

UNIT 5 Lecture 16

CONTROL SYSTEMS - THE ENDOCRINE SYSTEM

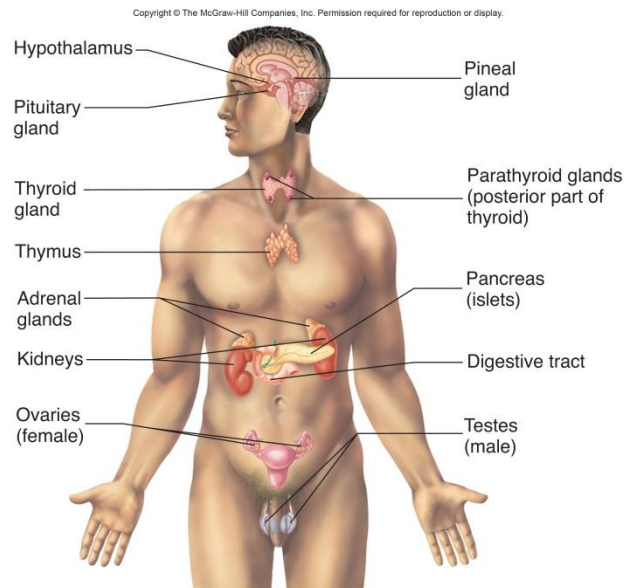
ENDOCRINE GLANDS

The body contains two types of glands; exocrine and endocrine glands. Exocrine glands (sudoriferous, sebaceous, and digestive) secrete their products through ducts into body cavities or onto body surfaces. Endocrine glands secrete their products (hormones) into extracellular spaces around the secretory cell. The secretion diffuses into capillaries and is carried away by the blood to a target tissue.

HORMONES

Hormones only affect specific target cells that have receptors to recognize a given hormone. Circulating hormones (endocrine) are hormones that pass into the blood to act on distant target cells, thus may linger for minutes or hours. Local hormones usually are inactivated quickly. For example paracrines act on neighboring cells and autocrines act on the same cell that secreted them.

Hormones can be classified by their chemical structure. Most hormones are either steroids or nonsteroids. Steroids are lipids that are derived from cholesterol; examples include the sex hormones and aldosterone. Biogenic amines are very simple molecules derived from amino acids; examples include the thyroid hormones (T_3 & T_4), epinephrine and norepinephrine (catecholamines). Peptides (short chains of amino acids) and proteins (long chains of amino acids) include thyroid stimulating hormone, antidiuretic hormone, insulin, glucagon, human growth hormone and others. Eicosanoids were recently discovered hormone and include prostaglandins and leukotrienes. Water soluble hormones circulate in free form in the blood; lipid-soluble steroid and thyroid hormones are carried attached to transport proteins.



MECHANISMS OF HORMONE ACTION

Hormones can also be classified by their mechanism of action. The mechanism depends on both the hormone and the target cell. (Insulin stimulates synthesis of glycogen in the liver and synthesis of triglycerides in adipose tissue. Lipid-soluble hormones diffuse through the cell membrane into a cell. In a target cell, the hormone binds to and activates receptors within the cytosol or nucleus altering gene expression. Water-soluble hormones activate plasma membrane receptors. First messenger is hormone that activates receptor on plasma membrane which

activates G-protein. A second messenger relays the message inside of the cell. Cyclic AMP (cAMP) is the best known second messenger.

Hormonal interactions depend on the hormone's concentration, abundance of receptors, influences by other hormones. In a permissive effect, the action of some hormones requires recent stimulation by other hormones. In some cases there may be a synergistic effect or antagonistic effect. Down-regulation occurs when the number of receptors decreases, thereby decreasing the responsiveness of the target cell. Up-regulation occurs when hormone is deficient and makes target tissue more receptive.

Control of Hormone Secretion

Most hormones are released on short bursts, with little or no release between bursts. Regulation maintains homeostasis and prevents over or underproduction. Hormone secretion is controlled by signals from the nervous system, by chemical changes in the blood, and by other hormones. Most control is through negative feedback systems. Once hormones have had their effects on their target tissue, they are broken down by different systems in the body. Hormones are removed from the blood by the same mechanisms as any other substance: metabolic destruction in the blood or by tissues (mainly liver and kidney), excretion by the liver into the bile, or excretion by the kidneys into the urine.

HYPOTHALAMUS AND PITUITARY GLAND

The hypothalamus is located at the base of the brain just above the pituitary gland and below the thalamus. Because of its central location, it can receive information from all over the brain. It is composed of many regions made up of groups of nerve cell bodies, which are called nuclei. Several of these nuclei control the release of hormones from the pituitary gland. The hypothalamus is involved with some of the body's homeostatic mechanisms, including the regulation of body temperature, water balance, and energy production. It is also involved in regulating the behavioral drives of thirst, hunger, and sexual behavior. In order to perform all of these complex and widespread functions, the hypothalamus receives large amounts of information from all around the body, including metabolic, hormonal, temperature, and neural information. The [hypothalamus](#) is the major integrating link between the [nervous](#) and endocrine systems. The hypothalamus and the pituitary gland regulate virtually all aspects of growth, development, metabolism, and homeostasis.

The pituitary gland consists of an anterior pituitary gland and posterior pituitary gland. Hormones of the anterior pituitary gland are controlled by releasing or inhibiting hormones produced by the hypothalamus. There are five cell types; somatotrophs which produce human growth hormone (hGH), lactotrophs which produce prolactin (PRL), corticotrophs that secrete ACTH and melanocyte stimulating hormone, thyrotrophs secrete thyroid-stimulating hormone (TSH), and gonadotrophs secrete follicle-stimulating hormone (FSH) and luteinizing hormone (LH).

Hormones of the Anterior Pituitary Gland

GH (somatotropin) stimulates body growth, has many effects on metabolism and is controlled by growth hormone inhibiting hormone-somatostatin (GHIH) and growth hormone releasing hormone (GHRH). Disorders associated with improper levels of hGH are pituitary dwarfism, giantism and acromegaly.

TSH regulates thyroid gland activities (T_3 - T_4 production) and is controlled by TRH (thyroid releasing hormone).

FSH regulates activities of the ovaries and testes and is controlled by (GnRH) gonadotropin releasing hormone.

LH regulates activities of the ovaries and testes and is controlled by (GnRH) gonadotropin releasing hormone.

Prolactin (PRL) helps initiate milk secretion and is controlled by PIH (prolactin inhibitory hormone) and PRH (prolactin releasing hormone).

Melanocyte-stimulating hormone increases skin pigmentation and is controlled by melanocyte-releasing hormone and melanocyte-inhibiting hormone.

ACTH regulates activities of the adrenal cortex and is controlled by CRH (corticotrophin releasing hormone).

Posterior Pituitary Gland

The posterior pituitary gland does not synthesize hormone, but it does store two hormones made in the hypothalamus. Oxytocin (OT) stimulates contraction of the uterus and ejection of milk from the breasts. OT secretion is controlled by uterine distention and nursing. Synthetic OT is often given to induce labor. The other hormone is Antidiuretic hormone (ADH). ADH stimulates water reabsorption by the kidneys and arteriolar constriction. The effect of ADH is to decrease urine volume and conserve body water. ADH is controlled by osmotic pressure of the blood. A disorder with secretion of ADH is Diabetes insipidus which is a result in a hypersecretion of ADH which results in the excretion of large amounts of dilute urine.

THYROID GLAND

[Thyroid gland](#) consists of thyroid follicles which secrete hormones T_3 and T_4 and parafollicular cells which secrete calcitonin. Thyroid hormones are synthesized from iodine and tyrosine. Thyroid hormones regulate the rate of metabolism, growth and development, and the reactivity of the nervous system. The receptors for these hormones are found within the nucleus of almost all cells in the body and can alter the transcription of genes to form many different proteins. Many of these proteins are enzymes that enhance the metabolic activity of these cells. As a result, T_3 and

T₄ are responsible for regulating the body's basal metabolic rate (BMR). BMR is the amount of oxygen and energy that the body is using at rest, or essentially, the least amount of energy that a person will use. T₃ and T₄ are also responsible for proper development of the nervous system in the fetus. In addition, these hormones help to maintain a person's alertness, responsiveness, and emotional state. Secretion is controlled by the level of iodine in the thyroid gland. Calcitonin lowers the blood level of calcium. Secretion is controlled by calcium levels in the blood. Cretinism, myxedema, Graves' disease and goiter are disorders associated with the thyroid gland.

PARATHYROID GLANDS

Parathyroid glands are embedded in the posterior surfaces of the thyroid gland. They secrete parathyroid hormone (PTH) which regulates the homeostasis of calcium and phosphate by increasing the blood calcium level and decreasing blood phosphate level. Secretion is controlled by blood calcium levels. Without PTH, the kidney would continually excrete calcium and this would eventually deplete the extracellular fluid and bones of this vital mineral. Tetany and Osteitis fibrosa are disorders associated with the parathyroid glands. Tetany results from a deficiency of calcium caused by hypothyroidism. Osteitis fibrosa is characterized by demineralized, weakened, and deformed bones resulting from hyperthyroidism.

ADRENAL GLANDS

The adrenal glands lie on top of each kidney and consist of an outer cortex and an inner medulla. Complete loss of adrenocortical hormones leads to death due to dehydration and electrolyte imbalance within days to a week. In the Adrenal Cortex are the zona glomerulosa, zona fasciculata, and zona reticularis. Cortical secretions include mineralcorticoids, glucocorticoids and gonadalcorticoids. Mineralcorticoids (Aldosterone) increase sodium and water reabsorption and decrease potassium reabsorption. Secretion is controlled by the renin-angiotensin pathway and the blood levels of potassium. Hypersecretion of aldosterone leads to muscular paralysis and hypertension.

Glucocorticoids (cortisol) promote normal organic metabolism, help resist stress and serves as anti-inflammatory substance. Cortisol is secreted when the body is under stress in order to increase blood glucose levels. Most of its actions are catabolic, stimulating glucose production. Secretion is controlled by CRH and ACTH from the anterior pituitary. Disorders of glucocorticoids production include Addison's disease (hyposecretion of glucocorticoids and aldosterone) and Cushing's disease (hypersecretion of cortisol and cortisone).

Gonadalcorticoids secreted by the adrenal glands usually have minimal effects. Excessive production results in virilism.

Adrenal Medulla

The adrenal medulla consists of hormone-producing cells, called chromaffin cells, which surround large blood-filled sinuses. Medullary secretions are epinephrine and norepinephrine. Hormones are released under stress by direct innervation from the autonomic nervous system and mimic sympathetic responses. They help the body reduce stress but are not essential for life.

PANCREAS

The pancreas produces exocrine (for digestion) and endocrine (hormones) secretions. Endocrine portion consists of pancreatic islets (islets of Langerhans) which are divided into four types of cells. Alpha cells secrete the hormone glucagon which increases blood glucose levels. Secretion is stimulated by low blood glucose level. Beta cells secrete the hormone insulin. Insulin decreases blood glucose levels and is stimulated by a high blood glucose. Disorders associated with Beta cell endocrine hormone secretion include diabetes mellitus and hyperinsulinism.

Delta cells secrete growth hormone inhibiting hormone (GHIH) which acts as a paracrine to inhibit the secretion of insulin and glucagon. F-cells secrete pancreatic polypeptide, which regulates the release of pancreatic digestive enzymes.

REPRODUCTIVE GLANDS

Ovaries produce estrogen and progesterone which are related to development and maintenance of female sexual characteristics, reproductive cycle, pregnancy, lactation and normal reproductive functions. Produce also inhibin and relaxin. These will be covered in extensively in the reproductive unit. Testes produce testosterone which is related to development and maintenance of male sexual characteristics and normal reproductive functions. Also produced is inhibin.

PINEAL GLAND

Attached to roof of third ventricle inside the brain is the pineal gland. It consists of pinealocytes, neuroglial cells and post ganglionic sympathetic fibers. The pineal gland secretes melatonin in a diurnal rhythm linked to the dark-light cycle. Seasonal affective disorder (SAD) is thought to be due to over-production of melatonin.

Hyposecretion and Hypersecretion

Inadequate release of hormones from the endocrine glands results in imbalances in the homeostasis which leads to disease. Too little hormone being released is known as hyposecretion whereas too much hormone released is called hypersecretion. The following table is a partial list of endocrine glands and the disease states that occur in hypo- and hypersecretion.

Gland	Hormone	Hyposecretion	Hypersecretion
Pituitary	HGH	Pituitary dwarfism	Giantism
	ADH	Diabetes insipidus	*****
Thyroid	TSH	Cretinism (in infants) or Myxedema (in adults)	Graves disease
Adrenal	Cortisol	*****	Cushing's disease
Pancreas	Insulin	Diabetes mellitus	*****

STRESS AND THE GENERAL ADAPTATION SYNDROME

Homeostatic mechanisms attempt to counteract the everyday stresses of living. If successful, the body maintains normal limits of chemistry, temperature and pressure. If stress is extreme, unusual, or long-lasting, these mechanisms may not be sufficient, which triggers the general adaptation syndrome. Stressors are the stimuli that produce the general adaptation syndrome. Include heat, cold, operations, poisons, infections, fever, and strong emotional responses. Stressors stimulate the hypothalamus via an immediate alarm reaction. They are slower to start, but longer lasting, resistance reaction.

Alarm Reaction

This alarm reaction is also called the fight-or-flight reaction that increases circulation, promotes catabolism for energy production, and decrease nonessential activities.

Resistance reaction is initiated by regulating hormones of the hypothalamus (CRH, GHRH, and TRH). They are long term reactions and accelerate catabolism for energy to counteract stress. Exhaustion can result from changes during alarm and resistance reactions. If stress causing exhaustion is too great, it may lead to death.

Stress and disease

Stress can lead to diseases such as gastritis, ulcerative colitis, irritable bowel syndrome, peptic ulcers, hypertension, asthma, rheumatoid arthritis, migraine headaches, anxiety and depression. One can also develop a chronic disease or dying prematurely if stressors are not reduced.

Why is this chapter important?

The last chapter details the organs of the body that produce hormones. Hormones along with the nervous system control all the functions that go on in the body. We covered what hormones were produced by which organ, what affected the release of those hormones, which sites were targeted, and what were the principal actions as a result of hormone interactions.