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Chapter 14

Endocrine System

→ The endocrine system consists of glands secreting hormones essential for maintenance of homeostasis throughout the body.
→ Hormones are chemical messengers that act to control and coordinate different functions of tissues and organs.
→ Various body activities like growth and development and metabolism are also regulated by hormones.
→ Each hormone is secreted from a particular gland and is distributed to the target tissues via blood.
→ Endocrine glands are ductless glands, thus release their products directly into the bloodstream, and are carried to their target cells.
→ On the other hand, exocrine glands secrete their products (excluding hormones and other chemical messengers) into the ducts, which are then transported to the bloodstream.
→ The endocrine system comprises of all the endocrine glands of the body.
→ Pituitary, pineal, thyroid, and adrenal, pancreas, parathyroid, thymus, and gonads (testis in males and ovary in females) are the endocrine glands found in humans .
→ These glands work in conjunction with the nervous system, and therefore this complex of two systems is referred to as the neuroendocrine system.
→ This system controls and coordinates various functions of the body, maintaining homeostasis (constancy of body fluids) within the body. The term neuroendocrinology defines the study of endocrine system in combination with the nervous system.

PITUITARY GLAND

- An endocrine gland, pituitary (hypophysis), is of the size of a pea and weighs nearly 0.5gm. Its diameter is 1 1.5cm (0.5 inch). A stalk, the infundibulum, and a funnel attach it to the hypothalamus.
- Since pituitary gland secretes hormones which control the other endocrine glands, it was named the master endocrine gland.

Location and Structure

- Pituitary gland lies within the pituitary (hypophyseal) fossa located at the base of the brain in the sphenoid bone (in the middle cranial fossa).
- From the inferior surface of the hypothalamus, it is seen as a protrusion resting on a small, bony cavity, known as sella tursica.
- The hypothalamic hormones are produced in the cell bodies or axons and move to the cells of anterior pituitary gland via the hypophyseal portal system.
- The posterior pituitary is under the direct neural regulation of hypothalamus.

Hormones

The pituitary gland secretes different hormones:

1) Anterior Pituitary: The hormones secreted by this part are:
   i) Growth Hormone (GH),
   ii) Thyroid Stimulating Hormone (TSH),
   iii) Adrenocorticotropic Hormone (ACTH).
   iv) Prolactin (PRL).
   v) Gonadotropins:
   (a) Follicle-Stimulating Hormone (FSH), and
   b) Luteinising Hormone (LH).
   (c) Melanocyte Stimulating Hormone (MSH))
2) Posterior Pituitary: The hormones secreted by this part are:
   (i) Antidiuretic Hormone (ADH, or vasopressin), and
   (ii) Oxytocin.

Growth Hormone (GH)

- Growth hormone is a peptide hormone that stimulates growth, cell reproduction, and cell regeneration in humans and other animals.

Functions

1) It is essential for growth as it gets involved in the proliferation of cells and complex metabolic reactions.
2) It increases the size and number of cells by initiating mitosis. It differentiates certain types of cells (like those of bones and muscles).
3) It also essentially takes part in the metabolism of proteins, carbohydrates, and fats.

Thyroid Stimulating Hormone (TSH)

- Thyroid stimulating hormone (or thyrotropin) triggers the production of thyroxine (T) and triiodothyronine (T_3) from the thyroid gland.
- The latter stimulates the metabolism of nearly all the body tissues.
- TSH is a glycoprotein hormone which is synthesised and secreted by thyrotrope cells in the anterior pituitary gland.

Functions

I. Production of Thyroid Hormone
II. Brown Adipose Tissue (BAT)
III. Detection of Imbalances in Thyroid Gland

Adrenocorticotropic Hormone (ATCH)

- Adrenocorticotropic hormone (or corticotropin) is produced and secreted by anterior pituitary gland in response to biological stress

- It is a polypeptide tropic hormone which forms an important constituent of the hypothalamic-pituitary-adrenal axis.
- ACTH also stimulates the production and release of corticosteroids.

Functions

1) It triggers the adrenal cortex cells (especially, in the zona fasciculata of adrenal glands) to secrete glucocorticoid steroid hormones. It does so by binding to the ACTH receptors present on the surface of adrenocortical cells of adrenal cortex.

2) It affects the secretion of steroid hormones by rapid short-term mechanisms (taking place within minutes) as well as by slower long-term mechanisms. It also facilitates the uptake of lipoproteins into the cortical cells, thus enhancing the bioavailability of cholesterol in the adrenal cortex cells.

Prolactin (PRL)

- Prolactin is a single-chain protein hormone secreted by lactotrophs present in the anterior pituitary gland. Various other body cells such as immune cells, brain cells, and decidua of the pregnant uterus also produce and secrete prolactin. It is synthesised as a prohormone.

Functions

1) Along with other hormones, it stimulates the development of mammary gland ducts.

2) It also stimulates milk production in women after delivery.

3) It is believed by the researchers that PRI. does not play any role in males, while some of them consider it regulating the production of androgen.

Gonadotropins (FSH and LH)

- Follicle-Stimulating Hormone (FSH) is produced and secreted by gonadotrophs of the anterior pituitary gland in humans and other animals.
- It regulates the development. growth, pubertal maturation, and reproductive processes in the body.
- FSH and Luteinising Hormone (LH) act as synergistic in reproduction, Increased secretion of FSH by the anterior pituitary leads to ovulation.

Functions

1) In Females: FSH stimulates the growth of ovarian follicle.

2) LH also stimulates the follicle cells to produce increased amount of oestrogen. However, ovulation is the major function of LH

3) In Males: Menotropins stimulate sperm production in some cases of male infertility.

Melanocyte Stimulating Hormone (MSH)

- Melanocyte stimulating hormone (or intermedin or melanotropin) is a peptide produced and secreted by the intermediate lobe of pituitary gland.
- After secretion it circulates in the blood and binds to the receptors present on the target cell surfaces.
- This hormone regulates the production of melanin in specialised cells, thus influencing changes in skin pigmentation.
- The hormone also regulates melanin concentration and distribution in the cells containing pigment (ie., the melanocytes in humans and chromatophores in lower vertebrates).

Functions

1) It stimulates the release and distribution of melanin.
2) In brain, it may play a signalling role.
3) Melanocytes present on the skin and eye produce melanin pigments.

Antidiuretic Hormone (ADH)

- Antidiuretic hormone (or arginine vasopressin) is a 9 amino acid peptide secreted by the posterior pituitary gland.
- Within the hypothalamic neurons, ADH and neurophysin (a carrier protein) are packed in secretory vesicles, and are released on hormone secretion.

Functions

1) It decreases the urine amount excreted and increases the water amount absorbed by the kidneys.
2) It also regulates the fluid balance in the body.

Oxytocin

- Oxytocin is mammalian neurohypophyseal hormone acting as a neuromodulator in brain.
- It involves in sexual reproduction during and after childbirth.
- After the cervix and uterus expands during labour, oxytocin is released in large amounts to facilitate birth and maternal bonding.
- The hormone is also secreted after stimulation of the nipples and breastfeeding.
- Oxytocin undergoes positive feedback mechanisms to facilitate childbirth and milk ejection

Functions

1) In the early stages of pregnancy. uterus is unresponsive to oxytocin. As the delivery time approaches, the muscles become sensitive to increased secretion of oxytocin. It stimulates contractions of smooth muscle tissues in the uterus wall during childbirth.
2) After childbirth, it stimulates milk ejection from the mammary glands. When an infant sucks the nipples, the nerve cells in the hypothalamus are stimulated to release oxytocin into the bloodstream. After its release, the special cells contract and release milk into the collecting chambers which further release the milk outside. This reflex is known as the milk let-down reflex.

Functions

- Various functions of different hormones secreted by pituitary gland

ADRENAL GLAND

- Adrenal glands (or suprarenal glands) are star-shaped endocrine glands.
- The term adrenal indicates its position (ad means near or at; -renes means kidneys; and supra- means above).
- These glands mainly regulate the stress response by producing corticosteroids and catecholamines, including cortisol and adrenaline (epinephrine), respectively.

Location and Structure

- Adrenal glands are positioned on the anterior portion of kidneys.
- It is divided into outer and inner zones, i.e., adrenal cortex and adrenal medulla, respectively.
- These two zones differ in structure, functions, and origin.
- The adrenal glands are highly vascularised.

Hormones

The hormones secreted by the adrenal cortex are collectively known as corticoids and are of the following types:

I. Glucocorticoids (e.g., cortisol) are secreted by zona fasciculata part of the adrenal cortex. These hormones stimulate gluconeogenesis, lipolysis, and proteolysis; and inhibit cellular uptake and utilisation of amino acids.

II. Mineralocorticoids (e.g., aldosterone and desoxycorticosterone) are secreted by zona glomerulosa part of the adrenal cortex. These hormones act on the renal tubules and stimulate the reabsorption of Na+ ions and water, and excretion of K* and phosphate ions. Thus, aldosterone helps in the maintenance of electrolytes, body fluid volume, osmotic pressure, and blood pressure.

III. Small amounts of androgenic steroids (e.g., androgens) are secreted by zona reticularis part of the adrenal cortex. These hormones are responsible for the development of symptoms of puberty, like growth of axial hair, pubic hair, and facial hair.

Functions

The adrenal gland performs the following functions:

1. It allows the body to deal with stress related to injury disease, work, or personal life.
2. It determines the energy released when the body responds to the changes in internal and external environment.
3. It secretes hormones which allow the body to mobilise its resources to escape or fight off danger (stress) and survive.

THYROID GLAND

- Thyroid is the largest endocrine gland (5×3cm), weighing 25gm in a healthy adult.
- It is brownish red in colour.
- It is immensely vascularised and receives 80-120ml of blood per minute.

Location and Structure

- Thyroid gland lies on the anterolateral side of the cervical trachea, extending from the level of the 5th cervical vertebra to the 1st thoracic vertebra. It comprises of two lobes (bilobed) interconnected by a transverse glandular band (isthmus) and appearing as a butterfly. It is therefore described as an H-shaped organ .

Hormone

- Thyroid Stimulating hormone released by the anterior pituitary gland regulates the secretion of thyroxine and Thyrocalcitonin (TCT) hormones from the thyroid gland.

Thyroxine

- Thyroxine is an iodine-containing amine hormone.

- It is made up of 65% of iodine and is tyrosine-derived.
- It exists as tetra-iodothyronine, and also sometimes as tri iodothyronine.

Functions

1) It regulates body's Basal Metabolic Rate (BMR).
2) It controls urine output by regulating the working of renal tubules.
3) It helps in homeothermy in warm blooded animals.
4) It stimulates protein synthesis.
5) It regulates the development of mental faculties.
6) It increases the action of adrenaline and nor adrenaline hormones.)

Thyrocalcitonin (TCT)

➲ Thyrocalcitonin is a long peptide hormone which is released by the parafollicular cells of the thyroid gland.
➲ Its secretion is controlled via feedback mechanism of increased levels of calcium in plasma.

Since TCT is a hypocalcaemic factor, it normalises the blood calcium level by:

1) Increasing deposition of calcium in the bones, thus checking osteoporosis, and
2) Decreasing reabsorption of calcium from urine, thus increasing Ca^{2+} ion excretion to prevent hypercalcaemia.

Functions

1) Along with the parathyroid hormone, it regulates the metabolism of calcium and phosphate.
2) It provides protection to the organism from the consequences of increased blood calcium levels.

Functions

Thyroid gland performs the following functions:

1) It controls the body's metabolic activities (the body's ability of converting food into energy).
2) It secretes hormones which regulate the vital organs and maintain the internal homeostasis.
3) It controls the breathing and heart rate.
4) It monitors the body weight, thus defective thyroid gland in an individual result in severe weight variation.
5) lts wings or lobes produce thyroid hormone.
6). It secretes a hormone which controls the internal body temperature and cholesterol levels.
7) The hormones it secretes also increase cellular metabolic activity, thus influencing the metabolic rate and protein synthesis, which in turn facilitates normal development (since development relies on protein synthesis).

PARATHYROID GLAND

➢ Parathyroid glands are small endocrine glands located in the neck and produce parathyroid hormone.
➢ Four parathyroid glands are positioned behind the thyroid gland, or within the thyroid gland (in rare cases) or in the chest.

- These glands regulate the calcium levels in blood and bones.

Structure

- Four pea-shaped parathyroid glands are either completely or partially embedded in the dorsal surface of thyroid gland; each lobe of thyroid has two oval-shaped, small sized (5 x 5mm) and yellow coloured parathyroid glands, Masses of polygonal cells (known as chief and oxyphil cells) arranged in cords make up the histological structure of a parathyroid gland.

Functions

Parathyroid gland produces and releases PTH to maintain the blood calcium level (whenever its level declines) by:

1) Breakdown of bone to release calcium, as bone stores: maximum amount of calcium,
2) Facilitating calcium absorption from food, and
3) Limiting calcium loss via urine.)

Hormone and its Function

Parathyroid Hormone (PTH), also called Collip's hormone increases the Ca^{2+} ion levels in blood.
It acts on bones and stimulates dissolution or de-mineralisation of their calcium.
It also stimulates reabsorption of Caion by the renal tubules and increases Ca^{2+} ion absorption from the digested food.

PTH increases the calcium level by stimulating the following processes:

1) Mobilisation of Calcium from Bone
2) Enhancing Absorption of Calcium from Small Intestine
3) Suppression of Calcium Loss in Urine

PANCREAS

- Pancreas is a large gland located near the duodenum and stomach.
- It lies obliquely on the posterior abdominal wall, partially to the right and to the left of the median plane.
- The right end of pancreas is large and is called the bead; then comes the short and constricted part the neck, which is continuous with the main part of the gland, the body; and the thin left end of the pancreas is the tail.

Location and Structure

- Pancreas is a retroperitoneal gland which is 12-15cm (5-6 inches) long and 2.5cm (1 inch) thick It is present on the posterior of the greater curvature of stomach.
- It is divided into a head, neck, body, and a tail; and is connected to the duodenum via two ducts.
- It is positioned such that it remains in a close association with the duodenum, stomach, spleen, inferior vena cava, abdominal aorta, and the left kidney.
- Head is the expanded portion fitted in the C-shaped duodenum curve; neck lies just behind the pylorus; body lies behind the stomach body; and tip of the tail comes in contact with the spleen.

- Exocrine cells release pancreatic juices into small ducts which combine to form the two larger ducts. i.e., the pan creatic and the accessory duct.
- These ducts transfer the juices into the small intestine.
- The pancreatic duct (or duct of Wirsung) and the common bile duct (from the liver and gallbladder) unites form the hepatopancreatic ampulla (or ampulla of Vater) which enters the duodenum on an elevation of its mucosa (called major duodenal papilla lying about 10cm inferior to the pyloric sphincter of stomach.

Hormones

The endocrine part of pancreas synthesises the following two hormones:

1) Insulin (secreted by the a-cells of islets of Langerhans), and
2) Glucagon (secreted by the B-cells of islets of Langerhans).

Both the hormones control the blood glucose levels by their opposing actions, i.e.

1) Insulin reduces the blood glucose levels, and
2) Glucagon increases the blood glucose levels:

Insuline

- Insulin is injected to normalise blood sugar level in individuals having type 1 diabetes (condition in which the body does not produce sufficient insulin, thus fails to control the blood sugar level) and type 2 diabetes (condition in which the body does not produce or use insulin in a normal way, thus blood sugar level becomes too high).
- However, injections are recommended only when these conditions do not respond to oral medications

Functions

Insulin reduces the levels of absorbed nutrients in blood when they rise above the normal level. When these nutrients (especially glucose) are in excess of immediate needs, insulin stores them by:

1) Acting on cell membranes and stimulating glucose uptake and its use by muscles and connective tissue cells
2) Increasing glycogenesis Glucose conversion to glycogen in liver and skeletal muscles,
3) Increasing amino acids uptake by cells, and protein, synthesis,
4) Promoting lipogenesis (fatty acids synthesis) and far storage in adipose tissues,
5) Decreasing glycogenolysis, and
6) Preventing protein and fat breakdown. gluconeogenesis (formation of new sugar from protein).

Glucagon

- Glucagon is a peptide hormone, produced by the pancreatic a-cells. Its action is the reverse of insulin, it increases the blood glucose levels.

Functions

1) It is a glycogenolytic hormone having highest potency, and it increases the blood glucose levels.

2) It is the body's second defence against hypoglycaemia in healthy individuals.
3) It stimulates neoglucogenesis in the presence of glucocorticoids and lipolysis in the peripheral tissues, which in turn stimulates ketogenesis.
4) It stimulates insulin secretion from the pancreatic β cells and is also involved in insulin secretion after ingestion of glucose,
5) It produces positive inotrople and chronotropic action on heart.

Functions

Since pancreas an exocrine as well as an endocrine gland, its functions are follows:

I. Functions of Exocrine Part: The exocrine part of pancreas are involved in:
   i) Digestion of Proteins: The inactive enzyme precursors (trypsinogen and chymotrypsinogen) are activated by enterokinase enzyme microvilli to yield active proteolytic enzymes (trypsin and chymotrypsin). These enzymes convert polypeptides to tripeptides, dipeptides; and amino acids.
   ii) Digestion of Carbohydrates: Pancreatic amylase converts the digestible polysaccharides (starches) to disaccharides by salivary amylase,
   iii) Digestion of Fats: Fats are converted to fatty acids and glycerol by lipase. Bile salts emulsify fats, ie, reduce the globule size to increase the surface area

II. 2) Function of Endocrine Part: The endocrine part of pancreas secrete insulin and glucagon, which control. the blood glucose levels.

GONADS

- Gonads are termed as primary sex organs.
- Male gonads (testes) and the female gonads (ovaries) produce gametes and secrete hormones.
- Gonadotropins released from the anterior lobe of pituitary glands maintain the growth and functions of gonads.
- The reproductive organs neither producing gametes nor secreting sex hormones but still playing significant roles are the secondary sex organs.
- The characters differentiating a male from a female externally are the exteral sex character

Ovaries

- Ovaries are oval-shaped paired organs present on either side of the uterus in the pelvis.
- These are the primary female sex organs and produce the female gamete (ovum) Several steroid hormones (ovarian hormones) are also secreted by ovaries.
- Each ovary is about 2-4cm long and is positioned on each side of the lower abdomen.

Functions

1) Ovaries release the female gametes or ovum.
2) They secrete, oestrogens and progestins.
3) They also secrete inhibin which participates in feedback control of pituitary FSH production.)

Testes

- The testes (singular testis) are located outside the abdominal cavity within a pouch called scrotum which is a deeply pigmented skin, made up of fibrous and connective tissues, and smooth muscles.
- They are oval-shaped and are 4.5cm in length. 2.5cm in width, and 3cm in thickness)

Functions

1) Testes produce sperm.
2) The Leydig cells of testes secrete testosterone.

Hormones of Gonads and their Functions

Human body secretes the following sex hormones

- Gonadotropin-Releasing Hormone (GARH: This hormone is secreted by the hypothala. It co the secretion of gonadotropin stimulating hormones (FSH and LH) from the pituitary
- Follicle-Stimulating Hormone (FSH): This hormone is secreted by the pituitary gland. Is females it wigges follicle growth, while in males, it triggen spers formation Hypothalamus produces gonadotropin releasing hormone which controls the amount of FSH
- Luteinizing Hormone (LH): This hormone is also secreted by the pituitary gland. In females, it cons the secretion of oestrogen and development of ovum while in males, it controls testosterone production Hypothalamus produces hormone which controls the amount of LH
- Testosterone: This male or masculinising sex hormone stimulates and maintains the secondary sex characters (like growth of beard), genitals and their capability to produce sperm, and bone and muscular growth
- Oestrogens and Progesterone: Both are steroidal hormones, secreted in women 17β-estradiol belongs to oestrogen family and is the most powerful and abundant hormone.
- Prolactin and Oxytocin: Both the hormones are secreted by the female pituitary gland. After childbirth milk secretion by the mammary gland is stimulated by prolactin, and milk ejection from nipples is stimulated by oxytocin. Uterus contraction at the time of delivery is another function of oxytocin.