16: The Endocrine System

Objectives

The Endocrine System: An Overview
1. Indicate important differences between hormonal and neural controls of body functioning.
2. List the major endocrine organs, and describe their body locations.
3. Distinguish between hormones, paracrines, and autocrines.

Hormones
4. Describe how hormones are classified chemically.
5. Describe the two major mechanisms by which hormones bring about their effects on their target tissues.
6. List three kinds of interaction of different hormones acting on the same target cell.
7. Explain how hormone release is regulated.

The Pituitary Gland and Hypothalamus
8. Describe structural and functional relationships between the hypothalamus and the pituitary gland.
9. List and describe the chief effects of anterior pituitary hormones.
10. Discuss the structure of the posterior pituitary, and describe the effects of the two hormones it releases.

Major Endocrine Glands
11. Describe important effects of the two groups of hormones produced by the thyroid gland.
12. Follow the process of thyroxine formation and release.
13. Indicate general functions of parathyroid hormone.
14. List hormones produced by the adrenal gland, and cite their physiological effects.
15. Briefly describe the importance of melatonin.
16. Compare and contrast the effects of the two major pancreatic hormones.
17. Describe the functional roles of hormones of the testes, ovaries, and placenta.

Hormone Secretion by Other Organs
18. Name a hormone produced by the heart.
19. State the location of enteroendocrine cells.
20. Briefly explain the hormonal functions of the kidney, skin, adipose tissue, bones, and thymus.

Developmental Aspects of the Endocrine System
21. Describe the effect of aging on endocrine system functioning.

Suggested Lecture Outline
I. The Endocrine System: An Overview (pp. 595–596; Fig. 16.1)

A. Endocrinology is the scientific study of hormones and the endocrine organs (p. 595; Fig. 16.1).
   1. Hormones are chemical messengers that are released to the blood and elicit target cell effects after a period of a few seconds to several days.
   2. Hormone targets include most cells of the body, and regulate reproduction, growth and development, electrolyte, water, and nutrient balance, cellular metabolism and energy balance, and mobilization of body defenses.
   3. Endocrine glands have no ducts, and release hormones through diffusion.
   4. Endocrine glands include the pituitary, thyroid, parathyroid, adrenal, and pineal glands.
   5. Several organs, such as the pancreas, gonads (testes and ovaries), and placenta, contain endocrine tissue.

B. Autocrines are local chemical messengers that act on the same cells that secrete them, while paracrines are local chemical messengers that act on neighboring cells, rather than the cells releasing them (p. 595).

II. Hormones (pp. 596–601; Figs. 16.2–16.4)

A. Chemistry of Hormones (p. 596)
   1. Hormones are long-distance chemical signals that are secreted by the cells to the extracellular fluid and regulate the metabolic functions of other cells.
   2. Most hormones are amino acid based, but gonadal and adrenocortical hormones are steroids, derived from cholesterol.
   3. Eicosanoids, which include leukotrienes and prostaglandins, derive from arachidonic acid.

B. Mechanisms of Hormone Action (pp. 596–598; Figs. 16.2–16.4)
   1. Hormones typically produce changes in membrane permeability or potential, stimulate synthesis of proteins or regulatory molecules, activate or deactivate enzymes, induce secretory activity, or stimulate mitosis.
   2. Water-soluble hormones (all amino acid–based hormones except thyroid hormone) exert their effects through an intracellular second messenger that is activated when a hormone binds to a membrane receptor.
   3. Lipid-soluble hormones (steroids and thyroid hormone) diffuse into the cell, where they bind to intracellular receptors, migrate to the nucleus, and activate specific target sequences of DNA.
   4. Second-messenger systems, activated when a hormone binds to a plasma membrane receptor, activate G proteins within the cell that alter enzyme activity.
   5. Direct gene activation occurs when a hormone binds to an intracellular receptor, which activates a specific region of DNA, causing the production of mRNA, and initiation of protein synthesis.

C. Target Cell Specificity (p. 598)
   1. Cells must have specific membrane or intracellular receptors to which hormones can bind.
2. Target cell response depends on three factors: blood levels of the hormone, relative numbers of target cell receptors, and affinity of the receptor for the hormone.

3. Target cells can change their sensitivity to a hormone by changing the number of receptors.

D. Half-Life, Onset, and Duration of Hormone Activity (p. 599)
1. The concentration of a hormone reflects its rate of release, and the rate of inactivation and removal from the body.
2. The half-life of a hormone is the duration of time a hormone remains in the blood, and is shortest for water-soluble hormones.
3. Target organ response and duration of response vary widely among hormones.

E. Interaction of Hormones at Target Cells (p. 600)
1. Permissiveness occurs when one hormone cannot exert its full effect without another hormone being present.
2. Synergism occurs when more than one hormone produces the same effects in a target cell, and their combined effects are amplified.
3. Antagonism occurs when one hormone opposes the action of another hormone.

F. Control of Hormone Release (p. 600; Fig. 16.4)
1. Most hormone synthesis and release is regulated through negative feedback mechanisms.
2. Endocrine gland stimuli may be humoral, neural, or hormonal.
3. Nervous system modulation allows hormone secretion to be modified by hormonal, humoral, and neural stimuli in response to changing body needs.

III. The Pituitary Gland and Hypothalamus (pp. 601–608; Figs. 16.5–16.7; Table 16.1)

A. The pituitary gland is situated in the sella turcica of the skull, and is connected to the brain via the infundibulum (p. 601; Fig. 16.5).

B. The pituitary has two lobes: the posterior pituitary, or neurohypophysis, which is neural in origin, and the anterior pituitary, or adenohypophysis, which is glandular in origin (pp. 601–603; Fig. 16.5).
1. The hypothalamo-hypophyseal tract is a neural connection between the hypothalamus and the posterior pituitary that extends through the infundibulum.
2. The hypothalamo-hypophyseal portal system is a vascular connection between the hypothalamus and the anterior pituitary that extends through the infundibulum.

C. Anterior Pituitary Hormones (pp. 603–605; Figs. 16.6–16.7; Table 16.1)
1. The anterior pituitary produces six hormones, four of which are tropic hormones that regulate secretion of other hormones, as well as a prohormone.
   a. Pro-opiomelanocortin (POMC) is a prohormone that can be split into adrenocorticotropic hormone, two natural opiates, and melanocyte-stimulating hormone.
   b. Growth hormone acts on target cells in the liver, skeletal muscle, bone, and other tissues to cause the production of insulin-like growth factors (IGFs).
   c. Thyroid-stimulating hormone (TSH) promotes secretion of the thyroid gland.
   d. Adrenocorticotropic hormone (ACTH) promotes release of corticosteroid hormones from the adrenal cortex.
e. Gonadotropins FSH (follicle-stimulating hormone) and LH (luteinizing hormone) regulate function of the gonads.

f. Prolactin stimulates the gonads and promotes milk production in humans.

D. The Posterior Pituitary and Hypothalamic Hormones (pp. 605-608; Table 16.1)

1. The posterior pituitary produces two neurohormones: oxytocin, which promotes uterine contraction and milk ejection, and antidiuretic hormone (ADH), which prevents wide swings in water balance.

IV. The Thyroid Gland (pp. 608–612; Figs. 16.8–16.10; Table 16.2)

A. The thyroid gland consists of hollow follicles with follicle cells that produce thyroglobulin, and parafollicular cells that produce calcitonin (p. 608; Fig. 16.8).

B. Thyroid hormone consists of two amine hormones, thyroxine ($T_4$) and triiodothyronine ($T_3$), that act on all body cells to increase basal metabolic rate and body heat production (pp. 609–612; Figs. 16.9–16.10; Table 16.2).

C. Calcitonin is a peptide hormone that lowers blood calcium by inhibiting osteoclast activity, and stimulates $Ca^{2+}$ uptake and incorporation into the bone matrix (pp. 611–612).

V. The Parathyroid Glands (pp. 612–614; Figs. 16.11–16.12)

A. The parathyroid glands contain chief cells that secrete parathyroid hormone, or parathormone (pp. 612–613; Figs. 16.11–16.12).

VI. The Adrenal (Suprarenal) Glands (pp. 614–620; Figs. 16.13–16.16; Table 16.3)

A. The adrenal glands, or suprarenal glands, consist of two regions: an inner adrenal medulla and an outer adrenal cortex (p. 614; Fig. 16.13).

B. The adrenal cortex produces corticosteroids from three distinct regions: the zona glomerulosa, the zona fasciculata, and the zona reticularis (pp. 614–618; Figs. 16.11–16-15; Table 16.3).

   1. Mineralocorticoids, mostly aldosterone, are essential to regulation of electrolyte concentrations of extracellular fluids.

   2. Aldosterone secretion is regulated by the renin-angiotensin mechanism, fluctuating blood concentrations of sodium and potassium ions, and secretion of ACTH.

   3. Glucocorticoids are released in response to stress through the action of ACTH.

   4. Gonadocorticoids are mostly weak androgens, which are converted to testosterone and estrogens in the tissue cells.

C. The adrenal medulla contains chromaffin cells that synthesize epinephrine and norepinephrine (pp. 618–620; Figs. 16.13, 16.16; Table 16.3).

VII. The Pineal Gland (p. 620)

A. The only major secretory product of the pineal gland is melatonin, a hormone derived from serotonin, in a diurnal cycle (p. 620).

B. The pineal gland indirectly receives input from the visual pathways in order to determine the timing of day and night (p. 620).

VIII. Other Endocrine Glands and Tissues (pp. 620–624; Figs. 16.17–16.18; Table 16.5)
A. The pancreas is a mixed gland that contains both endocrine and exocrine gland cells (pp. 620–623; Figs. 16.17–16.19; Table 16.5).
   1. Glucagon targets the liver where it promotes glycogenolysis, gluconeogenesis, and release of glucose to the blood.
   2. Insulin lowers blood sugar levels by enhancing membrane transport of glucose into body cells.

B. The Gonads and Placenta (p. 623)
   1. The ovaries produce estrogens and progesterone.
   2. The testes produce testosterone.
   3. The placenta secretes estrogens, progesterone, and human chorionic gonadotropin, which act on the uterus to influence pregnancy.

C. Hormone Secretion by Other Organs (p. 623; Table 16.5)
   1. The atria of the heart contain specialized cells that secrete atrial natriuretic peptide, resulting in decreased blood volume, blood pressure, and blood sodium concentration.
   2. The gastrointestinal tract contains enteroendocrine cells throughout the mucosa that secrete hormones to regulate digestive functions.
   3. The kidneys produce erythropoietin, which signals the bone marrow to produce red blood cells.
   4. The skin produces cholecalciferol, an inactive form of vitamin D₃.
   5. Adipose tissue produces leptin, which acts on the CNS to produce a feeling of satiety, and resistin, an insulin antagonist.
   6. Osteoblasts in skeletal tissue secrete osteocalcin, a hormone that promotes increased insulin secretion by the pancreas and restricts fat storage by adipocytes.
   7. The thymus produces thymopoietin, thymic factor, and thymosin, which are essential for the development of T lymphocytes and the immune response.

IX. Developmental Aspects of the Endocrine System (pp. 624, 626–627)

A. Endocrine glands derived from mesoderm produce steroid hormones; those derived from ectoderm or endoderm produce amines, peptides, or protein hormones (p. 624).

B. Environmental pollutants have been demonstrated to have effects on sex hormones, thyroid hormone, and glucocorticoids (p. 624).

C. Old age may bring about changes in rate of hormone secretion, breakdown, excretion, and target cell sensitivity (p. 626).

Cross References

Additional information on topics covered in Chapter 16 can be found in the chapters listed below.

1. Chapter 1: Negative feedback
2. Chapter 2: Steroids; amino acids
3. Chapter 3: General cellular function
4. Chapter 4: Endocrine glands
5. Chapter 6: Bone homeostasis; epiphyseal plate
6. Chapter 11: Enkephalin and beta-endorphin; norepinephrine and epinephrine
7. Chapter 12: Hypothalamus
8. Chapter 14: Norepinephrine and epinephrine
9. Chapter 19: Hepatic portal system; blood pressure control; atrial natriuretic peptide and blood pressure regulation
10. Chapter 21: Effect of thymic hormones
11. Chapter 23: Gastrin and secretin (hormones of the digestive system)
12. Chapter 24: Insulin and glucagon effects; hormone function related to general body metabolism
13. Chapter 25: Antidiuretic hormone function; aldosterone effects on renal tissue; renin-angiotensin mechanism of blood pressure regulation; role of atrial natriuretic factor and fluid-electrolyte balance
14. Chapter 26: Antidiuretic hormone function; aldosterone effects on renal tissue; renin-angiotensin mechanism of blood pressure regulation; role of parathyroid hormone and calcium balance related to development; role of atrial natriuretic peptide and fluid-electrolyte balance; estrogen and glucocorticoid function in fluid and electrolyte balance
15. Chapter 27: Function of gonadotropins; testosterone production; role of FSH and LH related to reproduction; role of relaxin and inhibin in reproduction; ovarian physiology; brain-testicular axis
16. Chapter 28: Stimulation of milk production by the mammary gland (due to prolactin secretion); results of oxytocin and prolactin release; role of parathyroid hormone and calcium balance related to development; functions of human placental lactogen and human chorionic thyrotropin; prostaglandins and reproductive physiology; role of relaxin

Laboratory Correlations

   Exercise 27: Functional Anatomy of the Endocrine Gland
   Exercise 28: Hormonal Action
   PhysioEx™ 8.0 Exercise 28B: Endocrine System Physiology: Computer Simulation
   Exercise 27: Functional Anatomy of the Endocrine Glands
   Exercise 28: Hormonal Action
   PhysioEx™ 8.0 Exercise 28B: Endocrine System Physiology: Computer Simulation

Critical Thinking/Discussion Topics

1. Discuss how the negative feedback mechanism controls hormonal activity and yet allows hypo- and hypersecretion disorders to occur.
2. Study why the pancreas, ovaries, testes, thymus gland, digestive organs, placenta, kidney, and skin are considered to have endocrine function. Relate the endocrine functions to their nonendocrine functions.
3. Discuss the role of the endocrine system in stress and stress responses.
4. Explain the basis of the fact that nervous control is rapid but of short-duration, whereas hormonal control takes time to start but the effects last a long time. How would body function change if the rate of hormone degradation increased? Decreased?

5. On the basis of their chemical properties, why do protein-based and steroid-based hormones utilize, respectively, second-messenger and intracellular receptor mechanisms of action?

6. Examine the consequences of increasing receptor number, decreasing receptor number, and increasing or decreasing rates of hormone release.

7. Give students the following scenario: You have just finished a large meal and are relaxing when suddenly threatened by a mugger. Have students explain autonomically and hormonally what occurs in the body. Encourage them to think in logical terms and to be as complete as possible.

**Library Research Topics**

1. Research the role of hormones in treatment of non-hormone-related disorders.
2. Study the inheritance aspect of certain hormones (such as diabetes mellitus, and certain thyroid gland disorders).
3. Research the role of prostaglandins in treatment of homeostatic imbalances.
4. Identify the various circadian rhythms in the body.
5. Research the methods used to test the levels of hormones in blood.
6. Define diabetes insipidus. How is this type of diabetes related to insulin-related diabetes?
7. Research the various diseases of the pituitary, and discuss what body effects will be produced.

**Objectives**

Section 16.1 The Endocrine System: An Overview (pp. 595–596)
Art Labeling: Location of Selected Endocrine Organs of the Body (Fig. 16.1, p. 595)
Interactive Physiology® 10-System Suite: Endocrine System Orientation
Interactive Physiology® 10-System Suite: Endocrine System Review

Section 16.2 Hormones (pp. 596–601)
Interactive Physiology® 10-System Suite: Biochemistry, Secretion, and Transport of Hormones
Interactive Physiology® 10-System Suite: The Actions of Hormones on Target Cells

Section 16.3 The Pituitary Gland and Hypothalamus (pp. 601–608)
MP3 Tutor Session: Hypothalamic Regulation
Interactive Physiology® 10-System Suite: The Hypothalamic–Pituitary Axis
Case Study: Endocrine System

Section 16.4 The Thyroid Gland (pp. 608–612)
Section 16.5 The Parathyroid Glands (pp. 612–614)
Section 16.6 The Adrenal (Suprarenal) Glands (pp. 614–620)
Interactive Physiology® 10-System Suite: Response to Stress

Section 16.7 The Pineal Gland (p. 620)
Section 16.8 Other Endocrine Glands and Tissues (pp. 620–624)
Case Study: Diabetes Mellitus

Section 16.9 Developmental Aspects of the Endocrine System (pp. 624, 626–627)
Chapter Summary

Memory Game: Endocrine Structure and Function
Memory Game: Endocrine-Related Regulatory Processes

PhysioEx™ 8.0: Endocrine System Physiology
Crossword Puzzle 16.1
Crossword Puzzle 16.2

Chapter Quizzes
Art Labeling Quiz
Matching Quiz
Multiple-Choice Quiz
True-False Quiz

Chapter Practice Test

Study Tools
Histology Atlas
myeBook
Flashcards
Glossary

CourseCompass™

Resources in the myA&P™ Chapter Guide are also available in the Chapter Contents section of the CourseCompass™. Students can also access A&P Flix animations, MP3 Tutor Sessions, Interactive Physiology® 10-System Suite, Practice Anatomy Lab™ 2.0, PhysioEx™ 8.0, and much more.

Software

4. Interactive Physiology® 10-System Suite: Endocrine System (BC; Win/Mac). Covers the identification of major glands and their target tissues as well as the classification and functions of hormones.

5. Practice Anatomy Lab™ 2.0: Human Cadaver, Anatomical Models, Histology, Cat, Fetal Pig (see p. 9 of this guide for full listing).

6. The Ultimate Human Body, Version 2.2 (see p. 9 of this guide for full listing).

orders.

Figure 16.11 The parathyroid glands.
Figure 16.12 Effects of parathyroid hormone on bone, the kidneys, and the intestine.
Figure 16.13 Microscopic structure of the adrenal gland.
Figure 16.14 Major mechanisms controlling aldosterone release from the adrenal cortex.
Figure 16.15 The effects of excess glucocorticoid.
Figure 16.16 Stress and the adrenal gland.
Figure 16.17 Photomicrograph of differentially stained pancreatic tissue.
Figure 16.18 Regulation of blood glucose levels by insulin and glucagon from the pancreas.

Table 16.1 Pituitary Hormones: Summary of Regulation and Effects
Table 16.2 Major Effects of Thyroid Hormone (T4 and T3) in the Body
Table 16.3  Adrenal Gland Hormones: Summary of Regulation and Effects
Table 16.4  Symptoms of Insulin Deficit (Diabetes Mellitus)
Table 16.5  Selected Examples of Hormones Produced by Organs Other Than the Major Endocrine Organs
A Closer Look  Sweet Revenge: Taming the DM Monster?
Making Connections  Homeostatic Interrelationships Between the Endocrine System and Other Body Systems

Answers to End-of-Chapter Questions

Multiple-Choice and Matching Question answers appear in Appendix G of the main text.

Short Answer Essay Questions

15. A hormone is a chemical messenger that is released into the blood to be transported throughout the body. (p. 595)

16. Binding of a hormone to intracellular receptors would result in the most long-lived response, because extracellular receptors activate second-messenger systems that are degraded rapidly by intracellular enzymes. (p. 597)

17. a. The anterior pituitary is connected to the hypothalamus by a stalk of tissue, the infundibulum (p. 601); the pineal gland is suspended from the roof of the third ventricle (p. 620); the pancreas is located dorsal to the stomach, and is partially retroperitoneal (pp. 620–621); the ovaries are retroperitoneal organs within the female pelvic cavity (p. 623); the testes are contained within an extra-abdominal pouch called the scrotum (p. 623); and the adrenal glands are located superior to the kidneys. (p. 614)

   b. The anterior pituitary produces six hormones: growth hormone, thyroid-stimulating hormone, adrenocorticotropic hormone, follicle stimulating hormone, luteinizing hormone, and prolactin (pp. 606–607); the pineal gland produces melatonin (p. 620); the pancreas produces glucagon and insulin, as well as small amounts of somatostatin (p. 621); the ovaries produce estrogen and progesterone (p. 623); the testes produce androgens, mostly testosterone (p. 623); and the adrenal glands produce cortical hormones mineralocorticoids, glucocorticoids, and gonadocorticoids, as well as adrenal medullary hormones epinephrine and norepinephrine. (pp. 614–615)

18. Endocrine regions that are important in stress response are the adrenal medulla and adrenal cortex. The adrenal medulla produces hormones that mimic the effects of neurotransmitters of the sympathetic division of the autonomic nervous system. The adrenal cortex produces the glucocorticoids (and mineralocorticoids) important in stress response. The adrenal medulla hormones function in the alarm reaction; the adrenal cortex hormones, in the resistance stage. (pp. 614, 616, 619)

19. The release of anterior pituitary hormones is controlled by hypothalamic-releasing (and hypothalamic-inhibiting) hormones. (p. 603)

20. The posterior pituitary is composed largely of axons of hypothalamic neurons that store and secrete antidiuretic hormone (ADH) and oxytocin, synthesized by the hypothalamic neurons. (p. 605)

21. A lack of iodine (required to make functional T$_3$ and T$_4$) causes a colloidal, or endemic, goiter. (p. 611)
22. Problems that elderly people might have as a result of decreasing hormone production include the following:
   a. chemical or borderline diabetes  
   b. lessening of basal metabolic rate  
   c. increase in body fat  
   d. osteoporosis (pp. 626–627)

23. Specialized cardiac muscle cells produce atrial natriuretic peptide, which promotes sodium and water loss in the kidneys. (p. 624) Neurons of the posterior pituitary secrete oxytocin, which promotes smooth muscle contraction in the uterus, or antidiuretic hormone, which causes an increase in water reabsorption in the kidneys. (pp. 605–606) In addition, adrenal medullary neurosecretory cells secrete epinephrine and norepinephrine. (p. 619)

24. High levels of stress may drive up cortisol secretion, contributing to memory loss or loss of cognitive function. Lower levels of aldosterone may cause plasma K\(^+\) to be somewhat elevated. Relative lack of estrogen can result in arteriosclerosis. The lack of estrogen, but little change in PTH, may also contribute to osteoporosis. In addition, glucose tolerance declines with age, leading to a rise in blood glucose, and fibrosis of the thyroid leads to a decline in basal metabolic rate. (pp. 616–617)

Critical Thinking and Clinical Application Questions

1. It is not unusual to find them in other regions of the neck or even the thorax. The adjacent neck regions should be checked first. (p. 612)
2. Insulin should be administered because symptoms are indicative of diabetic shock. (p. 622)
3. The hypersecreted hormone is growth hormone. The disorder is gigantism. The enlarging pituitary is pressing on his optic chiasma (or other parts of the visual pathway). (p. 603)
4. a. A likely possibility is that Sean has Addison’s disease, which is a hyposecretory disorder of the adrenal cortex affecting secretion of both glucocorticoids and mineralocorticoids. The primary mineralocorticoid, aldosterone, is responsible for promoting Na\(^+\) absorption coupled to K\(^+\) secretion in the nephron. The resulting hyposcretion of aldosterone would be responsible for his elevated plasma K\(^+\).
   b. An ACTH stimulation test will allow the clinician to differentiate between a pituitary insufficiency of ACTH secretion, or an adrenal insensitivity or insufficiency.
   c. If ACTH does not cause a normal elevation of cortisol, then the problem originates from the adrenals, and is likely Addison’s disease.
   d. If ACTH does cause an elevation of cortisol secretion, then likely a problem such as a tumor or malignancy exists within the anterior pituitary. (p. 618)
5. Mr. Proulx is suffering from Cushing’s disease, brought on by high levels of his prednisone. His overall lousy feeling is due to muscle weakness and possible hyperglycemia, the swelling is due to water and salt retention, and the anti-inflammatory effect of the drug plays a role in suppression of immune-related defense mechanisms, increasing his susceptibility to colds. (pp. 617–618)

Suggested Readings


