Chapter 26 Hormones and the Endocrine System

Introduction

- In lions, the hormone testosterone promotes the development and maintenance of male traits including
  - growth and maintenance of the mane and
  - increased height and weight.

The Nature of Chemical Regulation

- The endocrine system
  - consists of all hormone-secreting cells and
  - works with the nervous system in regulating body activities.
26.1 Chemical signals coordinate body functions

- The nervous system also communicates, regulates, and uses electrical signals via nerve cells.

26.1 Chemical signals coordinate body functions

- Comparing the endocrine and nervous systems:
  - The nervous system reacts faster.
  - The responses of the endocrine system last longer.

26.1 Chemical signals coordinate body functions

- Hormones are chemical signals, produced by endocrine glands, usually carried in the blood, and responsible for specific changes in target cells.
- Hormones may also be released from specialized nerve cells called neurosecretory cells.

26.2 Hormones affect target cells using two main signaling mechanisms

- Two major classes of molecules function as hormones in vertebrates.
  - The first class includes hydrophilic (water-soluble), amino-acid-derived hormones. Among these are proteins, peptides, and amines.
  - The second class of hormones are steroid hormones, which include small, hydrophobic molecules made from cholesterol.
Hormones affect target cells using two main signaling mechanisms

- Hormone signaling involves three key events:
  - reception,
  - signal transduction, and
  - response.

An amino-acid-derived hormone
- binds to plasma-membrane receptors on target cells and
- initiates a signal transduction pathway.

A steroid hormone can
- diffuse through plasma membranes,
- bind to a receptor protein in the cytoplasm or nucleus, and
- form a hormone-receptor complex that carries out the transduction of the hormonal signal.

THE VERTEBRATE ENDOCRINE SYSTEM
26.3 Overview: The vertebrate endocrine system consists of more than a dozen major glands

- Some endocrine glands (such as the thyroid) primarily secrete hormones into the blood.
- Other glands (such as the pancreas) have
  - endocrine and
  - nonendocrine functions.
- Other organs (such as the stomach) are primarily nonendocrine but have some cells that secrete hormones.

The following figure shows the locations of the major endocrine glands.

The following table summarizes the main hormones produced by the major endocrine glands and indicates how they
- function and
- are controlled.
Two endocrine glands are not discussed further.

- The **pineal gland**
  - is pea-sized, located near the center of the brain, and
  - secretes melatonin, a hormone that links environmental light conditions with biological rhythms.

- The **thymus gland**
  - lies above the heart, under the breastbone, and
  - secretes a peptide that stimulates the development of T-cells.

The hypothalamus, which is closely tied to the pituitary, connects the nervous and endocrine systems

- The **hypothalamus**
  - blurs the distinction between endocrine and nervous systems,
  - receives input from nerves about the internal conditions of the body and the external environment,
  - responds by sending out appropriate nervous or endocrine signals, and
  - uses the pituitary gland to exert master control over the endocrine system.

**The pituitary gland** consists of two parts.

- The **posterior pituitary**
  - is composed of nervous tissue,
  - is an extension of the hypothalamus, and
  - stores and secretes oxytocin and ADH, which are made in the hypothalamus.
26.4 The hypothalamus, which is closely tied to the pituitary, connects the nervous and endocrine systems

- The anterior pituitary
  - synthesizes and secretes hormones that control the activity of other glands and
  - is controlled by two types of hormones released from the hypothalamus:
    - releasing hormones stimulate the anterior pituitary, and
    - inhibiting hormones inhibit the anterior pituitary.

Pituitary secretions include
- growth hormone (GH) that promotes protein synthesis and the use of body fat for energy metabolism,
- endorphins that function as natural painkillers, and
- TRH (TSH-releasing hormone) that stimulates the thyroid (another endocrine gland) to release thyroxine.

26.5 The thyroid regulates development and metabolism

- The thyroid gland is located in the neck, just under the larynx (voice box).
- The thyroid gland produces two similar hormones, thyraxine ($T_4$) and triiodothyronine ($T_3$).
- These hormones regulate many aspects of metabolism, reproduction, and development.
26.5 The thyroid regulates development and metabolism

- Thyroid imbalance can cause disease.
  - Hyperthyroidism
    - results from too much T\textsubscript{4} and T\textsubscript{3} in the blood,
    - leads to high blood pressure, loss of weight, overheating, and irritability, and
    - produces Graves’ disease.
  - Hypothyroidism
    - results from too little T\textsubscript{4} and T\textsubscript{3} in the blood and
    - leads to low blood pressure, being overweight, and often feeling cold and lethargic.

- Iodine deficiency can produce a goiter, an enlargement of the thyroid. In this condition,
  - the thyroid gland cannot synthesize adequate amounts of T\textsubscript{4} and T\textsubscript{3}, and
  - the thyroid gland enlarges.

26.6 Hormones from the thyroid and parathyroid glands maintain calcium homeostasis

- Blood calcium level is regulated by antagonistic hormones each working to oppose the actions of the other hormone:
  - calcitonin, from the thyroid, lowers the calcium level in the blood, and
  - parathyroid hormone (PTH), from the parathyroid glands, raises the calcium level in the blood.
26.7 Pancreatic hormones regulate blood glucose levels

- The pancreas secretes two hormones that control blood glucose:
  - insulin signals cells to use and store glucose, and
  - glucagon causes cells to release stored glucose into the blood.

26.8 CONNECTION: Diabetes is a common endocrine disorder

- Diabetes mellitus
  - affects about 8% of the U.S. population and
  - results from a
    - lack of insulin or
    - failure of cells to respond to insulin.

There are three types of diabetes mellitus.

1. Type 1 (insulin-dependent) is
   - an autoimmune disease
   - caused by the destruction of insulin-producing cells.

2. Type 2 (non-insulin-dependent) is
   - caused by a reduced response to insulin,
   - associated with being overweight and underactive, and
   - the cause of more than 90% of diabetes.
26.8 CONNECTION: Diabetes is a common endocrine disorder

3. Gestational diabetes
   - can affect any pregnant woman and
   - lead to dangerously large babies, which can complicate delivery.

26.9 The adrenal glands mobilize responses to stress

- The endocrine system includes two adrenal glands, sitting on top of each kidney.
- Each adrenal gland is made of two glands fused together, the
  - adrenal medulla and
  - adrenal cortex.
- Both glands secrete hormones that enable the body to respond to stress.

- Nerve signals from the hypothalamus stimulate the adrenal medulla to secrete
  - epinephrine (adrenaline) and
  - norepinephrine (noradrenaline).
- These hormones quickly trigger the “fight-or-flight” responses, which are short-term responses to stress.
26.9 The adrenal glands mobilize responses to stress

- **Adrenocorticotropic hormone (ACTH)** from the pituitary causes the adrenal cortex to secrete
  - glucocorticoids
  - mineralocorticoids.

- The effects of these hormones cause long-term responses to stress.

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26.10 The gonads secrete sex hormones

- **Steroid sex hormones**
  - affect growth,
  - affect development, and
  - regulate reproductive cycles and sexual behavior.

- **Sex hormones include**
  - **estrogens**, which maintain the female reproductive system and promote the development of female characteristics,
  - **progestins**, such as progesterone, which prepare and maintain the uterus to support a developing embryo, and
  - **androgens**, such as **testosterone**, which stimulate the development and maintenance of the male reproductive system.

- The synthesis of sex hormones by the gonads is regulated by the
  - hypothalamus and
  - pituitary.
26.11 EVOLUTION CONNECTION: A single hormone can perform a variety of functions in different animals

- The peptide hormone prolactin (PRL) in humans stimulates mammary glands to grow and produce milk during late pregnancy.
- Suckling by a newborn stimulates further release of PRL.
- High PRL during nursing inhibits ovulation.

PRL has many roles unrelated to childbirth, suggesting that PRL is an ancient hormone diversified through evolution.

- In some nonhuman mammals, PRL stimulates nest building.
- In birds, PRL regulates fat metabolism and reproduction.
- In amphibians, PRL stimulates movement to water.
- In fish that migrate between salt and fresh water, PRL helps regulate salt and water balance.

You should now be able to

1. Explain how testosterone affects lions.
2. Compare the mechanisms and functions of the endocrine and nervous systems.
3. Distinguish between the two major classes of vertebrate hormones.
4. Describe the different types and functions of vertebrate endocrine organs.
5. Describe the interrelationships between the hypothalamus and pituitary glands.
6. Describe the functions of the thyroid and parathyroid glands.
7. Explain how insulin and glucagon manage blood glucose levels.
8. Describe the causes and symptoms of type 1 and type 2 diabetes and gestational diabetes.
9. Compare the functions of the adrenal gland hormones.
10. Describe the three major types of sex hormones and their functions.
11. Describe the diverse functions of prolactin in vertebrate groups and its evolutionary significance.