Consortium for Educational Communication

Module

on

Hormones

By

Dr. Sushma Appaiah., M. Sc., Ph.D

Founder & CEO, Giggles of Livez (Golz)

Nutrition Councellor

Roopanagar, Mysuru-570026

Karnataka, India

Text

Introduction

Hormones are defined as organic biologically active compounds of different chemical nature. Chemically they are amino acid derivatives, polypeptides or proteins or steroids. Hormones are produced and secreted by endocrine glands into circulation. They have profound physiological and biochemical activities.

Hormones are the chemical messengers of body. Human body secretes and circulates around fifty different hormones. Most of these chemical substances are produced by endocrine cells, from the glands. A gland is an organ that consist of cells, which secretes material into other regions. Human body has two types of glands viz; Exocrine glands and Endocrine glands.

i) Exocrine glands secretes nonhormonal chemicals into ducts, which transport to a specific location inside and outside the body, for e.g sweat glands, mucous glands, salivery glands and few digestive glands.

ii) Endocrine glands; They are ductless glands located throughout the body. They secrets hormones into the bloodstream through the fluid surrounding the cells.

The hormones then enter the blood system to circulate throughout the body and activate target cells **.**Specific stimulus for hormones secretion are**:** nervous impulse and concentration of the certain compound in blood passing through the endocrine gland. The endocrine system works with nervous system.

Classification of Hormones

Hormones can be classified into three category based on their chemical nature

Amino Acid Derivatives: These hormones are derivatives of amino

acid, tyrosine. They act as hormones e.g., thyroxine, adrenaline and noradrenaline, dopamine.

Polypeptides and Proteins: Many hormones are polypeptides or proteins by nature. These include insulin, glucagons, vasopressin, parathormone, hormones from anterior lobe of the pituitary body and hormones produced by the gastrointestinal tract.

Erythropoietin (EPO) is a glycoprotein. It acts on the bone marrow to increase the production of red blood cells.

Steroid Hormones: These contain steroid nucleus. The hormones of this category include male sex hormones (androgens), female sex hormones (estrogens and gestogens) and hormones of the adrenal cortex.

The hormones secreted by the various endocrine glands are listed in **Table 1.**

Mode of Action of Hormones:

Hormones exert their actions as**:** 1.Endocrine action, 2. Paracrine action and 3.Autocrine action .The mode of action of hormones can be explained under three heads

1) Action on cell membrane

2) Action on intracellular enzyme systems

3) Action on cell nucleus

1) *Action on cell membrane*: Hormones act on cell membranes in two different ways:

(a) They may alter the permeability of cell membrane: and

(b) They may activate some membrane bound enzyme system.

(a) Hormones may alter the permeability or transport of monosaccharides, amino acids, cations and nucleotides across the cell membrane. Thus, growth hormone increases amino acid

transport into muscle cells and insulin increases the active transport of glucose, amino acids, potassium ion, nucleosides and inorganic phosphate into muscle cells etc.

(b) Few hormones activate membrane bound enzymes. The only enzyme found in cell membrane sensitive to hormones is adenyl cyclase which coverts ATP to cyclic AMP. Cyclic AMP activates glycogen phosphorylase and hydroxylation of corticosteroids and regulates glycogen synthetase activity. The level of cyclic AMP in cell membrane may be increased or decreased by hormonal action, depending on the hormone and the tissue involved. For example, glucagons may produce more cyclic AMP in the liver cell membrane as compared to that in muscle cell membrane while adrenaline produces more cyclic AMP in the muscle cell membrane than in liver cell membrane. Insulin decreases the formation of cyclic AMP in liver cell membrane.

2) *Action on intracellular enzyme systems:* Certain hormones activate or inhibit specific enzyme systems within the cell. For example, ACTH activates glucose-6-phosphate dehydrogenase in the liver. Insulin increases the activity of the enzyme glucose kinase (Glucose-6-phosphorylase) in liver.

3) *Action on cell nucleus:* Few hormones are able to control the activity of specific genes and thus regulate the synthesis of mRNA and hence the enzymes present in the cells. Some hormones (isotopically) labeled are found to be localized in the nucleus. The steroid hormones increase the synthesis of all types of RNA by the nucleus. Current evidence indicates that hormones acting on nucleus and regulating RNA and protein synthesis, do so by influencing the enzymes and RNA involved in protein synthesis.

General functions of the hormones

1. They change the permeability of cell membrane, accelerate the penetration of substrates, enzymes, coenzymes into the cell and out of cell.
2. They act on the allosteric centers thereby affecting the activity of enzymes (Hormones penetrating membranes).

3. They affect the activity of enzymes through the messengers i.e cyclic AMP (cAMP).

The Hormones which cannot penetrate the membrane, acts on the genetic apparatus of the cell (nucleus, DNA) and promote the synthesis of enzymes for example steroid and thyroid hormones).

Hormonal receptors System

Hormonal receptors are based on their site of action. They are intracellular receptor, cell surface receptors and based on secondary messenger systems**.**

1. Intracellular Receptors:

•These are located inside target cells, in the cytoplasm or nucleus, and function as ligand-dependent transcription factors.

•The hormone-receptor complex binds to promoter regions of responsive genes and stimulates or sometimes inhibits transcription from those genes**.** example of insulin receptor is depicted in **Fig 1**

•Intracellular Receptors are composed of a single polypeptide chain that has three distinct domains: The amino-terminus, DNA binding domain, and the carboxy-terminus or ligand-binding domain.

•Steroid and thyroid hormones act on these receptors.

2. Cell surface receptors:

•These are located on the plasma membrane of target cells.

•Binding of hormone to receptor initiates a series of events which leads to generation of second messengers within the cell.

•The second messengers then trigger a series of molecular interactions that alter the physiologic state of the cell (*signal transduction*).

•Cell surface receptors are integral membrane proteins; they are composed of three parts: Extracellular domains, Transmembrane domains and Cytoplasmic or intracellular domains.

•Protein and peptide hormones and catecholamines act on these receptors.

3. Based on Second Messenger Systems:

•Water soluble hormones act through binding to cell surface receptors and activation of one of the second messenger systems.

•Multiple hormones utilize the same second messenger system. Also, a

single hormone can utilize more than one system.

•The small signal generated by hormone binding to its receptor is amplified within the cell into a cascade of actions that changes the cell's physiologic state.

•Examples are: Cyclic AMP, Protein kinase activity, Cyclic GMP, and Calcium and/or Phosphatidylinositide.

Transportation of hormones in the human body

Hormones are secreted directly into the blood. Peptide and protein hormones are secreted by exocytosis. Steroid or lipophilic hormones continuously penetrate the membrane (they are not accumulated in cells, their concentration in blood is determined by the speed of synthesis).The hormones which are protein and peptide in nature are circulated in free state. Steroid hormones and hormones of thyroid gland are bound with alpha-globulins or albumins

Catecholamine's can be found both in free state or bound with albumins, sulphates or glucuronic acid ,which reach the target organs based on their specific receptors.

Let us learn in detail about the endocrine gland.

E**ndocrine glands** are highly specialized group of cells responsible for making hormones. These glands are located throughout entire body. Each gland plays a specific role in the production of a particular hormone or group of hormones. These hormones are required to carry out specific functions and to keep the body in homeostasis or continual balance. In order to perform with maximum level of efficiency, homeostasis is highly significant. To maintain homeostatic balance, certain hormones are sent to specific cells and tissues to trigger a sensation which generates heat within the body and this leads to symptoms of shivering and the chattering of teeth. This alerts the body to be kept warm so that normal functions of body are restored by normalising the internal temperature. In case of continued fall of body temperature the body temperature reduces further, organs and systems will slowly malfunction.

Apart from regulation of homeostesis, they react to specific stimuli, regulates the growth, development and reproduction. They also produce and store energy.

Endocrine glands and their related organs joins to work like small factories. The specific endocrine gland receives message from the pituitary gland, which is also known as the master gland, stating how much hormone is needed and what is the site of action. The hormone then moves in the bloodstream till it reaches the targeted tissues or cells. These tissues and cells will have receptors which serve as binding sites for the attachment of the hormone. Once, the hormone gets attached to the binding sites, the hormone carries out its specific role to maintain homeostatic balance. **S**chematic representation of major hormones are presented in **Fig 3**

Location of the Endocrine Glands and role of hypothalmus

The pituitary gland is found inside the skull, just above the nasal passages. It is considered the master gland as it ensures the timely production and delivery of every hormone in the body. Hypothalamus, plays an essential role in delivery of messages to and fro from respective endocrine glands throughout the body.

Let's now learn about the various glands of endocrine system and the hormones secreted by them with their functions. **Table 2**

1. The pituitary gland: The pituitary gland consists of two parts – **(i)** the neurohypophysis or posterior lobe and **(ii)** the adenohypophysis or anterior lobe. The human pituitary weights about 0.5 g. in the adult, the adenohypophysis constituting 75 percent of the total weight. Functionally, both parts are controlled by hypothalamus.

A. The Anterior pituitary secretes:

•Luteinizing hormone (LH) and follicular stimulating hormone (FSH), which act on the gonads. In female, LH stimulates the menstruation cycle. In male, FSH stimulates testicular growth.

•Prolactin **(**PRL) stimulates the secretion of milk in the mammary gland, developed by the action of esterogen and progesterone.

•Adrenocortiotrpic hormone **(**ACTH), which acts on the adrenal cortex to regulate the secretion of glucocorticoids. ACTH stimulates the formation of cortical steroids from the cholesterol. Cortisol affects carbohydrate, protein and fat metabolism. It helps in coping with stress.

Decreased activity of ACTH causes Addison's disease which affects weight loss, low blood pressure, general weekness and can lead to heart failure. The hyperactivity of the ACTH results in cushing syndrome which causes obesity, increased blood sugar levels, high blood pressure.

•Growth hormone (GH), which acts on bone, muscle and liver. The GH affects the metabolism of carbohydrates, fats and proteins.

•Thyroid stimulating hormone or thyrotropin (TSH) which stimulates the release of thyroxine (T4) and triiodothyronine (T3) from thyroid gland. In absence of pituitary gland thyroxine synthesis does not take place and condition is known as myxoedema.

The thyrotrophic hormone increases the rates of the following reactions**.**

(i) Removal of inorganic iodide from blood by thyroid,

(ii) Incorporation of iodide in the thyroid hormone;

(iii) Release of thyroxine from the thyroid gland to circulation

B. The posterior pituitary secretes:

The hormones secreted by the neurohypophysis or posterior pituitary are:

a) Vasopressin b) Oxytocin and c) Coherin.

A brief account of the chemistry and functions of these hormones are given below.

a) Vasopressin: Vasopressin is the antidiuretic hormone (ADH). It is a polypeptide containing 9 amino acid residues **(fig 2)**.Vasopressin exerts a marked effect on the kidney tubules accelerating the rate of water reabsorption from the distal tubules. The half life of the hormone is approximately one minute, due to rapid inactivation in blood and excretion by the kidney. The regulation of absorbtion rate of water per minute is due to the ADH.

b) Oxytocin**:** Oxytocin is a hormone secreted by the neurohypophysis. Its secretion is controlled by hypothalamus. It acts on the smooth muscle of uterus and causes contraction of the muscle. It plays important role during childbirth.

c) Coherin: Coherin is a hormone secreted by the neurohypophysis. It induces prolonged rhythmic integrated contraction of the jejunum.

Adenohypophysis releases a number of hormones. Corticotropin-releasing hormone (CRH) which stimulates the release of ACTH from anterior pituitary. They may be broadly divided into two groups;

Trophic hormones viz., thyrotrophic hormone (TCH), Adrenocorticotrophin

(ACTH)

(i) Gonadotropin-releasing hormone (GnRH) which stimulates the release of FSH

and LH from anterior pituitary luteinizing hormone (LH), follicle stimulating hormone (FSH) and

(ii) Growth hormone (Somatotrophin: Prolactin and lipotrophins). Growth hormone-

releasing hormone (GHRH**)** which stimulates the release GH from anterior pituitary. Release of these hormones is regulated by specific hormones secreted by hypothalamus

The first category are called trophic hormones, as they stimulate other endocrine glands to secrete hormones while the second group of hormones act directly on the tissues concerned.

Prolactin releasing hormone (PRH) which stimulates the release of prolactin from anterior pituitary.

Thyrotropin-releasing hormone (TRH) which stimulates the release of thyroid stimulating hormone (primarily), also stimulate the prolactin release.

2. Thyroid gland secretes and regulates:
Thyroxine **(**T4**)** and Triiodothyronine (T3**)**, acting on metabolism. They increase cellular metabolic rates

3. Parathyroid glands secretes:
Parathyroid hormone **(**PTH), which regulates calcium homeostasis. The parathyroid hormone (PTH) is involved in regulation of the calcium levels in the blood are produced by parathyroid hormones. The PTH increases the reabsorption of calcium in the kidneys and uptake of calcium from the digestive system.

4. Pancreas secretes:
Insulin and Glucagon; both control glucose level in the blood. Hormones insulin and glucagon regulates the metabolism of blood glucose (sugar) each with an opposite effect. Insulin stimulates its target cells to take up and use glucose. This action lowers blood glucose levels. Glucagon stimulates its cells to breakdown stored glycogen and increase glucose levels in the blood.

5. The Adrenal gland: *is composed of*

A. Adrenal cortex which secretes: Aldosterone which increase blood volume by reabsorption of sodium in kidneys, thus maintains salt and water balance
Cortisol which affects glucose metabolism and immune status, regulates carbohydrate and protein metabolism.

Androstenedione which is an anabolic male hormone and/or substrate for estrogen.

B. Adrenal Medulla secretes: Catecholamines include Epinephrine and Norepinephrine, which act also as neurotransmitters. Initiates body's response to stress and the impulsive reflex to danger.

6. *Gonads:* these are either
A. Testes secretes:
Androgens; regulates the male sex hormones including testosterone and dihydrotestosterone.

Gonads are gamete producing organs. They are also involved in production of hormones known as steroid sex hormones. Sex hormones regulate the body changes that begin with puberty. Puberty is the adolescent stage during which the individual's sex organs mature and secondary sex characteristics, such as facial hair, appear.

Testosterone is an androgen that regulates male secondary sex characteristics. They are required for normal sperm production and the development of physical characteristics (secondary sex characteristics) associated with the male (Puberty). These characteristics include the growth of facial hair, increase in body size, and deepening of the voice.

B. Ovary secretes:
Estrogens; the female sex hormones including Estradiol and Estrone. and
Progesterone which maintains the growth of uterine lining.
Estrogens are required for the development of ova and for the formation of the physical characteristics (secondary sex characteristics) associated with the female. The characteristics include the development of the female reproductive system, the menstrual cycle begins, widening of the hips, and development of the breast (Puberty)

Hormone irregularities and disorders

Hormonal disorders cause many health disorders. Major health problems with hormones are discussed briefly.

Thyroid hormone

Hypothyroid and hyperthyroidism: The underproduction and overproduction of the thyroid hormone leads to these two conditions. As thyroid hormone regulates the energy metabolism and basal metabolic rate, the overall health gets affected. Also, the interaction of thyroid status and diabetes has also shown few association.

Insulin hormone

Resistance to hormone insulin is characteristic feature associated with diabetes type 2. India is the second largest population in the world with this type of diabetes. Insulin resistance means the inability to control the blood glucose with normal levels of insulin. This happens due to an abnormal insulin molecule or due to target tissue defects.

Conclusion: A hormone is a chemical substance, made in one place and delivered to another place. It regulates the body's activities. Hormones are secreted in small amounts into the bloodstream to influence the activity of distant cells. Hormones are produced by various organs of the body. Organs that produce hormones are called endocrine glands and form the endocrine system. The specific endocrine gland receives message from the pituitary gland, which is also known as the master gland, stating how much hormone is needed and what is the site of action. The hormone then moves in the bloodstream till it reaches the targeted tissues or cells. These tissues and cells will have receptors which serve as binding sites for the attachment of the hormone. Once, the hormone gets attached to the binding sites, the hormone carries out its specific role.

Table 1 Hormones Secreted by Major Endocrine Glands

Endocrine glands and hormones	**Endocrine glands and hormones**
Adenohypophysis	Corpus Luteum
Prolactin	Progesterone
Adrenocorticotrophin (ACTH)	Relaxin
Thyrotrophin (TSH)	Ovary
Samatotrophin (growth hormone)	Estrone and estradiol
Luteinizing or interstitial cellstimulating Hormone (LH or ICSH)	Placenta
Follicle-stimulating hormone (FSH)	Estrogens Progesterone Gonadotrophin
Neurohypophysis	Relaxin
Oxytocin	
Vasopressin (antidiuretic hormone)	Insulin
Coherin	Glucagon
	Testis
Pars Intermedia	Testosterone
Melanocyte-stimulating hormone (MSH)	Parathyroids
Adrenal Medulla	Parathormone
Epinephrine	Thyroid
Norepinephrine	Thyroxine and triodothyronine
Adrenal Cortex	Miscellaneous Hormones
Adrenal cortical steroids	Tissue hormones
Aldosterone	Hormones of the gastrointestinal

Corticosterone: 17 – hydroxycor- Ticosterone	tract Prostaglandins

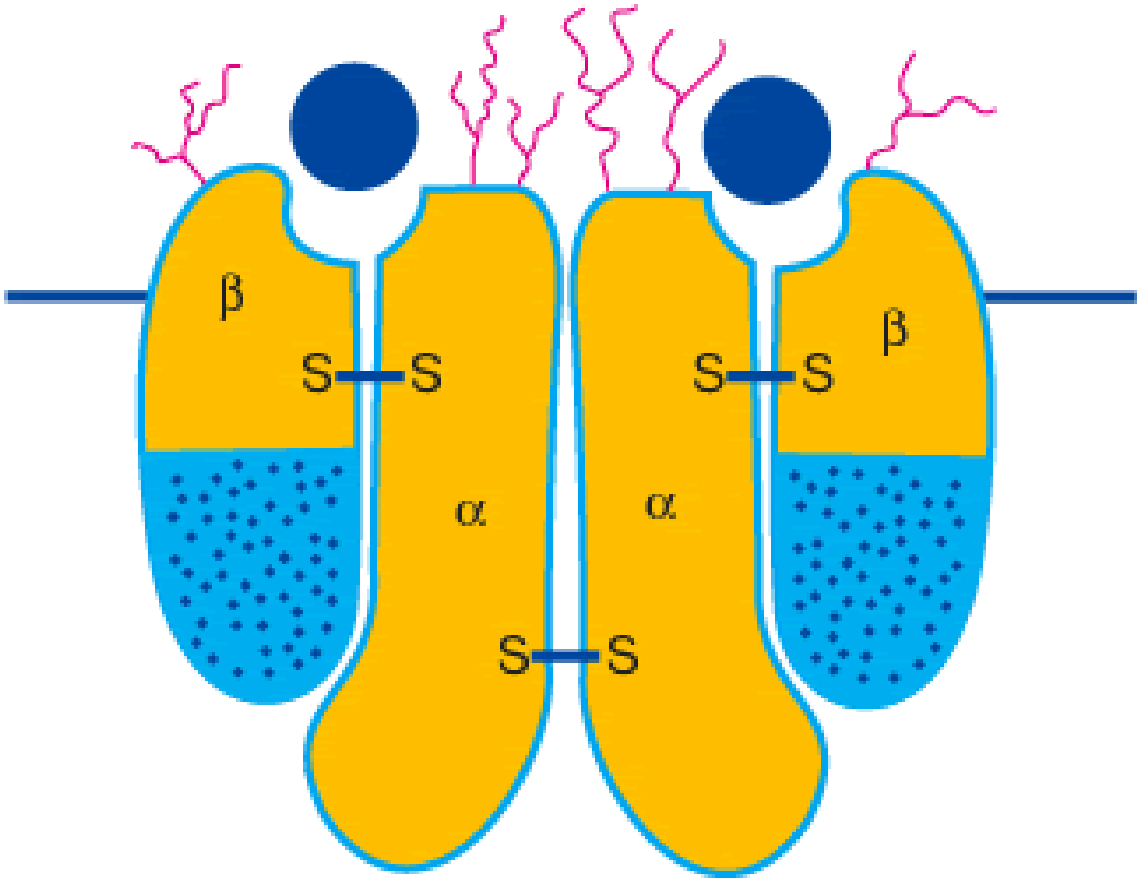
Source: Biochemistry for Medical Students, M. Swaminathan, Chapter- 26 Chemistry and Functions of Hormones

Table 2 Major Hormones and Their Functions

Endocrine Gland	Hormone	Exercise effect	Target organ	Major function
Hypothalamus	Releasing hormones	Increases with anticipation of exercise	Pituitary gland	Stimulates the pituitary gland to release hormones
	Inhibiting hormones	Increases with cessation of exercise	Pituitary gland	Inhibits release of pituitary gland hormones.

Anterior Pituitary	Growth Hormone (GH)	Increases with increasing exercise	All cells of the body	Stimulates growth in all organs/ tissues, increases protein synthesis, the mobilisation and use of fat for energy and inhibits carbohydrate metabolism
	Thyroid stimulating hormone(TSH)	Increases with increasing exercise	Thyroid gland	Controls the secretion of the hormones released by the thyroid
		Increases in response to exercise	Adrenal Cortex	Controls the secretion of hormones from the adrenal cortex
	Endorphins	Increases with long duration exercise		Blocks pain
Posterior Pituitary	Anti diuretic hormone (ADH)	Increases with increasing exercise	Kidneys	Stimulates water retention by the kidneys
Adrenal Medulla	Adrenaline (Epinephrine)	Increases with heavy exercise	Acts on most cells in the body prolonging and intensifying the sympathetic nervous system response to stress	Mobilises glucose, increases heart rate, heart contractility, oxygen use and blood flow to skeletal muscles Constricts blood vessels and elevates blood pressure.
	Nor adrenaline (Nor epinephrine)	Increases with increasing exercise intensity or duration	Acts on most cells in the body prolonging and intensifying the sympathetic nervous system response to stress	Mobilises glucose, increases heart rate, heart contractility, oxygen use and blood flow to skeletal muscles Constricts blood vessels and elevates blood pressure.
Adrenal Cortex	Aldosterone	Increases with exercise	Kidneys	Regulates electrolyte and fluid balance.

	Cortisol	Increases with heavy exercise	Most cells in the body	Increases blood sugar levels, aids the metabolism of fats, CHO and proteins, suppresses the immune system, has an anti-inflammatory action.
Pancreas	Insulin	Decreases with increasing exercise	All cells in the body	Controls blood glucose by lowering blood glucose levels
	Glucagon	Increases with increasing exercise	All cells in the body	Increases blood glucose, stimulates breakdown of glycogen and fat
Kidneys	Renin	Increases as blood pressure lowers	Adrenal Cortex	Assists in blood pressure control
Gonads: **Testes**	Testosterone	Increases with increasing exercise	Sex organs	Development of male sex organs, facial hair and change in voice
			Muscle	Promotes muscle growth
Ovaries	Oestrogen		Sex organs	Development of female sex organs, regulates menstrual cycle
			Adipose tissue	Storage of fat



-

Fig 1. Model of the insulin receptor (Jacobs, Cautrecasas, 1982)

Fig 2. Amino Acid Sequence of Vasopressin and Oxytocin

1 2 3 4 5 6 7 8 9

Cys-Tyr-Phe-Glu-Asp-Cys-Pro-Arg-Gly-NH2

Vasopressin

Cys-Tyr-Ilu-Glu-Asp-Cys-Pro-Leu-Gly-NH2

Oxytocin

Fig 3: Schematic representation of major hormones in human system

Hormones

Steroids **peptide hormones** **Amino acid derivatves** **Miscelleneousn**

(Insulin glycagon) **(Thyrodial hormones)** **(prostaglandins**

cytokinins)

Adrenal Cortical hormones (Corticoids) **Sex hormones**

Female sex **Male sex hormones**

Androgens

E.g., Testosterone

Estrogens (estrone esteradiol) **Progesterone**