Course: Animal form and function

Chapter: 4

COMMUNICATION III:

- THE ENDOCRINE SYSTEM

AND CHEMICAL MESSENGERS,

- MECHANISM OF HORMONE ACTION,
- AN OVERVIEW OF VERTEBRATE ENDOCRINE SYSTEM.

CHEMICAL MESSENGERS

The development of most animals depends on continued cell proliferation, growth, and differentiation. The integration of these events, as well as the communication and coordination of physiological processes, such as metabolism, respiration, excretion, movement, and reproduction, depend on chemical messengers—molecules that specialized cells synthesize and secrete.

Categories of Chemical messengers

- Local chemical messengers
- Neurotransmitters
- Neuropeptides
- Hormones
- Pheromones

1) Local chemical messengers

- Many cells secrete chemicals that alter physiological conditions in the immediate vicinity.
- Most of these chemicals act on adjacent cells and do not accumulate in the blood.

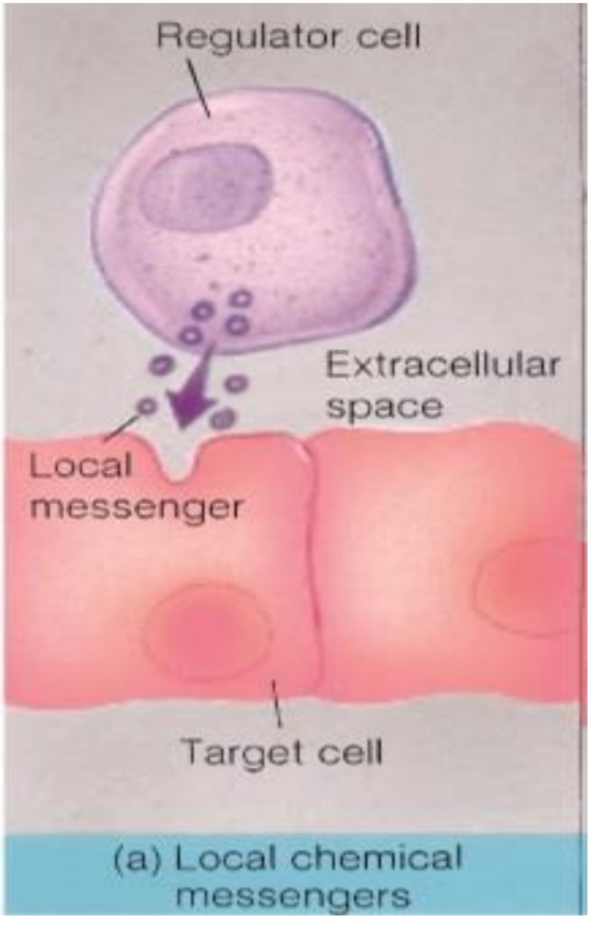


Fig (a): Short-distance local messengers act on an adjacent cell.

Examples:

✓ Vertebrate examples include some of the chemicals called lumones that the gut produces and that help regulate digestion.

✓ In a wound, mast cells secrete a substance called histamine that participates in the inflammatory response.

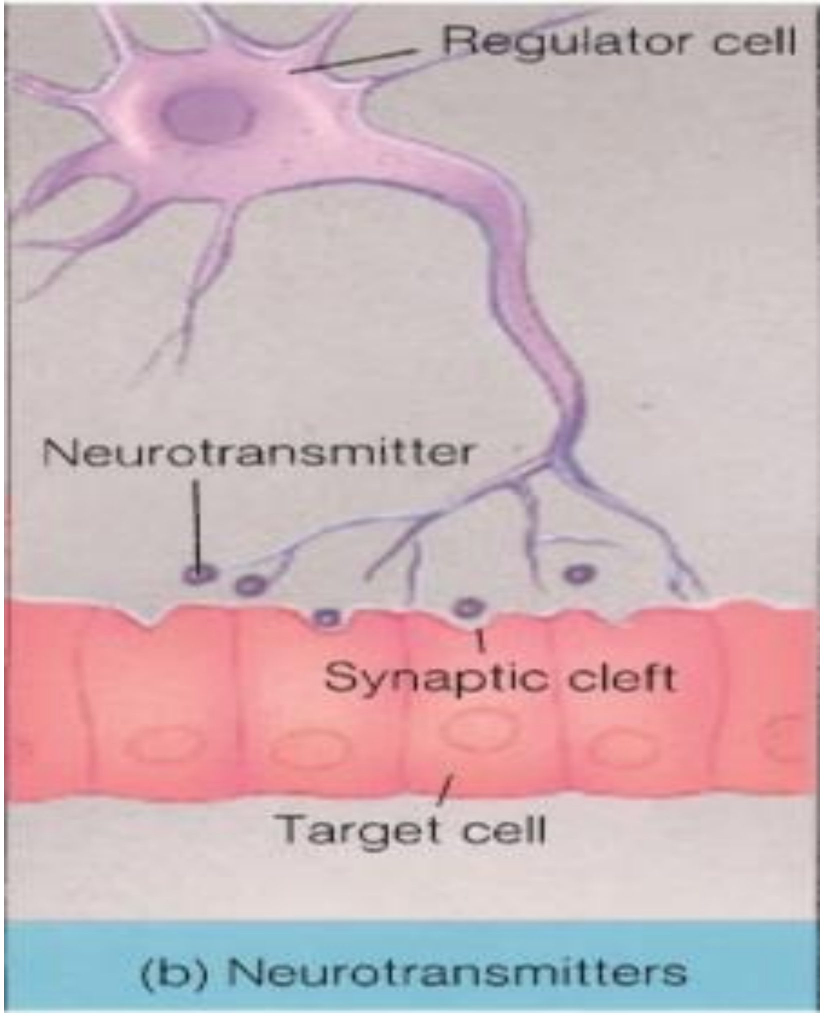
2) Neurotransmitters

neurons secrete chemicals called neurotransmitters that act on immediately adjacent target cells.

These chemical messengers reach high concentrations in the synaptic cleft, act quickly, and are actively degraded and recycled.

Examples:

- ✓ nitric oxide
- ✓ Acetylcholine etc.



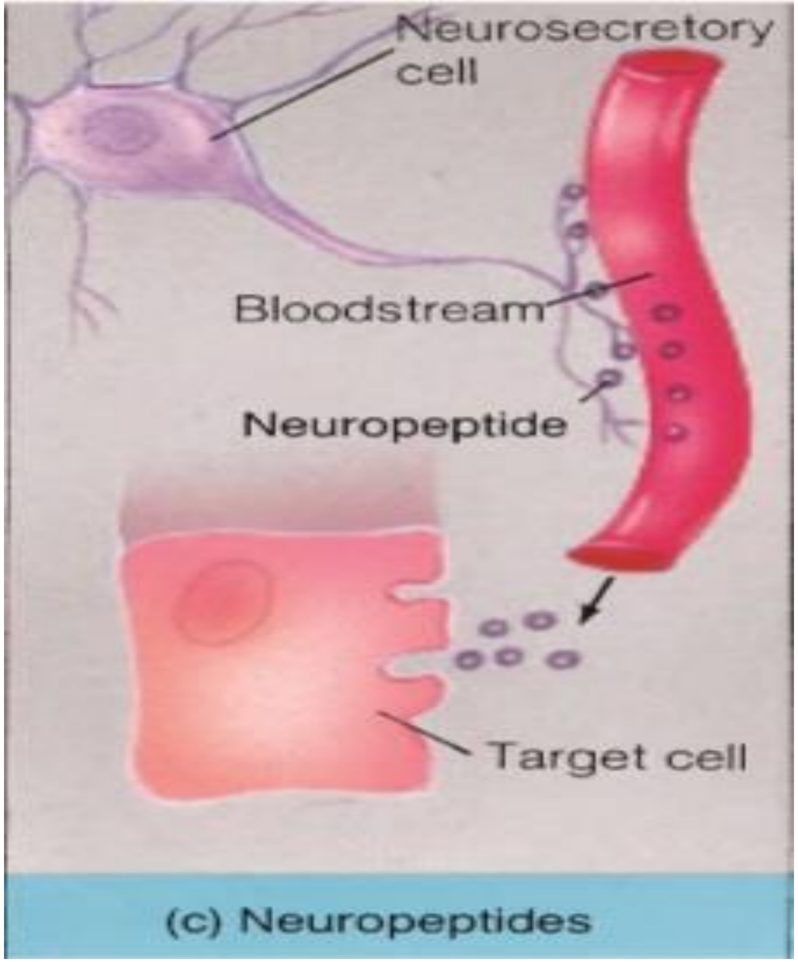
Fig(b): Individual nerve cells secrete neurotransmitters that cross the synaptic cleft to act on target cells.

3) Neuropeptides

- Some specialized neurons (called neurosecretory cells) secrete neuropeptides (neurohormones).
- The blood or other body fluids transport neuropeptides to nonadjacent target cells,

Examples:

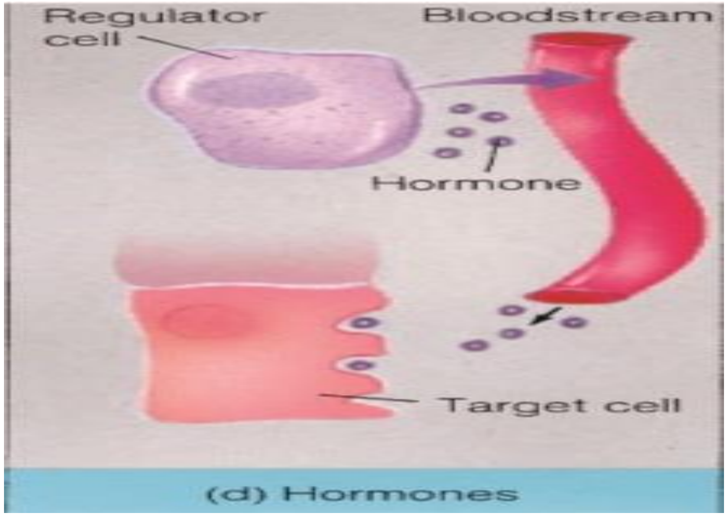
- ✓ In mammals certain nerve cells in the hypothalamus release a neuropeptide that causes the pituitary gland to release the hormone oxytocin, which induces powerful uterine contractions during the delivery of offspring.



Fig(c): Individual nerve cells can also secrete neuropeptides (neurohormones) that travel some distance in the bloodstream to reach a target cell.

4) Hormones

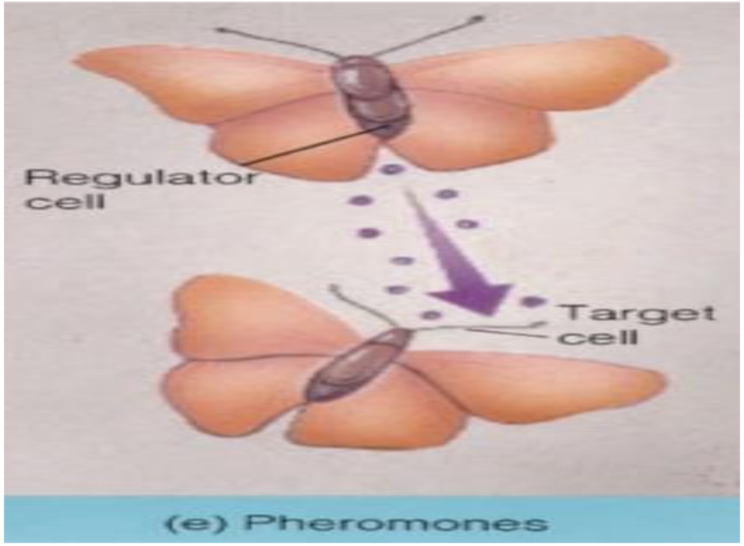
Endocrine glands or cells secrete hormones that the bloodstream transports to nonadjacent target cells.



Fig(d): Regulatory cells, usually in an endocrine gland, secrete hormones, which enter the bloodstream and travel to target cells.

5) Pheromones

Pheromones are chemical messengers released to the exterior of one animal that affect the behavior of another individual of the same species



Fig(e): Regulatory cells in exocrine glands secrete pheromones. They leave the body and stimulate target cells in another animal

FEEDBACK CONTROL SYSTEM OF HORMONE SECRETION

Positive feedback system

- reinforces the initial stimulus
- Positive feedback systems are relatively rare in animals
- usually lead to instability or pathological states

Negative feedback system

- monitor the amount of hormone secreted.
- altering the amount of cellular activity as needed to maintain homeostasis.

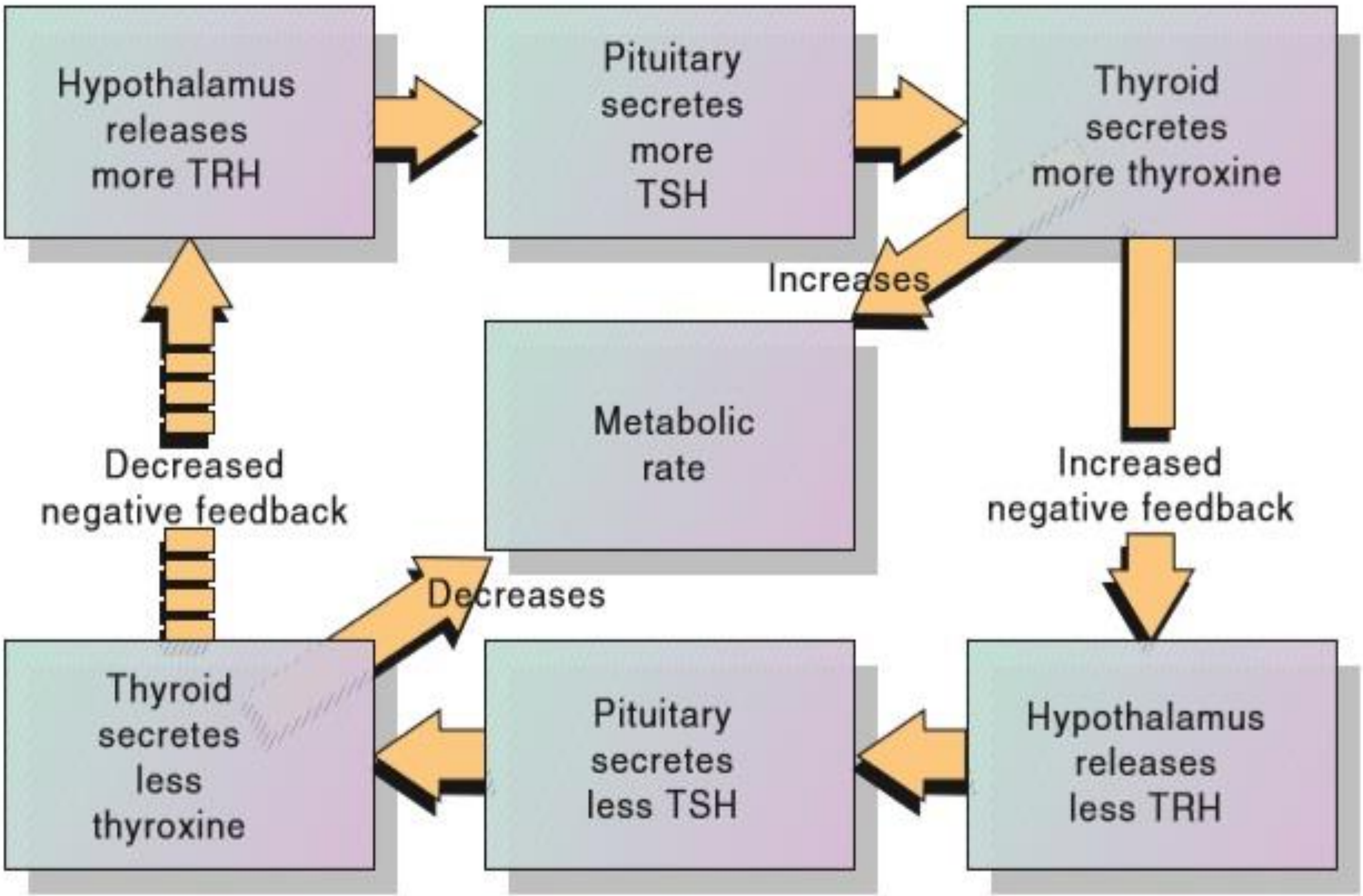
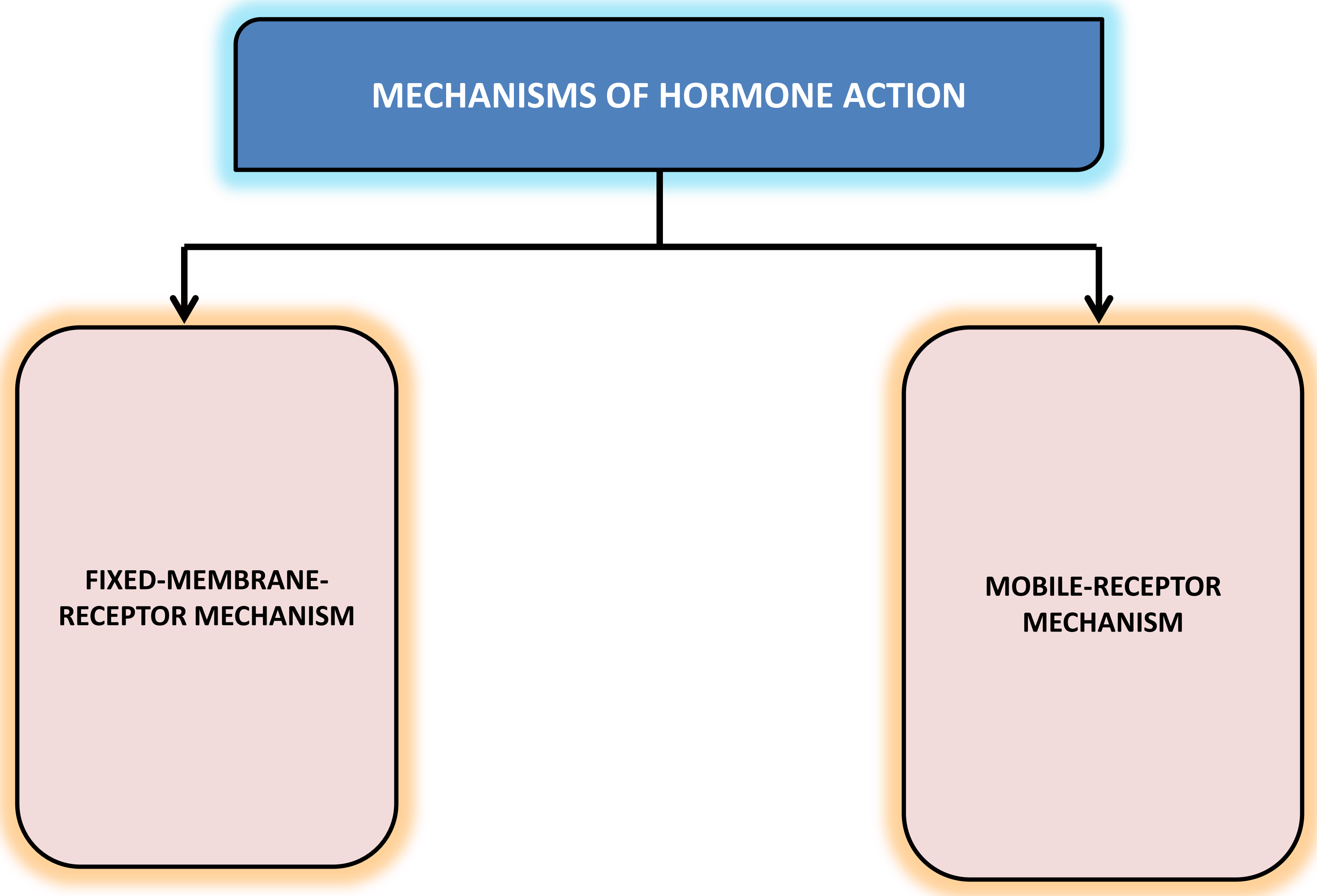


Fig: Hormonal Feedback. Negative feedback system that helps control metabolic rate in a vertebrate such as a dog. (TRH thyrotropin releasing hormone; TSH thyroid-stimulating hormone.)


MECHANISMS OF HORMONE ACTION
FIXED-MEMBRANE-RECEPTOR MECHANISM
MOBILE-RECEPTOR MECHANISM

FIXED-MEMBRANE-RECEPTOR MECHANISM

An endocrine cell secretes a water-soluble hormone that circulates through the blood stream

At the cells of the target organ, the hormone acts as a "first or extracellular messenger," binding to a specific receptor site for that hormone on the plasma membrane

The hormone-receptor complex activates the enzyme adenylate cyclase in the membrane

The activated enzyme converts ATP into a nucleotide called cyclic AMP, which becomes the "second (or intracellular) messenger."

Cyclic AMP diffuses throughout the cytoplasm and activates an enzyme called protein kinase, which causes the cell to respond with its distinctive physiological activity

After inducing the target cell to perform its specific function, the enzyme phosphodiesterase inactivates cyclic AMP

the receptor on the plasma membrane loses the first messenger and now becomes available for a new reaction.

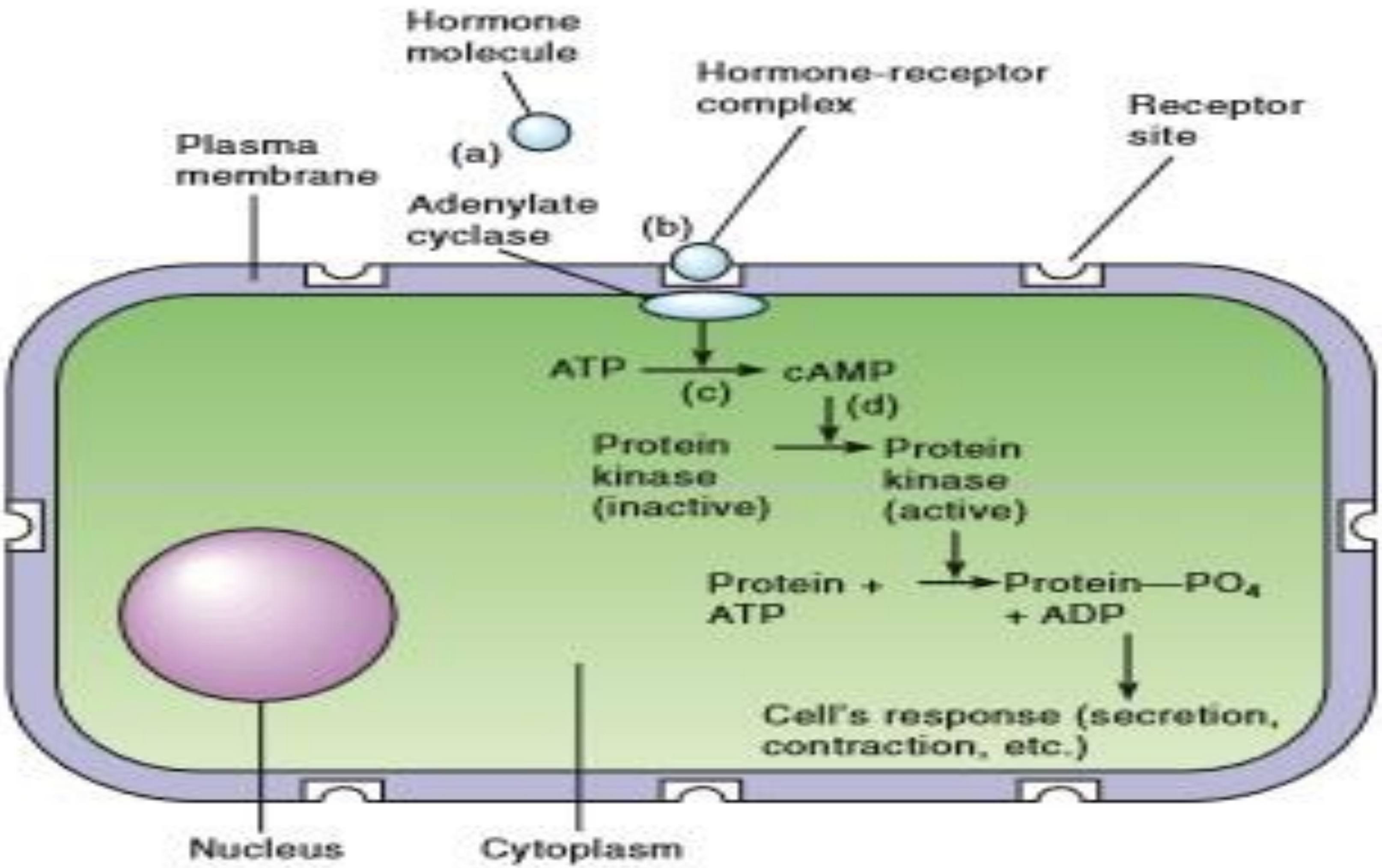


Fig: Steps of the Fixed-Membrane-Receptor Mechanism of Hormonal Action. (a) A protein hormone molecule (such as epinephrine) diffuses from the blood to a target cell. (b) The binding of the hormone to a specific plasma membrane receptor activates adenylate cyclase (a membrane-bound enzyme system). (c) This enzyme system catalyzes cyclic AMP formation (the second messenger) inside the cell. (d) Cyclic AMP (cAMP) diffuses throughout the cytoplasm and activates an enzyme called protein kinase, which then phosphorylates specific proteins in the cell, thereby triggering the biochemical reaction, leading ultimately to the cell's response

MOBILE-RECEPTOR MECHANISM

The mobile receptor mechanism involves the stimulation of protein synthesis

After being released from a carrier protein in the bloodstream, the steroid hormone enters the target cell by diffusion and binds to a specific protein receptor in the cytoplasm

This newly formed steroid-protein complex acquires an affinity for DNA that causes it to enter the nucleus of the cell, where it binds to DNA and regulates the transcription of specific genes to form messenger RNA

The newly transcribed mRNA leaves the nucleus and moves to the rough endoplasmic reticulum, where it initiates protein synthesis

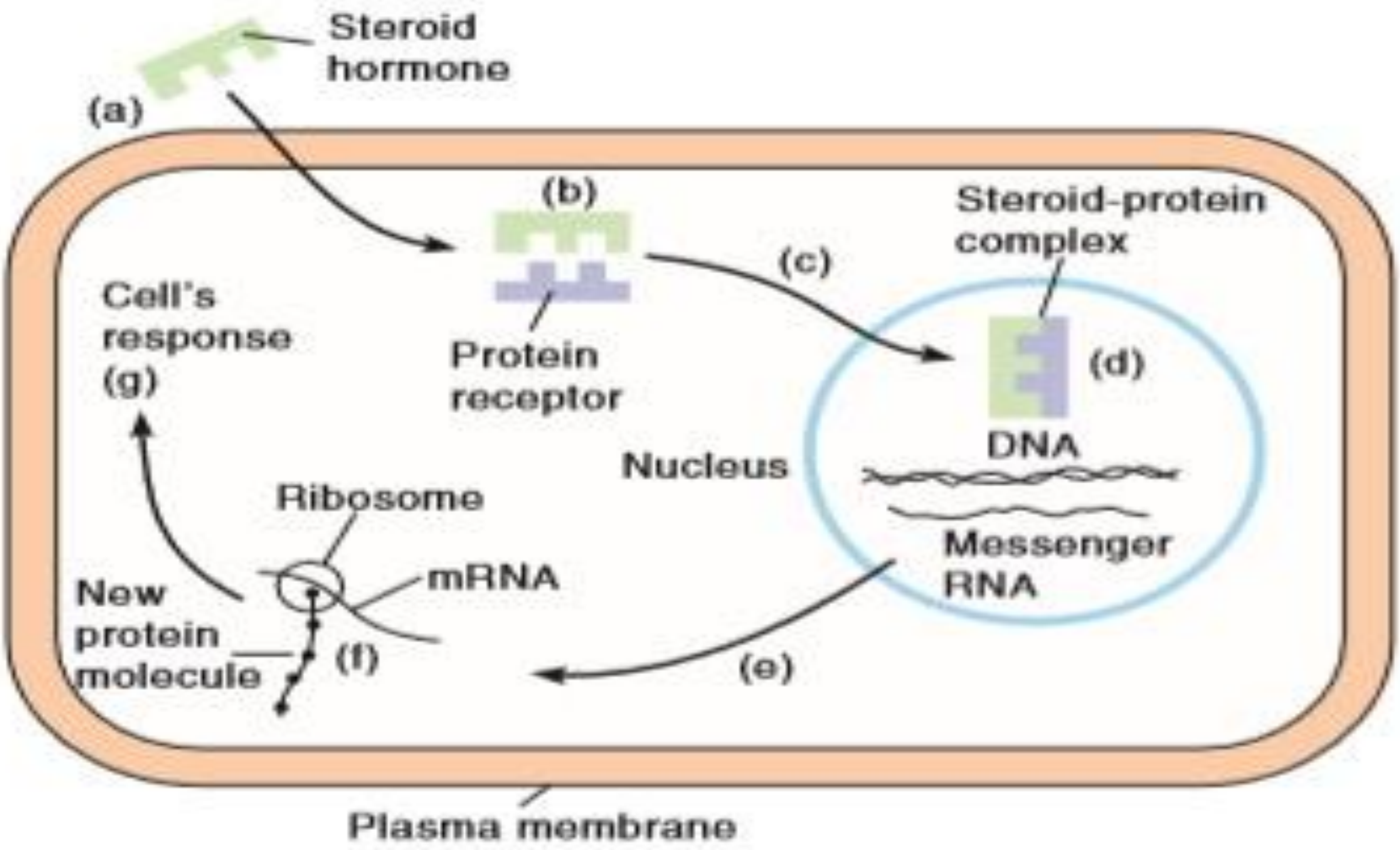


Fig: Steps of the Mobile-Receptor Mechanism. (a) A steroid hormone molecule (e.g., testosterone) diffuses from the blood to a target cell and then across the plasma membrane of the target cell. (b) Once in the cytoplasm, the hormone binds to a receptor that (c) carries it into the nucleus. (d) This steroid-protein complex triggers transcription of specific gene regions of DNA. (e) The messenger RNA transcript is then translated into a gene product via (f) protein synthesis in the cytoplasm. (g) The new protein then mediates the cell's response.

SOME HORMONES OF VERTEBRATES

As the earliest vertebrates evolved, hormone-producing cells and tissues developed, and came to be controlled in several ways. Sets of nerve cells in the brain direct some endocrine tissues, such as the medullary areas of the adrenal glands. The hypothalamus of the brain and the pituitary gland (hypophysis) control others. Still others function independently of either nerves or the pituitary gland.

Vertebrates possess two types of glands

1) exocrine glands

- ✓ Secrete chemicals into ducts.
- ✓ Empty into body cavities or onto body surfaces (e.g., mammary, salivary, and sweat glands

2) endocrine glands

- ✓ Have no ducts
- ✓ Secrete hormones, directly into the tissue space next to each endocrine cell.
- ✓ The hormones diffuse into the bloodstream, which carries them throughout the body to their target cells.

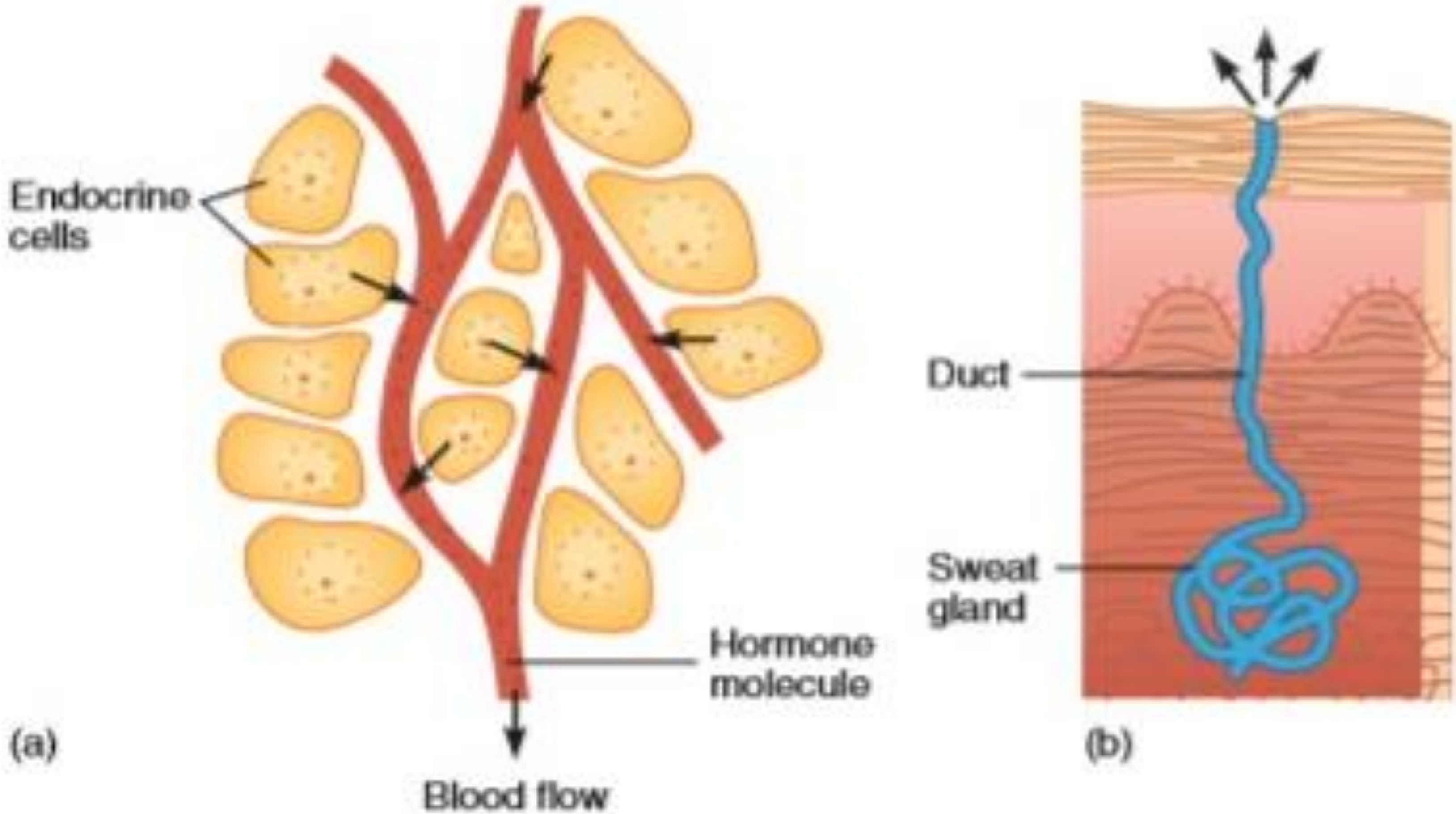


Fig: Vertebrate Glands with and without Ducts. (a) An endocrine gland, such as the thyroid, secretes hormones into the extracellular fluid. From there, the hormones pass into blood vessels and travel throughout the body. (b) An exocrine gland, such as a sudoriferous (sweat) gland, secretes material (sweat) into a duct that leads to a body surface

ENDOCRINE SYSTEM OF VERTEBRATES OTHER THAN BIRDS OR MAMMALS

Recent research has revealed the following three aspects of endocrinology that relate to species differences among these vertebrates:

1. Hormones (or neuropeptides) with the same function in different species may not be chemically identical.
2. Certain hormones are species-specific with respect to their function; conversely, some hormones produced in one species may be completely functional in another species.
3. A hormone from one species may elicit a different response in the same target cell or tissue of a different species.

In jawed fishes:

Three major regions secrete neuropeptides

pineal gland
of the epithalamus

- ✓ affect pigmentation .
- ✓ apparently inhibit reproductive development
- ✓ produces, melatonin, has broad effects on body metabolism

preoptic nuclei
of the hypothalamus

- ✓ control growth
- ✓ sleep
- ✓ locomotion

urophysis
in the spinal cord of the tail

- ✓ Control water and ion balance,
- ✓ blood pressure
- ✓ smooth muscle contractions

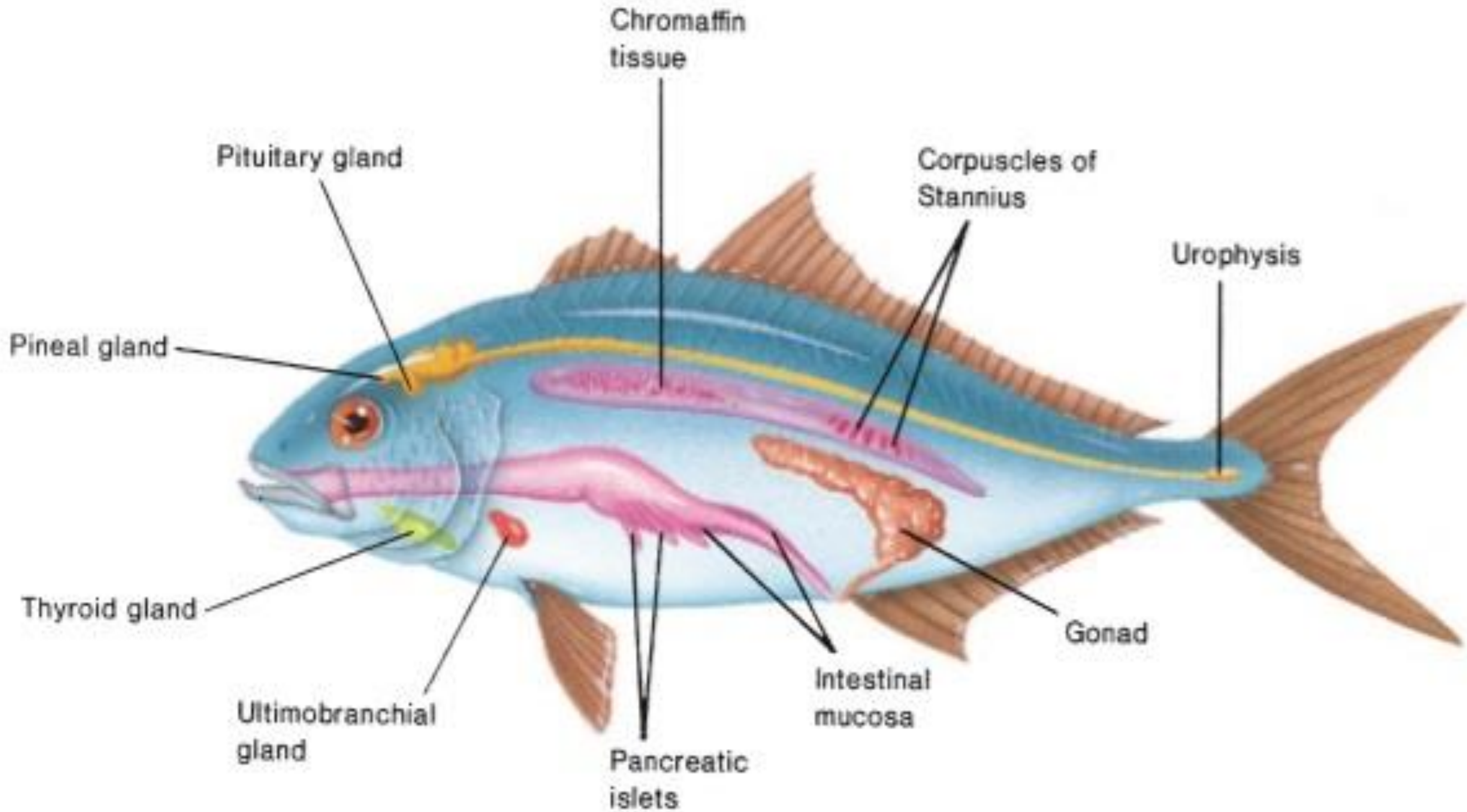


Fig: Approximate Locations of Endocrine Tissues (Glands) in a Bony Fish.

MAJOR VERTEBRATE ENDOCRINE TISSUES AND HORMONES

Pituitary gland

- ✓ Produces **Prolactin**
- ✓ stimulates reproductive migrations
- ✓ causes brooding behavior in some fishes.
- ✓ helps control water and salt balances
- ✓ essential for certain saltwater fishes to enter freshwater during spawning runs.

Thyroid

- ✓ Produces **thyroxine (T4)** and **triiodothyronine (T3)**
- ✓ control the rate of metabolism,
- ✓ growth
- ✓ tissue differentiation in vertebrates.

Ultimobranchial glands

- ✓ produce the hormone **calcitonin** that helps regulate
- ✓ the concentration of blood calcium.

✓ Endocrine cells (chromaffin tissue) or glands (adrenal glands)

- ✓ produce two hormones (epinephrine or adrenaline, and norepinephrine or noradrenaline)
- ✓ cause vasoconstriction
- ✓ increased blood pressure,
- ✓ changes in the heart rate, and
- ✓ increased blood glucose levels.
- ✓ involved in the "fight or-flight" reactions.

Fig: Hormonal Control of Frog Skin Color. The light-colored frog on the left was immersed in water containing the hormone melatonin. The dark-colored frog on the right received an injection of melanocytestimulating hormone.