Chapter 45: Hormones and the Endocrine System

Hormones

- Chemical signal that is secreted into the circulatory system and communicates regulatory messages within the body
- May reach all parts of the body but only certain types of cells (target cells) are equipped to respond
- Works independently and in conjunction with the nervous system to maintain homeostasis, development, and reproduction
  - Nervous system conveys high-speed electrical signals along specialized cells (neurons)
  - Endocrine system is made up of glands that secrete hormones that coordinate slower but longer-acting responses to stimuli

Hormones

- Hormones convey information through the bloodstream to target cells throughout the body
  - Proteins (and peptides), amines (from amino acids), and steroids are the three major classes of hormones.
- Signaling involves three events: reception, signal transduction, and response
- Binding of a hormone to its receptor initiates signal transduction leading to responses in the cytoplasm or a change in gene expression
- The same hormone may have different effects on cells that have different receptors for that hormone, different signal transduction pathways, or different proteins for carrying out the response.
Types of Signaling

- **Autocrine** - cells secrete a hormone or chemical messenger that binds to the same cell leading to changes in that cell.
- **Paracrine** - target cells are near the signal-releasing cell. Can have various functions: neurotransmitters, growth factors, prostaglandins (regulate aggregation of platelets).
- **Intracrine** - hormone acts inside a cell (usually on nuclear receptors).
- **Endocrine** - target cells are necessarily located near the signal-releasing cell and the signal travels through the bloodstream.

![Image](Fig. 45.2)

**Neuroendocrine Signaling**

- Specialized nerve cells called neurosecretory cells release neurohormones into the blood.
- Three types of hormonal pathways.
- All pathways consist of a feedback loop connecting a response to an initial stimuli.
- Many hormonal responses pathways involved in homeostasis are negative feedback pathways.

![Image](Fig. 45.2)

**Pheromones**

- Members of the same species sometimes communicate with pheromones (chemicals released into the environment).
- Used for marking trails, identifying food sources, defining territories, warning of predators, and attracting mates.
Endocrine Tissues and Organs

- In some tissues, endocrine cells are grouped together in ductless organs called endocrine glands.
- Endocrine glands secrete hormones directly into surrounding fluid.
- Exocrine glands have ducts which secrete substances onto body surfaces or into cavities.
- Classes of hormones: polypeptides, amines (derived from amino acids), and steroid hormones.

Major endocrine glands:
- Hypothalamus
- Pineal gland
- Pituitary gland
- Thyroid gland
- Parathyroid glands (behind thyroid)
- Adrenal glands (atop kidneys)
- Pancreas
- Ovaries (female)
- Testes (male)
- Thymus
- Heart
- Liver
- Stomach
- Kidneys
- Small intestine

Receptors

- Water soluble hormones have receptors embedded in the plasma membrane, projecting from the cell surface.
- Steroids, thyroid hormones, and the hormonal form of vitamin D enter target cells and bind to specific protein receptors in the cytoplasm or nucleus (intracellular receptors).
- The protein-receptor complex acts as a transcription factor in the nucleus, regulating transcription of specific genes.

Epinephrine

- Has multiple effects on mediating the body’s response to short term stress.
Generalized Endocrine and Neuroendocrine Pathways

Insulin and Glucagon
- Two types of cells that secrete insulin and glucagon (antagonistic hormones) that help maintain glucose homeostasis
- Cells found in clusters in the islets of Langerhans
  - Glucagon (produced by alpha cells) increases blood glucose levels
    - Stimulates glycogen breakdown to glucose in the liver, stimulates breakdown of fat and protein into glucose
  - Insulin (produced by beta cells) reduces blood glucose levels
    - Promotes cellular uptake of glucose, slows glycogen breakdown, promotes fat storage

Diabetes Mellitus
- Probably best-known endocrine disorder
- Caused by a deficiency of insulin or a decreased response to insulin in a target tissue
- Marked by elevated blood glucose levels
  - Type 1 diabetes mellitus (insulin-dependent) is an autoimmune disorder in which immune system cells destroy pancreatic beta cells
  - Type 2 diabetes mellitus (non-insulin-dependent) involves insulin deficiency or reduced response of target cells to change in insulin receptors
Hypothalamus and Pituitary Glands

- Control much of the endocrine system
- Hypothalamus - region of the lower brain that contains different sets of neurosecretory cells
  - Some of these cells produce direct-acting hormones that are stored and released from the posterior pituitary
  - Other hypothalamic cells produce tropic hormones that are secreted into the blood and transported to the anterior pituitary gland

Posterior Pituitary Gland

- The two hormones released from the posterior pituitary gland act directly on nonendocrine tissues
  - Oxytocin - induces uterine contractions and milk ejection
  - Antidiuretic hormone (ADH) - enhances water reabsorption in the kidneys
Anterior Pituitary Gland

- Tropic hormones of the hypothalamus control the release of hormones from the anterior pituitary

- Anterior pituitary gland produces both tropic (target other endocrine glands) and nontropic (target non-endocrine cells) hormones

- Tropic hormones act on target endocrine tissue to stimulate the release of hormones with direct effects

- Four tropic hormones:
  - Follicle-stimulating Hormone (FSH) - development, growth, maturation
  - Luteinizing hormone (LH) - ovulation (females), production of testosterone (males)
  - Thyroid-stimulating hormone (TSH)
  - Adrenocorticotropin hormone (ACTH)

- Nontropic hormones
  - Prolactin - stimulates lactation in mammals; water and salt balance in other animals (fish)
  - Melanocyte-stimulating hormone (MSH) - skin pigmentation in some vertebrates; fat metabolism in mammals
  - Endorphins (β-endorphin) - inhibit sensation of pain
  - Growth hormone (GH) - promotes growth directly and stimulates the production of growth factors by other tissues

Thyroid Gland

- Consists of two lobes and is located on the ventral surface of the trachea

- Produces two iodine-containing hormones: triiodothyronine (T3) and thyroxine (T4)

- Play a crucial role in stimulating metabolism and influence development and maturation

- Secretion of thyroid is controlled by the hypothalamus and anterior pituitary through two negative feedback loops

- Hypothyroidism - excess secretion of thyroid hormones causes Graves’ disease

Fig. 45.17
Parathyroid Hormone and Calcitonin

- Parathyroid hormone (PTH) and calcitonin are antagonistic.

  - Calcitonin - secreted by the thyroid gland
  - Stimulates Ca\(^{2+}\) deposition in the bones and secretion by the kidneys (lowers blood Ca\(^{2+}\) levels)

- PTH - secreted by the parathyroid glands
  - Has opposite effect on bones and kidneys (increases blood Ca\(^{2+}\) levels)
  - Also stimulates the kidneys to activate vitamin D which promotes intestinal uptake of Ca\(^{2+}\) from food

Adrenal Glands

- Adjacent to kidneys and made up of two glands: adrenal medulla and adrenal cortex

  - Adrenal Medulla - secretes epinephrine and norepinephrine (class of hormones called catecholamines)
    - Secreted in response to stress-activated impulses from the nervous system (fight-or-flight response)

  - Adrenal Cortex - also function in the response to stress (steroid hormones)
    - Glucocorticoids - influence glucose metabolism and the immune system (ex. cortisol)
    - Mineralocorticoids - affect salt and water balance (ex. aldosterone)
    - Sex hormones

Stress Response

(a) Short-term stress response and the adrenal medulla

Spinal cord (cross section)

Nerve signals

Hypothalamus

Anterior pituitary

Blood vessel

Nerve cell

Adrenal medulla secretes epinephrine and norepinephrine.

(b) Long-term stress response and the adrenal cortex

Nerve cell

ACTH

Blood vessel

Adrenal gland

Kidney

Adrenal cortex secretes mineralocorticoids and glucocorticoids.

Effects of epinephrine and norepinephrine:
- Glycogen broken down to glucose; increased blood glucose
- Increased blood pressure
- Increased breathing rate
- Increased metabolic rate
- Change in blood flow patterns, leading to increased alertness and decreased digestive, excretory, and reproductive system activity

Effects of mineralocorticoids:
- Retention of sodium ions and water by kidneys
- Increased blood volume and blood pressure
- Partial suppression of immune system

Effects of glucocorticoids:
- Proteins and fats broken down and converted to glucose, leading to increased blood glucose
Gonads

- Testes and ovaries produce most of the body's sex hormones (androgens, estrogens, and progestins)
- Testes - primarily synthesize androgens like testosterone
  - Testosterone - stimulates development and maintenance of male reproductive system
  - Can cause an increase in muscle and bone mass
- Ovaries - secrete estrogens (most importantly estradiol) and progesterone
  - Estradiol - responsible for maintenance of female reproductive system and development of secondary sex characteristics
  - Progesterone - preparing and maintaining the uterus

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<th>Embryonic gland removed</th>
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Pineal Gland

- Located in the brain and secretes melatonin (biological rhythms associated with reproduction)
- Melatonin release is controlled by light/dark cycles

Endocrine Disrupters

- 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 normal function of the hormone pathway