Chapter 16
Lecture Outline

See separate PowerPoint slides for all figures and tables pre-inserted into PowerPoint without notes.
Endocrine System
Points to ponder

• What is the endocrine system?
• Compare and contrast exocrine and endocrine glands.
• What are steroid and peptide hormones?
• Name the major glands and their functions in the endocrine system.
• What is diabetes (type 1 and 2) and how might you prevent type 1?
• How do the endocrine and nervous systems work with the rest of the systems in the body to maintain homeostasis?
Endocrine system

• Mostly comprised of glands

• Secretes hormones that move through the bloodstream to target cells

• Results in a slow but a prolonged response
Figure 16.2 The endocrine system.
What is a target cell?

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**Figure 16.3** Hormones target specific cells.
Exocrine vs. endocrine glands

- **Exocrine glands** secrete their products into ducts that carry these products to other organs or outside the body.

- **Endocrine glands** secrete their products directly into the bloodstream.
What are hormones?

- Hormones are chemical signals that promote communication between cells, body parts, and even individuals.
What are hormones?

• Hormones
  – **Prostaglandins** are local hormones that affect neighboring cells and thus are not carried in the bloodstream.
  – **Pheromones** are chemical signals that influence the behavior of other individuals.
What are hormones?

– **Peptide hormones** bind to a receptor in the plasma membrane causing the formation of cAMP which activates a cascade of enzymes.

– **Steroid hormones** are lipids that enter a cell and affect gene activity and thus protein synthesis.
1. Hormone binds to a receptor in the plasma membrane.

2. Binding leads to activation of an enzyme that changes ATP to cAMP.

3. cAMP activates an enzyme cascade.

4. Many molecules of glycogen are broken down to glucose, which enters the bloodstream.

5. Glucose (leaves cell and goes to blood)

Figure 16.4 Action of a peptide hormone.
Action of steroid hormones

1. Hormone diffuses through plasma membrane because it is lipid soluble.

2. Hormone binds to receptor inside nucleus.

3. Hormone-receptor complex activates gene and synthesis of a specific mRNA molecule follows.

4. mRNA moves to ribosomes, and protein synthesis occurs.

Figure 16.5 Action of a steroid hormone.
Major glands of the endocrine system

1. Hypothalamus
2. Posterior pituitary gland
3. Anterior pituitary gland
4. Thyroid gland
5. Parathyroid glands
6. Adrenal glands
7. Pancreas
8. Testes
9. Ovaries
10. Thymus
11. Pineal gland
1. Hypothalamus

• Regulates internal environment through the autonomic nervous system
  – Helps control heartbeat
  – Helps control body temperature
  – Helps control water balance
  – Controls glandular secretions
2. Posterior pituitary gland

- Stores antidiuretic hormone (ADH) and oxytocin that are produced by the hypothalamus
  - **ADH** regulates water balance by reabsorbing water into the bloodstream.
  - **Oxytocin** causes uterine contractions during childbirth and allows milk to be released during nursing.
3. Anterior pituitary gland

- Controlled by hypothalamic-releasing and hypothalamic-inhibiting hormones
3. Anterior pituitary gland

- Hormones produced by the anterior pituitary
  1. **Thyroid-stimulating hormone** (TSH) stimulates the thyroid to produce thyroid hormones.
  2. **Adrenocorticotropic hormone** (ACTH) stimulates the adrenal cortex to produce cortisol.
  3. **Gonadotropin hormones** stimulate gonads to produce sex cells and hormones.
3. Anterior pituitary gland

4. **Prolactin** (PRL) stimulates mammary glands to develop and produce milk only after childbirth.

5. **Melanocyte-stimulating hormone** (MSH) causes skin-color changes in many fishes, amphibians, and reptiles having melanophores, special skin cells that produce color variations.

6. **Growth hormone** (GH) promotes skeletal and muscular growth.
1. Neurosecretory cells produce ADH and oxytocin.

2. These hormones move down axons to axon terminals.

3. When appropriate, ADH and oxytocin are secreted from axon terminals into the bloodstream.


2. These hormones are secreted into a portal system.

3. Each type of hypothalamic hormone either stimulates or inhibits production and secretion of an anterior pituitary hormone.

4. The anterior pituitary secretes its hormones into the bloodstream, which delivers them to specific cells, tissues, and glands.

Figure 16.6
Hormones produced by the hypothalamus and pituitary.
What happens when the body produces too much or too little GH?

- **Pituitary dwarfism** – too little GH is produced during childhood; results in small stature

- **Gigantism** – too much GH is produced during childhood; results in poor health

- **Acromegaly** – overproduction of GH as an adult; results in larger than normal feet, hands, and face
What happens when plentiful GH is produced during childhood?

Figure 16.8 Growth hormone influences height.
What happens when GH is produced in high amounts during adulthood?

Figure 16.9 Overproduction of growth hormone in adults leads to acromegaly.
4. Thyroid gland

- It is a large gland located below the larynx.
- Iodine is needed in the diet to allow the thyroid gland to produce its hormones.
4. Thyroid gland

- It produces
  - thyroid hormone (TH) which regulates metabolism.
  - calcitonin which helps lower blood Ca^{2+} levels by stimulating the deposition of calcium in the bones.
Thyroid abnormalities

- **Simple goiter** – thyroid enlarges due to lack of iodine in the diet
Thyroid abnormalities

- **Hypothyroidism** – low blood levels of thyroid hormones
  
  **A. Congenital hypothyroidism**: thyroid does not develop properly and is characterized in a short, stocky person who may have mental retardation
  
  **B. Myxedema**: hypothyroidism in adults characterized by lethargy, weight gain, loss of hair, cold intolerance, and thick, puffy skin
Thyroid abnormalities

- **Hyperthyroidism** – excess thyroid hormones in the blood
  
  A. **Exophthalmic goiter**: characterized by enlargement of the thyroid gland, protrusion of the eyes, hyperactivity, and insomnia
  
  B. Thyroid tumor: can also cause hyperthyroidism
Thyroid abnormalities

Figure 16.10 Effects of insufficient dietary iodine, hypothyroidism, and hyperthyroidism.
5. Parathyroid glands

- Small glands embedded in the surface of the thyroid gland

- Produces parathyroid hormone (PTH)
  - Causes blood Ca\textsuperscript{2+} level to increase by promoting osteoclast activity
  - Promotes reabsorption of Ca\textsuperscript{2+} by the kidneys
Regulation of blood calcium

Thyroid gland secretes calcitonin into blood.

Bones take up Ca\(^2+\) from blood.

Blood Ca\(^2+\) lowers.

Blood Ca\(^2+\) rises.

Intestines absorb Ca\(^2+\) from digestive tract.

Kidneys reabsorb Ca\(^2+\) from kidney tubules.

Bones release Ca\(^2+\) into blood.

Parathyroid glands release PTH into blood.

Homeostasis (normal blood Ca\(^2+\))

activated vitamin D

parathyroid hormone (PTH)

Figure 16.11 Blood calcium homeostasis.
6. Adrenal glands

• Glands that sit on top of the kidneys

• Two parts of each gland
  – Adrenal medulla: controlled by the nervous system
  – Adrenal cortex: portions are controlled by ACTH from the anterior pituitary
The adrenal glands

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Figure 16.12 The adrenal glands.
Adrenal medulla

• Inner portion of the adrenal glands

• Hypothalamus initiates stimulation of hormone secretion in the adrenal medulla

• Produces hormones that allow a short-term response to stress ("fight or flight" response)
  – Epinephrine (adrenaline)
  – Norepinephrine
Adrenal cortex

- Outer portion of the adrenal glands
- Produces hormones that provide a long-term response to stress
Adrenal cortex

- Two major types of hormones
  - Glucocorticoids
    - regulate carbohydrate, protein, and fat metabolism.
    - suppress the body’s inflammatory response.
    - e.g., cortisol and cortisone
Adrenal cortex

- Mineralocorticoids
  - regulate salt and water balance.
  - e.g., aldosterone (targets the kidney)
16.4 Adrenal Glands

Summary of the adrenal glands

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Stress Response: Short Term

- Heartbeat and blood pressure increase.
- Blood glucose level rises.
- Muscles become energized.

Stress Response: Long Term

<table>
<thead>
<tr>
<th>Glucocorticoids</th>
<th>Protein and fat metabolism instead of glucose breakdown.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mineralocorticoids</td>
<td>Sodium ions and water are reabsorbed by kidney.</td>
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Figure 16.13 Response of the adrenal medulla and the adrenal cortex to stress.
Adrenal glands can malfunction

- **Addison disease** – hyposcretion of glucocorticoids by the adrenal cortex, characterized by bronzing of the skin

Figure 16.15 Addison disease.

a: © Custom Medical Stock Photo; b: © NMSB/Custom Medical Stock Photo
Adrenal glands can malfunction

**Cushing syndrome** – hypersecretion of glucocorticoids by the adrenal cortex, characterized by weight gain in the trunk of the body but not the arms and legs.

Figure 16.16
Cushing syndrome.

(both): Courtesy Shannon Halverson
7. Pancreas

- Fish-shaped organ behind the stomach

- Composed of two tissues
  - Exocrine: produces and secretes digestive juices
7. Pancreas

- Endocrine (islets of Langerhans): produces and secretes hormones
  
  1. Insulin – secreted when blood glucose is high; stimulates the uptake of glucose by cells (muscle and liver)

  2. Glucagon – secreted when blood glucose is low; stimulates the breakdown of glycogen in the liver
Regulation of blood glucose

16.5 Pancreas

Figure 16.18 Blood glucose homeostasis.

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What is diabetes?

• It is the inability to control blood glucose levels.

• There are two types: type 1 and type 2.

• 25.8 million people in the US have diabetes.
What is diabetes?

- General symptoms include
  - frequent urination.
  - unusual hunger and/or thirst.
  - unexplained change in weight.
  - blurred vision.
  - sores that heal slowly or not at all.
  - excessive fatigue.
What is diabetes?

- Long-term effects are blindness, loss of limbs, nerve deterioration, kidney, and cardiovascular disease.
Diabetes: Understanding the 2 types

• **Type 1**
  – It is normally early-onset.
  – Type 1 is an autoimmune disorder that tends to run in families.
  – Pancreatic cells are attacked and cannot produce insulin.
  – Need insulin injections are needed.
Diabetes: Understanding the 2 types

• Type 2
  – Type 2 is normally adult-onset and is the most common type.
  – It tends to occur in obese, sedentary people.
  – Cells do not respond to insulin.
  – Usually diet and exercise are important for controlling this and may even prevent this.
8. Testes

- Gonads found in males

- Produce **androgens** (e.g., testosterone)
  - Stimulates growth of the penis and testes
  - Responsible for male sex characteristics such as facial, underarm, and pubic hair
  - Prompts the larynx and vocal cords to enlarge, resulting in a lower voice
  - Promotes muscular strength
9. Ovaries

• Gonads found in females

• Produce **estrogen** and **progesterone**
  – Stimulate growth of the vagina and uterus
  – Responsible for secondary sex characteristics such as female body hair, fat distribution, and breast development
  – Responsible for egg maturation
  – Regulate the uterine cycle
Hormones produced by the testes and ovaries

Figure 16.20 The hormones produced by the testes and the ovaries.
10. Thymus

- The thymus lies beneath the sternum.
- This gland is largest and most active during childhood.
- T lymphocytes mature here.
- It secretes hormones called thymosins that aid in differentiation of lymphocytes.
11. Pineal gland

- Located in the brain
- Secretes melatonin that regulates the sleep/wake cycle (circadian rhythm)
- May also regulate sexual development

Figure 16.21 Melatonin production changes by season.
Hormones from other tissues

- **Erythropoietin** is secreted by the kidneys to increase red blood cell production.

- **Leptin** is produced by fat cells, and acts on the hypothalamus to give a feeling of being satiated.
Hormones from other tissues

• Prostaglandins
  – Groups of potent chemicals that are not carried in the bloodstream work locally on neighboring cells.
  – Some cause smooth muscle contraction.
  – They have a major impact on reproductive organs.
  – They have many other roles in the body.
  – Aspirin and ibuprofen block the synthesis of these.
Homeostasis

• The nervous and endocrine systems are important in maintaining homeostasis.
  – The hypothalamus bridges regulatory functions of both systems.
  – The nervous system is able to respond to changes in the external environment.
The nervous and endocrine systems coordinate the activities of the other systems. The brain receives sensory input and controls the activity of muscles and various glands. The endocrine system secretes hormones that influence the metabolism of cells, the growth and development of body parts, and homeostasis.

Nervous and Endocrine Systems

The respiratory center in the brain regulates the breathing rate. The lungs carry on gas exchange for the benefit of all systems, including the nervous and endocrine systems.

Respiratory System

Nervous and epinephrine regulate contraction of the heart and constriction/dilation of blood vessels. Hormones regulate blood glucose and ion levels. Growth factors promote blood cell formation. Blood vessels transport hormones to target cells.

Cardiovascular System

Nerves stimulate muscles that permit urination. Hormones (ADH and aldosterone) help kidneys regulate the water-salt balance and the acid-base balance of the blood.

Urinary System

Nerves stimulate smooth muscle and permit digestive tract movements. Hormones help regulate digestive juices that break down food to nutrients for neurons and glands.

Digestive System

Nerves stimulate muscles, whose contractions allow us to move out of danger. Androgens promote growth of skeletal muscles. Sensory receptors in muscles and joints send information to the brain. Muscles protect neurons and glands.

Muscular System

Growth hormone and sex hormones regulate the size of the bones; parathyroid hormone and calcitonin regulate their Ca^{2+} content and therefore bone strength. Bones protect nerves and glands.

Skeletal System

Nerves stimulate contractions that move gametes in ducts, and uterine contraction that occurs during childbirth. Sex hormones influence the development of the secondary sex characteristics.

Reproductive System

Nerves activate sweat glands and arrector pili muscles. Sensory receptors in skin send information to the brain about the external environment. Skin protects neurons and glands.

Integumentary System

Figure 16.22 The nervous system and endocrine system interact to control homeostasis.