CHEMICAL COORDINATION & INTEGRATION (ENDOCRINE SYSTEM)

You have already learnt that the neural system provides a point-to-point rapid coordination among organs. The neural coordination is fast but short-lived. As the nerve fibres do not innervate all cells of the body and the cellular functions need to be continuously regulated; a special kind of coordination and regulation has to be provided. This function is carried out by hormones. The neural system and the endocrine system jointly coordinate and regulate the physiological functions in the body.

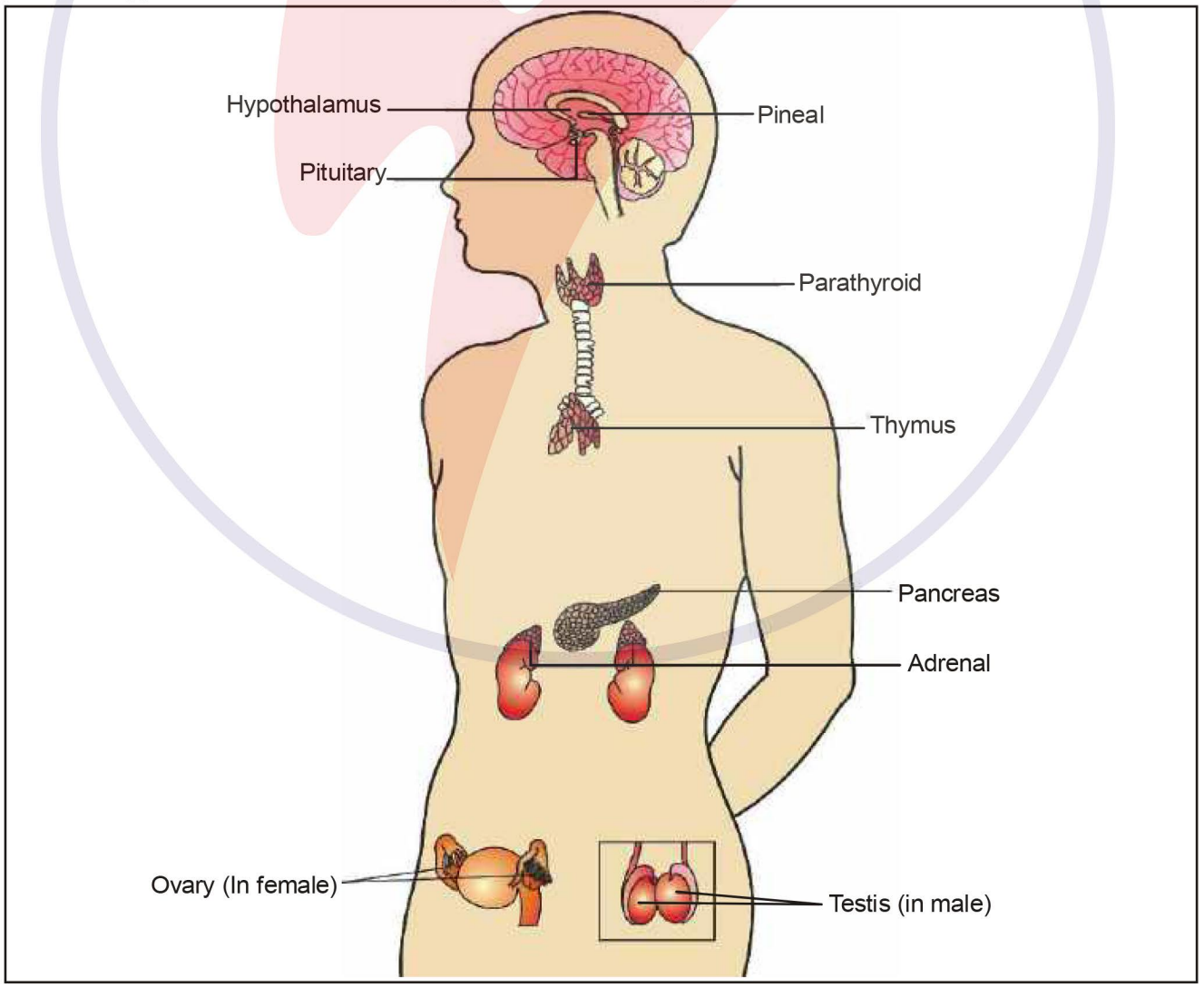
ENDOCRINE GLANDS AND HORMONES

Endocrine glands lack ducts and are hence, called ductless glands. Their secretions are called hormones. The classical definition of hormone as a chemical produced by endocrine glands and released into the blood and transported to a distantly located target organ has current scientific definition as follows: **Hormones are non-nutrient chemicals which act as intercellular messengers and are produced in trace amounts.**

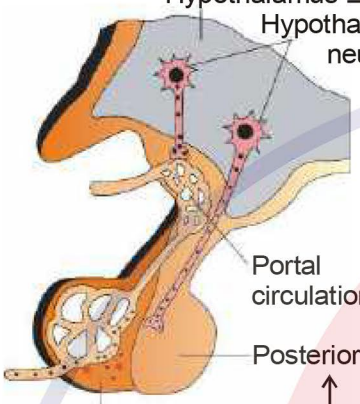
The new definition covers a number of new molecules in addition to the hormones secreted by the organised endocrine glands. Invertebrates possess very simple endocrine systems with few hormones whereas a large number of chemicals act as hormones and provide coordination in the vertebrates. The human endocrine system is described here.

HUMAN ENDOCRINE SYSTEM

The endocrine glands and hormone producing diffused tissues/cells located in different parts of our body constitute the endocrine system. Pituitary, pineal, thyroid, adrenal, pancreas, parathyroid, thymus and gonads (testis in males and ovary in females) are the organised endocrine bodies in our body. In addition to these, some other organs, e.g., gastrointestinal tract, liver, kidney, heart also produce hormones. A brief account of the structure and functions of all major endocrine glands and hypothalamus of the human body is given in the following sections.



HYPOTHALAMUS AND PITUITARY GLAND



Hypothalamus

Basal part of Diencephalon

Hypothalamic neurons

Releasing hormones

Inhibiting hormones

Regulation of synthesis and secretion

Stimulates Secretion

Inhibit Secretion

GnRH

Somatostatin

Hypophyseal portal system

Pituitary Gland (Anterior part)

⊕ Gonadotrophins

⊖ Growth Hormone

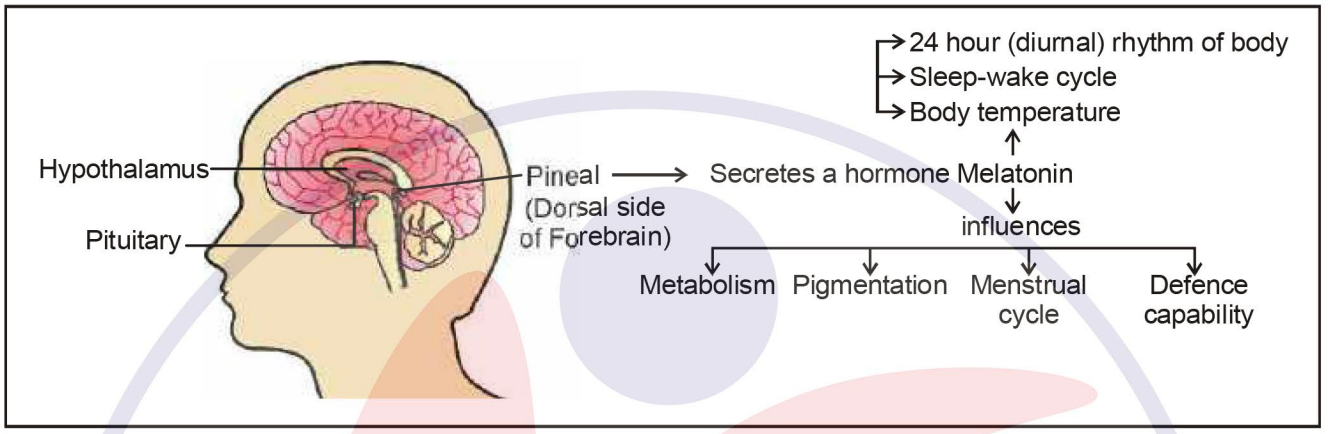
The posterior pituitary is under the direct neural regulation of the hypothalamus

PITUITARY GLAND (is located in a bony cavity called sella turcica and attached to hypothalamus by a stalk called infundibulum)

- Adenohypophysis
  - Pars Distalis
    - Growth hormone → Gigantism / Pituitary Dwarfism
    - Prolactin → Growth of mammary gland and formation of milk
    - TSH → Synthesis & Secretion of thyroid hormone
    - ACTH → Synthesis & Secretion of Glucocorticoids
    - LH → Males - spermatogenesis; Female - Growth & development of ovarian follicles
    - FSH → Males - spermatogenesis; Female - Growth & development of ovarian follicles
  - Pars Intermedia
    - MSH
    - Melanocytes – Regulation of skin pigmentation
- Neurohypophysis
  - Pars nervosa
    - Oxytocin
      - ✦ Acts on the smooth muscles of our body and stimulates their contraction.
      - ✦ In females, vigorous contraction of uterus at the time of child birth and milk ejection from the mammary gland.
    - Vasopressin
      - ✦ Acts at the kidney and stimulates resorption of water and electrolytes by the distal tubules and reduces water loss through urine (diuresis).
      - ✦ Also called as anti-diuretic hormone (ADH).

THE PINEAL GLAND

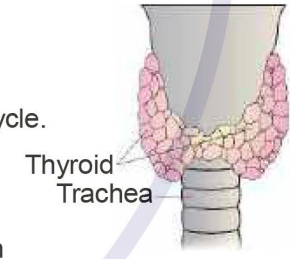
The pineal gland is located on the dorsal side of forebrain. Pineal gland secretes a hormone called melatonin. Melatonin plays a very important role in the regulation of a 24-hour (diurnal) rhythm of our body. For example, it helps in maintaining the normal rhythms of sleep-wake cycle, body temperature. In addition, melatonin also influences metabolism, pigmentation, the menstrual cycle as well as our defense capability.



Thyroid

- Two lobes on each side of trachea inter connected with a thin flap of connective tissue called Isthmus.
- Each thyroid follicle is composed of follicular cells enclosing a cavity.
- Iodine is essential for normal rate of hormone synthesis
  - Deficiency of iodine
    - Enlargement of thyroid gland - Goitre
    - Hypothyroidism → In adult women-irregular menstrual cycle.
      - During Pregnancy
        - Cretinism
        - Mental retardation
        - Low IQ
        - Deaf mutism
        - Abnormal skin

Tetraiodothyronine | Thyrocalcitonin (Blood calcium level) | Tri-iodothyronine



Cancer of thyroid gland → Rate of synthesis & secretion ↑ → Abnormal high levels → Hyper thyroidism

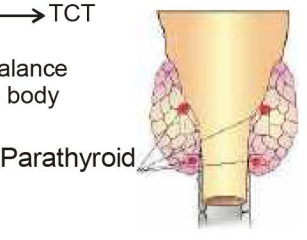
Thyroid Functions

- ✦ Regulation of B.M.R.
- ✦ Metabolism of carbohydrate, fat and proteins
- ✦ Supports Erythropoiesis
- ✦ Maintainance of H_2O & electrolyte balance

Parathyroid — Regulated by circulating levels of calcium ions → Parathyroid Hormone (Peptide in nature) — alongwith → TCT

- ↑ Ca^{++} level in blood
- Stimulate bone resorption
- Ca^{+2} ↑ reabsorption by renal tubules
- Ca^{+2} absorption from digested food (Hypercalcemic)

Ca^{+2} balance in the body



Thymus

- Lobular structure
- Dorsal side of heart & aorta
- peptide → Thymosins
  - Humoral immunity – Production of antibodies
  - Differentiation of T-lymphocytes – (Cell-Mediated Immunity)
- Degenerate in old individuals – ↓ production of thymosins – immune response weakens

Pancreas → Exocrine

Endocrine (1-2%) → **Islets of Langerhans**

- α → Glucagon (Hyperglycemic)
  - Hepatocytes – Glycogenolysis
  - Gluconeogenesis – Hyperglycemia
  - Decrease cellular glucose uptake and utilization
- β → Insulin
  - Stimulate glycogenesis
  - Increase cellular glucose uptake and utilization

↓

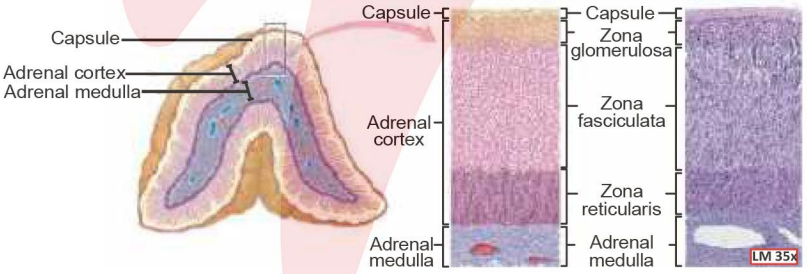
Rapid movement of glucose from blood to hepatocytes / adipocytes

↓

Decrease blood glucose level (Hypoglycemia)

Prolonged hypoerglycemia leads to a complex disorder – Diabetes mellitus, characterised by glycosuria and ketone urea. Diabetes patients are successfully treated with Insulin

Adrenal gland



Feature	Adrenal Cortex	Adrenal Medulla
Adrenal Gland Location	Outer region of the gland	Inner region of the gland
Made of Stimulation	Hormonal (stimulated by ACTH from anterior pituitary)	Neural (stimulated by preganglionic axons from sympathetic division of ANS
Hormones Produced	Corticosteroids : mineralocorticoids, glucocorticoids, gonadocorticoids	Epinephrine, norepinephrine
Effects of Hormones	Mineralcorticoids regulate the balance of electrolytes (e.g., Na^+ and K ions in the body Glucocorticoids elevate blood glucose levels during longterm stressful situations (e.g., fasting, injury, anxiety), and stimulate the body to use fats and proteins as energy resources Gonadocorticoids release a small amount of androgens (male sex hormones)	Prolongs fight-or-flight response of the sympathetic division of the ANS

Ovary (In female)

→ Primary female sex organ, produces one ovum during each menstrual cycle.

→ Composed of ovarian follicles and stromal tissues.

↓

2 Steroid Hormones

Estrogen	Progesterone
✦ Synthesised and secreted mainly by the growing ovarian follicles.	✦ Secreted mainly by the corpus luteum formed by ruptured follicles after ovulation.
✦ Stimulation of growth and activities of female secondary sex organs.	✦ Supports pregnancy.
✦ Development of growing ovarian follicles.	✦ Also acts on the mammary glands and stimulates the formation of alveoli (sac-like structures which store milk) and milk secretion.
✦ Appearance of female secondary sex characters (e.g., high pitch of voice, etc.), mammary gland development.	
✦ It also regulate female sexual behaviour.	

Testis (in male)

- ✦ Present in scrotal sac.
- ✦ Primary sex organ.
- ✦ Endocrine gland composed of stromal tissue and seminiferous tubules.
- ✦ Produce androgens mainly testosterone
- ✦ Androgens play a major stimulatory role in spermatogenesis.
- ✦ Hormones – Anabolic effects on protein and carbohydrate metabolism.

PANCREAS

Composite gland, both exocrine and endocrine gland.

The endocrine → 'Islets of Langerhans'. There are about 1 to 2 million Islets of Langerhans in a normal human pancreas representing only 1 to 2 per cent of the pancreatic tissue. The two main types of cells in the Islet of Langerhans are called á-cells and â-cells. The á-cells secrete a hormone called glucagon, while the â-cells secrete insulin.

Glucagon → peptide hormone → plays an important role in maintaining the normal blood glucose levels.

Glucagon acts mainly on the liver cells (hepatocytes) and stimulates glycogenolysis resulting in an increased blood sugar (hyperglycemia). In addition, this hormone stimulates the process of gluconeogenesis which also contributes to hyperglycemia. Glucagon reduces the cellular glucose uptake and utilisation. Thus, glucagon is a hyperglycemic hormone.

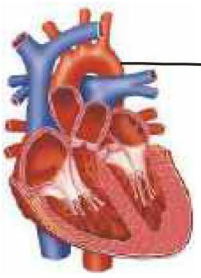
Insulin → peptide hormone → plays a major role in the regulation of glucose homeostasis. Insulin acts mainly on hepatocytes and adipocytes (cells of adipose tissue), and enhances cellular glucose uptake and utilisation. As a result, there is a rapid movement of glucose from blood to hepatocytes and adipocytes resulting in decreased blood glucose levels (hypoglycemia). Insulin also stimulates conversion of glucose to glycogen (glycogenesis) in the target cells.

The glucose homeostasis in blood is thus maintained jointly by the two – insulin and glucagons. Prolonged hyperglycemia leads to a complex disorder called diabetes mellitus which is associated with loss of glucose through urine and formation of harmful compounds known as ketone bodies. Diabetic patients are successfully treated with insulin therapy.

HORMONES OF NON-ENDOCRINE GLANDS

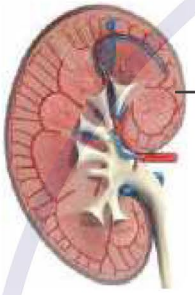
Hormones are also secreted by some tissues which are not endocrine glands.

(1)



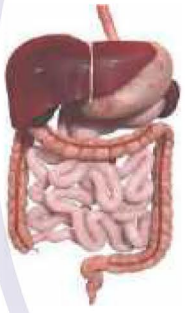
Atrial Natriuretic Factor (ANF) → High Blood Pressure → Vasodilation → Decrease in Blood Pressure

(2)



Juxta Glomerular Cells → Erythropoietin → Erythropoiesis

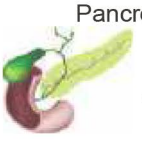
(3)



Endocrine Cells of Gastro-intestinal tract

- Gastrin → Gastric glands → Secretion of pepsinogen and hydrochloric acid (HCl)
- Secretin →  → Secretion of water & bicarbonate ions

Exocrine part of Pancreas

- Cholecystokinin →  → Secretion of pancreatic juice & bile juice

Pancreas

Gall Bladder

- Gastric Inhibitory peptide →  → Inhibits the gastric secretion & motility

Several other non-endocrine tissue secrete hormones called growth factors, which are essential for the normal growth of tissue and their repairing / regeneration.

On the basis of chemical nature, hormones are grouped as -

(I) Peptides, Polypeptide, Protein Hormone - insulin, glucagon, pituitary & hypothalamic hormones.

(ii) Steroids - Cortisol, estradiol, testosterone, progesterone.

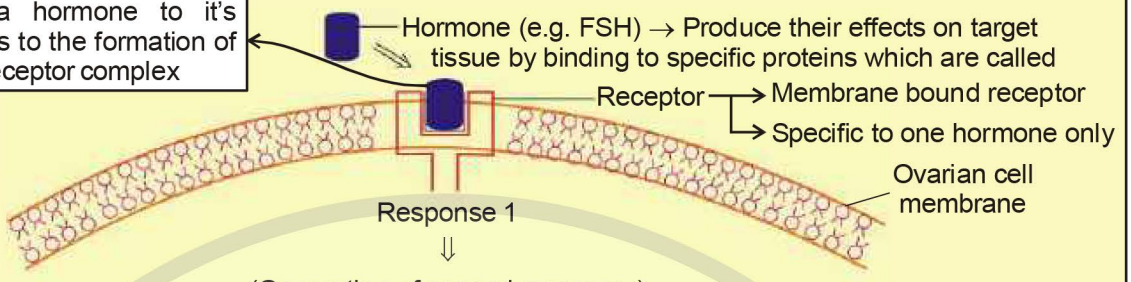
(iii) Iodothyronines - Thyroid hormones.

(iv) Amino acid derivatives - Epinephrine

MECHANISM OF HORMONE ACTION

PROTEIN HORMONE ACTION

Binding of a hormone to it's receptor leads to the formation of Hormone - Receptor complex



Response 1

⇓

(Generation of second messnger)

(Cyclic AMP or Ca^{++}/IP_3)

⇓

Biochemical responses in target tissue

⇓ Target tissue metabolism

Physiological responses

(e.g. ovarian growth)

STEROID HORMONE ACTION