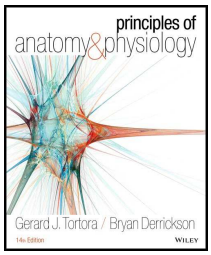


Principles of Anatomy and Physiology

14th Edition

CHAPTER 18

The Endocrine System

Comparison of Control by the Nervous and Endocrine Systems

- The **nervous** and **endocrine** systems act together to coordinate all systems of the body.
- The nervous system releases **neurotransmitters**; the endocrine system releases **hormones**.
- Most hormones circulate through the blood and bind to receptors on **"target cells."**
- Neurotransmitters also bind to receptors on "target" cells.

Comparison of Control by the Nervous and Endocrine Systems

TABLE 18.1

Comparison of Control by the Nervous and Endocrine Systems

CHARACTERISTIC	NERVOUS SYSTEM	ENDOCRINE SYSTEM
Mediator molecules	Neurotransmitters released locally in response to nerve impulses.	Hormones delivered to tissues throughout body by blood.
Site of mediator action	Close to site of release, at synapse; binds to receptors in postsynaptic membrane.	Far from site of release (usually); binds to receptors on or in target cells.
Types of target cells	Muscle (smooth, cardiac, and skeletal) cells, gland cells, other neurons.	Cells throughout body.
Time to onset of action	Typically within milliseconds (thousandths of a second).	Seconds to hours or days.
Duration of action	Generally briefer (milliseconds).	Generally longer (seconds to days).

Endocrine Glands

- **Exocrine glands** secrete their products into ducts. None of these are hormones.
- These glands include **sudoriferous (sweat)** glands, **sebaceous (oil)** glands, **mucous** glands, **digestive** glands and several other throughout the body.

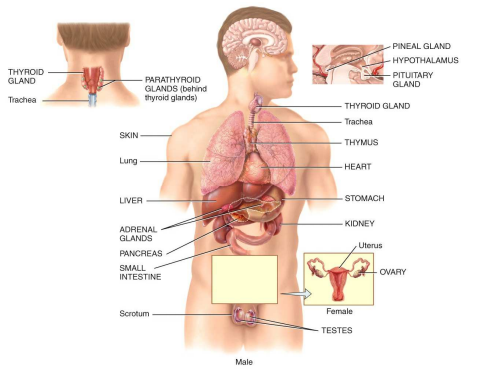
Endocrine Glands

- **Endocrine glands** secrete **hormones**. They do not have ducts and secrete their hormones directly into the **interstitial fluid** that surrounds them.
- The hormones diffuse into the blood stream through capillaries and are carried to **target cells** throughout the body.
- Endocrine glands include the **pituitary**, **thyroid**, **parathyroid**, **adrenal** and **pineal glands**.

Endocrine Glands

Certain organs and tissues that are not part of the endocrine system also secrete hormones. These include the **hypothalamus**, **thymus**, **pancreas**, **ovaries**, **testes**, **kidneys**, **stomach**, **liver**, **small intestine**, **skin**, **heart**, **adipose tissue** and **placenta**.

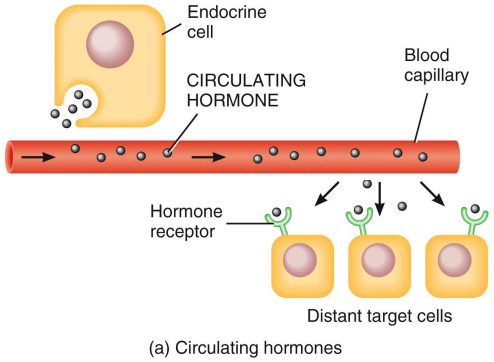
Endocrine Glands



Hormone Activity

- Hormones traveling throughout the body will only affect **target cells** that possess specific **protein receptors**.
- Receptors are continually being synthesized and broken down.
- Receptors may be **down-regulated** in the presence of high concentrations of hormone.
- Receptors may be **up-regulated** in the presence of low concentrations of hormone.

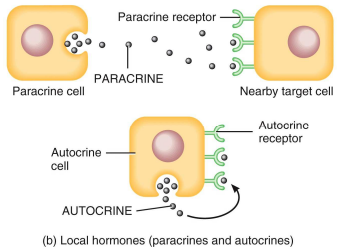
Hormone Activity



(a) Circulating hormones

Hormone Activity

Hormones that don't circulate are **local hormones (paracrines)**. Those that act on the same cell that secretes them are **autocrines**.



(b) Local hormones (paracrines and autocrines)

Hormone Activity

- Hormones are either **lipid-soluble** (steroid hormones, thyroid hormones, nitric oxide) or **water-soluble** (amine hormones, peptide and protein hormones, eicosanoid hormones).
- Water-soluble hormones circulate freely in the **plasma**.
- Lipid-soluble hormones circulate bound to **transport proteins**.

Hormone Activity

TABLE 18.2

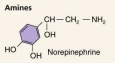
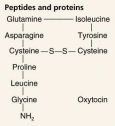
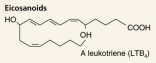
Summary of Hormones by Chemical Class

CHEMICAL CLASS	HORMONES	SITE OF SECRETION
LIPID-SOLUBLE		
Steroid hormones	Aldosterone, cortisol, androgens.	Adrenal cortex.
	Calcitriol.	Kidneys.
	Testosterone.	Testes.
	Estrogens, progesterone.	Ovaries.
Aldosterone		
Thyroid hormones	T_3 (triiodothyronine), T_4 (thyroxine).	Thyroid gland (follicular cells).
Triiodothyronine (T_3)		
Gas	Nitric oxide (NO).	Endothelial cells lining blood vessels.

Hormone Activity

TABLE 18.2

Summary of Hormones by Chemical Class

CHEMICAL CLASS	HORMONES	SITE OF SECRETION
WATER-SOLUBLE		
Amines  Norepinephrine	Epinephrine, norepinephrine (catecholamines).	Adrenal medulla.
	Melatonin.	Pineal gland.
	Histamine.	Mast cells in connective tissues.
	Serotonin.	Platelets in blood.
Peptides and proteins 	All hypothalamic releasing and inhibiting hormones.	Hypothalamus.
	Oxytocin, antidiuretic hormone.	Posterior pituitary.
	Human growth hormone, thyroid-stimulating hormone, adrenocorticotropic hormone, follicle-stimulating hormone, luteinizing hormone, prolactin, melanocyte-stimulating hormone.	Anterior pituitary.
	Insulin, glucagon, somatostatin, pancreatic polypeptide.	Pancreas.
	Parathyroid hormone.	Parathyroid glands.
	Calcitonin.	Thyroid gland (parafollicular cells).
	Gastrin, secretin, cholecystokinin, GIP (glucose-dependent insulinotropic peptide).	Stomach and small intestine (enteroendocrine cells).
	Erythropoietin.	Kidneys.
	Leptin.	Adipose tissue.
Eicosanoids  A leukotriene (LTB_4)	Prostaglandins, leukotrienes.	All cells except red blood cells.

Mechanisms of Hormone Action

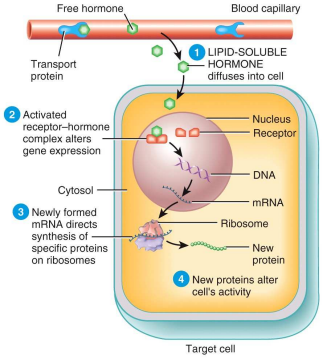
Responses to the same hormone may vary depending on the hormone itself and the target cell.

The response may be:

- Synthesis of new molecules
- Changing permeability of the cell membrane
- Stimulating transport of a substance into or out of the cell
- Altering the rate of metabolic actions
- Causing contraction of smooth or cardiac muscle

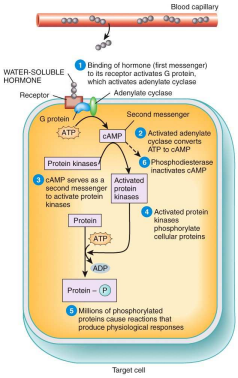
Mechanisms of Hormone Action

Lipid-soluble hormones bind to receptors within target cells.



Mechanisms of Hormone Action

Water-soluble hormones bind to receptors on the exterior surface of the target cell.



Mechanisms of Hormone Action

How a target cell responds to a hormone is based on:

- The hormone's concentration in the blood
- The number of hormone receptors on the target cell
- Influences exerted by other hormones
- Some hormones work more effectively when a second hormone is present to assist them (**synergistic effect**).
- Some hormones oppose the action of others (**antagonistic effect**).

Control of Hormone Secretion

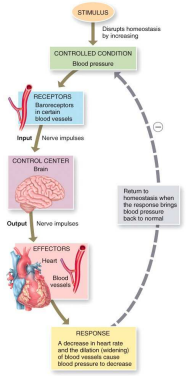
Hormones are secreted in short bursts when needed.

Secretion is regulated by:

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

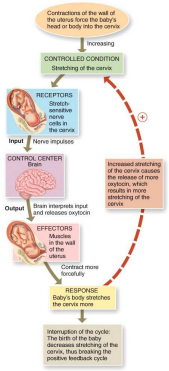
Control of Hormone Secretion

Most hormone regulation is achieved via **negative feedback**.



Control of Hormone Secretion

A few hormones operate via **positive feedback**.



Control of Hormone Secretion

Interactions Animation:

- Hormonal Cycles

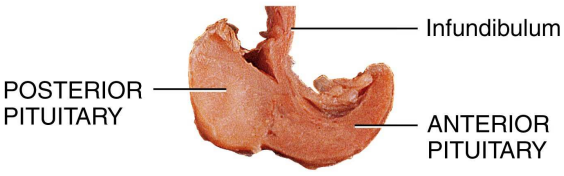
You must be connected to the Internet and in Slideshow Mode to run this animation.

Hypothalamus and Pituitary Gland

The **hypothalamus** and **pituitary gland** work together to control other endocrine glands. They are connected by the **infundibulum**.

Hypothalamus and Pituitary Gland

Dissection Shawn Miller,
Photograph Mark Nielsen

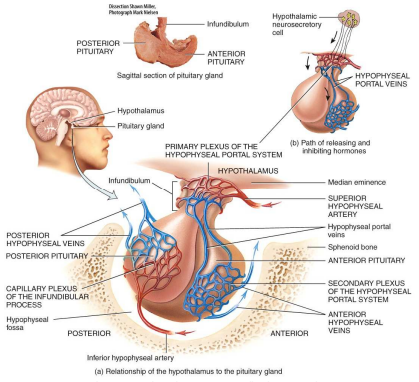


Sagittal section of pituitary gland

Hypothalamus and Pituitary Gland

- The **anterior lobe (adenohypophysis)** makes up 75% of the weight of the pituitary gland and secretes **7 hormones**.
- The **posterior lobe (neurohypophysis)** is made of neural tissue and releases two hormones made by the **hypothalamus**.
- The **hypothalamus** secretes **releasing** and **inhibiting hormones** that control the release of hormones by the pituitary gland. They reach the pituitary gland via the **hypophyseal portal system**.

Hypothalamus and Pituitary Gland



Hypothalamus and Pituitary Gland

The anterior pituitary gland secretes 7 hormones produced by 5 different types of cells.

TABLE 18.3

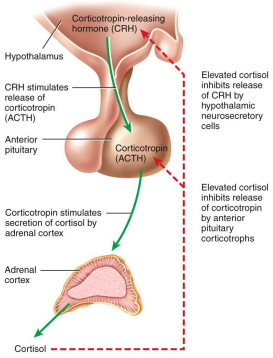
Hormones of the Anterior Pituitary

HORMONE	SECRETED BY	HYPOTHALAMIC RELEASING HORMONE (STIMULATES SECRETION)	HYPOTHALAMIC INHIBITING HORMONE (SUPPRESSES SECRETION)
Human growth hormone (hGH), also known as somatotropin	Somatotrophs.	Growth hormone–releasing hormone (GHRH), also known as somatocrinin.	Growth hormone–inhibiting hormone (GHIH), also known as somatostatin.
Thyroid-stimulating hormone (TSH), also known as thyrotropin	Thyrotrophs.	Thyrotropin-releasing hormone (TRH).	Growth hormone–inhibiting hormone (GHIH).
Follicle-stimulating hormone (FSH)	Gonadotrophs.	Gonadotropin-releasing hormone (GnRH).	—
Luteinizing hormone (LH)	Gonadotrophs.	Gonadotropin-releasing hormone (GnRH).	—
Prolactin (PRL)	Lactotrophs.	Prolactin-releasing hormone (PRRH).*	Prolactin-inhibiting hormone (PIH), which is dopamine.
Adrenocorticotropic hormone (ACTH), also known as corticotropin	Corticotrophs.	Corticotropin-releasing hormone (CRH).	—
Melanocyte-stimulating hormone (MSH)	Corticotrophs.	Corticotropin-releasing hormone (CRH).	Dopamine.

*Thought to exist, but exact nature is uncertain.

Hypothalamus and Pituitary Gland

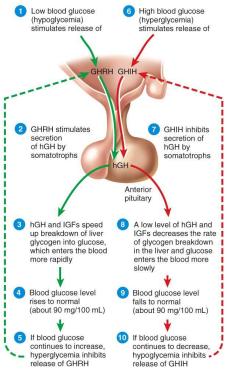
Negative feedback loops control the secretions of **thyrotrophs, gonadotrophs and corticotrophs**.



Hypothalamus and Pituitary Gland

- **Human growth hormone (hGH)** is the most plentiful anterior pituitary hormone.
- It is released in bursts every few hours by **somatotrophs**.
- Their activity is controlled by two hypothalamic hormones: **growth hormone-releasing hormone (GHRH) and growth hormone-inhibiting hormone (GHIH)**.

Hypothalamus and Pituitary Gland



Hypothalamus and Pituitary Gland

In summary, the anterior pituitary gland secretes **human growth hormone (hGH), thyroid-stimulating hormone (TSH), follicle-stimulating hormone (FSH), luteinizing hormone (LH), prolactin (PRL), adrenocorticotropic hormone (ACTH) and melanocyte-stimulating hormone (MSH).**

Hypothalamus and Pituitary Gland

TABLE 18.4

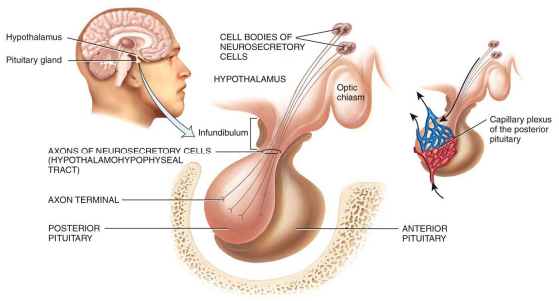
Summary of the Principal Actions of Anterior Pituitary Hormones

HORMONE	TARGET TISSUES	PRINCIPAL ACTIONS
Human growth hormone (hGH), also known as somatotropin	Liver (and other tissues)	Stimulates liver, muscle, cartilage, bone, and other tissues to synthesize and secrete insulinlike growth factors (IGFs); IGFs promote growth of body cells, protein synthesis, tissue repair, lipolysis, and elevation of blood glucose concentration.
Thyroid-stimulating hormone (TSH), also known as thyrotropin	Thyroid gland	Stimulates synthesis and secretion of thyroid hormones by thyroid gland.
Follicle-stimulating hormone (FSH)	Ovary; Testis	In females, initiates development of oocytes and induces ovarian secretion of estrogens. In males, stimulates testes to produce sperm.
Luteinizing hormone (LH)	Ovary; Testis	In females, stimulates secretion of estrogens and progesterone, ovulation, and formation of corpus luteum. In males, stimulates testes to produce testosterone.
Prolactin (PRL)	Mammary glands	Together with other hormones, promotes milk production by mammary glands.
Adrenocorticotropic hormone (ACTH), also known as corticotropin	Adrenal cortex	Stimulates secretion of glucocorticoids (mainly cortisol) by adrenal cortex.
Melanocyte-stimulating hormone (MSH)	Brain	Exact role in humans is unknown but may influence brain activity; when present in excess, can cause darkening of skin.

Hypothalamus and Pituitary Gland

- The **posterior pituitary gland** does not synthesize any hormones, but stores and releases from axon terminals two hormones produced by the **neurosecretory cells of the hypothalamus: oxytocin (OT) and anti-diuretic hormone (ADH)**.
- Axons from the neurosecretory cells form the **hypothalamohypophyseal tract**.

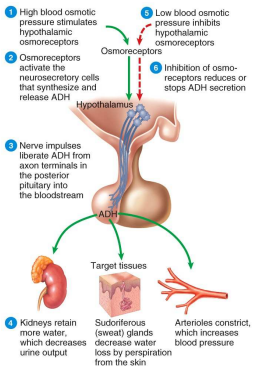
Hypothalamus and Pituitary Gland



Hypothalamus and Pituitary Gland

- The amount of **antidiuretic hormone (ADH)** secreted varies with blood osmotic pressure. Its function is to decrease urine output. **Osmoreceptors** (neurons) in the hypothalamus monitor blood osmotic pressure.
- An increase in blood volume causes a decrease in ADH secretion.
- A decrease in blood volume causes an increase in ADH secretion.

Hypothalamus and Pituitary Gland



Hypothalamus and Pituitary Gland

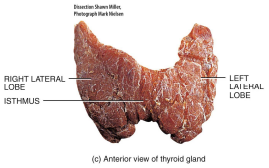
TABLE 18.5

Summary of Posterior Pituitary Hormones

HORMONE AND TARGET TISSUES	CONTROL OF SECRETION	PRINCIPAL ACTIONS
Oxytocin (OT) Uterus, Mammary glands	Neurosecretory cells of hypothalamus secrete OT in response to uterine distension and stimulation of nipples.	Stimulates contraction of smooth muscle cells of uterus during childbirth; stimulates contraction of myoepithelial cells in mammary glands to cause milk ejection.
Antidiuretic hormone (ADH) or vasopressin dneys, ud r er us s oat glands, rter les	Neurosecretory cells of hypothalamus secrete ADH in response to elevated blood osmotic pressure, dehydration, loss of blood volume, pain, or stress; inhibitors of ADH secretion include low blood osmotic pressure, high blood volume, and alcohol.	Conserves body water by decreasing urine volume; decreases water loss through perspiration; raises blood pressure by constricting arterioles.

Thyroid Gland

The **thyroid gland** is a butterfly-shaped gland located inferior to the larynx and anterior to the trachea. It has **right and left lateral lobes connected by an isthmus**. Some glands also have a **pyramidal lobe** projecting from the isthmus.

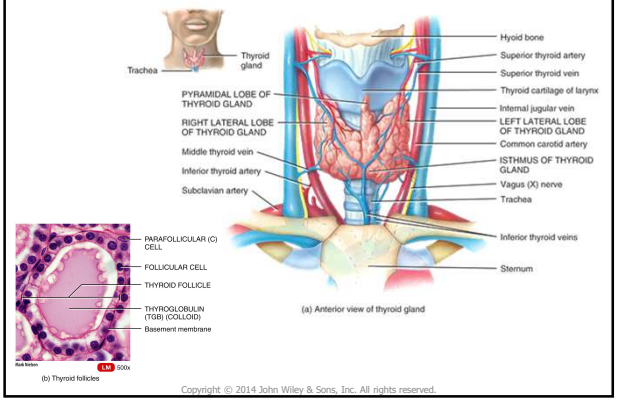


(c) Anterior view of thyroid gland

Thyroid Gland

- **Follicular cells** are stimulated by **TSH** to produce **thyroxine (tetraiodothyronine, T_4)** and **triiodothyronine (T_3)** known as **thyroid hormones**.
- **Parafollicular cells** produce the hormone **calcitonin** to help regulate calcium homeostasis.

Thyroid Gland

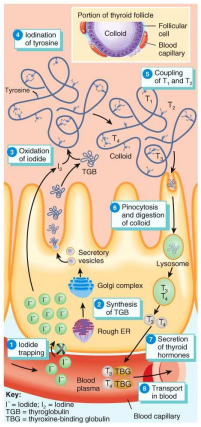


(a) Anterior view of thyroid gland

(b) Thyroid follicles

Thyroid Gland

T_3 and T_4 are synthesized and secreted in an 8 step process.



Thyroid Gland

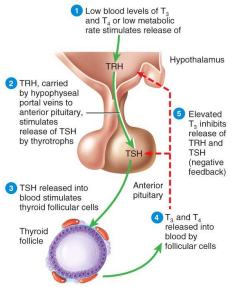
Thyroid hormones:

- Increase **basal metabolic rate (BMR)**
- Help maintain normal body temperature
- Stimulate protein synthesis
- Increase the use of glucose and fatty acids for ATP production
- Upregulate beta (β) receptors that attach to catecholamines
- Work with hGH and insulin to accelerate body growth

Thyroid Gland

Thyrotropin-releasing hormone (TRH) from the hypothalamus and **thyroid-stimulating hormone (TSH)** from the anterior pituitary stimulate synthesis and release of thyroid hormones in a 5 step process.

Thyroid Gland



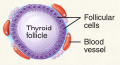
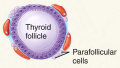
Actions of Thyroid Hormones:

- Increase basal metabolic rate
- Stimulate synthesis of Na^+/K^+ ATPase
- Increase body temperature (calorigenic 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

Thyroid Gland

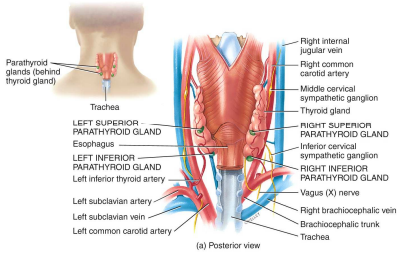
TABLE 18.6

Summary of Thyroid Gland Hormones

HORMONE AND SOURCE	CONTROL OF SECRETION	PRINCIPAL ACTIONS
T_4 (triiodothyronine) and T_3 (thyroxine) or thyroid hormones from follicular cells 	Secretion is increased by thyrotropin-releasing hormone (TRH), which stimulates release of thyroid-stimulating hormone (TSH) in response to low thyroid hormone levels, low metabolic rate, cold, pregnancy, and high altitudes; TRH and TSH secretions are inhibited in response to high thyroid hormone levels; high iodine level suppresses T_3/T_4 secretion.	Increase basal metabolic rate; stimulate synthesis of proteins; increase use of glucose and fatty acids for ATP production; increase lipolysis; enhance cholesterol excretion; accelerate body growth; contribute to development of nervous system.
Calcitonin (CT) from parafollicular cells 	High blood Ca^{2+} levels stimulate secretion; low blood Ca^{2+} levels inhibit secretion.	Lowers blood levels of Ca^{2+} and HPO_4^{2-} by inhibiting bone resorption by osteoclasts and by accelerating uptake of calcium and phosphates into bone extracellular matrix.

Parathyroid Glands

Located on the posterior aspect of each lobe of the thyroid gland are 2 **parathyroid glands** (one inferior and one superior).

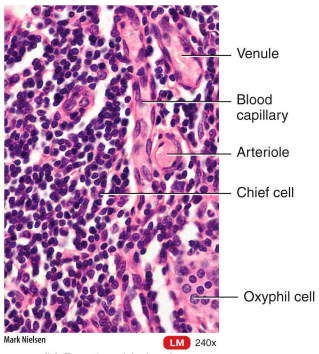


(a) Posterior view

Parathyroid Glands

- Parathyroid glands contain 2 types of cells:
  - **Chief cells (principal cells)** that produce **parathyroid hormone (PTH, parathormone)**
  - **Oxyphil cells** whose function is not known in normal parathyroid glands but which secrete excess PTH in cases of parathyroid cancer

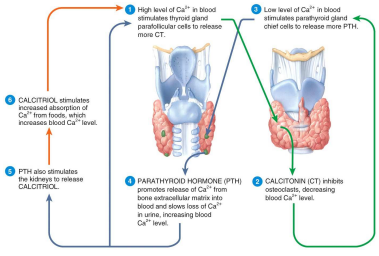
Parathyroid Glands



(b) Parathyroid gland

Parathyroid Glands

Calcitonin produced by the thyroid gland works in conjunction with **PTH** and **calcitriol** to regulate calcium homeostasis.



Parathyroid Glands

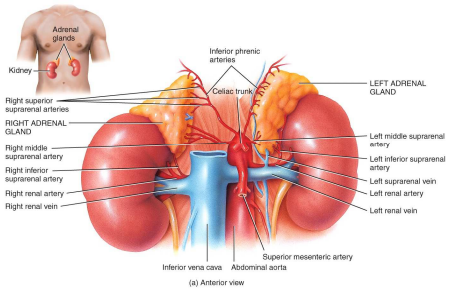
TABLE 18.7

Summary of Parathyroid Gland Hormone

HORMONE AND SOURCE	CONTROL OF SECRETION	PRINCIPAL ACTIONS
Chief cell  **Parathyroid hormone (PTH)** from chief cells	Low blood Ca^{2+} levels stimulate secretion; high blood Ca^{2+} levels inhibit secretion.	Increases blood Ca^{2+} and Mg^{2+} levels and decreases blood HPO_4^{2-} level; increases bone resorption by osteoclasts; increases Ca^{2+} reabsorption and HPO_4^{2-} excretion by kidneys; promotes formation of calcitriol (active form of vitamin D), which increases rate of dietary Ca^{2+} and Mg^{2+} absorption.

Adrenal Glands

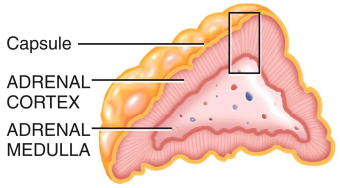
The **adrenal glands (suprarenal glands)** are located on top of each kidney.



(a) Anterior view

Adrenal Glands

The glands are divided into two regions: the outer **cortex** and the medial **medulla**. The glands are covered by a connective tissue capsule.

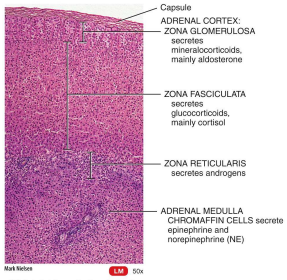


(b) Section through left adrenal gland

Adrenal Glands

The cortex is divided histologically into 3 regions:

- The zona glomerulosa
- The zona fasciculata
- The zona reticularis



(d) Subdivisions of adrenal gland

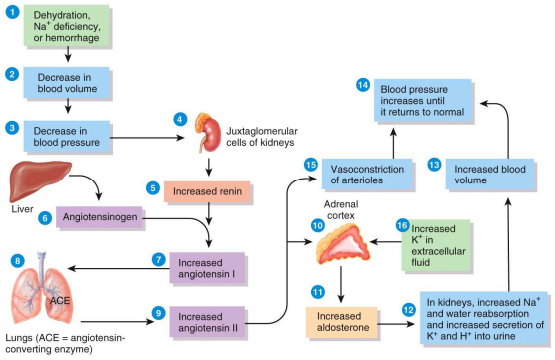
Adrenal Glands

- The zona glomerulosa secretes hormones called **mineralocorticoids** used to regulate mineral homeostasis.
- The zona fasciculata secretes hormones called **glucocorticoids** that affect glucose homeostasis.
- The zona reticularis secretes weak **androgens** (hormones with masculinizing effects).

Adrenal Glands

- **Aldosterone** is the major mineralocorticoid secreted by the adrenal gland. It helps regulate sodium and potassium homeostasis.
- The **renin-angiotensin-aldosterone (RAA) pathway** controls secretion of aldosterone.

Adrenal Glands



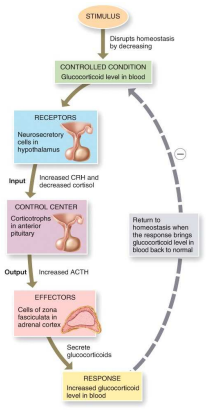
Adrenal Glands

Secretion of **glucocorticoids** (cortisol [hydrocortisone]-the most produced, cortisone and corticosterone) is regulated by **negative feedback**.

They help control:

- Protein breakdown
- Glucose formation
- Lipolysis
- Resistance to stress
- Inflammation
- Immune responses

Adrenal Glands



Adrenal Glands

- The major androgen secreted by the adrenal cortex is **dehydroepiandrosterone (DHEA)**. In **males**, after puberty the hormone **testosterone** is secreted in much larger quantities so DHEA has virtually no effect.
- In **females**, DHEA and other adrenal androgens play a major role in **promoting libido** and are converted to **estrogens**. In menopausal women, all female estrogens come from adrenal androgens.

Adrenal Glands

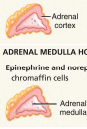
- The **adrenal medulla** is stimulated by sympathetic preganglionic neurons of the autonomic nervous system (ANS).
- **Chromaffin cells** secrete **epinephrine (adrenaline)** and **norepinephrine (noradrenaline)** both of which are involved in the **fight-or-flight response**.

Adrenal Glands

TABLE 18.8

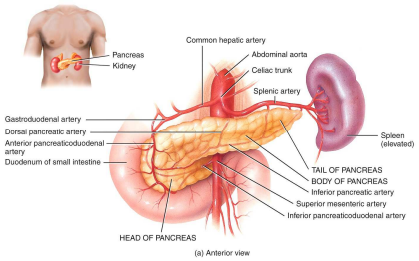
Summary of Adrenal Gland Hormones

HORMONE AND SOURCE	CONTROL OF SECRETION	PRINCIPAL ACTIONS
ADRENAL CORTEX HORMONES		
Mineralocorticoids (mainly aldosterone) from zona glomerulosa cells	Increased blood K^+ level and angiotensin II stimulate secretion.	Increase blood levels of Na^+ and water; decrease blood level of K^+.
Glucocorticoids (mainly cortisol) from zona fasciculata cells	ACTH stimulates release; corticotropin-releasing hormone (CRH) promotes ACTH secretion in response to stress and low blood levels of glucocorticoids.	Increase protein breakdown (except in liver), stimulate gluconeogenesis and lipolysis, provide resistance to stress, dampen inflammation, depress immune responses.
Androgens (mainly dehydroepiandrosterone, or **DHEA)** from zona reticularis cells	ACTH stimulates secretion.	Assist in early growth of axillary and pubic hair in both sexes; in females, contribute to libido and are source of estrogens after menopause.
ADRENAL MEDULLA HORMONES		
Epinephrine and norepinephrine from chromaffin cells	Sympathetic preganglionic neurons release acetylcholine, which stimulates secretion.	Enhance effects of sympathetic division of autonomic nervous system (ANS) during stress.



Pancreatic Islets

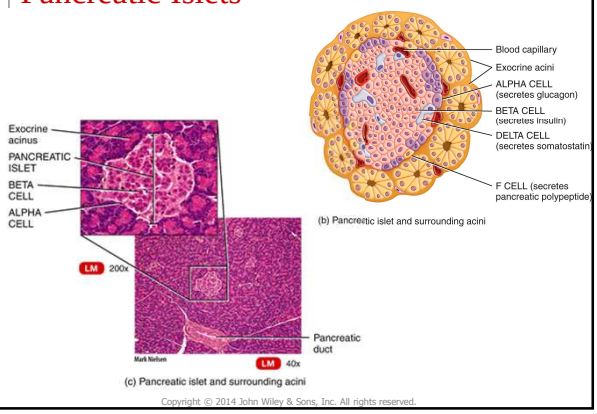
The **pancreas** is both an endocrine and exocrine gland. It is located in the curve of the duodenum.



Pancreatic Islets

- Almost all of the exocrine cells of the pancreas are arranged in clusters called **acini**. These produce **digestive enzymes** that are delivered to the gastrointestinal tract through ducts.
- Scattered among the acini are clusters of endocrine tissue called **pancreatic islets (islets of Langerhans)**.

Pancreatic Islets



Pancreatic Islets

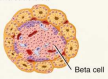
The islets include 4 types of cells that secrete different hormones:

- **Alpha (A) cells** - glucagon
- **Beta (B) cells** - insulin
- **Delta (D) cells** - somatostatin
- **F cells** - pancreatic polypeptide

Pancreatic Islets

TABLE 18.9

Summary of Pancreatic Islet Hormones

HORMONE AND SOURCE	CONTROL OF SECRETION	PRINCIPAL ACTIONS
Glucagon from alpha cells of pancreatic islets 	Decreased blood level of glucose, exercise, and mainly protein meals stimulate secretion; somatostatin and insulin inhibit secretion.	Raises blood glucose level by accelerating breakdown of glycogen into glucose in liver (glycogenolysis), converting other nutrients into glucose in liver (gluconeogenesis), and releasing glucose into blood.
Insulin from beta cells of pancreatic islets 	Increased blood level of glucose, acetylcholine (released by parasympathetic vagus nerve fibers), arginine and leucine (two amino acids), glucagon, GIP, hGH, and ACTH stimulate secretion; somatostatin inhibits secretion.	Lowers blood glucose level by accelerating transport of glucose into cells, converting glucose into glycogen (glycogenesis), and decreasing glycogenolysis and gluconeogenesis; increases lipogenesis and stimulates protein synthesis.

Pancreatic Islets

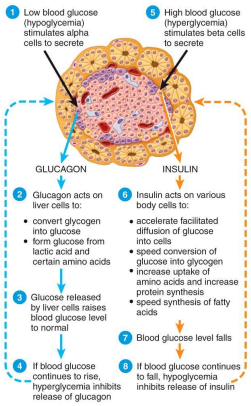
TABLE 18.9

Summary of Pancreatic Islet Hormones

HORMONE AND SOURCE	CONTROL OF SECRETION	PRINCIPAL ACTIONS
Somatostatin from delta cells of pancreatic islets 	Pancreatic polypeptide inhibits secretion.	Inhibits secretion of insulin and glucagon; slows absorption of nutrients from gastrointestinal tract.
Pancreatic polypeptide from F cells of pancreatic islets 	Meals containing protein, fasting, exercise, and acute hypoglycemia stimulate secretion; somatostatin and elevated blood glucose level inhibit secretion.	Inhibits somatostatin secretion, gallbladder contraction, and secretion of pancreatic digestive enzymes.

Pancreatic Islets

Secretion of **insulin and glucagon** are controlled by **negative feedback**.



Ovaries and Testes

- **Gonads** (ovaries and testes) produce **gametes** (**oocytes** and **sperm** respectively).
- **Ovaries** produce two **estrogens** (**estradiol** and **estrone**), **progesterone**, **relaxin** and **inhibin**.
- **Testes** produce **testosterone**.

Ovaries and Testes

TABLE 18.10

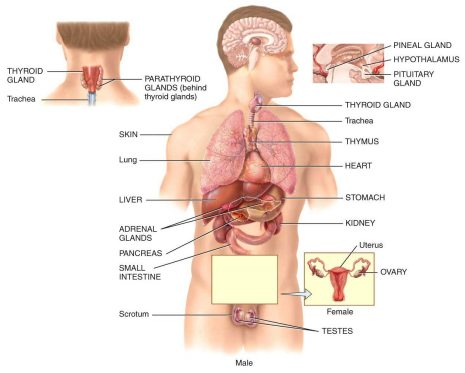
Summary of Hormones of the Ovaries and Testes

HORMONE	PRINCIPAL ACTIONS
OVARIAN HORMONES	
Estrogens and progesterone  Ovary	Together with gonadotropic hormones of anterior pituitary, regulate female reproductive cycle, maintain pregnancy, prepare mammary glands for lactation, and promote development and maintenance of female secondary sex characteristics.
Relaxin (RLX)	Increases flexibility of pubic symphysis during pregnancy; helps dilate uterine cervix during labor and delivery.
Inhibin	Inhibits secretion of FSH from anterior pituitary.
TESTICULAR HORMONES	
Testosterone 	Stimulates descent of testes before birth; regulates sperm production; promotes development and maintenance of male secondary sex characteristics.
Inhibin	Inhibits secretion of FSH from anterior pituitary.

Pineal Gland and Thymus

- The **pineal gland** is attached to the roof of the third ventricle of the brain and secretes **melatonin** which helps to regulate the body's biological clock.
- The **thymus** is located behind the sternum between the lungs. It produces **thymosin**, **thymic humoral factor (THF)**, **thymic factor (TF)** and **thymopoietin**, all of which promote maturation of the immune system's **T cells**.

Pineal Gland and Thymus



Other Endocrine Tissues and Organs, Eicosanoids, and Growth Factors

Several tissues and organs which are not part of the endocrine system are able to produce hormones.

Other Endocrine Tissues and Organs, Eicosanoids, and Growth Factors

TABLE 18.11
Summary of Hormones Produced by Other Organs and Tissues That Contain Endocrine Cells

HORMONE	PRINCIPAL ACTIONS
GASTROINTESTINAL TRACT	
Gastrin	Promotes secretion of gastric juice; increases movements of the stomach.
Glucose-dependent insulinotropic peptide (GIP)	Stimulates release of insulin by pancreatic beta cells.
Secretin	Stimulates secretion of pancreatic juice and bile.
Cholecystokinin (CCK)	Stimulates secretion of pancreatic juice; regulates release of bile from gallbladder; causes feeling of fullness after eating.
PLACENTA	
Human chorionic gonadotropin (hCG)	Stimulates corpus luteum in ovary to continue production of estrogens and progesterone to maintain pregnancy.
Estrogens and progesterone	Maintain pregnancy; help prepare mammary glands to secrete milk.
Human chorionic somatomammotropin (hCS)	Stimulates development of mammary glands for lactation.
KIDNEYS	
Renin	Part of reaction sequence that raises blood pressure by bringing about vasoconstriction and secretion of aldosterone.
Erythropoietin (EPO)	Increases rate of red blood cell formation.
Calcitriol* (active form of vitamin D)	Aids in absorption of dietary calcium and phosphorus.
HEART	
Atrial natriuretic peptide (ANP)	Decreases blood pressure.
ADIPOSE TISSUE	
Leptin	Suppresses appetite; may increase FSH and LH activity.

Other Endocrine Tissues and Organs, Eicosanoids, and Growth Factors

- **Eicosanoids** are locally-acting hormones derived from the 20-carbon fatty acid **arachadonic acid**.
- Certain hormones stimulate cell growth and division. Several newly discovered hormones called **growth factors** are involved in **tissue development, growth and repair**.

Other Endocrine Tissues and Organs, Eicosanoids, and Growth Factors

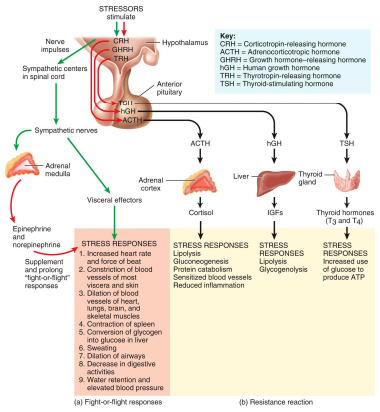
TABLE 18.12
Summary of Selected Growth Factors

GROWTH FACTOR	COMMENT
Epidermal growth factor (EGF)	Produced in submaxillary (salivary) glands; stimulates proliferation of epithelial cells, fibroblasts, neurons, and astrocytes; suppresses some cancer cells and secretion of gastric juice by stomach.
Platelet-derived growth factor (PDGF)	Produced in blood platelets; stimulates proliferation of neuroglia, smooth muscle fibers, and fibroblasts; appears to have role in wound healing; may contribute to atherosclerosis development.
Fibroblast growth factor (FGF)	Found in pituitary gland and brain; stimulates proliferation of many cells derived from embryonic mesoderm (fibroblasts, adrenocortical cells, smooth muscle fibers, chondrocytes, and endothelial cells); stimulates formation of new blood vessels (angiogenesis).
Nerve growth factor (NGF)	Produced in submandibular (salivary) glands and hippocampus of brain; stimulates growth of ganglia in embryo; maintains sympathetic nervous system; stimulates hypertrophy and differentiation of neurons.
Tumor angiogenesis factors (TAFs)	Produced by normal and tumor cells; stimulate growth of new capillaries, organ regeneration, and wound healing.
Transforming growth factors (TGFs)	Produced by various cells as separate molecules: TGF-alpha has activities similar to epidermal growth factor; TGF-beta inhibits proliferation of many cell types.

The Stress Response

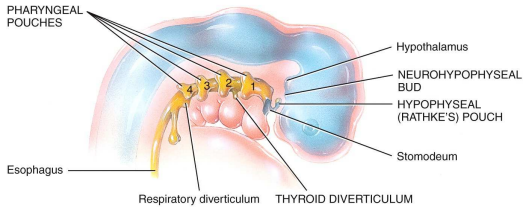
- **Eustress** is helpful, everyday stress that prepares us to meet challenges.
- **Distress** is any type of harmful stress that may be damaging.
- The **fight-or-flight response** (**first stage of the stress response**) stimulates the body's resources to prepare for immediate activity.
- The **resistance reaction** is the **second stage in the stress response** and lasts longer than the fight-or-flight response.

The Stress Response



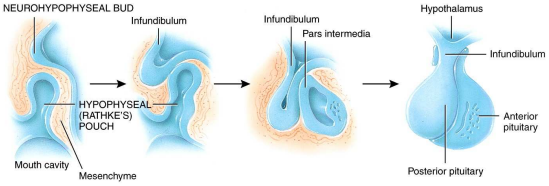
Development of the Endocrine System

Glands of the endocrine system develop from **all 3 primary germ layers**.



(a) Location of neurohypophyseal bud, hypophyseal (Rathke's) pouch, thyroid diverticulum, and pharyngeal pouches in 28-day embryo

Development of the Endocrine System

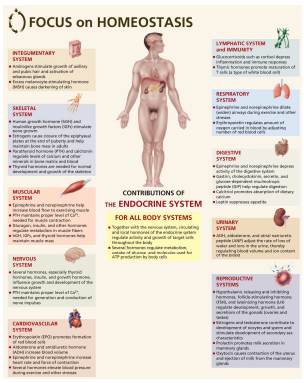


(b) Development of pituitary gland between 5 and 16 weeks

Aging and the Endocrine System

- Aging brings about changes in the levels of most hormones. Some increase while some decrease. In addition, levels of some hormones, like epinephrine and norepinephrine, remain the same.
- Histologically, most endocrine glands reduce in size and contain increasingly more fibrous connective tissue with age.

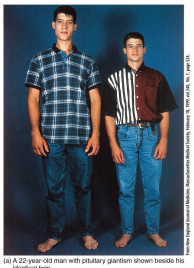
Focus on Homeostasis



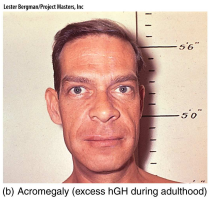
Endocrine Disorders

- There are many endocrine disorders. Some are more common than others.
- **Pituitary gigantism** and **acromegaly** are caused by excess secretion of **growth hormone**.
- **Goiter** is caused by a **reduction** in the production of **thyroid hormone**.
- **Graves disease (with associated exophthalmos)** develops due to **excess thyroid hormone**.
- **Cushing's syndrome** is caused by **excess secretion of glucocorticoids**.

Endocrine Disorders



(a) A 22-year-old man with pituitary giantism shown beside his identical twin



(b) Acromegaly (excess hGH during adulthood)

(c) Goiter (enlargement of thyroid gland)

(d) Exophthalmos (excess thyroid hormones, as in Graves disease)

(e) Cushing's syndrome (excess glucocorticoids)

End of Chapter 18