The Endocrine System

- Second messenger system of the body
- Uses chemical messages (hormones) that are released into the blood
- Hormones control several major processes
  - Reproduction
  - Growth and development
  - Mobilization of body defenses
  - Maintenance of much of homeostasis
  - Regulation of metabolism
Hormone Overview

- Hormones are produced by specialized cells
- Cells secrete hormones into extracellular fluids
- Blood transfers hormones to target sites
- These hormones regulate the activity of other cells
The Chemistry of Hormones

- Amino acid-based hormones
  - Proteins
  - Peptides
  - Amines
- Steroids – made from cholesterol
- Prostaglandins – made from highly active lipids
Mechanisms of Hormone Action

- Hormones affect only certain tissues or organs (target cells or organs)
- Target cells must have specific protein receptors
- Hormone binding influences the working of the cells
Effects Caused by Hormones

- Changes in plasma membrane permeability or electrical state
- Synthesis of proteins, such as enzymes
- Activation or inactivation of enzymes
- Stimulation of mitosis
Steroid Hormone Action

- Diffuse through the plasma membrane of target cells
- Enter the nucleus
- Bind to a specific protein within the nucleus
- Bind to specific sites on the cell’s DNA
- Activate genes that result in synthesis of new proteins
Steroid Hormone Action

(a) Steroid hormone action

Figure 9.1a
Nonsteroid Hormone Action

- Hormone binds to a membrane receptor
- Hormone does not enter the cell
- Sets off a series of reactions that activates an enzyme
- Catalyzes a reaction that produces a second messenger molecule
- Oversees additional intracellular changes to promote a specific response
Nonsteroid Hormone Action

Figure 9.1b

(b) Nonsteroid hormone action
Control of Hormone Release

- Hormone levels in the blood are maintained by negative feedback.
- A stimulus or low hormone levels in the blood triggers the release of more hormone.
- Hormone release stops once an appropriate level in the blood is reached.
Hormonal Stimuli of Endocrine Glands

- Endocrine glands are activated by other hormones

Figure 9.2a

(a) Hormonal

- The hypothalamus secretes hormones that...
- ...stimulate the anterior pituitary gland to secrete hormones that...
- ...stimulate other endocrine glands to secrete hormones.
Humoral Stimuli of Endocrine Glands

- Changing blood levels of certain ions stimulate hormone release

Figure 9.2b
Neural Stimuli of Endocrine Glands

- Nerve impulses stimulate hormone release
- Most are under control of the sympathetic nervous system
Location of Major Endocrine Organs

- Pineal gland
- Hypothalamus
- Pituitary gland
- Thyroid gland
- Parathyroid glands (on dorsal aspect of thyroid gland)
- Thymus gland
- Adrenal glands
- Pancreas
- Ovary (female)
- Testis (male)

Figure 9.3
Pituitary Gland

- Size of a grape
- Hangs by a stalk from the hypothalamus
- Protected by the sphenoid bone
- Has two functional lobes
  - Anterior pituitary – glandular tissue
  - Posterior pituitary – nervous tissue
Hormones of the Anterior Pituitary

- Six anterior pituitary hormones
  - Two affect non-endocrine targets
  - Four stimulate other endocrine glands (tropic hormones)

- Characteristics of all anterior pituitary hormones
  - Proteins (or peptides)
  - Act through second-messenger systems
  - Regulated by hormonal stimuli, mostly negative feedback
Hormones of the Anterior Pituitary

Figure 9.4

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Growth Hormone (GH)

- General metabolic hormone
- Major effects are directed to growth of skeletal muscles and long bones
- Causes amino acids to be built into proteins
- Causes fats to be broken down for a source of energy
Functions of Other Anterior Pituitary Hormones

- Prolactin (PRL)
  - Stimulates and maintains milk production following childbirth
  - Function in males is unknown
- Adrenocorticotropic hormone (ACTH)
  - Regulates endocrine activity of the adrenal cortex
- Thyroid-stimulating hormone (TSH)
  - Influences growth and activity of the thyroid
Functions of Other Anterior Pituitary Hormones

- Gonadotropic hormones
  - Regulate hormonal activity of the gonads
    - Follicle-stimulating hormone (FSH)
      - Stimulates follicle development in ovaries
      - Stimulates sperm development in testes
Functions of Other Anterior Pituitary Hormones

- Gonadotrophic hormones (continued)
  - Luteinizing hormone (LH)
    - Triggers ovulation
    - Causes ruptured follicle to become the corpus luteum
    - Stimulates testosterone production in males
      - Referred to as interstitial cell-stimulating hormone (ICSH)
Pituitary - Hypothalamus Relationship

- Release of hormones is controlled by releasing and inhibiting hormones produced by the hypothalamus.
- Hypothalamus produces two hormones that are transported to neurosecretory cells of the posterior pituitary.
- The posterior pituitary is not strictly an endocrine gland, but does release hormones.
Hormones of the Posterior Pituitary

- **Oxytocin**
  - Stimulates contractions of the uterus during labor
  - Causes milk ejection

- **Antidiuretic hormone (ADH)**
  - Can inhibit urine production
  - In large amounts, causes vasoconstriction leading to increased blood pressure (vasopressin)
Hormones of the Posterior Pituitary

Figure 9.5

- Hypothalamic neurosecretory cells
- Optic chiasma
- Axon terminals
- Arterial blood supply
- Posterior lobe
- Capillary bed
- Anterior lobe of the pituitary
- Venous drainage
- ADH
  - Kidney tubules
- Oxytocin
  - Mammary glands
  - Uterine muscles
Thyroid Gland

- Found at the base of the throat
- Consists of two lobes joined by central mass or isthmus
- Produces two hormones
  - Thyroid hormone
  - Calcitonin
Thyroid Gland

Figure 9.6

(a)

Thyroid cartilage
Common carotid artery
Trachea
Brachiocephalic artery
Aorta
Isthmus of thyroid gland
Left subclavian artery
Left lobe of thyroid gland
Thyroid Hormone

- Major metabolic hormone
- Composed of two active iodine-containing hormones
  - Thyroxine (T\textsubscript{4}) – secreted by thyroid follicles
  - Triiodothyronine (T\textsubscript{3}) – conversion of T\textsubscript{4} at target tissues
Calcitonin

- Decreases blood calcium levels by causing its deposition on bone
- Antagonistic to parathyroid hormone
- Produced by C (parafollicular) cells
Parathyroid Glands

- Tiny masses on the posterior of the thyroid
- Secrete parathyroid hormone
  - Stimulate osteoclasts to remove calcium from bone and release it into the blood
  - Stimulate the kidneys and intestine to absorb more calcium
  - Raises calcium levels in the blood
Adrenal Glands

- Two glands
  - Cortex – outer glandular region in three layers
  - Medulla – inner neural tissue region
- Sits on top of the kidneys
Hormones of the Adrenal Cortex

- Mineralocorticoids (mainly aldosterone)
  - Produced in outer adrenal cortex
  - Regulate mineral content in blood, water, and electrolyte balance
  - Target organ is the kidney
  - Production stimulated by renin and aldosterone
  - Production inhibited by atrial natriuretic peptide
Hormones of the Adrenal Cortex

Figure 9.10

- Decreased blood volume and/or blood pressure
- Stress
- Hypothalamus
  - CRH
- Anterior pituitary
  - ACTH
- Increased blood pressure or blood volume
- Heart
- Atrial natriuretic peptide (ANP)

Decreased Na⁺ or increased K⁺ in blood

Direct stimulating effect

Indirect effect via angiotensin

Mineralocorticoid-producing part of adrenal cortex

Enhanced secretion of aldosterone targets kidney tubules

Increased absorption of Na⁺ and water; increased K⁺ excretion

Increased blood volume and blood pressure
Hormones of the Adrenal Cortex

- Glucocorticoids (including cortisone and cortisol)
  - Produced in the middle layer of the adrenal cortex
  - Promote normal cell metabolism
  - Help resist long-term stressors
  - Released in response to increased blood levels of ACTH
Hormones of the Adrenal Cortex

• Sex hormones
  • Produced in the inner layer of the adrenal cortex
  • Androgens (male) and some estrogen (female)
Hormones of the Adrenal Medulla

- Produces two similar hormones (catecholamines)
  - Epinephrine
  - Norepinephrine
- These hormones prepare the body to deal with short-term stress
Roles of the Hypothalamus and Adrenal Glands in the Stress Response

**Short term**
- Hypothalamus
  - Nerve impulses
  - Spinal cord
  - Preganglionic sympathetic fibers
  - Adrenal medulla
  - Catecholamines (Epinephrine and norepinephrine)

**More prolonged**
- Stress
  - Releasing hormone
  - Corticotrope cells of anterior pituitary
  - ACTH
  - Adrenal cortex
  - Mineralocorticoids
  - Glucocorticoids

**Short-term stress response**
1. Increased heart rate
2. Increased blood pressure
3. Liver converts glycogen to glucose and releases glucose to blood
4. Dilation of bronchioles
5. Changes in blood flow patterns, leading to increased alertness and decreased digestive and kidney activity
6. Increased metabolic rate

**Long-term stress response**
1. Retention of sodium and water by kidneys
2. Increased blood volume and blood pressure
3. Proteins and fats converted to glucose or broken down for energy
4. Increased blood sugar
5. Suppression of immune system

Figure 9.12

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Pancreatic Islets

- The pancreas is a mixed gland
- The islets of the pancreas produce hormones
  - Insulin – allows glucose to cross plasma membranes into cells from beta cells
  - Glucagon – allows glucose to enter the blood from alpha cells
- These hormones are antagonists that maintain blood sugar homeostasis
Pancreatic Islets

Figure 9.13

- Exocrine cells of pancreas
- Beta (β) cell
- Capillaries
- Alpha (α) cells
- Cord of β cells secreting insulin into capillaries
Pancreatic Hormones and Blood Sugar

Figure 9.14

Insulin-secreting cells of the pancreas activated; release insulin into the blood

Uptake of glucose from blood is enhanced in most body cells

Blood glucose levels decline to set point; stimulus for insulin release diminishes

Elevated blood sugar levels

Liver takes up glucose and stores it as glycogen

Stimulus: rising blood glucose levels (e.g., after eating four jelly doughnuts)

Imbalance

Homeostasis: Normal blood glucose levels (90 mg/100ml)

Stimulus: declining blood glucose levels (e.g., after skipping a meal)

Low blood sugar levels

Rising blood glucose levels return blood sugar to homeostatic set point; stimulus for glucagon release diminishes

Liver breaks down glycogen stores and releases glucose to the blood

Glucagon-releasing cells of pancreas activated; release glucagon into blood; target is the liver

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Pineal Gland

- Found on the third ventricle of the brain
- Secretes melatonin
  - Helps establish the body’s wake and sleep cycles
  - May have other as-yet-unsubstantiated functions
Thymus

- Located posterior to the sternum in upper thorax
- Largest in infants and children
- Produces thymosin
  - Matures some types of white blood cells
  - Important in developing the immune system
Hormones of the Ovaries

- **Estrogens**
  - Produced by Graafian follicles of the ovaries or the placenta
  - Stimulates the development of secondary female characteristics
  - Matures female reproductive organs
  - Helps prepare the uterus to receive a fertilized egg
  - Helps maintain pregnancy
  - Prepares the breasts to produce milk
Hormones of the Ovaries

- Progesterone
  - Produced by the corpus luteum
  - Acts with estrogen to bring about the menstrual cycle
  - Helps in the implantation of an embryo in the uterus
Hormones of the Testes

- Interstitial cells of testes are hormone-producing
- Produce several androgens
- Testosterone is the most important androgen
  - Responsible for adult male secondary sex characteristics
  - Promotes growth and maturation of male reproductive system
  - Required for sperm cell production
Other Hormone-Producing Tissues and Organs

- Parts of the small intestine
- Parts of the stomach
- Kidneys
- Heart
- Placenta – temporary organ
- Some tumors
- Many other areas have scattered endocrine cells
Endocrine Function of the Placenta

- Produces hormones that maintain the pregnancy
- Some hormones play a part in the delivery of the baby
- Produces human chorionic gonadotropin (HCG) in addition to estrogen, progesterone, and other hormones
Developmental Aspects of the Endocrine System

- Most endocrine organs operate smoothly until old age
  - Menopause is brought about by lack of efficiency of the ovaries
  - Problems associated with reduced estrogen are common – osteoporosis
  - Growth hormone production declines with age
  - Many endocrine glands decrease output with age