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

• Other endocrine tissues are:
  • Heart
  • Kidney
  • Adipose cells
  • Digestive tract
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 (T₄)
- Triiodothyronine (T₃)
- Calcitonin (CT)

**Thymus**
- (Undergoes atrophy during adulthood)
- Thymosins

**Suprarenal Glands**
- Each suprarenal gland is subdivided into:
  - Medulla: Epinephrine (E)
  - Norepinephrine (NE)
  - Cortex: Cortisol, corticosterone, aldosterone, androgens

**Suprarenal Glands**
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**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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An Overview of the Endocrine System

- Hormones (which means to “excite”) are organized into four groups
  - **Amino acid derivatives**
    - Structurally similar to amino acids
    - Examples: thyroid hormones and suprarenal medulla hormones are derivatives of tyrosine / melatonin is a derivative of tryptophan
  - **Peptide hormones**
    - These hormones are chains of amino acids
    - Examples: all hormones from the pituitary gland are peptide hormones
An Overview of the Endocrine System

- Hormones are organized into four groups
  - **Steroid hormones**
    - These are derived from cholesterol
    - Examples: reproductive hormones and suprarenal cortex hormones
  - **Eicosanoids**
    - Derived from arachidonic acid, which is a fatty acid of cell membranes
    - Examples: prostaglandin, leukotrienes, and thromboxane
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 19.1 The Endocrine System

**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<sub>4</sub>)
- Triiodothyronine (T<sub>3</sub>)
- Calcitonin (CT)

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**Suprarenal Glands**
- Each suprarenal gland is subdivided into:
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**Parathyroid Glands**
- (on posterior surface of thyroid gland)
- Parathyroid hormone (PTH)

**Heart**
- Natriuretic peptides: Atrial natriuretic peptide (ANP), Brain natriuretic peptide (BNP)

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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
Hormones secreted by pars distalis of pituitary gland control other endocrine organs
Release of ADH and oxytocin
Secretion of epinephrine and norepinephrine
Preganglionic motor fibers
Suprarenal gland
Medulla
The Pituitary Gland

• The pituitary gland is 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 peptide hormones
    • Neurohypophysis: posterior lobe releases two peptide hormones
Figure 19.1 The Endocrine System

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    - Aldosterone
    - Androgens

Parathyroid Glands
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- Testes (male): Androgens (especially testosterone), inhibin
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The Pituitary Gland

• The Neurohypophysis
  • Innervated by nerves from the hypothalamus
  • Releases **ADH (antidiuretic hormone)**
    • Targets the nephrons of the kidneys
    • Causes the kidneys to retain water (prevents dehydration)
    • Constricts peripheral blood vessels (elevates blood pressure)
The Pituitary Gland

• The Neurohypophysis
  • Releases OT (oxytocin)
    • Targets the smooth muscles of the uterus
    • Targets the contractile cells of the mammary glands
    • Causes contraction of smooth muscles of the uterus resulting in uterine contractions
    • Causes the myoepithelial cells of the mammary glands to release milk from the nipple
    • In males: OT causes smooth muscle contractions in the prostate gland
The Pituitary Gland

- The Adenohypophysis
  - Controlled by secretions of the regulatory hormones from the hypothalamus
  - Made of three different regions
    - **Pars distalis**: secretes the majority of the hormones
    - **Pars intermedia**: secretes melanocyte-stimulating hormone
    - **Pars tuberalis**: wraps around a portion of the infundibulum
Figure 19.3a  Gross Anatomy and Histological Organization of the Pituitary Gland and Its Subdivisions

- **Optic chiasm**
- **Infundibulum**
- **Diaphragma sellae**
- **Pars tuberalis**
- **Pars distalis**
- **Pars intermedia**
- **Adenohypophysis** (anterior lobe)
- **Median eminence**
- **Mamillary body**
- **Third ventricle**
- **HYPOTHALAMUS**
- **Neurohypophysis** (posterior lobe)
- **Sphenoid (sella turcica)**

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

• The Adenohypophysis
  • Consists of five different cell types
    • **Thyrotropes**: release thyroid-stimulating hormone (TSH)
    • **Corticotropes**: release adrenocorticotropic hormone (ACTH) and melanocyte-stimulating hormone (MSH)
    • **Gonadotropes**: release follicle-stimulating hormone (FSH) and luteinizing hormone (LH)
    • **Lactotropes**: release prolactin (PRL)
    • **Somatotropes**: release growth hormone (GH; also called somatotropin)
The Pituitary Gland

- The Hypophyseal Portal System
  - Within the infundibulum is a plexus of capillaries
    - Capillaries are fenestrated
    - Regulatory hormones leave the hypothalamus and pass through the portal vessels to the adenohypophysis
The Pituitary Gland

- Hormones of the Adenohypophysis
  - Hormones released by the pars distalis:
    - Thyroid-stimulating hormone (TSH)
    - Adrenocorticotrophic hormone (ACTH)
    - Follicle-stimulating hormone (FSH)
    - Luteinizing hormone (LH)
    - Prolactin (PRL)
    - Growth hormone (GH); also called somatotropin
  - Hormone released by the pars intermedia:
    - Melanocyte-stimulating hormone (MSH)
The Pituitary Gland

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

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

• Hormones of the Adenohypophysis
  • Follicle-stimulating hormone
    • Targets the ovaries of females
    • Causes maturation of oocytes
    • Causes the release of estrogen
    • Targets the seminiferous tubules of males
    • Causes sperm production
Hormones of the Adenohypophysis

**Luteinizing hormone**
- Targets the ovaries in females
- Causes ovulation
- Causes the release of progestin (progesterone)
- Targets the interstitial cells in males
- Causes the release of androgens (testosterone)
- Causes the release of estrogen
- FSH and LH are also called gonadotropins
The Pituitary Gland

- Hormones of the Adenohypophysis
  - **Prolactin**
    - Targets the mammary glands
    - Causes the production of milk
  - **Growth hormone**
    - Also called somatotropin
    - Targets general cells and skeletal muscles
    - Causes protein synthesis resulting in growth
    - Targets liver cells
    - Causes the release of somatomedins, which stimulate protein synthesis in muscles and cartilage cells
• Hormones of the Adenohypophysis
  • **Melanocyte-stimulating hormone**
    • Targets the melanocyte cells of the skin
    • Causes the production of *melanin*
### Table 19.1 The Pituitary Hormones

<table>
<thead>
<tr>
<th>Hormone</th>
<th>Targets</th>
<th>Hormonal Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Adenohypophysis (Anterior Lobe)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>PARS DISTALIS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thyroid-stimulating hormone (TSH)</td>
<td>Thyroid gland</td>
<td>Secretion of thyroid hormones ($T_3$, $T_4$)</td>
</tr>
<tr>
<td>Adrenocorticotropic hormone (ACTH)</td>
<td>Suprarenal cortex (zona fasciculata)</td>
<td>Glucocorticoid secretion</td>
</tr>
<tr>
<td><strong>Gonadotropins:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Follicle-stimulating hormone (FSH)</td>
<td>Follicle cells of ovaries in female</td>
<td>Estrogen secretion, follicle development</td>
</tr>
<tr>
<td></td>
<td>Nurse cells of testes in male</td>
<td>Stimulation of sperm maturation</td>
</tr>
<tr>
<td>Luteinizing hormone (LH)</td>
<td>Follicle cells of ovaries in female</td>
<td>Ovulation, formation of corpus luteum, progesterone secretion</td>
</tr>
<tr>
<td></td>
<td>Interstitial cells of testes in male</td>
<td>Testosterone secretion</td>
</tr>
<tr>
<td>Prolactin (PRL)</td>
<td>Mammary glands in female</td>
<td>Production of milk</td>
</tr>
<tr>
<td>Growth hormone (GH)</td>
<td>All cells</td>
<td>Growth, protein synthesis, lipid mobilization and catabolism</td>
</tr>
<tr>
<td><strong>PARS INTERMEDIA (NOT ACTIVE IN NORMAL ADULTS)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Melanocyte-stimulating hormone (MSH)</td>
<td>Melanocytes</td>
<td>Increased melanin synthesis in epidermis</td>
</tr>
<tr>
<td><strong>Neurohypophysis (Posterior Lobe)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>NEURAL LOBE (PARS NERVOSA)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Antiuretic hormone (ADH or vasopressin)</td>
<td>Kidneys</td>
<td>Reabsorption of water; elevation of blood volume and pressure</td>
</tr>
<tr>
<td>Oxytocin (OT)</td>
<td>Uterus, mammary glands (females)</td>
<td>Labor contractions, milk ejection</td>
</tr>
<tr>
<td></td>
<td>Ductus deferens and prostate gland (males)</td>
<td>Contractions of ductus deferens and prostate gland; ejection of secretions</td>
</tr>
</tbody>
</table>
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

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

**Adrenal Cortex**

- Suprarenal gland
  - Medulla
  - Cortex
  - Adrenocorticotropic hormone (ACTH)

**Thyroid Gland**

- Thyroid hormones (T₃, T₄)
  - Glucocorticoids (cortisol, corticosterone)
  - Thyroid hormones
  - Somatomedins

**Liver**

- Prolactin (PRL)
- Growth hormone (GH)
- Follicle-stimulating hormone (FSH)
- Luteinizing hormone (LH)
- Melanocyte-stimulating hormone (MSH)

**Blood Vessels**

- Anterior lobe of the pituitary gland
- Posterior lobe of the pituitary gland
- Hypophyseal portal system

**Targets**

- Bone, muscle, other tissues
- Mammary glands
- Testes of male
- Ovaries of female
- Thyroid hormones
- Adrenocorticotropic hormone (ACTH)
- Growth hormone (GH)
- Prolactin (PRL)
- Follicle-stimulating hormone (FSH)
- Luteinizing hormone (LH)
- Melanocyte-stimulating hormone (MSH)
- Antidiuretic hormone (ADH)

**Female Uterine Smooth Muscle and Mammary Glands**

**Male Smooth Muscle in Ductus deferens and Prostate Gland**

**Melanocytes (Uncertain Significance in Healthy Adults)**
The Thyroid Gland

- The thyroid gland is on the anterior surface of the trachea
  - Highly vascularized
    - Supplied by the superior thyroid artery (from the external carotid artery)
    - Supplied by the inferior thyroid artery (from the thyrocervical trunk)
  - Made of two lobes connected via an isthmus
  - Consists of thyroid follicles
  - This is the only gland that stores its hormone products
Figure 19.1 The Endocrine System

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 (T4)
- Triiodothyronine (T3)
- Calcitonin (CT)

Thymus
(Undergoes atrophy during adulthood)
- Thymosins

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
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<tr>
<td>ADH</td>
<td>Antidiuretic hormone</td>
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</table>
Figure 19.6a Anatomy and Histological Organization 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
- Internal jugular vein
- Cricoid cartilage of larynx
- Left lobe of thyroid gland
- Isthmus of thyroid gland
- Inferior thyroid artery
- Inferior thyroid veins

Location and anatomy of the thyroid gland
The Thyroid Gland

• Thyroid follicles manufacture thyroid hormones
  • Follicles are lined with simple cuboidal epithelium and T thyrocytes (follicular cells)
    • Follicular cells secrete thyroglobulin into the follicle
    • Follicular cells transport iodine into the follicle
    • The combination of iodine and the colloidal material within the follicle results in the formation of the thyroid hormones
The Thyroid Gland

- Hormones of the thyroid gland
  - **Calcitonin (CT)**
    - Targets osteoclasts of bones
    - Causes a decrease in blood calcium ion concentration by:
      - Stimulating calcium ion excretion at the kidneys
      - Inhibiting osteoclast activity (therefore calcium ions do not leave the bones to enter the blood)
Thyroid Follicles and Thyroid Hormones

- Hormones of the thyroid gland
  - **Thyroxine** (T\(_4\))
    - Targets general cells
    - Causes an increase in metabolism
  - **Triiodothyronine** (T\(_3\))
    - Targets general cells
    - Causes an increase in metabolism
Figure 19.6a–c  Anatomy and Histological Organization of the Thyroid Gland

**a** 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

**b** 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

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

- Thyroid follicle
- Thyroglobulin stored in colloid of follicle
- Cuboidal epithelium of follicle
- C thyrocyte cell
<table>
<thead>
<tr>
<th>Gland/Cells</th>
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<tr>
<td>T thyrocytes</td>
<td>Thyroxine (T₄),</td>
<td>Most cells</td>
<td>Increase energy utilization, oxygen consumption, growth, and development.</td>
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<td>Triiodothyronine (T₃)</td>
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<td>Calcitonin (CT)</td>
<td>Bone and kidneys</td>
<td>Decreases calcium ion concentrations in body fluids; uncertain significance in healthy nonpregnant adults</td>
</tr>
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</table>
The Thyroid Gland

• Negative feedback cycle of the thyroid gland
  • 1. Decreased concentration of $T_3$ and $T_4$
  • 2. Triggers release of TRH from the hypothalamus
  • 3. TRH targets the adenohypophysis
  • 4. Causes the release of TSH
  • 5. TSH targets the thyroid gland
  • 6. Triggers release of $T_3$ and $T_4$
  • 7. Normal levels of $T_3$ and $T_4$ are restored
Figure 19.7 The Regulation of Thyroid Secretion

Hypothalamus releases TRH

Pituitary gland releases TSH

Homeostasis Disturbed
Decreased $T_3$ and $T_4$ concentrations in blood or low body temperature

HOMEOSTASIS
Normal $T_3$ and $T_4$ concentrations, normal body temperature

Adenohypophysis releases TSH

Homeostasis Restored
Increased $T_3$ and $T_4$ concentrations in blood

Thyroid follicles release $T_3$ and $T_4$
The Parathyroid Glands

• The parathyroid glands are located on the posterior portion of the thyroid gland
  • Highly vascularized
    • Superior pair are supplied by the superior thyroid artery
    • Inferior pair are supplied by the inferior thyroid artery
Figure 19.1 The Endocrine System

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**Pars distalis (anterior lobe):**
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- GH
- PRL
- FSH
- LH
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**Neurohypophysis (posterior lobe):**
- Release of oxytocin and ADH

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

**Thymus**
- Thymosins (Undergoes atrophy during adulthood)

**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)

**Parasitic Islets**
- Insulin, glucagon

**Gonads**
- Testes (male):
  - Androgens (especially testosterone), inhibin
- Ovaries (female):
  - Estrogens, progestins, inhibin
The location and size of the parathyroid glands on the posterior surface of the thyroid lobes.

The histology of the parathyroid and thyroid glands.

A histological section showing parathyroid cells and oxyphil cells of the parathyroid gland.
The Parathyroid Glands

- Hormone Production
  - Release **parathyroid hormone (PTH)**
    - Targets osteoclast cells and kidneys
    - Causes osteoclast cells to remove calcium ions from bone
    - Osteoclasts will put calcium ions into the blood thus increasing blood calcium ion levels
    - Causes kidneys to reduce calcium ion excretion thus increasing blood calcium ion levels
    - Causes kidneys to produce **calcitriol**
    - Calcitriol promotes the small intestine to absorb calcium ions into the bloodstream, thus increasing blood calcium ion levels
### Table 19.2 Hormones of the Thyroid Gland, Parathyroid Glands, and Thymus

<table>
<thead>
<tr>
<th>Gland/Cells</th>
<th>Hormones</th>
<th>Targets</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PARATHYroids</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parathyroid cells</td>
<td>Parathyroid hormone (PTH)</td>
<td>Bone and kidneys</td>
<td>Increases calcium ion concentrations in body fluids; increases bone mass</td>
</tr>
<tr>
<td>Thymus</td>
<td>“Thymosins” (see Chapter 23)</td>
<td>Lymphocytes</td>
<td>Maturation and functional competence of immune system</td>
</tr>
</tbody>
</table>

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The Thymus Gland

• The thymus gland is posterior to the sternum
• Hormone production
  • Produces thymosin
    • Targets lymphocytes
    • Causes lymphocytes to develop into T cells
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

**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 (T₄)
- Triiodothyronine (T₃)
- Calcitonin (CT)

**Thymus**
- (Undergoes atrophy during adulthood)
- Thymosins

**Suprarenal Glands**
- Each suprarenal gland is subdivided into:
  - Medulla: Epinephrine (E)
  - Norepinephrine (NE)
  - Cortex: Cortisol, corticosterone, aldosterone, androgens

**Parathyroid Glands**
- (on posterior surface of thyroid gland)
- Parathyroid hormone (PTH)

**Heart**
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- Brain natriuretic peptide (BNP)

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- Insulin, glucagon

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

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The Suprarenal Glands

- The suprarenal glands (adrenal glands) are located attached to the superior border of the kidneys
- These glands are highly vascularized
  - Supplied by branches from the renal artery
  - Supplied by the inferior phrenic artery
  - Supplied by the middle suprarenal artery from the descending aorta
KEY TO PITUITARY HORMONES

ACTH  Adrenocorticotropic hormone
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Thyroxine (T\textsubscript{4})
Triiodothyronine (T\textsubscript{3})
Calcitonin (CT)

Thymus
(Undergoes atrophy during adulthood)
Thymosins

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Ovaries (female):
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Thymus (Undergoes atrophy during adulthood)

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Numerous hormones (detailed in Chapter 25)

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Release of oxytocin and ADH

Suprarenal Glands
Each suprarenal gland is subdivided into:
Medulla:
Epinephrine (E)
Norepinephrine (NE)
Cortex:
Cortisol, corticosterone, aldosterone, androgens

Testis

Ovary

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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
Figure 19.9ab Anatomy and Histological Organization of the Suprarenal Gland

A suprarenal gland cut to show both the cortex and the medulla. Note the orientation of the section for part (c).

Anterior view of the kidney and suprarenal gland. Note the sectional plane for part (b).
Figure 19.9bc  Anatomy and Histological Organization of the Suprarenal Gland

A suprarenal gland cut to show both the cortex and the medulla. Note the orientation of the section for part (c).

b Histology of the suprarenal gland showing identification of the major regions
The Suprarenal Glands

- Suprarenal medulla
  - Produces epinephrine and norepinephrine
- Suprarenal cortex
  - Zona glomerulosa
    - Produces mineralocorticoids such as aldosterone
  - Zona fasciculata
    - Produces glucocorticoids such as cortisol, cortisone, and corticosterone
  - Zona reticularis
    - Produces small amounts of androgens
The Suprarenal Glands

• Hormones of the Suprarenal Cortex
  • **Zona glomerulosa** (aldosterone production)
    • Targets the kidney
    • Causes retention of sodium ions and water thereby reducing ion and water loss from the body
  • **Zona fasciculata** (cortisol, cortisone, and corticosterone)
    • Targets the liver
    • Causes the liver to synthesize glucose and glycogen
The Suprarenal Glands

• Hormones of the Suprarenal Cortex
  • **Zona reticularis**
    • Targets general cells
    • Causes the secretion of small amounts of androgens
    • Causes development of pubic hair
The Suprarenal Glands

• Hormones of the Suprarenal Medulla
  • Epinephrine (adrenaline) and norepinephrine (noradrenaline)
    • Target most cells
    • Cause an increase in cardiac activity
    • Cause an increase in blood pressure
    • Cause an increase in glycogen breakdown
<table>
<thead>
<tr>
<th>Region/Zone</th>
<th>Hormones</th>
<th>Targets</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cortex</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zona glomerulosa</td>
<td>Mineralocorticoids (MC), primarily aldosterone</td>
<td>Kidneys</td>
<td>Increase renal reabsorption of sodium ions and water (especially in the presence of ADH) and accelerate urinary loss of potassium ions</td>
</tr>
<tr>
<td>Zona fasciculata</td>
<td>Glucocorticoids (GC): cortisol (hydrocortisone), corticosterone; cortisol converted to cortisone and released by the liver</td>
<td>Most cells</td>
<td>Release amino acids from skeletal muscles, lipids from adipose tissues; promote formation of liver glycogen and glucose; promote peripheral utilization of lipids (glucose-sparing); anti-inflammatory effects</td>
</tr>
<tr>
<td>Zona reticularis</td>
<td>Androgens</td>
<td></td>
<td>Uncertain significance under normal conditions</td>
</tr>
<tr>
<td>Medulla</td>
<td>Epinephrine, norepinephrine</td>
<td>Most cells</td>
<td>Increased cardiac activity, blood pressure, glycogen breakdown, blood glucose; release of lipids by adipose tissue (see Chapter 17)</td>
</tr>
</tbody>
</table>
Endocrine Functions of the Kidneys and Heart

- The kidneys produce:
  - Renin (enzyme)
  - Erythropoietin (hormone – EPO)
  - Calcitriol (hormone)

- The heart produces:
  - Atrial natriuretic peptide (hormone – ANP)
  - Brain natriuretic peptide (hormone – BNP)
Figure 19.1 The Endocrine System

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<th>Description</th>
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<tr>
<td>MSH</td>
<td>Melanocyte-stimulating hormone</td>
</tr>
<tr>
<td>ADH</td>
<td>Antidiuretic hormone</td>
</tr>
</tbody>
</table>

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Endocrine Functions of the Kidneys and Heart

• The kidneys (responding to low blood pressure):
  • Release renin into the bloodstream
  • Renin converts angiotensinogen to angiotensin I
    • Angiotensinogen is produced by the liver
  • Angiotensin I converts to angiotensin II
    • An enzyme from the lungs causes this conversion
    • The enzyme is the angiotensin-converting enzyme (ACE)
  • Angiotensin II causes the suprarenal cortex to release aldosterone
Endocrine Functions of the Kidneys and Heart

• The kidneys (responding to low blood pressure)
  • Aldosterone causes the kidneys to put sodium ions and water into the bloodstream
  • This raises blood pressure back to homeostatic conditions
  • Angiotensinogen II causes blood vessel constriction
  • This raises blood pressure back to homeostatic conditions
Endocrine Functions of the Kidneys and Heart

• The kidneys (responding to low calcium ion levels)
  • **Parathyroid hormone** targets the kidneys
  • Kidney cells release **calcitriol**
  • Calcitriol causes the small intestine to absorb calcium ions into the bloodstream
  • This raises the calcium ion levels back to homeostatic conditions
Endocrine Functions of the Kidneys and Heart

• The kidneys (production of calcitriol)
  • We obtain cholecalciferol (vitamin D) from:
    • Skin
    • Diet
  • Cholecalciferol is converted to intermediate products in the liver
  • Those liver products are converted to calcitriol in the kidneys
    • Calcitriol is the biologically active form of vitamin D
Endocrine Functions of the Kidneys and Heart

• The heart (responding to high blood pressure)
  • High blood pressure (many times) is due to high volume
  • The heart cells in the right atrium detect high volume
  • The heart cells release ANP and BNP
  • These hormones inhibit ADH and aldosterone
  • The result is the loss of water and sodium ions
    • Blood pressure and volume return to homeostatic conditions
The Pancreas and Other Endocrine Tissues

• Functions of the Pancreas
  • Endocrine function
    • Consists of **pancreatic islets**
    • Produces hormones
  • Exocrine function
    • Consists of **pancreatic lobules**
    • Produces digestive enzymes
Figure 19.1 The Endocrine System

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**Adipose Tissue**
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**Digestive Tract**
Numerous hormones (detailed in Chapter 25)

**Pancreatic Islets**
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Testes (male):
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**KEY TO PITUITARY HORMONES**
- ACTH: Adrenocorticotropic hormone
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- LH: Luteinizing hormone
- MSH: Melanocyte-stimulating hormone
- ADH: Antidiuretic hormone

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The Pancreas and Other Endocrine Tissues

- The pancreas is highly vascularized
  - It has fenestrated capillaries
  - Supplied by the pancreaticoduodenal arteries
  - Supplied by the pancreatic arteries
- 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
Figure 19.10a  Anatomy and Histological Organization of the Pancreas

The gross anatomy of the pancreas

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

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Figure 19.10ab Anatomy and Histological Organization of the Pancreas

The gross anatomy of the pancreas

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

General histology of the pancreatic islets

- Pancreatic acini (exocrine cells)
- Pancreatic islet (islet of Langerhans)
- Endocrine cells:
  - α cells (glucagon)
  - β cells (insulin)
  - δ cells (somatostatin)
  - F cells (pancreatic polypeptide)

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The Pancreas and Other Endocrine Tissues

• Hormones of the Pancreas
  • **Glucagon**
    • Produced by alpha cells of the islets
    • Stimulates the liver to break down glycogen to form glucose
    • Stimulates the liver to put glucose into the bloodstream
    • This raises blood glucose levels
  • **Insulin**
    • Produced by beta cells of the islets
    • Increases the rate of glucose absorption by body cells
    • This lowers blood glucose levels
The Pancreas and Other Endocrine Tissues

• Hormones of the Pancreas
  • **Somatostatin**
    • Produced by the delta cells of the islets
    • Inhibits production of glucagon
    • Inhibits production of insulin
    • Slows the rate of absorption along the small intestine
    • All of this results in inhibiting growth
  • **Pancreatic polypeptide (PP)**
    • Produced by the F cells of the islets
    • Inhibits gallbladder contractions
    • Helps regulate the production of some pancreatic enzymes
Table 19.4 Hormones of the Pancreas

<table>
<thead>
<tr>
<th>Structure/Cells</th>
<th>Hormones</th>
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<th>Effects</th>
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<tbody>
<tr>
<td><strong>PANCREATIC ISLETS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alpha cells</td>
<td>Glucagon</td>
<td>Liver, adipose tissues</td>
<td>Mobilization of lipid reserves; glucose synthesis and glycogen breakdown in liver; elevation of blood glucose concentrations</td>
</tr>
<tr>
<td>Beta cells</td>
<td>Insulin</td>
<td>All cells except those of brain, kidneys, digestive tract epithelium, and RBCs</td>
<td>Facilitation of uptake of glucose by cells; stimulation of lipid and glycogen formation and storage; decrease in blood glucose concentrations</td>
</tr>
<tr>
<td>Delta cells</td>
<td>Somatostatin</td>
<td>Alpha and beta cells, digestive</td>
<td>Inhibition of secretion of insulin and glucagon epithelium</td>
</tr>
<tr>
<td>F cells</td>
<td>Pancreatic polypeptide (PP)</td>
<td>Gallbladder and pancreas, possibly gastrointestinal tract</td>
<td>Inhibits gallbladder contractions; regulates production of some pancreatic enzymes; may control nutrient absorption</td>
</tr>
</tbody>
</table>
Endocrine Tissues of the Reproductive System

• Testes
  • The interstitial cells release **testosterone**
    • Promotes the production of sperm
    • Maintains the secretory glands
    • Influences secondary sex characteristics
    • Stimulates muscle growth
  • The sustentacular cells release **inhibin**
    • Depresses the secretion of FSH
    • Inhibin and FSH interact to maintain sperm production at normal levels
Figure 19.1 The Endocrine System

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Calcitonin (CT)

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**Testis**
Androgens (especially testosterone), inhibin

**Ovary**
Estrogens, progestins, inhibin

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- LH: Luteinizing hormone
- MSH: Melanocyte-stimulating hormone
- ADH: Antidiuretic hormone
Endocrine Tissues of the Reproductive System

- Ovaries
  - Oocytes begin to develop in follicles
  - 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
  - Corpus luteum releases relaxin
Endocrine Tissues of the Reproductive System

• Ovaries
  • **Progesterone** prepares the body for pregnancy
    • Progesterone targets the endometrial lining
    • Causes a thickening of the lining to prepare a place for the implantation of a fertilized egg
    • Progesterone targets the mammary tissue
    • Causes the mammary tissue to prepare for secretory functions
  • **Relaxin** also prepares the body for pregnancy
    • Loosens the pubic symphysis
    • Relaxes the cervical muscles
    • Stimulates mammary gland development
Table 19.6 Hormones of the Reproductive System

<table>
<thead>
<tr>
<th>Structure/Cells</th>
<th>Hormones</th>
<th>Primary Targets</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TESTES</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interstitial cells</td>
<td>Androgens</td>
<td>Most cells</td>
<td>Support functional maturation of sperm; protein synthesis in skeletal muscles; male secondary sex characteristics and associated behaviors</td>
</tr>
<tr>
<td>Nurse cells</td>
<td>Inhibin</td>
<td>Anterior lobe of pituitary gland</td>
<td>Inhibits secretion of FSH</td>
</tr>
<tr>
<td><strong>OVARIES</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Follicular cells</td>
<td>Estrogens (especially estradiol)</td>
<td>Most cells</td>
<td>Support follicle maturation; female secondary sex characteristics and associated behaviors</td>
</tr>
<tr>
<td></td>
<td>Inhibin</td>
<td>Anterior lobe of pituitary gland</td>
<td>Inhibits secretion of FSH</td>
</tr>
<tr>
<td>Corpus luteum</td>
<td>Progestins (especially progesterone)</td>
<td>Uterus, mammary glands</td>
<td>Prepare uterus for implantation; prepare mammary glands for secretory functions</td>
</tr>
<tr>
<td></td>
<td>Relaxin</td>
<td>Pubic symphysis, uterus, mammary glands</td>
<td>Loosens pubic symphysis; relaxes uterine (cervical) muscles; stimulates mammary gland development</td>
</tr>
</tbody>
</table>
The Pineal Gland

- The Pineal Gland
  - Part of the epithalamus
  - Contains neurons, glial cells, and special secretory cells called pinealocytes
    - Pinealocytes synthesize the hormone melatonin
- Melatonin
  - Slows the maturation of sperm, oocytes, and reproductive organs
  - Production rate rises at night and declines during the day
Hormones and Aging

• Exhibits relatively few changes with advancing age
• One can expect:
  • 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

Direct Release of Hormones

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

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