Summary: The Nature of Chemical Regulation

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April 1, 2020

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1 Communication through electrical and chemical signals

The **nervous system** and the **endocrine system** serve as the body's principal coordination organ systems. As their names suggest, the endocrine system establishes coordination in a *chemical* manner, while the nervous system establishes such coordination in an *electrical* manner.

1.1 An overview of the endocrine system

The endocrine system establishes communication by releasing chemical signals called **hormones** throughout the bloodstream. In contrast to other methods of coordination, the secretion of hormones is well suited for:

- Coordinating response to stimuli such as dehydration, low levels of glucose, and stress
- Regulating long-term developmental processes, such as the metamorphosis of a tadpole into a frog
- Mediating behavior changes that underline sexual maturity

In other words: the endocrine system is most useful in scenarios where a change is both gradual and systemic—that is, it affects the entire body, not a localized region.

Generally, hormones used in the production of signals that travel through the endocrine are secreted by the **endocrine glands**. Endocrine glands common to various species of animals are:

- **The pituitary gland**: regulates growth and reproduction
- **The thyroid gland**: regulates metabolism

1.2 An overview of the nervous system

In contrast with the endocrine system, electrical signals are usually the sole actor in mediating signal transmission—that is, electircal signals are the signals emitted in a nervous system. However, such nervous systems are not conveyed through the utilization of the entire bloodstream, but usually a network of interconnected nerve cells called neurons.

Again, in contrast to the systemic, widespread nature of endocrine signaling, nervous system signaling is inherently differentiated:

1. Only in the nervous system do specialized cell junctions act immediately in signal transmission
2. Messages may be communicated through the nervous system in fractions of a second, whereas messages communicated through the endocrine system may take several seconds to arrive, simply due to the nature of each message's transmission
3. The effects of electircal signaling are fleeting—that is, endocrine-mediated messaging results in the communication of a "message" that may leave a long-lasting effect on the organism in question

1.3 Convergence of the endocrine and nervous systems

In some cases, both the nervous and endocrine systems might be requried in order to achieve a particular task. In this instance, a **neurosecretory cell** may be utilized. A neurosecretory cell conducts electrical signals, and also secrestes hormones into the blood, should the need arise.

2 Hormone signaling mechanisms

There exist two further classifications of the hormone: water-soluble hormones and lipid-soluble hormones.

2.1 Water-soluble hormones

Unlike lipid-soluble hormones, water-soluble hormones are not capable of breaching the lipid-bilayer surrounding a cell. Thus, they affect the cell without entering it: water-soluble hormones simply bind to receptor proteins embedded in the lipid-bilayer of the cell.

2.2 Lipid-soluble hormones

As implied by its name, the lipid-soluble hormone is capable of diffusing through the lipid-bilayer of a cell, and binds to receptors *inside the cell*, rather than by binding to receptors embedded in the surface of the cell.

In other words, should one wish to derive the mechanism by which a hormone will affect a cell, they need simple consult the following logical derivation tree:

- Types of signals
  - Electrical signals
  - Chemical signals
    - Receptor location
      - Plasma membrane
        - Water-soluble hormone
      - Cell interior
        - Lipid-soluble
        - hormone

Once again, the sole distinction between these two classes of hormones simply lies in their chemical composition, which accounts for differing abilities to diffuse through the plasma membrane, which, in turn, dictates which receptors a hormone may bind to:

1. For a water-soluble hormone: the hormone must bind to a receptor embedded in the membrane, which transducts the signal
2. For a lipid-soluble hormone: the hormone may bind to a receptor inside the cell, thereby acting as a signal transductor itself

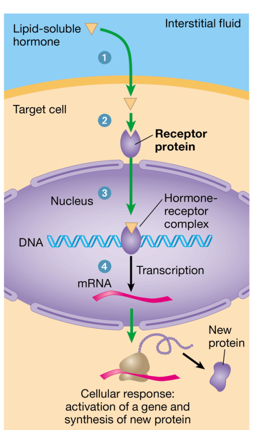


Figure 1: The pathway of a lipid-soluble hormone

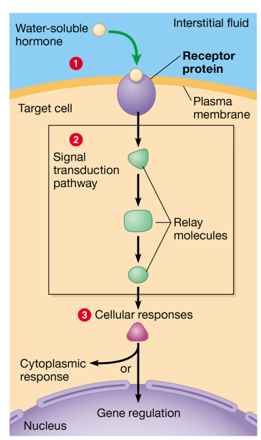


Figure 2: The pathway of a water-soluble hormone

3 Glands in the vertebrate endocrine system

There is a wide diversity of organs comprising the endocrine system: some serve only to secrete hormones, while others serve many purposes.

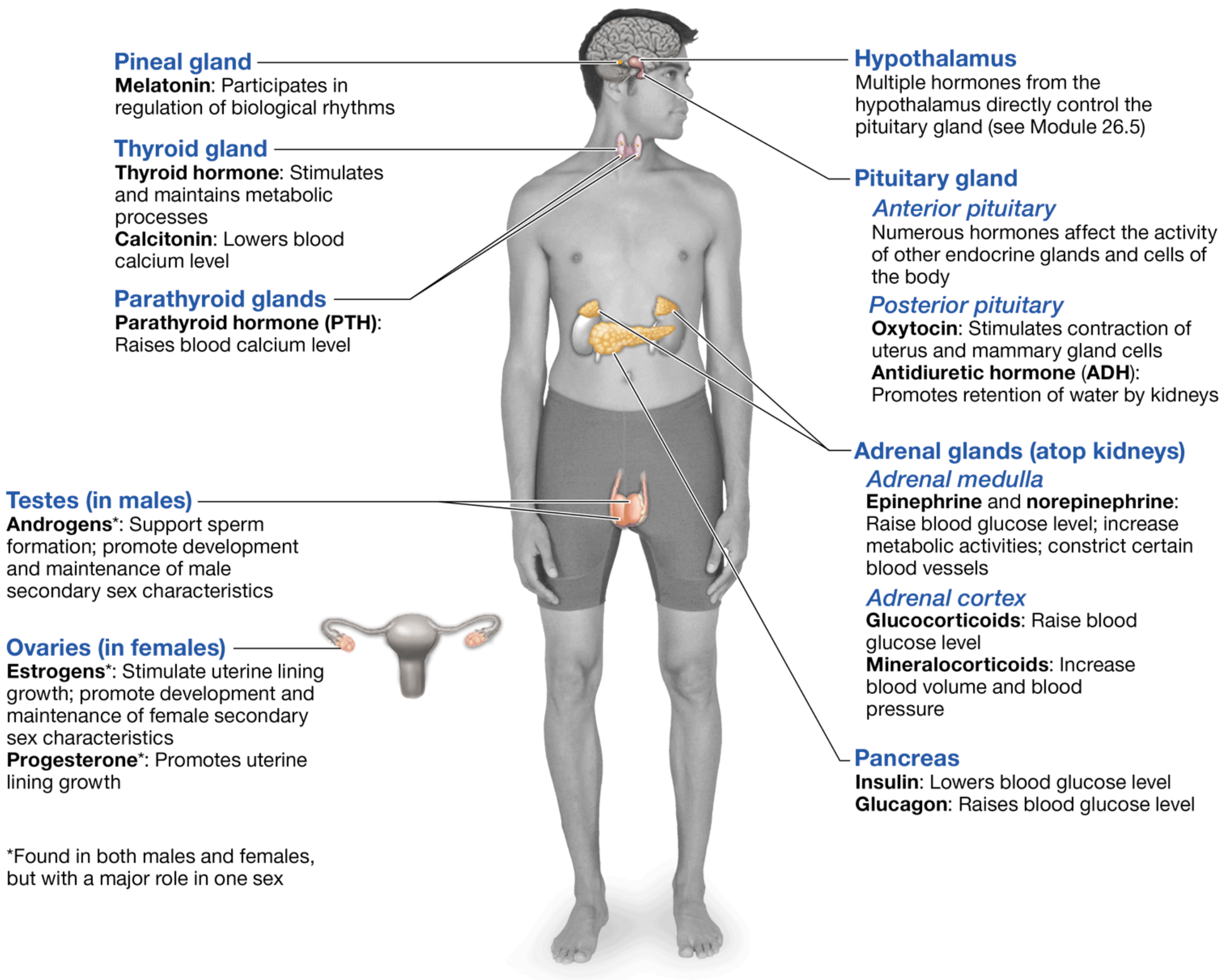


Figure 3: The many glands comprising the human endocrine system

As is made evident by the severe variations in structure and function indicated in the above figure, it follows that the stimuli responsible for the secretion of hormones produced by these glands is just as differentiated. Some common methods for gland activation are:

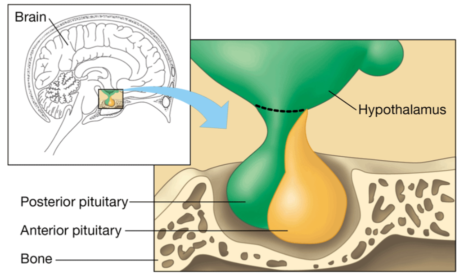
- A change in nutrients or ion concentration
- Stimulation by the nervous system
- Stimulation by hormones secreted by other endocrine system glands

For example, the **pineal gland**, a gland located near the center of the brain that synthesizes and secretes melatonin, is controlled by a group of neurons in the brian that receive light from the eye.

4 The hypothalamus

4.1 An overview

The **hypothalamus** is a section of the brain responsible for the proper functioning of the endocrine system. Furthermore, the hypothalamus conveys information received by the nerves to the endocrine and nervous systems. Generally, the hypothalamus serves as the outside world's first line of communication to the endocrine system's top-level glands. The pituitary gland, for example, is controlled directly by the hypothalamus.



4.2 The pituitary gland

The pituitary gland can be divided into a posterior lobe and an anterior lobe. The posterior portion of the pituitary gland can be categorized as a nervous cell, while the anterior portion of the gland is a member of the endocrine system: the posterior pituitary is an extension of the hypothalamus, and secretes hormones synthesized in the hypothalamus. The anterior pituitary, on the other hand, both synthesizes and secrestes hormones, which extert control over other endocrine glands.

The hypothalamus can extert control over the anterior pituitary by secreting an inhibiting or releasing hormone: the former of the two stimulates the anterior pituitary, causing the secretion of the hormone in question, while an inhibiting hormone induces the halting of the secretion of the hormone in question. Hormones secreted as a result of the secretion of releasing hormones may induce a broad range of function. Thyroid-stimulating hormone, for example, regulates the metabolic effects of the thyroid, and is secreted as a result of the secretion of release hormone. Some hormones like prolactin, for example, do not cause other hormones ot be secreted, but directly stimulate the mammary glands, causing the production of milk.

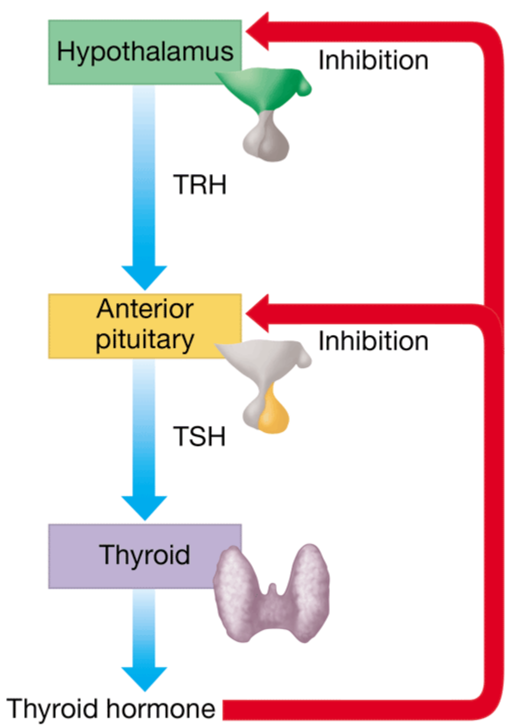


Figure 4: The broad range of functionality, and mechanisms by which TRH may induce secretion or inhibition of hormones.

5 The role of the thyroid in regulating development and metabolism

The **thyroid gland** is responsible for the production of **thyroid hormone**, which stimulates metabolism in virtually every cell in the body. As is the case with virtually every member of the endocrine system, the thyroid hormone can be disambiguated into thyroxines (T_4) and triidothyronines (T_3). However, in most animals, these two hormones each aid in the development of bone and nerve cells and play a part in maintaining homeostasis.

5.1 Conditions that may result from sub-optimal levels of T_3 or T_4

Both hyperthroidism—an excess of thyroid hormone in the blood—and a lack of thyroid hormone in the blood are unwanted in most organisms. For example, in the case of hyperthroidism, one might experience overheating, profuse sweating, irritability, high blood pressure, and weight loss (e.g., Grave's disease). Hypothroidism, on the other hand, causes symptoms of the opposite nature, and is often caused by an autoimmune reaction.

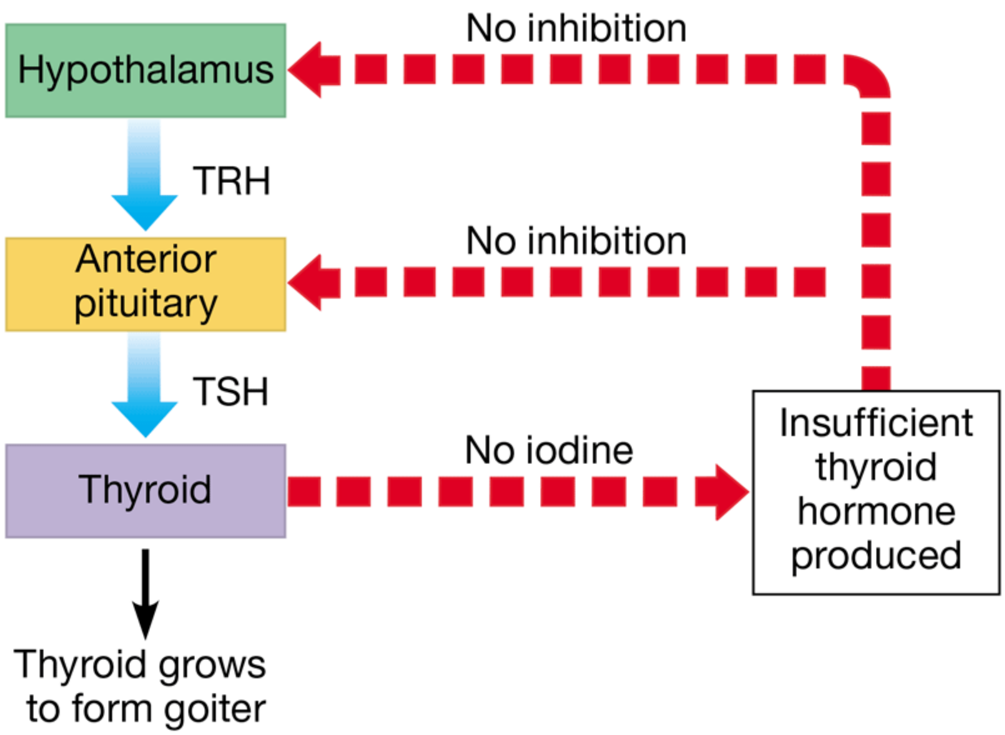
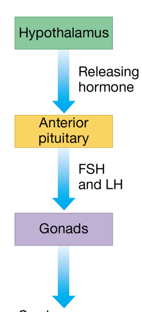


Figure 5: The delicate relationship betweeen goiter and hypothyroidism.

6 The gonads secrete sex hormones

The **gonads** are responsible for regulating sexual behavior and reproductive cycles, as well as the production of gametes.

As is the case with most other glands, the synthesis of its hormone, the sex hormone, is catalyzed by the secretion of a releasing hormone from the hypothalamus. Generally, there are three types of sex hormones produced by the gonads: estrogens, progesterone, and androgens. Naturally, males and females posess each of these three categories of sex hormones, while the concentration of such hormones differs between sexes.



7 Pancreatic hormones

The **pancreas** both secretes digestive enzymes and secretes protein hormones: insulin and glucagon into the blood. Insulin, on one hand, is used to stimulate the consumption of sugar from the bloodstream—that is, as a result of the secretion of insulin, bloodsugar will decrease. Glucagon, on the other hand, is used to stimulate the detachment of sugar molecules from cells, causing an increase in bloodsugar levels. In this respect, these two hormones are **antagonistic**—that is, they have effects that counter each other.

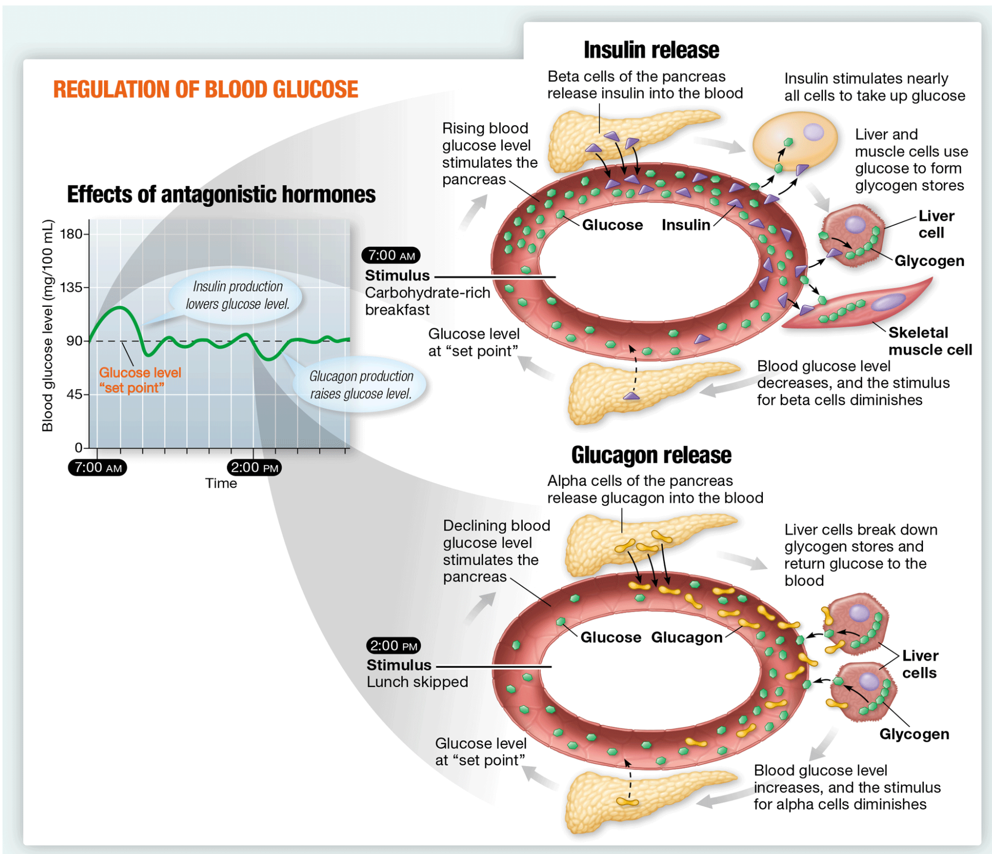


Figure 6: The regulation of bloodsugar levels

8 The role of the adrenal glands in mobilizing stress responses

Above each of the kidneys, there is an **adrenal gland** responsible for enabling a systemic response to stress. Furthermore, each of the adrenal glands is split into two glands fused together: the **adrenal medulla** and the **adrenal cortex**. These two glands differ largely in the type of stress triggering their responses, and the types of hormones released as a result of encountering a certain stimulus.

The adrenal medulla, on one hand, prepares the body for *sudden action*— it is responsible for inducing a "fight or flight" response in the body. In circumstances where a response from the adrenal medulla is required, two hormones are secreted: **epinephrine** and **norepinephrine**. Each of these hormones, in turn, stimulates the liver to release glucose into the bloodstream, accounting for an increased strength amid a "fight or flight" response.

The adrenal cortex, by contrast, is active when blood volume, pressure, or sugar decreases. Once this gland is activated, various **corticosteroids** are released—in humans, mineralcorticoids and glucocorticoids are the most important. The former of the two aforementioned derivatives of the corticosteroid family acts by stimulating the reabsorption of sodium ions and water, increasing the volume of the blood and raising blood pressure. Glucorticoids, on the other hand, simply increase the volume of cellular fuel by "falling back" to sources of energy outside of glucose (e.g., proteins).