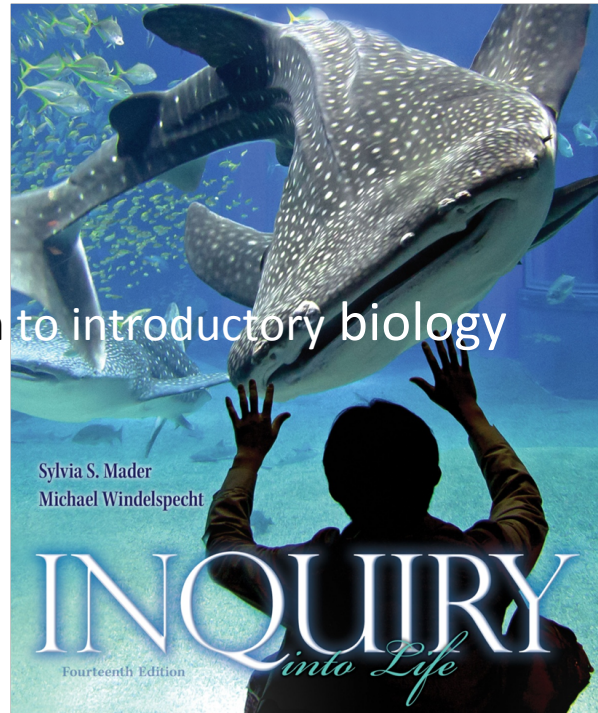


Fundamental Biology

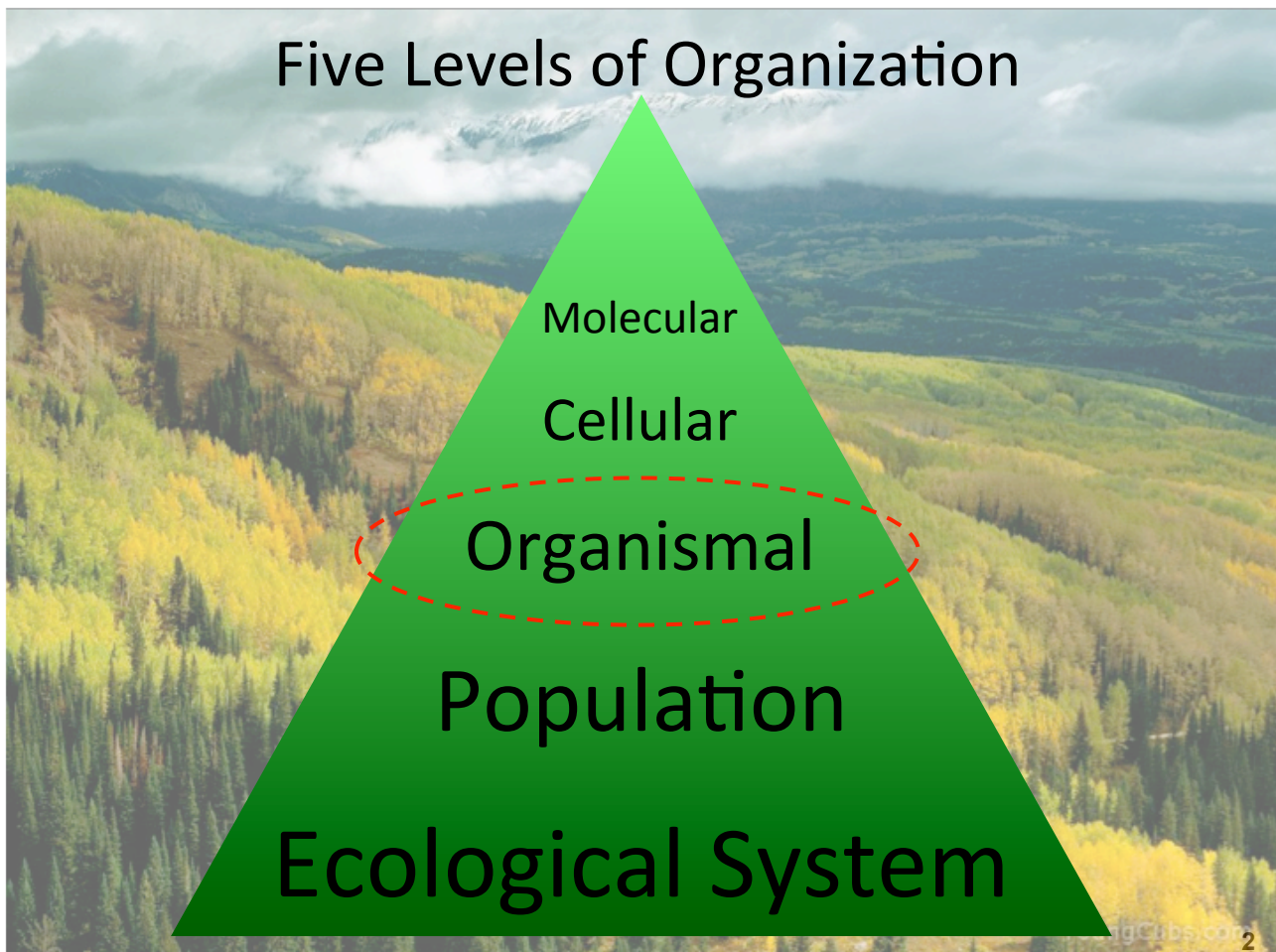
BI 1101

an interdisciplinary approach to introductory biology

Anggraini Barlian,
Iriawati
Tjandra Anggraeni
SITH-ITB



1



Learning outcomes

After this lecture, you should be able to:

1. Explain how testosterone affects lions.
2. Compare the mechanisms and functions of the endocrine and nervous systems.
3. Distinguish between the two major classes of vertebrate hormones.
4. Describe the different types and functions of vertebrate endocrine organs.
5. Describe the interrelationships between the hypothalamus and pituitary glands.
6. Describe the functions of the thyroid and parathyroid glands.

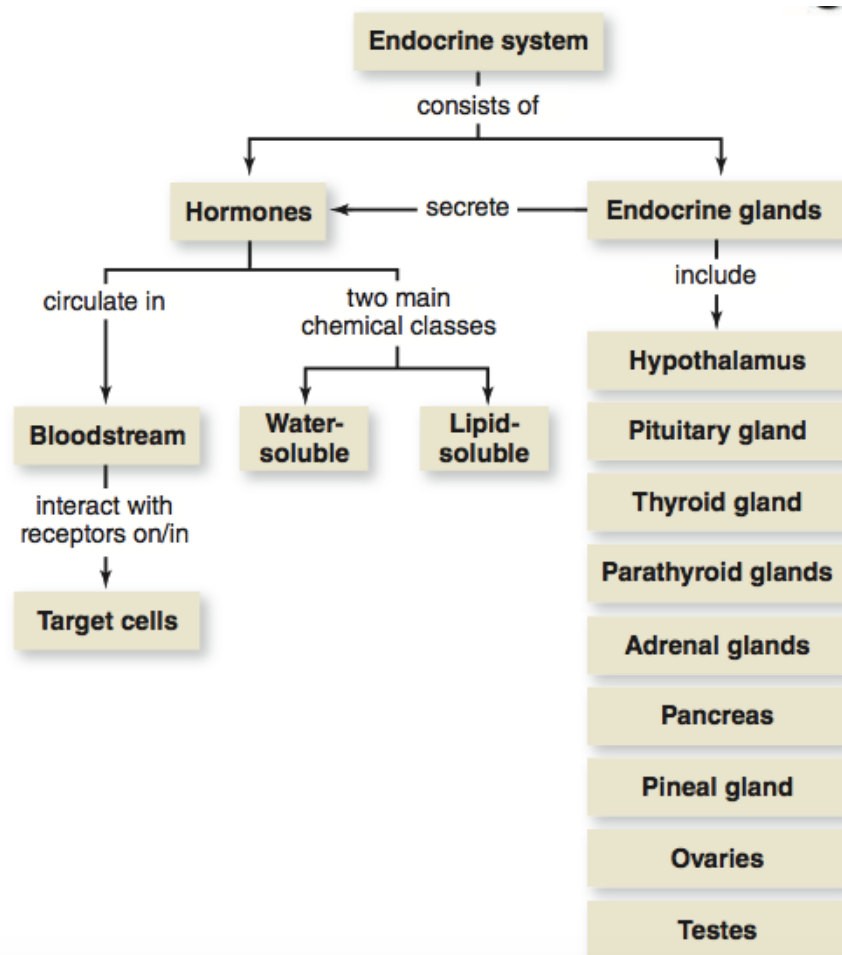
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You should now be able to

7. Explain how insulin and glucagon manage blood glucose levels.
8. Describe the causes and symptoms of type 1 and type 2 diabetes and gestational diabetes.
9. Compare the functions of the adrenal gland hormones.
10. Describe the three major types of sex hormones and their functions.
11. Describe the diverse functions of prolactin in vertebrate groups and its evolutionary significance.

HORMONE AND ENDOCRINE SYSTEM

5



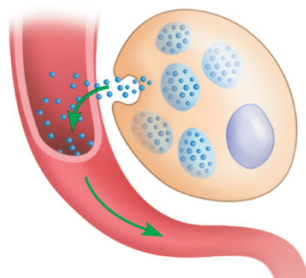
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Introduction

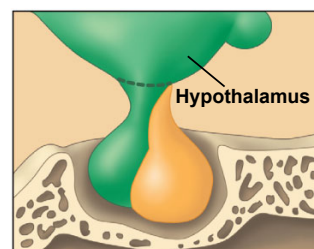
- In lions, the hormone testosterone promotes the development and maintenance of male traits including
 - growth and maintenance of the mane and
 - increased height and weight.



Chapter 26: Big Ideas



**The Nature of
Chemical Regulation**



**The Vertebrate
Endocrine System**



**Hormones and
Homeostasis**

THE NATURE OF CHEMICAL REGULATION

Chemical signals coordinate body functions

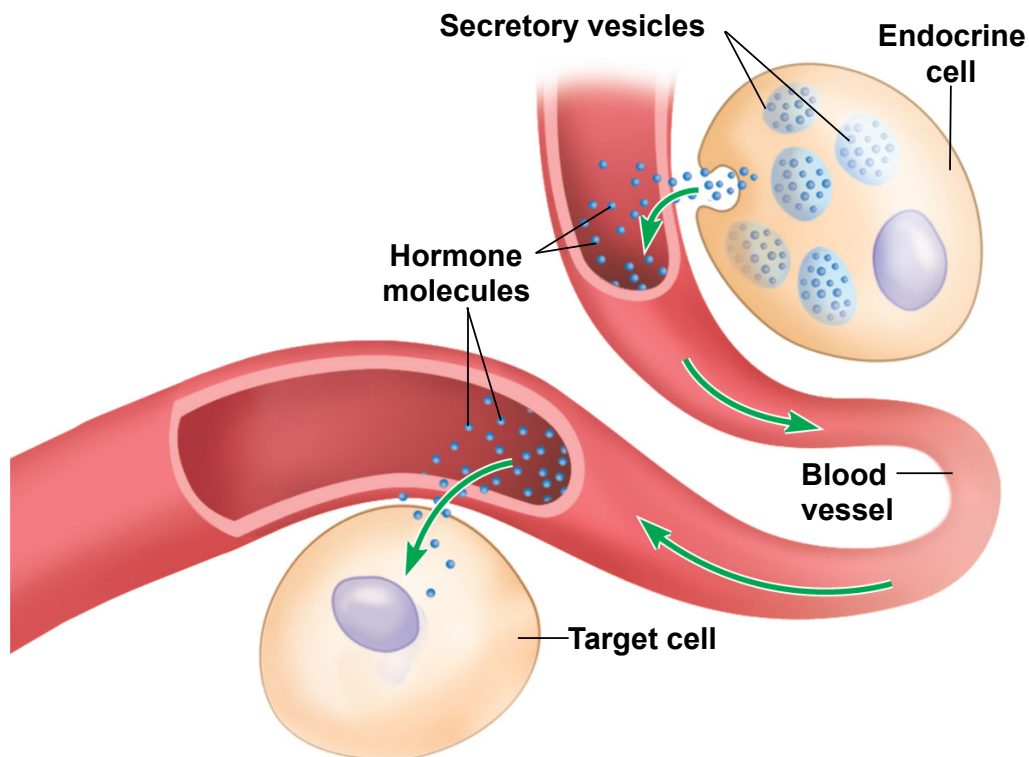
- The **endocrine system**
 - consists of all hormone-secreting cells and
 - works with the nervous system in regulating body activities.
- The nervous system also
 - communicates,
 - regulates, and
 - uses electrical signals via nerve cells.

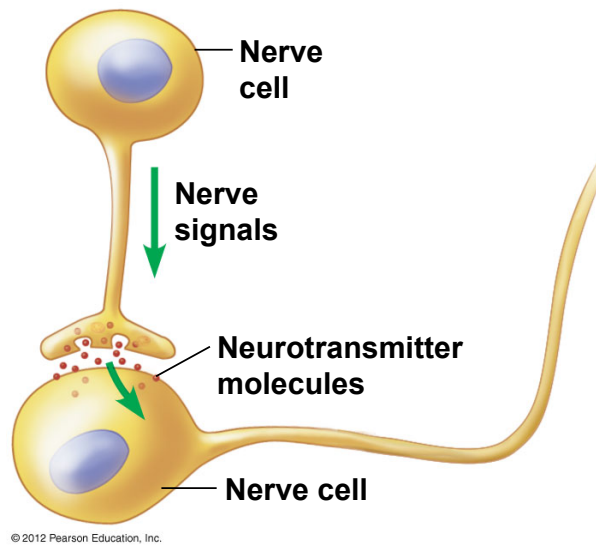
Comparing the endocrine and nervous systems

- The nervous system reacts faster.
- The responses of the endocrine system last longer.

Chemical signals coordinate body functions

- **Hormones** are
 - chemical signals,
 - produced by endocrine glands,
 - usually carried in the blood, and
 - responsible for specific changes in **target cells**.
- Hormones may also be released from specialized nerve cells called **neurosecretory cells**.





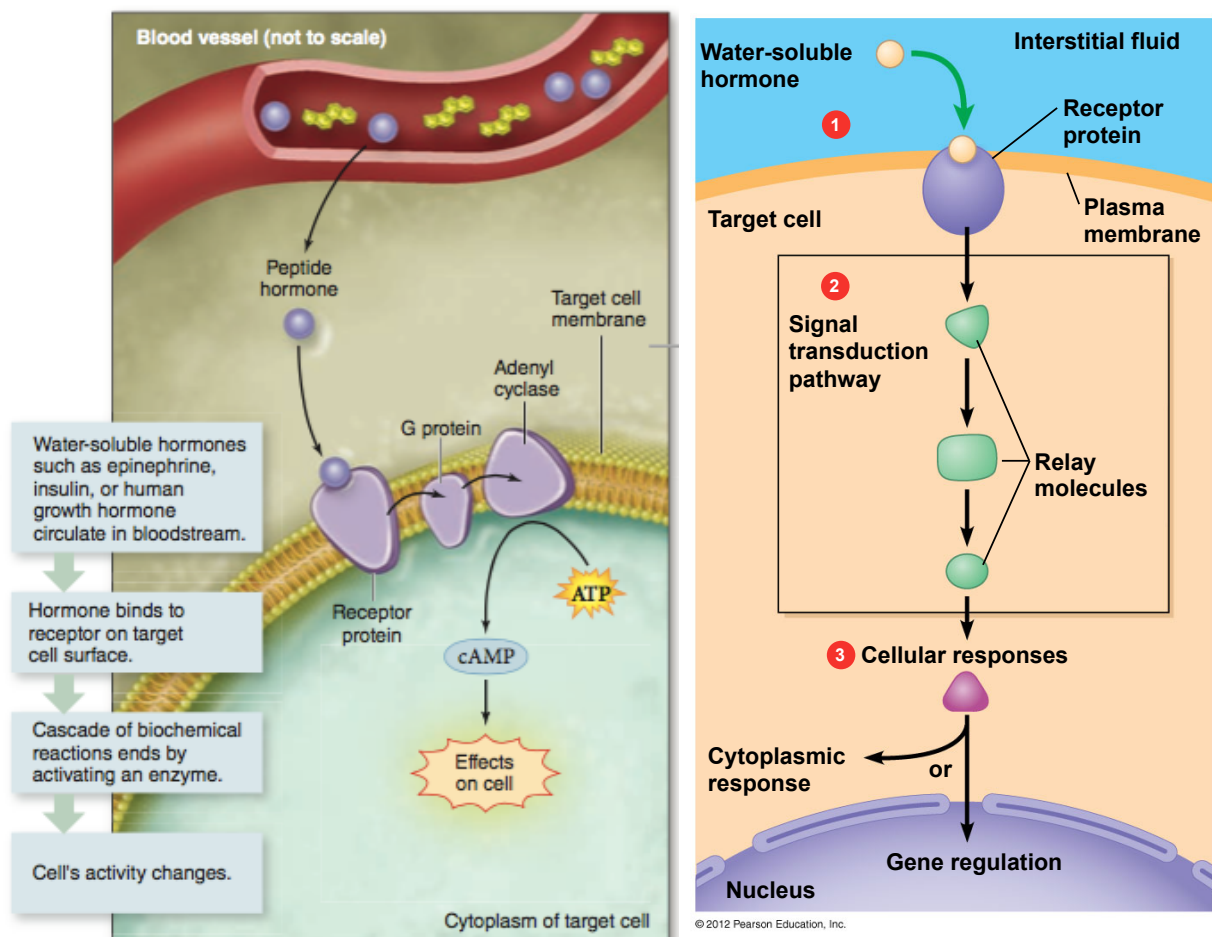
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Hormones affect target cells using two main signaling mechanisms

- Two major classes of molecules function as hormones in vertebrates.
 - The first class includes hydrophilic (water-soluble), **amino-acid-derived hormones**. Among these are
 - proteins,
 - peptides, and
 - amines.
 - The second class of hormones are **steroid hormones**, which include small, hydrophobic molecules made from cholesterol.

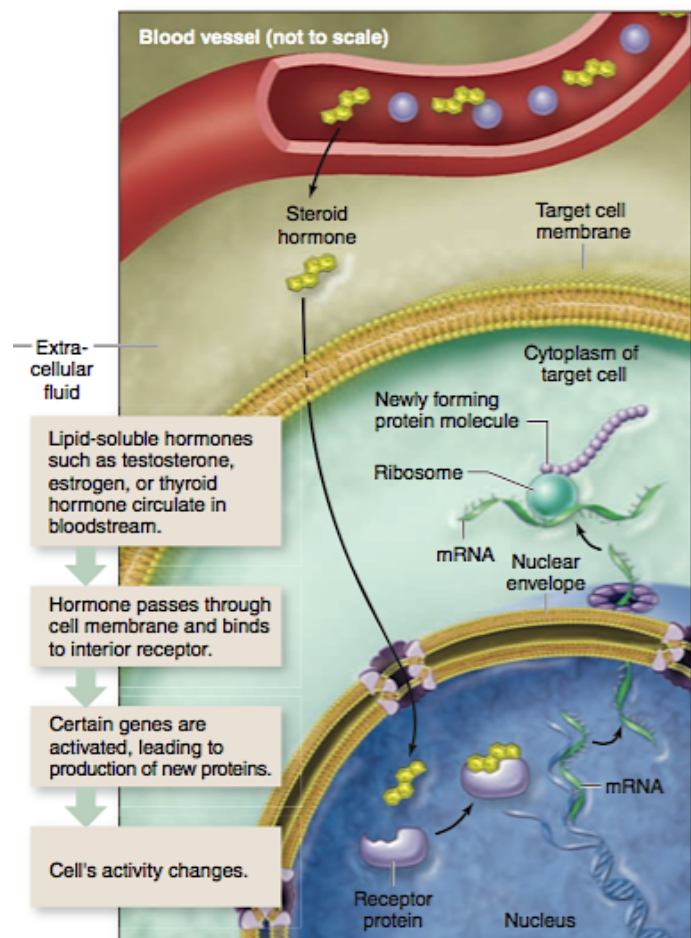
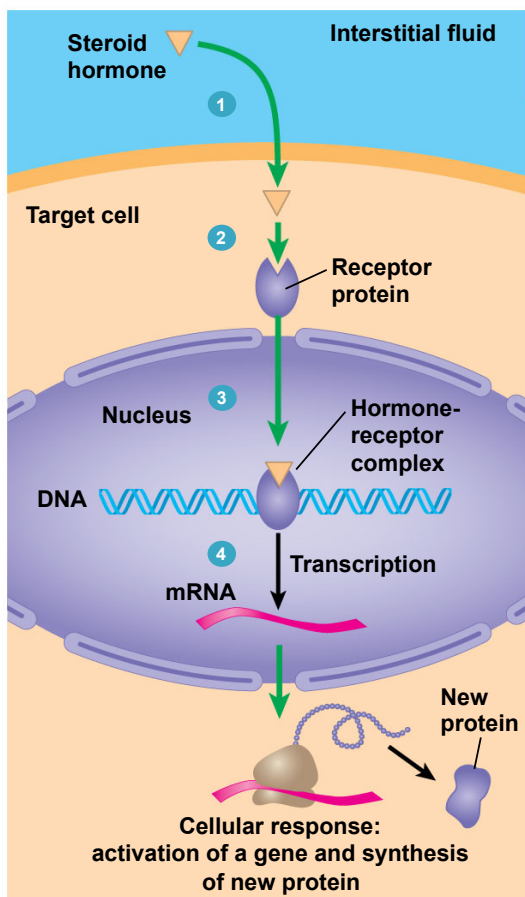
Hormones affect target cells using two main signaling mechanisms

- Hormone signaling involves three key events:
 - reception,
 - signal transduction, and
 - response.
- An **amino-acid-derived hormone**
 - binds to plasma-membrane receptors on target cells and
 - initiates a signal transduction pathway.



Hormones affect target cells using two main signaling mechanisms

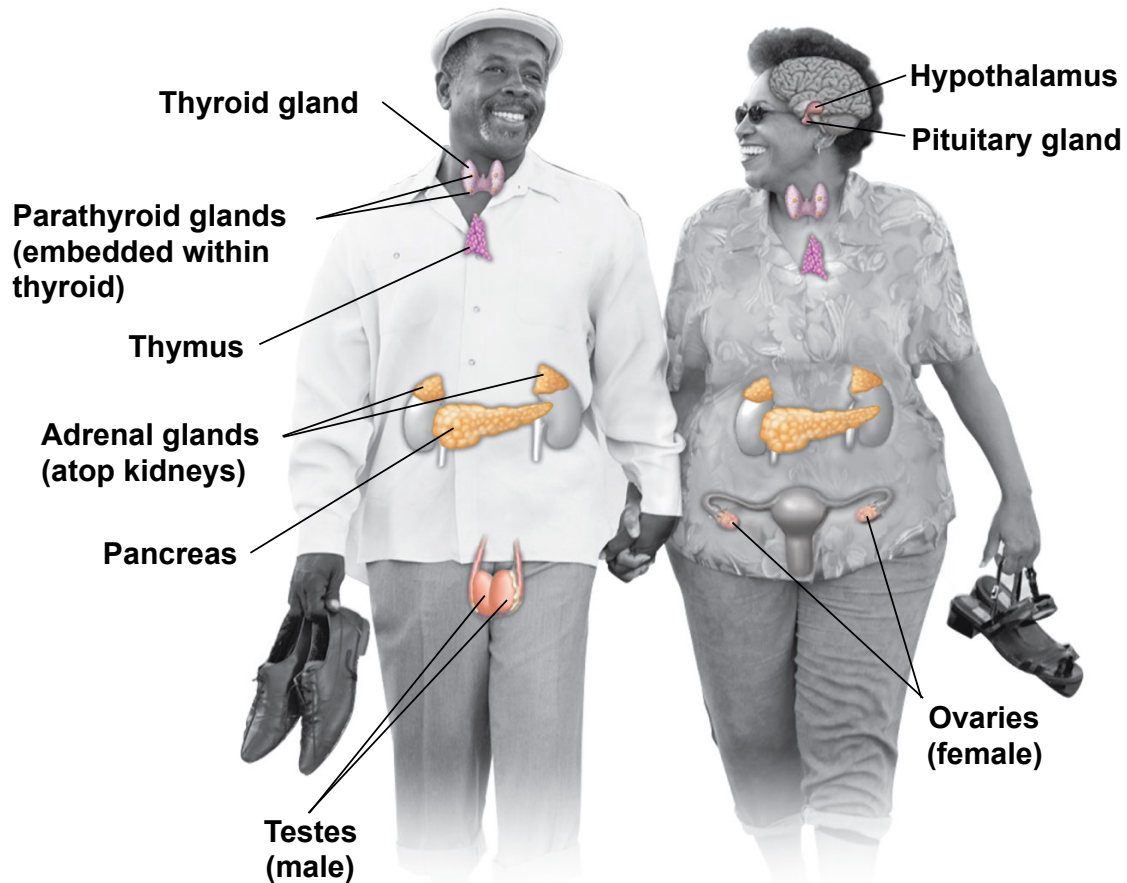
- A **steroid hormone** can
 - diffuse through plasma membranes,
 - bind to a receptor protein in the cytoplasm or nucleus, and
 - form a hormone-receptor complex that carries out the transduction of the hormonal signal.



THE VERTEBRATE ENDOCRINE SYSTEM

The vertebrate endocrine system consists of more than a dozen major glands

- Some endocrine glands (such as the thyroid) primarily secrete hormones into the blood.
- Other glands (such as the pancreas) have
 - endocrine and
 - Non-endocrine functions.
- Other organs (such as the stomach) are primarily non-endocrine but have some cells that secrete hormones.
















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The vertebrate endocrine system consists of more than a dozen major glands






- The following table summarizes the main hormones produced by the major endocrine glands and indicates how they
 - function and
 - are controlled.

TABLE 26.3 MAJOR HUMAN ENDOCRINE GLANDS AND SOME OF THEIR HORMONES

Gland (module)	Hormone	Chemical Class	Representative Actions	Regulated by
Hypothalamus (26.4)	 Hormones released by the posterior pituitary and hormones that regulate the anterior pituitary (see below)			
Pituitary gland (26.4) Posterior lobe (releases hormones made by hypothalamus)	 Oxytocin	Peptide	Stimulates contraction of uterus during labor and ejection of milk from mammary glands	Nervous system
	 Antidiuretic hormone (ADH)	Peptide	Promotes retention of water by kidneys	Water/salt balance
Anterior lobe	 Growth hormone (GH)	Protein	Stimulates growth (especially bones) and metabolic functions	Hypothalamic hormones
	Prolactin (PRL)	Protein	Stimulates milk production and secretion in females	Hypothalamic hormones
	Follicle-stimulating hormone (FSH)	Protein	Stimulates production of ova and sperm	Hypothalamic hormones
	Luteinizing hormone (LH)	Protein	Stimulates ovaries and testes	Hypothalamic hormones
	Thyroid-stimulating hormone (TSH)	Protein	Stimulates thyroid gland	Thyroxine in blood; hypothalamic hormones
	Adrenocorticotropic hormone (ACTH)	Peptide	Stimulates adrenal cortex to secrete glucocorticoids	Glucocorticoids; hypothalamic hormones
Pineal gland (26.3)	 Melatonin	Amine	Involved in rhythmic activities (daily and seasonal)	Light/dark cycles
Thyroid gland (26.5-6)	 Thyroxine (T ₄) and triiodothyronine (T ₃)	Amine	Stimulate and maintain metabolic processes	TSH
	Calcitonin	Peptide	Lowers blood calcium level	Calcium in blood
Parathyroid glands (26.5-6)	 Parathyroid hormone (PTH)	Peptide	Raises blood calcium level	Calcium in blood
Thymus (26.3)	 Thymosin	Peptide	Stimulates T cell development	Not known
Adrenal gland (26.9)	 Adrenal medulla	Epinephrine and norepinephrine	Increase blood glucose; increase metabolic activities; constrict certain blood vessels	Nervous system
	 Adrenal cortex	Glucocorticoids Mineralocorticoids	Increase blood glucose Promote reabsorption of Na ⁺ and excretion of K ⁺ in kidneys	ACTH K ⁺ in blood
Pancreas (26.7-8)	 Insulin	Protein	Lowers blood glucose	Glucose in blood
	Glucagon	Protein	Raises blood glucose	Glucose in blood
Testes (26.10)	 Androgens	Steroid	Support sperm formation; promote development and maintenance of male secondary sex characteristics	FSH and LH
Ovaries (26.10)	 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









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TABLE 26.3 MAJOR HUMAN ENDOCRINE GLANDS AND SOME OF THEIR HORMONES

Gland (module)	Hormone	Chemical Class	Representative Actions	Regulated by
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	Follicle-stimulating hormone (FSH)	Protein	Stimulates production of ova and sperm	Hypothalamic hormones
	Luteinizing hormone (LH)	Protein	Stimulates ovaries and testes	Hypothalamic hormones
	Thyroid-stimulating hormone (TSH)	Protein	Stimulates thyroid gland	Thyroxine in blood; hypothalamic hormones
	Adrenocorticotropic hormone (ACTH)	Peptide	Stimulates adrenal cortex to secrete glucocorticoids	Glucocorticoids; hypothalamic hormones
Pineal gland (26.3)	 Melatonin	Amine	Involved in rhythmic activities (daily and seasonal)	Light/dark cycles

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TABLE 26.3 | MAJOR HUMAN ENDOCRINE GLANDS AND SOME OF THEIR HORMONES

Gland (module)		Hormone	Chemical Class	Representative Actions	Regulated by
Thyroid gland (26.5–6)		Thyroxine (T ₄) and triiodothyronine (T ₃)	Amine	Stimulate and maintain metabolic processes	TSH
		Calcitonin	Peptide	Lowers blood calcium level	Calcium in blood
Parathyroid glands (26.5–6)		Parathyroid hormone (PTH)	Peptide	Raises blood calcium level	Calcium in blood
Thymus (26.3)		Thymosin	Peptide	Stimulates T cell development	Not known
Adrenal gland (26.9)					
Adrenal medulla		Epinephrine and norepinephrine	Amine	Increase blood glucose; increase metabolic activities; constrict certain blood vessels	Nervous system
Adrenal cortex		Glucocorticoids	Steroid	Increase blood glucose	ACTH
		Mineralocorticoids	Steroid	Promote reabsorption of Na ⁺ and excretion of K ⁺ in kidneys	K ⁺ in blood
Pancreas (26.7–8)		Insulin	Protein	Lowers blood glucose	Glucose in blood
		Glucagon	Protein	Raises blood glucose	Glucose in blood
Testes (26.10)		Androgens	Steroid	Support sperm formation; promote development and maintenance of male secondary sex characteristics	FSH and LH
Ovaries (26.10)		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

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The vertebrate endocrine system consists of more than a dozen major glands

- Two endocrine glands are not discussed further.
 - The **pineal gland**
 - is pea-sized, located near the center of the brain, and
 - secretes melatonin, a hormone that links environmental light conditions with biological rhythms.
 - The **thymus gland**
 - lies above the heart, under the breastbone, and
 - secretes a peptide that stimulates the development of T-cells.

The hypothalamus, which is closely tied to the pituitary, connects the nervous and endocrine systems

- **The hypothalamus**

- blurs the distinction between endocrine and nervous systems,
- receives input from nerves about the internal conditions of the body and the external environment,
- responds by sending out appropriate nervous or endocrine signals, and
- uses the pituitary gland to apply master control over the endocrine system.

Hormones of the Hypothalamus and Pituitary

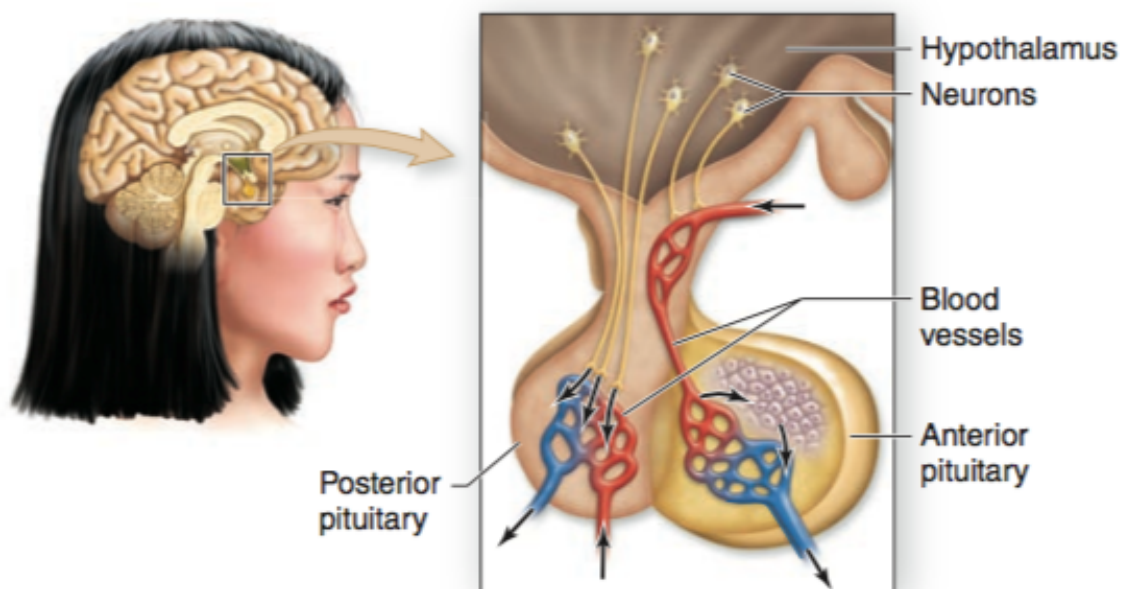
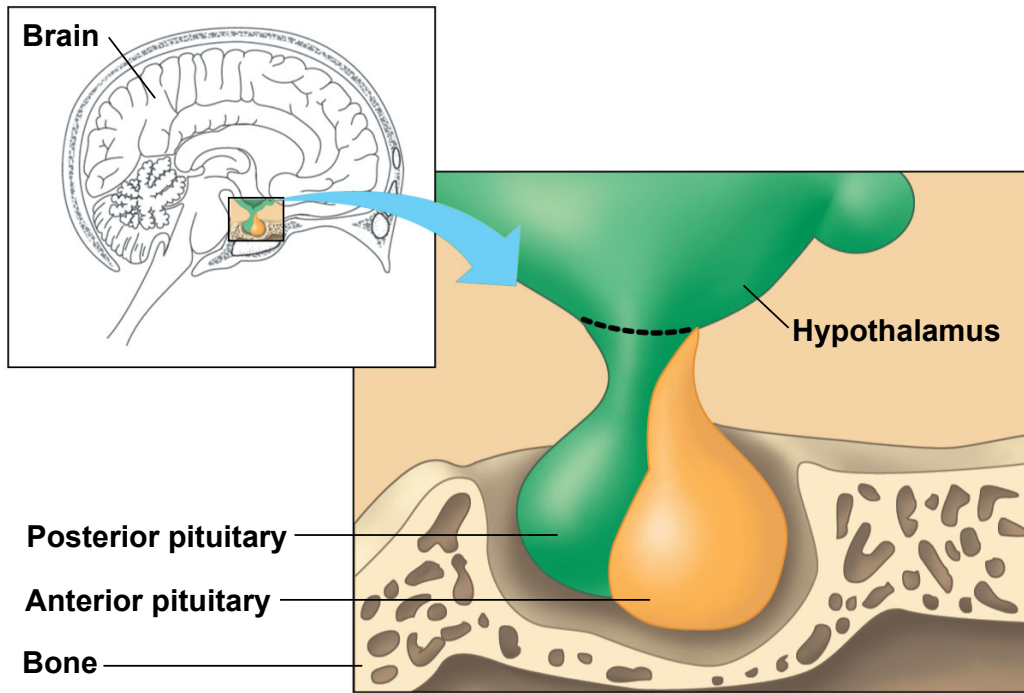


Figure 26.4A



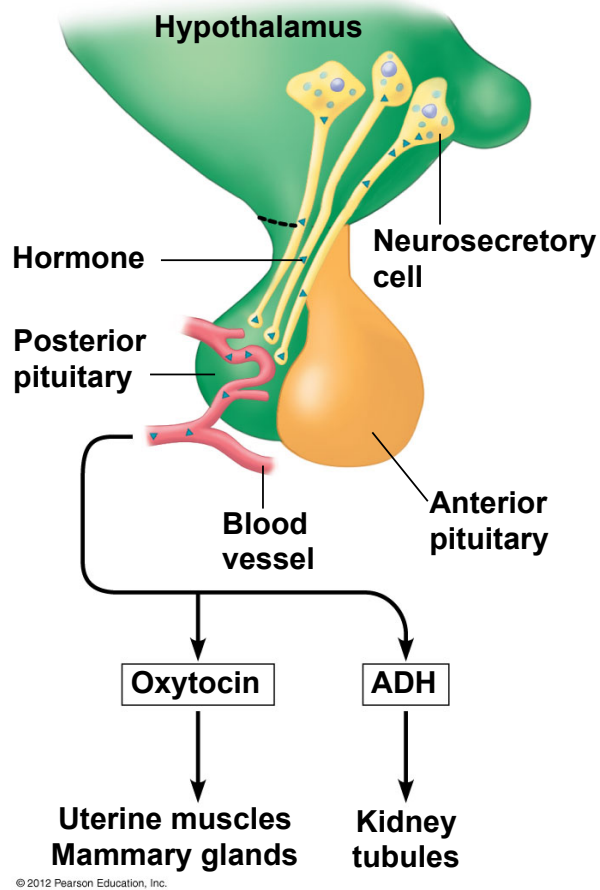
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The hypothalamus, which is closely tied to the pituitary, connects the nervous and endocrine systems

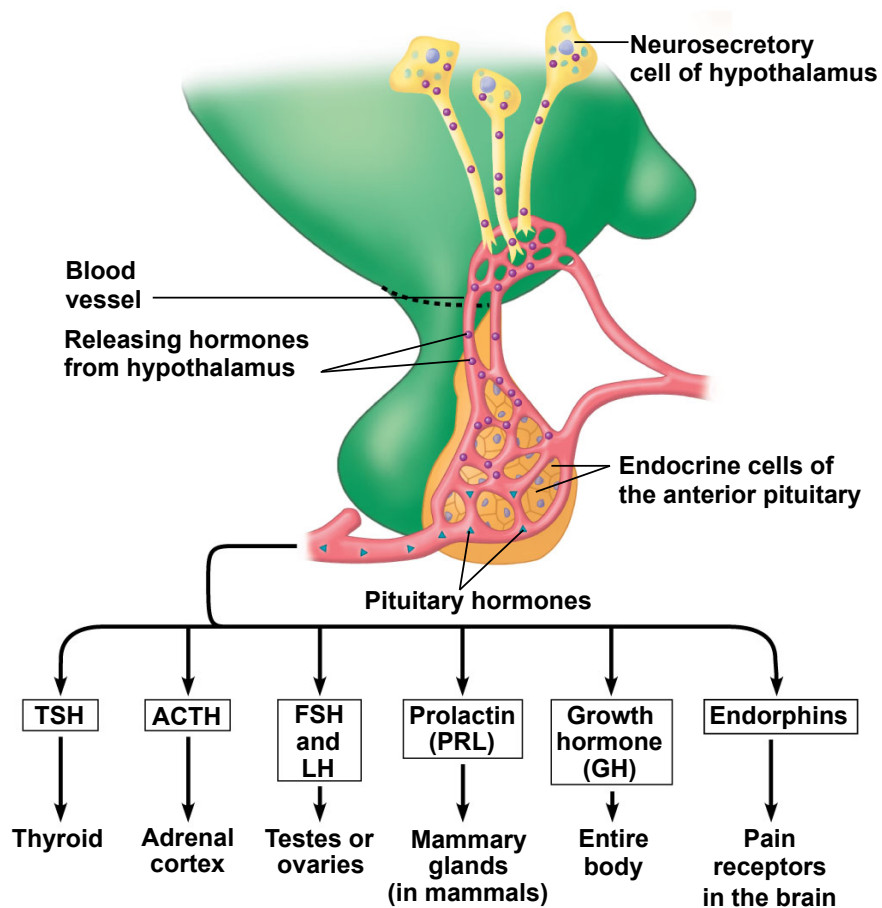
- The **pituitary gland** consists of two parts.
 - The **posterior pituitary**
 - is composed of nervous tissue,
 - is an extension of the hypothalamus, and
 - stores and secretes oxytocin and ADH, which are made in the hypothalamus.

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Figure 26.4B



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The hypothalamus, which is closely tied to the pituitary, connects the nervous and endocrine systems

▪ The **anterior pituitary**

- synthesizes and secretes hormones that control the activity of other glands and
- is controlled by two types of hormones released from the hypothalamus:
 - **releasing hormones** stimulate the anterior pituitary, and
 - **inhibiting hormones** inhibit the anterior pituitary.

The hypothalamus, which is closely tied to the pituitary, connects the nervous and endocrine systems

- Pituitary secretions include
 - **growth hormone (GH)** that promotes protein synthesis and the use of body fat for energy metabolism,
 - **endorphins** that function as natural painkillers, and
 - **TRH (TSH-releasing hormone)** that stimulates the thyroid (another endocrine gland) to release thyroxine.

Source	Hypothalamus																												
																													
	<table><tr><th>Hormone</th><th colspan="3">Releasing hormones</th><th colspan="3">Inhibiting hormones</th></tr><tr><th>Type</th><td colspan="3">Peptide</td><td colspan="3">Peptide</td></tr><tr><th>Action</th><td colspan="3">Stimulate release of hormones from anterior pituitary</td><td colspan="3">Inhibit release of hormones from anterior pituitary</td></tr></table>									Hormone	Releasing hormones			Inhibiting hormones			Type	Peptide			Peptide			Action	Stimulate release of hormones from anterior pituitary			Inhibit release of hormones from anterior pituitary	
Hormone	Releasing hormones			Inhibiting hormones																									
Type	Peptide			Peptide																									
Action	Stimulate release of hormones from anterior pituitary			Inhibit release of hormones from anterior pituitary																									
Source	Posterior pituitary		Anterior pituitary																										
Hormone	Antidiuretic hormone (ADH), a.k.a. vasopressin	Oxytocin	Growth hormone (GH)	Prolactin	Thyroid stimulating hormone (TSH)	Adreno-corticotrophic hormone (ACTH)	Follicle-stimulating hormone (FSH) and luteinizing hormone (LH)	Endorphins																					
Type	Peptide	Peptide	Protein	Protein	Glycoprotein	Peptide	Glycoprotein	Peptide																					
Target cells	 Kidney	 Mammary glands and uterus	 Most cells in the body	 Mammary glands	 Thyroid	 Adrenal cortex	 Testes Ovaries	 Pain receptors in the brain																					
Major responses	Promotes conservation of water	Stimulates smooth muscle contraction	Stimulates tissue growth	Stimulates milk secretion	Stimulates secretion of thyroid hormones	Stimulates secretion of glucocorticoid hormones	Stimulate secretion of sex hormones; stimulate oocyte development and ovulation (in females) and sperm production (in males)	Relieve pain																					

HORMONES AND HOMEOSTASIS

The thyroid regulates development and metabolism

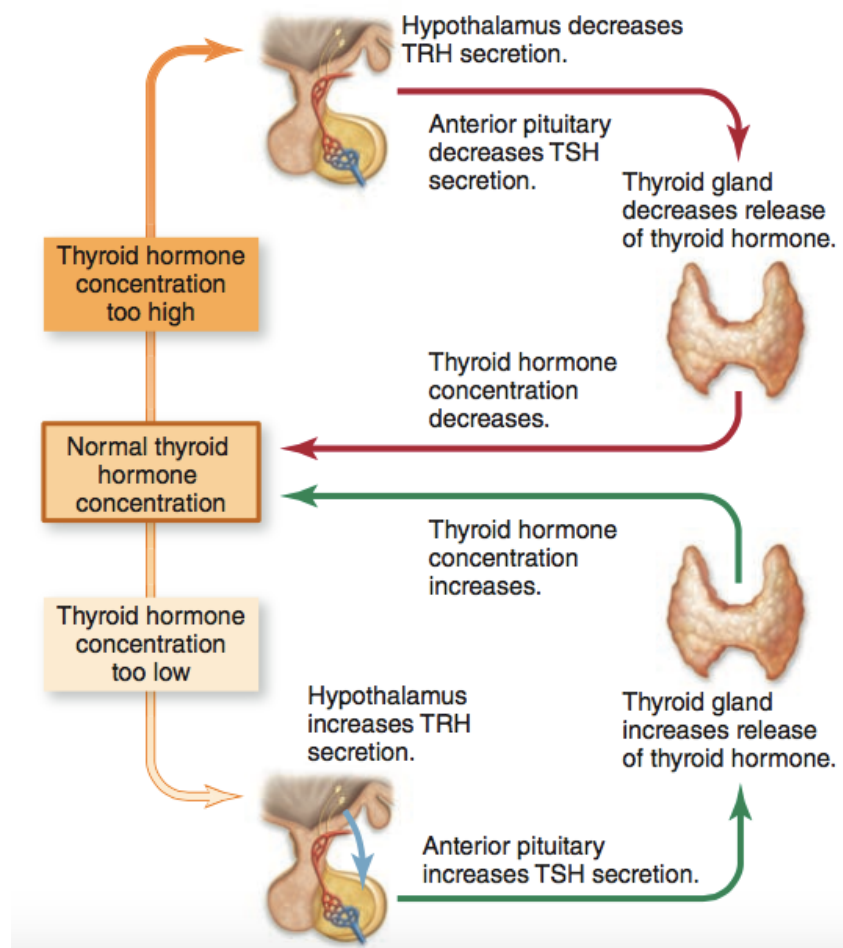
- The **thyroid gland** is located in the neck, just under the larynx (voice box).
- The thyroid gland produces two similar hormones,
 - **thyroxine** (T_4) and
 - **triiodothyronine** (T_3).
- These hormones regulate many aspects of
 - metabolism,
 - reproduction, and
 - development.



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Thyroid Hormone Regulation



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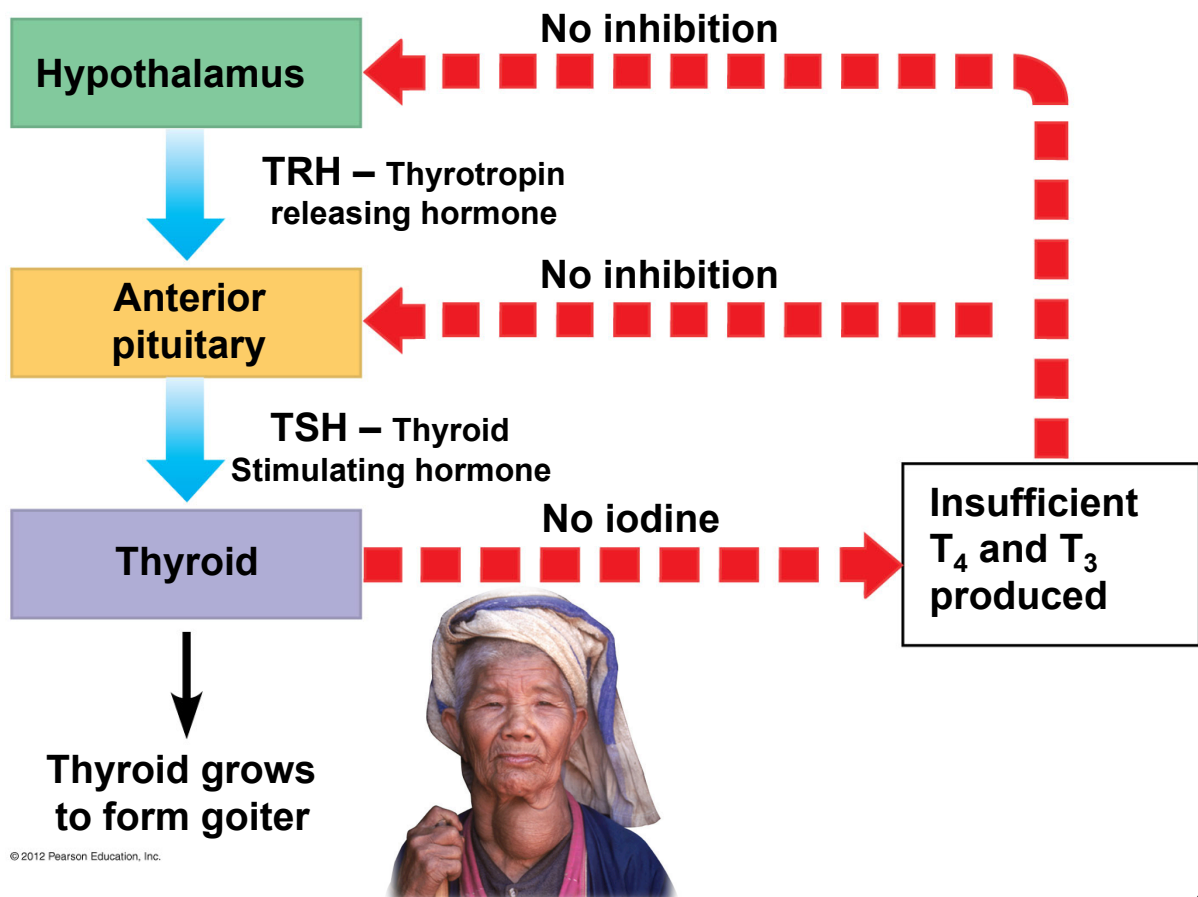
The thyroid regulates development and metabolism

- Thyroid imbalance can cause disease.
 - Hyperthyroidism
 - results from too much T_4 and T_3 in the blood,
 - leads to high blood pressure, loss of weight, overheating, and irritability, and
 - produces Graves' disease.
 - Hypothyroidism
 - results from too little T_4 and T_3 in the blood and
 - leads to low blood pressure, being overweight, and often feeling cold and lethargic.

The thyroid regulates development and metabolism

- Iodine deficiency can produce a **goiter**, an enlargement of the thyroid. In this condition,
 - the thyroid gland cannot synthesize adequate amounts of T_4 and T_3 , and
 - the thyroid gland enlarges.

Figure 26.5B

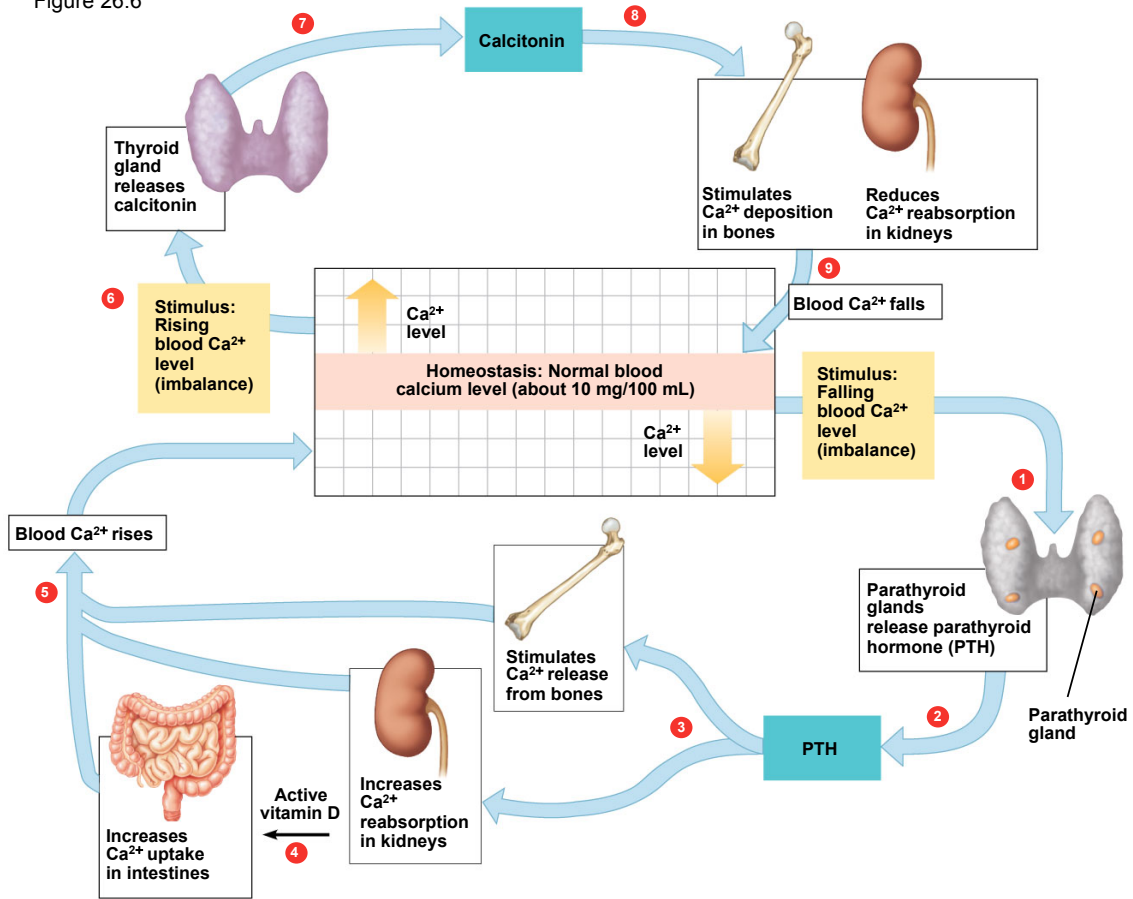


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Hormones from the thyroid and parathyroid glands maintain calcium homeostasis

- Blood calcium level is regulated by **antagonistic hormones** each working to oppose the actions of the other hormone:
 - **calcitonin**, from the thyroid, lowers the calcium level in the blood, and
 - **parathyroid hormone (PTH)**, from the **parathyroid glands**, raises the calcium level in the blood.

Figure 26.6

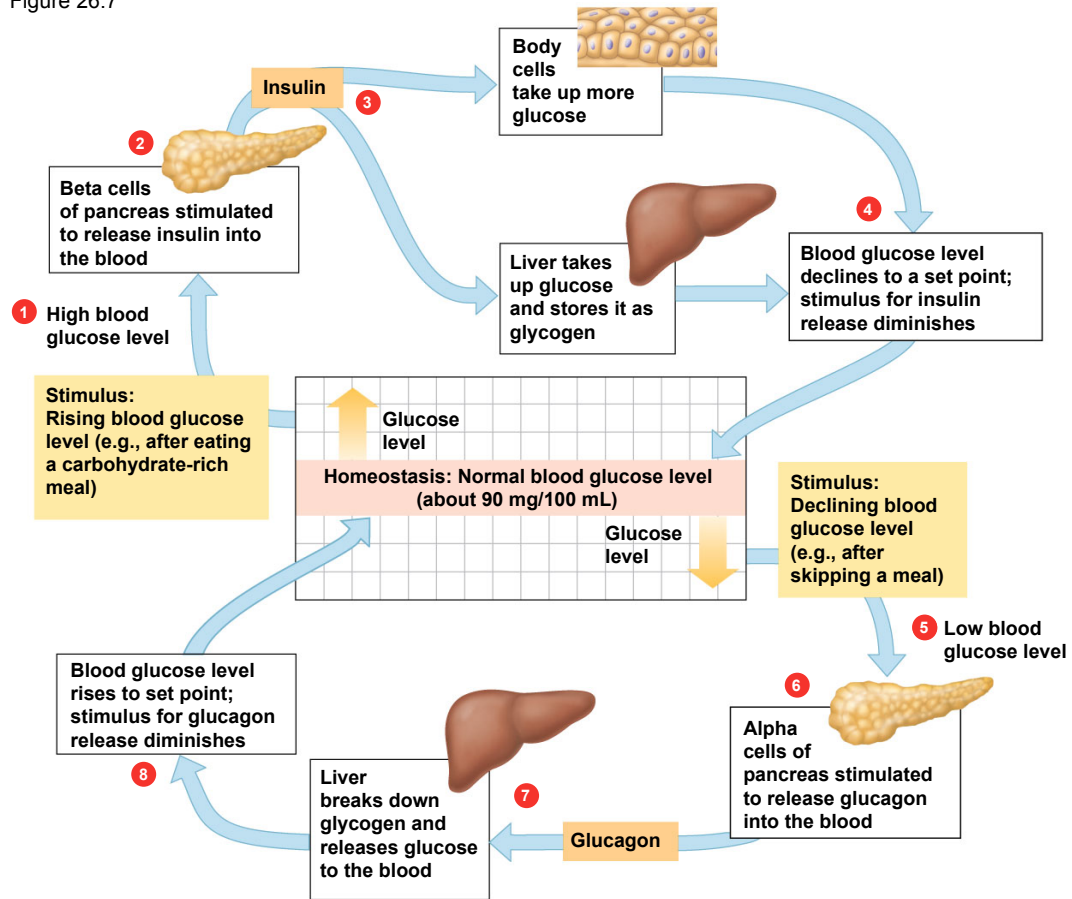


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Pancreatic hormones regulate blood glucose levels

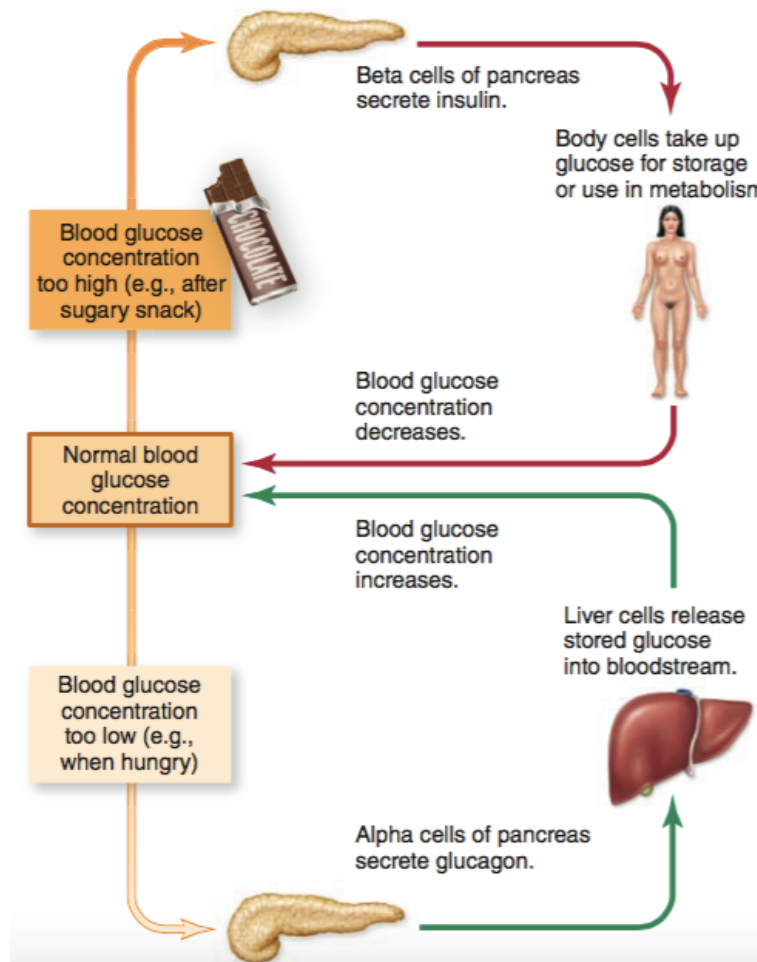
- The **pancreas** secretes two hormones that control blood glucose:
 - **insulin** signals cells to use and store glucose, and
 - **glucagon** causes cells to release stored glucose into the blood.

Figure 26.7



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Diabetes is a common endocrine disorder

- Diabetes mellitus
 - affects about 8% of the U.S. population and
 - results from a
 - lack of insulin or
 - failure of cells to respond to insulin.
- There are three types of diabetes mellitus.
 1. Type 1 (insulin-dependent) is
 - an autoimmune disease
 - caused by the destruction of insulin-producing cells.

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Diabetes is a common endocrine disorder

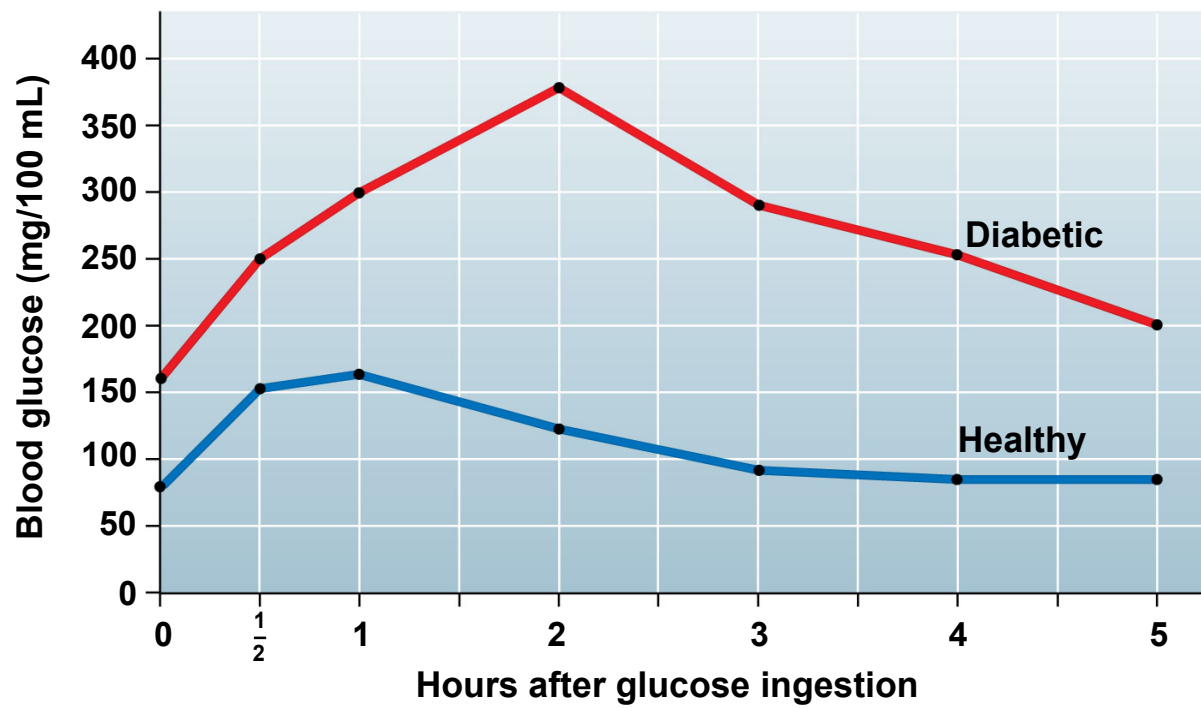
2. Type 2 (non-insulin-dependent) is
 - caused by a reduced response to insulin,
 - associated with being overweight and underactive, and
 - the cause of more than 90% of diabetes.
3. Gestational diabetes
 - can affect any pregnant woman and
 - lead to dangerously large babies, which can complicate delivery.

Figure 26.8A
























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Figure 26.8B



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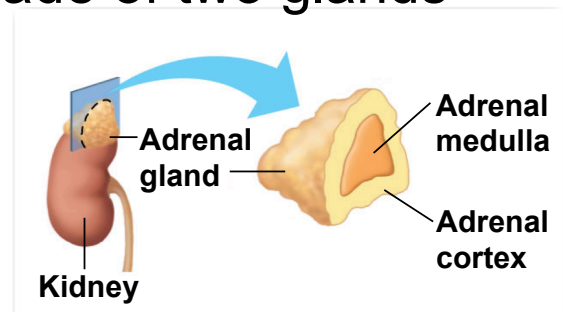
Hormones That Regulate Metabolism

Source	 Thyroid 		 Parathyroid 	 Adrenal medulla 	 Adrenal cortex 		 Pancreas 		 Pineal gland 
Hormone	Thyroid hormones (thyroxine, triiodothyronine)		Parathyroid hormone (PTH)	Epinephrine, norepinephrine	Mineralo-corticoids	Gluco-corticoids	Insulin	Glucagon	Melatonin
Type	Amine	Peptide	Peptide	Amine	Steroid	Steroid	Peptide	Protein	Amine
Target cells	 All tissues	 Bone	 Bone, digestive organs, kidneys	 Blood vessels	 Kidney	 All tissues	 All tissues	 Liver, adipose tissue	 Other endocrine glands
Major responses	Increase metabolic rate	Increases rate of calcium deposition	Releases calcium from bone, increases calcium absorption in digestive organs and kidneys	Raise blood pressure, constrict blood vessels, slow digestion	Maintain blood volume and electrolyte balance	Increase glucose levels in blood and brain	Increases uptake of glucose	Stimulates breakdown of glycogen into glucose and of fats into fatty acids	Regulates effects of light-dark cycles

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The adrenal glands mobilize responses to stress

- The endocrine system includes two **adrenal glands**, sitting on top of each kidney.
- Each adrenal gland is made of two glands fused together, the
 - **adrenal medulla** and
 - **adrenal cortex**.



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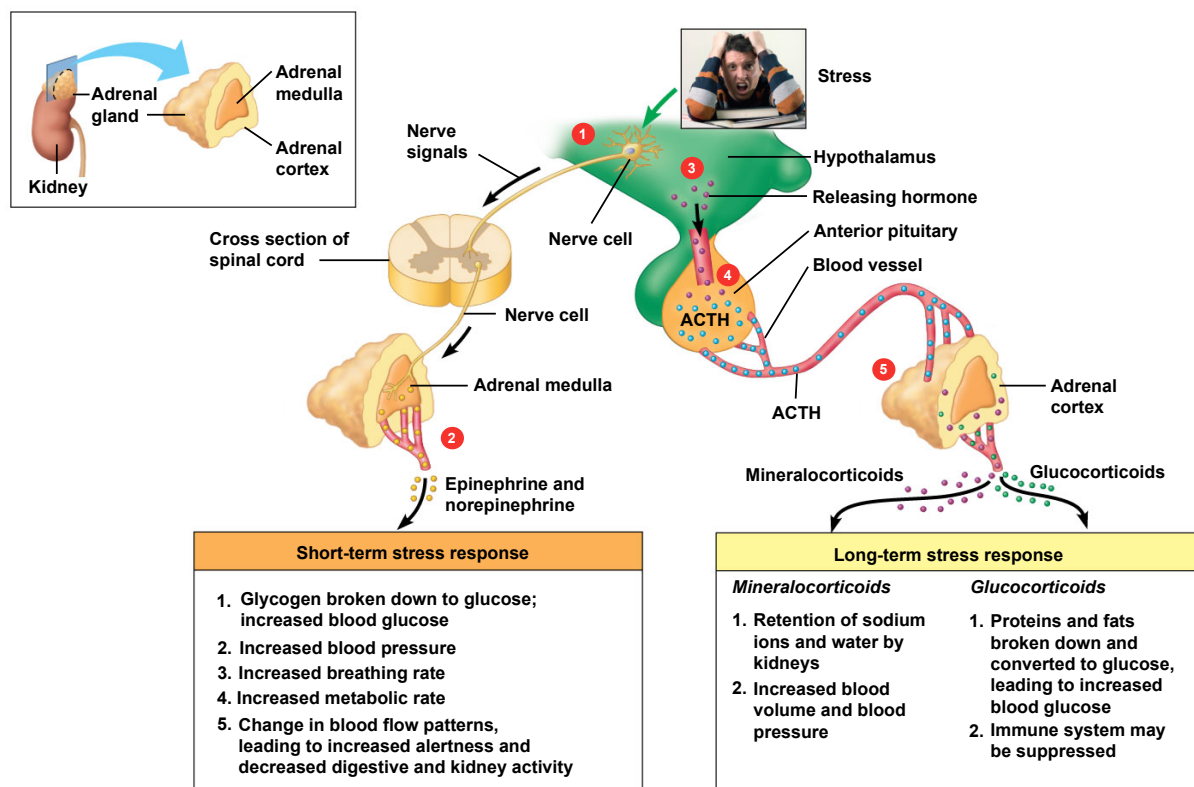
- Both glands secrete hormones that enable the body to respond to stress.

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The adrenal glands mobilize responses to stress

- Nerve signals from the hypothalamus stimulate the adrenal medulla to secrete
 - **epinephrine** (adrenaline) and
 - **norepinephrine** (noradrenaline).
- These hormones quickly trigger the “fight-or-flight” responses, which are short-term responses to stress.

Figure 26.9



The adrenal glands mobilize responses to stress

- **Adrenocorticotrophic hormone (ACTH)** from the pituitary causes the adrenal cortex to secrete
 - **glucocorticoids** and
 - **mineralocorticoids**.
- The effects of these hormones cause long-term responses to stress.


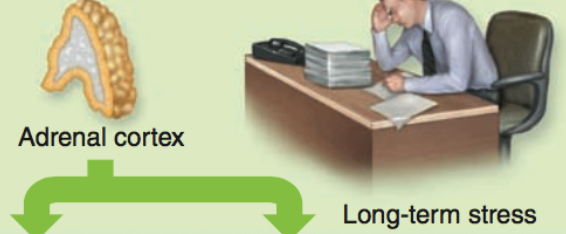
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Long-term stress response	
<i>Mineralocorticoids</i>	<i>Glucocorticoids</i>
1. Retention of sodium ions and water by kidneys	1. Proteins and fats broken down and converted to glucose, leading to increased blood glucose
2. Increased blood volume and blood pressure	2. Immune system may be suppressed

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Hormones of the Adrenal Glands

Source	 <p>Adrenal medulla</p> <p>Short-term stress</p>	 <p>Adrenal cortex</p> <p>Long-term stress</p>	
Hormone	Epinephrine, norepinephrine	Mineralocorticoids	Glucocorticoids
Major responses	<ul style="list-style-type: none"> • Increase heart rate and blood pressure • Dilate airways, so breathing rate increases • Increase metabolic rate • Slow digestion 	<ul style="list-style-type: none"> • Maintain blood volume 	<ul style="list-style-type: none"> • Increase glucose synthesis • Constrict blood vessels, raising blood pressure • Suppress immune system

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The gonads secrete sex hormones

- Steroid sex hormones
 - affect growth,
 - affect development, and
 - regulate reproductive cycles and sexual behavior.
- The synthesis of sex hormones by the gonads is regulated by the
 - hypothalamus and
 - pituitary.

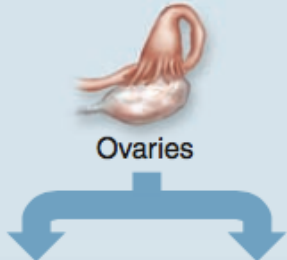
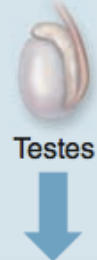
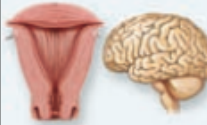




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The gonads secrete sex hormones

- Sex hormones include
 - **estrogens**, which maintain the female reproductive system and promote the development of female characteristics,
 - **progestins**, such as progesterone, which prepare and maintain the uterus to support a developing embryo, and
 - **androgens**, such as **testosterone**, which stimulate the development and maintenance of the male reproductive system.

Hormones of the Ovaries and Testes

Source	 Ovaries		 Testes
Hormone	Progesterone	Estrogen	Testosterone
Type	Steroid	Steroid	Steroid
Target cells	 Uterine lining, hypothalamus, pituitary, other tissues	 Uterine lining, hypothalamus, pituitary, other tissues	 Sperm-producing cells, hypothalamus, pituitary, other tissues
Major responses	Regulates menstrual cycle, prepares body for pregnancy	Regulates menstrual cycle, maintains secondary sex characteristics in females	Promotes sperm development, maintains secondary sex characteristics in males

EVOLUTION CONNECTION: A single hormone can perform a variety of functions in different animals

- The peptide hormone prolactin (PRL) in humans stimulates mammary glands to grow and produce milk during late pregnancy.
- Suckling by a newborn stimulates further release of PRL.
- High PRL during nursing inhibits ovulation.

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EVOLUTION CONNECTION: A single hormone can perform a variety of functions in different animals

- PRL has many roles unrelated to childbirth, suggesting that PRL is an ancient hormone diversified through evolution.
 - In some nonhuman mammals, PRL stimulates nest building.
 - In birds, PRL regulates fat metabolism and reproduction.
 - In amphibians, PRL stimulates movement to water.
 - In fish that migrate between salt and fresh water, PRL helps regulate salt and water balance.