

Hormones

13th lect. of medical chemistry
Dr. Salih Mahdi Salman



Communication Systems

Two systems coordinate communication throughout the body: the endocrine system and the nervous system

1. The endocrine system secretes hormones that coordinate slower but longer-acting responses including reproduction, development, energy metabolism, growth, and behavior.
2. The nervous system conveys high-speed electrical signals along specialized cells called neurons; these signals regulate other cells.

Intercellular Communication

Endocrine versus Nervous system

Nervous System

1. Nervous system performs short term crisis management
2. The nervous system sends electrical messages to control and coordinate the body
3. Nerve impulse is delivered by the axon of a nerve cell called neuron

Endocrine System

1. Endocrine system regulates long term ongoing metabolic activity
2. The endocrine system uses chemicals messenger called hormones to "communicate".
3. Hormones are transported by the blood vessels

Endocrinology

The study of hormones, the endocrine system, and their role in the physiology of the body.

The Endocrine System

The body's slow chemical communication system; a set of glands that secrete hormones into the blood stream.

Functions of the Endocrine System

1. Metabolism and tissue maturation.
2. Ion regulation.
3. Water balance.
4. Immune system regulation.
5. Heart rate and blood pressure regulation.
6. Control of blood glucose and other nutrients.
7. Control of reproductive functions.
8. Uterine contractions and milk release

The endocrine system

The endocrine system includes all the organs and tissues that produce hormones

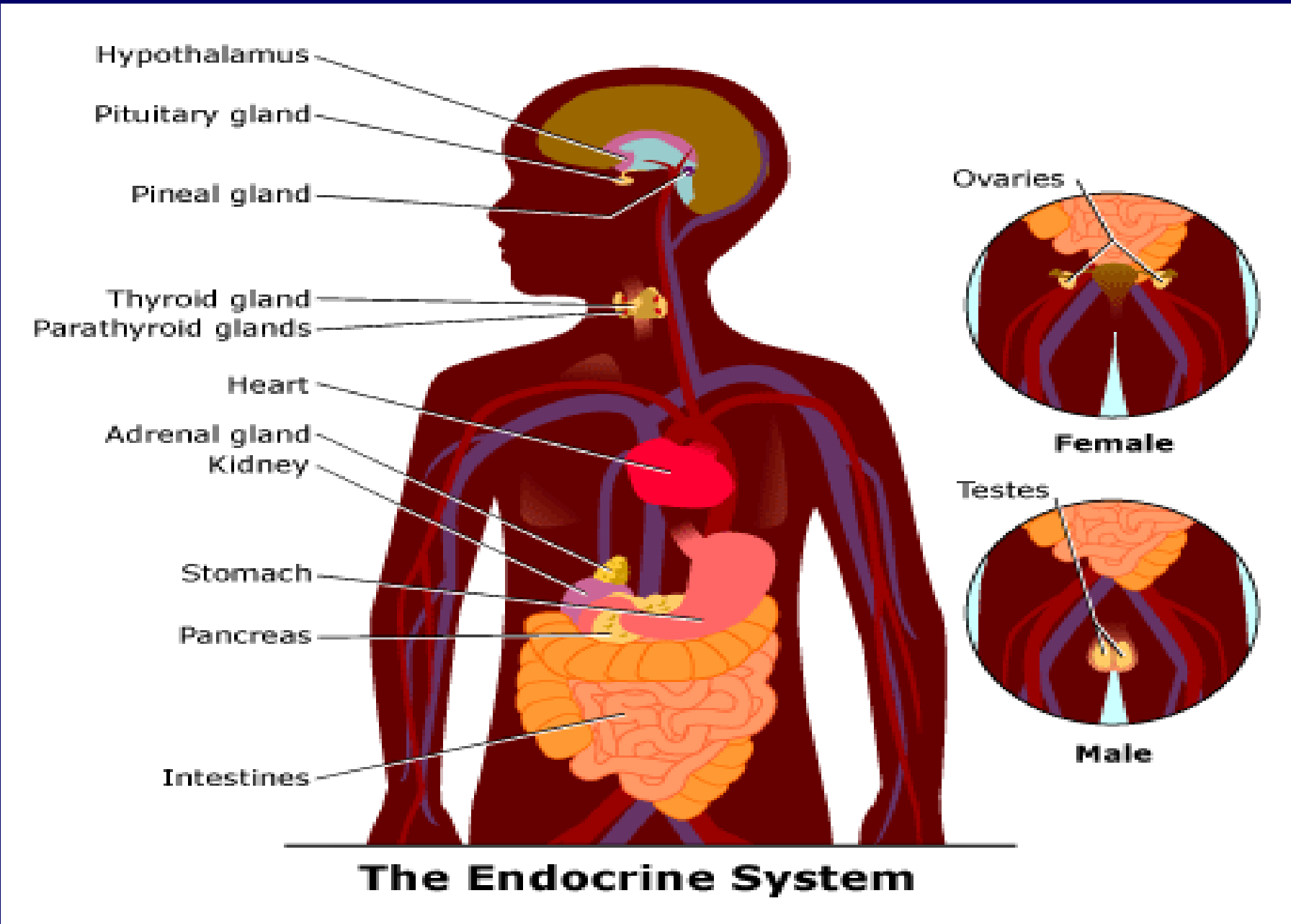
Includes

1. Endocrine glands, which are specialized to secrete hormones ,Also organs, like the liver, that secrete hormones in addition to other functions.
2. Exocrine glands secrete their products, such as saliva or milk, into a duct for transport to the outside

Endocrine system

Following are important endocrine glands;-

1. Hypothalamus
2. Pituitary gland
3. Pineal Gland
4. Thyroid gland
5. Parathyroid gland
6. Thymus
7. Adrenal Gland
8. Gonads (testes/ovaries)
9. Pancreatic Islet
10. Heart
11. Kidney
12. Digestive Tract



Hormones

Hormone a chemical released from living cells that travels some distance to target tissues to have a biological effect.

Hormones chemical messengers convey information via the bloodstream to target cells throughout the body.

Secreted in very small amounts.

Target cells have specific receptors.

Regulates cell reactions by affecting gene expression (often gene transcription factors)

Advantages of using chemical messengers

1. Chemical molecules can spread to all tissues through the blood.
2. Chemical signals can persist longer than electrical ones.
3. Many different kinds of chemicals can act as hormones; different hormones can target different tissues.

Methods of intercellular communication by secreted molecules

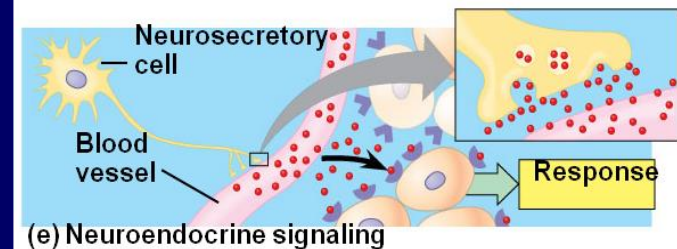
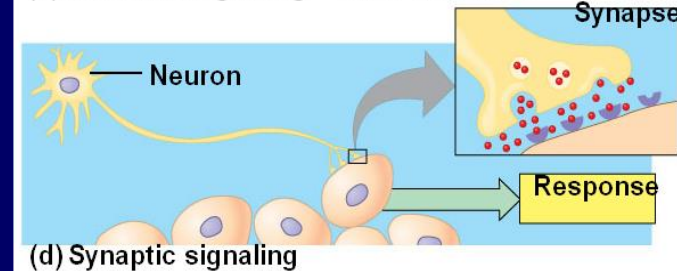
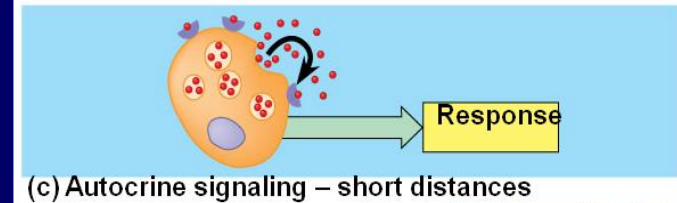
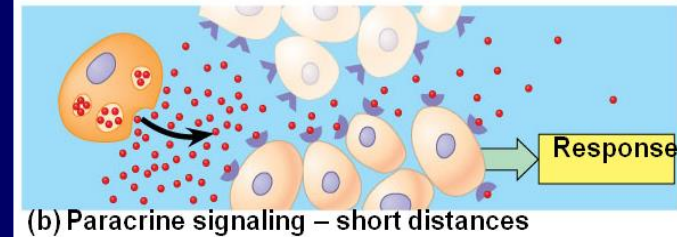
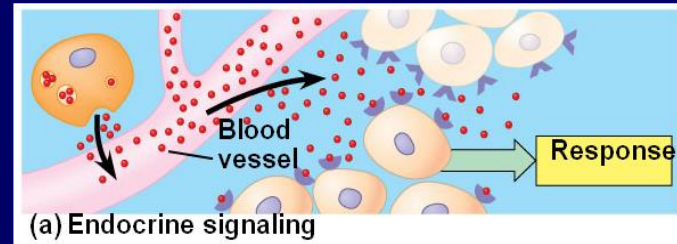
a. Circulating - circulate in blood throughout body

b. Paracrine - act on neighboring cells

c. Autocrine - act on the same cell that secreted them

d. Neurons form specialized junctions with target cells, called **synapses**. At synapses, neurons secrete molecules called **neurotransmitters** that diffuse short distance

e. Neuroendocrine signaling, specialized neurosecretory cells secrete molecules called **neurohormones** that travel to target cells via the bloodstream



Hormones characteristics

Molecules that function as hormones must exhibit two basic characteristics:-

1. Must be sufficiently complex to convey regulatory information to their target cells
2. Must be adequately stable to resist destruction before reaching their target cells

Three chemical classes meet these requirements:-

Hormone structure

Based on their chemical structure hormones are classified into three general classes (groups) of hormones.

- 1) Amino acid derivatives hormones e.g. epinephrine, Structurally similar to amino acids
- 2) Peptide hormones e.g. insulin
Chains of amino acids
- 3) Lipid derivatives hormones e.g. eicosanoids and steroid hormones (prostaglandin is an example of a steroid hormone)

HORMONES

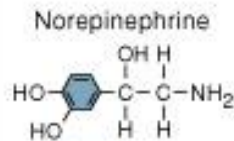
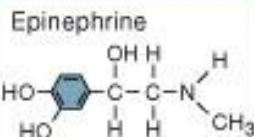
Classified by chemical structure

AMINO ACID DERIVATIVES

Small molecules structurally related to individual amino acids

DERIVATIVES OF TYROSINE

CATECHOLAMINES



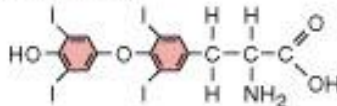
(Secreted by adrenal medulla)



(Secreted by hypothalamus)

THYROID HORMONES (Secreted by thyroid gland)

Thyroxine (T₄)



GLYCOPROTEINS

Pituitary gland

Thyroid-stimulating hormone (TSH)
Luteinizing hormone (LH)
Follicle-stimulating hormone (FSH)

Kidneys

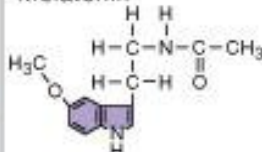
Erythropoietin (EPO)

Reproductive organs

Inhibin

DERIVATIVE OF TRYPTOPHAN

Melatonin



(Secreted by pineal gland)

PEPTIDE HORMONES

Chains of amino acids

EICOSANOIDS

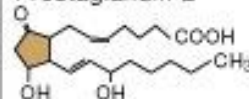
Lipid derivatives of arachidonic acid

Include:

Leukotrienes
Prostaglandins
Thromboxanes
Prostacyclins

EXAMPLE:

Prostaglandin E



SHORT POLYPEPTIDES AND SMALL PROTEINS (Under 200 amino acids)

Hypothalamus

ADH, oxytocin, regulatory hormones

Pituitary gland

ACTH, growth hormone (GH), MSH, prolactin (PRL)

Pancreas

Insulin, glucagon

Parathyroid gland

Parathyroid hormone (PTH)

C cells of thyroid

Calcitonin (CT)

Heart

Atrial natriuretic peptide (ANP)

Brain natriuretic peptide (BNP)

Adipose tissue

Leptin, resistin

Lymphatic system

Hormones discussed in Chapter 22

Digestive tract

Hormones discussed in Chapter 24

LIPID DERIVATIVES

STEROID HORMONES

Structurally related to cholesterol

Gonads

Androgens

Estrogens

Progestins

Adrenal cortex

Mineralocorticoids

Glucocorticoids

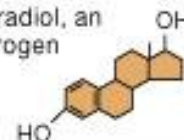
Androgens

Kidneys

Calcitriol

EXAMPLE:

Estradiol, an estrogen



Types of Hormones

1. Protein hormones: These comprise amino acids, those that are only several amino acids in length are called **peptide hormones**, whereas larger ones are called **polypeptide hormones**. They include:

- 1. Insulin:** Made in the pancreas, it increases the entry of glucose into the cells, and regulates fat storage.
- 2. Glucagons:** Made in the pancreas, are responsible for increasing the conversion of stored fats to blood glucose.
- 3. Leptin:** Produced by the fat cells, it informs the brain how much fat is contained in the body.

2. Steroid Hormones. These are derived from cholesterol from the diet and exert their effects in two ways:

- i) They bind directly to membrane receptors.
- ii) As they are fat soluble they pass through cell membranes where they attach to receptors in the cytoplasm. Here they determine gene expression.

There are several types of steroid hormones:

a) Corticoids.

Glucocorticoids (principally cortisol) are released by the adrenal glands in response to stress.

They increase the breakdown of fats and proteins into glucose .

Mineralocorticoids (e.g. aldosterone) are also produced by the adrenal glands and reduce salt secretion in the kidneys.

b) Sex Steroids. These are released mainly by the ovaries and testes but also by the adrenal glands.

They comprise:

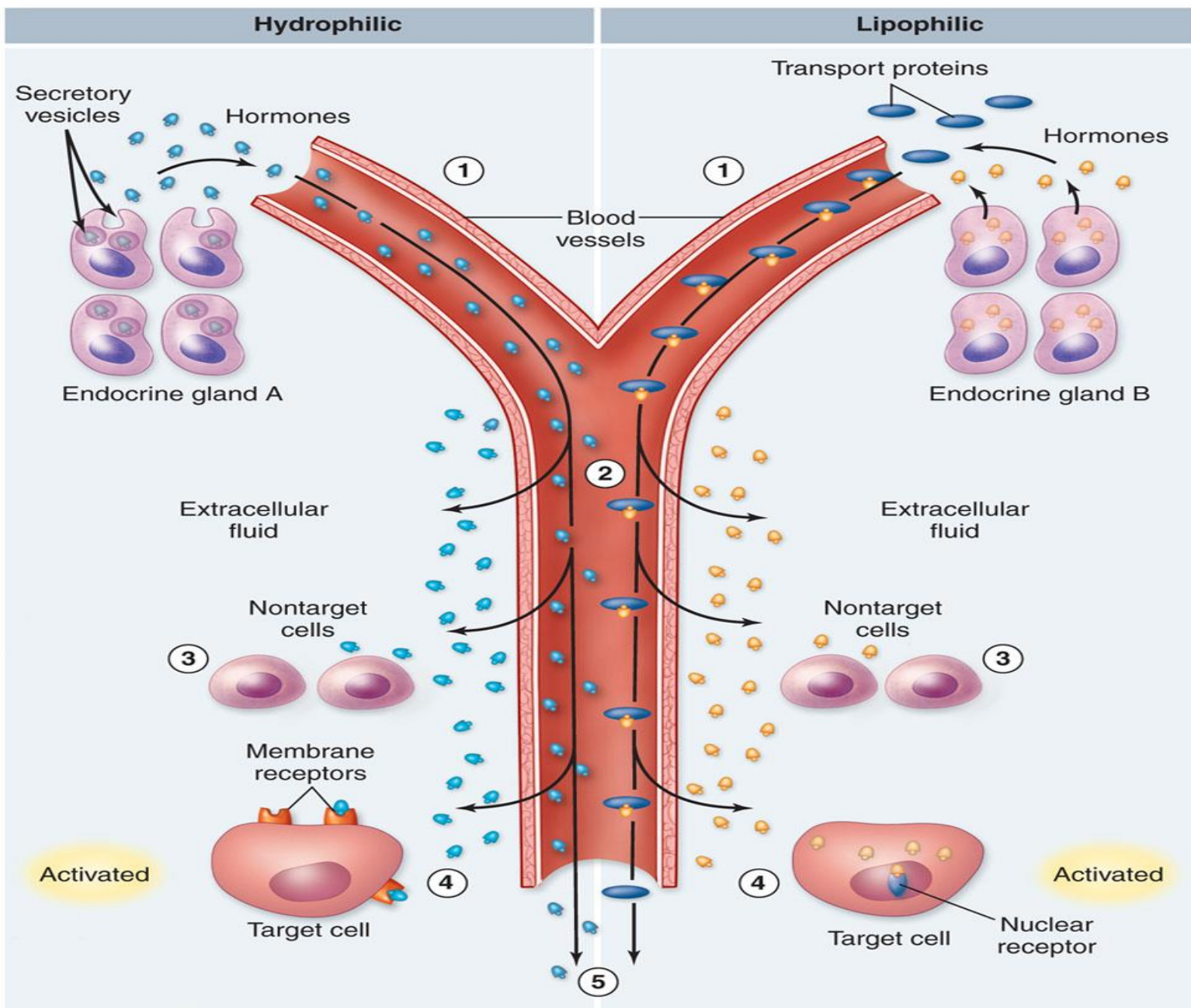
Androgens: Testosterone is produced in large amounts in males and has masculinising and defeminising effects; maintaining male secondary sexual characteristics and promoting courtship, aggressive and sexual behaviours.

Estrogens: Estradiol is produced in large amounts in females and has feminising effects, promoting female secondary sexual characteristics, water retention, calcium metabolism, sexual behaviour and maternal behaviours.

Progesterone prepares the uterus for the implantation of a fertilised ovum and regulates the stages of pregnancy.

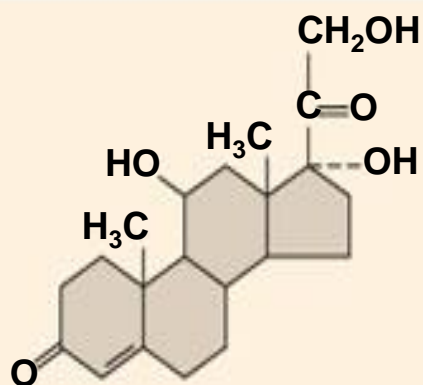
Hormones may be categorized as:

1. **Lipophilic (nonpolar) = fat-soluble**
Steroid hormones and thyroid hormones
Bind to intracellular receptors
2. **Hydrophilic (polar) = water-soluble**
All other hormones
Bind to extracellular receptors



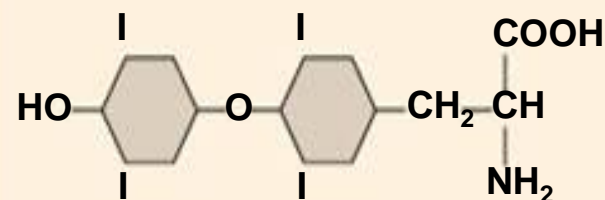
Lipophilic hormones include

- ## Cortisol (Hydrocortisone)



Chemical structure of Steroid 1: A four-ring steroid nucleus with a ketone group at C3, a double bond at C5, a methyl group at C10, and a hydroxyl group at C17.

Thyroxine



1. These hormones circulate in the blood bound to transport proteins.
2. Dissociate from carrier at target cells.
3. Pass through the cell membrane and bind to an intracellular receptor, either in the cytoplasm or the nucleus.
4. Hormone-receptor complex binds to hormone response elements in DNA Regulate gene expression

Hydrophilic Hormones

Hydrophilic hormones include the peptide, protein and catecholamine hormones.

Too large or polar to cross cell membrane
Hormones bind to extracellular receptors

Signaling by hormones

Signaling by any of these hormones involves three steps:

1. Reception
2. Signal transduction
3. Response

Binding of a hormone to its receptor initiates a signal transduction pathway leading to responses in the cytoplasm or a change in gene expression

Mechanisms of hormone action

Response depends on both hormone and target cell.

Lipid-soluble hormones bind to receptors inside target cells

Water-soluble hormones bind to receptors on the plasma membrane

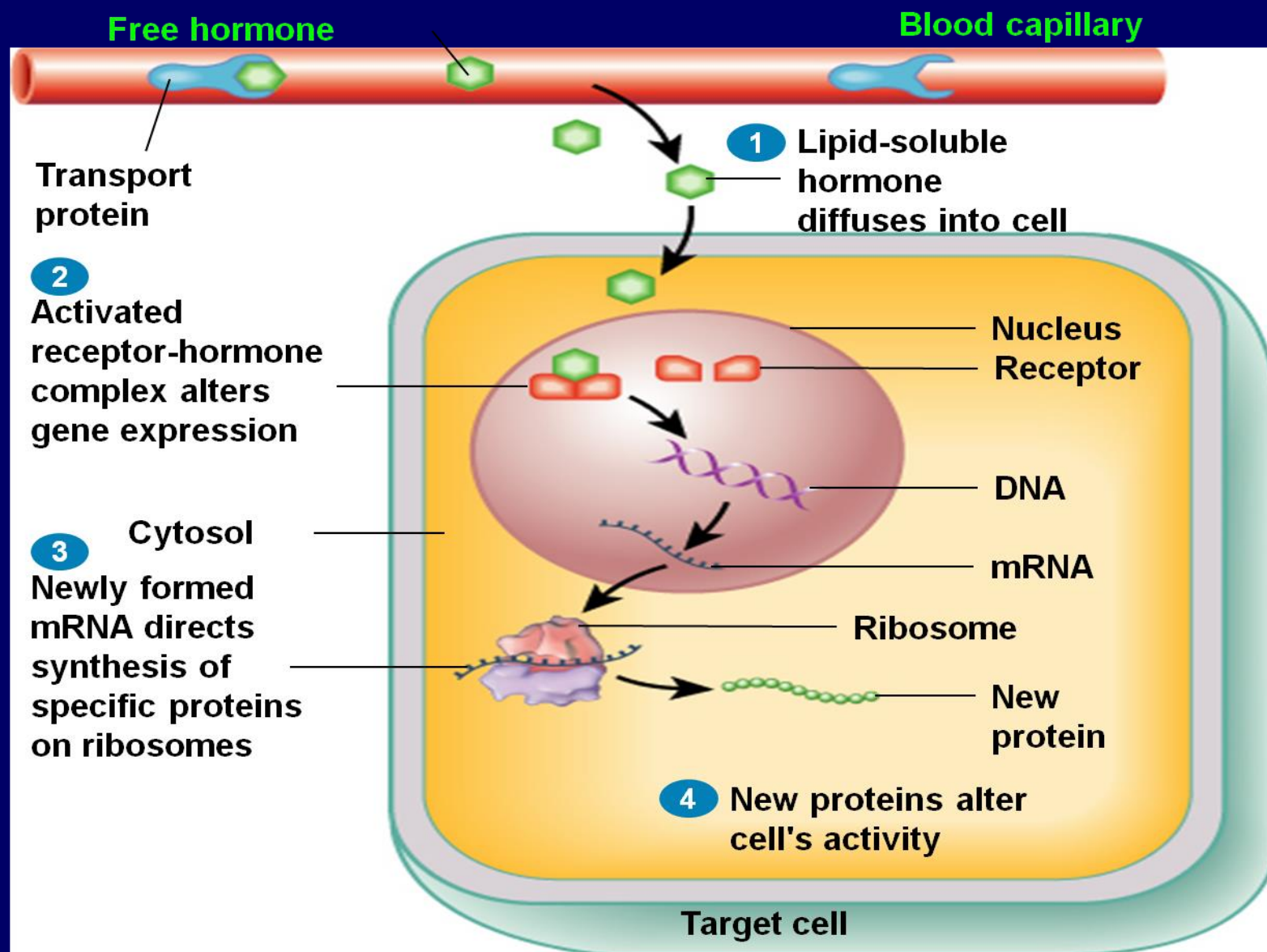
Activates second messenger system

Amplification of original small signal

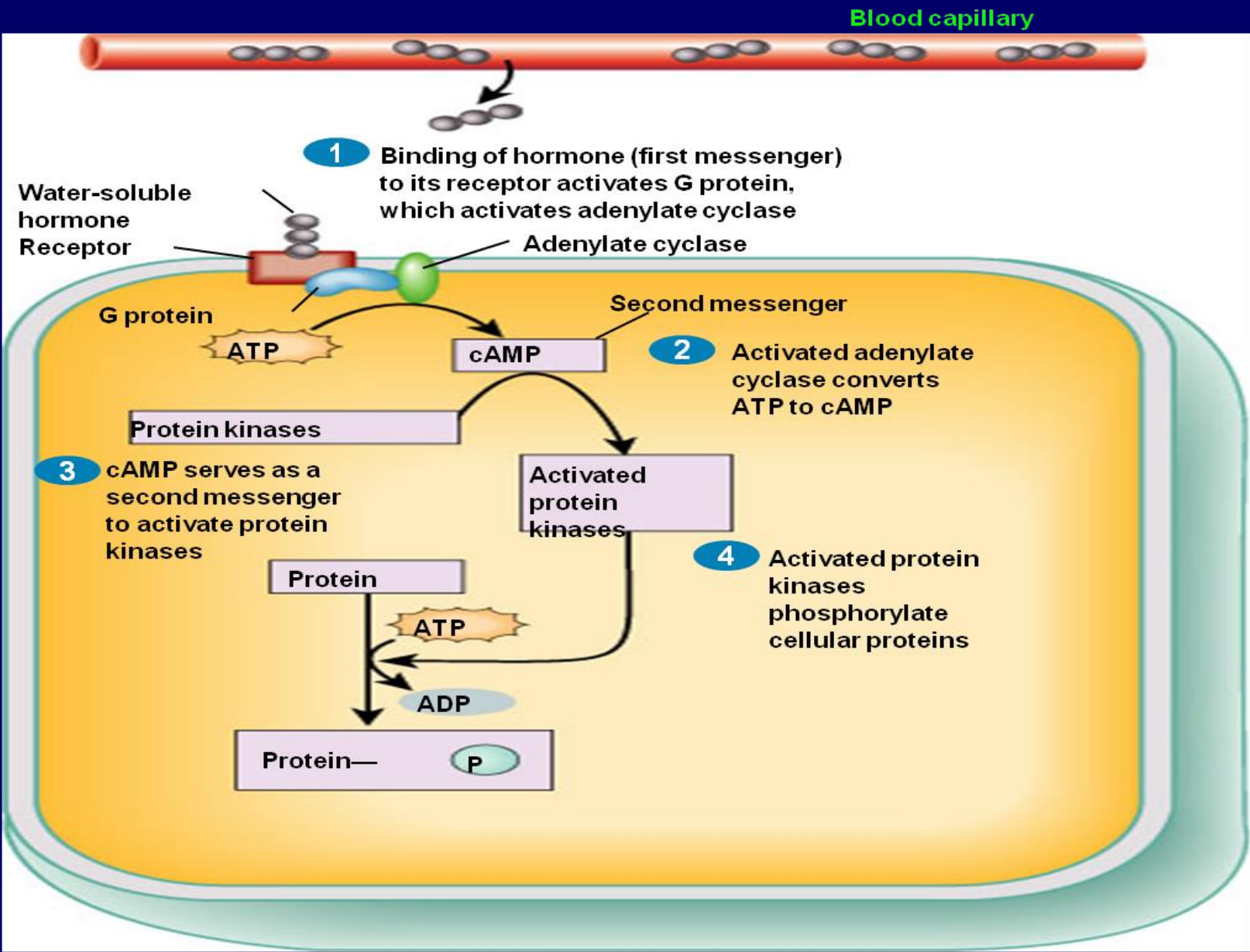
Responsiveness of target cell depends on

1. Hormone's concentration
2. Abundance of target cell receptors
3. Influence exerted by other hormones

Lipid-soluble Hormones



Water-soluble Hormones



Target cell

Types of receptors

1. Receptors for the water soluble hormones are found on the surface of the target cell, on the plasma membrane.

These types of receptors are coupled to various second messenger systems which mediate the action of the hormone in the target cell.

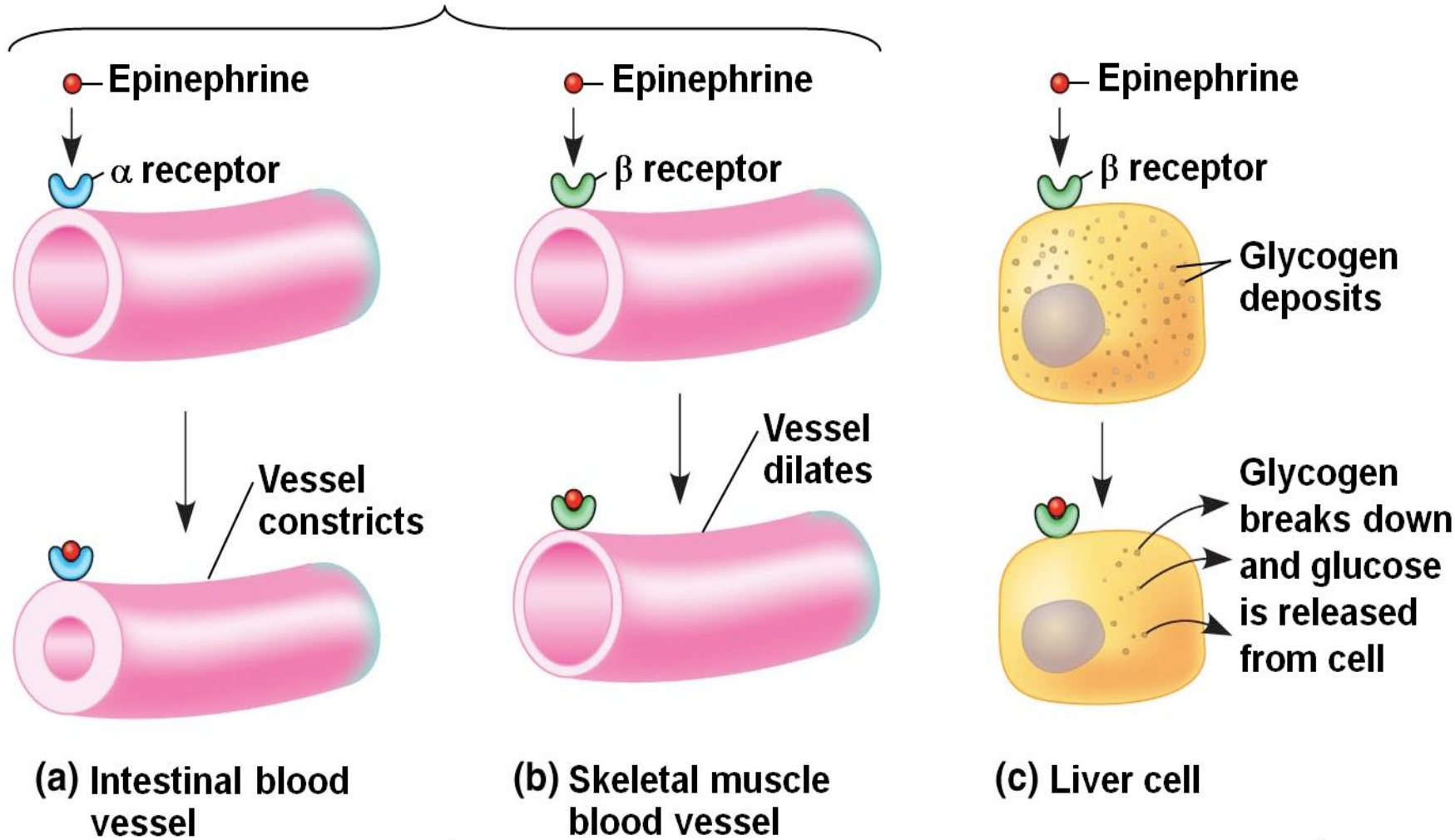
2. Receptors for the lipid soluble hormones reside in the nucleus (and sometimes the cytoplasm) of the target cell.

Because these hormones can diffuse through the lipid bilayer of the plasma membrane, their receptors are located on the interior of the target cell

The same hormone may have different effects on target cells that have

1. Different receptors for the hormone
2. Different signal transduction pathways
3. Different proteins for carrying out the response

Different receptors → different cell responses



Different intracellular proteins → different cell responses

Hormones and their receptors

Hormone	Class of hormone	Location
Amine (epinephrine)	Water-soluble	Cell surface
Amine (thyroid hormone)	Lipid soluble	Intracellular
Peptide/ protein	Water soluble	Cell surface
Steroids and Vitamin D	Lipid Soluble	Intracellular

Control of Hormone Release

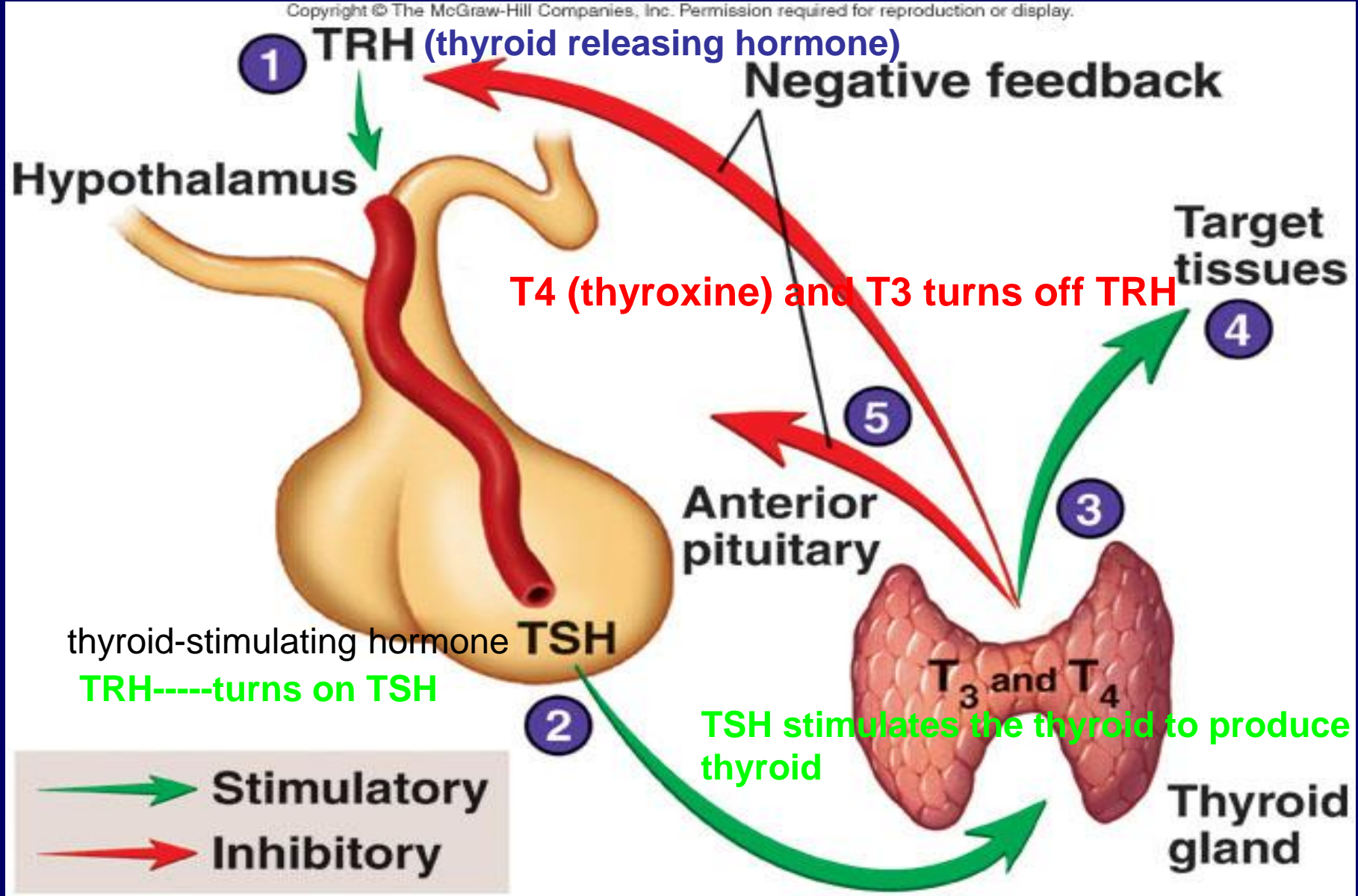
Hormone release is controlled by two key structures in the brain:

1. **Hypothalamus:** This is located at the base of the brain and consists of several interconnected nuclei.

The hypothalamic nuclei synthesise releasing hormones that either stimulate or inhibit the release of hormones from the pituitary gland.

The hypothalamus controls secretion of hormones which in their turn control the secretion of hormones by the thyroid gland, the adrenal cortex and gonads: in this way the brain controls these endocrine glands.

Negative Feedback in the Hypothalamus



2. Pituitary Gland

This is called 'the master gland' as it produces at least 10 hormones which influence the other endocrine glands via the hypothalamus.

It consists of two separate regions.

The anterior pituitary and the posterior pituitary each share distinct connections with the hypothalamus.

Anterior Pituitary Gland

The four strictly **tropic** hormones are:

1. **Luteinizing Hormone (LH):** Increases production of progesterone and stimulates ovulation in females. In males it increases production of testosterone.
2. **Follicle-Stimulating Hormone (FSH):** Increases production of estrogen and maturation of the ovum (in females) and sperm (in males).
3. **Thyroid-Stimulating Hormone (TSH):** Controls secretions of the thyroid gland.
4. **Adrenocorticotrophic Hormone (ACTH):** Controls secretions of the adrenal gland.

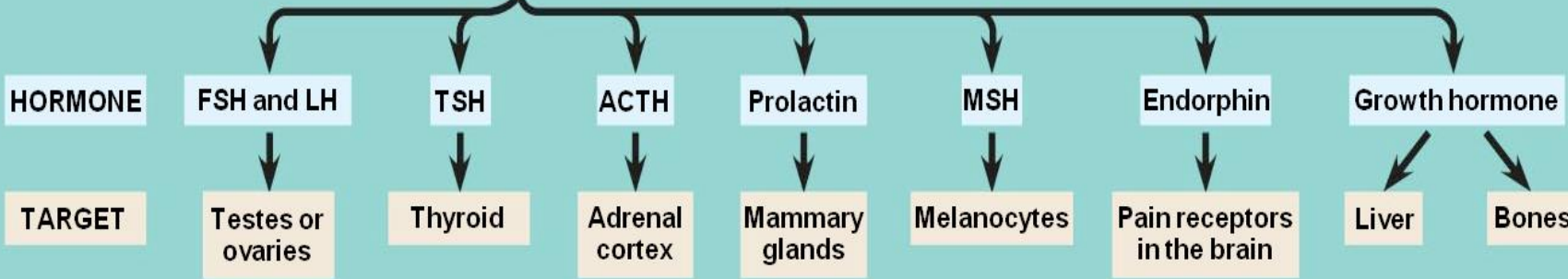
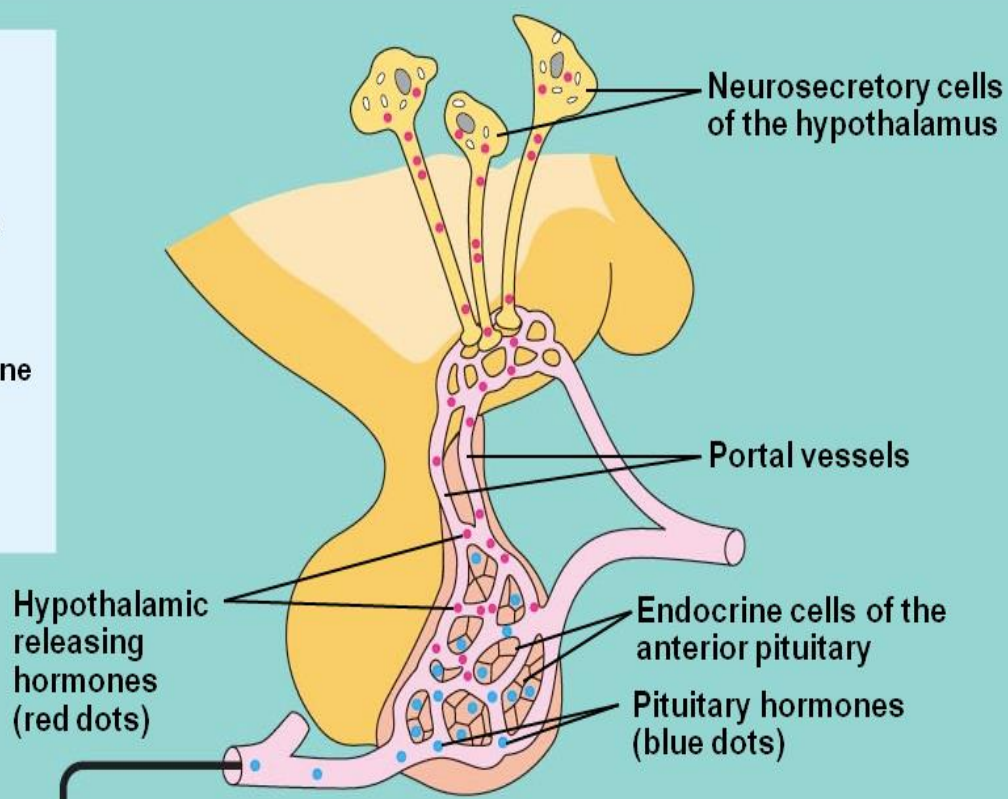
Each **tropic** hormone acts on its target endocrine tissue to stimulate release of hormone(s) with direct metabolic or developmental effects

Non-tropic hormones are those that act directly on targeted tissues or cells, and not on other endocrine .

Nontropic hormones produced by the anterior pituitary:

1. **Prolactin** stimulates lactation in mammals but has diverse effects in different vertebrates
2. **MSH** influences skin pigmentation in some vertebrates and fat metabolism in mammals
3. **Endorphins** inhibit pain

- Tropic Effects Only
 - FSH, follicle-stimulating hormone
 - LH, luteinizing hormone
 - TSH, thyroid-stimulating hormone
 - ACTH, adrenocorticotrophic hormone
- Nontropic Effects Only
 - Prolactin
 - MSH, melanocyte-stimulating hormone
 - Endorphin
- Nontropic and Tropic Effects
 - Growth hormone



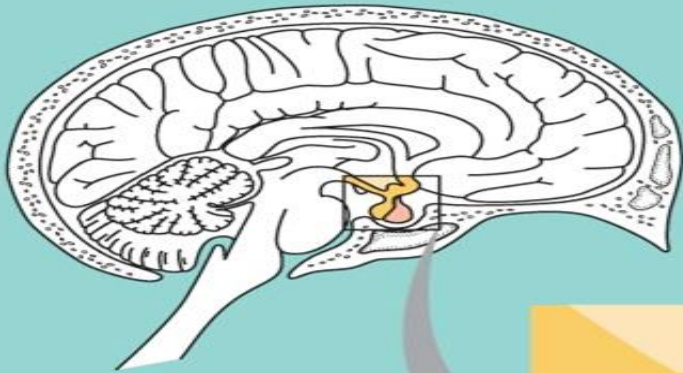
Posterior Pituitary Gland

Posterior Pituitary Gland does not synthesize hormones.

Stores and releases hormones made by the hypothalamus.

The two hormones released from the **posterior pituitary** act directly on nonendocrine tissues

1. **Oxytocin** induces uterine contractions and milk ejection
2. **Antidiuretic hormone (ADH)** enhances water reabsorption in the kidneys, Also decreases water lost through sweating and constriction of arterioles which increases blood pressure (vasopressin)



Oxytocin induces uterine contractions and milk ejection
Antidiuretic hormone (ADH) enhances water reabsorption in the kidneys

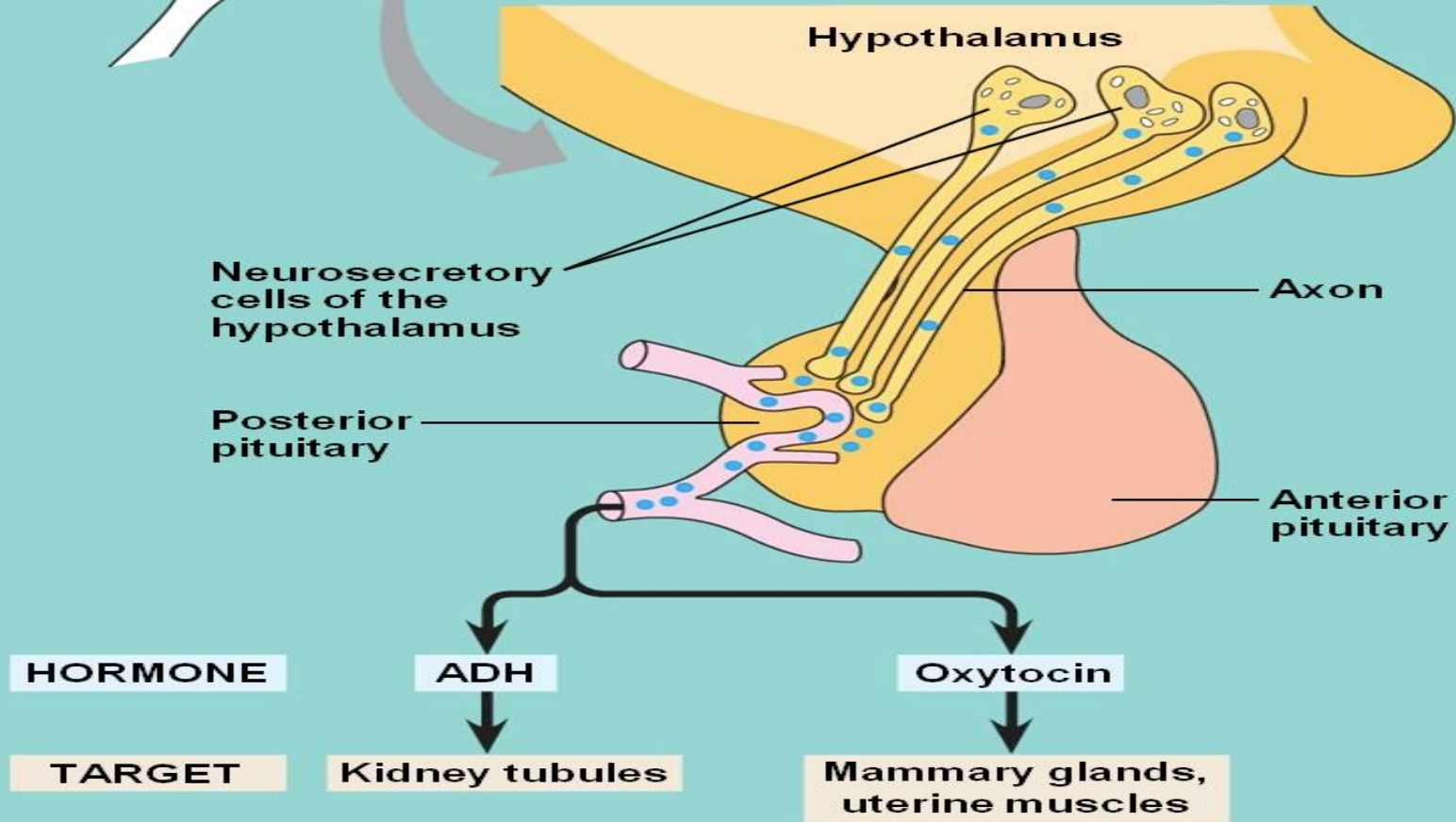


Table 45.1 Major Human Endocrine Glands and Some of Their Hormones










Gland		Hormone	Chemical Class	Representative Actions	Regulated By
Hypothalamus		Hormones released from the posterior pituitary and hormones that regulate the anterior pituitary (see below)			
Posterior pituitary gland (releases neurohormones 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 gland		Growth hormone (GH)	Protein	Stimulates growth (especially bones) and metabolic functions	Hypothalamic hormones
		Prolactin	Protein	Stimulates milk production and secretion	Hypothalamic hormones
		Follicle-stimulating hormone (FSH)	Glycoprotein	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	Hypothalamic hormones
		Adrenocorticotrophic hormone (ACTH)	Peptide	Stimulates adrenal cortex to secrete glucocorticoids	Hypothalamic hormones
Thyroid gland		Triiodothyronine (T ₃) and thyroxine (T ₄)	Amines	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 Major Human Endocrine Glands and Some of Their Hormones (continued)

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	Amines	Raise blood glucose level; increase metabolic activities; constrict certain blood vessels	Nervous system
Adrenal cortex	Glucocorticoids	Steroids	Raise blood glucose level	ACTH
	Mineralocorticoids	Steroids	Promote reabsorption of Na ⁺ and excretion of K ⁺ in kidneys	K ⁺ in blood; angiotensin II
Gonads				
Testes	Androgens	Steroids	Support sperm formation; promote development and maintenance of male secondary sex characteristics	FSH and LH
Ovaries 	Estrogens	Steroids	Stimulate uterine lining growth; promote development and maintenance of female secondary sex characteristics	FSH and LH
	Progestins	Steroids	Promote uterine lining growth	FSH and LH
Pineal gland 	Melatonin	Amine	Involved in biological rhythms	Light/dark cycles



Thank you for your attention

