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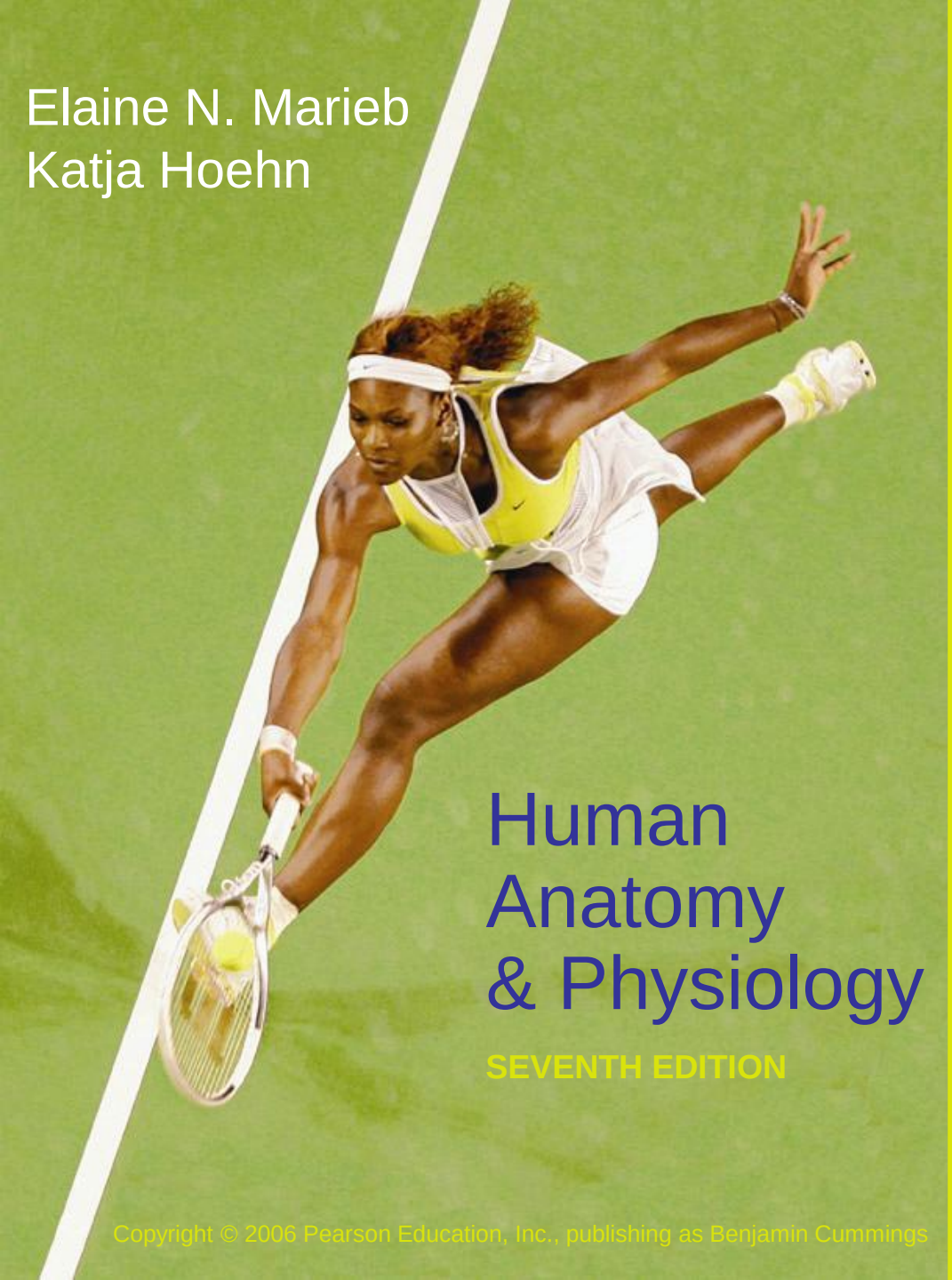


Human Anatomy & Physiology

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
- The hypothalamus has both neural functions and releases hormones

Major Endocrine Organs

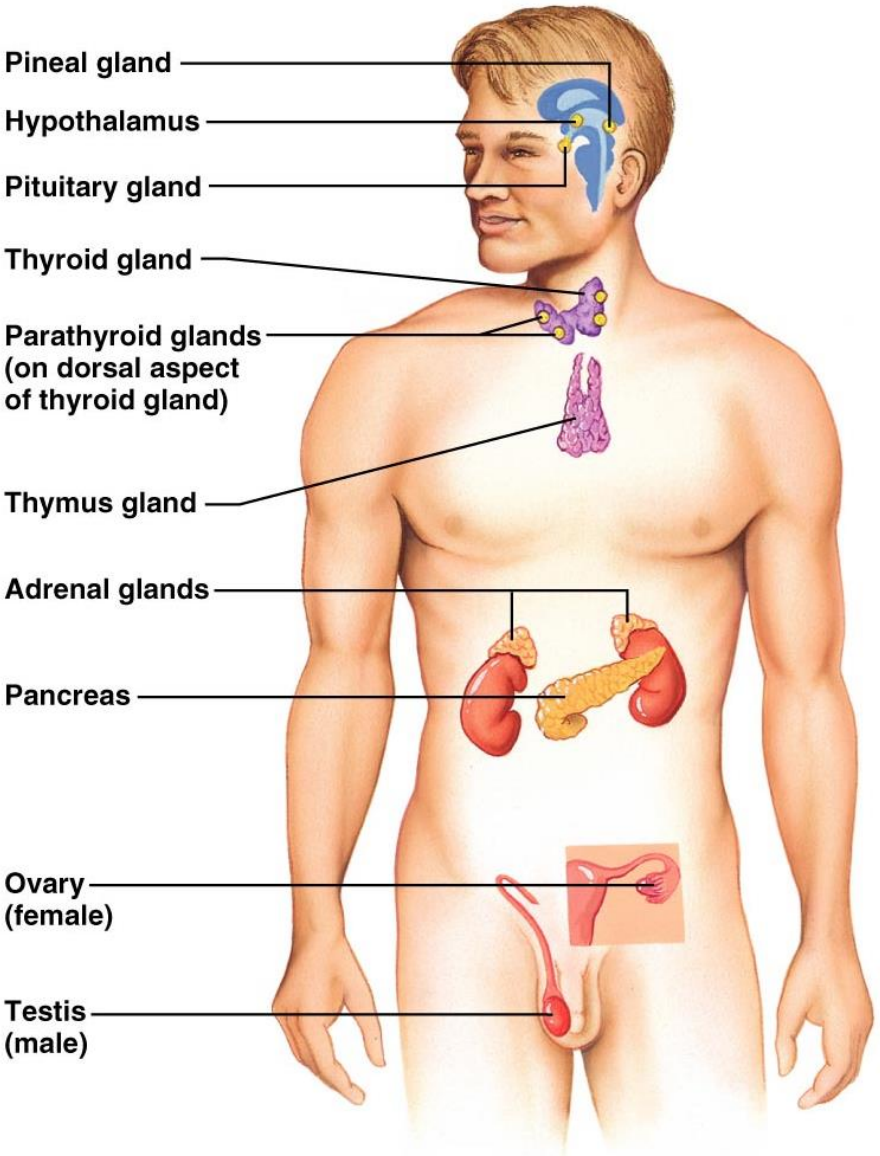


Figure 16.1

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

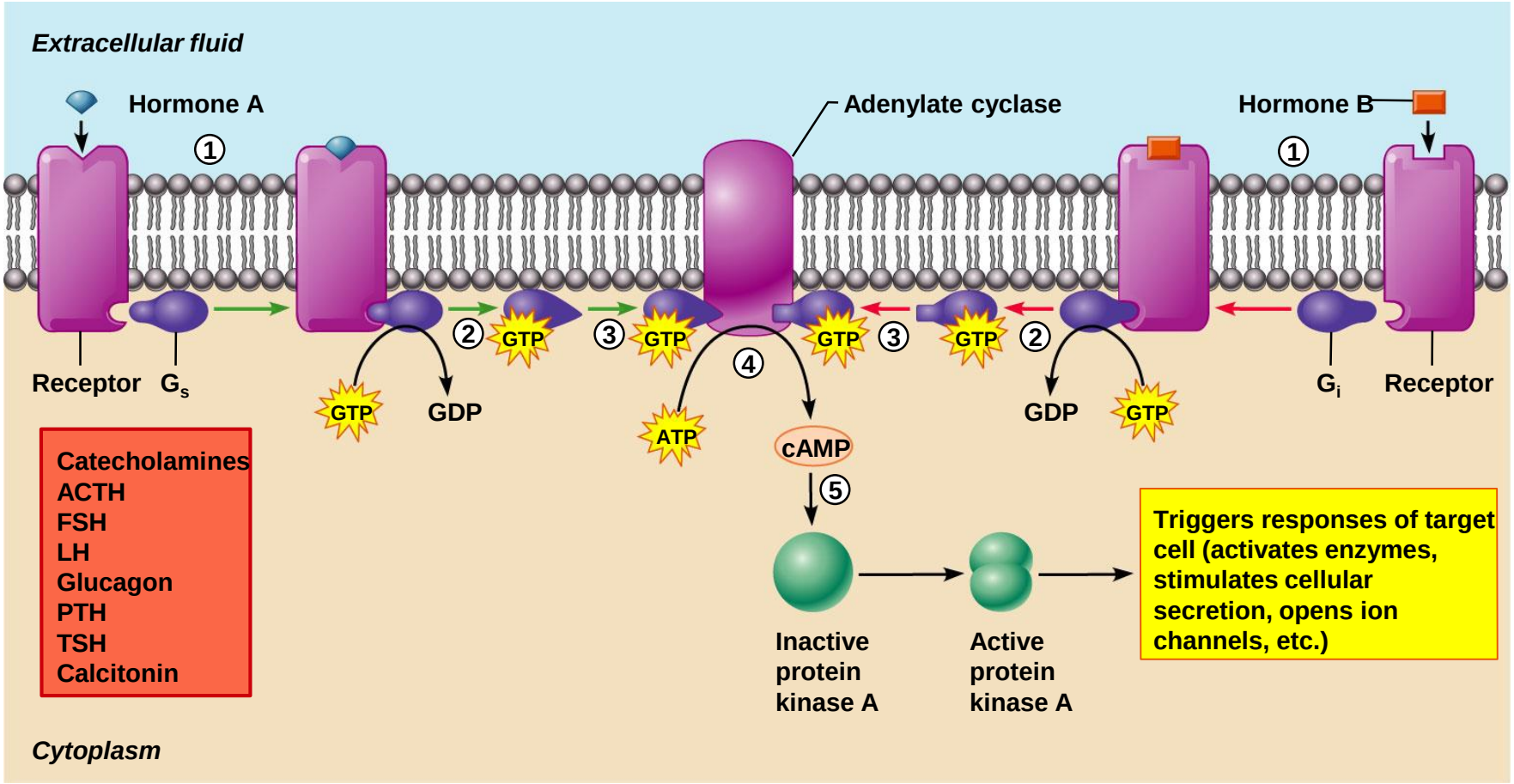


Figure 16.2

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

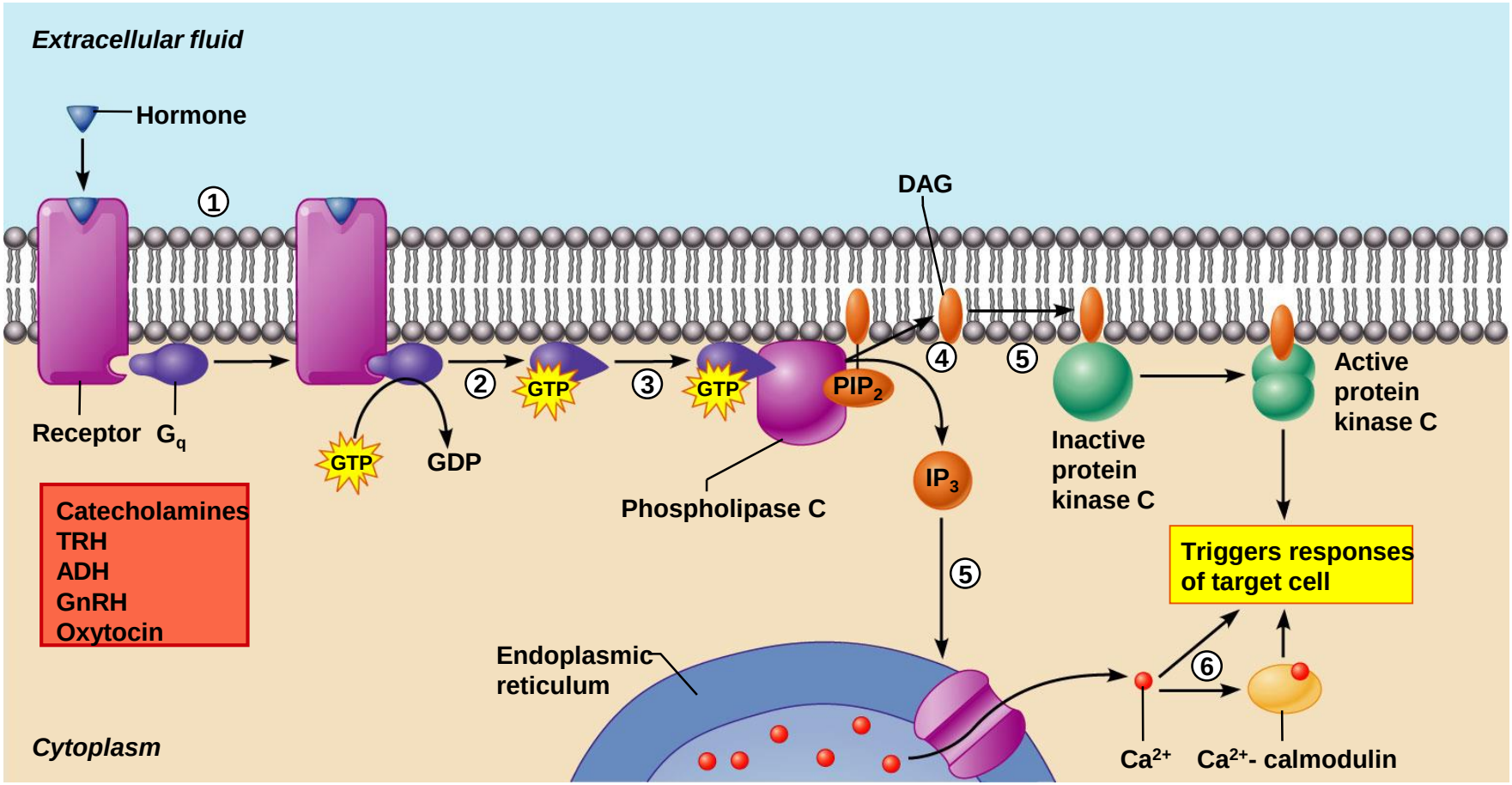


Figure 16.3

Steroid Hormones

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

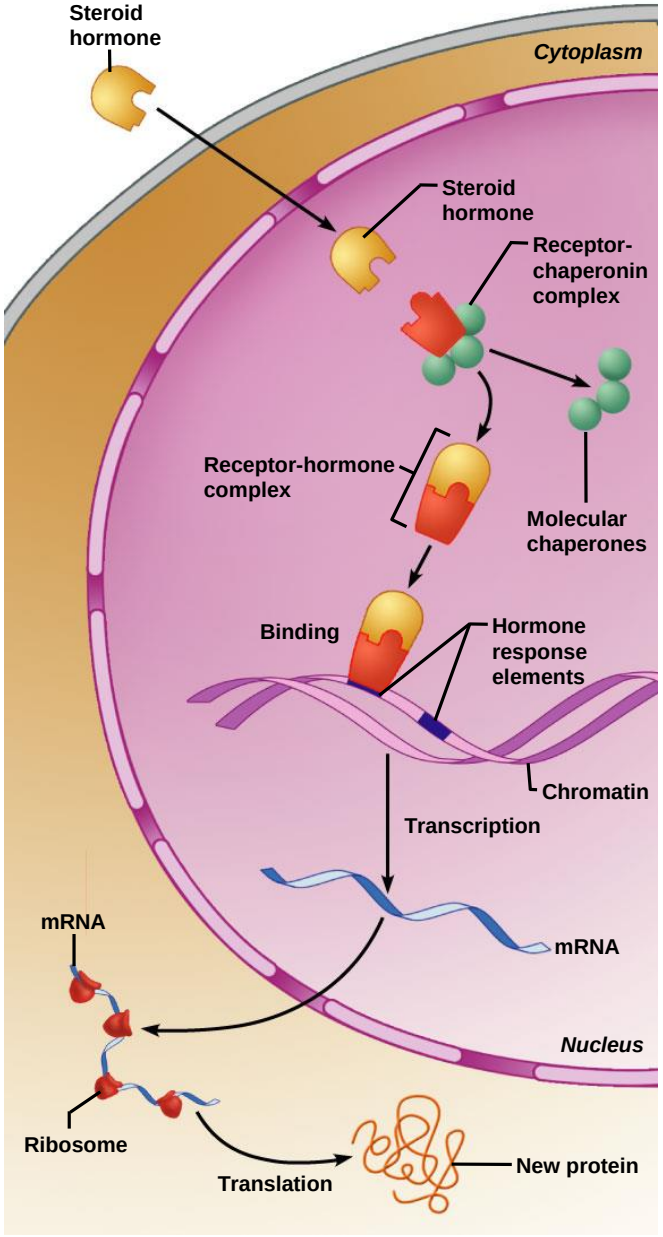


Figure 16.4

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

Interaction of Hormones at Target Cells

- Three types of hormone interaction
  - Permissiveness – one hormone cannot exert its effects without another hormone being present
  - Synergism – more than one hormone produces the same effects on a target cell
  - Antagonism – one or more hormones opposes the action of another hormone

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

Humoral Stimuli

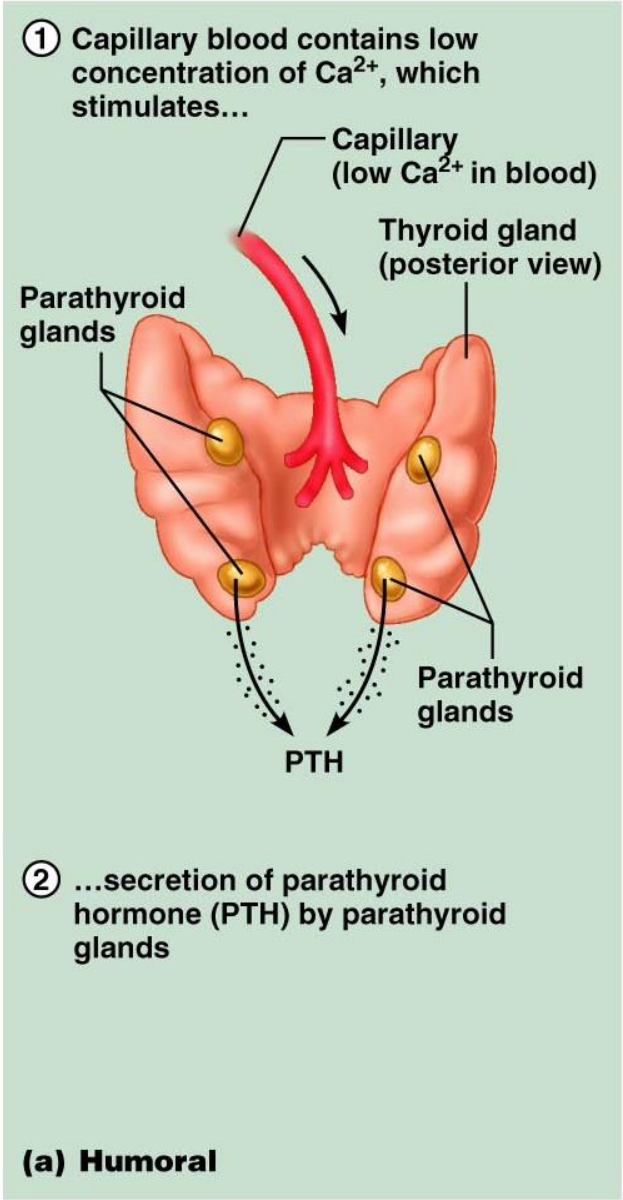


Figure 16.5a

Neural Stimuli

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

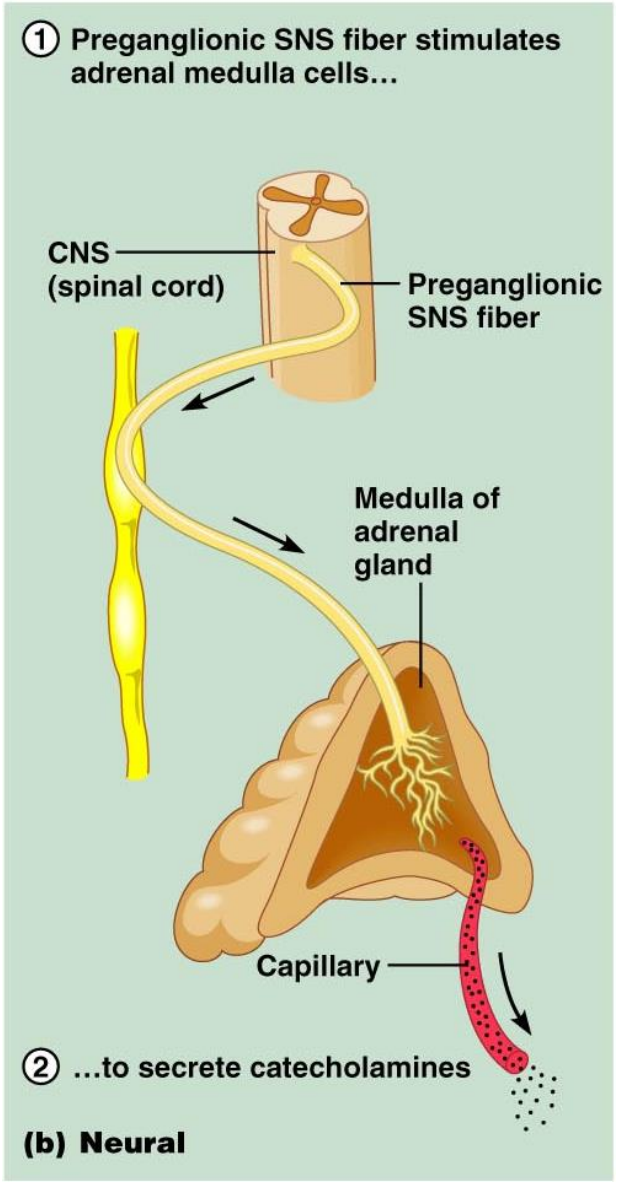


Figure 16.5b

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

Hormonal Stimuli

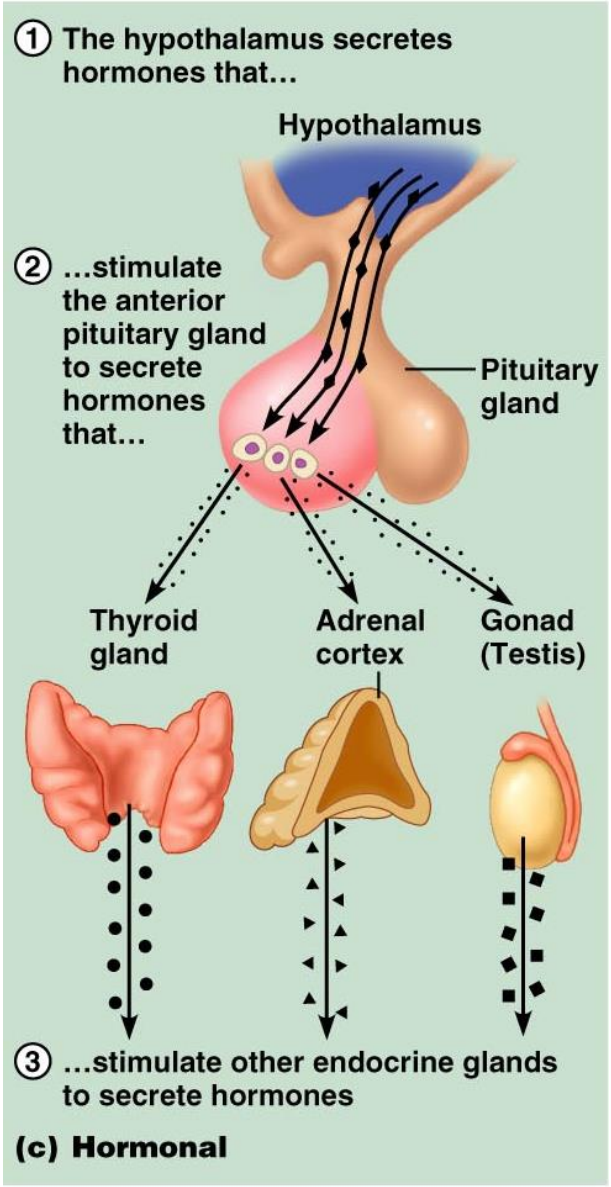


Figure 16.5c

Nervous System Modulation

- The nervous system can override normal endocrine controls
  - For example, control of blood glucose levels
    - Normally the endocrine system maintains blood glucose
    - Under stress, the body needs more glucose
    - The hypothalamus and the sympathetic nervous system are activated to supply more glucose

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)

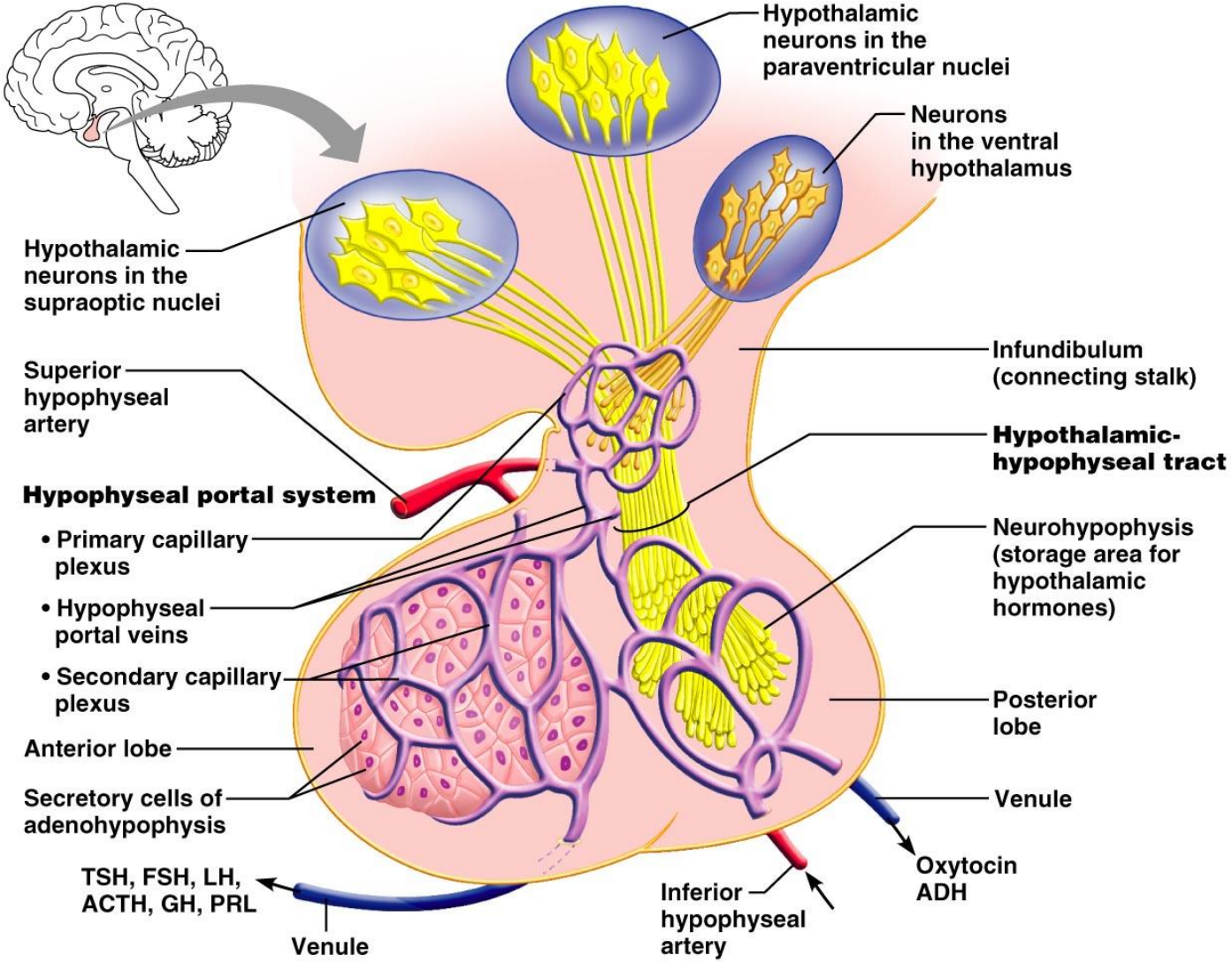


Figure 16.6

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

- The tropic hormones that are released are:
  - Thyroid-stimulating hormone (TSH)
  - Adrenocorticotropic hormone (ACTH)
  - Follicle-stimulating hormone (FSH)
  - Luteinizing hormone (LH)

Growth Hormone (GH)

- Produced by somatotropic cells of the anterior lobe that:
  - Stimulate most cells, but target bone and skeletal muscle
  - Promote protein synthesis and encourage the use of fats for fuel
- Most effects are mediated indirectly by somatomedins

Growth Hormone (GH)

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

Metabolic Action of Growth Hormone

- GH stimulates liver, skeletal muscle, bone, and cartilage to produce insulin-like growth factors
- Direct action promotes lipolysis and inhibits glucose uptake

Metabolic Action of Growth Hormone (GH)

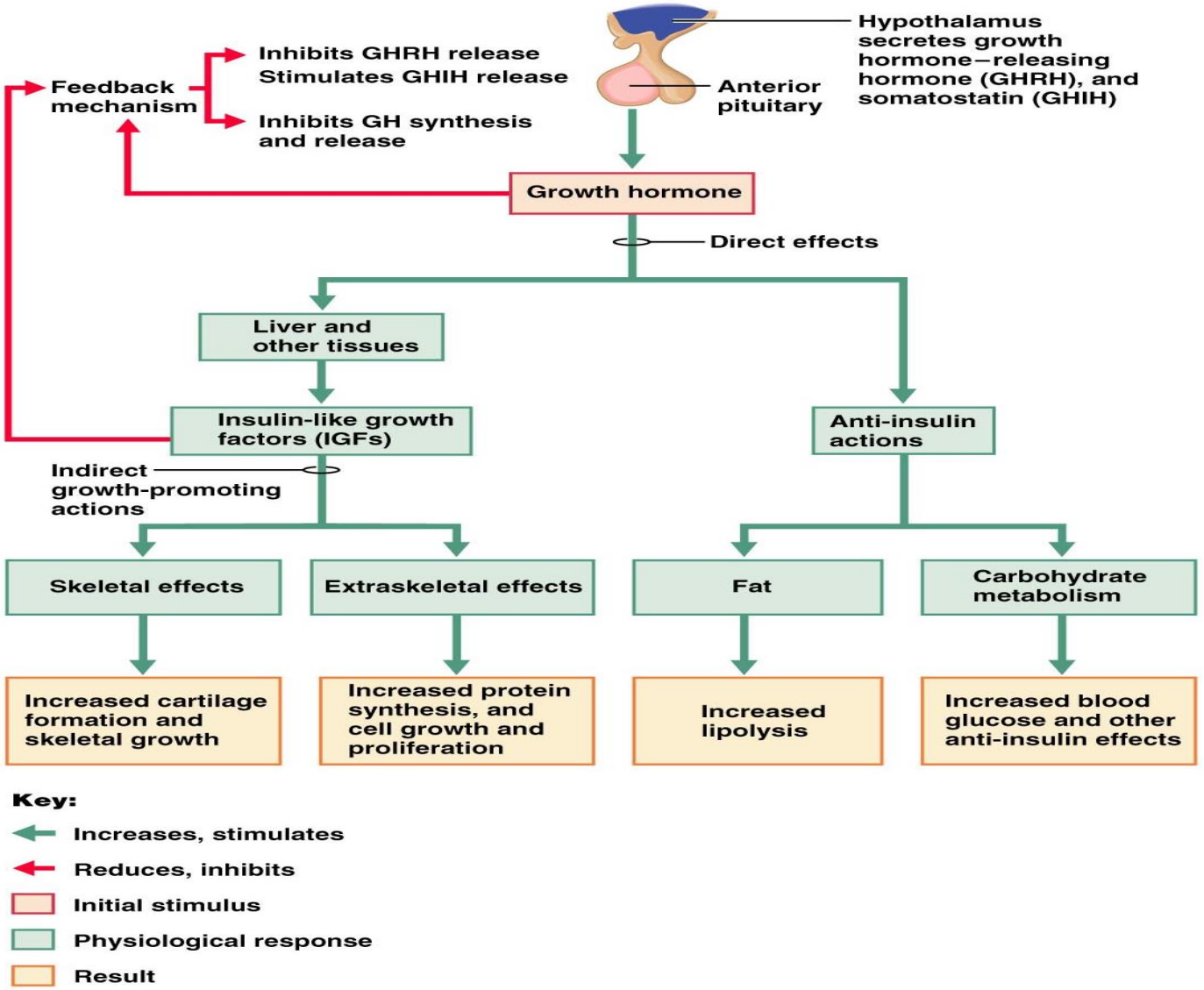


Figure 16.7

Thyroid Stimulating Hormone (Thyrotropin)

- Stimulates the normal development and secretory activity of the thyroid
- Triggered by hypothalamic peptide thyrotropin-releasing hormone (TRH)
- Rising blood levels of thyroid hormones act on the pituitary and hypothalamus to block the release of TSH

Adrenocorticotropic Hormone (Corticotropin)

- Stimulates the adrenal cortex to release corticosteroids
- Triggered by hypothalamic corticotropin-releasing hormone (CRH) in a daily rhythm
- Internal and external factors such as fever, hypoglycemia, and stressors can trigger the release of CRH

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)

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

Oxytocin

- 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
- Osmoreceptors monitor the solute concentration of the blood in 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

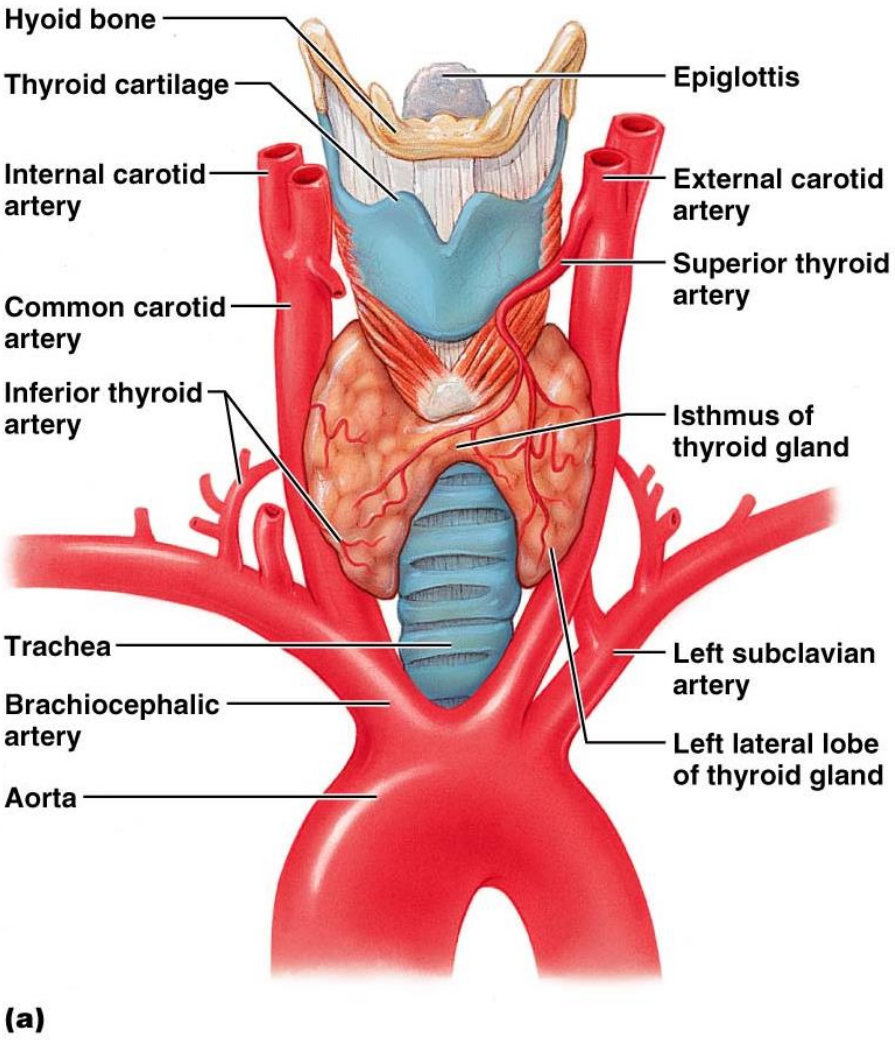


Figure 16.8

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

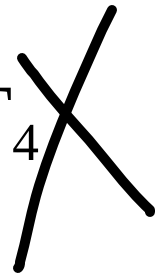
- TH is concerned with:
  - Glucose oxidation
  - Increasing metabolic rate
  - Heat production
- TH plays a role in:
  - Maintaining blood pressure
  - Regulating tissue growth
  - Developing skeletal and nervous systems
  - Maturation and reproductive capabilities

Synthesis of Thyroid Hormone

- Thyroglobulin is synthesized and discharged into the lumen
- Iodides (I^-) are actively taken into the cell, oxidized to iodine (I_2), and released into the lumen
- Iodine attaches to tyrosine, mediated by peroxidase enzymes, forming T_1 (monoiodotyrosine, or MIT), and T_2 (diiodotyrosine, or DIT)

Synthesis of Thyroid Hormone

- Iodinated tyrosines link together to form T_3 and T_4
- Colloid is then endocytosed and combined with a lysosome, where T_3 and T_4 are cleaved and diffuse into the bloodstream



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

Calcitonin

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

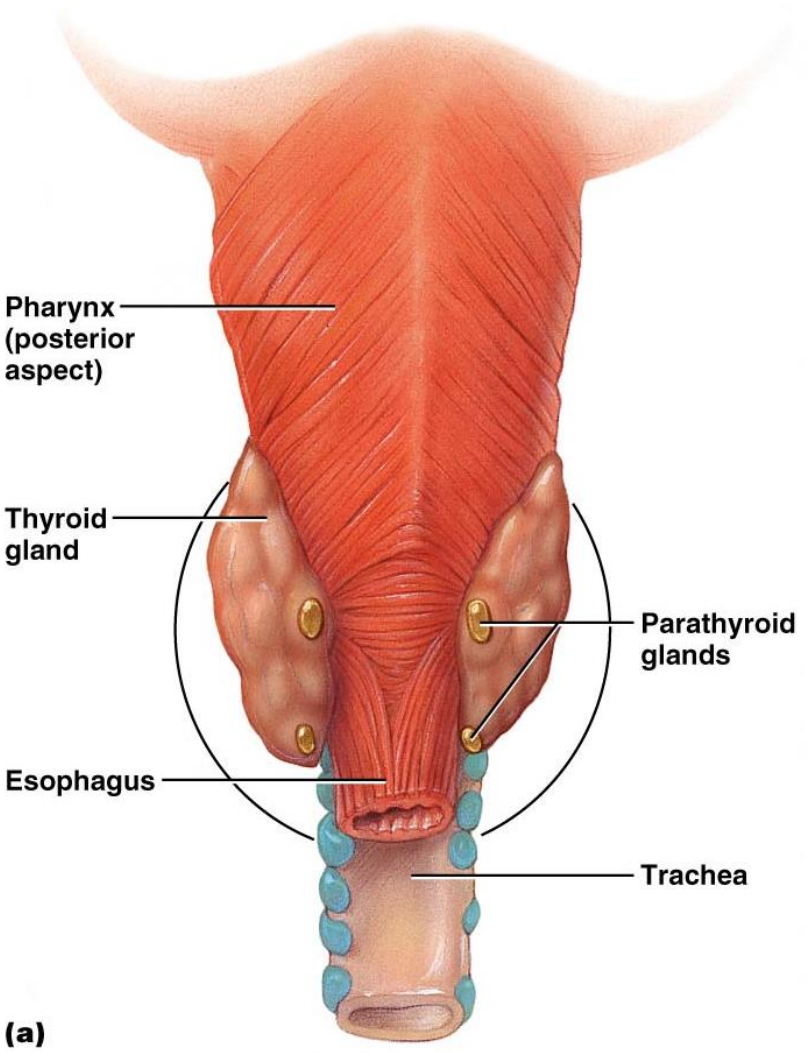
Calcitonin

- 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



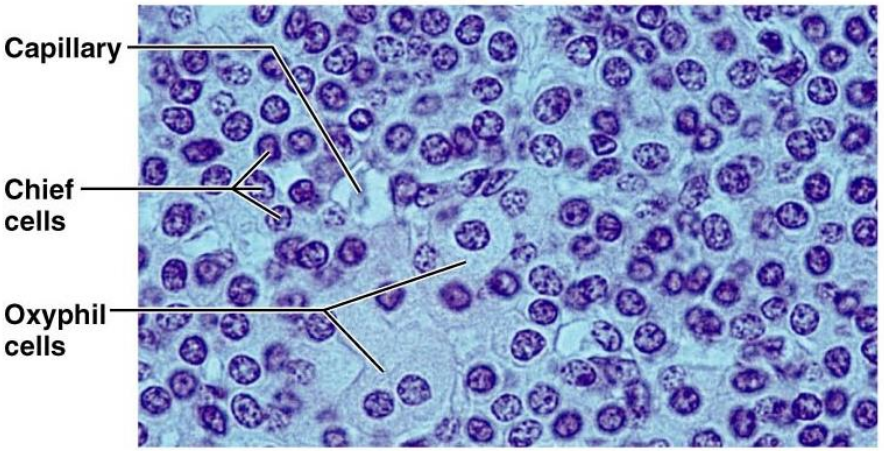


Figure 16.11

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

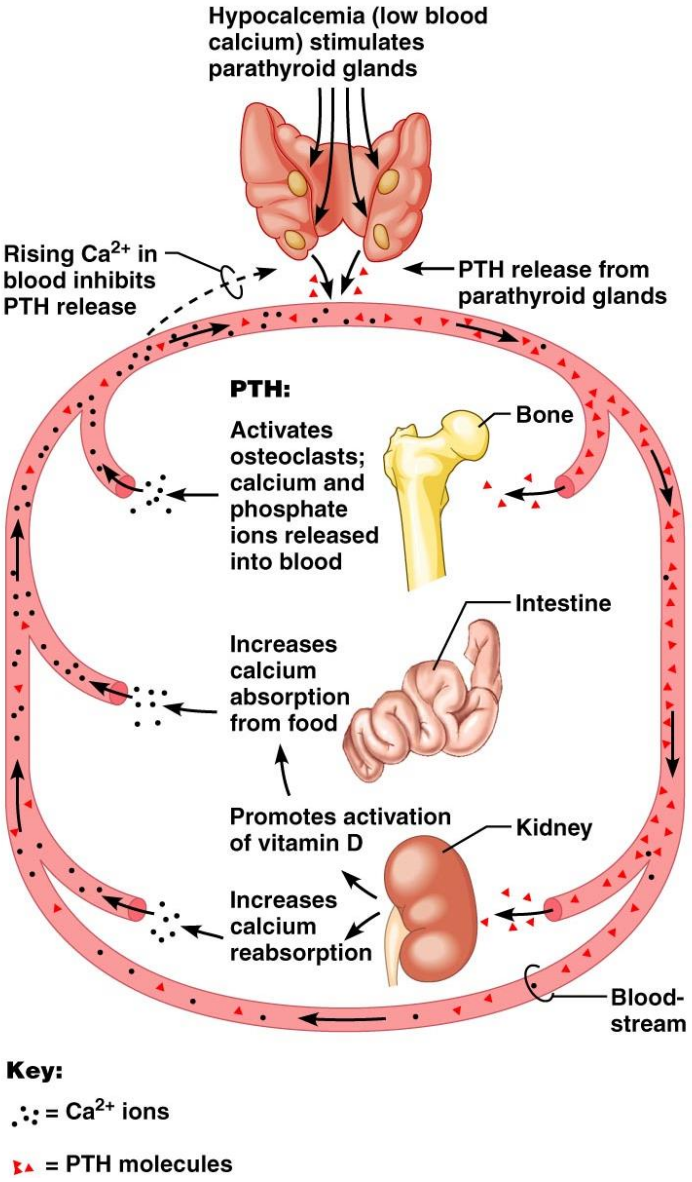


Figure 16.12

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

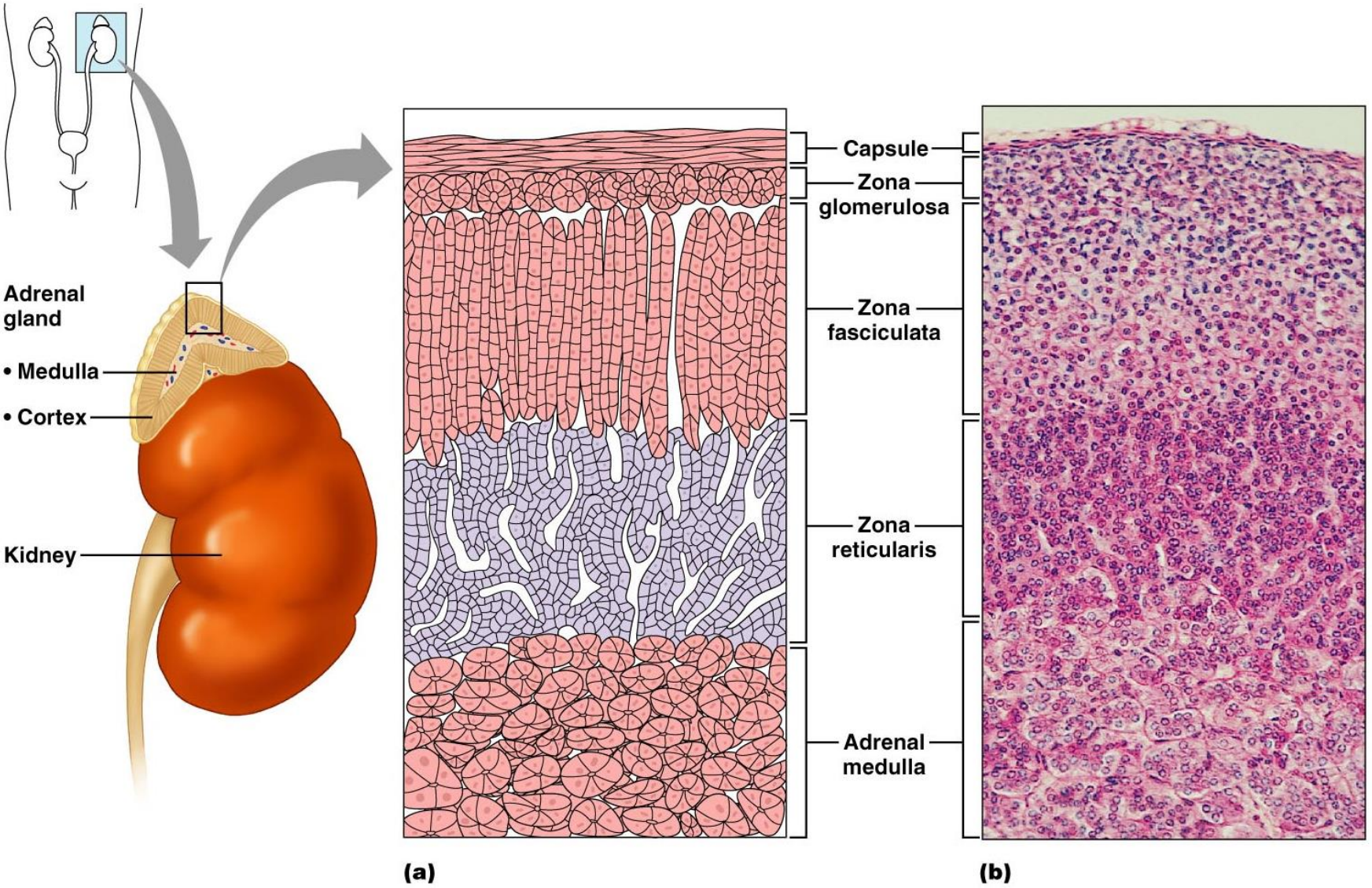


Figure 16.13a, b

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

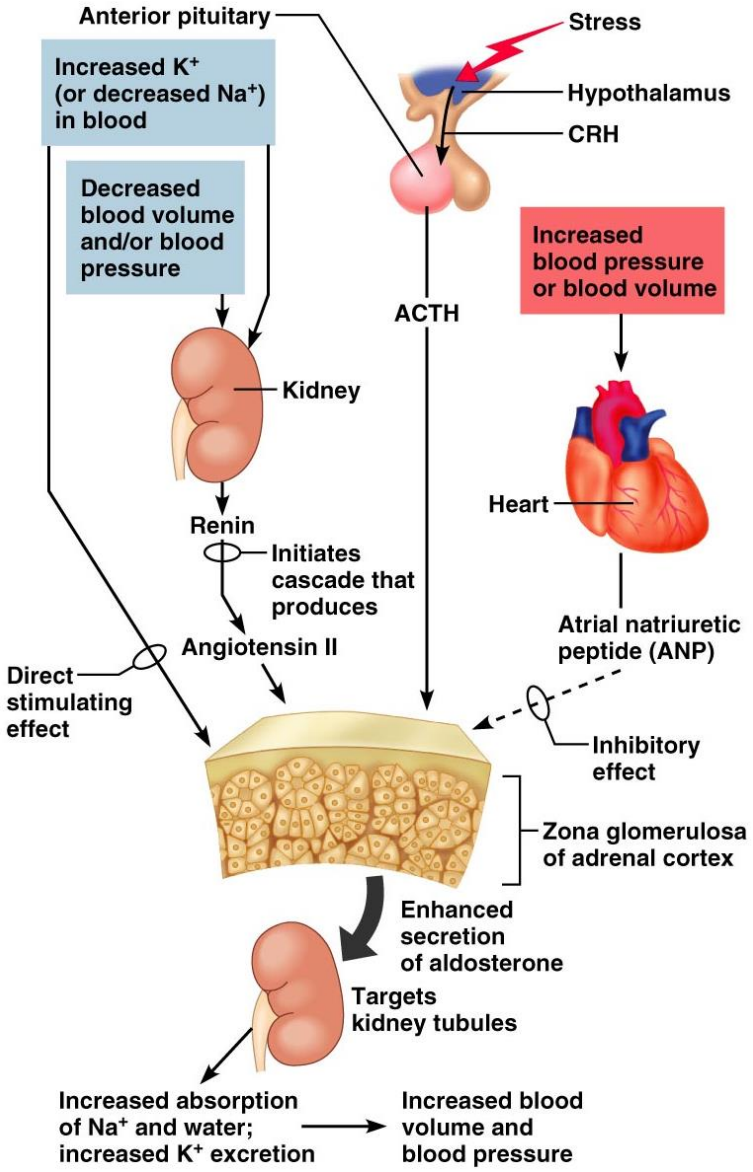


Figure 16.14

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

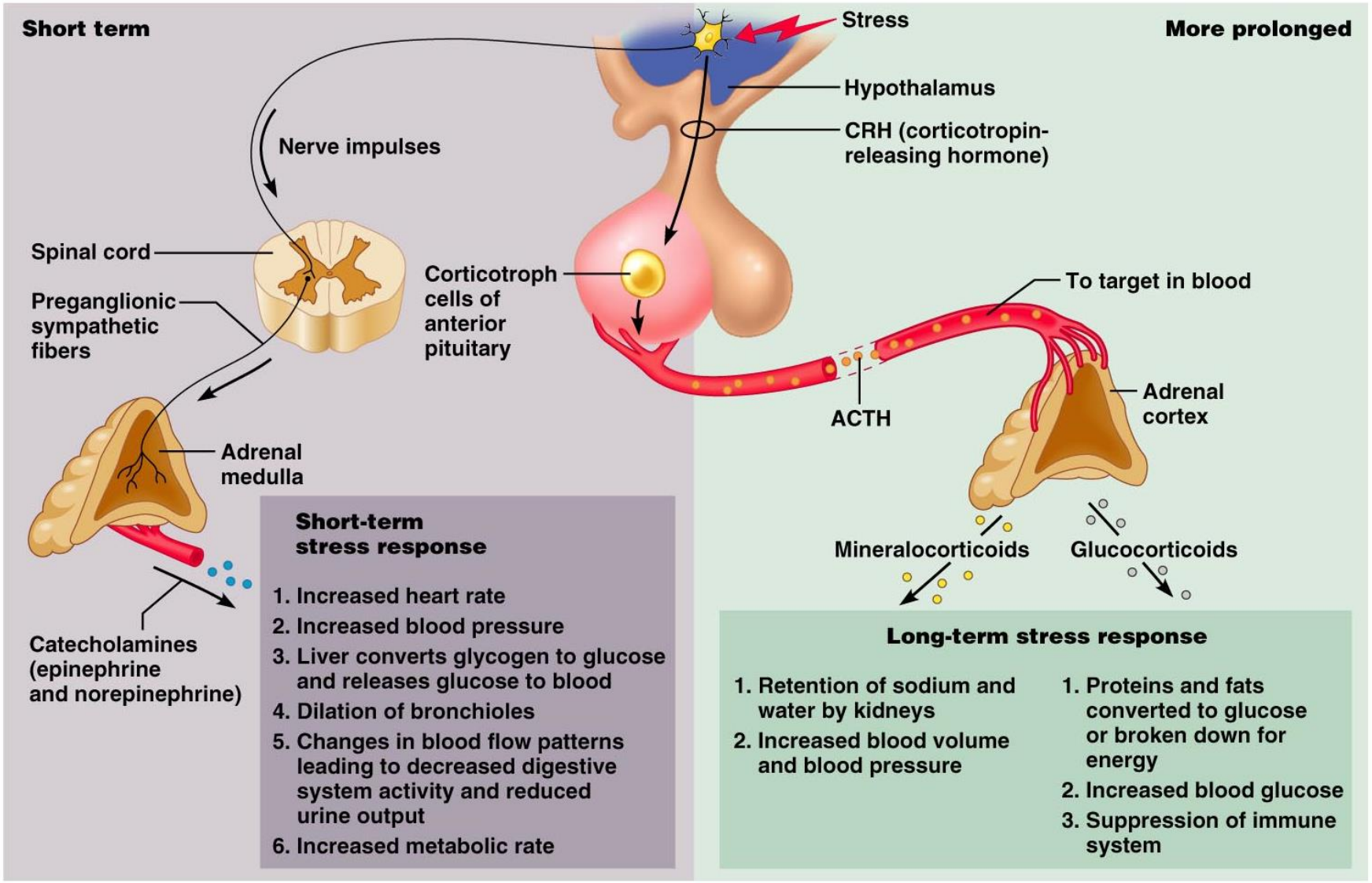


Figure 16.16

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