CHAPTER-22

CHEMICAL COORDINATION AND INTEGRATION

INTRODUCTION

The endocrine system comprises of endocrine glands and their hormones.

Though different endocrine glands are different in embryonic origin and are isolated from one another but these interact with one another to collectively form an endocrine system.

Animals have three types of glands – **exocrine**, **endocrine,** and **heterocrine**.

Exocrine glands have ducts for discharging their secretions. Therefore, they are called as **duct glands**. E.g., liver, sweat gland, sebaceous gland, gastric glands, and some intestinal glands.

Endocrine glands lack ducts and pass secretions into the surrounding blood directly. Therefore, they are called **ductless glands**. E.g., thyroid, parathyroid, adrenal, pituitary, pineal body, and thymus.

Heterocrine glands consist of both exocrine and endocrine tissue. The exocrine discharge its secretion by a duct and the endocrine tissue discharges its secretion into the blood. The pancreas and gonads are heterocrine glands. These are also called **mixed glands**.

Endocrinology is the study of endocrine glands, hormones & the endocrine system.

The Father of endocrinology was **Thomas Addison**.

The endocrine system in association with the nervous system functions in a coordinated way to maintain a homeostatic state within the body.

DIFFERENCE BETWEEN NERVOUS AND ENDOCRINE COORDINATION

Nervous Co-ordination	Endocrine Co-ordination
1. Information passes as electrical impulses along nerve fibres.	1. Information passes as a chemical substance through the blood and lymph.
2. There is rapid transmission of information.	2. There is slow transmission of information.
3. Response is immediate.	3. Response is usually slow.
4. Response is very exact.	4. Response is usually widespread.
5. Response is short lived.	5. Response is long-lasting.

HORMONES

The hormone is a chemical produced by endocrine glands and released into the blood and transported to a distantly located target organ.

Hormones are non-nutrient chemicals that act as intercellular messengers and are produced in trace amounts.

The first hormone discovered was secretin. It was discovered by two English physiologists: William M. Bayliss and Ernest H. Starling in 1903.

A hormone that stimulates another endocrine gland to secrete its hormone is called **trophic hormone**.

The term hormone was coined by Starling (1905) from the Greek word hormone means to excite. It is a misnomer because several hormones are known to have an inhibitory effect (e.g., somatostatin).

PROPERTIES OF HORMONES

- These are secreted by the endocrine gland (biogenic in origin).
- Their secretions are released directly into blood (except local hormones, e.g., gastrin).
- These are carried to distantly located specific organs, called the target organ.
- These have specific physiological action (excitatory or inhibitory). These co-ordinate different physical, mental, and metabolic activities and maintain homeostasis.
- The hormones have low molecular weight, e.g., ADH has a molecular weight of 600-2000 daltons.
- These act in very low concentration.
- Hormones are non-antigenic means that they cannot stimulate the production of antibodies.
- These are mostly short-lived, so have no cumulative effect.
- Some hormones are quick-acting, e.g., adrenaline, while some act slowly, e.g., estrogen of the ovary.
- Some hormones are secreted in an inactive form called **prohormone**, e.g., pro-insulin.
- Hormones after their action are destroyed in the endocrine liver and kidney.

Similarities between hormones and enzymes are :

- Easily soluble and diffusible.
- Not obtained from the food, but synthesized by the body.
- Required and secreted in minute quality.
- Not stored (except thyroxine) and have high specificity.

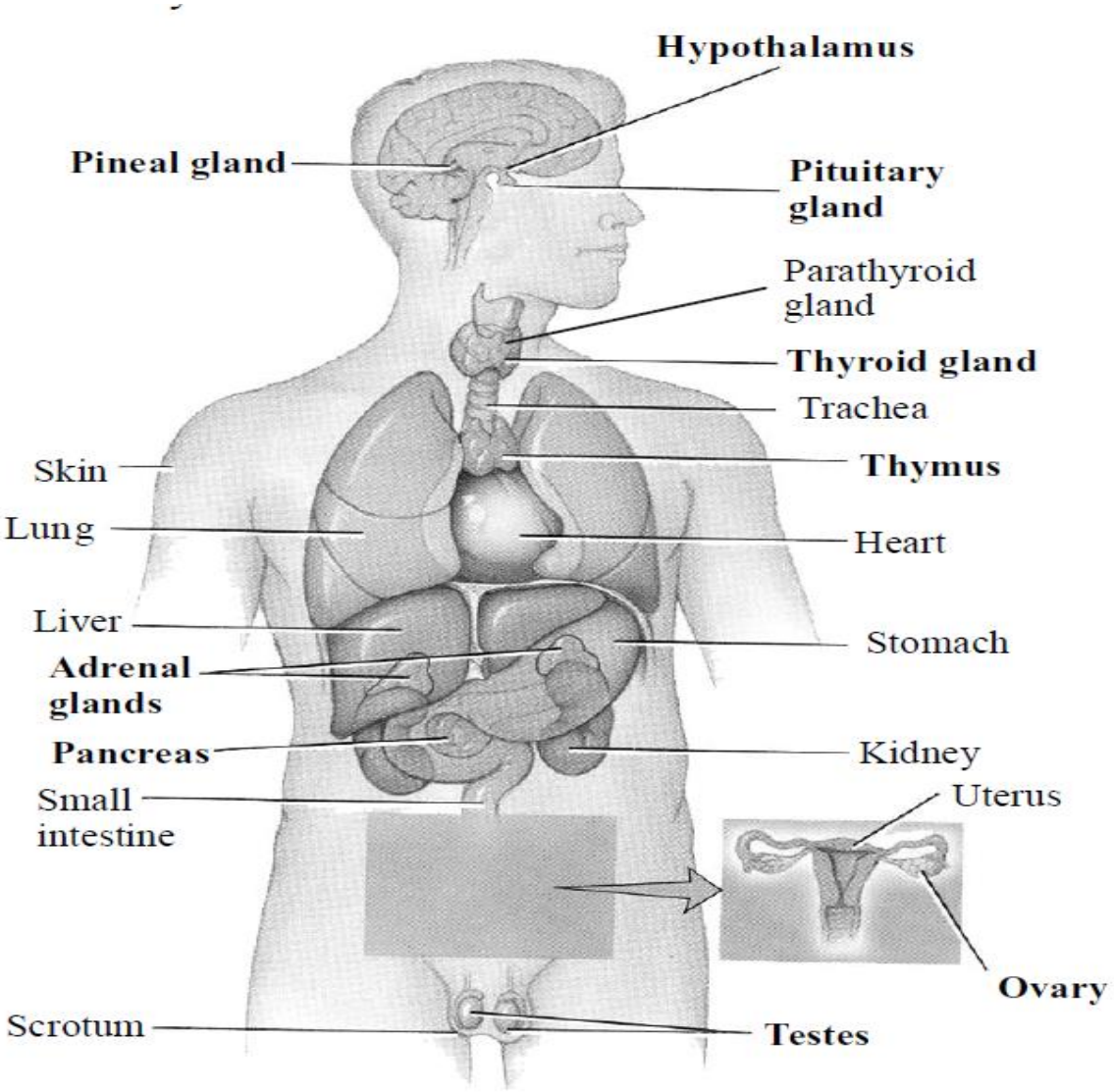
DIFFERENCE BETWEEN HORMONE AND ENZYMES

S. No.	Characters	Enzymes	Hormones
1.	Chemistry	Always proteinaceous	May be proteinaceous or amine or steroids.
2.	Molecular weight	Macromolecules with high molecular weights.	Have low molecular weights.
3.	Diffusibility	Non-diffusible through cell membrane.	Diffusible through cell membrane.
4.	Site of action	Either act intracellularly or carried by some duct to another site.	Generally carried by blood to a target organ.
5.	Mode of action	Always act as biocatalysts and increase the rate of metabolic physiological process.	May be excitatory or inhibitatory in their physiological action.
6.	Reversibility	These catalyze reversible reactions.	Hormone controlled reactions are not reversible.
7.	Effect of concentration	Reaction rate increase with increase in their concentration upto a limit.	Deficiency or excess of hormone causes metabolic disorders and diseases.
8.	Speed	Act quickly	Some are quick acting, while some are slow acting with a lag period.
9.	Consumption	Not used in metabolic functions.	Used up in metabolic functions.

HORMONE ENDOCRINE SYSTEM

The endocrine system of humans consists of various endocrine glands present in different regions of the body.

The major glands that form the human endocrine system are the hypothalamus, pituitary gland, pineal, thyroid, parathyroid, thymus, adrenal gland, pancreas, testes, and ovaries.



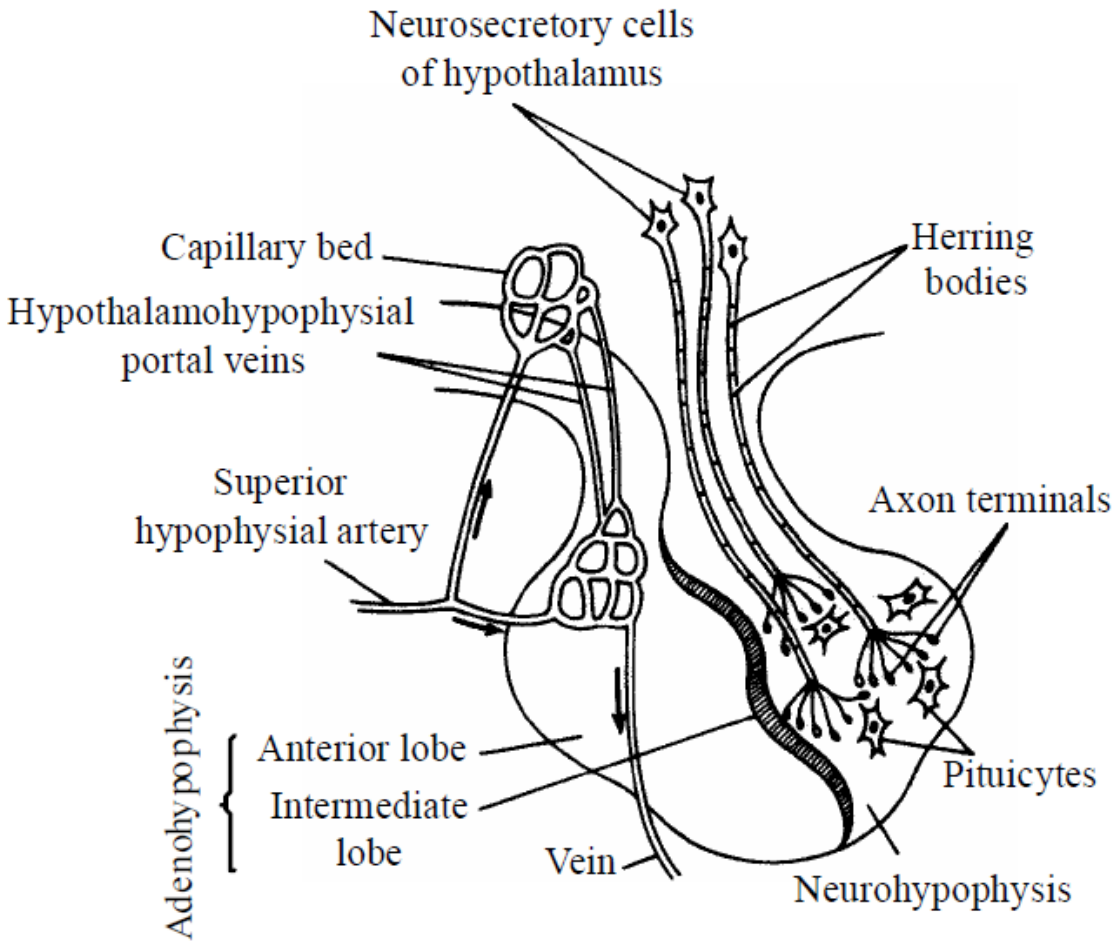
HYPOTHALAMUS

The hypothalamus is a part of the forebrain and appeared as the floor of the diencephalon. It is the main link between the endocrine and nervous systems.

It contains several groups of **neurosecretory cells** (called hypothalamic nuclei) which produce **hormones** (called **neuro-hormone**). These hormones regulate the synthesis and secretion of pituitary hormones.

The hormones produced by the hypothalamus are of two types – the **releasing hormones** which stimulate secretion of **pituitary hormones** (called trophic hormones) and the **inhibiting hormones** that inhibit secretions of pituitary hormones.

Hormones originating in the hypothalamic neurons, pass through axons, and are released from their nerve endings. Hormones reach the pituitary gland through a portal circulatory system and regulate the functions of the anterior pituitary. The posterior pituitary is under the direct neural regulation of the hypothalamus.



Blood supply to the pituitary

SPECIFIC HORMONES RELEASED BY THE HYPOTHALAMUS AND THEIR EFFECT ON PITUITARY GLAND

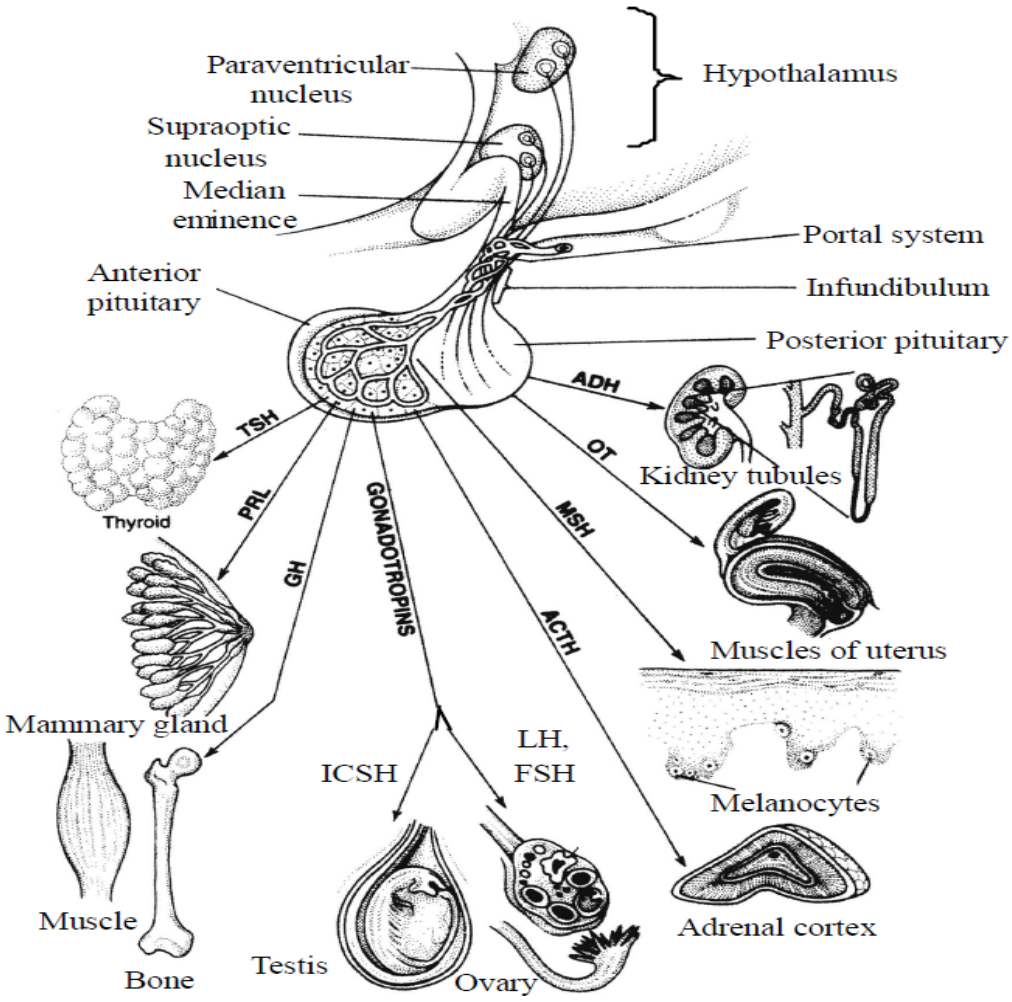
S. No.	Releasing hormone from hypothalamus	Hormones released from anterior pituitary in response to releasing hormone
1.	TSH-RH (Thyrotropin releasing hormone or TSH releasing hormone)	TSH and & Prolactin secretion
2.	ACTH-RH (Adreno corticotropic releasing hormone)	ACTH & β-endorphin secretion.
3.	GnRH (Gonadotrophic releasing hormone) (a) FSH releasing factor (b) LH releasing factor (c) Prolactin releasing and inhibiting factor	FSH LH Releases or inhibits prolactin or luteotrophin hormone
4.	GH-RH (Growth hormone releasing hormone and GH-IH (Growth hormone inhibiting hormone, also called **somatostatin**).	Release or inhibition of growth hormone (also called **somatotropin**, *i.e.* GH or STH)
5.	MSH-RH (Melanocyte releasing hormone) or MSH-inhibiting hormone	Release or inhibition of intermediate pituitary to secrete MSH

PITUITARY GLAND

The pituitary gland, located in a bony cavity called **sella turcica** and is attached to the floor of the Diencephalon (forebrain) through a stalk.

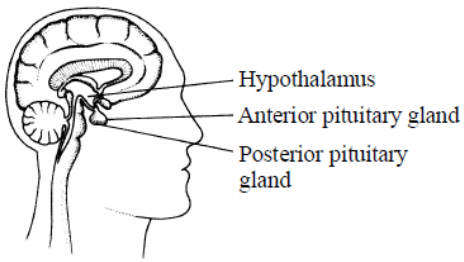
The pituitary gland plays the most important regulatory role in the body. Besides regulating growth, sex, and general behaviour, it also regulates the secretory activities of other principal endocrine glands and cells. Most appropriately, therefore, pituitary has been referred to as "**The**

Master gland" of the body, or the "**Chief Executive of Endocrine System**", or "**The Leader of Endocrine Orchestra**".



The diagram to show the hormones of the pituitary gland and their target tissues and organs

The pituitary gland is divided into two parts–**adenohypophysis** and **neurohypophysis**.



Location of the pituitary gland

Adenohypophysis

Adenohypophysis is formed of 3 parts – pars distalis, pars tuberalis, and pars intermedia.

The pars distalis and pars tuberalis region of the pituitary are commonly called anterior pituitary.

Hormones of the anterior pituitary are growth hormone (GH), thyroid-stimulating hormone (TSH), follicle-stimulating hormone (FSH), luteinizing hormone (LH), interstitial cell-stimulating hormone (ICSH), prolactin (PRL), and adrenocorticotropic hormone (ACTH).

The growth hormone stimulates the liver to form "somatomedins" ("Insulin-like growth factors"). These somatomedins have a potent effect on bone growth.

Pars intermedia secretes melanocyte-stimulating hormone (MSH).

In humans, the pars intermedia is almost merged with pars distalis.

Neurohypophysis

Neurohypophysis has three main parts – pars nervosa (infundibular process), median eminence, and infundibular stalk.

Neurohypophysis (pars nervosa) is also known as the **posterior pituitary**. It stores and releases two hormones - **oxytocin** and **vasopressin**, which are actually synthesized by the hypothalamus and are transported axonally to the neurohypophysis.

DISORDERS OF GROWTH HORMONE

- **Hypersecretion of GH** stimulates abnormal growth of the body leading to gigantism and acromegaly whereas **hyposecretion of GH** results in stunted growth resulting in pituitary dwarfism and Simmonds disease.
- **Proportionate gigantism**: Hypersecretion (oversecretion of growth hormone) during the growth period (childhood and adolescence) causes excessive growth (hypergrowth) of all body parts, resulting in a symmetrically giant body. This is called proportionate gigantism.
- **Acromegaly**: It occurs in adults. In this, the long bones do not grow in length due to closed epiphyseal plate at their ends, but the bones of hands, feet, lower jaw, and rib cage thicken. Simultaneously, eyelids, lips, tongue, nose, chin, etc. also enlarge. Soles,

DISORDER OF THYROID STIMULATING HORMONE

- Hyposecretion of TSH leads to thyroid atrophy while hyperactivity produces symptoms similar to Grave's disease.

DISORDER OF ACTH

- Hypersecretion of ACTH leads to rheumatoid arthritis while hyposecretion leads to excessive growth of the adrenal cortex.

DISORDERS OF GONADOTROPINS

- Hyposecretion of ICSH results in impaired development of external genitalia and LH results in sterility in females and FSH fails gamete formation.

DISORDERS OF PROLACTIN

- Hypersecretion of prolactin
- May hinder menstruation
- May cause impotency.
- In pigeons and doves, it stimulates the epithelial cells of the crop in both males and females to secrete "pigeon milk" for the nutrition of newly hatched infants.

DISORDER OF ANTIDIURETIC HORMONE (ADH)

- Hypersecretion of ADH causes **diabetes insipidus**. It is characterized by micturating dilute urine several times a day which results in excessive thirst (polydipsia) and dehydration.
- Alcohol inhibits the secretion of ADH, so increases urine output, increases in the count of erythrocyte, amount of haemoglobin, etc.

PINEAL GLAND

The pineal gland is composed of modified nerve cells called **pinealocytes**.

It is a stalked small rounded gland and can be found deep in the brain at the top of the third ventricle (called pineal recess) where it has close communication with the cerebrospinal fluid. Due to its position, it is also called **epiphysis cerebri**.

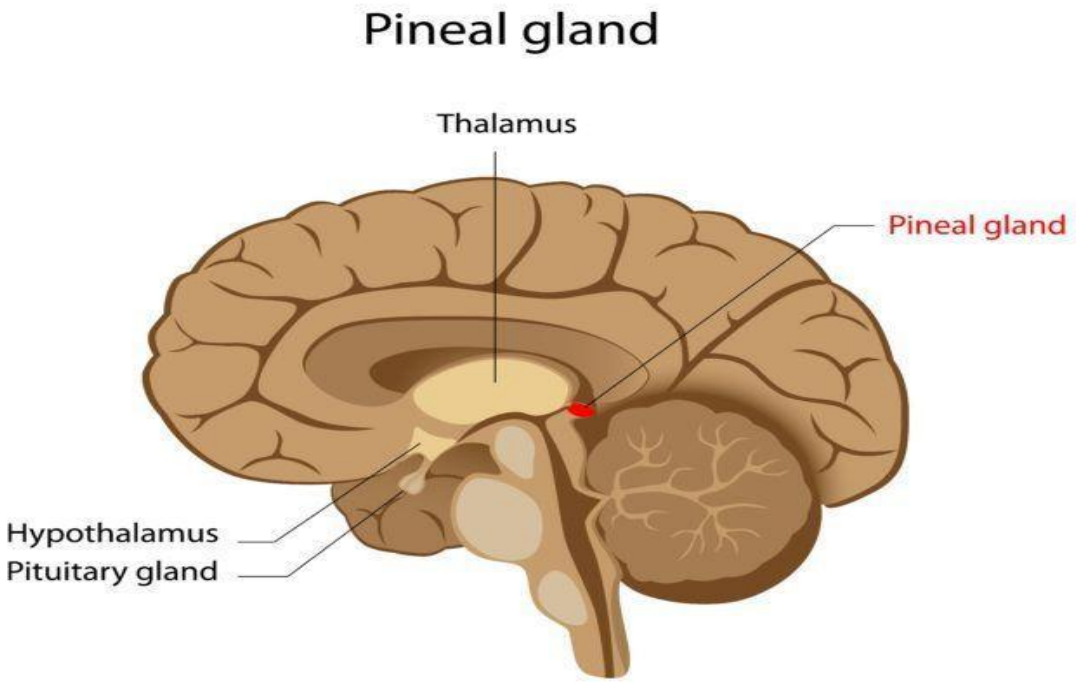
Pineal secretes two biogenic hormone - **melatonin** and **serotonin**.

Melatonin plays a very important role in integrating photoperiod and affecting circadian rhythms. For example, it helps in maintaining the normal rhythm of the sleep-wake cycle, body temperature. Also, melatonin influences metabolism, pigmentation, the menstrual cycle as well as our defence capability.

Light falling on the retina of the eye decreases melatonin production, darkness stimulates melatonin synthesis. Girls blind from birth attain puberty earlier than normal, apparently because there is no inhibitory effect of melatonin on ovarian function.

Melatonin is also a potent antioxidant. Melatonin causes atrophy of gonads in several animals.

Serotonin acts as a vasoconstrictor and helps to decrease the diameter of the blood vessel.



THYMUS

The thymus gland is a lobular structure located on the dorsal side of the heart and the aorta. It is the **first developing lymphoid organ**.

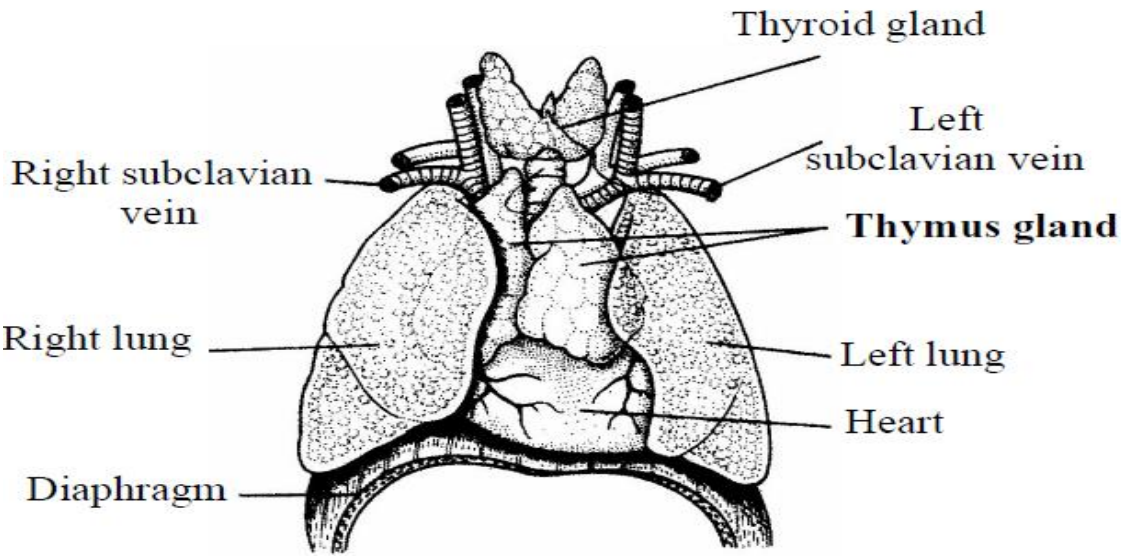


Fig. : Location of the thymus gland

The thymus is divided into two parts - the **outer cortex** and **inner medulla**.
The thymus gland acts as a **hematopoietic** as well as an **endocrine gland**.
This gland secretes the peptide hormones called **thymosin** and **thymopoietin**.
Thymosin plays a major role in the differentiation of T lymphocytes, which provide cell-mediated immunity. Also, thymosin promotes the production of antibodies to provide humoral immunity.
Thymopoietin (also called thymine I and II) inhibits acetylcholine release at motor release endings.

DISORDER OF THYMUS GLAND

- Hypersecretion of thymosin hormone may lead to myasthenia gravis, characterized by abnormal muscular excitation.

THYROID GLAND

The thyroid gland is located on either side of the trachea.

It is bilobed and both the lobes are interconnected with a thin flap of connective tissue called **isthmus**.

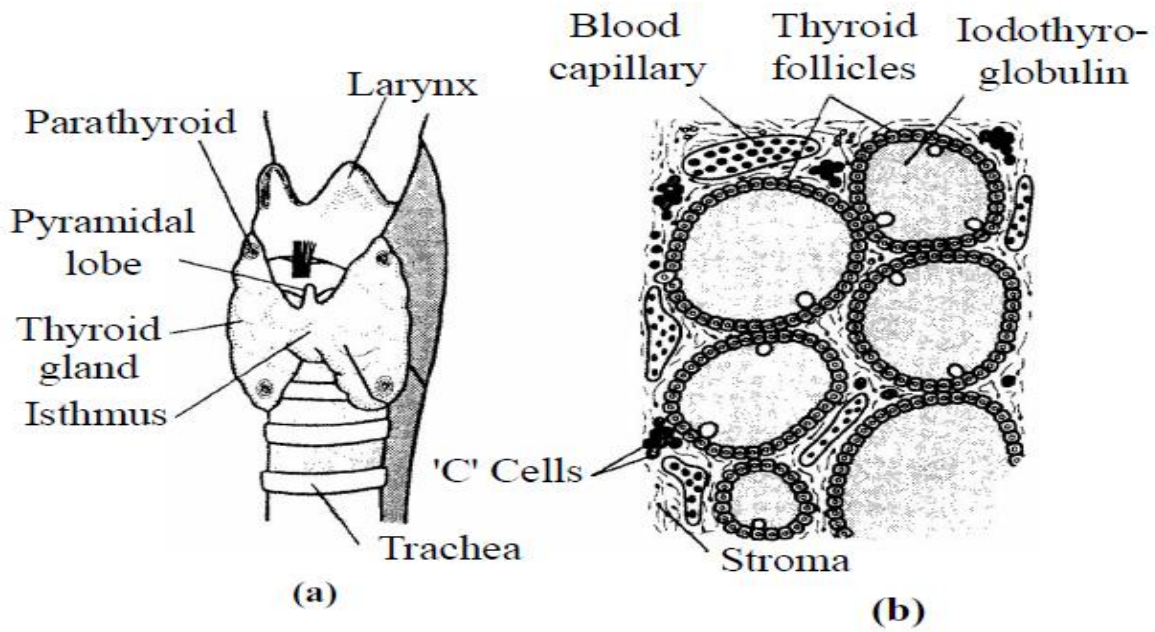


Fig. : (a) Thyroid gland, (b) Follicles suspended in the stroma of a lobule

The thyroid gland is the **largest endocrine gland** in the body.
Endostyle of lower vertebrates like Herdmania, Amphioxus is homologous of the thyroid gland.

The thyroid is the only endocrine gland in the body that stores its hormone in its inactive state.
Thyroid follicles contain **thyroglobulin**. Thyroglobulin is a large protein molecule that contains multiple copies of one amino acid tyrosine.

These follicular cells secrete two hormones - **tetraiodothyronine or thyroxine (T_4)** and **triiodothyronine (T_3)**.
The thyroid needs iodine to produce these hormones.

Thyroid hormones play an important role in regulating basal metabolic rate and calcium balance. These hormones also support the process of red blood cell formation and control the metabolism of carbohydrates, proteins, and fats. Maintenance of water and electrolyte balance is also influenced by thyroid hormones.

Thyroxine stimulates the metamorphosis of tadpole larva in amphibians.
Thyroid tissue is made up of two types of cells– **follicular cells** and **parafollicular cells**.

Parafollicular cells are groups of endocrine cells scattered in the connective tissue and between the thyroid follicles.
Parafollicular cells of the thyroid gland also secrete a non-iodinated protein hormone called **thyrocalcitonin (TCT)** which regulates the blood calcium levels.

Calcitonin (thyrocalcitonin) plays an important role in calcium and phosphorus metabolism. In particular, calcitonin can decrease blood calcium levels at least in part by effects on two well-studied target organs-bone & kidney.

DISORDERS OF THYROID GLAND

- **Myxoedema**: It occurs due to deficiency of thyroxine in adults like cretinism, it also has low BMR (by 30 - 40%); low body temperature, reduced heart rate, pulse rate, blood pressure, and cardiac output, low sugar and iodine level in the blood, etc. But the peculiar feature of myxoedema is that face and hands become swollen due to the deposition of albuminous myxomatous tissue. It can also be corrected by thyroxine administration. It is also called Gull's disease.

- **Endemic or simple goitre or colloid goitre**: It occurs due to a deficiency of iodine in drinking water. It is non-genetic (sporadic goitre is a genetic disease) and is characterized by enlargement of the thyroid gland due to an increase in the number and size of acinal cells of the thyroid gland. It is more common in people of the hilly region (hence called endemic goitre). To prevent goitre, the table salt is iodized these days.

- **Exophthalmic goitre (Grave's disease)**: It occurs due to the overactivity of the thyroid gland. Exophthalmic goitre tumour is usually accompanied with some asymmetrical protrusion (Exophthalmos) of the eyeballs, imparting an angry, frightened, or staring look to the patient. The protrusion of eyeballs is due to the accumulation of mucus in eye orbits.

PARATHYROID GLAND

Parathyroid glands are present on the backside of the thyroid gland. There are usually 4 parathyroid glands, one pair each in the two lobes of the thyroid gland.

The parathyroid glands secrete a peptide hormone called **parathyroid hormone (PTH) / Collip's hormone**. The secretion of PTH from chief cells is regulated by circulating levels of calcium ions.

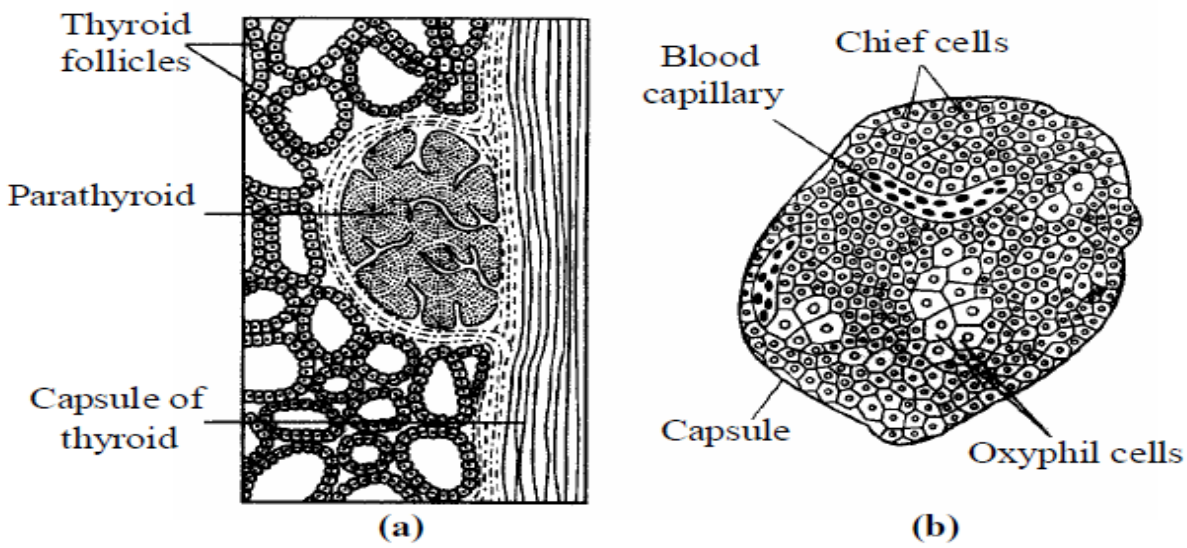


Fig.: (a) Parathyroid gland embedded in the surface of the thyroid, (b) Ultrastructure of a parathyroid gland.

Parathyroid hormone (PTH)

- increases the Ca^{2+} levels in the blood
- acts on bones and stimulates the process of bone resorption (dissolution/demineralization)
- also stimulates reabsorption of Ca^{2+} by the renal tubules and increases Ca^{2+} absorption from the digested food.
- PTH is a hypercalcemic hormone, i.e., it increases the blood Ca^{2+} levels. Along with TCT, it plays a significant role in calcium balance in the body.

DISORDERS OF PTH

(1) Hypoparathyroidism (Hyposecretion of parathormone)

- It is rare, however, in under secretion of parathormone, the level of calcium in ECF falls (hypocalcemia), and that of phosphates rises (hyperphosphatemia). This causes neuromuscular hyperexcitability, excessive perspiration, gooseflesh (raising of hairs and prickly sensation in the skin), cooling of hands and feet, painful muscle spasms, and convulsions, and trembling.

- Sometimes some skeletal muscles, usually of hands and feet, fail to relax after a contraction, and remain in "sustained contraction". This is called "Tetany". Tetany of laryngeal, thoracic, and phrenic muscles, which help in breathing, causes death because the patient fails to breathe (asphyxia).

- Childhood hypoparathyroidism retards growth, particularly of bones, teeth, hair, and brain. Vitamin D is administered to such children.

(2) Hyperparathyroidism (Hypersecretion of parathormone)

- **Osteoporosis**: It occurs usually due to the overgrowth of one or more parathyroid glands. It causes demineralization of bones which, therefore, become soft, weak, distorted, and fragile. This is called osteoporosis.

- **Hypercalcemia**: Simultaneously, due to a sharp rise in calcium level in blood and ECF (hypercalcemia) and a sharp fall in phosphate level (hypophosphatemia), muscles and nerves are weakened.

- **Hypercalciuria**: Calcium is excreted in urine (hypercalciuria), thirst increases owing to copious urination, appetite is lost, constipation and headache become common, and often, kidney stones are formed. The only treatment so far known is the removal of an extra part of the glands by the operation.

ADRENAL GLAND

Adrenal glands are two small yellowish glands located on superior to kidney (hence called **suprarenal gland**)

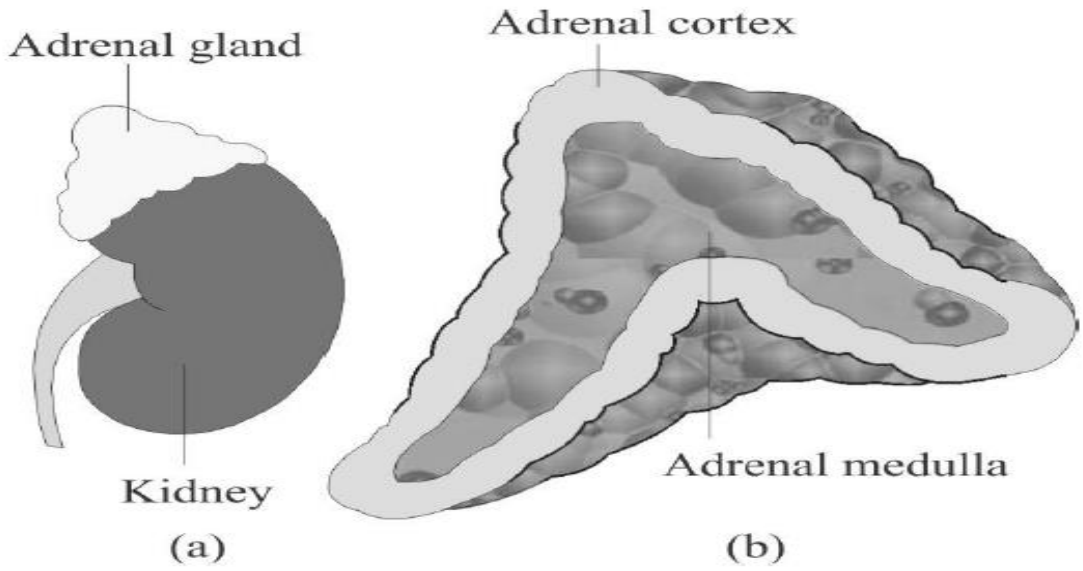


Fig. : Diagrammatic representation of (a) Adrenal gland above kidney (b) Section showing two parts of the adrenal gland

Each gland is composed of two types of tissues - the centrally located **adrenal medulla**, and outside this lies the **adrenal cortex**.

The **adrenal medulla** consists of chromaffin cells and secretes two hormones - **adrenaline (or epinephrine)** and **noradrenaline (or norepinephrine)**. These are commonly called **catecholamines**.

Adrenaline and nor-adrenaline are derived from amino acid tyrosine and are rapidly secreted in response to the stress of any kind and during emergencies. Hence, called **emergency hormones** or **hormones of fight** or **fright or flight**.

These hormones increase alertness, pupillary dilation, piloerection (raising of hairs), sweating, etc. Both the hormones increase the heartbeat, the strength of heart contraction, and the rate of respiration.

Catecholamines also stimulate the breakdown of glycogen resulting in an increased concentration of glucose in the blood. Also, they stimulate the breakdown of lipids and proteins.

The secretion of adrenaline is 5-10 times higher than nor-adrenaline.

The adrenal cortex can be divided into three layers - zona reticularis (inner layer), zona fasciculata (middle layer), and zona glomerulosa (outer layer).
Zona glomerulosa secretes mineralocorticoids primarily aldosterone.
Zona fasciculata secretes glucocorticoids mainly cortisol.

Zona reticularis secretes sex corticoids including testosterone.
The adrenal cortex secretes many steroid hormones, which are commonly called as corticoids. **Corticoids**, which are involved in carbohydrate metabolism are called glucocorticoids. **Cortisol** is the main glucocorticoid.

Glucocorticoids stimulate gluconeogenesis, lipolysis, and proteolysis; and inhibit cellular uptake and utilization of amino acids.

Cortisol maintains the cardiovascular system as well as the kidney functions and produces anti-inflammatory reactions and suppresses the immune response. Cortisol stimulates RBC production.

Corticoids, which regulate the balance of water and electrolytes in our body is called mineralocorticoids. Aldosterone is the main mineralocorticoid.

Aldosterone (also called salt retaining hormone) acts mainly at the renal tubules and stimulates the reabsorption of Na^+ 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.

Small amounts of **androgenic steroids** are also secreted by the adrenal cortex (Zona reticularis and Zona fasciculata) which play a role in the growth of axial hair, pubic hair, and facial hair during puberty.

DISORDERS OF ADRENAL HORMONES

- **Undersecretion of sex hormones** causes impotence in males and disorders of the menstrual cycle in females.
- Excessive deposits of melanin, particularly in the skin of open parts of the body like face, hands, feet, neck, teats, etc, cause deep bronzing of skin in these parts.
- An increase in H^+ concentration in blood may cause acidosis.
- **Pheochromocytoma** is due to hypersecretion of adrenaline. It causes high blood pressure, a high level of sugar in blood and urine, high metabolic rate, nervousness, and sweating.
- **Hypersecretion**: Oversecretion of adrenocorticoids (hypercorticism) causes the following disorders and diseases -
- Glucose level rises in the blood (hyperglycemia). This may lead to diabetes mellitus.
- Retention of sodium and water in the ECF increases blood pressure, causing severe hypertension and associated symptoms like severe headaches.
- loss of H^+ in urine may cause alkalosis.
- Excessive secretion of sex corticoids (androgen) due to tumour of the adrenal cortex results in **Virilism** and **hirsutism** in females and **gynecomastia** in males.

PANCREAS

The pancreas is located within the curve of the duodenum. It is the second-largest gland of the body.

The pancreas is a heterocrine gland as it has both exocrine and endocrine tissues.

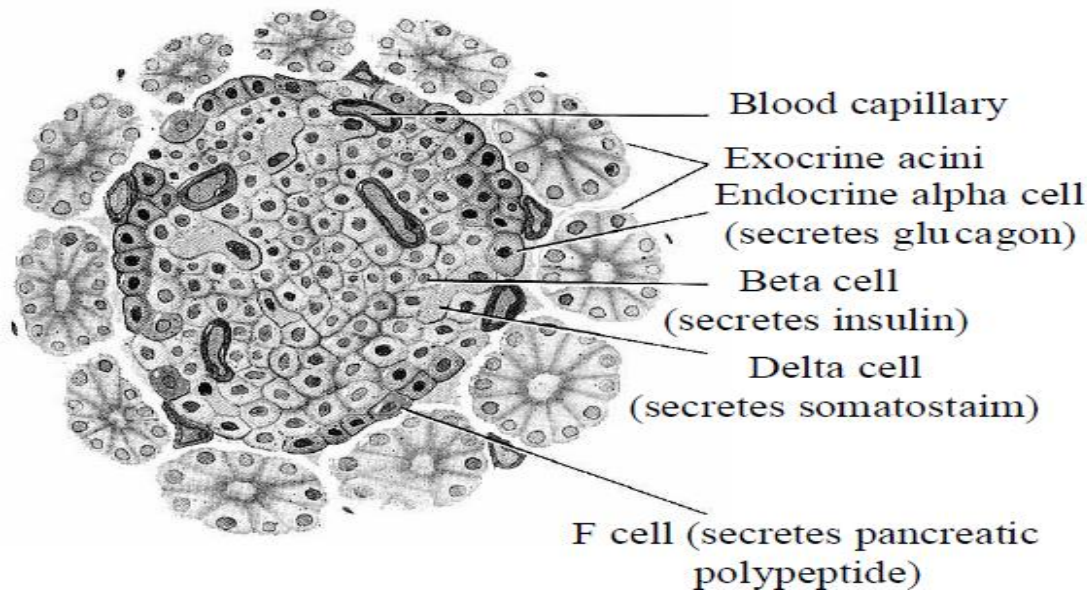


Fig.: T.S. of the pancreas

The exocrine part occurs as **acini** and endocrine pancreas consists of '**Islets of Langerhans**'.

Hormones secreting cells present in Islet of Langerhans are given in the table below.

Type of cells	Hormones
α-cell	Glucagon
β -cell	Insulin
ε -cell	Ghrelin
δ -cell	Somatostatin
F-cell/γ -cell	Pancreatic polypeptide

Glucagon is a peptide hormone and plays an important role in maintaining normal blood glucose levels. It acts mainly on the liver cells (hepatocytes) and stimulates glycogenolysis resulting in

increased blood sugar (hyperglycemia). Glucagon reduces cellular glucose uptake and utilization. Thus, glucagon is a hyperglycemic hormone.
Insulin is a peptide hormone, which plays a major role in the regulation of glucose homeostasis. Insulin acts mainly on hepatocytes and adipocytes (cells of adipose tissue) and enhances cellular glucose uptake and utilization. Insulin also stimulates the conversion of glucose to glycogen (glycogenesis) in the target cells.

The normal range of blood sugar is 80-120 mg/100 ml of blood.
Gastrin is similar to the one produced by the pyloric stomach
Somatostatin controls α and β cells of the pancreas.
Pancreatic polypeptide checks the secretory activity of digestive glands and increases glycogenolysis.

DISORDERS OF PANCREAS

- **Hyposecretion** leads to diabetes mellitus, which is associated with loss of glucose through urine and the formation of harmful compounds known as **ketone bodies**.
- It occurs due to either deficient insulin production or due to the failure of cells to take up insulin from the blood. It is characterized by **hyperglycemia** (300-1200 mg/100 ml), **polyuria** (excessive urination due to an increase in water content in urine), **polydipsia** (excessive thirst), **glycosuria** (glucose in the urine), loss of weight and tiredness, dehydration, reduced healing power, etc.

TESTIS

The testis is present in the scrotal sac (outside abdomen) of male individuals.

Testis performs dual functions as a primary sex organ as well as an endocrine gland.

The testis is composed of seminiferous tubules and stromal or interstitial tissue.

The Leydig cells or interstitial cells, present in the intertubular spaces produce a group of hormones called **androgens** (mainly **testosterone**).

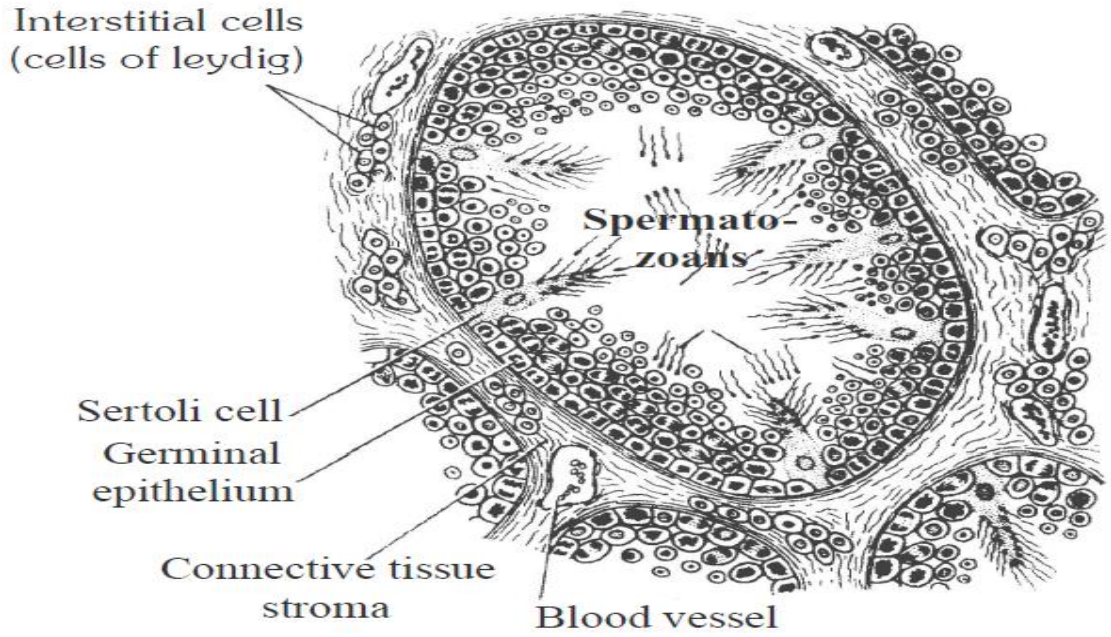


Fig.: Testes

Androgens regulate the development, maturation, and functions of the male accessory sex organs like epididymis, vas deferens, seminal vesicles, prostate gland, urethra, etc. These hormones stimulate muscular growth, growth of facial and axillary hair, aggressiveness, low pitch of voice, etc.

Androgens play a major stimulatory role in the process of spermatogenesis (formation of spermatozoa). Androgens act on the central neural system and influence **male sexual behaviour (libido)**. These hormones produce anabolic (synthetic) effects on protein and carbohydrate metabolism.

Failure of testosterone secretion in male-causes **eunuchoidism**. Eunuch has undeveloped secondary sex organs like the prostate, seminal vesicle, and penis and it does not produce sperm.

OVARY

The ovary is the primary female sex organ that lies in the abdominal cavity.

It produces one ovum during each menstrual cycle and also produces two groups of steroid hormones called **estrogen** and **progesterone**.

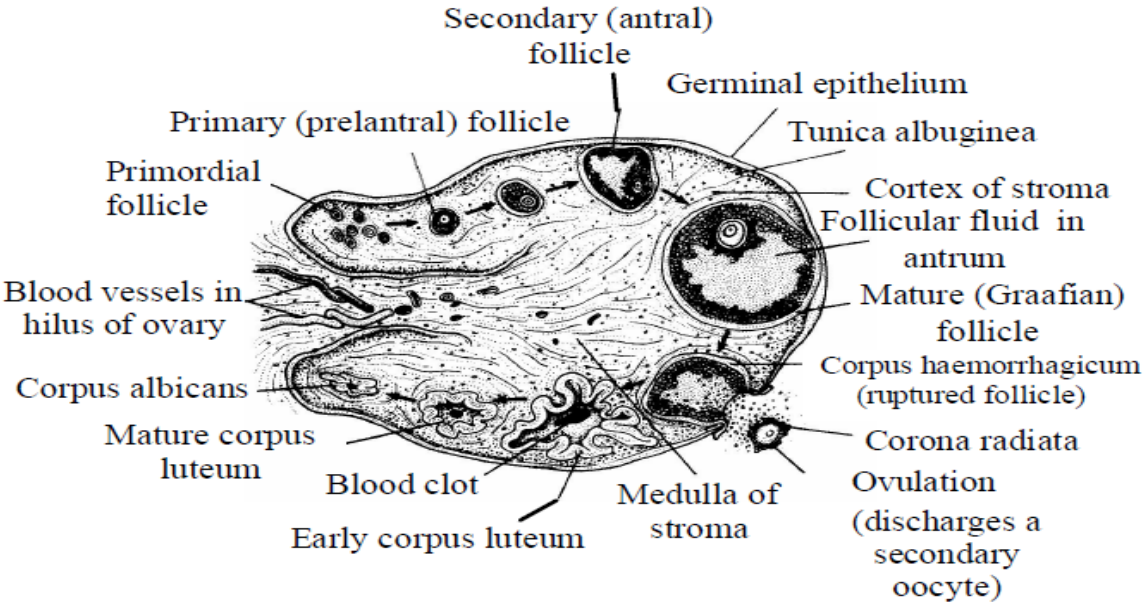


Fig. : Ovary

The ovary is composed of ovarian follicles and stromal tissues. It secretes estrogen and progesterone.

The estrogen is synthesized and secreted mainly by the growing ovarian follicles. After ovulation, the ruptured follicle is converted to a structure called **corpus luteum**, which secretes mainly progesterone.

Estrogens produce wide-ranging actions such as stimulation of growth and activities of female secondary sex organs, development of growing ovarian follicles, the appearance of female secondary sex characters (e.g., the high pitch of voice, etc.), mammary gland development.

Progesterone supports pregnancy and also acts on the mammary glands and stimulates the formation of alveoli (sac-like structures which store milk) and milk secretion.

HORMONES OF HEART, KIDNEY AND GASTROINTESTINAL TRACT

The atrial wall of the heart secretes a very important peptide hormone called **atrial natriuretic factor (ANF)**, which decreases blood pressure. When blood pressure is increased, ANF is secreted which causes dilation of the blood vessels. This reduces blood pressure.

The juxtaglomerular cells of the kidney produce a peptide hormone called **erythropoietin** which stimulates **erythropoiesis (formation of RBC)**.

Endocrine cells present in different parts of the gastro-intestinal tract secrete four major peptide hormones, namely **gastrin**, **secretin**, **cholecystokinin (CCK),** and **gastric inhibitory peptide (GIP)**.

Gastrin acts on the gastric glands and stimulates the secretion of hydrochloric acid and pepsinogen.

Secretin acts on the exocrine pancreas and stimulates the secretion of water and bicarbonate ions.

CCK acts on both pancreas and gallbladder and stimulates the secretion of pancreatic enzymes and bile juice, respectively.

GIP inhibits gastric secretion and motility.

MECHANISM OF HORMONE ACTION

- Hormones produce their effects on target tissues by binding to specific proteins called hormone receptors located in the target tissues only.
- Each receptor is specific to one hormone only and hence receptors are specific.
- Hormone-receptor complex formation leads to certain biochemical changes in the target tissue. Target tissue metabolism and hence physiological functions are regulated by hormones.
- Hormones that interact with intracellular receptors (e.g., steroid hormones, iodothyronines, etc.) mostly regulate gene expression or chromosome function by the interaction of the hormone-receptor complex with the genome.
- The hormone-receptor complex may act in one of the two ways - **formation of cAMP** and **change in membrane permeability**.

(1) Formation of cAMP

- The hormone-receptor complex causes the release of an enzyme adenyl cyclase, from the receptor site. This enzyme hydrolyses the ATP into c-AMP. The c-AMP activates the existing enzyme system of the cell. This accelerates the metabolic reactions in the cell.
- The hormone is called the **first messenger** and the c-AMP is termed that. E.g., Adrenaline causes the secretion of glucose from the liver cell from this mechanism.

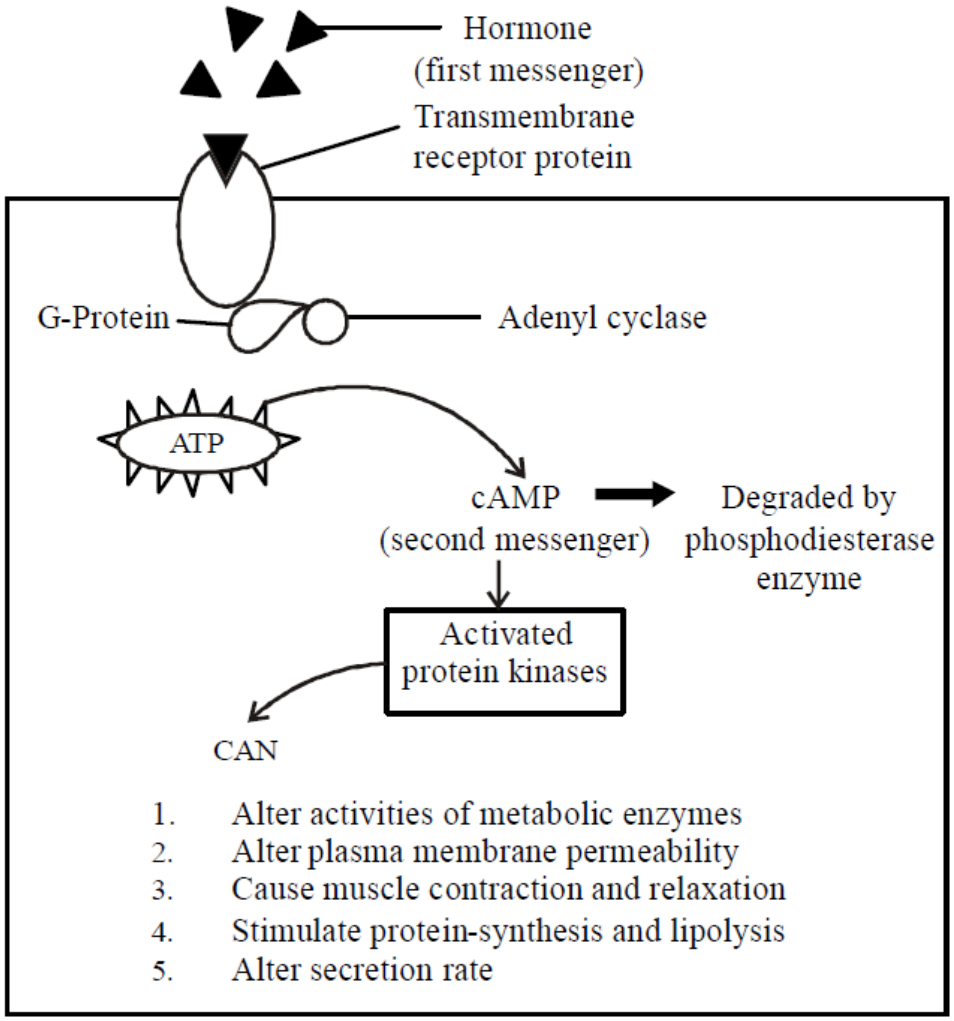


Fig. : Mechanism of hormone action on the cell surface

(2) Change in membrane permeability

- The receptor proteins of some hormones are large transmembrane intrinsic protein acting as ion channels for facilitated diffusion of Na^+, K^+, Ca^{2+}, etc. On binding with a specific hormone, these receptor proteins undergo conformational changes, so that the membrane permeability for ions is altered, resulting in important changes in metabolism.
- For example, insulin promotes the entry of glucose from the blood into the muscle cells by increasing the permeability of sarcolemma to glucose.
- The **steroid hormones act within the cell**. Their small, lipid-soluble molecules pass through the cell membrane and bind to specific receptor molecules present in the cytoplasm. The receptor molecules carry them into the nucleus. Here, the **receptor hormone complex** binds to a specific receptor site on the chromosome and activates certain genes that were previously repressed. The activated gene transcribe mRNA which

directs the synthesis of the enzyme (a protein molecule) in the cytoplasm. The enzyme molecule promotes the metabolic reactions in the cell.

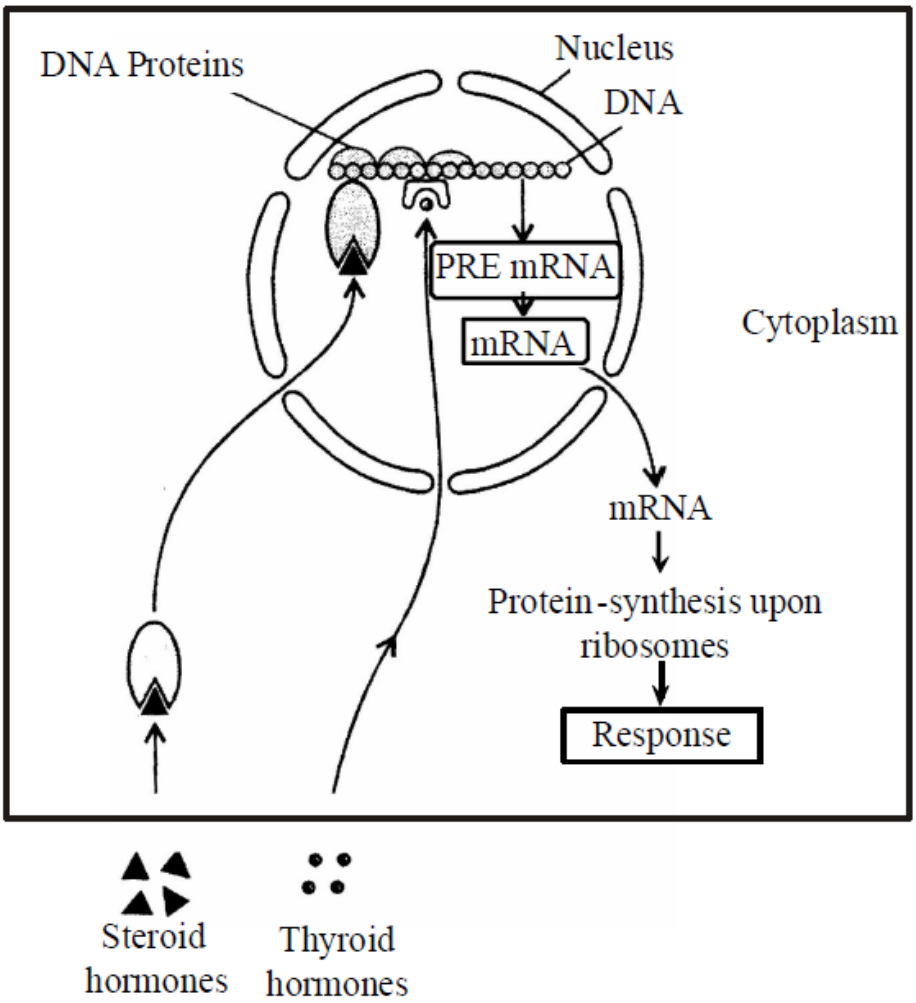


Fig. : Mechanism of hormone action within a cell

IMPORTANT TERMS

Endocrine glands: These are ductless glands that secrete hormones directly into the bloodstream.

Hormones: non-nutrient chemicals, synthesized in trace amounts, act as intracellular messengers and are specific in their action.

Hypothalamus: It is the basal part of the diencephalon.

Releasing hormones: Stimulate secretion of pituitary hormones, e.g., Gonadotropin-releasing hormone stimulates the pituitary gland to synthesize gonadotrophins.

Inhibiting hormones: Inhibit secretions of pituitary hormones, e.g., Somatostatin inhibits the secretion of growth hormone. Pituitary Gland :

Adenohypophysis: Pars intermedia: Produces only one hormone melanocyte-stimulating hormone.

Growth hormone (GH): Oversecretion leads to gigantism and low secretion causes dwarfism.

Prolactin (PRL): Growth of mammary glands and formation of milk in them.

Thyroid-stimulating hormone (TSH): Stimulates synthesis and secretion of thyroid hormones from the thyroid gland.

Adrenocorticotrophic hormone (ACTH): Stimulates synthesis and secretion of steroid hormones called glucocorticoids from the adrenal cortex.

Luteinizing hormone (LH): Synthesis and secretion of hormones called androgens in males, and helps in ovulation and maintenance of corpus luteum in females.

Follicle-stimulating hormone (FSH): Regulate spermatogenesis in males and growth and development of ovarian follicles in females.

ParsNervosa :

•Oxytocin helps in the contraction of the uterus during childbirth and milk ejection from the mammary gland in females.

•**Vasopressin:** Acts on the kidney and stimulates reabsorption of water and electrolytes by distal tubules to reduce water loss through urine. It is also called an Anti-Diuretic Hormone (ADH).

PINEAL GLAND

Located on the dorsal side of ore brain

•**Hyperthyroidism:** This occurs due to cancer or due to the development of nodules in thyroid glands. Effects body physiology as abnormally high levels of thyroid hormones is synthesized. 3).

•Also secretes a protein hormone called Thyrocalcitonin (TCT) which regulates blood calcium level.

Glucocorticoids:
Involved in carbohydrate metabolism.
Stimulates gluconeogenesis, lipolysis, and proteolysis

Insulin: Peptide hormone, acts on hepatocytes, and adipocytes to enhance cellular glucose uptake, stimulates the conversion of glucose to glycogen (glycogenesis), so decreases blood glucose level called hypoglycemic hormone.

TESTIS: A pair of testis composed of seminiferous tubules and interstitial cells is present in the scrotal sac of males.

Ovary: Air of ovaries that produce one ovum in each menstrual cycle is present in the abdomen in females.

Gastrin: Acts on gastric glands and stimulates the secretion of hydrochloric acid and pepsinogen.

Secretin: Acts on the pancreas and stimulates the secretion of water and bicarbonate ions.

Cholecystokinin (CCK): Acts on the pancreas and gall bladder to stimulate secretion of pancreatic juice and bile juice respectively.

Gastric inhibitory peptide (GIP): Inhibits gastric secretion and motility.

Mechanism of hormone action: By hormone receptors of two kinds, i.e., (a) Located on the membrane of the target cell

These are intracellular receptors.

Hormones (steroid hormones, iodothyronines, etc.) interact with them and cause physiological and developmental effects of regulating gene expression.