Endocrine control mechanism

The multiple activities of the cells, tissues, and organs of the body are coordinated by the interplay of several types of chemical messenger systems: ***Endocrine hormones, Neurotransmitters, Neuroendocrine hormones, Paracrine, Autocrine, and Cytokines.***

Endocrine hormones

The endocrine hormones are chemical substance released by **glands** or **specialized cells** into the circulating blood and influence the function of target cells at another location in the body. The hormones play a key role in regulating almost all body functions, including: metabolism, growth and development, water and electrolyte balance, reproduction and behavior.

Chemical structure and synthesis of hormones

Three general classes of hormones exist:

1. ***Proteins and polypeptides,*** including hormones secreted by the anterior and posterior pituitary gland, the pancreas (insulin and glucagon), the parathyroid gland (parathyroid hormone), and many others. These hormones range in size from small peptides with as few as three amino acids (thyrotropin releasing hormone) to proteins with almost 200 amino acids (growth hormone and prolactin).

2. ***Steroids*** secreted by the adrenal cortex (cortisol and aldosterone), the ovaries (estrogen and progesterone), the testes (testosterone), and the placenta (estrogen

and progesterone). The chemical structure of steroid hormones is similar to that of cholesterol, and in most instances, hormones are synthesized from cholesterol.

3. ***Derivatives of the amino acid tyrosine,*** secreted by the thyroid (thyroxine and triiodothyronine) and the adrenal medullae (epinephrine and norepinephrine).

The thyroid and the adrenal medullary hormones, are formed by the actions of enzymes in the cytoplasmic compartments of the glandular cells.

Feedback control of hormone secretion

Although the plasma concentrations of many hormones fluctuate in response to various stimuli that occur throughout the day, all hormones appear to be closely controlled. In most instances, this control is exerted through ***negative feedback mechanisms*** that ensure a proper level of hormone activity at the target tissue. After a stimulus causes release of the hormone, conditions or products resulting from the action of the hormone tend to suppress its further release. In other words, the hormone (or one of its products) has a negative feedback effect to prevent oversecretion of the hormone or overactivity at the target tissue.

Transport of hormones in the blood

Water-soluble hormones (peptides and catecholamines) are dissolved in the plasma and transported from their sites of synthesis to target tissues, where they diffuse out of the capillaries, into the interstitial fluid, and ultimately to target cells.

Steroid and thyroid hormones circulate in the blood while being mainly bound to plasma proteins. Usually less than 10 percent of steroid or thyroid hormones in the plasma exist free in solution. However, protein bound hormones cannot easily diffuse across the capillaries and gain access to their target cells and are therefore biologically inactive until they dissociate from plasma proteins.

Pituitary gland and hypothalamus

The ***pituitary gland*** (Figure 1), also called the *hypophysis,* is a small gland about 1 centimeter in diameter and 0.5 to 1 gram in weight that lies in the ***sella turcica,*** a bony cavity at the base of the brain, and is connected to the hypothalamus by the ***pituitary* (or *hypophysial*) stalk**. Physiologically, the pituitary gland is divisible into two distinct portions: the ***anterior pituitary,*** also known as the ***adenohypophysis,*** and the ***posterior pituitary,*** also known as the ***neurohypophysis***. Between these portions is a small, relatively avascular zone called the ***pars intermedia,*** which is much less developed in the human being but is larger and much more functional in some animals.

Six major peptide hormones plus several other hormones of lesser importance are secreted by the anterior pituitary, and two important peptide hormones are secreted by the posterior pituitary.

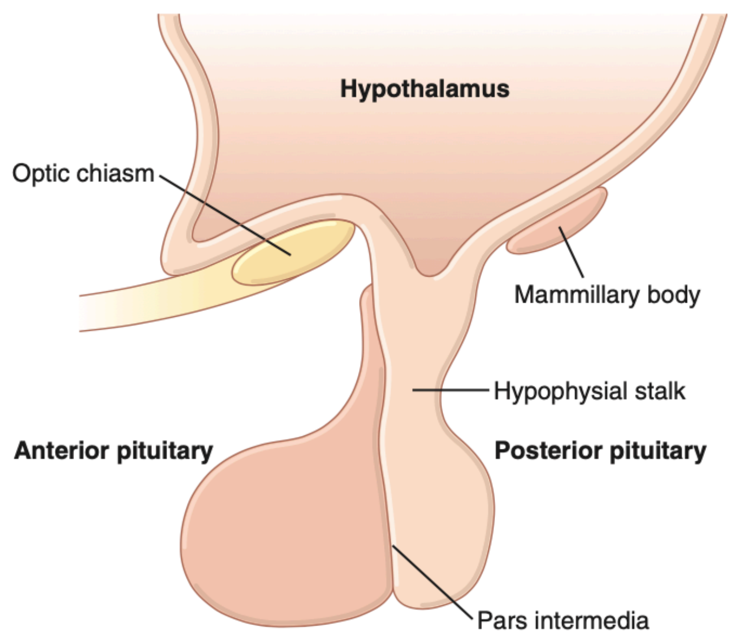

Figure 1: pituitary gland and hypothalamus

The hormones of the anterior pituitary play major roles in the control of metabolic functions throughout the body, as shown in **Figure 2**.

- ***Growth hormone*** **(hGH)** promotes growth of the entire body by affecting protein formation, cell multiplication, and cell differentiation.

- ***Adrenocorticotropin (corticotropin)*** **(ACTH)** controls the secretion of some of the adrenocortical hormones, which affect metabolism of glucose, proteins, and fats.

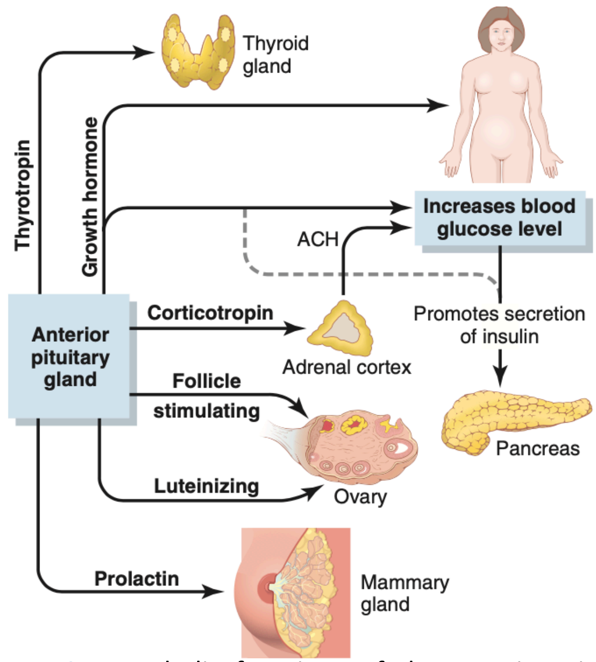

Figure 2: Metabolic functions of the anterior pituitary hormones. ACH, adrenal corticosteroid hormones.

- ***Thyroid-stimulating hormone (thyrotropin)*** **(TSH)** controls the secretion rate of thyroxine and triiodothyronine by the thyroid gland, and these hormones control the rates of most intracellular chemical reactions in the body.

- ***Prolactin*** **(PRL)** promotes mammary gland development and milk production.

- Two separate gonadotropic hormones, ***follicle stimulating hormone*** **(FSH)** and ***luteinizing hormone*** **(LH)**, control growth of the ovaries and testes, as well as their hormonal and reproductive activities.

The two hormones secreted by the posterior pituitary play other roles.

- ***Antidiuretic hormone*** (also called ***vasopressin***) controls the rate of water excretion into the urine, thus helping to control the concentration of water in the body fluids.

• ***Oxytocin*** helps express milk from the glands of the breast to the nipples during suckling and helps in the delivery of the baby at the end of gestation.

Usually, there is one cell type for each major hormone formed in the anterior pituitary gland. At least five cell types can be differentiated in the anterior pituitary. **Table 1** provides a summary of these cell types, the hormones they produce, and their physiological actions.

Table 1: Cells and Hormones of the Anterior Pituitary Gland and Their Physiological Functions

Cell	Hormone	Chemistry	Physiological Action
Somatotropes	Growth hormone (GH) (somatotropin)	Single chain of 191 amino acids	Stimulates body growth; stimulates secretion of insulin-like growth factor-1; stimulates lipolysis; inhibits actions of insulin on carbohydrate and lipid metabolism
Corticotropes	Adrenocorticotropic hormone (ACTH) (corticotropin)	Single chain of 39 amino acids	Stimulates production of glucocorticoids and androgens by the adrenal cortex; maintains size of zona fasciculata and zona reticularis of cortex
Thyrotropes	Thyroid-stimulating hormone (TSH) (thyrotropin)	Glycoprotein of two subunits, α (89 amino acids) and β (112 amino acids)	Stimulates production of thyroid hormones by thyroid follicular cells; maintains size of follicular cells
Gonadotropes	Follicle-stimulating hormone (FSH)	Glycoprotein of two subunits, α (89 amino acids) and β (112 amino acids)	Stimulates development of ovarian follicles; regulates spermatogenesis in the testis
	Luteinizing (LH) hormone	Glycoprotein of two subunits, α (89 amino acids) and β (115 amino acids)	Causes ovulation and formation of the corpus luteum in the ovary; stimulates production of estrogen and progesterone by the ovary; stimulates testosterone production by the testis
Lactotropes-Mammotropes	Prolactin (PRL)	Single chain of 198 amino acids	Stimulates milk secretion and production

Hypothalamus controls pituitary secretion

Secretion from the posterior pituitary is controlled by <u>nerve signals</u> that originate in the hypothalamus and terminate in the posterior pituitary. In contrast, secretion by the anterior pituitary is controlled by hormones called ***hypothalamic releasing*** and ***hypothalamic inhibitory hormones*** secreted within the hypothalamus and then conducted, as shown in **Figure 3**, to the anterior pituitary through minute blood vessels called ***hypothalamic-hypophysial portal vessels***. In the anterior pituitary, these releasing and inhibitory hormones act on the glandular cells to control their secretion.

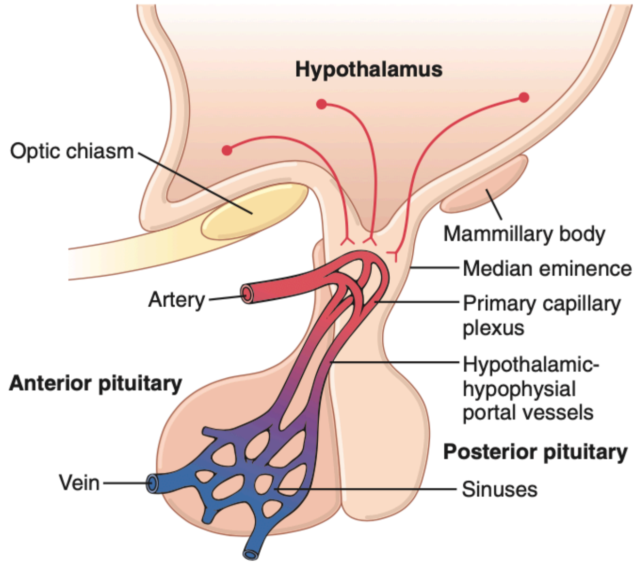

Figure 3: Hypothalamic-hypophysial portal system

The hypothalamus receives signals from many sources in the nervous system. Thus, when a person is exposed to pain, a portion of the pain signal is transmitted into the hypothalamus. Likewise, when a person experiences some powerful depressing or exciting thought, a portion of the signal is transmitted into the hypothalamus. Olfactory stimuli denoting pleasant or unpleasant smells transmit strong signals directly and through the amygdaloid nuclei into the hypothalamus. Even the concentrations of nutrients, electrolytes, water, and various hormones in the blood excite or inhibit various portions of the hypothalamus. Thus, the hypothalamus is a collecting center for information concerning the internal well-being of the body, and much of this information is used to control secretions of the many important pituitary hormones.

Hypothalamic hormones are secreted into the median eminence.

Special neurons in the hypothalamus synthesize and secrete the *hypothalamic releasing* and *inhibitory hormones* that control secretion of the anterior pituitary hormones. These neurons originate in various parts of the hypothalamus and send their nerve fibers to the **median eminence**, an extension of hypothalamic tissue into the pituitary stalk.

The endings of these fibers are different from most endings in the central nervous system, in that their function is not to transmit signals from one neuron to another but rather to secrete the hypothalamic releasing and inhibitory hormones into the tissue fluids. These hormones are immediately absorbed into the hypothalamic- hypophysial portal system and carried directly to the sinuses of the anterior pituitary gland.

Hypothalamic releasing and inhibitory hormones

The function of the releasing and inhibitory hormones is to control secretion of the anterior pituitary hormones. For most of the anterior pituitary hormones, it is the releasing hormones that are important, but for prolactin, a hypothalamic inhibitory hormone probably exerts more control. The major hypothalamic releasing and inhibitory hormones are the following:

1. ***Thyrotropin-releasing hormone*** **(TRH)**, which causes release of thyroid-stimulating hormone.
2. ***Corticotropin-releasing hormone*** **(CRH)**, which causes release of adrenocorticotropin (ACTH).
3. ***Growth hormone–releasing hormone*** **(GHRH)**, which causes release of growth hormone.
4. ***Growth hormone inhibitory hormone*** **(GHIH)**, also called ***somatostatin,*** which inhibits release of growth hormone.

5. ***Gonadotropin-releasing hormone*** **(GnRH)**, which causes release of the two gonadotropic hormones, luteinizing hormone (LH) and follicle-stimulating hormone (FSH).
6. ***Prolactin inhibitory hormone*** **(PIH)**, which causes inhibition of prolactin secretion.

Additional hypothalamic hormones include one that stimulates prolactin secretion and perhaps others that inhibit release of the anterior pituitary hormones.

Posterior pituitary gland and its relation to the hypothalamus

The ***posterior pituitary gland,*** also called the ***neurohypophysis,*** is composed mainly of glial-like cells called ***pituicytes***. The pituicytes do not secrete hormones; they act simply as a supporting structure for large numbers of ***terminal nerve fibers*** and ***terminal nerve endings*** from nerve tracts that originate in the ***supraoptic*** and ***paraventricular nuclei*** of the hypothalamus, as shown in Figure 4. These tracts pass to the neurohypophysis through the ***pituitary stalk*** (hypophysial stalk). The nerve endings are bulbous knobs that contain many secretory granules. These endings lie on the surfaces of capillaries, where they secrete two posterior pituitary hormones: (1) ***antidiuretic hormone*** **(ADH)**, also called ***vasopressin,*** and (2) ***oxytocin***.

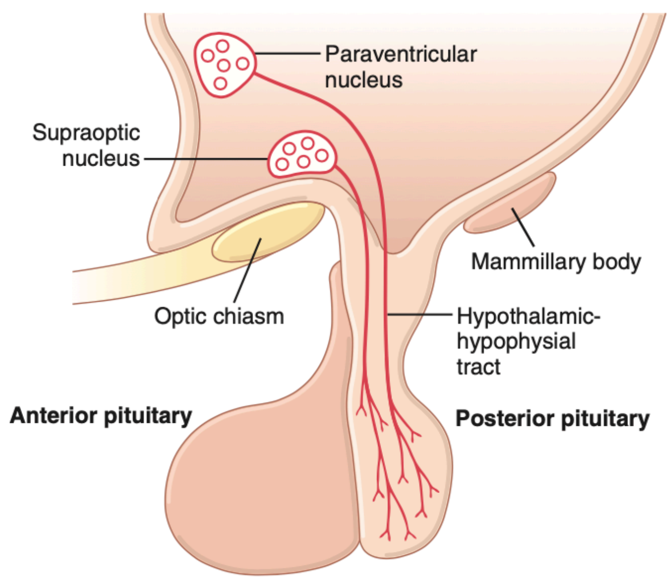

Figure 4: Hypothalamic control of the posterior pituitary.

ADH is formed primarily in the ***supraoptic nuclei,*** whereas oxytocin is formed primarily in the ***paraventricular nuclei.*** Each of these nuclei can synthesize about one sixth as much of the second hormone as of its primary hormone.

Physiological functions of antidiuretic hormone

ADH cause decreased excretion of water by the kidneys (antidiuresis). Briefly, in the absence of ADH, the collecting tubules and ducts become almost impermeable to water, which prevents significant reabsorption of water and therefore allows extreme loss of water into the urine, also causing extreme dilution of the urine. Conversely, in the presence of ADH, the permeability of the collecting ducts and tubules to water increases greatly and allows most of the water to be reabsorbed as the tubular fluid passes through these ducts, thereby conserving water in the body and producing very concentrated urine. Whereas minute concentrations of ADH cause increased water conservation by the kidneys, higher concentrations of ADH have a potent effect of constricting the arterioles throughout the body and therefore increasing the arterial pressure. For this reason, ADH has another name, ***vasopressin***.

Physiological functions of oxytocin

Oxytocin causes contraction of the pregnant uterus

The hormone ***oxytocin,*** in accordance with its name, powerfully stimulates contraction of the pregnant uterus, especially toward the end of gestation. Therefore, many obstetricians believe that this hormone is at least partially responsible for causing birth of the baby.

Oxytocin aids in milk ejection by the breasts

In lactation, oxytocin causes milk to be expressed from the alveoli into the ducts of the breast so that the baby can obtain it by suckling. oxytocin causes contraction of ***myoepithelial cells*** that lie outside of and form a latticework surrounding the alveoli of the mammary glands. In less than a minute after the beginning of suckling, milk begins to flow.

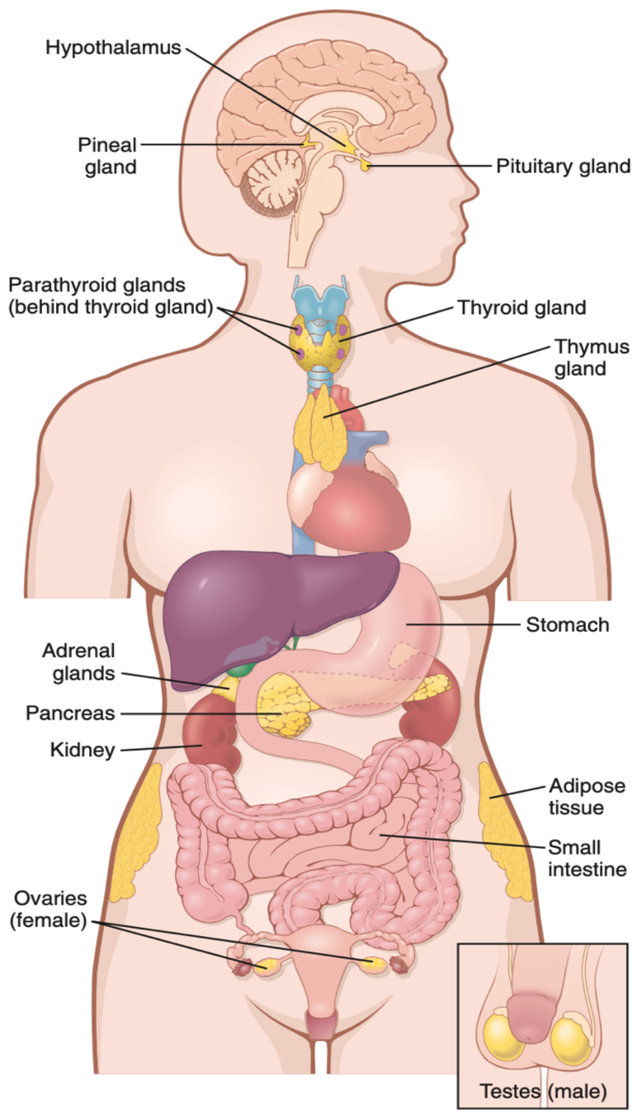

Figure 5: The distribution of endocrine glands and tissue in the body