Hole's Human Anatomy and Physiology

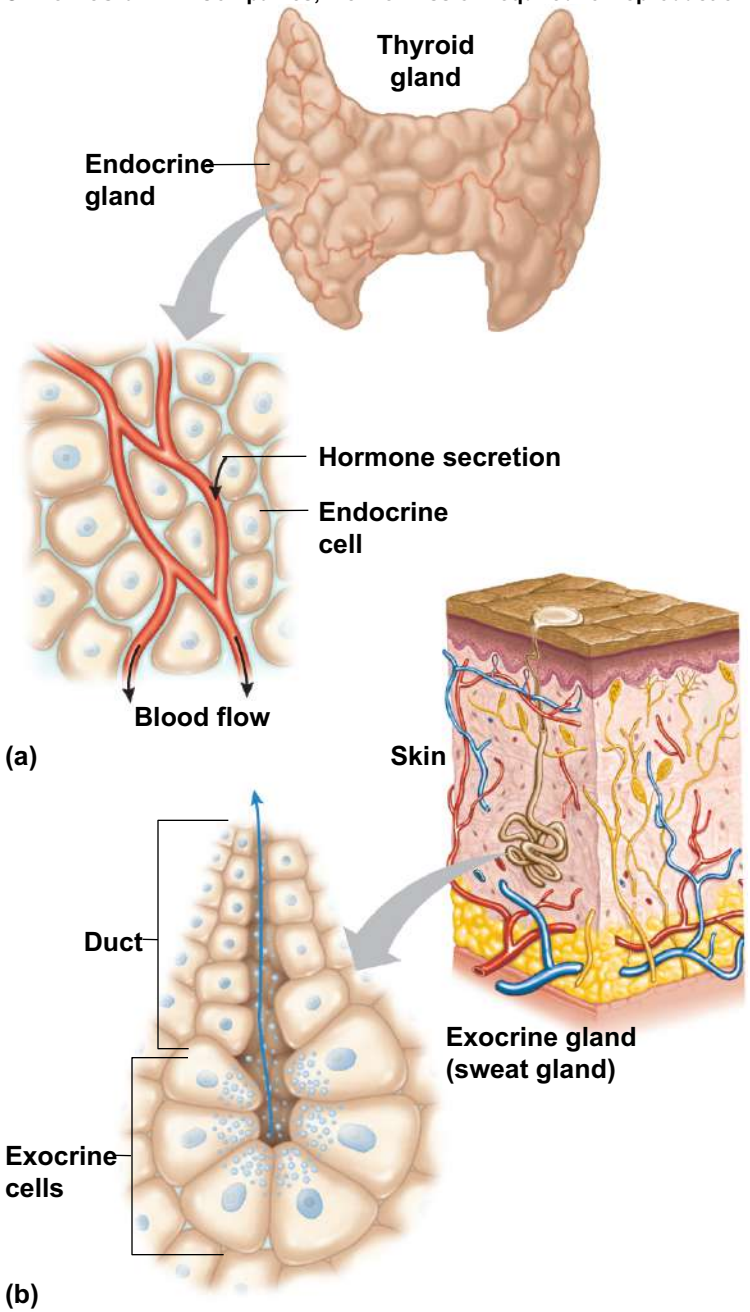
Twelfth Edition

Shier ◆ Butler ◆ Lewis

Chapter 13 Endocrine System

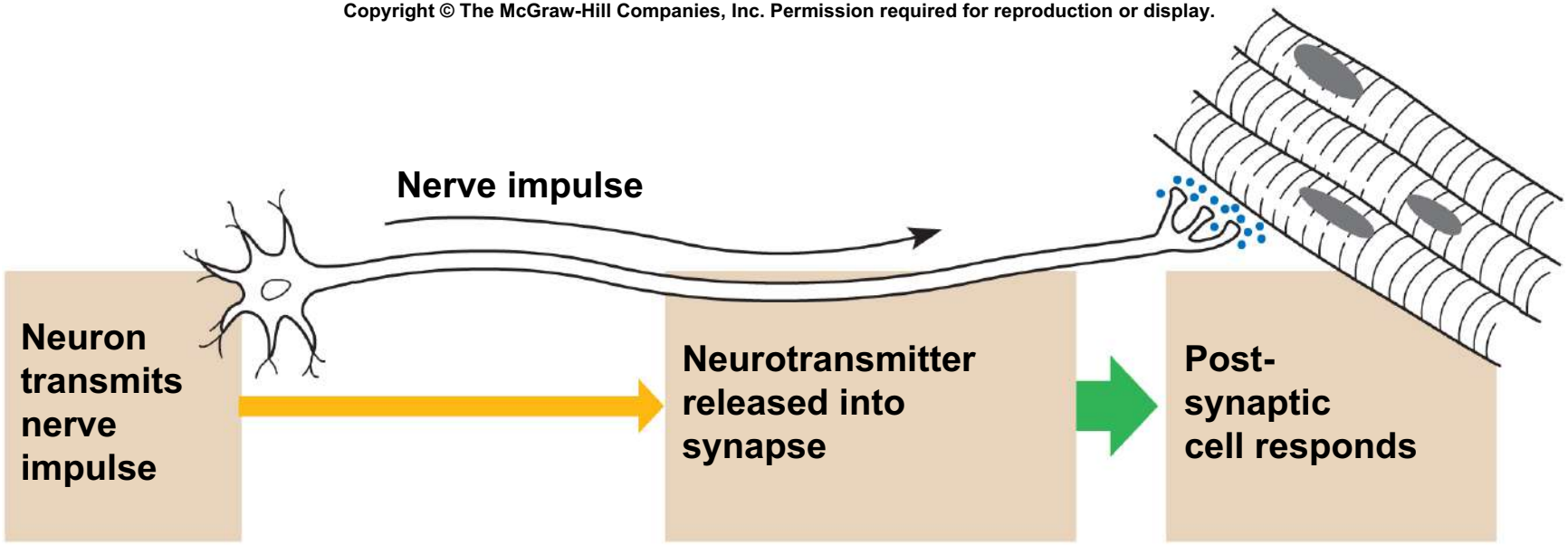
13.1: Introduction

- **The endocrine system assists the nervous system with communication and control of the body**
- **The cells, tissues, and organs are called endocrine glands**
  - They are ductless
  - They use the bloodstream
  - They secrete hormones
  - There are also similar glands called paracrine and autocrine glands that are quasi-endocrine
- **Other glands that secrete substances are the exocrine glands**
  - They have ducts
  - They deliver their products directly to a specific site



13.2: General Characteristics of the Endocrine System

- **The endocrine and nervous systems communicate using chemical signals**
  - Neurons release neurotransmitters into a synapse affecting postsynaptic cells
  - Endocrine glands release hormones into the bloodstream to specific target cell receptors



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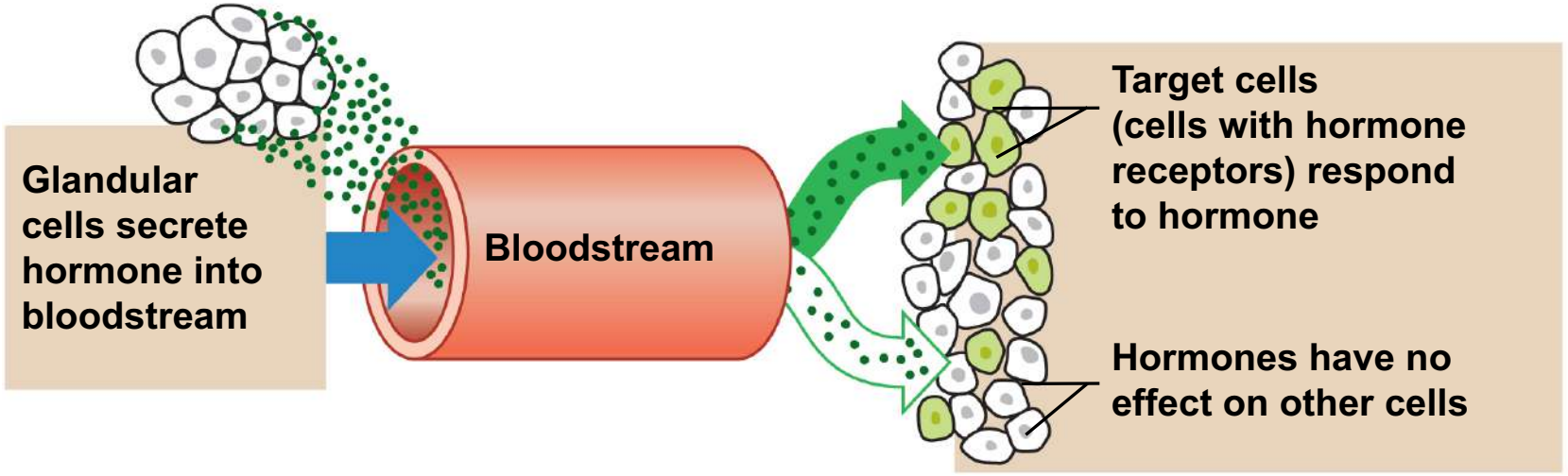


(b)

TABLE 13.1 | A Comparison Between the Nervous System and the Endocrine System

	Nervous System	Endocrine System
Cells	Neurons	Glandular epithelium
Chemical signal	Neurotransmitter	Hormone
Specificity of action	Receptors on postsynaptic cell	Receptors on target cell
Speed of onset	Seconds	Seconds to hours
Duration of action	Very brief unless neuronal activity continues	May be brief or may last for days even if secretion ceases

Chemistry of Hormones

Chemically, hormones are either Steroid or Non-Steroid

Steroid or steroid-like hormones examples:

- Sex hormones
- Adrenal cortex hormone

Characteristics:

- Lipids
- Complex rings of carbon and hydrogen atoms
- Insoluble in water
- Soluble in lipid cell membranes
- Easily diffused into cells

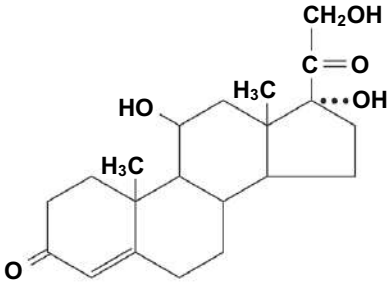
Chemistry of Hormones

Non-steroid hormones such as:

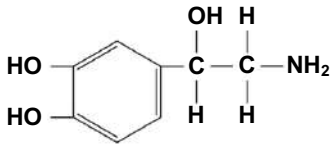
- Amines
- Proteins
- Peptides
- Glycoproteins

Characteristics:

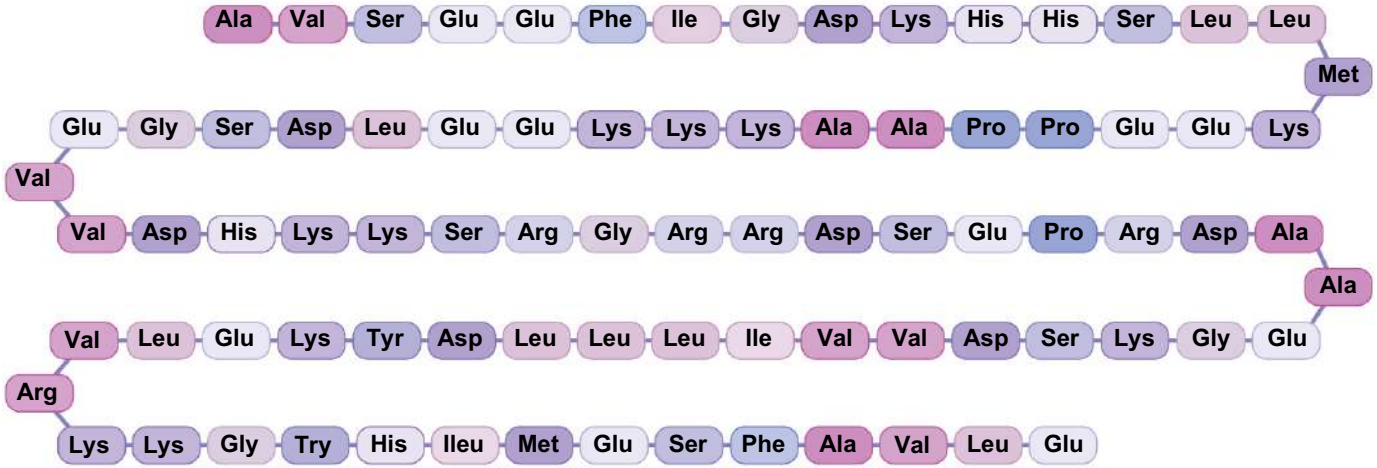
- Composed of long chains of amino acids
- Secreted by parathyroid and anterior/posterior pituitary gland
- Synthesized in the adrenal medulla



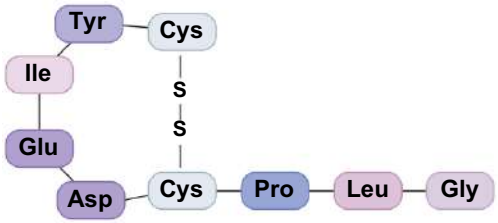
(a) Cortisol



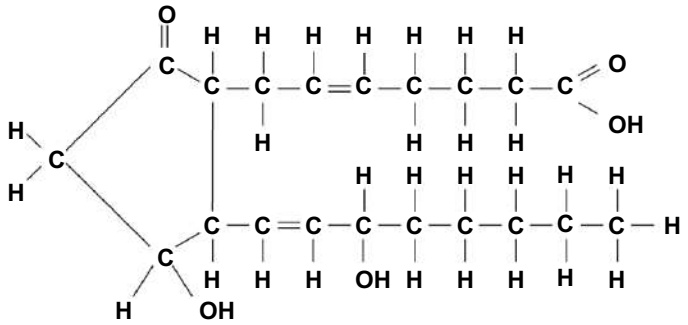
(b) Norepinephrine



(c) Parathyroid ho rm one (PTH)



(d) Oxytocin



(e) Prostaglandin PGE_2

TABLE 13.2 | Hormone Names and Abbreviations

Source	Name	Abbreviation	Synonym
Hypothalamus	Corticotropin-releasing hormone	CRH	
	Gonadotropin-releasing hormone	GnRH	Luteinizing hormone releasing hormone (LHRH)
	Somatostatin	SS	Growth hormone release-inhibiting hormone (GRIH)
	Growth hormone-releasing hormone	GHRH	
	Prolactin release-inhibiting hormone	PIH	Dopamine
	Prolactin-releasing factor*	PRF*	
	Thyrotropin-releasing hormone	TRH	
Anterior pituitary gland	Adrenocorticotropic hormone	ACTH	Corticotropin
	Follicle-stimulating hormone	FSH	Follitropin
	Growth hormone	GH	Somatotropin (STH)
	Luteinizing hormone	LH	Lutropin, interstitial cell-stimulating hormone (ICSH)
	Prolactin	PRL	
	Thyroid-stimulating hormone	TSH	Thyrotropin
Posterior pituitary gland	Antidiuretic hormone	ADH	Vasopressin
	Oxytocin	OT	
Thyroid gland	Calcitonin		
	Thyroxine	T_4	Tetraiodothyronine
	Triiodothyronine	T_3	
Parathyroid gland	Parathyroid hormone	PTH	Parathormone
Adrenal medulla	Epinephrine	EPI	Adrenalin
	Norepinephrine	NE	Noradrenalin
Adrenal cortex	Aldosterone		
	Cortisol		Hydrocortisone
Pancreas	Glucagon		
	Insulin		
	Somatostatin	SS	

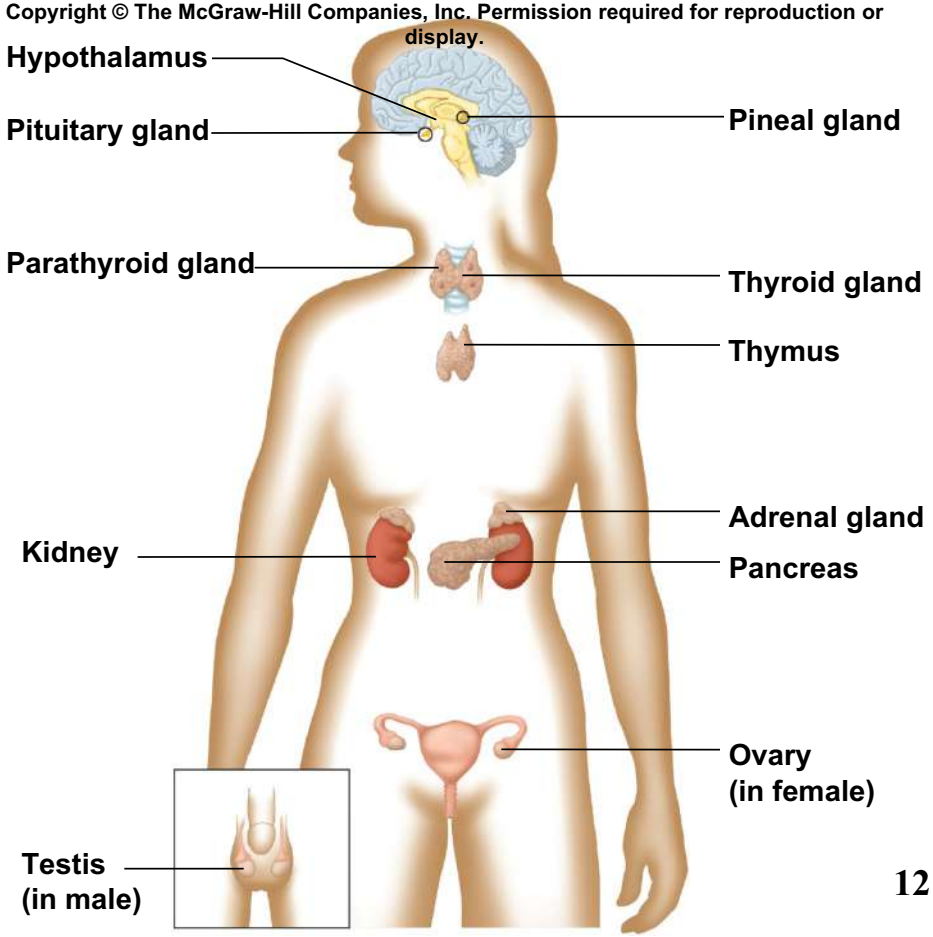
*"Factor" is used because a specific prolactin-releasing hormone has not yet been identified.

TABLE 13.3 | Types of Hormones

Type of Compound	Formed from	Examples
Amines	Amino acids	Norepinephrine, epinephrine
Peptides	Amino acids	ADH, OT, TRH, SS, GnRH
Proteins	Amino acids	PTH, GH, PRL
Glycoproteins	Protein and carbohydrate	FSH, LH, TSH
Steroids	Cholesterol	Estrogens, testosterone, aldosterone, cortisol

13.3: Hormone Action

- **Hormones are released into the extracellular spaces surrounding endocrine cells**



Action of Hormones

- **Steroid Hormones**

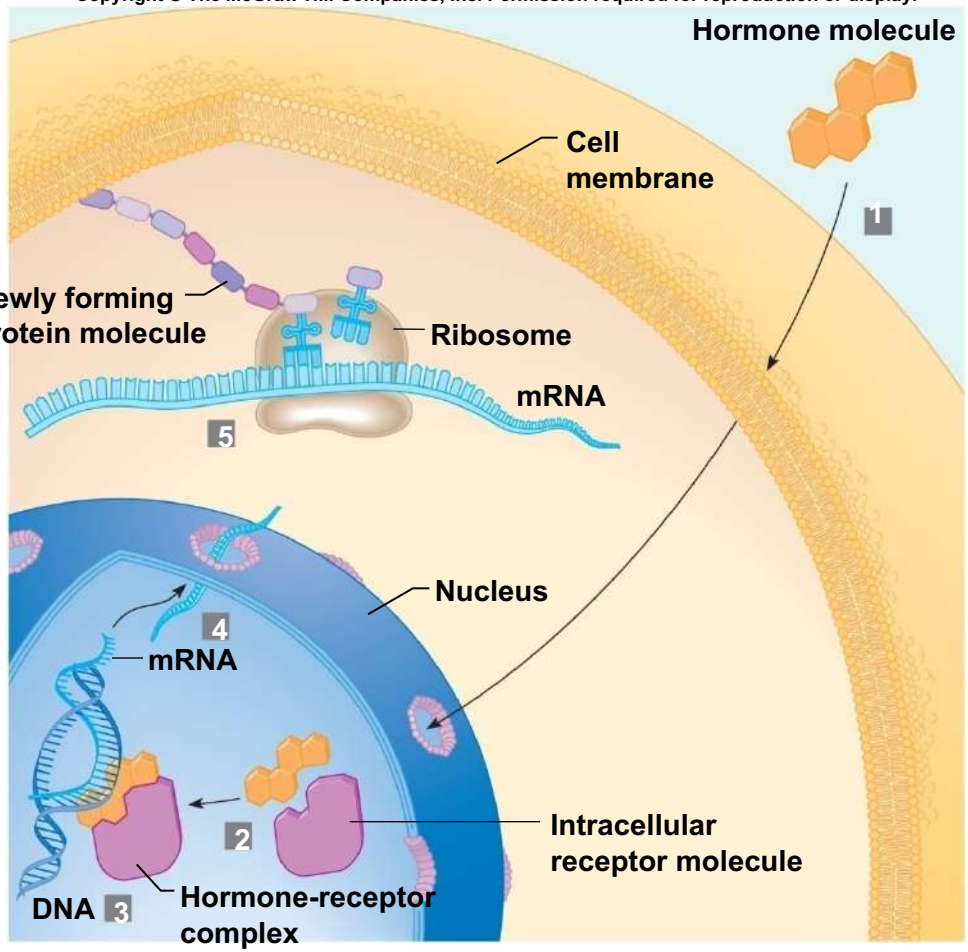


TABLE 13.4 | Sequence of Steroid Hormone Action

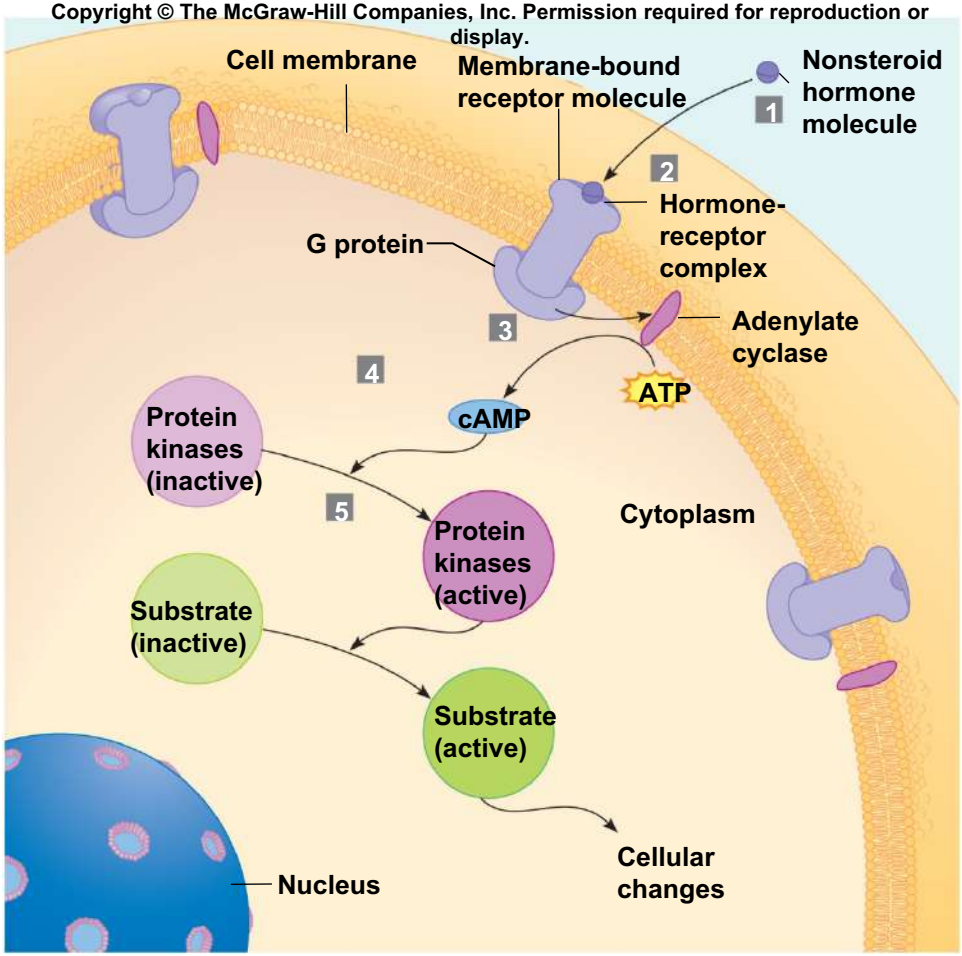
1. Endocrine gland secretes steroid hormone.
2. Steroid hormone diffuses through target cell membrane and enters cytoplasm or nucleus.
3. Hormone combines with a receptor molecule in the cytoplasm or nucleus.
4. Steroid hormone-receptor complex binds to DNA and promotes transcription of messenger RNA.
5. Messenger RNA enters the cytoplasm and directs protein synthesis.
6. Newly synthesized proteins produce hormone's specific effects.

Action of Hormones

- **Non-steroid Hormones**

TABLE 13.5 | Sequence of Actions of Nonsteroid Hormone Using Cyclic AMP

1. Endocrine gland secretes nonsteroid hormone.
2. Body fluid carries hormone to its target cell.
3. Hormone combines with receptor site on membrane of its target cell, activating G protein.
4. Adenylate cyclase molecules are activated in target cell's membrane.
5. Adenylate cyclase circularizes ATP into cyclic AMP.
6. Cyclic AMP activates protein kinases.
7. Protein kinases activate protein substrates in the cell that change metabolic processes.
8. Cellular changes produce the hormone's effects.



13.1 Clinical Application

Using Hormones to Improve Athletic Performance

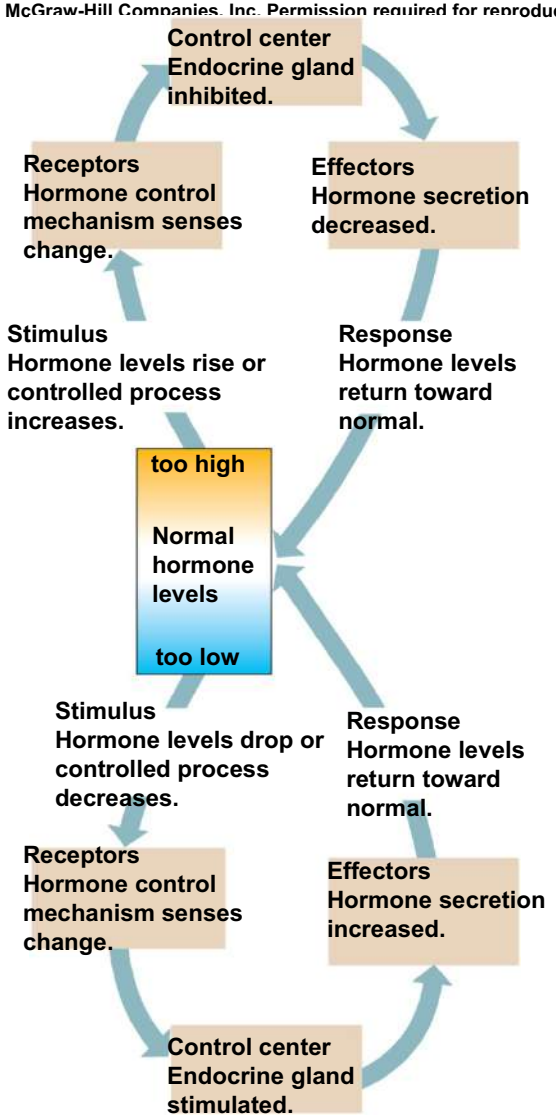
Prostaglandins

- **Prostaglandins:**
  - Are paracrine substances
  - Are very potent in small amounts
  - Are not stored in cells but synthesized just before release
  - Rapidly inactivate
  - Regulate cellular responses to hormones
  - Can activate or inhibit adenylate cyclase
    - Controls cAMP production
    - Alters a cells response to hormones
  - Has a wide variety of effects

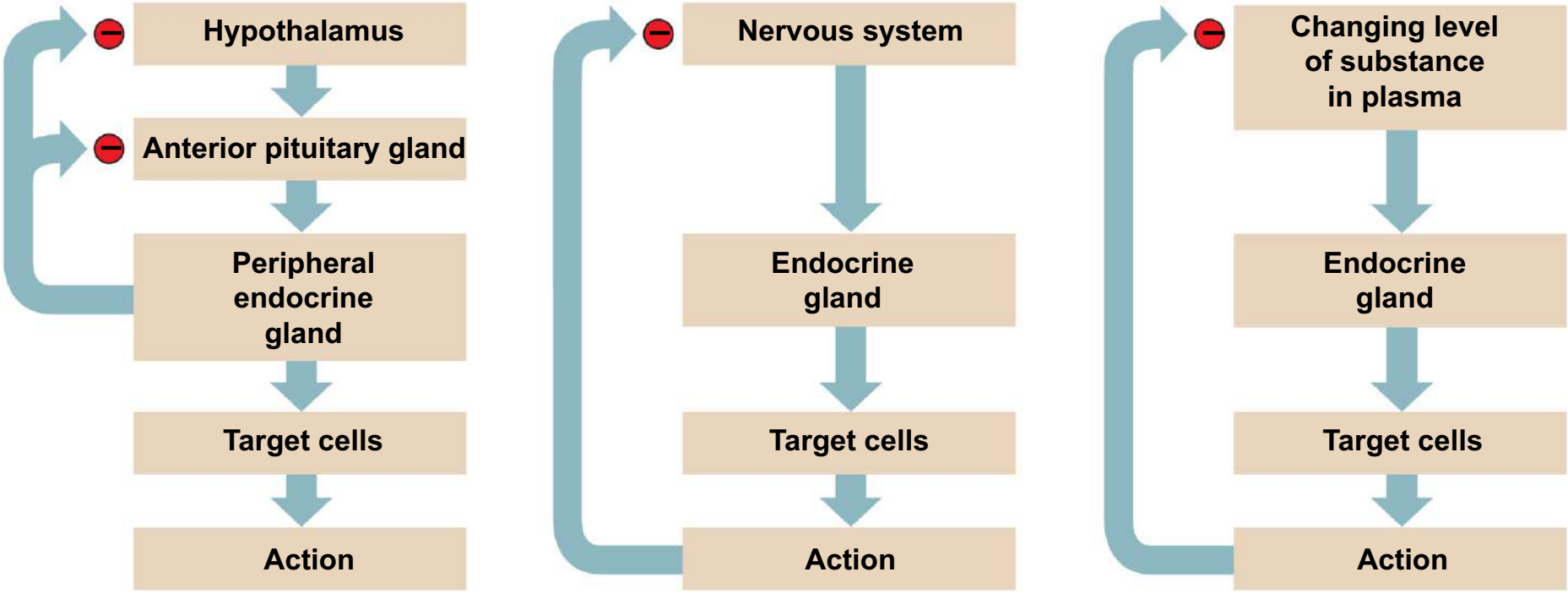
13.4: Control of Hormonal Secretions

- **Primarily controlled by negative feedback mechanism**
- **Hormones can be short-lived or may last for days**
- **Hormone secretions are precisely regulated**

Control Sources

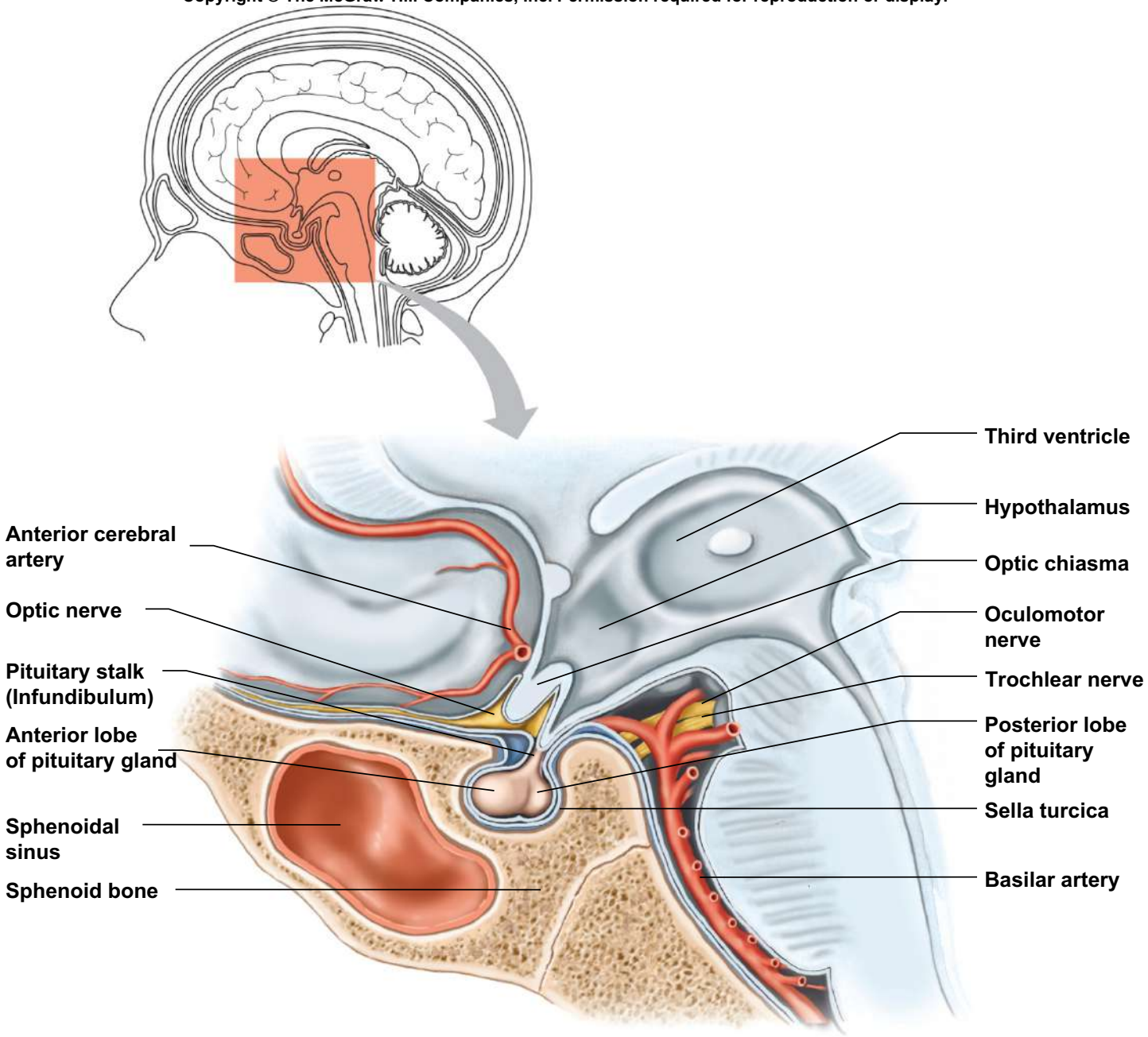


Control Sources



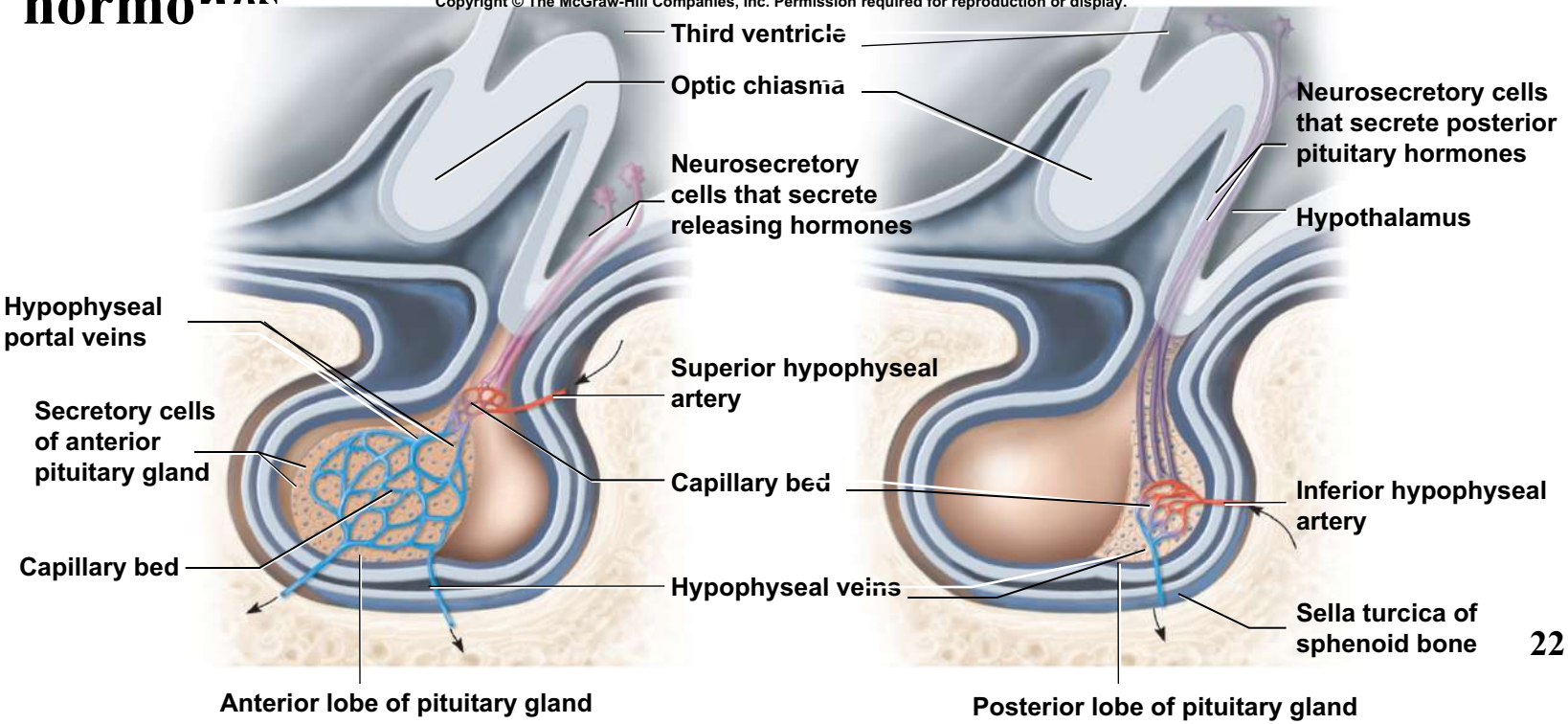
13.5: Pituitary Gland

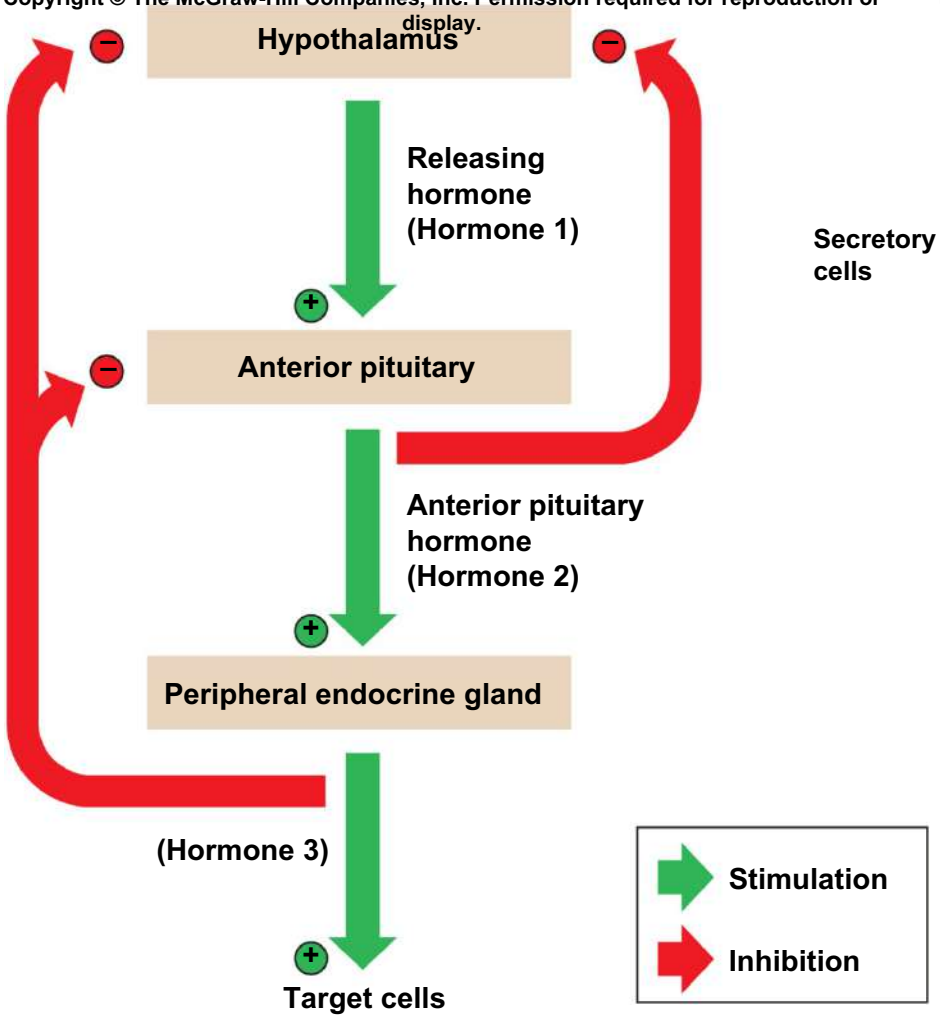
- **Lies at the base of the brain in the sella turcica**
- **Consists of two distinct portions:**
  - Anterior pituitary (adenohypophysis)
  - Posterior pituitary (neurohypophysis)

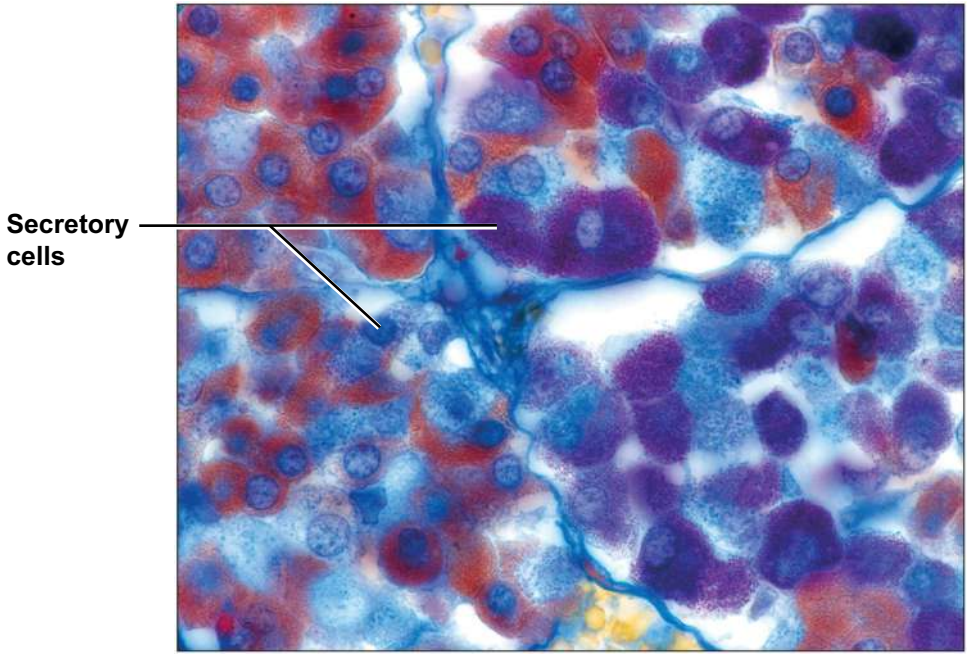


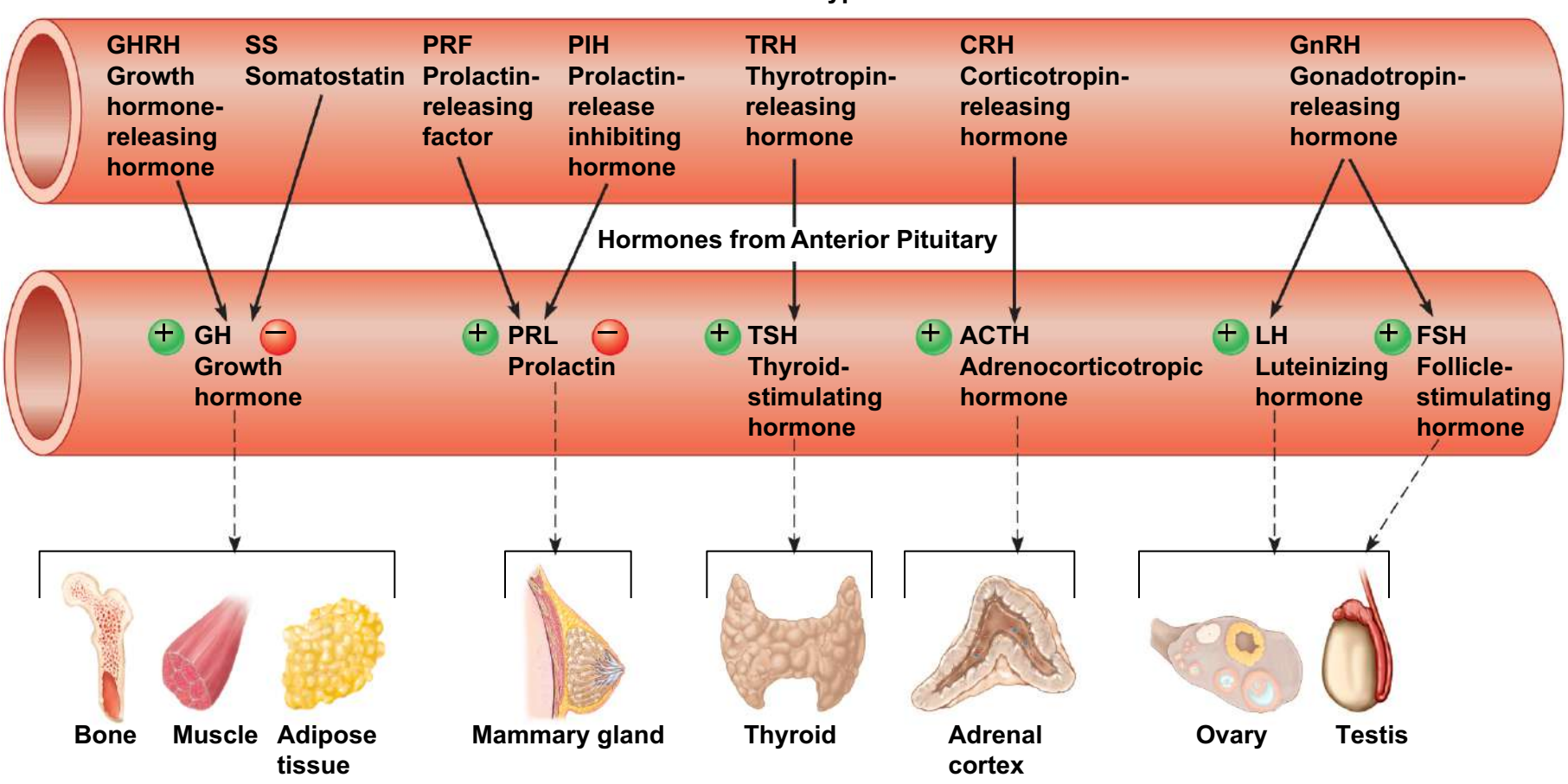
Anterior Pituitary Hormones

- Hypothalamic releasing hormones stimulate cells of anterior pituitary to release hormones
- Nerve impulses from hypothalamus stimulate nerve endings in the posterior pituitary gland to release hormones









13.2 Clinical Application

Growth Hormone Ups and Downs

Posterior Pituitary Hormones

- **Structurally consists of nerve fibers and neuroglia v. glandular epithelial cells of the anterior pituitary gland**
- **The nerve fibers originate in the hypothalamus**
- **Two hormones are produced:**
  - Antidiuretic hormone (vasopressin)
  - Oxytocin

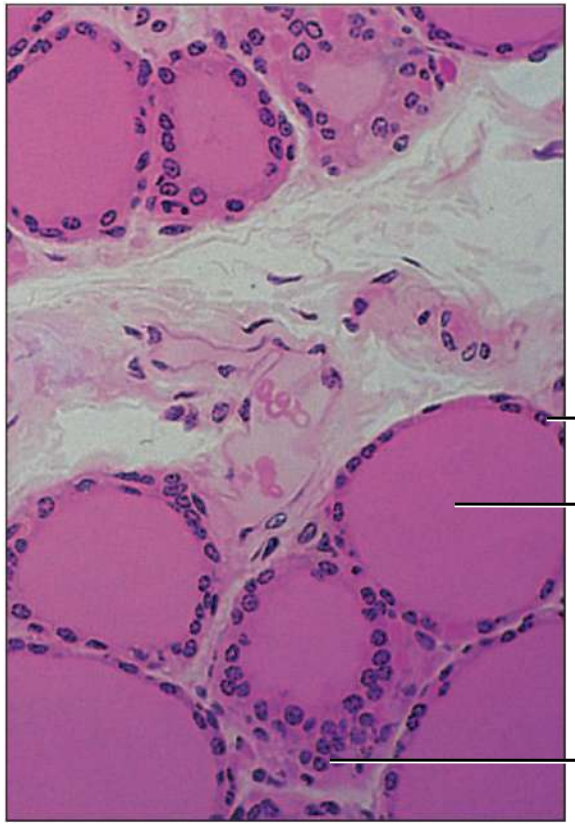
TABLE 13.6 | Hormones of the Pituitary Gland

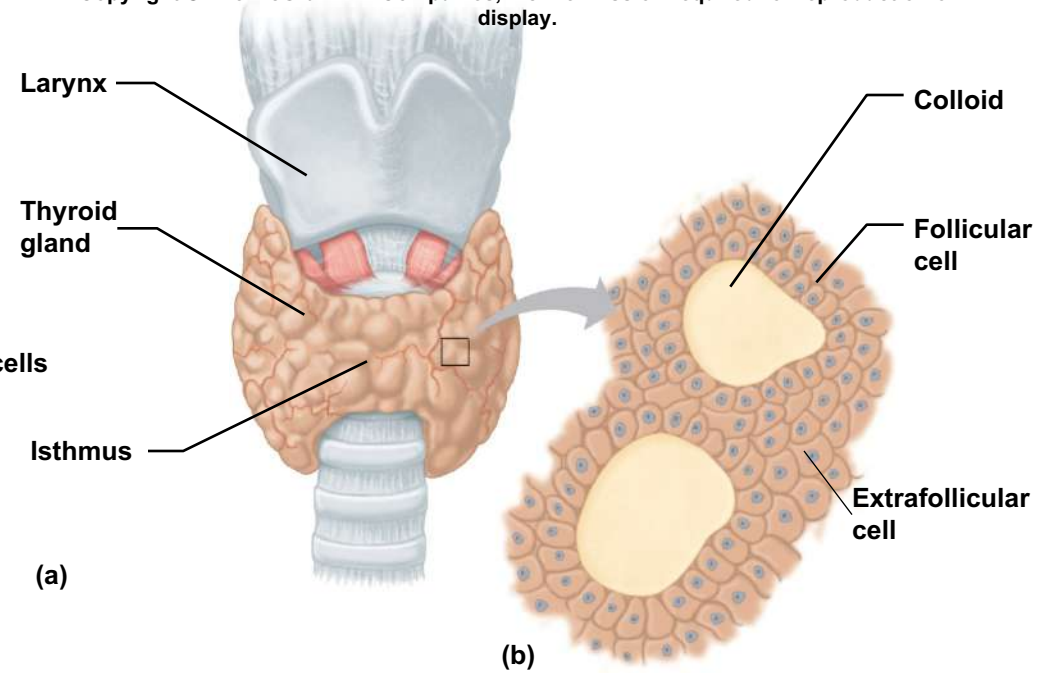
Anterior Lobe Hormone	Action	Source of Control
Growth hormone (GH)	Stimulates increase in size and rate of division of body cells; enhances movement of amino acids through membranes; promotes growth of long bones	Secretion inhibited by somatostatin (SS) and stimulated by growth hormone-releasing hormone (GHRH) from the hypothalamus
Prolactin (PRL)	Sustains milk production after birth; amplifies effect of LH in males	Secretion inhibited by prolactin-release inhibiting hormone (PIH) and may be stimulated by yet to be identified prolactin-releasing factor (PRF) from the hypothalamus
Thyroid-stimulating hormone (TSH)	Controls secretion of hormones from the thyroid gland	Thyrotropin-releasing hormone (TRH) from the hypothalamus
Adrenocorticotropic hormone (ACTH)	Controls secretion of certain hormones from the adrenal cortex	Corticotropin-releasing hormone (CRH) from the hypothalamus
Follicle-stimulating hormone (FSH)	Development of egg-containing follicles in ovaries; stimulates follicular cells to secrete estrogen; in males, stimulates production of sperm cells	Gonadotropin-releasing hormone (GnRH) from the hypothalamus
Luteinizing hormone (LH)	Promotes secretion of sex hormones; releases egg cell in females	Gonadotropin-releasing hormone (GnRH) from the hypothalamus
Posterior Lobe Hormone	**Action**	**Source of Control**
Antidiuretic hormone (ADH)	Causes kidneys to reduce water excretion; in high concentration, raises blood pressure	Hypothalamus in response to changes in blood water concentration and blood volume
Oxytocin (OT)	Contracts muscles in uterine wall and those associated with milk-secreting glands	Hypothalamus in response to stretch in uterine and vaginal walls and stimulation of breasts

13.6: Thyroid Gland

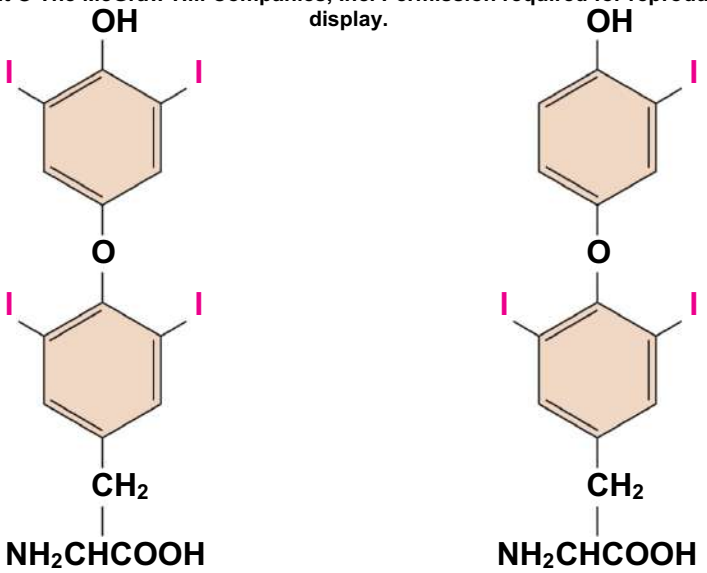
- **The thyroid gland has two lateral lobes and lies just below the larynx**
- **It produces three hormones:**
  - T3 (thyroxine)
  - T4 (triiodothyronine)
  - Calcitonin

Structure of the Gland





Thyroid Hormones



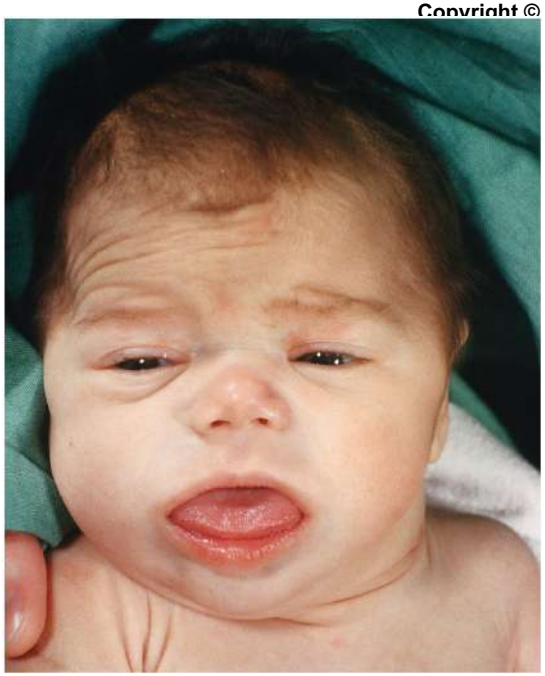
Thyroxine (T_4) Triiodothyronine (T_3)

TABLE 13.7 | Hormones of the Thyroid Gland

Hormone	Action	Source of Control
Thyroxine (T_4)	Increases rate of energy release from carbohydrates; increases rate of protein synthesis; accelerates growth; stimulates activity in the nervous system	TSH from the anterior pituitary gland
Triiodothyronine (T_3)	Same as above, but five times more potent than thyroxine	Same as above
Calcitonin	Lowers blood calcium and phosphate ion concentrations by inhibiting release of calcium and phosphate ions from bones and by increasing the rate at which calcium and phosphate ions are deposited in bones; increases excretion of calcium by the kidneys	Elevated blood calcium ion concentration, digestive hormones

TABLE 13.8 | Disorders of the Thyroid Gland

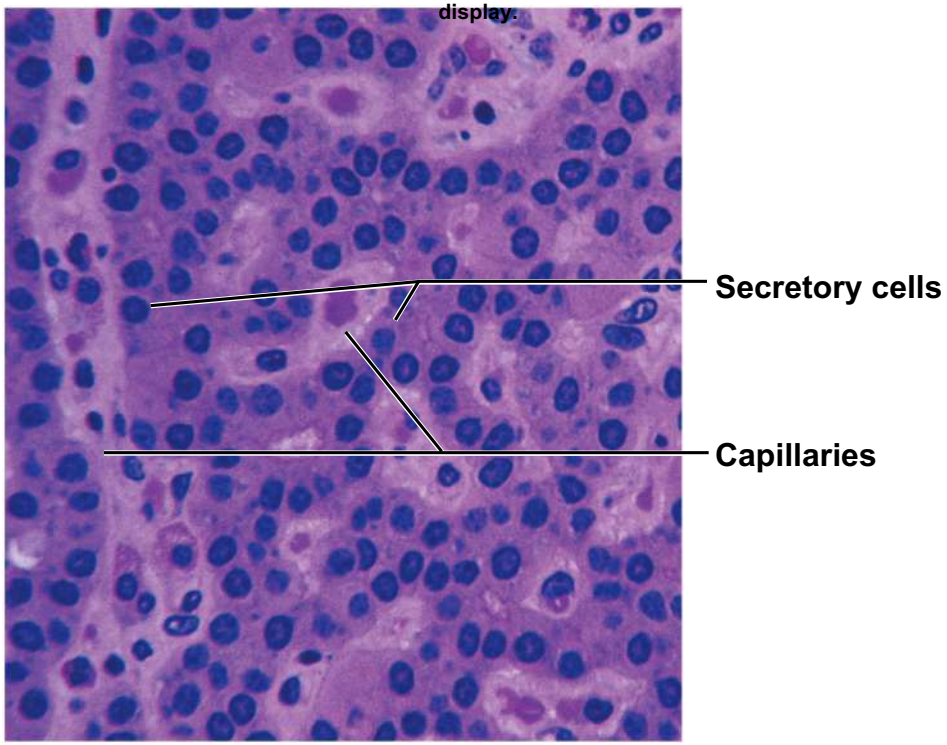
Condition	Mechanism/Symptoms
Hyperthyroid	
Hyperthyroidism	High metabolic rate, sensitivity to heat, restlessness, hyperactivity, weight loss, protruding eyes, goiter
Graves disease	Autoantibodies (against self) bind TSH receptors on thyroid cell membranes, mimicking action of TSH, overstimulating gland (hyperthyroidism); exopthalmia (protrusion of the eyes) and goiter
Hypothyroid	
Hashimoto disease	Autoantibodies (against self) attack thyroid cells, resulting in hypothyroidism
Hypothyroidism (infantile)	Cretinism—stunted growth, abnormal bone formation, mental retardation, low body temperature, sluggishness
Hypothyroidism (adult)	Myxedema—low metabolic rate, sensitivity to cold, sluggishness, poor appetite, swollen tissues, mental dullness
Simple goiter	Deficiency of thyroid hormones due to iodine deficiency; because no thyroid hormones inhibit pituitary release of TSH, thyroid is overstimulated and enlarges but functions below normal (hypothyroidism)

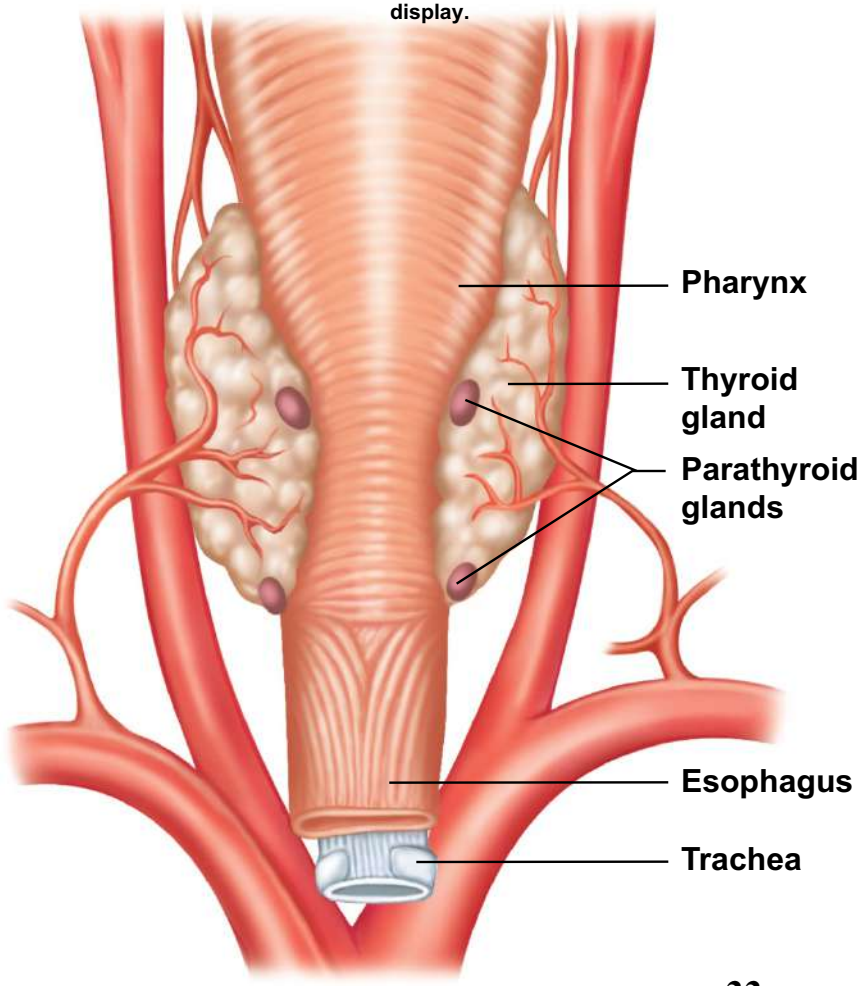


13.7: Parathyroid Glands

- **The parathyroid glands are on the posterior surface of the thyroid gland**
- **There are typically four parathyroid glands**
- **It secretes one hormone:**
    - PTH (parathyroid hormone or parathormone)

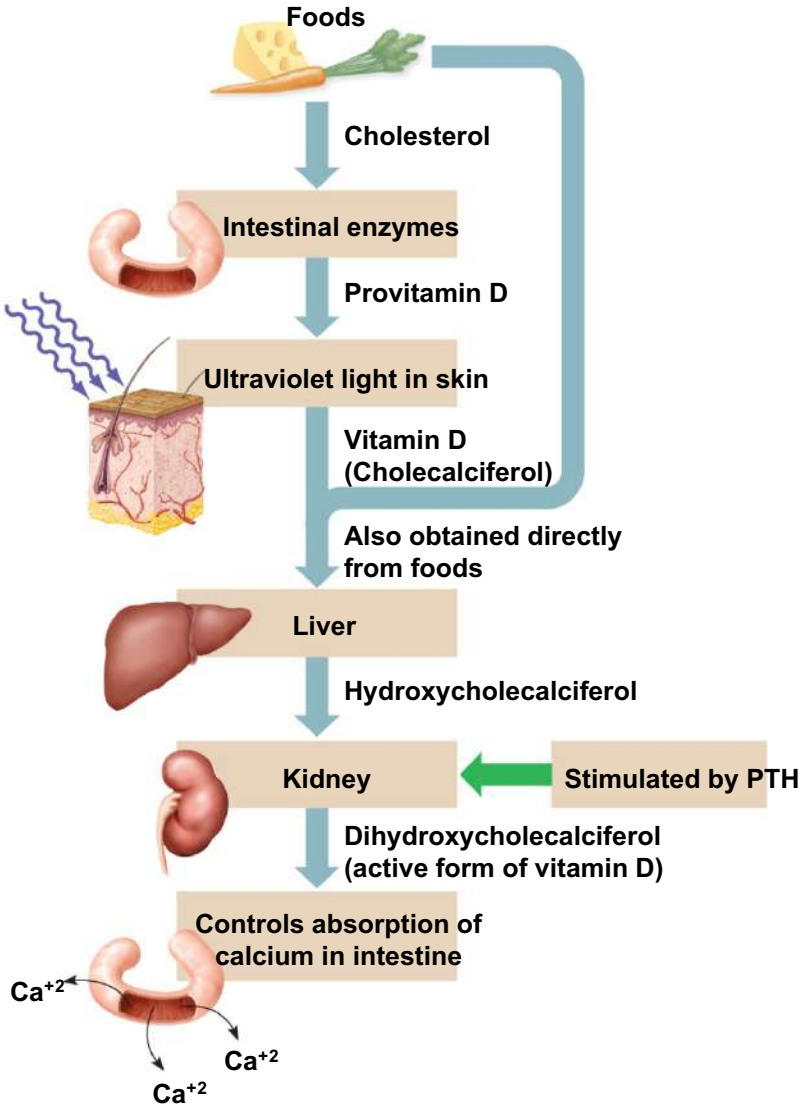
Structure of the Glands





Posterior view

Parathyroid Hormone



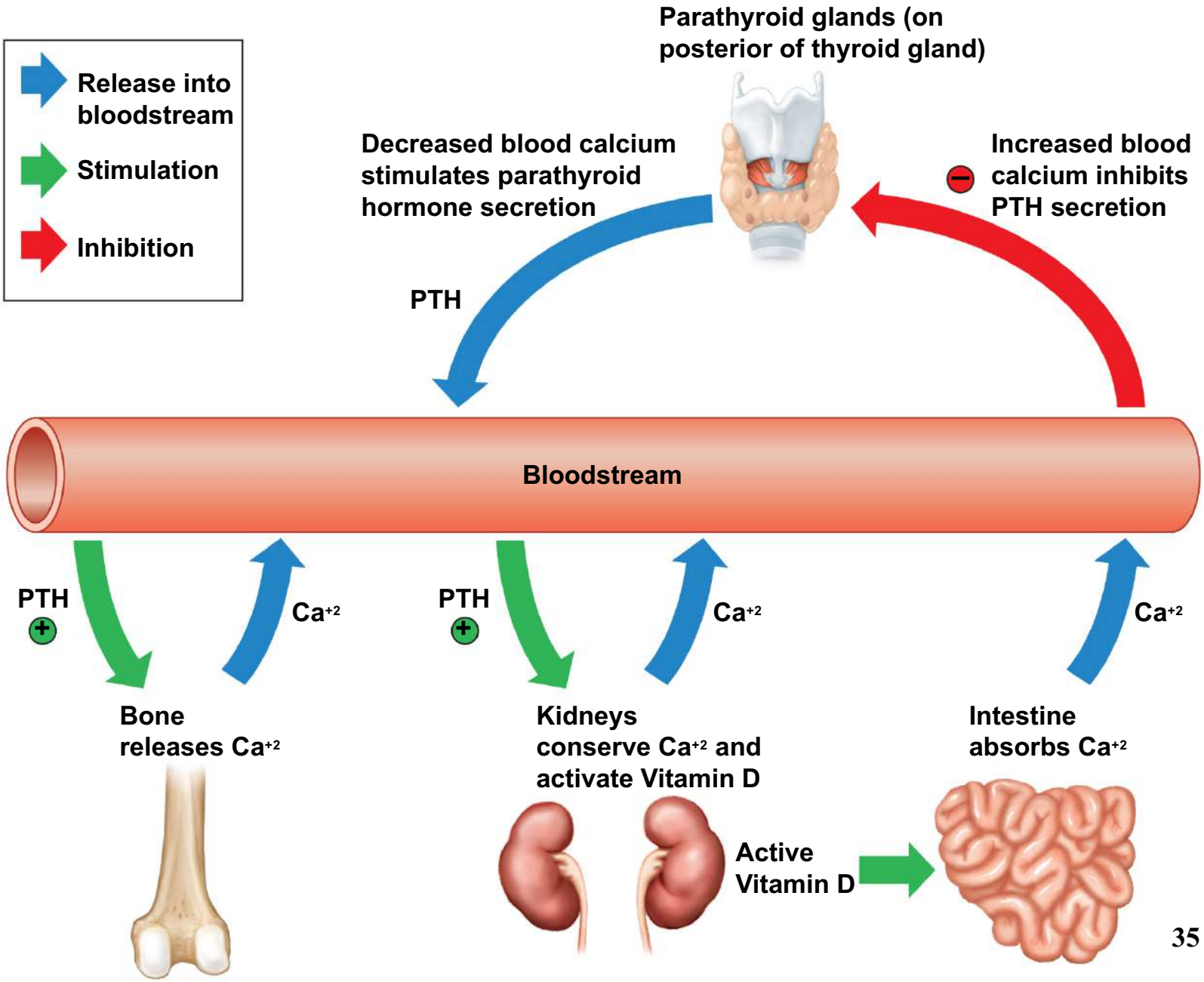


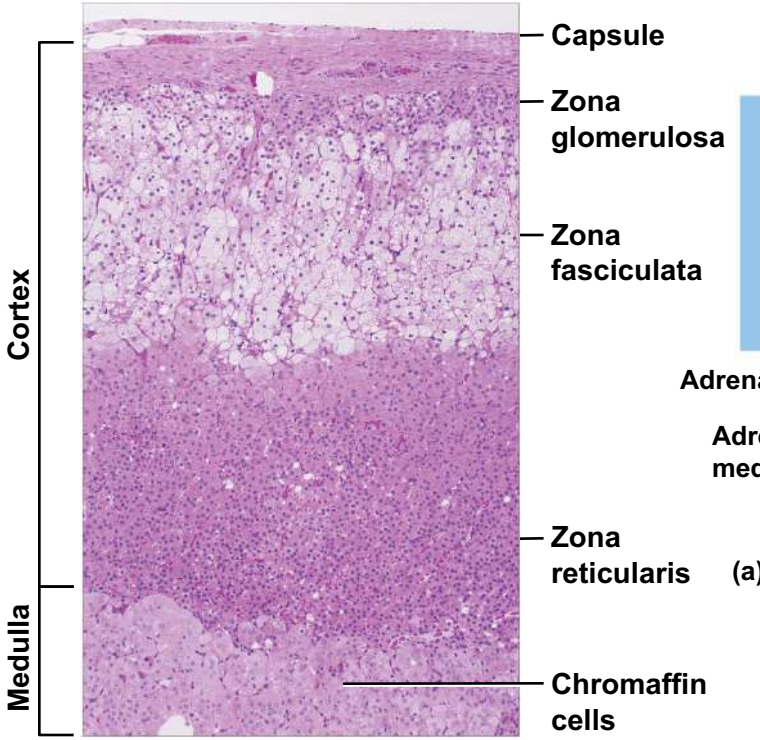
TABLE 13.9 | Disorders of the Parathyroid Glands

Condition	Symptoms/Mechanism	Cause	Treatment
Hyperparathyroidism	Fatigue, muscular weakness, painful joints, altered mental functions, depression, weight loss, bone weakening. Increased PTH secretion overstimulates osteoclasts.	Tumor	Remove tumor, correct bone deformities
Hypoparathyroidism	Muscle cramps and seizures. Decreased PTH secretion reduces osteoclast activity, diminishing blood calcium ion concentration.	Inadvertent surgical removal; injury	Calcium salt injections, massive doses of vitamin D

13.8: Adrenal Glands

- **The adrenal glands are closely associated with the kidneys**
- **The gland sits like a cap on each kidney**
- **Hormones are secreted from two different areas of the gland, the adrenal cortex and the adrenal medulla**
- **Numerous hormones are secreted by the adrenal glands**

Structure of the Glands



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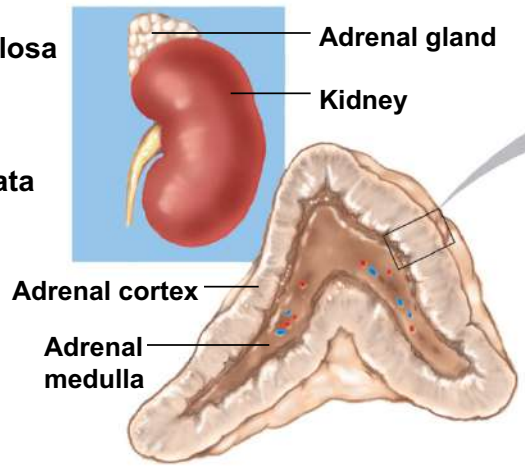
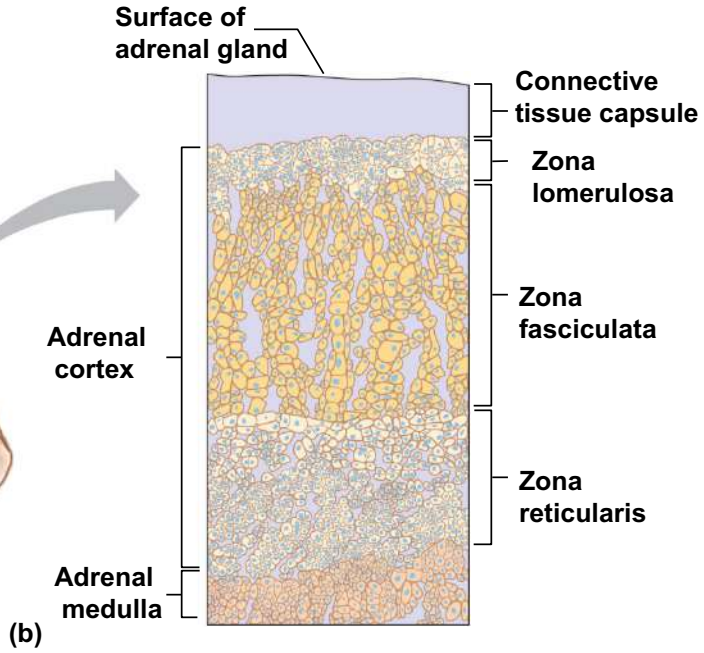




Hormones of the Adrenal Medulla

TABLE 13.10 | Comparative Effects of Epinephrine and Norepinephrine

Structure or Function Affected	Epinephrine	Norepinephrine
Heart	Rate increases Force of contraction increases	Rate increases Force of contraction increases
Blood vessels	Vessels in skeletal muscle vasodilate, decreasing resistance to blood flow	Blood flow to skeletal muscles increases, resulting from constriction of blood vessels in skin and viscera
Systemic blood pressure	Some increase due to increased cardiac output	Great increase due to vasoconstriction, counteracted in muscle blood vessels during exercise
Airways	Dilated	Some dilation
Reticular formation of brain	Activated	Little effect
Liver	Promotes breakdown of glycogen to glucose, increasing blood sugar level	Little effect on blood glucose level
Metabolic rate	Increases	Increases

Hormones of the Adrenal Cortex

TABLE 13.11 | Hormones of the Adrenal Cortex

Hormone	Action	Factors Regulating Secretion
Aldosterone	Helps regulate the concentration of extracellular electrolytes by conserving sodium ions and excreting potassium ions	Electrolyte concentrations in body fluids and renin-angiotensin mechanism
Cortisol	Decreases protein synthesis, increases fatty acid release, and stimulates glucose synthesis from noncarbohydrates	CRH from the hypothalamus and ACTH from the anterior pituitary gland
Adrenal androgens	Supplement sex hormones from the gonads; may be converted into estrogens	

13.3 Clinical Application

Disorders of the Adrenal Cortex

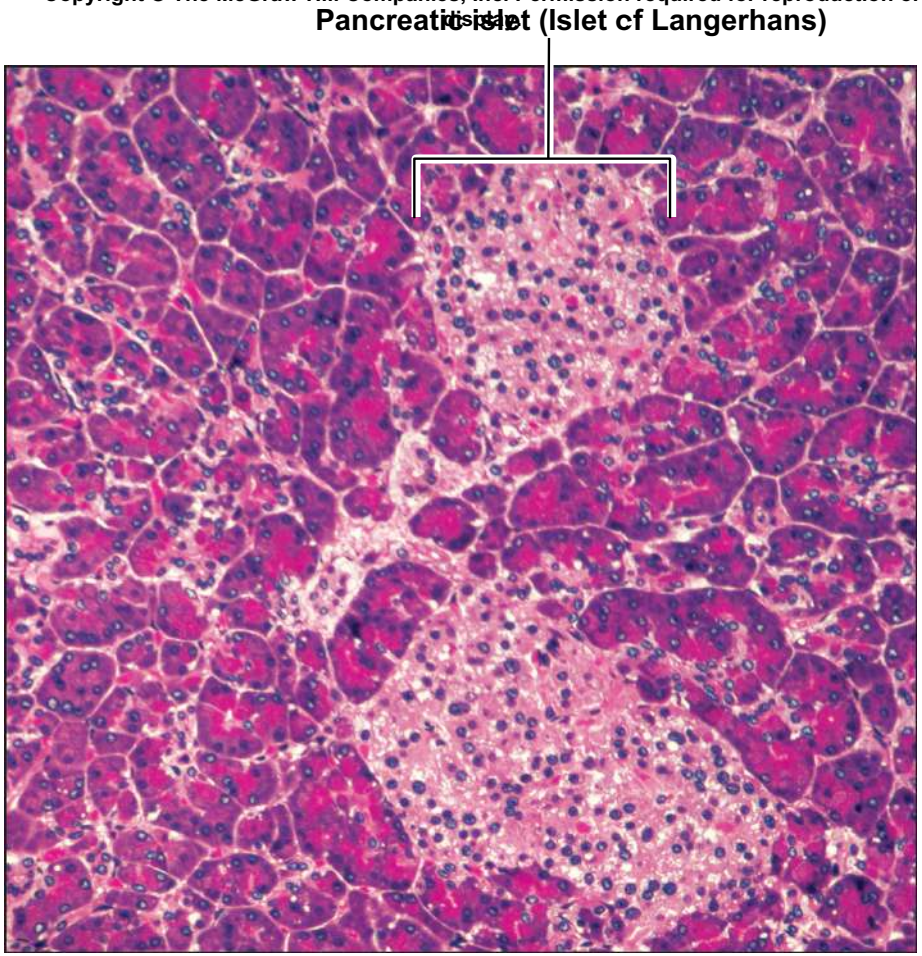
13.1 From Science to Technology

Treating Diabetes

13.9: Pancreas

- **The pancreas has two major types of secretory tissue**
- **This is why it is a dual functioning organ as both an exocrine gland and endocrine gland**
- **Three hormones are secreted from the islet cells:**
  - Alpha cells secrete glucagon
  - Beta cells insulin
  - Delta cells secrete somatostatin

Structure of the Gland



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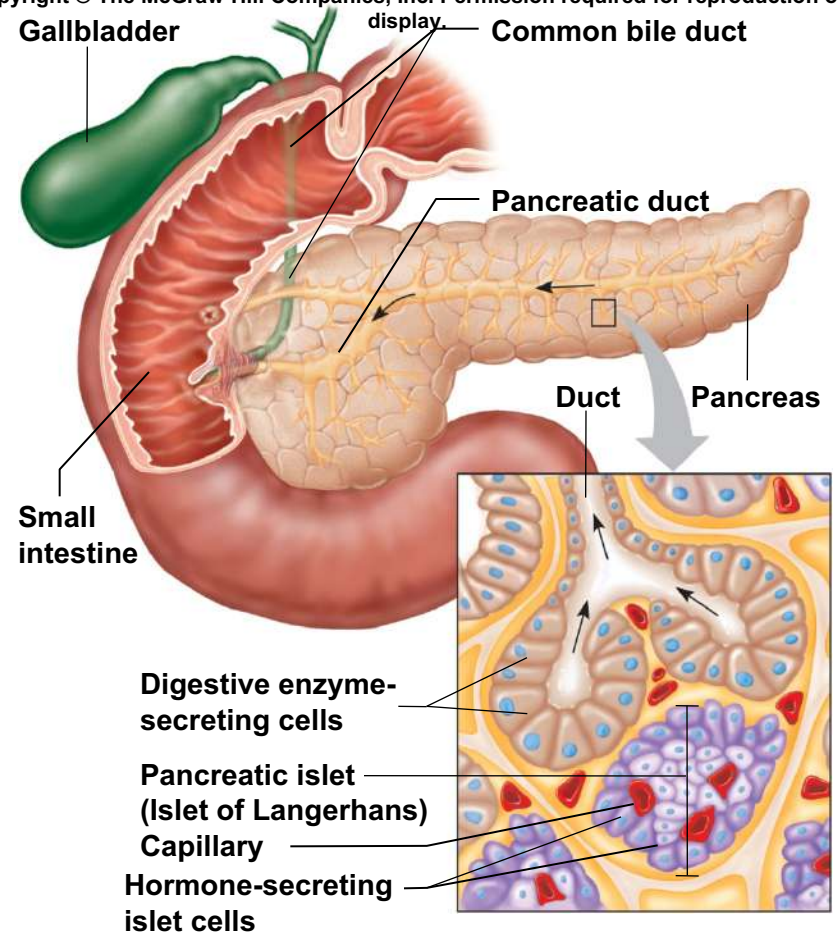
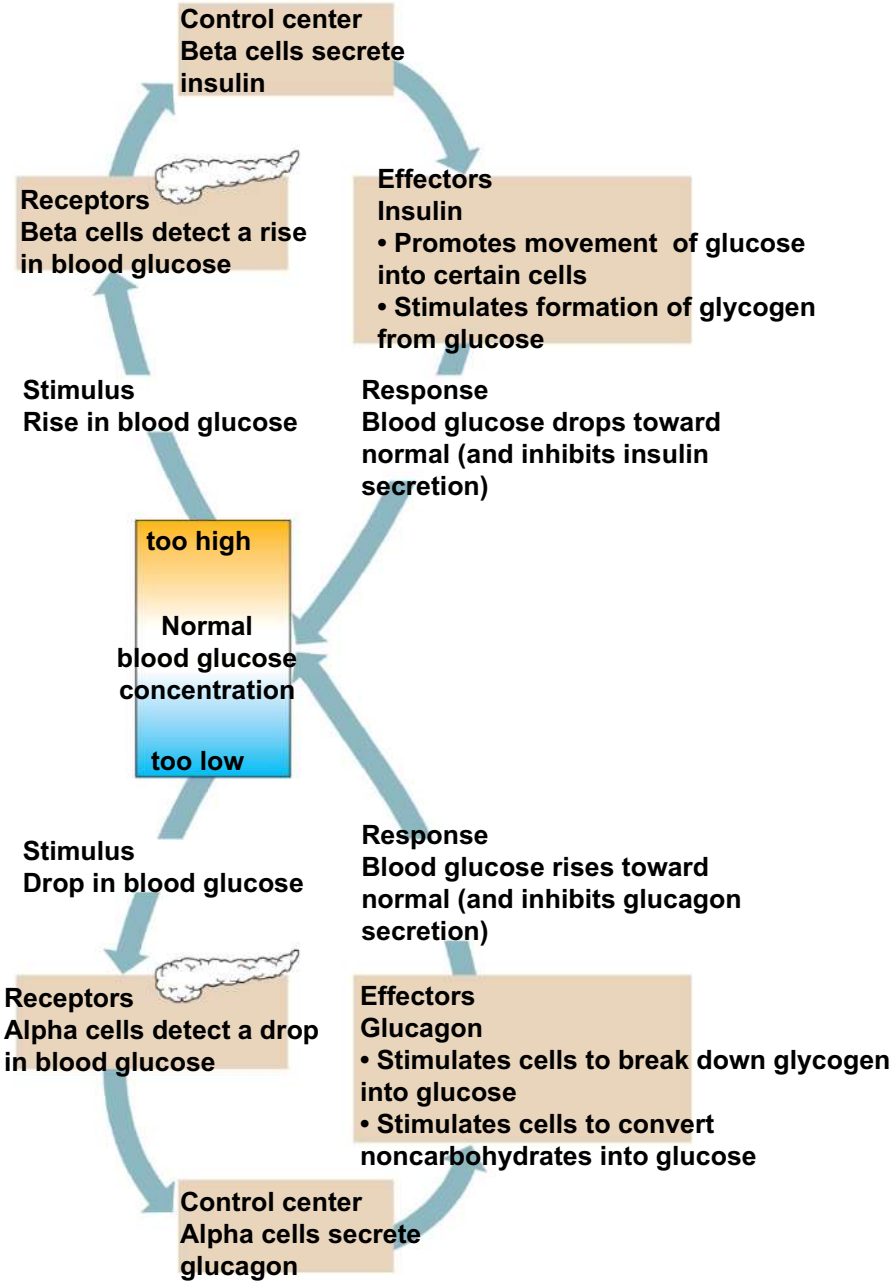


Hormones of the Pancreatic Islets

TABLE 13.12 | Hormones of the Pancreatic Islets

Hormone	Action	Source of Control
Glucagon	Stimulates the liver to break down glycogen and convert noncarbohydrates into glucose; stimulates breakdown of fats	Blood glucose concentration
Insulin	Promotes formation of glycogen from glucose, inhibits conversion of noncarbohydrates into glucose, and enhances movement of glucose through adipose and muscle cell membranes, decreasing blood glucose concentration; promotes transport of amino acids into cells; enhances synthesis of proteins and fats	Blood glucose concentration
Somatostatin	Helps regulate carbohydrates	Not determined



13.4 Clinical Application

Diabetes Mellitus

13.10: Other Endocrine Glands

Pineal Gland

- Secretes melatonin
- Regulates circadian rhythms

Thymus Gland

- Secretes thymosins
- Promotes development of certain lymphocytes
- Important in role of immunity

Reproductive Organs

- Ovaries produce estrogens and progesterone
- Testes produce testosterone
- Placenta produces estrogens, progesterone, and gonadotropin

Other organs: digestive glands, heart, and kidney

13.11: Stress and Its Effects

- **Survival depends on maintaining homeostasis**
- **Factors that change the internal environment are potentially life-threatening**
- **Sensing such dangers directs nerve impulses to the hypothalamus**
- **This can trigger a loss of homeostasis**

Types of Stress

- **Two types of stress:**
  - Physical stress
  - Psychological stress

Responses to Stress

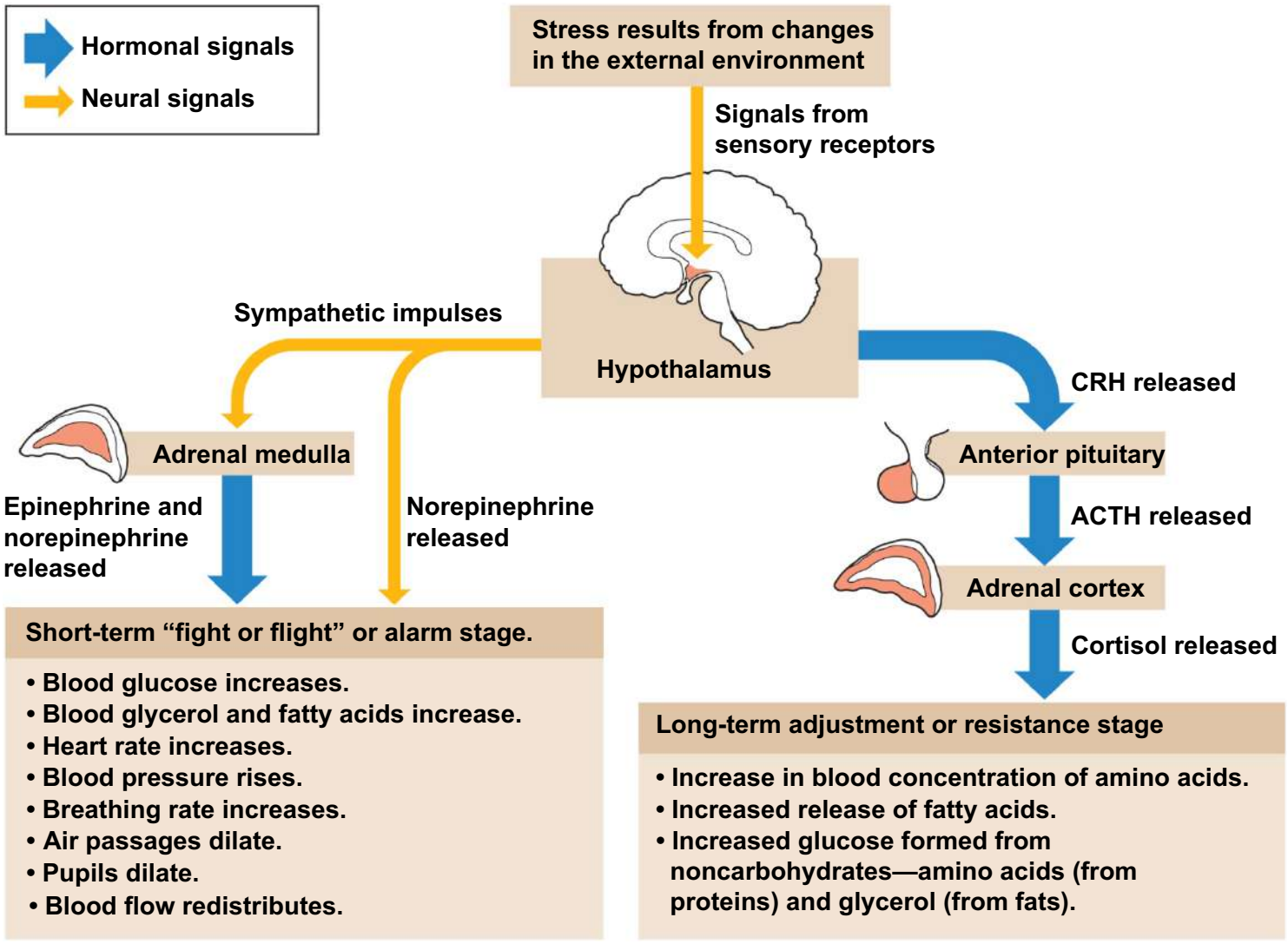


TABLE 13.13 | Major Events in the General Stress Syndrome

1. In response to stress, nerve impulses are transmitted to the hypothalamus.
2. Sympathetic impulses arising from the hypothalamus increase blood glucose concentration, blood glycerol concentration, blood fatty acid concentration, heart rate, blood pressure, and breathing rate. They dilate air passages, shunt blood into skeletal muscles, and increase secretion of epinephrine from the adrenal medulla.
3. Epinephrine intensifies and prolongs sympathetic actions.
4. The hypothalamus secretes CRH, which stimulates secretion of ACTH by the anterior pituitary gland.
5. ACTH stimulates release of cortisol by the adrenal cortex.
6. Cortisol increases the concentration of blood amino acids, releases fatty acids, and forms glucose from noncarbohydrate sources.
7. Secretion of glucagon from the pancreas and growth hormone from the anterior pituitary increase.
8. Glucagon and growth hormone aid mobilization of energy sources and stimulate uptake of amino acids by cells.
9. Secretion of ADH from the posterior pituitary increases.
10. ADH promotes the retention of water by the kidneys, which increases blood volume.
11. Renin increases blood levels of angiotensin II, which acts as a vasoconstrictor and also stimulates aldosterone secretion by the adrenal cortex.
12. Aldosterone stimulates sodium retention by the kidneys.

13.12: Lifespan Changes

- **Endocrine glands decrease in size**
- **Muscular strength decreases as GH levels decrease**
- **ADH levels increase due to slower break down in liver and kidneys**
- **Calcitonin levels decrease; increase risk of osteoporosis**
- **PTH level changes contribute to risk of osteoporosis**
- **Insulin resistance may develop**
- **Changes in melatonin secretion affect the body clock**
- **Thymosin production declines increasing risk of infections**

Important Points in Chapter 13:
Outcomes to be Assessed

13.1: Introduction

✓ Define hormone.

✓ Distinguish between endocrine and exocrine glands.

13.2: General Characteristics of the Endocrine System

✓ Explain what makes a cell a target cell for a hormone.

✓ List some important functions of hormones.

13.3: Hormone Action

✓ Describe how hormones can be classified according to their chemical composition.

✓ Explain how steroid and non-steroid hormones affect their target cells.

Important Points in Chapter 13:
Outcomes to be Assessed

13.4: Control of Hormone Secretion

✓ Discuss how negative feedback mechanisms regulate hormone secretion.

✓ Explain how the nervous system controls hormone secretion.

13.5-13.10: Pituitary Gland – Other Endocrine Glands

✓ Name and describe the locations of the major endocrine glands and list the hormones that they secrete.

✓ Describe the actions of the various hormones and their contributions to homeostasis.

✓ Explain how the secretion of each hormone is regulated.

Important Points in Chapter 13:
Outcomes to be Assessed

13.11: Stress and Its Effects

✓ Distinguish between physical and psychological stress.

✓ Describe the general stress response.

13.12: Lifespan Changes

✓ Describe some of the changes associated with aging of the endocrine system.

Quiz 13

Complete Quiz 13 now!

Read Chapter 14.