Chapter 18: The Endocrine System
Nervous and Endocrine Systems

- Act together to coordinate functions of all body systems
- Nervous system
  - Nerve impulses/ Neurotransmitters
  - Faster responses, briefer effects, acts on specific target
- Endocrine system
  - Hormone – mediator molecule released in 1 part of the body but regulates activity of cells in other parts
  - Slower responses, effects last longer, broader influence
Endocrine Glands

- 2 kinds of glands
  - Exocrine – ducted
  - Endocrine – ductless
    - Secrete products into interstitial fluid, diffuse into blood

- Endocrine glands include
  - Pituitary, thyroid, parathyroid, adrenal and pineal glands
  - Hypothalamus, thymus, pancreas, ovaries, testes, kidneys, stomach, liver, small intestine, skin, heart, adipose tissue, and placenta not exclusively endocrine glands
Hormone Activity

- Hormones affect only specific target tissues with specific receptors
- Receptors constantly synthesized and broken down
  - Down-regulation
  - Up-regulation
Hormone types

- Circulating – circulate in blood throughout body
- Local hormones – act locally
  - Paracrine – act on neighboring cells
  - Autocrine – act on the same cell that secreted them
Chemical classes of hormones

- **Lipid-soluble** – use transport proteins
  - Steroid
  - Thyroid
  - Nitric oxide (NO)
- **Water-soluble** – circulate in “free” form
  - Amine
  - Peptide/protein
  - Eicosanoid
Mechanisms of Hormone Action

- Response depends on both hormone and target cell
- Lipid-soluble hormones bind to receptors inside target cells
- Water-soluble hormones bind to receptors on the plasma membrane
  - Activates second messenger system
  - Amplification of original small signal
- Responsiveness of target cell depends on
  - Hormone’s concentration
  - Abundance of target cell receptors
  - Influence exerted by other hormones
    - Permissive, synergistic and antagonistic effects
Lipid-soluble and Water-soluble Hormones
Lipid-soluble hormone diffuses into cell

**Blood capillary**

**Transport protein**

1. Lipid-soluble hormone diffuses into cell

**Activated receptor-hormone complex alters gene expression**

2. Activated receptor-hormone complex alters gene expression

**Nucleus**

- Receptor
- mRNA
- DNA

**Cytosol**

- mRNA
- Ribosome
- New protein

3. Newly formed mRNA directs synthesis of specific proteins on ribosomes

**New proteins alter cell's activity**

4. New proteins alter cell's activity

**Target cell**
Binding of hormone (first messenger) to its receptor activates G protein, which activates adenylate cyclase. Activated adenylate cyclase converts ATP to cAMP. cAMP serves as a second messenger to activate protein kinases. Activated protein kinases phosphorylate cellular proteins. Millions of phosphorylated proteins cause reactions that produce physiological responses.
Control of Hormone Secretion

- Regulated by
  - Signals from nervous system
  - Chemical changes in the blood
  - Other hormones

- Most hormonal regulation by negative feedback
  - Few examples of positive feedback
Hypothalamus and Pituitary Gland

- Hypothalamus is a major link between nervous and endocrine system
- Pituitary attached to hypothalamus by infundibulum
  - Anterior pituitary or adenohypophysis
  - Posterior pituitary or neurohypophysis
Hypothalamus and Pituitary Gland

(a) Relationship of the hypothalamus to the pituitary gland

(b) Path of releasing and inhibiting hormones

(c) Histology of anterior pituitary

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Anterior pituitary

- Release of hormones stimulated by releasing and inhibiting hormones from the hypothalamus
- Also regulated by negative feedback
- Hypothalamic hormones made by neurosecretory cells transported by hypophyseal portal system
- Anterior pituitary hormones that act on other endocrine systems called tropic hormones
Hormones of the Anterior Pituitary

- Human growth hormone (hGH) or somatostatin
  - Stimulates secretion of insulin-like growth factors (IGFs) that promote growth, protein synthesis

- Thyroid-stimulating hormone (TSH) or thyrotropin
  - Stimulates synthesis and secretion of thyroid hormones by thyroid

- Follicle-stimulating hormone (FSH)
  - Ovaries initiates development of oocytes, testes stimulates testosterone production

- Luteinizing hormone (LH)
  - Ovaries stimulates ovulation, testes stimulates testosterone production
Hormones of the Anterior Pituitary

- Prolactin (PRL)
  - Promotes milk secretion by mammary glands

- Adrenocorticotropic hormone (ACTH) or corticotropin
  - Stimulates glucocorticoid secretion by adrenal cortex

- Melanocyte-stimulating Hormone (MSH)
  - Unknown role in humans
Effects of hGH and IGFs
1. Low blood glucose (hypoglycemia) stimulates release of GHRH.
2. GHRH stimulates secretion of hGH by somatotrophs.
3. hGH and IGFs speed up breakdown of liver glycogen into glucose, which enters the blood more rapidly.
4. Blood glucose level rises to normal (about 90 mg/100 mL).
5. If blood glucose continues to increase, hyperglycemia inhibits release of GHRH.
6. High blood glucose (hyperglycemia) stimulates release of GHIH.
7. GHIH inhibits secretion of hGH by somatotrophs.
8. A low level of hGH and IGFs decreases the rate of glycogen breakdown in the liver and glucose enters the blood more slowly.
9. Blood glucose level falls to normal (about 90 mg/100 mL).
10. If blood glucose continues to decrease, hypoglycemia inhibits release of GHIH.
Posterior pituitary

- Does not synthesize hormones
- Stores and releases hormones made by the hypothalamus
  - Transported along hypothalamohypophyseal tract
- Oxytocin (OT)
- Antidiuretic hormone (ADH) or vasopressin
Hypothalamohypophyseal tract

- Hypothalamus
- Pituitary gland
- Paraventricular nucleus
- Neurosecretory cell
- Supraoptic nucleus
- Optic chiasm
- Infundibulum
- Hypothalamohypophyseal tract
- Axon terminal
- Posterior pituitary
- Anterior pituitary
- Capillary plexus of the infundibular process

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Oxytocin (OT)

- During and after delivery of baby affects uterus and breasts
- Enhances smooth muscle contraction in wall of uterus
- Stimulates milk ejection from mammary glands
Antidiuretic Hormone (ADH)

- Decreases urine production by causing the kidneys to return more water to the blood
- Also decreases water lost through sweating and constriction of arterioles which increases blood pressure (vasopressin)
Osmoreceptors
High blood osmotic pressure stimulates hypothalamic osmoreceptors

Osmoreceptors activate the neurosecretory cells that synthesize and release ADH

Nerve impulses liberate ADH from axon terminals in the posterior pituitary into the bloodstream

Kidneys retain more water, which decreases urine output
Sudoriferous (sweat) glands decrease water loss by perspiration from the skin
Arterioles constrict, which increases blood pressure

Inhibition of osmoreceptors reduces or stops ADH secretion
Thyroid Gland

- Located inferior to larynx
- 2 lobes connected by isthmus
- Thyroid follicles produce thyroid hormones
  - Thyroxine or tetraiodothyronine ($T_4$)
  - Triiodothyronine ($T_3$)
    - Both increase BMR, stimulate protein synthesis, increase use of glucose and fatty acids for ATP production
- Parafollicular cells or C cells produce calcitonin
  - Lowers blood $Ca^{2+}$ by inhibiting bone resorption
Thyroid Gland

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Control of thyroid hormone secretion

- Thyrotropin-releasing hormone (TRH) from hypothalamus
- Thyroid-stimulating hormone (TSH) from anterior pituitary
- Situations that increase ATP demand also increase secretion of thyroid hormones
Actions of Thyroid Hormones:

Increase basal metabolic rate
Stimulate synthesis of Na⁺/K⁺ ATPase
Increase body temperature (calorogenic effect)
Stimulate protein synthesis
Increase the use of glucose and fatty acids for ATP production
Stimulate lipolysis
Enhance some actions of catecholamines
Regulate development and growth of nervous tissue and bones
Parathyroid Glands

- Embedded in lobes of thyroid gland
- Usually 4
- Parathyroid hormone (PTH) or parathormone
  - Major regulator of calcium, magnesium, and phosphate ions in the blood
  - Increases number and activity of osteoclasts
  - Elevates bone resorption
- Blood calcium level directly controls secretion of both calcitonin and PTH via negative feedback
Roles of Calcitonin, Parathyroid hormone, Calcitrol in Calcium Homeostasis
1. High level of Ca\(^{2+}\) in blood stimulates thyroid gland parafollicular cells to release more CT.

2. Low level of Ca\(^{2+}\) in blood stimulates parathyroid gland chief cells to release more PTH.

3. CALCITONIN inhibits osteoclasts, thus decreasing blood Ca\(^{2+}\) level.

4. PARATHYROID HORMONE (PTH) promotes release of Ca\(^{2+}\) from bone extracellular matrix into blood and slows loss of Ca\(^{2+}\) in urine, thus increasing blood Ca\(^{2+}\) level.

5. PTH also stimulates the kidneys to release CALCITRIOL.

6. CALCITRIOL stimulates increased absorption of Ca\(^{2+}\) from foods, which increases blood Ca\(^{2+}\) level.
Adrenal Glands

- 2 structurally and functionally distinct regions
  - Adrenal cortex
    - Mineralocorticoids affect mineral homeostasis
    - Glucocorticoids affect glucose homeostasis
      - cortisol
    - Androgens have masculinizing effects
      - Dehydroepiandrosterone (DHEA) only important in females
  - Adrenal medulla
    - Modified sympathetic ganglion of autonomic nervous system
    - Intensifies sympathetic responses
    - Epinephrine and norepinephrine
Adrenal Glands

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Pancreatic Islets

- Both exocrine and endocrine gland
- Roughly 99% of cells produce digestive enzymes
- Pancreatic islets or islets of Langerhans
  - Alpha or A cells secrete glucagon – raises blood sugar
  - Beta or B cells secrete insulin – lowers blood sugar
  - Delta or D cells secrete somatostatin – inhibits both insulin and glucagon
  - F cells secrete pancreatic polypeptide – inhibits somatostatin, gallbladder contraction, and secretion of pancreatic digestive enzymes
Pancreas
Negative Feedback Regulation of Glucagon and Insulin
Glucagon acts on hepatic cells to secrete:
- convert glycogen into glucose (glycogenolysis)
- form glucose from lactic acid and certain amino acids (gluconeogenesis)

Glucose released by hepatocytes raises blood glucose level to normal.

If blood glucose continues to rise, hyperglycemia inhibits release of glucagon.

High blood glucose (hyperglycemia) stimulates beta cells to secrete insulin.

Insulin acts on various body cells to:
- accelerate facilitated diffusion of glucose into cells
- speed conversion of glucose into glycogen (glycogenogenesis)
- increase uptake of amino acids and increase protein synthesis
- speed synthesis of fatty acids (lipogenesis)
- slow glycogenolysis
- slow gluconeogenesis

Blood glucose level falls.

If blood glucose continues to fall, hypoglycemia inhibits release of insulin.
Ovaries and Testes

- Gonads – produce gametes and hormones
- Ovaries produce 2 estrogens (estradiol and estrone) and progesterone
  - With FSH and LH regulate menstrual cycle, maintain pregnancy, prepare mammary glands for lactation, maintain female secondary sex characteristics
  - Inhibin inhibits FSH
  - Relaxin produced during pregnancy
- Testes produce testosterone – regulates sperm production and maintains male secondary sex characteristics
  - Inhibin inhibits FSH
Pineal Gland

- Attached to roof of 3rd ventricle of brain at midline
- Masses of neuroglia and pinealocytes
- Melatonin – amine hormone derived from serotonin
- Appears to contribute to setting biological clock
- More melatonin liberated during darkness than light
Thymus and Other Endocrine Tissues

- Thymus
  - Located behind sternum between the lungs
  - Produces thymosin, thymic humoral factor (THF), thymic factor (TF), and thymopoietin
  - All involved in T cell maturation
The Stress Response

- Eustress in helpful stress / Distress is harmful
- Body’s homeostatic mechanisms attempt to counteract stress
- Stressful conditions can result in stress response or general adaptation syndrome (GAS)
  - 3 stages – initial flight-or-fight, slower resistance reaction, eventually exhaustion
  - Prolonged exposure to cortisol can result in wasting of muscles, suppression of immune system, ulceration of GI tract, and failure of pancreatic beta cells