Physiology of the Endocrine System

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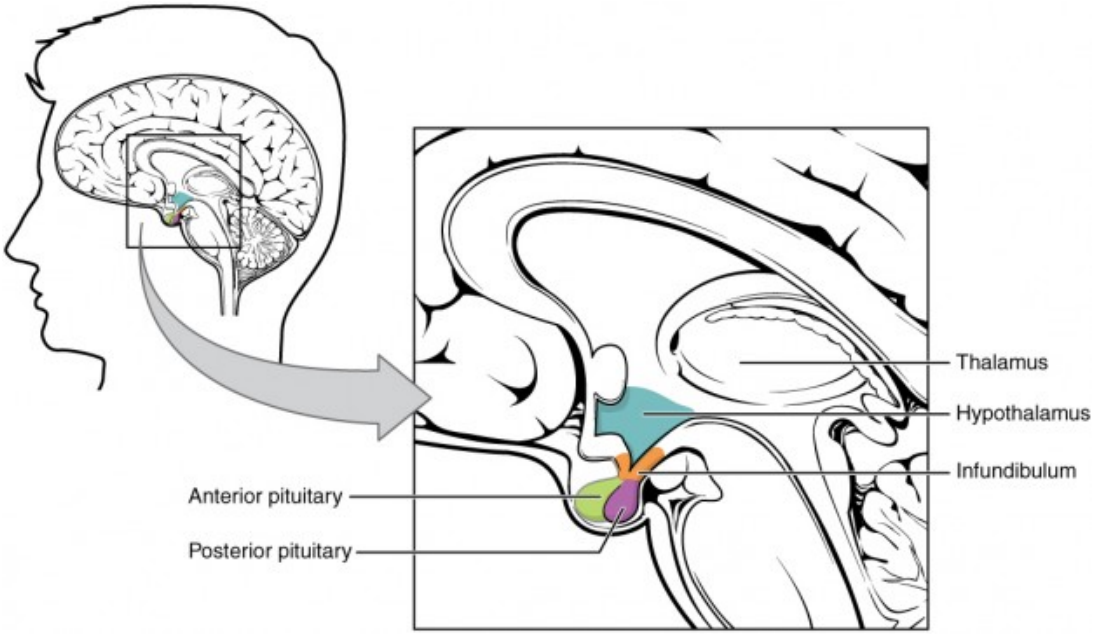
The special field of endocrinology deals with the hormonal system. This includes, among other things, the function of hormones, the anatomy, and physiology of endocrine glands and the feedback mechanisms of hormone regulation. This article explains the physiology of the endocrine system and provides graphical illustrations. The physiology of the endocrine system is a vast field that plays a role in all medical specialties; medical students are required to master the intricacies of this topic.



Endocrine Glands and Exocrine Glands

Endocrine glands release hormones inside the interstitium, i.e. in the space between the cells. Exocrine glands possess special excretory ducts. An example would be sweat glands.

Endocrine Glands and Their Physiology

The most important hormone-producing sites are:

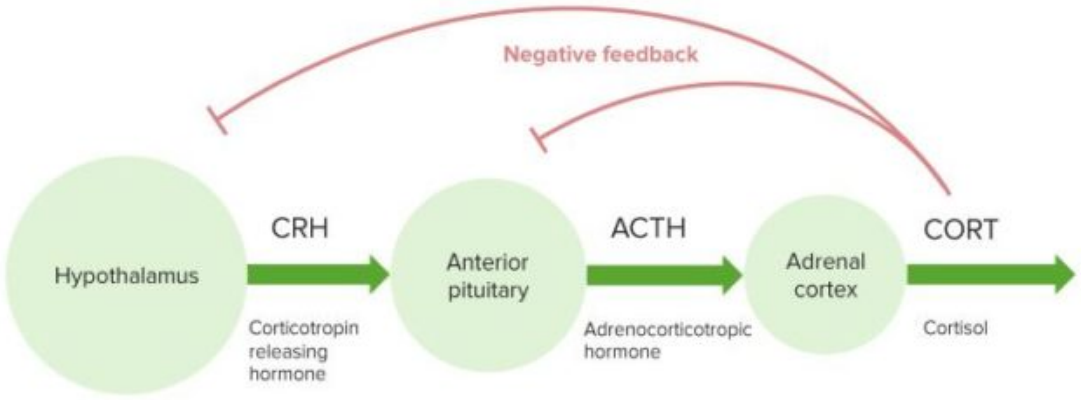
- Hypothalamus (located in the lower part of the diencephalon)
- Hypophysis (pituitary gland)
- Thyroid gland (*glandula thyroidea*)
- Parathyroid gland (*glandula parathyroidea*)
- Epiphysis (pineal gland)
- Pancreas

- Adrenal glands (glandulae)
- Gonads (gonads and ovary)
- Thymus (it recedes during puberty)

Apart from the hypothalamus, these organs all release their hormones into the blood circulation. Most hormones of the hypothalamus are released into the portal vein system.

Hormones are Messenger Substances

Hormones are chemical messengers that are produced by the body. They carry information to target organs and thus enable the coordination of function and metabolism. Hormonal communication is a bit slower than the exchange of information via neurons. Neuronal communication happens within a few seconds, while hormones need at least several minutes—if not longer. Hormones are differentiated depending on their site of production and on their chemical structure (principles of synthesis).



'Hormone Types: Transport and Mechanisms of Action' Image created by Lecturio

Differentiation According to Ste of Production

Hormones that are categorized according to where they are formed include **glandular hormones, tissue hormones, neurosecretory hormones,** and **mediator substances**.

Glandular and tissue hormones

Glandular hormones are produced by endocrine glands and released into the bloodstream. This process is also referred to as endocrine secretion. Hormones are transported from their site of production to the site of action. **Glandular hormones** are further differentiated into **adenotrophic hormones** and **peripheral hormones**. An example of an adenotrophic hormone is **ACTH (adrenocorticotrophic hormone)**. A peripheral hormone is, e.g., **insulin**.

Tissue hormones owe their name to the fact that they are produced in specialized tissue cells. They are transported to their target organ via diffusion (**paracrine regulation**). Site of production and site of action can be located very close to each other but can also be very far apart. An example of a tissue hormone is gastrin, a peptide hormone found in the gastrointestinal tract.

Neurosecretory hormones and mediator substances

Neurosecretory substances are, for example, the hormones of the hypothalamus. They are produced in specialized **neurosecretory cells**. The hormones are transported to their target organ via the bloodstream.

Mediator substances are chemical signaling substances that cannot be strictly separated from **neurotransmitters**. They can be produced in many different cells. They usually act locally because they can be degraded very rapidly. An example of a **mediator substance** is histamine.

Differentiation According to Chemical Structure

Steroid hormones, eicosanoids, and hormones derived from amino acids are part of this group.

Synthesis of steroid hormones

Steroid hormones have a basic structure composed of **steran**. They are not stored in glands but are released into the blood right after their production. Therefore, their synthesis is strictly regulated, in order to prevent overproduction.

Synthesis of hormones derived from amino acids

Low molecular amino acid derivatives, peptides (polypeptides) and proteins (proteohormones) belong to the group of **steroid hormones**. There are major differences in the production—and also the effect—of the amino acid-derived hormones. During the production (**biosynthesis**) of proteohormones, as a 1st step, preprohormones are formed. These are long polypeptide chains. The peptides are brought into the endoplasmic reticulum, and then the signal sequence is split off. The result is called a peptide hormone.

Peptide hormones are changed further in the process of posttranslational modification. Afterward, they are stored inside granula, from where they can be released in case of corresponding stimulation (**exocytosis**).

Synthesis of eicosanoids

Eicosanoids are, for instance, prostaglandins. They cannot only emit hormonal signals and are produced in different types of tissue as well as in cells.

The Operating Principles of Hormones

Hormones usually take effect in the target organ. They bind to a specific receptor (proteins) at the target site. These proteins have:

- High-affinity
- Low capacity
- High specificity

Hormones transmit their effect by influencing gene activity and activating “**second messengers.**” Gene activity is especially affected by steroid hormones. Thyroxin also acts this way. Second messengers are signaling molecules that send out a signal to a target cell. This results in an enhanced effect, which can trigger different consequences. Additionally, hormones can influence metabolism.

Hormones of the hypothalamus

The **hypothalamus** is located below the thalamus and coordinates water balance, salt metabolism, and blood pressure. Furthermore, it controls body temperature and intake of food. It also manages sexual behavior and sleep. Within the hormonal system, the hypothalamus regulates the amount of produced hormones. The synthesis of all hormones necessary for this process takes places inside the neurons. Even the release of hormones of the hypothalamus is controlled by hormones.

Hormones of the hypothalamus are GnRH (gonadotropin-releasing hormone), TRH (thyrotropin-releasing hormone), GH-RH (growth hormone-releasing hormone) and CRH (corticotropin-releasing hormone).

Hormones of the hypophysis

ACTH (adrenocorticotropic hormone) belongs to this group of hormones. It controls the release of cortisol and is also called “stress hormone.” Further hormones are TSH (thyroid-stimulating hormones), which have an effect on the thyroid gland and influence the release of T3 and T4.

Moreover, the hypophysis produces FSH (follicle-stimulating hormone) and LH (luteinizing hormone). Both are important for the development of gender and fertility. Prolactin is synthesized by the hypophysis as well. It has an effect on the mammary gland and activates the production of milk. One more hormone of the hypophysis is the growth hormone that regulates growth. However, it does not regulate growth directly but by stimulating another hormone.

Hormones of the thyroid gland

Thyroxin (T4) and **triiodothyronine** (T3) are produced by the thyroid gland. Both hormones can be found freely in the blood, but they can also bind to proteins (carrier proteins). The hormone **thyreotropin** (TSH) on the other hand is produced by the pituitary gland and transported to the thyroid gland via the bloodstream. Its function is to regulate the thyroid hormones T3 and T4. In the case of suspected thyroid diseases, TSH is usually controlled 1st.

The lower limit for men is 0.4 µU/mL, the upper limit is 2.5. The lower limit for women is 0.3 µU/mL, the upper limit is 1.0. The **glandula parathyroidea** (parathyroid gland) produces the **parathyroid hormone**, which is responsible for balancing the relationship between calcium and phosphate in the blood.

Hormones of the epiphysis (pineal gland)

The epiphysis produces the hormones **epiphysin** and **melatonin**, which regulate the daily rhythm.

Hormones of the pancreas

The pancreas produces insulin, somatostatin, and glucagon. Insulin and glucagon regulate the blood sugar level. Somatostatin inhibits the release of digestive juice. Insulin and glucagon are synthesized in the so-called islets of Langerhans. Glucagon is produced in alpha-cells, insulin in beta-cells. The production of somatostatin takes place in delta-cells. All 3 types of hormones are released after food intake. A high blood sugar level leads to the release of insulin. If the blood sugar level decreases, glucagon is released to raise the blood sugar level again. Insulin and glucagon can be inhibited with the **amylin** and **pancreatostatin**.

Hormones of the adrenals

The adrenals produce different hormones, which are classified into three major groups: cortisol, aldosterone, and androgens. These hormones are steroid hormones. They are stimulated by ACTH from the hypophysis. ACTH is controlled by CRH from the hypothalamus. Hormones continuously interact with each other. This is also referred to as control circuit. Cortisol belongs to the group of glucocorticoids and has an effect on metabolism. This includes fat and protein breakdown but also the synthesis of sugar.

Moreover, it inhibits inflammation and suppresses the immune system. Aldosterone is necessary for water balance and salt metabolism.

It contains sodium and potassium of the required level for maintaining health. Sodium can bind water, which increases blood volume and blood pressure. Androgens are the sex hormones. About 5% of all androgens in men are produced in the adrenals.

Hormones of the gonads (ovary and testis)

The gender-specific sex hormones are produced by the gonads, which are the ovaries and the testes. The produced hormones are androgens, gestagens, and estrogens. The production of said hormones has to be stimulated by other hormones.

Estrogen is necessary for the mucosa in the uterus to grow, which is a precondition for every pregnancy. Pregnancy itself is regulated by numerous hormones. Testosterone belongs to the group of androgens and is responsible for the gender-specific outer appearance and sex drive of males. These hormones are subject to a control circuit of the hypothalamus, hypophysis, and gonads.

Hormones of the thymus

The thymus is an organ, which is fully developed at birth and forms back during puberty. The thymus is important for the development of the immune system and growth. The hormones are produced inside thymus-epithelial cells and include peptides like thymosine, thymopoetin, and thymosterine.

Pathologies in Endocrinology

Possible diseases of the thyroid gland

Low TSH-values can be an indication for **hyperthyroidism**, **cancerous disease** or **secondary under-activity of the thyroid gland**. High values are an indication for a

primary under-activity. **Struma** (crop) is an inflammation of the **thyroid gland**.

Possible diseases of the pancreas

Diabetes mellitus type 2 is 1 of the most frequent diseases of the pancreas. It leads to insulin resistance. However, **hormone deficiency** is part of the disease. Diabetes type 2 results from an excessive intake of food, inactivity and genetic predisposition. Diabetes type 1, on the other hand, is an autoimmune process that results in a total insulin deficiency. The patient is insulin-dependent. This type of diabetes often follows acute diseases like gastrointestinal diseases or infectious diseases. However, research about this process is still ongoing.

Possible diseases of the adrenals

A frequent disease of the adrenals is **Morbus Cushing**, which leads to the increased production of cortisol. A possible reason for this disease could be a tumor, which produces hormones itself that promote the release of cortisol. Morbus Cushing can trigger further diseases like e.g., diabetes. Overproduction of aldosterone can cause Conn syndrome. This disease results in increased blood pressure because of decreasing potassium levels.

References

Notes