Endocrine System

Always willing to lend a helping gland
Functions of the Endocrine System

• Regulates metabolic activities through hormones
• Controls reproduction, growth and development, cellular metabolism, energy balance, electrolytes, water, and nutrients.
Endocrine Glands of the Body

- Pituitary
- Thyroid
- Parathyroid
- Adrenal
- Pineal
- Thymus
Organs of the body that contain endocrine tissue and produce hormones include:

- Ovaries
- Testes
- Pancreas
- Hypothalmus
Hormones

- Chemical substances produced by cells and excreted into extracellular fluid to control metabolic function in the body
- Cells have special receptors for the attachment of hormones
- There are three factors that can affect target cell activation.
  1. Blood levels of the hormone
  2. The number of receptors on target cells
  3. The strength of the bond created between the target cell receptor and the hormone
- The half-life of a hormone or the length of time it can exist is in the blood can range from half a minute to thirty minutes
Hormone Release

1. Paracrine – the hormone acts on a neighboring cell without entering the blood.

2. Autocrine – the hormone is released and binds to the cell that produces it.

3. Endocrine – any hormone that is released and travels in the blood to its target cell.

Pheromones – special class of hormones that are secreted into the environment and changes the behavior of another individual.
Hormone Classification

• Hormones can be classified chemically into four broad groups: amino-acid based hormones, steroids, eicosanoids and monoamines

• Amino-acid based hormones
  – small to large molecular size
  – Example: simple AA derivatives (amines, peptides) to proteins

• Steroids
  – produced from cholesterol
  – gonadal hormones and adrenocortical hormones

• Monoamines
  – catecholamines (epinephrine, norepinephrine, dopamine), melatonin & TH

• Eicosanoids
  – chemicals that have a localized effect and do not truly circulate through the body
  – leukotrienes - mediate inflammation and allergic reactions
  – prostaglandins - multiple effects from stimulating labor and blood clotting to raising blood pressure
  – Prostacyclin – inhibits blood clotting & vasoconstriction
  – Thromboxanes- stimulate vasoconstriction & clotting
Types of Changes Hormones Induce

- Can alter the permeability of the cell membrane by opening or closing ion channels.
- Can stimulate mitosis or induce secretory activity.
- Can stimulate the production of proteins or enzymes and then activate or deactivate the enzyme.
- There are two ways or mechanisms that hormones can use to act upon a target cell. One system uses an amino acid based hormone and a second messenger system. The other causes direct gene activation.
Amino Acid-Based Hormone and a Second Messenger

• Amino acid-based hormones cannot pass through the cell membrane and therefore, must use an intracellular second messenger. In this system, the second messenger is generated when the hormone binds to the cell membrane.

• The best understood example of this mechanism type is the cyclic AMP mechanism. The steps of the system are outlined.
Cyclic AMP Mechanism

• The first messenger (the hormone) binds to its receptor on the outside of the cell membrane.
• The receptor changes shape and is able to bind to the G protein.
• The G protein binds to GTP and is activated, GDP is displaced.
• The activated G protein binds to an enzyme, adenylate cyclase, hydrolyzes the GTP and activates the enzyme. The G protein is inactive once more.
• Adenylate cyclase generates cyclic AMP from ATP. Cyclic AMP is the second messenger.
• Cyclic AMP travels freely through the cell activating protein kinases (other enzymes).
• The protein kinases phosphorylate many proteins activating some or inhibiting others.
Cyclic AMP Mechanism

**Figure 17.1** Second-messenger mechanisms of amino acid–based hormones. (a) Mechanisms that generate cyclic AMP by activation of adenylate cyclase are mediated by G proteins, which are activated when the hormone (first messenger) binds to plasma membrane receptors. Cyclic AMP (the second messenger) acts intracellularly to activate protein kinase enzymes that mediate the cell’s responses to the hormone. A list of hormones that act through these mechanisms is provided.
PIP-Calcium Signal Mechanism

• The hormone binds to its receptor causing it to change conformation and bind to an inactive G protein.
• GTP binds to the G protein inducing activation and displacing GDP.
• The activated G protein activates a phospholipase enzyme by binding to it and then becomes inactive.
• Phospholipase causes phosphatidyl inositol biphosphate (PIP$_2$) to split into two second messengers, inositol triphosphate (IP$_3$) and diacylglycerol (DAG).
• IP$_3$ causes the release of Ca$^{+2}$ from the ER and diacylglycerol (DAG) activates certain protein kinases. The calcium ions alter the activity of certain enzymes and ion channels in the cell membrane. Some Ca$^{+2}$ could bind to a protein called calmodulin which activates enzymes to amplify cellular response.
FIGURE 17.1 (continued)  
Second-messenger mechanisms of amino acid—based hormones.  
(b) Some mechanisms utilize Ca\(^{2+}\) as an intracellular messenger. The activated G protein stimulates phospholipase (an enzyme in the plasma membrane) which cleaves PIP into two fragments—inositol triphosphate (IP\(_3\)) and diacylglycerol (DAG), which act as intracellular second messengers to activate protein kinases and increase the cytoplasmic concentration of Ca\(^{2+}\). Ions act as a second messenger by activity of cellular proteins. A summary of hormones that act through this mechanisms is provided.
Direct Gene Activation

- Direct gene activation is a mechanism by which lipid soluble hormones, like steroids, bring about changes in cellular activity.
- The hormone diffuses into its target cell and binds to an intracellular receptor.
- The receptor is activated by coupling.
- The activated complex moves to the chromatin.
- The hormone binds to a DNA associated receptor protein which causes transcription to occur.
- The mRNA is translated producing the desired protein.
1.2 Direct gene activation of steroid hormones. Lipid-soluble hormone diffuses through the membrane of the target cell and binds to the cellular receptor—chaperonin complex located in the nucleus. Once hormone binding occurs, the chaperonin complex dissociates from the receptor and the hormone-receptor complex is activated by phosphorylation and binds to specific receptor proteins on the chromatin, initiating transcription of certain genes. The messenger RNA formed migrates into the cytoplasm, where it directs synthesis of specific proteins.
Hormone Stimulation

- Humoral Stimuli
- Neural Stimuli
- Hormonal Stimuli
Pituitary Gland or Hypophysis

- Sits in sella turcica of the sphenoid bone of the skull
- Approximately the size of a pea
- Looks like a pea attached to a stalk called the infundibulum
  - The infundibulum connects to the hypothalamus.
- There are two major lobes, a neural lobe and a glandular lobe.
  - The glandular lobe or anterior lobe of the pituitary produces several hormones. The anterior lobe is also called adenohypophysis.
  - The neural lobe or posterior lobe stores hormones created by hypothalamus and is composed of cells called pituicytes and nerve fibers that release neurohormones produced by the hypothalamus. The neurohypophysis is composed of the posterior lobe and infundibulum.
Relationship Between Pituitary and the Hypothalamus

• The posterior lobe of the pituitary gland is a growth of the hypothalamus. Communication with the hypothalamus occurs through the hypothalamic-hypophyseal tract stemming from the supraoptic and paraventricular nuclei. These neurons secrete two neurohormones which are transported to the posterior pituitary gland. The supraoptic neurons produce antidiuretic hormones (ADH) and the paraventricular neurons synthesize oxytocin.

• The adenohypophysis communicates with the hypothalamus through the hypophyseal portal system. This system, the hypothalamus secretes its hormone products to regulate the release of the adenohypophyseal hormones.
Relationship Between Pituitary and the Hypothalamus

- paraventricular nucleus
- supraoptic nucleus
- neurosecretory cells
- median eminence
- infundibular stem
- optic chiasma
- hypophyseal portal vein
- pars tuberalis
- arterial blood
- pars nervosa of neurohypophysis
- pars distalis of adenohypophysis
- venous drainage

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Hormones of the Adenohypophyseal

- The following are tropic hormones or tropins. Tropins regulate the secretion of hormones from other endocrine glands and all use a cyclic AMP second messenger system.
- Growth Hormone (GH)
- IGFs
- Thyroid Stimulating Hormone (TSH) or Thyrotropin
- Adrenocorticotropic Hormone (ACTH) or corticotropin
- Follicle Stimulating Hormone (FSH)
- Lutenizing Hormone (LH)
- Prolactin (PRL)
- Pro-opiomelanocortin (POMC)
Hormones of the Posterior Pituitary

- Oxytocin
- Antidiuretic Hormone (ADH)
Thyroid Gland

- **Location**: in the anterior neck, on the trachea, inferior to the larynx
- **Size**: largest endocrine gland
- **Physical Description**: butterfly shaped with two lateral lobes connected by a tissue mass called the isthmus, composed of hollow follicles that produce thyroglobulin
- **Hormones of the Thyroid Gland**
  - Thyroid Hormone (TH)
  - Calcitonin
Parathyroid Gland

- **Location**: Mainly found sitting anterior to the thyroid gland, but some have been reportedly found in the neck or thorax.

- **Physical Description**: tiny, yellow brown glands, usually there are four, but the precise number varies, two cell types, oxyphil cells and chief cells.

- **Hormones of the Parathyroid**
  - Parathyroid hormone (PTH) or parathormone.
Adrenal Glands or Suprarenal Glands

- **Location**: directly superior to the kidneys
- **Physical Description**: A set of pyramid shaped glands each enclosed in a fibrous capsule and a cushion of fat
Adrenal Glands or Suprarenal Glands

• Hormones of the Medulla
  – Catecholamines (epinephrine, norepinephrine, dopamine

• Hormones of the Cortex
  – Mineralocorticoids
  – Glucocorticoids
  – Sex Steroids
Pancreas

- **Location:** posterior to the stomach
- **Physical Description:** soft, triangular gland composed of endocrine and exocrine gland cells
Gonads

• Ovaries
• Testes
Pineal Gland

• The pineal gland is a tiny, cone shaped gland found hanging from the roof of the third ventricle in the diencephalon. The secretory cells of the pineal gland are called pinealocytes. Its major product is melatonin which is responsible for making us sleepy.
The thymus gland can be found posterior to the sternum. This lobulated gland is larger in children and infants, but diminishes in size throughout a person’s lifetime. The major hormone product is the peptide hormones of the family thymopoietins and thymosins. These hormones are necessary for the normal development of T lymphocytes found in the immune system.