The Endocrine System

PowerPoint® Lecture Presentations prepared by Jason LaPres
Lone Star College—North Harris

NOTE: Presentations extensively modified for use in MCB 244 & 246 at the University of Illinois by Dr. Kwast & Dr. Brown (2011-2012)
Objectives

• Have an understanding of the significance of intercellular communication in the body, primarily the different forms of intercellular communication utilized by the nervous system and the endocrine system.

• Be familiar with the major components of the endocrine system and know the major structural classes of hormones as well as the mechanisms of action hormones have on their target cells.

• Know the location, hormones and functioning of the pituitary gland

• Be familiar with some effects of abnormal pituitary function

• Know the location, hormones produced and functioning of the following endocrine glands: thyroid, parathyroid, adrenal (suprarenal), pancreas

• Know the functions of the hormones produced by the kidneys, heart, thymus, testes, ovaries and adipose tissue, pineal gland
Introduction to the Endocrine System

- The Endocrine System
  - Functionally it regulates long-term processes like:
    - Growth
    - Development
    - Reproduction
  - It uses chemical messengers to relay information and instructions between cells
  - The goal, being to maintain homeostasis.
  - The key is communication.
Homeostasis and Intercellular Communication

- To understand how the communication is effective, we have to understand the different forms of communication possible.
- These include:
  - Direct communication
  - Paracrine communication
  - Endocrine communication
Direct Communication

- Exchange of ions and molecules between adjacent cells across gap junctions
- Occurs between two cells of same type
- Highly specialized and relatively rare

Table 18–1

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Transmission</th>
<th>Chemical Mediators</th>
<th>Distribution of Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct communication</td>
<td>Through gap junctions</td>
<td>Ions, small solutes, lipid-soluble</td>
<td>Usually limited to adjacent cells of the same type that are interconnected by connexons</td>
</tr>
</tbody>
</table>

© 2012 Pearson Education, Inc.
Paracrine Communication

- Uses chemical signals to transfer information from cell to cell within single tissue
- Most common form of intercellular communication

| Paracrine communication | Through extracellular fluid | Paracrine factors | Primarily limited to a local area, where paracrine factor concentrations are relatively high. Target cells must have appropriate receptors |

From Table 18-1
Endocrine Communication

- Endocrine cells release chemicals (hormones) into bloodstream
- Alters metabolic activities of many tissues and organs simultaneously

From Table 18-1
Synaptic communication

• Chemical communication (via neurotransmitter release) across a synapse between a **neuron** and an **effector** (neuron, muscle, gland)

From Table 18-1
Structurally, chemical communication is managed via a variety of organs which are classified as:

- True “endocrine” glands
- Organs with “endocrine” functions (i.e. produce hormones)
Endocrine glands/tissues include:

- Hypothalamus
- Pituitary gland
- Pineal gland
- Parathyroid glands
- Thyroid gland
- Thymus
- Heart
- Kidney
- Suprarenal glands
- Pancreas
- Digestive tract
- Adipose tissue
- Gonads (testes, ovaries)
Endocrine Glands and Organs with Endocrine function

Hypothalamus
- Production of ADH, oxytocin, and regulatory hormones

Pineal Gland
- Melatonin

Pituitary Gland
- Anterior lobe: ACTH, TSH, GH, PRL, FSH, LH, and MSH
- Posterior lobe: Release of oxytocin and ADH

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

Organs with Secondary Endocrine Functions
- Heart: Secretes natriuretic peptides. • Atrial natriuretic peptide (ANP) • Brain natriuretic peptide (BNP)
- Thymus: (Undergoes atrophy during adulthood) Secrtes thymosins
- Adipose Tissue: Secretes • Leptin
- Digestive Tract: Secretes numerous hormones involved in the coordination of system functions, glucose metabolism, and appetite
- Kidneys: Secretes • Erythropoietin (EPO) • Calcitriol
- Gonads:
  - Testes (male): Androgens (especially testosterone), inhibin
  - Ovaries (female): Estrogens, progestins, inhibin

© 2012 Pearson Education, Inc.
Homeostasis and Intercellular Communication

For chemical communication to occur you need to have two things:

1. Target Cells (with hormone receptors)
   - Are specific cells that possess receptors needed to bind and “read” hormonal messages

2. Hormones
   - Stimulate synthesis of enzymes or structural proteins
   - Increase or decrease rate of synthesis
   - Turn existing enzyme or membrane channel “on” or “off”
Hormones

- Can be divided into three groups
  - Amino acid derivatives
  - Peptide hormones
  - Lipid derivatives

- They can either circulate freely (mostly peptide hormones) or bound to transport proteins (mostly lipid derived hormones)
Structural Classification of Hormones

- Amino acid derivatives
  - Use 1 amino acid as base structure
  - Tyrosine - thyroid hormones, catecholamines
  - Tryptophan - melatonin

From Figure 18-2
Structural Classification of Hormones

- **Peptide hormones**
  - Assembled from chains of amino acids joined together; two groups are:
    - Glycoproteins
    - Short polypeptides/proteins
  - Most diverse family of hormones

---

**Peptide Hormones**

Peptide hormones are chains of amino acids. Most peptide hormones are synthesized as prohormones—inactive molecules that are converted to active hormones before or after they are secreted.

**Glycoproteins**

These proteins are more than 200 amino acids long and have carbohydrate side chains. The glycoproteins include thyroid-stimulating hormone (TSH), luteinizing hormone (LH), and follicle-stimulating hormone (FSH) from the anterior lobe of the pituitary gland, as well as several hormones produced in other organs.

**Short Polypeptides/Small Proteins**

This group of peptide hormones is large and diverse. It includes hormones that range from short chain polypeptides, such as antidiuretic hormone (ADH) and oxytocin (OXT) (each 9 amino acids long), to small proteins, such as growth hormone (GH; 191 amino acids) and prolactin (PRL; 198 amino acids). This group includes all the hormones secreted by the hypothalamus, heart, thymus, digestive tract, pancreas, and posterior lobe of the pituitary gland, as well as several hormones produced in other organs.
Structural Classification of Hormones

- Lipid derivates
- Assembled using lipids (arachadonic acid; cholesterol) as base structural units and examples include:
  - Steroid hormones (estrogens, androgens, corticosteroids, calcitriol)
  - Eicosanoids

From Figure 18-2
Secretion of hormones

• Structural makeup of a hormone will also determine how a hormone circulates
  • Lipid soluble hormones (steroid hormones/ thyroid hormones) – long circulation period (hours to days)
    • Require special transport proteins
  • Water soluble hormones (peptide hormones, catecholamines) – short circulation period (minutes)
    • Removed via, enzyme degradation, diffusion, metabolized by liver and/or target cell
Mechanisms of Hormone Action

Another way to characterize hormones is by their mechanism of action.

1. Membrane acting hormones
   - Catecholamines, peptide hormones, eicosanoids

2. Nuclear hormones *
   - Thyroid hormones, steroid hormones
Mechanisms of Hormone Action: Plasma membrane acting hormones

• Hormones and Plasma Membrane Receptors
  • Catecholamines and peptide hormones
    • Are not lipid soluble
    • Unable to penetrate plasma membrane
    • Bind to receptor proteins at outer surface of plasma membrane (extracellular receptors)
Mechanisms of Hormone Action: Plasma membrane acting hormones

• Because they bind to membrane receptors, catecholamines and peptide hormones’ effects are
  • Indirect - don’t directly effect intracellular activities of the target cell.
  • Use intracellular intermediary to exert effects as part of a first messenger-second messenger signaling pathway
Mechanisms of Hormone Action: Plasma membrane acting hormones

First messenger = hormone

- leads to **second messenger**
- may act as enzyme activator, inhibitor, or cofactor
- results in change in rates of metabolic reactions

- **Examples of second messengers include:**
  - Cyclic-AMP (cAMP)
    - Derivative of ATP
  - Cyclic-GMP (cGMP)
    - Derivative of GTP
  - Calcium ions
Mechanisms of Hormone Action: Plasma membrane acting hormones

- **cAMP signaling pathway**
  - G Protein (binds GTP) coupled receptors is part of an enzyme complex (adenylate cyclase) coupled to membrane hormone receptor
  - Involved in link between first messenger (**hormone**) and second messenger (**cAMP**)
  - Activated when hormone binds to receptor at membrane surface and results in change in concentration of second messenger cyclic-AMP (cAMP) within cell:
    - increased cAMP level accelerates metabolic activity within cell

From figure 18-3
Mechanisms of Hormone Action: Plasma membrane acting hormones

- **Inositol triphosphate (IP3) signaling pathway**
  - Activated G protein/hormone complex triggers
    - G protein activates enzyme phospholipase C (PLC)
    - Enzyme triggers receptor cascade:
      - production of **diacylglycerol (DAG)** and **inositol triphosphate (IP3)** from membrane phospholipids
      - Causes opening of calcium ion channels in membrane
      - release of **calcium ions** (second messenger) from intracellular stores
      - Calcium binds to intracellular protein (calmodulin) which then activates intracellular enzymes

From figure 18-3
Mechanisms of Hormone Action: Nuclear acting hormones

- Hormones and Intracellular Receptors
  - Alter rate of DNA transcription in nucleus
  - Change patterns of protein synthesis
  - Includes steroids and thyroid hormones

Figure 18-4
Mechanisms of Hormone Action

Another way to characterize hormones is by their mechanism of action.

1. Membrane acting hormones
   - Catecholamines, peptide hormones, eicosanoids

2. Nuclear hormones *
   - Thyroid hormones*, steroid hormones
Mechanisms of Hormone Action: Nuclear acting hormones

- Hormones and Intracellular Receptors
  - Directly affect metabolic activity and structure of target cell
  - The direct effects are NOT due to altering transcription at the nuclear level – referred to the “non-genomic” effects

From figure 18-4
Regulation of Hormone Production/Activity

- Both hormone production and activity at the target tissue are subject to regulation.

- At the target – mediated by receptor regulation (up/down regulation).

- At the source of production – mediated by endocrine reflexes.
Regulation of Hormone Production/Activity

• **Down-regulation**
  • Presence of a hormone triggers decrease in number of hormone receptors
  • When levels of particular hormone are high, cells become less sensitive

• **Up-regulation**
  • Absence of a hormone triggers increase in number of hormone receptors
  • When levels of particular hormone are low, cells become more sensitive
Endocrine Reflexes

- Endocrine Reflexes
  - In **most** cases, controlled by negative feedback mechanisms ...however there are cases where positive feedback reflexes are used
    - Stimulus triggers production of hormone whose effects **increase** intensity of the stimulus which results in an **increase** in production of the hormone
    - E.g. suckling, labor
Endocrine Reflexes

- Endocrine reflexes can be triggered by
  - **Humoral stimuli**
    - Changes in composition of extracellular fluid
  - **Hormonal stimuli**
    - Arrival or removal of specific hormone
  - **Neural stimuli**
    - Arrival of neurotransmitters at neuroglandular junctions
Endocrine Reflexes

• Simple Endocrine Reflex
  • Involves only one hormone (e.g. ANP production by the heart; insulin production by the pancreas)
  • Controls hormone secretion by the heart, pancreas, parathyroid gland, and digestive tract

• Complex Endocrine Reflex
  • Involves
    • One or more intermediary steps
    • Two or more hormones
    • The hypothalamus
    • Eg. hypothalamic-pituitary axis of hormone production
Endocrine Reflexes

- Neuroendocrine Reflexes
  - Pathways include both neural and endocrine components (e.g. anterior pituitary – suprarenal communication)

- Reflexes mediated by complex commands/patterns
  - Issued by changing
    - Amount of hormone secreted
    - Pattern of hormone release:
      - hypothalamic and pituitary hormones released in sudden bursts
      - frequency changes response of target cells
Major glands of the endocrine system: hypothalamic-pituitary axis

• Most of the body’s endocrine gland activity is mediated by the communication between the hypothalamus and the anterior pituitary
Anatomy of The Pituitary Gland

- Also called hypophysis

- Anatomically:
  - Lies within sella turcica
  - Encapsulated by the diaphragma sellae - dural sheet that locks pituitary in position and physically isolates it from cranial cavity
  - Hangs inferior to hypothalamus
  - Connected by infundibulum

Figure 18-6
Anatomy of The Pituitary Gland

- Structurally the pituitary is divided into two lobes:
  - Anterior lobe (adenohypophysis)
  - Posterior lobe (neurohypophysis)
- Each lobe is individually regulated by the hypothalamus

Figure 18-6
Anatomy of The Pituitary Gland

Posterior pituitary:

- **Median Eminence**
  - Swelling near attachment of infundibulum
  - Where hypothalamic neuron release regulatory factors
    - Into interstitial fluids
    - Through fenestrated capillaries

Figure 18-7
Anatomy of The Pituitary Gland

Anterior Pituitary

- Portal Vessels transport hormones of hypothalamus to ant. pit.
  - Blood vessels link two capillary networks
  - Entire complex is portal system
    - Ensures that regulatory factors reach intended target cells before entering general circulation

Figure 18-7
Two Classes of Hypothalamic Regulatory Hormones

- **Releasing hormones (RH)**
  - Stimulate synthesis and secretion of one or more hormones at anterior lobe

- **Inhibiting hormones (IH)**
  - Prevent synthesis and secretion of hormones from the anterior lobe

Rate of secretion is controlled by negative feedback

From Figure 18-8 & Table 18-2
Anatomy of The Pituitary Gland: Anterior Pituitary

- Hormones of the anterior lobe “turn on” endocrine glands or support other organs - trophic/tropic hormones

- Can be subdivided into three regions:
  1. Pars distalis
  2. Pars intermedia
  3. Pars tuberalis

From Figure 18-6
## Table 18-2: The Pituitary Hormones

<table>
<thead>
<tr>
<th>Region/Area</th>
<th>Hormone</th>
<th>Target</th>
<th>Hormonal Effect</th>
<th>Hypothalamic Regulatory Hormone</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ANTERIOR LOBE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pars distalis</td>
<td>Thyroid-stimulating hormone (TSH)</td>
<td>Thyroid gland</td>
<td>Secretion of thyroid hormones</td>
<td>Thyrotropin-releasing hormone (TRH)</td>
</tr>
<tr>
<td></td>
<td>Adrenocorticotropic hormone (ACTH)</td>
<td>Adrenal cortex (zona fasciculata)</td>
<td>Secretion of glucocorticoids (cortisol, corticosterone)</td>
<td>Corticotropin-releasing hormone (CRH)</td>
</tr>
<tr>
<td><strong>Gonadotropins:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Follicle-stimulating</td>
<td></td>
<td>Follicle cells of ovaries</td>
<td>Secretion of estrogen, follicle development</td>
<td></td>
</tr>
<tr>
<td>hormone (FSH)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nurse cells of testes</td>
<td>Stimulation of sperm maturation</td>
<td>Gonadotropin-releasing hormone (GnRH)</td>
</tr>
<tr>
<td>Luteinizing hormone</td>
<td></td>
<td>Follicle cells of ovaries</td>
<td>Ovulation, formation of corpus luteum, secretion of progesterone</td>
<td>Gonadotropin-releasing hormone (GnRH)</td>
</tr>
<tr>
<td>(LH)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Interstitial cells of testes</td>
<td>Secretion of testosterone</td>
<td>Gonadotropin-releasing hormone (GnRH)</td>
</tr>
<tr>
<td>Prolactin (PRL)</td>
<td>Mammary glands</td>
<td>Production of milk</td>
<td></td>
<td>Prolactin-releasing factor (PRF)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Prolactin-inhibiting hormone (PIH)</td>
</tr>
<tr>
<td>Growth hormone (GH)</td>
<td>All cells</td>
<td>Growth, protein synthesis, lipid mobilization and catabolism</td>
<td></td>
<td>Growth hormone–releasing hormone (GH–RH)</td>
</tr>
<tr>
<td><strong>Pars intermedia</strong></td>
<td>Melanocyte-stimulating hormone (MSH)</td>
<td>Melanocytes</td>
<td>Increased melanin synthesis in epidermis</td>
<td>Melanocyte-stimulating hormone–inhibiting hormone (MSH–IH)</td>
</tr>
</tbody>
</table>

© 2012 Pearson Education, Inc.
Anatomy of The Pituitary Gland: Posterior Pituitary

- Posterior lobe (neurohypophysis)
  - Contains unmyelinated axons of hypothalamic neurons
  - Two populations of neurons responsible for producing hormones of post. pit.
    - supraoptic nuclei (antidiuretic hormone/ADH)
    - paraventricular nuclei (oxytocin/OXT)

Figure 18-7
# Hormones of The Posterior Pituitary Gland

## Table 18–2  The Pituitary Hormones

<table>
<thead>
<tr>
<th>Region/Area</th>
<th>Hormone</th>
<th>Target</th>
<th>Hormonal Effect</th>
<th>Hypothalamic Regulatory Hormone</th>
</tr>
</thead>
<tbody>
<tr>
<td>POSTERIOR LOBE</td>
<td><strong>Antidiuretic hormone (ADH)</strong></td>
<td>Kidneys</td>
<td>Reabsorption of water, elevation of blood volume and pressure</td>
<td>None: Transported along axons from supraoptic nucleus to the posterior lobe of the pituitary gland</td>
</tr>
<tr>
<td></td>
<td><strong>Oxytocin (OXT)</strong></td>
<td>Uterus, mammary glands (females) Ductus deferens and prostate gland (males)</td>
<td>Labor contractions, milk ejection Contraction of ductus deferens and prostate gland</td>
<td>None: Transported along axons from paraventricular nucleus to the posterior lobe of the pituitary gland</td>
</tr>
</tbody>
</table>
Putting it all together: Hypothalamic-pituitary reflexes

- Release of ant. pituitary hormones are mediated by complex endocrine reflexes (negative feedback)
- Know these pathways!!!

From Figure 18-8
Putting it all together
Hypothalamic/Pituitary Hormones

- Collectively the nine hormones of the pituitary (anterior and posterior) are peptide.
- Hormones bind to membrane receptors.
- Use cAMP as second messenger.

From Figure 18-9
The Thyroid Gland

- Lies anterior to thyroid cartilage of larynx
- Consists of two **lobes** connected by narrow **isthmus**
  - Thyroid follicles
    - Hollow spheres lined by cuboidal epithelium
    - Cells surround follicle cavity that contains viscous colloid
    - Surrounded by network of capillaries that
      - deliver nutrients and regulatory hormones
      - accept secretory products and metabolic wastes
The Thyroid Gland: Thyroid hormones

- **Thyroglobulin (Globular Protein)**
  - Synthesized by follicle cells
  - Secreted into colloid of thyroid follicles
  - Molecules contain the amino acid tyrosine

- **Thyroxine (T₄) – “pro-hormone”**
  - Also called tetraiodothyronine
  - Contains four iodide ions

- **Triiodothyronine (T₃) – “active hormone”**
  - Contains three iodide ions

---

© 2012 Pearson Education, Inc.

Figure 18-11a
Actions of Thyroid Hormones

- Actions of Thyroid Hormones
  - Enter target cells by transport system
  - Affect most cells in body
  - Bind to receptors in
    - Cytoplasm
    - Surfaces of mitochondria
    - Nucleus
  - In children, essential to normal development of
    - Skeletal, muscular, and nervous systems
Actions of Thyroid Hormones

• Calorigenic Effect
  • Cell consumes more energy resulting in increased heat generation
  • Is responsible for strong, immediate, and short-lived increase in rate of cellular metabolism
# Actions of Thyroid Hormones

## Table 18–3: Effects of Thyroid Hormones on Peripheral Tissues

1. Elevates rates of oxygen consumption and energy consumption; in children, may cause a rise in body temperature
2. Increases heart rate and force of contraction; generally results in a rise in blood pressure
3. Increases sensitivity to sympathetic stimulation
4. Maintains normal sensitivity of respiratory centers to changes in oxygen and carbon dioxide concentrations
5. Stimulates red blood cell formation and thus enhances oxygen delivery
6. Stimulates activity in other endocrine tissues
7. Accelerates turnover of minerals in bone

© 2012 Pearson Education, Inc.
Actions of Thyroid Hormones

When the system fails…

• Hypothyroidism
  • Cretinism, myxedema, low metabolic rate, impaired mental development, shortened stature

• Hyperthyroidism, Graves disease
  • High metabolic rate, exophthalmos
Actions of Thyroid Hormones

When the system fails…

• Hypothyroidism
  • Cretinism, myxedema, low metabolic rate, impaired mental development, shortened stature

• Hyperthyroidism, Graves disease
  • High metabolic rate, exophthalmos
The Thyroid Gland: Calcitonin

- **C (Clear) Cells of the Thyroid Gland**
  - Produce calcitonin (CT)
    - Helps regulate concentrations of Ca$^{2+}$ in body fluids
    - Lower plasma Ca$^{2+}$ levels by inhibiting osteoclasts in bone reducing calcium excretion by the kidneys
    - Most important during childhood
Parathyroid Glands: Parathyroid hormone

- Embedded in posterior surface of thyroid gland
- Parathyroid hormone (PTH)
  - Produced by chief cells in response to low concentrations of Ca^{2+}
Four Effects of PTH

1. It stimulates osteoclasts
   - Accelerates mineral turnover and releases Ca\(^{2+}\) from bone

2. It inhibits osteoblasts
   - Reduces rate of calcium deposition in bone

3. It enhances reabsorption of Ca\(^{2+}\) at kidneys, reducing urinary loss

4. It stimulates formation and secretion of calcitriol at kidneys
   - Effects complement or enhance PTH
   - Enhances Ca\(^{2+}\), PO\(_4\)\(^{3-}\) absorption by digestive tract

Figure 18-13
When the system fails…

- **Hypoparathyroidism**
  - Muscle weakness, neurological problems…can be fatal
- **Hyperparathyroidism**
  - Neurologic & muscular problems
  - Brittle bones
## Summary of Thyroid & Parathyroid Hormones

<table>
<thead>
<tr>
<th>Gland/Cells</th>
<th>Hormone</th>
<th>Target</th>
<th>Hormonal Effect</th>
<th>Regulatory Control</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>THYROID GLAND</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Follicular epithelium</td>
<td>Thyroxine (T&lt;sub&gt;4&lt;/sub&gt;)</td>
<td>Most cells</td>
<td>Increases energy utilization, oxygen consumption, growth, and development</td>
<td>Stimulated by TSH from the anterior lobe of the pituitary gland</td>
</tr>
<tr>
<td></td>
<td>Triiodothyronine (T&lt;sub&gt;3&lt;/sub&gt;)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C cells</td>
<td>Calcitonin (CT)</td>
<td>Bone, kidneys</td>
<td>Decreases Ca&lt;sup&gt;2+&lt;/sup&gt; concentrations in body fluids</td>
<td>Stimulated by elevated blood Ca&lt;sup&gt;2+&lt;/sup&gt; levels; actions opposed by PTH</td>
</tr>
<tr>
<td><strong>PARATHYROID GLANDS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parathyroid (chief) cells</td>
<td>Parathyroid hormone (PTH)</td>
<td>Bone, kidneys</td>
<td>Increases Ca&lt;sup&gt;2+&lt;/sup&gt; concentrations in body fluids</td>
<td>Stimulated by low blood Ca&lt;sup&gt;2+&lt;/sup&gt; levels; PTH effects enhanced by calcitriol and opposed by calcitonin</td>
</tr>
</tbody>
</table>

© 2012 Pearson Education, Inc.
Suprarenal (Adrenal) Glands

- Lie along superior border of each kidney
- Subdivided into
  - Superficial suprarenal cortex
    - Stores lipids, especially cholesterol and fatty acids
    - Manufactures steroid hormones: adrenocortical steroids (corticosteroids)
  - Inner suprarenal medulla
    - Secretory activities controlled by sympathetic division of ANS
    - Produces epinephrine (adrenaline) and norepinephrine
    - Metabolic changes persist for several minutes
Suprarenal (Adrenal) Glands

Suprarenal Cortex

• Subdivided into three regions:
  1. Zona glomerulosa
  2. Zona fasciculata
  3. Zona reticularis

Figure 18-14b & c
Suprarenal Glands

• **Zona Glomerulosa**
  - Outer region of suprarenal cortex
  - Produces mineralocorticoids
    - For example, **aldosterone**:
      - stimulates conservation of sodium ions and elimination of potassium ions
      - increases sensitivity of salt receptors in taste buds
    - Secretion responds to:
      - drop in blood Na\(^+\), blood volume, or blood pressure
      - rise in blood K\(^+\) concentration

Figure 18-14c
Suprarenal Glands

- **Zona Fasciculata**
  - Produces **glucocorticoids**
  - For example, **cortisol** (hydrocortisone) with **corticosterone**
    - Liver converts cortisol to **cortisone**
  - Secretion regulated by negative feedback and mediated by CRH (hypothalamus) and ACTH (ant. pituitary)

Figure 18-14c
Suprarenal Glands

- Zona Fasciculata (cont’d)
  - Accelerates glucose synthesis and glycogen formation
  - Shows anti-inflammatory effects
    - Inhibits activities of white blood cells and other components of immune system

Figure 18-14c
Suprarenal Glands

- **Zona Reticularis**
  - Network of endocrine cells
  - Forms narrow band bordering each suprarenal medulla
  - Produces androgens under stimulation by ACTH

Figure 18-14c
Suprarenal Glands

- **Suprarenal Medulla**
  - Produces catecholamine hormones
    - **epinephrine** (adrenaline)
      - 75 to 80% of medullary secretions
    - **norepinephrine** (noradrenaline)
      - 20 to 25% of medullary secretions
  - Mediate sympathetic “fight-or-flight” responses
Suprarenal Glands

- When the system fails...
  - Disorders include:
    - Cushing’s disease
    - Addison’s disease
    - Adrenogenital syndrome
    - Pheochromocytoma

Figure 18-14b
# Suprarenal Glands

<table>
<thead>
<tr>
<th>Table 18–5</th>
<th>The Adrenal Hormones</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Region/Zone</th>
<th>Hormone</th>
<th>Primary Target</th>
<th>Hormonal Effect</th>
<th>Regulatory Control</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CORTEX</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zona \text{glomerulosa}</td>
<td>Mineralocorticoids (primarily aldosterone)</td>
<td>Kidneys</td>
<td>Increase renal reabsorption of Na(^+) and water (especially in the presence of ADH) and accelerate urinary loss of K(^+)</td>
<td>Stimulated by angiotensin II, elevated plasma K(^+) or a fall in plasma Na(^+); inhibited by ANP and BNP</td>
</tr>
<tr>
<td>Zona \text{fasciculata}</td>
<td>Glucocorticoids (cortisol [hydrocortisone], corticosterone)</td>
<td>Most cells</td>
<td>Release of amino acids from skeletal muscles and lipids from adipose tissues; promote liver formation of glucose and glycogen; promote peripheral utilization of lipids; anti-inflammatory effects</td>
<td>Stimulated by ACTH from the anterior lobe of the pituitary gland</td>
</tr>
<tr>
<td>Zona \text{reticularis}</td>
<td>Androgens</td>
<td>Most cells</td>
<td>Not important in adult men; encourages bone growth, muscle growth, and blood formation in children and women</td>
<td>Stimulated by ACTH from the anterior lobe of the pituitary gland</td>
</tr>
</tbody>
</table>

| MEDULLA     |                             |                |                                                                                           |                                                                                                           |
|-------------|                             |                |                                                                                           |                                                                                                           |
| Epinephrine, norepinephrine | Most cells | Increases cardiac activity, blood pressure, glycopen breakdown, blood glucose levels; releases lipids by adipose tissue | Stimulated during sympathetic activation by sympathetic preganglionic fiber |                                                                                                           |
Pancreas

- Lies between
  - Inferior border of stomach
  - And proximal portion of small intestine
- Contains exocrine and endocrine cells
Pancreas

Endocrine Pancreas

- Consists of cells that form clusters known as **pancreatic islets**, or islets of Langerhans
  - **Alpha cells** produce glucagon
  - **Beta cells** produce insulin
  - **Delta cells** produce peptide hormone identical to GH-IH
  - **F cells** secrete pancreatic polypeptide (PP)

Figure 18-16b
Pancreas: Insulin & Glucagon

Regulation of Blood Glucose Levels via Insulin and Glucagon

- **When levels rise**
  - Beta cells secrete insulin, stimulating transport of glucose across plasma membranes

- **When levels decline**
  - Alpha cells release glucagon, stimulating glucose release by liver

Figure 18-17
Pancreas: Insulin & Glucagon

• Insulin
  • Is a peptide hormone released by beta cells
  • Affects target cells
    • Accelerates glucose uptake
    • Accelerates glucose utilization (glycolysis) and enhances ATP production
    • Stimulates glycogen formation (glycogenesis) (liver and muscle)
    • Stimulates amino acid absorption and protein synthesis
    • Stimulates triglyceride formation (lipogenesis) in adipose tissue

Figure 18-17
Pancreas: Insulin & Glucagon

**Glucagon**
- Released by alpha cells
- Mobilizes energy reserves
- Affects target cells
  - Stimulates breakdown of glycogen *(glycogenolysis)* in **skeletal muscle** and **liver** cells
  - Stimulates breakdown of triglycerides *(lipolysis)* in **adipose tissue**
  - Stimulates production of glucose *(gluconeogenesis)* in **liver**

Figure 18-17
Pancreas: Insulin & Glucagon

When the system fails….

- Due to problems with insulin (production or target tissue responsiveness)
- Results in the metabolic syndrome diabetes mellitus
- Two types:
  - Type I – Insulin dependent (loss of beta cells = no insulin production)
  - Type II – Non-insulin dependent = tissues develop insulin resistance (tissues stop responding to insulin)
# Pancreas: Insulin & Glucagon

<table>
<thead>
<tr>
<th>Table 18-6</th>
<th>Hormones Produced by the Pancreatic Islets</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Structure/Cells</strong></td>
<td><strong>Hormone</strong></td>
</tr>
<tr>
<td><strong>PANCREATIC ISLETS</strong></td>
<td></td>
</tr>
<tr>
<td>Alpha cells</td>
<td>Glucagon</td>
</tr>
<tr>
<td>Beta cells</td>
<td>Insulin</td>
</tr>
<tr>
<td>Delta cells</td>
<td>GH–IH (somatostatin)</td>
</tr>
<tr>
<td>F cells</td>
<td>Pancreatic polypeptide (PP)</td>
</tr>
</tbody>
</table>
Endocrine Tissues of Other Systems

• Many organs of other body systems have secondary endocrine functions
  • Intestines (digestive system)
  • Kidneys (urinary system)
  • Heart (cardiovascular system)
  • Thymus (lymphoid system and immunity)
  • Gonads (reproductive system)
Hormone Interactions

- Antagonistic (opposing) effects
- Synergistic (additive) effects
- Permissive effects: one hormone is necessary for another to produce effect
- Integrative effects: hormones produce different and complementary results
Hormone Interactions: Endocrine Regulation of Growth & Development

• Hormones Important to Growth
  • GH
  • Thyroid hormones
  • Insulin
  • PTH
  • Calcitriol
  • Reproductive hormones
Hormone Interactions: Endocrine Regulation of Growth & Development

- **Growth Hormone (GH)**
  - **Source:** anterior pituitary
  - **Target:** liver (promotes IGF/somatomedin release)
  - **Effects:**
    - **In children**
      - Supports muscular and skeletal development
    - **In adults**
      - Maintains normal blood glucose concentrations ("glucose-sparing effects")
      - Mobilizes lipid reserves
Hormone Interactions: Endocrine Regulation of Growth & Development

• Thyroid Hormones
  • If absent during fetal development or for first year
    • Nervous system fails to develop normally
    • Mental retardation results (cretinism)
  • If $T_4$ concentrations decline before puberty
    • Normal skeletal development will not continue
  • Most common global cause of thyroid deficiency is dietary (iodine deficiency)
Hormone Interactions: Endocrine Regulation of Growth & Development

- Growth Hormone (GH), when the system fails….
  - Dwarfism
  - Gigantism
  - Acromegaly
# Hormone Interactions: Endocrine Disorders

## Table 18–9  Clinical Implications of Endocrine Malfunctions

<table>
<thead>
<tr>
<th>Hormone</th>
<th>Underproduction or Tissue Insensitivity</th>
<th>Principal Signs and Symptoms</th>
<th>Overproduction or Tissue Hypersensitivity</th>
<th>Principal Signs and Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growth hormone (GH)</td>
<td>Pituitary growth failure</td>
<td>Retarded growth, abnormal fat distribution, low blood glucose hours after a meal</td>
<td>Gigantism, acromegaly</td>
<td>Excessive growth</td>
</tr>
<tr>
<td>Antidiuretic hormone (ADH) or vasopressin (VP)</td>
<td>Diabetes insipidus</td>
<td>Polyuria, dehydration, thirst</td>
<td>SIADH (syndrome of inappropriate ADH secretion)</td>
<td>Increased body weight and water content</td>
</tr>
<tr>
<td>Thyroxine (T₄), triiodothyronine (T₃)</td>
<td>Myxedema, cretinism</td>
<td>Low metabolic rate; low body temperature; impaired physical and mental development</td>
<td>Hyperthyroidism, Graves disease</td>
<td>High metabolic rate and body temperature</td>
</tr>
<tr>
<td>Parathyroid hormone (PTH)</td>
<td>Hypoparathyroidism</td>
<td>Muscular weakness, neurological problems, formation of dense bones, tetany due to low blood Ca²⁺ concentrations</td>
<td>Hyperparathyroidism</td>
<td>Neurological, mental, muscular problems due to high blood Ca²⁺ concentrations; weak and brittle bones</td>
</tr>
<tr>
<td>Insulin</td>
<td>Diabetes mellitus (type 1)</td>
<td>High blood glucose, impaired glucose utilization, dependence on lipids for energy; glycosuria</td>
<td>Excess insulin production or administration</td>
<td>Low blood glucose levels, possibly causing coma</td>
</tr>
</tbody>
</table>

© 2012 Pearson Education, Inc.
## Hormone Interactions: Endocrine Disorders

### Table 18–9  Clinical Implications of Endocrine Malfunctions

<table>
<thead>
<tr>
<th>Hormone</th>
<th>Underproduction or Tissue Insensitivity</th>
<th>Principal Signs and Symptoms</th>
<th>Overproduction or Tissue Hypersensitivity</th>
<th>Principal Signs and Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mineralocorticoids (MCs)</td>
<td>Hypoaldosteronism</td>
<td>Polyuria, low blood volume, high blood K⁺, low blood Na⁺ concentrations</td>
<td>Aldosteronism</td>
<td>Increased body weight due to Na⁺ and water retention; low blood K⁺ concentration</td>
</tr>
<tr>
<td>Glucocorticoids (GCs)</td>
<td>Addison’s disease</td>
<td>Inability to tolerate stress, mobilize energy reserves, or maintain normal blood glucose concentrations</td>
<td>Cushing’s disease</td>
<td>Excessive breakdown of tissue proteins and lipid reserves; impaired glucose metabolism</td>
</tr>
<tr>
<td>Epinephrine (E), norepinephrine (NE)</td>
<td>None identified</td>
<td></td>
<td>Pheochromocytoma</td>
<td>High metabolic rate, body temperature, and heart rate; elevated blood glucose levels</td>
</tr>
<tr>
<td>Estrogens (females)</td>
<td>Hypogonadism</td>
<td>Sterility, lack of secondary sex characteristics</td>
<td>Adrenogenital syndrome</td>
<td>Overproduction of androgens by zona reticularis of adrenal cortex leads to masculinization</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Precocious puberty</td>
<td>Premature sexual maturation and related behavioral changes</td>
</tr>
<tr>
<td>Androgens (males)</td>
<td>Hypogonadism</td>
<td>Sterility, lack of secondary sex characteristics</td>
<td>Adrenogenital syndrome (gynecomastia)</td>
<td>Abnormal production of estrogen, sometimes due to adrenal or interstitial cell tumors; leads to breast enlargement</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Precocious puberty</td>
<td>Premature sexual maturation and related behavioral changes</td>
</tr>
</tbody>
</table>