Chapter 16
Raging Hormones: The Endocrine System

In This Chapter
- Absorbing what endocrine glands do
- Checking out the ringmasters: Pituitary and hypothalamus glands
- Surveying the supporting glands
- Understanding how the body balances under stress

The human body has two separate command and control systems that work in harmony most of the time but also work in very different ways. Designed for instant response, the nervous system cracks its cellular whip using electrical signals that make entire systems hop to their tasks with no delay (refer to Chapter 15). By contrast, the endocrine system's glands use chemical signals called hormones that behave like the steering mechanism on a large, fully loaded ocean tanker; small changes can have big impacts, but it takes quite a bit of time for any evidence of the change to make itself known. At times, parts of the nervous system stimulate or inhibit the secretion of hormones, and some hormones are capable of stimulating or inhibiting the flow of nerve impulses.

The word “hormone” originates from the Greek word hormao, which literally translates as “I excite.” And that's exactly what hormones do. Each chemical signal stimulates some specific part of the body, known as target tissues or target cells. The body needs a constant supply of hormonal signals to grow, maintain homeostasis, reproduce, and conduct myriad processes.

In this chapter, we go over which glands do what and where, as well as review the types of chemical signals that play various roles in the body. You also get to practice discerning what the endocrine system does, how it does it, and why the body responds like it does.

No Bland Glands

Technically, there are ten or so primary endocrine glands with various other hormone-secreting tissues scattered throughout the body. Unlike exocrine glands (such as mammary glands and sweat glands), endocrine glands have no ducts to convey their secretions. Instead, hormones move directly into extracellular spaces surrounding the gland and from there move into capillaries and the greater bloodstream. Although they spread throughout the body in the bloodstream, hormones are uniquely tagged by their chemical composition. Thus they have separate identities and stimulate specific receptors on target cells so that usually only the intended cells or tissues respond to their signals.

All of the many hormones can be classified either as steroid (derived from cholesterol) or nonsteroid (derived from amino acids and other proteins). The steroid hormones—which include testosterone, estrogen, progesterone, and cortisol—are the ones most closely
associated with emotional outbursts and mood swings. Steroidal hormones, which are nonpolar (see Chapter 2 for details on cell diffusion), penetrate cell membranes easily and initiate protein production at the nucleus.

Nonsteroid hormones are divided among four classifications:

- Some are derived from modified amino acids, including such things as epinephrine and norepinephrine, as well as melatonin.
- Others are peptide-based, including an antidiuretic hormone called ADH, oxytocin, and a melanocytes-stimulating hormone called MSH.
- Glycoprotein-based hormones include follicle-stimulating hormone (FSH), luteinizing hormone (LH), and chorionic gonadotropin — all closely associated with the female reproductive system.
- Protein-based nonsteroid hormones include such crucial substances as insulin and growth hormone as well as prolactin and parathyroid hormone.

Hormone functions include controlling the body’s internal environment by regulating its chemical composition and volume, activating responses to changes in environmental conditions to help the body cope, influencing growth and development, enabling several key steps in reproduction, regulating components of the immune system, and regulating organic metabolism.

See if all this hormone-speak is sinking in:

1.–5. Mark the statement with a T if it’s true or an F if it’s false:

   1. ____ The endocrine system brings about changes in the metabolic activities of the body tissue.
   2. ____ The amount of hormone released is determined by the body’s need for that hormone at the time.
   3. ____ The glands of the endocrine system are composed of cartilage cells.
   4. ____ Endocrine glands aren’t functional in reproductive processes.
   5. ____ Some hormones can be derivatives of amino acids, whereas others are synthesized from cholesterol.

6. Glands that secrete their product into the interstitial fluid, which flows into the blood, are
   a. Exocrine glands
   b. Endocrine glands
   c. Heterocrine glands
   d. Pericrinal glands
   e. Interocrine glands

7. Cells that respond to a hormone are
   a. Affectors
   b. Effectors
   c. Target cells
   d. Chromosomal cells
   e. Rickets cells
Mastering the Ringmasters

The key glands of the endocrine system include the pituitary (also called the hypophysis), adrenal (also referred to as suprarenal), thyroid, parathyroid, thymus, pineal, islets of Langerhans (within the pancreas), and gonads (testes in the male and ovaries in the female). But of all these, it’s the pituitary working in concert with the hypothalamus in the brain that really keeps things rolling (see Figure 16-1).

The hypothalamus is the unsung hero linking the body’s two primary control systems — the endocrine system and the nervous system. Part of the brain and part of the endocrine system, the hypothalamus is connected to the pituitary via a narrow stalk called the infundibulum that carries regular system status reports to the pituitary. In its supervisory role, the hypothalamus provides neurohormones to control the pituitary gland and influences food and fluid intake as well as weight control, body heat, and the sleep cycle.

The hypothalamus sits just above the pituitary gland, which is nestled in the middle of the human head in a depression of the skull’s sphenoid bone called the sella turcica.

The pituitary’s anterior lobe, also called the adenohypophysis or pars distalis, is sometimes called the “master gland” because of its role in regulating and maintaining the other endocrine glands. Hormones that act on other endocrine glands are called tropic hormones; all the hormones produced in the anterior lobe are polypeptides. Two capillary beds connected by venules make up the hypophyseal portal system, which connect the anterior lobe with the hypothalamus.
Among the hormones produced in the anterior lobe of the pituitary gland are the following:

- **Follicle-stimulating hormone (FSH):** Signals an immature Graafian follicle in an ovary to mature into an ovum, which then produces the hormone estrogen. Negative feedback from the estrogen blocks further secretion of FSH. Guys, don’t think you needn’t worry about FSH: It’s present in you, too, encouraging development and maturation of sperm.

- **Luteinizing hormone (LH):** Stimulates formation of the yellow body, or corpus luteum, on the surface of the ovary after an ovum has been released. In men, LH stimulates the development of interstitial cells and fresh production of testosterone.

- **Lactogenic hormone, or prolactin (PRL):** Promotes milk production in mammary glands, which are considered nonendocrine targets.

- **Interstitial-cell stimulating hormone (ICSH):** Stimulates formation and secretion of testosterone.

- **Thyrotropic hormone, or thyroid-stimulating hormone (TSH):** Controls the development and release of thyroid gland hormones thyroxin and triiodothyronine. The hypothalamus regulates TSH secretion by secreting thyrotropin-releasing hormone (TRH).

- **Adrenocorticotropic hormone (ACTH), or corticotropin:** Is a polypeptide composed of 39 amino acids that regulates the development, maintenance, and secretion of the cortex of the adrenal gland.

- **Somatotropic hormone, or growth hormone (GSH):** Stimulates body weight growth and regulates skeletal growth. This is the only hormone secreted by the anterior lobe that has a general effect on nearly every cell in the body (also regarded as nonendocrine targets).

For a review of the male and female reproductive systems, flip to Chapters 13 and 14.

The posterior lobe, or neurohypophysis, of the pituitary gland stores and releases secretions produced by the hypothalamus. This lobe is connected to the hypothalamus by the hypothophysal tract, nerve axons with cell bodies lying in the hypothalamus. Whereas the adenohypophysis is made up of epithelial cells, the neurohypophysis is largely composed of modified nerve fibers and neuroglial cells called pituicytes.

Among the hormones produced in the posterior lobe of the pituitary gland are the following:

- **Oxytocin:** Stimulates contraction of the uterine smooth muscle during childbirth and release of breast milk in nursing women

- **Vasopressin, or antidiuretic hormone (ADH):** Constricts smooth muscle tissue in the blood vessels, elevating blood pressure and increasing the amount of water reabsorbed by the kidneys, which reduces the production of urine. The hypothalamus has special neurons called osmoreceptors that monitor the amount of solute in the blood.

See how much of this information you’re absorbing:
Q. The hormone that stimulates ovulation is the
   a. Follicle-stimulating hormone (FSH)
   b. Antidiuretic hormone (ADH)
   c. Oxytocin
   d. Thyroid-stimulating hormone (TSH)
   e. Luteinizing hormone (LH)

A. The correct answer is luteinizing hormone (LH). Don’t be fooled into thinking it’s FSH; that hormone does its job earlier, when it encourages an ovum to mature.

8.-12. Mark the statement with a T if it’s true or an F if it’s false:
   8. _____ The pituitary gland consists of two parts: an endocrine gland and modified nerve tissue.
   9. _____ The pituitary gland is found in the sella turcica of the temporal bone.
   10. _____ The adenohypophysis is called the master gland because of its influence on all the body’s tissues.
   11. _____ ADH causes constriction of smooth muscle tissue in the blood vessels, which elevates the blood pressure.
   12. _____ The neurohypophysis stores and releases secretions produced by the hypothalamus.

13. The gland that does the most to regulate and maintain the function of other glands is the
    a. Pineal
    b. Pituitary
    c. Thyroid
    d. Thymus
    e. Parathyroid

14. Which of the following is not a pituitary hormone?
    a. Progesterone
    b. Follicle-stimulating hormone (FSH)
    c. Growth hormone (GSH)
    d. Prolactin
    e. Luteinizing hormone (LH)
Supporting Cast of Glandular Characters

While the pituitary orchestrates the show at center stage, the endocrine system enjoys the support of a number of other important glands. Lying in various locations throughout the body, these glands secrete check-and-balance hormones that keep the body in tune.

Topping off the kidneys: The adrenal glands

Also called suprarenals, the adrenal glands lie atop each kidney. The central area of each is called the adrenal medulla, and the outer layers are called the adrenal cortex. Each glandular area secretes different hormones. The cells of the cortex produce over 30 steroids, including the hormones aldosterone, cortisone, and some sex hormones. The medullar cells secrete epinephrine (you may know it as adrenaline) and norepinephrine (also known as noradrenaline).

Made up of closely packed epithelial cells, the adrenal cortex is loaded with blood vessels. Layers form an outer, middle, and inner zone of the cortex. Each zone is composed of a different cellular arrangement and secretes different steroid hormones.

- The zona glomerulosa (outer zone) produces aldosterone.
- The zona fasciculata (middle zone) secretes cortisone (also called cortisol).
- The zona reticularis (inner zone) secretes small amounts of gonadocorticoids or sex hormones.

The following are among the hormones produced by the cortex:

- Aldosterone, or mineralocorticoid, regulates electrolytes (sodium and potassium mineral salts) retained in the body. It promotes the conservation of water and reduces urine output.
- Cortisone, or cortisol, acts as an antagonist to insulin, causing more glucose to form and increasing blood sugar to maintain normal levels. Elevated levels of cortisone speed up protein breakdown and inhibit amino acid absorption.
- Androgens and estrogen are cortical sex hormones. Androgens generally convey antifeminine effects, thus accelerating maleness, although in women adrenal androgens maintain the sexual drive. Too much androgen in females can cause virilism (male secondary sexual characteristics). Estrogen has the opposite effect, accelerating femaleness. Too much estrogen in a male produces feminine characteristics.

The adrenal medulla is made of irregularly shaped chromaffin cells arranged in groups around blood vessels. The sympathetic division of the autonomic nervous system controls these cells as they secrete adrenaline and noradrenaline. Both hormones have similar molecular structure and physiological functions. The adrenal cortex produces approximately 80 percent adrenaline and 20 percent noradrenaline. Adrenaline accelerates the heartbeat, stimulates respiration, slows digestion, increases muscle efficiency, and helps muscles resist fatigue. Noreadrenaline does similar things but also raises blood pressure by stimulating contraction of muscular arteries.
The terms “adrenaline” and “noradrenaline” are interchangeable with the terms “epinephrine” and “norepinephrine.” You’re likely to encounter both in textbooks and exams.

**Thriving with the thyroid**

The largest of the endocrine glands, the thyroid is like a large butterfly with two lobes connected by a fleshy isthmus positioned in the front of the neck, just below the larynx and on either side of the trachea. A transport mechanism called the iodide pump moves the iodides from the bloodstream for use in creating its two primary hormones, thyroxin and triiodothyronine, which regulate the body’s metabolic rate. Extrafollicular cells (also called parafollicular or C cells) secrete calcitonin, a polypeptide hormone that helps regulate the concentration of calcium and phosphate ions by inhibiting the rate at which they leave the bones. High blood calcium levels stimulate the secretion of more calcitonin.

Thyroxin (T4) and triiodothyronine (T3) regulate cellular metabolism throughout the body, but the thyroid needs iodine to manufacture those hormones. Iodine insufficiency causes the thyroid to swell in a condition called a goiter.

**Pairing up with the parathyroid**

The parathyroid consists of four pea-sized glands that lie posterior to the thyroid gland secreting parathormone, or parathyroid hormone (PTH). This large polypeptide regulates the balance of calcium levels in the blood and bones as well as controls the rate at which calcium is excreted into urine. When blood calcium levels dip, the parathyroid secretes PTH, which increases calcium absorption from the intestine, decreases calcium excretion, increases phosphate excretion, removes calcium from the bones, and stimulates secretion of calcitonin by the thyroid C cells. Blood calcium ion homeostasis is critical to the conduction of nerve impulses, muscle contraction, and blood clotting.

**Pinging the pineal gland**

The pineal gland, also called the epiphysis, is a small, oval gland thought to play a role in regulating the body’s biological clock. It lies between the cerebral hemispheres and is attached to the thalamus near the roof of its third ventricle.

Because it both secretes a hormone and receives visual nerve stimuli, the pineal gland is considered part of both the nervous system and the endocrine system. Its hormone melatonin is believed to play a role in circadian rhythms, the pattern of repeated behavior associated with the cycles of night and day. The pineal gland is affected by changes in light, producing its highest levels of secretion at night and its lowest levels during daylight hours.

**Thumping the thymus**

As discussed in Chapter 11, the thymus is thought to secrete a group of peptides called thymosin that affect the production of lymphocytes (white blood cells). Thymosin promotes the production and maturation of T lymphocyte cells as part of the body’s immune system. The gland is large in children and atrophies with age.
Pressing the pancreas

The pancreas is both an exocrine and an endocrine gland, which means that it secretes some substances through ducts while others go directly into the bloodstream. (We cover its exocrine functions in Chapter 9.) The pancreatic endocrine glands are clusters of cells called the islets of Langerhans. Within the islets are a variety of cells, including

- A cells (alpha cells) that secrete the hormone glucagon, a polypeptide of 29 amino acids that increases blood sugar
- B cells (beta cells) that secrete insulin, a two-linked polypeptide chain of 21 amino acids that decreases blood sugar levels, increases lipid synthesis, and stimulates protein synthesis
- D cells (delta cells) that secrete somatostatin, a growth hormone-inhibiting factor that inhibits the secretion of insulin and glucagons
- F cells (PP cells) that secrete a pancreatic polypeptide that regulates the release of pancreatic digestive enzymes

See if all this information has your hormones raging:

15–19. Mark the statement with a T if it’s true or an F if it’s false:

15. _____ The adrenal glands are located in the cortex of the kidneys.
16. _____ Adrenaline is functional in the absorption of stored carbohydrates and fat.
17. _____ Aldosterone is functional in regulating the amount of insulin in the body.
18. _____ The sympathetic division of the autonomic nervous system controls the cells of the adrenal medulla.
19. _____ The layers of the adrenal medulla form outer, middle, and inner zones.

20. The endocrine gland that initiates antibody development by producing thymosin is the
   a. Pineal body
   b. Pituitary gland
   c. Thymus
   d. Hypothalamus
   e. Adrenal gland

21. The hormone that regulates the amount of electrolytes retained in the body is
   a. Aldosterone
   b. Cortisone
   c. Epinephrine
   d. Androgens
   e. Norepinephrine
22.–26. Mark the statement with a T if it’s true or an F if it’s false:
   
   22. ____ Iodine is a necessary component of thyroxin (T₄) and triiodothyronine (T₃).
   23. ____ Follicular cells of the thyroid produce hormones that affect the metabolic rate of the body.
   24. ____ A transport mechanism called the sodium pump moves the iodides into the follicle cells.
   25. ____ Thyroxin (T₄) is normally secreted in lower quantity than triiodothyronine (T₃).
   26. ____ The hormone calcitonin helps regulate the concentration of sodium and potassium.

27. Which statement is not true of the pineal gland?
   a. It secretes melatonin.
   b. Nerve fibers stimulate the pineal cells.
   c. As light decreases, secretion increases.
   d. It’s a small, oval gland.
   e. It promotes immunity.

28. Insufficiency of iodine causes the thyroid gland to enlarge, causing
   a. Dwarfism
   b. Diabetes
   c. Giantism
   d. Acromegaly
   e. Simple or endemic goiter

29.–33. Mark the statement with a T if it’s true or an F if it’s false:
   
   29. ____ The parathyroid gland contains cells that secrete parathormone or parathyroid hormone (PTH).
   30. ____ Melatonin is a polypeptide that regulates the balance of calcium in the blood and bones.
   31. ____ The pineal gland responds to light, producing higher levels of secretions at night than during the day.
   32. ____ Thymosin promotes the production and maturation of erythrocyte cells.
   33. ____ The parathyroid hormone can prompt calcium to move from bone.

34. The endocrine gland that produces 80 percent epinephrine is the
   a. Hypothalamus
   b. Pituitary
   c. Medulla of the adrenal
   d. Thyroid
   e. Thymus
35. The endocrine gland associated with metabolic rate is the
   a. Parathyroid
   b. Thyroid
   c. Pineal
   d. Posterior lobe of the pituitary
   e. Thymus

Dealing with Stress: Homeostasis

Nothing upsets your delicate cells more than a change in their internal environment. A stimulus such as fear or pain provokes a response that upsets your body's carefully maintained equilibrium. Such a change initiates a nerve impulse to the hypothalamus that activates the sympathetic division of the autonomic nervous system and increases secretions from the adrenal glands. This change — called a stressor — produces a condition many know oh so well: stress. The body's immediate response is to push for homeostasis — keeping everything the same inside.

The body's effort to maintain homeostasis invokes a series of reactions called the general stress syndrome that's controlled by the hypothalamus. When the hypothalamus receives stress information, it responds by preparing the body for fight or flight; in other words some kind of decisive, immediate, physical action. This reaction increases blood levels of glucose, glycerol, and fatty acids; increases the heart rate and breathing rate; redirects blood from skin and internal organs to the skeletal muscles; and increases the secretion of adrenaline from the adrenal medulla. The hypothalamus releases corticotropin-releasing hormone (CRH) that stimulates the anterior lobe of the pituitary to secrete adrenocorticotropic hormone (ACTH), which tells the adrenal cortex to secrete more cortisone. That cortisone supplies the body with amino acids and an extra energy source needed to repair any injured tissues that may result from the impending crisis.

As part of the general stress syndrome, the pancreas produces glucagon, and the anterior pituitary secretes growth hormones, both of which prepare energy sources and stimulate the absorption of amino acids to repair damaged tissue. The posterior pituitary secretes antidiuretic hormone, making the body hang on to sodium ions and spare water. The subsequent decrease in urine output is important to increase blood volume, especially if there's bleeding or excessive sweating.

Wow. With the body gearing up like that every time, it's no wonder that people subjected to repeated stress are often sickly.

We try not to stress you out with these practice questions:

36.–40. Mark the statement with a T if it's true or an F if it's false:
   
   36. _____ The hypothalamus controls reactions to combat general stress syndrome.
   37. _____ The pancreas is an endocrine gland only.
   38. _____ During stress, the pancreas produces thyroxin (T₄).
   39. _____ Alpha cells in the pancreas secrete the hormone insulin.
   40. _____ Changes in the body's environment called stressors produce a condition called stress.
41. When changes occur in the body’s internal environment, a reaction is initiated by
   a. Neurohormones
   b. Glucocorticoids
   c. The hypothalamus
   d. The adrenal cortex
   e. The pituitary gland

42. Stress activates a set of body responses called
   a. The survival response
   b. The general stress syndrome
   c. The repair response
   d. The resistance response
   e. The stress reflex

43. The body’s initial reaction to a stressor is
   a. Fight or flight response
   b. Repair response
   c. To promote rapid wound healing
   d. Stress reflex
   e. To promote normal metabolism

44. Which of the following is a response to stress?
   a. Decrease the heart rate
   b. Increase the urine output
   c. Redirect blood from the skeletal muscles
   d. Increase the respiratory rate
   e. Decrease the glucose in the blood

45. The pancreas, testes, and ovaries all have this in common:
   a. All are influenced by hormones from the parathyroid.
   b. All are considered to be both exocrine and endocrine.
   c. None were formed from embryonic tissues.
   d. They influence secondary sex characteristics.
   e. They have no blood supply.
46.-55. Use the terms that follow to identify the structures of the endocrine system shown in Figure 16-2:

- Thyroid gland
- Pineal gland
- Pituitary gland
- Adrenal gland
- Ovaries
- Parathyroid gland
- Testes
- Hypothalamus
- Pancreas
- Brain

Figure 16-2: The endocrine system.