The Endocrine System

Objectives
• Compare the major chemical classes and general mechanisms of hormones.
• Describe the location and structure of the pituitary gland, and explain its relationship with the hypothalamus.
• Describe the location and structure of each of the endocrine glands.
• Identify the hormones produced by each of the endocrine glands and specify the functions of those hormones.
• Describe the functions of the hormones produced by the kidneys, heart, thymus, testes, ovaries, and adipose tissue.
• Explain how hormones interact to produce coordinated physiological responses.

Endocrine versus nervous system
• Nervous system performs short term crisis management
• Endocrine system regulates long term ongoing metabolic
• Endocrine communication is carried out by endocrine cells releasing hormones
  • Alter metabolic activities of tissues and organs by acting at target cells
• Paracrine communication involves chemical messengers between cells within one tissue

Endocrine system
• Includes all cells and endocrine tissues that produce hormones or paracrine factors

Hormone structure
• Amino acid derivatives
  • Structurally similar to amino acids
• Peptide hormones
  • Chains of amino acids
• Lipid derivatives
  • Steroid hormones and eicosanoids

Hormones can be
• Freely circulating
  • Rapidly removed from bloodstream
• Bound to transport proteins

Mechanisms of hormone action
• Receptors for catecholamines, peptide hormones, eicosanoids are in the cell membranes of target cells
• Thyroid and steroid hormones cross the membrane and bind to receptors in the cytoplasm or nucleus
The Pituitary Gland or Hypophysis
• Releases nine important peptide hormones
• All nine bind to membrane receptors and use cyclic AMP as a second messenger

The anterior lobe (adenohypophysis)
• Thyroid stimulating hormone (TSH)
  • Triggers the release of thyroid hormones from thyroid gland
  • Thyrotropin releasing hormone promotes the release of TSH
• Adrenocorticotropic hormone (ACTH)
  • Stimulates the release of glucocorticoids by the adrenal gland
  • Corticotrophin releasing hormone causes the secretion of ACTH
• Follicle stimulating hormone (FSH)
  • Stimulates follicle development/estrogen secretion in females; sperm in males
• Leutinizing hormone (LH)
  • Causes ovulation/progestin production in females; androgen production in males
• Gonadotropin releasing hormone (GNRH)
  • Promotes the secretion of FSH and LH
• Prolactin (PH)
  • Stimulates the development of mammary glands and milk production
• Growth hormone (GH or somatotropin)
  • Stimulates cell growth and replication
• Melanocyte stimulating hormone (MSH)
  • Stimulates melanocytes to produce melanin

The posterior lobe of the pituitary gland (neurohypophysis)
• Contains axons of hypothalamic nerves
• Antidiuretic hormone (ADH)
  • Decreases the amount of water lost at the kidneys
  • Elevates blood pressure
• Oxytocin (OT)
  • Stimulates contractile cells in mammary glands
  • Stimulates smooth muscle cells in uterus

The Thyroid Gland
• Lies near the thyroid cartilage of the larynx
• Two lobes connected by an isthmus
• Release several hormones such as thyroxine (T4) and triiodothyronine (T3)
• Hormones are bound to mitochondria, thereby increasing ATP production, control energy utilization, Exert a calorigenic effect
Cells of the thyroid gland
• C cells produce calcitonin (CT)
  • Helps regulate calcium concentration in body fluids
  • Works in a negative feedback mechanism with PTH

The Parathyroid Glands
• Four parathyroid glands
• Embedded in the posterior surface of the thyroid gland
• Chief cells produce parathyroid hormone (PTH) when Ca^{++} is low in fluids

The Adrenal Glands

Adrenal cortex
• Manufactures steroid hormones (corticosteroids)
• Cortex produces
  • Mineralocorticoids – increase renal reabsorption of Na^+ and H_2O
  • Glucocorticoids – glucose metabolism
  • Androgens – dominate sex hormone in females

Adrenal medulla
• Produces epinephrine (~75-80 percent)
• Produces norepinephrine (~25-30 percent)

The Pineal gland
• Synthesize melatonin
• Suggested functions include inhibiting reproductive function, protecting against damage by free radicals, setting circadian rhythms

The Pancreas

The pancreatic islets
• Clusters of endocrine cells within the pancreas called islets of Langerhans or pancreatic islets
  • Alpha cells secrete glucagons
  • Beta cells secrete insulin

Insulin and glucagon
• Insulin lowers blood glucose by increasing the rate of glucose uptake and utilization
• Glucagon raises blood glucose by increasing the rates of glycogen breakdown and glucose manufacture by the liver
**Diabetes mellitus** is high blood glucose

- high urine output (full of extra glucose)
- excessive thirst (loss of fluid)
- excessive hunger (glucose not entering cells)

**Type I** – Insulin-dependent – genetic (juvenile)

**Type II** – Non-insulin dependent (age onset) decrease in insulin cell receptors

> 90% all cases. Controlled by diet, exercise & drugs

Can also be gestational, or from reactions to drugs

**The Endocrine Tissues of Other Systems**

**The Intestines**

- Produce hormones important to the coordination of digestive activities

**The Kidneys**

- Produce calcitriol and erythropoietin (EPO) and the enzyme rennin
  - Calcitriol = stimulates Ca^{++} and phosphate ion absorption along the digestive tract
  - EPO stimulates red blood cell production by bone marrow
  - Renin converts angiotensinogen to angiotensin I

**Angiotensin I converted to angiotensin II in the lungs**

- Stimulates adrenal production of aldosterone
- Stimulates pituitary gland release of ADH
- Promotes thirst
- Elevates blood pressure

**The Heart**

- Specialized muscle cells produce natriuretic peptides when BP becomes excessive
  - Generally oppose actions of angiotensin II

**The Thymus**

- Produces thymosins
  - Help develop and maintain normal immune defenses

**The Gonads**

- Interstitial cells of the testes produce testosterone
  - Most important sex hormone in males
- In females, oocytes develop in follicles
  - Follicle cells produce estrogens
• After ovulation, the follicle cells form a corpus luteum that releases a mixture of estrogens and progesterone

**Adipose tissues secrete**
• Leptin, a feedback control for appetite
• Resistin, which reduces insulin sensitivity

**Hormones often interact, producing**
• Antagonistic (opposing) effects
• Synergistic (additive) effects
• Permissive effects (one hormone is required for the other to produce its effect)
• Integrative effects (hormones produce different but complimentary results)

**Hormones and growth**
• Normal growth requires the interaction of several endocrine organs
• Six hormones are important
  • GH
  • Thyroid hormones
  • Insulin
  • PTH
  • Calcitriol
  • Reproductive hormones

**Hormones and stress**
• Stress = any condition that threatens homeostasis
• GAS (General Adaptation Syndrome) is our bodies response to stress-causing factors
• Three phases to GAS
  • Alarm phase (immediate, fight or flight, directed by the sympathetic nervous system)
  • Resistance phase (dominated by glucocorticoids)
  • Exhaustion phase (breakdown of homeostatic regulation and failure of one or more organ systems)

**Hormones and behavior**
• Many hormones affect the CNS
• Changes in the normal mixture of hormones significantly alters intellectual capabilities, memory, learning, and emotional states

**Endocrine system**
• Few functional changes with age
  • Chief change is a decline in concentration of reproductive hormones