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.
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

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

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
epinephrine has multiple effects in mediating the body's response to short-term stress.

- Epinephrine binds to receptors on the plasma membrane of liver cells.
- This triggers the release of messenger molecules that activate enzymes and result in the release of glucose into the bloodstream.

**Pathway for Water-Soluble Hormones**

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**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.

**Multiple Effects of Hormones**

- 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

**Signaling by Local Regulators**

- 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.

**Coordination of Neuroendocrine and Endocrine Signaling**

- In insects, molting and development are controlled by a combination of hormones:
  - A brain hormone (PTTH) stimulates release of ecdysteroid from the prothoracic glands.
  - 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

**Simple Hormone Pathways**

- In a simple neuroendocrine pathway, the stimulus is received by a sensory neuron, which stimulates a neurosecretory cell.
- The neurosecretory cell secretes a neurohormone, which enters the bloodstream and travels to target cells.

**Insulin and Glucagon: Control of Blood Glucose**

- **Insulin** (decreases blood glucose) and **glucagon** (increases blood glucose) are antagonistic hormones that help maintain glucose homeostasis.
- The pancreas has clusters of endocrine cells called pancreatic islets with alpha cells that produce glucagon and beta cells that produce insulin.

**Diabetes Mellitus**

- **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 and anterior pituitary
  - 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 anterior pituitary to secrete prolactin (PRL), which has a role in milk production
Table 45.1b: Major Human Endocrine Glands and Some of Their Hormones (continued)

<table>
<thead>
<tr>
<th>Gland</th>
<th>Hormone</th>
<th>Chemical Class</th>
<th>Actions</th>
<th>Disorders of Thyroid Function and Regulation</th>
</tr>
</thead>
</table>
| Adrenal cortex       | Adrenaline                                  | Amine                            | Causes alpha and beta receptors activation   | 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 |

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

Disorders of Thyroid Function and Regulation

- Hypothyroidism, too little thyroid function, can produce symptoms such as:
  - Weight gain, lethargy, cold intolerance
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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 (Ca\(^{2+}\)) 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

![](image1.png)

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

![](image2.png)

**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

• 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
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.

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Light/dark cycles control release of melatonin.

Primary functions of melatonin appear to relate to biological rhythms associated with reproduction.

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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:

- the body’s source of epinephrine.
- the body’s source of growth hormones.
- the body’s source of most of its digestive enzymes.
- the ability to coordinate swallowing and breathing.