Chapter 45

Hormones and the Endocrine System

PowerPoint Lectures for
Biology, Seventh Edition
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- Overview: The Body's Long-Distance Regulators
- An animal hormone
  - Is a chemical signal that is secreted into the circulatory system and communicates regulatory messages within the body
- Hormones may reach all parts of the body
  - But only certain types of cells, target cells, are equipped to respond

- Insect metamorphosis
  - Is regulated by hormones

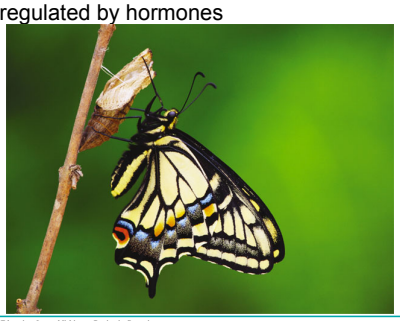


Figure 45.1

- Concept 45.1: The endocrine system and the nervous system act individually and together in regulating an animal's physiology
- Animals have two systems of internal communication and regulation
  - The nervous system and the endocrine system

- The nervous system
  - Conveys high-speed electrical signals along specialized cells called neurons
- The endocrine system, made up of endocrine glands
  - Secretes hormones that coordinate slower but longer-acting responses to stimuli

Overlap Between Endocrine and Nervous Regulation

- The endocrine and nervous systems
  - Often function together in maintaining homeostasis, development, and reproduction

- Specialized nerve cells known as neurosecretory cells
  - Release neurohormones into the blood
- Both endocrine hormones and neurohormones
  - Function as long-distance regulators of many physiological processes

Control Pathways and Feedback Loops

- There are three types of hormonal control pathways

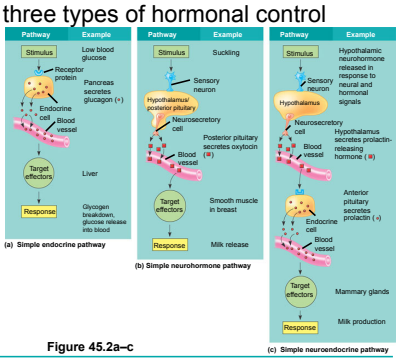


Figure 45.2a–c

- A common feature of control pathways
  - Is a feedback loop connecting the response to the initial stimulus
- Negative feedback
  - Regulates many hormonal pathways involved in homeostasis

- Concept 45.2: Hormones and other chemical signals bind to target cell receptors, initiating pathways that culminate in specific cell responses
- Hormones convey information via the bloodstream
  - To target cells throughout the body

- Three major classes of molecules function as hormones in vertebrates
  - Proteins and peptides
  - Amines derived from amino acids
  - Steroids

- Signaling by any of these molecules involves three key events
  - Reception
  - Signal transduction
  - Response

Cell-Surface Receptors for Water-Soluble Hormones

- The receptors for most water-soluble hormones
  - Are embedded in the plasma membrane, projecting outward from the cell surface

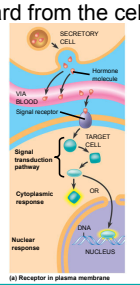


Figure 45.3a (a) Receptor in plasma membrane

- Binding of a hormone to its receptor
  - Initiates a signal transduction pathway leading to specific responses in the cytoplasm or a change in gene expression

- The same hormone may have different effects on target cells that have
  - Different receptors for the hormone
  - Different signal transduction pathways
  - Different proteins for carrying out the response

- The hormone epinephrine
  - Has multiple effects in mediating the body's response to short-term stress

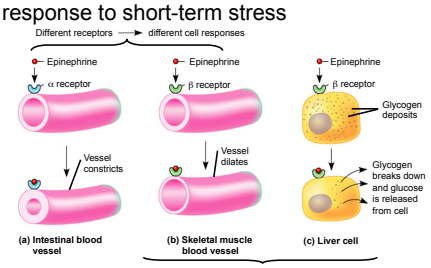


Figure 45.4a–c

Intracellular Receptors for Lipid-Soluble Hormones

- Steroids, thyroid hormones, and the hormonal form of vitamin D
  - Enter target cells and bind to specific protein receptors in the cytoplasm or nucleus

- The protein-receptor complexes
  - Then act as transcription factors in the nucleus, regulating transcription of specific genes

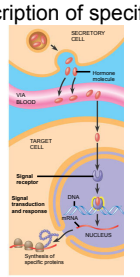


Figure 45.3b (b) Receptor in cell nucleus

Paracrine Signaling by Local Regulators

- In a process called paracrine signaling
  - Various types of chemical signals elicit responses in nearby target cells

- Local regulators have various functions and include
  - Neurotransmitters
  - Cytokines and growth factors
  - Nitric oxide
  - Prostaglandins

- Prostaglandins help regulate the aggregation of platelets
  - An early step in the formation of blood clots

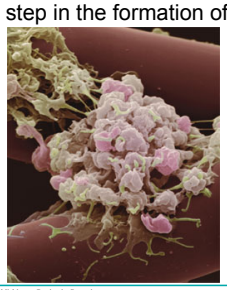


Figure 45.5

- Concept 45.3: The hypothalamus and pituitary integrate many functions of the vertebrate endocrine system
- The hypothalamus and the pituitary gland
  - Control much of the endocrine system

- The major human endocrine glands

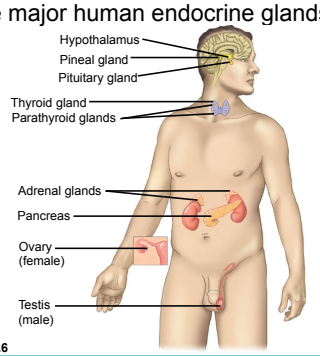


Figure 45.6

- Major human endocrine glands and some of their hormones

Table 45.1 Major Human Endocrine Glands and Some of Their Hormones

Gland	Hormone	Chemical Class	Representative Actions	Regulated By
Hypothalamus	Hormones released from the posterior pituitary and hormones that regulate the anterior pituitary (see below)			
Pituitary gland				
Posterior pituitary (releases neurohormones made in hypothalamus)	Oxytocin	Peptide	Stimulates contraction of uterus and mammary gland cells	Nervous system
	Antidiuretic hormone (ADH)	Peptide	Promotes retention of water by kidneys	Water/salt balance
Anterior pituitary	Growth hormone (GH)	Protein	Stimulates growth (especially bones) and metabolic functions	Hypothalamic hormones
	Prolactin (PRL)	Protein	Stimulates milk production and secretion	Hypothalamic hormones
	Follicle-stimulating hormone (FSH)	Glycoprotein	Stimulates production of ova and sperm	Hypothalamic hormones
	Luteinizing hormone (LH)	Glycoprotein	Stimulates ovaries and testes	Hypothalamic hormones
	Thyroid-stimulating hormone (TSH)	Glycoprotein	Stimulates thyroid gland	Thyroxine in blood; hypothalamic hormones
	Adrenocorticotropic hormone (ACTH)	Peptide	Stimulates adrenal cortex to secrete glucocorticoids	Glucocorticoids; hypothalamic hormones
Thyroid gland	Triiodothyronine (T_3) and thyroxine (T_4)	Amine	Stimulate and maintain metabolic processes	TSH
	Calcitonin	Peptide	Lowers blood calcium level	Calcium in blood
Parathyroid glands	Parathyroid hormone (PTH)	Peptide	Raises blood calcium level	Calcium in blood

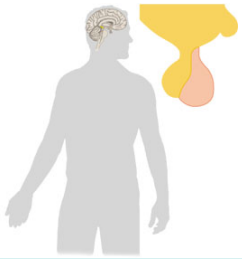
Table 45.1

Gland	Hormone	Chemical Class	Representative Actions	Regulated By
Pancreas	Insulin	Protein	Lowers blood glucose level	Glucose in blood
	Glucagon	Protein	Raises blood glucose level	Glucose in blood
Adrenal glands				
Adrenal medulla	Epinephrine and norepinephrine	Amine	Raise blood glucose level; increase metabolic activities; constrict certain blood vessels	Nervous system
Adrenal cortex	Glucocorticoids	Steroid	Raise blood glucose level	ACTH
	Mineralocorticoids	Steroid	Promote reabsorption of Na and excretion of K in kidneys	K in blood
Gonads				
Testes	Androgens	Steroid	Support sperm formation; promote development and maintenance of male secondary sex characteristics	FSH and LH
Ovaries	Estrogens	Steroid	Stimulate uterine lining growth; promote development and maintenance of female secondary sex characteristics	FSH and LH
	Progesterone	Steroid	Promotes uterine lining growth	FSH and LH
Pineal gland	Melatonin	Amine	Involved in biological rhythms	Light/dark cycles

Table 45.1

Relation Between the Hypothalamus and Pituitary Gland

- The hypothalamus, a region of the lower brain
  - Contains different sets of neurosecretory cells



- Some of these cells produce direct-acting hormones
  - That are stored in and released from the posterior pituitary, or neurohypophysis

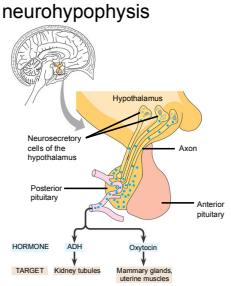


Figure 45.7

- Other hypothalamic cells produce tropic hormones
  - That are secreted into the blood and transported to the anterior pituitary or adenohypophysis

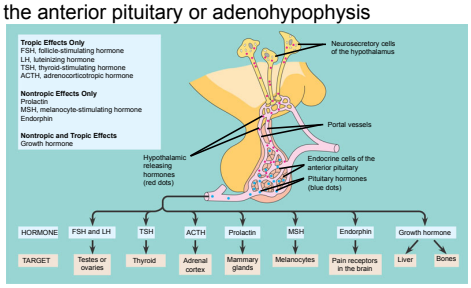


Figure 45.8

- The anterior pituitary
  - Is a true-endocrine gland
- The tropic hormones of the hypothalamus
  - Control release of hormones from the anterior pituitary

Posterior Pituitary Hormones

- The two hormones released from the posterior pituitary
  - Act directly on nonendocrine tissues

- Oxytocin
  - Induces uterine contractions and milk ejection
- Antidiuretic hormone (ADH)
  - Enhances water reabsorption in the kidneys

Anterior Pituitary Hormones

- The anterior pituitary
  - Produces both tropic and nontropic hormones

Tropic Hormones

- The four strictly tropic hormones are
  - Follicle-stimulating hormone (FSH)
  - Luteinizing hormone (LH)
  - Thyroid-stimulating hormone (TSH)
  - Adrenocorticotropic hormone (ACTH)

- Each tropic hormone acts on its target endocrine tissue
  - To stimulate release of hormone(s) with direct metabolic or developmental effects

Nontropic Hormones

- The nontropic hormones produced by the anterior pituitary include
  - Prolactin
  - Melanocyte-stimulating hormone (MSH)
  - β-endorphin

- Prolactin stimulates lactation in mammals
  - But has diverse effects in different vertebrates
- MSH influences skin pigmentation in some vertebrates
  - And fat metabolism in mammals
- Endorphins
  - Inhibit the sensation of pain

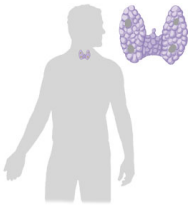
Growth Hormone

- Growth hormone (GH)
  - Promotes growth directly and has diverse metabolic effects
  - Stimulates the production of growth factors by other tissues

- Concept 45.4: Nonpituitary hormones help regulate metabolism, homeostasis, development, and behavior
- Many nonpituitary hormones
  - Regulate various functions in the body

Thyroid Hormones

- The thyroid gland
  - Consists of two lobes located on the ventral surface of the trachea
  - Produces two iodine-containing hormones, triiodothyronine (T_3) and thyroxine (T_4)



- The hypothalamus and anterior pituitary
  - Control the secretion of thyroid hormones through two negative feedback loops

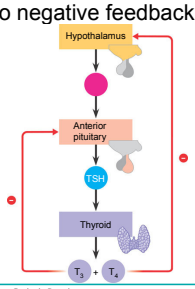


Figure 45.9

- The thyroid hormones
  - Play crucial roles in stimulating metabolism and influencing development and maturation

- Hyperthyroidism, excessive secretion of thyroid hormones
  - Can cause Graves' disease in humans

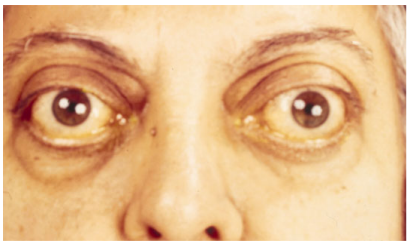


Figure 45.10

- The thyroid gland also produces calcitonin
  - Which functions in calcium homeostasis

Parathyroid Hormone and Calcitonin: Control of Blood Calcium

- Two antagonistic hormones, parathyroid hormone (PTH) and calcitonin
  - Play the major role in calcium (Ca^{2+}) homeostasis in mammals

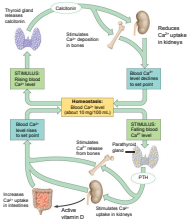
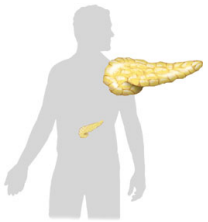


Figure 45.11

- Calcitonin, secreted by the thyroid gland
  - Stimulates Ca^{2+} deposition in the bones and secretion by the kidneys, thus lowering blood Ca^{2+} levels
- PTH, secreted by the parathyroid glands
  - Has the opposite effects on the bones and kidneys, and therefore raises Ca^{2+} levels
  - Also has an indirect effect, stimulating the kidneys to activate vitamin D, which promotes intestinal uptake of Ca^{2+} from food

Insulin and Glucagon: Control of Blood Glucose

- Two types of cells in the pancreas
  - Secrete insulin and glucagon, antagonistic hormones that help maintain glucose homeostasis and are found in clusters in the islets of Langerhans



- Glucagon
  - Is produced by alpha cells
- Insulin
  - Is produced by beta cells

- Maintenance of glucose homeostasis

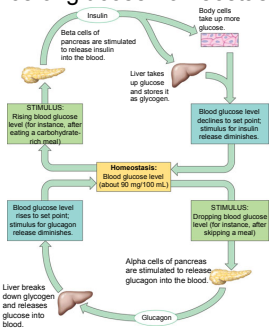


Figure 45.12

Target Tissues for Insulin and Glucagon

- Insulin reduces blood glucose levels by
  - Promoting the cellular uptake of glucose
  - Slowing glycogen breakdown in the liver
  - Promoting fat storage

- Glucagon increases blood glucose levels by
  - Stimulating the conversion of glycogen to glucose in the liver
  - Stimulating the breakdown of fat and protein into glucose

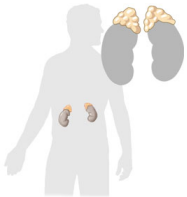
Diabetes Mellitus

- Diabetes mellitus, perhaps the best-known endocrine disorder
  - Is caused by a deficiency of insulin or a decreased response to insulin in target tissues
  - Is marked by elevated blood glucose levels

- Type I diabetes mellitus (insulin-dependent diabetes)
  - Is an autoimmune disorder in which the immune system destroys the beta cells of the pancreas
- Type II diabetes mellitus (non-insulin-dependent diabetes)
  - Is characterized either by a deficiency of insulin or, more commonly, by reduced responsiveness of target cells due to some change in insulin receptors

Adrenal Hormones: Response to Stress

- The adrenal glands
  - Are adjacent to the kidneys
  - Are actually made up of two glands: the adrenal medulla and the adrenal cortex



Catecholamines from the Adrenal Medulla

- The adrenal medulla secretes epinephrine and norepinephrine
  - Hormones which are members of a class of compounds called catecholamines

- These hormones
  - Are secreted in response to stress-activated impulses from the nervous system
  - Mediate various fight-or-flight responses

Stress Hormones from the Adrenal Cortex

- Hormones from the adrenal cortex
  - Also function in the body's response to stress
  - Fall into three classes of steroid hormones

- Glucocorticoids, such as cortisol
  - Influence glucose metabolism and the immune system
- Mineralocorticoids, such as aldosterone
  - Affect salt and water balance
- Sex hormones
  - Are produced in small amounts

- Stress and the adrenal gland

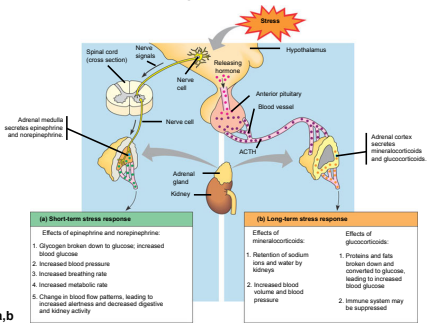
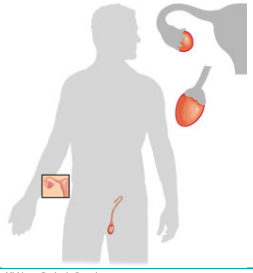


Figure 45.13a,b

Gonadal Sex Hormones

- The gonads—testes and ovaries
  - Produce most of the body's sex hormones: androgens, estrogens, and progestins



- The testes primarily synthesize androgens, the main one being testosterone
  - Which stimulate the 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 many health risks

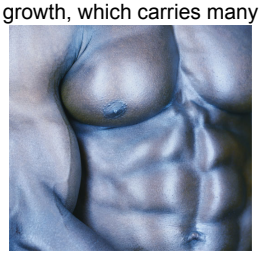


Figure 45.14

- Estrogens, the most important of which is estradiol
  - Are responsible for the 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

Melatonin and Biorhythms

- The pineal gland, located within the brain
  - Secretes melatonin

- Release of melatonin
  - Is controlled by light/dark cycles
- The primary functions of melatonin
  - Appear to be related to biological rhythms associated with reproduction

- Concept 45.5: Invertebrate regulatory systems also involve endocrine and nervous system interactions
- Diverse hormones
  - Regulate different aspects of homeostasis in invertebrates

- In insects
  - Molting and development are controlled by three main hormones

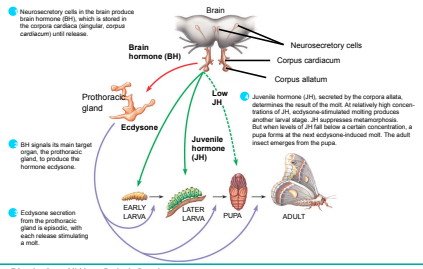


Figure 45.15

- Brain hormone
  - Is produced by neurosecretory cells
  - Stimulates the release of ecdysone from the prothoracic glands

- Ecdysone
  - Promotes molting and the development of adult characteristics
- Juvenile hormone
  - Promotes the retention of larval characteristics