Elaine N. Marieb
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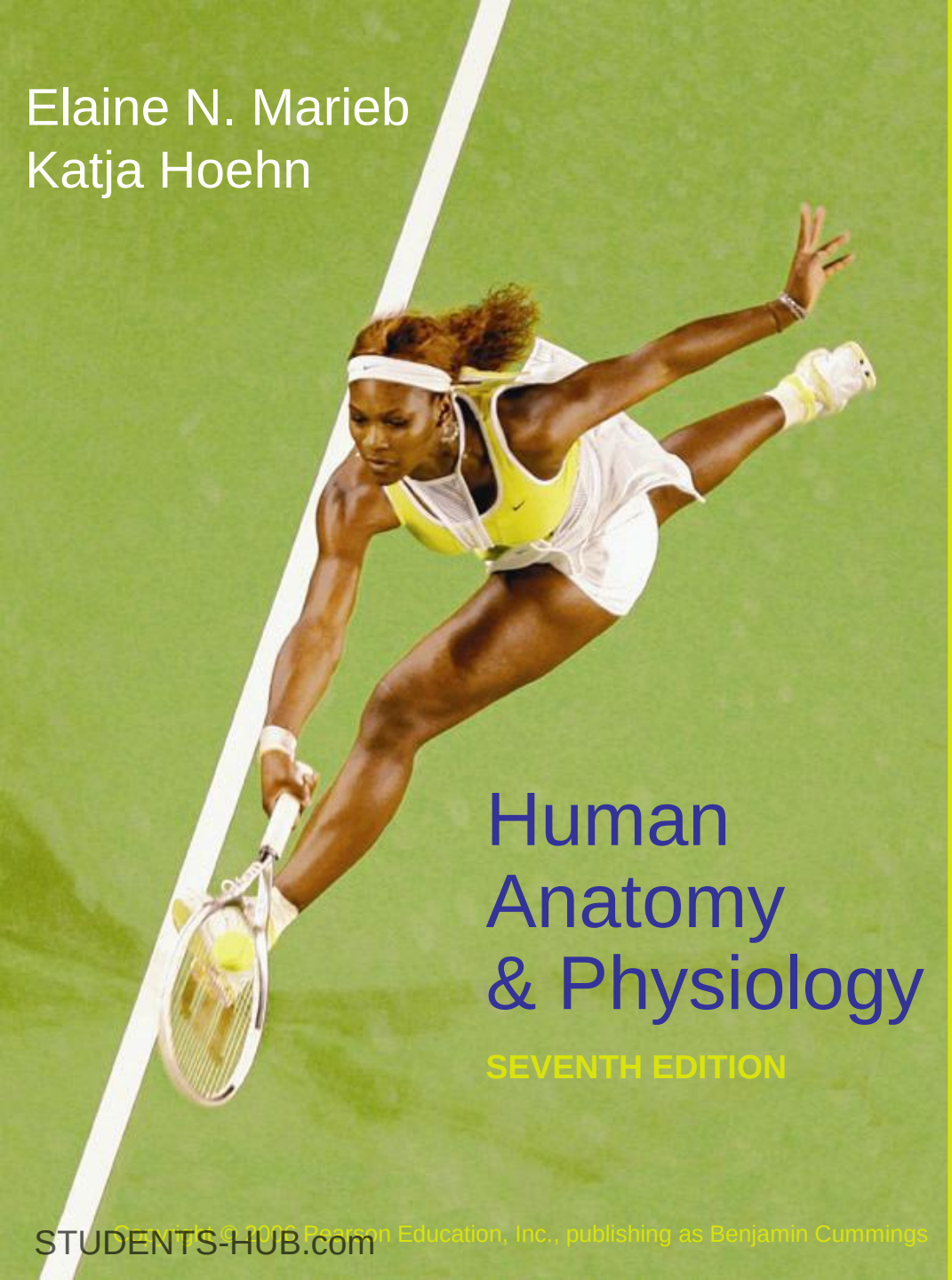


Human Anatomy & Physiology

SEVENTH EDITION

PowerPoint® Lecture Slides
prepared by Vince Austin,
Bluegrass Technical
and Community College

CHAPTER 16 PART A

The Endocrine System

Endocrine System: Overview

- **Endocrine system** – the body's second great controlling system which influences metabolic activities of cells by means of hormones
- **Endocrine glands** – pituitary, thyroid, parathyroid, adrenal, pineal, and thymus
- The pancreas and gonads produce both hormones and exocrine products

Endocrine System: Overview

- The hypothalamus has both neural functions and releases hormones
- Other tissues and organs that produce hormones – adipose cells, pockets of cells in the walls of the small intestine, stomach, kidneys, and heart

PLAY

***InterActive Physiology* ®: Endocrine System Review**

Major Endocrine Organs

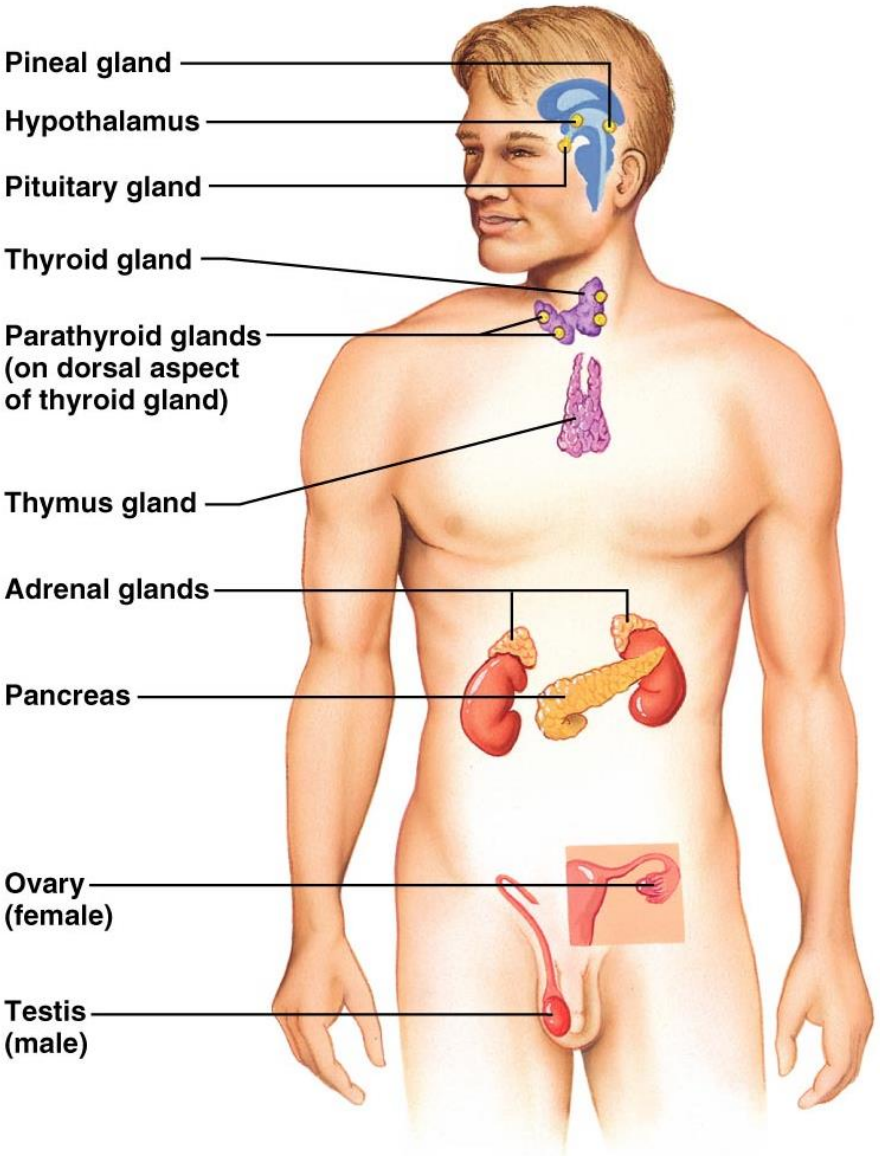


Figure 16.1

Autocrines and Paracrines

- **Autocrines** – chemicals that exert effects on the same cells that secrete them
- **Paracrines** – locally acting chemicals that affect cells other than those that secrete them
- These are not considered hormones since hormones are long-distance chemical signals

Hormones

- **Hormones** – chemical substances secreted by cells into the extracellular fluids
  - Regulate the metabolic function of other cells
  - Have lag times ranging from seconds to hours
  - Tend to have prolonged effects
  - Are classified as amino acid-based hormones, or steroids

Types of Hormones

- Amino acid based
  - Amines, thyroxine, peptide, and protein hormones
- Steroids – gonadal and adrenocortical hormones

InterActive Physiology ®:
Biochemistry, Secretion, and Transport of Hormones

Hormone Action

- Hormones alter target cell activity by one of two mechanisms
  - Second messengers:
    - Regulatory G proteins
    - Amino acid–based hormones
  - Direct gene activation
    - Steroid hormones
- The precise response depends on the type of the target cell

Mechanism of Hormone Action

- Hormones produce one or more of the following cellular changes in target cells
  - Alter plasma membrane permeability
  - Stimulate protein synthesis
  - Activate or deactivate enzyme systems
  - Induce secretory activity
  - Stimulate mitosis

PLAY

InterActive Physiology ®:
The Actions of Hormones on Target Cells

Amino Acid-Based Hormone Action: cAMP Second Messenger

- Hormone (first messenger) binds to its receptor, which then binds to a G protein
- The G protein is then activated as it binds GTP, displacing GDP
- Activated G protein activates the effector enzyme adenylate cyclase
- Adenylate cyclase generates cAMP (second messenger) from ATP
- cAMP activates protein kinases, which then cause cellular effects

Amino Acid-Based Hormone Action: cAMP Second Messenger

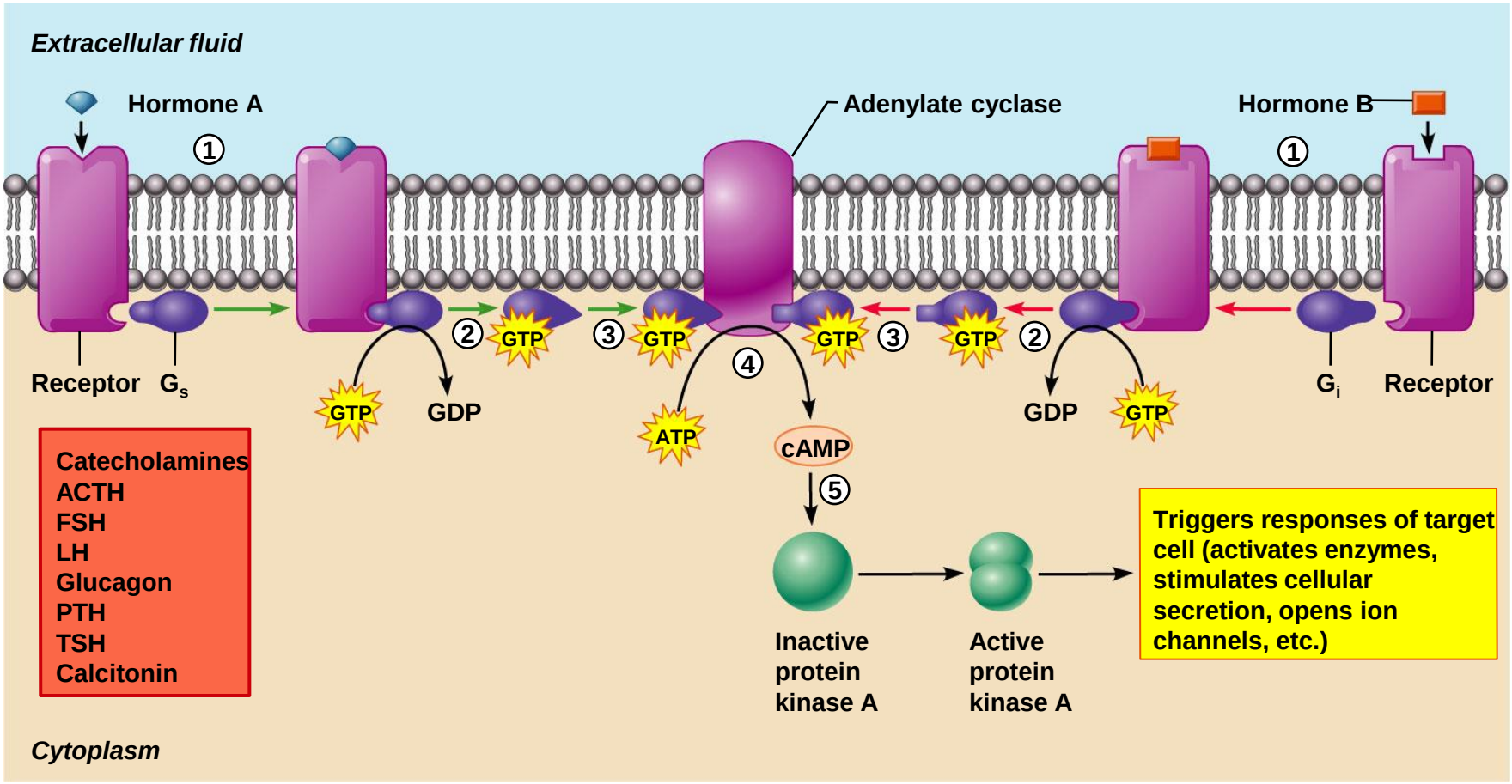
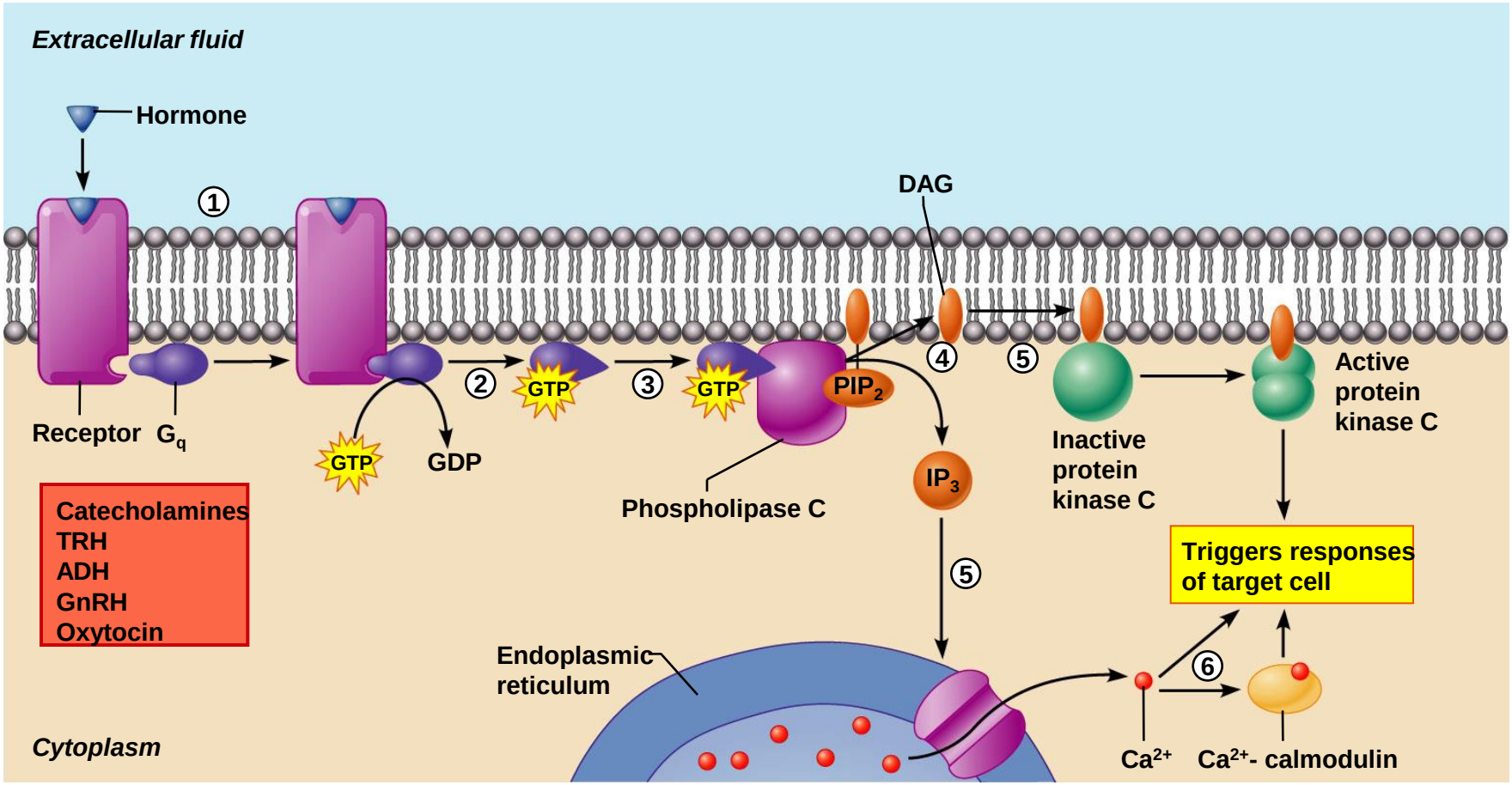


Figure 16.2

Amino Acid-Based Hormone Action: PIP-Calcium

- Hormone binds to the receptor and activates G protein
- G protein binds and activates phospholipase
- Phospholipase splits the phospholipid PIP_2 into diacylglycerol (DAG) and IP_3 (both act as second messengers)
- DAG activates protein kinases; IP_3 triggers release of Ca^{2+} stores
- Ca^{2+} (third messenger) alters cellular responses

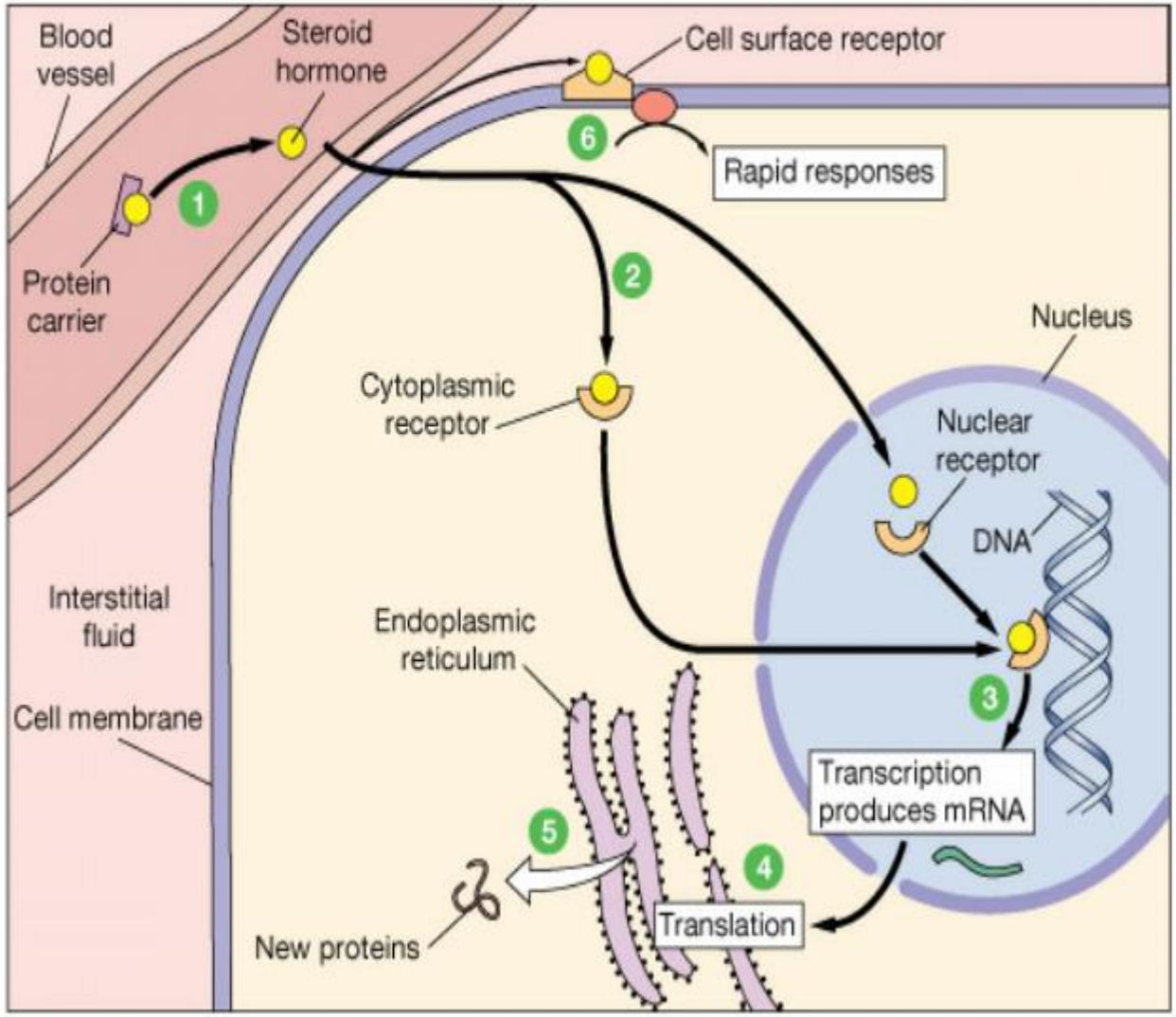
Amino Acid-Based Hormone Action: PIP Mechanism



Steroid Hormones

- This interaction prompts DNA transcription to produce mRNA
- The mRNA is translated into proteins, which bring about a cellular effect

Steroid hormone action



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. The receptor-hormone complex binds to DNA and activates or represses one or more genes.
4. Activated genes create new mRNA that moves back to the cytoplasm.
5. Translation produces new proteins for cell processes.
6. Some steroid hormones also bind to membrane receptors that use second messenger systems to create rapid cellular responses.

Target Cell Specificity

- Hormones circulate to all tissues but only activate cells referred to as target cells
- Target cells must have specific receptors to which the hormone binds
- These receptors may be intracellular or located on the plasma membrane

Target Cell Specificity

- Examples of hormone activity
  - ACTH receptors are only found on certain cells of the adrenal cortex
  - Thyroxin receptors are found on nearly all cells of the body

Target Cell Activation

- Target cell activation depends on three factors
  - Blood levels of the hormone
  - Relative number of receptors on the target cell
  - The affinity of those receptors for the hormone
- Up-regulation – target cells form more receptors in response to the hormone
- Down-regulation – target cells lose receptors in response to the hormone

Hormone Concentrations in the Blood

- Hormones circulate in the blood in two forms – free or bound
  - Steroids and thyroid hormone are attached to plasma proteins
- Concentrations of circulating hormone reflect:
  - Rate of release
  - Speed of inactivation and removal from the body
- Hormones are removed from the blood by:
  - Degrading enzymes
  - The kidneys
  - Liver enzyme systems

Control of Hormone Release

- Blood levels of hormones:
  - Are controlled by negative feedback systems
  - Vary only within a narrow desirable range
- Hormones are synthesized and released in response to:
  - Humoral stimuli
  - Neural stimuli
  - Hormonal stimuli

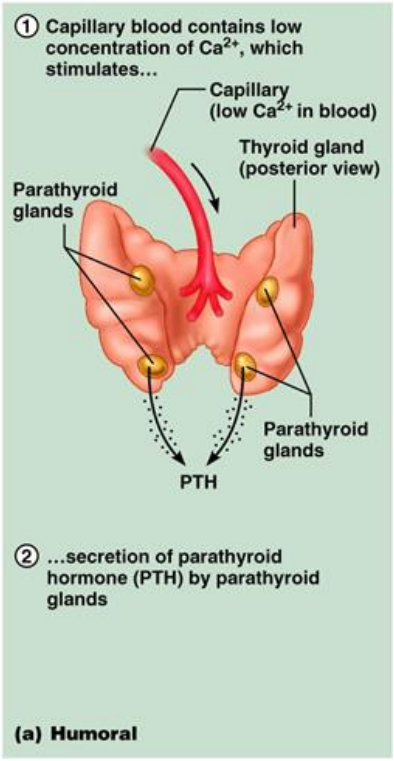
Humoral Stimuli

- **Humoral stimuli** – secretion of hormones
- in direct response to changing blood
- levels of ions and nutrients
- Example: concentration of calcium ions in the blood
  - Declining blood Ca^{2+} concentration stimulates

the parathyroid glands to secrete PTH

(parathyroid hormone)

  - PTH causes Ca^{2+} concentrations to rise and the stimulus is removed



Neural Stimuli

- **Neural stimuli** – nerve fibers stimulate hormone release
  - Preganglionic sympathetic nervous system (SNS) fibers stimulate the adrenal medulla to secrete catecholamines

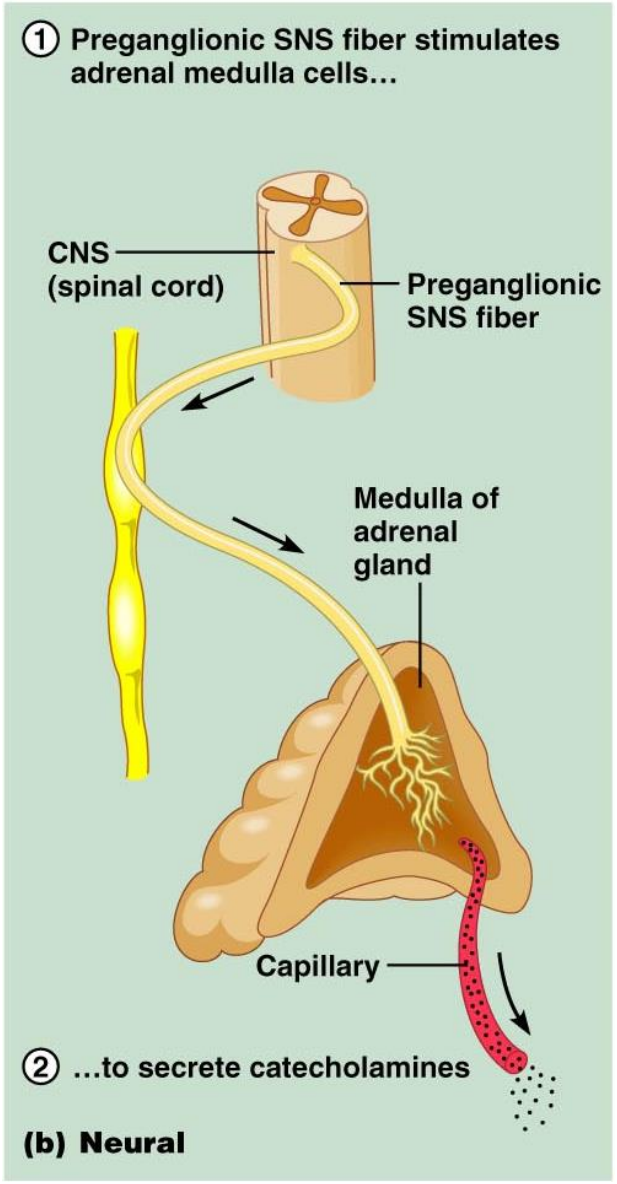


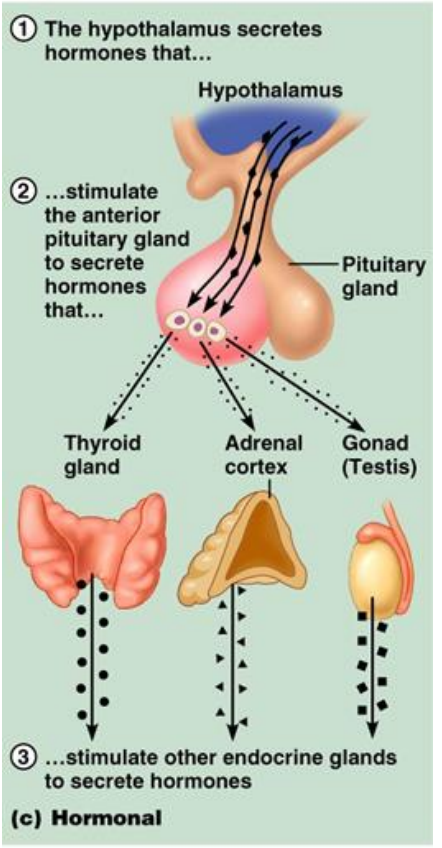
Figure 16.5b

Hormonal Stimuli

- **Hormonal stimuli** – release of hormones in response to hormones produced by other endocrine organs
  - The hypothalamic hormones

  stimulate the anterior pituitary
  - In turn, pituitary hormones

  stimulate targets to secrete still more hormones



Major Endocrine Organs: Pituitary (Hypophysis)

- **Pituitary gland** – two-lobed organ that secretes nine major hormones
- Neurohypophysis – posterior lobe (neural tissue) and the infundibulum
  - Receives, stores, and releases hormones from the hypothalamus
- Adenohypophysis – anterior lobe, made up of glandular tissue
  - Synthesizes and secretes a number of hormones

Major Endocrine Organs: Pituitary (Hypophysis)

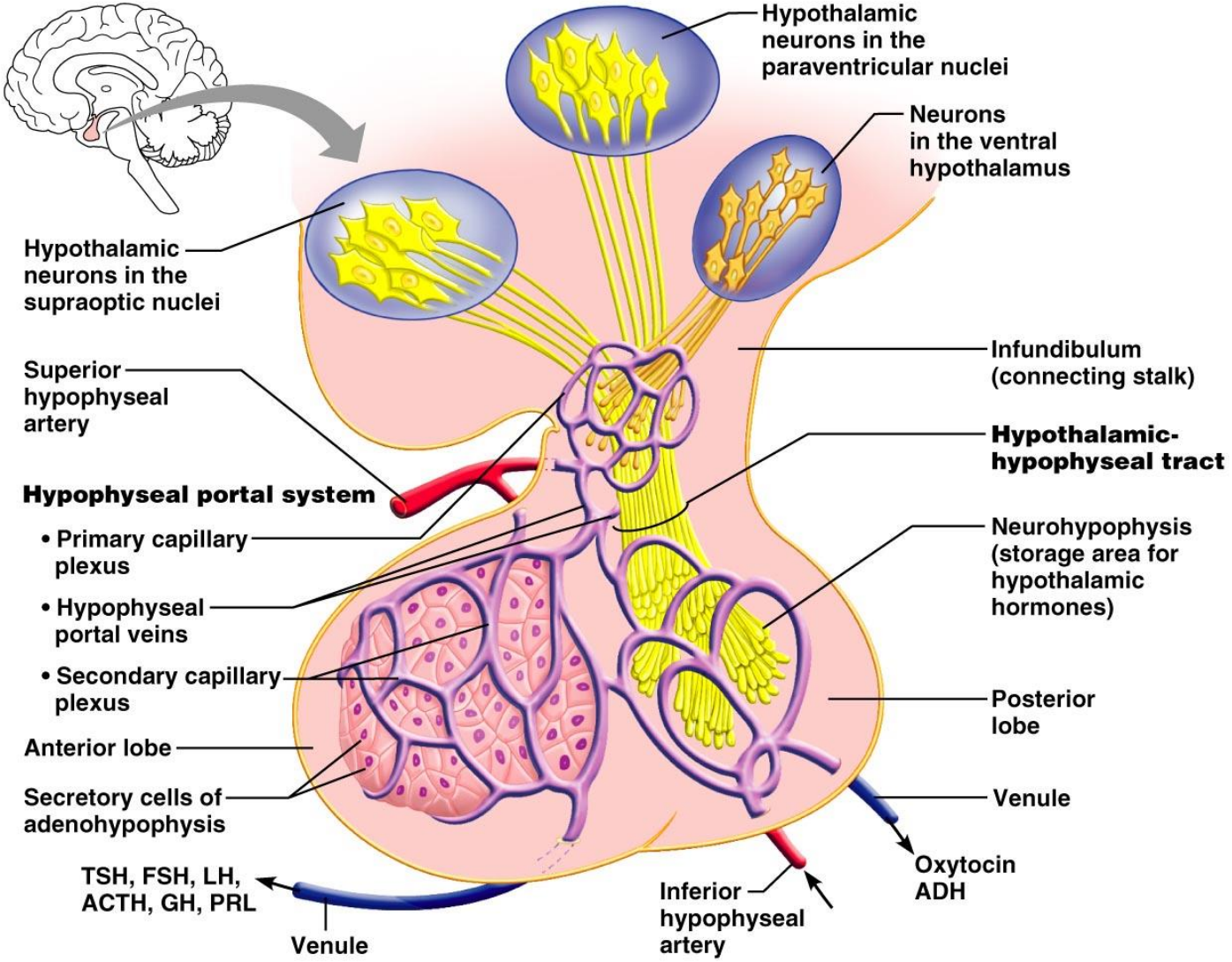


Figure 16.6

Hormones of the Anterior Pituitary

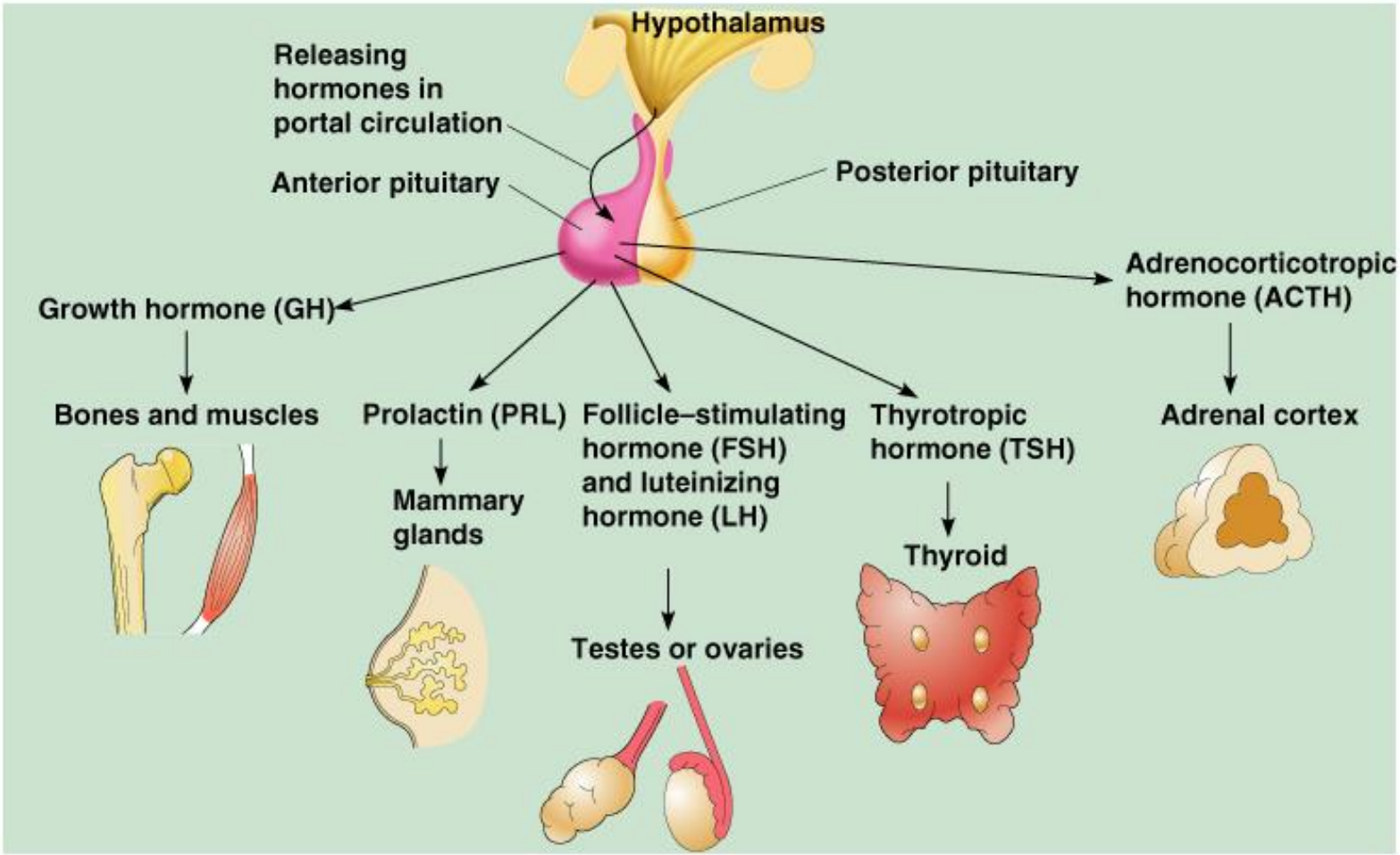


Figure 9.4

Pituitary-Hypothalamic Relationships: Posterior Lobe

- The posterior lobe is a downgrowth of hypothalamic neural tissue
- Has a neural connection with the hypothalamus (hypothalamic-hypophyseal tract)
- Nuclei of the hypothalamus synthesize oxytocin and antidiuretic hormone (ADH)
- These hormones are transported to the posterior pituitary

Pituitary-Hypothalamic Relationships: Anterior Lobe

- There is a vascular connection, the hypophyseal portal system, consisting of:
  - The primary capillary plexus
  - The hypophyseal portal veins
  - The secondary capillary plexus

PLAY

InterActive Physiology ®: **The Hypothalamic Pituitary Axis**

Adenophypophyseal Hormones

- The six hormones of the adenohypophysis:
  - Abbreviated as GH, TSH, ACTH, FSH, LH, and PRL
  - Regulate the activity of other endocrine glands

Activity of the Adenophypophysis

- The hypothalamus sends a chemical stimulus to the anterior pituitary
  - Releasing hormones stimulate the synthesis and release of hormones
  - Inhibiting hormones shut off the synthesis and release of hormones

Activity of the Adenophypophysis

- Tropic hormones are hormones that act on another endocrine glands.
- Non-tropic hormones stimulate directly the target cell.
- The tropic hormones that are released are:
  - Thyroid-stimulating hormone (TSH)
  - Adrenocorticotropic hormone (ACTH)
  - Follicle-stimulating hormone (FSH)
  - Luteinizing hormone (LH)

Gonadotropins

- Gonadotropins – follicle-stimulating hormone (FSH) and luteinizing hormone (LH)
  - Regulate the function of the ovaries and testes
  - FSH stimulates gamete (egg or sperm) production
  - Absent from the blood in prepubertal boys and girls
  - Triggered by the hypothalamic gonadotropin-releasing hormone (GnRH) during and after puberty

Functions of Gonadotropins

- In females
  - LH works with FSH to cause maturation of the ovarian follicle
  - LH works alone to trigger ovulation (expulsion of the egg from the follicle)
  - LH promotes synthesis and release of estrogens and progesterone

Functions of Gonadotropins

- In males
  - LH stimulates interstitial cells of the testes to produce testosterone
  - LH is also referred to as interstitial cell-stimulating hormone (ICSH)

Growth Hormone (GH)

- Produced by somatotropic cells of the anterior lobe that:
  - Stimulate most cells, but target bone and skeletal muscle (stimulate the growth skeletal muscles and long bones of the body).
  - Promote protein synthesis and encourage the use of fats for fuel
- Play an important role in determining final body size.

Growth Hormone (GH)

- Antagonistic hypothalamic hormones regulate GH
  - Growth hormone–releasing hormone (GHRH) stimulates GH release
  - Growth hormone–inhibiting hormone (GHIH) inhibits GH release

Growth Hormone (GH)

- Target: skeletal muscles and long bones
- Function: build up proteins
  - Massive increase in size of bone and muscle
    - Hyposecretion in childhood – dwarfism
    - Hypersecretion in childhood – gigantism
    - Hypersecretion in adult – acromegaly

Metabolic Action of Growth Hormone

- GH stimulates liver, skeletal muscle, bone, and cartilage to produce insulin-like growth factors
- Anti Insulin action, **Diabetogenic effect of GH**

(decreasing the rate of glucose uptake and metabolism, and stimulate the breakdown of glycogen from the liver)

- Direct action promotes lipolysis and inhibits glucose uptake

Metabolic Action of Growth Hormone (GH)

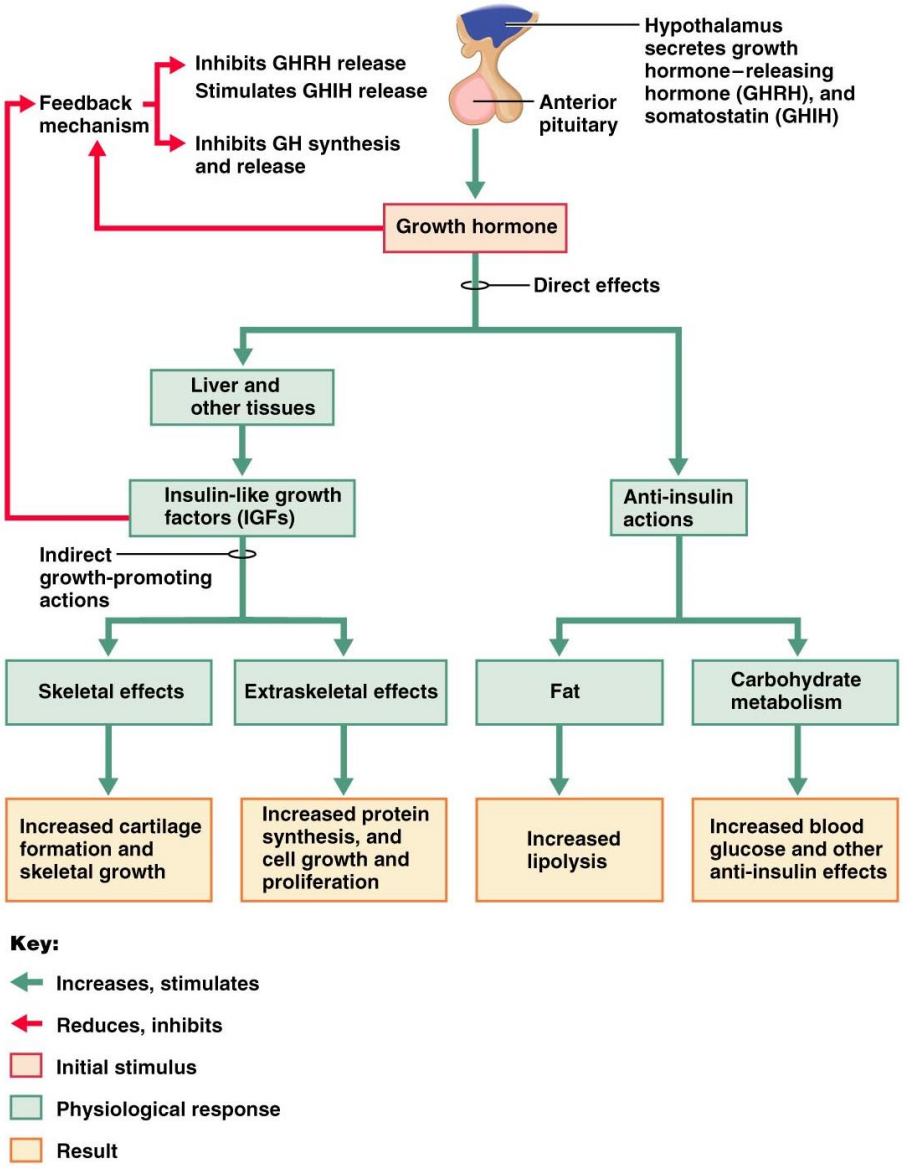


Figure 16.7

Prolactin (PRL)

- In females, stimulates milk production by the breasts
- Triggered by the hypothalamic prolactin-releasing hormone (PRH)
- Inhibited by prolactin-inhibiting hormone (PIH)
- Blood levels rise toward the end of pregnancy
- Suckling stimulates PRH release and encourages continued milk production

The Posterior Pituitary and Hypothalamic Hormones

- Posterior pituitary – made of axons of hypothalamic neurons, stores antidiuretic hormone (ADH) and oxytocin
- ADH and oxytocin are synthesized in the hypothalamus
- ADH influences water balance
- Oxytocin stimulates smooth muscle contraction in breasts and uterus
- Both use PIP-calcium second-messenger mechanism

Oxytocin

- Oxytocin is a strong stimulant of uterine contraction
- Regulated by a positive feedback mechanism to oxytocin in the blood
- This leads to increased intensity of uterine contractions, ending in birth
- Oxytocin triggers milk ejection (“letdown” reflex) in women producing milk
- Synthetic and natural oxytocic drugs are used to induce or hasten (speeds up) labor

Antidiuretic Hormone (ADH)

- ADH helps to avoid dehydration or water overload
  - Prevents urine formation
- Osmoreceptors monitor the solute concentration of the blood
- With high solutes, ADH preserves water
- With low solutes, ADH is not released, thus causing water loss
- Alcohol inhibits ADH release and causes copious urine output

Thyroid Gland

- The largest endocrine gland, located in the anterior neck, consists of two lateral lobes connected by a median tissue mass called the isthmus
- Composed of follicles that produce the glycoprotein thyroglobulin
- Colloid (thyroglobulin + iodine) fills the lumen of the follicles and is the precursor of thyroid hormone
- Other endocrine cells, the parafollicular cells, produce the hormone calcitonin

Thyroid Gland

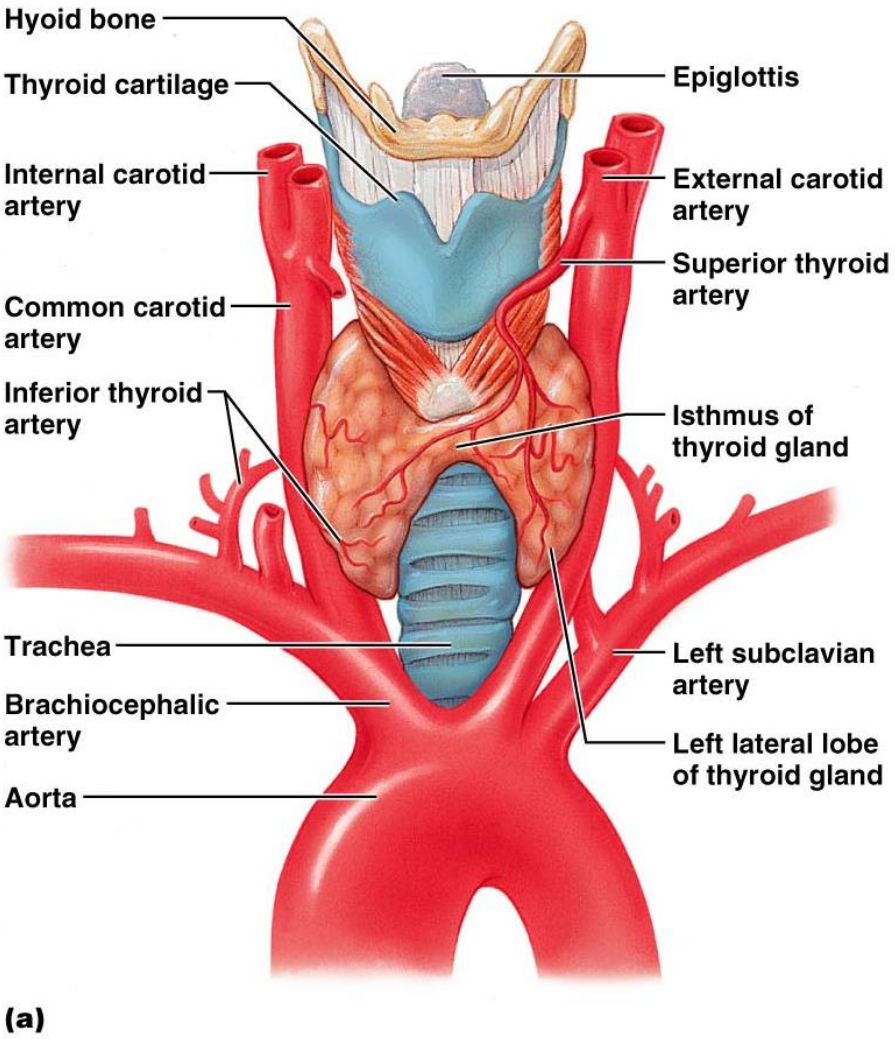


Figure 16.8

Thyroid Hormone

- Thyroid hormone – major metabolic hormone
- Consists of two related iodine-containing compounds
  - T_4 – thyroxine; has two tyrosine molecules plus four bound iodine atoms
  - T_3 – triiodothyronine; has two tyrosines with three bound iodine atoms

Effects of Thyroid Hormone

- TH is concerned with:
  - Glucose oxidation
  - Increasing metabolic rate
  - Heat production
- TH plays a role in:
  - Maintaining blood pressure
  - Regulating tissue growth
  - Developing skeletal and nervous systems
  - Maturation and reproductive capabilities

Transport and Regulation of TH

- T_4 and T_3 bind to thyroxine-binding globulins (TBGs) produced by the liver
- Both bind to target receptors, but T_3 is ten times more active than T_4
- Peripheral tissues convert T_4 to T_3
- Mechanisms of activity are similar to steroids
- Regulation is by negative feedback
- Hypothalamic thyrotropin-releasing hormone (TRH) can overcome the negative feedback

Thyroid disorders

- In **Hyperthyroidism**: T_3 and/or T_4 are high and the level of TSH in the blood is low, due to the negative feedback control
- In **Hypothyroidism**: TSH is high and both T_3 and T_4 are low.

Effects of Thyroid Hormone

- **Abnormalities:**
  - **Goitre**: enlargement of thyroid gland

  - **Creatinism**: Hypothyroidism in childhood:
  - **Myxedema**: Hypothyroidism in adult
  - **Grave's disease**: autoimmune hyperthyroidism, causes eys bulge

Calcitonin

- A peptide hormone produced by the parafollicular, or C, cells
- Lowers blood calcium levels in children
- Antagonist to parathyroid hormone (PTH)

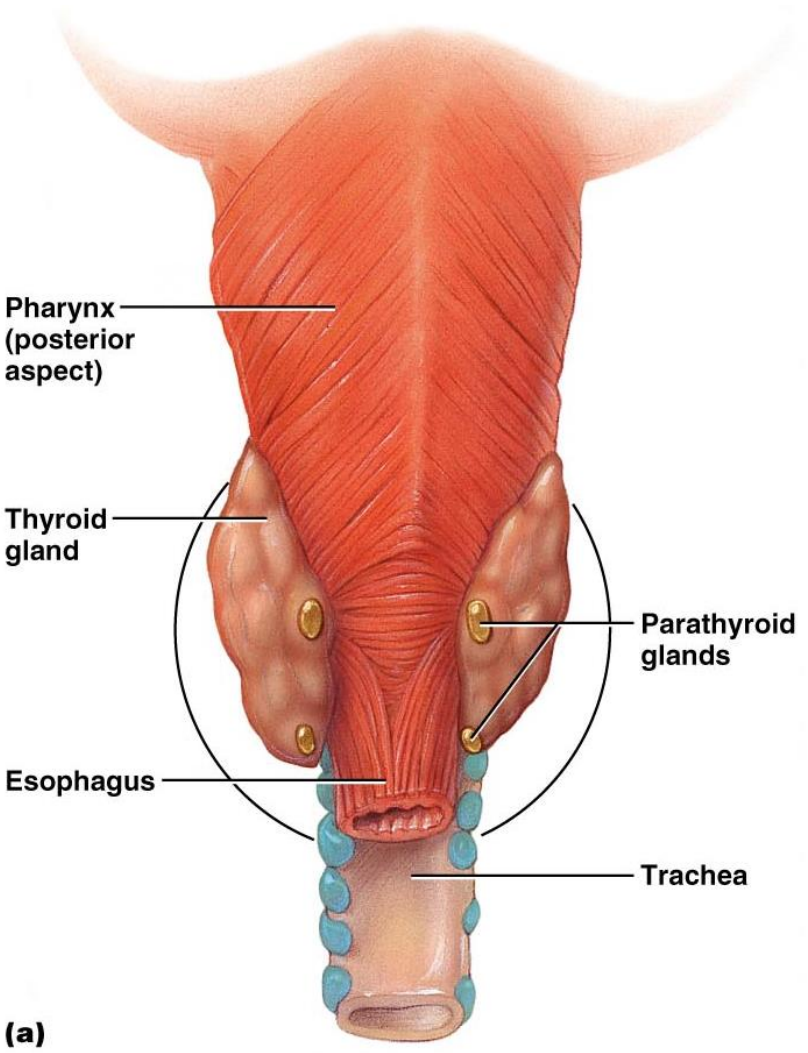
Calcitonin

- Calcitonin targets the skeleton, where it:
  - Inhibits osteoclast activity (and thus bone resorption) and release of calcium from the bone matrix
  - Stimulates calcium uptake and incorporation into the bone matrix
- Regulated by a humoral (calcium ion concentration in the blood) negative feedback mechanism

Parathyroid Glands

- Tiny glands embedded in the posterior aspect of the thyroid
- Cells are arranged in cords containing oxyphil and chief cells
- Chief (principal) cells secrete PTH
- PTH (parathormone) regulates calcium balance in the blood

Parathyroid Glands



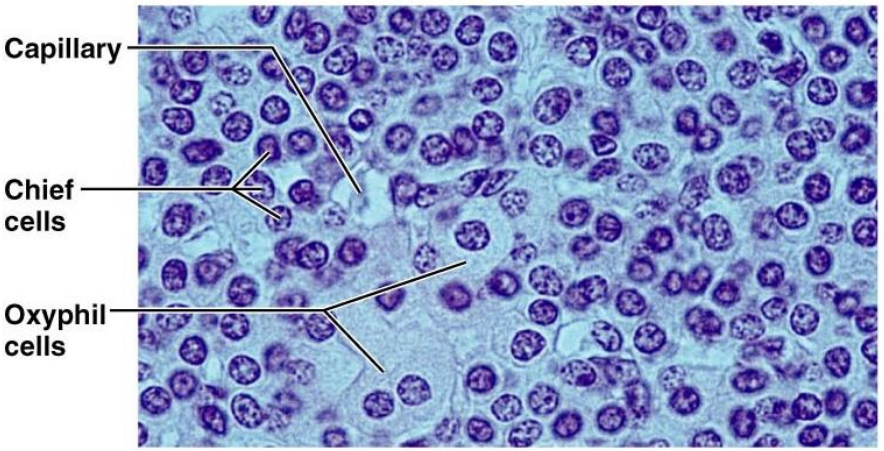


Figure 16.11

Effects of Parathyroid Hormone

- PTH release increases Ca^{2+} in the blood as it:
  - Stimulates osteoclasts to digest bone matrix
  - Enhances the reabsorption of Ca^{2+} and the secretion of phosphate by the kidneys
  - Increases absorption of Ca^{2+} by intestinal mucosal
- Rising Ca^{2+} in the blood inhibits PTH release

Effects of Parathyroid Hormone

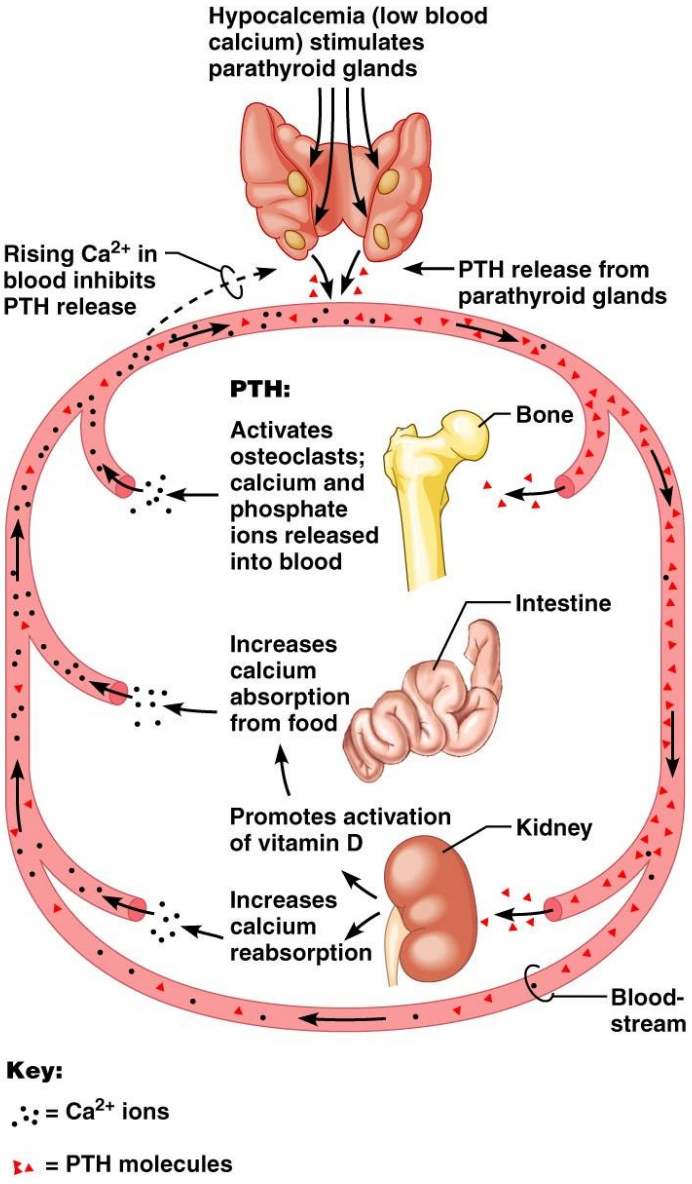


Figure 16.12

Adrenal (Suprarenal) Glands

- Adrenal glands – paired, pyramid-shaped organs atop the kidneys
- Structurally and functionally, they are two glands in one
  - Adrenal medulla – neural tissue that acts as part of the SNS
  - Adrenal cortex – glandular tissue derived from embryonic mesoderm

Adrenal Cortex

- Synthesizes and releases steroid hormones called corticosteroids
- Different corticosteroids are produced in each of the three layers
  - **Zona glomerulosa** – mineralocorticoids (chiefly aldosterone)
  - **Zona fasciculata** – glucocorticoids (chiefly cortisol)
  - **Zona reticularis** – gonadocorticoids (chiefly androgens)

Adrenal Cortex

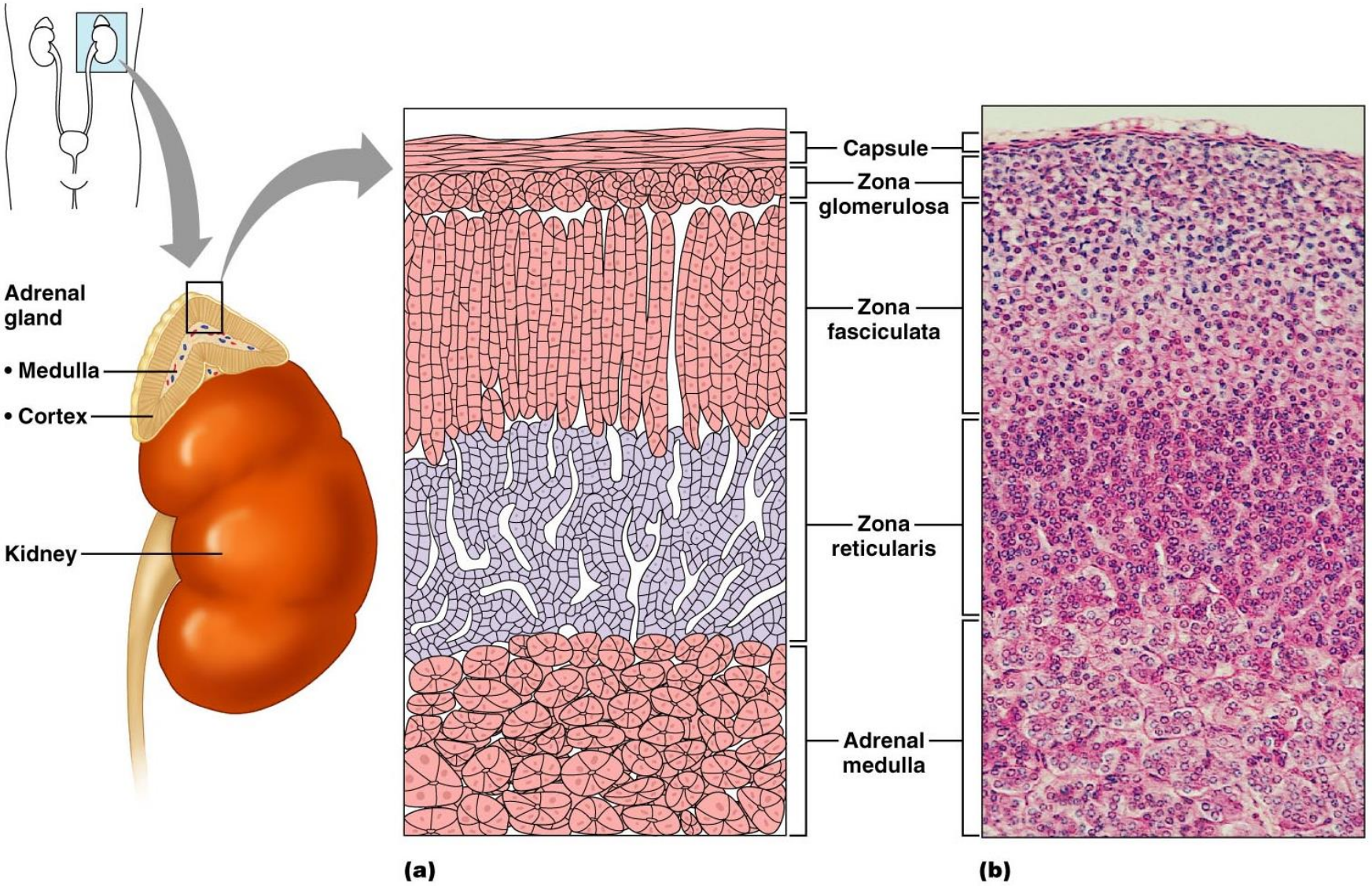


Figure 16.13a, b

Mineralocorticoids

- Regulate electrolytes in extracellular fluids
- Aldosterone – most important mineralocorticoid
  - Maintains Na^+ balance by reducing excretion of sodium from the body
  - Stimulates reabsorption of Na^+ by the kidneys

Mineralocorticoids

- Aldosterone secretion is stimulated by:
  - Rising blood levels of K^+
  - Low blood Na^+
  - Decreasing blood volume or pressure

The Four Mechanisms of Aldosterone Secretion

- **Renin-angiotensin mechanism** – kidneys release renin, which is converted into angiotensin II that in turn stimulates aldosterone release
- **Plasma concentration of sodium and potassium** – directly influences the zona glomerulosa cells
- **ACTH** – causes small increases of aldosterone during stress
- **Atrial natriuretic peptide (ANP)** – inhibits activity of the zona glomerulosa

Major Mechanisms of Aldosterone Secretion

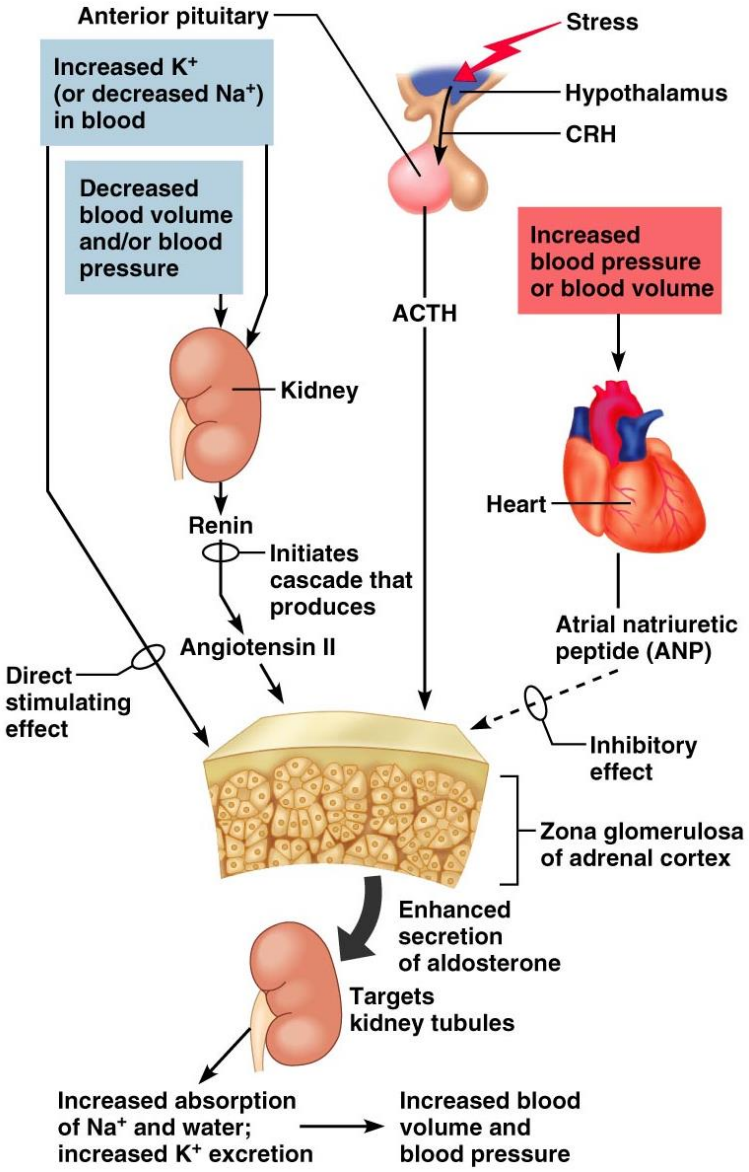


Figure 16.14

Glucocorticoids (Cortisol)

- Help the body resist stress by:
  - Keeping blood sugar levels relatively constant
  - Maintaining blood volume and preventing water shift into tissue
- Cortisol provokes:
  - Gluconeogenesis (formation of glucose from noncarbohydrates)
  - Rises in blood glucose, fatty acids, and amino acids

Excessive Levels of Glucocorticoids

- Excessive levels of glucocorticoids:
  - Depress cartilage and bone formation
  - Inhibit inflammation
  - Depress the immune system
  - Promote changes in cardiovascular, neural, and gastrointestinal function

Gonadocorticoids (Sex Hormones)

- Most gonadocorticoids secreted are androgens (male sex hormones), and the most important one is testosterone
- Androgens contribute to:
  - The onset of puberty
  - The appearance of secondary sex characteristics
  - Sex drive in females
- Androgens can be converted into estrogens after menopause

Adrenal Medulla

- Made up of chromaffin cells that secrete epinephrine and norepinephrine
- Secretion of these hormones causes:
  - Blood glucose levels to rise
  - Blood vessels to constrict
  - The heart to beat faster
  - Blood to be diverted to the brain, heart, and skeletal muscle

Adrenal Medulla

- Epinephrine is the more potent stimulator of the heart and metabolic activities
- Norepinephrine is more influential on peripheral vasoconstriction and blood pressure

Stress and the Adrenal Gland

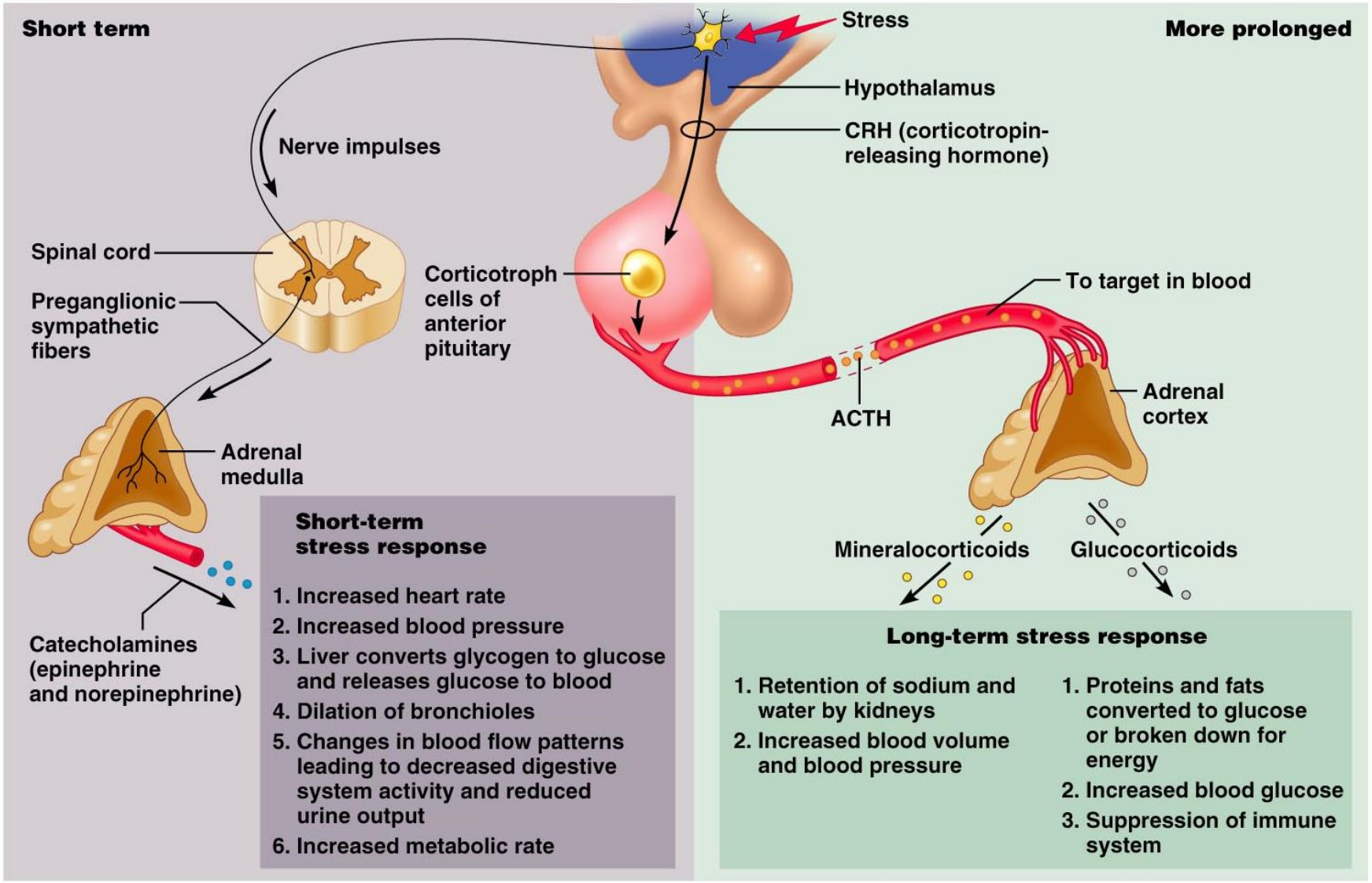


Figure 16.16

Pancreas

- A triangular gland, which has both exocrine and endocrine cells, located behind the stomach
- Acinar cells produce an enzyme-rich juice used for digestion (exocrine product)
- Pancreatic islets (islets of Langerhans) produce hormones (endocrine products)
- The islets contain two major cell types:
  - Alpha (α) cells that produce glucagon
  - Beta (β) cells that produce insulin

Glucagon

- A 29-amino-acid polypeptide hormone that is a potent hyperglycemic agent
- Its major target is the liver, where it promotes:
  - Glycogenolysis – the breakdown of glycogen to glucose
  - Gluconeogenesis – synthesis of glucose from lactic acid and noncarbohydrates
  - Release of glucose to the blood from liver cells

Insulin

- A 51-amino-acid protein consisting of two amino acid chains linked by disulfide bonds
- Synthesized as part of proinsulin and then excised by enzymes, releasing functional insulin
- Insulin:
  - Lowers blood glucose levels
  - Enhances transport of glucose into body cells
  - Counters metabolic activity that would enhance blood glucose levels

Effects of Insulin Binding

- The insulin receptor is a tyrosine kinase enzyme
- After glucose enters a cell, insulin binding triggers enzymatic activity that:
  - Catalyzes the oxidation of glucose for ATP production
  - Polymerizes glucose to form glycogen
  - Converts glucose to fat (particularly in adipose tissue)

Diabetes Mellitus (DM)

- Results from Hyposecretion or hypoactivity of insulin
- The three cardinal signs of DM are:
  - Polyuria – huge urine output
  - Polydipsia – excessive thirst
  - Polyphagia – excessive hunger and food consumption
- Hyperinsulinism – excessive insulin secretion, resulting in hypoglycemia

Gonads: Female

- Paired ovaries in the abdominopelvic cavity produce estrogens and progesterone
- They are responsible for:
  - Maturation of the reproductive organs
  - Appearance of secondary sexual characteristics
  - Breast development and cyclic changes in the uterine mucosa

Gonads: Male

- Testes located in an extra-abdominal sac (scrotum) produce testosterone
- Testosterone:
  - Initiates maturation of male reproductive organs
  - Causes appearance of secondary sexual characteristics and sex drive
  - Is necessary for sperm production
  - Maintains sex organs in their functional state

Pineal Gland

- Small gland hanging from the roof of the third ventricle of the brain
- Secretory product is melatonin
- Melatonin is involved with:
  - Day/night cycles
  - Physiological processes that show rhythmic variations (body temperature, sleep, appetite)

Thymus

- Lobulated gland located deep to the sternum
- Major hormonal products are thymopoietins and thymosins
- These hormones are essential for the development of the T lymphocytes (T cells) of the immune system

Other Hormone-Producing Structures

- **Heart** – produces atrial natriuretic peptide (ANP), which reduces blood pressure, blood volume, and blood sodium concentration
- **Gastrointestinal tract** – enteroendocrine cells release local-acting digestive hormones
- **Placenta** – releases hormones that influence the course of pregnancy

Other Hormone-Producing Structures

- **Kidneys** – secrete erythropoietin, which signals the production of red blood cells
- **Skin** – produces cholecalciferol, the precursor of vitamin D
- **Adipose tissue** – releases leptin, which is involved in the sensation of satiety, and stimulates increased energy expenditure

Interaction of Hormones at Target Cells

- Three types of hormone interaction
  - **Permissiveness** – one hormone cannot exert its effects without another hormone being present (Ex. cortisol exerts a permissive effect on GH, , thyroid hormones increases the number of receptors available for epinephrine)
  - **Synergism** – Effects of two hormones favor each other but the net effect exceeds the sum of individual effects . Example: Glucagon, cortisol, and epinephrine on blood glucose
  - **Antagonism** – one or more hormones opposes the action of another hormone

Synergism

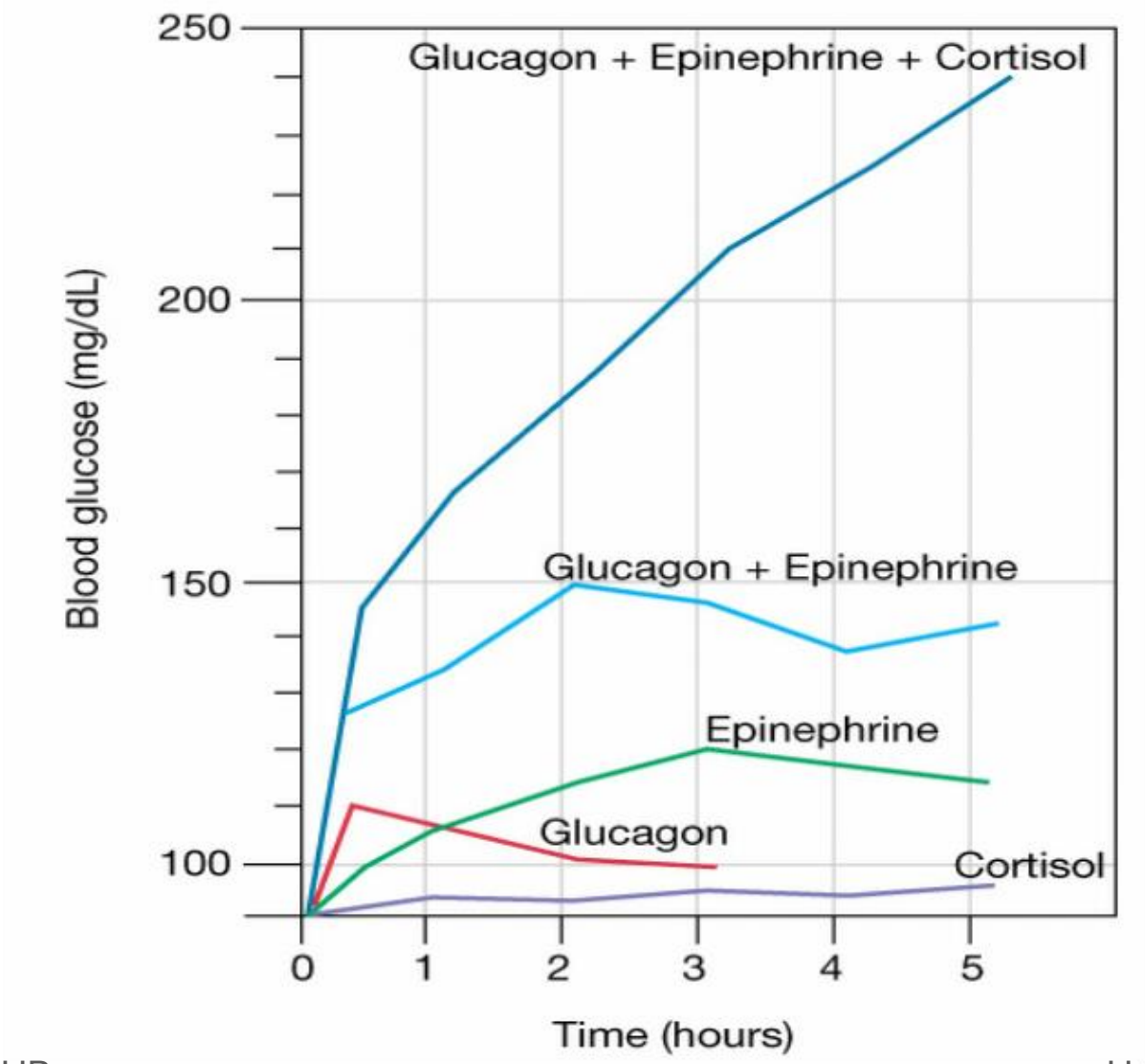
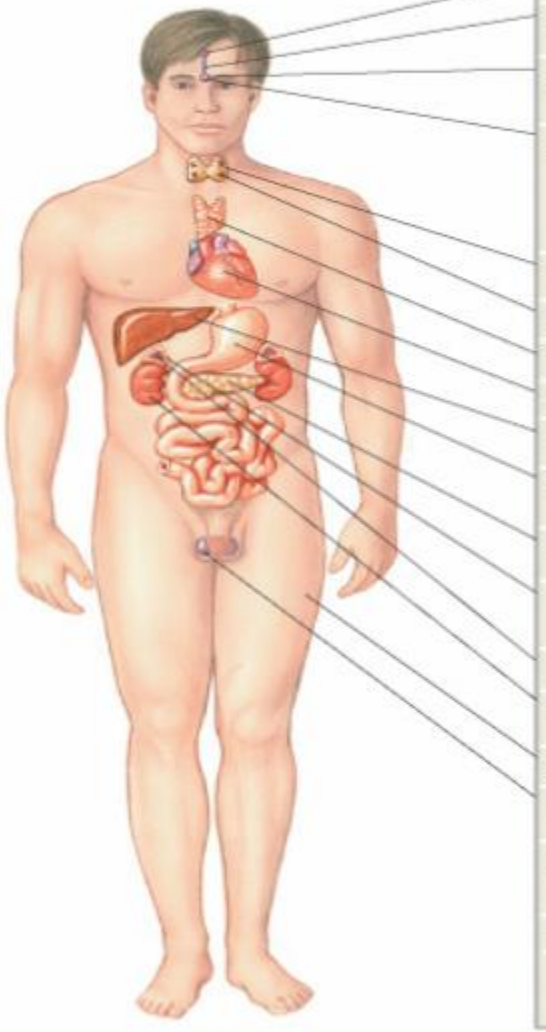


TABLE 9.2 Hormones Produced by Organs Other Than the Major Endocrine Organs

Hormone	Chemical composition	Source	Stimulus for secretion	Target organ/Effects
Prostaglandins (PGs); several groups indicated by letters A–I (PGA–PGI)	Derived from fatty acid molecules	Plasma membranes of virtually all body cells	Various (local irritation, hormones, etc.)	Have many targets, but act locally at site of release. Examples of effects include: increase blood pressure by acting as vasoconstrictors; cause constriction of respiratory passageways; stimulate muscle of the uterus, promoting labor; enhance blood clotting; promote inflammation and pain; increase output of digestive secretions by stomach; cause fever.
Gastrin	Peptide	Stomach	Food	*Stomach:* stimulates glands to release hydrochloric acid (HCl).
Intestinal gastrin	Peptide	Duodenum of small intestine	Food, especially fats	*Stomach:* inhibits HCl secretion and gastrointestinal tract mobility.
Secretin	Peptide	Duodenum	Food	*Pancreas:* stimulates release of bicarbonate-rich juice. *Liver:* increases release of bile. *Stomach:* reduces secretions.
Cholecystokinin (CCK)	Peptide	Duodenum	Food	*Pancreas:* stimulates release of enzyme-rich juice. *Gallbladder:* stimulates expulsion of stored bile. *Duodenal papilla:* causes sphincter to relax, allowing bile and pancreatic juice to enter duodenum.
Erythropoietin	Glycoprotein	Kidney	Hypoxia	*Bone marrow:* stimulates production of red blood cells.
Active vitamin D_3	Steroid	Kidney (activates provitamin D made by epidermal cells)	PTH	*Intestine:* stimulates active transport of dietary calcium across intestinal cell membranes.
Atrial natriuretic peptide (ANP)	Peptide	Heart	Stretching of atria of heart	*Kidney:* inhibits sodium ion reabsorption and renin release. *Adrenal cortex:* inhibits secretion of aldosterone, thereby decreasing blood volume and blood pressure.
Leptin	Peptide	Adipose tissue	Fatty foods	*Brain:* suppresses appetite and increases energy expenditure.
Resistin	Peptide	Adipose tissue	Unknown	*Fat, muscle, liver:* antagonizes insulin's action on liver cells.

Summary of the Endocrine System



Location	Gland or cell?	Chemical class
Pineal gland	Gland	Amine
Hypothalamus	Clusters of neurons	Peptides
Posterior pituitary	Extensions of hypothalamic neurons	Peptides
Anterior pituitary	Gland	Peptides
Thyroid	Gland	Iodinated amines Peptide
Parathyroid	Gland	Peptide
Thymus	Gland	Peptides
Heart	Cells	Peptide
Liver	Cells	Peptides
Stomach and small intestine	Cells	Peptides
Pancreas	Gland	Peptide
Adrenal cortex	Gland	Steroids
Adrenal medulla	Gland	Amines
Kidney	Cells	Peptide Steroid
Skin	Cells	Steroid
Testes (male)	Glands	Steroids Peptide
Ovaries (female)	Glands	Steroids Peptide
Adipose tissue	Cells	Peptide
Placenta (pregnant females only)	Gland	Steroids Peptide

Summary of the Endocrine System

Hormone	*Target*	*Main Effect*
Melatonin	Unclear in humans	Circadian rhythms. Other effects uncertain
Trophic hormones (see Fig. 7-13) See posterior pituitary	Anterior pituitary	Release or inhibit pituitary hormones
Oxytocin (OT)	Breast and uterus	Milk ejection; labor and delivery; behavior
Vasopressin (ADH) Prolactin (PRL) Growth hormone (GH, somatotropin) Corticotropin (ACTH) Thyrotropin (TSH) Follicle stimulating hormone (FSH) Luteinizing hormone (LH)	Kidney Breast Many tissues Adrenal cortex Thyroid gland Gonads Gonads	Water reabsorption Milk production Growth and metabolism Cortisol release Thyroid hormone synthesis and release Egg or sperm production; sex hormone production Sex hormone production; egg or sperm production
Triiodothyronine and thyroxine (T_3, T_4) Calcitonin (CT)	Many tissues Bone	Metabolism, growth and development Plasma calcium levels (minimal effect in humans)
Parathyroid hormone (PTH)	Bone, kidney	Regulate plasma calcium and phosphate levels
Thymosin, thymopoietin	Lymphocytes	Lymphocyte development
Atrial natriuretic peptide (ANP)	Kidneys	Increase sodium excretion
Angiotensinogen Insulin-like growth factors (IGF)	Adrenal cortex, blood vessels, brain Many tissues	Aldosterone secretion, increase blood pressure Growth

Summary of the Endocrine System

Hormone	Target	Main Effect
Gastrin, cholecystokinin (CCK), secretin, and others	GI tract and pancreas	Assist digestion and absorption of nutrients
Insulin, glucagon, somatostatin (SS), pancreatic polypeptide	Many tissues	Metabolism of glucose and other nutrients
Aldosterone Cortisol Androgens	Kidney Many tissues Many tissues	Na^+ and K^+ homeostasis Stress response Sex drive in females
Epinephrine, norepinephrine	Many tissues	Fight-or-flight response
Erythropoietin (EPO) 1,25 Dihydroxy-vitamin D_3 (calciferol)	Bone marrow Intestine	Red blood cell production Increase calcium absorption
Vitamin D_3	Intermediate form of hormone	Precursor of 1,25 dihydroxy-vitamin D_3
Androgen Inhibin	Many tissues Anterior pituitary	Sperm production, secondary sex characteristics Inhibit FSH secretion
Estrogens and progesterone Ovarian inhibin Relaxin (pregnancy)	Many tissues Anterior pituitary Uterine muscle	Egg production, secondary sex characteristics Inhibit FSH secretion Relaxes muscle
Leptin	Hypothalamus, other tissues	Food intake, metabolism, reproduction
Estrogens and progesterone (P) Chorionic somatomammotropin (CS) Chorionic gonadotropin (CG)	Many tissues Many tissues Corpus luteum of ovary	Fetal and maternal development Metabolism Hormone secretion