Chemical Coordination and Integration

Introduction to Human Endocrine System

Hormones are the organic chemicals produced by the body, which are released into the blood.

The key feature of the hormones is that they are secreted by the ductless glands. The glands that secrete hormones do not have ducts. Hormones are released directly into the blood stream and reach the target organ.

Differences between Hormonal Control and Nervous Control

Hormonal Control	Nervous Control
Transmitted chemically through blood	Transmitted electro-chemically through nerve fibres
Transmitted slowly	Transmitted rapidly
Affects different organs	Affects specific organs
Is not affected by previous experience	Is affected by previous experience
Has both long lasting and short lasting effects	Has short lasting effect

The endocrine system works in association with nervous system to control and coordinate our bodies. They contribute to the maintenance of homeostasis in our bodies.

Homeostasis is the capacity of an organism to adjust itself and cope up with external stress to maintain a steady state.

Glands

A cell, tissue, or an organ that secretes chemical messengers required for coordinating a specific function is called a **gland**. Glands are mainly divided into two broad categories - **endocrine and exocrine.**

Exocrine gland	Endocrine gland

These glands possess ducts for discharging their secretions on the body surface. The sebaceous glands present in the skin, salivary glands present in the buccal cavity, and gastric glands present in the walls of the stomach etc. are a few examples of exocrine glands.	These glands do not discharge their secretions through ducts. Hence, they are also known as ductless glands. They discharge their secretions directly into the bloodstream. Their secretions are known as hormones. The pituitary gland, thyroid gland, adrenal gland etc. are a few examples endocrine glands.

Characteristics of Hormones

- Hormones are the organic chemicals that are secreted in response to environmental changes in or outside the body.
- Hormones are secreted by ductless glands and transported along with the blood stream to the site of their action. The site of their production and the organ of their influence are different.
- They can be amino-acid derivatives, proteins, or steroids.
- Being low molecular weight substances, they can easily diffuse through the cell membrane.
- They are produced in small quantities and are effective in extremely lower concentrations.
- Abnormal production of hormones (be it less or more) affects the body in a negative manner.

Some of the ductless glands that secrete hormones are thyroid gland, adrenal gland, pituitary gland, parathyroid gland, gonads, etc.

Human Endocrine System

- Pituitary, pineal, thyroid, adrenal, pancreas, parathyroid, thymus, and gonads are the organised endocrine glands in our body.
- In addition, GI tract, liver, kidney, heart also produce hormones.

Human Endocrine System and Hypothalamus, Pineal, Thyroid, Parathyroid

Hypothalamus

- Basal part of diencephalon in forebrain
- It has several groups of neurosecretory cells (known as nuclei) that produce hormones. The synthesis and secretion of pituitary hormones is regulated by these hormones.
- Hormones originate from hypothalamic neurons, pass through axons, and are released from their nerve endings.
- Reach pituitary gland through a portal circulatory system and regulate the functioning of anterior pituitary
- Hormones from hypothalamus are of two types:

Releasing Hormones	Inhibiting Hormones
Stimulate secretion of pituitary hormones Example – Gonadotropin Releasing Hormone (GnRH)	Inhibit secretion of pituitary hormones Example – Somatostatin

Pineal Gland

- Location – Dorsal side of forebrain
- Secretes melatonin that regulates 24-hour (diurnal) rhythm of the body such as sleep-wake cycle, body temperature, etc.
- Melatonin also regulates metabolism, pigmentation, and menstrual cycle.

Thyroid Gland

- Location – Two lobes of thyroid gland are located on either side of trachea.
- Isthmus – Thin flap of connective tissue interconnecting the thyroid glands
- Composition – Follicles + Stromal tissues

- Follicular cells synthesize two hormones:

- Tetraiodothyronine or thyroxine (T_4)
- Triiodothyronine (T_3)
- Importance of thyroid hormones:
- Regulates BMR (Basal Metabolism Rate)
- Supports the process of RBC synthesis
- Maintains water-electrolyte balance

- Insufficient secretion of thyroxine results in

- goitre (enlargement of thyroid gland due to deficiency of iodine)
- cretinism (dwarfism and mental retardation in children)
- myxoedema (swelling in hands and face of an adult)

- Excessive secretion of thyroid hormone leads to hyperthyroidism. This may occur due to cancer of thyroid gland or development of nodules of thyroid glands. A person suffering from hyperthyroidism show following symptoms:
- Goitre in neck (exophthalmic goitre)
- Protruded eyes
- Increased heart beat
- Increased metabolic rate

Parathyroid Gland

- Location – Four parathyroid glands are present on back side of thyroid glands.
- Secretes – Parathyroid hormone (PTH)
- Secretion of PTH is regulated by circulating level of calcium ions.

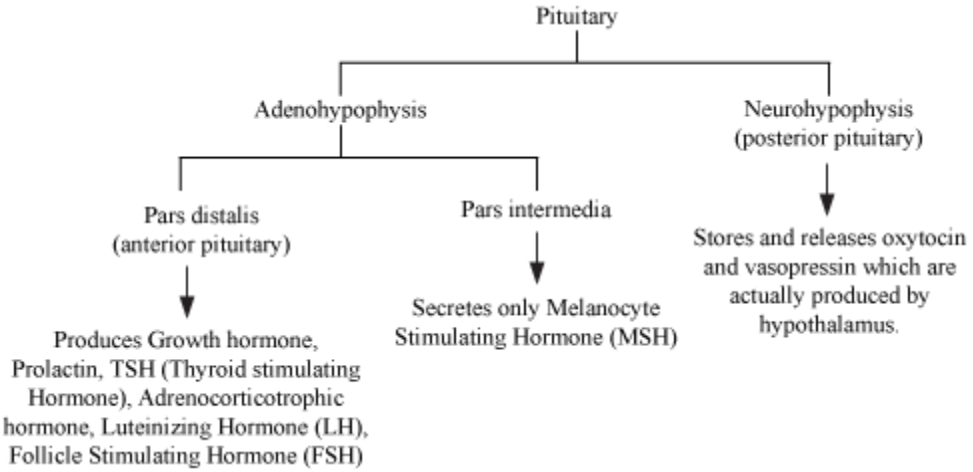
- PTH is a hypercalcemic hormone. It increases blood calcium levels by

- dissolution/demineralization from bones
- reabsorption of Ca^{2+} by renal tubules
- Ca^{2+} absorption from digested food

Human Endocrine System & Pituitary Gland and Thymus Gland

Pituitary Gland

- Location: In the bony cavity called sella tursica; attached to the hypothalamus via a stalk



Pituitary Hormone	**Functions**
GH	Over secretion in children – Gigantism Over secretion in adults – Acromegaly (extra growth of bones in jaws, hands or feet) Under secretion – Dwarfism
Prolactin	Growth of mammary glands and formation of milk in them
TSH	Synthesis and release of thyroid hormones

Adrenocorticotrophic hormone (ACTH)	Stimulates synthesis and secretion of steroid hormones called glucocorticoids from the adrenal cortex
LH	In males – Stimulates synthesis and secretion of androgens from the testis In females – Induces ovulation and maintenance of the corpus luteum
FSH	In males – Along with androgens, regulate spermatogenesis In females – Stimulates growth and development of ovarian follicles
MSH	Acts on melanocytes and regulates pigmentation of the skin
Oxytocin	Helps in the contraction of the smooth muscles of the uterus during child birth, and milk ejection from mammary glands
Vasopressin	Stimulates re-absorption of water from the distal tubules, and hence, prevents loss of water through urine (diuresis); therefore, also called anti-diuretic hormone (ADH) Deficiency of vasopressin causes diabetes insipidus (frequent urination, leading to excessive water loss and increased thirst; no sugar is found in the urine).

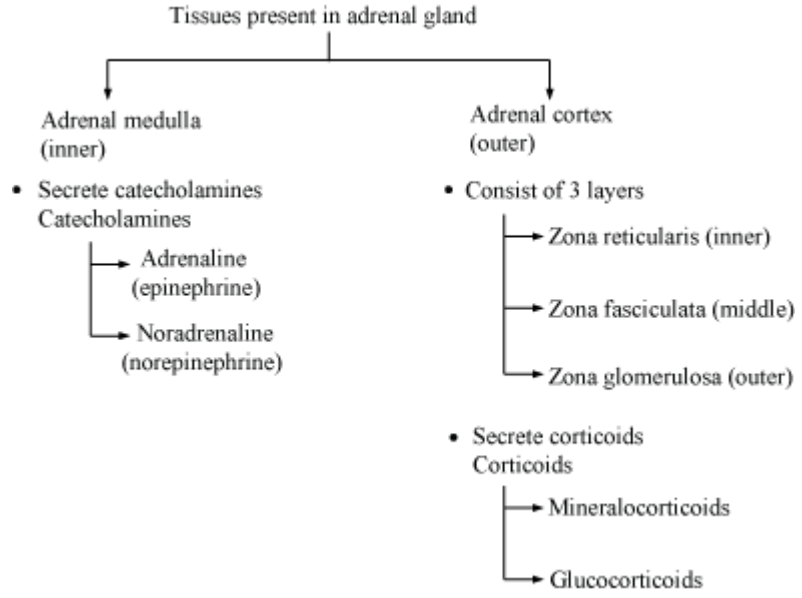
Thymus

- Location: Dorsal side of the heart and the aorta
- Importance: Development of the immune system
- Secretion: Peptide hormone called thymosins
- Role of thymosins:
- Differentiation of T-lymphocytes (Cell Mediated Immunity)
- Promotes production of antibodies (Humoral Immunity)
- Thymus is degenerated in old people. Hence, their immune response becomes weak.

Human Endocrine System and Adrenal, Pancreas and Gonads

Adrenal Gland

Location: 1 pair – 1 gland at the anterior part of each kidney



- **Catecholamine:**

- Emergency hormones or hormones of fight or flight
- Increases alertness, pupilary dilation, piloerection (raising of hair)
- Increases heart beat, respiration rate
- Stimulates the breakdown of glucose, lipids and proteins

- **Glucocorticoid:**

- Stimulates gluconeogenesis, lipolysis and proteolysis
- Inhibits uptake and utilisation of amino acids
- Suppresses immune response by producing anti-inflammatory reaction (Example – Cortisol)
- Stimulates RBC production (Example – Cortisol)

- **Mineralocorticoid: Example – Aldosterone**

- Acts on renal tubule and stimulates re-absorption of Na^+ and water
- Stimulates excretion of K^+
- Maintains electrolysis, osmotic pressure and blood pressure
- Androgenic steroids plays a role in the growth of axial, facial and pubic hair during puberty

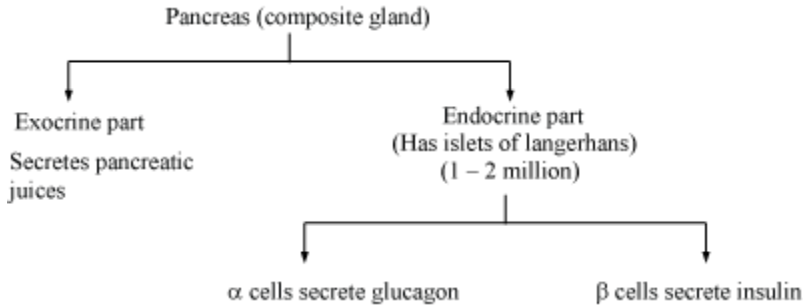
Hyposecretion of hormones from adrenal cortex results in **Addison's disease.**
Symptoms:

- Loss of energy and weight
- Skin pigmentation
- Hypoglycemia
- Sensitivity to cold
- Increased susceptibility to infections, etc

Hypersecretion of hormones from adrenal cortex causes **Cushing's Syndrome.**
Symptoms:

- Obesity
- Hyperglycemia
- Osteoporosis
- Weakness, etc

Panceas



- **Glucagon: Hyperglycemic hormone**

- A peptide hormone
- Maintains the normal blood glucose level
- Acts on liver cells and stimulates glycogenolysis, resulting in hyperglycemia
- Stimulates gluconeogenesis (synthesis of glucose from sources like fats)

- **Insulin: Hypoglycemic hormone**

- A peptide hormone
- Stimulates liver cells to enhance the cellular glucose uptake and utilisation
- Moves the glucose from the blood to hepatocytes and adipocytes
- Converts glucose into glycogen

- Glucagon + Insulin = Maintain glucose homeostasis

Insufficient secretion of insulin causes **Diabetes mellitus**
Symptoms:

- High sugar concentration in blood

- Excretion of glucose with urine
- Increased thirst
- Loss of weight

Over secretion of insulin causes **hypoglycemia.** It results in low glucose level in blood. Under extreme cases, brain may enter in a state of of coma.
An overdose of insulin to a diabetic patient may also result in hypoglycemic conditions. As a result, the patient may become unconscious. This phenomena is called **insulin shock**. It can be reversed by instant intake of sweet biscuits or candies.

Testis

- Location: scrotal sac, in males
- Testis is composed of seminiferous tubules, and stromal or interstitial tissues.
- In the intertubular spaces, Leydig cells (interstitial cells) are present that secrete androgens, mainly testosterone.

- Functions of androgens:

- Development, maturation and functioning of the male accessory sex organs like vas deferens and seminal vesicles
- Stimulate muscular growth, growth of facial hair, low pitch voice, etc.
- Stimulatory role in spermatogenesis
- Act on the CNS and influence male sexual behaviour (libido)
- Anabolism of proteins and carbohydrates

Ovary

- Location: inside abdomen, in females
- Hormones produced: Oestrogen and progesterone
- Ovary is composed of ovarian follicles and stromal tissues
- Ovarian follicles: Secrete oestrogen

$$\text{Ovarian follicle} \xrightarrow{\text{Ovulation}} \text{Corpus luteum} \xrightarrow{\text{Secretes}} \text{Progesterone}$$

- **Functions of oestrogen:**

- Growth and functioning of the female secondary sex organs
- Development of growing follicles and mammary glands
- Regulates female secondary sex characters (Examples – high pitch voice)

- **Functions of progesterone:**

- Acts on mammary glands and stimulates formation of alveoli-like structures storing milk

- Milk secretion

Non-Endocrine Hormones & Hormones of Heart, Kidney and GI Tract

Non-Endocrine Hormones

Organs such as the heart, the kidney and the GI (gastro intestinal) tract also secrete hormones.

Growth factors are secreted by some non-endocrine tissues, which are essential for normal growth/repair/regeneration of tissues.

Heart

- Walls of the heart secretes peptide hormone ANF (Atrial Natriuretic Factor)
- When blood pressure increases, ANF is secreted and causes vasodilation, which reduces blood pressure.

Kidney

- Juxtaglomerular cells of the kidney produce erythropoietin that stimulates erythropoiesis (RBC formation).

GI Tract

Hormone	**Function**
Gastrin	Acts on the gastric glands; stimulates secretion of HCl and pepsinogen
Secretin	Acts on the exocrine pancreas; stimulates secretion of water and bicarbonate ions
Cholecystokinin (CCK)	Acts on the pancreas and the gall bladder; stimulates secretion of pancreatic enzyme and bile juice
Gastric inhibitory peptide (GIP)	Inhibits gastric secretion and mobility

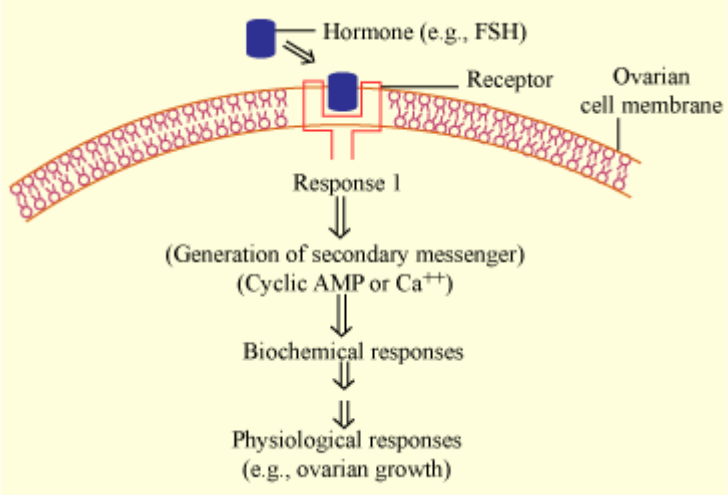
Mechanism of Hormone Action

Mechanism of Hormone Action

- Hormones exhibit their effects only after binding to their specific receptors located in the target tissues to form **hormone-receptor complex**.
- Membrane-bound receptors: Present on the cell membrane of the target cell
- Intracellular receptors: Present inside the target cell
- This specific reaction leads to biochemical changes in the target tissue, and regulates its metabolism and physiological changes.
- On the basis of their chemical nature, hormones are of 4 types.

Peptide/protein hormone	E.g., insulin, glucagon, pituitary and hypothalamic hormones
Steroids	E.g., cortisol, testosterone, progesterone
Iodothyronines	E.g., thyroid hormones
Amino acid derivatives	E.g., epinephrine

- Hormones interacting with the membrane-bound receptors do not enter the cells, but generate secondary messengers (e.g., cyclic AMP, IP_3). These secondary messengers regulate cellular metabolism.



- Hormones interacting with the intracellular receptors (e.g., steroid hormones, iodothyronines) regulate gene expression by the interaction of the hormone–receptor

complex with the genome.