

CHEMICAL CO-ORDINATION AND INTEGRATION

- Body functions are controlled and regulated by two neuro endocrine system, nervous and endocrine.
- Nervous regulation is very fast, taking only milliseconds and limited to only a part of target. Hormonal regulation is a bit slower but influence all the sensitive cells of target tissue.
- Nervous system is also known to stimulate endocrine system.
- Endocrine system is a system of isolated glands that pour their secretions directly into venous blood or lymph for passage to different body organs in order to control their functioning, metabolism, cell permeability growth, differentiation and stress conditions. Endocrine system comprises endocrine glands and their hormones. The branch of science that is connected with the study of endocrine glands, hormones and their effects is known as endocrinology.

TYPES OF GLANDS

- Glands is an organ, tissue or cell that secretes a chemical from performing a particular functions.
 - (i) **Exocrine glands:** It is a gland that pours its secretion on the surface or into a particular region by means of ducts for performing a metabolic activity. Example, sebaceous glands, sweat gland, salivary glands, gastric glands, intestinal gland.
 - (ii) **Endocrine glands:** It is an isolated gland which secretes informational molecules or hormones that are poured into venous blood or lymph for reaching the target organ because the gland is not connected with the target organ by any duct. Endocrine gland is therefore, also called duct less glands.
 - (iii) **Heterocrine gland:** It is a gland that has both exocrine and endocrine region, the former pouring their secretion through ducts and latter pouring their secretion directly into blood.
 - (iv) **Mixed organs:** It is an organ which has both an endocrine activity and a metabolic or cytogenic activity. Example; gonads
- **Target cell/ organ:** It is organ/ cell on which the product of another system acts. In hormonal system there can be three types of targets- primary, secondary and final. For example, the primary target of TRH (Thyrotropin Releasing Hormone) is anterior pituitary which releases TSH(Thyrotropin or Thyroid Stimulating Hormone) that has thyroid as secondary target. The secondary target or thyroid releases thyroxine which controls metabolic relations of different body cells (final target).

HORMONES

- Hormones are secreted in minute quantities and are transported through blood to different parts of the body or target organs.

- When some hormones work together to control a process, this is called synergism e.g. FSH and LH.
- When two hormones work against each other to control a process, this is called antagonism eg. Insulin and glucagon and calcitonin and parathormone.
- Hormones receptors are found either exposed on the surface of the cell or within the cell, depending on the type of hormone. In very basic terms, binding of hormone to receptors triggers a cascade of reactions within the cell that affects function.
- The secretion of hormones is regulated by feed back mechanisms
- Synthesis and release of some hormones is regulated by nerves and the hormones may also influence nerve activities.

PROPERTIES OF HORMONES

- (i) They have low molecular weight.
- (ii) They are soluble in water and blood.
- (iii) They have no cumulative effect.
- (iv) They can act in very low concentration.
- (v) They are non-antigenic.
- (vi) They are organic catalysts.
- (vii) They may act slowly or quickly.
- (viii) Hormone controlled reactions are not reversible.
- (ix) Their excess or deficiency leads to disorders.
- (x) They do not provide energy or building materials
- (xi) Hormones are produced in inactive form called prohormones. Eg. Proinsulin → Insulin
- (xii) It is also called messenger because it has effect at a site different from the site it is synthesized.

CLASSIFICATION OF HORMONES

- (i) Amino acid derivative hormones
The hormones epinephrine (adrenaline), norepinephrine (noradrenaline) and thyroxine are derived from amino acid tyrosine.
- (ii) Peptide hormones
The hormones oxytocin and vasopressin are composed of peptides.
- (iii) Protein hormones
The somatotropic, thyrotropic and gonadotropic hormones, insulin, glucagon, parathormone, human chorionic gonadotropin, human chorionic somatomammotropin (HCS) and relaxin are made up of proteins.
- (iv) Steroid hormones

The hormones secreted by the adrenal cortex, testes and ovaries are composed of steroids. Placental estradiol and progesterone are also steroid hormones.

ROLE OF HORMONES IN HOMEOSTASIS

- Homeostasis means keeping the internal chemical environment of the body constant. Hormones help maintain homeostasis by these integrated action and feedback control

Negative feedback control

- In this, synthesis of hormonal slows or halts when its level in the blood rises above normal. Eg. Blood – glucose homeostasis. Secretion of hormone may be under the negative feedback control of a metabolite.
- For instance, increase in blood-glucose level on eating a carbohydrate-rich meal, stimulates pancreas to secrete insulin. Insulin stimulates the target cells to take up glucose, which is utilized in cell respiration or is stored as glycogen. This lowers the blood-glucose level to normal.
- With the fall in blood-glucose level, insulin secretion decreases.

Positive feedback control

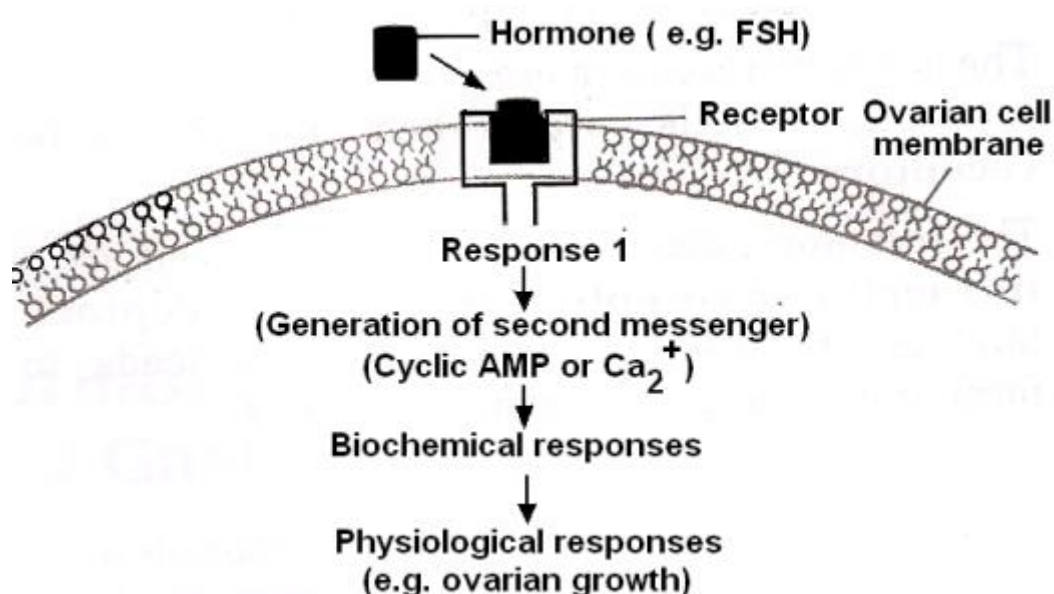
- In the positive feedback control an accumulating biochemical increases its own production.
- For example, uterine contraction at the onset of labour stimulates the release of the hormone, oxytocin, which intensifies uterine contractions.
- The contraction further stimulate the production of oxytocin. The cycle of increase stops suddenly after the birth of the baby.

MECHANISM OF HORMONE ACTION

- All hormones produce their specific effects on the target tissues /cells by binding to the specific proteins called as hormone receptors. These receptors are located on target tissues only. There are basically two types of receptors present in target tissues. These are:
 1. Membrane bound receptors
 2. Intra cellular receptors
- The hormone receptors present on the cell membrane of the target cells are called membrane – bound receptors.
- The receptors present inside the target cell are called intracellular receptors. The binding of hormone to its receptors leads to the formation of hormone –receptor complex. The formation of this complex leads to some biochemical changes in the target tissue. The target tissue metabolism and the physiological functions are regulated by the hormones.

PEPTIDE HORMONE ACTION

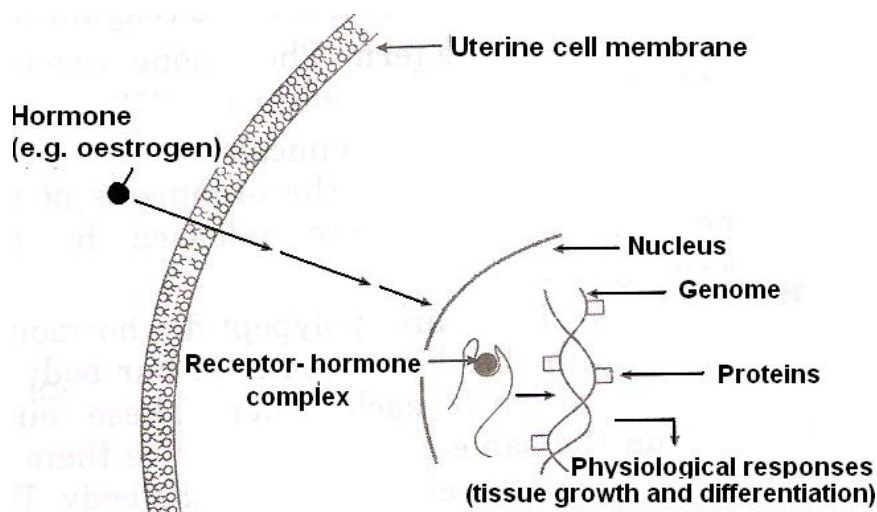
- The hormones that are derivatives of amino acids, polypeptides or proteins are formed of large molecules are called peptide hormones. These being insoluble in lipids cannot enter the target cell.
- These act at the surface of target cell as primary messengers and bind to the cell surface receptor forming the hormone receptor complex. This mechanism was discovered by Nobel Prize winner EW Sutherland in 1950. It involves following steps:
 - (i) Hormone called first messenger attaches to the cell surface receptors protein on the outer surface of plasma membrane of the target cell, forming a hormone receptor complex.
 - (ii) These complex activates the enzyme adenylyl-cyclase
 - (iii) Adenylyl cyclase catalyses the conversion of ADP to cyclic AMP (Cyclic adenosine monophosphate or cAMP) on the inner surface of plasma membrane.
 - (iv) cAMP serves as the 'second messenger' or intercellular hormonal mediator delivering information inside the target cells. This activates appropriate cellular enzyme by cascade effect. This induces the cell machinery to perform its specialized function.
 - (v) Ca^{2+} may be involved along with cAMP.
 - (vi) cAMP has a very short existence. It is rapidly degraded by the cAMP phosphodiesterase.
- Water soluble hormones, such as amines, peptides, proteins and glycoproteins exert their control through cyclic AMP. These are quick acting hormones and produce immediate effect.



STEROID HORMONE ACTION

- Steroid hormones and thyroid hormones do not bind to the cell surfaces receptors. Being lipid soluble, these are able to enter the cells and their nuclei and influence the gene action.

- The hormone binds the receptors forming a hormone –receptors complex. It binds to the transcription factors that in turn bind to DNA and particular gene is activated and transcribed. Their transcription leads to the synthesis of a specific protein to influence the metabolism of recipient cell.
- Thus, the peptide hormones activate existing enzymes in the cell, while steroid hormones bring about the synthesis of new enzymes. Steroid hormones act slowly than peptides but have a more sustained effect on metabolism



PINEAL GLAND

- It is a stalked small rounded gland named so after its resemblance with pine cone. Pineal gland is found behind the anterior choroid plexus on the epithalamus. It has a variable size. Weight is about 150 mg. The gland is richly vascularised. Unlike lower animals, human pineal gland is devoid of light sensitive cells. The gland is neurosecretory transducer and functions as biological clock, calcification occurs in middle age. It has pineal and glial cells. The gland secretes two biogenic amine hormones.
 - (i) Serotonin: Also by disintegrating blood cells. Constricts (vasoconstriction) blood vessels at a place of injury.
 - (ii) Melatonin: The hormone develops pale skin colour in amphibians. Its release is governed by diurnal dark-light cycle. Light inhibits melatonin secretion. The effect is routed through retinal neurons – hypothalamus – pinal gland. Melatonin concentration is maximum in midnight and minimum during noon. The hormone controls sleep, mood, ovarian cycle, delay, puberty, opposes FSH and LH hormones.

HYPOTHALAMUS

Floor of diencephalon has nuclei of grey matter with neurosecretory cells producing neurohormons. Some of them are poured into adenohipophysis (anterior and intermediate pituitary) through hypophysial portal system while two hormones (oxytocin and ADH) are directly

taken by nerve cells into neurohypophysis (posterior pituitary) cell bodies of the secretory neurons of oxytocin and ADH hormones are located within supraoptic and paraventricular nuclei of hypothalamus. Their unmyelinated nerve fibres form hypothalamohypophysial tract in infundibulum which ends in neurohypophysis. The hormones are transported as neurophysin bound secretory granules through the nerve fibres. Hormones poured in adeno hypophysis function as releasing or inhibiting hormones. They are peptide in nature.

1. Thyrotropin Releasing Hormone (TRH)
Stimulates anterior pituitary to secrete thyrotropin or thyroid stimulating hormone.
2. Adrenocorticotropin Releasing Hormone (ARH)
Stimulates anterior pituitary to secrete adrenocorticotropin hormone.
3. Gonadotropin Releasing Hormone (GnRH)
Stimulates secretion of gonadotropins by adeno hypophysis which are of two types, FSH and LH.
4. Somatotropin Releasing Hormone or Growth Hormone Releasing Hormone (SRH or GHRH)
Stimulates production of growth hormone or somatotrophic hormone by anterior pituitary.
5. Somatostatin or Growth Hormone Inhibiting Hormone (GHIH)
It inhibits adeno hypophysis to secrete growth hormone.
6. Prolactin Releasing Hormone (PRH)
The anterior pituitary is stimulated to secrete prolactin.
7. Prolactin Inhibiting Hormone (PIH)
The hypothalamic hormone stops synthesis of PRH by anterior pituitary. Hormone prolactin is under predominant inhibitory control through neurotransmitter dopamine produced by tubero-infundibular neurons.
8. Melanocyte Stimulating Hormone Releasing Hormone (mSH – RH)
The releasing hormone induces intermediate pituitary to secrete mSH
9. Melanocyte Stimulating Hormone Inhibiting Hormone (mSH – IH)
The inhibiting hormone stops synthesis of mSH.

PITUITARY GLANDS

- The pituitary or master gland acts as a regulating unit of the activity of most of the other endocrine glands. It is the most protected gland and lies in a bony cavity called as hypophysial fossa or sella turcica of sphenoid bone. This gland is attached to hypothalamus by infundibulum.
- The gland consists of two parts: adeno hypophysis and neurohypophysis.

HORMONES SECRETED BY ADENOHYPHYSIS

- The adenohiphysis is formed of two lobes i.e. anterior and intermediate lobe. These both lobes are formed by embryonic buccal cavity (Rathke's pouch). Adenohiphysis contains three types of cells. These are basophils acidophils, chromophils.
 - a) Growth Hormone or Somatotropin Hormone (GH or STH)
 - i) It stimulates body growth, protein and fat and carbohydrate metabolism
 - ii) Hyposecretion of this hormone causes dwarfism during the skeletal growth period.
 - iii) Hypersecretion of this hormone during the period of skeletal growth causes gigantism characterized by excessive growth of bones, with the enlargement of internal organs as well.
 - iv) Hypersecretion in adulthood causes acromegaly. Here, the bones becomes abnormally thick due to ossification of periosteum and thickening of soft tissues as well.
 - b) FSH or Follicle Stimulating Hormone.
 - i) It is produced by the basophilic cells, along with galactose mannose etc.
 - ii) Function: In females → growth of ovarian follicles up to ovulation
In males → Development of seminiferous tube and maintenance of spermatogenesis.
 - c) Lutenizing Hormone or interstitial cell stimulating hormone (LH or ICSH)
 - i) It is produced by basophilic cells. The hormone stimulates the testis to secrete the male sex hormones, testosterone and the corpus luteum in ovaries to secrete female sex hormones called progesterone.
 - d) Prolactin
It is produced by acidophilc cells. This hormone stimulates lactation (milk production) and has a direct effect on the breasts immediately after parturition.
 - e) Adrenocorticotropic Hormone
 - i) It is secreted by the corticotropic cells of anterior pituitary.
 - ii) It stimulates the flow of blood to the adrenal cortex, increases the concentration of cholesterol and steroids within the gland and increases the output of steroid hormones, especially cortisol.
 - iii) Hyposecretion causes acute psoriasis and dermatitis (the diseases of skin)
 - iv) Its hypersecretion causes cushing's disease characterized by obesity, skin pigmentation increases, excessive hair, demineralization of bone and loss of sexual function.

f) Thyroid stimulating hormone or TSH

It is secreted by special basophilic cells. The hormone promotes growth and function of thyroid gland. Its secretion is stimulated by a hypothalamic thyrotropin release factor (TRF)

g) Lipotropin Hormone

It is in the form of a complex with I, II and β -Lipotropins. It stimulates fatty acid liberation from adipose tissue. Hyposecretion causes obesity and hypersecretion causes thickness.

HORMONES SECRETED BY NEUROHYPOPHYSIS

- The neurohypophysis is formed by the posterior lobe of pituitary gland. This lobe is developed from the diencephalon of brain. It is a part, developed from hypothalam and remains connected to it. Its cells are called pituicytes.
- These are called supraoptic and paraventricular nuclei. The hormones of neurohypophysis are transported from hypothalamus to the gland via specialized portal system called hypophysial portal system. This lobe secretes two hormones. Which are synthesized in hypothalamus.

a) Oxytocin

A peptide hormone, initiates vigorous uterine constrictions in females at the time of child birth, milk secretion by mammary glands, contraction of smooth muscles and stimulates adenohypophysis to secrete prolactin.

b) Vasopressin or ADH (Antidiuretic hormone)

- i) Increases reabsorption of water in kidneys resulting in the decrease in the rate of urine production. Its other function include contraction of arterioles, capillaries.
- ii) It reduces heart rate and helps in micturition as well. Hyposecretion of this hormone causes diabetes insipidus. Water balance is distributed unless fluid intake is greatly increased to compensate for excess loss.

PITUITARY DISORDERS

a) Gigantism

It is caused by excess of growth hormone from early age. It is characterized by large and well proportioned body.

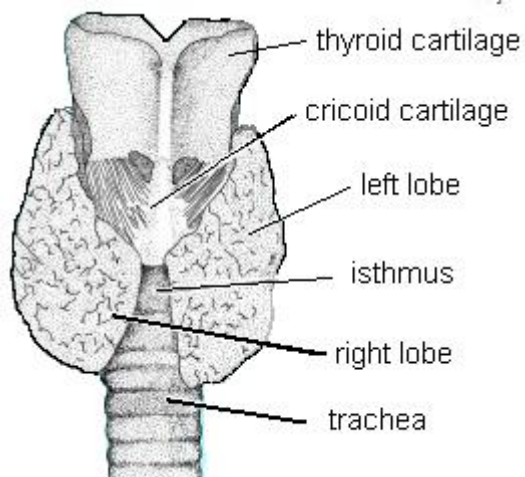
b) Simmond's disease

It is caused due to the atrophy or degeneration of anterior lobe of pituitary gland. In this disease, the skin of face becomes dry and wrinkled and shows premature ageing.

THYROID GLAND

- Thyroid gland (largest endocrine gland) is present in the neck between the trachea and larynx. It is bilobed with a connecting isthmus.
- The microscopic structure of the thyroid gland shows thyroid follicles composed of cubical epithelium and filled with a homogenous material called colloid. Small amount of loose connective tissue forms stroma of the gland. Besides containing blood capillaries, the stroma contains small clusters of specialized parafollicular cells or 'c' cells.
- Thyroid hormones are produced by the secretory cells lining the follicle and stored in the colloid until needed. So each follicle accumulates a storage form of the circulating thyroid hormone- thyroglobulin
- Thyroglobulin is a large protein molecule that contains multiple copies of one amino acid tyrosine.
- Thyroid gland produces two hormones-thyroxine (T_4) and tri-iodothyronine (T_3) together called thyroidal hormone. Both are iodinated forms of an amino acid called tyrosine. T_3 and T_4 contain 3 and 4 iodine atoms respectively. T_3 is more potent and active than T_4 .
- Thyroid hormones
 - (i) Increases the metabolic rate of the body and enhance heat production and maintain BMR (basal metabolic rate)
 - (ii) Promote growth of body tissues and mental faculties.
 - (iii) Stimulates body differentiation.
- The deficiency of thyroid hormone secretion (hypothyroidism) during infancy causes cretinism and myxoedema in a adults.
- Symptoms of cretinism includes slow body growth and mental development, low heart rate blood pressure and body temperature, pot belly pigeon chest and protruding tongue.
- Symptoms of myxoedema or Gull's disease includes puffy appearance, lack of alertness, intelligence and initiative, slow heart beat, low body temperature and reproductive failure.
- Simple goiter (Iodine deficiency goiter is the enlargement of thyroid gland accompanied with cretinism or myxoedema. It is caused due to dietary deficiency of iodine.
- 21st October is celebrated as Iodine Deficiency Disorder Day
- Exophthalmic goiter or Grave's disease is caused due to over secretion of thyroid hormones. It is an autoimmune disease in which the person produces antibodies that mimic the action of TSH but are not regulated by normal negative feedback control. Its symptoms includes protrusion of eye balls, loss of weight, rise in body temperature, rapid heartbeat, nervousness, tremor and tastelessness.
- Hashimoto's disease- In this disease all aspects of thyroid hormone are impaired. It is an autoimmune disease in which the thyroid gland is destroyed by autoimmunity.

- Thyroid gland also secretes non-iodinized calcium lowering hormone call calcitonin or thyrocalcitonin from parafollicular cells lying scattered in between the thyroid follicles.
- Calcitonin is hypocalcemic and hypophosphatemic peptide hormone of parafollicular or c-cells of extra-follicular part of thyroid. It checks excess plasma Ca^{2+} and phosphate by decreasing mobilization from bones and prevention of re-absorption in nephrons. The hormone has an opposite effect to parathormone produced by parathyroid. Deficiency of calcitonin results in osteoporosis or loss of bone density



PARATHYROID GLAND

- Parathyroid gland is present as four small pouches, two of each are embedded in the posterior surface of each lobe of thyroid gland. The gland is developed as epithelial buds from third and fourth pairs of pharyngeal pouches. The hormone secreted by parathyroid gland is parathormone or collip's hormone.
- It is a linear polypeptide with about 84 amino acids and molecular weight of 9500 Daltons.
- The two types of cells present in parathyroid gland are
 - (i) Chief cells or principal cells
These cells contain prominent Golgi apparatus, endoplasmic reticulum and secretory granules. They are involved in the synthesis and secretion of parathormones.
 - (ii) Oxyphil cells or eosinophils
These cells contain oxyphil granules and large number of mitochondria in cytoplasm. Their function is unknown.
- Parathormone (PTH) acts directly on bone to increases bone reabsorption and mobilize Ca^{2+} ions in the blood. It is a hypercalcemic and hypophosphatemic hormone.

DISORDERS OF PYRATHYROID GLAND

(a) Hyperparathyroidism

Excess secretion of parathormone, usually by benign tumours of all the gland, causes reabsorption of calcium from bones, raising the blood calcium level.

The effects may be formation of renal calculi complicated by pyelonephritis and renal complicated by pyelonephritis and renal failure, muscle weakness, general fatigue, calcification of soft tissue, osteoporosis.

(b) Hypoparathyroidism

Parathormone deficiency causes an abnormally low level of ionized calcium in the blood. This reduces absorption of calcium from the small intestine and reabsorption from bones and glomerular filtrate lead to tetany

In tetany, there are very strong painful spasms of skeletal muscles, causing characteristics bending inwards of the hands forearms and feet.

THYMUS GLAND

- The thymus gland is located in the upper part of the thorax near the heart. It is a soft, pinkish, bilobed mass of lymphoid tissue. It is a prominent gland at the time of birth but it gradually atrophies in the adult.
- Hassall's corpuscles are spherical or oval bodies present in thymus. They are phagocytic in function.
- Thymus secretes a hormone named thymosin which stimulates the development of and differentiation of T-cells, increasing resistance to infections. It also hastens attainment of sexual maturity.

ADRENAL GLANDS

- There are two adrenal glands, situated on the upper side of each kidney enclosed within the renal fascia. They are about 4cm long and 3cm thick. Internally, the gland is differentiated into cortical and medullary tissues. The gland was discovered by Eustachius and its endocrine nature was suggested by WB Canon. It has two parts adrenal cortex and adrenal medulla.

ADRENAL CORTEX

- The adrenal cortex produces three groups of hormones from cholesterol. They are collectively called adrenocorticoids.

These are given below

(a) Glucocorticoids

- Cortisol and corticosterone are the main glucocorticoids. They are essential for life. Their secretion is stimulated by Adrenocorticotrophic hormone from the anterior pituitary and by stress.
- Glucocorticoids have widespread effects on body system. The main functions include the regulation of carbohydrate metabolism promotion of the formation and storage of glycogen

and promotion of sodium and water reabsorption from the renal tubules. They are released during allergic reactions.

- They secreted by zona fasciculata, middle zone of adrenal cortex. It consists of cells arranged in long, straight columns.

(b) Mineralcorticoids

Aldosterone is the main mineralocorticoid. It is secreted by zona glomerulosa, outer zone that constitutes about 15% of the gland and has closely packed cells arranged in spherical clusters and arched columns.

- Its functions are associated with maintenance of the electrolyte balance in the body.
- The amount of aldosterone produced is influenced by the sodium level in blood. If there is a fall in the sodium blood level, more aldosterone is secreted and more sodium is reabsorbed.

(c) Sexcorticoids (androgen)

- Zona reticularis is the inner zone and consists of cells arranged in branching cords which secrete sexcorticoids.
- They are associated with deposition of protein in muscles and retention of nitrogen.
- These hormones are secreted as DHEA (Dehydroxy epiandrosterone). Which is a precursor of both testosterone and oestrogens.

ADRENAL MEDULLA

- The adrenal medulla is completely surrounded by the cortex. It is an outgrowth of tissue from the same source as the nervous system and its functions are closely allied to those of the sympathetic part of the autonomic nervous system.
- It is stimulated by its extensive sympathetic nerve supply to produce adrenaline or epinephrine and noradrenaline or norepinephrine in the ratio of 1:4. These are commonly called as catecholamines.

(a) Adrenaline : It is associated with potentiating the conditions needed for fight or flight.

- When the body is under stress, homeostasis is disturbed. The immediate response is sometimes described as preparing for fight or flight
- These hormones increases alertness, pupillary dilation, sweating etc. Both these hormones increases heart beat, strength of heat contraction and rate of respiration.

(b) Nor-adrenaline: This is the postganglionic chemical transmitter of the sympathetic nervous system. The main function of nor-adrenaline is the maintenance of blood pressure by causing general vasoconstriction, except of the coronary arteries.

DISORDERS

(a) Hypersecretion of glucocorticoids

- Hyper secretion of cortisol (cushing's syndrome) has a wide variety of effects but they may not all be present at the same time. These include.
- Painful adiposity of the face (moon face), neck and trunk
- Excess protein catabolism, causing thinning of sub-cutaneous tissue and muscle, wasting, especially of the limbs.
- Suppression of growth hormone, causing arrest of growth in children.
- Osteoporosis and kyphosis, if vertebral bodies are involved
- Susceptibility to infection due to reduced febrile response, depressed immune response and phagocytosis, impaired migration of phagocytes.
- Insomnia, excitability, euphoria, psychotic depression.
- Hypertension menstrual disturbances, peptic ulceration

(b) Hyposecretion of glucocorticoids

Inadequate secretion of cortisol causes diminished gluconeogenesis, low blood glucose, muscle weakness and pallor.

(c) Hypersecretion of mineralocorticoids

Excess aldosterone (conn's syndrome) affects kidney function, causing

- Excessive reabsorption of sodium chloride and water causing hypertension
- Excessive excretion of potassium causing hypokalemia, which leads to cardiac arrhythmia and muscle weakness.

(d) Hyposecretion of mineralocorticoids

Hypoaldosteronism results in failure of kidneys to regulate sodium, potassium and water excretion, leading to

- Blood sodium deficiency and potassium excess
- Dehydration, low blood volume and low blood pressure
- Addison's disease is due to the hyposecretion of all adrenal cortex hormones. There is electrolyte upset with low plasma Na^+ through increased urinary elimination and high plasma K^+ , reduced blood volume, lower blood pressure, marked anaemia, hypoglycaemia, great muscular weakness, nausea, vomiting, diarrhoea and bronze pigmentation.

(e) Hypersecretion of sex corticoids

- Virilism is due to excessive secretion of sex corticoids caused by adrenal tumour results in appearance of male secondary characters in females like male voice, beard moustaches, stoppage of menstruation and growth of clitoris.
- Hirsutism is presence of facial and excess body hair in females due to adrenal virilism.

KIDNEY

- The kidneys secrete three hormones: rennin, erythropoietin and calcitriol
- Whenever the rate of ultrafiltration falls, the cells of their juxtaglomerular complex secrete and release into blood a compound named renin. It acts upon a plasma protein angiotensinogen, separating a compound called angiotensin – II from it.
- Angiotensin –II accelerates heart beat and constricts arterioles, thereby increasing blood pressure. This enhances the rate of ultrafiltration.
- Simultaneously, the angiotensin-II stimulates adrenal cortex to secrete aldosterone and enhances water and sodium reabsorption from nephrons. These factors also elevate blood pressure.
- The oxygen shortage stimulates the kidney cells to secrete a hormone named erythropoietin (a circulating glycoprotein) into the blood.
- Erythropoietin stimulates the bone marrow to increase the production of RBCs.
- Vitamin D exists in two forms: Calciferol or D₂ and cholecalciferol or D₃
- Calcitriol is the active form of vitamin cholecalciferol (D₃). It promotes absorption of Ca⁺² and phosphorus in the small intestine and accelerates bone formation.

PANCREAS

- The pancreas lies inferior to the stomach in a bend of the duodenum. It is both an exocrine and an endocrine gland.
- Pancreas has group of cells called islets of Langerhans. These produce endocrine secretions. Four kinds of cells have been identified in the islets
 - Alpha cells (about 15%) produce glucagon.
 - Beta cells (about 65%) produce insulin.
 - Delta cells or D-cells (about 5%) produce somatostatin.
 - Pancreatic polypeptide cells (15%) produce pancreatic polypeptide.
- Glucagon stimulates the liver to convert stored glycogen into glucose in the blood. Glucagon is controlled by feedback in accordance with the level of glucose in the blood. When the blood sugar rises, the secretion of glucagon is suppressed and when it drops the secretion of glucagon is stimulated. Glucagon is also called an 'anti-insulin' hormone.
- Insulin is antagonistic to glucagon. Insulin decreases the level of glucose in the blood. It acts by increasing the rate at which glucose out of the blood and into the cells and by stimulating muscle cells to take up sugar from the blood and convert it to glycogen.
- Like glucagon, insulin is primarily regulated by feedback from the blood glucose concentration.
- When the blood sugar level drops, the secretion of insulin is suppressed. When the blood sugar level increases, the secretion of insulin is stimulated.

- It promotes protein synthesis in tissue from amino acids and reduces catabolism of proteins. It is an anabolic hormone. It increases the synthesis of fat in the adipose tissue from fatty acids and reduces the breakdown and oxidation of fat.
- Somatostatin seems to suppress the release of hormones from the pancreas and digestive tract.
- Pancreatic polypeptide inhibits the release of digestive secretion of the pancreas.
- The most common endocrine disorder of the pancreas is the diabetes mellitus (hyperglycemia), now recognized to exist in two forms – insulin dependent and non insulin dependent.
- The insulin dependent diabetes mellitus (IDDM) is caused by a failure of the Beta cells to produce adequate amounts of insulin while the non-insulin dependent diabetes mellitus (NIDDM) appears to involve failure of insulin to facilitate the movement of glucose into the cells.
- In both disorders the blood glucose concentration is elevated above the normal range.
- Some of the glucose is excreted in the urine and water follows the glucose, causing excessive urination and dehydration of body tissues. This causes excessive thirst (polydipsia). The cells are unable to utilize their proteins for it. The person becomes very weak. Degradation of fats increases, producing ketone bodies (ketosis). Blood cholesterol level rises.
- Hypoglycemia occurs when the blood glucose level falls below normal. Symptoms of hypoglycemia include weakness, profuse sweating, irritability, confusion, unconsciousness and convulsions.

GONADS

- Gonads are the sex glands, the ovaries and the testis. They produce ova and sperm respectively but also secrete hormones.

MALE SEX HORMONES

- Male sex hormones or androgens are produced by testis. They are secreted by Leydig cells or interstitial cells found in the connective tissue around seminiferous tubules. Androgens are steroid hormones produced under control of ICSH (LH) of pituitary gland with maximum activity at puberty. Two common androgens are testosterone and androsterone. Dihydrosterone is the active form of testosterone.
- Testosterone is first produced during foetal growth under the influence of chorionic gonadotropin of placenta. There is a spurt of testosterone production at the age of 10-13 years when puberty begins. Testosterone production declines after the age of 50 years. At the time of puberty testosterone causes development of male secondary sex organs external / accessory male sex characters, growth of body tissue, broadening of shoulders,

growth of muscles, higher metabolism, increased sebaceous gland activity, normal skin and formation of sperms through spermatogenesis is mainly due to FSH. Development of external genitalia in the male foetus is under the control of testosterone produced by testes. Deficient androgen secretion causes eunuchoidism

EUNUCHOIDISM

- Eunuchoidism is a hormonal disorder due to non-secretion of testosterone in a genetically male individual. The secondary male sex organs are under developed and non-functional. The accessory male character fails to develop. Spermatozoa are not formed. Castration is artificial removal of testes. Secondary male characters do not differentiate. Castrated human males are called eunuchs.

FEMALE SEX HORMONES

- They belong to both steroid and protein categories. The hormones are secreted by growing graafian/ ovarian, corpus luteum and placenta.
1. Estrogens
They are steroid hormones secreted by growing ovarian follicles under instructions from anterior pituitary through FSH. Estrogens include estradiol, estriol and estrone. Estradiol is the principal estrogen. Its maximum concentration is found at the time of puberty. Later it shows cyclic rise and fall during menstrual cycle. During pregnancy estradiol is secreted by placenta. At puberty the hormone is required for development of female secondary sex organs, external / accessory female sex characters, body contour and onset of menstrual cycle. Later on the hormone helps in maintaining the traits and organs in reproductive tract. During menstrual cycle, estrogen released from growth ovarian follicle inhibits FSH secretion and stimulates LH secretion from pituitary increasing blood supply to uterine epithelium.
 2. Progesterone
It is a steroid hormone secreted by corpus luteum under the influence of LH of anterior pituitary in the second half of menstrual cycle and hCG of placenta during pregnancy. The placenta also secretes the hormone. Routinely progesterone causes temporary changes in endometrial lining of uterus for receiving egg. During pregnancy it helps in attaching embryo to uterine wall development of placenta, maintenance of pregnancy and growth of secretory alveoli in mammary glands. Progesterone checks ovulation. Hyposecretion results in abortion and misconception.
 3. Relaxin
The proteinaceous hormone is secreted by corpus luteum towards the close of gestation period for loosening of pelvic ligaments. Softening dilating and relaxing of uterus for decreasing discomfort of carriage and easy child birth.

4. Human Chorionic Gonadotropin (hCG)

The proteinaceous hormone is secreted by placenta for maintaining corpus luteum, hCG in urine is an indication of pregnancy.

5. Human placental Lactogenic hormone (HPL)

The hormone produced by placenta prepares the mammary glands to secrete milk.

6. Inhibin / Actin

Hormones produced by corpus luteum, placenta and testes that inhibits or activates gonadotrophic activity of pituitary gland and hypophysis.

HYPOGONADISM

- Defect or injury to hypothalamus, pituitary testes or ovaries. In male hypogonadism, there is deficient production of testosterone due to hypofunction of Leyding cells or deficient formation of sperms on account of hypofunction of sertoli cells. Both the defects may be present. Male musculature and male secondary sexual characteristics do not develop. In female hypogonadism there is deficient secretion of estrogen, little development of secondary sexual characters of females and non-development of reproductive cycles.

PRECOCIOUS PUBERTY

- It is early maturation of primary sex organs. Ovary before the age of 11 years and testes before the age of 12 years. Sexual pseudoprecocity in boys occurs due to excess formation of testosterone as there is tumour growth in testes or adrenals. It results in early enlargement of penis, development of pubic and axillary hair, faster body growth, masculinisation and then stunting . Similarly, sexual pseudoprecocity in girls results from excessive production of estrogen due to tumours in ovaries / adrenals. Breast and pubic hair develop early but ovarian cycle does not occur.

GYNAECOMASTIA

- It is the development of breast tissue in males due to
 - (i) Perturbation of estrogen to androgens ratio.
 - (ii) Temporary increase in circulating estrogen during neonatal period and during puberty.
 - (iii) Decreased testosterone in later life

HEART

- It produces a peptide hormone atrial natriuretic factor (ANF) in case of hypertension. The hormone inhibits renin (in kidneys) and ADH secretion (in pituitary)

SALIVARY GLANDS

- The glands produce proteinaceous hormone parotine required for calcification of teeth.

GASTROINTESTINAL MUCOSA

1. Gastrin

It is produced by pyloric mucosa and duodenum (small quantity by γ -cells in pancreas) in response to presence of food in stomach. Stimulus is provided by vagus nerve. Gastrin stimulates secretion of gastric juices and churning movements of stomach. Hypersecretion produces gastric ulcers and other gastric problems.

2. Motilin

It is secreted by duodenum in response to food and acidity. Motilin controls motility of stomach and intestine

3. Secretin

Entry of HCl in duodenum stimulates secretion of secretin from duodenal mucosa. The hormone stimulates secretion of water and bicarbonate in bile and pancreatic juice. It inhibits stomach movements and secretion of gastric juice. Secretin was the first hormone to be isolated.

4. Enterogastrone

It is believed to be produced by duodenum in response to chyme. Enterogastrone stops digestive activity in stomach.

5. Cholecystokinin

It is produced by duodenum and jejunum in response to presence of food. Cholecystokinin stimulates the flow of pancreatic enzymes and contraction of gall bladder.

6. Pancreozymin

The hormone is believed to be secreted by duodenal mucosa and required for the flow of pancreatic juice. Both cholecystokinin and pancreozymin are now believed to be one structure.

7. Enterocrinin

The hormone secreted by duodenal mucosa stimulates crypts of Lieberkuhan for secretion of succus or intestinal juice.

8. Duocrinin

Intestinal hormone that stimulates secretion of mucus and HCO_3 from Brunner's gland

9. Villikin

Intestinal hormone that stimulates movements of intestinal villi

10. Gastric Inhibitory Peptide (GIP)

It is secreted by mucosa in the upper part of small intestine in response to fat and protein in chyme, monosaccharides also have a stimulating effect. GIP inhibits gastric mobility and secretion for slowing down of passage of food. It stimulates insulin secretion.