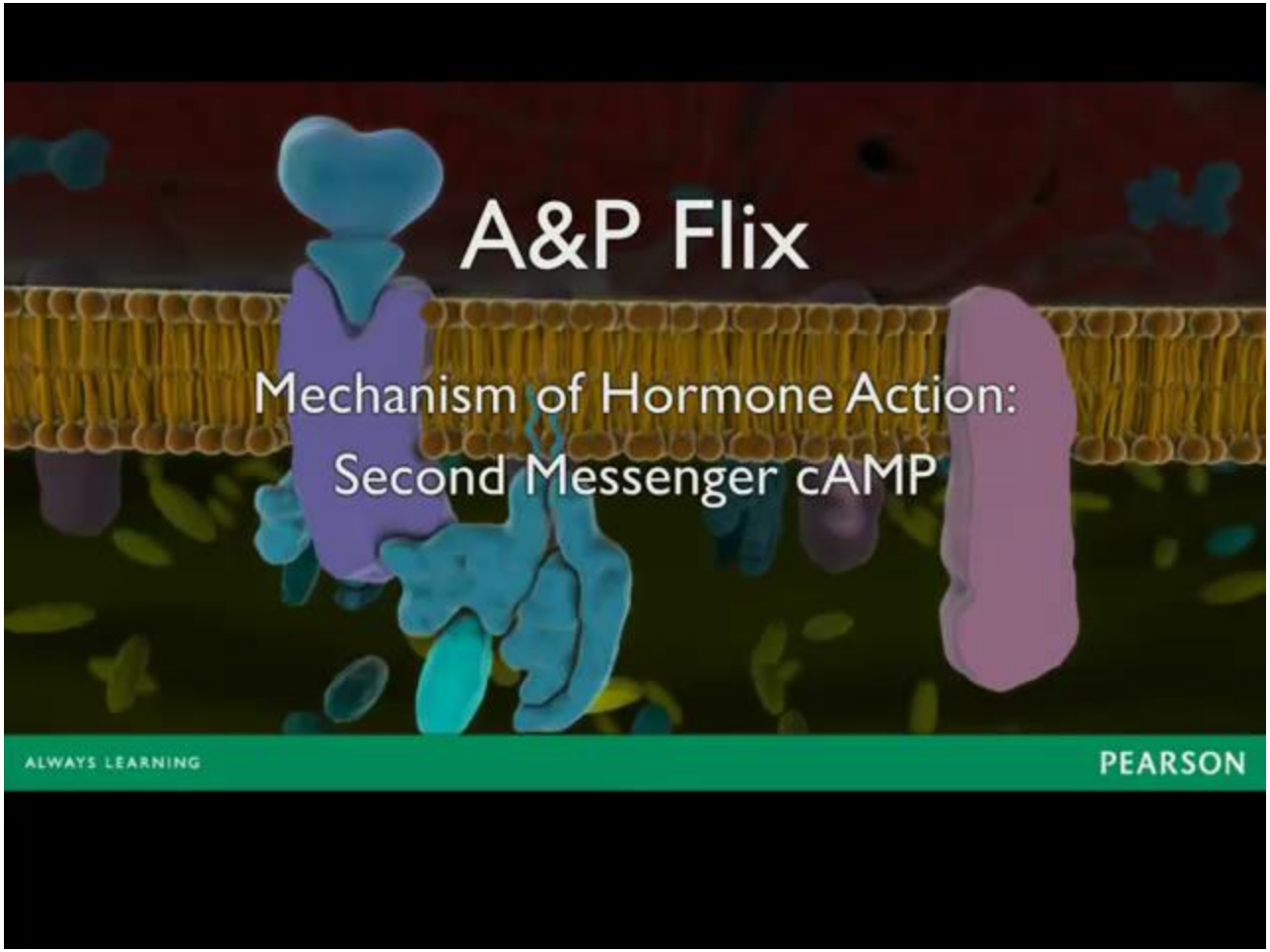
Two possible receptor locations on target cells (continued)

1. Receptor in plasma membrane (continued)
   - Examples of second messengers
     - **Cyclic AMP (cAMP)**
       - Derivative of ATP
       - Increased levels may activate enzymes or open ion channels, accelerating cell metabolic activity
       - Decreased levels has inhibitory effect on cell
     - Calcium ions (Ca^{2+})
       - Generally function in combination with intracellular protein called **calmodulin** to activate enzymes

G protein–coupled receptors



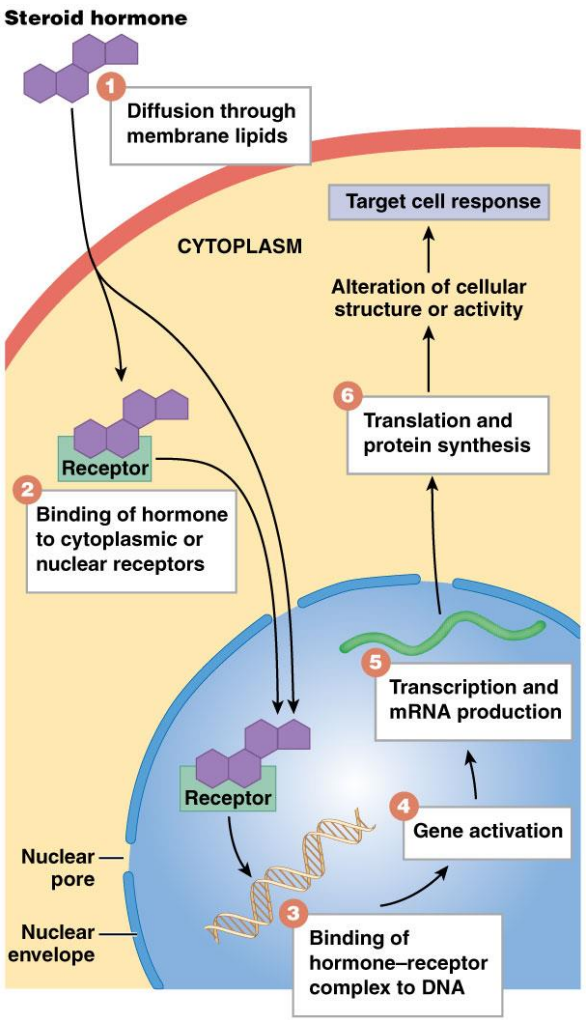
A&P Flix: Mechanism of Hormone Action: Second Messenger cAMP



Module 16.4: Hormone binding

Two possible receptor locations on target cells (continued)

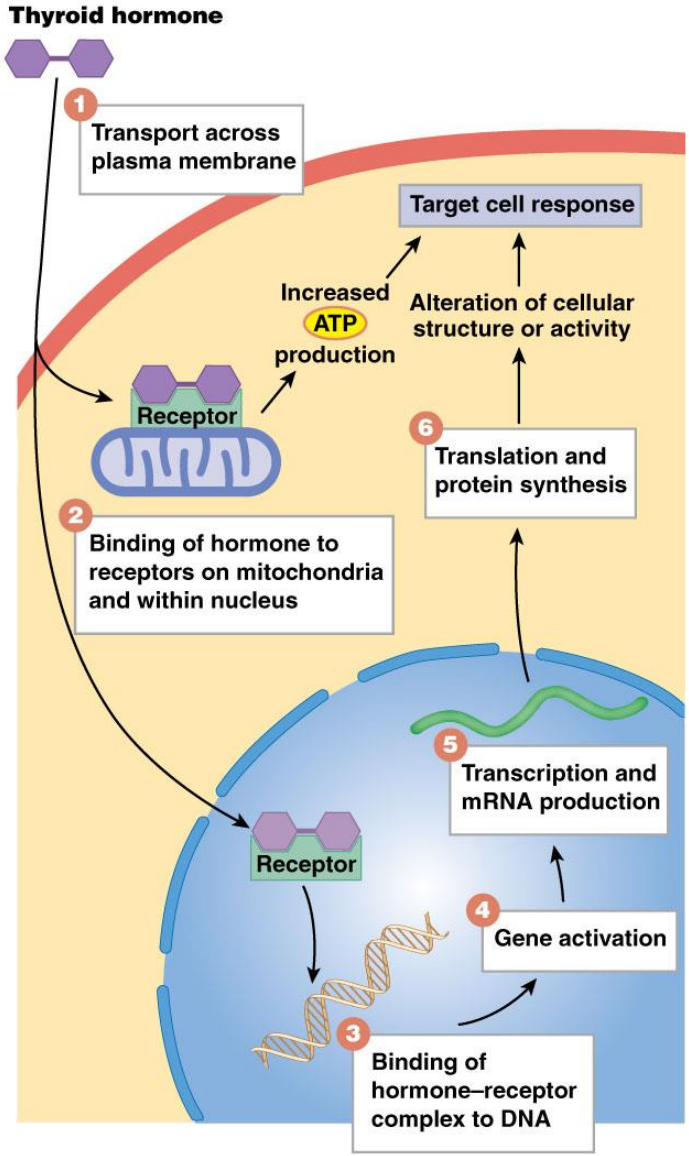
2. Receptor in cytoplasm or nucleus (intracellular receptors)
   - **Steroid hormones**
     - Lipid-soluble hormones diffuse through plasma membrane
     - Alter activity of specific genes
     - Affect DNA transcription rate, changing pattern of protein synthesis
     - Change synthesis of enzyme and structural proteins affecting cell's metabolic activity and structure



Module 16.4: Hormone binding

Two possible receptor locations on target cells (continued)

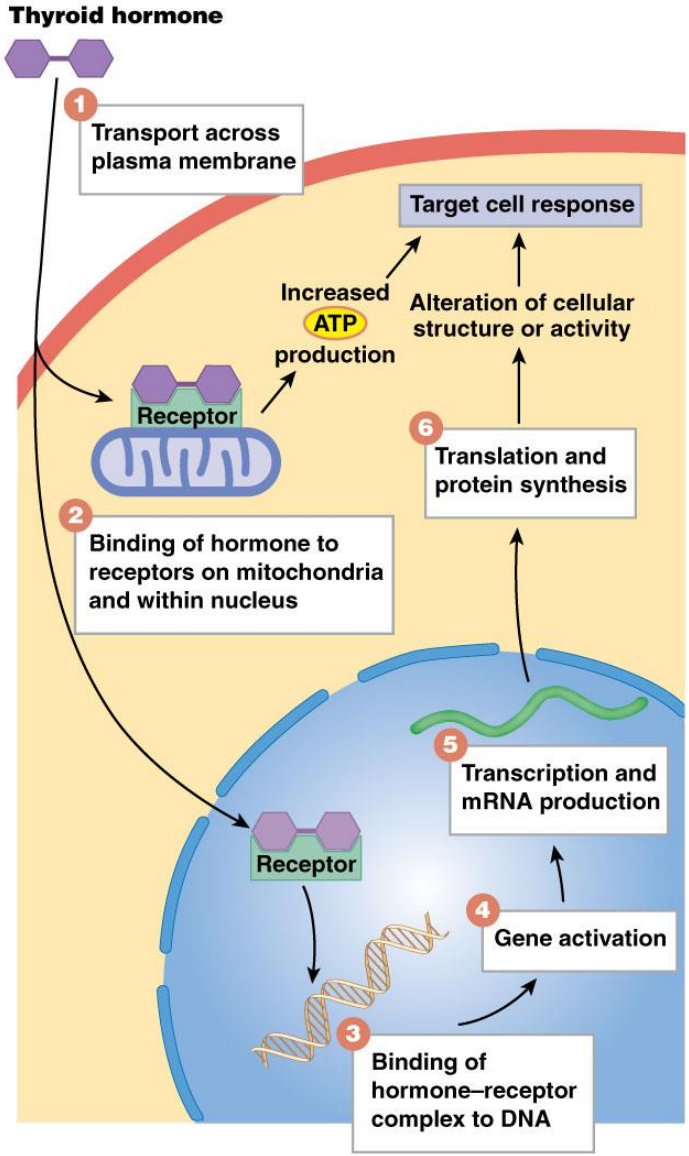
2. Receptor in cytoplasm or nucleus (continued)
   - **Thyroid hormones**
     - Transported across cell membrane by carrier-mediated processes
     - Bind to receptors on mitochondria
       - Increase rate of ATP production



Module 16.4: Hormone binding

Two possible receptor locations on target cells (continued)

2. Receptor in cytoplasm or nucleus (continued)
   - **Thyroid hormones** (continued)
     - Bind to receptors in nucleus
       - Activate specific genes or change rate of transcription
       - Affects cell's metabolic activity and structure



Module 16.4: Review

A. Define *hormone receptor*.
B. Differentiate between a first messenger and a second messenger.
C. Which type of hormone diffuses across the plasma membrane and binds to receptors in the cytoplasm?

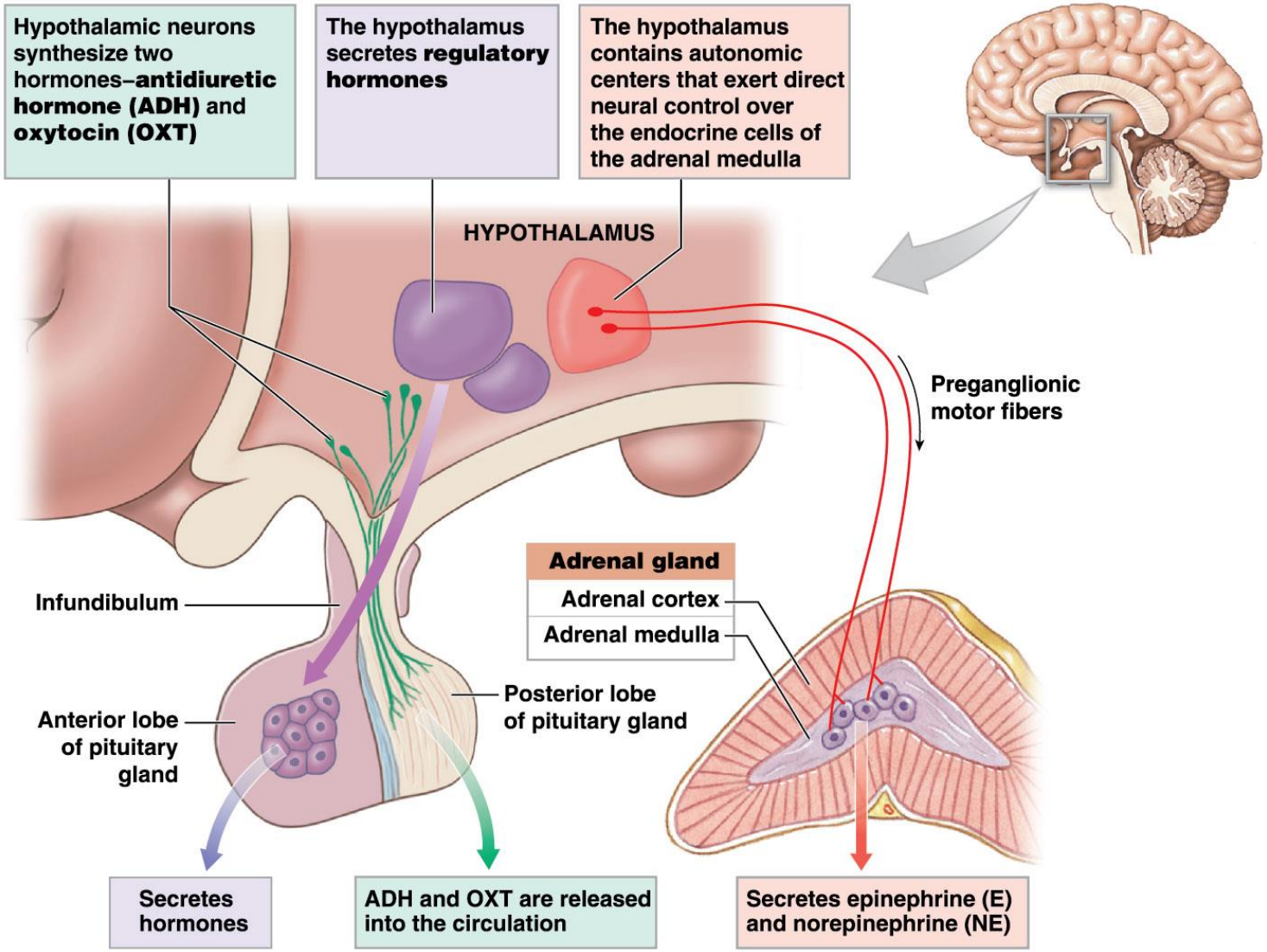
Learning Outcome: Explain the general mechanisms of hormonal action.

Module 16.5: The hypothalamus exerts direct or indirect control over the activities of many endocrine organs

Hypothalamus

- Provides highest level of endocrine function by integrating nervous and endocrine systems
- Three mechanisms of integration
  1. Hypothalamic neurons synthesize two hormones that are transported to and released by the posterior pituitary
     1. **Antidiuretic hormone (ADH)**
        - Synthesized by the supraoptic nuclei
     2. **Oxytocin (OXT)**
        - Synthesized by the paraventricular nuclei

Regulation through the hypothalamus

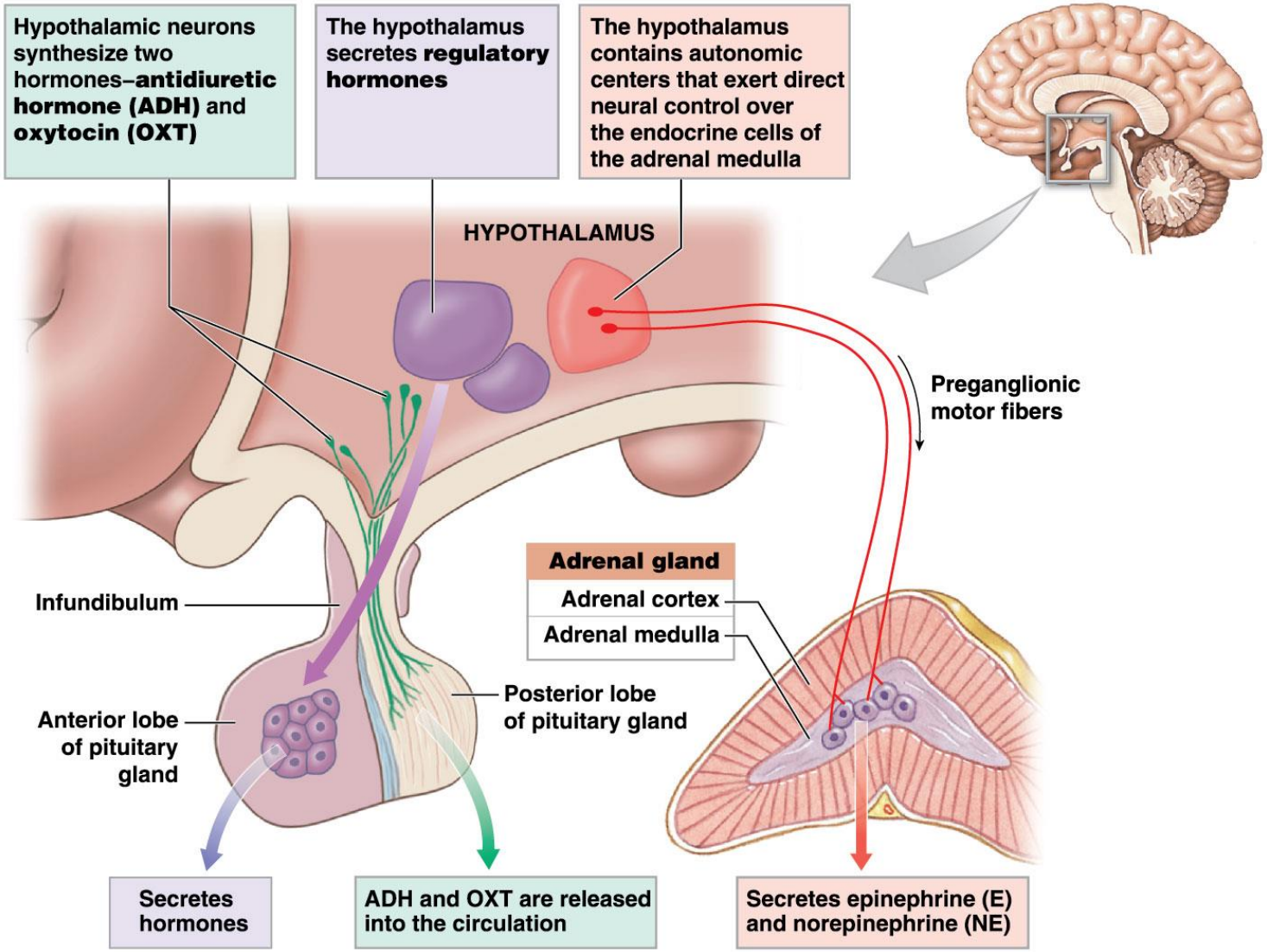


Module 16.5: The hypothalamus exerts direct or indirect control

Hypothalamus (continued)

- Three mechanisms of integration (continued)
  2. Secretes **regulatory hormones** that control anterior pituitary gland endocrine cells
  3. Contains autonomic centers that directly stimulate the endocrine cells in the adrenal medulla
     - Stimulated in response to sympathetic division activation
     - In response, adrenal medulla releases epinephrine and norepinephrine into bloodstream

Regulation through the hypothalamus



Module 16.5: The hypothalamus exerts direct or indirect control

Hypophyseal portal system

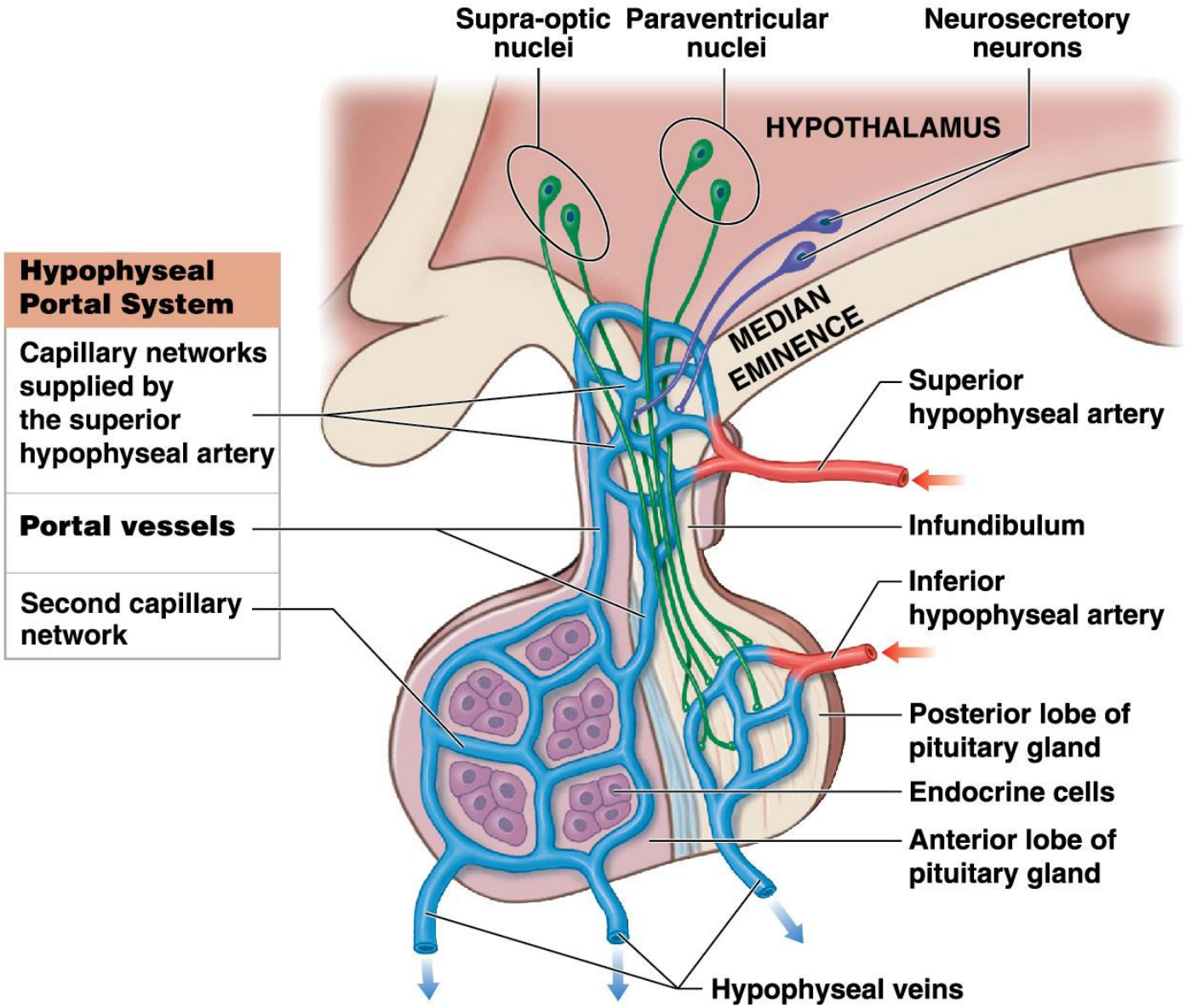
- Capillary networks and interconnecting vessels between the hypothalamus and the pituitary gland (*hypophysis,* pituitary gland)
  - Regulatory hormones released from the hypothalamus at the **median eminence** of infundibulum
  - Move from interstitial fluid into **fenestrated capillaries**
  - Carried to anterior pituitary in **portal vessels** (portal veins)
  - Form second capillary network within the anterior pituitary

Module 16.5: The hypothalamus exerts direct or indirect control

Hypophyseal portal system (continued)

- Allows hypothalamic hormones to reach target cells in anterior pituitary directly, without mixing and diluting in general circulation

Hypophyseal portal system



Module 16.5: The hypothalamus exerts direct or indirect control

Hypophyseal portal system (continued)

- Two classes of regulatory hormones
  1. **Releasing hormones (RH)**
     - Stimulate synthesis and secretion of one or more hormones at anterior lobe
  2. **Inhibiting hormones (IH)**
     - Prevent synthesis and secretion of one or more hormones at anterior lobe

Module 16.5: Review

A. Define *regulatory hormone*.
B. Identify the three mechanisms by which the hypothalamus integrates neural and endocrine function.
C. Name and describe the characteristics and functions of the blood vessels that link the hypothalamus with the anterior lobe of the pituitary gland.

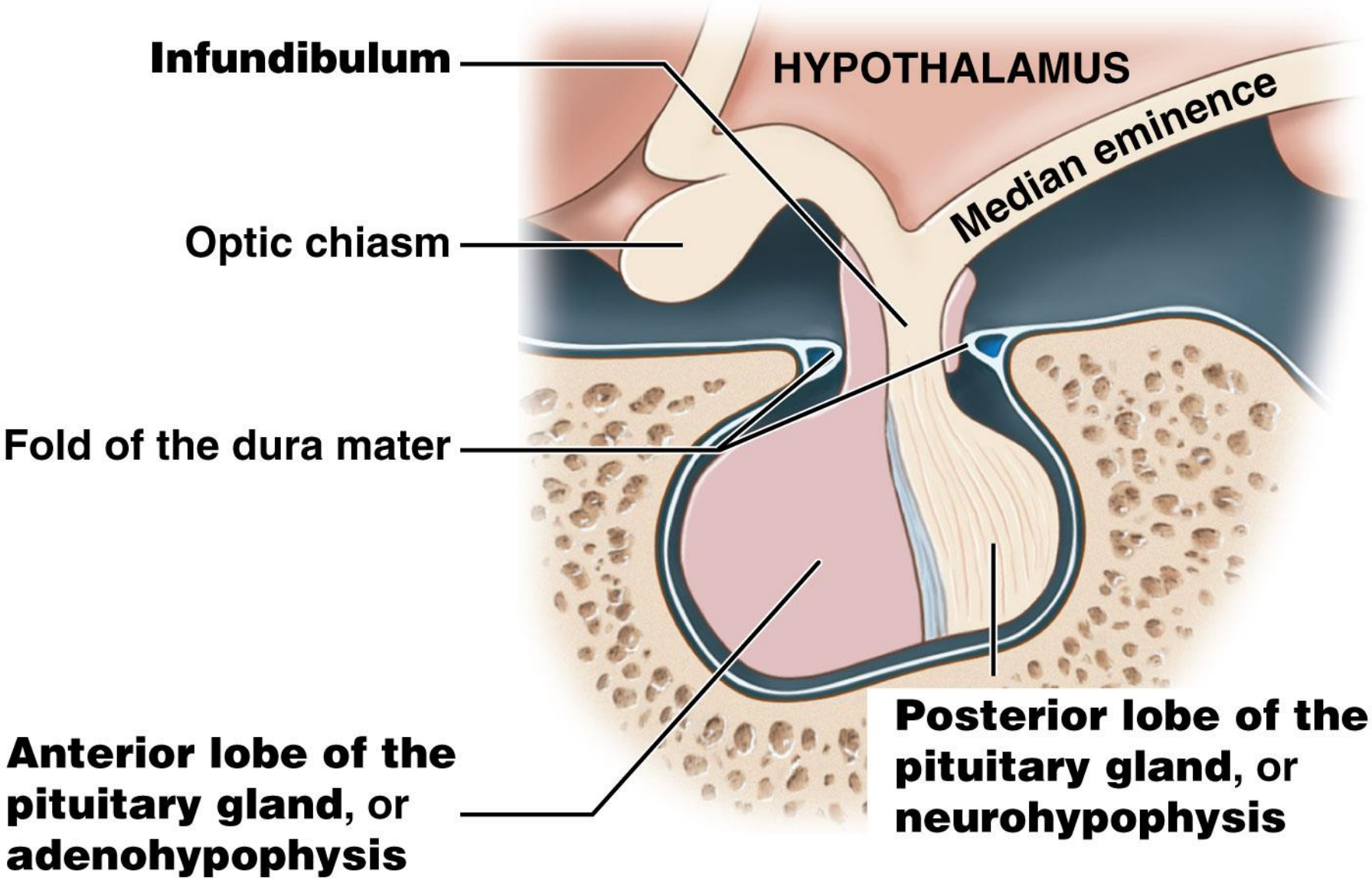
Learning Outcome: Describe how the hypothalamus controls endocrine organs.

Module 16.6: The anterior lobe of the pituitary gland produces and releases 7 tropic hormones, while the posterior lobe releases 2 hormones

Pituitary gland, or hypophysis

- Small, oval gland nestled within sella turcica of sphenoid bone
- Releases nine peptide hormones
  - Seven from anterior lobe (**adenohypophysis**)
    - Called **tropic** (*trope,* a turning) **hormones** because they “turn on” other endocrine glands
  - Two from posterior pituitary (**neurohypophysis**)
  - All nine bind to membrane receptors and use cAMP as second messenger

The pituitary gland

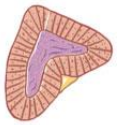


Module 16.6: The pituitary gland

Hormones of the anterior lobe

1. **Thyroid-stimulating hormone (TSH)**
   - Targets the thyroid gland
   - Stimulates release of thyroid hormones
   - Released in response to **thyrotropin-releasing hormone** (**TRH**) from hypothalamus
   - Release is decreased when thyroid hormone levels rise (negative feedback)

Hormones of the Anterior Lobe

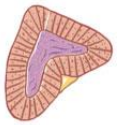
TSH	ACTH	Gonadotropins (FSH and LH)		GH	PRL	MSH
Thyroid-stimulating hormone	Adreno-corticotropic hormone	Follicle-stimulating hormone	Luteinizing hormone	Growth hormone	Prolactin	Melanocyte-stimulating hormone
						
Thyroid gland	Adrenal gland	Ovary	Testis	Musculo-skeletal system	Mammary gland	

Module 16.6: The pituitary gland

Hormones of the anterior lobe (continued)

2. **Adrenocorticotropic hormone (ACTH)**
   - Also known as *corticotropin*
   - Stimulates release of steroid hormones from adrenal cortex
     - Specifically those that affect glucose metabolism
   - Released in response to **corticotropin-releasing hormone** (**CRH**) from hypothalamus

Hormones of the Anterior Lobe

TSH	ACTH	Gonadotropins (FSH and LH)		GH	PRL	MSH
Thyroid-stimulating hormone	Adreno-corticotropic hormone	Follicle-stimulating hormone	Luteinizing hormone	Growth hormone	Prolactin	Melanocyte-stimulating hormone
						
Thyroid gland	Adrenal gland	Ovary	Testis	Musculo-skeletal system	Mammary gland	

Module 16.6: The pituitary gland

Hormones of the anterior lobe (continued)

- **Gonadotropins**
  - Regulate activities of the gonads
  - Released in response to **gonadotropin-releasing hormone** (**GnRH**) from hypothalamus

3. **Follicle-stimulating hormone (FSH)**
   - Females: promotes ovarian follicle development and (in combination with LH) stimulates secretion of **estrogens**
   - Males: promotes maturation of developing sperm
   - Inhibited by **inhibin** (peptide released by gonads)

Module 16.6: The pituitary gland

Hormones of the anterior lobe (continued)

- **Gonadotropins** (continued)
  4. **Luteinizing hormone (LH)**
     - Females
       - Induces ovulation
       - Promotes secretion of estrogen and progesterone
         - Prepares body for possible pregnancy
     - Males
       - Stimulates interstitial cells of testes to produce sex hormones (**androgens**), primarily testosterone

Module 16.6: The pituitary gland

Hormones of the anterior lobe (continued)

5. **Growth hormone (GH)**
   - Stimulates cell growth and reproduction by accelerating rate of protein synthesis
     - Skeletal muscle and chondrocytes are particularly sensitive to GH
   - Regulated by two hypothalamic hormones
     - **Growth hormone–releasing hormone (GH–RH)**
     - **Growth hormone–inhibiting hormone (GH–IH)**
   - Actions of growth hormone can be direct or indirect

Module 16.6: The pituitary gland

Hormones of the anterior lobe (continued)

5. **Growth hormone** (continued)
   - Indirect action of growth hormone (primary mechanism)
     - Liver cells respond to GH by synthesizing and releasing **somatomedins** (compounds that stimulate tissue growth) or **insulin-like growth factors (IGFs)**
       - Receptors for these on various cells in the body including skeletal muscle and cartilage
         - Response is increased uptake of amino acids and incorporation into new proteins

Module 16.6: The pituitary gland

Hormones of the anterior lobe (continued)

5. **Growth hormone** (continued)
   - Direct actions of growth hormone
     - Epithelial and connective tissues
       - Stimulates stem cell division and differentiation
     - Adipose tissue
       - Stimulates breakdown of stored triglycerides, releasing fatty acids into blood
       - Tissues use these fatty acids instead of glucose to generate ATP (called **glucose-sparing effect**)
     - Liver
       - Stimulates breakdown of glycogen reserves, releasing glucose into bloodstream

Module 16.6: The pituitary gland

Hormones of the anterior lobe (continued)

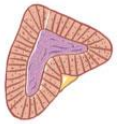
6. **Prolactin** (*pro-*, before + *lac*, milk) **(PRL)**
   - Works with other hormones to stimulate mammary gland development
   - In pregnancy and nursing period, stimulates milk production by mammary glands
   - Released in response to several prolactin-releasing factors
   - Inhibited by **prolactin-inhibiting hormone (PIH)**
   - Stimulated by **prolactin-releasing hormones (PRH)**

Module 16.6: The pituitary gland

Hormones of the anterior lobe (continued)

7. **Melanocyte-stimulating hormone (MSH)**
   - Possibly released from the *pars intermedia* of anterior lobe
   - Stimulates melanocytes of skin to increase melanin production
   - In adults, that portion of the anterior lobe is almost nonfunctional
     - Usually no MSH in circulation

Hormones of the Anterior Lobe

TSH	ACTH	Gonadotropins (FSH and LH)		GH	PRL	MSH
Thyroid-stimulating hormone	Adreno-corticotropic hormone	Follicle-stimulating hormone	Luteinizing hormone	Growth hormone	Prolactin	Melanocyte-stimulating hormone
						
Thyroid gland	Adrenal gland	Ovary	Testis	Musculo-skeletal system	Mammary gland	

Module 16.6: The pituitary gland

Hormones of the posterior lobe

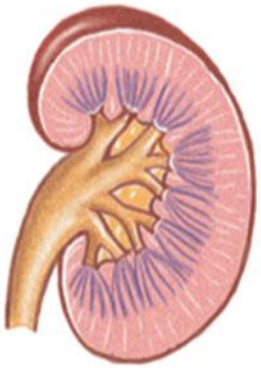
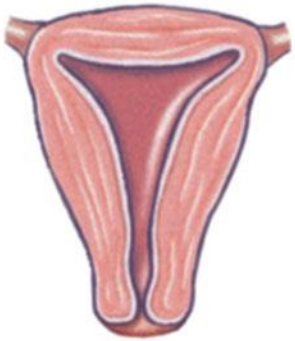
1. **Antidiuretic hormone (ADH)**
   - Also known as *vasopressin* (*VP*)
   - Released in response to a variety of stimuli
     - Main stimulus is an increase in solute concentration of blood (sensed by **osmoreceptors**) or a decrease in blood pressure or volume
   - Primary function is to act on kidneys to retain water and decrease urination
     - Also causes vasoconstriction (helps increase blood pressure)
   - Release is inhibited by alcohol

Module 16.6: The pituitary gland

Hormones of the posterior lobe (continued)

2. **Oxytocin** (*okytokos*, swift birth) **(OXT)**
   - Released in response to sensory input
     - Example of a *neuroendocrine response*
   - Stimulates:
     - Smooth muscle contraction in wall of uterus
       - Promotes labor and delivery
     - Contraction of myoepithelial cells in the mammary glands
       - Promotes ejection of milk
   - Also has unclear functions in sexual activity
     - Circulating levels rise during sexual arousal

Hormones of the posterior lobe

Hormones of the Posterior Lobe	
ADH	**OXT**
Antidiuretic hormone	**Oxytocin**
	
Kidney	**Uterus**

Module 16.6: Review

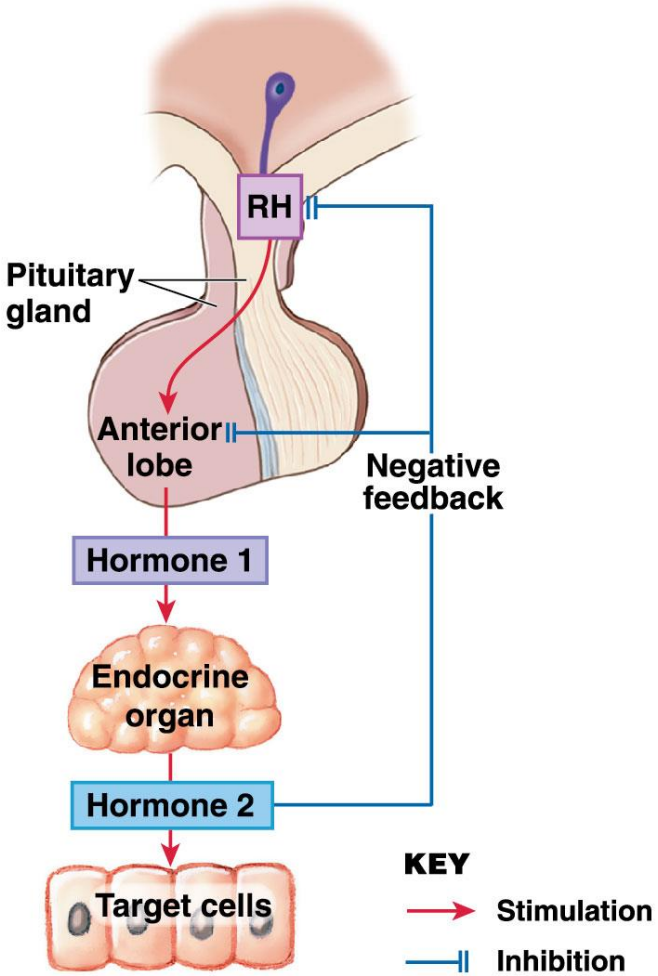
A. Name the two lobes of the pituitary gland.
B. Identify the nine pituitary hormones and their target tissues.
C. In a dehydrated person, how would the amount of ADH released by the posterior lobe of the pituitary change?

Learning Outcome: Describe the location and structure of the pituitary gland, and identify pituitary hormones and their functions.

Module 16.7: Negative feedback mechanisms control the secretion rates of the hypothalamus and the pituitary gland

Negative feedback

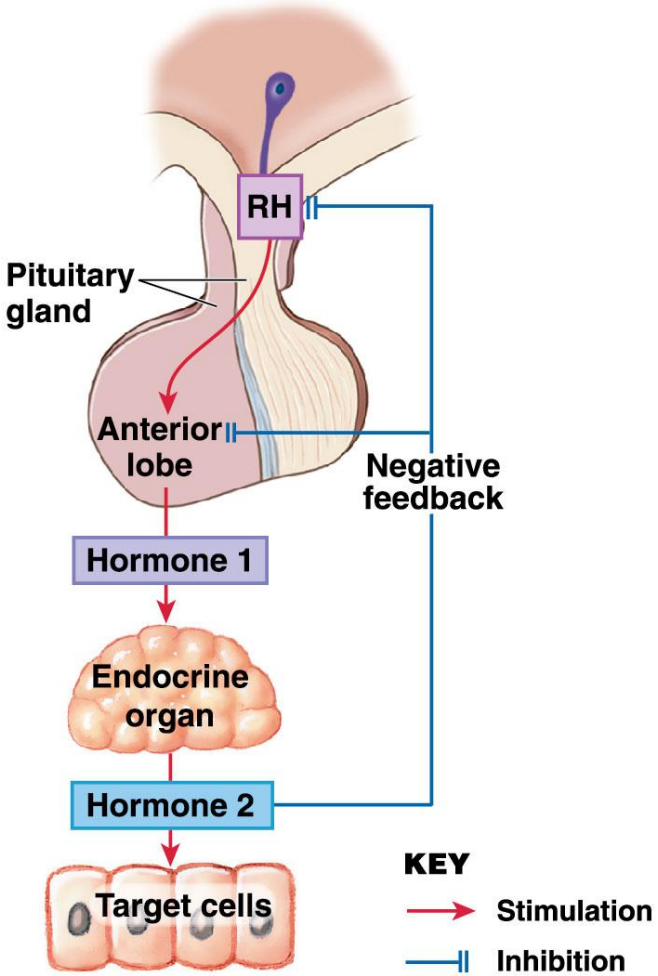
- Typical control mechanism for hormone secretion
- *Example*
  - Hypothalamic releasing hormone triggers release of hormone by anterior pituitary gland, which triggers release of a second hormone by the target gland



Module 16.7: Negative feedback between hypothalamus and pituitary gland

Negative feedback (continued)

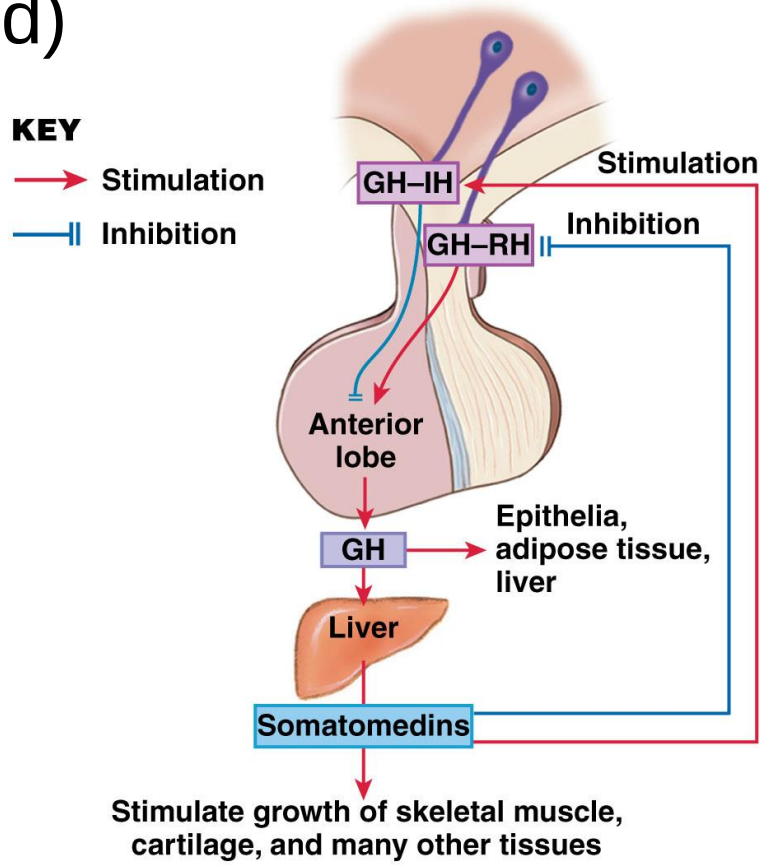
- *Example* (continued)
  - Second hormone suppresses secretion of both hypothalamic releasing hormone and pituitary hormone



Module 16.7: Negative feedback between hypothalamus and pituitary gland

Negative feedback (continued)

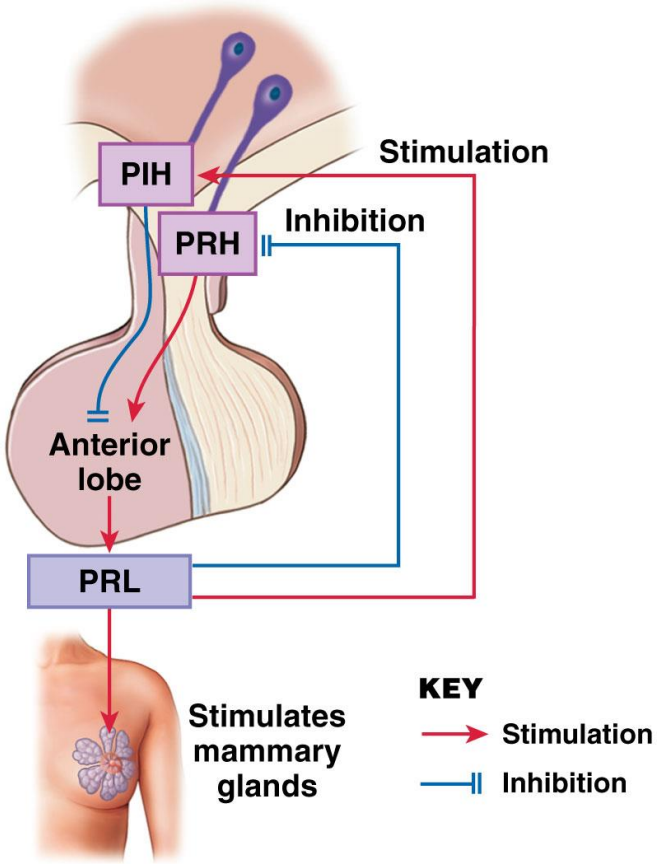
- In some cases, both releasing and inhibiting hormones are part of the regulatory process
- Growth hormone
  - **Somatomedins** released by the liver influence hypothalamic hormones
    - Inhibit release of GH–RH
    - Stimulate release of GH–IH



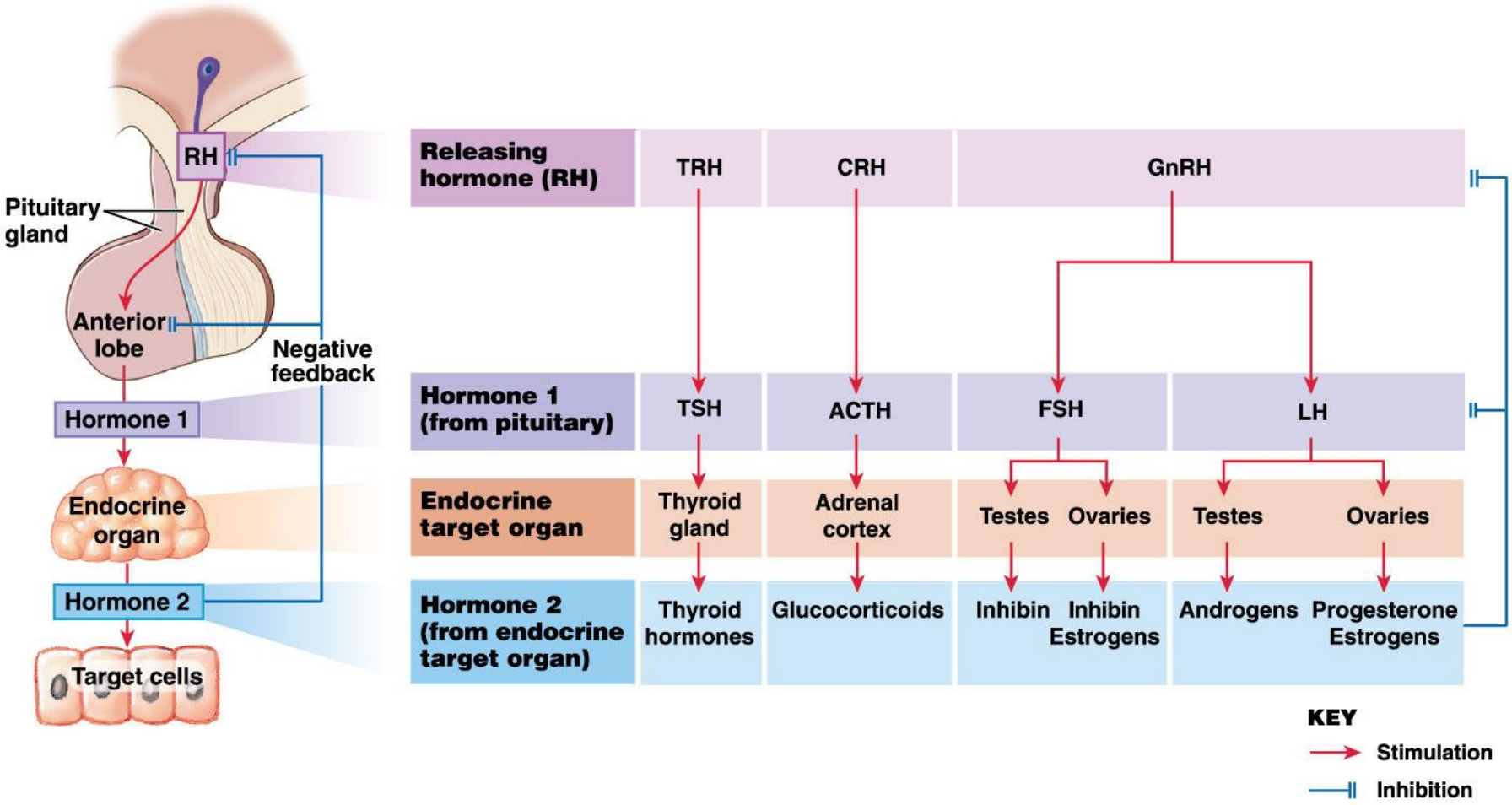
Module 16.7: Negative feedback between hypothalamus and pituitary gland

Negative feedback (continued)

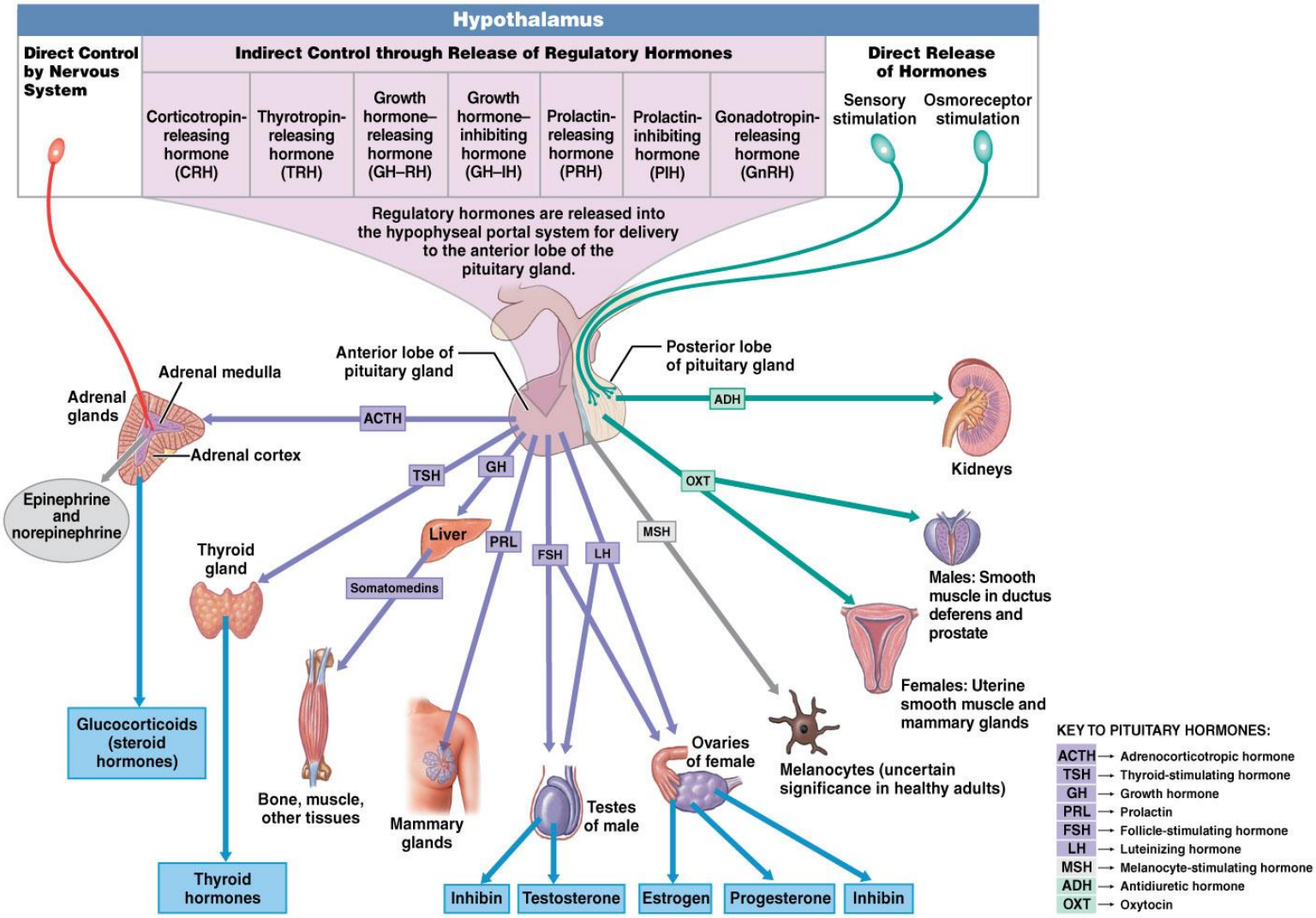
- In some cases, both releasing and inhibiting hormones are part of the regulatory process (continued)
  - Prolactin (PRL)
    - PRL inhibits release of PRH (prolactin-releasing hormone)
    - PRL stimulates release of PIH (prolactin-inhibiting hormone)



Negative feedback regulation



Hormone relationships with the hypothalamus



Module 16.7: Review

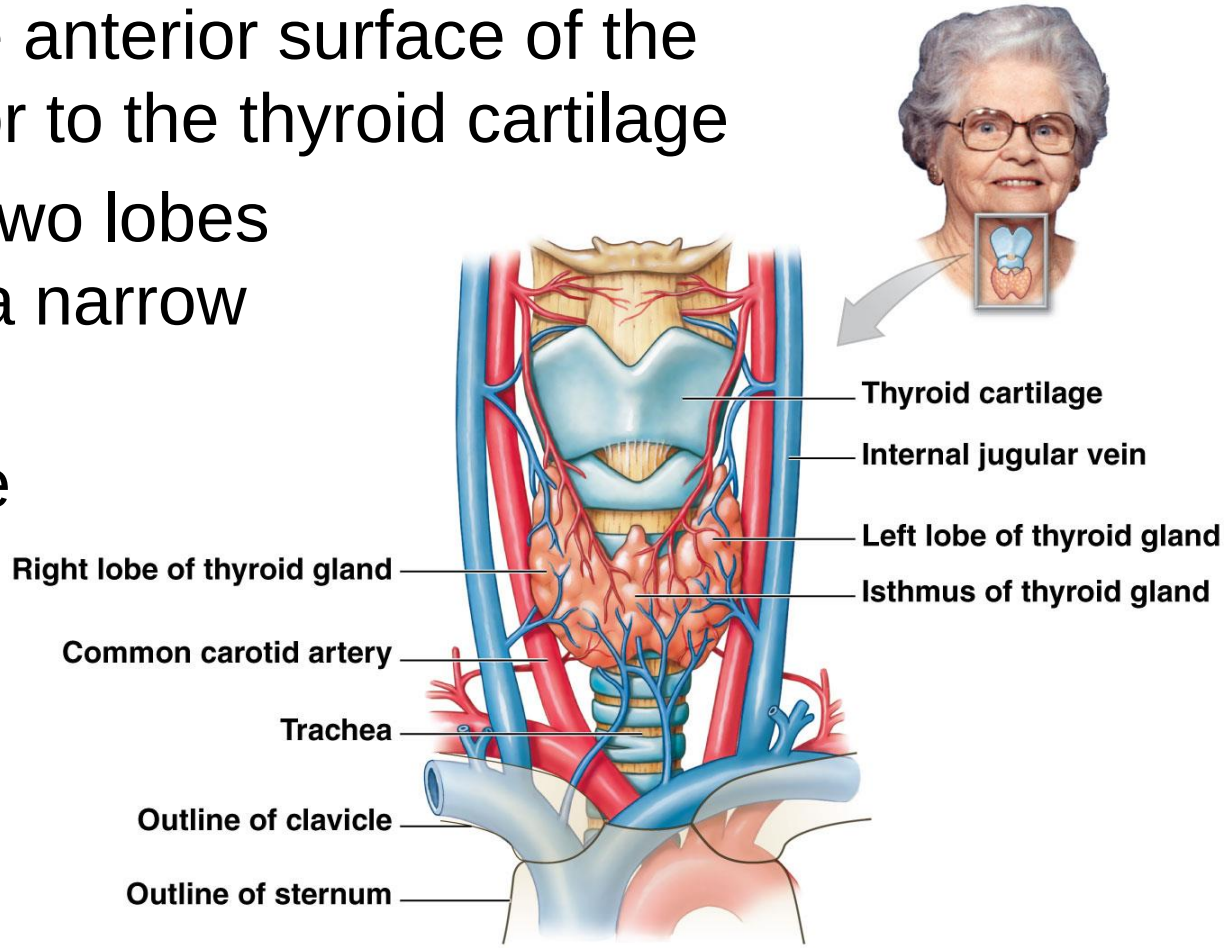
A. List the hypothalamic releasing hormones.
B. The release of which pituitary hormone would lead to an increased level of somatomedins in the blood?
C. What effects would increased circulating levels of glucocorticoids have on the pituitary secretion of ACTH?

Learning Outcome: Describe the role of negative feedback in the functional relationship between the hypothalamus and the pituitary gland.

Module 16.8: The thyroid gland contains follicles and requires iodine to produce hormones that stimulate tissue metabolism

Thyroid gland gross anatomy

- Located on the anterior surface of the trachea, inferior to the thyroid cartilage
- Composed of two lobes connected by a narrow **isthmus**
- Size is variable
  - Easily felt with fingers



Module 16.8: The thyroid gland

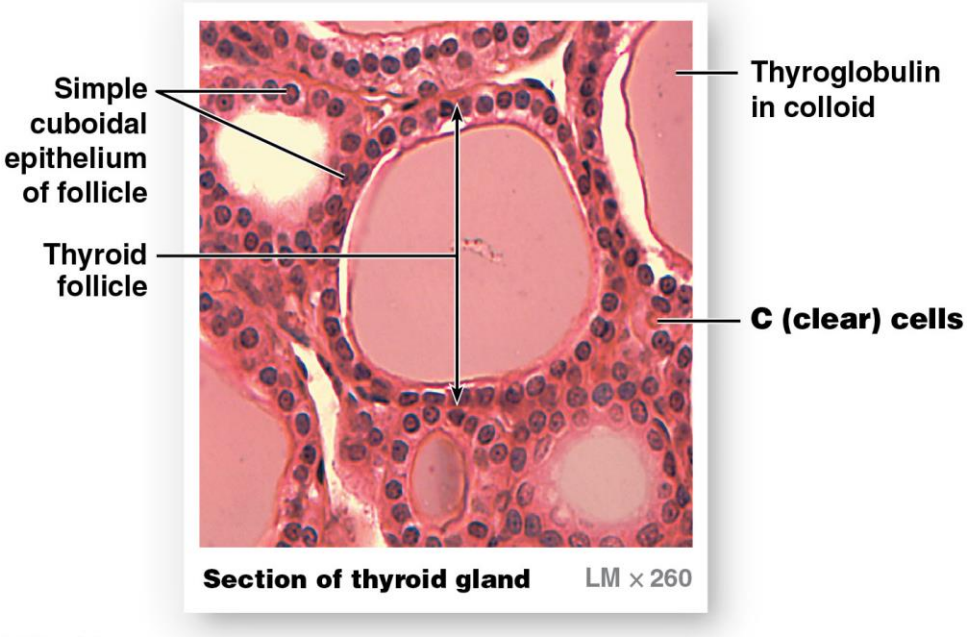
Thyroid gland histology

- Contains large numbers of **thyroid follicles**
  - Hollow spheres lined by simple cuboidal epithelium
  - Follicle cavity holds viscous colloid (fluid packed with dissolved proteins)
  - Into that colloid, follicle cells secrete a globular protein called **thyroglobulin**
    - Molecule containing the amino acid tyrosine (building block of thyroid hormones)
  - Network of capillaries surrounds each follicle, transporting nutrients, wastes, and secretory products

Module 16.8: The thyroid gland

Thyroid gland histology (continued)

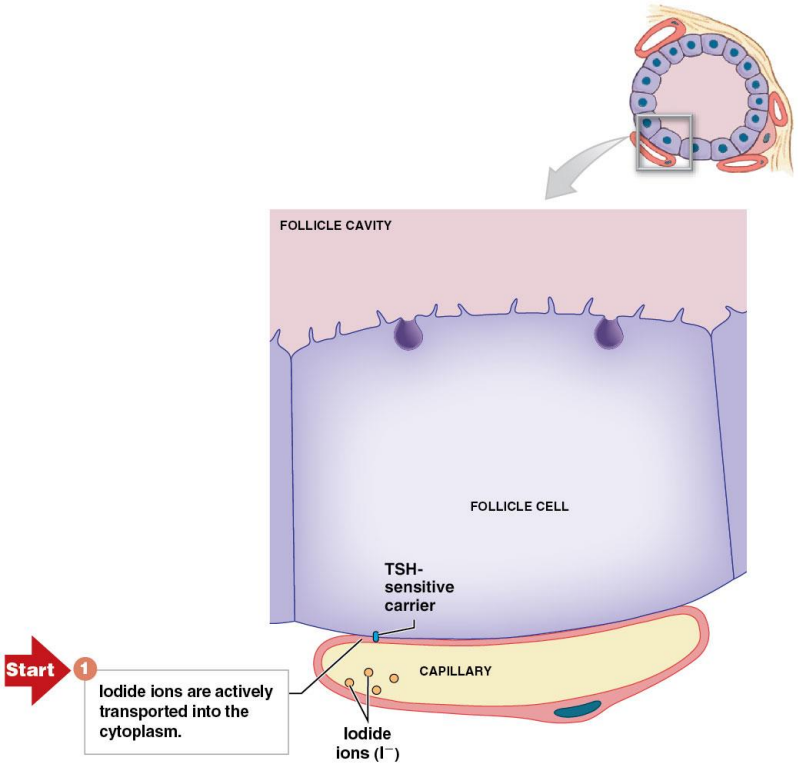
- **C (clear) cells**
  - Found between basement membrane of follicle cells
  - Secrete hormone **calcitonin (CT)**
    - Helps to regulate calcium ion concentrations in body fluids



Module 16.8: The thyroid gland

Thyroid hormone production and storage

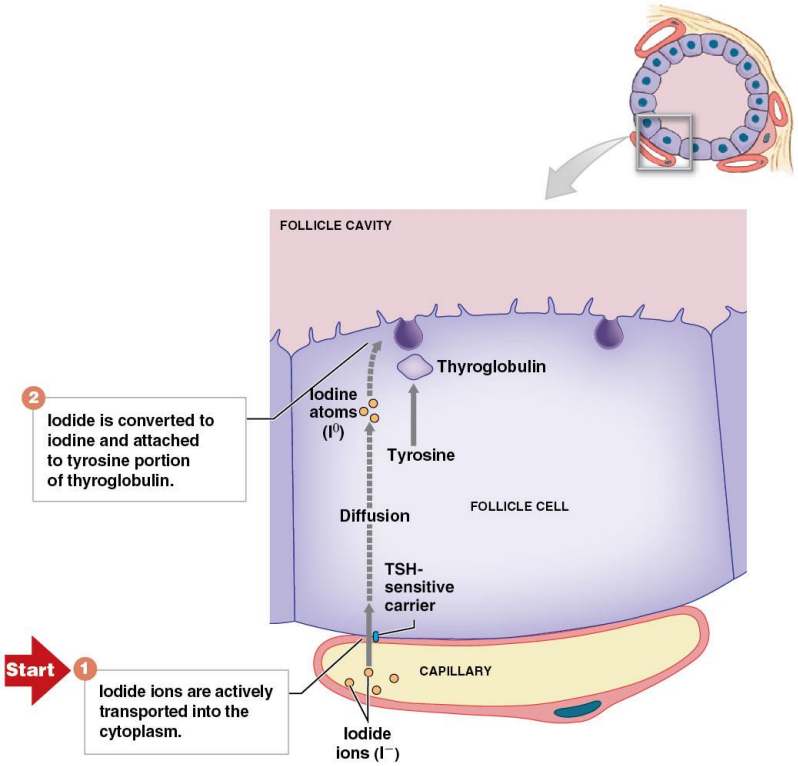
1. Iodide ions from diet delivered to thyroid gland and taken up by follicle cells



Module 16.8: The thyroid gland

Thyroid hormone production and storage (continued)

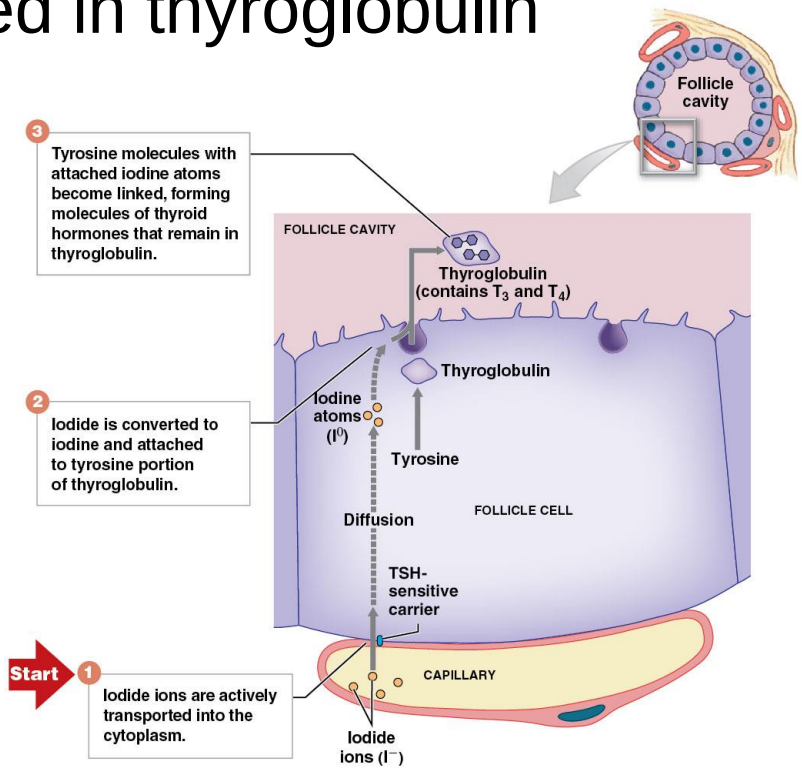
2. Enzymes convert iodide ions to iodine atoms and attach them to tyrosine portions of thyroglobulin molecule



Module 16.8: The thyroid gland

Thyroid hormone production and storage (continued)

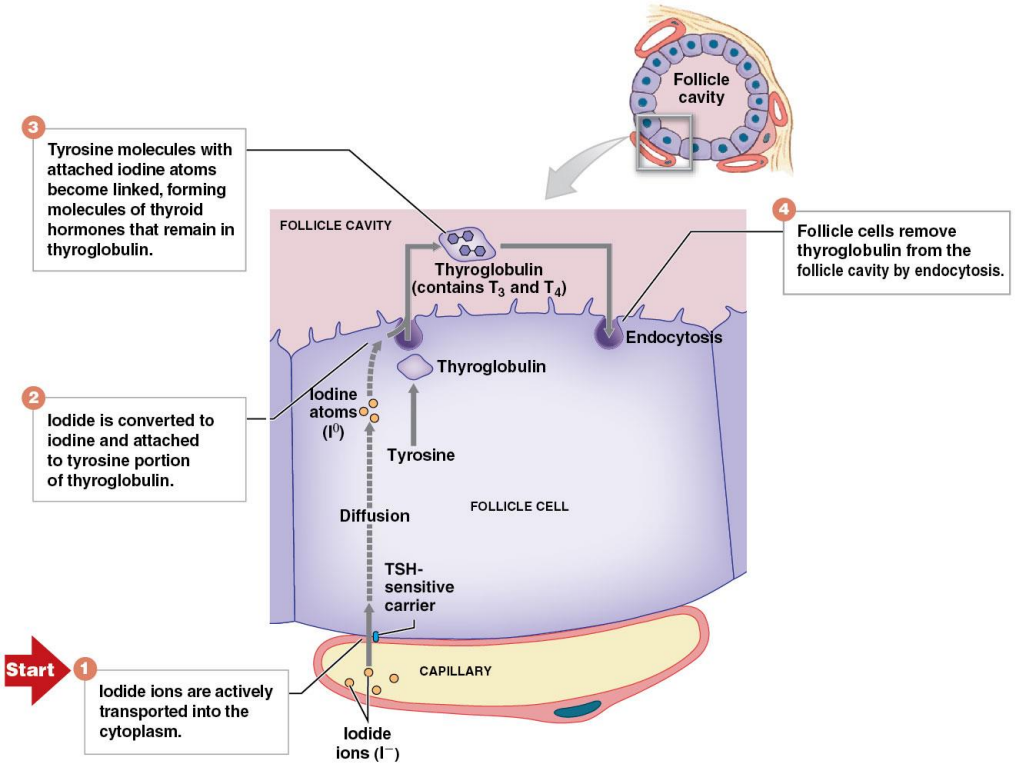
3. **Thyroxine** (T_4), with four iodine atoms and **triiodothyronine** (T_3), with three iodine atoms are produced and stored in thyroglobulin



Module 16.8: The thyroid gland

Thyroid hormone production and storage (continued)

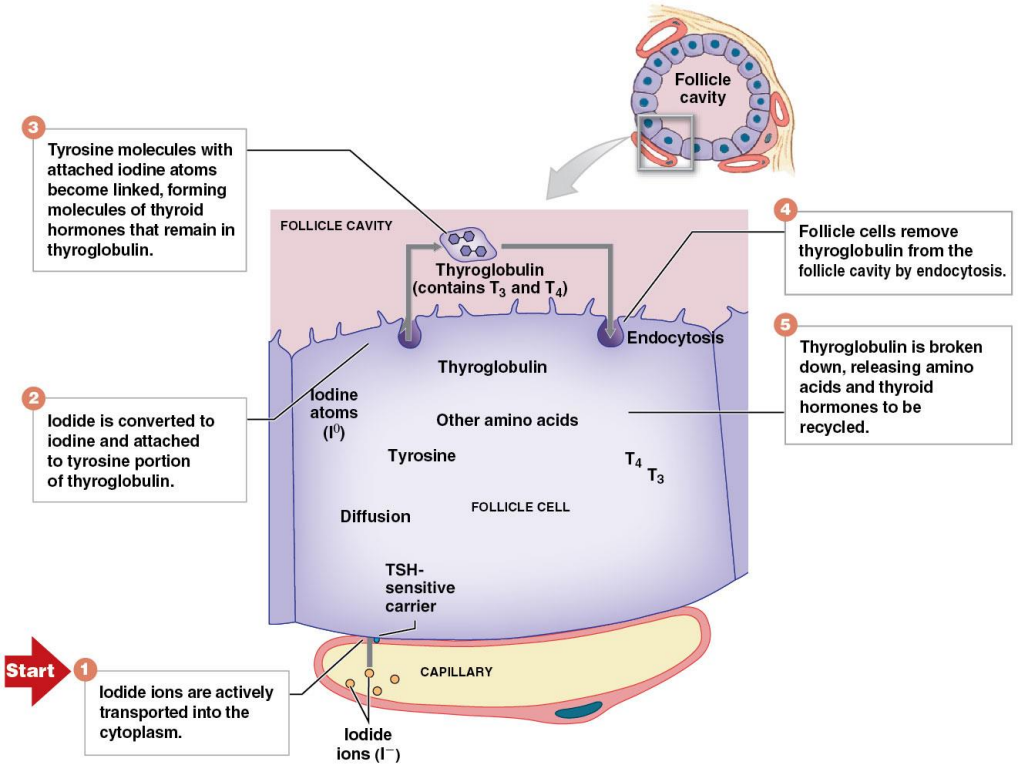
4. Follicle cells remove thyroglobulin from follicle by endocytosis



Module 16.8: The thyroid gland

Thyroid hormone production and storage (continued)

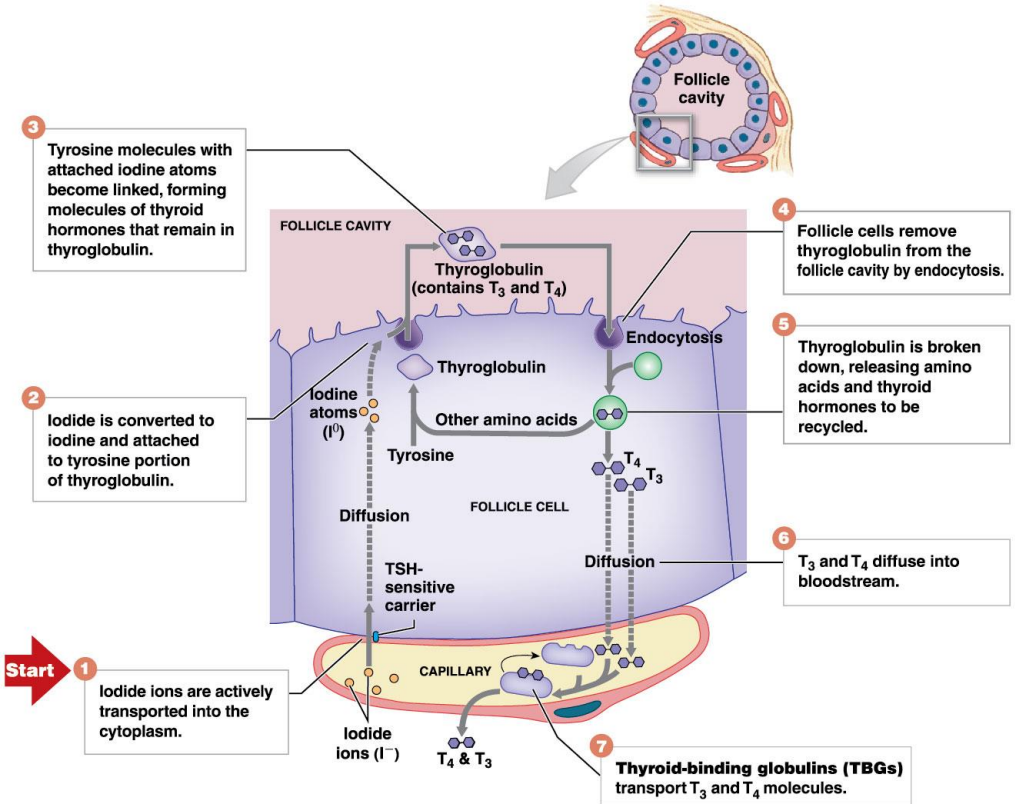
5. Lysosomal enzymes break down thyroglobulin, releasing thyroid hormones and amino acids into cytoplasm
   - Amino acids used to synthesize more thyroglobulin



Module 16.8: The thyroid gland

Thyroid hormone production and storage (continued)

6. T_4 (~90 percent of thyroid secretions) and T_3 (<10 percent) diffuse across basement membrane and enter bloodstream

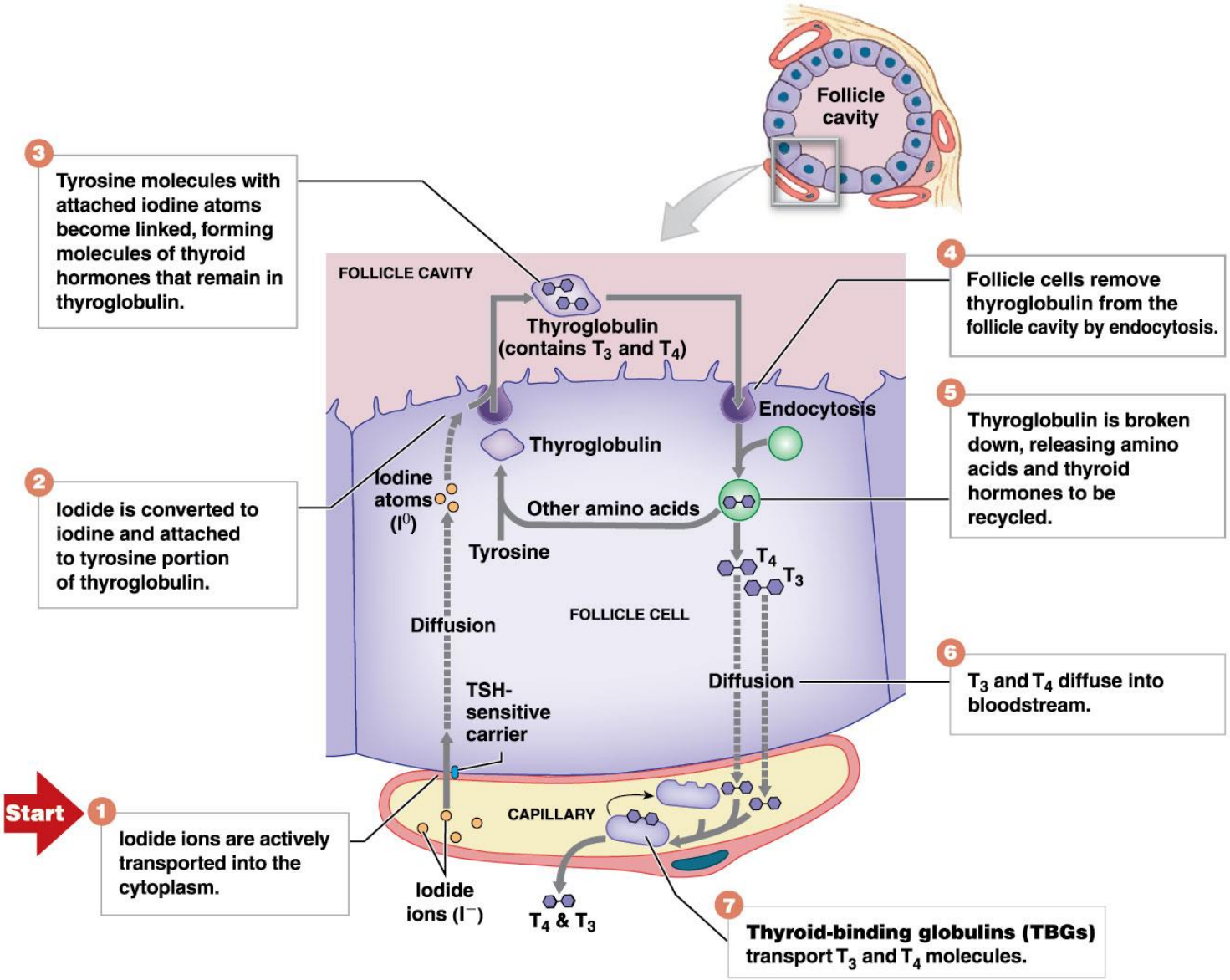


Module 16.8: The thyroid gland

Thyroid hormone production and storage (continued)

7. ~75 percent of T_4 and ~70 percent of T_3 molecules travel in the blood attached to transport proteins (**thyroid-binding globulins**)
   - Hormones are released by proteins gradually
   - Most of the rest of T_4 and T_3 attach to **transthyretin** or albumin
     - Bloodstream contains ~1 week of reserve supply

Production and storage of thyroid hormone



Effects of thyroid hormone on peripheral tissues

Effects of Thyroid Hormones on Peripheral Tissues

- Increased rates of oxygen consumption and energy consumption; in children, may cause a rise in body temperature
- Increased heart rate and force of contraction; generally results in a rise in blood pressure
- Increased sensitivity to sympathetic stimulation
- Maintenance of normal sensitivity of respiratory centers to changes in oxygen and carbon dioxide concentrations
- Stimulation of red blood cell formation and thus enhanced oxygen delivery
- Stimulation of activity in other endocrine tissues
- Accelerated turnover of minerals in bone

Module 16.8: Review

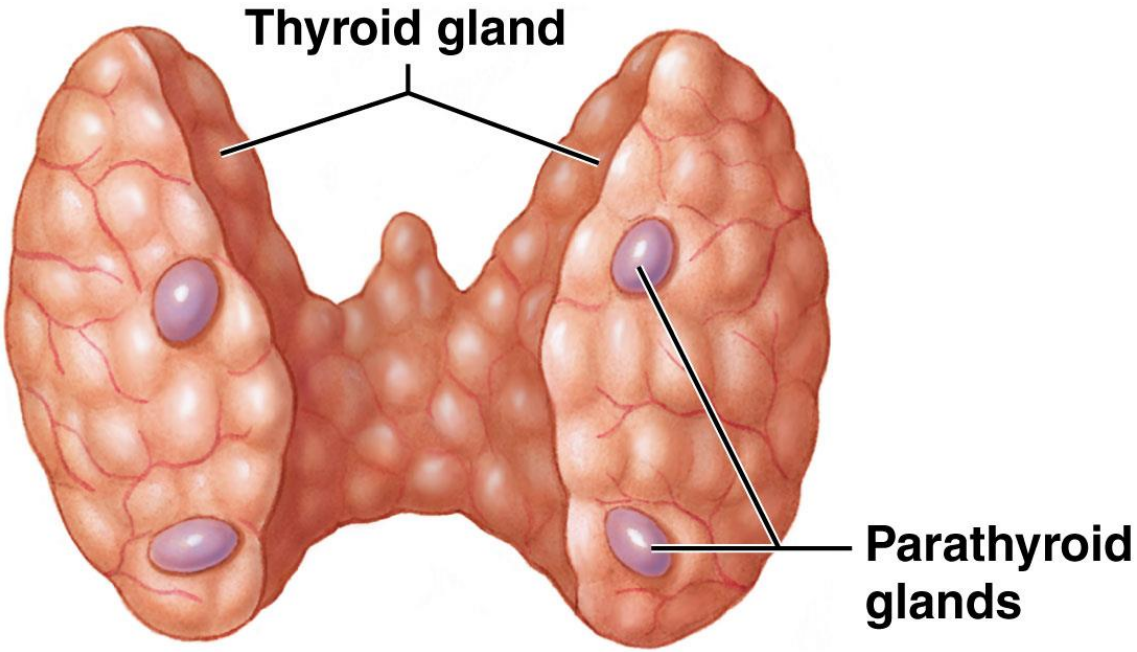
A. What thyroid hormone aids in calcium regulation?
B. Name the hormones of the thyroid gland.
C. Why do signs and symptoms of decreased thyroxine concentration not appear until about a week after a thyroidectomy (surgical removal of the thyroid gland)?

Learning Outcome: Describe the location and structure of the thyroid gland, identify the hormones it produces, and specify the functions of those hormones.

Module 16.9: Parathyroid hormone, produced by the parathyroid glands, is the primary regulator of blood calcium ion levels

Parathyroid gland anatomy

- Two pairs embedded in posterior surface of the thyroid gland



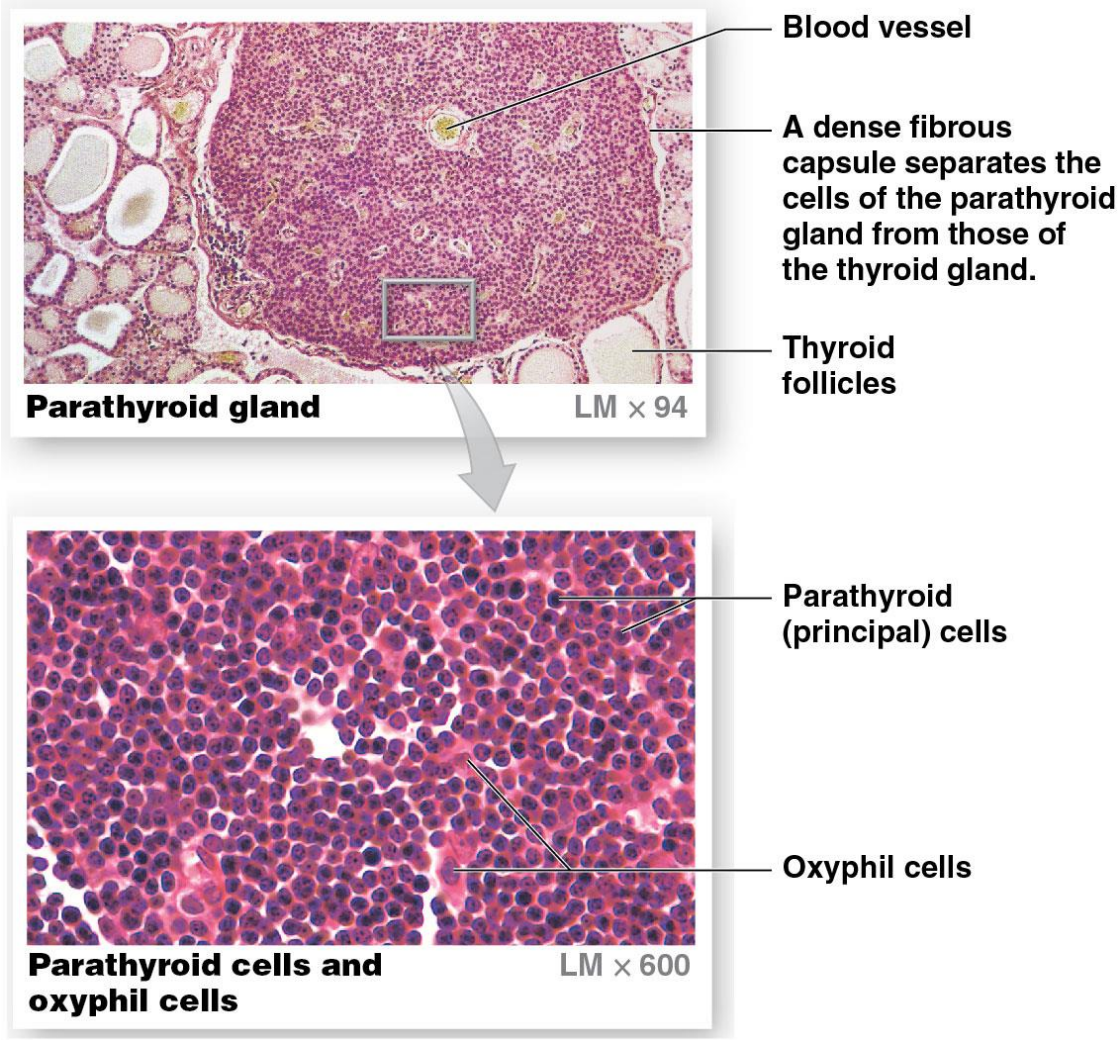
Module 16.9: The parathyroid gland

Parathyroid gland cells

- Contain two cell populations

1. Oxyphil cells (no known functions)
2. **Parathyroid (principal) cells**
   - Produce **parathyroid hormone (PTH)**
     - Increases calcium levels in extracellular fluids
   - Monitor calcium levels in blood (like thyroid C cells)
     - When calcium levels fall below normal, PTH is released
     - Causes increase in calcium levels

Parathyroid histology

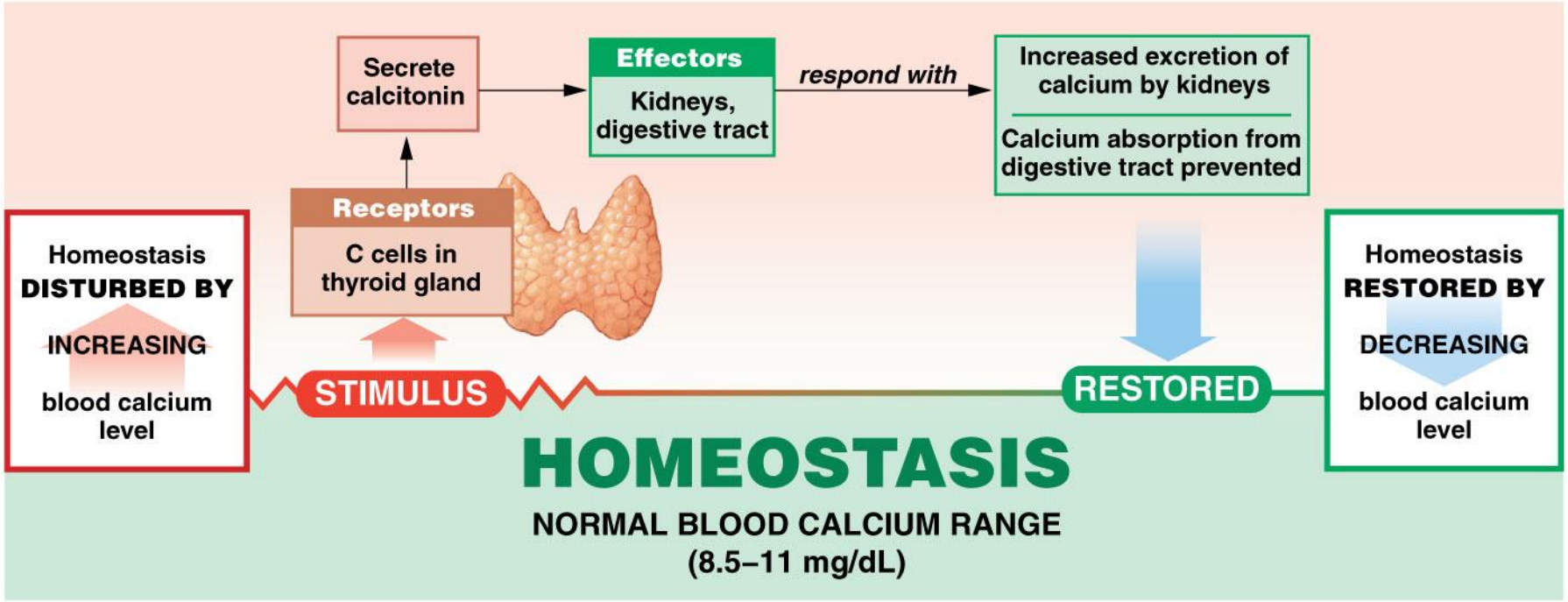


Module 16.9: The parathyroid gland

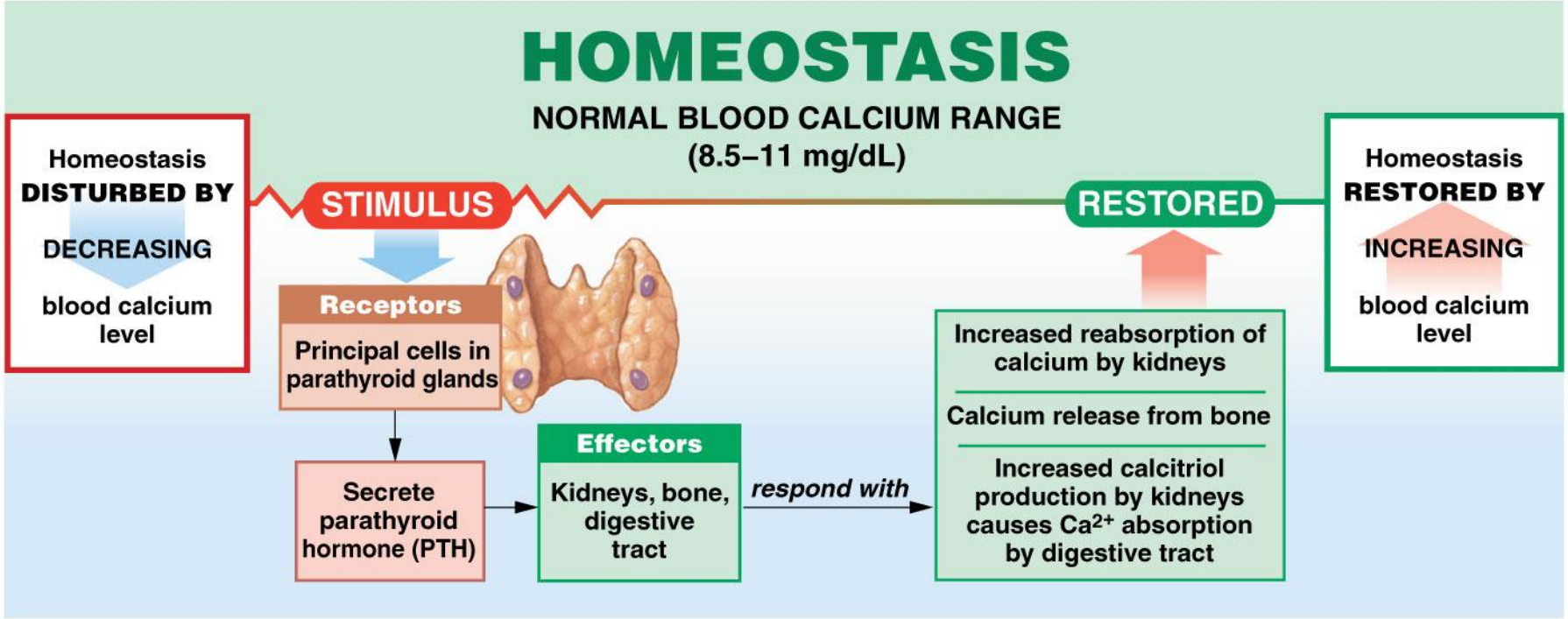
Calcium homeostasis

- PTH and calcitonin (from the thyroid gland) have opposing effects
- In healthy adults, PTH (along with calcitriol) is primary regulator of circulating Ca^{2+} concentrations
  - Removal of thyroid gland has no effect on Ca^{2+}
    - Dietary intake and metabolic demand balanced so that increased calcium levels are very rare
  - Calcitonin can be administered clinically in metabolic disorders with excessive calcium and excessive bone formation

Calcium homeostasis



Calcium homeostasis



Effects of parathyroid hormone on peripheral Tissues

Effects of Parathyroid Hormone on Peripheral Tissues

- PTH mobilizes calcium from bone by affecting osteoblast and osteoclast activity. PTH stimulates osteoblasts to secrete a growth factor known as RANKL. Osteoclasts have no PTH receptors, but both precursor and mature osteoclasts have RANKL receptors. This growth factor results in an increase in osteoclasts and osteoclast activity. With more osteoclasts, the rates of mineral turnover and Ca^{2+} release accelerate. As bone matrix erodes, blood Ca^{2+} rises.
- PTH enhances the reabsorption of Ca^{2+} by the kidneys, reducing urinary losses.
- PTH stimulates the formation and secretion of calcitriol by the kidneys. In general, the effects of calcitriol complement or enhance those of PTH, but calcitriol also enhances Ca^{2+} and PO_4^{3-} absorption by the digestive tract.

Module 16.9: Review

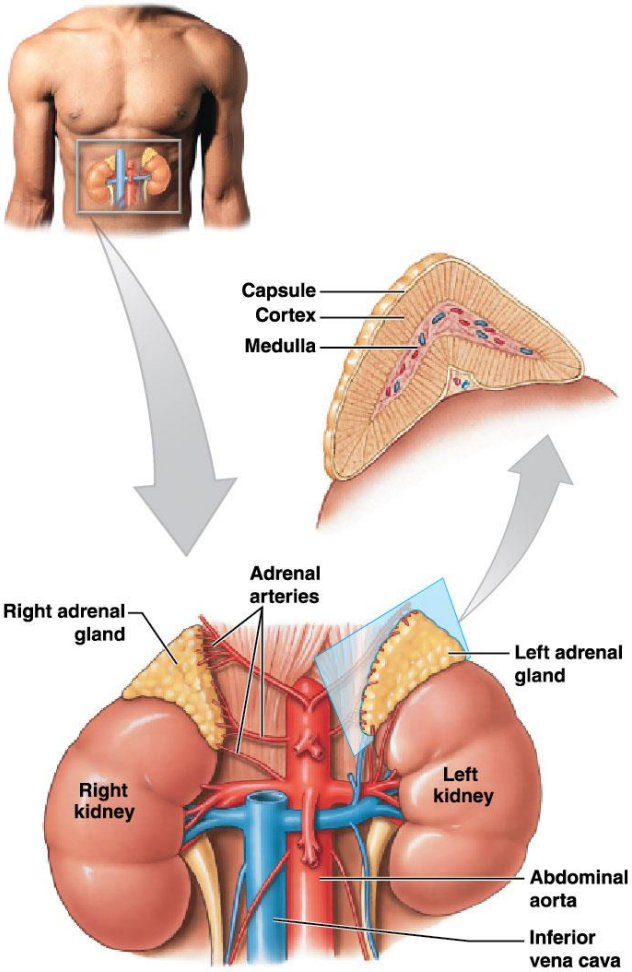
A. Describe the locations of the parathyroid glands.
B. Explain how parathyroid hormone increases blood calcium level.
C. Decreased blood calcium level would result in increased secretion of which hormone?

Learning Outcome: Describe the location of the parathyroid glands, and identify the functions of the hormone they produce.

Module 16.10: The adrenal hormones are involved in metabolic regulation, electrolyte balance, and stress responses

Adrenal gland gross anatomy

- Also called the suprarenal (*supra*, above + *ren*, kidney) gland
  - Sits on superior border of each kidney
- Retroperitoneal (like the kidneys)
  - Only anterior surface covered by parietal peritoneum
- Rich supply of blood vessels



Module 16.10: Adrenal glands

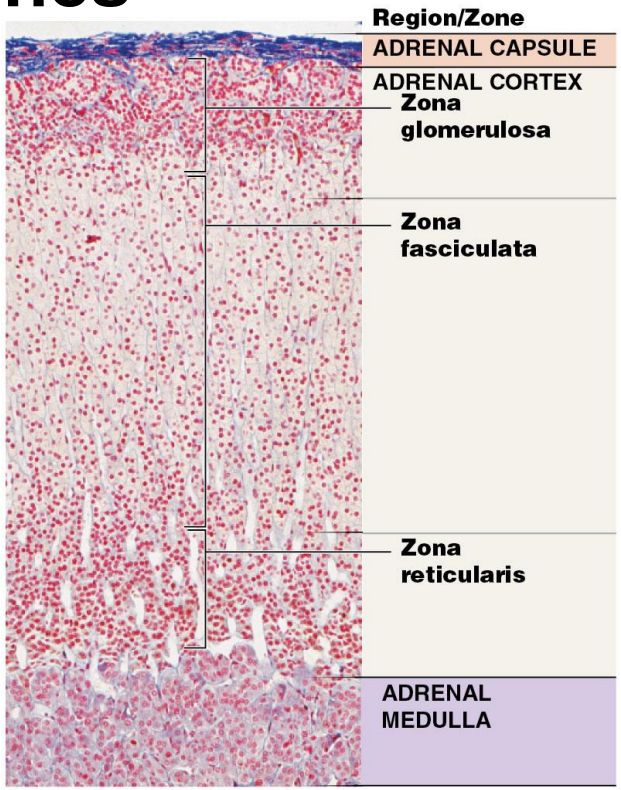
Adrenal gland layers

- **Adrenal capsule**
  - Thin, outer connective tissue
- **Adrenal cortex** (outer region)
  - Yellowish in color
    - Due to stored lipids, especially cholesterol and various fatty acids
  - Produces more than 24 steroid hormones collectively known as **corticosteroids**
    - Affect metabolism of target cells
    - Vital to maintaining life
- **Adrenal medulla** (inner region)
  - Produces epinephrine and norepinephrine

Module 16.10: Adrenal glands

Adrenal cortex zones and hormones

1. **Zona glomerulosa**
   - Outer region of the adrenal cortex
   - Secretes **mineralocorticoids** (primarily **aldosterone**)
     - Increases renal reabsorption of Na^+ and water
       - Especially in presence of ADH
     - Accelerates renal loss of K^+
   - Release stimulated by decreased blood pressure and volume through renin-angiotensin-aldosterone system and inhibited by hormones opposing that system

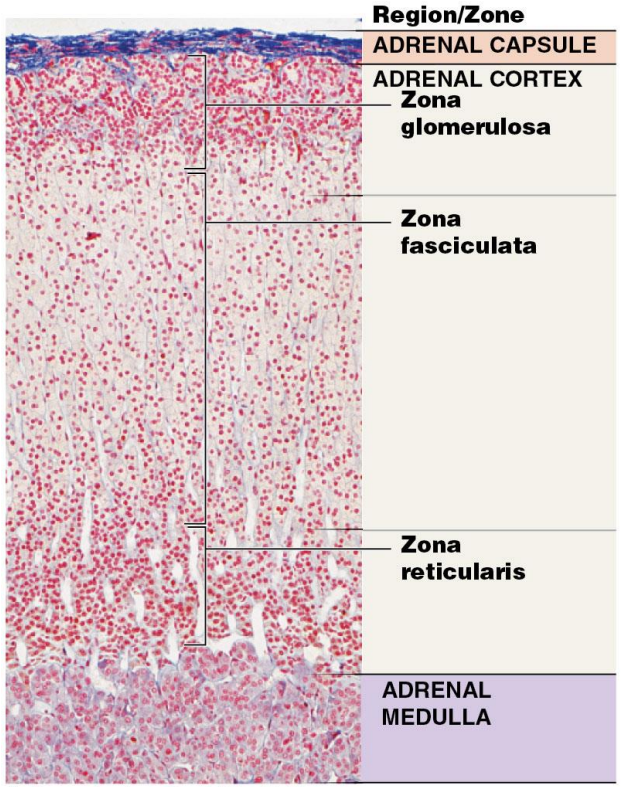


Adrenal gland LM × 250

Module 16.10: Adrenal glands

Adrenal cortex zones and hormones (continued)

2. **Zona fasciculata** (*fasciculus*, little bundle)
   - Large, central portion of adrenal cortex
   - Secretes **glucocorticoids**
     - Primarily **cortisol** and **corticosterone**
     - Liver converts some cortisol to **cortisone**
   - Secretion stimulated by ACTH from anterior pituitary gland



Adrenal gland LM × 250

Module 16.10: Adrenal glands

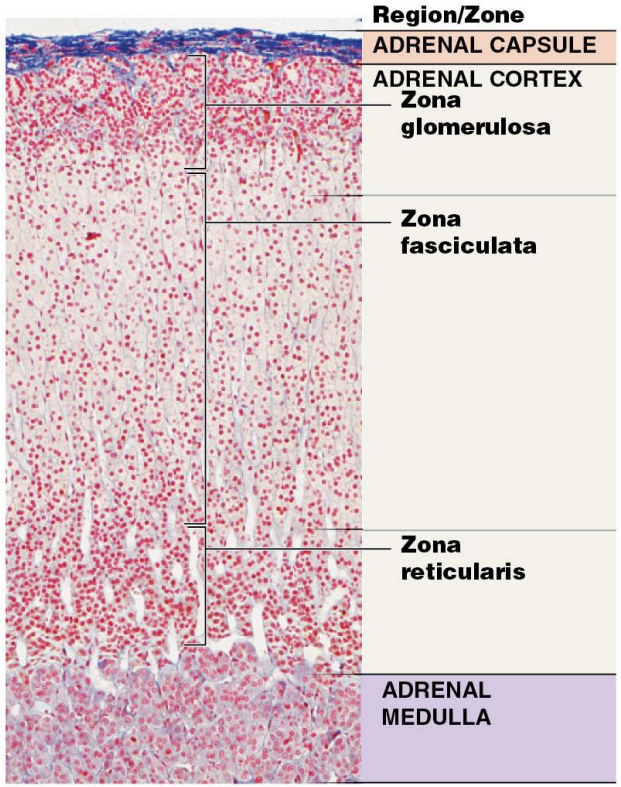
Adrenal cortex zones and hormones (continued)

2. **Zona fasciculata** (continued)
   - Actions of glucocorticoids
     - Affect glucose metabolism
       - Increase rates of liver glucose and glycogen formation
       - Stimulate release of amino acids from skeletal muscles
       - Stimulate release of lipids from adipose tissue
       - Promote lipid catabolism
     - All supplement glucose-sparing effects of GH
     - Cortisol also has an **anti-inflammatory** effect
   - Secretion stimulated by ACTH

Module 16.10: Adrenal glands

Adrenal cortex zones and hormones (continued)

3. **Zona reticularis** (*reticulum*, network)
   - Forms narrow band bordering each adrenal medulla
   - Secretes small quantities of androgens stimulated by ACTH
     - May be converted to estrogens in bloodstream
     - Minimal effects in normal adults
     - Stimulate development of pubic hair (in both males and females) before puberty

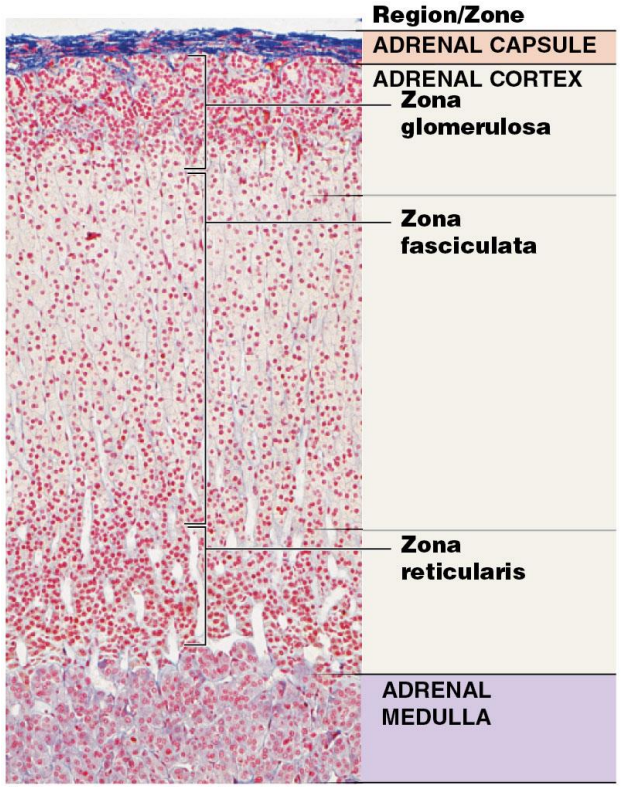


Adrenal gland LM × 250

Module 16.10: Adrenal glands

Adrenal medulla

- Secretes epinephrine and norepinephrine
- Actions of these hormones
  - Increased cardiac activity
  - Increased blood pressure
  - Increased glycogen breakdown and blood glucose
- Secreted in response to sympathetic nervous system stimulation



Adrenal gland LM × 250

Module 16.10: Review

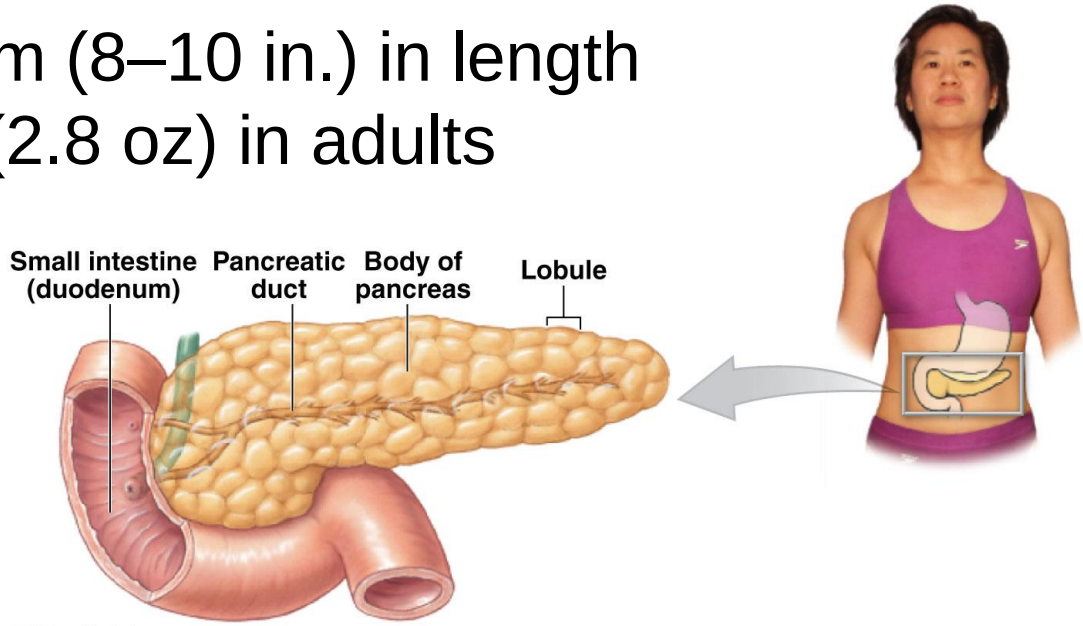
A. Name the regions and zones of an adrenal gland from superficial to deep.
B. Cite the hormones secreted by each region of an adrenal gland.
C. What effect would increased cortisol levels have on blood glucose level?

Learning Outcome: Describe the location, structure, and functions of the adrenal glands, identify the hormones produced, and specify the functions of each hormone.

Module 16.11: The pancreatic islets secrete insulin and glucagon, which regulate glucose use by most cells

Pancreas gross anatomy

- Mostly retroperitoneal
- Lies in loop formed between inferior border of the stomach and proximal portion of small intestine
- Slender, pale organ with nodular (lumpy) texture
- Measures 20–25 cm (8–10 in.) in length and weighs ~80 g (2.8 oz) in adults



Module 16.11: The pancreas

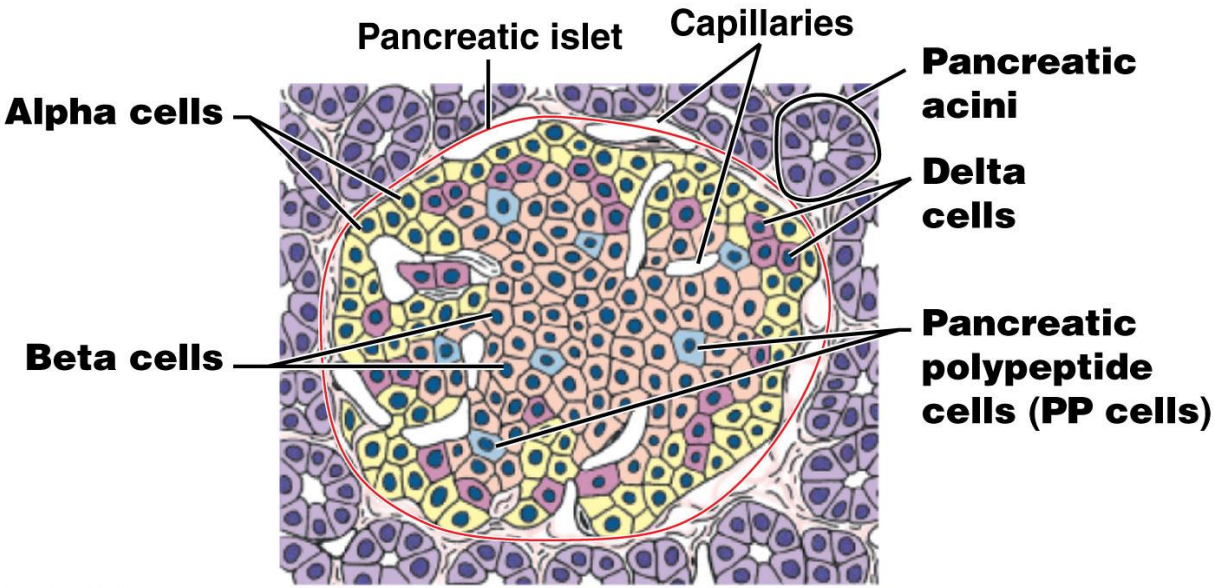
Two pancreatic regions

1. **Exocrine pancreas** (99 percent of volume)
   - Clusters of cells (**pancreatic acini**) and attached ducts
   - Secrete alkaline, enzyme-rich fluid
   - Fluid flows to intestinal tract through **pancreatic ducts**
2. **Endocrine pancreas** (1 percent of volume)
   - Small groups of hormone-producing cells scattered in clusters called **pancreatic islets** or *islets of Langerhans*
   - About 2 million islets in a typical pancreas

Module 16.11: The pancreas

Pancreatic islet cells and hormones

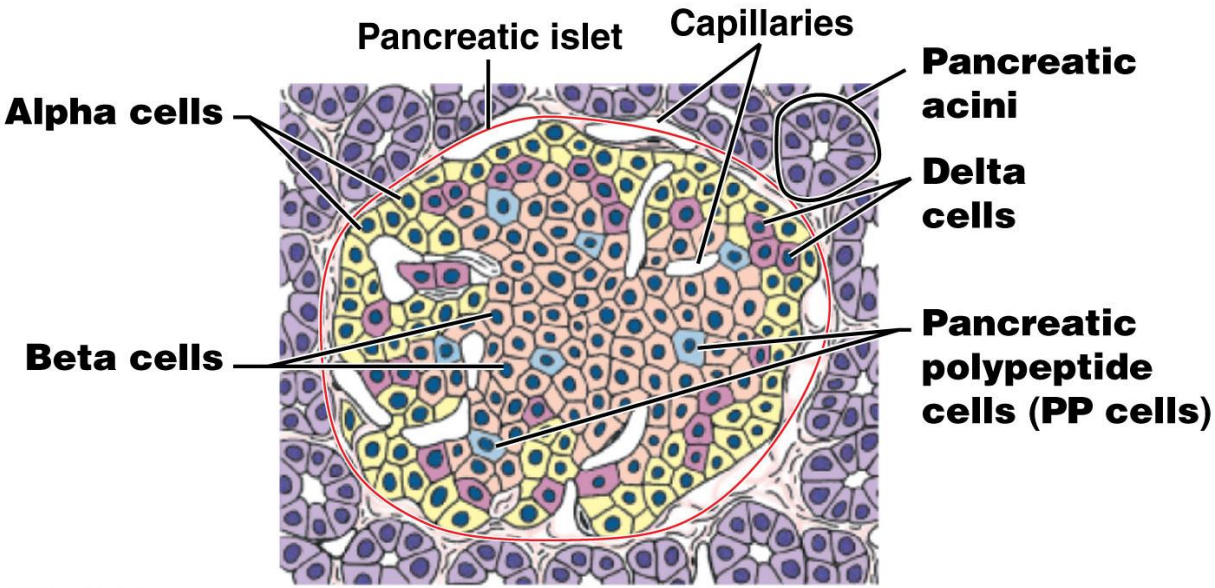
- **Alpha cells**
  - Produce **glucagon**
    - Raises blood glucose
      - Increases rate of glycogen breakdown and glucose release by liver



Module 16.11: The pancreas

Pancreatic islet cells and hormones (continued)

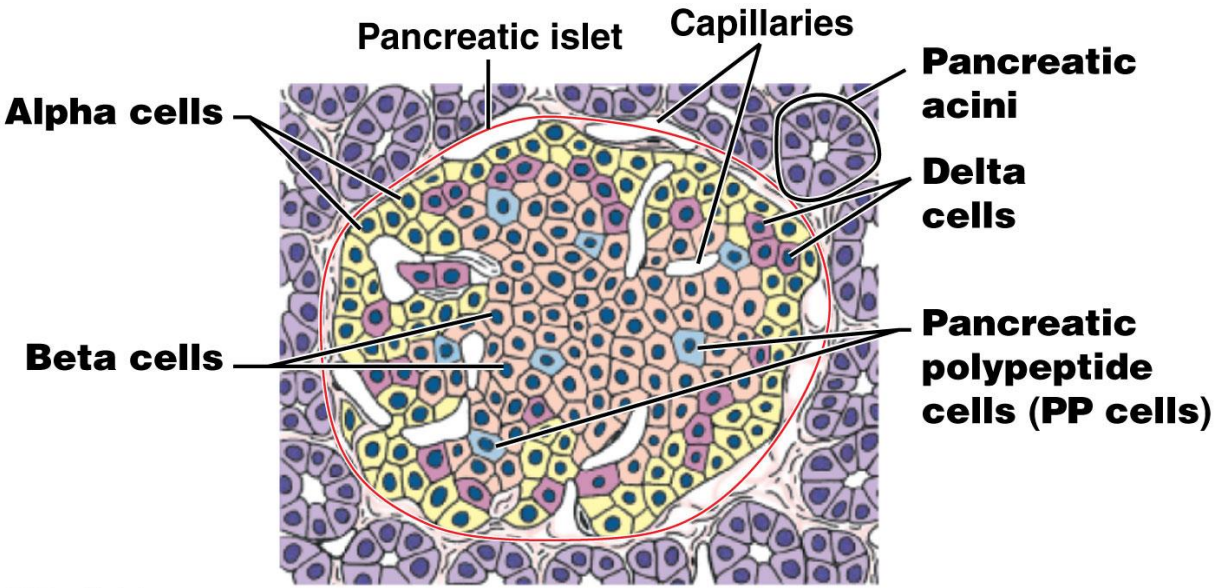
- **Beta cells**
  - Produce **insulin**
    - Lowers blood glucose
      - Increases glucose uptake and utilization by cells
      - Increases glycogen production in liver and skeletal muscles



Module 16.11: The pancreas

Pancreatic islet cells and hormones (continued)

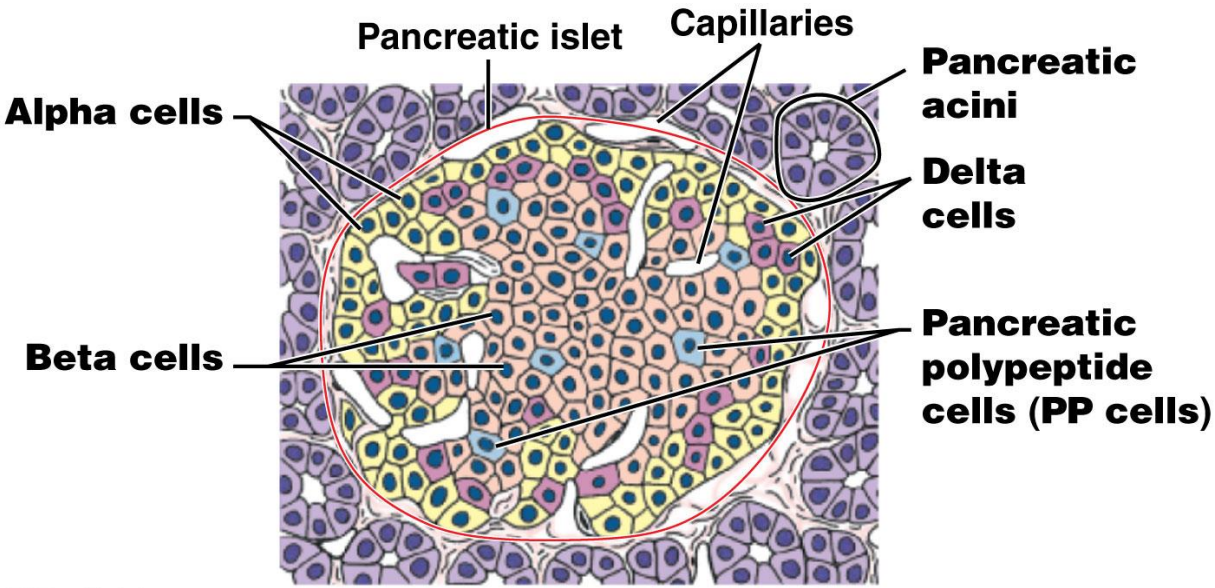
- **Delta cells**
  - Produce peptide hormone identical to growth hormone–inhibiting hormone (GH–IH)
    - Suppresses release of glucagon and insulin
    - Slows rates of food absorption and enzyme secretion in intestinal tract



Module 16.11: The pancreas

Pancreatic islet cells and hormones (continued)

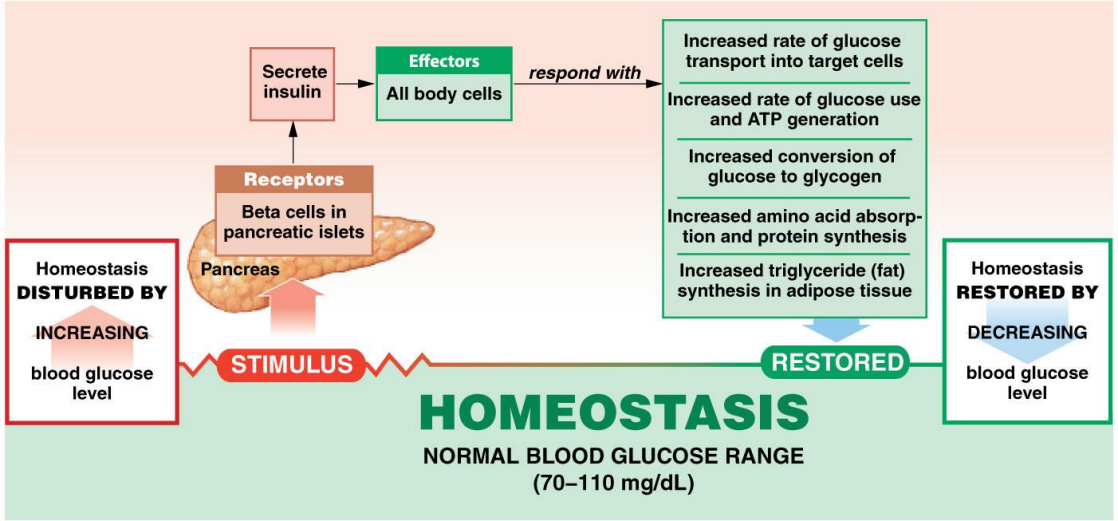
- **Pancreatic polypeptide cells (PP cells)**
  - Produce *pancreatic polypeptide* (*PP*)
    - Inhibits gallbladder contraction
    - Regulates production of some pancreatic enzymes
    - May help control rate of nutrient absorption



Module 16.11: The pancreas

Glucose homeostasis

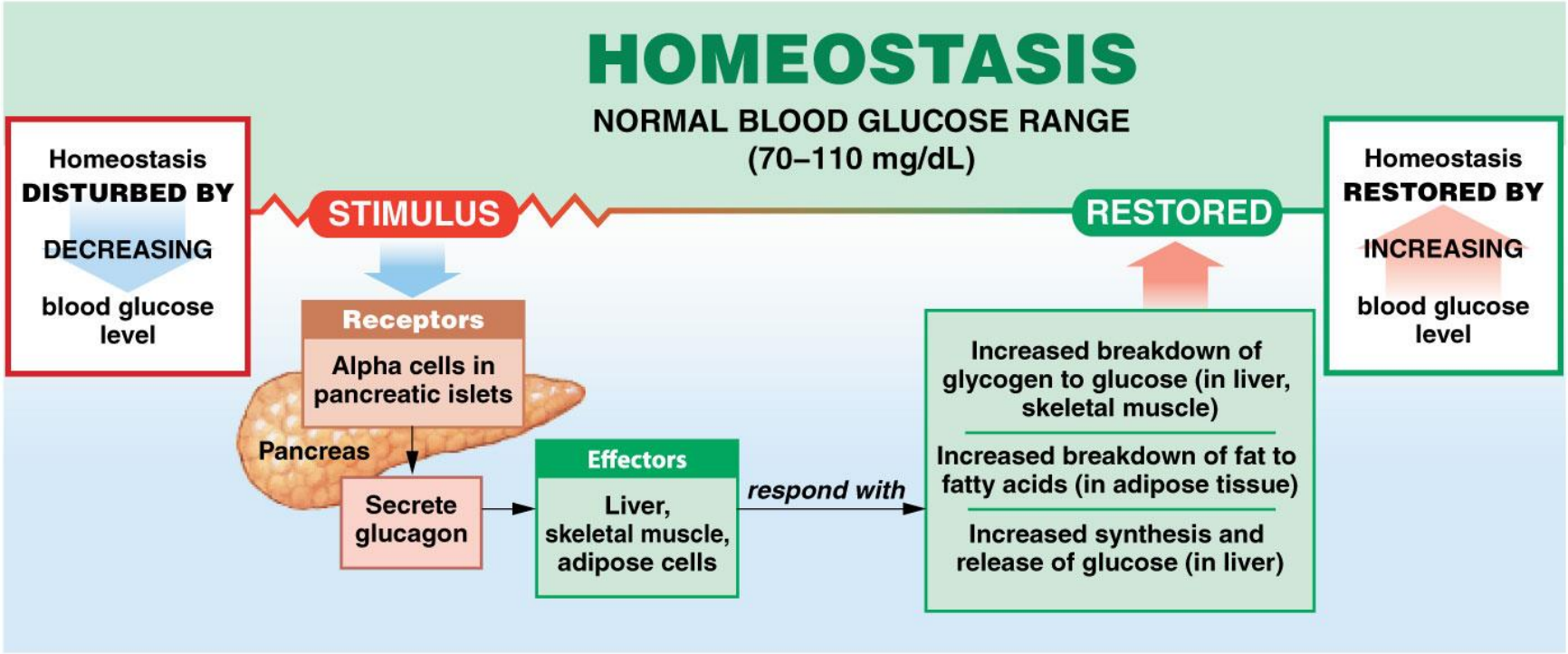
- Insulin and glucagon are primary hormones controlling blood glucose levels
  - Have opposing effects
- As blood glucose rises:
  - Beta cells secrete insulin
  - Stimulates transport of glucose into target cells



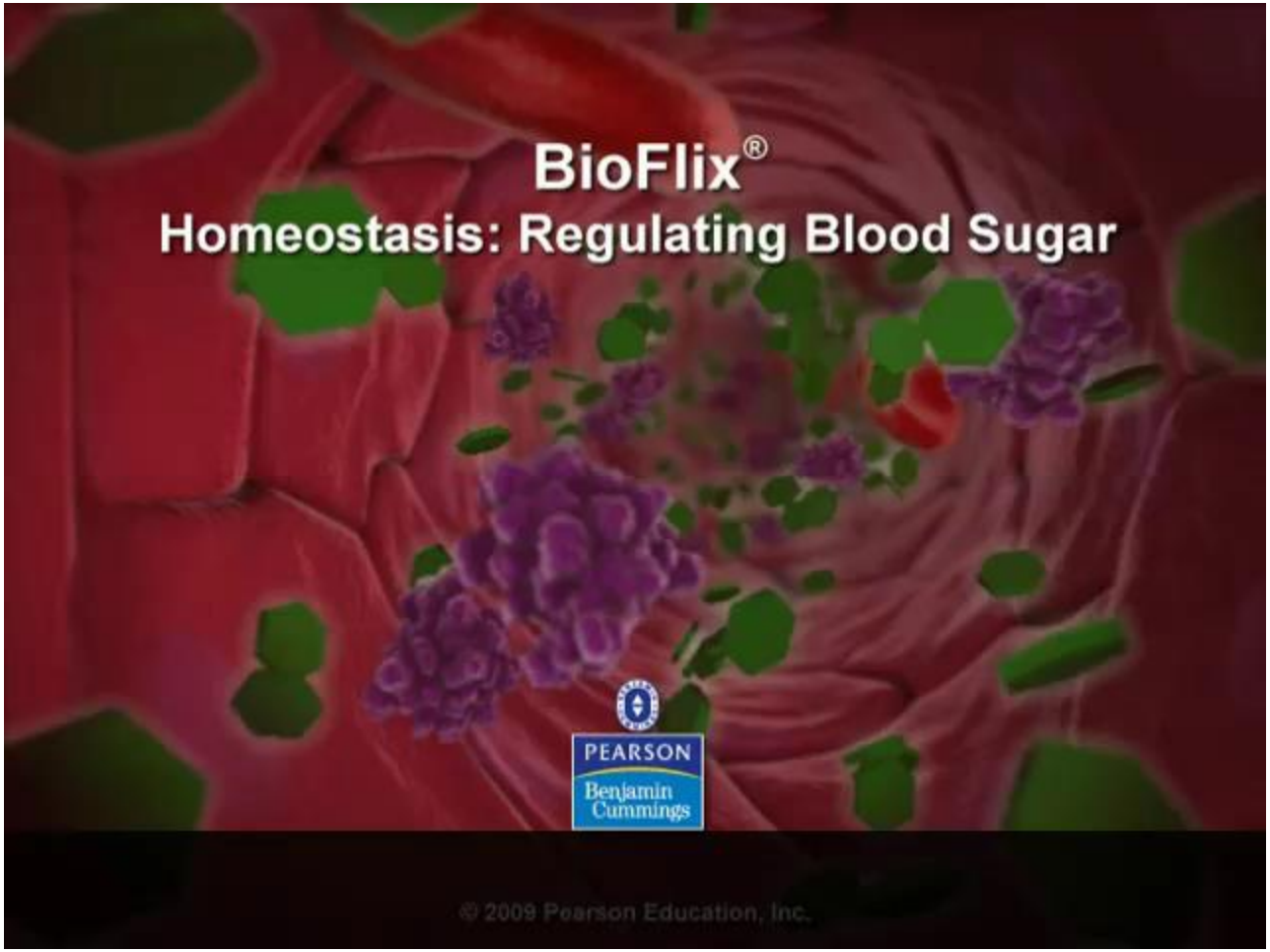
Module 16.11: The pancreas

Glucose homeostasis (continued)

- As blood glucose declines:
  - Alpha cells secrete glucagon
  - Stimulates glycogen breakdown and glucose release



BioFlix: Homeostasis: Regulating Blood Sugar



Module 16.11: Review

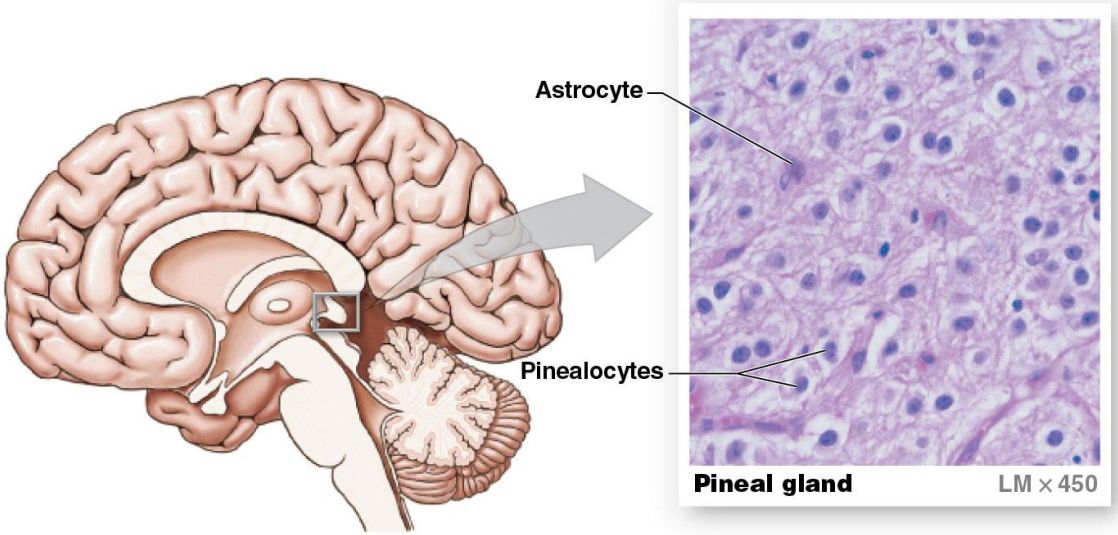
A. Identify the types of cells in the pancreatic islets and the hormones produced by each.
B. The secretion of which hormone lowers blood glucose concentration?
C. What is the effect of increased glucagon levels on the amount of glycogen stored in the liver?

Learning Outcome: Describe the location and structure of the pancreas, identify the hormones it produces, and specify the functions of those hormones.

Module 16.12: The pineal gland of the epithalamus secretes melatonin, which affects the circadian rhythm

Pineal gland

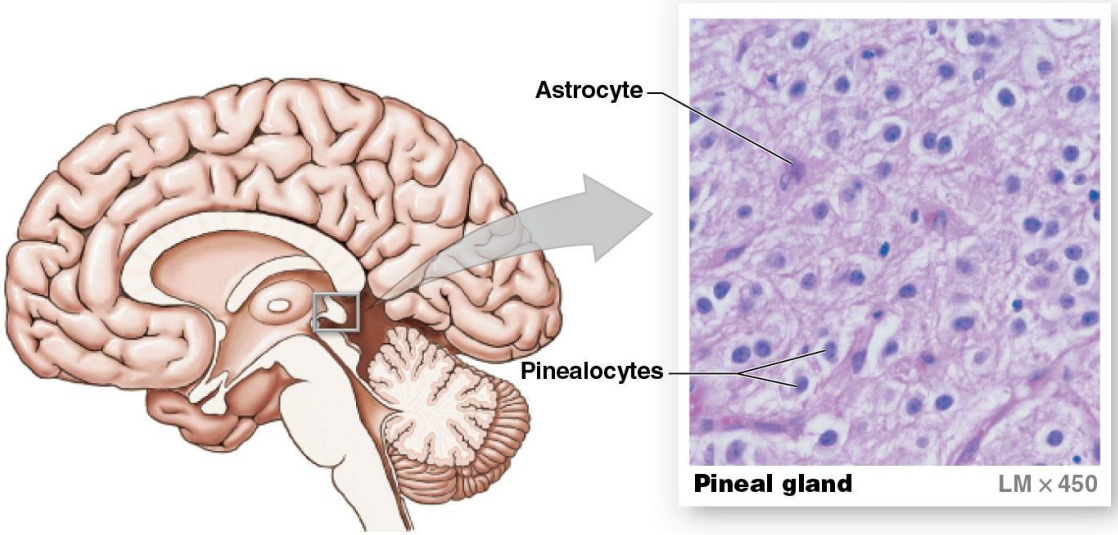
- Part of epithalamus
- Lies in posterior portion of third ventricle roof
- Contains neurons, neuroglia, and secretory cells called **pinealocytes**



Module 16.12: The pineal gland

Pineal gland (continued)

- Pinealocytes produce **melatonin** from molecules of serotonin (a neurotransmitter)
- Collaterals from the visual pathway enter the pineal gland and affect rate of melatonin production
  - Rate lowest during daylight and highest at night



Functions of melatonin in humans

Functions of Melatonin in Humans

- **Setting circadian rhythms.**
- **Inhibiting reproductive functions.**
- **Protecting against damage by free radicals.**

Module 16.12: Review

A. Identify the hormone-secreting cells of the pineal gland.
B. Increased amounts of light would inhibit the production of which hormone?
C. List three functions suggested for melatonin in humans.

Learning Outcome: Describe the location of the pineal gland, and identify the functions of the hormone that it produces.

Module 16.13: Clinical Module: Diabetes mellitus is an endocrine disorder characterized by an excessively high blood glucose level

Diabetes mellitus (*mellitum*, honey)

- Characterized by glucose concentrations high enough to overwhelm kidney reabsorption
  - **Hyperglycemia** (presence of abnormally high blood glucose levels)
  - **Glycosuria** (glucose in urine)
  - **Polyuria** (excessive urine production)
- Can be caused by genetic abnormalities or mutations resulting in:
  - Inadequate insulin production
  - Synthesis of abnormal insulin molecules
  - Production of defective insulin-receptor proteins

Module 16.13: Diabetes mellitus

Diabetes mellitus types

- **Type 1 diabetes**
  - Inadequate insulin production from pancreatic beta cells
  - Individuals must receive insulin daily
    - Through injection or continuous infusion from insulin pump or other device
  - Only 5–10 percent of all diabetes cases
  - Often develops in children and young adults

Module 16.13: Diabetes mellitus

Diabetes mellitus types (continued)

- **Type 2 diabetes**
  - Most common form of diabetes mellitus
  - Body produces normal amounts of insulin
  - Tissues do not respond properly
    - Condition called insulin resistance
  - Associated with obesity
  - Can be treated with diet, exercise, and medications that alter rate of glucose synthesis and release by the liver

Module 16.13: Diabetes mellitus

Clinical problems caused by diabetes mellitus

- About 25.8 million people in the U.S. have some form of diabetes mellitus
- If untreated, disrupts metabolic activities throughout the body
  - Without insulin (or functioning insulin receptors), cells cannot absorb glucose from surroundings
  - Tissues respond as if in chronic starvation
  - Break down lipids and proteins as alternate energy sources
- Also causes abnormal changes in blood vessel structure

Module 16.13: Diabetes mellitus

Clinical problems caused by diabetes mellitus (continued)

- **Diabetic retinopathy**
  - Partial or complete blindness caused by damage to capillaries in the retina
- Increased risk of heart attack
  - Three to five times more likely for a given age group
  - Due to degenerative blockages in cardiac circulation

Module 16.13: Diabetes mellitus

Clinical problems caused by diabetes mellitus (continued)

- **Diabetic nephropathy**
  - Degenerative changes in the kidneys that can lead to kidney failure

Module 16.13: Diabetes mellitus

Clinical problems caused by diabetes mellitus (continued)

- **Diabetic neuropathy**
  - Caused by abnormal blood flow to neural tissue
- Peripheral tissue damage in the distal limbs
  - Blood flow is reduced
  - Can lead to tissue death, ulceration, infection
  - In feet, could lead to loss of toes or major portion of one or both feet

Module 16.13: Review

A. Define *diabetes mellitus*.
B. Describe the two types of diabetes mellitus.
C. Identify some clinical problems associated with diabetes mellitus.

Learning Outcome: Explain diabetes mellitus: its types, clinical manifestations, and treatments.

Section 2: Hormones and System Integration

Learning Outcomes

16.14 Explain how hormones interact to produce coordinated physiological responses.

16.15 Describe the functions of the hormones produced by the kidneys and the heart.

16.16 Explain the roles of other endocrine organs and hormones in normal growth and development.

16.17 Define the general adaptation syndrome, and compare homeostatic responses with stress responses.

Section 2: Hormones and System Integration

Learning Outcomes (continued)

16.18 **Clinical Module:** Describe key endocrine disorders, citing their characteristic signs and symptoms.

Module 16.14: Hormones interact to produce coordinated physiological responses

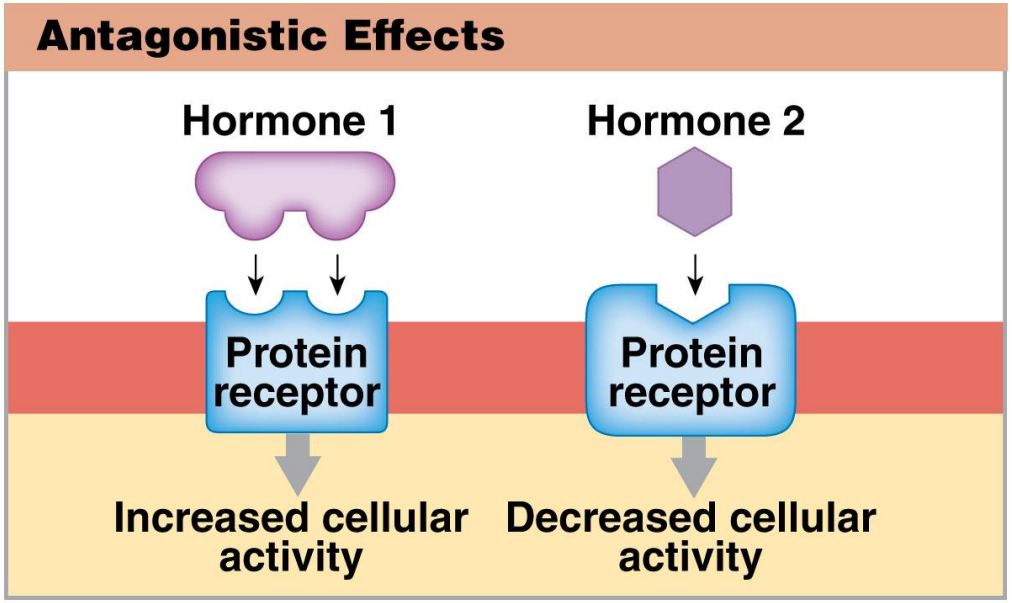
Four types of hormone interactions

- Cells have more than one type of hormone receptors, so can respond to multiple hormones simultaneously
- Receiving instructions from two hormones at the same time has four possible outcomes
  1. **Antagonistic effects**
  2. **Additive effects**
  3. **Permissive effects**
  4. **Integrative effects**

Module 16.14: Hormone interactions

Antagonistic (opposing) **effects**

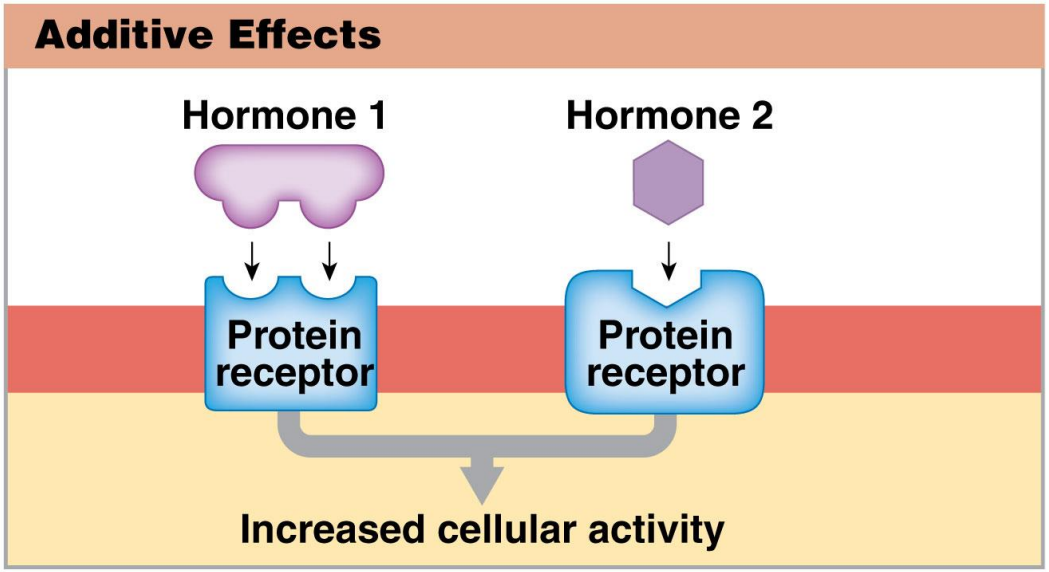
- Net result depends on balance between hormones
- In general, observed effects are weaker than those produced by either hormone unopposed
- *Examples*
  - PTH vs. calcitonin
  - Insulin vs. glucagon



Module 16.14: Hormone interactions

Additive effects

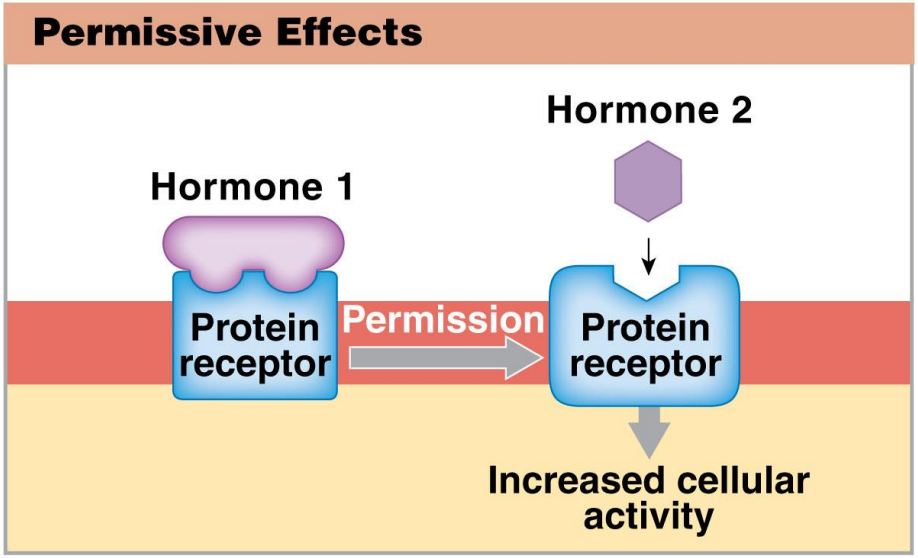
- Net result from two hormones is greater than each acting alone
  - In some cases, result is greater than the sum of individual effects
    - Called a **synergistic effect** (*synairesis,* a drawing together)
- *Example*
  - Glucose-sparing action of GH is enhanced in the presence of glucocorticoids



Module 16.14: Hormone interactions

Permissive effects

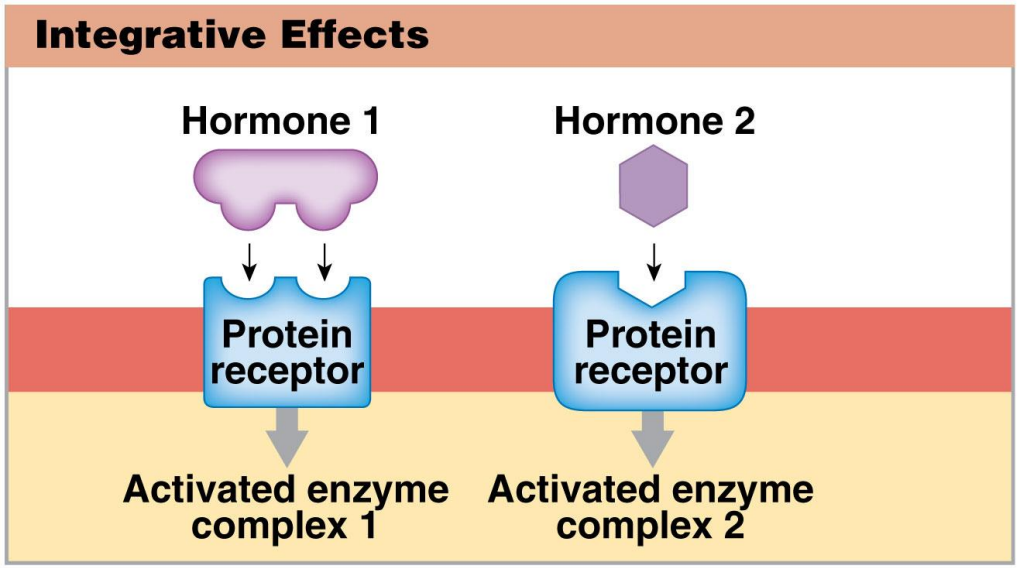
- One hormone is needed for second hormone to produce its effect
- *Example*
  - Epinephrine changes rate of cellular energy consumption only in presence of thyroid hormones



Module 16.14: Hormone interactions

Integrative effects

- Hormones produce different but complementary effects
- Important in coordinating activities of diverse physiological systems
- *Example*
  - Effects of calcitriol and PTH on tissues in calcium metabolism



Module 16.14: Review

A. Define *synergistic effect*.
B. Which of the four hormonal effects are involved in a negative feedback response?
C. What kind of effect do hormones have if they produce different but complementary effects?

Learning Outcome: Explain how hormones interact to produce coordinated physiological responses.

Module 16.15: Regulation of blood pressure and blood volume involves hormones from primary endocrine organs and from endocrine tissues in the heart and kidneys

Blood pressure and volume homeostatic regulation

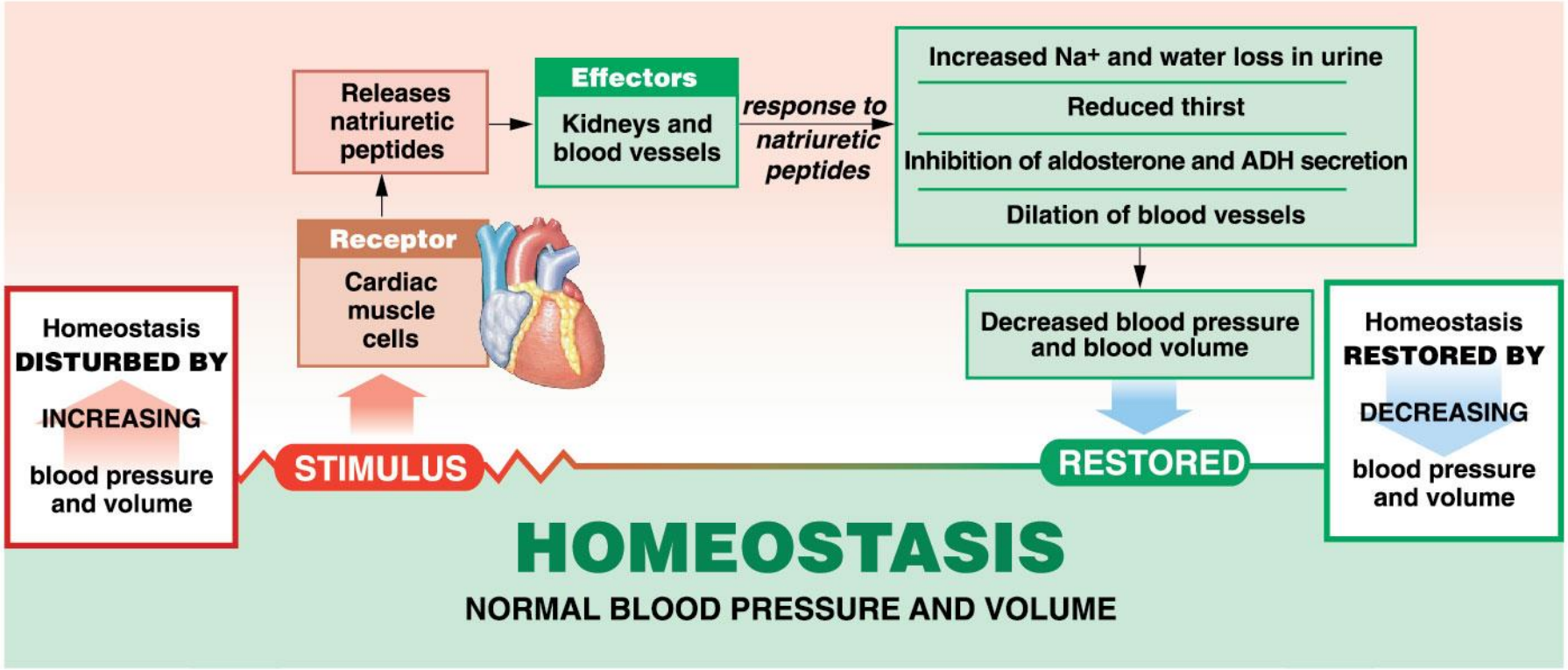
- Long-term regulation of blood pressure and volume involves:
  - Pituitary gland
  - Adrenal glands
  - Endocrine cells in the:
    - Heart
    - Kidneys

Module 16.15: Regulation of blood pressure and blood volume

Blood pressure and volume homeostatic regulation (continued)

- To decrease blood pressure:
  - Endocrine cells in the heart walls respond to overstretching by releasing:
    - **Natriuretic peptides** (*natrium,* sodium + *ouresis,* urination)
      - Promotes Na^+ and water loss at kidneys
      - Inhibits release of renin, ADH, and aldosterone
      - Suppresses thirst
      - Overall effect is reduction of blood volume and pressure

Blood pressure regulation

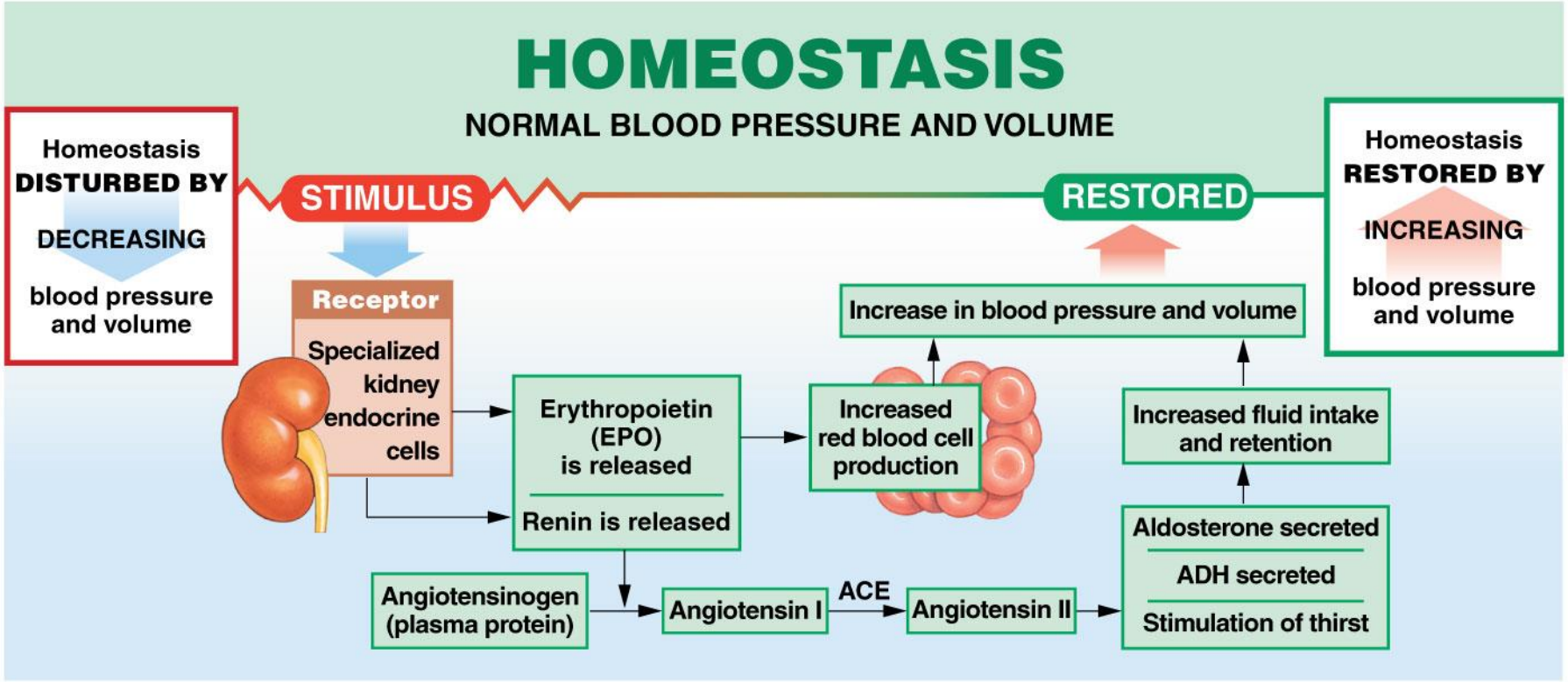


Module 16.15: Regulation of blood pressure and blood volume

Blood pressure and volume homeostatic regulation (continued)

- To increase blood pressure and volume:
  - Endocrine cells in the kidneys release:
    - **Erythropoietin (EPO)**
      - Increases red blood cell production
      - Leads to increased blood volume
    - **Renin**
      - Activates **renin-angiotensin-aldosterone system** (**RAAS**)
      - Leads to increased fluid intake and fluid retention

Blood pressure regulation



Module 16.15: Review

A. Name the hormones secreted by the heart.
B. Name the hormone and enzyme secreted by the kidneys.

Learning Outcome: Describe the functions of the hormones produced by the kidneys and the heart.

Module 16.16: Normal growth requires the cooperation of many endocrine organs

Homeostatic regulation of growth

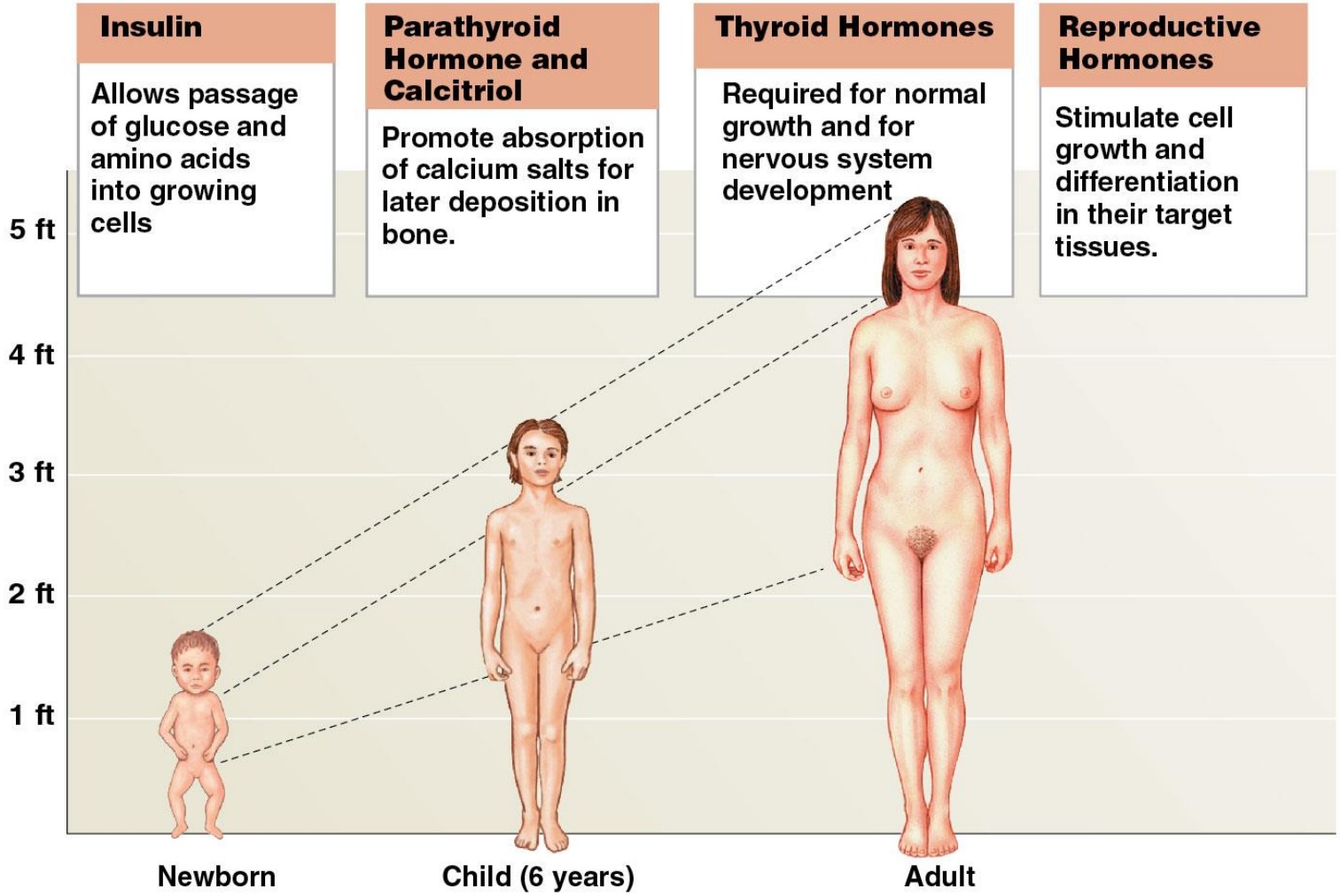
- Requires cooperation of many endocrine organs
- Hormones involved are regulated independently
- Hormonal mixture alters metabolic operations
- Combined effects of changing mixture produce unique growth patterns
- Circulating levels of hormones are regulated independently

Module 16.16: Cooperation of endocrine organs

Primary hormones regulating growth

- **Insulin**
  - Allows passage of glucose and amino acids across plasma membrane into growing cells
- **PTH and calcitonin**
  - PTH and calcitriol
    - Promote absorption of calcium salts for bone deposition
  - Bones need both to properly mineralize and to be strong and flexible

Hormones during development



Module 16.16: Cooperation of endocrine organs

Primary hormones regulating growth (continued)

- **Thyroid hormones**
  - Required for proper nervous system and skeletal system development
- **Reproductive hormones**
  - Affect osteoblast activity at various locations
  - Stimulate target cell growth and differentiation
  - Androgens in males, estrogens in females have different target tissues
    - Produces differential growth resulting in sex-related differences in skeletal proportions and secondary sex characteristics

Module 16.16: Cooperation of endocrine organs

Primary hormones regulating growth (continued)

- **Growth hormone**
  - In children
    - Supports protein synthesis and cellular growth in skeletal and muscular development
  - In adults
    - Assists in energy metabolism and storage

Growth Hormone	
In Children	**In Adults**
The effects of GH on protein synthesis and cellular growth are most apparent in children. GH supports their muscular and skeletal development.	In adults, GH helps to maintain normal blood glucose concentrations and to mobilize lipid reserves stored in adipose tissue. It is not the primary hormone involved, however, and an adult with a GH deficiency but normal levels of thyroid hormones, insulin, and glucocorticoids will have no physiological problems.

Module 16.16: Review

A. Identify several hormones necessary for normal growth and development.

Learning Outcome: Explain the roles of other endocrine organs and hormones in normal growth and development.

Module 16.17: The stress response is a predictable response to any significant threat to homeostasis

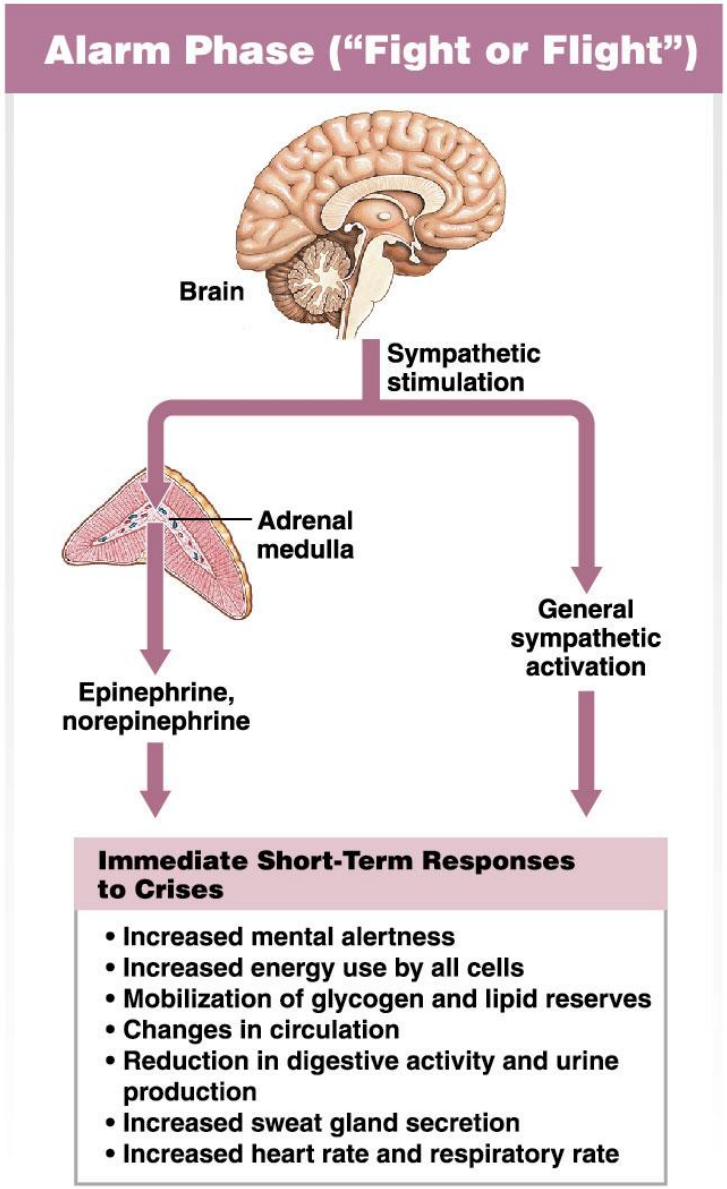
Stress

- Any physical or emotional condition that threatens homeostasis
- Stress can be mediated by specific adjustments
  - *Example:* shivering as a response to drop in body temperature
- Exposure to a wide variety of stress-causing factors leads to general hormonal and physiological responses
  - Responses called **stress response**, or **general adaptation syndrome** (**GAS**)

Module 16.17: The stress response

Three phases of the stress response

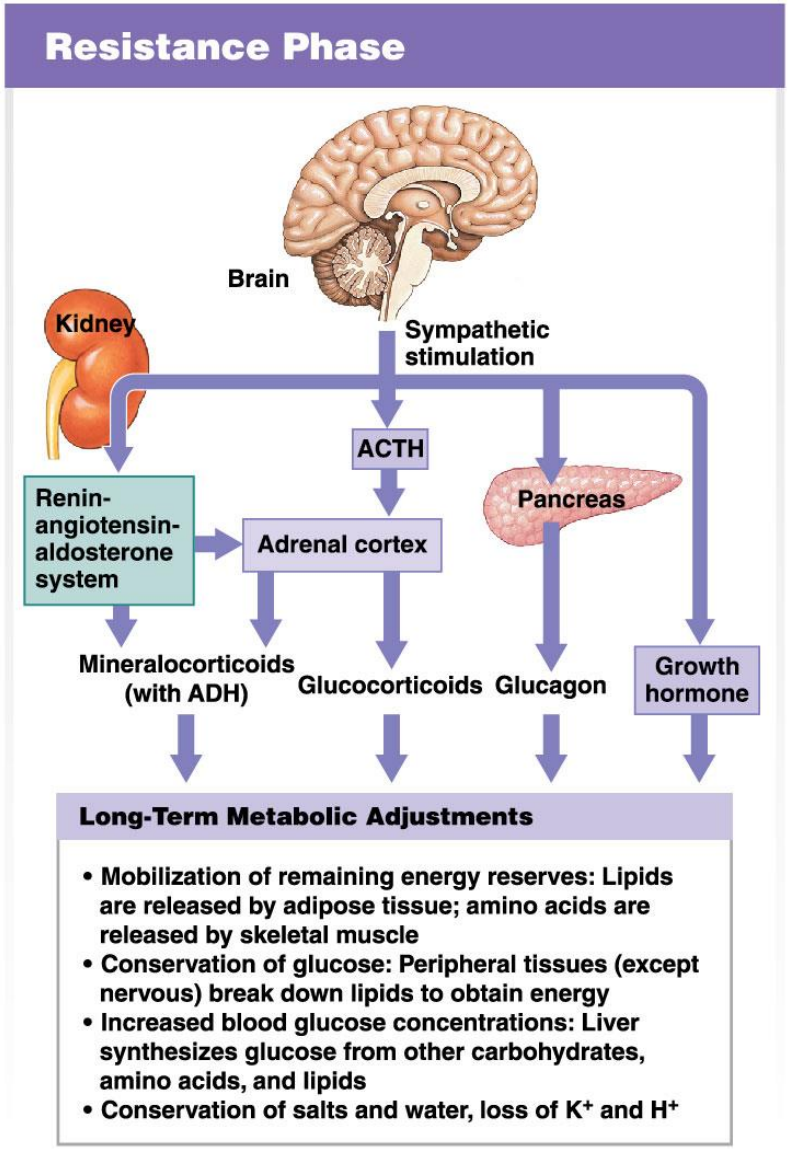
1. **Alarm phase**
   - Immediate sympathetic response to stress
     - Epinephrine is dominant hormone
   - Two main responses
     1. Energy reserves mobilized (mainly glucose)
     2. General “fight or flight” responses



Module 16.17: The stress response

Three phases of the stress response (continued)

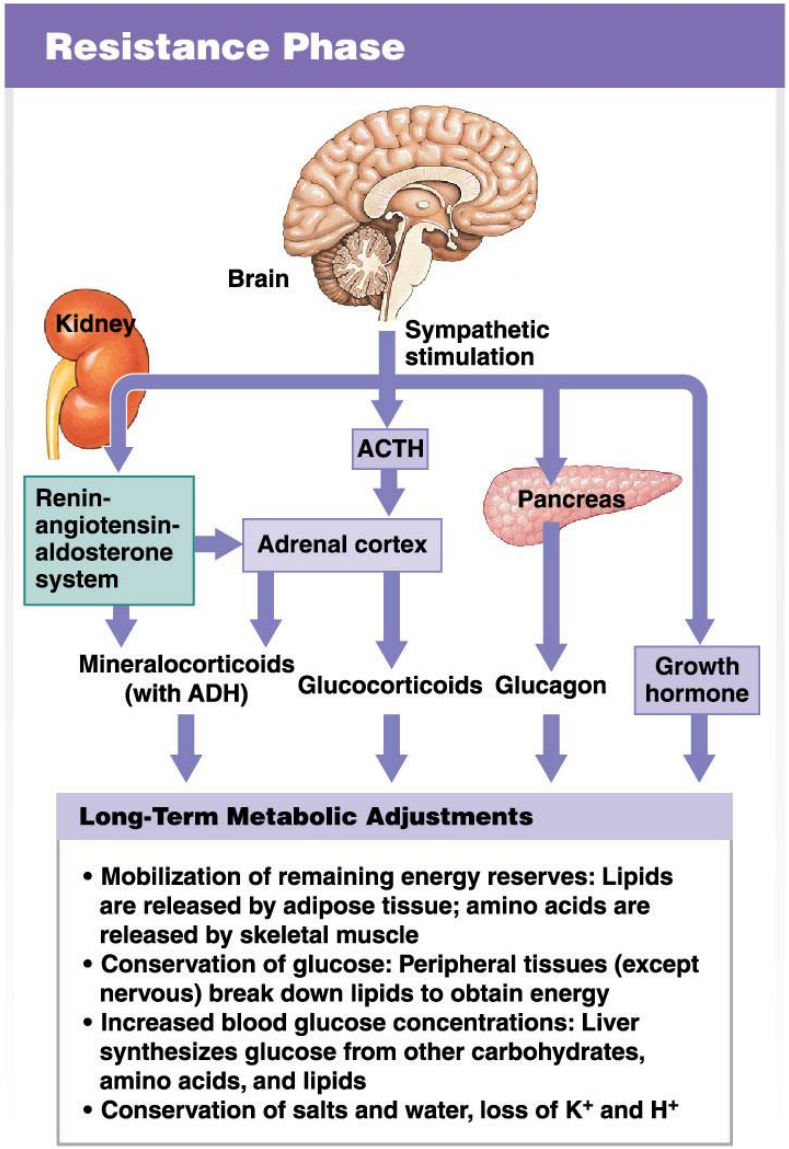
2. **Resistance phase**
   - Entered after a few hours of stress
   - Glucocorticoids are dominant hormones
     - Epinephrine, GH, and thyroid hormones also involved



Module 16.17: The stress response

Three phases of the stress response (continued)

2. **Resistance phase** (continued)
   - Continued high energy demands
     - Glycogen reserves exhausted
     - Body shifts to utilizing lipids and amino acids
   - Overall effect is mobilization of body's energy reserves while reserving glucose for neural tissues



Module 16.17: The stress response

Three phases of the stress response (continued)

3. **Exhaustion phase**
   - When energy reserves cannot be maintained, resistance phase ends
     - Could be period of weeks or months
   - Homeostatic regulation breaks down
   - Organ systems begin to fail
   - Mineral and electrolyte imbalances (Na^+, K^+, others) contribute to malfunction

Exhaustion Phase

Factors That Can Trigger the Exhaustion Phase

- Exhaustion of lipid reserves and the breakdown of structural proteins as the body's primary energy source, damaging vital organs
- Infections that develop as a result of the suppression of inflammation and of the immune response, a secondary effect of the glucocorticoids that are essential to the metabolic activities of the resistance phase
- Cardiovascular damage and complications resulting from the ADH- and aldosterone-related elevations in blood pressure and blood volume
- Inability of the adrenal cortex to continue producing glucocorticoids, which results in a failure to maintain acceptable blood glucose concentration
- Failure to maintain adequate fluid and electrolyte balance

Module 16.17: Review

A. List the three phases of the stress response.
B. Describe the resistance phase.
C. During which phase of the general adaptation syndrome is there a collapse of vital systems?

Learning Outcome: Define the general adaptation syndrome, and compare homeostatic responses with stress responses.

Module 16.18: Clinical Module: Overproduction or underproduction of hormones can cause endocrine disorders

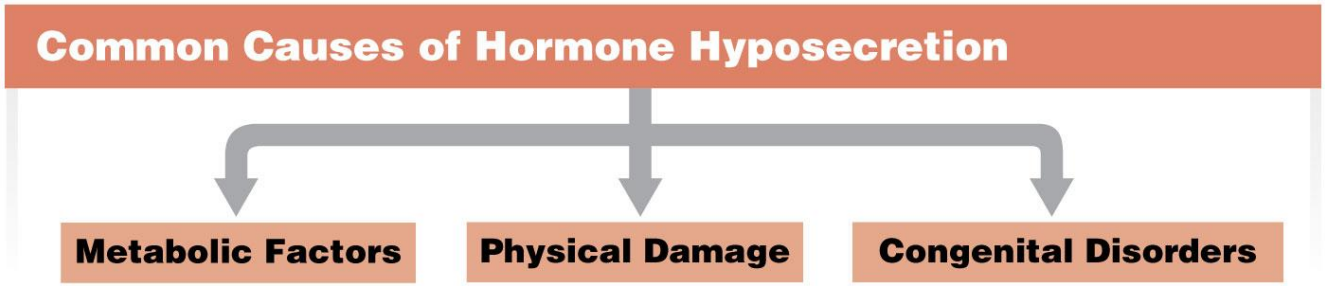
Causes of endocrine disorders

- Abnormalities at various levels can cause endocrine disorders
  - At endocrine gland
  - At endocrine or neural control mechanisms
  - At target tissues
- Effects are usually caused by underproduction (**hyposecretion**) or overproduction (**hypersecretion**) of hormones
  - Disorders from hyposecretion most common

Module 16.18: Endocrine disorders

Common causes of hormone hyposecretion

- Metabolic factors
  - Deficiency in key substance needed to synthesize hormone
    - *Example:* hypothyroidism caused by inadequate iodine in the diet
- Physical damage
  - Interruption to normal circulatory supply
  - Damage to endocrine cell or target cell



Module 16.18: Endocrine disorders

Common causes of hormone hyposecretion (continued)

- Congenital disorders (inability to produce normal amounts of hormone) possibly due to various factors:
  - Gland is too small
  - Required enzymes are abnormal
  - Receptors are relatively insensitive
  - Gland cells lack receptors to become stimulated

Module 16.18: Endocrine disorders

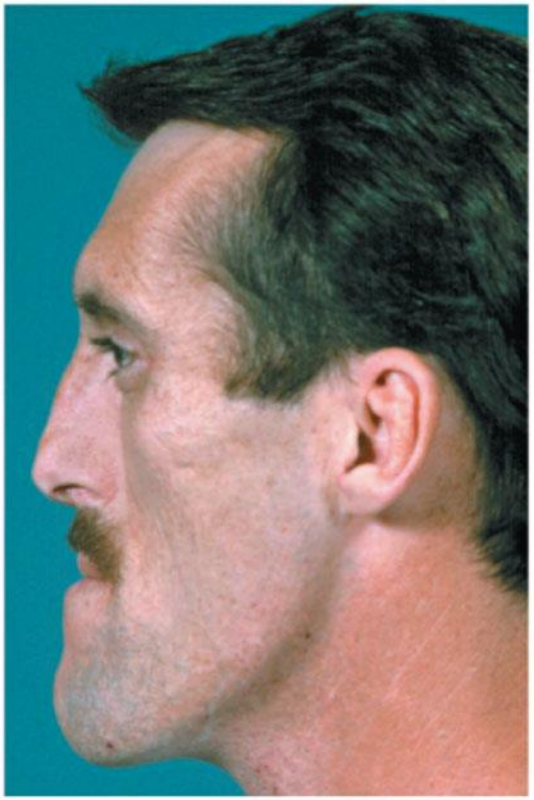
Endocrine abnormalities

- Can also be caused by presence of abnormal receptors in target tissues
  - Glands and regulatory mechanisms normal
  - Peripheral cells unable to respond to circulating hormone
  - Best example: type 2 diabetes
    - Peripheral cells do not respond to insulin

Module 16.18: Endocrine disorders

Acromegaly

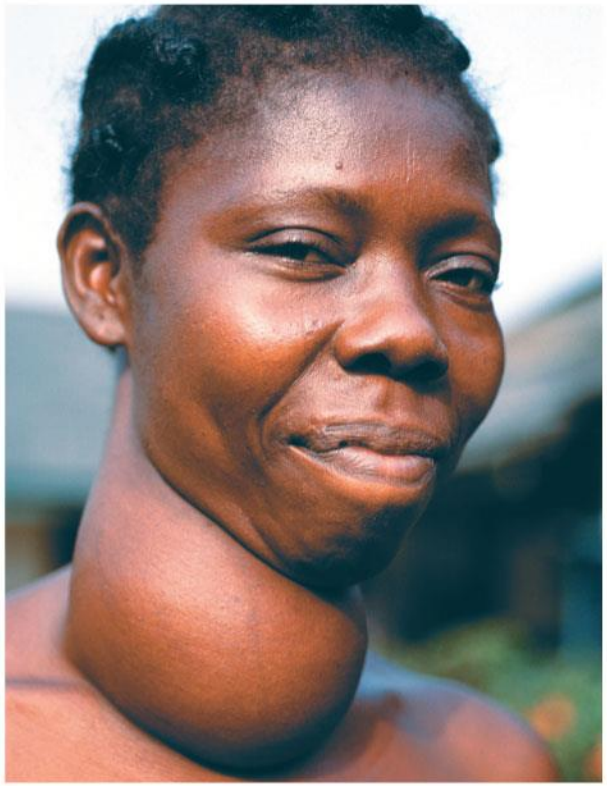
- Results from overproduction of growth hormone after epiphyseal plates have fused
- No increase in height
- Bone shapes change
- Cartilaginous areas of skeleton enlarge
- Signs include:
  - Broad facial features
  - Enlarged lower jaw



Module 16.18: Endocrine disorders

Thyroid disorders

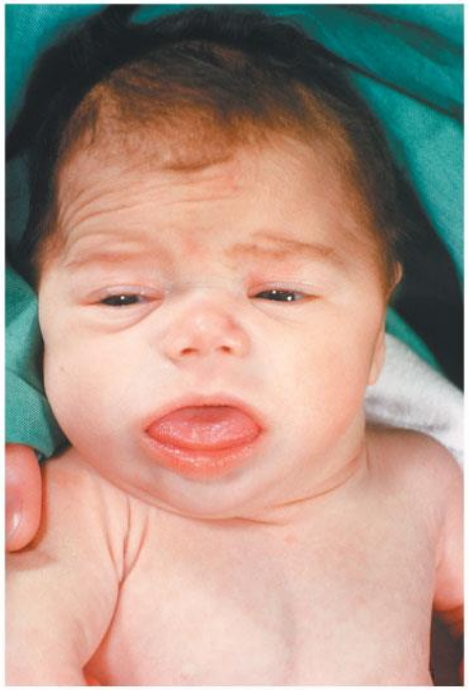
- **Goiter**
  - Enlarged thyroid gland
  - Usually associated with thyroid hyposecretion due to nutritional iodine deficiency



Module 16.18: Endocrine disorders

Thyroid disorders (continued)

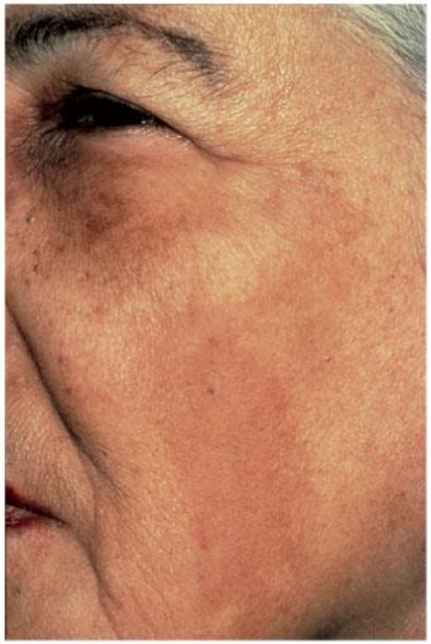
- **Infantile hypothyroidism**
  - Congenital disorder due to thyroid hormone deficiency
  - Characterized by mental disability, puffy face, and thick tongue



Module 16.18: Endocrine disorders

Adrenal gland disorders

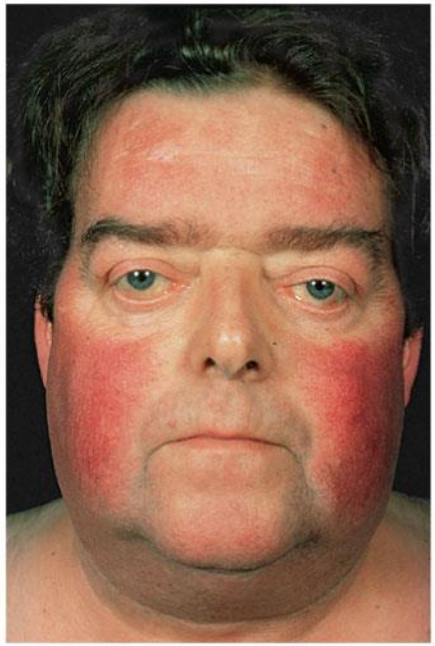
- **Addison's disease**
  - Caused by hyposecretion of corticosteroids, especially glucocorticoids
  - Pigment changes in skin result from stimulation of melanocytes by ACTH (structurally similar to MSH)



Module 16.18: Endocrine disorders

Adrenal gland disorders (continued)

- **Cushing's disease**
  - Caused by hypersecretion of glucocorticoids
  - Lipid reserves are mobilized
  - Adipose tissue accumulates in cheeks and at the base of the neck



An overview of endocrine disorders

An Overview of Endocrine Disorders

Hormone	Results of Under-production or Tissue Insensitivity	Principal Signs and Symptoms	Results of Over-production or Tissue Hypersensitivity	Principal Signs and Symptoms
Growth hormone (GH)	Pituitary growth failure	Delayed growth, abnormal fat distribution, low blood glucose hours after a meal	Gigantism, acromegaly	Excessive growth
Antidiuretic hormone (ADH)	Diabetes insipidus	Polyuria, dehydration, thirst	Syndrome of inappropriate ADH secretion (SIADH)	Increased body weight and water content
Thyroxine (T_4) and **triiodothyronine (T_3)**	Hypothyroidism, infantile hypothyroidism, myxedema (in adults)	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 (muscular spasms due to low blood Ca^{2+} level)	Hyperparathyroidism	Neurological, mental, and muscular problems due to high blood Ca^{2+} concentrations; weak and brittle bones

An overview of endocrine disorders

An Overview of Endocrine Disorders

Hormone	Results of Under-production or Tissue Insensitivity	Principal Signs and Symptoms	Results of Over-production or Tissue Hypersensitivity	Principal Signs and Symptoms
Insulin	Diabetes mellitus (type 1)	High blood glucose, impaired glucose utilization, dependence on lipids for energy, glycosuria	Excess insulin production (or administering too much insulin)	Low blood glucose levels, possibly causing coma
Mineralocorticoids (MCs) Example: aldosterone	Hypoaldosteronism	Polyuria, low blood volume, high blood K^+ and low blood Na^+ concentrations	Aldosteronism	Increased body weight due to Na^+ and water retention, low blood K^+ concentration
Glucocorticoids (GCs) Example: cortisol	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

An overview of endocrine disorders

An Overview of Endocrine Disorders

Hormone	Results of Under-production or Tissue Insensitivity	Principal Signs and Symptoms	Results of Over-production or Tissue Hypersensitivity	Principal Signs and Symptoms
Epinephrine (E) and **norepinephrine (NE)**	None identified	None identified	Pheochromocytoma (benign tumor of the adrenal medulla)	High metabolic rate, blood pressure, and heart rate; increased 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 estrogens, sometimes due to adrenal or interstitial cell tumors; leads to breast enlargement
			Precocious puberty	Premature sexual maturation and related behavioral changes

Module 16.18: Review

A. Define the prefixes *hyper-* and *hypo-* in the context of endocrine disorders.
B. Identify three common causes of hormone hyposecretion.
C. What condition is characterized by increased body weight due to Na^+ and water retention and a low blood K^+ concentration?

Learning Outcome: Describe key endocrine disorders, citing their characteristic signs and symptoms.