# Chapter 45

# Hormones and the Endocrine System

PowerPoint Lectures for
***Biology, Seventh Edition***
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**Lectures by Chris Romero**

- Overview: The Body's Long-Distance Regulators
- An animal hormone
  - Is a chemical signal that is secreted into the circulatory system and communicates regulatory messages within the body
- Hormones may reach all parts of the body
  - But only certain types of cells, target cells, are equipped to respond

- Insect metamorphosis
  - Is regulated by hormones

**Figure 45.1**

- Concept 45.1: The endocrine system and the nervous system act individually and together in regulating an animal's physiology
- Animals have two systems of internal communication and regulation
  - The nervous system and the endocrine system

- The nervous system
  - Conveys high-speed electrical signals along specialized cells called neurons
- The endocrine system, made up of endocrine glands
  - Secretes hormones that coordinate slower but longer-acting responses to stimuli

# Overlap Between Endocrine and Nervous Regulation

- The endocrine and nervous systems
  - Often function together in maintaining homeostasis, development, and reproduction

- Specialized nerve cells known as neurosecretory cells
  - Release neurohormones into the blood
- Both endocrine hormones and neurohormones
  - Function as long-distance regulators of many physiological processes

# Control Pathways and Feedback Loops

- There are three types of hormonal control pathways

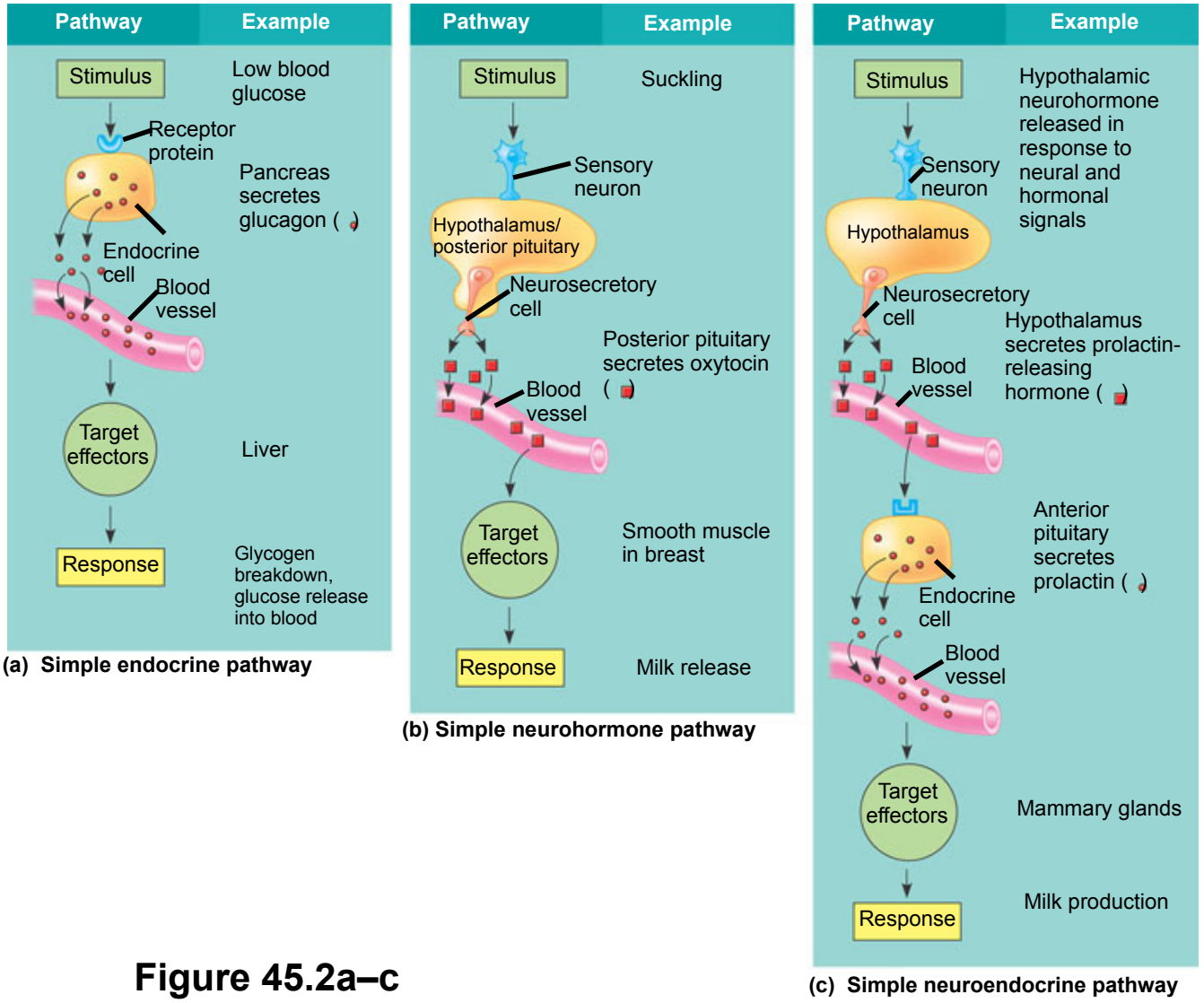



**Figure 45.2a–c**

- Concept 45.2: Hormones and other chemical signals bind to target cell receptors, initiating pathways that culminate in specific cell responses
- Hormones convey information via the bloodstream
  - To target cells throughout the body

- Three major classes of molecules function as hormones in vertebrates
  - Proteins and peptides
  - Amines derived from amino acids
  - Steroids

- Signaling by any of these molecules involves three key events
  - Reception
  - Signal transduction
  - Response

# Cell-Surface Receptors for Water-Soluble Hormones

- The receptors for most water-soluble hormones
  - Are embedded in the plasma membrane, projecting outward from the cell surface

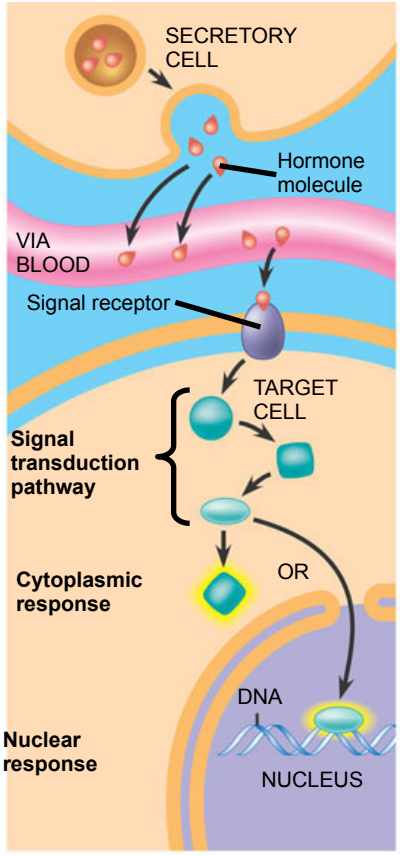



**Figure 45.3a**

- The hormone epinephrine
  - Has multiple effects in mediating the body's response to short-term stress

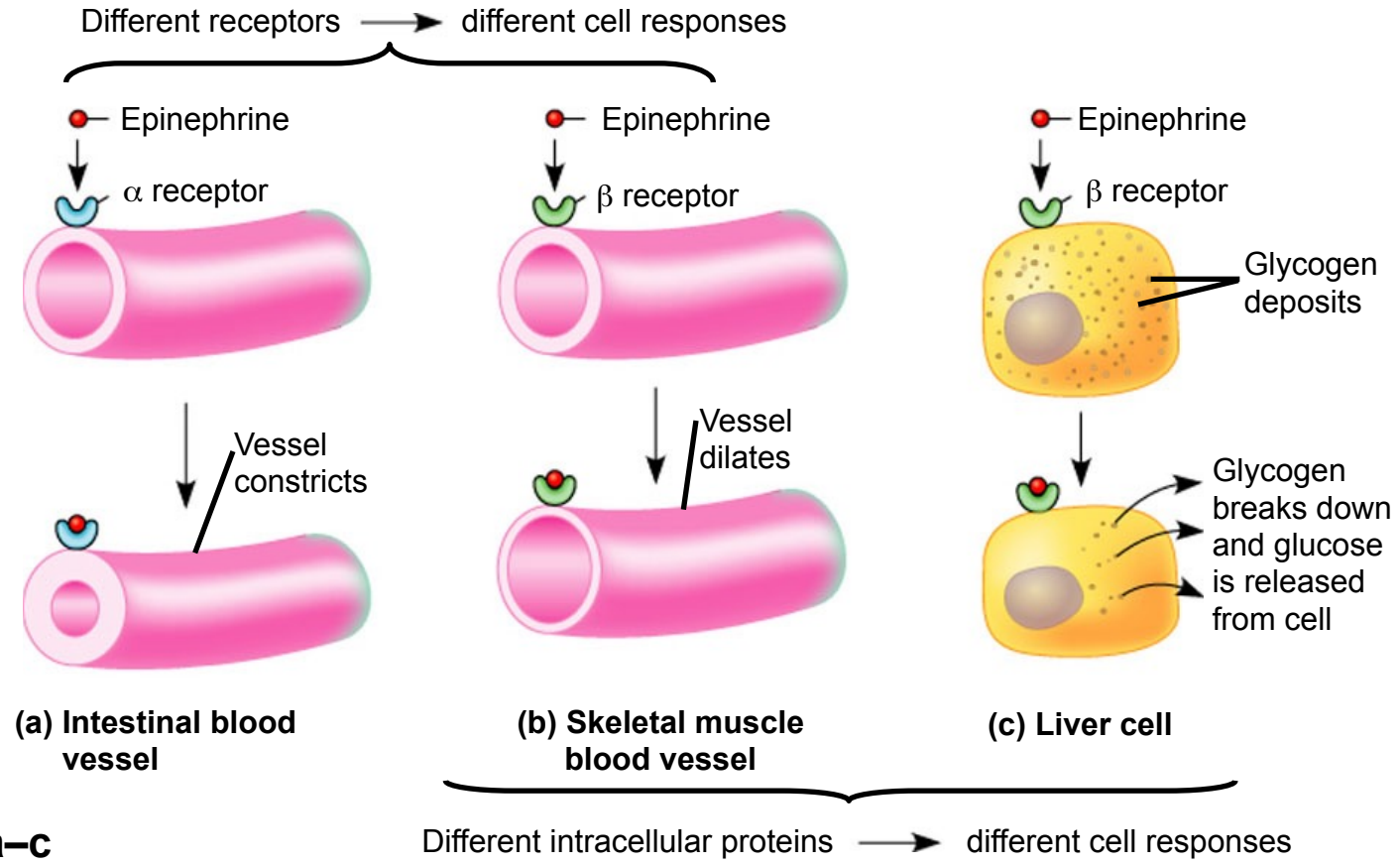



**Figure 45.4a–c**

- The protein-receptor complexes
  - Then act as transcription factors in the nucleus, regulating transcription of specific genes

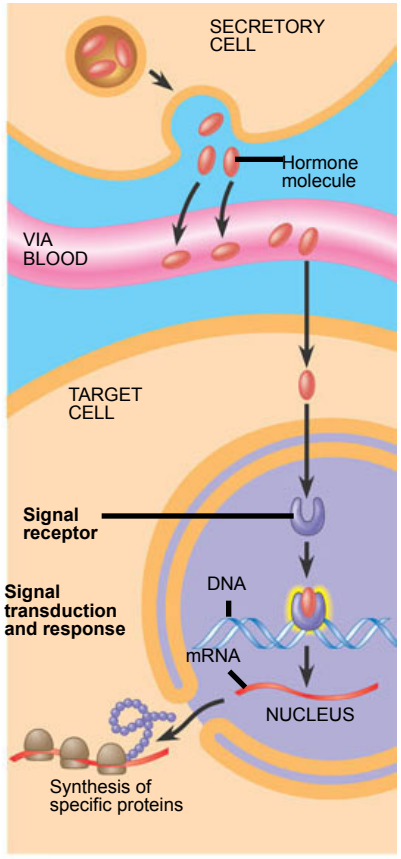



**Figure 45.3b** (b) Receptor in cell nucleus

# Paracrine Signaling by Local Regulators

- In a process called paracrine signaling
  - Various types of chemical signals elicit responses in nearby target cells

- Local regulators have various functions and include
  - Neurotransmitters
  - Cytokines and growth factors
  - Nitric oxide
  - Prostaglandins

- Prostaglandins help regulate the aggregation of platelets
  - An early step in the formation of blood clots

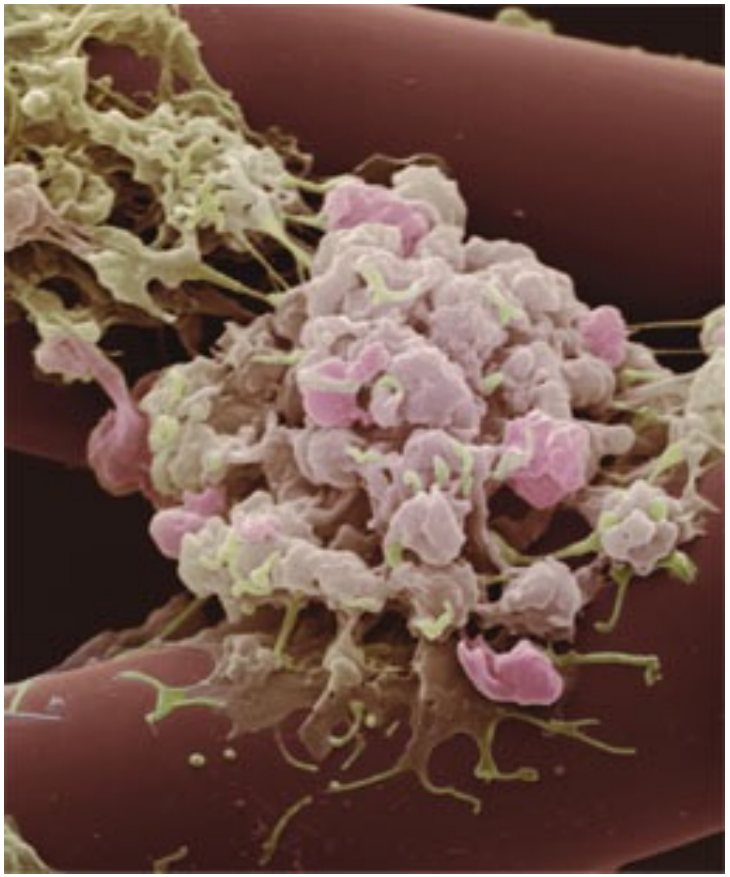


**Figure 45.5**

- Concept 45.3: The hypothalamus and pituitary integrate many functions of the vertebrate endocrine system
- The hypothalamus and the pituitary gland
  - Control much of the endocrine system

- The major human endocrine glands

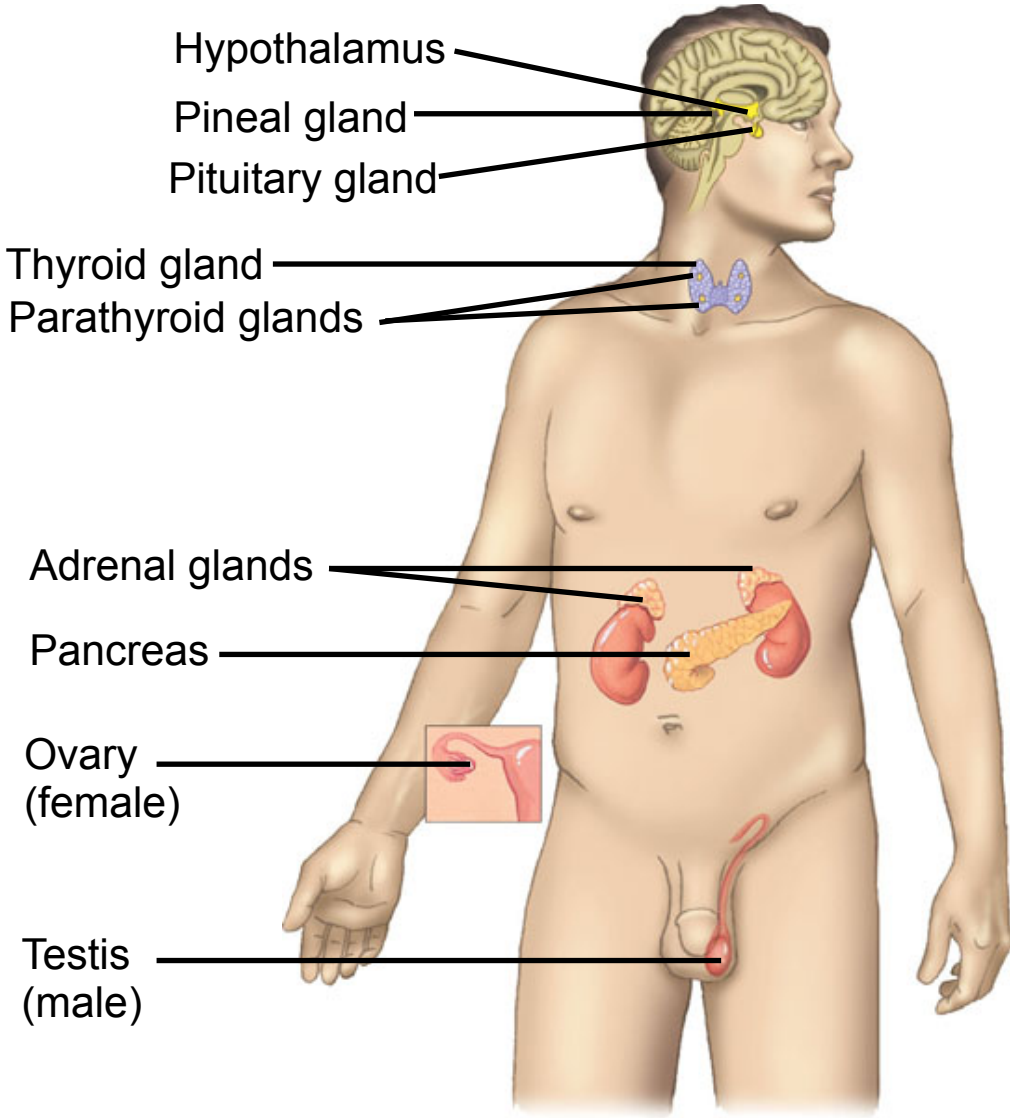



**Figure 45.6**

- Major human endocrine glands and some of their hormones

**Table 45.1 Major Human Endocrine Glands and Some of Their Hormones**

| Gland | Hormone | Chemical Class | Representative Actions | Regulated By |
|---|---|---|---|---|
| **Hypothalamus**  | Hormones released from the posterior pituitary and hormones that regulate the anterior pituitary (see below) | | | |
| **Pituitary gland** Posterior pituitary (releases neuro-hormones made in hypothalamus)  | Oxytocin | Peptide | Stimulates contraction of uterus and mammary gland cells | Nervous system |
| | Antidiuretic hormone (ADH) | Peptide | Promotes retention of water by kidneys | Water/salt balance |
| Anterior pituitary  | Growth hormone (GH) | Protein | Stimulates growth (especially bones) and metabolic functions | Hypothalamic hormones |
| | Prolactin (PRL) | Protein | Stimulates milk production and secretion | Hypothalamic hormones |
| | Follicle-stimulating hormone (FSH) | Glycopr otein | Stimulates production of ova and sperm | Hypothalamic hormones |
| | Luteinizing hormone (LH) | Glycoprotein | Stimulates ovaries and testes | Hypothalamic hormones |
| | Thyroid-stimulating hormone (TSH) | Glycoprotein | Stimulates thyroid gland | Thyroxine in blood; hypothalamic hormones |
| | Adrenocorticotropic hormone (ACTH) | Peptide | Stimulates adrenal cortex to secrete glucocorticoids | Glucocorticoids; hypothalamic hormones |
| **Thyroid gland**  | Triiodothyronine ($T_3$) and thyroxine ($T_4$) | Amine | Stimulate and maintain metabolic processes | TSH |
| | Calcitonin | Peptide | Lowers blood calcium level | Calcium in blood |
| **Parathyroid glands**  | Parathyroid hormone (PTH) | Peptide | Raises blood calcium level | Calcium in blood |

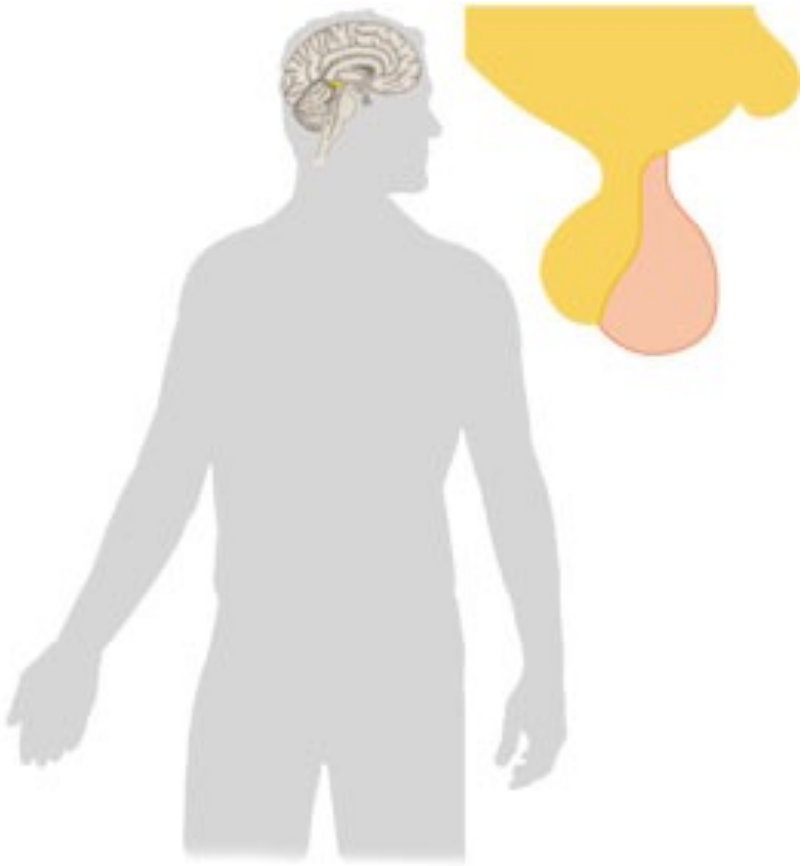
**Table 45.1**

| Gland | Hormone | Chemical Class | Representative Actions | Regulated By |
|---|---|---|---|---|
| **Pancreas**  | Insulin | Protein | Lowers blood glucose level | Glucose in blood |
| | Glucagon | Protein | Raises blood glucose level | Glucose in blood |
| **Adrenal glands**  | | | | |
| Adrenal medulla | Epinephrine and norepinephrine | Amine | Raise blood glucose level; increase metabolic activities; constrict certain blood vessels | Nervous system |
| Adrenal cortex | Glucocorticoids | Steroid | Raise blood glucose level | ACTH |
| | Mineralocorticoids | Steroid | Promote reabsorption of Na and excretion of K in kidneys | K in blood |
| **Gonads** | | | | |
| Testes  | Androgens | Steroid | Support sperm formation; promote development and maintenance of male secondary sex characteristics | FSH and LH |
| Ovaries  | Estrogens | Steroid | Stimulate uterine lining growth; promote development and maintenance of female secondary sex characteristics | FSH and LH |
| | Progesterone | Steroid | Promotes uterine lining growth | FSH and LH |
| **Pineal gland**  | Melatonin | Amine | Involved in biological rhythms | Light/dark cycles |

**Table 45.1**

# Relation Between the Hypothalamus and Pituitary Gland

- The hypothalamus, a region of the lower brain
  - Contains different sets of neurosecretory cells



- Some of these cells produce direct-acting hormones
  - That are stored in and released from the posterior pituitary, or neurohypophysis

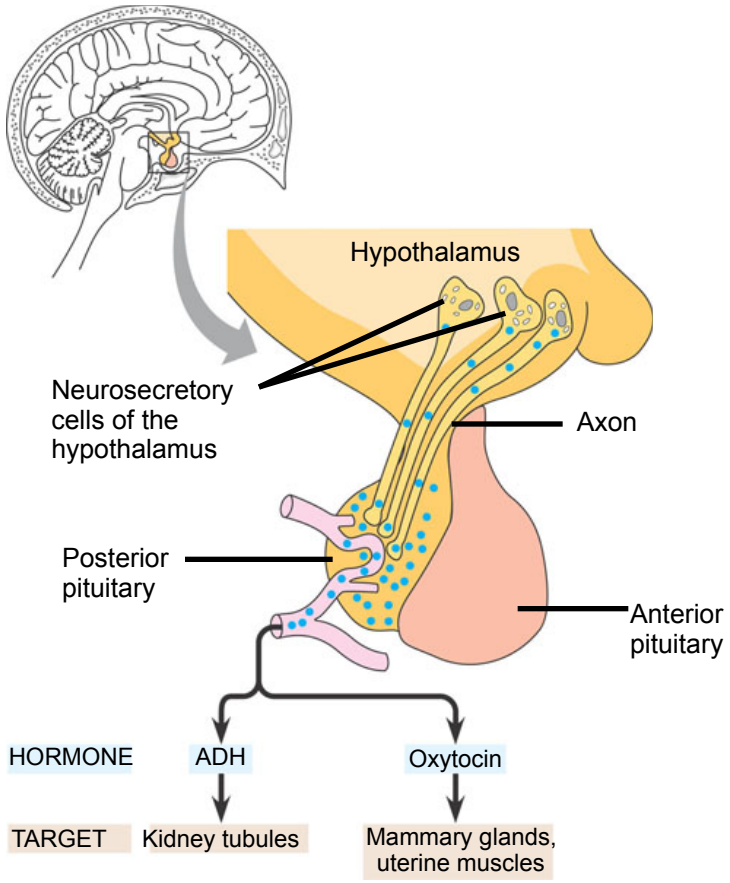



**Figure 45.7**

- Other hypothalamic cells produce tropic hormones
  - That are secreted into the blood and transported to the anterior pituitary or adenohypophysis

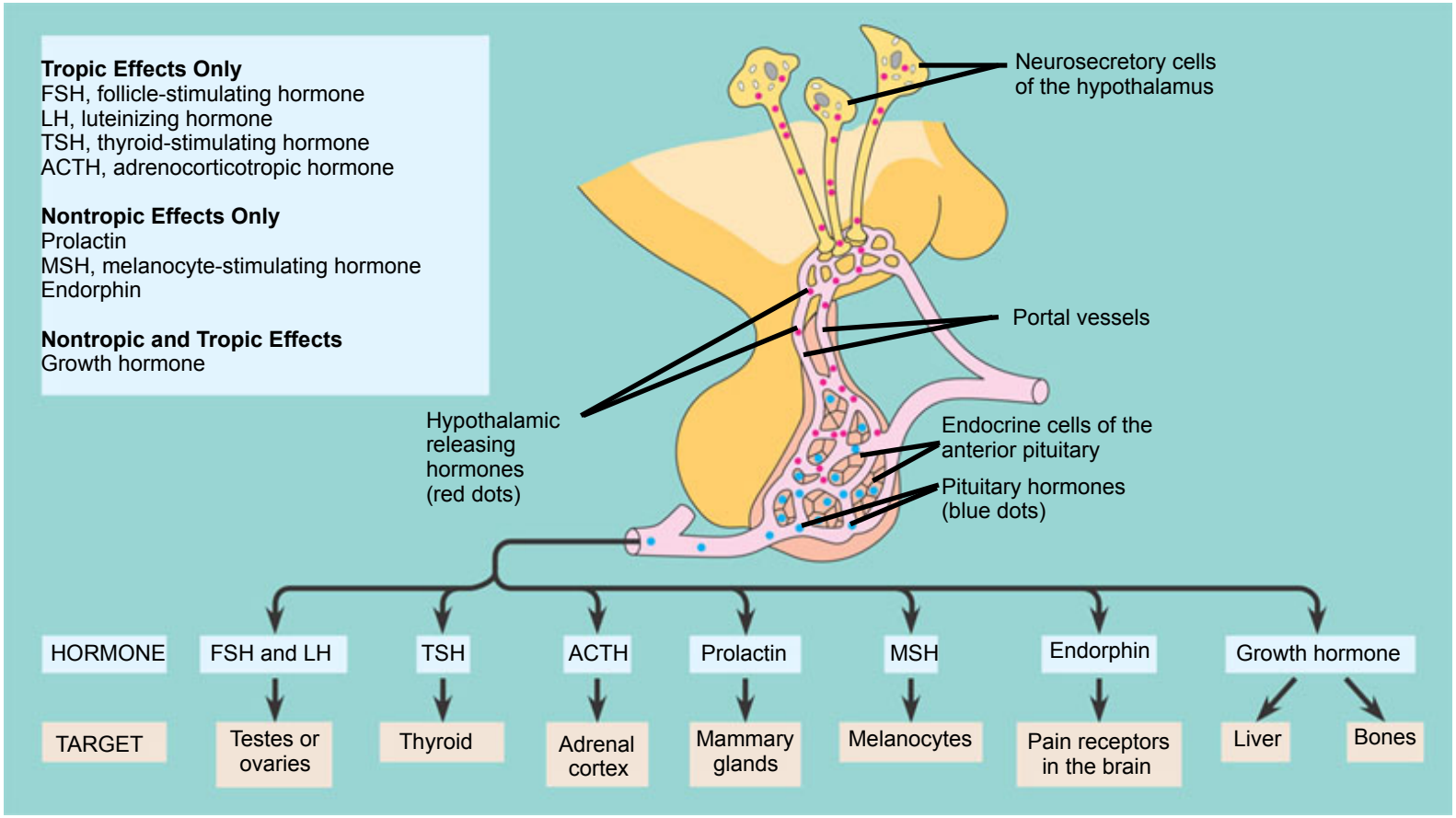



**Figure 45.8**

- The anterior pituitary
  - Is a true-endocrine gland
- The tropic hormones of the hypothalamus
  - Control release of hormones from the anterior pituitary

- Oxytocin
  - Induces uterine contractions and milk ejection
- Antidiuretic hormone (ADH)
  - Enhances water reabsorption in the kidneys

# *Tropic Hormones*

- The four strictly tropic hormones are
  - Follicle-stimulating hormone (FSH)
  - Luteinizing hormone (LH)
  - Thyroid-stimulating hormone (TSH)
  - Adrenocorticotropic hormone (ACTH)

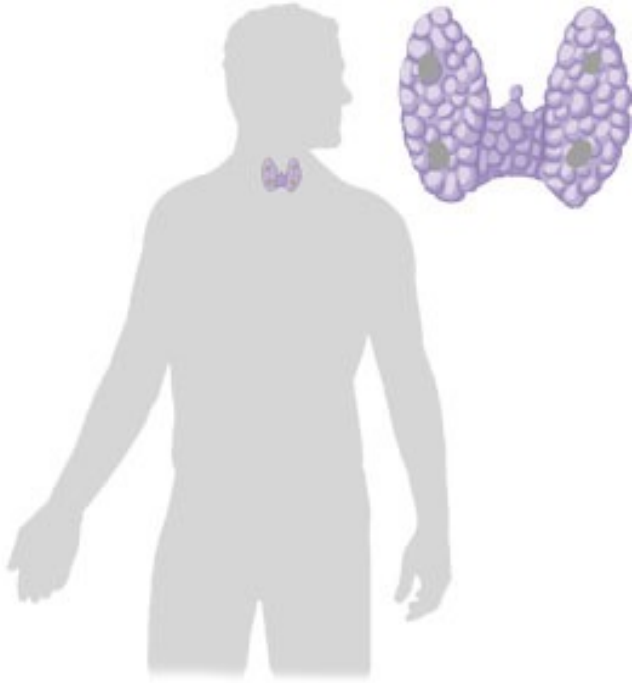
- Prolactin stimulates lactation in mammals
  - But has diverse effects in different vertebrates
- MSH influences skin pigmentation in some vertebrates
  - And fat metabolism in mammals
- Endorphins
  - Inhibit the sensation of pain

# *Growth Hormone*

- Growth hormone (GH)
  - Promotes growth directly and has diverse metabolic effects
  - Stimulates the production of growth factors by other tissues

# Thyroid Hormones

- The thyroid gland
  - Consists of two lobes located on the ventral surface of the trachea
  - Produces two iodine-containing hormones, triiodothyronine ($T_3$) and thyroxine ($T_4$)



- The hypothalamus and anterior pituitary
  - Control the secretion of thyroid hormones through two negative feedback loops

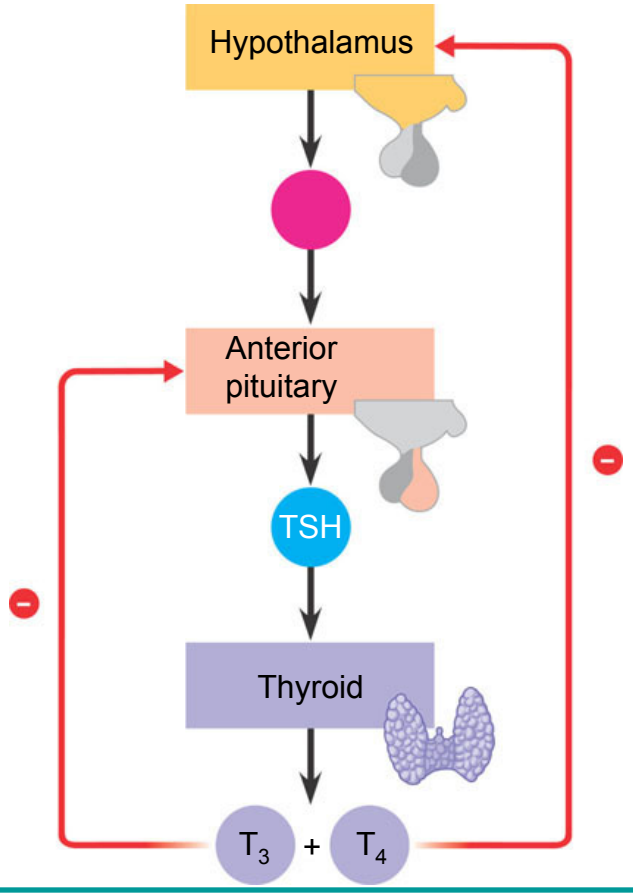



**Figure 45.9**

- The thyroid hormones
  - Play crucial roles in stimulating metabolism and influencing development and maturation

- Hyperthyroidism, excessive secretion of thyroid hormones
  - Can cause Graves' disease in humans

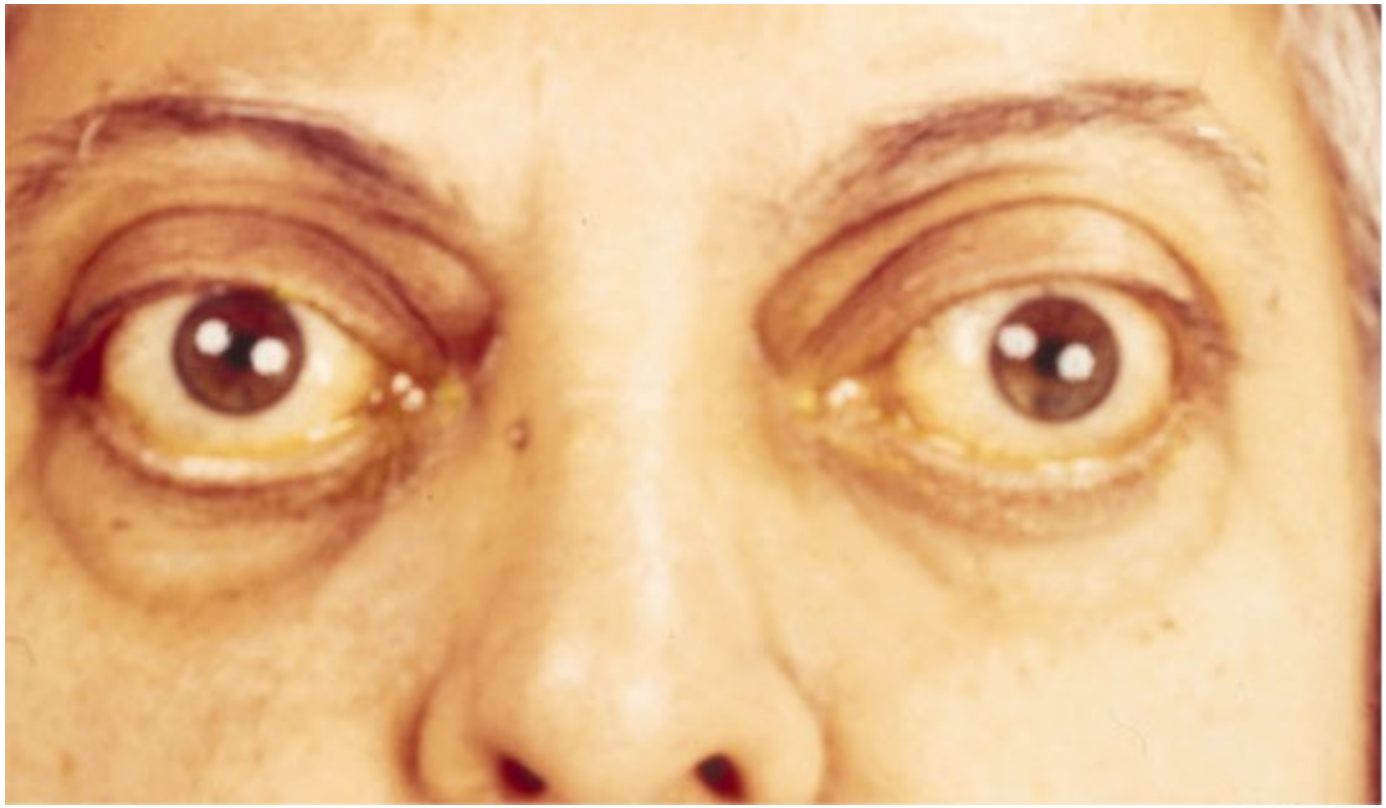


**Figure 45.10**

- The thyroid gland also produces calcitonin
  - Which functions in calcium homeostasis

# Parathyroid Hormone and Calcitonin: Control of Blood Calcium

- Two antagonistic hormones, parathyroid hormone (PTH) and calcitonin
  - Play the major role in calcium ($Ca^{2+}$) homeostasis in mammals

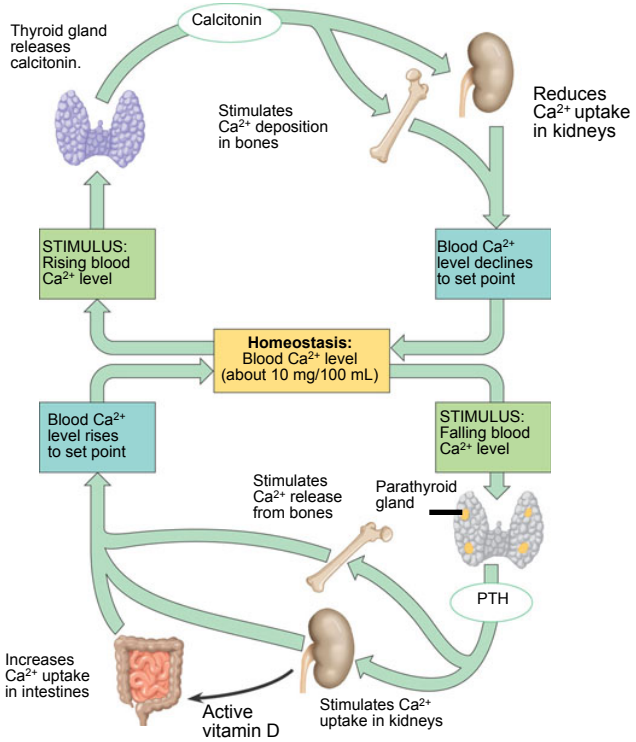
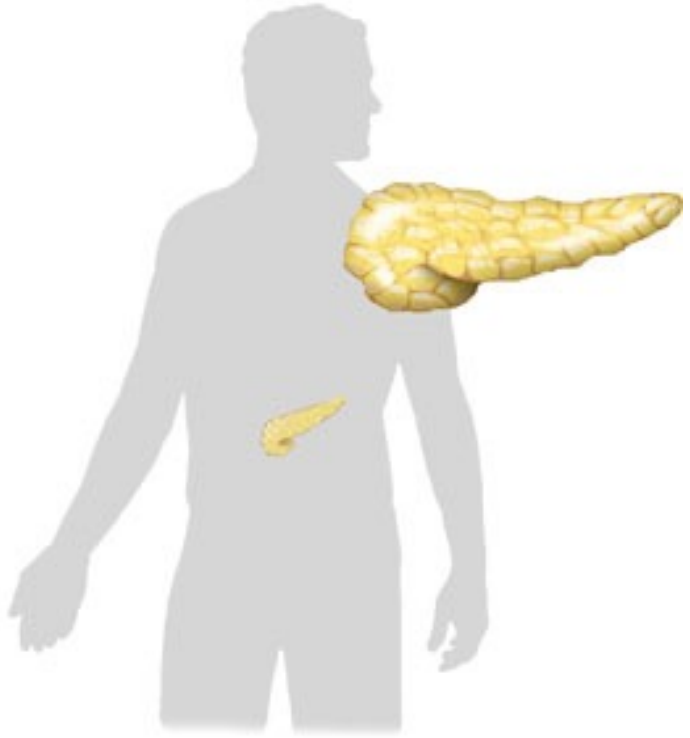



**Figure 45.11**

- Calcitonin, secreted by the thyroid gland
  - Stimulates $Ca^{2+}$ deposition in the bones and secretion by the kidneys, thus lowering blood $Ca^{2+}$ levels
- PTH, secreted by the parathyroid glands
  - Has the opposite effects on the bones and kidneys, and therefore raises $Ca^{2+}$ levels
  - Also has an indirect effect, stimulating the kidneys to activate vitamin D, which promotes intestinal uptake of $Ca^{2+}$ from food

# Insulin and Glucagon: Control of Blood Glucose

- Two types of cells in the pancreas
  - Secrete insulin and glucagon, antagonistic hormones that help maintain glucose homeostasis and are found in clusters in the islets of Langerhans



- Glucagon
  - Is produced by alpha cells
- Insulin
  - Is produced by beta cells

- Maintenance of glucose homeostasis

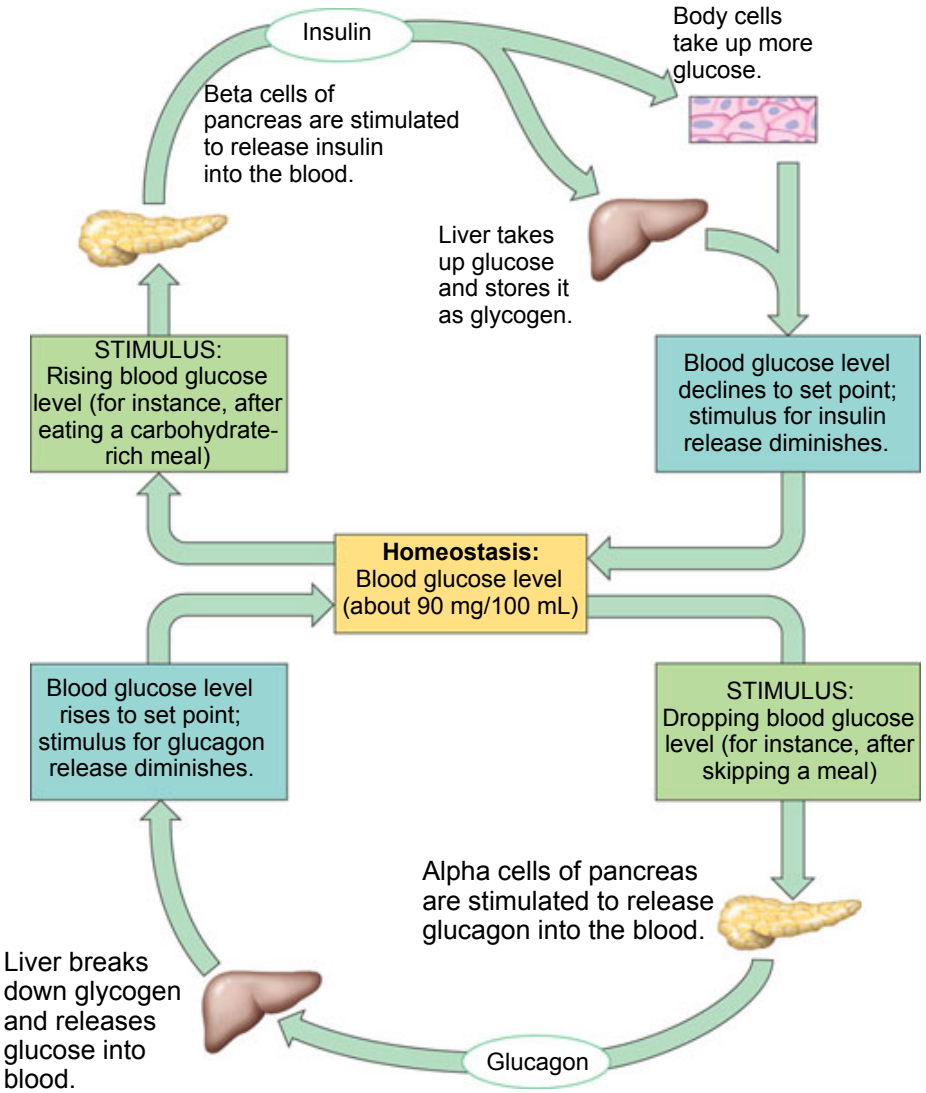



**Figure 45.12**

# *Target Tissues for Insulin and Glucagon*

- Insulin reduces blood glucose levels by
  - Promoting the cellular uptake of glucose
  - Slowing glycogen breakdown in the liver
  - Promoting fat storage

- Glucagon increases blood glucose levels by
  - Stimulating the conversion of glycogen to glucose in the liver
  - Stimulating the breakdown of fat and protein into glucose

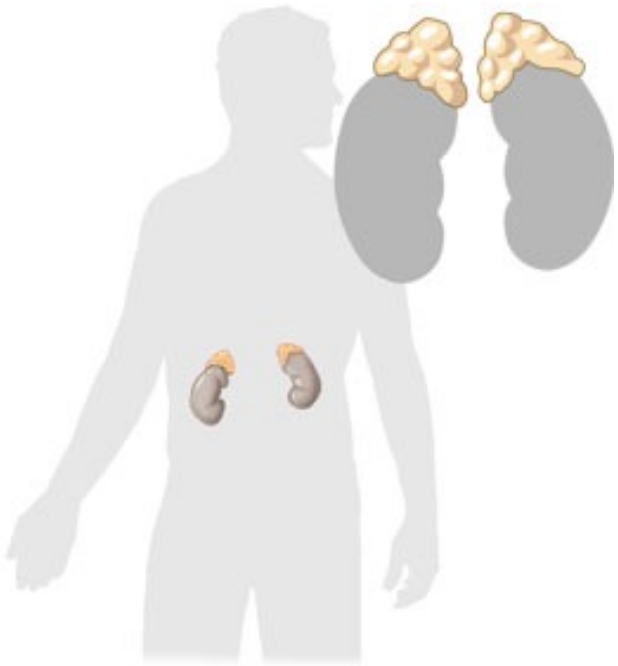
# *Diabetes Mellitus*

- Diabetes mellitus, perhaps the best-known endocrine disorder
  - Is caused by a deficiency of insulin or a decreased response to insulin in target tissues
  - Is marked by elevated blood glucose levels

- Type I diabetes mellitus (insulin-dependent diabetes)
  - Is an autoimmune disorder in which the immune system destroys the beta cells of the pancreas
- Type II diabetes mellitus (non-insulin-dependent diabetes)
  - Is characterized either by a deficiency of insulin or, more commonly, by reduced responsiveness of target cells due to some change in insulin receptors

# Adrenal Hormones: Response to Stress

- The adrenal glands
  - Are adjacent to the kidneys
  - Are actually made up of two glands: the adrenal medulla and the adrenal cortex



# *Catecholamines from the Adrenal Medulla*

- The adrenal medulla secretes epinephrine and norepinephrine
  - Hormones which are members of a class of compounds called catecholamines

- These hormones
  - Are secreted in response to stress-activated impulses from the nervous system
  - Mediate various fight-or-flight responses

# *Stress Hormones from the Adrenal Cortex*

- Hormones from the adrenal cortex
  - Also function in the body's response to stress
  - Fall into three classes of steroid hormones

- Glucocorticoids, such as cortisol
  - Influence glucose metabolism and the immune system
- Mineralocorticoids, such as aldosterone
  - Affect salt and water balance
- Sex hormones
  - Are produced in small amounts

- Stress and the adrenal gland

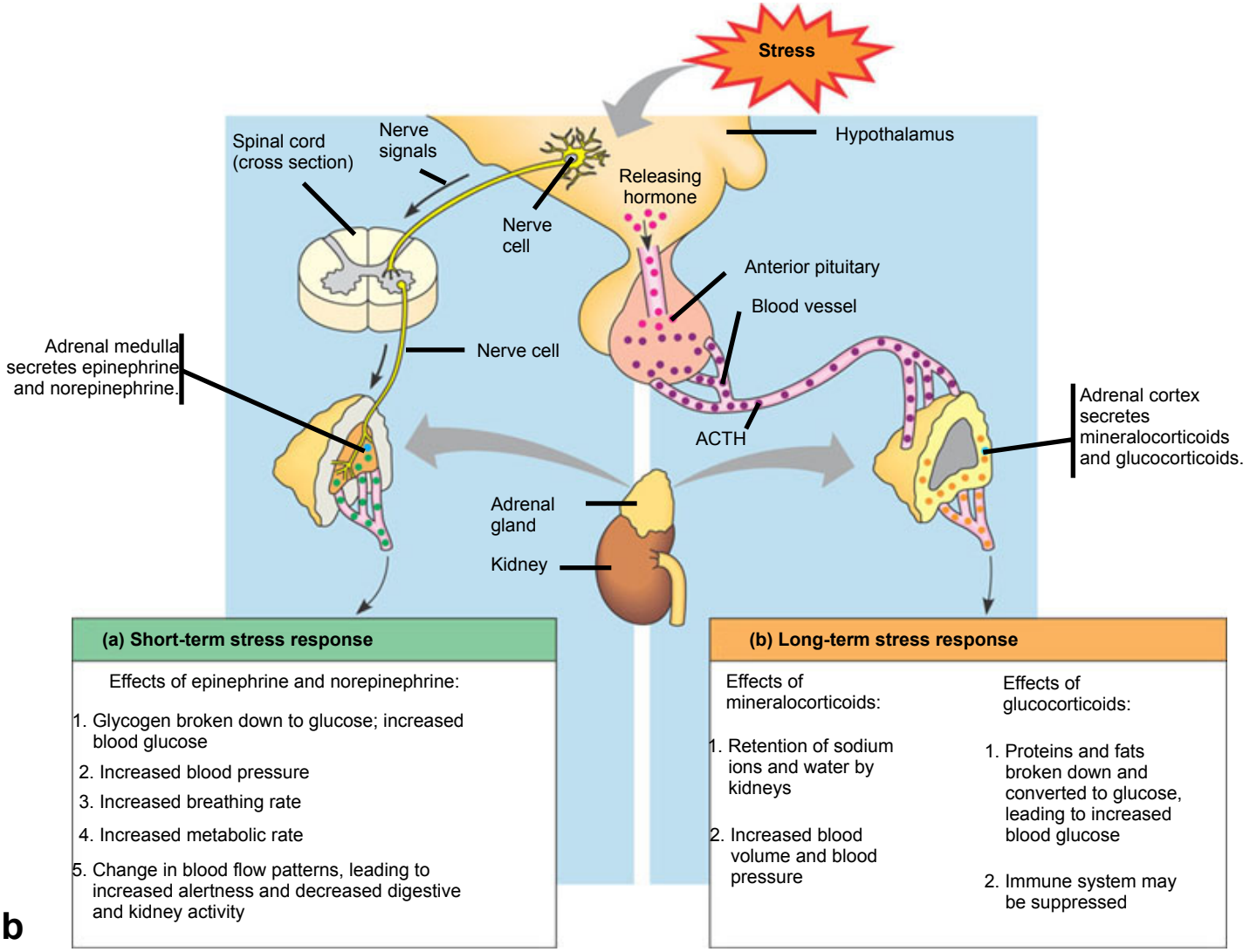
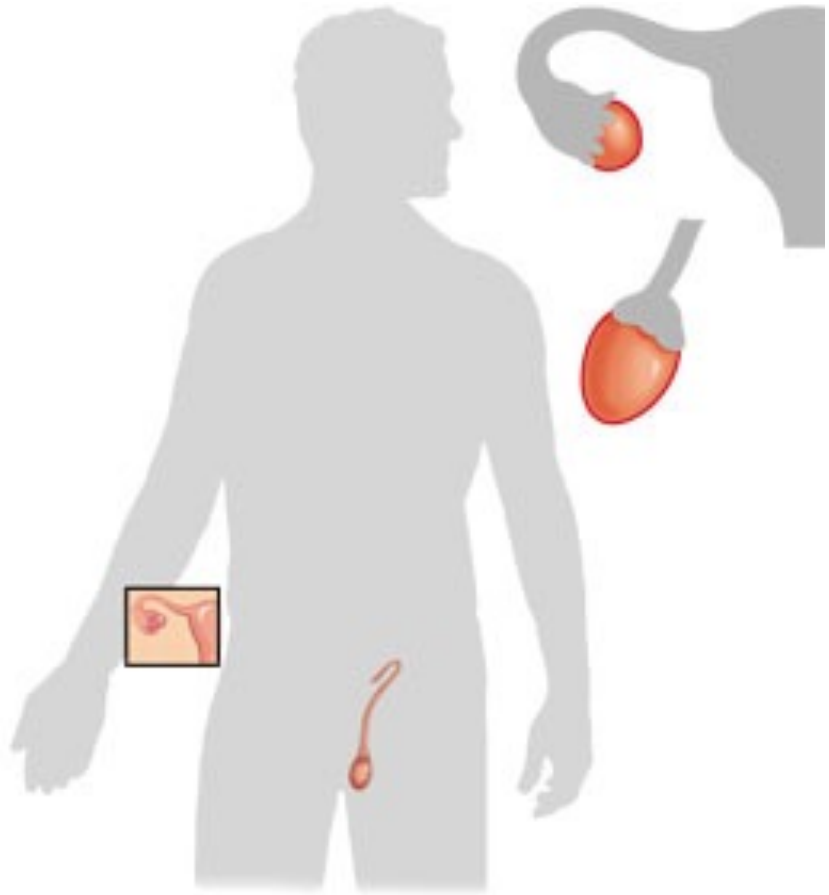



**Figure 45.13a,b**

# Gonadal Sex Hormones

- The gonads—testes and ovaries
  - Produce most of the body's sex hormones: androgens, estrogens, and progestins



- The testes primarily synthesize androgens, the main one being testosterone
  - Which stimulate the 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 many health risks

**Figure 45.14**

- Estrogens, the most important of which is estradiol
  - Are responsible for the 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

# Melatonin and Biorhythms

- The pineal gland, located within the brain
  - Secretes melatonin

- Release of melatonin
  - Is controlled by light/dark cycles
- The primary functions of melatonin
  - Appear to be related to biological rhythms associated with reproduction

- In insects
  - Molting and development are controlled by three main hormones

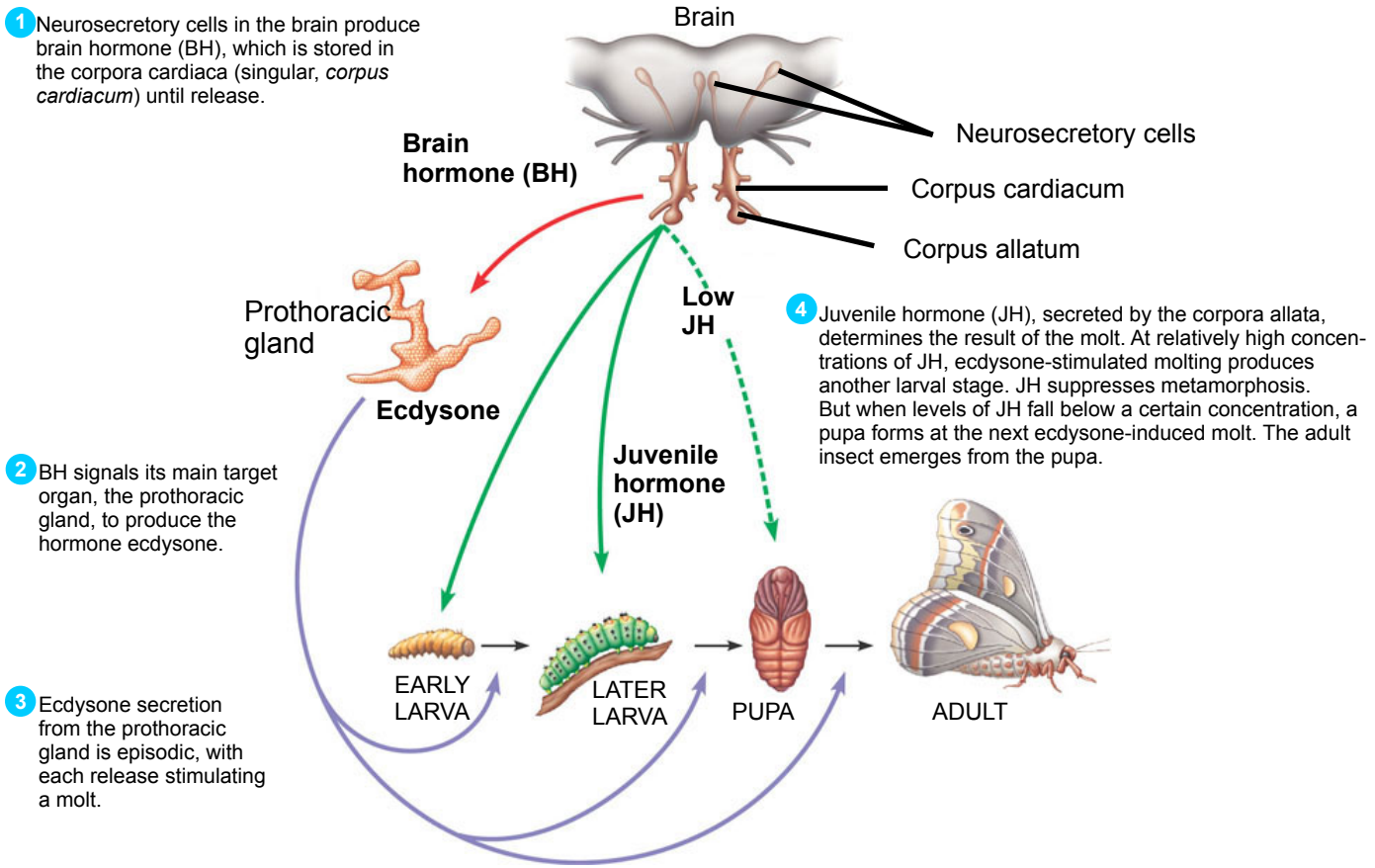



**Figure 45.15**

- Brain hormone
  - Is produced by neurosecretory cells
  - Stimulates the release of ecdysone from the prothoracic glands

- Ecdysone
  - Promotes molting and the development of adult characteristics
- Juvenile hormone
  - Promotes the retention of larval characteristics