To aid in making the transition from the previous three chapters to this one, Chapter 16 begins by highlighting a significant similarity: both the endocrine system and nervous system function to achieve and maintain stability of the internal environment. The chapter further demonstrates that each system may work alone or in concert as a single neuroendocrine system, performing the same general functions within the body—communication, integration, and control. Both systems perform the regulatory functions by means of chemical messengers sent to specific cells. The focus shifts from neurons, neurotransmitter molecules, and receptors to hormone molecules and their specific target cells. In fact, the transition from the nervous system to the endocrine system will seem completely natural to students as they come to realize that many cells actually have receptors for both neurotransmitters and hormones. In fact, neurosecretory cells are simply modified neurons that secrete chemical messengers which diffuse into the bloodstream rather than across a synapse. In such cases, the chemical messenger is called a hormone rather than a neurotransmitter.

Objectives
After students have completed this chapter, they should be able to:

1. Compare endocrine structure and function with nervous structure and function.
2. Identify the different ways to classify hormones.
3. Differentiate between the mechanisms of action of steroid and nonsteroid hormones.
4. Describe endocrine reflexes.
5. Discuss the chemical nature, classification, and mechanism of action of prostaglandins.
6. Discuss the size, location, and anatomical components of the pituitary gland.
7. List the hormones of the adenohypophysis, describe their general functions, and identify the primary locations of their target cells.
8. Describe a typical negative feedback system.
9. List and identify the action of the hormones stored and released by the neurohypophysis.
10. Discuss the structure, location, and functions of the thyroid and parathyroid glands.
11. Compare and contrast the functions of the hormones produced by the cells of the adrenal cortex with those secreted by the adrenal medulla.
12. Describe the types of cells found in the pancreatic islets and their hormone secretions.
13. List and identify the functions of the pancreatic hormones.
14. List and identify the hormonal functions of the ovaries and testes.
15. List the hormones associated with the placenta, the thymus, the mucous lining of the gastrointestinal tract, and the heart.

Lecture Outline

I. Introduction (p. 484)
   A. Comparison of nervous and endocrine systems (Table 16-1; Fig.16-1)
   B. Definitions
      1. Hormone
      2. Receptor
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3. Target cells, target tissues, and target organs (Fig. 16-6)

B. Endocrine glands compared to exocrine glands

C. Location of endocrine glands (Fig. 16-2; Table 16-2)

II. Hormones (p. 486)

A. Classification of hormones (Fig. 16-3)
   1. Steroid hormones (Fig. 16-4)
   2. Nonsteroid hormones (Fig. 16-5)

B. How hormones work (p. 488)
   1. General principles of hormone action (Fig. 16-6)
      a. Synergism
      b. Permissiveness
      c. Antagonism
   2. Mechanism of steroid hormone action (Fig. 16-7)
      a. Lipid soluble steroid hormone detaches from protein carrier in blood
      b. Steroid hormone passes through cell plasma membrane
      c. Steroid hormone enters nucleus and combines with receptor
      d. Hormone-receptor complex binds to specific site on DNA
      e. Transcription of mRNA is triggered
      f. A new protein—usually an enzyme or channel protein—is synthesized
      g. The new protein produces specific effects in the target cell.
         Function changes
   3. Mechanisms of nonsteroid hormone action (p. 489)
      a. Second messenger mechanism using cAMP (Fig. 16-8)
         1) Nonsteroid hormone first messenger binds to plasma membrane receptor
         2) Hormone-receptor complex activates the G protein
         3) Activated G protein reacts with GTP
         4) GTP activates adenyl cyclase
         5) Adenyl cyclase converts ATP to cyclic AMP (second messenger)
         6) cAMP either activates or inactivates protein kinase
         7) Protein kinase activates specific intracellular enzymes
         8) Intracellular enzymes mediate specific reactions in the cell and thus modify its action
      b. Second messenger mechanism using calcium-calmodulin (Fig. 16-9)
1) Nonsteroid hormone first messenger binds to plasma membrane receptor
2) Hormone-receptor complex activates the G protein and PIP2
3) Activated G protein and PIP2 open calcium channels
4) Calcium ions diffuse into cell and bind to calmodulin
5) Ca\(^{++}\)-calmodulin complex is the second messenger
6) Second messenger bind to specific enzymes, which promotes or inhibits the enzyme action, thus modifying the cells action

c. Nuclear receptor mechanism (p. 491)
   1) T\(_3\) and T\(_4\) enter target cells
   2) These amino acids bind to receptors associated with DNA of target cell.
   3) This triggers transcription of mRNA and thus synthesis of new enzymes and modification of cell function; similar to steroid hormone functioning

4. Regulation of hormone secretion
   a. Negative feedback loop (usually) (Fig. 16-10)
   b. Anterior pituitary affected by releasing or inhibiting hormones
   c. Input from nervous system

III. Prostaglandins (Fig. 16-11)
   A. Description
      1. "Tissue hormone"
      2. Nine different structural classes
         a. At least 16 different prostaglandins
      3. Lipid molecules
      4. Related to leukotrienes and thromboxanes
      5. Wide variety of effects

IV. Pituitary Gland (Hypophysis) (Fig. 16-12)
   A. Structure of the pituitary gland (p. 495)
      1. Location
      2. Parts
         a. Infundibulum
         b. Adenohypophysis
         c. Neurohypophysis
   B. Adenohypophysis (anterior pituitary)
      1. Cell types (Fig. 16-13)
         a. Somatotrophs

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b. Corticotrophs
c. Thyrotrophs
d. Lactotrophs
e. Gonadotrophs

2. Adenohypophysis hormones (Fig. 16-14; Table 16-4)
a. Growth hormone (GH), or somatotropin (STH)
   1) Increases protein anabolism
   2) Increases fat catabolism
   3) Inhibits glucose metabolism
   4) Increases blood glucose levels
b. Prolactin (p. 496)
   1) Milk secretion
c. Tropic hormones (stimulation of other endocrine glands)
   1) Thyroid-stimulating hormone (TSH)
   2) Adrenocorticotropic hormone (ACTH)
   3) Follicle-stimulating hormone (FSH)
   4) Luteinizing hormone (LH)
e. Control of secretion in the adenohypophysis (p. 498)
   1) Hypophyseal portal system (Fig. 16-15)
   2) Releasing hormones (Table 16-3)
   3) Negative feedback loop with hypothalamus (Fig. 16-16)

C. Neurohypophysis (posterior pituitary) (Fig. 16-14)
1. Hormone production in hypothalamus
2. Axons forming hypothalamohypophyseal tract (Fig. 16-17)
3. Posterior pituitary hormones (Table 16-4)
   a. Antidiuretic hormone (ADH)
      1) Produced when body is dehydrated
      2) Increases water reabsorption into the blood
   b. Oxytocin (p. 501)
      1) Stimulates uterine contraction
      2) Milk ejection from the breast

V. Pineal Gland (p. 502)
A. Part of both nervous and endocrine systems
B. Principal hormone secretion—melatonin
   1. Supports body's biological clock
   2. Thought to induce sleep

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VI. Thyroid Gland (Fig. 16-18)
   A. Structure of the thyroid gland (Fig. 16-19)
      1. Follicles filled with thyroid colloid
   B. Thyroid hormone (Table 16-5)
      1. \( T_4 \) (Thyroxine)
      2. \( T_3 \) (Triiodothyronine)—the active thyroid hormone
      3. Regulation of metabolic rate
   C. Calcitonin (CT) (Table 16-5)
      1. Produced by parafollicular cells
      2. Moves calcium from blood into bone (Fig. 16-21)

VII. Parathyroid Glands (Fig. 16-18)
   A. Structure (Fig. 16-20)
   B. Parathyroid hormone (PTH) (parathormone) (Table 16-5)
      1. Increases blood calcium levels (Fig. 16-24)
      2. Antagonist to calcitonin (Fig. 16-21)

VIII. Adrenal Glands (p. 506)
   A. Structure (Fig. 16-22)
      1. Adrenal cortex
         a. Zona glomerulosa (secretion of mineralocorticoids)
            1) Aldosterone (Table 16-6)
               a) Sodium and water retention
               b) Potassium and hydrogen ion loss
               c) Controlled by renin-angiotensin mechanism
                  (Fig. 16-23)
            b. Zona fasciculata (secretion of glucocorticoids)
               1) Cortisol (Table 16-6)
                  a) Mobilizes proteins for gluconeogenesis
                  b) Accelerates mobilization and metabolism of lipids
                  c) Increases blood pressure
                  d) In high concentration, causes decrease in antibody formation
                  e) Has antiinflammatory qualities
                  f) Increases with stress response
                  g) Controlled mainly by negative feedback that involves ACTH
            c. Zona reticularis (secretion of gonadocorticoids) (Table 16-6)
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1) Normal production of adrenal androgens (male hormones)

2) Stimulates axillary and pubic hair growth in boys and girls

2. Adrenal medulla (p. 509)
   a. Innervated by sympathetic preganglionic fibers (Fig. 16-24)
   b. Catecholamines secreted into bloodstream
      1) Epinephrine (adrenaline)—80% of medulla's secretion
      2) Norepinephrine (noradrenaline)—20% of medulla's secretion
      3) Bind to receptors of sympathetic effectors

IX. Pancreatic Islets (Fig. 16-25)
   A. Structure of the pancreatic islets (Fig. 16-26)
      1. Alpha cells—secrete glucagon
      2. Beta cells—secrete insulin
      3. Delta cells—secrete somatostatin
      4. Pancreatic polypeptide cells—secrete pancreatic polypeptide
   B. Pancreatic hormones (Table 16-7)
      1. Glucagon (Fig. 16-27)
         a. Converts glycogen to glucose in liver cells
         b. Stimulates gluconeogenesis
         c. Increases glucose levels in blood
      2. Insulin (Fig. 16-27)
         a. Moves glucose, amino acids, fatty acids into cells
         b. Antagonist to glucagon; decreases blood glucose levels
      3. Somatostatin
         a. Inhibits secretion of glucagon, insulin, and pancreatic polypeptide
         b. Inhibits growth hormone secretion from anterior pituitary
      4. Pancreatic polypeptide
         a. Influences absorption in digestive tract

X. Gonads (p. 513)
   A. Testes
      1. Androgens—mainly testosterone—produced by interstitial cells (Fig. 31-6)
         a. Testosterone responsible for male sexual characteristics and sperm production
         b. Regulated by LH levels in blood
B. Ovaries—hormones regulated by FSH and LH (Fig. 32-16)
   1. Estrogens, including estradiol and estrone
      a. Promote female sexual characteristics
      b. Help regulate the menstrual cycle
   2. Progesterone
      a. Secreted by the corpus luteum
      b. Maintains (with estrogen) the lining of the uterus

XI. Placenta (p. 513)
   A. Human chorionic gonadotropin
      1. Maintains uterine lining during pregnancy
      2. Presence in urine used as pregnancy test

XII. Thymus (p. 514)
   A. Thymosin and thymopoietin
      1. Stimulate production of T cell lymphocytes

XIII. Gastric and Intestinal Mucosa (p. 514)
   A. Gastrin, secretin, and cholecystokinin-pancreozymin
      1. Regulate secretory and motor activities in digestion

XIV. Heart (p. 514)
   A. Atrial natriuretic hormone
      1. Promotes sodium loss (and water loss) from the body into the urine

XV. Cycle of Life: Endocrine System
   A. Endocrine regulation of body processes begins in the womb
   B. Most reproductive hormones are not secreted until puberty
   C. Male reproductive hormone production tapers off in late adulthood; female reproductive hormones decline more suddenly and completely

XVI. The Big Picture: The Endocrine System and the Whole Body (p. 518)
   A. The partnership of the nervous and endocrine systems affords precision control over body functions
   B. Understanding hormonal regulatory mechanisms is vital to appreciate fully the nature of homeostasis in the human organism

XVII. Mechanisms of Disease (Table 16-8)
   A. Endocrine disorders
      1. Hypersecretion
         a. High hormone levels
         b. Mechanisms causing hypersecretion
            1) Abnormal proliferation of endocrine cells
            2) Autoimmunity
            3) Feedback mechanism failure

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2. Hyposcretion
   a. Low hormone levels
   b. Mechanisms causing hyposcretion
      1) Endocrine tumors
      2) Abnormal feedback loop function
      3) Immune function abnormality
      4) Target cell insensitivity to tropic hormones