Hormones and the Endocrine System

The Body's Long-Distance Regulators

Animal **hormones** are chemical signals that are secreted into the circulatory system and communicate regulatory messages within the body.

Although a given hormone can reach all cells of the body, only some cells have receptors for that hormone. Each hormone binds to specific receptors in the body.

A hormone elicits a response—such as a change in metabolism—in specific *target cells*, those that have the matching receptor. Cells lacking a receptor for that hormone are unaffected.

- Chemical signaling by hormones is the function of the **endocrine system**, one of the two basic systems for communication and regulation in the animal body. The other major communication and control system is the **nervous system**, a network of specialized cells –**neurons**- that transmit signals along dedicated pathways.

- These signals in turn regulate neurons, muscle cells, and endocrine cells. Since signaling by neurons can regulate the release of hormones, the nervous and endocrine systems often overlap in function.

Hormones and other signaling molecules bind to target receptors, triggering specific response pathways

- **Chemical signals bind to receptor proteins on target cells**.
- Only target cells respond to the signal.

Types of Secreted Signaling Molecules

- ***Secreted chemical signals*** include
  - *Hormones*
  - *Local regulators*
  - *Neurotransmitters*
  - *Neurohormones*
  - *Pheromones*

Hormones

Endocrine signals (hormones) are secreted into extracellular fluids and travel via the bloodstream. *Hormones mediate responses to environmental stimuli and regulate growth, development, and reproduction.*

Endocrine glands are ductless and secrete hormones directly into surrounding fluid.

Exocrine glands have ducts and secrete substances onto body surfaces or into body cavities (for example, tear ducts; salivary glands; bile from liver etc.).

Local Regulators

Many types of cells produce and secrete local regulators, molecules that act over short distances and reach their target cells solely by diffusion. Once secreted, local regulators act on their target cells within seconds or even milliseconds.

Local regulators help to regulate blood pressure, nervous system function, and reproduction.

Local regulators are divided into two types:

- *Paracrine* signals act on cells near the secreting cell.
- *Autocrine* signals act on the secreting cell itself.

Classes of Local Regulators

One group of local regulators, the prostaglandins, are modified fatty acids. Many other local regulators, including cytokines and growth factors, are polypeptides, and some are gases.

Nitric oxide (NO), a gas, functions in the body as both a local regulator and a neurotransmitter. When the level of oxygen in the blood falls, endothelial cells in blood vessel walls synthesize and release NO, which activates an enzyme that relaxes the cells. The result is vasodilation.

Neurotransmitters and Neurohormones

Secreted molecules are crucial for two types of signaling by neurons. In *synaptic signaling*, *Neurons (nerve cells) contact target cells at synapses*. At most synapses, neurons secrete molecules called neurotransmitters that diffuse a very short distance and bind to receptors on the target cells. Neuro-transmitters are central to sensation, memory, cognition, and movement.

In *neuroendocrine signaling*, specialized neurons called neurosecretory cells secrete neurohormones. Neurohormones are a class of hormones that originate *from neurons in the brain* , which diffuse into the bloodstream.

Pheromones

Members of a particular animal species sometimes communicate with each other via **pheromones**, chemicals that are released into the external environment.

Pheromones serve a wide range of functions that include defining territories, warning of predators, and attracting potential mates.

signal transduction pathway

The binding of a water-soluble hormone to a receptor protein triggers events at the plasma membrane that result in a cellular response. The response may be the activation of an enzyme, a change in the uptake or secretion of specific molecules, or a rearrangement of the cytoskeleton.

The series of changes in cellular proteins that converts the extracellular chemical signal to a specific intracellular response is called signal transduction.

Signaling by any of these hormones involves three key events:

- *Reception*
- *Signal transduction*
- *Response*

Pathway for Lipid-Soluble Hormones

- The *response to a lipid-soluble hormone is usually a change in gene expression*.
- Steroids, thyroid hormones, and the hormonal form of vitamin D enter target cells and *bind to protein receptors in the cytoplasm or nucleus*.
- These hormone-receptor complexes then act as *transcription factors* in the nucleus, regulating transcription of specific genes.

Multiple Effects of Hormones

Many hormones elicit more than one type of response in the body. Consider, for example, epinephrine. This hormone triggers glycogen breakdown in the liver. However, epinephrine also *increases* blood flow to major skeletal muscles and *decreases* blood flow to the digestive tract.

- Thus, the same hormone may have different effects on target cells that have
  - *Different receptors* for the hormone
  - *Different signal transduction pathways*
  - *Different proteins* for carrying out the response.

- A hormone can also have different effects in different species.

Endocrine Tissues and Organs

Some endocrine cells are found in organs that are part of other organ systems. For example, the stomach contains isolated endocrine cells that help regulate digestive processes by secreting the hormone gastrin.

More often, endocrine cells are grouped in ductless organs called endocrine glands, such as the thyroid and parathyroid glands and the gonads, either testes in males or ovaries in females.

Feedback Regulation

A feedback loop linking the response back to the initial stimulus is characteristic of control pathways. Often, regulation involves negative feedback, in which *the response reduces the initial stimulus*. For instance, bicarbonate release in response to secretin increases pH in the intestine, eliminating the stimulus and thereby shutting off secretin. By decreasing hormone signaling, negative feedback regulation prevents excessive pathway activity.

Whereas positive feedback reinforces a stimulus, leading to an even greater response. For example, in the oxytocin pathway, the mammary glands secrete milk in response to circulating oxytocin. Milk released in response to the oxytocin leads to more suckling and therefore more stimulation. Activation of the pathway is sustained until the baby stops suckling. When mammals give birth, oxytocin induces target cells in the uterine muscles to contract.

Antagonistic hormones

- Antagonistic hormones work in an opposite function.
- For example insulin and glucagon are antagonistic hormones that help maintain glucose homeostasis.
- The pancreas has endocrine cells called islets of Langerhans with

- *alpha cells* that produce glucagon

- *beta cells* that produce insulin.

Coordination of Endocrine and Nervous Systems

- In vertebrates, coordination of endocrine signaling relies heavily on a region of the brain called the hypothalamus. The hypothalamus receives information from the nervous system and initiates responses through the endocrine system.
- Attached to the hypothalamus is the pituitary gland composed of the posterior pituitary and anterior pituitary.

Posterior Pituitary Hormones

- Oxytocin induces uterine contractions and the release of milk (positive feedback regulation).
- Antidiuretic hormone (ADH) enhances water reabsorption in the kidneys (=Vasopressin)

Anterior Pituitary Hormones

- Hormone production in the anterior pituitary is controlled by releasing and inhibiting hormones from the hypothalamus
- For example, the production of *thyrotropin releasing hormone* (*TRH*) in the hypothalamus stimulates secretion of the *thyroid stimulating hormone* (*TSH*) from the anterior pituitary.

Tropic Hormones

- A **tropic hormone** regulates the function of endocrine cells or glands.
- The four strictly tropic hormones are:
  - **Thyroid-stimulating hormone (TSH)**
  - **Follicle-stimulating hormone (FSH)**
  - **Luteinizing hormone (= Lutropin = LH)**
  - **Adrenocorticotropic hormone (ACTH)**

Non-tropic Hormones

- Nontropic hormones produced by the anterior pituitary are:
  - **Prolactin (PRL)**
  - **Melanocyte-stimulating hormone (MSH)**
- Prolactin stimulates lactation in mammals but has diverse effects in different vertebrates.
- MSH influences skin pigmentation in some vertebrates and fat metabolism in mammals.

Growth Hormone

- Growth hormone (GH) is secreted by the anterior pituitary gland and has tropic and nontropic actions.
- It promotes growth directly and has diverse metabolic effects.
- It also *stimulates production of growth factors*.
- An excess of GH can cause gigantism, while a lack of GH can cause dwarfism.

Hormone Cascade Pathways

- A hormone can stimulate the release of a series of other hormones, the last of which activates a nonendocrine target cell; this is called a hormone cascade pathway.
- For example; the release of thyroid hormone results from a hormone cascade pathway involving the hypothalamus, anterior pituitary, and thyroid gland.

Pineal Gland

- The pineal gland, located in the brain, secretes melatonin.
- Light/dark cycles control release of melatonin.
- Primary functions of melatonin appear to relate to *biological rhythms associated with reproduction*.

Thyroid Hormones

- The thyroid gland consists of two lobes on the ventral surface of the trachea.
- It produces two iodine-containing hormones: triiodothyronine (T_3) and thyroxine (T_4).
- Proper thyroid function requires dietary iodine for thyroid hormone production.

Parathyroid Hormone and Vitamin D: Control of Blood Calcium

- Two antagonistic hormones regulate the homeostasis of calcium (Ca^{2+}) in the blood of mammals
  - Parathyroid hormone (PTH) is released by the parathyroid glands
  - Calcitonin is released by the thyroid gland

- PTH increases the level of blood Ca^{2+}
  - It releases Ca^{2+} from bone and stimulates reabsorption of Ca^{2+} in the kidneys
  - It also has an indirect effect, stimulating the kidneys to activate vitamin D, which promotes intestinal uptake of Ca^{2+} from food
- Calcitonin decreases the level of blood Ca^{2+}
  - It stimulates Ca^{2+} deposition in bones and secretion by kidneys

Adrenal Hormones

- The *adrenal glands* are adjacent to the kidneys.
- Each adrenal gland actually consists of two glands: the *adrenal medulla* (inner portion) and *adrenal cortex* (outer portion).

Catecholamines

- The adrenal medulla secretes *epinephrine (adrenaline) and norepinephrine (noradrenaline).*
- These hormones are members of a class of compounds called catecholamines.
- They are secreted in response to stress-activated impulses from the nervous system.
- They mediate various *fight-or-flight responses*.

- Epinephrine and norepinephrine
  - Trigger the release of glucose and fatty acids into the blood
  - Increase oxygen delivery to body cells
  - Direct blood toward heart, brain, and skeletal muscles, and away from skin, digestive system, and kidneys.
- *The release of epinephrine and norepinephrine occurs in response to nerve signals from the hypothalamus*.

Steroid Hormones

- The adrenal cortex releases a family of steroids called corticosteroids in response to stress.
- These hormones are triggered by a hormone cascade pathway via the hypothalamus and anterior pituitary.
- Humans produce two types of corticosteroids: glucocorticoids and mineralocorticoids.

Gonadal Sex Hormones

- The gonads = testes and ovaries, produce most of the sex hormones: androgens, estrogens, and progestins.
- All three sex hormones are found in both males and females, but in different amounts.