HUMAN ENDOCRINE SYSTEM

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The human endocrine system, along with the exocrine and heterocrine glands helps in the control and co-ordination of the body. Both the nervous and the endocrine systems collectively form the neuro-endocrine system. The study of these two systems is called neuro-endocrinology. Thomas Addison is known as the father of endocrinology.

The human endocrine system consists of various endocrine glands present in different parts of the body. Hypothalamus is present in the basal part of the diencephalon while the pituitary gland, the master gland of the endocrine system is present below the hypothalamus. Pineal gland is present on the dorsal side of the forebrain. Thyroid gland, the largest endocrine gland, is located on the ventral and lateral sides of the upper part of the trachea, while parathyroid glands are four pea-shaped glands embedded wholly or partially in the dorsal surface of the thyroid gland. Thymus gland is located just above the heart; and pancreas, the second-largest endocrine gland is located in the loop of the duodenum. Adrenal glands are present on the upper surface of both the kidneys. The gonads are also endocrine glands. In males, the scrotal sac bears a pair of testis, while in females, the abdomen bears a pair of ovaries. The endocrine glands pour their secretions directly into the blood due to the absence of ducts. Hence, the endocrine glands are also known as ductless glands and the secretions of these glands are called hormones.

Hormones are chemical messengers secreted in trace amounts by glands or neurons. Each hormone usually affects the target cells and regulates a definite physiological effect, by binding to the hormone receptors found either on the surface of the cell or within its cytoplasm. The hormones are degraded by tissues and are excreted by the liver as bile and by the kidneys as urine.

Hormones are also secreted by the exocrine glands such as the salivary glands, the sweat glands and the sebaceous glands, which release their secretions through ducts, hence called duct glands. The pancreas and the gonads have both exocrine and endocrine properties, hence called heterocrine glands. In these glands, the exocrine part releases its secretions through ducts while the endocrine part releases its hormones directly into the blood. In addition to these glands and organs, hormones are also secreted by the gastro-intestinal tract, the liver, the kidneys and the heart.

HORMONES SECRETING GLANDS AND TISSUES

The thymus and adrenal glands, along with other tissues secrete hormones, which travel through the blood to reach the target organs. The thymus gland helps in the development of the immune system. It secretes thymosin which aids in cell-mediated immunity by differentiating T-lymphocytes and humoral immunity by secreting antibodies.

The adrenal glands consist of adrenal cortex and medulla. The adrenal cortex secretes mineralocorticoids and glucocorticoids. The primary mineralocorticoid is aldosterone, which maintains the body’s fluid volume, electrolytes, osmotic pressure and blood pressure. The glucocorticoids secreted by the adrenal cortex stimulate gluconeogenesis, lipolysis and proteolysis. Glucocorticoids include cortisol, cortisone and corticosterone hormones. Cortisol helps in anti-inflammatory reactions and also stimulates RBC production and suppresses the immune response. The adrenal cortex also secretes small amounts of testosterone, which stimulates the development of secondary sexual characters.

The adrenal medulla secretes adrenaline or epinephrine and noradrenaline or norepinephrine, collectively called the catecholamines. These hormones increase the strength of heart contractions, heartbeat and the rate of respiration. They are also rapidly secreted in response to stress and emergency situations and are thus called the emergency hormones or hormones of fight or flight. They are also known as 3F glands and 4S glands, where the 3Fs stands for fright, fight and flight and 4Ss stands for sugar metabolism, salt metabolism, sex hormones and source of energy.

The tissues present in the heart, kidneys and gastrointestinal tract are not categorised as endocrine glands, but still secrete hormones. In the heart, the atrial wall secretes atrial natriuretic factor (ANF), which helps decrease blood pressure. When blood pressure increases, ANF is secreted. This dilates the blood vessels, thereby reducing blood pressure. The juxtaglomerular cells present in the kidneys produce erythropoietin that stimulates the formation of RBCs. The gastrointestinal tract secretes hormones, namely gastrin, secretin, cholecystokinin and gastric inhibitory peptide. Gastrin secreted by the gastrin cells of the stomach stimulates the secretion of pepsinogen and hydrochloric acid.

Secretin, secreted by the duodenal wall stimulates the exocrine region of the pancreas to secrete water and bicarbonate ions into the duodenum. Cholecystokinin secreted by the small intestine stimulates the pancreas and liver to secrete pancreatic enzymes and bile respectively. Gastric inhibitory peptides secreted by the small intestine inhibit gastric secretion and motility. Non-endocrine tissues secrete hormones such as angiogenin and vascular endothelial growth factors (VEGF) which are responsible for the repair and regeneration of tissues.

HETEROCRINE GLANDS

The pancreas, testis and ovaries have both endocrine and exocrine glands called heterocrine or composite glands. The endocrine part of the pancreas is formed of Islets of Langerhans, which comprise of alpha cells, beta cells, delta cells and F cells. Alpha cells secrete glucagon, while the beta cells secrete insulin. Delta cells secrete somatostatin whereas F cells secrete the pancreatic polypeptide.

Glucagon secreted by alpha cells acts on the target organs like the liver and the adipose tissues. The secretion of glucagon is stimulated by low blood glucose levels, which increases the blood glucose level by glycogenolysis and gluconeogenesis and by inhibiting the conversion of glucose into lactic acid. Insulin, secreted by the beta cells, act on the target organs like the liver, adipose tissue and the muscles. The secretion of insulin is stimulated by high glucose levels in blood and stimulates glycogenesis in muscle and liver cells. Furthermore, insulin prevents gluconeogenesis and promotes glycolysis. The degeneration of beta cells leads to the deficiency of insulin, which causes insulin-dependent diabetes mellitus. Somatostatin, secreted by the delta cells, act on the target organs like the pancreas and intestine. It inhibits the secretion of both glucagon and insulin, along with the intestinal absorption of glucose. Pancreatic polypeptide secreted by F cells increases glycogenolysis and regulates gastrointestinal activity.

The exocrine part of the testis and the ovaries produce gametes while the endocrine part secretes hormones. The interstitial cell-stimulating hormone or ICSH of the anterior pituitary stimulates the testis to secrete androgens, namely testosterone, androsterone, epiandrosterone and dehydro-epiandrosterone. Testosterone controls the growth and development of male secondary sex organs, secondary sexual characteristics and stimulates spermatogenesis.

Each ovary secretes estrogen and progesterone. Estrogen is secreted by the growing ovarian follicles and stimulates the growth and functioning of the female secondary sex organs and release of egg from the ovum. After ovulation, the ruptured follicle converts into a corpus luteum. The luteinizing hormone of the anterior pituitary gland stimulates the secretion of progesterone from the corpus luteum, which in turn stimulates the proliferation of the endometrium of the uterus and prepares it for implantation. Moreover, it helps in placenta formation and the development of the foetus in the uterus. Progesterone also acts on the mammary glands and stimulates the formation of alveoli, which store milk.

THYROID AND PARATHYROID GLANDS

Thyroid and parathyroid glands regulate various metabolic reactions in the human body. The thyroid gland located in the neck has two lobes interconnected by the isthmus. The thyroid gland is made up of follicles and stromal tissues. The follicular cells produce two hormones namely, triiodothyronine or T_3, tetraiodothyronine or thyroxin or T_4, whereas the parafollicular cells scattered between the follicles and the stroma produce thyrocalcitonin or TCT. The synthesis and secretion of T_3 and T_4 is regulated by the thyroid-stimulating hormone or TSH produced by the anterior pituitary gland.

Thyroid hormones regulate tissue growth and development, formation of red blood cells, metabolism of proteins, carbohydrates and fats, water and electrolyte balance, and the basal metabolic rate. For the normal rate of synthesis of thyroid hormones, the presence of iodine in the diet is a must. Deficiency of iodine in our diet leads to simple goitre, characterised by the enlargement of the thyroid gland. In pregnant women, hypothyroidism, can lead stunted growth in children called cretinism, characterised by mental retardation. It can also be caused due to the absence of iodine in the diet. Hypersecretion of thyroid hormones occurs due to cancer or development of nodules in the thyroid glands which leads to Graves' disease or exophthalmic goitre in adults. It is characterised by an enlarged thyroid gland, protrusion of the eyeballs etc.

Hyposecretion of thyrocalcitonin causes osteoporosis, characterised by increasing calcium deposition in the bones.

There are two pairs of parathyroid glands partially embedded in the thyroid lobes dorsally, which secrete parathyroid hormone or PTH. The circulating levels of calcium ions regulate the secretion of PTH. PTH increases the activity of osteoclasts that results in elevated bone resorption, which releases ionic calcium and phosphates into the blood. PTH even increases the level of calcium in the blood, by stimulating the reabsorption of calcium by the renal tubules and increases calcium absorption from digested food. Hyposecretion of the parathyroid hormone causes parathyroid tetany, characterised by muscle spasms, contraction of the muscles of the face, hands, feet etc. Hypersecretion of the parathyroid hormone causes ostetitis, fibrosa, cystica, characterized by replacing bones with cysts and fibrous tissues. Hypersecretion of parathyroid hormone also produces stones in the kidneys and ureters.

HYPOTHALAMUS, PITUITARY GLAND AND PINEAL GLAND

The three endocrine glands in the brain are the hypothalamus, pituitary and pineal glands.
The hypothalamus contains neuro-secretory cells that produce neurohormones - releasing hormones and inhibiting hormones, which regulate the synthesis and secretion of pituitary hormones. The releasing hormone such as GnRH stimulates the release of FSH and

LH from the pituitary. While the inhibiting hormone such as somatostatin inhibits the release of the growth hormone from the pituitary. Hypothalamus maintains homeostasis inside the body and regulates most of its physiological activities.

The pituitary gland is the master of endocrine glands, because it produces hormones that control the thyroid gland, the adrenal cortex and the gonads. The pituitary is divided into the adenohypophysis and the neurohypophysis. It includes pars intermedia and pars distalis. The pars distalis produces GH, PRL, TSH, ACTH, LH and FSH. The pars intermedia secretes MSH.

The GH acts on the liver, skeletal muscle, cartilage, bone and causes cells to grow and multiply. Hyposecretion of this hormone during childhood causes dwarfism and hypersecretion causes gigantism; and hypersecretion in adults causes acromegaly. PRL stimulates the development of the mammary glands during pregnancy and lactation after childbirth. TSH stimulates the secretion of T_3 and T_4 by the thyroid gland. ACTH stimulates secretion of glucocorticoids and the sex corticoids by the adrenal cortex. In females, LH stimulates ovulation of the graafian follicles, formation of the corpus luteum and secretion of progesterone by the corpus luteum. Hyposecretion of this hormone leads to sterility in females. In males, LH stimulates the leydig cells in the testes to secrete androgens. FSH, stimulates the development of several ovarian follicles in the ovaries. In males, FSH and androgens stimulate spermatogenesis in the seminiferous tubules.

Together FSH and LH are called gonadotrophins. MSH secreted by the pars intermedia, regulates skin pigmentation by stimulating the melanocytes. The posterior lobe of the pituitary gland is under the direct neural control of the hypothalamus. It synthesis oxytocin and vasopressin and are transported to the posterior lobe of pituitary through axons. In females, oxytocin enhances contraction of smooth muscle cells in the wall of the uterus at the time of childbirth, and milk ejection from the mammary glands. Vasopressin stimulates the kidneys to reabsorb water and electrolytes into the blood by the distal tubules. It thereby reduces the loss of water through urine, hypo secretion of it leads to diabetes insipidus. Pineal gland secretes melatonin, which regulates the twenty-four hour rhythm of the body.

CONTROL OF HORMONAL SECRETIONS

Hormones are minute, chemical messengers secreted into blood by endocrine glands of the body to act on target organs.

Control of hormonal secretions

Hormonal secretions are controlled in the body. Feed-back mechanism is followed in controlling hormonal secretion by endocrine glands.

Normal levels of blood glucose

- Normal glucose level in the blood, early in the morning is 80 to 100 milligrams per 100 millilitres of blood.
- Glucose levels in the blood shoot up to 140 to 160 milligrams per 100 millilitres of blood after we consume our food.
- Insulin and Glucagon are the hormones which regulate the glucose levels in the blood. Exocrine part of pancreas releases these hormones, insulin and glucagon.

Feedback mechanism

A mechanism that informs the body about the changes taking place and enables it to take appropriate action. The feedback mechanism consists of three main components namely receptors, a control centre and effectors.

- Receptors are basically specialised cells that detect any changes in the body and carry the information to the control centre.
- Control centre is either the brain or the endocrine glands that set the further course of action by putting the effectors into action.
- Effectors are the muscles and organs that respond to the message sent by the control centre and thereby establish the internal balance in the body.

Example to explain feedback mechanism

Feedback mechanism involving secretion of insulin and glucagon is elucidated with some examples.

1) When the glucose level in the blood is high, it gets detected by the receptors on the beta cells of the pancreas.

- The pancreas then responds by secreting the hormone insulin into the blood.
- This insulin induces the cells of the liver and muscles to absorb the excess glucose and store it in the form of glycogen
- In this way, the level of glucose in the blood is brought back to normal.

2) When the glucose level in the body drops, it gets detected by the receptors on the alpha cells of the pancreas.

- The pancreas then responds by secreting the hormone glucagon into the blood stream.
- The glucagon then enters the liver, where it accelerates the breakdown of glycogen into glucose.
- When this glucose is released into the blood, the glucose level gets restored to normal.

Negative feedback mechanism

- The feedback mechanism observed in controlling the body’s glucose level is termed as negative feedback mechanism. This is because the changes in the blood glucose levels elicit a negative reaction from the pancreas.
- When the glucose level rises, the pancreas releases insulin to lower it. When the glucose level falls below the normal range, the pancreas immediately releases glucagon to restore the normal level.
- Hence, glucose level in the body is regulated by negative feedback mechanism.

Positive feedback mechanism

Parturition or child-birth is controlled through a positive feedback mechanism.

- The changes taking place in the body elicit a positive response from the control centre. During child birth, the placenta starts secreting hormones that set in motion mild uterine contractions.
- When these contractions are sensed by the pituitary gland, it starts releasing oxytocin. Oxytocin is a hormone that causes stronger uterine contractions.

- The simultaneous uterine contractions and release of oxytocin makes the contractions stronger with every passing minute and ultimately results in the expulsion of the baby from the mother’s uterus.
- Once the baby is expelled, the uterine contractions cease, which in turn signal the pituitary gland to stop the release of oxytocin.

Release of hormones from endocrine glands is almost controlled by the feedback mechanism.