About This Chapter

- Hormones
- The classification of hormones
- Control of hormone release
- Hormone interactions
- Endocrine pathologies
- Hormone evolution

Hormones: Function

- Control
  - Rates of enzymatic reactions
  - Transport of ions or molecules across cell membranes
  - Gene expression and protein synthesis

Figure 7.1 An endocrine disorder in ancient art
### Figure 7.2-2 ANATOMY SUMMARY – Hormones

<table>
<thead>
<tr>
<th>Location</th>
<th>Hormone</th>
<th>Primary Target(s)</th>
<th>Main Effect(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pineal gland</td>
<td>Melatonin [A]</td>
<td>Brain, other tissues</td>
<td>Circadian rhythm; immune function; antioxidant</td>
</tr>
<tr>
<td>Hypothalamus (N)</td>
<td>Trophic hormones [P] (see Fig. 7.8)</td>
<td>Anterior pituitary</td>
<td>Release or inhibit pituitary hormones</td>
</tr>
<tr>
<td>Posterior pituitary (N)</td>
<td>Oxytocin [P]</td>
<td>Breast and uterus</td>
<td>Milk ejection; labor and delivery; behavior</td>
</tr>
<tr>
<td>Anterior pituitary (G)</td>
<td>Prolactin [P]</td>
<td>Breast</td>
<td>Milk production</td>
</tr>
<tr>
<td></td>
<td>Growth hormone (somatotropin) [P]</td>
<td>Adrenal cortex</td>
<td>Growth factor secretion</td>
</tr>
<tr>
<td>Corticotropin (ACTH) [P]</td>
<td>Thyrotropin (TSH) [P]</td>
<td>Thyroid gland</td>
<td>Growth and metabolism</td>
</tr>
<tr>
<td>Follicle-stimulating hormone [P]</td>
<td>Thyroid gland</td>
<td>Gonads</td>
<td>Thyroid hormone synthesis</td>
</tr>
<tr>
<td>Luteinizing hormone [P]</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**KEY**
- G = gland
- C = endocrine cells
- N = neurons
- P = peptide
- S = steroid
- A = amino acid–derived

### Figure 7.2-3 ANATOMY SUMMARY – Hormones

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<tr>
<th>Location</th>
<th>Hormone</th>
<th>Primary Target(s)</th>
<th>Main Effect(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thyroid gland</td>
<td>Triiodothyronine and thyroxine [A]</td>
<td>Many tissues</td>
<td>Metabolism, growth, and development</td>
</tr>
<tr>
<td></td>
<td>Calcitonin [P]</td>
<td>Bone</td>
<td>Plasma calcium levels (minimal effect in humans)</td>
</tr>
<tr>
<td>Parathyroid gland</td>
<td>Parathyroid hormone [P]</td>
<td>Bone, kidney</td>
<td>regulates plasma Ca²⁺ and phosphate levels</td>
</tr>
<tr>
<td>Thymus gland</td>
<td>Thymus, thymopoietin [P]</td>
<td>Lymphocytes</td>
<td>Lymphocyte development</td>
</tr>
<tr>
<td>Heart (C)</td>
<td>Atrial natriuretic peptide [P]</td>
<td>Kidney</td>
<td>Increases Na⁺ secretion</td>
</tr>
<tr>
<td>Liver (G)</td>
<td>Angiotensinogen [P]</td>
<td>Adrenal cortex, blood vessels</td>
<td>Aldosterone secretion; increases blood pressure</td>
</tr>
<tr>
<td></td>
<td>Insulin-like growth factors [P]</td>
<td>Many tissues</td>
<td>Growth</td>
</tr>
<tr>
<td>Pancreas (G)</td>
<td>Glicentin, cholecystokinin, secretin, and others [P]</td>
<td>Many tissues</td>
<td>Assist digestion and absorption of nutrients</td>
</tr>
</tbody>
</table>

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### Figure 7.2-4 ANATOMY SUMMARY – Hormones

<table>
<thead>
<tr>
<th>Location</th>
<th>Hormone</th>
<th>Primary Target(s)</th>
<th>Main Effect(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adrenal cortex (G)</td>
<td>Aldosterone [S]</td>
<td>Kidney</td>
<td>Na⁺ and K⁺ homeostasis</td>
</tr>
<tr>
<td></td>
<td>Cortisol [S]</td>
<td>Many tissues</td>
<td>Stress response</td>
</tr>
<tr>
<td>Kidney (C)</td>
<td>Epinephrine [P]</td>
<td>Many tissues</td>
<td>Fight-or-flight response</td>
</tr>
<tr>
<td></td>
<td>1,25 Dihydroxy-vitamin D³ (calcidiol) [S]</td>
<td>Bone marrow</td>
<td>Red blood cell production</td>
</tr>
<tr>
<td>Skin (C)</td>
<td>Vitamin D³ [S]</td>
<td>Intermediate form of hormone</td>
<td>Increases calcium absorption</td>
</tr>
</tbody>
</table>

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### Figure 7.2-5 ANATOMY SUMMARY – Hormones

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<thead>
<tr>
<th>Location</th>
<th>Hormone</th>
<th>Primary Target(s)</th>
<th>Main Effect(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Testes (male) (G)</td>
<td>Androgens [S]</td>
<td>Many tissues</td>
<td>Sperm production, secondary sex characteristics</td>
</tr>
<tr>
<td></td>
<td>Testosterone [P]</td>
<td>Anterior pituitary</td>
<td>Inhibits FSH secretion</td>
</tr>
<tr>
<td>Ovaries (female) (G)</td>
<td>Estrogen, progesterone [S]</td>
<td>Many tissues</td>
<td>Egg production, secondary sex characteristics</td>
</tr>
<tr>
<td></td>
<td>Estriol [P]</td>
<td>Anterior pituitary</td>
<td>Inhibits FSH secretion</td>
</tr>
<tr>
<td>Adipose tissue (C)</td>
<td>Leptin, adiponectin, melatonin</td>
<td>Many tissues</td>
<td>Hypothalamic, other tissues</td>
</tr>
<tr>
<td>Placenta (pregnant females only) (C)</td>
<td>Estrogen, progesterone [S]</td>
<td>Many tissues</td>
<td>Metabolism</td>
</tr>
<tr>
<td></td>
<td>Chorionic somatomammotropin [P]</td>
<td>Many tissues</td>
<td>Hormone secretion</td>
</tr>
</tbody>
</table>

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Hormones

- Cell-to-cell communication molecules
  - Chemical signals
  - Secreted by a cell or group of cells
  - Transported by blood
  - Distant target tissue receptors
  - Activates physiological response at low concentrations
- Pheromones: elicit physiological or behavioral response on other organisms of the same species

Hormones: Classification by Chemical Class

- Peptide or protein hormones
- Steroid hormones
- Amino acid–derived or amine hormones
### Table 7.1 Comparison of Peptide, Steroid, and Amino Acid-Derived Hormones

<table>
<thead>
<tr>
<th>Hormone Type</th>
<th>Synthesis and Storage</th>
<th>Release from Parent Cell</th>
<th>Transport in Blood</th>
<th>Half-Life</th>
<th>Location of Receptor</th>
<th>Response to Receptor-Ligand Binding</th>
<th>General Target Response</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peptide/protein hormone</td>
<td>Made in advance; stored in secretory vesicles</td>
<td>Exocytosis</td>
<td>Dissolved in plasma</td>
<td>Short</td>
<td>Cell membrane</td>
<td>Activation of second messenger systems; may activate genes</td>
<td>Modification of existing proteins and induction of new protein synthesis</td>
<td>Insulin, parathyroid hormone, estrogen, androgens, cortisol, epinephrine, norepinephrine, thyroid hormone (T₄)</td>
</tr>
<tr>
<td>Steroid hormone</td>
<td>Made in advance; stored in secretory vesicles</td>
<td>Simple diffusion</td>
<td>Bound to carrier protein</td>
<td>Long</td>
<td>Cytoplasm or nucleus; some have membrane receptors also</td>
<td>Activation of genes for transcription and translation; may have nongenomic actions</td>
<td>Induction of new protein synthesis</td>
<td>Estrogen, androgens, cortisol, thyroid hormone (T₄)</td>
</tr>
<tr>
<td>Amino acid (Tyrosine Derivative) Hormone</td>
<td>Made in advance; stored in secretory vesicles</td>
<td>Exocytosis</td>
<td>Dissolved in plasma</td>
<td>Short</td>
<td>Cell membrane</td>
<td>Activation of second messenger systems</td>
<td>Modification of existing proteins</td>
<td>Epinephrine, norepinephrine</td>
</tr>
<tr>
<td>Thyroid hormone</td>
<td>Made in advance; precursor stored in secretory vesicles</td>
<td>Simple diffusion</td>
<td>Bound to carrier protein</td>
<td>Long</td>
<td>Nucleus</td>
<td>Activation of genes for transcription and translation</td>
<td>Induction of new protein synthesis</td>
<td>Thyroid hormone (T₄)</td>
</tr>
</tbody>
</table>

**Figure 7.3 ESSENTIALS – Peptide Hormone Synthesis and Processing**

- Messenger RNA on the ribosomes binds amino acids into a peptide chain called a preprohormone. This chain is directed into the ER lumen by a signal sequence of amino acids.
Messenger RNA on ribosomes binds amino acids into a peptide chain called a preprohormone. This chain is directed into the ER lumen by a signal sequence of amino acids.

Enzymes in the ER chop off the signal sequence, creating an inactive prohormone.

The prohormone passes from the ER through the Golgi complex.

Secretory vesicles containing enzymes and prohormone bud off the Golgi. The enzymes chop the prohormone into one or more active peptides plus additional peptide fragments.

The secretory vesicle releases its contents by exocytosis into the extracellular space.
Messenger RNA on the ribosomes binds amino acids into a polypeptide chain called a preprohormone. The polypeptide chain is directed into the ER lumen by a signal sequence of amino acids.

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The secretory vesicle releases its contents by exocytosis into the extracellular space. The hormone moves into the circulation for transport to its target.

PreproTRH (thyrotropin-releasing hormone) has six copies of the 3-amino acid hormone TRH.

PreproTRH (242 amino acids)

6 TRH

Other peptide fragments

The peptide chain of insulin's prohormone folds back on itself with the help of disulfide (S—S) bonds. The prohormone cleaves to insulin and C-peptide.
Endocrine System Review

Interactive Physiology® Animation: Endocrine System: Endocrine System Review

Hormones: Steroid

- Cholesterol-derived
  - Lipophilic and easily cross membranes
- Bind carrier proteins in blood
  - Longer half-life
- Cytoplasmic or nuclear receptors
  - Genomic effect to activate or repress genes for protein synthesis
  - Slower acting
- Cell membrane receptors
  - Nongenomic responses
Steroid hormones act primarily on intracellular receptors.

1. Most hydrophobic steroids are bound to plasma protein carriers. Only unbound hormones can diffuse into the target cell.
2. Steroid hormone receptors are in the cytoplasm or nucleus.
3. Some steroid hormones also bind to membrane receptors that use second messenger systems to create rapid cellular responses.
4. The receptor-hormone complex binds to DNA and activates or represses one or more genes.
5. Activated genes create new mRNA that moves back to the cytoplasm.
6. Translation produces new proteins for cell processes.

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Activated genes create new mRNA that moves back to the cytoplasm.

Hormones: Amino Acid–Derived, or Amine

- Derived from one of two amino acids
  - Tryptophan
  - Tyrosine
- Ring structure
Amine Hormones: Examples

- Melatonin
- Catecholamines
  - Epinephrine
  - Norepinephrine
  - Dopamine
- Thyroid hormones

FIGURE QUESTION Determine how each catecholamine molecule differs from the tyrosine molecule.

Tyrosine is the parent amino acid for catecholamines and thyroid hormones.

Catecholamines are made by modifying the side groups of tyrosine.

Thyroid hormones are synthesized from two tyrosines and iodine (I) atoms.

Thyroxine (Tetraiodothyronine, T₄)

Triiodothyronine (T₃)

Endocrine Reflex Pathways

- Stimulus
- Sensor
- Input signal
- Integration
- Output (efferent) signal (hormone in blood)
- Targets
- Response physiological action
- Negative feedback
The Actions of Hormones on Target Cells

Interactive Physiology® Animation: Endocrine System: The Actions of Hormones on Target Cells

Chapter 7b

Introduction to the Endocrine System
Neurohormones: Major Groups

- Adrenal medulla
  - Catecholamines
- Hypothalamus
  - Posterior pituitary is neural tissue
  - Anterior pituitary is endocrine tissue

The pituitary gland sits in a protected pocket of bone, connected to the brain by a thin stalk. Infundibulum is the stalk that connects the pituitary to the brain. Posterior pituitary is an extension of the neural tissue. Anterior pituitary is a true endocrine gland of epithelial origin.
Neurohormone is made and packaged in cell body of neuron.
Vesicles are transported down the cell.
Vesicles containing neurohormone are stored in posterior pituitary.
Neurohormones are released into blood.

Neurohormones from the hypothalamus control release of the anterior pituitary hormones. The hypothalamic hormones reach the anterior pituitary through a specialized region of the circulation called a portal system.

Endocrine cells release their peptide hormones into the second set of capillaries for distribution to the rest of the body.

The anterior pituitary is a true endocrine gland that secretes six classic hormones. Neurohormones from the hypothalamus control release of the anterior pituitary hormones. The hypothalamic hormones reach the anterior pituitary through a specialized region of the circulation called a portal system.
Endocrine Control

- A trophic hormone controls the secretion of another hormone
- Hypothalamic-hypophyseal portal system
- Three integrating centers
  - Hypothalamic stimulation—from CNS
  - Anterior pituitary stimulation—from hypothalamic trophic hormones
  - Endocrine gland stimulation—from anterior pituitary trophic hormones (except prolactin)
Hormone Interactions

- **Synergism**
  - Combined effect is greater than the sum of individual effects
- **Permissiveness**
  - Need second hormone to get full effect
- **Antagonism**
  - One substance opposes the action of another
  - Competitive inhibitors vs. functional antagonism
  - Glucagons oppose insulin

Endocrine Pathologies

- **Hypersecretion**: excess hormone
  - Caused by tumors or exogenous iatrogenic treatment
  - Negative feedback
- **Hyposecretion**: deficient hormone
  - Caused by decreased synthesis materials or atrophy
  - Absence of negative feedback
Pathologies: Abnormal Receptors

- Down-regulation
  - Decreased number of receptors
  - Hyperinsulinemia
- Receptor and signal transduction abnormalities
  - Testicular feminization syndrome
  - Pseudohypothyroidism
Hormone Evolution

- Evolutionary conservation of hormone function
- Proteomics
  - Calcitonin gene-related peptide example
- Vestigial
  - Melanocyte-stimulating hormone example
- Comparative endocrinology
  - Pineal gland and melatonin example

The pineal gland is a pea-sized structure buried deep in the brain of humans. Nearly 2000 years ago, its "seat of the soul" was thought to act as a valve that regulated the flow of vital spirits and knowledge into the brain. By 1950, however, scientists had decided that it was a vestigial structure with no known function.

Melatonin is the "darkness hormone," secreted at night as we sleep. It is the chemical messenger that transmits information about light-dark cycles to the brain center that governs the body's biological clock.

Melatonin is an amino acid–derived hormone made from tryptophan.

Summary

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- The classification of hormones
- Control of hormone release
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- Endocrine pathologies
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