The Endocrine System: An Overview

- A system of ductless glands
- Secrete messenger molecules called hormones
- Interacts closely with the nervous system
- Endocrinology
  - Study of hormones and endocrine glands

Endocrine Organs

- Scattered throughout the body
- Pure endocrine organs are the ...
  - Pituitary, pineal, thyroid, parathyroid, and adrenal glands
- Organs containing endocrine cells include:
  - Pancreas, thymus, gonads, and the hypothalamus
  - Plus other organs secrete hormones (e.g., kidney, stomach, intestine)
- Hypothalamus is a neuroendocrine organ
  - Produces hormones and has nervous functions
  - Endocrine cells are of epithelial origin

Location of the Major Endocrine Glands

Hormones

- Classes of hormones
  - Amino acid–based hormones
  - Steroids—derived from cholesterol
- Basic hormone action
  - Circulate throughout the body in blood vessels
  - Influences only specific tissues— those with target cells that have receptor molecules for that hormone
  - A hormone can have different effects on different target cells (depends on the receptor)

Control of Hormones Secretion

- Secretion triggered by three major types of stimuli:
  - Humoral—simplest of endocrine control mechanisms
    - Secretion in direct response to changing ion or nutrient levels in the blood
    - Example: Parathyroid monitors calcium
      - Responds to decline by secreting hormone to reverse decline
Control of Hormones Secretion

- Secretion triggered by three major types of stimuli (continued)
  - **Neural**
    - Sympathetic nerve fibers stimulate cells in the adrenal medulla
    - Induces release of epinephrine and norepinephrine
  - **Hormonal**
    - Stimuli received from other glands
    - Certain hormones signal secretion of other hormones
      - Example: Hypothalamus secretes hormones → stimulates pituitary → stimulates other glands

Types of Endocrine Gland Stimuli

- **Neural stimulus**
  - Neuronal stimulation
  - Stimulates cells in the adrenal medulla
  - Induces release of epinephrine and norepinephrine

- **Hormonal stimulus**
  - Hormones received from other glands
  - Certain hormones signal secretion of other hormones
    - Example: Hypothalamus secretes hormones → stimulates pituitary → stimulates other glands

Control of Hormone Secretion

- Always controlled by feedback loops
  - Blood concentration declines below a minimum → More hormone is secreted
  - Blood concentration exceeds maximum → Hormone production is halted

The Pituitary Gland

- Secretes nine major hormones
- Attached to the hypothalamus by the infundibulum
- Two basic divisions of the pituitary gland
  - **Adenohypophysis** (anterior lobe)
    - Has three major divisions
      - Pars distalis, pars intermedia, and pars tuberalis
  - **Neurohypophysis** (posterior lobe) — has two major divisions
    - Pars nervosa and infundibular

The Anterior Lobe

- The pars distalis—largest division of the anterior lobe
  - Contains five different endocrine cell groups
  - Makes and secretes seven different hormones
    - **Tropic hormones** regulate hormone secretion by other glands
      - Include: TSH, ACTH, FSH, LH
      - GH, PRL, and MSH
      - Act directly on non-endocrine target tissues
The Anterior Lobe

- **Growth hormone, GH** (somatotropic hormone)
  - Produced by somatotropic cells
  - Stimulates body growth by stimulating increased protein production and growth of epiphyseal plates
  - Stimulates growth directly and indirectly by the liver’s secretion of insulin-like growth factor-1.

- **Thyroid-stimulating hormone, TSH**
  - Produced by thyrotropic cells
  - Signals thyroid gland to secrete thyroid hormone

- **Adrenocorticotropic hormone, ACTH**
  - Stimulates the adrenal cortex to secrete hormones that help cope with stress

- **Melanocyte-stimulating hormone, MSH**
  - In humans, MSH functions in appetite suppression
  - Gonadotropins — are produced by gonadotropic cells and affect the gonads
  - Follicle-stimulating hormone, FSH, and luteinizing hormone, LH

- **Prolactin** — produced by prolactin cells
  - Targets milk-producing glands in the breast — stimulates milk production
  - Endocrine cells of the pars distalis
  - Clustered in spheres and branching cords

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Table 17.1: Pituitary Hormones: Summary of Target Organs and Effects

<table>
<thead>
<tr>
<th>Hormone (Cell Type)</th>
<th>Target Organ and Effects</th>
<th>Effects of Hypersecretion</th>
<th>Effects of Hyposecretion</th>
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</thead>
<tbody>
<tr>
<td><strong>Growth hormone</strong></td>
<td>Thyroid, liver, muscle, and cartilage</td>
<td>Stimulation of protein synthesis</td>
<td>Growth retardation</td>
</tr>
<tr>
<td><strong>Thyroid-stimulating hormone</strong></td>
<td>Thyroid gland</td>
<td>Stimulation of thyroid hormone synthesis</td>
<td>Hypothyroidism</td>
</tr>
<tr>
<td><strong>Adrenocorticotropic hormone</strong></td>
<td>Adrenal cortex</td>
<td>Stimulation of glucocorticoid synthesis</td>
<td>Cushing’s disease</td>
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<td>Ovaries, testes</td>
<td>Stimulation of gametogenesis</td>
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<td>Water retention</td>
<td>Hypovolemia</td>
</tr>
<tr>
<td><strong>Thyroid-stimulating hormone</strong></td>
<td>Brain</td>
<td>Calmness</td>
<td>Hyperactivity</td>
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Hypothalamic Control of Hormone Secretion from the Anterior Lobe

- The hypothalamus
  - Controls secretion of anterior lobe hormones
  - Exerts control by secreting:
    - Releasing hormones—prompt anterior lobe to release hormones
    - Inhibiting hormones—turn off secretion of anterior lobe hormones

Hypothalamic Control of Hormone Secretion from the Anterior Lobe

- Releasing hormones
  - Are secreted like neurotransmitters
  - Enter a primary capillary plexus
  - Travel in hypophyseal portal veins to a secondary capillary plexus
    - (hypothalamohypophyseal portal system)
    - From the secondary capillary plexus, hormones secreted by the anterior lobe enter general circulation and travel to target organs

The Posterior Lobe

- Is structurally part of the brain
- Its axons make up the hypothalamic–hypophyseal tract
- Arises from neuronal cell bodies in the hypothalamus
  - Supraoptic nucleus
  - Paraventricular nucleus

The Posterior Lobe

- Does not make hormones
- Stores and releases hormones made in the hypothalamus
- Releases two peptide hormones
  - Antidiuretic hormone (ADH) [aka, vasopressin]
  - Oxytocin (OT)
The Posterior Lobe

- ADH (vasopressin)
  - Made in supraoptic nucleus
  - Targets kidneys to reabsorb water
- Oxytocin
  - Produced in the paraventricular nucleus
  - Induces smooth muscle contraction of reproductive organs, ejects milk during breast feeding, and signals contraction of the uterus during childbirth

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The Thyroid Gland

- Located in the anterior neck
- Largest pure endocrine gland
- Composed of follicles and areolar connective tissue
- Produces two hormones
  - Thyroid hormone (TH)
  - Calcitonin

The Parathyroid Glands

- Lie on the posterior surface of the thyroid gland
- Contain two types of endocrine cells
  - Chief cells
    - Produce parathyroid hormone (PTH)
    - Increases blood concentration of Ca²⁺
  - Oxyphil cells
    - Function unknown

![Figure 17.5a](https://example.com/figure17_5a)
![Figure 17.5b](https://example.com/figure17_5b)
The Parathyroid Glands

(a) Location of parathyroid glands, posterior view

(b) Photomicrograph of parathyroid gland tissue (360×)

- Pharynx
- Thyroid gland
- Esophagus
- Trachea
- Parathyroid glands

Capillary

Parathyroid cells
(sercrete parathyroid hormone)
Oxyphil cells

The Adrenal (Suprarenal) Glands

- Pyramid-shaped glands located on the superior surface of each kidney
- Supplied by about 60 suprarenal arteries
- Nerve supply is almost exclusively sympathetic fibers

The Adrenal (Suprarenal) Glands

- Two endocrine glands in one
  - Adrenal medulla—a cluster of neurons
    - Derived from neural crest
    - Part of the sympathetic nervous system
  - Adrenal cortex—forms the bulk of the gland
    - Derived from somatic mesoderm
- All adrenal hormones help one cope with danger, terror, or stress

The Adrenal Medulla

- Chromaffin cells
  - Are modified ganglionic sympathetic neurons
  - Secrete amine hormones epinephrine and norepinephrine
    - Enhance “fight-or-flight” response
    - Hormones are stored in secretory vesicles
    - Are arranged in spherical clusters and some branching cords

The Adrenal Cortex

- Secretes lipid-based steroid hormones
- Cortex is composed of three layers (zones)
  - Zona glomerulosa—cells arranged in spherical clusters
  - Zona fasciculata—cells arranged in parallel cords; contains lipid droplets
  - Zona reticularis—cells arranged in a branching network

The Adrenal Cortex

- Hormones are corticosteroids
- Adrenal corticosteroids are of two main classes
  - Mineralocorticoids
  - Glucocorticoids
- Also secretes androgens
Mineralocorticoids
- **Aldosterone**—secreted by the zona glomerulosa
  - Secreted in response to decline in blood volume or blood pressure
  - Is the terminal hormone of the renin-angiotensin mechanism

Glucocorticoids
- **Cortisol** is the main type
  - Secreted by zona fasciculata and zona reticularis
  - Helps the body deal with stressful situations

The Adrenal Gland—Gross and Microscopic

Stress and the Adrenal Gland
- **Short-term stress**
  1. Increased heart rate
  2. Increased blood pressure
  3. Liver converts glycogen to glucose and releases glucose to blood
  4. Dilation of bronchioles
  5. Changes in blood flow patterns leading to decreased digestive system activity and reduced urine output
  6. Increased metabolic rate

- **Long-term stress response**
  1. Retention of sodium and water by kidneys
  2. Increased blood volume and blood pressure
  3. Proteins and fats converted to glucose or broken down for energy
  4. Increased blood glucose
  5. Suppression of immune system

The Pineal Gland
- Located on the roof of the diencephalon
- Shaped like a pine cone
- "Pineal sand" is radiopaque
  - Used as a landmark to identify other brain structures in X rays
- Pinealocytes secrete **melatonin**
  - A hormone that regulates circadian rhythms

The Pancreas
- Located in the posterior abdominal wall
- Contains endocrine and exocrine cells
  - **Exocrine cells**
    - Acinar cells—secrete digestive enzymes
  - **Endocrine cells**
    - Pancreatic islet cells—islets of Langerhans
  - About one million islets—scattered throughout the pancreas
The Pancreas

- Main endocrine cell types
  - **Alpha cells** (α cells)—secrete glucagon
    - Signals liver to release glucose from glycogen
    - Raises blood sugar
  - **Beta cells** (β cells)—secrete insulin
    - Signals most body cells to take up glucose from the blood
    - Promotes storage of glucose as glycogen in liver
    - Lowers blood sugar

The Pancreas

- Pancreatic islets contain two rare cell types
  - Delta (∂) cells
    - Secrete somatostatin
      - Inhibits secretion of insulin and glucagon
  - F (PP) cells
    - Secrete **pancreatic polypeptide**
      - May inhibit exocrine activity of the pancreas

The Thymus

- Located in the lower neck and anterior thorax
- Important immune organ
- Site at which T-lymphocytes arise from precursor cells

The Gonads

- Main sources of sex hormones
  - Testes and ovaries
  - Male
    - Interstitial cells secrete androgens
      - Primarily testosterone
        - Promotes the formation of sperm
        - Maintains secondary sex characteristics
  - Female
    - Ovaries
      - Androgens secreted by the **theca folliculi**
        - Converted to estrogen by follicular granulosa cells
        - Estrogen
          - Maintains secondary sex characteristics
        - Progesterone
          - Prepares the uterus for pregnancy

Other Endocrine Structures

- Endocrine cells occur within
  - **The heart**
    - Atria contain **atrial natriuretic peptide** (ANP)
  - **The GI tract**
    - Enteroendocrine cells
  - **The placenta**
    - Sustains the fetus and secretes several steroid protein hormones
Other Endocrine Structures
- The kidneys
  - Cells of the juxtaglomerular apparatus (JGA) secrete renin
  - Endothelial cells and interstitial connective tissue—secrete erythropoietin
- The skin
  - Modified cholesterol molecules convert to a precursor of vitamin D

Pituitary Disorders
- Gigantism
  - Hypersecretion of GH in children
- Pituitary dwarfism
  - Hyposecretion of GH
- Diabetes insipidus
  - Pars nervosa does not make enough ADH

Disorders of the Pancreas: Diabetes Mellitus
- Caused by
  - Insufficient secretion of insulin
  - Resistance of body cells to the effects of insulin
- Type 1 diabetes
  - Develops suddenly, usually before age 15
  - T cell–mediated autoimmune response destroys beta cells

Diabetes Mellitus
- Type 2 diabetes
  - Adult onset
  - Usually occurs after age 40
  - Cells have lowered sensitivity to insulin
  - Controlled by dietary changes and regular exercise

Disorders of the Thyroid Gland
- Grave’s disease
  - Most common type of hyperthyroidism
  - Immune system makes abnormal antibodies
    - Stimulates the oversecretion of TH by follicle cells
    - Leads to nervousness, weight loss, sweating, and rapid heart rate

Disorders of the Thyroid Gland
- Myxedema
  - Adult hypothyroidism
  - Antibodies attack and destroy thyroid tissue
  - Low metabolic rate and weight gain are common symptoms
Disorders of the Thyroid Gland

- **Endemic goiter**
  - Due to lack of iodine in the diet
- **Cretinism**
  - Hypothyroidism in children
  - Short, disproportionate body, thick tongue, and mental retardation

Disorders of the Adrenal Cortex

- **Cushing’s syndrome**
  - Caused by hypersecretion of glucocorticoid hormones—usually a pituitary tumor
- **Addison’s disease**
  - Hyposecretory disorder of the adrenal cortex
  - Deficiencies of both mineralocorticoids and glucocorticoids

The Endocrine System Throughout Life

- **Thyroid gland**
  - Forms from a thickening of endoderm on the floor of the pharynx
- **Parathyroids and the thymus gland**
  - From endoderm lining the pharyngeal pouches

Embryological Origin of Selected Endocrine Organs

- **Pineal gland**
  - Originates from ependymal cells
- **Pituitary gland**—dual origin
  - Adenohypophysis originates from the roof of the mouth
  - Neurohypophysis grows inferiorly from the floor of the brain
Embryological Origin of Selected Endocrine Organs

- Adrenal gland—dual origin gland
  - Adrenal medulla—from neural crest cells of nearby sympathetic trunk ganglia
  - Adrenal cortex—from mesoderm lining the coelom

(a) Week 6. Inferior extension of the floor of the diencephalon forms the neurohypophyseal bud.

(b) Week 6. Inferior extension of the floor of the diencephalon forms the neurohypophyseal bud.

(c) Week 7. Hypophyseal pouch pinches off the surface ectoderm and is closely associated with the neurohypophyseal bud.

(d) Week 8. Hypophyseal pouch forms the anterior lobe of pituitary; neurohypophyseal bud forms the posterior lobe. Distinct portions of each differentiate.

The Endocrine System Throughout Life

- Endocrine organs operate effectively until old age
  - Anterior pituitary
  - Increase in connective tissue and lipofuscin
  - Decrease in vascularization and number of hormone-secreting cells
  - Adrenal cortex
  - Normal rates of glucocorticoid secretion continue
  - Adrenal medulla
  - No age-related changes in catecholamines

- Thyroid hormones
  - Decrease slightly with age
- Parathyroid glands
  - Little change with aging
  - GH, DHEA, and the sex hormones
  - Marked drops in secretion with age