

The Endocrine System

Outline

- 16.1 The endocrine system is one of the body's two major control systems (pp. 596–597; Fig. 16.1)
- A. Endocrinology is the scientific study of hormones and the endocrine organs. (p. 596; 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, as well as adipose tissue, thymus, intestine, stomach, kidneys, and heart 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. 597)
- 16.2 The chemical structure of a hormone determines how it acts (p. 597; Table 16.1)
- A. The chemical structure of a hormone determines its solubility in water, which, in turn, affect how it is transported in the blood, how long it lasts before it is degraded, and what receptors it can act upon. (p. 597; Table 16.1)
1. Most hormones are amino-acid based, but gonadal and adrenocortical hormones are steroids, derived from cholesterol.
 2. Eicosanoids, which include leukotrienes and prostaglandins, derive from arachidonic acid.
- 16.3 Hormones act through second messengers or by activating specific genes (pp. 597–600; Figs. 16.2–16.3)
- A. Hormones can only influence target cells: cells that have receptors for a given hormone. (p. 597)
- B. Plasma Membrane Receptors and Second-Messenger Systems (pp. 597–599; Fig. 16.2)
1. The cyclic AMP signaling mechanism involves a hormone binding to a receptor, activating a G-protein, which ultimately results in generation of cyclic AMP, a second messenger that, through the action of protein kinase enzymes that activate enzymes or cause membrane transport.
 2. The PIP₂-calcium signaling mechanism acts through a G protein to activate kinase enzymes, and release Ca⁺⁺ from intracellular storage, leading to a change in enzyme activity, or channel transport.
 3. Other signaling mechanisms use different second messengers, or work without second messengers to initiate specific cellular responses.
- C. Intracellular Receptors and Direct Gene Activation (p. 600–601; Fig. 16.3)

1. Direct gene activation occurs when a lipid-soluble hormone or thyroid hormone binds to an intracellular receptor, which activates a specific region of DNA, causing the production of mRNA and initiation of protein synthesis.
- 16.4 Three types of stimuli cause hormone release (pp. 601–602; Fig. 16.4)
- A. Most hormone synthesis and release is regulated through negative feedback mechanisms. (p. 601)
 - B. Endocrine gland stimuli may be humoral, neural, or hormonal. (pp. 601–602; Fig. 16.4)
 1. Critical ions or nutrients that act as stimuli controlling the secretion of hormones are humoral stimuli.
 2. If nerve fibers stimulate hormone release, then the stimulus for release is neural.
 3. If the secretion of a hormone is in response to hormones produced by other endocrine glands, it follows a hormonal pattern of secretion.
 - C. Nervous system modulation allows hormone secretion to be modified by hormonal, humoral, and neural stimuli in response to changing body needs. (p. 602)
- 16.5 Cells respond to a hormone if they have a receptor for that hormone (p. 602–603)
- A. A target cell responds to hormone binding by prompting the cell to activate a preprogrammed response. (p. 602)
 - B. 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. (p. 602)
 - C. Target cells can change their sensitivity to a hormone by changing the number of receptors. (pp. 602–603)
 1. Persistently low levels of hormone can cause a cell to up-regulate, increasing the number of receptors, but persistently high levels of hormone can cause a cell to down-regulate, decreasing the number of hormone receptors.
 - E. Half-Life, Onset, and Duration of Hormone Activity (pp. 602–603)
 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.
 - F. Interaction of Hormones at Target Cells (p. 603)
 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.
- 16.6 The hypothalamus controls release of hormones from the pituitary gland in two different ways (pp. 603–611; Figs. 16.5–16.7; Focus Figure 16.1; Table 16.2)
- A. The pituitary gland is situated in the sella turcica of the skull, and is connected to the brain via the infundibulum. (p. 603; 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. 603–604; Fig. 16.5; Focus Figure 16.1)
 - C. Pituitary-Hypothalamic Relationships (p. 604–605; Focus Figure 3.1)
 - 1. The hypothalamic-hypophyseal tract is a neural connection between the hypothalamus and the posterior pituitary that extends through the infundibulum.
 - 2. The hypothalamic-hypophyseal portal system is a vascular connection between the hypothalamus and the anterior pituitary that extends through the infundibulum.
 - D. The Posterior Pituitary and Hypothalamic Hormones (pp. 605–608; Table 16.2)
 - 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.
 - E. Anterior Pituitary Hormones (pp. 608–611; Figs. 16.5–16.7; Focus Figure 16.1; Table 16.2)
 - 1. The anterior pituitary produces six hormones, four of which are tropic hormones that regulate secretion of other hormones, as well as a pro-hormone.
 - a. Pro-opiomelanocortin (POMC) is a prohormone that can be split into adrenocorticotrophic 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. Adrenocorticotrophic 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.
- 16.7 The thyroid gland controls metabolism (pp. 611–615; Figs. 16.–16.1; Table 16.)
- A. The thyroid gland consists of hollow follicles with follicular cells that produce thyroglobulin and parafollicular cells that produce calcitonin. (pp. 611–612; 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. 612–615; Figs. 16.9–16.10; Table 16.3)
 - 1. The thyroid can store a three- to four-months' supply of thyroid hormone.
 - 2. Synthesis of thyroid hormone involves several steps:
 - a. Thyroglobulin is synthesized and secreted to the follicle lumen.
 - b. Iodide is trapped and oxidized to iodine, which is then attached to the tyrosine portion of thyroglobulin.
 - c. Iodinated tyrosines are linked to form T_3 and T_4 .

- d. To secrete T_3 and T_4 , thyroglobulin colloid is transported into follicular cells, where the thyroglobulin is removed, allowing the hormone to diffuse into the bloodstream.
 - C. Calcitonin, secreted by C cells of the thyroid, is a peptide hormone that lowers blood calcium by inhibiting osteoclast activity, stimulating Ca^{++} uptake and incorporation of Ca^{++} into the bone matrix. (p. 615)
- 16.8 The parathyroid glands are primary regulators of blood calcium levels (pp. 615–616; Figs. 16.11–16.12)
- A. The parathyroid glands are located on the posterior aspect of the thyroid. (p. 615)
 - B. Parathyroids secrete parathyroid hormone, or parathormone, which causes osteoclasts to break down bone, increases absorption of Ca^{++} in the kidneys, and activates vitamin D, which aids in the absorption of calcium from food. (pp. 615–616; Figs. 16.11–16.12)
- 16.9 The adrenal glands produce hormones involved in electrolyte balance and the stress response (pp. 616–622; Figs. 16.13–16.16; Table 16.4)
- A. The adrenal glands, or suprarenal glands, consist of two regions: an inner adrenal medulla and an outer adrenal cortex. (p. 617; Fig. 16.13)
 - B. The adrenal cortex produces corticosteroids from three distinct regions: the zona glomerulosa produces mineralocorticoids, the zona fasciculata produces glucocorticoids, and the zona reticularis produces sex steroids. (pp. 617–620; Figs. 16.13–16.15; Table 16.4)
 - 1. Mineralocorticoids, mostly aldosterone, are essential to regulation of electrolyte concentrations of extracellular fluids, raising plasma Na^+ and lowering plasma K^+ .
 - a. Aldosterone secretion is regulated by the renin-angiotensin-aldosterone mechanism, fluctuating blood concentrations of sodium and potassium ions, and secretion of ACTH.
 - 2. Glucocorticoids are released in response to stress through the action of ACTH and primarily cause gluconeogenesis, as well as use of fats and amino acid by body cells.
 - 3. Gonadocorticoids are mostly weak androgens, which are converted to testosterone and estrogens in the tissue cells.
 - C. The adrenal medulla contains medullary chromaffin cells that synthesize catecholamines epinephrine and norepinephrine. (pp. 620–622; Figs. 16.13, 16.16; Table 16.4)
 - 1. About 80% of the hormone stored is epinephrine, and 20% norepinephrine.
 - 2. Adrenal catecholamines produce brief stress-mediated responses.
- 16.10 The pineal gland secretes melatonin (p. 622)
- A. The only major secretory product of the pineal gland is melatonin, a hormone derived from serotonin, in a diurnal cycle. (p. 622)
 - B. The pineal gland indirectly receives input from the visual pathways in order to determine the timing of day and night. (p. 622)
- 16.11 The pancreas, gonads, and most other organs secrete hormones (pp. 622–627; Figs. 16.17–16.19; Tables 16.4–16.5)
- A. The pancreas is a mixed gland that contains both endocrine and exocrine gland cells. (pp. 622–624; Figs. 16.17–16.19)

1. Scattered among the exocrine cells are pancreatic islets that have two major populations of hormone-producing cells: α cells that produce glucagon, and β cells that produce insulin.
 2. Glucagon targets the liver, where it promotes glycogenolysis, gluconeogenesis, and release of glucose to the blood.
 3. Insulin lowers blood glucose levels by enhancing membrane transport of glucose into body cells and inhibits glucose production through glycogen breakdown or conversion of amino acids or fats to glucose.
- B. The Gonads and Placenta (pp. 624–625)
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 (pp. 625–627; Table 16.5)
1. Adipose tissue produces leptin, which acts on the CNS to produce a feeling of satiety; also resistin, an insulin antagonist, and adiponectin, which increases sensitivity to insulin.
 2. The gastrointestinal tract contains enteroendocrine cells throughout the mucosa that secrete hormones to regulate digestive functions.
 3. The atria of the heart contain specialized cells that secrete atrial natriuretic peptide, resulting in decreased blood volume, blood pressure, and blood sodium concentration.
 4. The kidneys produce erythropoietin, which signals the bone marrow to produce red blood cells.
 5. The skin produces cholecalciferol, an inactive form of vitamin D₃.
 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.

Developmental Aspects of the Endocrine System (pp. 627–629)

- A. Endocrine glands derived from mesoderm produce steroid hormones; those derived from ectoderm or endoderm produce amines, peptides, or protein hormones. (p. 627)
- B. Environmental pollutants have been demonstrated to have effects on sex hormones, thyroid hormone, and glucocorticoids. (p. 627)
- C. Old age may bring about changes in rate of hormone secretion, breakdown, excretion, and target cell sensitivity. (pp. 627–629)
 1. The amount of connective tissue in the anterior pituitary increases, vascularization decreases, and the number of hormone-secreting cells declines.
 2. As long as an individual is not chronically stressed, cortisol secretion and adrenal medullary secretion remain normal.
 3. Ovaries atrophy and become unresponsive to gonadotropins; testosterone production starts to decline in very old age.
 4. The thyroid fibroses and production of thyroid hormone decreases, but parathyroids change very little with age.