20.1 Overview of the Endocrine System

- **The endocrine system** consists of glands and tissues that secrete hormones.
- **Hormones** are chemicals that affect other glands or tissues, located far away from the sites of hormone production.
- Like the nervous system, the endocrine system influences other organ systems in maintaining homeostasis.
  - Influence on cellular metabolism, growth and development

**Growth factors** – hormones that promote cell division and mitosis

- **Local hormones** – not carried by the blood
  - Affect tissues locally
  - Ex: prostaglandins
20.1 Overview of the Endocrine System

- **Endocrine glands**
  - Have no ducts
  - Secrete hormones into tissue fluid
  - Hormones diffuse into the bloodstream

- **Exocrine glands**
  - Secrete their products through ducts
    - Ex: salivary glands send saliva to the mouth through salivary ducts

---

Hormones and Homeostasis

- Homeostasis requires cooperation between the endocrine and nervous systems.

<table>
<thead>
<tr>
<th>Endocrine System</th>
<th>Nervous System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Secretes hormones into the blood</td>
<td>Transmits nerve impulses</td>
</tr>
<tr>
<td>Slower response</td>
<td>Faster response</td>
</tr>
<tr>
<td>More prolonged response</td>
<td>Less prolonged response</td>
</tr>
</tbody>
</table>

- The blood concentration of a substance prompts an endocrine gland to secrete its hormones.
  - Ex: The parathyroid gland secretes a hormone when blood Ca$^{2+}$ level falls below normal.
  - Osteoclasts respond to hormone by slowly releasing Ca$^{2+}$ from bone.
  - It takes time for the response, but it is long-lasting.
The Endocrine System

Table 20.1: Principal Endocrine Glands and Hormones

<table>
<thead>
<tr>
<th>Principal Endocrine Gland</th>
<th>Reference Hormone(s)</th>
<th>Chemical Class</th>
<th>Target Tissue(s)</th>
<th>Chief Functions of Hormone(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypothalamus</td>
<td>Multiple hormones</td>
<td>Small peptides</td>
<td>Central nervous system</td>
<td>Control of pituitary gland secretion</td>
</tr>
<tr>
<td>Pituitary</td>
<td>Multiple hormones</td>
<td>Small peptides</td>
<td>Endocrine organs</td>
<td>Growth, reproductive, and stress responses</td>
</tr>
<tr>
<td>Thyroid</td>
<td>Thyroxine, calcitonin</td>
<td>Amines, peptides</td>
<td>Muscles, bones, heart</td>
<td>Energy metabolism, growth, and development</td>
</tr>
<tr>
<td>Parathyroid</td>
<td>Parathyroid hormone</td>
<td>Amino acid衍生物s</td>
<td>Bones, muscles</td>
<td>Calcium homeostasis</td>
</tr>
<tr>
<td>Adrenal</td>
<td>Cortisol, aldosterone</td>
<td>Hormones, peptides</td>
<td>Kidneys, liver</td>
<td>Blood glucose regulation, metabolism of lipids and proteins</td>
</tr>
<tr>
<td>Gonads</td>
<td>Estrogen, testosterone</td>
<td>Steroids, proteins</td>
<td>Reproductive organs</td>
<td>Reproduction, growth, and development</td>
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</tbody>
</table>

Table 20.2: Principal Endocrine Glands and Hormones

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Figure 20.1: The Endocrine System Diagram
Hormones and Homeostasis

- Production of most hormones controlled by two things
  - Negative feedback
    - Sensitive to either the condition it regulates or the blood level of the hormone it is producing
  - Action of other hormones
    - Insulin and glucagon

- Example of negative feedback
  - As the blood glucose level rises, the pancreas secretes insulin.
  - Insulin causes the liver to store glucose, and glucose is removed from the blood.
  - The stimulus for insulin production is, thereby, inhibited.
  - The pancreas stops secreting insulin.
Hormones and Homeostasis

- Hormone regulation by release of an antagonistic hormone
  - The effect of insulin is offset by the secretion of glucagon.
  - Insulin lowers the blood sugar level, while glucagon raises it.

The Action of Hormones

- Hormones act on target cells.
  - May increase uptake of a substance
  - May bring about alteration of structure of target cell
- Hormones fall into two chemical classes.
  - Peptide hormones – peptides, proteins, glycoproteins or modified amino acids
  - Steroid hormones – same complex of four rings, but varying side chains

The Action of Hormones

- Hormones function as chemical signals.
  - Chemical signals - a means of communication between cells, body parts, or even individuals
  - Typically affect the metabolism of target cells with appropriate receptors
    - For peptide hormones, receptors on cell surface
    - For steroid hormones, receptors inside cell (cytoplasm or nucleus)
The Action of Hormones

- The peptide hormone initiates a chemical signaling process after binding to its receptor; it serves as the first messenger.
- The activated receptor leads to the production of a second messenger, (cAMP is most common).
- The 2nd messenger sets in motion an enzymatic cascade.
- Each enzyme, in turn, activates another enzyme.
- During each step in the cascade, more reactions occur (1000-fold response possible).
The Action of Hormones

- The steroid hormone has an alternate way because it can diffuse through the target cell membrane.
- The hormone can bind to its receptor either in the cytoplasm or nucleus.
- The hormone receptor complex then binds to DNA to activate transcription of a certain gene into mRNA.
- mRNA translation results in enzymes or other proteins that can carry out a response to the hormone.

Steroid Hormone Action

Pheromones

- **Pheromones** are chemical signals that act between individuals of the same species.
  - Effects better known in animals other than humans
    - Ex: female moths release an attractant that acts on male moths even miles away
  - Humans do produce pheromones
    - Airborne chemicals released by scalp, oral cavity, axilla, genital areas
    - Possibly plays role in mate attraction
    - Axillary secretions can affect the menstrual cycle
20.2 Hypothalamus and Pituitary Gland

- The **hypothalamus** regulates the internal environment in two ways.
  - Through the autonomic nervous system
    - Heartbeat, blood pressure, appetite, body temperature, water balance
  - Through control of **pituitary gland** secretions
    - Posterior pituitary
    - Anterior pituitary

Posterior Pituitary

- Neurons in the hypothalamus called **neurosecretory cells** produce **antidiuretic hormone** (ADH) and oxytocin.
  - Hormones travel down axons and are stored in axon terminals in the **posterior pituitary**.

Posterior Pituitary

- **ADH - Antidiuretic hormone**
  - Released from posterior pituitary in response to increased concentration of blood (not enough water)
  - Causes increased reabsorption of water in the kidneys
    - As water reabsorption occurs, the blood concentration becomes normal and ADH is shut off.
### Posterior Pituitary

- **Oxytocin**
  - Causes uterine contractions and milk letdown during lactation
  - Neurological impulses from pressure and irritation of uterus causes oxytocin release
  - Oxytocin causes contractions which causes more pressure and irritation \( \Rightarrow \) more oxytocin \( \Rightarrow \) more contractions
  - An example of positive feedback

### Anterior Pituitary

- A **portal system**, consisting of two capillary networks connected by a vein, lies between the hypothalamus and the anterior pituitary.
  - Hypothalamus controls the anterior pituitary by producing
    - **Hypothalamic-releasing hormones**
      - Stimulates the anterior pituitary gland to release certain hormones
    - **Hypothalamic-inhibiting hormones**
      - Prevents the secretion of certain hormones

### Anterior Pituitary

- Three anterior pituitary hormones have target effects on other glands.
  - **Thyroid-stimulating hormone** (TSH) stimulates the thyroid gland to produce thyroid hormones.
  - **Adrenocorticotropic hormone** (ACTH) stimulates the adrenal cortex to produce glucocorticoids.
  - **Gonadotrophic hormones** (FSH and LH) stimulate the gonads to produce estrogen and testosterone.
20.2 Hypothalamus and Pituitary Gland

- Anterior Pituitary
  - In each instance, the blood level of the last hormone in the hypothalamus-anterior pituitary-target gland control system exerts negative feedback over secretions of the first two structures.

Anterior Pituitary

- Three anterior pituitary hormones do not affect other glands.
  - **Prolactin (PRL)** stimulates the mammary glands to synthesize milk.
  - **Melanocyte-stimulating hormone (MSH)** stimulates the pigment-producing melanocytes of the skin.
  - **Growth hormone (GH)** stimulates bone and muscle growth and increases protein synthesis and fat metabolism.

Hypothalamus and the Pituitary

Figure 20.5
20.3 Thyroid and Parathyroid Glands

• The **thyroid gland** is a large gland located in the neck.
  – Attached to the trachea just below larynx
• The **parathyroid glands** are embedded in the posterior surface of the thyroid gland.

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**Thyroid Gland**

• Thyroid gland has many follicles, each a small spherical structure of thyroid cells that produce
  – **Triiodothyronine** \( (T_3) \) (three iodine atoms)
  – **Thyroxine** \( (T_4) \) (four iodine atoms)
• Thyroid requires iodine to produce these hormones
  – Iodine deficiency causes simple goiter
• \( T_3 \) and \( T_4 \) increase metabolic rate
  – Stimulate most body cells to metabolize glucose and utilize more energy

---

**Thyroid Gland**

• Thyroid gland also produces **calcitonin**
  – Calcium-regulating hormone
  – Produced in response to increased blood calcium levels
  – Causes uptake of calcium by bone
  • Calcium is important in muscle contraction, nerve conduction, and blood clotting
Parathyroid Glands

- Parathyroid glands produce parathyroid hormone (PTH)
  - Causes an increase in blood calcium and a decrease in blood phosphate
  - Increases osteoclast activity and the reabsorption of calcium by the kidneys
    - Also stimulates activation of vitamin D needed for calcium absorption in the digestive tract
  - When blood calcium levels increase, PTH is shut off

Regulation of Blood Calcium Level

20.4 Adrenal Glands

- The adrenal glands sit atop the kidneys.
  - Two parts of the adrenal gland that function independently
    - Adrenal medulla (outer portion)
      - Under the control of the nervous system
    - Adrenal cortex (inner portion)
      - Under the control of adrenocorticotropic hormone (ACTH), an anterior pituitary hormone
Adrenal Medulla

• The hypothalamus initiates nerve impulses by way of the brain stem, spinal cord, and sympathetic nerves to the **adrenal medulla**.
• The adrenal medulla secretes two hormones
  – Epinephrine (adrenaline)
  – Norepinephrine (NE)
• Epinephrine and norepinephrine bring rapid short-term changes.
  – Response to stress (fight or flight response)

Adrenal Cortex

• Hormones of the **adrenal cortex** result in long-term changes.
  – Two types of hormones
    • **Glucocorticoids**
      – Regulate carbohydrate, protein, and fat metabolism leading to an increase in blood glucose level
    • **Mineralocorticoids**
      – Regulate salt and water balance leading to an increase in blood volume and blood pressure

Adrenal Cortex: Glucocorticoids

• **Cortisol** is the principal glucocorticoid hormone stimulated by ACTH.
• Actions
  – Promotes breakdown of muscle proteins to amino acids
    • Liver uses amino acids to make glucose
  – Promotes metabolism of fatty acids, spares glucose
  – Overall: Promotes a rise in blood glucose
    • Beneficial under stress
  – Counteracts inflammatory response
    • Can also suppress the immune system
Adrenal Cortex: Mineralocorticoids

- Mineralocorticoid secretion is not controlled by the anterior pituitary.
  - **Aldosterone** is the principal mineralocorticoid hormone that targets the kidney.
    - Increases absorption of Na⁺, excretion of K⁺
    - Regulates blood volume and pressure
    - Secretion controlled through release of renin from the kidney

Adrenal Cortex: Mineralocorticoids

- **Renin**
  - Released when blood Na⁺ levels and blood pressure are low
  - Activates angiotensinogen to angiotensin I
  - Converts angiotensin I to angiotensin II by enzyme in lung capillaries
  - Angiotensin II stimulates adrenal cortex to release aldosterone
  - Effect: Angiotensin II constricts arterioles
    - Aldosterone causes the kidneys to reabsorb sodium.
    - Blood pressure rises.

Regulation of Blood Pressure and Volume

[Diagram of blood pressure regulation]

Figure 20.8
Adrenal Cortex: Mineralocorticoids

- **Atrial natriuretic hormone (ANH)**
  - Produced when atria of the heart are stretched
  - Represents an increase in blood volume
  - Inhibits the release of aldosterone
  - Results in natriuresis: excretion of Na\(^+\) in the urine
  - Water follows passively so blood volume and therefore pressure decreases

---

20.5 Pancreas

- **Pancreas** is composed of two types of tissue
  - The exocrine portion secretes digestive enzymes released into the small intestine by ducts.
  - **Pancreatic islets** are the endocrine portion of the gland.
    - Three types of endocrine islet cells
      - **Alpha cells** produce glucagon
      - **Beta cells** produce insulin
      - **Delta cells** produce somatostatin
20.5 Pancreas

- **Insulin**
  - Released after eating
  - Stimulates uptake of glucose by cells
    - Especially muscle, liver, and adipose cells
    - Decreases blood glucose

- **Glucagon**
  - Released before eating when glucose is low
  - Targets liver and adipose tissue
  - Increases blood glucose

---

**Regulation of Blood Glucose Level**

Figure 20.9

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**20.5 Pancreas**

- **Somatostatin**
  - Also known as growth hormone inhibiting hormone
  - Also produced by cells in the stomach and small intestine
  - Main effects
    - Inhibit release of growth hormone by the anterior pituitary
    - Suppress the release of various hormones produced by the digestive system, including insulin and glucagon
20.6 Other Endocrine Glands

- The gonads are the testes in males and the ovaries in females.
- The gonads are endocrine glands.
- Other glands and certain tissues also produce hormones.

Testes and Ovaries

- **Testes**
  - Produce sperm and **androgens** (e.g., **testosterone**)
  - Responsible for male secondary sex characteristics
    - Beard growth, enlargement of vocal cords and larynx
  - Stimulate oil production by oil glands
  - Involved in pattern baldness
  - Responsible for increased muscle development

Testes and Ovaries

- Some athletes take supplemental amounts of illegal anabolic steroids.
  - Include testosterone or related chemicals
  - Many side effects from taking anabolic steroids
    - Acne
    - Body odor
    - Baldness
Testes and Ovaries

- **Ovaries**
  - Produce eggs, estrogen, and progesterone
  - **Estrogen**
    - Stimulates growth of uterus and vagina
    - Required for egg maturation
    - Responsible for secondary sex characteristics
      - Breast development along with progesterone
      - Breast development along with estrogen
    - Body hair
  - **Progesterone**
    - Regulation of uterine cycle along with estrogen

Thymus and Pineal Glands

- **Thymus gland**
  - Largest and most active during childhood
  - Secretes *thymosins*, hormones involved with maturation of T-lymphocytes

- **Pineal gland**
  - Produces melatonin
    - Involved with sleep/wake cycles and circadian rhythms
Hormones from Other Tissues

- Some organs usually not considered endocrine glands can secrete hormones.
- The heart produces natriuretic hormone.
- The stomach and small intestine produce hormones that regulate digestive secretions.
- Other tissues secrete hormones.

Leptin

- **Leptin**
  - Leptin is a protein hormone produced by adipose tissue.
  - Leptin stimulates the satiety center in the hypothalamus to signal that an individual has had enough to eat.
  - It is thought that leptin in obese individuals may be ineffective.

Growth Factors

- **Growth factors**
  - Stimulate mitosis in tissues
  - Some released in blood, others act locally
    - **Granulocyte-macrophage colony-stimulating factor**
      - Produced by many different tissues
      - Causes bone marrow stem cells to produce granulocytes and macrophages
    - **Platelet-derived growth factor**
      - Wound healing
    - **Epidermal growth factor and nerve growth factor**
      - Wound healing
Prostaglandins

- **Prostaglandins**
  - Produced from arachidonic acid
  - Act locally; effects depend on location
    - Muscle contractions in uterus
    - Mediation of pyrogens’ effects

20.8 Disorders of the Endocrine System

- The endocrine glands play a major role in regulating the development and function of many body systems.
- An increase or decrease in production of a hormone can cause significant disease.
- Cancer often causes an increase in hormone secretion by affecting the gland.
- Various conditions that destroy glands result in decreased secretion of a hormone.

Disorders of the Pituitary Gland

- **Diabetes insipidus (DI)**
  - The posterior pituitary secretes too little ADH. (antidiuretic hormone)
    - Large amounts of urine are produced, resulting in dehydration.
- **Pituitary dwarfism**
  - Too little growth hormone is secreted by the anterior pituitary.
    - Condition is characterized by small stature but normal proportions.
Disorders of the Pituitary Gland

- **Gigantism**
  - Excess growth hormone is produced during childhood.
  - Gigantism also promotes the development of diabetes mellitus.

![Gigantism Image](image)

Figure 20.11

- **Acromegaly**
  - Excess growth hormone in adulthood
  - Long bones cannot grow, so the effect is noticeable in the hands, feet, and facial bones.

![Acromegaly Image](image)

Figure 20.12

- **Cushing Syndrome**
  - Excess production of ACTH (usually by tumor)
  - Adrenal cortex then produces excess cortisol
  - Protein is metabolized, fat is deposited in the midsection

![Cushing Syndrome Image](image)

Figure 20.13
Disorders of the Thyroid, Parathyroid and Adrenal Glands

- **Hypothyroidism**
  - Not enough thyroid hormone is produced.
  - Failure of thyroid function in infancy or childhood results in *congenital hypothyroidism*.
    - Individuals are short and stocky; mental retardation results if treatment does not begin within 1st two months of life
  - Treatment consists of the administration of thyroid hormones.

- **Hashimoto thyroiditis** is a form of hypothyroidism that occurs in adults.
  - The immune system produces antibodies that destroy the thyroid gland.
  - *Myxedema* is a group of clinical symptoms in adults not treated for the condition.
    - Symptoms include: weight gain, hair loss, constipation or slow heart rate
  - Treatment is the administration of thyroid hormones.
Disorders of the Thyroid, Parathyroid and Adrenal Glands

• Goiter
  – Lack of dietary iodine makes the thyroid unable to produce sufficient T3 and T4.
  – The thyroid gland is consequently constantly stimulated by TSH.
  – The result is an enlarged thyroid gland.

Disorders of the Thyroid, Parathyroid and Adrenal Glands

• Hyperthyroidism
  – Results from oversecretion of thyroid hormones
    • Graves disease arises from antibodies reacting with the TSH receptor, mimicking effect of TSH.
      – Symptoms include protruding eyes, nervousness, hyperactivity, and abnormal heart rhythms.

Disorders of the Thyroid, Parathyroid and Adrenal Glands

• Disorders of the parathyroid
  – Insufficient parathyroid production results in a drop in blood calcium levels.
  – The body shakes from continuous muscle contraction (tetany).
Disorders of the Thyroid, Parathyroid and Adrenal Glands

- Disorders of the adrenal glands
  - Addison disease
    - The most common cause is destruction of the adrenal cortex by the immune system.
    - Symptoms include weakness, weight loss, abdominal pain, and a bronzing of the skin.
    - Decreased production of mineral corticoids can affect Na\(^+\) and K\(^+\) levels, which can adversely affect the heart.

![Image](https://via.placeholder.com/150)

Diabetes Mellitus

- Diabetes mellitus
  - Affects an estimated 25.8 million Americans, or 8.3% of the population (as of 2010)
  - Affects ability to regulate glucose metabolism
    - Type 1 sufferers do not produce enough insulin.
    - Type 2 sufferers cannot use insulin produced.
      - Blood glucose rises, glucose and water are lost in the urine
      - Cells do not take up the glucose
      - Causes increased thirst, increased hunger
    - A glucose tolerance test is often used for diagnosis.

![Image](https://via.placeholder.com/150)

Glucose Tolerance Test

![Graph](https://via.placeholder.com/150)
Diabetes Mellitus

- Two types of diabetes mellitus
  - **Type 1** – insulin-dependent
    - Lack of insulin may be due to exposure to environmental agent, such as a virus, or an autoimmune condition.
    - As cells break down fats for energy, ketones build up in the blood.
      - Ketoacidosis → coma → death
    - Insulin overdose can cause hypoglycemia, unconsciousness
      - Immediate ingestion of glucose required to counteract

- **Type 2**
  - Insulin-resistant
  - Linked to obesity - adipose tissue may produce a substance that impairs insulin receptor function
  - Insulin levels often low - cells may not have sufficient insulin receptors
  - Controlled by diet, exercise, medications

---

The following graphs display blood glucose and insulin levels in people with normal insulin response, and Type 1 and Type 2 diabetics.
Diabetes Mellitus

- Diabetics need to monitor their blood sugar several times daily, regardless of which diabetes type they have.
- Monitoring is usually done by poking a finger to obtain blood drops to be tested using an external device.
- New testing devices are being introduced.
- Insulin pumps are replacing the needle and syringe as an injection method.

Long-term complication of diabetes

- Blindness
- Kidney disease
- Cardiovascular disorders
  - Can lead to reduced blood flow to limbs (gangrene)
- Diabetic coma in pregnancy (if not managed)
  - The child has a higher risk of being stillborn or dying shortly after birth.