Hormones and the Endocrine System

- The endocrine system secretes hormones that coordinate slower but longer-acting responses including reproduction, development, energy metabolism, growth, and behavior.
- The nervous system conveys high-speed electrical signals along specialized cells called neurons; these signals regulate other cells.

Hormones and other signaling molecules bind to target receptors, triggering specific response pathways

- Intercellular Communication
  - The ways that signals are transmitted between animal cells are classified by two criteria:
    - The type of secreting cell
    - The route taken by the signal in reaching its target
- Endocrine Signaling
  - Hormones secreted into extracellular fluids by endocrine cells reach their targets via the bloodstream
  - Endocrine signaling maintains homeostasis, mediates responses to stimuli, regulates growth and development

Paracrine and Autocrine Signaling

- Local regulators are molecules that act over short distances, reaching target cells solely by diffusion.
- In paracrine signaling, the target cells lie near the secreting cells.
- In autocrine signaling, the target cell is also the secreting cell.

Synaptic and Neuroendocrine Signaling

- In synaptic signaling, neurons form specialized junctions with target cells, called synapses.
- At synapses, neurons secrete molecules called neurotransmitters that diffuse short distances and bind to receptors on target cells.
- In neuroendocrine signaling, specialized neurosecretory cells secrete molecules called neurohormones that travel to target cells via the bloodstream.

Figure 45.2a

Figure 45.2b

Signaling by Pheromones

- Members of the same animal species sometimes communicate with pheromones, chemicals that are released into the environment.
- Marking trails leading to food, defining territories, warning of predators, and attracting potential mates.

Endocrine Tissues and Organs

- In some tissues, endocrine cells are grouped together in ductless organs called endocrine glands.
– secrete hormones directly into surrounding fluid
– contrast with exocrine glands, which have ducts and which secrete substances onto body surfaces or into cavities

**Figure 45.4**

**Chemical Classes of Hormones**

- Three major classes of molecules function as hormones in vertebrates
  - Polypeptides (proteins and peptides)
  - Amines derived from amino acids
  - Steroid hormones
- Lipid-soluble hormones (steroid hormones) pass easily through cell membranes, while water-soluble hormones (polypeptides and amines) do not
- The solubility of a hormone correlates with the location of receptors inside or on the surface of target cells

**Cellular Response Pathways**

- Water-soluble hormones are secreted by exocytosis, travel freely in the bloodstream, and bind to cell-surface receptors
- Lipid-soluble hormones diffuse across cell membranes, travel in the bloodstream bound to transport proteins, and diffuse through the membrane of target cells

**Figure 45.7-2**

**Pathway for Lipid-Soluble Hormones**

- usually a change in gene expression
- Steroids, thyroid hormones, and the hormonal form of vitamin D enter target cells and bind to protein receptors in the cytoplasm or nucleus
- Protein-receptor complexes then act as transcription factors in the nucleus, regulating transcription of specific genes

**Figure 45.9**

**Signaling by Local Regulators**

- Local regulators are secreted molecules that link neighboring cells or directly regulate the secreting cell
- Types of local regulators
  - Cytokines and growth factors
  - Nitric oxide (NO)
  - Prostaglandins

**Coordination of Neuroendocrine and Endocrine Signaling**

- The endocrine and nervous systems generally act coordinately to control reproduction and development
- For example, in larvae of butterflies and moths, the signals that direct molting originate in the brain

**Figure 45.11**

- In insects, molting and development are controlled by a combination of hormones
  - A brain hormone (PTTH) stimulates release of ecdysteroid from the prothoracic
The endocrine system secretes hormones that coordinate slower but longer-term processes. Endocrine signaling regulates homeostasis, development, and behavior. Growth hormone (GH) is secreted by the anterior pituitary gland and has tropic and nontropic effects. Luteinizing hormone (LH) regulates ovulation and the menstrual cycle.

The route taken by the signal in reaching its target cell depends on the location and nature of its receptors. Soluble molecules (steroids) pass easily through cell membranes, whereas larger molecules (polypeptides and amines) require specific receptors on the surface of target cells. The release of thyroid hormone results from a hormone cascade pathway involving the hypothalamus.

The solubility of a hormone correlates with the location of receptors inside or on the target cell membrane. They mediate various fight-flight responses including reproduction, development, energy metabolism, growth, and metamorphosis. For example, juvenile hormone promotes retention of larval characteristics. Ecdysone promotes molting (in the presence of juvenile hormone) and development (in the absence of juvenile hormone) of adult characteristics.

Feedback regulation and antagonistic hormone pairs are common in endocrine systems. Hormones are assembled into regulatory pathways. Diabetes Mellitus is perhaps the best-known endocrine disorder. It is caused by a deficiency of insulin or a decreased response to insulin in target tissues. It is marked by elevated blood glucose levels. Type 1 diabetes mellitus (insulin-dependent) is an autoimmune disorder in which the immune system destroys pancreatic beta cells. Type 2 diabetes mellitus (non-insulin-dependent) involves insulin deficiency or reduced response of target cells due to change in insulin receptors.

The hypothalamus and pituitary are central to endocrine regulation. The hypothalamus receives information from the nervous system and initiates responses through the endocrine system. Attached to the hypothalamus is the pituitary gland, composed of the posterior pituitary gland and the anterior pituitary gland. The posterior pituitary stores and secretes hormones that are made in the hypothalamus. The anterior pituitary makes and releases hormones under regulation of the hypothalamus.

Posterior Pituitary Hormones

The two hormones released from the posterior pituitary act directly on nonendocrine tissues. Oxytocin regulates milk secretion by the mammary glands. Antidiuretic hormone (ADH) regulates physiology and behavior.

Anterior Pituitary Hormones

Hormone production in the anterior pituitary is controlled by releasing and inhibiting hormones from the hypothalamus. For example, prolactin-releasing hormone from the hypothalamus stimulates the release of prolactin.
The endocrine system secretes hormones that coordinate slower but longer

Each adrenal gland actually consists of two glands: the

DES is an endocrine disruptor, a molecule that interrupts the normal function of a

The endocrine and nervous systems generally act coordinately to control

In neuroendocrine signaling, specialized neurosecretory cells secrete molecules

b) are protein molecules.

In paracrine signaling, the target cells lie near the secreting cells

Lipid

the hypothalamus.

The type of secreting cell

In autocrine signaling, the target cell is also the secreting cell

(inner
tissues catabolize or destroy the hormones.

Hormones

Glucocorticoids, such as cortisol, influence glucose metabolism and the immune

A brain hormone (PTTH) stimulates release of ecdysteroid from the prothoracic

Members of the same animal species sometimes communicate with pheromones,

Growth hormone (GH) is secreted by the anterior pituitary gland and has tropic and

hormone (ACTH)

In mammals, progestins, which include progesterone, are primarily involved in

Calcitonin decreases the level of blood Ca

The gonads, testes and ovaries, produce most of the sex hormones: androgens,

Humans produce two types of corticosteroids: glucocorticoids and mineralocorticoids

from food

(non

All three sex hormones are found in both males and females, but in significantly

In insects, molting and development are controlled by a combination of hormones

In larvae of butterflies and moths, the signals that direct molting

Between 1938 and 1971 some pregnant women at risk for complications were

Thyroid hormone

Hormone production in the anterior pituitary is controlled by releasing and inhibiting

The anterior pituitary gland is the master gland of the endocrine system.

It releases Ca

It is marked by elevated blood glucose levels

Steroids, thyroid hormones, and the hormonal form of vitamin D enter target cells

They are secreted in response to stress

In the body, hormones are produced in cells, typically in specialized endocrine glands.

It attracts potential mates

Distances and bind to receptors on target cells

Hormone cascade pathways typically involve negative feedback

Figure 45.16

Table 45.1a

Table 45.1b

Thyroid Regulation: A Hormone Cascade Pathway

• A hormone can stimulate the release of a series of other hormones, the last of which
  activates a nonendocrine target cell; this is called a hormone cascade pathway
• The release of thyroid hormone results from a hormone cascade pathway involving
  the hypothalamus, anterior pituitary, and thyroid gland
• Hormone cascade pathways typically involve negative feedback

Figure 45.17

Disorders of Thyroid Function and Regulation

• Hypothyroidism, too little thyroid function, can produce symptoms such as
  – Weight gain, lethargy, cold intolerance
• Hyperthyroidism, excessive production of thyroid hormone, can lead to
  – High temperature, sweating, weight loss, irritability, and high blood pressure
• Thyroid hormone refers to a pair of hormones
  – Triiodothyronin (T₃), with three iodine atoms
  – Thyroxine (T₄), with four iodine atoms

Evolution of Hormone Function

• Function of a given hormone may diverge between species
• Thyroid hormone plays a role in metabolism across many lineages, but in frogs has
  taken on a unique function: stimulating the resorption of the tadpole tail during
  metamorphosis

Tropic and Nontropic Hormones

• A tropic hormone regulates the function of endocrine cells or glands
• Three primarily tropic hormones are
  – Follicle-stimulating hormone (FSH)
  – Luteinizing hormone (LH)
  – Adrenocorticotropic hormone (ACTH)
• Growth hormone (GH) is secreted by the anterior pituitary gland and has tropic and
  nontropic actions
• It promotes growth directly and has diverse metabolic effects
• It stimulates production of growth factors
• An excess of GH can cause gigantism, while a lack of GH can cause dwarfism
  •

Endocrine glands respond to diverse stimuli in regulating homeostasis,

development, and behavior

• Endocrine signaling regulates homeostasis, development, and behavior
  •

Parathyroid Hormone and Vitamin D: Control of Blood Calcium

• Two antagonistic hormones regulate the homeostasis of calcium (Ca²⁺) in the blood
of mammals

- PTH increases the level of blood Ca\(^{2+}\)
  - It releases Ca\(^{2+}\) from bone and stimulates reabsorption of Ca\(^{2+}\) in the kidneys
  - It also has an indirect effect, stimulating the kidneys to activate vitamin D, which promotes intestinal uptake of Ca\(^{2+}\) from food
- Calcitonin decreases the level of blood Ca\(^{2+}\)
  - It stimulates Ca\(^{2+}\) deposition in bones and secretion by kidneys

**Adrenal Hormones: Response to Stress**

- The adrenal glands are adjacent to the kidneys
- Each adrenal gland actually consists of two glands: the adrenal medulla (inner portion) and adrenal cortex (outer portion)

**Catecholamines from the Adrenal Medulla**

- The adrenal medulla secretes epinephrine (adrenaline) and norepinephrine (noradrenaline)
- These hormones are members of a class of compounds called catecholamines
- They are secreted in response to stress-activated impulses from the nervous system
- They mediate various fight-or-flight responses

- Epinephrine and norepinephrine
  - Trigger the release of glucose and fatty acids into the blood
  - Increase oxygen delivery to body cells
  - Direct blood toward heart, brain, and skeletal muscles and away from skin, digestive system, and kidneys
- The release of epinephrine and norepinephrine occurs in response to involuntary nerve signals

**Steroid Hormones from the Adrenal Cortex**

- The adrenal cortex releases a family of steroids called corticosteroids in response to stress
- These hormones are triggered by a hormone cascade pathway via the hypothalamus and anterior pituitary (ACTH)
- Humans produce two types of corticosteroids: glucocorticoids and mineralocorticoids

**Figure 45.21b**

- Glucocorticoids, such as cortisol, influence glucose metabolism and the immune system
- Mineralocorticoids, such as aldosterone, affect salt and water balance
- The adrenal cortex also produces small amounts of steroid hormones that function as sex hormones

**Gonadal Sex Hormones**

- The gonads, testes and ovaries, produce most of the sex hormones: androgens, estrogens, and progestins
• All three sex hormones are found in both males and females, but in significantly different proportions

The testes primarily synthesize androgens, mainly testosterone, which stimulate development and maintenance of the male reproductive system
• Testosterone causes an increase in muscle and bone mass and is often taken as a supplement to cause muscle growth, which carries health risks

Estrogens, most importantly estradiol, are responsible for maintenance of the female reproductive system and the development of female secondary sex characteristics
• In mammals, progestins, which include progesterone, are primarily involved in preparing and maintaining the uterus
• Synthesis of the sex hormones is controlled by FSH and LH from the anterior pituitary

**Endocrine Disruptors**
• Between 1938 and 1971 some pregnant women at risk for complications were prescribed a synthetic estrogen called diethylstilbestrol (DES)
• Daughters of women treated with DES are at higher risk for reproductive abnormalities, including miscarriage, structural changes, and cervical and vaginal cancers
• DES is an endocrine disruptor, a molecule that interrupts the normal function of a hormone pathway, in this case, that of estrogen

**Melatonin and Biorhythms**
• The pineal gland, located in the brain, secretes melatonin
• Light/dark cycles control release of melatonin
• Primary functions of melatonin appear to relate to biological rhythms associated with reproduction

**All Hormones**
• a) are lipid-soluble molecules.
• b) are protein molecules.
• c) elicit the same biological response from all of their target cells.
• d) are carried to target cells in the blood.
• e) are produced by endocrine glands.

**Hormones are transported throughout the circulatory system, but they affect only specific tissues or cells because**
   A. only the capillaries at the target will let the hormones out of the blood.
   B. only the target cells have receptors for the hormone.
   C. the nontarget tissues catabolize or destroy the hormones.
   D. the hormones know where their targets are located.

**Oxytocin, the milk-release hormone secreted from nerve endings (axon terminals) in the posterior pituitary gland, is synthesized in**
• a) the anterior pituitary gland.
The role of the pancreas as an endocrine gland that mediates glucose homeostasis is of great importance to health, but a patient whose pancreas has been surgically removed also loses

a) the body's source of epinephrine.
b) the body's source of growth hormones.
c) the body's source of most of its digestive enzymes.
d) the ability to coordinate swallowing and breathing.