The Endocrine System

- Like nervous system, endocrine system provides communication and control.
- Messages are relayed from one cell to another via chemical messengers (hormones).
- Unlike nervous system which provides instant but short-lived communication, endocrine system allows for slower-acting but long-term communication.
- Many similarities also exist:
  - Both systems rely on release of chemicals with specific binding onto target receptors.
  - Both systems use many of the same chemicals (ex: epinephrine and norepinephrine).
  - Control set up via negative feedback systems.
  - End goal of both systems is the same: homeostasis.

The Endocrine System

- Includes all endocrine cells and tissues in the body.
- Endocrine cells are secretory gland cells that release product internally (as opposed to exocrine glands that release onto epithelial surfaces).
- Chemicals released may act locally (prostaglandins), or on other cells elsewhere (hormones).
Hormone Structure

- Hormones can be divided into three basic groups based on chemical structure.
  - Amino acid derivatives
    - Small molecules that are structurally similar to amino acids.
    - Include epinephrine, norepinephrine, thyroid hormones, melatonin.
  - Peptide hormones
    - Chains of amino acids.
    - Include short chains (antidiuretic hormone (ADH), oxytocin).
    - And long protein-like chains (growth hormone, prolactin).
    - Largest class of all hormones and includes all hormones secreted by hypothalamus, pituitary gland, heart, kidneys, thymus, digestive tract, and pancreas.
  - Lipid derivatives
    - Two classes: steroid hormones (derived from cholesterol), and hormones derived from arachidonic acid.
    - Steroid hormones are structurally similar to cholesterol, and are released by reproductive organs and adrenal glands.
    - Arachidonic acid-derived hormones include the prostaglandins and are important in various extracellular activities including blood clotting.

Mechanism of Hormone Action

- We have learned about the importance of proteins in defining the general shape and metabolism of the cell.
- Structural proteins provide shape.
- Enzymes direct metabolic processes.
- Hormones affect the identity, activity or quantity of specific structural and enzymatic proteins.
- Hormones have specific cellular targets (target cells).
- Sensitivity of target cell to particular hormone depends on the presence or absence of specific receptors (on membrane or in cytoplasm) to that particular hormone.
Mechanism of Hormone Action

First and Second Messengers

- Certain hormones cannot diffuse through the cell membrane due to their insolubility in lipids and their large size.
- These include epinephrine, norepinephrine, peptide hormones.
- These hormones are known as first messengers because they target specific cell receptors on membrane.
- When this binding occurs, a second messenger in the cytoplasm is activated.
- Second messenger will modulate cellular activities (activation or inhibition).
First and Second Messengers

- Cyclic AMP (c-AMP) is a common and important second messenger.
- 1st messenger binds to cell membrane.
- This activates enzyme adenylate cyclase.
- Enzyme catalyzes conversion of ATP to cAMP.

Intracellular Receptors

- Steroid hormones and thyroid hormones can cross cellular membrane.
- Receptors are present within cytoplasm.
- Hormone-receptor complex binds to specific DNA segments, allowing activation or inhibition of specific genes.
- For example: testosterone stimulates production of enzymes and proteins within skeletal muscle causing increase in muscle mass and strength.
Control of Endocrine Activity

- Control of hormonal activity may be direct or indirect.
- Direct pathway involves endocrine cells releasing secretions into blood stream as a result of changes in extracellular fluid composition.
  - Decrease in calcium levels causes release of parathyroid hormone, causing release of calcium by target cells.
- Indirect pathway set up via negative feedback through the hypothalamus.
  - Controls adrenal cells via autonomic pathways.
  - Releases various hormones.
  - Secretes specialized regulatory hormones which regulate activity of pituitary gland.

The Pituitary Gland

- Also called the hypophysis.
- Located in sella turcica within sphenoid bone.
- All pituitary hormones bind to membrane receptors on target cells and use cAMP as a second messenger.
- Infundibulum connects pituitary gland to hypothalamus.
- Contains distinct anterior and posterior regions.
Anterior Pituitary Gland

- Contains endocrine cells within capillary network.
- Controlled by regulatory hormones produced by hypothalamus.
- The vascular network here is called the hypophyseal portal system.
- Entry of hormones produced by pituitary gland into vascular system occurs at the hypophyseal port.

Hypothalamic Control of the Anterior Pituitary

- Regulatory hormones released by hypothalamus are transported directly to anterior pituitary via the hypophyseal system.
Anterior Pituitary Hormones

- **Thyroid stimulating hormone (TSH)**
  - Stimulates hormone production by the thyroid gland.
  - Increase in thyroid hormones inhibit TSH production via negative feedback through hypothalamus.
- **Adrenocorticotrophic hormone (ACTH)**
  - Stimulates adrenal glands to release steroid hormones.
  - Important in the metabolism of glucose.
- **Follicle-stimulating hormone (FSH)**
  - Promotes reproductory functions (egg development and sperm production)
- **Luteinizing hormone (LH)**
  - Also supports reproductory functions.
  - Induces ovulation in women, promotes secretion of various hormones including progesterone (women) and testosterone (men).
- **Prolactin (PRL)**
  - Stimulates development of mammary glands and production of breast milk.
- **Growth hormone (GH)**
  - Stimulates cell growth and replication by increasing rates of protein synthesis.
- **Melanocyte-stimulating hormone (MSH)**
  - Stimulates melanocytes (normal human function is still unknown).

The Posterior Pituitary

- Contains axons from the hypothalamus.
- Two hormones are secreted in response to hypothalamic stimulation.
- Antidiuretic hormone is released when electrolytes in blood rise, or when blood pressure or volume fall.
  - ADH causes kidneys to retain more water.
  - ADH also causes vasoconstriction.
- Oxytocin is also released to cause uterine muscles in women to contract during later stages of pregnancy.
Pituitary Hormones and their Targets

The Thyroid Gland

- Located below the anterior portion of the larynx.
- Red in color due to high degree of vascularity.
- Thyroid follicles are spheroid-shaped structures that are present throughout thyroid.
- Cavity within each follicle is filled with colloidal fluid (fluid suspended with proteins).
- Thyroid hormones are stored within these follicles.
- Upon stimulation, epithelial cells on surface move hormones from inside to outside.
The Thyroid Gland

Thyroid Hormones

- Released hormones are instantly bound by carrier proteins present within blood.
- Hormones are derivatives of amino acid tyrosine (plus 3 – 4 iodine atoms).
- Thyroxine ($T_4$) is the most common thyroid hormone.
- Thyroid hormones act by diffusing into cytoplasm of the cell to reach receptor sites on mitochondria and in the nucleus.
- Causes increase in ATP production, and activates genes responsible for enzymes that increase cellular metabolism.
- Normal production of thyroid hormones establish background rates of cellular metabolism.
C Cells and Calcitonin

- Additional group of endocrine cells present in thyroid gland.
- These are called C-cells (produce hormone calcitonin).
- Calcitonin assists in the regulation of calcium ion levels in body fluids.
- C-cells release calcitonin when calcium levels rise.
- Calcitonin targets bones and kidneys.
  - Decreases osteoclast activity and stimulates calcium excretion by kidneys.
- Reduction in calcium levels turns off calcitonin switch.

The Regulation of Calcium Ions

- Know the pathways by which calcium is regulated in the body.
- Includes thyroid and parathyroid glands.
The Parathyroid Gland

- Two pairs of parathyroid glands are embedded on posterior surfaces of the thyroid gland.
- Two different cell populations found in parathyroid gland.
- Chief cells produce parathyroid hormone.
  - These monitor calcium levels also and release parathyroid hormone (PTH) when calcium levels fall.
  - PTH stimulates osteoclasts, reduces urinary elimination of calcium, promotes reabsorption of calcium by intestine.
- Function of other group of cells is still unknown.

The Thymus

- Specialized secretory gland located in thoracic cavity, just behind the sternum.
- Increase in size as child grows; decreases after puberty.
- Responsible for producing various hormones (thymosins) that are important in maintaining immunologic defenses.