

CAMPBELL BIOLOGY: CONCEPTS & CONNECTIONS,
NINTH EDITION, GLOBAL EDITION
PowerPoint Lectures

Chapter 26

Hormones and the Endocrine System



潘建源 Chien-Yuan Pan

神經細胞生理研究室

生命科學系

生科館 Rm730

Introduction

- Toxic chemicals that interfere with the endocrine system are aptly named *endocrine disruptors*.
- Endocrine disruptors include
 - atrazine, an ingredient in weed killers and a contaminant found in farm water runoff that makes its way to ground and surface reservoirs, and
 - bisphenol A (BPA), used in many plastics that line bottles, canned goods, and other manufactured drinking water and food containers.

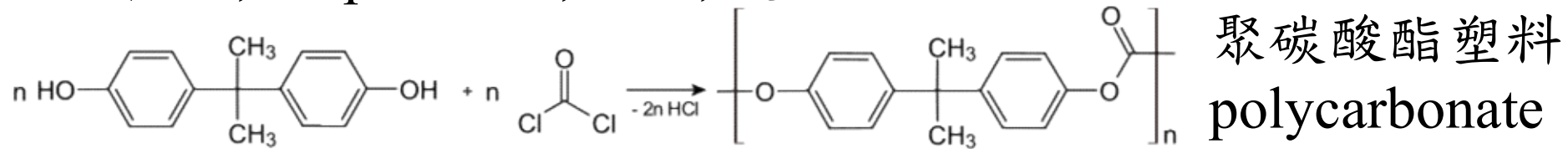
Endocrine disruption

Collection | 04 September 2017

<https://www.nature.com/collections/bgbvkwbrvk>

Endocrine-disrupting chemicals (EDCs)

酚甲烷, Bisphenol A, BPA, 雙酚A



聚碳酸酯塑料是一種透明且不易碎的材料，常被用於生產各種水瓶（包括嬰兒用的奶瓶）運動裝備、醫療器械、牙充填的材料、密封劑、眼鏡鏡片、CD與DVD和家用電器外殼。酚甲烷也被常用於合成聚砵和聚醚、在塑化劑中作抗氧化劑、在PVC的生產中作阻聚劑。其中環氧樹脂幾乎被用於所有食品與罐裝飲料包裝的內層塗料。然而基於對人體健康的考慮，在日本，環氧樹脂幾乎完全被PET替代。酚甲烷也是合成阻燃劑四溴酚甲烷的前體。以前它也曾被用於殺菌。生產無碳複寫紙和**感熱紙**時，酚甲烷可以作為顯色劑以實現複寫或對熱源產生反應，前者被廣泛應用在銷售時點情報系統的收銀小票上。另外，酚甲烷也是輸水管道的內層塗料。(Wiki 酚甲烷)

模擬人體的雌激素(estrogen)，而具有內分泌干擾之作用(即俗稱之環境荷爾蒙)，但以往多認為雙酚A模擬雌激素的作用甚弱(約僅萬分之一)。

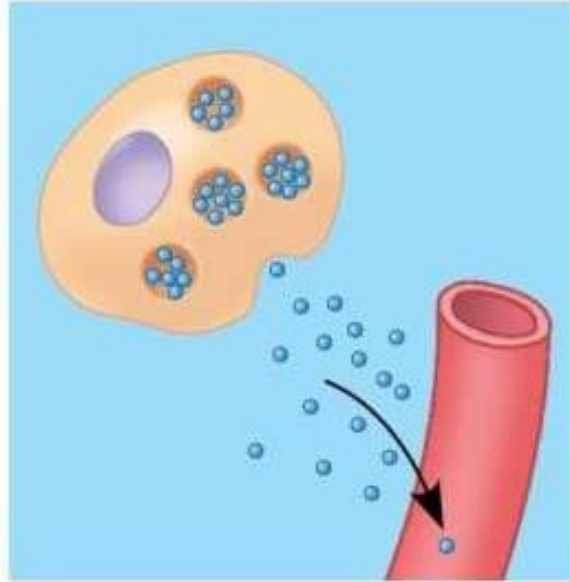
2010.9 加拿大禁止， then Euro。 **BPA-free**產品會比較好賣嗎？

臺灣 2010.1.1 列為第四類毒性化學物質(化學物質有污染環境或危害人體健康之虞者。)

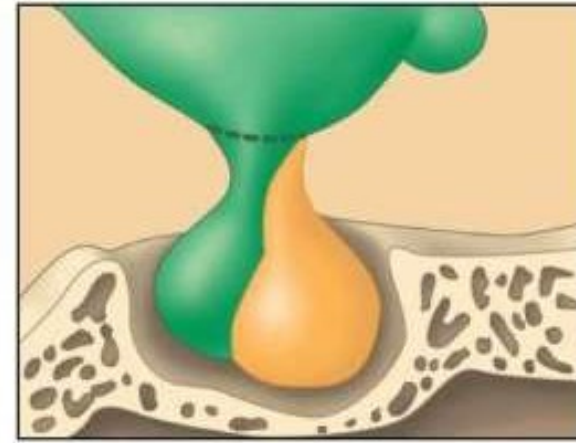
Is BPA as dangerous to human health as once thought?

<http://www.pottsmc.com/lifestyle/20140529/is-bpa-as-dangerous-to-human-health-as-once-thought>

A February 2014 study by FDA researchers found that low doses of the compound did not affect the health of rats over a **90-day** study period. While study rats exposed to **higher doses** of BPA had lower body weights, abnormal female reproductive development and altered hormone levels, there were **no such effects in rats exposed to lower doses** more akin to what humans experience.



**The Nature of
Chemical Regulation**
26.1-26.3



**The Vertebrate
Endocrine System**
26.4-26.5



**Hormones and
Homeostasis**
26.6-26.12

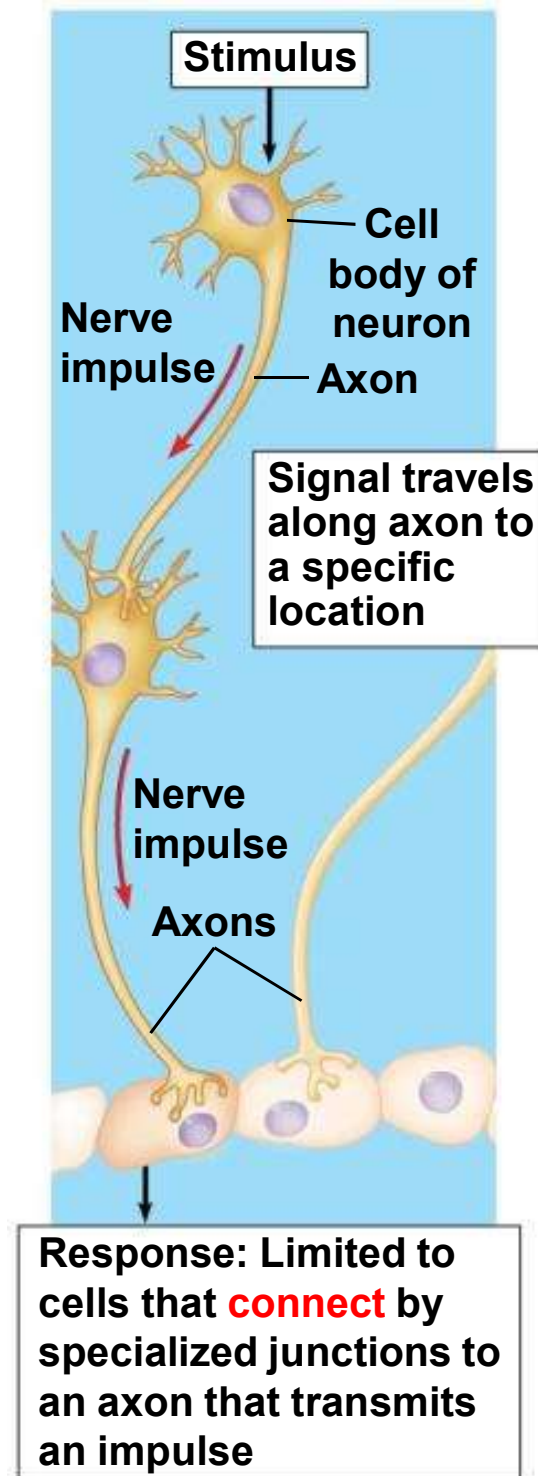
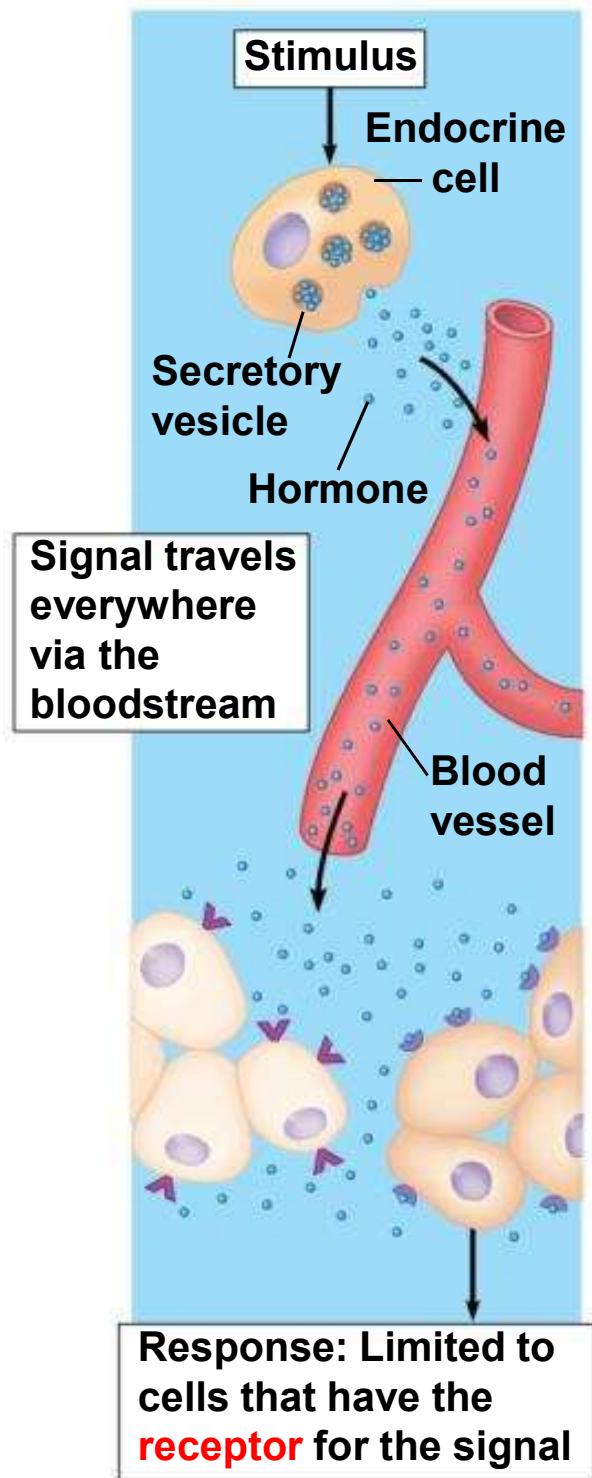
THE NATURE OF CHEMICAL REGULATION

26.1 Chemical and electrical signals coordinate body functions

- Organ systems must communicate with one another
 - to maintain **homeostasis** and
 - to carry out other coordinated functions.
- Organ systems use chemical and electrical signals that travel through the body by way of two major organ systems:
 1. the endocrine system and
 2. the nervous system.
- The **endocrine system** is a group of interacting glands and tissues throughout the animal body that produce and secrete chemicals to initiate and maintain body functions and activities.

26.1 Chemical and electrical signals coordinate body functions

- In the endocrine system, chemical signals called **hormones**
 - are made and secreted mainly by organs called **endocrine glands**,
 - are released into the bloodstream by endocrine cells,
 - are carried to all locations in the body, and
 - affect only **target cells** that have receptors for that specific hormone.
- The nervous system also communicates, regulates, and uses electrical signals via nerve cells called neurons.
- Comparing the endocrine and nervous systems
 - The nervous system reacts faster.
 - The responses of the endocrine system **last longer**.



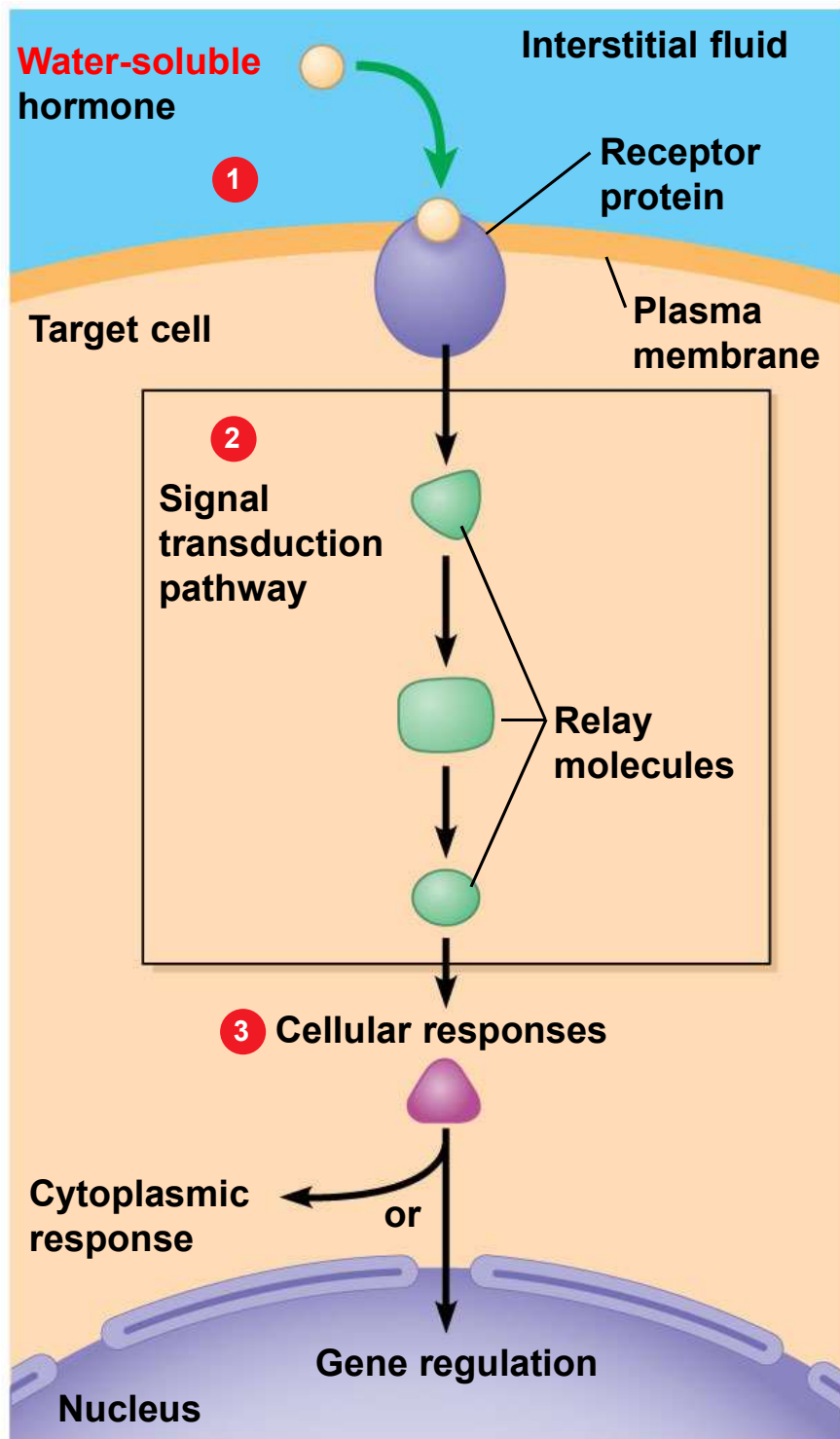
26.2 Hormones affect target cells using two main signaling mechanisms

- Hormone signaling involves three stages:
 1. *Reception* of the signal occurs when a hormone binds to a specific receptor protein on or in the target cell.
 2. *Signal transduction* converts the signal from one form to another.
 3. *Response* is a change in the cell's behavior.
- Based on chemical properties, hormones can be classified into two groups.
 1. The water-soluble hormones include proteins, short polypeptides, and some modified versions of single amino acids. Most hormones produced by the endocrine glands are water-soluble.
 2. The lipid-soluble hormones include the steroid hormones, small molecules made from cholesterol.

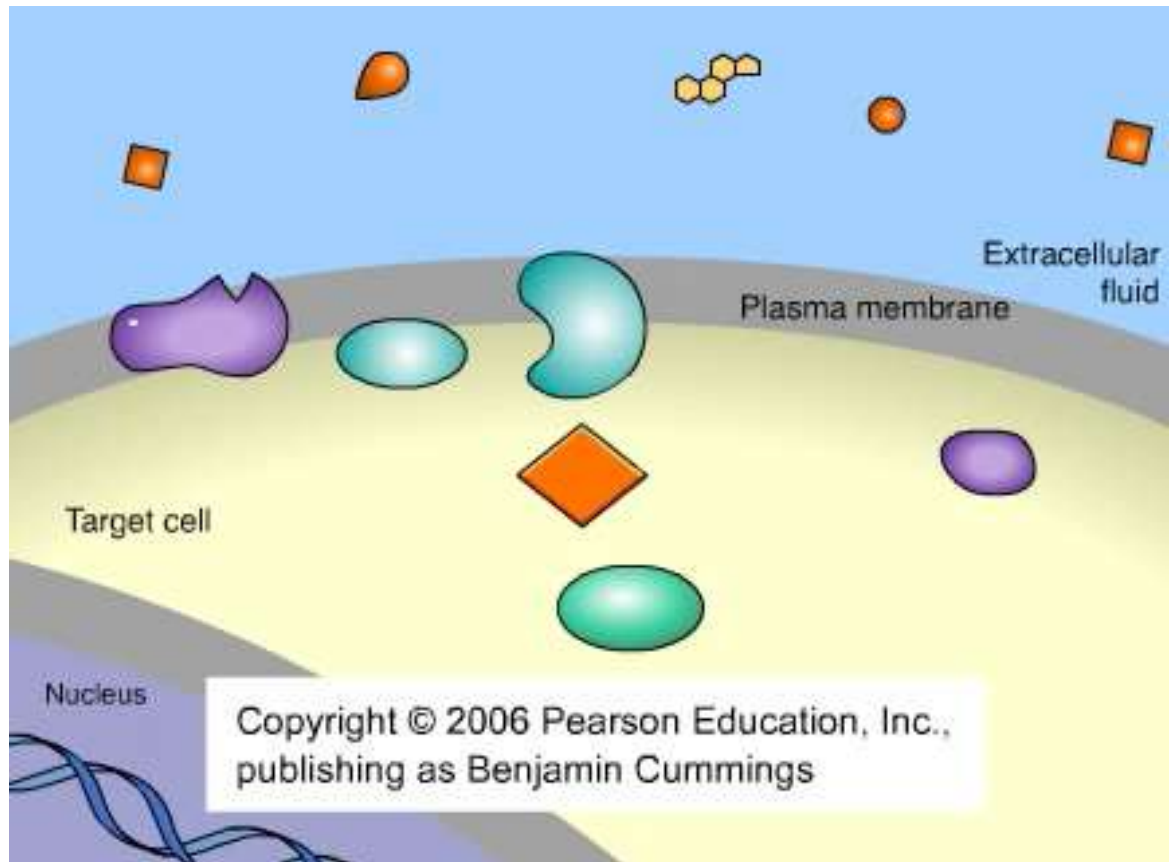
固醇類

26.2 Hormones affect target cells using two main signaling mechanisms

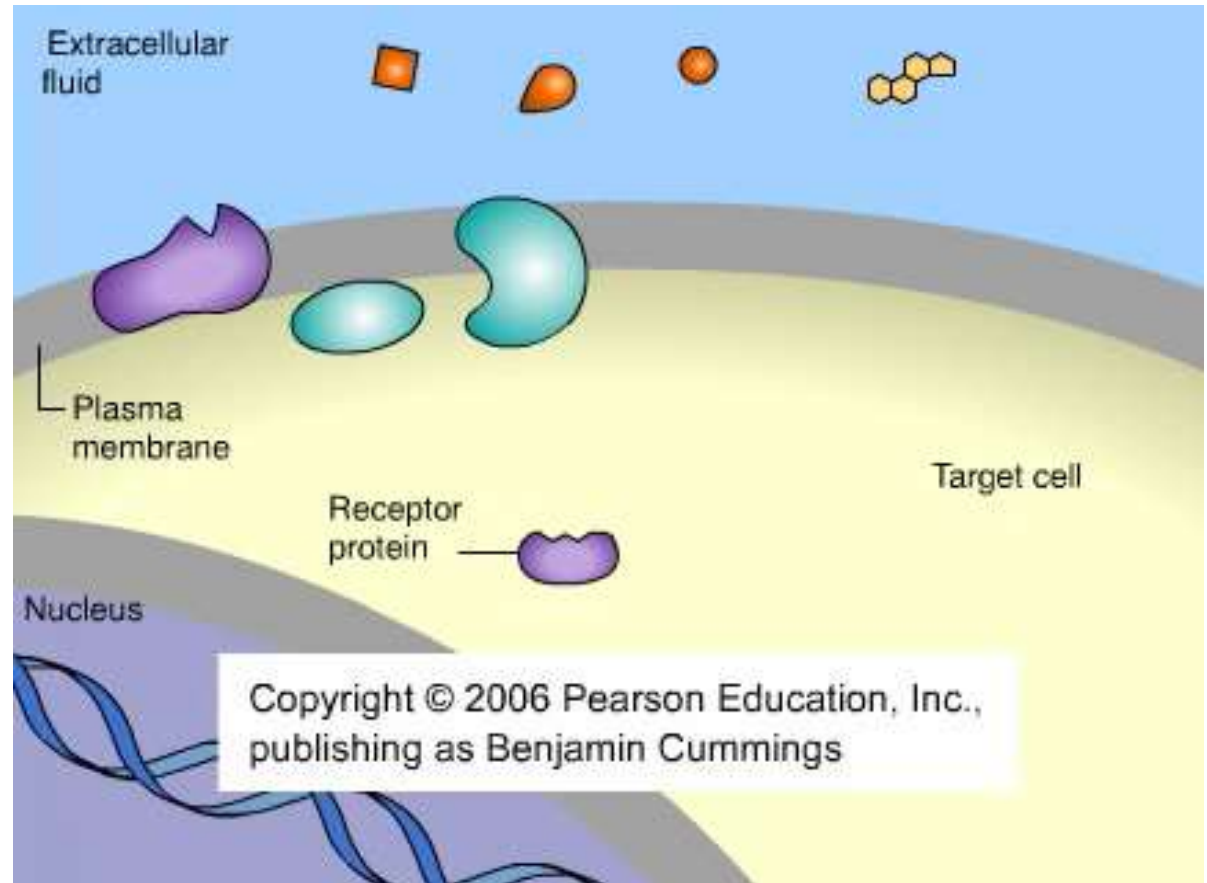
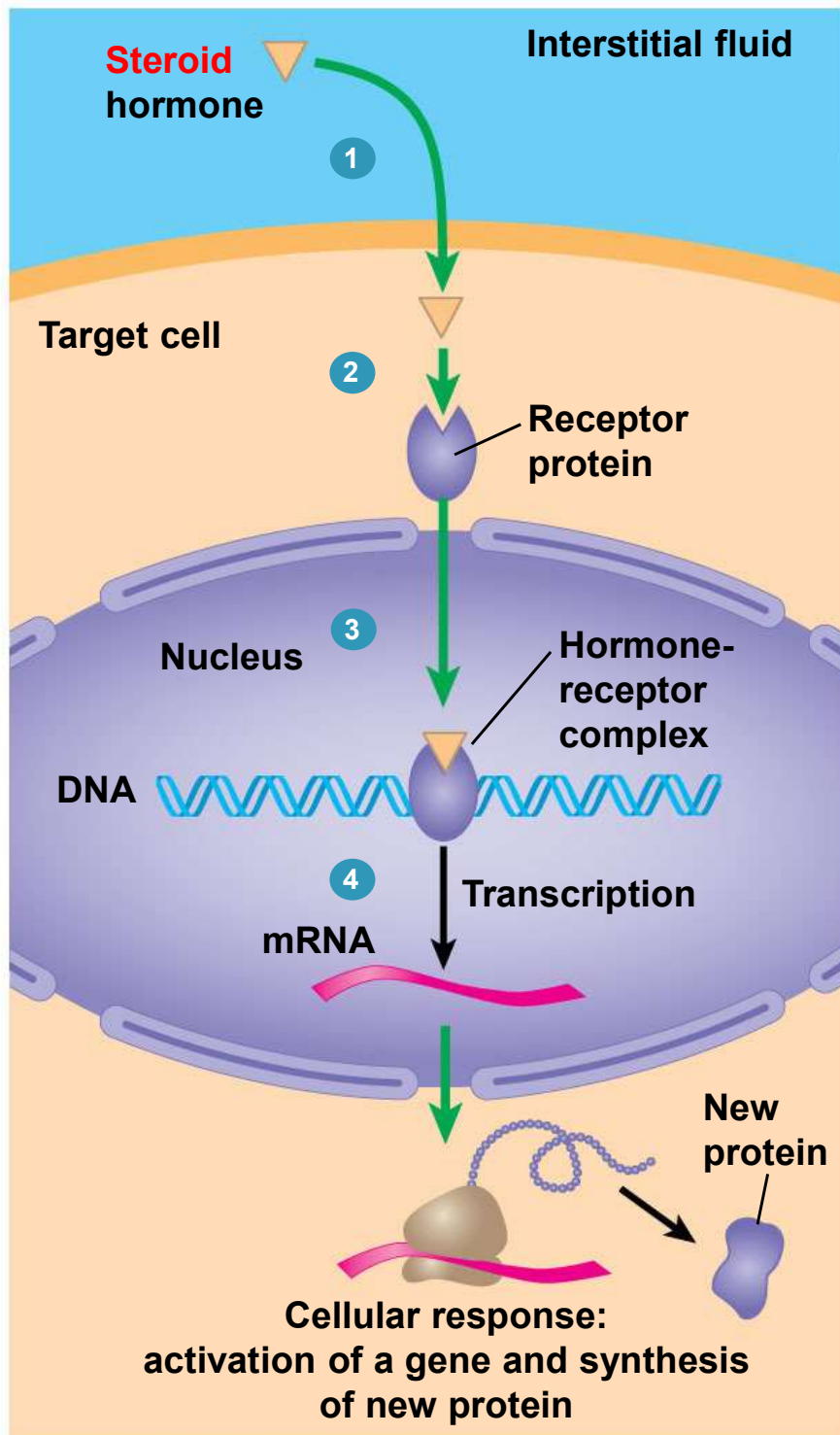
- **Water-soluble** hormones cannot pass through the phospholipid bilayer of the plasma membrane, but they can bring about cellular changes without entering their target cells.
- **Lipid-soluble** hormones, such as steroid hormones,
 - pass through the phospholipid bilayer and
 - bind to receptors inside the cell.



Animation: Water-Soluble Hormone



Animation: Lipid-Soluble Hormone

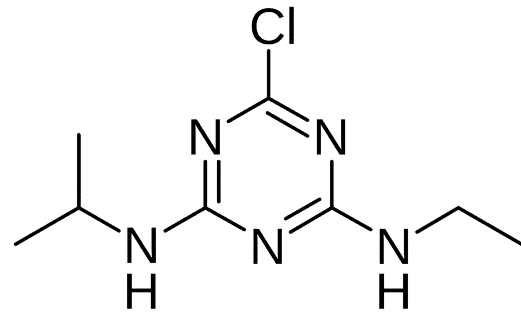


26.3 SCIENTIFIC THINKING: A widely used weed killer demasculinizes male frogs

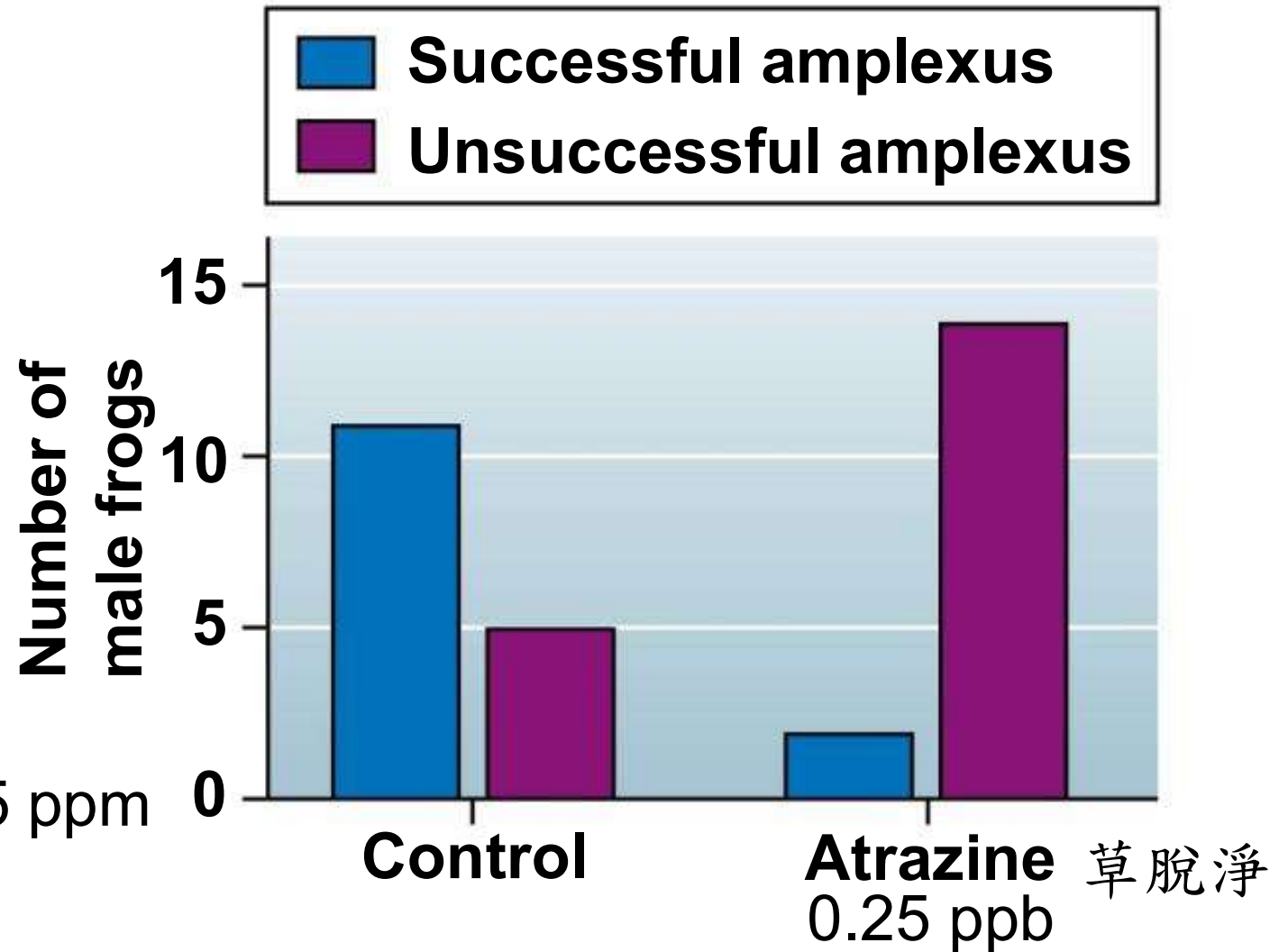
- Almost all of us are routinely exposed to chemicals called **endocrine disruptors**, such as atrazine, found in weed-killers, and BPA in food and beverage containers, which specifically mimic the lipid-soluble hormone estrogen.
- Scientists use controlled studies to test whether a chemical causes specific biological effects.
- Scientists exposed developing male frogs to **very low levels** of atrazine for **three years**.
 - An equal number of control and atrazine-exposed adult males of similar weights were placed into a pool with females.
 - A **mating contest** was set up, in which control males and atrazine-exposed males competed for females.
 - The scientists recorded each male frog's ability to successfully grasp a female with his front legs during a mating behavior called amplexus.



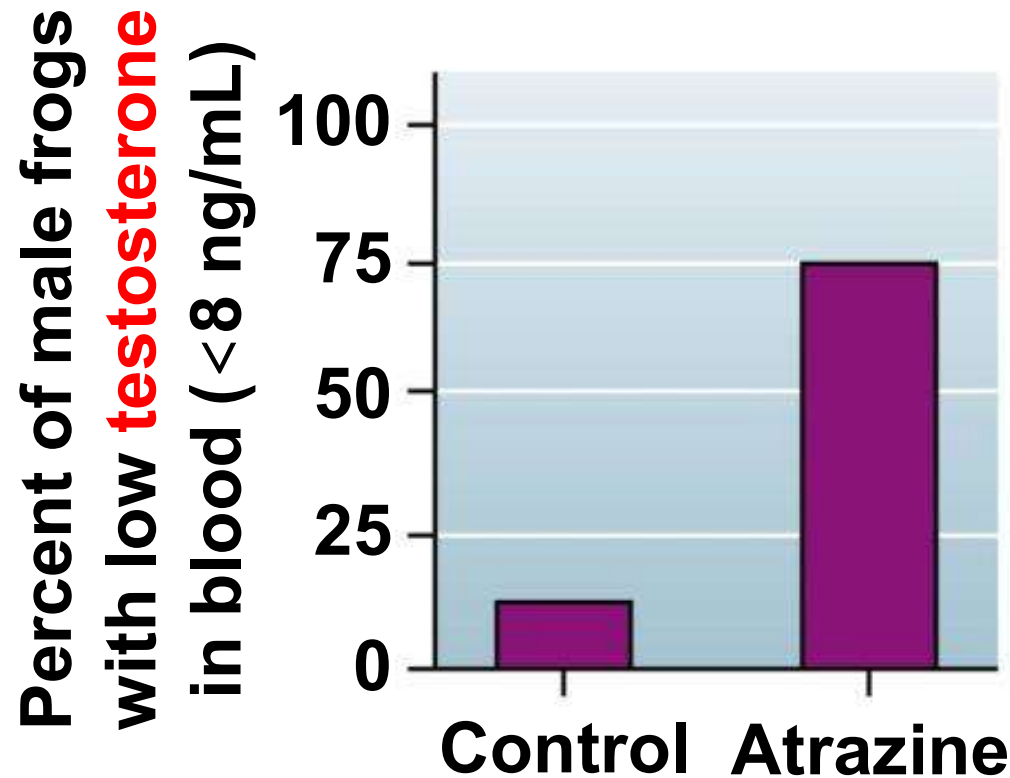
抱合



農藥殘留容許值：0.25 ppm
飲用水：3 ppb



Data from T. B. Hayes et al., Atrazine induces complete feminization and chemical castration in male African clawed frogs (*Xenopus laevis*), *Proceedings of the National Academy of Sciences* 107: 10 (2007).



- Atrazine's demasculinizing effect on male frogs was demonstrated by
 - reduced mating behaviors,
 - testosterone deficiencies, and
 - some sex reversals.

Data from T. B. Hayes et al., Atrazine induces complete feminization and chemical castration in male African clawed frogs (*Xenopus laevis*), *Proceedings of the National Academy of Sciences* 107: 10 (2007).

1 ppb = 1 ng/ml

THE VERTEBRATE ENDOCRINE SYSTEM

26.4 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 nonendocrine functions.
- Other organs (such as the stomach) are primarily nonendocrine but have some cells that secrete hormones.
- The following figure shows
 - the locations of the major endocrine glands and
 - the main hormones they produce.

Pineal gland

(Melatonin helps regulate biological rhythms.)

Thyroid gland

(Thyroid hormone affects metabolic processes; calcitonin lowers blood calcium.)

Parathyroid glands

(Parathyroid hormone raises blood calcium.)

Testes (in males)

(Androgens support sperm formation and promote development of male secondary sex characteristics.)

Ovaries (in females)

(Estrogens stimulate uterine lining growth and promote development of female secondary sex characteristics; progestins promote uterine lining growth.)



Hypothalamus

(Multiple hormones control the pituitary gland.)

Pituitary gland

Anterior pituitary

(Multiple hormones affect other endocrine glands and cells.)

Posterior pituitary

(Oxytocin stimulates mammary gland cells and contraction of uterus; antidiuretic hormone promotes retention of water by kidneys.)

Adrenal glands (atop kidneys)

Adrenal medulla

(Epinephrine and norepinephrine raise blood glucose, increase metabolic activities, and constrict some blood vessels.)

Adrenal cortex

(Glucocorticoids raise blood glucose; mineralocorticoids promote reabsorption of Na⁺ and excretion of K⁺ in kidneys.)

Pancreas

(Insulin lowers blood glucose; glucagon raises blood glucose.)

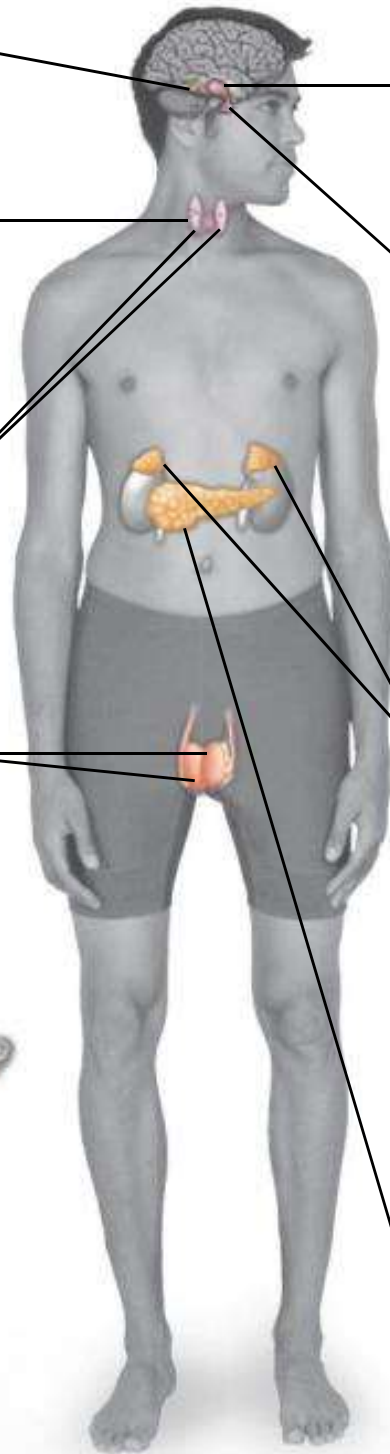


TABLE 26.3

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 催產激素	Peptide	Stimulates contraction of uterus during labor and ejection of milk from mammary glands	Nervous system
腦垂腺 後葉		抗利尿激素 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
前葉		Prolactin (PRL) 泌乳激素	Protein	Stimulates milk production and secretion in females	Hypothalamic hormones
濾泡刺激素		Follicle-stimulating hormone (FSH)	Protein	Stimulates production of ova and sperm	Hypothalamic hormones
黃體激素		Luteinizing hormone (LH)	Protein	Stimulates ovaries and testes	Hypothalamic hormones
甲狀腺促進素		Thyroid-stimulating hormone (TSH)	Protein	Stimulates thyroid gland	Thyroxine in blood; hypothalamic hormones
腎上腺素皮質醇促進素		Adrenocorticotrophic 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
松果體					

TABLE 26.3

MAJOR HUMAN ENDOCRINE GLANDS AND SOME OF THEIR HORMONES

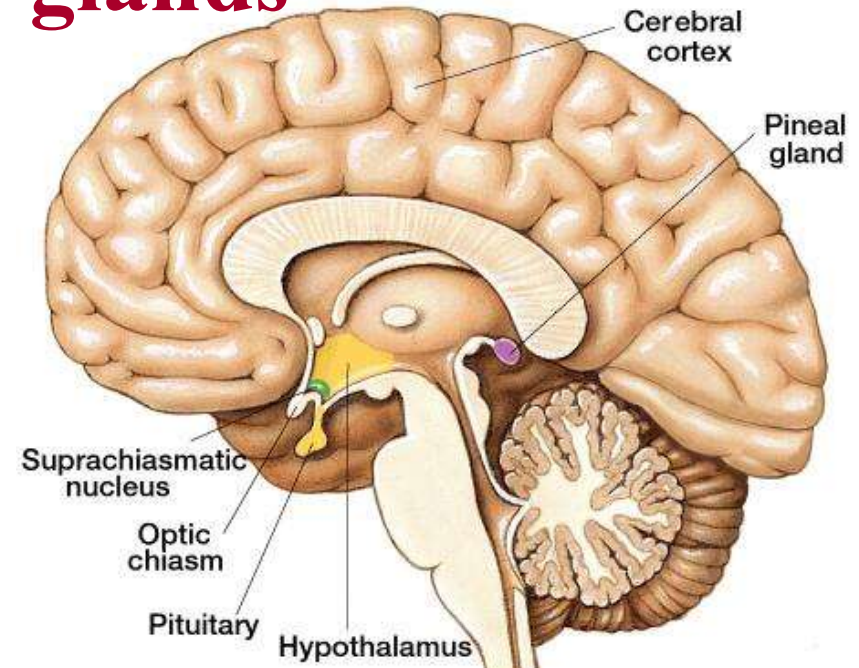
Gland (module)		Hormone	Chemical Class	Representative Actions	Regulated by
Thyroid gland (26.5–6) 甲狀腺		Thyroxine (T ₄) and triiodothyronine (T ₃) Calcitonin	Amine Peptide	Stimulate and maintain metabolic processes Lowers blood calcium level	TSH Calcium in blood
Parathyroid glands (26.5–6) 副甲狀腺		Parathyroid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

- What stimulates an endocrine gland to produce a hormone?
- We can categorize stimuli into three major types.
 1. For some endocrine glands, a change in levels of certain ions and nutrients is the stimulus.
 2. Other endocrine glands, such as the adrenal glands, are stimulated directly by the nervous system.
 3. Hormones can also stimulate endocrine glands.
- The hormones produced by endocrine glands have a wide range of effects, including
 - regulating ion and nutrient levels, water balance, and metabolism,
 - controlling reproduction, growth, and development, and
 - initiating responses to stress and the environment.
- For a particular example of hormonal effects, let's take a brief look at the pineal gland.

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

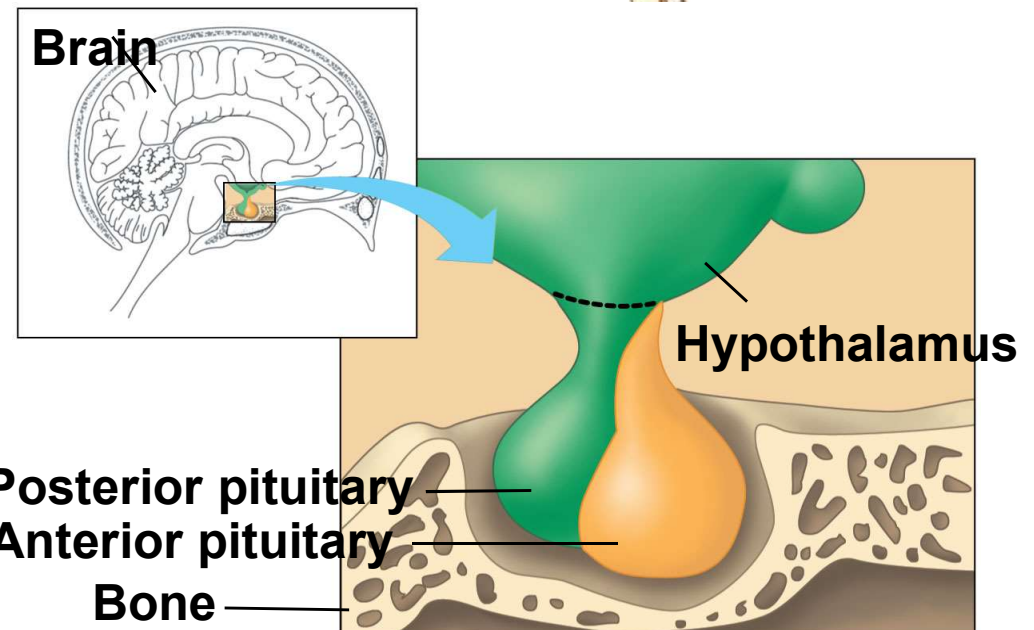
The pineal gland

- 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**.

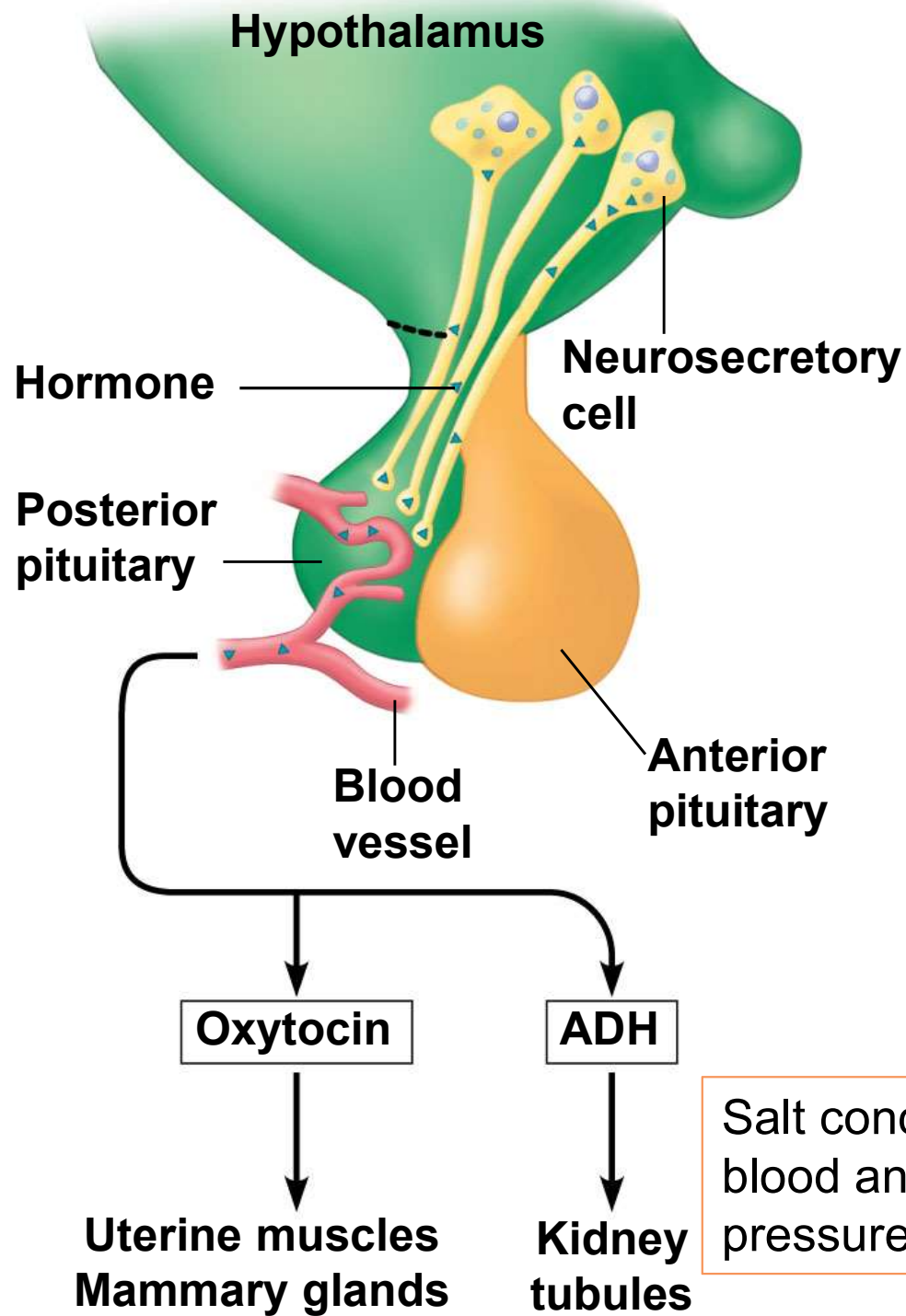


26.5 The hypothalamus, which is closely tied to the pituitary, connects the nervous and endocrine systems

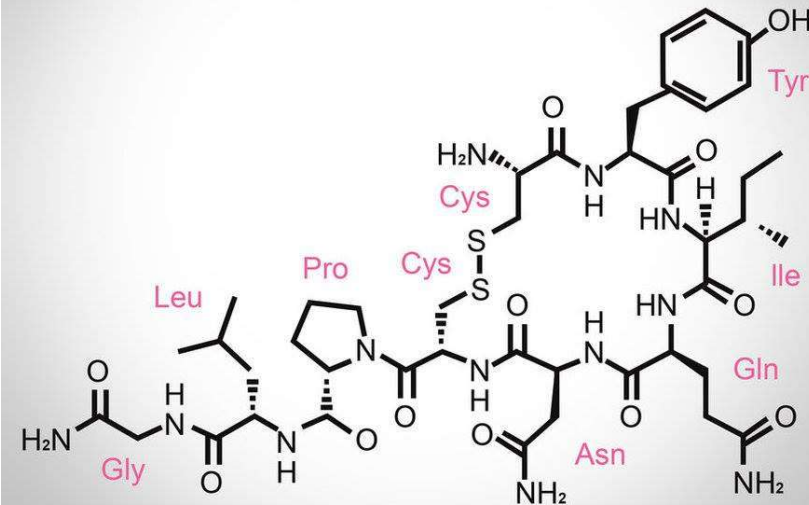
■ The **hypothalamus**

- is the main control center of the endocrine system,
- 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
- directly **controls the pituitary gland**, which in turn secretes hormones that influence numerous body functions.
- The **pituitary gland** consists of two parts: an anterior lobe and a posterior lobe.

- In the **posterior pituitary**, a set of neurosecretory cells extends **from the hypothalamus** into the posterior pituitary, connecting them structurally and functionally.



this is love.

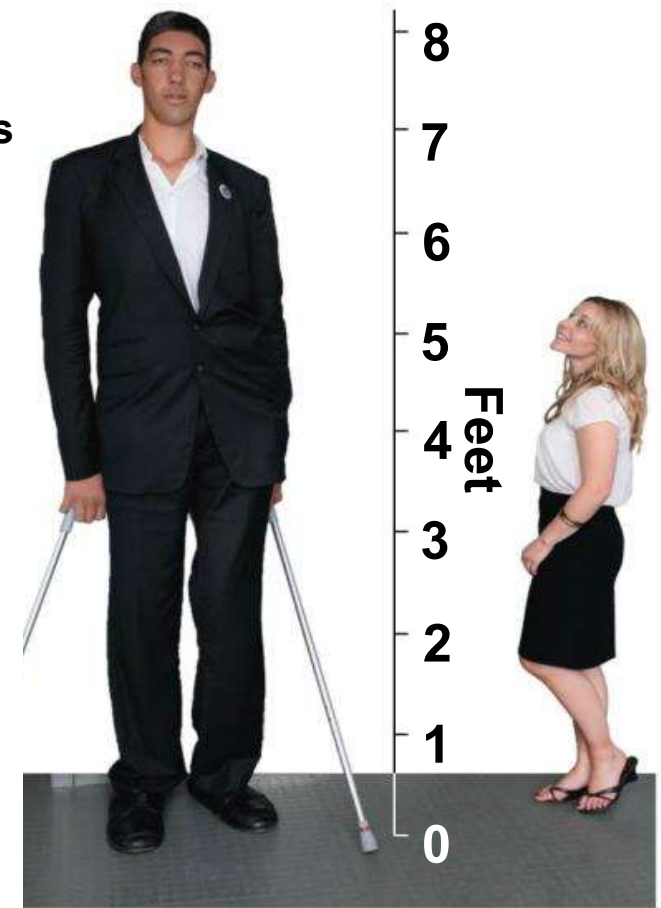
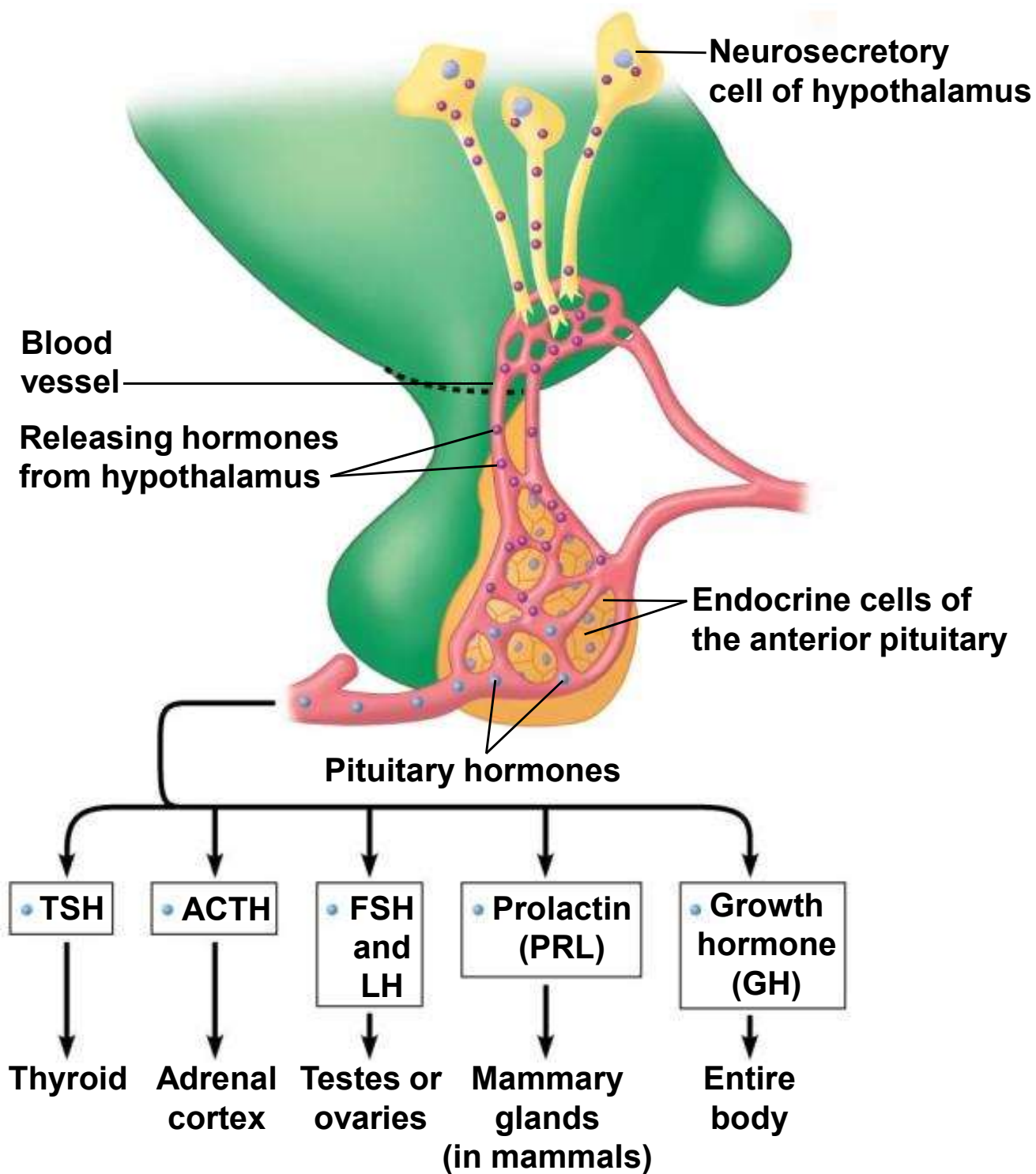


<https://blogs.unimelb.edu.au/sciencecommunication/2017/10/20/oxytocin-the-love-hormone-or-the-hate-hormone/>

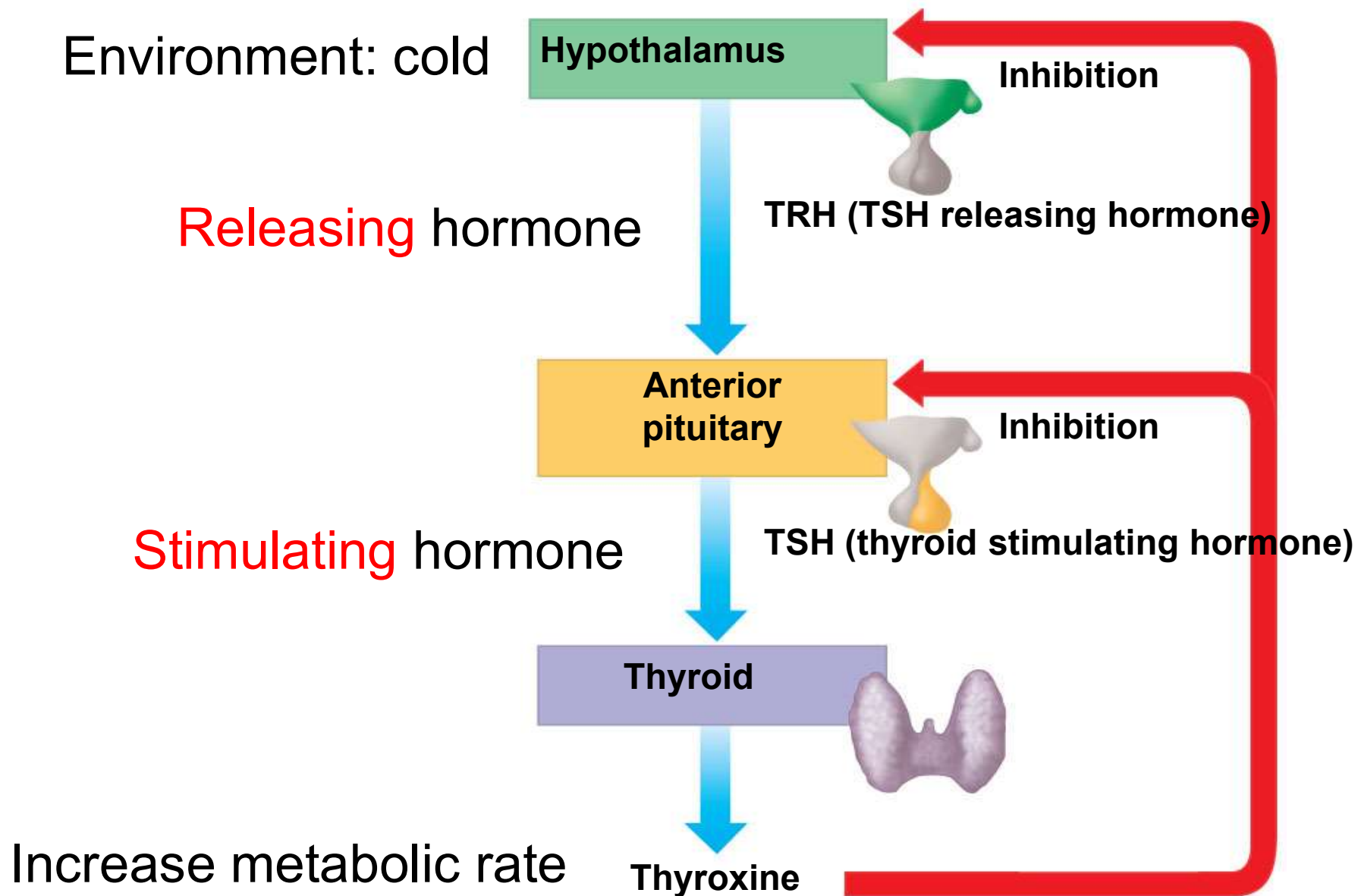
26.5 The hypothalamus, which is closely tied to the pituitary, connects the nervous and endocrine systems

- The hormones oxytocin and antidiuretic hormone
 - are produced by these neurosecretory cells and
 - are stored in the posterior pituitary.
- Neurosecretory cells in the **anterior pituitary** secrete two kinds of hormones into short blood vessels that connect to the anterior pituitary.
 1. **Releasing hormones** stimulate the anterior pituitary to secrete one or more specific hormones.
 2. **Inhibiting hormones** induce the anterior pituitary to stop secreting one or more specific hormones.

- Many of the protein hormones secreted from the anterior pituitary stimulate other endocrine glands to produce their hormones. These include
 - **thyroid-stimulating hormone (TSH)**, which regulates hormone production by the thyroid gland,
 - adrenocorticotrophic hormone (ACTH), which stimulates the adrenal cortex, which in turn releases hormones that affect water balance and metabolism,
 - follicle-stimulating hormone (FSH) and luteinizing hormone (LH), which stimulate the testes and ovaries to produce reproductive hormones,
 - **prolactin (PRL)**, which in mammals, directly stimulates the mammary glands to produce milk, and
 - **growth hormone (GH)**, which promotes protein synthesis and the use of body fat for energy metabolism.



- **Feedback control** of the hypothalamus and pituitary serves as a useful example of a *hormone cascade pathway* directed by the hypothalamus.
 - The hypothalamus secretes a releasing hormone known as **TRH (TSH-releasing hormone)**.
 - In turn, TRH stimulates the anterior pituitary to produce thyroid-**stimulating** hormone (TSH).
 - Under the influence of TSH, the thyroid grows and **secretes** thyroid hormone into the blood.

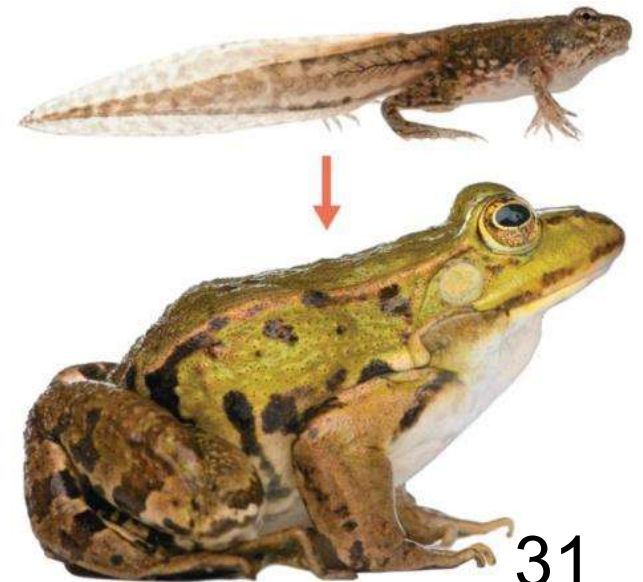
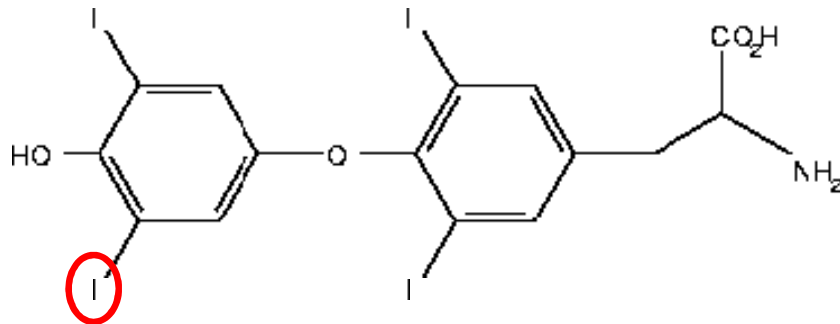


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HORMONES AND HOMEOSTASIS

26.6 The thyroid regulates development and metabolism

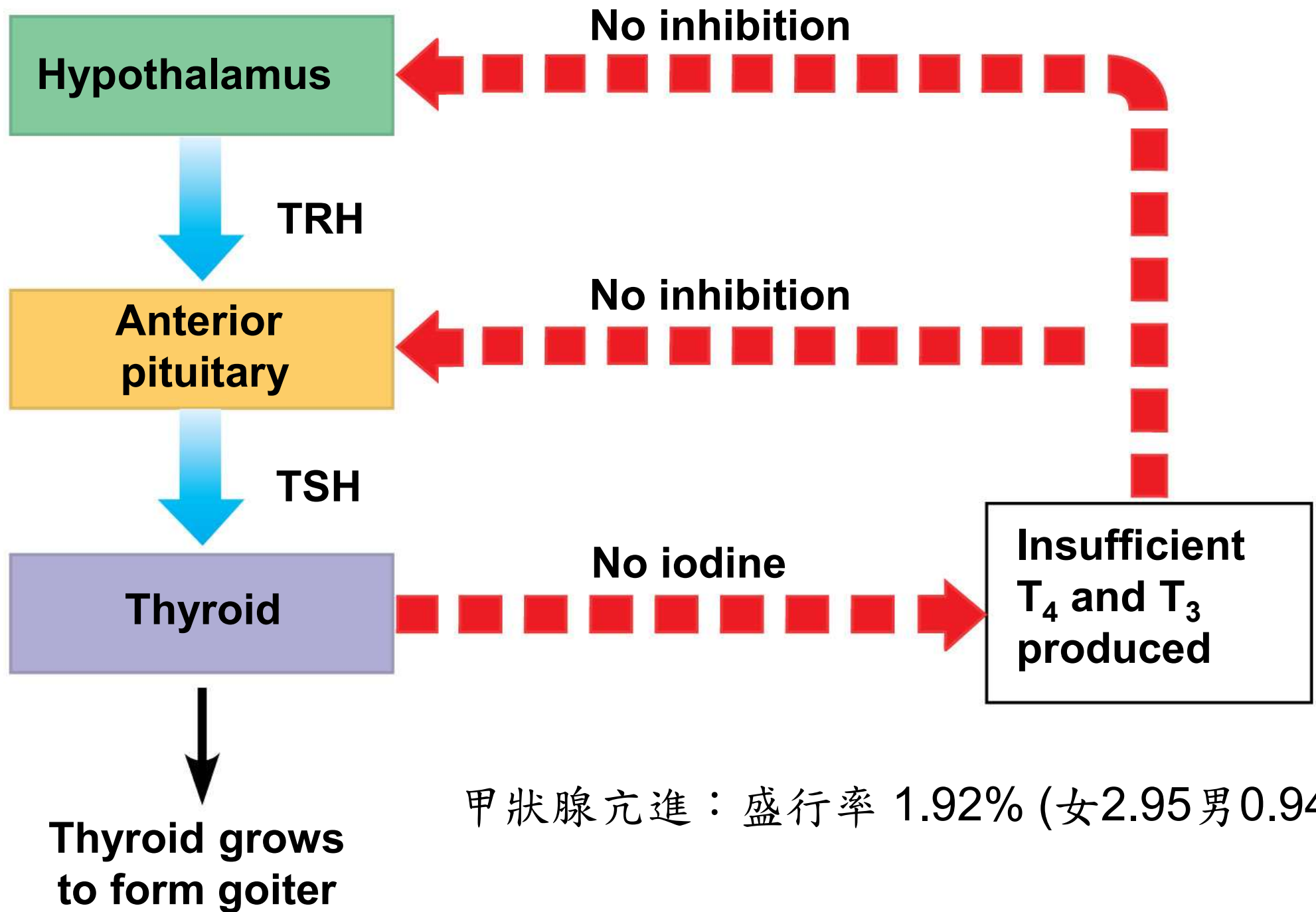
- The **thyroid gland** is located in the neck, just under the larynx (voice box).
- The thyroid gland produces two similar hormones,
 - **thyroxine (T_4)** and
 - **triiodothyronine (T_3)**.
- These hormones regulate many aspects of
 - metabolism,
 - reproduction, and
 - development.



26.6 The thyroid regulates development and metabolism

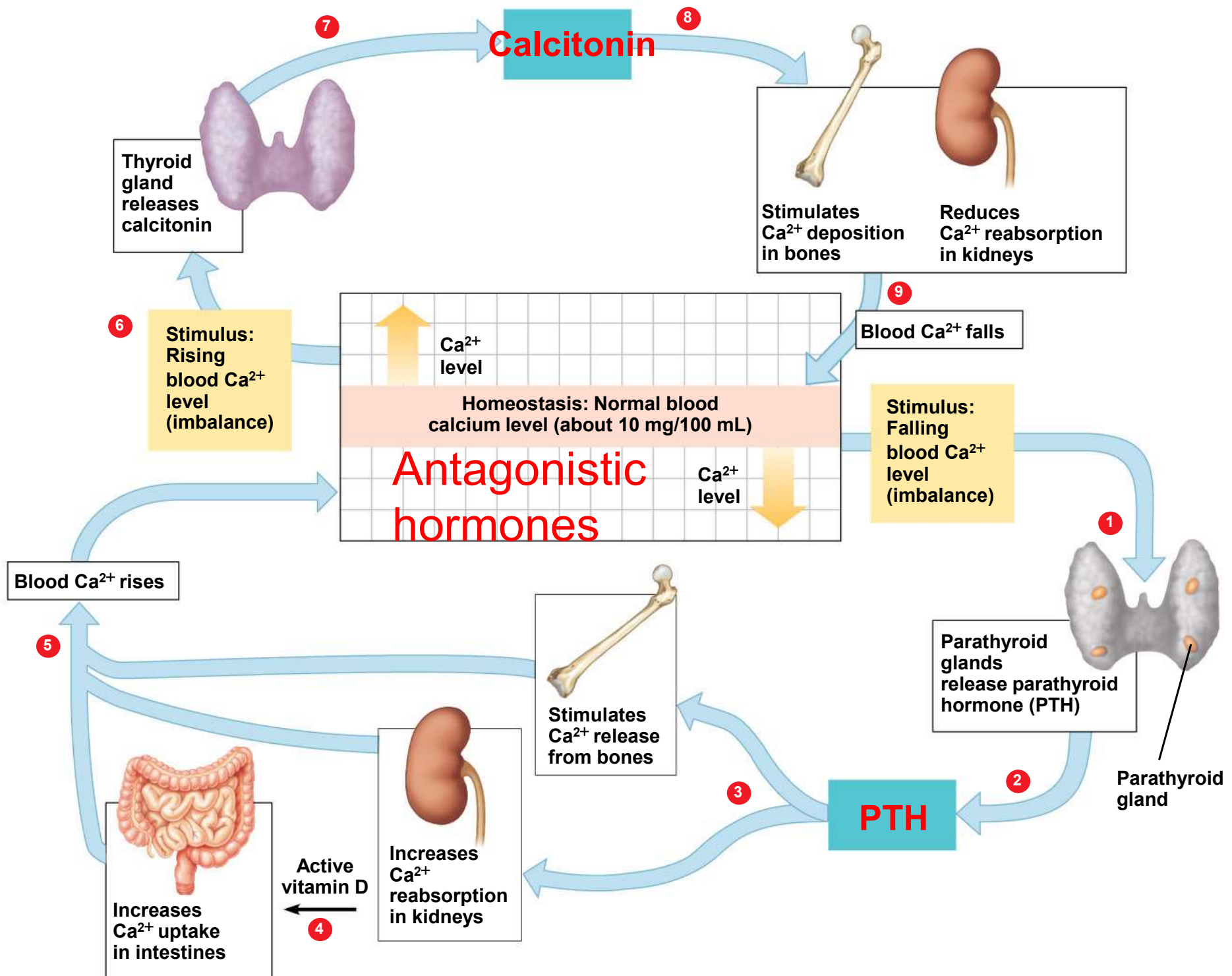
- Thyroid imbalance can cause disease.
 - Hyperthyroidism 甲狀腺亢進
 - results from too much T_4 and T_3 in the blood,
 - leads to high blood pressure, loss of weight, overheating, and irritability, and
 - produces **Graves' disease**.
 - Hypothyroidism
 - results from too little T_4 and T_3 in the blood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





甲狀腺亢進：盛行率 1.92% (女2.95男0.94)

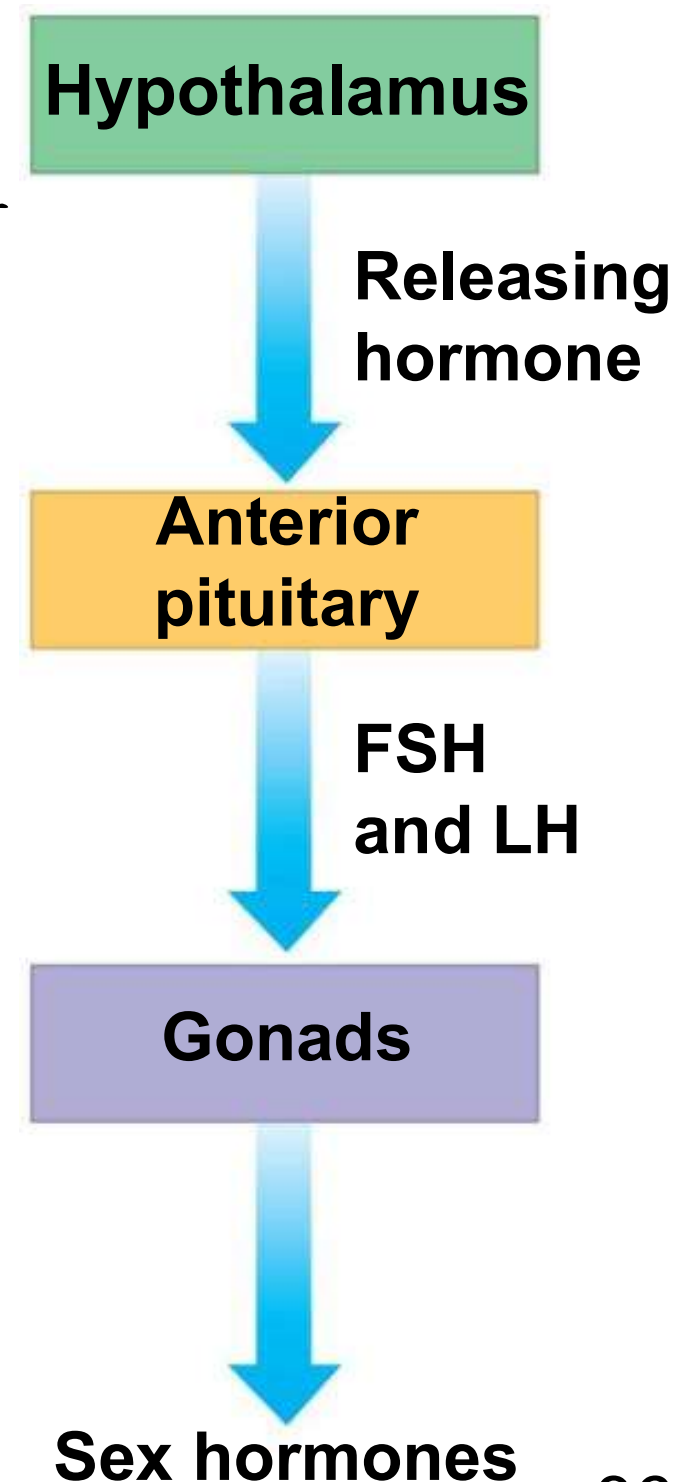
Figure 26.6



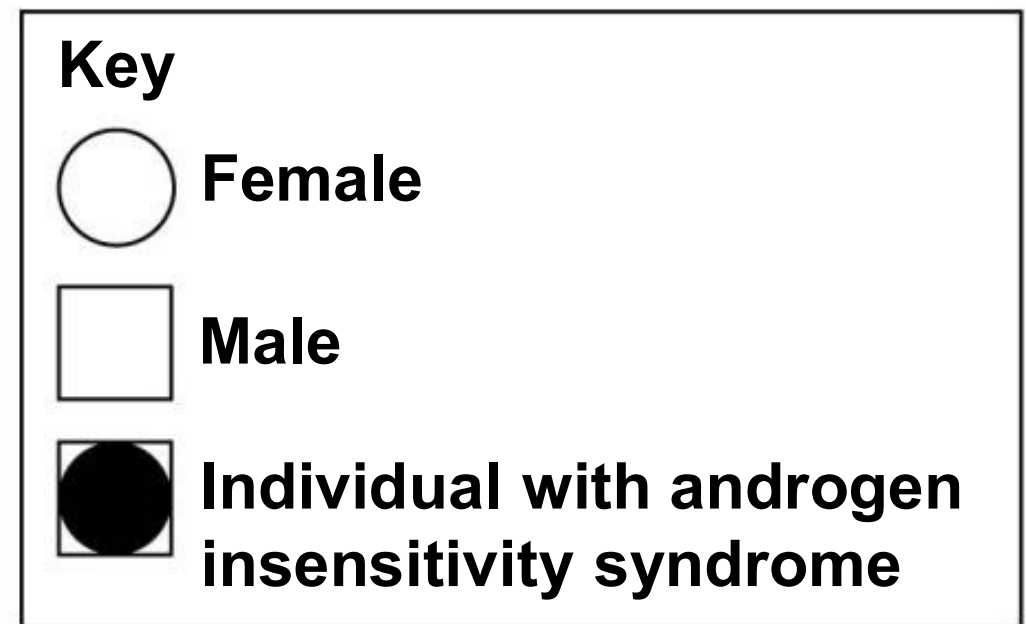
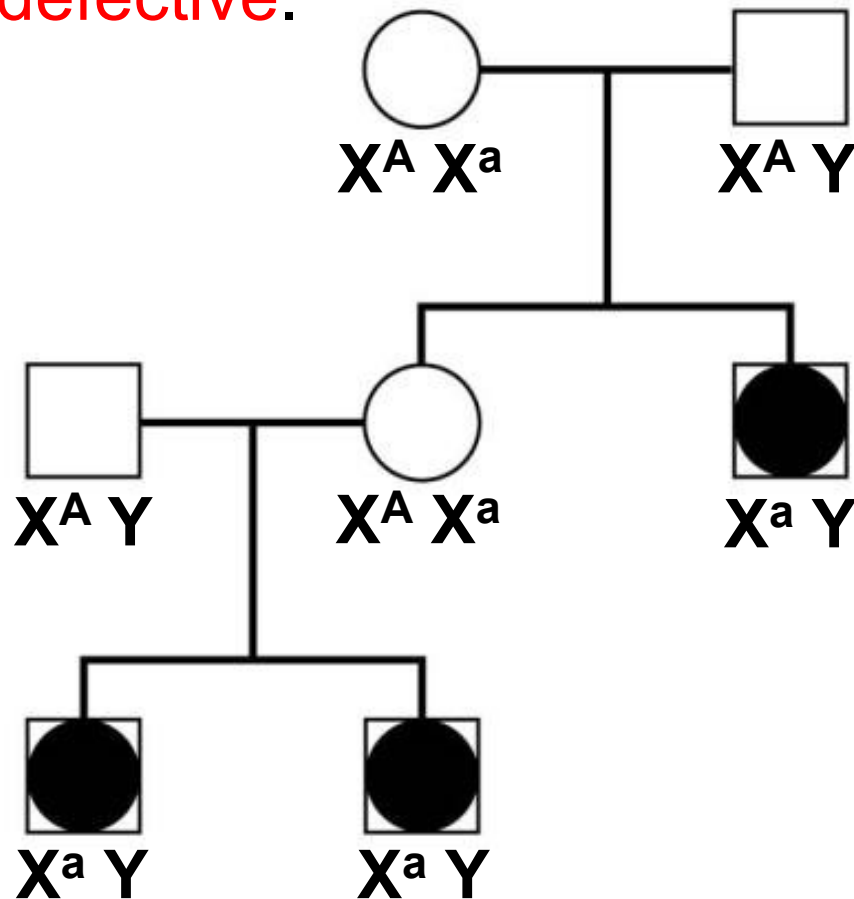
26.7 The gonads secrete sex hormones

- The **gonads**, or sex glands (ovaries in the female and testes in the male),
 - secrete sex hormones and
 - produce gametes (ova and sperm).
- 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.

- The gonads of mammals produce three major categories of sex hormones.
 1. **Estrogens** maintain the female 雌激素 **reproductive** system and promote the development of female **characteristics**.
 2. **Progestins**, such as progesterone, prepare and maintain the uterus to support a **developing embryo**. 助孕素
 3. **Androgens**, such as **testosterone**, stimulate the development and maintenance of the male reproductive system. 雄激素



- Imbalance of sex hormones can complicate the development of sexual characteristics.
- *Androgen insensitivity syndrome* is an **X-linked recessive trait** that results when testosterone enters the target cell but cannot bind to its nuclear receptor because the **nuclear receptor is defective**.



26.7 The gonads secrete sex hormones

- The process of **sex determination is driven by androgens** in a very similar manner in all vertebrates, suggesting that androgens had this role early in evolution.
- Testosterone causes
 - the aggressive male behavior in elephant seals and
 - the development of manes in male lions.

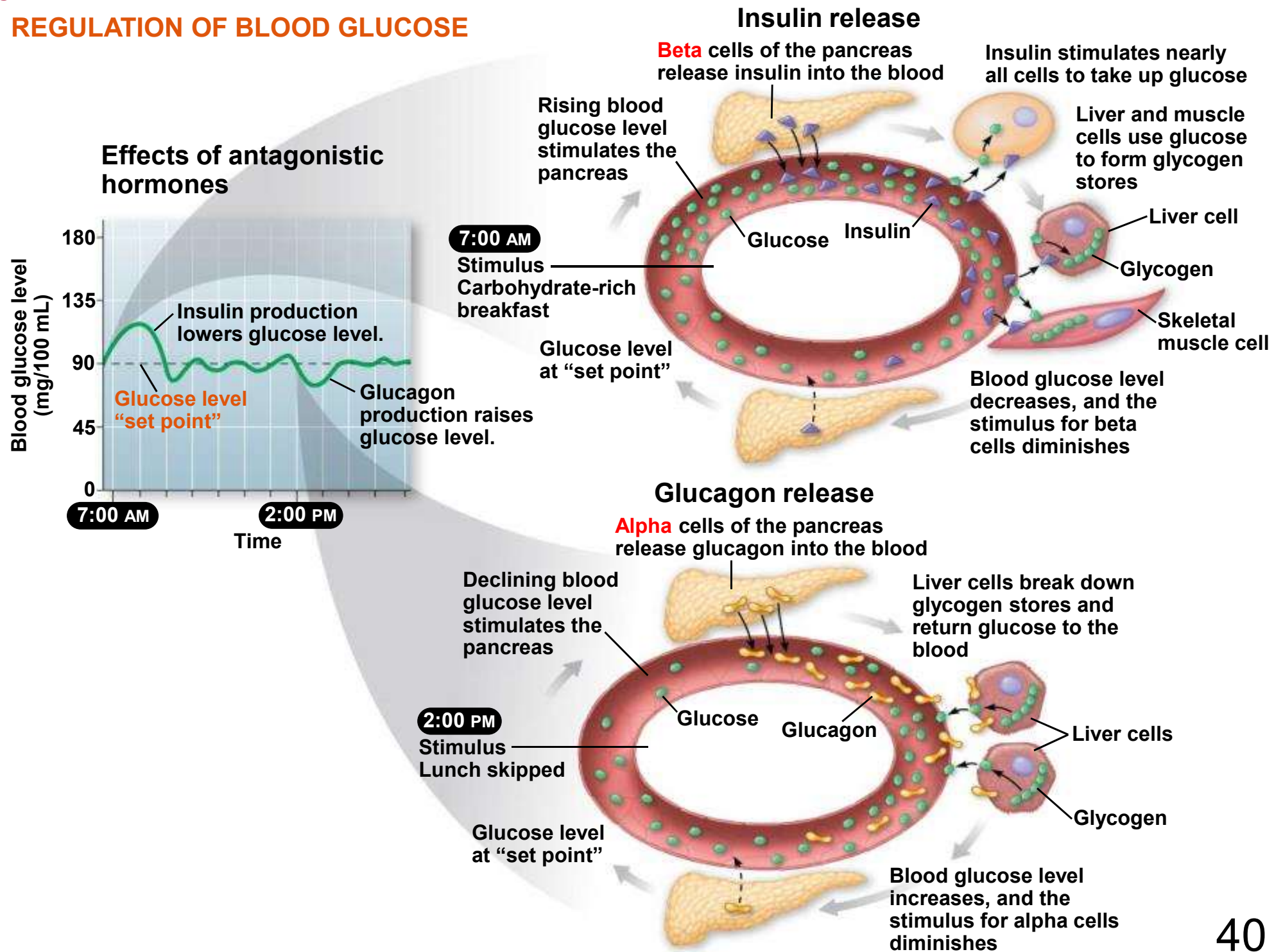


26.8 Pancreatic hormones regulate blood glucose levels

- The **pancreas** is a gland with dual functions.
 - It secretes digestive enzymes into the small intestines.
 - It secretes two protein hormones, **insulin** and **glucagon**, directly into the blood.
- Insulin and glucagon are said to be **antagonistic** hormones because the effects of one oppose the effects of the other.
- The balance in secretion of insulin and glucagon maintains a homeostatic “set point” of glucose in the blood.
- Two negative feedback systems manage the amount of glucose circulating in the blood.

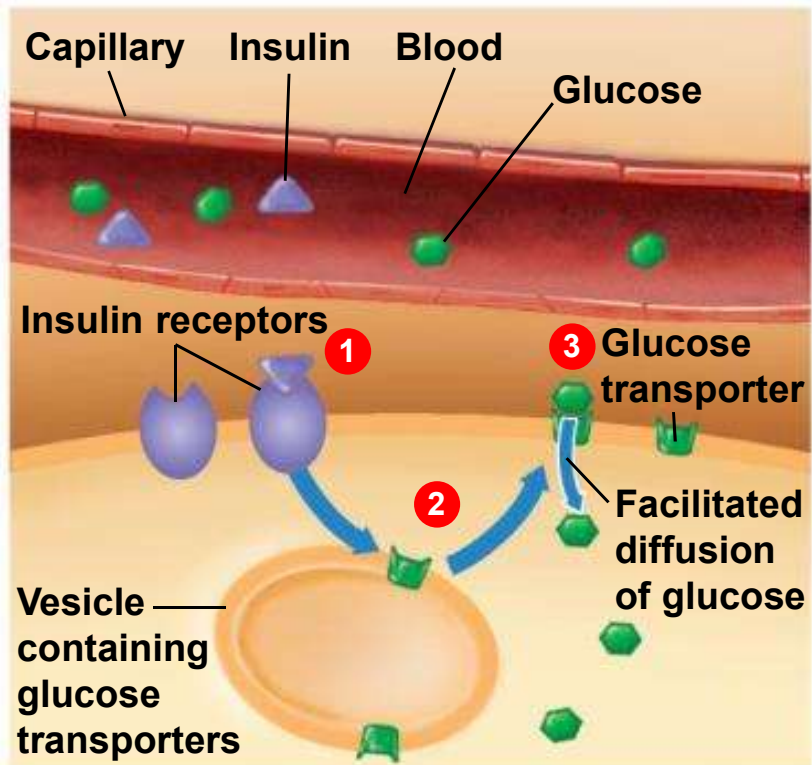
Figure 26.8-0-3

REGULATION OF BLOOD GLUCOSE

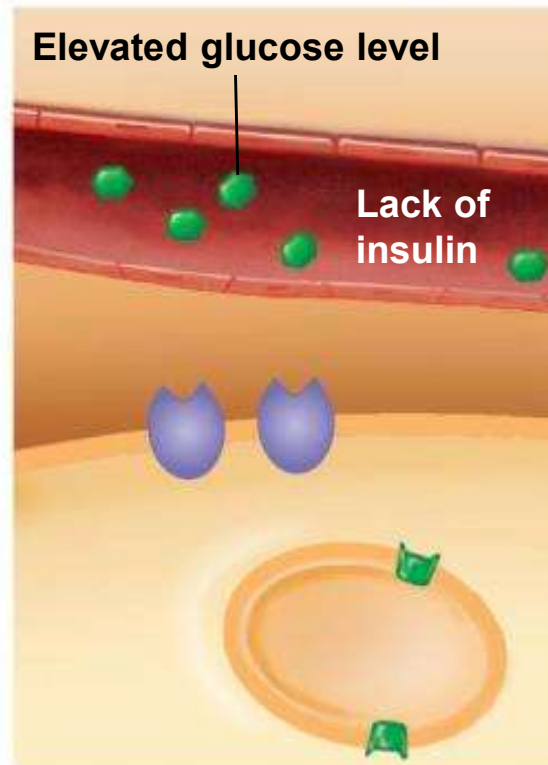


26.9 CONNECTION: Diabetes is a common endocrine disorder

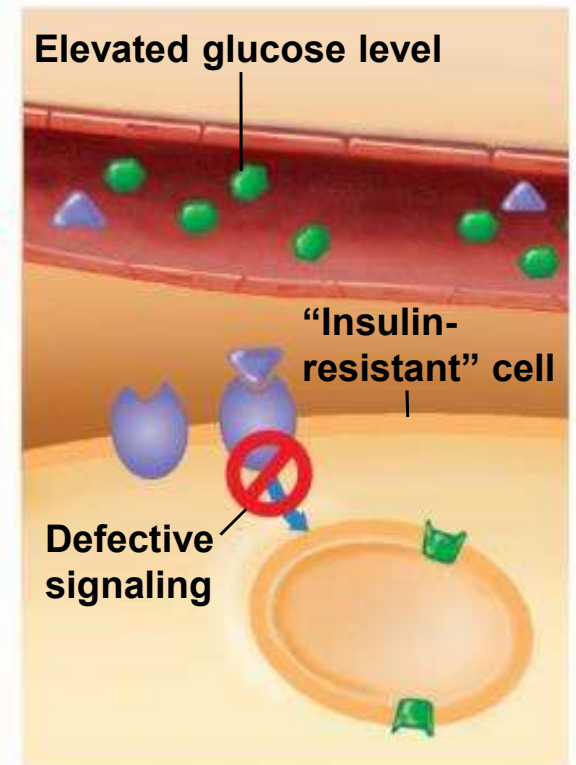
- **Diabetes mellitus** is a serious hormonal disorder caused by the body's inability to produce and/or use insulin, thereby decreasing the absorption of glucose from the blood and resulting in elevated blood glucose levels, or **hyperglycemia**.
- Diabetes is quickly becoming a major public health crisis.
- Muscle or fat cells normally respond to insulin by taking up glucose from the blood, thus lowering blood glucose levels.
- In this process, the binding of insulin to the insulin receptor initiates internal cell signals that result in glucose transporters being shuttled from vesicles to the plasma membrane, and glucose enters the target cell via facilitated diffusion.
- 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. 臺灣：近百萬患者，佔死因6%



Normal glucose and insulin levels



Type I diabetes:
insulin is absent

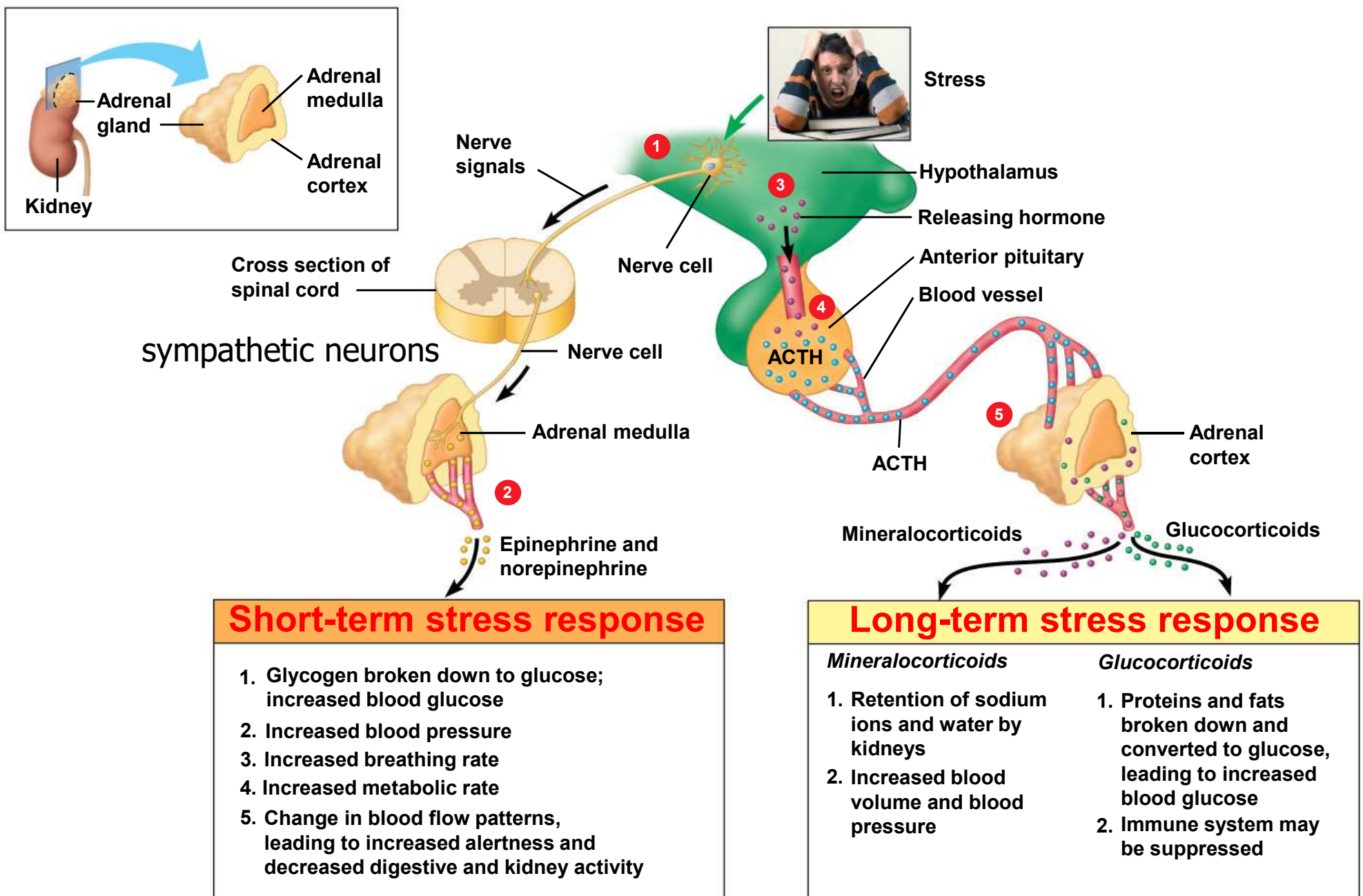


Type II diabetes: insulin
signaling is defective
90%

- There are three types of diabetes mellitus.
 1. Type 1 (insulin-dependent) is an autoimmune disease caused by the destruction of insulin-producing cells.
 - Patients can be treated with injections, several times daily, of human insulin, which is produced by genetically engineered bacteria.
 2. Type 2 (non-insulin-dependent)
 - is caused by a reduced response to insulin,
 - is associated with being overweight and underactive, and **Diet & exercise**
 - is the cause of more than 90% of diabetes.
 3. Gestational diabetes 妊娠性糖尿病 : 4% of pregnant women
 - can affect any pregnant woman and
 - can lead to dangerously **large babies**, which can complicate delivery.

26.10 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
 1. a central portion called the **adrenal medulla** and
 2. an outer portion called the **adrenal cortex**.
- Both glands secrete hormones that enable the body to respond to **stress**.
- Nerve signals from the hypothalamus stimulate the adrenal medulla to secrete
sympathetic neurons
 - **epinephrine** (adrenaline) and **norepinephrine** (noradrenaline).
- These hormones quickly trigger the “fight-or-flight” responses, which are short-term responses to stress.
- **Adrenocorticotrophic hormone (ACTH)** from the pituitary causes the adrenal cortex to secrete **corticosteroids**, which include
 - **glucocorticoids**, which function mainly in mobilizing cellular fuel, thus reinforcing the effects of glucagon, and
 - **mineralocorticoids**, which act mainly on salt and water balance.
- Both help maintain homeostasis when the body experiences long-term stress.



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Suppress defense system,
treat inflammation, pain relieve

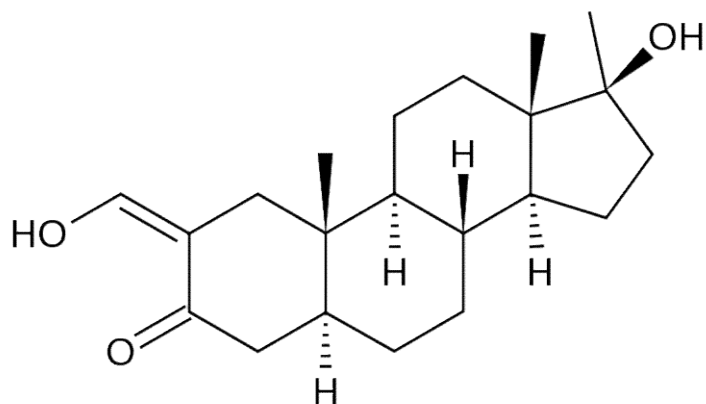
類固醇引起的骨質疏鬆症

(glucocorticoid induced osteoporosis, GIOP)

類固醇的治療對過敏與發炎反應之病患而言，是緩解症狀的必須用藥，然而該類藥物也勢必會造成明顯的副作用包括骨質疏鬆症等。使用類固醇六個月以上的病患約50%會罹患不同程度之骨質疏鬆症。（骨質疏鬆協會）

Oxymetholone, anadrol

treatment of osteoporosis and anemia;
stimulating muscle growth; considered
by bodybuilders to have the strongest
anabolic effect; **heptotoxic** (肝毒性)



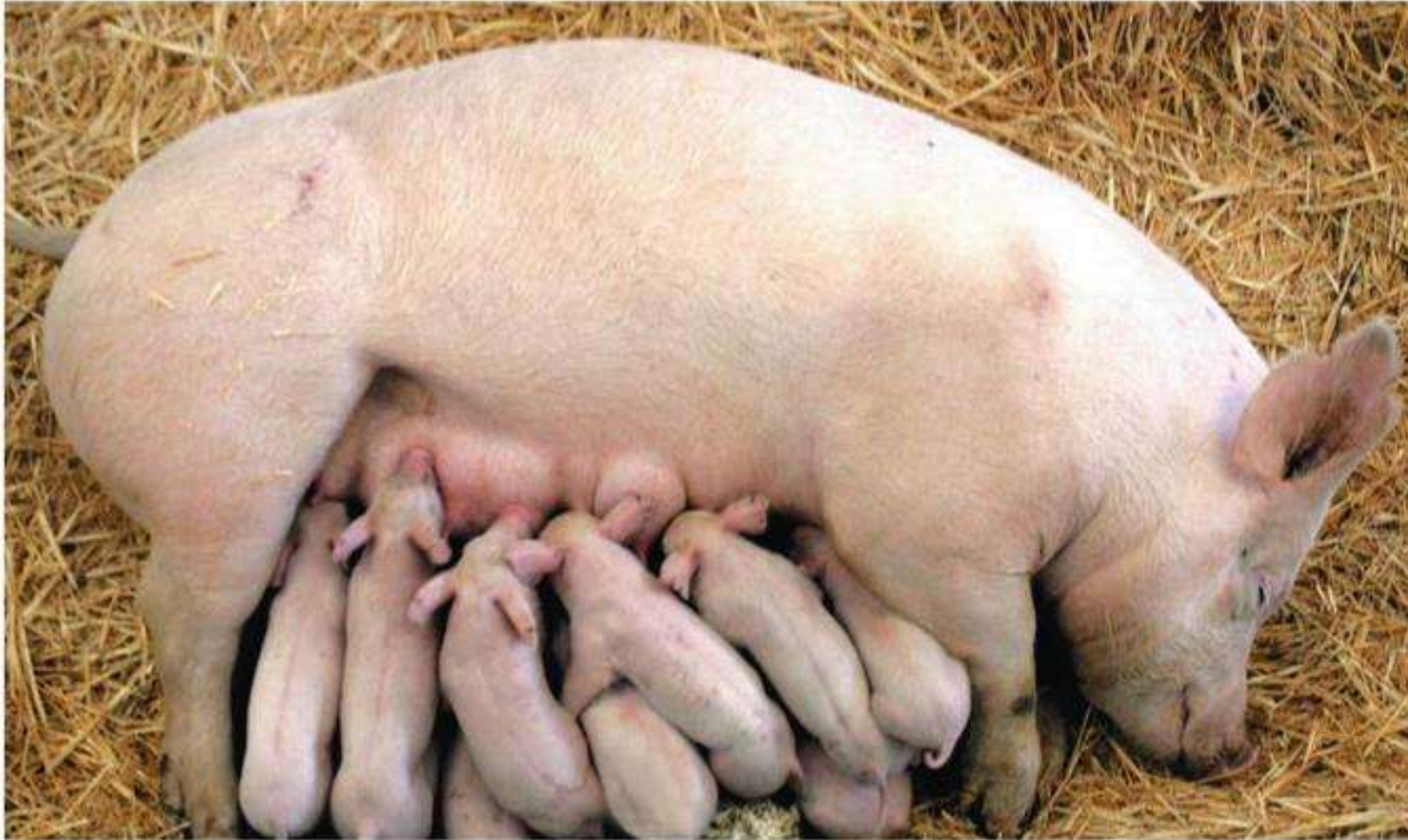
Bodybuilding anabolic steroid!

副作用

http://steroidsideeffect.blogspot.com/2011/12/blog-post_526.html

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

- The hormone prolactin (PRL)
 - is produced and secreted by the anterior pituitary under the direction of the hypothalamus and
 - 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**.
- 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.



Suckling promotes PRL production

26.12 CONNECTION: Hormones can promote social behaviors

- Recently, scientists studied whether it is a hormone that induces the human-dog relationship.
- The hormone oxytocin plays a part in
 - uterine contractions,
 - mammary milk ejection, and
 - promotes mating and maternal bonds.
- Levels of the hormone rise
 - when human mothers gaze into the eyes of their babies and
 - when dog owners received long gazes from their dogs.

You should now be able to

1. Define endocrine disruptors and give two common examples.
2. Compare the mechanisms and functions of the endocrine and nervous systems.
3. Distinguish between the two major classes of vertebrate hormones.
4. Describe experiments demonstrating atrazine's demasculinizing effect on male frogs.
5. Describe the different types and functions of vertebrate endocrine organs.
6. Describe the specific structure, location, and function of the pineal gland.
7. Describe the interrelationships between the hypothalamus and pituitary glands.
8. Describe the functions of the thyroid gland.
9. Describe the three major types of sex hormones and their functions.
10. Explain how insulin and glucagon manage blood glucose levels.
11. Describe the causes and symptoms of type 1 diabetes, type 2 diabetes, and gestational diabetes.
12. Compare the functions of the adrenal gland hormones.
13. Describe the diverse functions of prolactin in vertebrate groups and its evolutionary significance.
14. Explain how hormones can promote social behaviors.