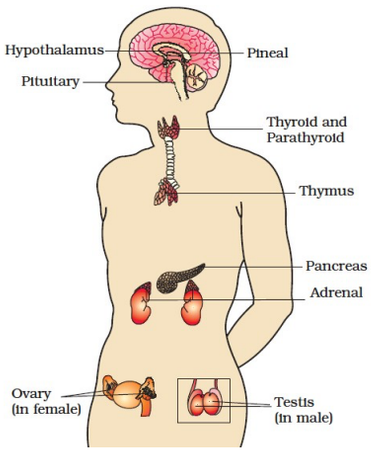
CHEMICAL CO-ORDINATION AND INTEGRATION

Endocrine system includes **endocrine (ductless) glands** and their secretions **(hormones).**
Hormones are **non-nutrient** chemicals that act as **intercellular messengers** and are produced in trace amounts.

HUMAN ENDOCRINE GLANDS

They include

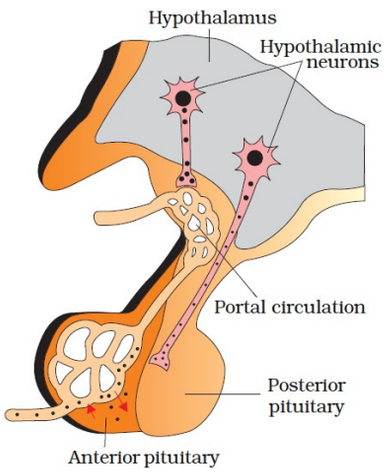
1. **Hypothalamus**
2. **Pituitary**
3. **Pineal**
4. **Thyroid**
5. **Parathyroid**
6. **Thymus**
7. **Adrenals**
8. **Pancreas (Islets of Langerhans)**
9. **Gonads (Testis & Ovary)**



1. HYPOTHALAMUS

Neurosecretory cells (nuclei) of hypothalamus secrete the following types of hormones:

- **Releasing hormones:** Stimulate secretion of **pituitary hormones. E.g. gonadotropin releasing hormone (GnRH)** stimulates pituitary to release **gonadotropins (FSH & LH).**
- **Inhibiting hormones:** Inhibit secretion of **pituitary hormones.** E.g. **Somatostatin** inhibits release of growth hormone from pituitary.
- **Oxytocin & vasopressin:** These are transported axonally and stored in pituitary. *(See pituitary gland).*



Hypothalamus and Pituitary

2. PITUITARY GLAND

- It is located in a bony cavity called **sella tursica.**
- It is attached to **hypothalamus** bya stalk.
- It is divided into anterior **Adenohypophysis** & posterior **Neurohypophysis.**

a. Adenohypophysis

It has 2 parts: **Pars distalis** and **Pars intermedia.**

Pars distalis (Anterior pituitary): It produces

- **Somatotropin (Growth hormone, GH):** For body growth. Its **over-secretion** causes **Gigantism** (abnormal growth). **Hyposecretion** causes **Dwarfism** (stunted growth). **Over-secretion** of **GH** in adults (mainly in middle age) causes **Acromegaly** (severe disfigurement especially of face). It leads to serious complications and premature death. Early diagnosis of the disease is difficult. It may be undetected for many years.
- **Prolactin (PRL):** Regulates growth of **mammary glands** and **milk production.**
- **Thyroid stimulating hormone (TSH):** Stimulates **thyroid gland** to secrete **thyroid hormones.**
- **Adrenocorticotrophic hormone (ACTH):** Stimulates **adrenal cortex** to synthesise & secrete **steroid hormones (glucocorticoids).**
- **Follicle stimulating hormone (FSH):** Stimulates gonadal activity. **In males,** FSH & androgens regulate sperm formation **(spermatogenesis). In females, FSH** stimulates growth and development of **ovarian follicles.**
- **Luteinizing hormone (LH):** Stimulates gonadal activity. **In males,** it stimulates synthesis and secretion of androgens from testis. **In females,** it induces ovulation and maintains the corpus luteum.

Pars intermedia: In human, it is almost merged with pars distalis. It produces **Melanocyte stimulating hormone (MSH).** It acts on **melanocytes** to regulate skin pigmentation.

b. Neurohypophysis

It stores **Oxytocin & Vasopressin** from hypothalamus.

i. **Oxytocin:** Contracts **smooth muscles.** In females, it stimulates contraction of uterus during child birth, and milk ejection from the mammary gland.

ii. **Vasopressin or Anti-diuretic hormone (ADH):** Stimulates **reabsorption of water** & **electrolytes** by **DCT** of kidney and thereby reduces **diuresis** (loss of water through urine). Deficiency of ADH results in diminished ability of the kidney to conserve water. It leads to water loss and dehydration. This is called **Diabetes insipidus.**

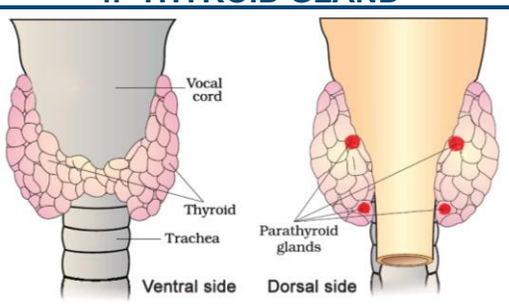
3. PINEAL GLAND

Smallest endocrine gland.
It is located on dorsal side of forebrain. Secretes **melatonin.**

Functions of melatonin:

- Regulates **diurnal (24-hour) rhythm** of body. E.g. sleep-wake cycle, body temperature etc.
- Influences metabolism, pigmentation & menstrual cycle.
- Influences defense capability.

4. THYROID GLAND



- Largest endocrine gland.
- It includes 2 lobes on either side of the trachea. The lobes are interconnected with **isthmus** (a connective tissue).
- Thyroid gland is made of **follicles** & **stromal tissues.**

Follicular cells secrete the following hormones:

- **Thyroxin (tetraiodothyronine, T_4) & Triiodothyronine (T_3):** Their functions are
  - Regulation of **basal metabolic rate (BMR).**
  - Physical, mental and sexual development.
  - Support **RBC formation.**
  - Control **metabolism** of carbohydrates, proteins & fats.
  - Maintain **water** and **electrolyte balance.**
- **Thyrocalcitonin (TCT):** A protein hormone. It regulates (lowers) **blood calcium** levels (Hypocalcaemic hormone).

Iodine is essential for normal hormone synthesis in thyroid.

Hypothyroidism (Goiter):

- Enlargement of thyroid gland due to deficiency of **iodine.**
- In adult women, it causes irregular menstrual cycle.
- Hypothyroidism during pregnancy affects the baby causing stunted growth (cretinism), mental retardation, low intelligence quotient, abnormal skin, deaf-mutism etc.

Hyperthyroidism:

- Abnormal increase of thyroid hormones resulting in adverse effects on the physiological activities.
- It is caused due to development of the nodules or the cancer of thyroid gland.
- **Exophthalmic goiter (Grave's disease):** It is a form of Hyperthyroidism. Symptoms are enlargement of thyroid gland, protruded eyeballs, increased BMR & weight loss.

5. PARATHYROID GLAND

4 parathyroid glands are present on back side of the thyroid gland, one pair each in the two lobes of thyroid gland. They secrete **Parathyroid hormone (PTH) –** a peptide hormone.

Functions of parathyroid hormone:

- Increases **Ca^{2+} level** in blood **(hypercalcaemic hormone).**
- Stimulates the **bone resorption (demineralization).**
- Stimulates the **reabsorption of Ca^{2+}** by the **renal tubules** and increases **Ca^{2+} absorption** from the **digested food.**
- Along with **TCT,** it helps in **calcium balance** in the body.

6. THYMUS GLAND

It is located between lungs behind sternum on the ventral side of aorta. It secretes **Thymosins** (peptide hormones).

Functions of thymosins:

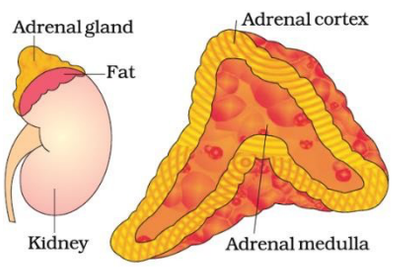
- Differentiation of **T-lymphocytes.** It provides **cell-mediated immunity.**
- Promote **antibody** production for **humoral immunity.**

Thymus is degenerated in old individuals. So, production of thymosins decreases. As a result, immune responses of old persons become weak.

7. ADRENAL GLAND

It has 2 parts: **Adrenal cortex & Adrenal medulla.**

a. Adrenal cortex It has 3 layers: inner **zona reticularis,** middle **zona fasciculata** & outer **zona glomerulosa.**



It produces the following **corticoid hormones:**

- **Glucocorticoids** (mainly **cortisol**):
  - Involved in **carbohydrate metabolism.**
  - Stimulate **gluconeogenesis, lipolysis and proteolysis.**
  - Inhibit cellular uptake and utilization of **amino acids.**
  - Maintain **cardiovascular** system and **kidney** functions.
  - Cortisol stimulates **RBC production.**
  - Produces **anti-inflammatory reactions** and suppress immune response.
- **Mineralocorticoids** (mainly **aldosterone**):
  - Regulate the **water** (body fluid volume), **electrolytic** balance, **osmotic pressure** and **blood pressure.**
  - Aldosterone stimulates **reabsorption of Na^+ & water** from renal tubules and excretion of **K^+ and PO_4^{3-} ions.**
- **Androgenic corticoids:** For growth of **axial hair, pubic hair** and **facial hair** during puberty.

Deficiency of corticoid hormones affects carbohydrate metabolism. It causes acute weakness and fatigue. This condition is called **Addison's disease.**

b. Adrenal medulla

- Produces **catecholamine** hormones such as **Adrenaline (epinephrine) & Noradrenaline (norepinephrine).**
- They are rapidly secreted in response to stress emergency situations so called **emergency hormones (hormones of Fight or Flight).**
- These increase alertness, pupillary dilation, piloerection (rising of hairs), sweating, heartbeat, heart contraction and respiratory rate. Stimulate glycogenolysis to increase glucose in blood. Also stimulate lipolysis and proteolysis.

8. PANCREAS (ISLETS OF LANGERHANS)

- A **composite (heterocrine)** gland i.e. **exocrine + endocrine.**
- **Islets of Langerhans** are the endocrine part. There are about 1-2 million Islets (1-2% of pancreatic tissue).
- **α cells** and **β cells** in the islets secrete peptide hormones such as **Glucagon** and **Insulin** respectively. They maintain **Glucose homeostasis** in blood.

- **Glucagon:** Hyperglycemic factor. It
  - Acts on **hepatocytes** and stimulates **glycogenolysis** resulting in an increased blood sugar **(hyperglycemia).**
  - Stimulates **gluconeogenesis.**
  - Reduces the cellular glucose uptake and utilization.
- **Insulin:** Hypoglycemic factor. It
  - Acts on **hepatocytes** and **adipocytes** to enhance cellular glucose uptake and utilization. So, glucose from blood rapidly moves to hepatocytes and adipocytes. Thus, blood glucose level decreases **(hypoglycemia).**
  - Stimulates **glycogenesis** (glucose converts to glycogen).

Prolonged hyperglycemia leads to **Diabetes mellitus** (loss of glucose through urine and formation of harmful compounds like ketone bodies). Treatment is **insulin therapy.**

9. TESTIS (MALE GONAD)

- It is the male primary sex organ and an endocrine gland.
- A pair of testis is present in the **scrotal sac**.
- It is formed of **seminiferous tubules** and **interstitial (stromal) tissues.**

- **Leydig (interstitial) cells** in the inter-tubular spaces produce hormones called **androgens** (mainly **testosterone).**

Functions of androgens:

- Regulate development, maturation and functions of the **accessory sex organs.**
- **Spermatogenesis** (sperm production).
- Stimulate sexual behavior **(libido),** growth of muscles, hairs, aggressiveness, low pitch voice etc.
- Help in anabolism of protein and carbohydrate.

10. OVARY (FEMALE GONAD)

- It is the female primary sex organ.
- A pair of ovaries is located in the abdomen.
- It produces one ovum during each menstrual cycle.
- Ovary is formed of **ovarian follicles** and **stromal tissues**.
- **Ovarian follicles** produce **Estrogen** (a steroid hormone).
- After ovulation, ruptured follicle forms a structure called **Corpus luteum.** It secretes **progesterone** (a steroid hormone).

Functions of Estrogen:

- Growth and activities of female **secondary sex organs.**
- Development of **ovarian follicles** & **mammary glands.**
- Female **secondary sex characters** (e.g. high pitch voice) and **sexual behavior.**

Functions of Progesterone:

- It supports **pregnancy.**
- It acts on **mammary glands** to stimulate formation of **alveoli** (sacs to store milk) and **milk secretion.**

HORMONES OF HEART, KIDNEY & GASTROINTESTINAL TRACT

1. **Atrial wall of heart:** Produce a peptide hormone called **Atrial natriuretic factor (ANF).** When BP increases, ANF causes dilation of blood vessels to reduce the BP.
2. **JGA of kidney:** Produces **Erythropoietin** (peptide hormone). Stimulates **erythropoiesis** (formation of RBC).
3. **Gastro-intestinal tract:** Produce peptide hormones. E.g.
   - **Gastrin:** Stimulates **gastric glands** to secrete **HCl** and **pepsinogen.**
   - **Secretin:** Stimulates **exocrine pancreas** to secrete **water** and **bicarbonate ions.**
   - **Cholecystokinin (CCK):** Stimulates secretion of **bile** from gall bladder and pancreatic enzymes from pancreas.
   - **Gastric inhibitory peptide (GIP):** Inhibits **gastric secretion.**

Several other **non-endocrine tissues** secrete hormones called **growth factors.** These help for the normal growth of tissues and their repairing or regeneration.

Based on the chemical nature, hormones are various types:

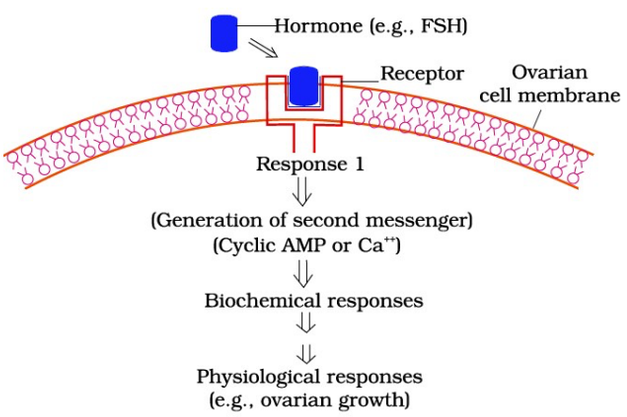
a. **Peptide, polypeptide, protein hormones:** Insulin, glucagon, pituitary hormones, hypothalamic hormones etc.
b. **Steroids:** Cortisol, testosterone, estradiol & progesterone.
c. **Iodothyronines** (thyroid hormones).
d. **Amino-acid derivatives:** Adrenaline, nor-adrenaline etc.

MECHANISM OF HORMONE ACTION

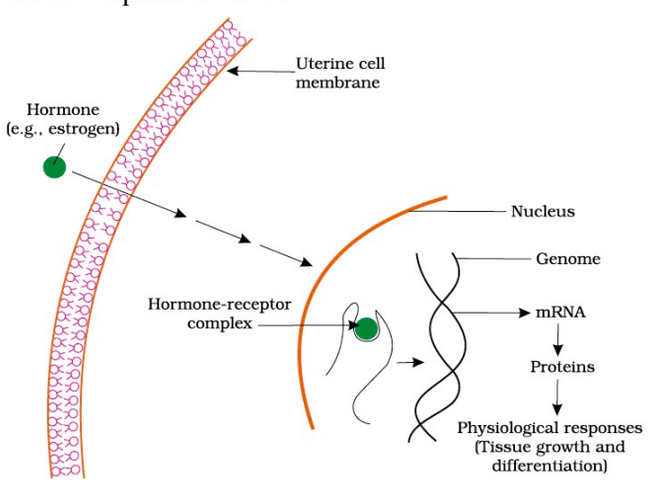
- Hormones produce their effects by binding to the specific proteins **(hormone receptors)** located in **target tissues.**
- A hormone binds to its specific receptor to form **hormone-receptor complex**.
- It leads to biochemical changes in target tissue and thereby regulates metabolism and physiological functions.

Hormone receptors are 2 types:

- **Membrane-bound receptors:** Some hormones (e.g. protein hormone, FSH) interact with membrane-bound receptors (do not enter the target cell). It generates **second messengers** (e.g. cyclic AMP, IP_3, Ca^{2+}). It in turn regulates **cellular metabolism** and causes **physiological effects.**



- **Intracellular receptors** (mostly **nuclear receptors):** Some hormones (e.g. steroid hormones, iodothyronines) interact with intracellular receptors. They mostly regulate **gene expression** or **chromosome function** by the interaction of hormone-receptor complex with the genome. Cumulative biochemical actions result in physiological and developmental effects.



MODEL QUESTIONS

1. Note the relationship between first two words and suggest a suitable word for fourth place.
   a) Alpha cell: Glucagon Beta cell: ……
   b) Glucocorticoids: Cortisol Mineralocorticoids: ……..
   c) Follicular cells: Thyroid Neurosecretory cells: ……
   d) Ovarian follicles: Estrogen Corpus luteum: ……..
2. Odd one out. Justify your answer.
   a) TSH, FSH, MSH, LH
   b) Cortisol, adrenaline, aldosterone, androgenic corticoids
3. Match the following

A	B	C
Thyroid	Insulin	Addison's disease
Pituitary	Cortisol	Goiter
Pancreas	Thyroxine	Gigantism
Adrenal gland	Growth hormone	Diabetes mellitus

4. In a 5-year old boy, thymus gland is found to be non-functional. How will it affect his immune system?
5. On a hot day, would you expect ADH level in blood to be high or low? Explain.
6. Analyze the facts given in three columns, find their relationship and fill the blanks.

Thymus	a) ----------	Differentiation of T-lymphocytes
b) ----------	Adrenaline	Emergency hormone
Kidney	Erythropoietin	c) ----------
Pancreas	d) ----------	Decrease blood glucose level

7. Make pairs using following terms:

   Hypoglycemic factor, Glucagon, TCT, Hypercalcemic factor, Hyperglycemic factor, PTH, Hypocalcemic factor, Insulin
8. Anitha saw a snake on her way to school. She was frightened and her heart rate and breathing rate increased.
   a) Name the hormones which are dominant at that time in her blood.
   b) Which endocrine gland produces the hormone? c) To which organ this endocrine gland is attached?
9. Prepare flowcharts showing the mechanism of action of a protein hormone and a steroid hormone on target tissues.