

UNIT 18

CHEMICAL COORDINATION

KEY CONCEPTS

18.1 Hormones: the chemical messengers

18.2 Endocrine system of man

18.3 Feedback mechanism

The cellular functions need to be continuously regulated. The nerve fibers do not innervate all the cells of the body; a special kind of coordination system is thus required. The **endocrine system** serves the role to coordinates most body cells. The hormonal system is concerned with control of the different metabolic functions of the body, such as the rate of chemical reactions, the transport of substances through the cell membranes, growth, and secretions. This coordination is called **chemical coordination**.

18.1 HORMONES: THE CHEMICAL MESSENGERS

The glands are structures made up of one or more cells that make and release some product called secretion. These glands are classified as exocrine glands and the endocrine glands. **Exocrine glands** (exo = outside; crine = to secrete), secrete their products onto the target surface directly or through ducts. Liver, salivary glands, sweat glands, and the tear glands have ducts; the unicellular goblet cells on the other hand directly release mucin on the target surface by exocytosis. **Endocrine glands** (endo = within; crine = to secrete) are ductless glands. They produce hormones, and secrete by exocytosis directly into the extracellular spaces. From there the hormones enter the blood or lymphatic fluid and travel to specific target site.

18.1.1 Chemical nature of hormones:

Chemically, hormones are of three basic types i.e. steroids, amino acids or their derivatives, and proteins or polypeptides.

Steroid hormones:

These are derivatives of cholesterol. Different steroidal hormones are secreted by, the adrenal cortex (cortisol and aldosterone), the ovaries (estrogen and progesterone), the testes (testosterone) and the placenta (estrogen and progesterone).

Derivatives of amino acid tyrosine:

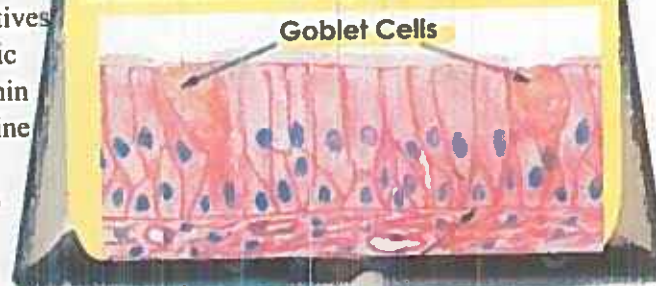
Two groups of hormones are derivatives of amino acid tyrosine. The metabolic hormones thyroxine and triiodothyronine from thyroid glands and epinephrine and norepinephrine from adrenal medullae are all derived from amino acid tyrosine.

Proteins or peptides:

Many important endocrine hormones are proteins, peptides or immediate derivatives of these. Growth hormone and prolactin are protein while antidiuretic

For Your Information

The goblet cell is a unicellular exocrine gland. Goblet cells are scattered in the epithelial linings of the intestinal and respiratory tracts. In humans, all such glands produce mucin. The mucin is a complex glycoprotein that dissolves in water when secreted, to form mucus, a slimy



hormone and oxytocin are peptides of nine amino acids each. Insulin, glucagon and parathormone are large polypeptides.

18.2 ENDOCRINE SYSTEM OF MAN

Endocrine system is the type of glandular system, consists of some 20 ductless glands lying in different parts of the body.

18.2.2 Pituitary gland:

Pituitary gland is located in the brain under the hypothalamus. It is red grey in colour, about the size of a pea, pituitary gland weighs about 0.5 g. It is attached to hypothalamus by a stalk called infundibulum.

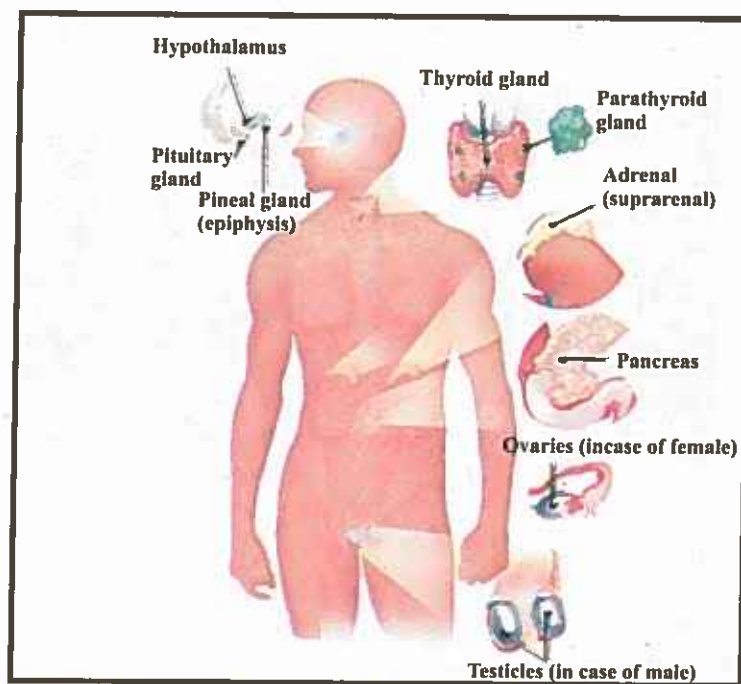


Fig: 18.1 Location of various endocrine gland in human body

It is divided into three lobes, the anterior pituitary, posterior pituitary and the intermediate pituitary.

Anterior pituitary:

Classically, the anterior pituitary is considered the master gland of the endocrine system because it secretes numerous hormones, many of which regulate the activity of other endocrine glands. Four out of six anterior pituitary hormones (thyroid stimulating hormone, adrenocorticotrophic hormone, follicle stimulating

hormone, and luteinizing hormone) are tropic hormones (tropi = turn on, change), which are hormones that regulate the secretory action of other endocrine glands.

Growth hormone (GH) or somatotropin has a direct effect on growth and development of all the body parts, particularly skeleton and skeletal muscles during childhood and adolescence. GH stimulates cell growth and cell division. It also stimulates uptake of amino acids into cells and increase rate of protein synthesis.

Deficiency of GH results in dwarfism. Development is much slower and individual has short stature, however, the body parts stay in proportion and brain development and IQ are unaffected.

Gigantism is resulted by over secretion of GH during childhood. As the bones are still capable of growth, person becomes a giant. Over secretion of GH in adult life causes acromegaly. Bones are no longer capable of increasing in length but grow in thickness. Acromegaly is characterized by enlarging the hands, feet, skull, nose and jawbone.



Fig: 18.2 a. Gigantism makes a person look like a giant.



Fig: 18.2 b. Acromegaly results in abnormal thickness of bones

Thyrotrophin releasing factor (TRF) from hypothalamus stimulates the synthesis and release of thyroid stimulating hormone (TSH) from the anterior pituitary. TSH regulates the endocrine function of the thyroid gland. TSH release is regulated by the negative feedback of thyroxin acting on hypothalamus and anterior pituitary.

- **Adrenocorticotrophic hormone (ACTH):** Its secretion is stimulated by adrenocorticotrophin releasing factor (CRF) from the hypothalamus. ACTH acts on adrenal cortex and stimulates the secretion of glucocorticoids and androgens.

- **Follicle stimulating hormone (FSH):** FSH is a gonadotroph. Its secretion is stimulated by GnRH from the hypothalamus. In females it stimulates maturation of ovarian follicle and estrogen production. In males it stimulates the development of germinal epithelium and sperm production in the testes.

Chemical Coordination

Chapter 18

- **Luteinizing hormone (LH):** Its secretion is controlled by GnRH. In females its target site is ovary. It triggers ovulation and ovarian production of estrogen and progesterone. It also causes the luteinization i.e. converts ruptured follicle to a glandular structure called corpus luteum and maintains it. In males LH is also known as interstitial cell stimulating hormone (ICSH). It promotes testosterone production in interstitial cells of the testes.
- During pregnancy, secretion of prolactin cause enlargement of the mammary glands and prepare for the production of milk (lactation). It inhibits menstrual cycle in lactating women.

Intermediate (median) lobe:

In humans, intermediate pituitary is a thin layer of cells between the anterior and posterior pituitary. It produces melanocyte stimulating hormone (MSH). Melanocyte stimulating hormone increases in humans during pregnancy also. It stimulates the production and release of melanin by melanocytes in skin and hair which darken the colour of the skin especially during pregnancy.

Posterior lobe:

Posterior pituitary stores antidiuretic hormone (ADH or vasopressin) and oxytocin. These hormones are released in response to nerve impulses from hypothalamus.

- **Antidiuretic hormone:** Diuresis means urine production. Antidiuretic is any substance which inhibits urine formation. Osmoreceptors in hypothalamus monitor the solute concentration of blood.

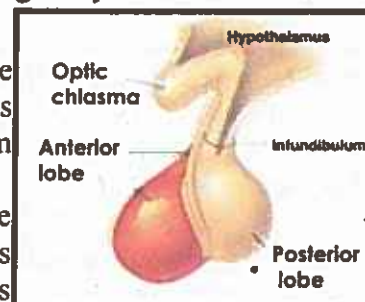


Fig: 18.3 Lobes of pituitary gland.

ADH is released when solute concentration increases as a result of water loss. It acts on kidney tubules to enhance water reabsorption. More water is reabsorbed, concentrated urine is produced. Blood volume increases and solute concentration become normal.

- **Oxytocin:** (ocytocia=childbirth); oxytocin is released during child birth and in nursing women. Stretching of the uterus and cervix during parturition is a strong stimulus for the release of oxytocin. Low level of progesterone in blood to the end of pregnancy and neural stimuli of mother during child birth also stimulate release of oxytocin. During birth it is released in waves, and results in labour contractions.

In lactating women, suckling causes the release of oxytocin. The letdown reflex, also known as the milk ejection reflex, is set off by this hormone.

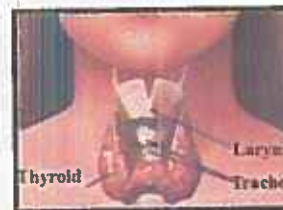
18.2.3 Thyroid gland:

Thyroid gland is composed of two lobes which are located on either side of the trachea inferior to the larynx. Thyroid gland produces three active hormones, triiodothyronine (T_3), thyroxine (T_4), and calcitonin.

Tri & Tetra iodothyronine (T_3 and T_4):

T_3 and T_4 are iodine containing hormones. Tri iodothyronine contains three iodine atoms in structure and thyroxine contains four, hence the names T_3 and T_4 . TSH from anterior pituitary stimulates production and release of both hormones of the thyroid. The level of thyroxine circulating in the blood regulates the secretion of these hormones from the thyroid gland by negative feedback mechanisms involving the hypothalamus and anterior pituitary. These hormones show a variety of physiological effects.

Promote basal metabolic rate of the body enhance glucose catabolism and synthesis of cholesterol in the liver and promote development of nervous system in fetus and infants. They act on muscles for their development and functioning and promote growth and maturation of skeleton. These hormones also promote normal motility of the gastrointestinal tract.

**Fig: 18.4 Thyroid Gland****Hyperthyroidism:**

Overactivity of thyroid causes Graves' disease. Graves' disease is believed to be an autoimmune disease. The serum of patients contains abnormal antibodies that mimic TSH and continuously stimulate thyroxine release.

The symptoms include high metabolic rate, rapid and irregular heartbeat, nervousness, increased ventilation rate, increased body temperature, sweating, and weight loss despite adequate food intake. **Mostly exophthalmia** (protrusion of the eyeballs) results from Graves's disease and is a classic symptom of hyperthyroidism. Thyroid related exophthalmia results from swelling of the tissues around the eye and within the orbit that develops in reaction to the high levels of thyroxine.

**Fig: 18.5 Exophthalmia is a classic symptom of hyperthyroidism.****Hypothyroidism:**

The underactivity of the thyroid gland may be due to the lack of TSH production by the anterior pituitary, iodine deficiency in the food, or failure of the enzyme system involved in thyroxine production.

Thyroid hormones cannot be synthesized without iodine, and this can cause problems in regions where farm soil and drinking water have little or no iodine. In the absence of iodine, thyroid hormone levels in the blood decrease. The anterior pituitary detects the decrease and secretes more TSH-excessively. So excess TSH over stimulates the thyroid gland and causes it to enlarge. (Since thyroid hormones are not being synthesized, the outcome is hypothyroidism.)



Fig: 18.6 Patient suffering from goiter.

The resulting tissue enlargement is a form of *goiter*. Goiter caused by iodine deficiency is no longer common in countries where iodized salt is widely used. Elsewhere, hundreds of thousands of people still suffer from the disorder, which is easily preventable.

If there is a deficiency of thyroxin at birth, it results in a severe hypothyroidism in infants called cretinism. Child is mentally retarded with poor physical growth and disproportionate body size. Bone maturation and puberty are severely delayed and infertility is common.

In adults, the full-blown hypothyroid syndrome is called myxedema (means “mucous swelling” as body weight increases due to the formation and storage of a semifluid material under the skin). Symptoms include a low metabolic rate, feeling chilled, puffy eyes, thick and dry skin with hair lost from the scalp and eyebrows, edema, tongue swelling, constipation; lethargy, and mental sluggishness (but not mental retardation). Myxedema may result from lack of iodine; the thyroid gland enlarges and protrudes. This condition is called endemic or colloidal goiter.

Calcitonin:

The thyroid gland also secretes calcitonin. This hormone plays a minor but direct role in controlling extracellular levels of calcium ions (Ca^{2+}). When the levels rise, calcitonin promotes calcium deposition into bones. When the levels return to normal, thyroid cells decrease their secretion of calcitonin.

Calcitonin inhibits Ca^{2+} absorption by the intestines and decreases its reabsorption by the kidney tubules allowing its excretion in urine. It also inhibits potassium ions reabsorption in kidney tubules.

Calcitonin appears more important in childhood, when the skeleton grows quickly and the bones are changing dramatically in mass, size, and shape. If deficient, Ca^{2+} are not deposited in bones and high blood Ca^{2+} level causes disturbance in the functioning of muscles and nervous system and may lead to kidney stones.

18.2.4 Parathyroid:

In human there are four parathyroid glands. All four glands are located on the thyroid gland. They are small, light coloured lumps that stick out from the ventral surface of the thyroid gland.

The parathormone is the single most important hormone of parathyroids controlling the calcium balance of the blood. Its release is triggered by low blood Ca^{2+} levels and inhibited by high blood calcium levels. Parathormone stimulates osteoclasts to reabsorb bone mineral and liberating calcium into blood. It stimulates absorption of calcium in the small intestine and also its reabsorption in the kidney tubules.

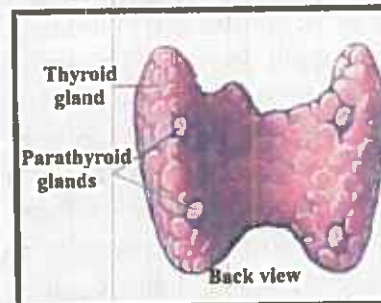


Fig: 18.7 Parathyroid glands are present on the thyroid gland.

Over secretion of parathormone is usually a result of a parathyroid gland tumor. Calcium is released from the bones, and bones get soften and tend to fracture spontaneously. Blood calcium level elevates (hypercalcemia) which depresses nervous system and causes weakness of muscles. Excess calcium salts precipitate in the kidneys leading to stone formation.

Under secretion of parathormone causes hypocalcemia. This increases the excitability of neurons. Also it can lead to tetany in which muscles remain in contracted state. If untreated, it can be fatal.

18.2.5 Pancreas (Islets of Langerhans)

The pancreas is a double gland as it serves both as exocrine and endocrine gland. The bulk of the gland is exocrine and is formed of acinar cells which synthesize pancreatic juice rich in digestive enzymes. Pancreatic juice is delivered to the duodenum by pancreatic duct during food digestion.

Endocrine pancreas consists of islets of Langerhans. In human pancreas has about one million islets scattered among the acinar cells. Each islet is a small mass of cells with two major types of cells; glucagon producing α cells and insulin producing β cells.

Insulin:

It is released by β cells in response to a rise in blood glucose level. Its overall effect is to:

- Reduce blood glucose level to the normal level.
- Increases the rate of glucose uptake by most body cells especially skeletal muscles and fat cells.
- Promotes glycogenesis in liver and muscle cells.

Chemical Coordination

Chapter 18

- Increases the use of glucose in cellular respiration.
- Promotes the conversion of excess glucose to fats.
- Inhibits gluconeogenesis (glucose synthesis).
- Increases the rate of uptake of amino acids into the cells and the rate of protein synthesis.

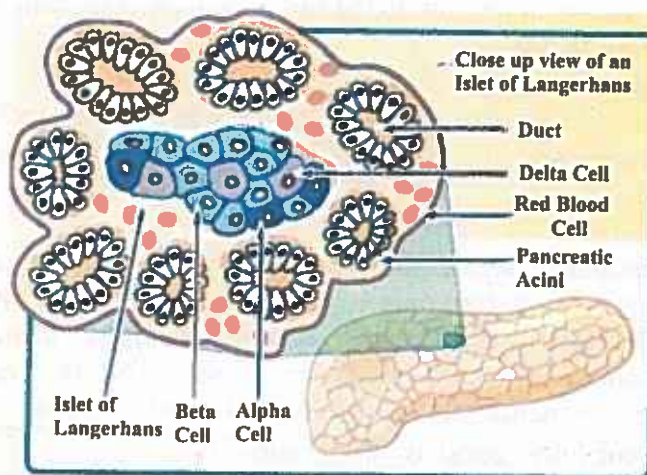


Fig: 18.8 Pancreas showing Islets of Langerhans

If insulin is deficient or is hypoactive, blood glucose level after meal remains high (hyperglycemia). Kidneys cannot reabsorb such high volume of glucose from the filtrate and excess of glucose begins to be lost from the body in the urine (glycosuria). This metabolic disease is known as diabetes mellitus. The three cardinal signs of diabetes mellitus are:

- Polyuria; a condition in which abnormally large volume of urine is produced.
- Polydipsia; a condition of excessive thirst.
- Polyphagia; a condition of excessive hunger ingestion of food.

Low blood glucose level causes breakdown of the muscle tissue, loss of weight and tiredness. If untreated diabetes finally leads to the disruption of the heart activity and oxygen transport, and severe depression of the nervous system leads to coma and death. Hypersecretion (a rare disorder) of insulin results in hypoglycemia. Other effects include hunger, sweating, irritability, double vision, unconsciousness, and even death.

Glucagon:

Glucagon is a hyperglycemic agent. It is released by α cells when blood glucose level is low. Sympathetic nervous system also stimulates its secretion. High blood glucose levels, insulin, and somatostatin suppress its secretion.

Its role is to increase the blood glucose level.

- It promotes glycogenolysis
- It promotes gluconeogenesis; synthesis of glucose from lactic acid and other non-carbohydrate compounds like proteins and fats.
- Promotes release of glucose to the blood by liver cells, which causes blood glucose levels to rise.

18.2.6 Adrenal glands:

Human body has a pair of adrenal glands one above each kidney. Each adrenal gland is composed of two types of tissues: Outer adrenal cortex and the adrenal medulla.

Adrenal cortex:

It produces many steroid hormones, collectively called corticosteroids or corticoids. Among them Aldosterone is chief mineralocorticoid. It is secreted in response to low blood pressure, and low level of Na^+ and high K^+ in blood. ACTH has also some effect in its secretion. It works to increase blood Na^+ level especially acting on kidney tubules to enhance sodium and thus water reabsorption.

Adrenal medulla consists of modified ganglionic sympathetic neurons that synthesize epinephrine and norepinephrine. The two hormones exert the same effects. Epinephrine is the more potent stimulator of metabolic activities, bronchial dilation, and increased blood flow to skeletal muscles and the heart, but norepinephrine has the greater influence on peripheral vasoconstriction and blood pressure. Epinephrine is used clinically as a heart stimulant and to dilate the bronchioles during acute asthmatic attacks

18.2.7 The Gonads:

Gonads are special type of endocrine glands which beside hormone secretions also produce gametes. Female gonads are ovaries while male gonads are testes..

Ovaries: Besides producing ova, the ovaries produce several hormones, most importantly estrogens and progesterone. The estrogens are responsible for maturation of the reproductive organs and the appearance of the secondary sex characteristics of females at puberty.

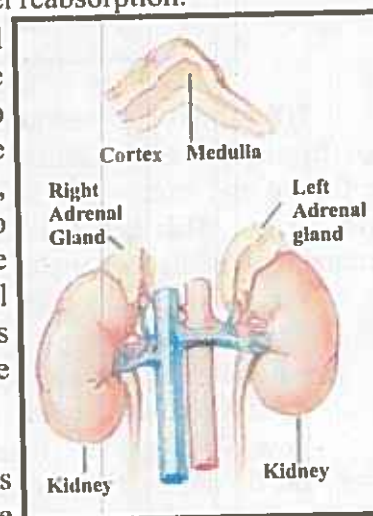


Fig: 18.9 Adrenal glands are located on the top of each kidney.

Acting with progesterone, estrogens promote breast development and cyclic changes in the uterine mucosa in the menstrual cycle. Progesterone promotes further thickening and vascularization of the uterus for the implantation of zygote, maintains pregnancy and causes the development of breasts during pregnancy.

- **Testes:** The male testes, located in an extra-abdominal skin pouch called the scrotum, produce sperm and male sex hormones, primarily testosterone. During puberty, testosterone initiates the maturation of the male reproductive organs and the appearance of secondary sex characteristics and sex drive. In addition, testosterone is necessary for normal sperm production and maintains the reproductive organs in their mature functional state in adult males.

18.3 FEEDBACK MECHANISM

It is a type of interaction in which a controlling mechanism is itself controlled by the product of reactions it is controlling. After receiving the signal, a change occurs to correct the deviation by depressing it with negative feedback or enhancing it with positive feedback.

18.3.1 Negative feedback:

Negative feedback is a mechanism to maintain homeostasis. This feedback results in a reversal of the direction of change. Negative feedback tends to stabilize a system, correcting deviations from the set point. A good example of negative feedback is with the hormone, insulin. Insulin is produced by the pancreas. Insulin is released by the pancreas in response to consumption of glucose. The amount of glucose in the blood rises and the pancreas detects this increase. It then secretes insulin into the blood. Insulin increases glucose uptake in target cells. Glucose uptake by cells decreases blood glucose levels - this decrease is detected by the pancreas and in response, it stops secreting insulin into the bloodstream.

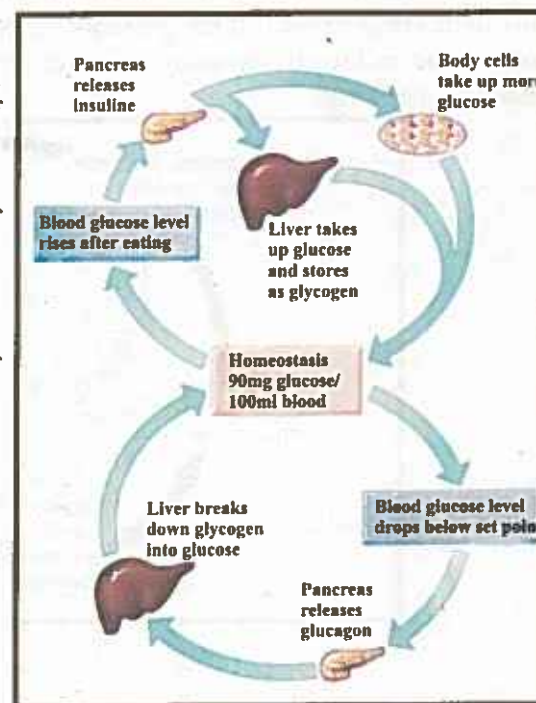


Fig: 18.10 Feedback Mechanism

If blood glucose levels fall below normal levels insulin secretion is inhibited. At the same time, the alpha cells of the pancreas respond by secreting glucagon. It accelerates the breakdown of glycogen to glucose in liver and skeletal muscle cells. It increases the breakdown of fats to fatty acids and glycerol in adipose tissue and, consequently, the release of these substances into the bloods. Glucagon also stimulates liver cells to increase glucose synthesis (from glycerol absorbed from the blood) and glucose release into the blood. These effects collectively cause an increase in blood glucose levels back to normal levels.

18.3.2 Positive feedback

Positive feedback response is to amplify the change in the variable. This has a destabilizing effect, so does not result in homeostasis. Positive feedback is less common than negative feedback, but it has its applications.

Positive feedback enables childbirth. The hormone oxytocin stimulates and enhances labor contractions. As a baby moves towards the birth canal, it presses against the pressure receptors in the muscular part of the uterus. These receptors evoke a release of oxytocin from the pituitary gland. When the oxytocin reaches responsive receptors in the muscles of the uterus it further increases muscular tension thus increasing stimuli to the pressure receptors. This goes on as "labour" until the pressure is relieved: the baby is born; oxytocin is no longer evoked and labor contractions cease.

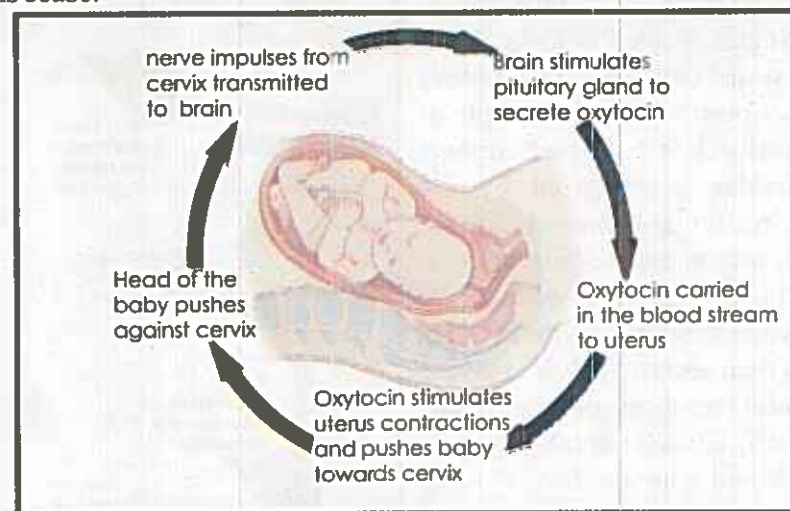


Fig: 18.11 Positive Feedback Mechanism

KEY POINTS

- The endocrine system serves the role to coordinate most body cells
- Endocrine glands are structures made up of one or more cells that make and release hormones. These glands are classified as exocrine glands and the endocrine glands.
- Chemically, hormones are of three basic types i.e. steroids, amino acids or their derivatives, and proteins or polypeptides.
- Pituitary gland signals other glands to put forth hormones. The pituitary also secretes growth hormone, and anti-diuretic hormone, prolactin, and oxytocin, a hormone which causes contractions of the uterus during labor.
- Thyroid gland produces the hormones thyroxin, triiodothyronine and calcitonin, which stimulate metabolism, body heat production and bone growth.
- Parathyroid glands regulate the use and function of calcium and phosphorus in the body.
- Pancreas: The abdominal organ which secretes insulin and glucagon, which control the utilization of sugar, the body's chief source of energy.
- Adrenal glands are two small glands which are present on top of each kidney. They release hydrocortisone, which effects metabolism. They also produce androgens and aldosterone, which maintains blood pressure and the body's salt and potassium balance.
- Ovaries are female glands which produce the hormones estrogen and progesterone, produce eggs in the ovaries and influence female characteristics.
- Testes are male glands which secrete testosterone, which stimulates sperm production and development of male characteristics.
- It is a type of interaction in which a controlling mechanism is itself controlled by the product of reactions it is controlling. After receiving the signal, a change occurs to correct the deviation by depressing it with or enhancing it with positive feedback.



EXERCISE?

1- Multiple Choice Questions

- (i) Which one of the following condition is resulted from excess GH in adults?
- | | |
|-----------------------|-----------------------|
| (a) Cushing's disease | (b) acromegaly |
| (c) hyperthyroidism | (d) diabetes mellitus |
- (ii) _____ regulates the kidney's retention of water.
- | | |
|---------------|-----------------------|
| (a) prolactin | (b) oxytocin |
| (c) thyroxine | (d) vasopressin (ADH) |
- (iii) Which of the following hormones is not released by the anterior pituitary?
- | |
|------------------------------------|
| (a) melanocyte-stimulating hormone |
| (b) gonadotropin-releasing hormone |
| (c) thyroid-stimulating hormone |
| (d) growth hormone |
- (iv) Parathyroid hormone acts to ensure that
- | |
|---|
| (a) calcium levels in the blood never drop too low |
| (b) sodium levels in urine are constant |
| (c) potassium levels in the blood don't escalate |
| (d) the concentration of water in the blood is sufficient |
- (v) The adrenal cortex produces _____.
- | | |
|-----------------|-----------------|
| (a) adrenaline | (b) calcitonin |
| (c) epinephrine | (d) aldosterone |
- (vi) Oxytocin is secreted by the endocrine gland named:
- | | |
|-----------------------|-------------------|
| (a) pituitary gland | (b) thyroid gland |
| (c) parathyroid gland | (d) adrenal gland |
- (vii). Deficiency of vasopressin or ADH by the pituitary gland leads to a disorder in which the patients kidneys have lessened ability to absorb water is:
- | | |
|-----------------------|-------------------------|
| (a) diabetes mellitus | (b) diabetes insipidus |
| (c) goiter | (d) exophthalmic goiter |

EXERCISE?

- (viii) The function(s) of oxytocin is/are to _____.
- cause the uterus to contract
 - induce labor
 - stimulate the release of milk from the mother's mammary glands when her baby is nursing.
 - all of the above
- (ix) In humans, MSH (melanocyte-stimulating hormone) _____.
- regulates primary skin color
 - causes the thyroid to produce thyroxin
 - governs the rate of tanning
 - concentration is very low

2-

Short Questions

- Differentiate between endocrine and exocrine glands.
- Why anterior pituitary gland is called master gland?
- List down the effects of Hyperthyroidism.
- Why pancreas is known as double gland?
- Why insulin is so vital for normal survival?

3-

Long Questions

- Describe the chemical nature of hormone by giving the examples of important hormones.
- Explain the role of hormones secreted by anterior lobe of pituitary.
- Discuss the regulation of calcium level in the body also discuss the effects of hypercalcemia and hypocalcemia.
- Describe the hormone involve in the regulation of reproductive functions.
- Analyze the phenomenon of feedback mechanism by taking an appropriate example from chemical coordination.

4-

Interpreting and Communication

- State the role of artificially synthesized steroids in sports and their long term effects on its user.
- Explain on what grounds some companies claim the growth is possible in people having short heights.

5-

Online Learning

- www.tutorvista.com/Biology
- www.cliffsnotes.com/.../Hormones-and-Glands
- www.nos.org/secscicour/CHAPTER28.pdf
- www.hormone.org