CAMPBELL

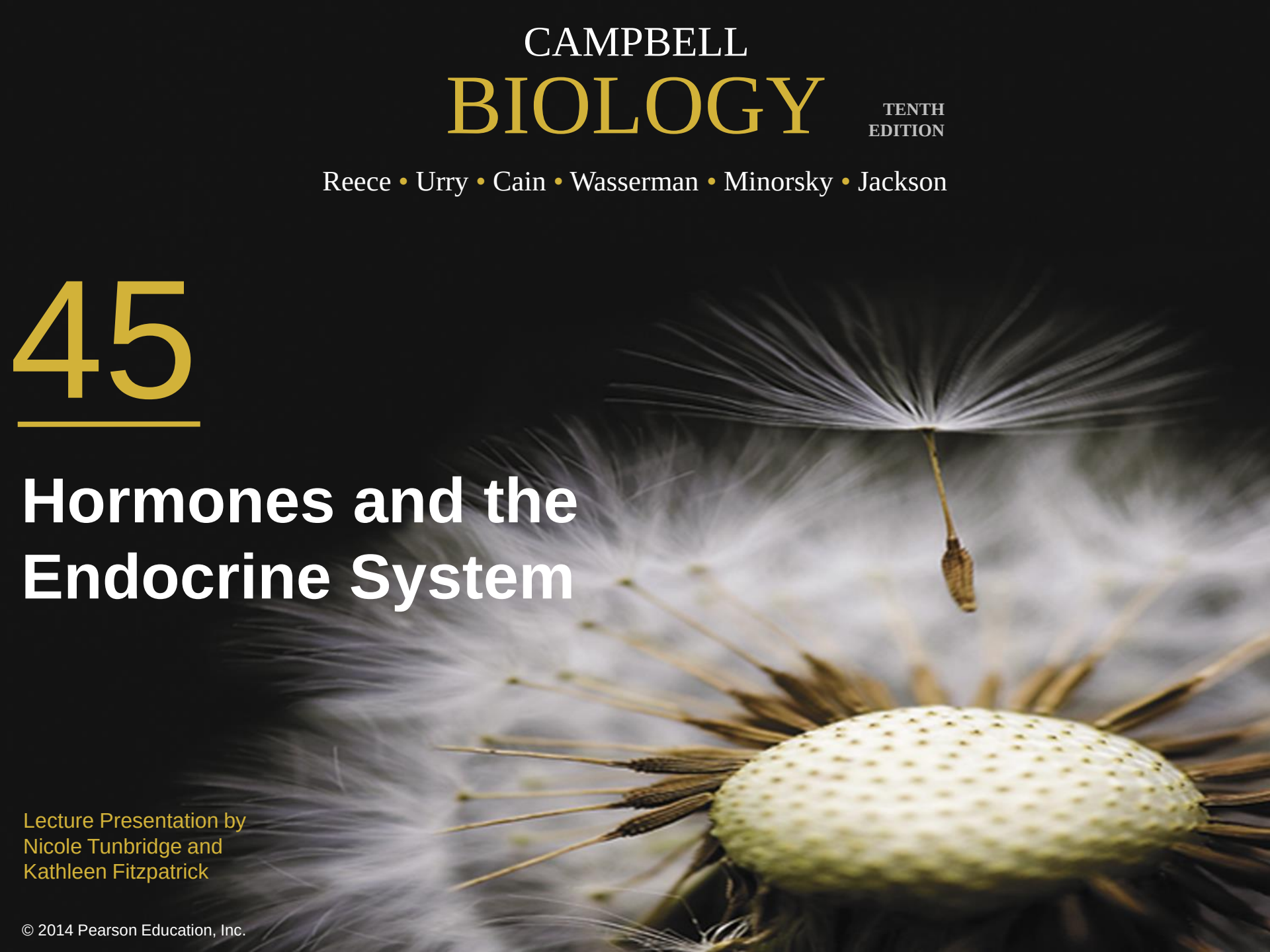
BIOLOGY

TENTH EDITION

Reece • Urry • Cain • Wasserman • Minorsky • Jackson

45

Hormones and the Endocrine System

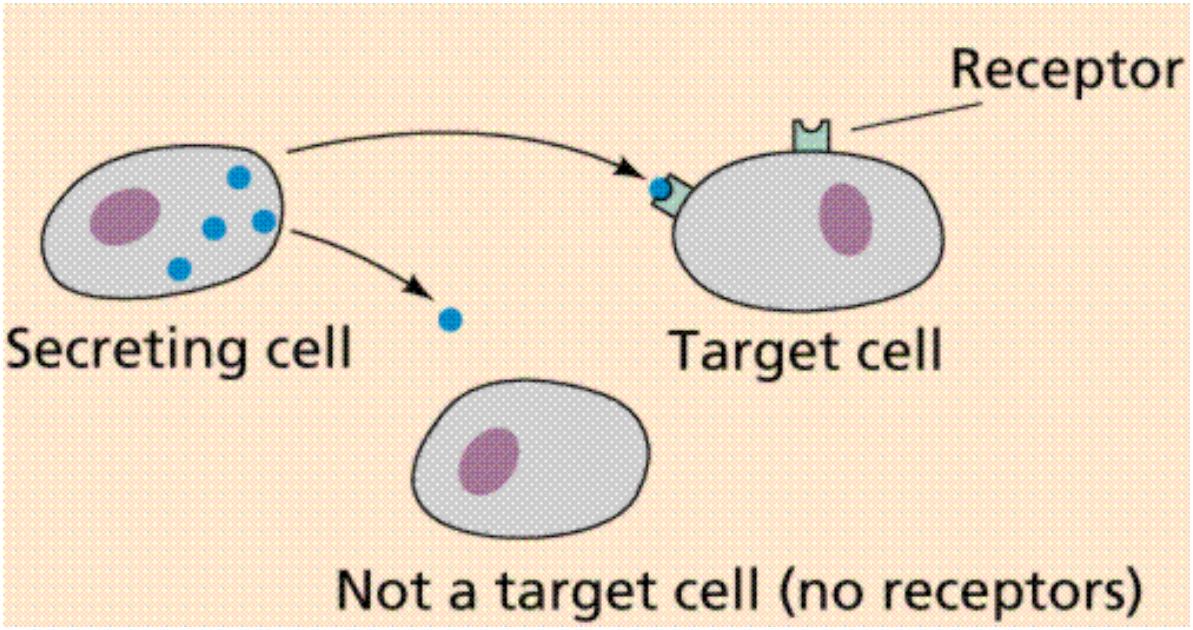


Lecture Presentation by
Nicole Tunbridge and
Kathleen Fitzpatrick

1. Overview of Endrocrine Hormone Signaling

The Body's Long-Distance Regulators

- Animal **hormones** are chemical signals that are secreted into the circulatory system and communicate regulatory messages within the body
- Hormones reach all parts of the body, but only target cells have receptors for that hormone



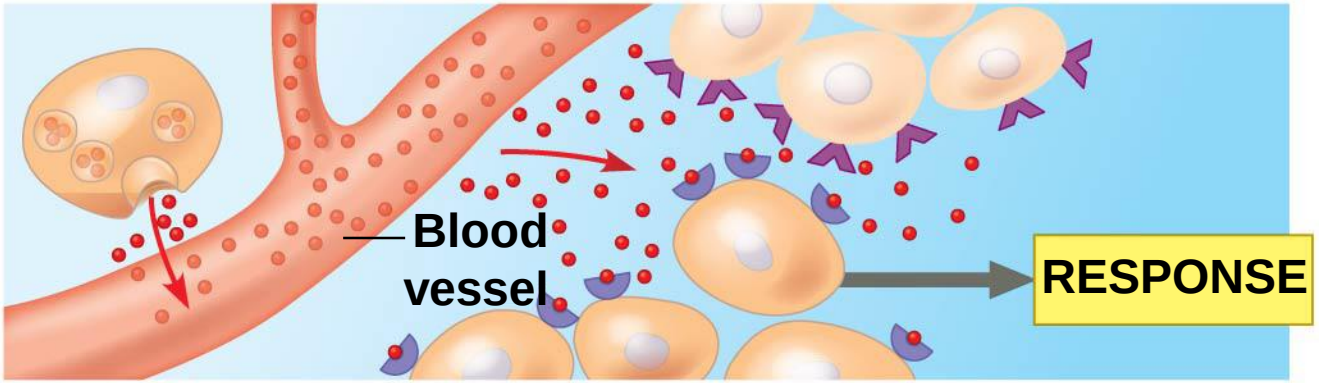
Intercellular Communication

- The ways that signals are transmitted between animal cells are classified by two criteria
  - The type of secreting cell
  - The route taken by the signal in reaching its target

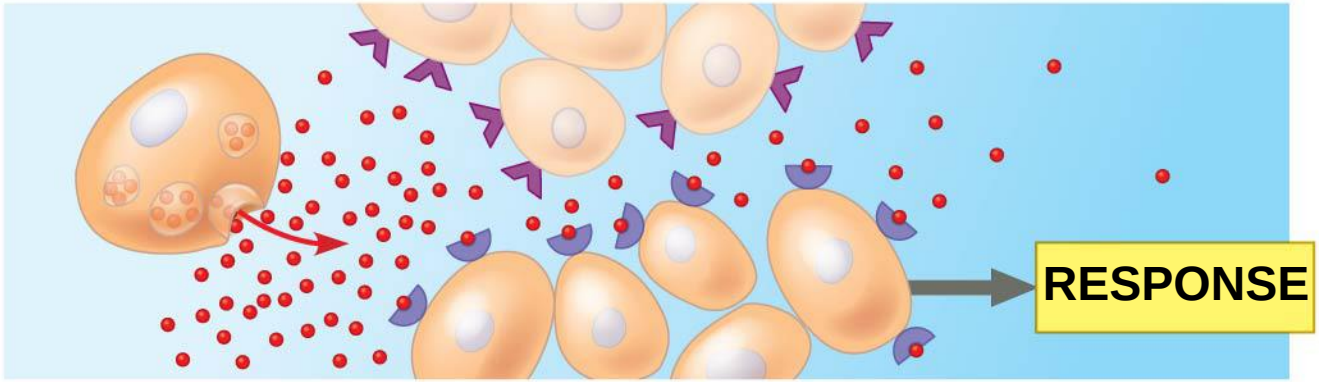
Paracrine and Autocrine Signaling

- **Local regulators** are molecules that act over short distances, reaching target cells solely by diffusion
- In **paracrine signaling**, the target cells lie near the secreting cells
- In **autocrine signaling**, the target cell is also the secreting cell

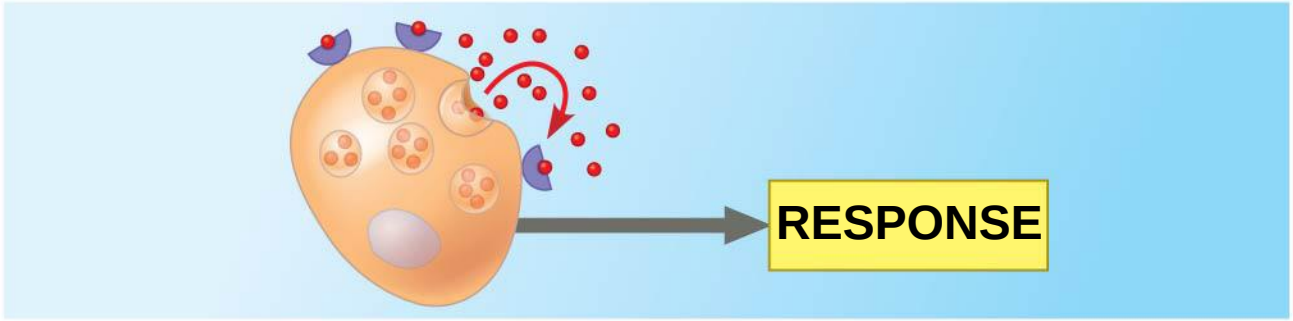
Figure 45.2a



(a) Endocrine signaling



(b) Paracrine signaling



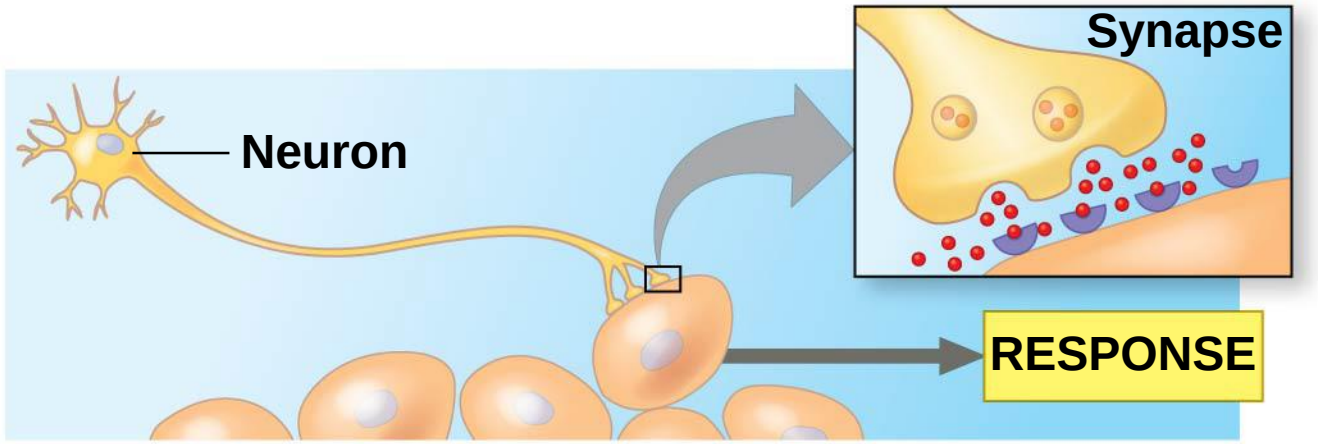
(c) Autocrine signaling

- Paracrine and autocrine signaling play roles in processes such as blood pressure regulation, nervous system function, and reproduction
- Local regulators that mediate such signaling include the **prostaglandins**
  - Prostaglandins function in reproduction, the immune system, and blood clotting

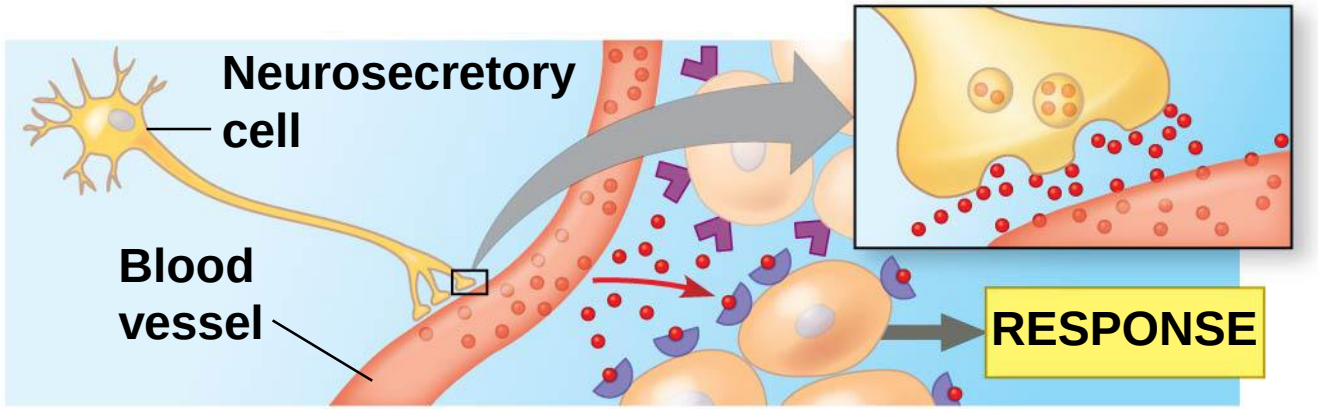
Synaptic and Neuroendocrine Signaling

- In synaptic signaling, neurons form specialized junctions with target cells, called **synapses**
- At synapses, neurons secrete molecules called **neurotransmitters** that diffuse short distances and bind to receptors on target cells
- In neuroendocrine signaling, specialized neurosecretory cells secrete molecules called **neurohormones** that travel to target cells via the bloodstream

Figure 45.2b



(d) Synaptic signaling



(e) Neuroendocrine signaling

Signaling by Pheromones

- Members of an animal species sometimes communicate with **pheromones**, chemicals that are released into the environment
- Pheromones serve many functions, including marking trails leading to food, defining territories, warning of predators, and attracting potential mates

Classes of Local Regulators

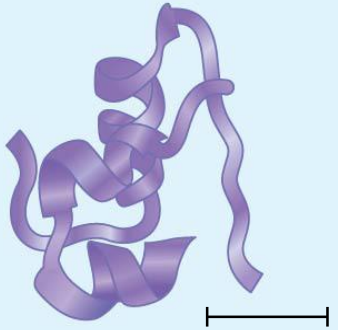
- Local regulators such as the prostaglandins are modified fatty acids
- Others are polypeptides and some are gases
  - **Nitric oxide** (**NO**) is a gas that functions in the body as both a local regulator and a neurotransmitter
    - When the level of oxygen in blood falls, NO activates an enzyme that results in vasodilation, increasing blood flow to tissues

Classes of Hormones

- Hormones fall into three major classes: **polypeptides, steroids**, and **amines**
- Polypeptides and amines are water-soluble whereas steroid hormones and other largely nonpolar hormones are lipid-soluble

Water-soluble (hydrophilic)

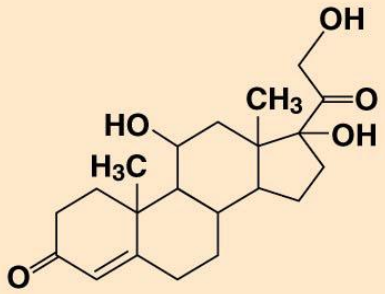
Polypeptides



Insulin

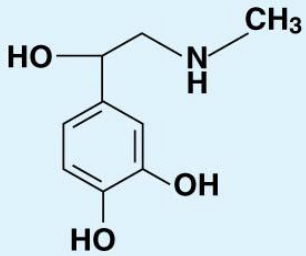
Lipid-soluble (hydrophobic)

Steroids

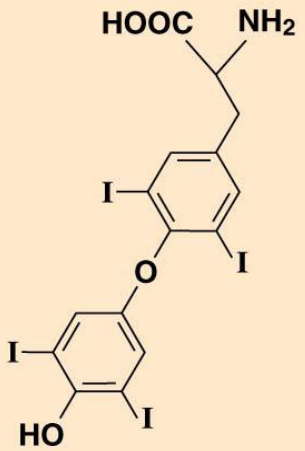


Cortisol

Amines



Epinephrine

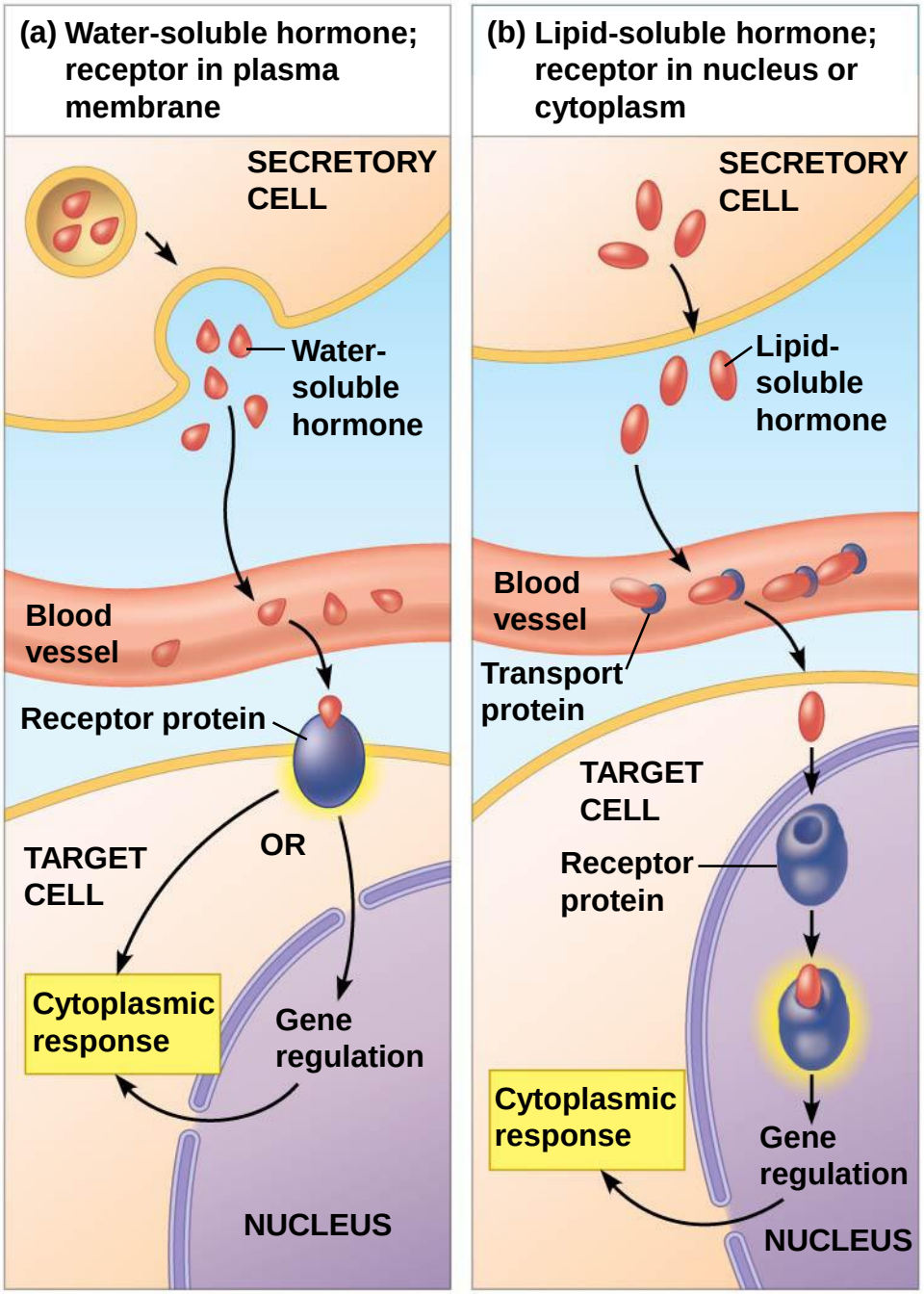


Thyroxine

Cellular Response Pathways

- Water-soluble hormones are secreted by exocytosis, travel freely in the bloodstream, and bind to cell-surface receptors
- Lipid-soluble hormones diffuse across cell membranes, travel in the bloodstream bound to transport proteins, and diffuse through the membrane of target cells
- They bind to receptors in the cytoplasm or nucleus of the target cells

Figure 45.5



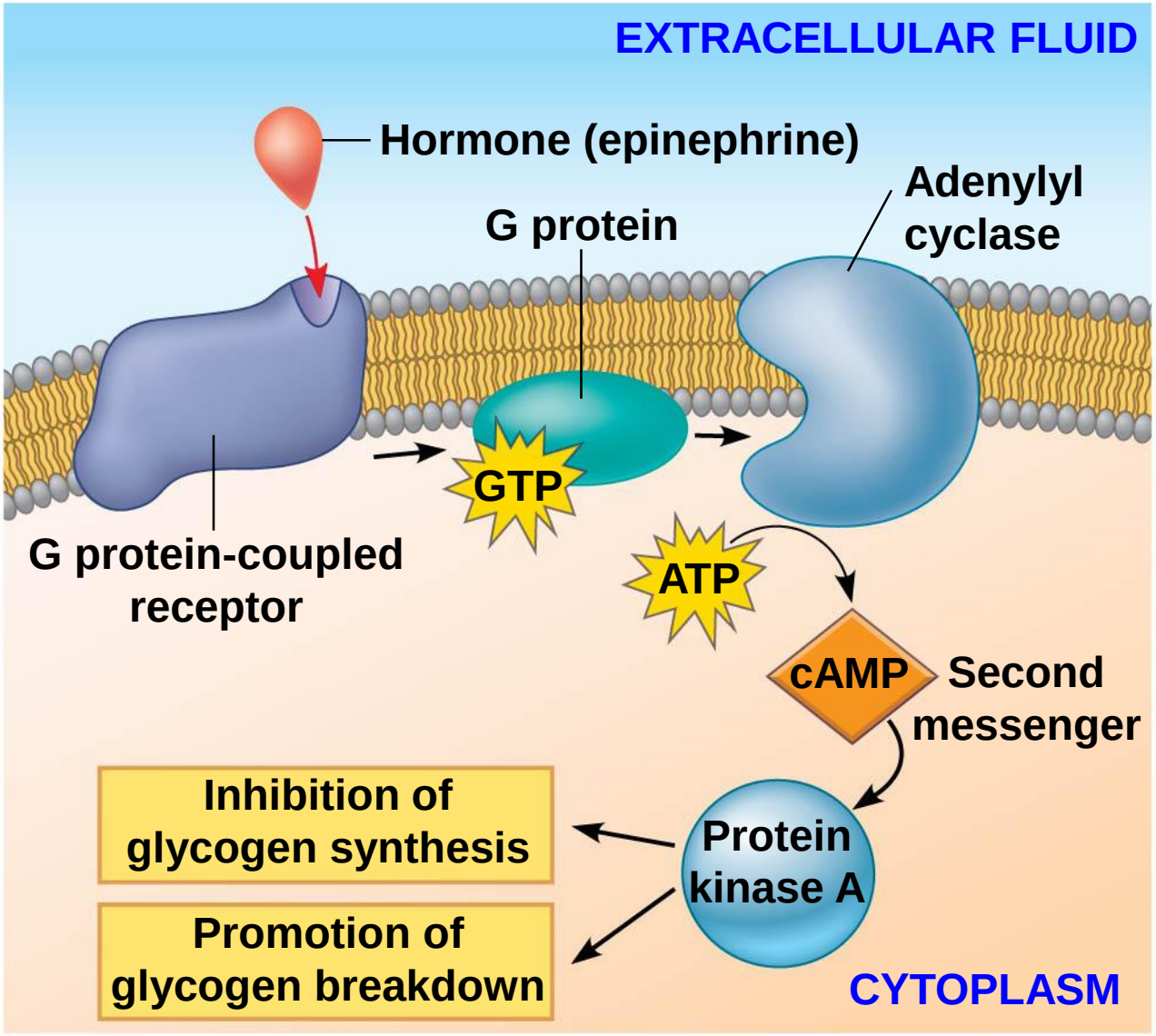
Water-Soluble Hormones require Signal Transduction

For example:

- The hormone **epinephrine** has multiple effects in mediating the body's response to short-term stress
- Epinephrine binds to receptors on the plasma membrane of liver cells
- This triggers the release of messenger molecules that activate enzymes and result in the release of glucose into the bloodstream

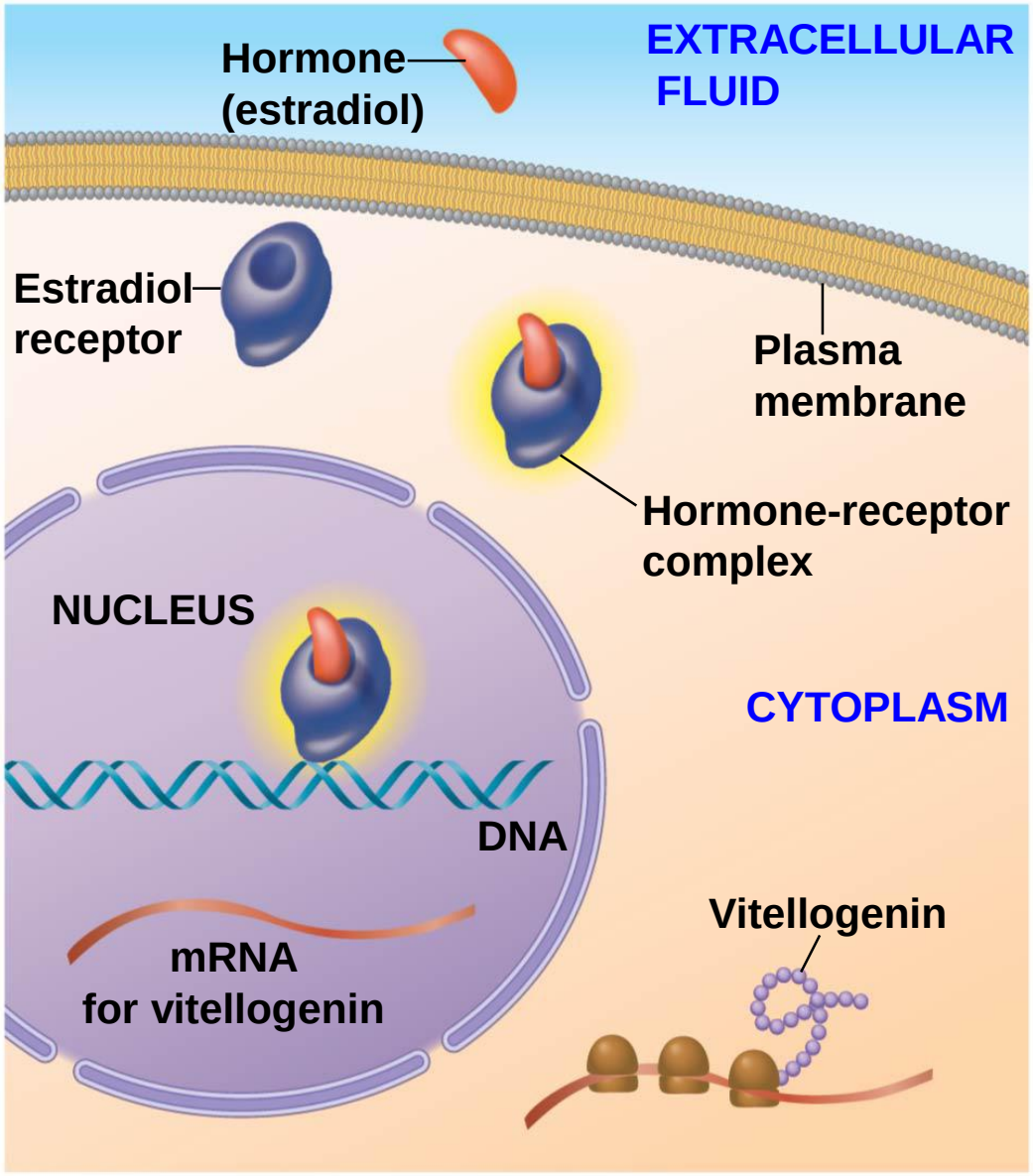
Figure 45.6

An Example of Signal Transduction



Signaling with Lipid-Soluble Hormones

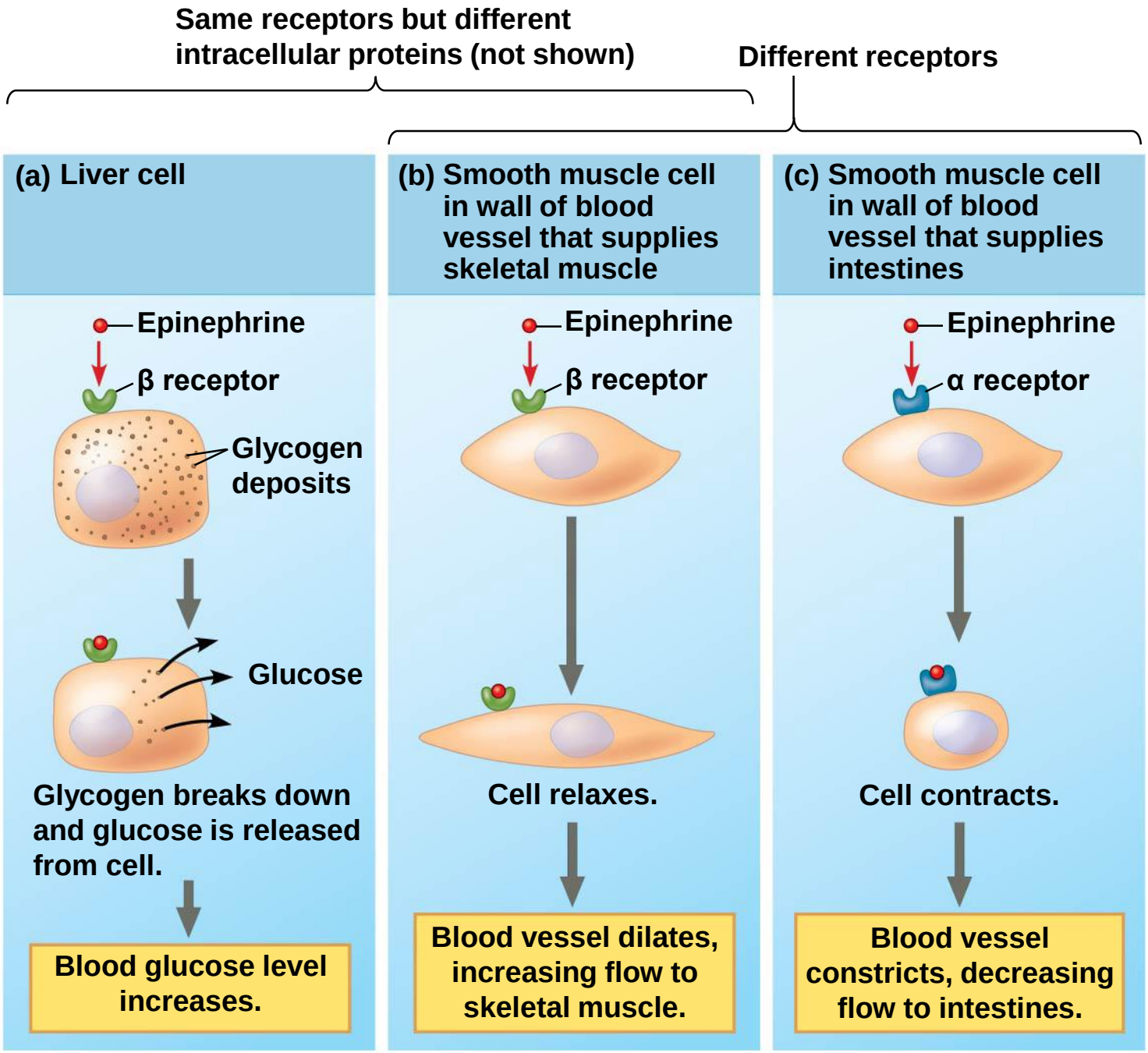
- When a steroid hormone binds to its cytosolic receptor, a hormone-receptor complex forms that moves into the nucleus
- There, the receptor part of the complex acts as a transcriptional regulator of specific target genes



Multiple Effects of Hormones

- The same hormone may have different effects on target cells that have
  - Different receptors for the hormone
  - Different signal transduction pathways
- For example, the hormone epinephrine can increase blood flow to major skeletal muscles, but decrease blood flow to the digestive tract

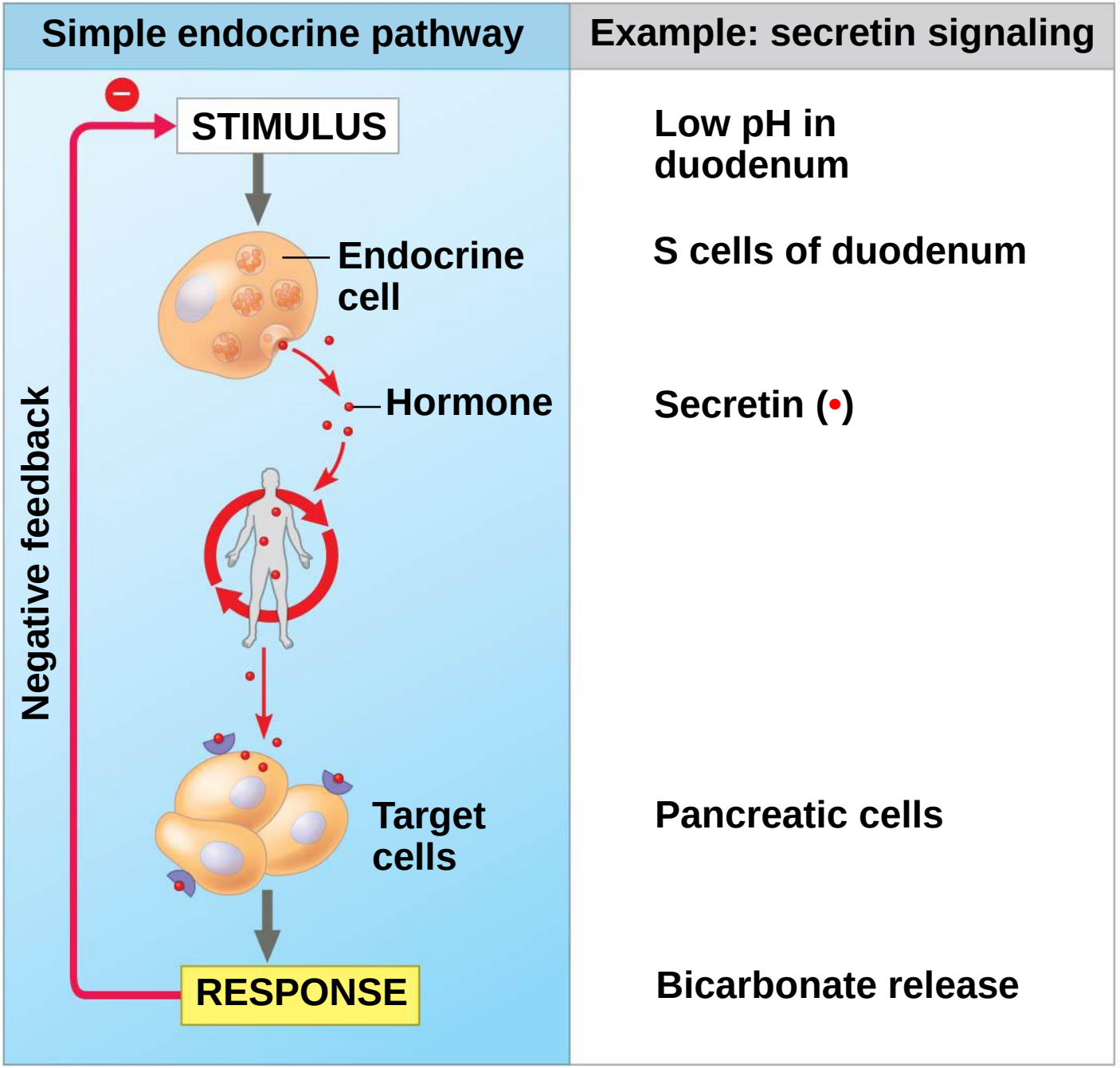
Figure 45.8



Feedback Regulation

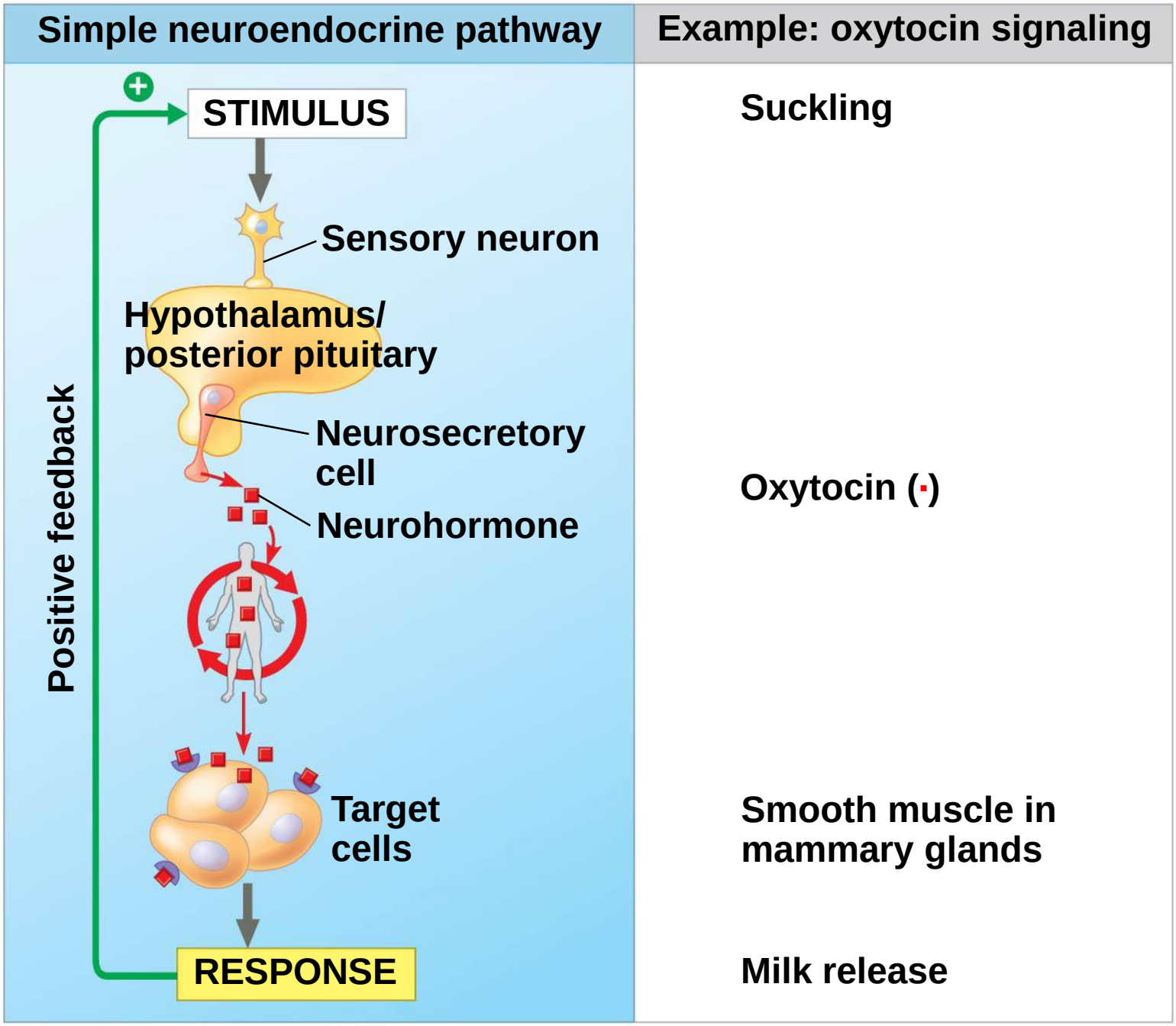
- A **negative feedback** loop inhibits a response by reducing the initial stimulus, thus preventing excessive pathway activity
  - For example, the release of acidic contents of the stomach into the duodenum stimulates endocrine cells there to secrete secretin
  - This causes target cells in the pancreas, a gland behind the stomach, to raise the pH in the duodenum

Figure 45.10



- **Positive feedback** reinforces a stimulus to produce an even greater response
- For example, in mammals oxytocin causes the release of milk, causing greater suckling by offspring, which stimulates the release of more oxytocin

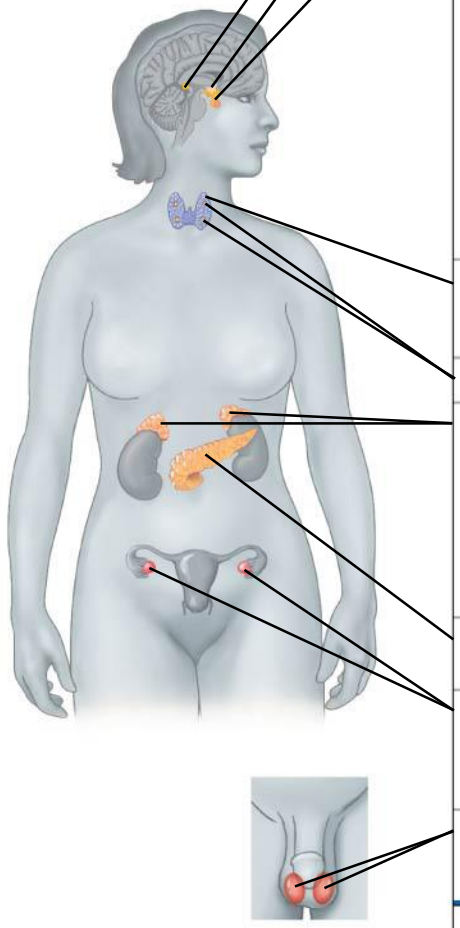
Figure 45.11



Endocrine Tissues and Organs

- Endocrine cells are often grouped in ductless organs called **endocrine glands**, such as the thyroid and parathyroid glands, testes, and ovaries
- In contrast, **exocrine glands**, such as salivary glands have ducts to carry secreted substances onto body surfaces or into body cavities

Figure 45.9



Endocrine gland	Hormones
Pineal gland	• **Melatonin:** Participates in regulation of biological rhythms.
Hypothalamus	• **Hormones released from posterior pituitary (oxytocin and vasopressin)** • **Releasing and inhibiting hormones:** Regulate anterior pituitary
Pituitary gland	
Anterior pituitary	• **Follicle-stimulating hormone (FSH)** and **luteinizing hormone (LH):** Stimulate ovaries and testes • **Thyroid-stimulating hormone (TSH):** Stimulates thyroid gland • **Adrenocorticotropic hormone (ACTH):** Stimulates adrenal cortex • **Prolactin:** Stimulates mammary gland cells • **Growth hormone (GH):** Stimulates growth and metabolic functions
Posterior pituitary	• **Oxytocin:** Stimulates contraction of smooth muscle cells in uterus and mammary glands • **Vasopressin:** (also called **antidiuretic hormone, ADH**): Promotes retention of water by kidneys; influences social behavior and bonding
Thyroid gland	• **Thyroid hormone (T_3 and T_4):** Stimulates and maintains metabolic processes • **Calcitonin:** Lowers blood calcium level
Parathyroid glands	• **Parathyroid hormone (PTH):** Raises blood calcium level
Adrenal glands	
Adrenal medulla	• **Epinephrine** and **norepinephrine:** Raise blood glucose level; increase metabolic activities; constrict certain blood vessels.
Adrenal cortex	• **Glucocorticoids:** Raise blood glucose level • **Mineralocorticoids:** Promote reabsorption of Na^+ and excretion of K^+ in kidneys
Pancreas	• **Insulin:** Lowers blood glucose level • **Glucagon:** Raises blood glucose level
Ovaries (female)	• **Estrogens*:** Stimulate uterine lining growth; promote development and maintenance of female secondary sex characteristics • **Progestins*:** Promote uterine lining growth
Testes (male)	• **Androgens*:** Support sperm formation; promote development and maintenance of male secondary sex characteristics

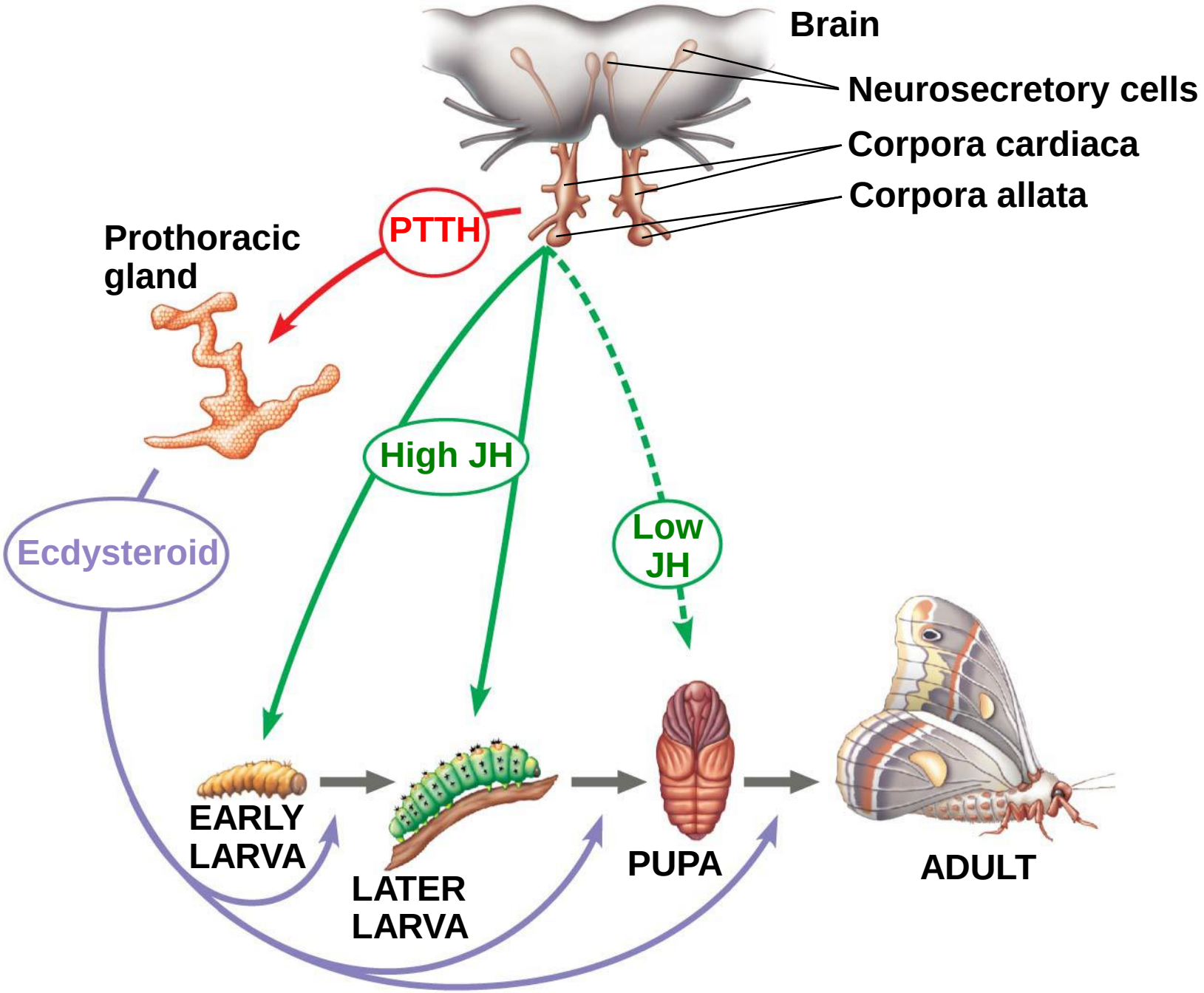
*Found in both males and females, but with a major role in one sex

2. Coordination of the Endocrine and Nervous Systems

Invertebrates

- The endocrine pathway that controls the molting of larva originates in the larval brain where neurosecretory cells produce PTTH
- In the prothoracic gland, PTTH directs the release of ecdysteroid
- Bursts of ecdysteroid trigger each successive molt as well as metamorphosis
- Metamorphosis is not triggered until the level of another hormone, JH (juvenile hormone), drops

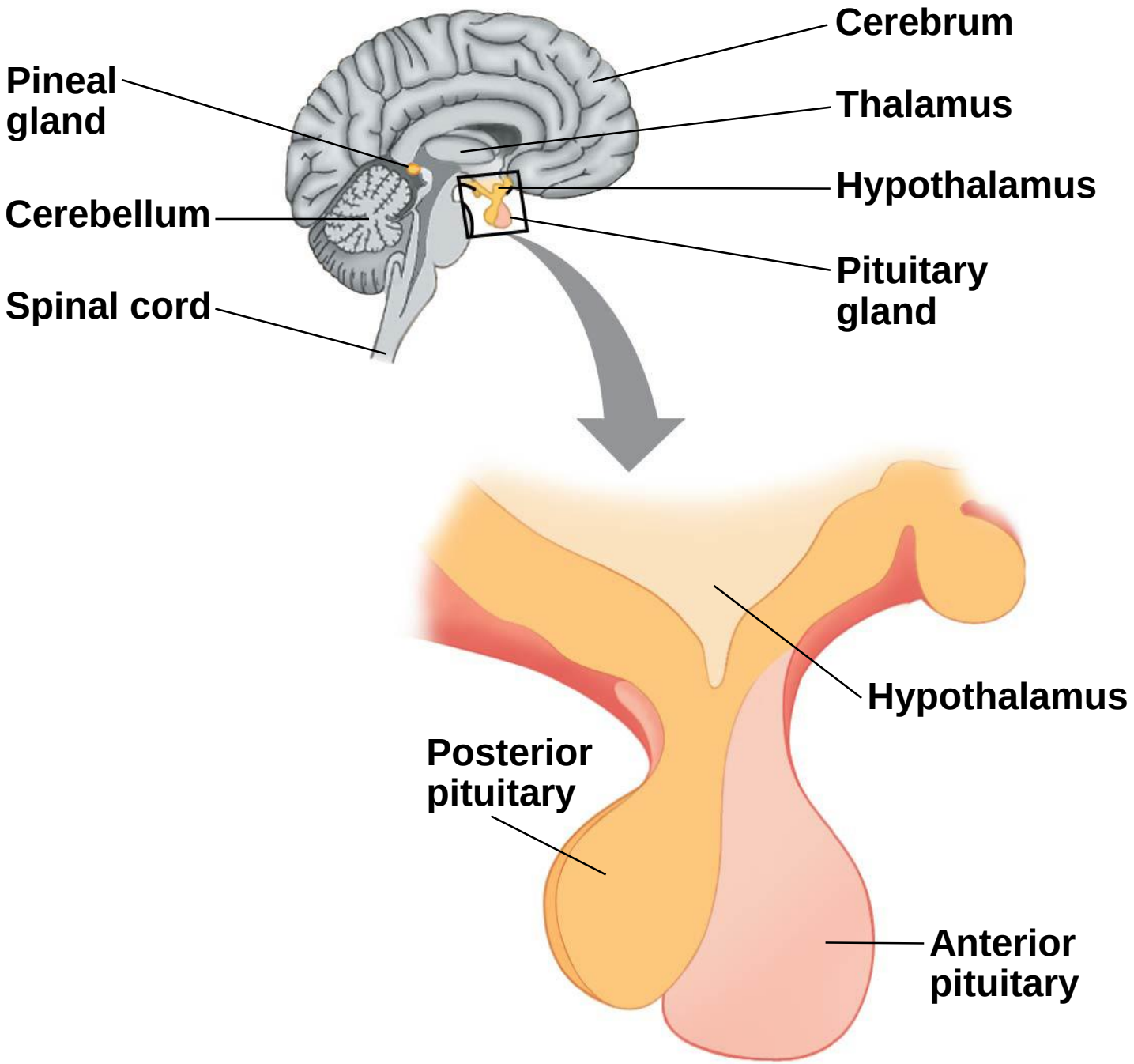
Figure 45.12-4



Vertebrates

- The **hypothalamus** receives information from the nervous system and initiates responses through the endocrine system
- Attached to the hypothalamus is the **pituitary gland**, composed of the posterior pituitary and anterior pituitary
- The **posterior pituitary** stores and secretes hormones that are made in the hypothalamus
- The **anterior pituitary** makes and releases hormones under regulation of the hypothalamus

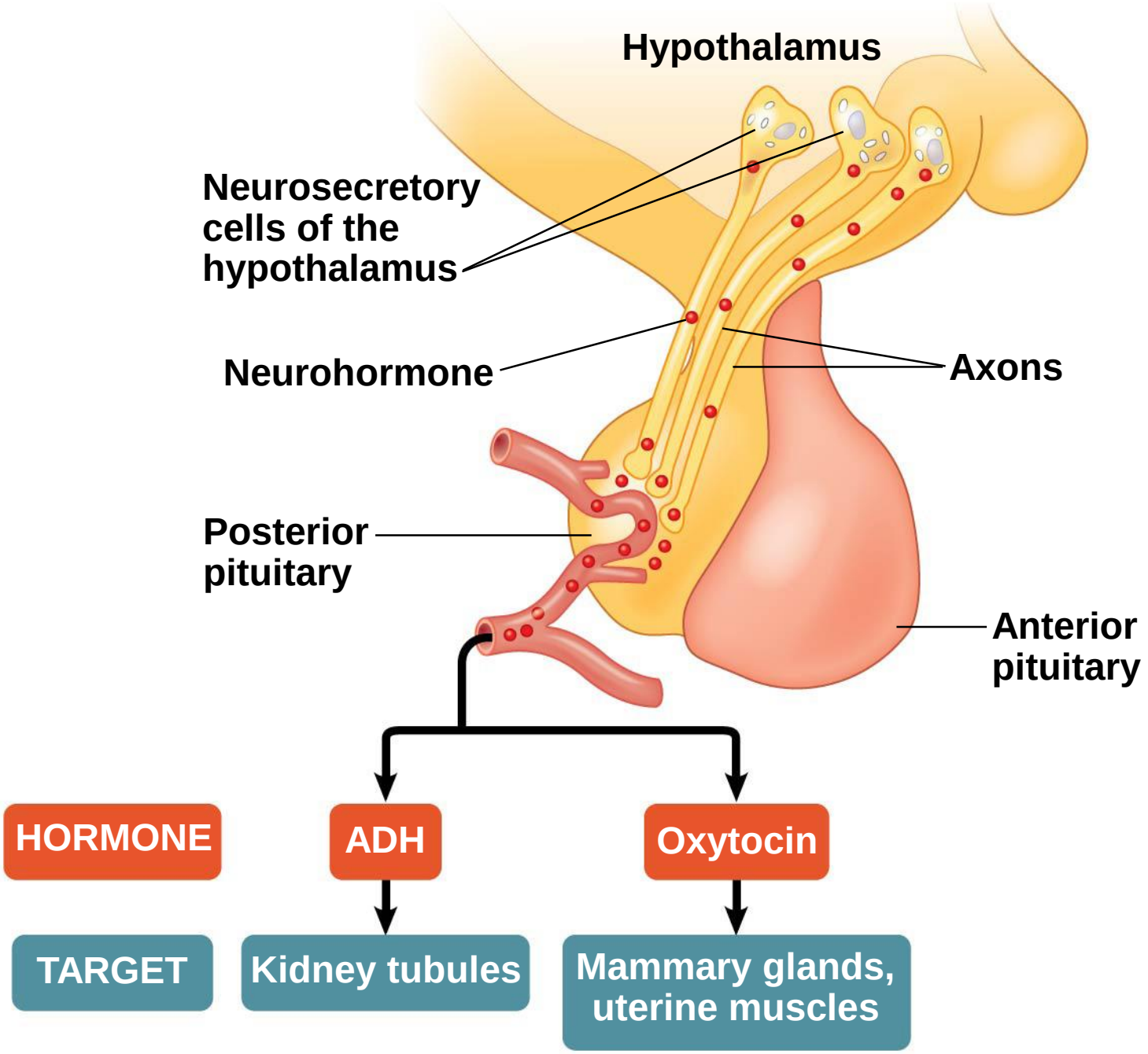
Figure 45.13



Posterior Pituitary Hormones

- Neurosecretory cells of the hypothalamus synthesize the two posterior pituitary hormones
  - **Antidiuretic hormone** (**ADH**) regulates physiology and behavior
  - Oxytocin regulates milk secretion by the mammary glands

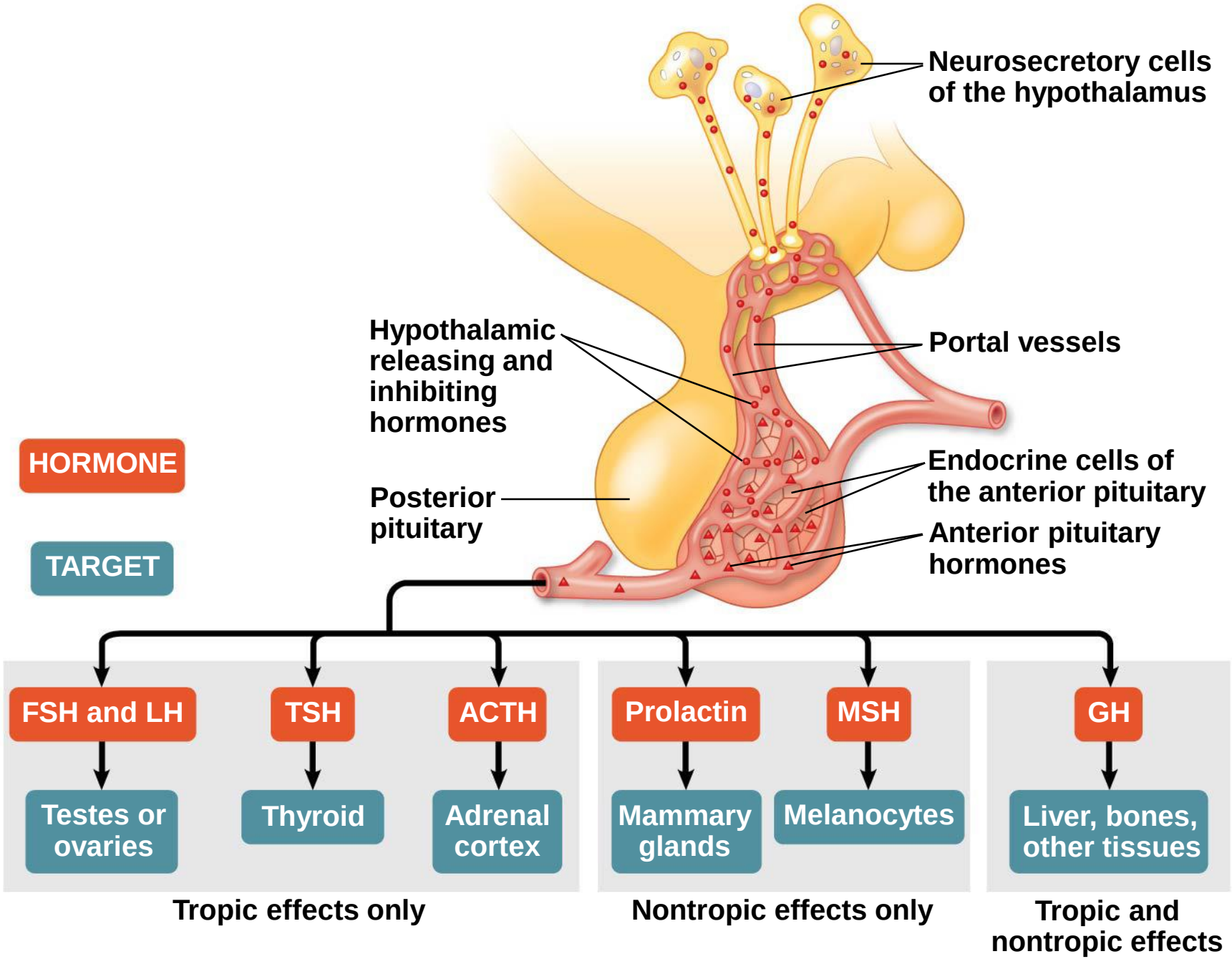
Figure 45.14



Anterior Pituitary Hormones

- Hormone production in the anterior pituitary is controlled by releasing hormones and inhibiting hormones secreted by the hypothalamus
- For example, prolactin-releasing hormone from the hypothalamus stimulates the anterior pituitary to secrete **prolactin** (**PRL**), which has a role in milk production

Figure 45.15



Hormone Cascades

- Sets of hormones from the hypothalamus, anterior pituitary, and a target endocrine gland are often organized into a hormone cascade pathway
- The anterior pituitary hormones in these pathways are called **tropic hormones** – hormones that target other endocrine glands
  - **Non-tropic hormones** stimulate targets other than endocrine glands

Thyroid Regulation: A Hormone Cascade Pathway

- In humans and other mammals, **thyroid hormone** regulates many functions
- If thyroid hormone level drops in the blood, the hypothalamus secretes thyrotropin-releasing hormone (TRH) causing the anterior pituitary to secrete thyroid-stimulating hormone (TSH)
- TSH stimulates release of thyroid hormone by the **thyroid gland**

Figure 45.16a

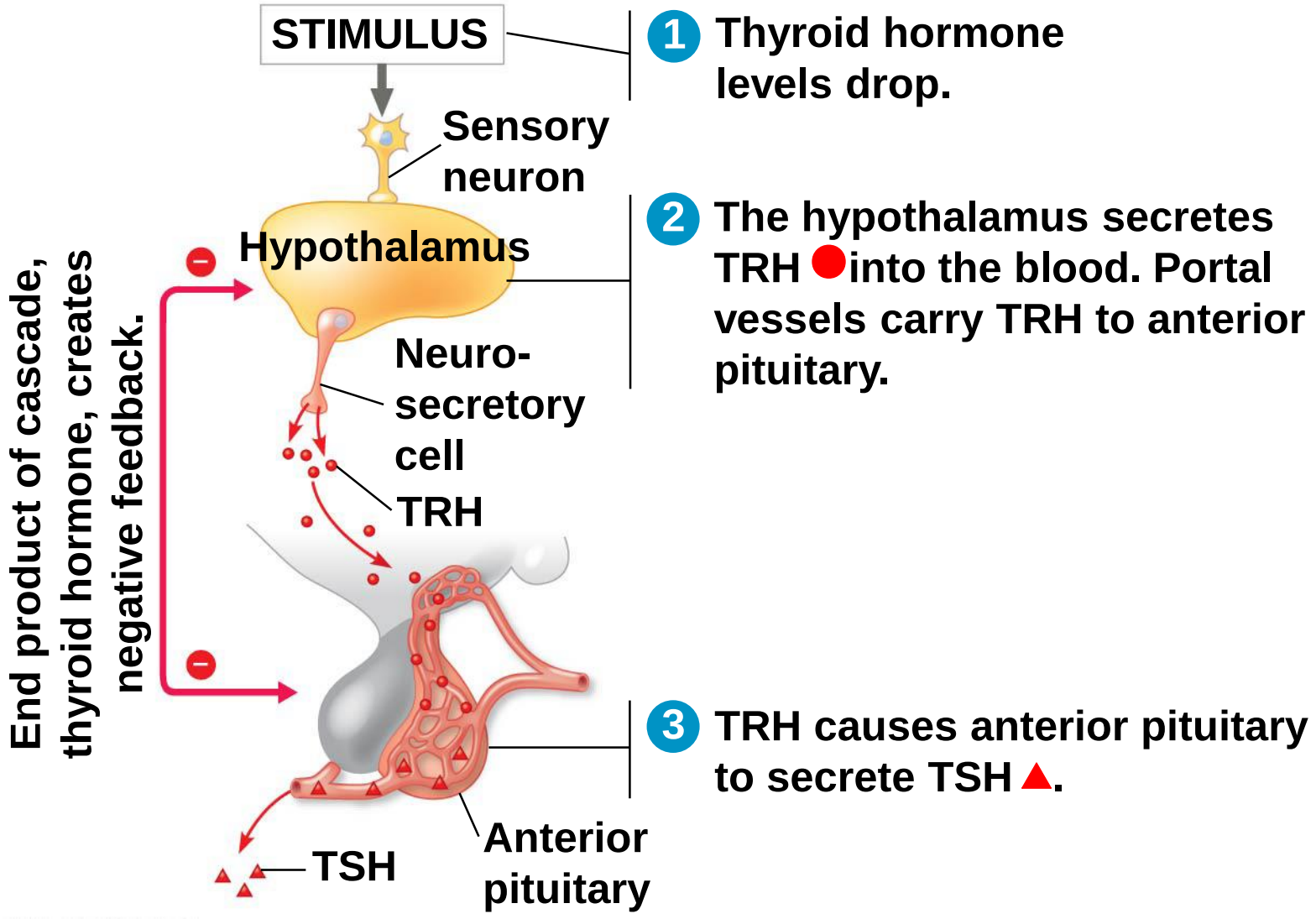
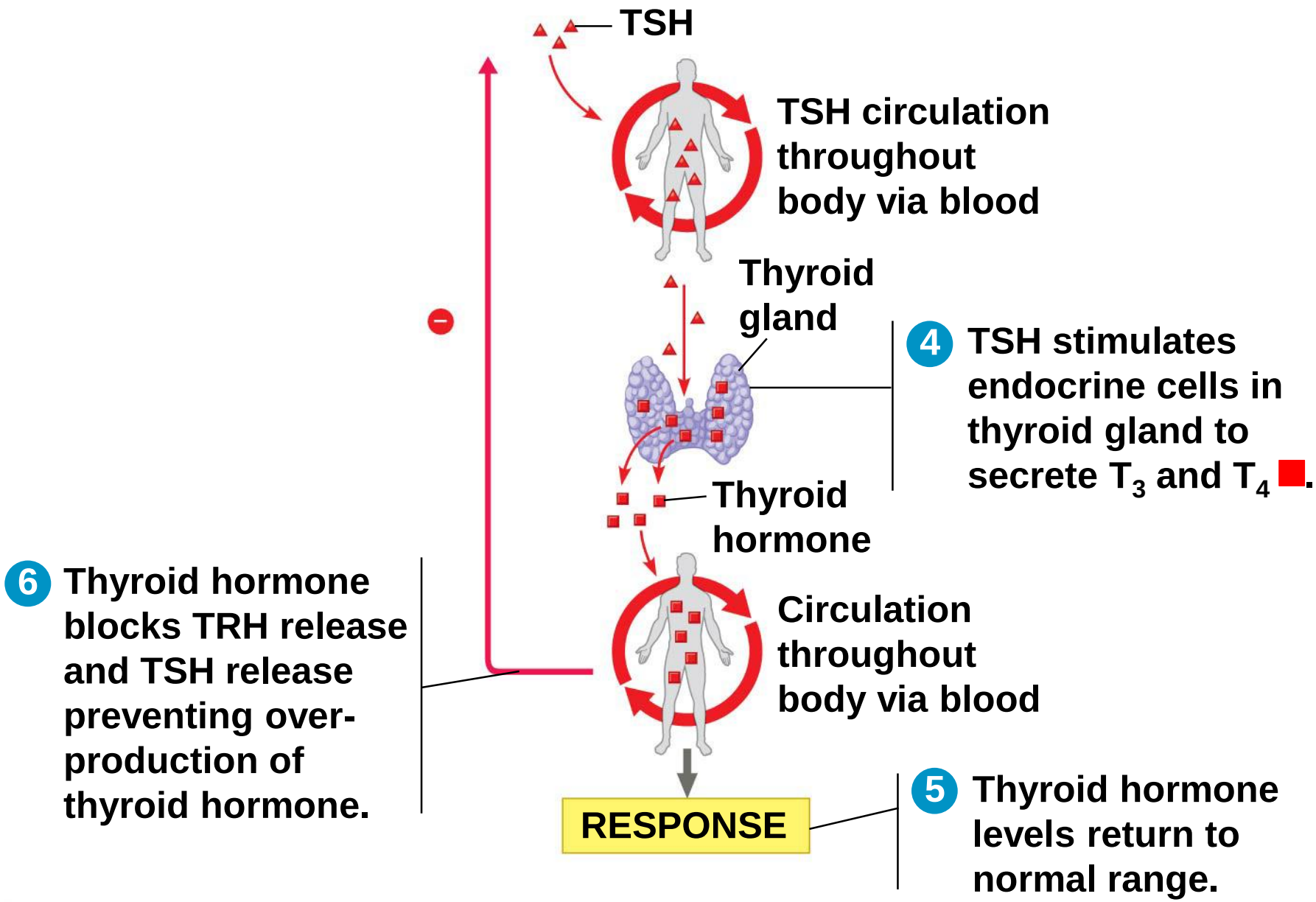


Figure 45.16b



Disorders of Thyroid Function and Regulation

- Hypothyroidism, too little thyroid function, can produce symptoms such as
  - Weight gain, lethargy, cold intolerance
- Hyperthyroidism, excessive production of thyroid hormone, can lead to
  - High temperature, sweating, weight loss, irritability, and high blood pressure
- Malnutrition can alter thyroid function

- Graves' disease, a form of hyperthyroidism caused by autoimmunity, is typified by protruding eyes
- *Thyroid hormone* refers to a pair of hormones
  - Triiodothyronin (T_3), with three iodine atoms
  - Thyroxine (T_4), with four iodine atoms
- Insufficient dietary iodine leads to an enlarged thyroid gland, called a goiter

Hormonal Regulation of Growth

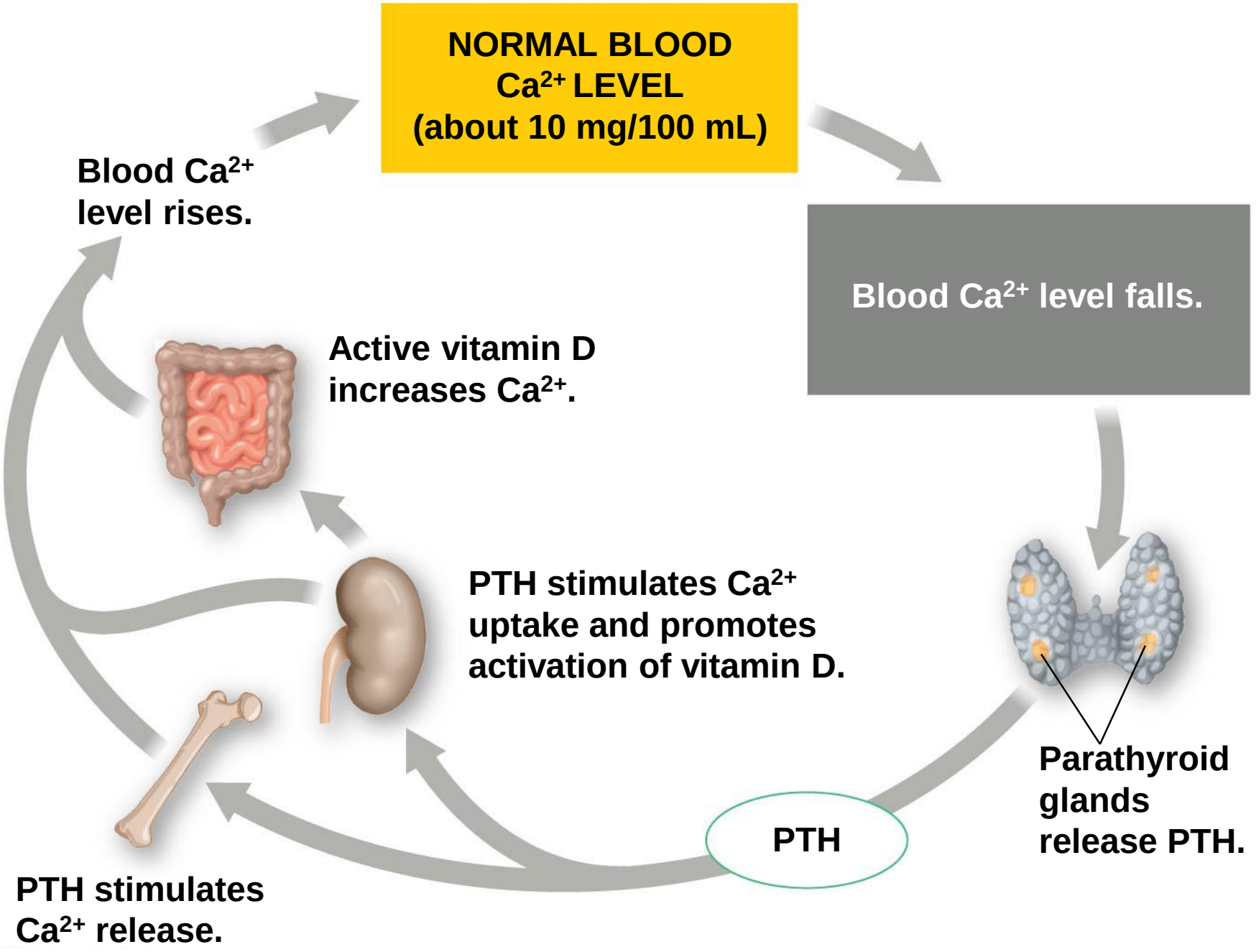
- **Growth hormone** (**GH**) is secreted by the anterior pituitary gland and has tropic and nontropic effects
- It promotes growth directly and has diverse metabolic effects
- It stimulates production of growth factors
- An excess of GH can cause gigantism, while a lack of GH can cause dwarfism

3. Other Endocrine Hormones

Parathyroid Hormone and Vitamin D: Control of Blood Calcium

- Two antagonistic hormones regulate the homeostasis of calcium (Ca^{2+}) in the blood of mammals
  - **Parathyroid hormone** (**PTH**) is released by the **parathyroid glands**
  - **Calcitonin** is released by the thyroid gland

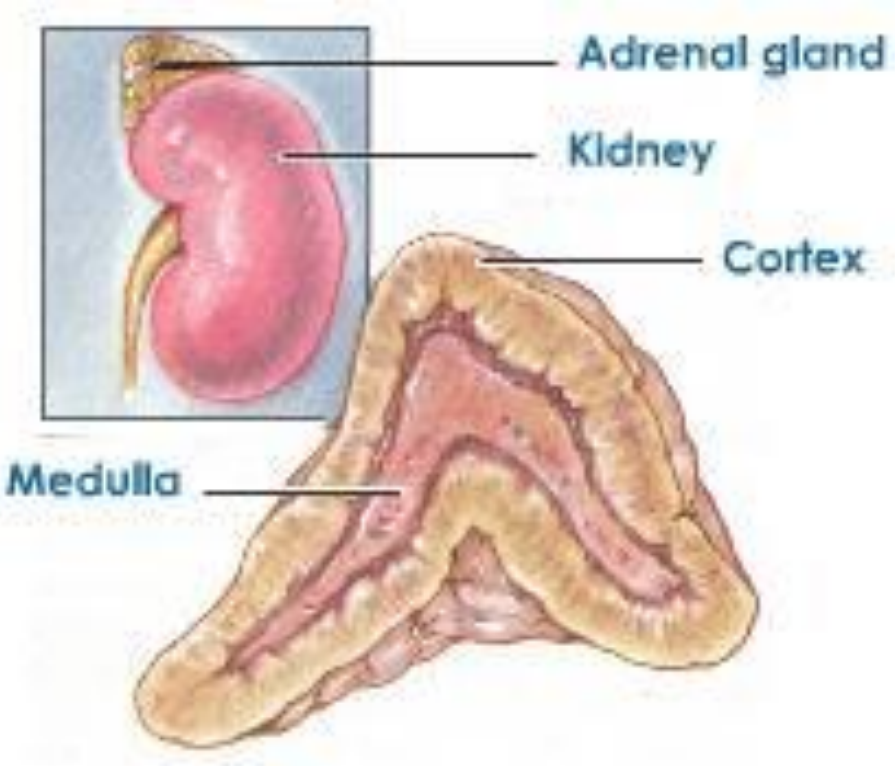
Figure 45.19



- PTH increases the level of blood Ca^{2+}
  - It releases Ca^{2+} from bone and stimulates reabsorption of Ca^{2+} in the kidneys
  - It also has an indirect effect, stimulating the kidneys to activate vitamin D, which promotes intestinal uptake of Ca^{2+} from food
- Calcitonin decreases the level of blood Ca^{2+}
  - It stimulates Ca^{2+} deposition in bones and secretion by kidneys

Adrenal Hormones: Response to Stress

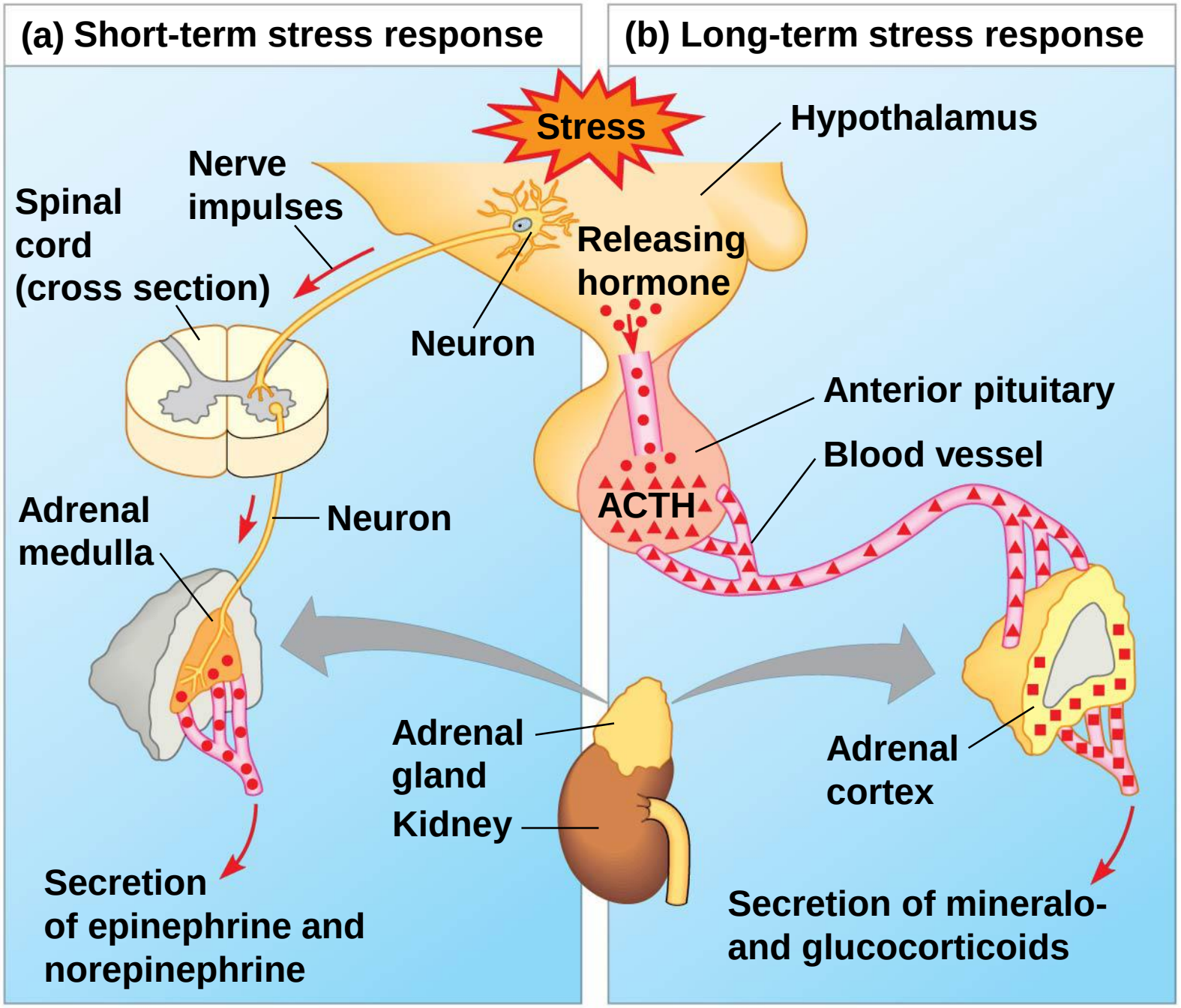
- The adrenal glands are associated with the kidneys
- Each **adrenal gland** actually consists of two glands: the *adrenal medulla* (inner portion) and *adrenal cortex* (outer portion)



Catecholamines from the Adrenal Medulla

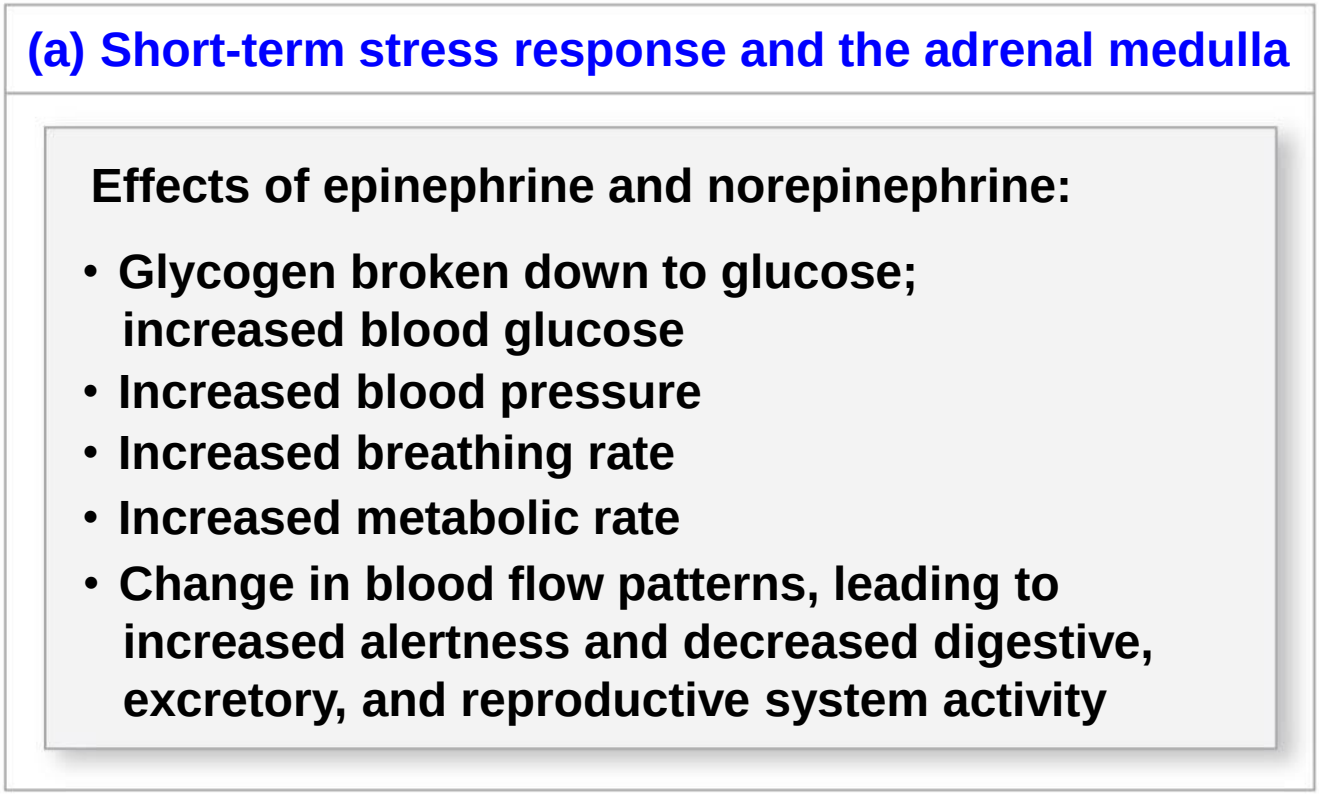
- The adrenal medulla secretes **epinephrine** (adrenaline) and **norepinephrine** (noradrenaline)
- These hormones are members of a class of compounds called **catecholamines**
- They are secreted in response to stress-activated impulses from the nervous system

Figure 45.20a



Epinephrine and Norepinephrine

- Trigger the release of glucose and fatty acids into the blood
- Increase oxygen delivery to body cells
- Direct blood toward heart, brain, and skeletal muscles and away from skin, digestive system, and kidneys



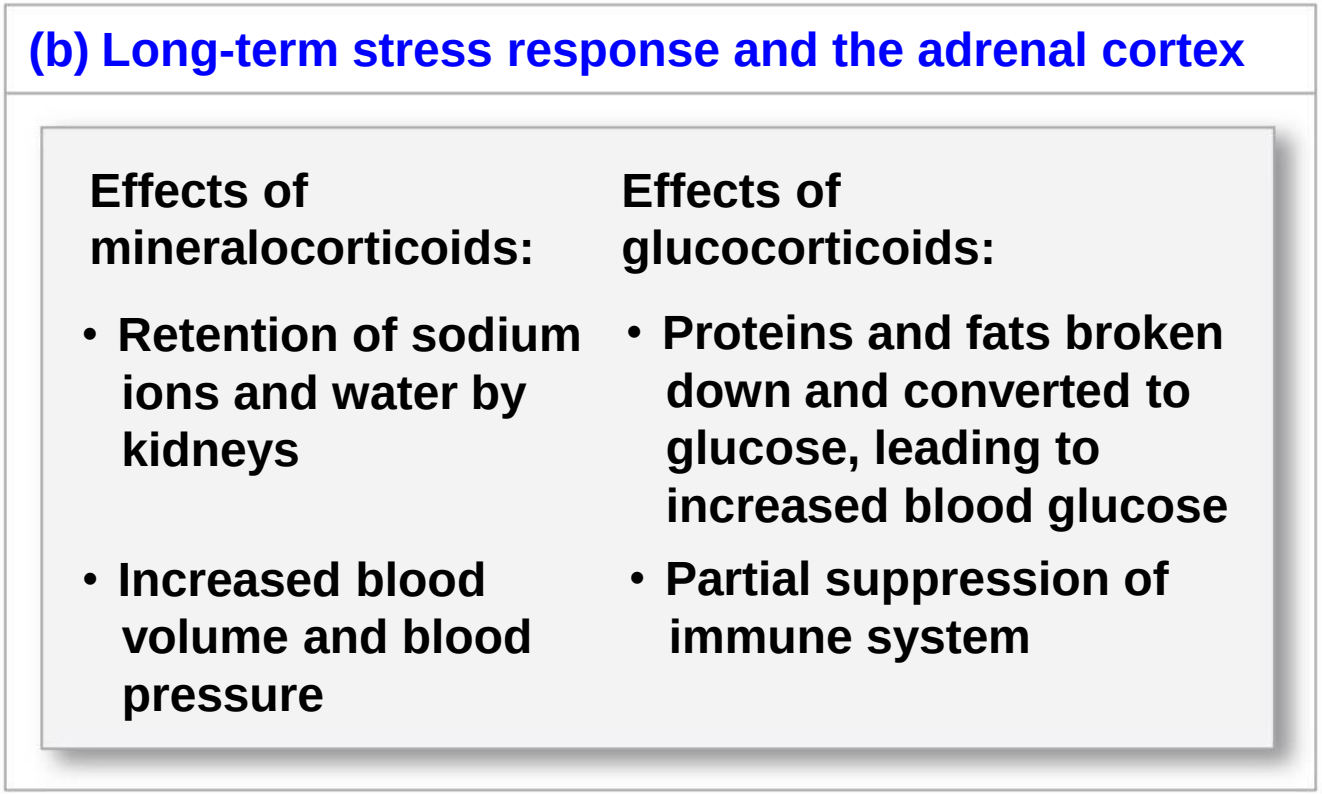
Steroid Hormones from the Adrenal Cortex

- The adrenal cortex reacts to endocrine signals
- It releases a family of steroids called **corticosteroids** in response to stress
- These hormones are triggered by a hormone cascade pathway via the hypothalamus and anterior pituitary
- Humans produce two types of corticosteroids: **glucocorticoids** and **mineralocorticoids**

Figure 45.20c

- **Glucocorticoids**, such as cortisol, influence glucose metabolism and the immune system

- **Mineralocorticoids**, such as aldosterone, affect salt and water balance



Sex Hormones

- The gonads, testes and ovaries, produce most of the sex hormones: **androgens**, **estrogens**, and **progestins**
- All three sex hormones are found in both males and females, but in significantly different proportions

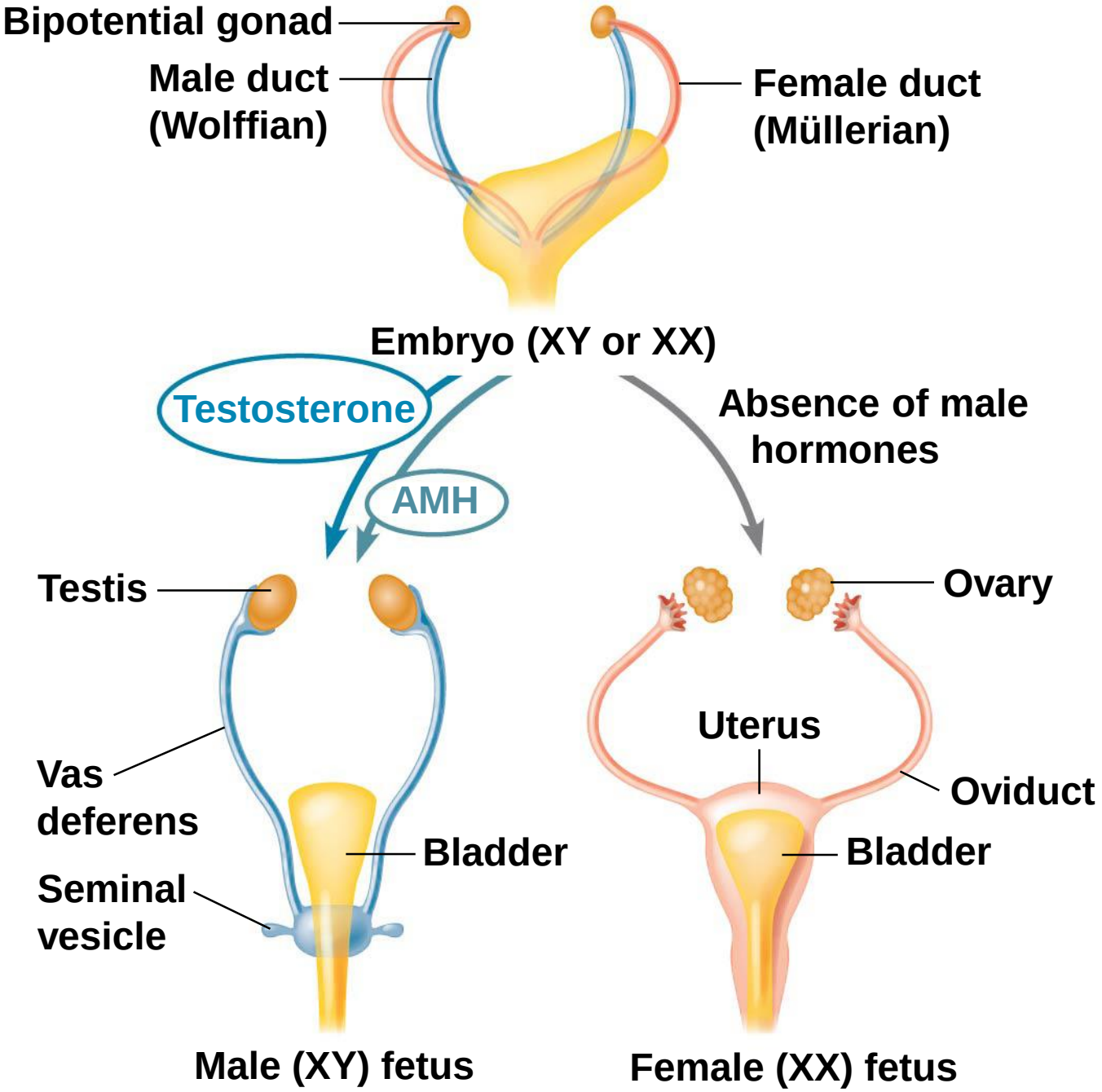
Androgens

- The testes primarily synthesize **androgens**, mainly **testosterone**, which stimulate development and maintenance of the male reproductive system
- Testosterone causes an increase in muscle and bone mass and is often taken as a supplement to cause muscle growth, which carries health risks

Estrogens & Progestins

- **Estrogens**, most importantly **estradiol**, are responsible for maintenance of the female reproductive system and the development of female secondary sex characteristics
- In mammals, **progestins**, which include **progesterone**, are primarily involved in preparing and maintaining the uterus
- Synthesis of the sex hormones is controlled by follicle-stimulating hormone and luteinizing hormone from the anterior pituitary

Figure 45.21



Hormones and Biological Rhythms

- The **pineal gland**, located in the brain, secretes **melatonin**
- Primary functions of melatonin appear to relate to biological rhythms associated with reproduction and with daily activity levels
- The release of melatonin by the pineal gland is controlled by a group of neurons in the hypothalamus called the suprachiasmatic nucleus (SCN)