The Endocrine System
Introduction

- The nervous system and the endocrine system work together to monitor the body’s activities
  - The nervous system: produces short-term, very specific responses
  - The endocrine system: many times it produces long-term, general responses
Introduction

• The endocrine system releases chemicals called **hormones**
  • Hormones leave a gland or gland-like structure
  • The hormone enters into the bloodstream
  • The hormone travels to its target organ or tissue
  • The hormone causes the target organ to respond
An Overview of the Endocrine System

- The main endocrine organs are:
  - Pituitary gland
  - Hypothalamus
  - Thyroid gland
  - Thymus gland
  - Suprarenal glands
  - Pineal gland
  - Parathyroid glands
  - Pancreas
  - Reproductive glands
An Overview of the Endocrine System

The Hypothalamus and Endocrine Regulation

- Hypothalamus functions via three mechanisms
  - Secretes regulatory hormones
    - Secretes releasing hormones (RH)
    - Secretes inhibiting hormones (IH)
  - Acts as an endocrine organ
    - Releases antidiuretic hormone and oxytocin to the pituitary gland
  - Contains autonomic nervous system centers
    - Exerts control over the suprarenal medulla
Figure 19.2 Hypothalamic Control over Endocrine Organs

1. Secretion of regulatory hormones to control activity of pars distalis (anterior lobe) of pituitary gland
2. Production of ADH and oxytocin
3. Control of sympathetic output to suprarenal medullae

Pars distalis (anterior lobe) of pituitary gland
Neurohypophysis (posterior lobe) of pituitary gland
Medulla
Suprarenal gland
Preganglionic motor fibers

Hormones secreted by pars distalis of pituitary gland control other endocrine organs
Release of ADH and oxytocin
Secretion of epinephrine and norepinephrine
The Pituitary Gland = the hypophysis

- Attached to the hypothalamus via the infundibulum
- Sits in the hypophyseal fossa of the sella turcica
- Consists of two lobes
  - **Adenohypophysis**: anterior lobe releases nine hormones
  - **Neurohypophysis**: posterior lobe releases two hormones
The Pituitary Gland

• The Neurohypophysis
  • Innervated by nerves from the hypothalamus
  • Releases **ADH (antidiuretic hormone)**
    • Causes the kidneys to retain water (prevents dehydration)
    • Constricts peripheral blood vessels (elevates blood pressure)
  • Releases **OT (oxytocin)**
    • Causes uterine contractions
    • Causes mammary glands to release milk from the nipple
Figure 19.3a Gross Anatomy and Histological Organization of the Pituitary Gland and Its Subdivisions

- **Optic chiasm**
- **Infundibulum**
- **Diaphragm sellae**
- **Pars tuberalis**
- **Pars distalis**
- **Pars intermedia**
- **Neurohypophysis** (posterior lobe)
- **Sphenoid** (sella turcica)

**Relationship of the pituitary gland to the hypothalamus**
The Pituitary Gland

• Hormones of the Adenohypophysis
  • Thyroid-stimulating hormone (TSH)
  • Adrenocorticotropic hormone (ACTH)
  • Follicle-stimulating hormone (FSH)
  • Luteinizing hormone (LH)
  • Prolactin (PRL)
  • Growth hormone (GH); also called somatotropin
  • Melanocyte-stimulating hormone (MSH)
The Pituitary Gland

• Hormones of the Adenohypophysis
  
  • **Thyroid-stimulating hormone**
    • Causes the thyroid gland to release thyroid hormones (*calcitonin*, *thyroxine*, and *triiodothyronine*)

• **Adrenocorticotropic hormone**
  • Causes the suprarenal cortex to release *glucocorticoids*
The Pituitary Gland

• Hormones of the Adenohypophysis
  • **Follicle-stimulating hormone**
    • Causes the release of estrogen
    • Causes sperm production
  
• **Luteinizing hormone**
  • Causes ovulation
  • Causes the release of progestin (progesterone)
  • Causes the release of androgens (testosterone)
  
• FSH and LH are also called gonadotropins
The Pituitary Gland

• Hormones of the Adenohypophysis
  • **Prolactin**
    • Causes the production of milk
  • **Growth hormone** (Also called somatotropin)
    • Causes protein synthesis resulting in growth
  • **Melanocyte-stimulating hormone**
    • Causes the production of melanin
The Thyroid Gland

- The thyroid gland is on the anterior surface of the trachea
  - Made of two lobes connected via an isthmus
  - Consists of thyroid follicles
  - This is the only gland that stores its hormone products
The Thyroid Gland

- Hormones of the thyroid gland
  - **Calcitonin (CT)**
    - Causes a decrease in blood calcium ion
  - **Thyroxine ($T_4$)**
    - Causes an increase in metabolism
  - **Triiodothyronine ($T_3$)**
    - Causes an increase in metabolism
Figure 19.6a–c  Anatomy and Histological Organization of the Thyroid Gland

Location and anatomy of the thyroid gland

- Hyoid bone
- Superior thyroid artery
- Thyroid cartilage of larynx
- Superior thyroid vein
- Common carotid artery
- Right lobe of thyroid gland
- Middle thyroid vein
- Thyrocervical trunk
- Trachea
- Outline of clavicle
- Outline of sternum

Histological organization of the thyroid

- Internal jugular vein
- Cricoid cartilage of larynx
- Left lobe of thyroid gland
- Isthmus of thyroid gland
- Inferior thyroid artery
- Inferior thyroid veins

Histological details of the thyroid gland showing thyroid follicles and both of the cell types in the follicular epithelium

- C thyrocyte cell
- Cuboidal epithelium of follicle
- Thyroglobulin stored in colloid of follicle
- Thyroid follicle
- Follicles of the thyroid gland

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The Parathyroid Glands

- The parathyroid glands are located on the posterior portion of the thyroid gland.

Hormone Production
- Release parathyroid hormone (PTH)
  - Causes an increase in blood calcium ion levels.
Figure 19.8 Anatomy and Histological Organization of the Parathyroid Glands

A. The location and size of the parathyroid glands on the posterior surface of the thyroid lobes

B. The histology of the parathyroid and thyroid glands

C. A histological section showing parathyroid cells and oxyphil cells of the parathyroid gland

Parathyroid gland
Parathyroid (chief) cells
Oxyphil cells
Thyroid follicles
Blood vessel
Connective tissue capsule of parathyroid gland
Parathyroid and thyroid gland
LM × 600
LM × 100
The Thymus Gland

- The thymus gland is posterior to the sternum
- Hormone production
  - Produces thymosin
    - Causes lymphocytes to develop into T cells
The Suprarenal Glands

- The suprarenal glands (adrenal glands) are located attached to the superior border of the kidneys.
The Suprarenal Glands

• The suprarenal glands are made of two parts
  • Suprarenal medulla
  • Suprarenal cortex

• The suprarenal cortex is made of three distinct zones
  • Zona glomerulosa
  • Zona fasciculata
  • Zona reticularis
c Histology of the suprarenal gland showing identification of the major regions
The Suprarenal Glands

- **Suprarenal medulla**
  - Produces **epinephrine** (adrenaline) and **norepinephrine** (noradrenaline)
  - Cause an increase in cardiac activity, blood pressure and in glycogen breakdown

- **Suprarenal cortex**
  - **Zona glomerulosa**
    - Produces mineralocorticoids such as **aldosterone**
    - Causes retention of sodium ions and water thereby reducing ion and water loss from the body
  - **Zona fasciculata**
    - Produces glucocorticoids such as **cortisol**, **cortisone**, and **corticosterone**
    - Causes the liver to synthesize glucose and glycogen
  - **Zona reticularis**
    - Produces small amounts of **androgens**
The Pancreas and Other Endocrine Tissues

- The pancreas is about 20–25 cm long
  - The large rounded end connects to the duodenum of the small intestine
  - The pointed tail extends toward the spleen
- Functions of the Pancreas
  - Endocrine function
    - Consists of **pancreatic islets**
    - Produces hormones
  - Exocrine function
    - Consists of **acinar cells**
    - Produces digestive enzymes
Figure 19.10ab Anatomy and Histological Organization of the Pancreas

The gross anatomy of the pancreas

- **Common bile duct**
- **Pancreatic duct**
- **Body of pancreas**
- **Lobule**
- **Tail**
- **Head of pancreas**
- **Small intestine (duodenum)**
- **Accessory pancreatic duct**

**General histology of the pancreatic islets**

- **Pancreatic acini (exocrine cells)**
- **Pancreatic islet (islet of Langerhans)**
- **Endocrine cells:**
  - \( \beta \) cells (insulin)
  - \( \alpha \) cells (glucagon)
  - \( \delta \) cells (somatostatin)
  - \( F \) cells (pancreatic polypeptide)
The Pancreas and Other Endocrine Tissues

- **Hormones of the Pancreas**
  - **Glucagon**
    - Produced by alpha cells of the islets
    - This raises blood glucose levels
  - **Insulin**
    - Produced by beta cells of the islets
    - This lowers blood glucose levels
  - **Somatostatin**
    - Produced by the delta cells of the islets
    - This results in inhibiting growth
Endocrine Tissues of the Reproductive System

• Testes
  • The interstitial cells release **testosterone**
    • Promotes the production of sperm
  • The sustentacular cells release **inhibin**
    • Depresses the secretion of FSH
Endocrine Tissues of the Reproductive System

- **Ovaries**
  - Oocytes maturate due to **FSH**
  - Follicular cells produce **estradiol**
  - Mature eggs are ovulated due to **LH**
  - After ovulation, the follicle becomes a **corpus luteum**
  - Corpus luteum releases **progesterone**
    - prepares the body for pregnancy
  - Corpus luteum releases **relaxin**
    - prepares the body for pregnancy
The Pineal Gland

- The Pineal Gland
  - synthesize the hormone **melatonin**
- Melatonin
  - Production rate rises at night and declines during the day
Figure 19.1 The Endocrine System

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

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\textsubscript{4})
Triiodothyronine (T\textsubscript{3})
Calcitonin (CT)

Thymus

(Undergoes atrophy during adulthood)
Thymosins

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

Suprarenal Glands

Each suprarenal gland is subdivided into:
Medulla:
Epinephrine (E)
Norepinephrine (NE)
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

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Clinical note:
Endocrine abnormalities

(a) Acromegaly results from the over-production of growth hormone after the epiphyseal plates have fused. Bone shapes change and cartilaginous areas of the skeleton enlarge. Note the broad facial features and the enlarged lower jaw.

(b) Cretinism results from thyroid hormone insufficiency in infancy.

(c) An enlarged thyroid gland, or goiter, is usually associated with thyroid hypossecretion due to nutritional iodine insufficiency.

(d) Addison’s disease is caused by hypossecretion of corticosteroids, especially glucocorticoids. Pigment changes result from stimulation of melanocytes by ACTH, which is structurally similar to MSH.

(e) Cushing’s disease is caused by hypersecretion of glucocorticoids. Lipid reserves are mobilized, and adipose tissue accumulates in the cheeks and at the base of the neck.
Hormones and Aging

• Exhibits relatively few changes with advancing age
  • The changes in reproductive hormone levels at puberty
  • The decline in the concentration of reproductive hormones at menopause in women
Summary of the Endocrine System

• Summary
  • The nervous system controls the release of some hormones
  • The pituitary gland releases hormones of which some control the action of other glands
  • The hypothalamus controls the release of some pituitary hormones
  • There are other tissues of the body that act like glands but are not typically called glands
Figure 19.4 Pituitary Hormones and Their Targets

**Hypothalamus**

Direct Control by Nervous System

Indirect Control Through Release of Regulatory Hormones

Regulatory hormones are released into the hypophyseal portal system for delivery to the anterior lobe of the pituitary.

Direct Release of Hormones

Sensory stimulation

Osmoreceptor stimulation

**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

**Hormones and Their Targets**

- Thyroid gland: Thyroid hormones (T<sub>3</sub>, T<sub>4</sub>), Somatomedins
- Liver: Glucocorticoids (cortisol, corticosterone), Inhibin, Testosterone, Estrogen, Progesterone
- Suprarenal gland: Epinephrine and norepinephrine
- Kidneys: Glucocorticoids, Somatomedins
- Posterior lobe of pituitary gland: ADH, Oxytocin
- Posterior lobe of pituitary gland: Regulatory hormones for adrenal cortex
- Suprarenal gland: Aldosterone, Epinephrine, Norepinephrine
- Males: Smooth muscle in ductus deferens and prostate gland
- Females: Uterine smooth muscle and mammary glands
- Melanocytes: Melanocyte-stimulating hormone
- Ovaries: Estrogen, Progesterone, Inhibin
- Testes: Androgens, Estrogens, Inhibin

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