# ANATOMY OF THE ENDOCRINE SYSTEM

HUMAN ANATOMY

College of Pharmacy

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# LEARNING OUTCOME

- Explain the role of the endocrine system in maintaining homeostasis and its integration with the nervous system
- Identify major endocrine glands, their hormones, and target organs (e.g., insulin from pancreatic beta cells)
- Relate endocrine dysfunction to common disorders and associated pharmacotherapies

# ENDOCRINE SYSTEM

- Maintenance of **homeostasis** involves coordinating activities of organs and systems throughout the body
- The nervous system and endocrine system **work together** to **monitor and adjust physiologic activities**
- In general, the nervous system performs **fast, short-term** very specific responses to environmental stimuli

  - chemical messengers are **neurotransmitters**
- The endocrine system regulates **slow, long-term,** ongoing metabolic processes throughout the body

  - **chemical messengers** are **hormones**

# ENDOCRINE SYSTEM

**Definition:**

*"A network of **ductless glands that secrete hormones** directly **into the bloodstream** to regulate distant target organs."*

**Key Features:**

- **Hormones:** Chemical messengers (e.g., insulin, cortisol)
- **Target Organs:** Specific tissues with hormone receptors
- **Feedback Loops:** Maintain **homeostasis**

**Major Functions:**

- Maintain homeostasis
- Controls **metabolism, growth, reproduction, mood, and electrolyte balance**
- Works with the nervous system for coordinated responses

# HORMONE CONTROL BY FEEDBACK MECHANISMS

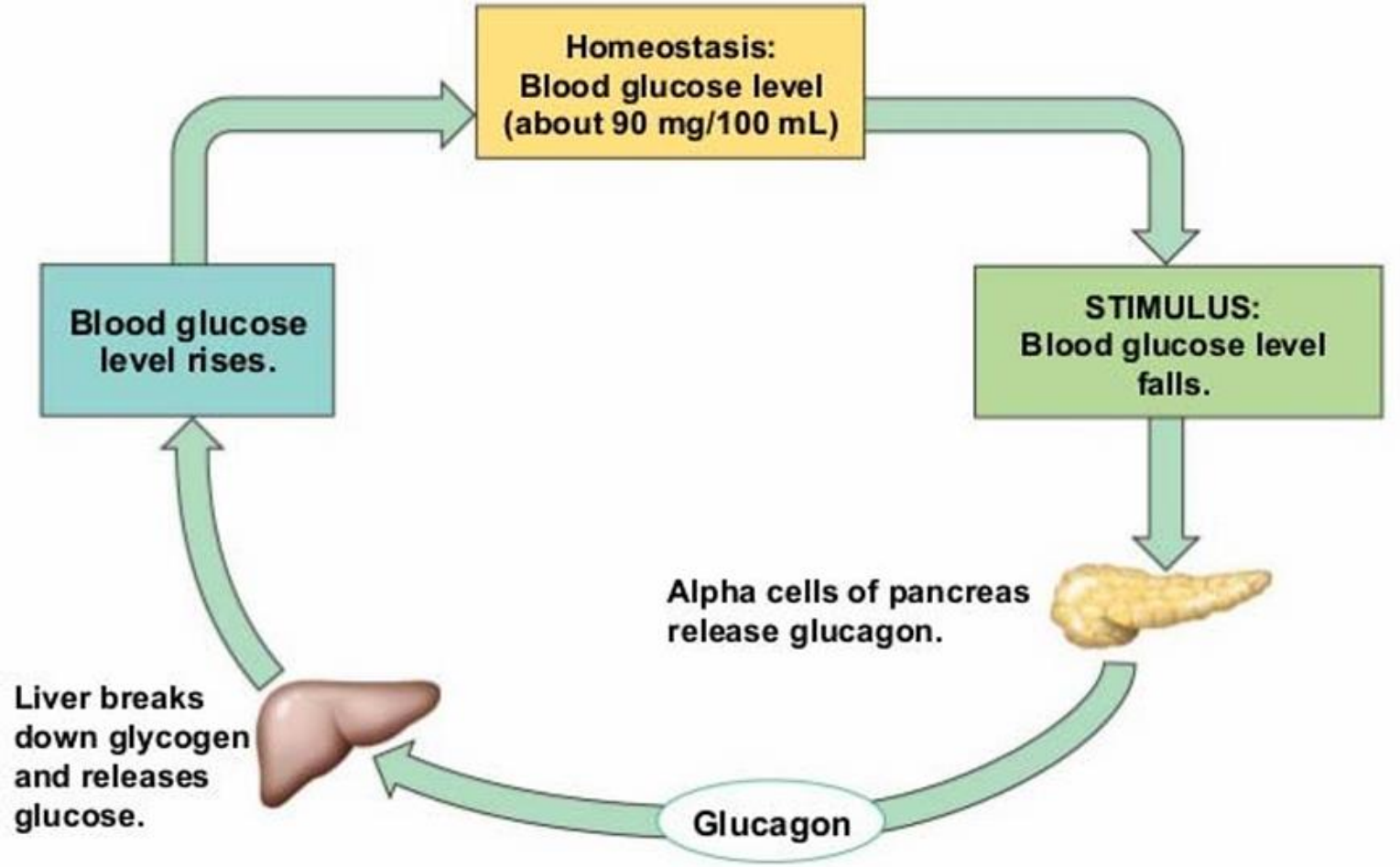



Figure 14: The Insulin Glucagon Loop

**KEY TO PITUITARY HORMONES**

| | |
|---|---|
| ACTH | Adrenocorticotropic hormone |
| TSH | Thyroid-stimulating hormone |
| GH | Growth hormone |
| PRL | Prolactin |
| FSH | Follicle-stimulating hormone |
| LH | Luteinizing hormone |
| MSH | Melanocyte-stimulating hormone |
| ADH | Antidiuretic hormone |

- **'Pure' endocrine glands:** pituitary, pineal, thyroid, parathyroid, and adrenal
- **Organs containing endocrine cells**: pancreas, thymus, gonads, and hypothalamus

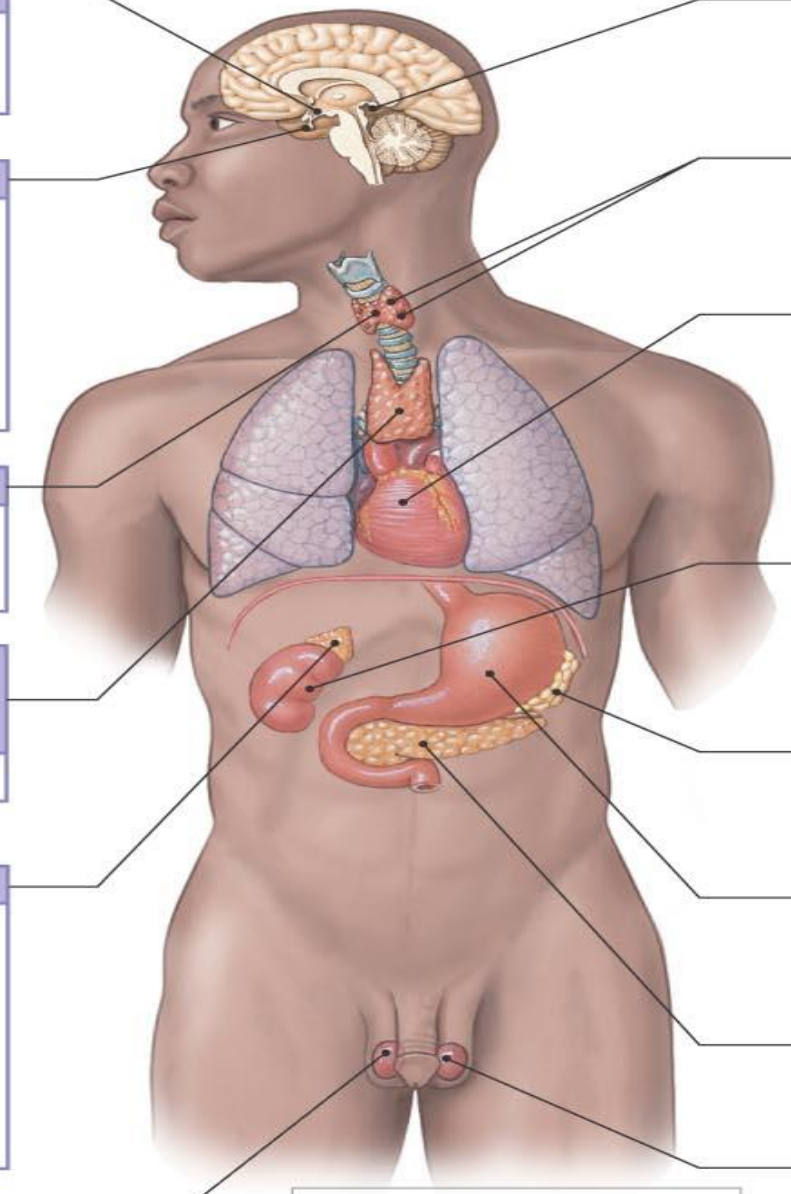
**HYPOTHALAMUS**
Production of ADH, oxytocin, and regulatory hormones

**PITUITARY GLAND**
Pars distalis (anterior lobe):
ACTH, TSH, GH, PRL, FSH, LH, and MSH
Neurohypophysis (posterior lobe):
Release of oxytocin and ADH

**THYROID GLAND**
Thyroxine ($T_4$)
Triiodothyronine ($T_3$)
Calcitonin (CT)

**THYMUS**
(Undergoes atrophy during adulthood)
Thymosins

**SUPRARENAL GLANDS**
Each suprarenal gland is subdivided into:
Suprarenal medulla:
Epinephrine (E)
Norepinephrine (NE)
Suprarenal cortex:
Cortisol, corticosterone, aldosterone, androgens




**PINEAL GLAND**
Melatonin

**PARATHYROID GLANDS**
(on posterior surface of thyroid gland)
Parathyroid hormone (PTH)

**HEART**
Natriuretic peptides:
Atrial natriuretic peptide (ANP)
Brain natriuretic peptide (BNP)

**KIDNEY**
Erythropoietin (EPO)
Calcitriol
*(Chapters 19 and 26)*

**ADIPOSE TISSUE**
Leptin
Resistin

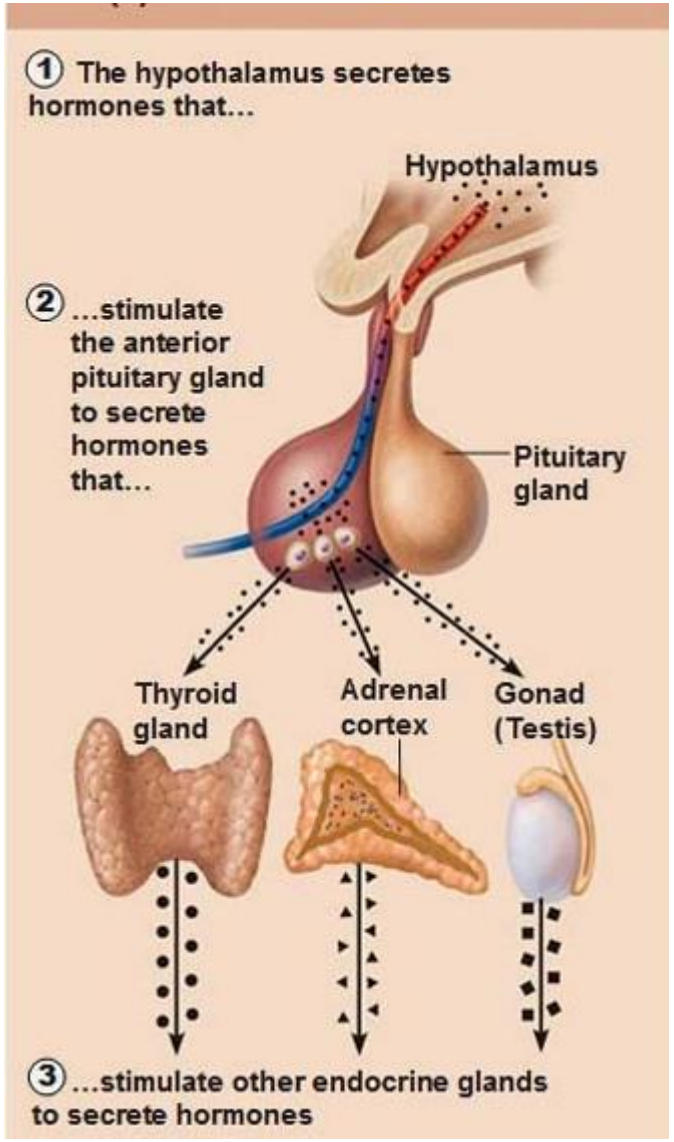
**DIGESTIVE TRACT**
Numerous hormones
*(detailed in Chapter 25)*

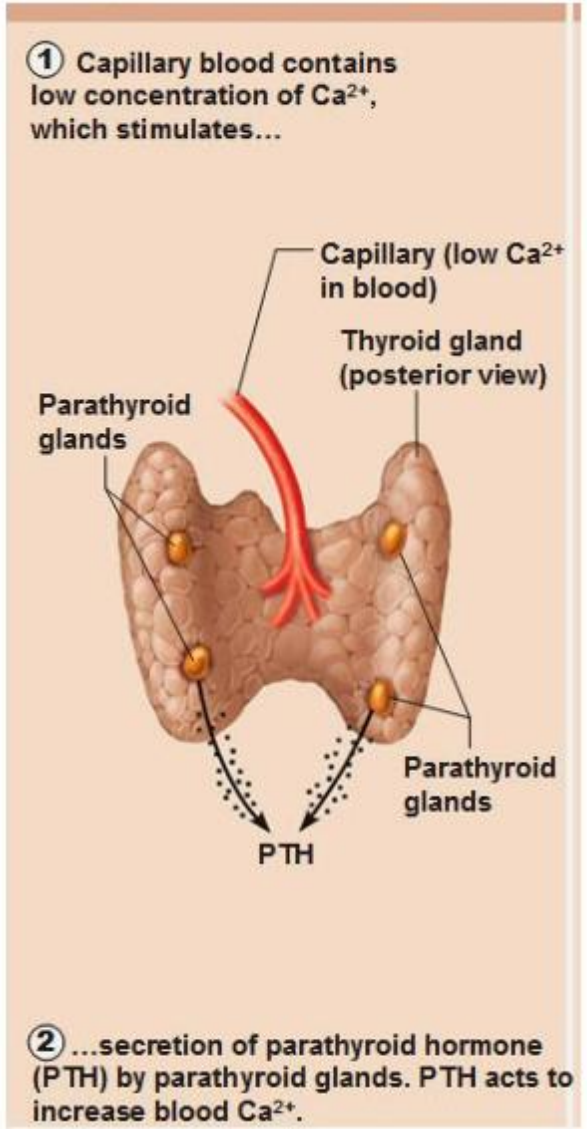
**PANCREATIC ISLETS**
Insulin, glucagon

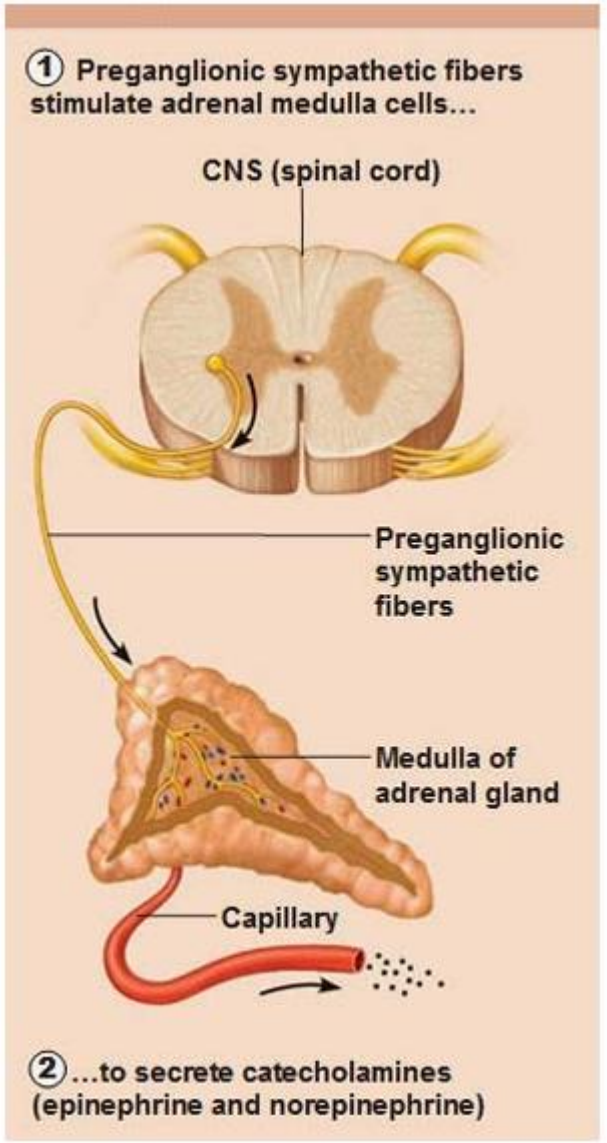
**GONADS**
Testes (male):
Androgens (especially testosterone), inhibin
Ovaries (female):
Estrogens, progestins, inhibin

# Types of Endocrine Gland Stimuli

- Hormonal---- Hormone
- Humoral---- Critical level of ions/nutrients
- Neural----- Neural input



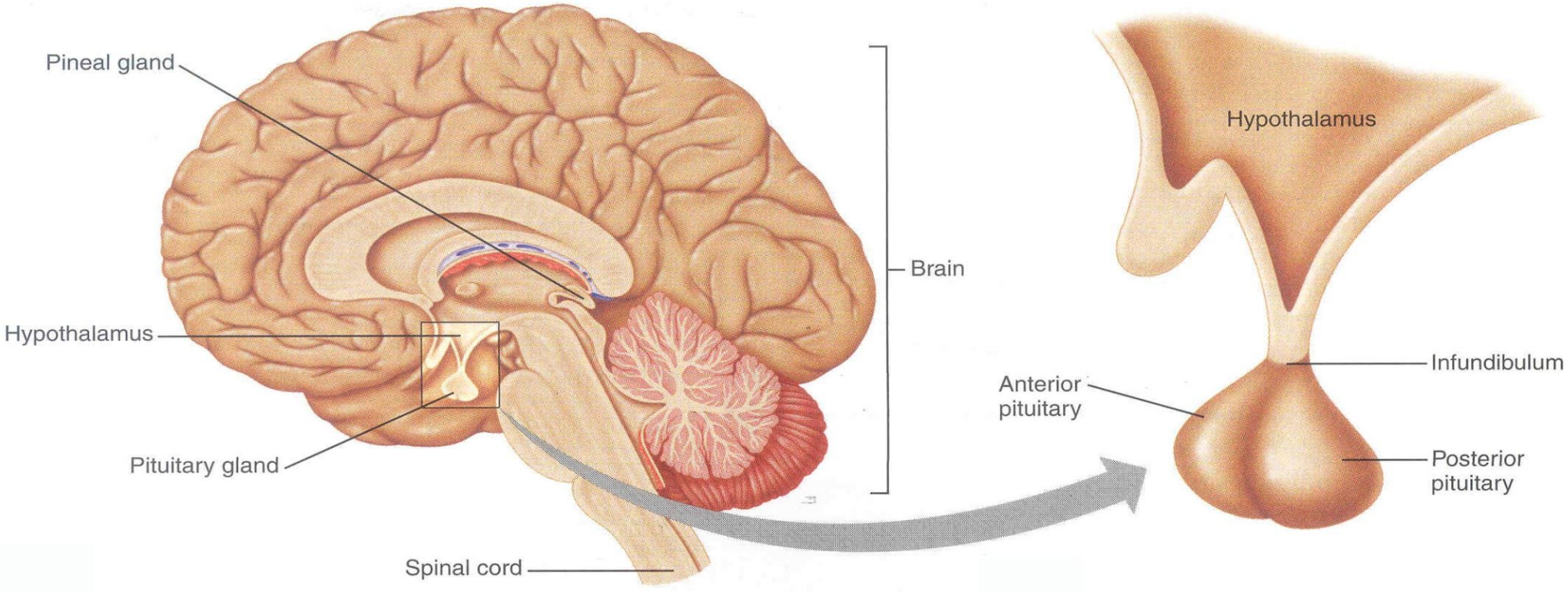



# OUTLINE-ENDOCRINE

- Hypothalamus
- Pituitary Glands
  - Anterior Pituitary
  - Posterior Pituitary
- Pineal Gland
- Thyroid Gland
- Parathyroid Gland
- Adrenal glands
- Pancreas
- Gonads
- Other endocrine organs (Heart, Kidney, Placenta, and Skin)

# HYPOTHALAMUS & PITUITARY GLAND

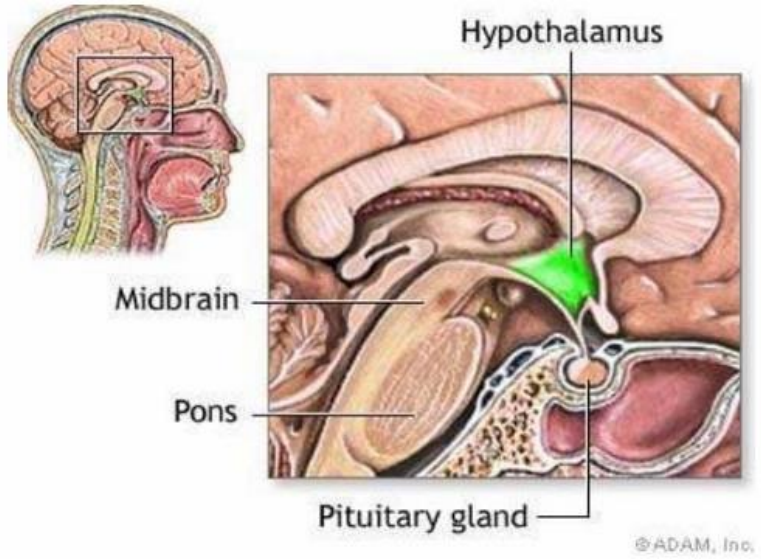


# HYPOTHALAMUS

- **Overview:** The neuroendocrine control center that bridges the nervous and endocrine systems; Composed of different nuclei that synthesize different hormones in response to physiological changes
- **Location:** below the thalamus, above the brainstem
- **Function:** Controls **pituitary hormone release**, maintains **homeostasis** (temperature, hunger, thirst), and manages **stress response** and **circadian rhythms**

**Hormones Secreted:**

- **Releasing hormones (releasing factors) (RH)**
  Secreted like neurotransmitters from neuronal axons into capillaries and veins to anterior pituitary
  1. **TRH**-----stimulates TSH production
  2. **CRH**-----stimulates ACTH production
  3. **GnRH** (=LHRH)---stimulates FSH and LH production
  4. **PRF**-----stimulates PRL production
  5. **GHRH**----stimulates GH production
- Inhibiting hormones (**IH**)
  1. **GH inhibiting hormone** ---inhibits GH production
  2. **PIF**-----inhibits PRL production



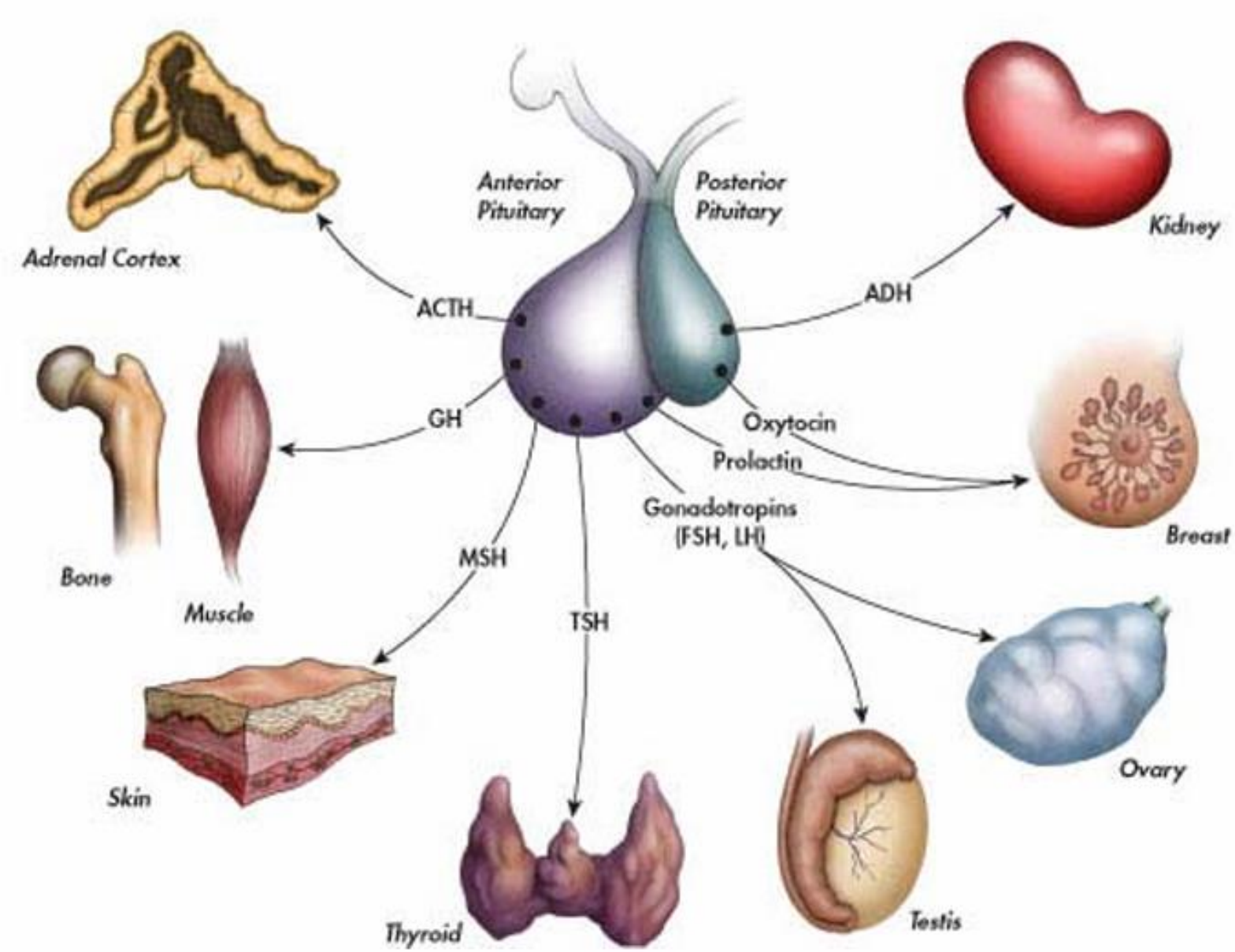
# PITUITARY GLAND

- **Overview:** *"Master gland" that regulates other endocrine glands*
- **Location:** Base of the brain, in the sella turcica (connected to the hypothalamus)
- Hypothalamus and pituitary glands connected by stalk (infundibulum) containing nerve fibers (posterior pituitary) and blood vessels (anterior pituitary)

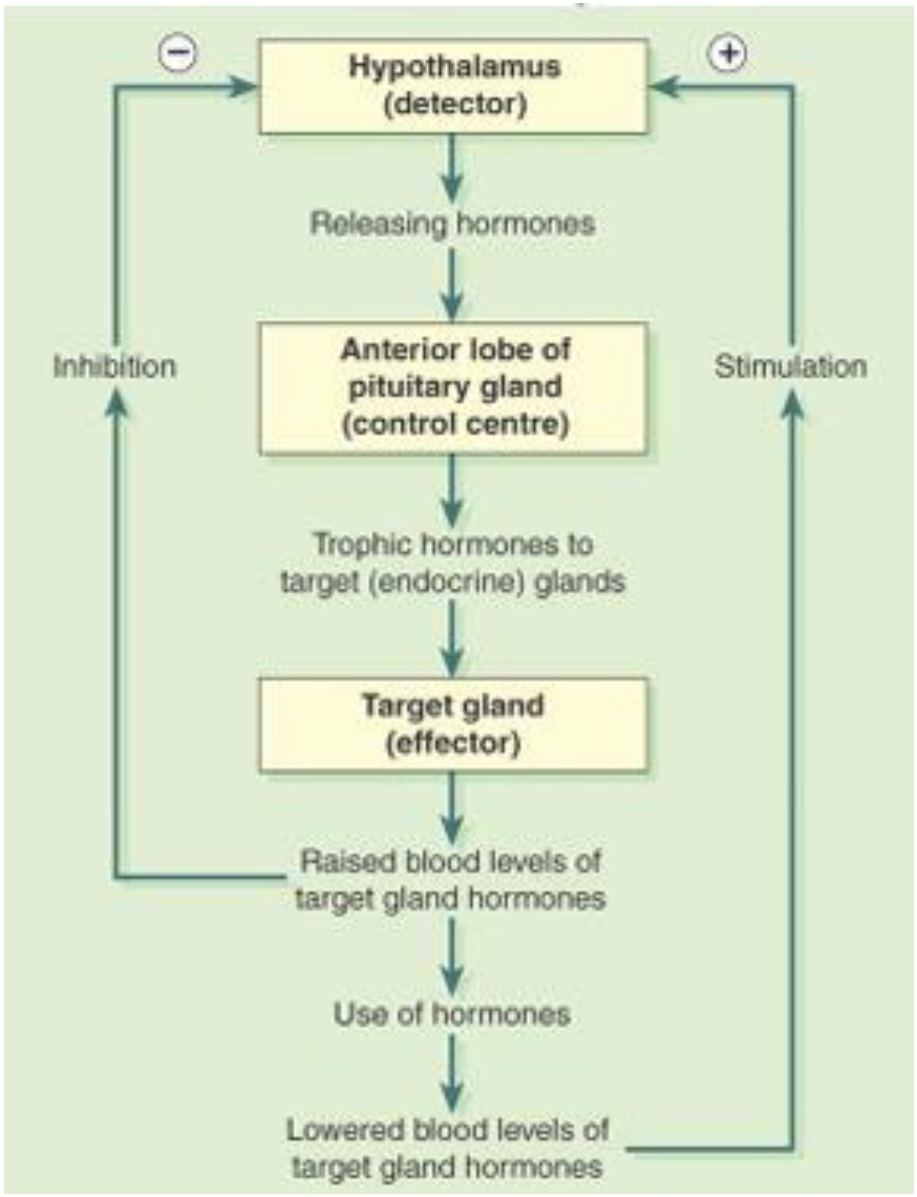
1. **Anterior lobe (Adenohypophysis):**
   - *True endocrine gland* (secretes hormones)
   - **Hormones:** GH, ACTH, TSH, FSH, LH, Prolactin
   - **Control:** Hypothalamic releasing hormones via blood portal system
2. **Posterior lobe (Neurohypophysis):**
   - *Neural extension of hypothalamus* (stores/releases)
   - **Hormones:** ADH, Oxytocin (made in hypothalamus)
   - **Transport:** Via hypothalamo-hypophyseal tract

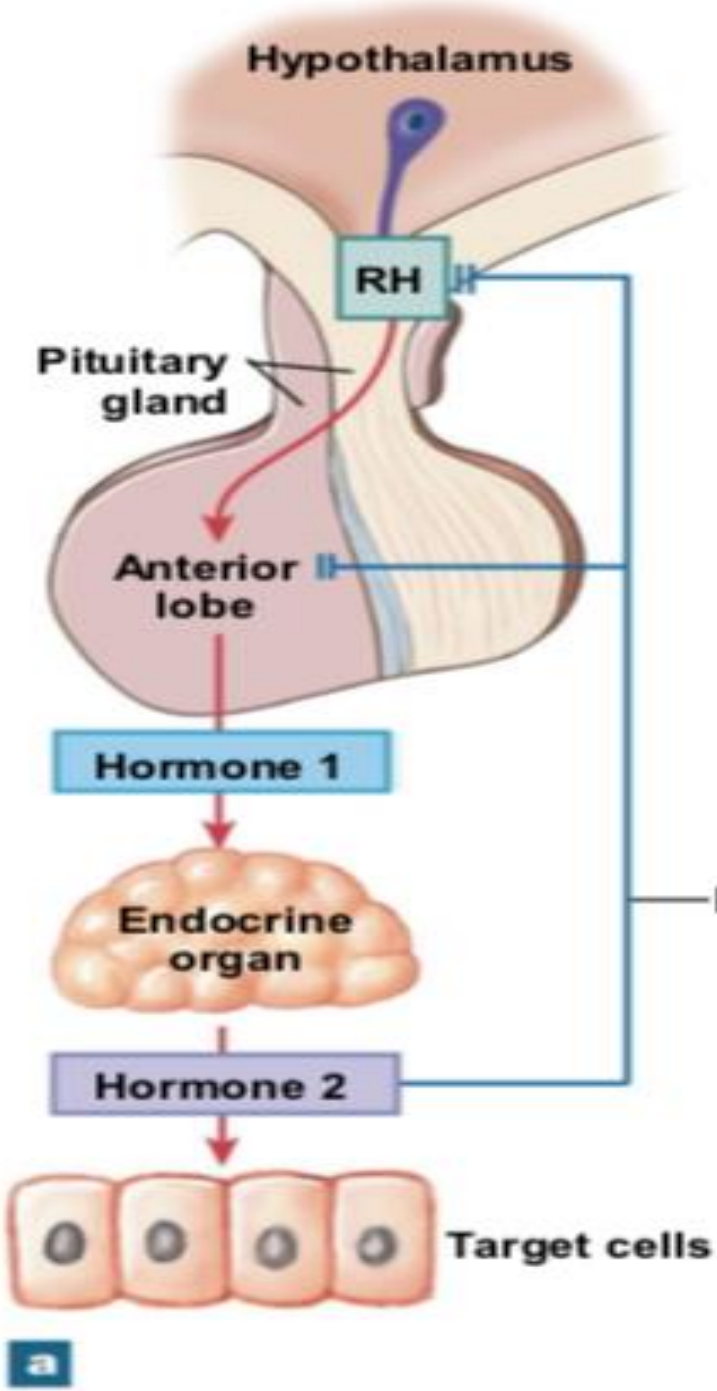
- **Function:** Controls growth, metabolism, reproduction, stress response, and water balance

# Hormones Produced by the Anterior Pituitary



# Regulation of Secretion of Anterior Pituitary Hormones






| 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<br>Estrogens |
| | LH | Ovaries | Progestins<br>Estrogens |
| | | Testes | Androgens |

Negative feedback

KEY

Stimulation

Inhibition

# Hormones - Posterior Pituitary

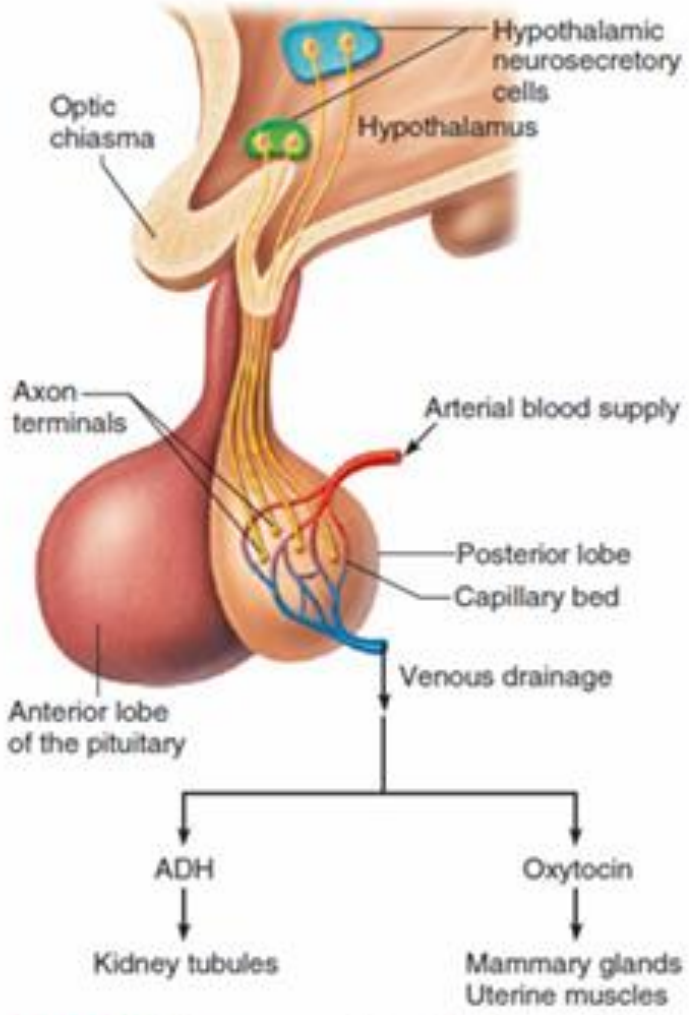
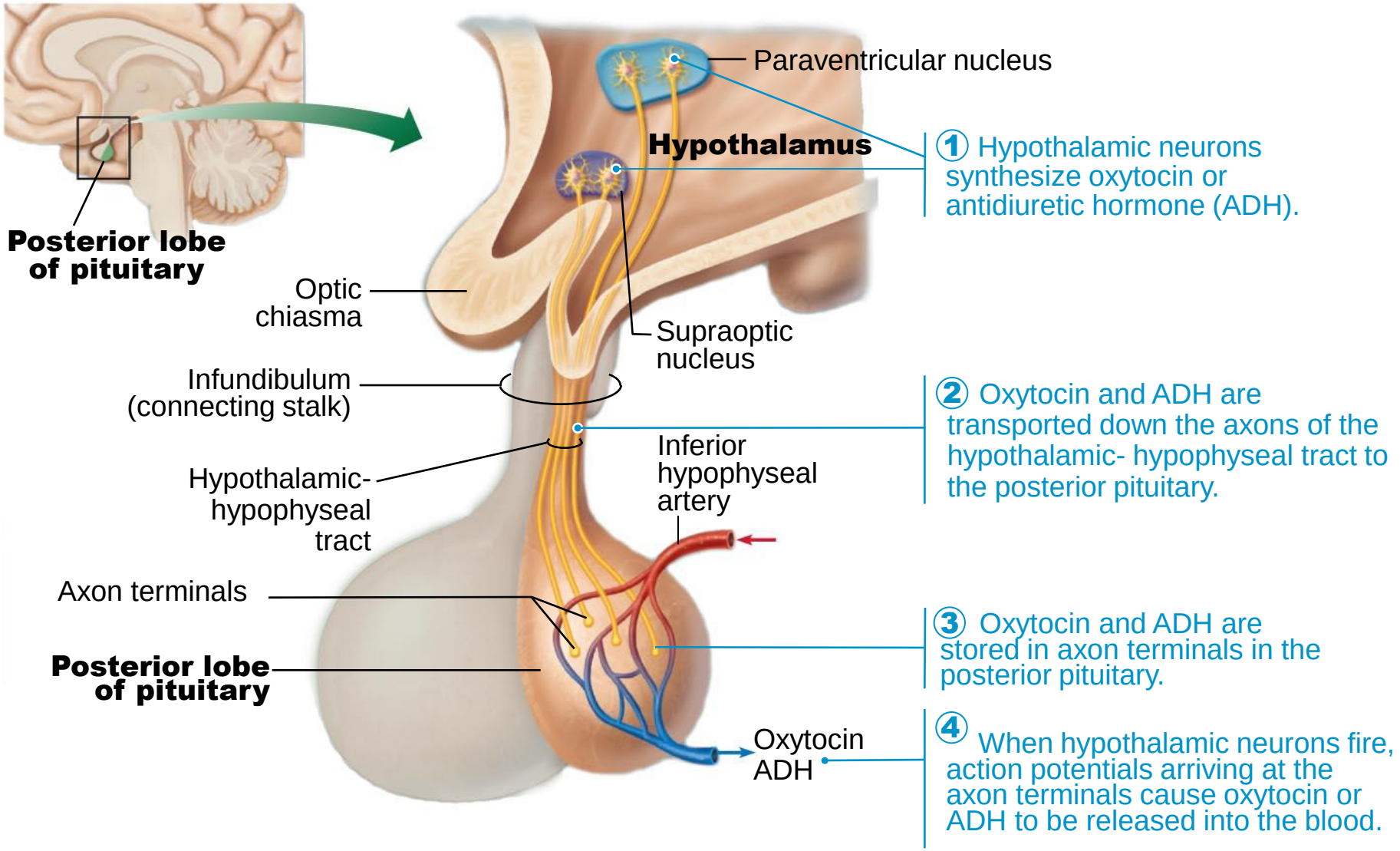



Figure 9.4 Hormones released by the posterior lobe of the pituitary and their target organs.

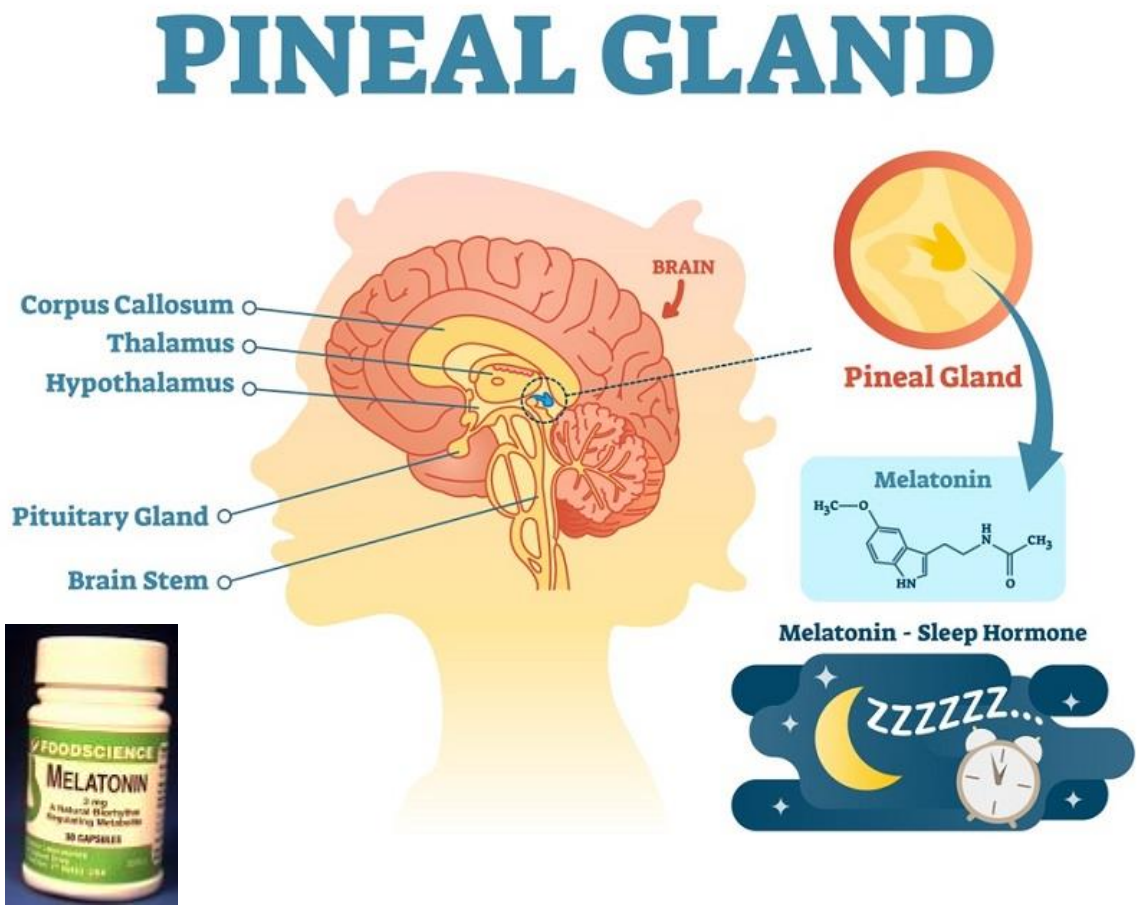

Posterior lobe of pituitary
Paraventricular nucleus
Hypothalamus
Optic chiasma
Supraoptic nucleus
Infundibulum (connecting stalk)
Hypothalamic-hypophyseal tract
Inferior hypophyseal artery
Axon terminals
Posterior lobe of pituitary
Oxytocin
ADH
① Hypothalamic neurons synthesize oxytocin or antidiuretic hormone (ADH).
② Oxytocin and ADH are transported down the axons of the hypothalamic- hypophyseal tract to the posterior pituitary.
③ Oxytocin and ADH are stored in axon terminals in the posterior pituitary.
④ When hypothalamic neurons fire, action potentials arriving at the axon terminals cause oxytocin or ADH to be released into the blood.

# DISTURBANCE OF GROWTH HORMONE SECRETION

- **Pituitary Dwarfism:** Decreased secretion of GH during childhood
- **Gigantism:** Increased production of GH is produced during childhood
- **Acromegaly:** Overproduction of GH in adult, results in larger than normal feet, hands, and face


# PINEAL GLAND

- **Overview:** *Regulator of sleep-wake cycles*
- **Location:** Epithalamus of the brain
- **Hormone Secreted:** Melatonin
- **Function:** Modulates circadian rhythm (The biological clock of the diurnal (night/day) rhythm) and seasonal cycles

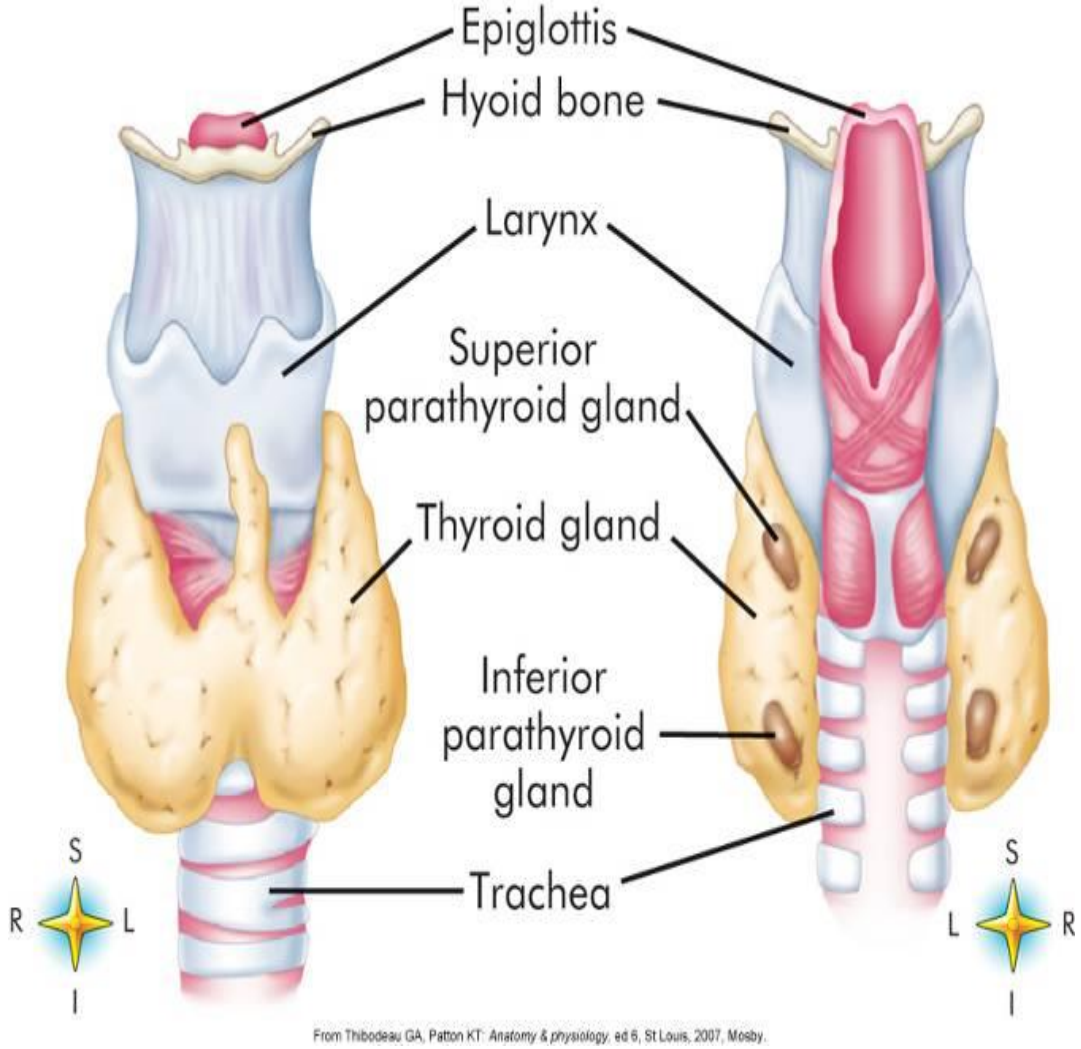


# THYROID GLAND

- **Overview:** Two lateral lobes connected via an isthmus, thyroid gland is a key regulator of metabolism and calcium homeostasis
- **Location:** Anterior neck, on trachea inferior to the larynx (butterfly-shaped)
- **Hormones Secreted:** Thyroxine (T4), Triiodothyronine (T3), Calcitonin

**Function:**

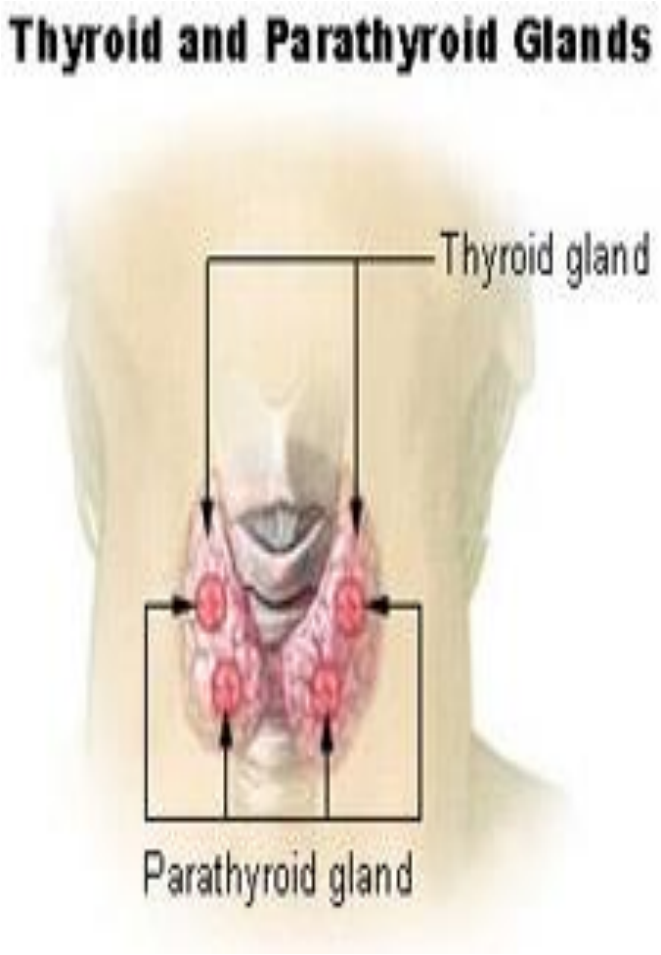
- T3/T4: ↑ Metabolic rate, growth, and development
- Calcitonin: involved with calcium and phosphorus metabolism (Lowers blood calcium levels)



From Thibodeau GA, Patton KT: *Anatomy & physiology*, ed 6, St Louis, 2007, Mosby.

# PARATHYROID GLAND

- **Overview:** *Tiny glands critical for calcium balance*
- **Location:** Embedded on the posterior surface of thyroid gland (usually 4 glands)
- **Hormone Secreted:** Parathyroid hormone (PTH)
- **Function:** ↑ Blood calcium by stimulating bone resorption (osteoclast), kidney reabsorption, and vitamin D activation



# THYROID ABNORMALITIES

a. Simple goiter

b. Congenital hypothyroidism


c. Exophthalmic goiter

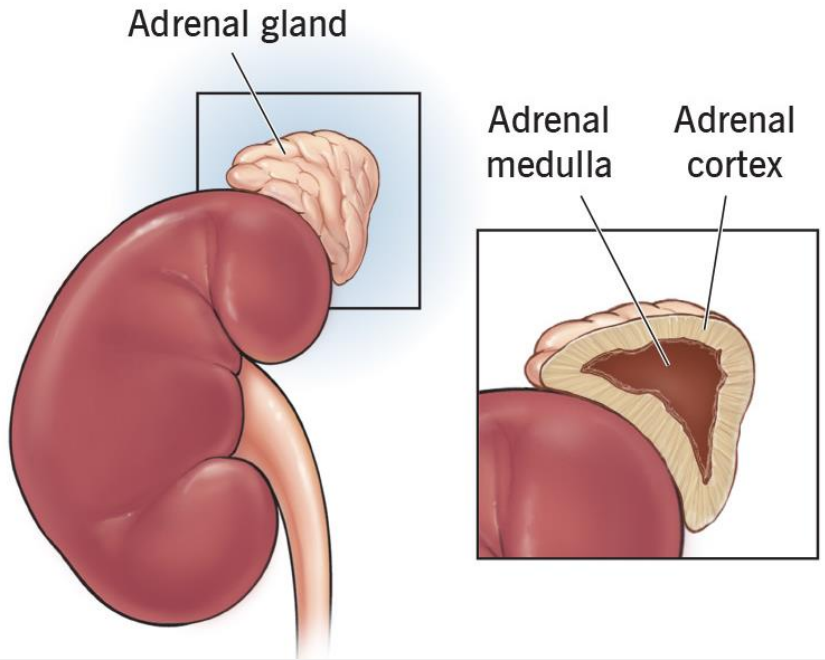
# ADRENAL GLAND

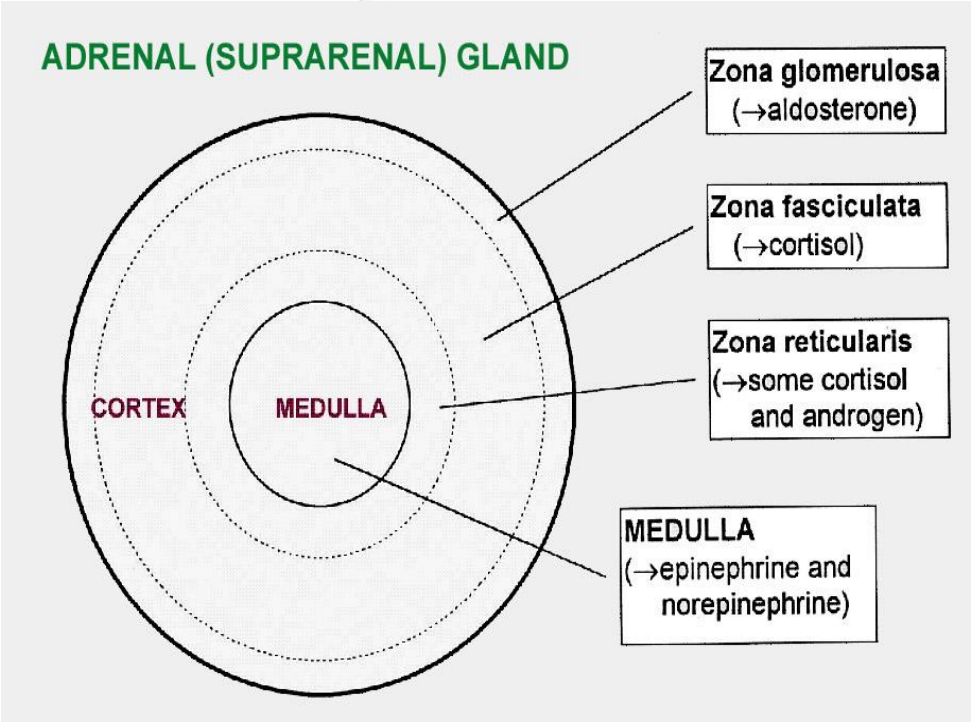
- **Overview:** Paired, pyramid-shaped suprarenal organs for Stress-response and metabolic regulation
- **Location:** On top of each kidney (2 parts: cortex & medulla)

**Hormones Secreted:**

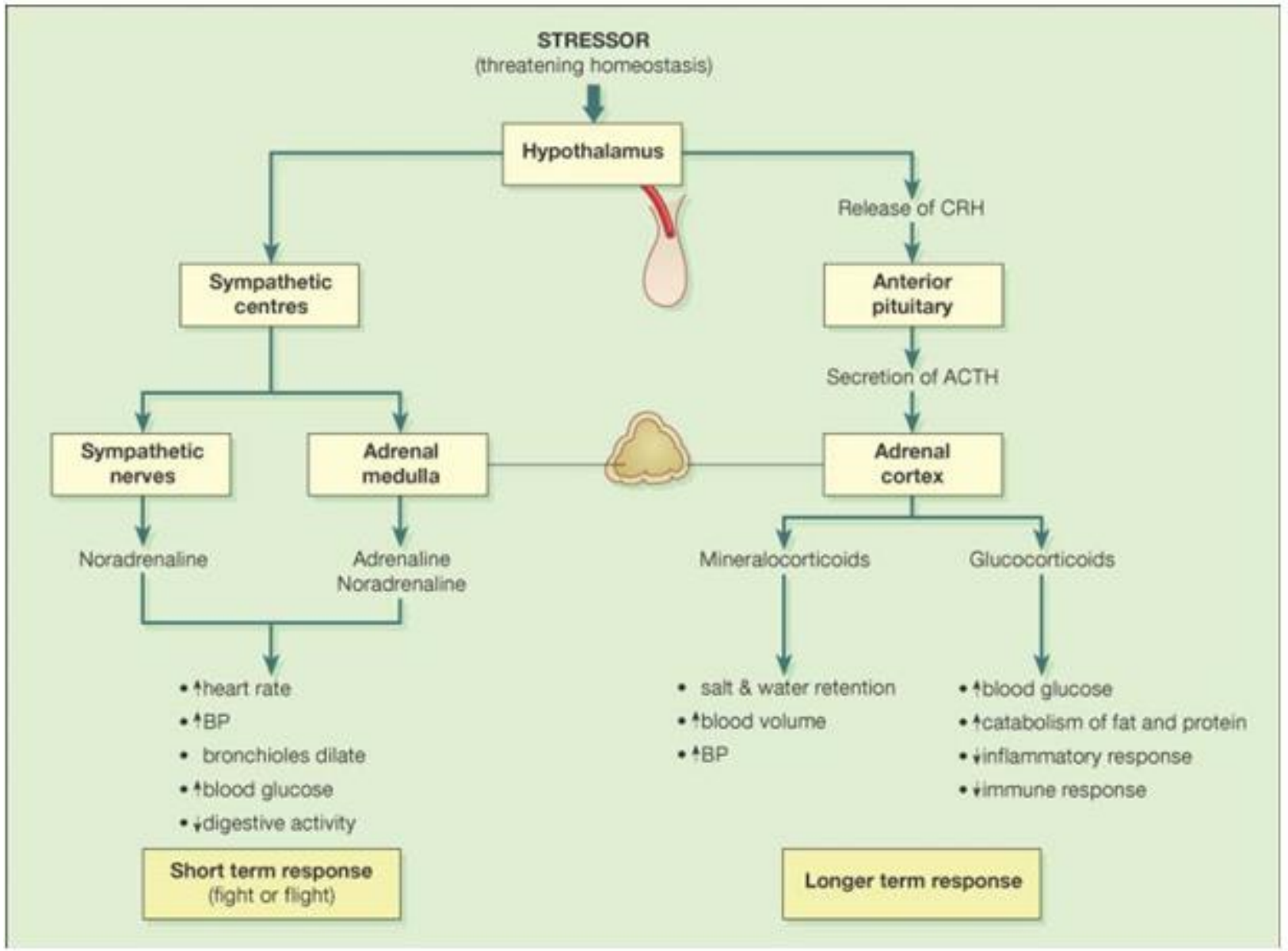
- **Cortex (glandular tissues):** Cortisol (stress), Aldosterone (Na+/K+ balance), Androgens(sex hormone/secondary sex characteristics)
- **Medulla (nervous tissues):** Epinephrine/Norepinephrine (fight-or-flight, acute response to stress)

**Function:** Manages stress, blood pressure, electrolytes, and metabolism



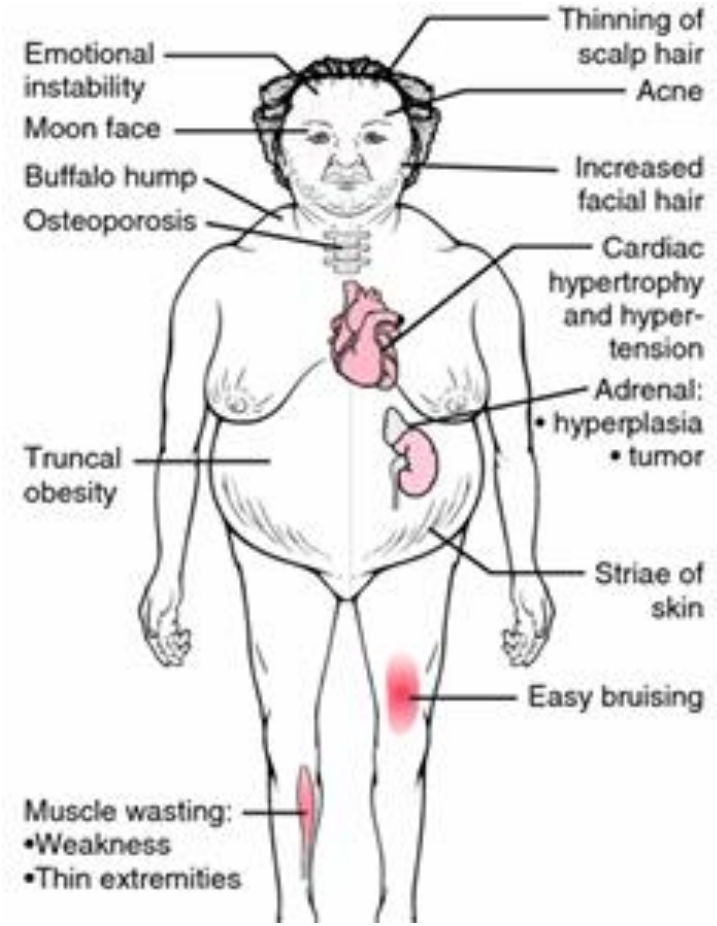



# Response to Stressors



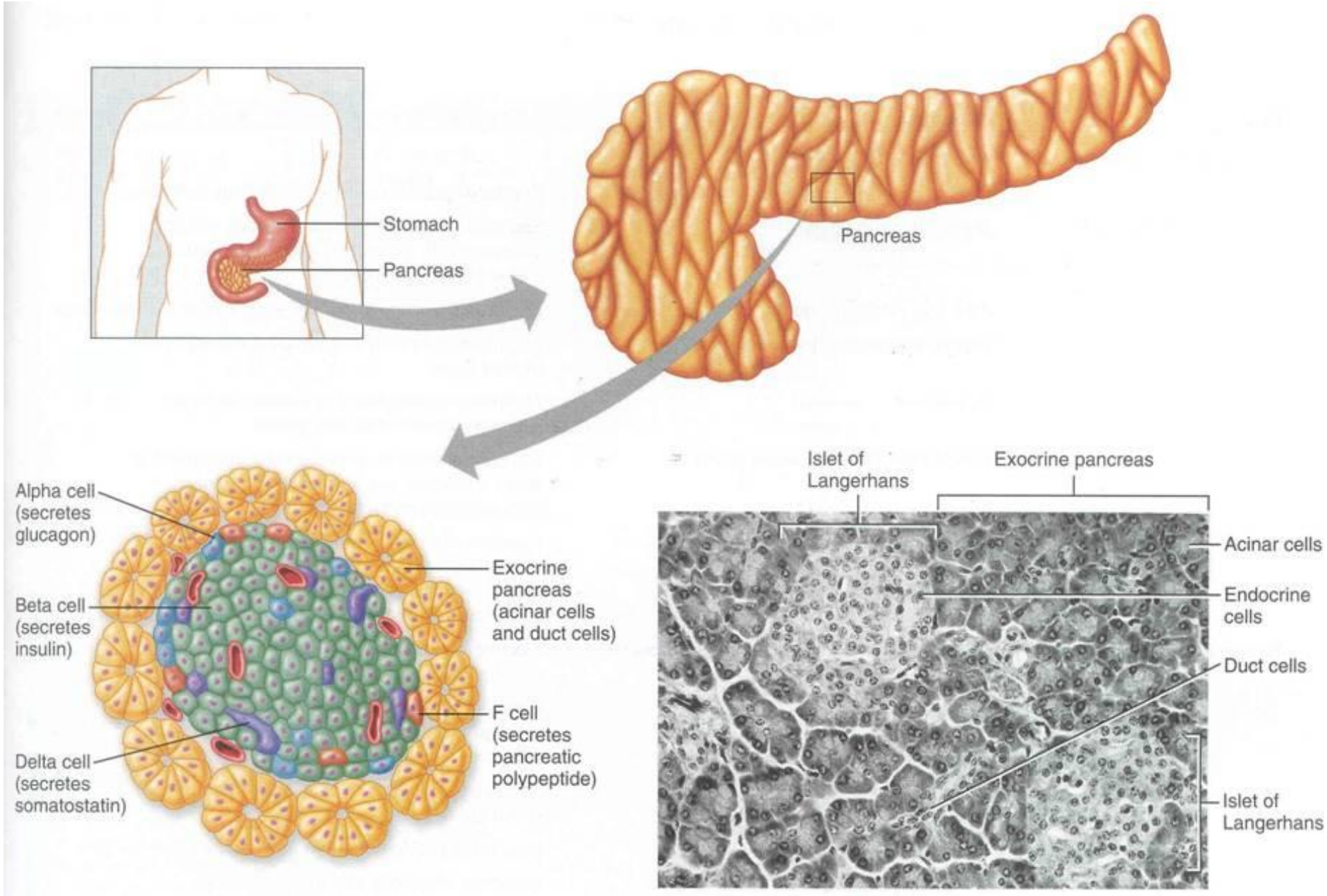
# CUSHING SYNDROME

- Hypersecretion of glucocorticoids by the adrenal cortex, characterized by
  - Weight gain in the trunk of the body but not arms and legs (due to mobilization of fat from periphery)
  - Hyperglycemia
  - Hypertension



# PANCREAS (ENDOCRINE PARTS)

- **Overview:** *Dual-function gland (endocrine + exocrine)*
  - Acinar cells (forming most of the pancreas)
    - *Exocrine* function
    - Secrete digestive enzymes
  - Islet cells (of Langerhans)
    - ***Endocrine* function**
- **Location:** Behind the stomach
- **Hormones Secreted (Islets of Langerhans=endocrine cells)**
  1. Alpha cells (25%): Glucagon (↑ blood glucose)
  2. Beta cells (70%): Insulin (↓ blood glucose)
  3. Delta cells (5%): Somatostatin (inhibit glucagon & insulin)
- **Function:** Maintains blood glucose homeostasis


Stomach
Pancreas
Pancreas
Alpha cell (secretes glucagon)
Beta cell (secretes insulin)
Delta cell (secretes somatostatin)
Exocrine pancreas (acinar cells and duct cells)
F cell (secretes pancreatic polypeptide)
Islet of Langerhans
Exocrine pancreas
Acinar cells
Endocrine cells
Duct cells
Islet of Langerhans

# THYMUS GLAND

- **Overview:**
  *"Primary lymphoid organ training immune cells"*

**Location:**

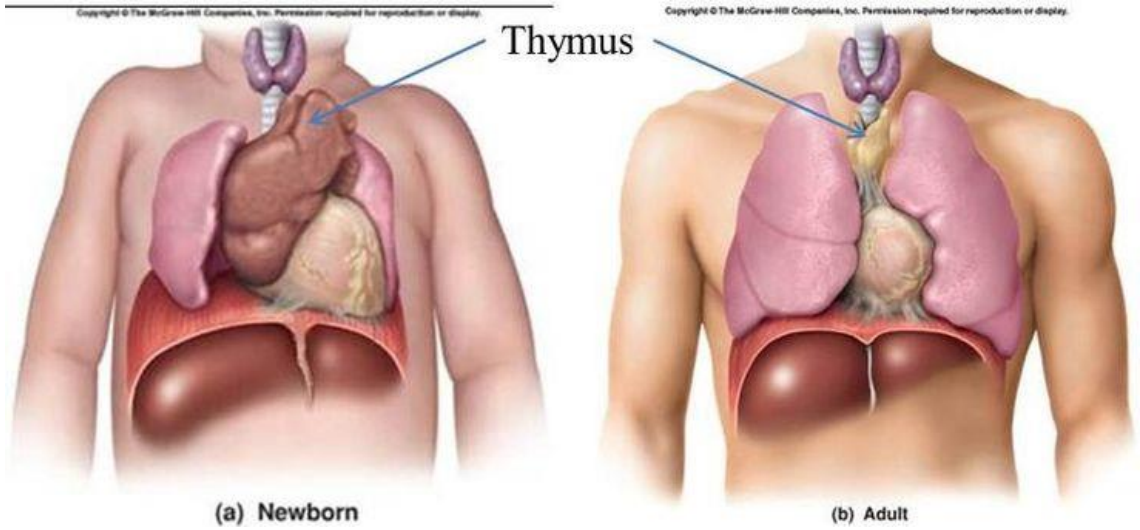
- Thoracic cavity, behind sternum and just ventral to great vessels of heart.
- Until puberty, a large structure, after which it begins to atrophy and gets replaced with adipose tissue

**Hormones Secreted:**

- **Thymosin**
- **Thymopoietin**
- **Thymulin**

**Functions:**

- Matures **T-lymphocytes** (critical for immunity)
- Programs immune tolerance (prevents autoimmunity)



# ENDOCRINE CELLS IN VARIOUS ORGANS

- **The kidneys:**
  - Juxtaglomerular cells secrete renin
    - **Renin** indirectly signals adrenal cortex to secrete aldosterone
  - **Erythropoietin:** signals bone marrow to increase RBC production
- **The heart**: atrial natriuretic peptide (ANP)
  - Stimulates kidney to secrete more salt
  - Thereby decreases excess blood volume, high BP and high blood sodium concentration
- **GI tract & derivatives**: Diffuse neuroendocrine system (DNES)
- **The placenta:** secretes steroid and protein hormones
  - Estrogens, progesterone
  - HCG (human chorionic gonadotropin hormone)
- **The skin:**
  - Modified cholesterol with UV exposure becomes Vitamin D precursor
  - Vitamin D necessary for calcium metabolism: signals intestine to absorb CA++

**Table 9.2 Hormones Produced by Organs Other Than the Major Endocrine Organs**

| Hormone | Chemical composition | Source | Stimulus for secretion | Target organ/Effects |
|---|---|---|---|---|
| Prostaglandins (PGs); several groups indicated by letters A–I (PGA–PGI) | Derived from fatty acid molecules | Plasma membranes of virtually all body cells | Various (local irritation, hormones, etc.) | Have many targets but act locally at site of release. Examples of effects include the following: increase blood pressure by acting as vasoconstrictors; cause constriction of respiratory passageways; stimulate muscle of the uterus, promoting menstrual pain and labor; enhance blood clotting; promote inflammation and pain; increase output of digestive secretions by stomach; cause fever. |
| Gastrin | Peptide | Stomach | Food | *Stomach:* stimulates glands to release hydrochloric acid (HCl). |
| Intestinal gastrin | Peptide | Duodenum of small intestine | Food, especially fats | *Stomach:* stimulates gastric glands and motility. |
| Secretin | Peptide | Duodenum | Food | *Pancreas:* stimulates release of bicarbonate-rich juice.<br>*Liver:* increases release of bile.<br>*Stomach:* reduces secretions and motility. |
| Cholecystokinin (CCK) | Peptide | Duodenum | Food | *Pancreas:* stimulates release of enzyme-rich juice.<br>*Gallbladder:* stimulates expulsion of stored bile.<br>*Duodenal papilla:* causes sphincter to relax, allowing bile and pancreatic juice to enter duodenum. |
| Erythropoietin | Glycoprotein | Kidney | Hypoxia | *Bone marrow:* stimulates production of red blood cells. |
| Active vitamin $D_3$ | Steroid | Kidney (activates provitamin D made by epidermal cells) | PTH | *Intestine:* stimulates active transport of dietary calcium across intestinal cell membranes. |
| Atrial natriuretic peptide (ANP) | Peptide | Heart | Stretching of atria of heart | *Kidney:* inhibits sodium ion reabsorption and renin release.<br>*Adrenal cortex:* inhibits secretion of aldosterone, thereby decreasing blood volume and blood pressure. |
| Leptin | Peptide | Adipose tissue | Fatty foods | *Brain:* suppresses appetite and increases energy expenditure. |
| Resistin | Peptide | Adipose tissue | Unknown | *Fat, muscle, liver:* antagonizes insulin's action on liver cells. |

# THANK YOU