

The Endocrine System

The Endocrine System

- Second-messenger system of the body
- Uses chemical messengers (hormones) that are released into the blood
- Hormones control several major processes
 - Reproduction
 - Growth and development
 - Mobilization of body defenses
 - Maintenance of much of homeostasis
 - Regulation of metabolism

Hormone Overview

- Hormones are produced by specialized cells
- Cells secrete hormones into extracellular fluids
- Blood transfers hormones to target sites
- These hormones regulate the activity of other cells

The Chemistry of Hormones

- Hormones are classified chemically as
 - Amino acid-based, which includes
 - Proteins
 - Peptides
 - Amines
 - Steroids—made from cholesterol
 - Prostaglandins—made from highly active lipids

Mechanisms of Hormone Action

- Hormones affect only certain tissues or organs (target cells or target organs)
- Target cells must have specific protein receptors
- Hormone-binding alters cellular activity

Effects Caused by Hormones

- Changes in plasma membrane permeability or electrical state
- Synthesis of proteins, such as enzymes
- Activation or inactivation of enzymes
- Stimulation of mitosis
- Promotion of secretory activity

The Chemistry of Hormones

- Two mechanisms in which hormones act
 - Direct gene activation
- Second-messenger system

Direct Gene Activation

(Steroid Hormone Action)

- Diffuse through the plasma membrane of target cells
- Enter the nucleus
- Bind to a specific protein within the nucleus
- Bind to specific sites on the cell's DNA
- Activate genes that result in synthesis of new proteins

Second-Messenger System

(Nonsteroid Hormone Action)

- Hormone binds to a membrane receptor
- Hormone does not enter the cell
- Sets off a series of reactions that activates an enzyme
- Catalyzes a reaction that produces a second-messenger molecule
- Oversees additional intracellular changes to promote a specific response

Major Endocrine Glands and Hormones

Control of Hormone Release

- Hormone levels in the blood are mostly maintained by negative feedback
- A stimulus or low hormone levels in the blood triggers the release of more hormone
- Hormone release stops once an appropriate level in the blood is reached

Hormonal Stimuli of Endocrine Glands

- Most common stimuli
- Endocrine glands are activated by other hormones
 - Examples:
 - Anterior pituitary hormones

Humoral Stimuli of Endocrine Glands

- **Changing blood levels of certain ions stimulate hormone release**
- *Humoral* indicates various body fluids such as blood and bile
 - Examples:
 - Parathyroid hormone
 - Calcitonin

- Insulin

Neural Stimuli of Endocrine Glands

- Nerve impulses stimulate hormone release
 - Most are under the control of the sympathetic nervous system
 - Examples include the release of norepinephrine and epinephrine by the adrenal medulla

Major Endocrine Organs

- Pituitary gland
- Thyroid gland
- Parathyroid glands
- Adrenal glands
- Pineal gland
- Thymus gland
- Pancreas
- Gonads (Ovaries and Testes)
- Hypothalamus

Location of Major Endocrine Organs

Pituitary Gland

- Size of a pea
- Hangs by a stalk from the hypothalamus in the brain
- Protected by the sphenoid bone
- Has two functional lobes
 - Anterior pituitary—glandular tissue
 - Posterior pituitary—nervous tissue
- Often called the “master endocrine gland”

Hormones of the Anterior Pituitary

- Six anterior pituitary hormones
 - Two affect non-endocrine targets
 - Growth hormone
 - Prolactin
 - Four stimulate other endocrine glands (tropic hormones)
 - Thyroid-stimulating hormone (thyrotropic hormone)
 - Adrenocorticotrophic hormone
 - Two gonadotropic hormones
- **Characteristics of all anterior pituitary hormones**
 - Proteins (or peptides)
 - Act through second-messenger systems

- Regulated by hormonal stimuli, mostly negative feedback
- **Growth hormone**
 - General metabolic hormone
 - Major effects are directed to growth of skeletal muscles and long bones
 - Plays a role in determining final body size
 - Causes amino acids to be built into proteins
- Causes fats to be broken down for a source of energy
 - Growth hormone (GH) disorders
- Pituitary dwarfism results from hyposecretion of GH during childhood
 - Gigantism results from hypersecretion of GH during childhood
 - Acromegaly results from hypersecretion of GH during adulthood
- Prolactin (PRL)
 - Stimulates and maintains milk production following childbirth
 - Function in males is unknown
- Adrenocorticotrophic hormone (ACTH)
 - Regulates endocrine activity of the adrenal cortex
- **Thyroid-stimulating hormone (TSH)**
 - Influences growth and activity of the thyroid gland
- **Gonadotropic hormones**
 - Regulate hormonal activity of the gonads
- Follicle-stimulating hormone (FSH)
 - Stimulates follicle development in ovaries
 - Stimulates sperm development in testes
- Luteinizing hormone (LH)
 - Triggers ovulation of an egg in females
 - Stimulates testosterone production in males

Pituitary–Hypothalamus Relationship

- Hormonal release is regulated by releasing and inhibiting hormones produced by the hypothalamus
- Hypothalamus produces two hormones
 - These hormones are transported to neurosecretory cells of the posterior pituitary
 - Oxytocin
 - Antidiuretic hormone
- The posterior pituitary is not strictly an endocrine gland, but does release hormones

Hormones of the Posterior Pituitary

- **Oxytocin**
 - Stimulates contractions of the uterus during labor, sexual relations, and breastfeeding
 - Causes milk ejection in a nursing woman
- **Antidiuretic hormone (ADH)**
 - Inhibits urine production by promoting water reabsorption by the kidneys
 - In large amounts, causes vasoconstriction leading to increased blood pressure
 - Also known as vasopressin

Thyroid Gland

- Found at the base of the throat
- Consists of two lobes and a connecting isthmus
- Produces two hormones
 - Thyroid hormone
 - Calcitonin
- **Thyroid hormone**
 - Major metabolic hormone
 - Composed of two active iodine-containing hormones
 - Thyroxine (T₄)—secreted by thyroid follicles
 - Triiodothyronine (T₃)—conversion of T₄ at target tissues
- **Thyroid hormone disorders**
 - **Goiters**
 - Thyroid gland enlarges due to lack of iodine
 - Salt is iodized to prevent goiters
 - **Cretinism**
 - Caused by hyposecretion of thyroxine
 - Results in dwarfism during childhood
 - **Myxedema**
 - Caused by hypothyroidism in adults
 - Results in physical and mental sluggishness
 - **Graves' disease**
 - Caused by hyperthyroidism
 - Results in increased metabolism, heat intolerance, rapid heartbeat, weight loss, and exophthalmos
- Calcitonin

- Decreases blood calcium levels by causing its deposition on bone
- Antagonistic to parathyroid hormone
- Produced by parafollicular cells
- Parafollicular cells are found between the follicles

Parathyroid Glands

- Tiny masses on the posterior of the thyroid
- Secrete parathyroid hormone (PTH)
 - Stimulate osteoclasts to remove calcium from bone
 - Stimulate the kidneys and intestine to absorb more calcium
 - Raise calcium levels in the blood

Hormonal Regulation of Calcium in Blood

Adrenal Glands

- Sit on top of the kidneys
- Two regions
 - Adrenal cortex—outer glandular region has three layers
 - Mineralocorticoids secreting area
 - Glucocorticoids secreting area
 - Sex hormones secreting area
 - Adrenal medulla—inner neural tissue region

Hormones of the Adrenal Cortex

- **Mineralocorticoids** (mainly aldosterone)
 - Produced in outer adrenal cortex
 - Regulate mineral content in blood
 - Regulate water and electrolyte balance
 - Target organ is the kidney
 - Production stimulated by renin and aldosterone
 - Production inhibited by atrial natriuretic peptide (ANP)
- **Glucocorticoids (including cortisone and cortisol)**
 - Produced in the middle layer of the adrenal cortex
 - Promote normal cell metabolism
 - Help resist long-term stressors
 - Released in response to increased blood levels of ACTH

Roles of the Hypothalamus and Adrenal Glands in the Stress Response

Hormones of the Adrenal Cortex

- Sex hormones

- Produced in the inner layer of the adrenal cortex
- Small amounts are made throughout life
- Mostly androgens (male sex hormones) are made but some estrogens (female sex hormones) are also formed
- **Adrenal cortex disorders**
 - Addison's disease
 - Results from hyposecretion of all adrenal cortex hormones
 - Bronze skin tone, muscles are weak, burnout, susceptibility to infection
 - Hyperaldosteronism
 - May result from an ACTH-releasing tumor
 - Excess water and sodium are retained leading to high blood pressure and edema
- **Adrenal cortex disorders**
 - Cushing's syndrome
 - Results from a tumor in the middle cortical area of the adrenal cortex
 - "Moon face," "buffalo hump" on the upper back, high blood pressure, hyperglycemia, weakening of bones, depression
 - Masculinization
 - Results from hypersecretion of sex hormones
 - Beard and male distribution of hair growth
- Produces two similar hormones (catecholamines)
 - Epinephrine (adrenaline)
 - Norepinephrine (noradrenaline)
 - These hormones prepare the body to deal with short-term stress ("fight or flight") by
 - Increasing heart rate, blood pressure, blood glucose levels
 - Dilating small passageways of lungs

Hormones of the Adrenal Cortex

Pancreatic Islets

- The pancreas is a mixed gland and has both endocrine and exocrine functions
- The pancreatic islets produce hormones
 - Insulin—allows glucose to cross plasma membranes into cells from beta cells
 - Glucagon—allows glucose to enter the blood from alpha

- cells
- These hormones are antagonists that maintain blood sugar homeostasis

Pineal Gland

- Found on the third ventricle of the brain
- Secretes melatonin
 - Helps establish the body's wake and sleep cycles
 - Believed to coordinate the hormones of fertility in humans

Location of Major Endocrine Organs

Thymus Gland

- Located posterior to the sternum
- Largest in infants and children
- Produces thymosin
 - Matures some types of white blood cells
 - Important in developing the immune system

Gonads

- Ovaries
 - Produce eggs
 - Produce two groups of steroid hormone
 - Estrogens
 - Progesterone
- Testes
 - Produce sperm
 - Produce androgens, such as testosterone

Hormones of the Ovaries

- **Estrogens**
 - Stimulate the development of secondary female characteristics
 - Mature female reproductive organs
 - With progesterone, estrogens also
 - Promote breast development
 - Regulate menstrual cycle
- **Progesterone**
 - Acts with estrogen to bring about the menstrual cycle
 - Helps in the implantation of an embryo in the uterus
 - Helps prepare breasts for lactation

Hormones of the Testes

- Produce several androgens

- Testosterone is the most important androgen
- Responsible for adult male secondary sex characteristics
- Promotes growth and maturation of male reproductive system
- Required for sperm cell production

Other Hormone-Producing Tissues and Organs

- Parts of the small intestine
- Parts of the stomach
- Kidneys
- Heart
- Many other areas have scattered endocrine cells

Endocrine Function of the Placenta

- Produces hormones that maintain the pregnancy
- Some hormones play a part in the delivery of the baby
- Produces human chorionic gonadotropin (hCG) in addition to estrogen, progesterone, and other hormones

Developmental Aspects of the Endocrine System

- Most endocrine organs operate smoothly until old age
 - Menopause is brought about by lack of efficiency of the ovaries
 - Problems associated with reduced estrogen are common
 - Growth hormone production declines with age
 - Many endocrine glands decrease output with age