Section C: The Vertebrate Endocrine System

1. The hypothalamus and pituitary integrate many functions of the vertebrate endocrine system
2. The pineal gland is involved in biorhythms
3. Thyroid hormones function in development, bioenergetics, and homeostasis
4. Parathyroid hormone and calcitonin balance blood calcium
5. Endocrine tissues of the pancreas secrete insulin and glucagon, antagonistic hormones that regulate blood glucose
6. The adrenal medulla and adrenal cortex help the body manage stress
7. Gonadal steroids regulate growth, development, reproductive cycles, and sexual behavior
Introduction

- **Tropic hormones** target other endocrine glands and are important to understanding chemical coordination.

- Humans have nine endocrine glands.
1. The hypothalamus and pituitary integrate many functions of the vertebrate endocrine system

- The hypothalamus integrates endocrine and nervous function.
  - Neurosecretory cells of the hypothalamus produce hormones.
    - Releasing hormones stimulate the anterior pituitary (adenohypophysis) to secrete hormones.
    - Inhibiting hormones prevent the anterior pituitary from secreting hormones.
Fig. 45.6b
- The **posterior pituitary** (neurohypophysis) stores and secretes hormones produced by the hypothalamus.

(a) The posterior pituitary

Fig. 45.6a
<table>
<thead>
<tr>
<th>Gland</th>
<th>Hormone</th>
<th>Chemical Class</th>
<th>Representative Actions</th>
<th>Regulated By</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypothalamus</td>
<td>Hormones released by the posterior pituitary and hormones that regulate the anterior pituitary (see below)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pituitary gland</td>
<td>Oxytocin</td>
<td>Peptide</td>
<td>Stimulates contraction of uterus and mammary gland cells</td>
<td>Nervous system</td>
</tr>
<tr>
<td></td>
<td>Antidiuretic hormone (ADH)</td>
<td>Peptide</td>
<td>Promotes retention of water by kidneys</td>
<td>Water/salt balance</td>
</tr>
<tr>
<td></td>
<td>Growth hormone (GH)</td>
<td>Protein</td>
<td>Stimulates growth (especially bones) and metabolic functions</td>
<td>Hypothalamic hormones</td>
</tr>
<tr>
<td></td>
<td>Prolactin (PRL)</td>
<td>Protein</td>
<td>Stimulates milk production and secretion</td>
<td>Hypothalamic hormones</td>
</tr>
<tr>
<td></td>
<td>Follicle-stimulating hormone (FSH)</td>
<td>Glycoprotein</td>
<td>Stimulates production of ova and sperm</td>
<td>Hypothalamic hormones</td>
</tr>
<tr>
<td></td>
<td>Luteinizing hormone (LH)</td>
<td>Glycoprotein</td>
<td>Stimulates ovaries and testes</td>
<td>Hypothalamic hormones</td>
</tr>
<tr>
<td></td>
<td>Thyroid-stimulating hormone (TSH)</td>
<td>Glycoprotein</td>
<td>Stimulates thyroid gland</td>
<td>Thyroxine in blood; hypothalamic hormones</td>
</tr>
<tr>
<td></td>
<td>Adrenocorticotropic hormone (ACTH)</td>
<td>Peptide</td>
<td>Stimulates adrenal cortex to secrete glucocorticoids</td>
<td>Glucocorticoids; hypothalamic hormones</td>
</tr>
<tr>
<td>Thyroid gland</td>
<td>Triiodothyronine (T&lt;sub&gt;3&lt;/sub&gt;) and thyroxine (T&lt;sub&gt;4&lt;/sub&gt;)</td>
<td>Amine</td>
<td>Stimulate and maintain metabolic processes</td>
<td>TSH</td>
</tr>
<tr>
<td></td>
<td>Calcitonin</td>
<td>Peptide</td>
<td>Lowers blood calcium level</td>
<td>Calcium in blood</td>
</tr>
<tr>
<td>Parathyroid glands</td>
<td>Parathyroid hormone (PTH)</td>
<td>Peptide</td>
<td>Raises blood calcium level</td>
<td>Calcium in blood</td>
</tr>
<tr>
<td>Gland</td>
<td>Hormone</td>
<td>Chemical Class</td>
<td>Representative Actions</td>
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<td>----------------------</td>
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</tr>
<tr>
<td>Pancreas</td>
<td>Insulin</td>
<td>Protein</td>
<td>Lowers blood glucose level</td>
<td>Glucose in blood</td>
</tr>
<tr>
<td></td>
<td>Glucagon</td>
<td>Protein</td>
<td>Raises blood glucose level</td>
<td>Glucose in blood</td>
</tr>
<tr>
<td>Adrenal glands</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adrenal medulla</td>
<td>Epinephrine and norepinephrine</td>
<td>Amine</td>
<td>Raise blood glucose level; increase metabolic activities; constrict certain blood vessels</td>
<td>Nervous system</td>
</tr>
<tr>
<td>Adrenal cortex</td>
<td>Glucocorticoids</td>
<td>Steroid</td>
<td>Raise blood glucose level</td>
<td>ACTH</td>
</tr>
<tr>
<td></td>
<td>Mineralocorticoids</td>
<td>Steroid</td>
<td>Promote reabsorption of Na(^+) and excretion of K(^+) in kidneys</td>
<td>K(^+) in blood</td>
</tr>
<tr>
<td>Gonads</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Testes</td>
<td>Androgens</td>
<td>Steroid</td>
<td>Support sperm formation; promote development and maintenance of male secondary sex characteristics</td>
<td>FSH and LH</td>
</tr>
<tr>
<td>Ovaries</td>
<td>Estrogens</td>
<td>Steroid</td>
<td>Stimulate uterine lining growth; promote development and maintenance of female secondary sex characteristics</td>
<td>FSH and LH</td>
</tr>
<tr>
<td></td>
<td>Progesterone</td>
<td>Steroid</td>
<td>Promotes uterine lining growth</td>
<td>FSH and LH</td>
</tr>
<tr>
<td>Pineal gland</td>
<td>Melatonin</td>
<td>Amine</td>
<td>Involved in biological rhythms</td>
<td>Light/dark cycles</td>
</tr>
<tr>
<td>Thymus</td>
<td>Thymosin</td>
<td>Peptide</td>
<td>Stimulates T lymphocytes</td>
<td>Not known</td>
</tr>
</tbody>
</table>

Table 45.1 (continued)
• Hormones manufactured by the hypothalamus and released by the posterior pituitary.

• **Oxytocin**: a peptide.
  
  • Stimulates contraction of the uterus and mammary glands.
  
  • Secretion regulated by the nervous system.

• **Antidiuretic hormone (ADH)**: a peptide.
  
  • Promotes retention of water by the kidneys.
  
  • Secretion regulated by water/salt balance.
• Anterior pituitary hormones.
  
  • **Growth hormone (GH):** a protein.
    
    • Stimulates growth and metabolism.
    
    • Secretion regulated by hypothalamic hormones.
    
    • Acts directly on tissues or acts via **growth factors**.
    
    • **Gigantism:** excessive GH during development.
    
    • **Acromegaly:** excessive GH production during adulthood.
    
    • **Hypopituitary dwarfism:** childhood GH deficiency.
• **Prolactin (PRL):** a protein.
  • Stimulates milk production and secretion.
  • Secretion regulated by hypothalamic hormones.
• **Gonadotropins:** glycoproteins.
  • **Follicle-stimulating hormone (FSH).**
    • Stimulates production of sperm and ova.
    • Secretion regulated by hypothalamic hormones.
  • **Luteinizing hormone (LH).**
    • Stimulates ovaries and testes.
    • Secretion regulated by hypothalamic hormones.
• **Thyroid-stimulating hormone (TSH):** a glycoprotein.
  • Stimulates thyroid gland.
  • Secretion regulated by thyroxine in blood.
  • Secretion regulated by hypothalamic hormones.

• **Adrenocorticotropic hormone (ACTH):** a peptide
  • Stimulates adrenal cortex secretion of glucocorticoids
  • Secretion regulated by glucocorticoids and hypothalamic hormones.
• Melanocyte-stimulating hormone (MSH): a peptide.
  • May play a role in fat metabolism.

• Endorphins: peptides.
  • Inhibit pain perception.
  • Effects mimicked by heroin and other opiate drugs.
2. The pineal gland is involved in biorhythms

- The **pineal gland** is a small mass of tissue near the center of the mammalian brain.
  - The pineal gland secretes the hormone, **melatonin**, an amine.
    - Involved in biological rhythms associated with reproduction.
    - Secretion regulated by light/dark cycles.
3. Thyroid hormones function in development, bioenergetics, and homeostasis

- The **thyroid gland** of mammals consists of two lobes located on the ventral surface of the trachea.
  - **Triiodothyronine** (**T₃**) and **thyroxine** (**T₄**): amines.
  - Stimulates and maintain metabolic processes.
  - Secretion regulated by TSH hormones.
• Hyperthyroidism is the excessive secretion of thyroid hormones, exhibited by high body temperature, profuse sweating, weight loss, irritability, high blood pressure.

• An insufficient amount of thyroid hormones is known as hypothyroidism.
  • Infants: cretinism.
  • Adults: weight gain, lethargy, cold intolerance.
  • Goiter: often associated with iodine deficiency.

• **Calcitonin**: a peptide.
  • Lowers blood calcium levels.
  • Secretion regulated by calcium in blood.
• **Calcitonin**: a peptide.
  - Lowers blood calcium levels.
  - Secretion regulated by calcium in blood.
4. Parathryoid hormone and calcitonin regulate blood calcium level

• The four parathyroid glands are embedded in the surface of the thyroid gland.
• They secrete **parathyroid hormone (PTH)**, a peptide.
  • Raises blood calcium levels.
  • Secretion regulated by calcium in the blood.
  • Causes osteoclasts to break down bone, releasing $\text{Ca}^{2+}$ into the blood.
  • Stimulates the kidneys to reabsorb $\text{Ca}^{2+}$.
  • Stimulates kidneys to convert **vitamin D** to its active form.
  • PTH and calcitonin are antagonistic hormones.
  • Hypoparathyroidism: tetany.
• A lack of PTH causes hypoparathyroidism, a tetany.
  • Calcium levels in the blood drop.
  • There are convulsive contractions of the skeletal muscles.
Fig. 45.9

Calcitonin

Thyroid gland releases calcitonin

Stimulates Ca\(^{2+}\) deposition in bones
Reduces Ca\(^{2+}\) uptake in kidneys

STIMULUS: Rising blood Ca\(^{2+}\) level
High

Homeostasis: Blood calcium level
Low

STIMULUS: Falling blood Ca\(^{2+}\) level

Parathyroid glands release parathyroid hormone (PTH)

PTH

Parathyroid gland

Active vitamin D

Stimulates Ca\(^{2+}\) release from bones
Increases Ca\(^{2+}\) uptake in kidneys
Increases Ca\(^{2+}\) uptake in intestines
5. Endocrine tissues of the pancreas secrete insulin and glucagon, antagonistic hormones that regulate blood glucose

• The pancreas has both endocrine and exocrine functions.
  • Exocrine function: secretion of bicarbonate ions and digestive enzymes.
  • Endocrine function: insulin and glucagon secreted by islets of Langerhans.
• **Insulin**: a protein secreted by beta cells.
  • Lowers blood glucose levels.
    • Stimulates all body cells (except brain cells) to take up glucose.
    • Slows glycogenolysis.
    • Inhibits gluconeogenesis.
  • Secretion regulated by glucose in blood (negative feedback).
• Hypoinsulinism: diabetes mellitus.
  • Hereditary factors and obesity play a role in its development.
  • High blood sugar levels – sugar excreted in the urine.
  • Symptoms: excessive urination and excessive thirst.
  • If severe: fat substitutes for glucose as major fuel source → production of acidic metabolites → life threatening lowering of blood pH.
• **Type I diabetes mellitus** (insulin-dependent diabetes).
  - Autoimmune disorder.
  - Usually appears in childhood.
  - Treatment: insulin injections.

• **Type II diabetes mellitus** (non-insulin-dependent diabetes).
  - Usually due to target cells having a decreased responsiveness to insulin.
  - Usually occurs after age 40 – risk increases with age.
  - Accounts for over 90% of diabetes cases.
• **Glucagon**: a protein secreted by alpha cells.
  • Raises blood glucose levels.
    • Stimulates glyogenolysis in the liver and skeletal muscle.
    • Secretion regulated by glucose in blood (negative feedback).
Fig. 45.10

**Insulin**
- Body cells take up more glucose
  - Beta cells of pancreas stimulated to release insulin into the blood
  - Liver takes up glucose and stores it as glycogen
  - Blood glucose level declines to a set point; stimulus for insulin release diminishes

**Homeostasis:** Blood glucose level
- STIMULUS:
  - Rising blood glucose level (e.g., after eating a carbohydrate-rich meal)
  - Removal of excess glucose from blood
  - Low blood glucose level (e.g., after skipping a meal)

- Blood glucose level rises to set point; stimulus for glucagon release diminishes
- Alpha cells of pancreas stimulated to release glucagon into the blood
- Liver breaks down glycogen and releases glucose to the blood
- Glucagon

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6. The adrenal medulla and adrenal cortex help the body manage stress

- The **adrenal glands** are located adjacent to the kidneys.
  - The **adrenal cortex** is the outer portion.
  - The **adrenal medulla** is the inner portion.
• Adrenal medulla.
  • Developmentally and functionally related to the nervous system.
• Epinephrine (adrenaline) and norepinephrine (noradrenaline).
  • Catecholamines: amines synthesized from tyrosine.
  • Secretion regulated by the nervous system in response to stress.
• **Epinephrine** (adrenaline) and **norepinephrine** (noradrenaline).

  • **Catecholamines:** amines synthesized from tyrosine.
  
  • Secretion regulated by the nervous system in response to stress.
  
  • Raises blood glucose level and blood fatty acid level.
  
  • Increase metabolic activities.
    
    • Increases heart rate and stroke volume and dilates bronchioles.
  
    • Shunts blood away from skin, digestive organs, and kidneys, and increases blood flow to heart, brain, and skeletal muscle.
• **Adrenal cortex** reacts to stress.
  
  • Secretion of **corticosteroids** is regulated by the nervous system in response to stress.
• **Glucocorticoids.**

  - Raises blood glucose level.
  - Secretion regulated by ACTH (negative feedback).
  - Abnormally high doses are administered as medication to suppress the inflammation response.
• **Mineralocorticoids** (example: aldosterone, which affects salt and water balance).
  
  • Promotes reabsorption of $\text{Na}^+$ and excretion of $\text{K}^+$ in kidneys.
  
  • Secretion regulated by $\text{K}^+$ in blood.
• A third group of corticosteroids are sex hormones.
  • Androgens secreted by the adrenal cortex may account for the female sex drive.
  • The adrenal cortex also secretes small amounts of estrogens and progesterone.
• **Thymosin**: a peptide.
  • Stimulates T lymphocytes.
7. Gonadal steroids regulate growth, development, reproductive cycles, and sexual behavior

- Testes.
  - **Androgens** (example: testosterone): steroids.
    - Supports sperm formation.
    - Promote development and maintenance of male sex characteristics.
    - Secretion regulated by FSH and LH.
• **Ovaries** secrete estrogens and progesterone.
  
  • **Estrogens**: steroids.
    
    • Stimulate uterine lining growth.
    
    • Promote development and maintenance of female sex characteristics.
    
    • Secretion regulated by FSH and LH.
  
  • **Progestins** (example: progesterone): steroids.
    
    • Promotes uterine lining growth.
    
    • Secretion regulated by FSH and LH.