INTRODUCTION:
All the physiological activities are regulated by two major systems in the body.

1. Nervous system
2. Endocrine system

These two systems interact with each other and regulate the body functions. The endocrine system is an information signal system like the nervous system, yet its effects and mechanism are classically different. The endocrine system’s effects are slow to initiate, and prolonged in their response, lasting from a few hours up to weeks. The nervous system sends information very quickly, and responses are generally short lived.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Endocrine System</th>
<th>Nervous System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organs</td>
<td>Endocrine glands and organs, such as the testes, ovaries, heart, liver, kidneys, stomach, small intestine, and placenta</td>
<td>Brain, spinal cord, and nerves</td>
</tr>
<tr>
<td>Cells</td>
<td>Cells that release hormones</td>
<td>Neurons and glial cells</td>
</tr>
<tr>
<td>Target cells</td>
<td>Cells throughout the body that have receptors for the hormones</td>
<td>Postsynaptic neurons, muscle fibers, and gland cells</td>
</tr>
<tr>
<td>Cell-to-cell communication</td>
<td>Hormones transported in fluids, such as blood and interstitial fluid</td>
<td>Action potentials propagated along neuron axons to synapses</td>
</tr>
<tr>
<td>Activation of target cells</td>
<td>Hormones bind to receptors on plasma membranes or inside cells</td>
<td>Neurotransmitters bind to receptors on plasma membranes; ionic current flow in electrical synapses</td>
</tr>
<tr>
<td>Regulation of target cells</td>
<td>Usually amplitude-modulated signals</td>
<td>Frequency-modulated signals</td>
</tr>
<tr>
<td>Speed of response</td>
<td>Slower (seconds to hours)</td>
<td>Faster (usually milliseconds)</td>
</tr>
<tr>
<td>Length of response</td>
<td>Longer (seconds to days, even after hormonal stimulation stops)</td>
<td>Shorter (milliseconds to seconds, unless neuron stimulation persists)</td>
</tr>
<tr>
<td>Effects</td>
<td>Widespread; hormones carried by the blood can stimulate target cells in many locations</td>
<td>Specific; neurons stimulate the cells with which they synapse</td>
</tr>
</tbody>
</table>

Cell to cell signaling: cell to cell signaling refers to the transfer of information from one cell to another. It is also called cell signaling or intercellular communication. The cells of the body communicate with each other through some chemical substances called chemical messengers.

Chemical messengers: The chemical messengers are the substances involved in cell signaling. These chemical messengers are mainly secreted from endocrine glands. Some chemical messengers are secreted by nerve endings and the cells of several other tissues also. All these chemical messengers carry the message (signal) from the signaling cells (controlling cells) to the target cells.

Classification of chemical messengers:
Generally the chemical messengers are classified into two types:

1. Classical hormones- secreted by endocrine glands
2. Local hormones- secreted from other tissues
However the recent method of classification divides chemical messengers into four types:

1. **Endocrine messengers**: These are also known as classical hormones. A hormone is defined as a chemical messenger synthesized by endocrine glands and transported by blood to the target organs or tissues (i.e. site of action)

   E.g. Growth hormone (GH), Insulin.

2. **Paracrine messengers**: These are also known as local hormones. These are the chemical messengers, which diffuse from the control cells to the target cells through the interstitial fluid. E.g. Prostaglandin's (PG’s), histamine.

3. **Autocrine messengers**: These are the chemical messengers that control the source cells (which secrete them). E.g. Leukotrienes.

4. **Neurocrine or neural messengers**: These are two types. Those are neurotransmitter and neurohormone.

   **Neurotransmitter**: It is an endogenous signaling molecule that carries information from one nerve cell to another nerve cell or muscle or other tissue.

   **Neurohormone**: It is a chemical substance that is replaced by the nerve cell directly into the blood and transported to a distant target cells.

Endocrine Glands: endocrine glands are defined as the glands which synthesize and release the classical hormones into the blood.

**General features of the endocrine glands:**

1. These are ductless glands.
2. Endocrine glands have a rich supply of blood.
3. Hormones produced by endocrine glands are secreted into blood stream.
4. Hormones travel in the blood to reach target cells close by or far away from point of secretion.
5. Hormone receptors are specific binding sites on the target cell.
6. Unlike the nervous system, the endocrine system is anatomically discontinuous.
The major endocrine glands are:
1. Pituitary gland
2. Thyroid gland
3. Parathyroid glands
4. Adrenal gland
5. Pancreas
6. Gonads
7. Others

The major functions regulated by the endocrine system are growth, healing, water balance, blood pressure, calcium metabolism, energy metabolism and stress.

**Chemistry of hormones:** Based on chemical structure, hormones may be classified into three groups. Those are proteins, steroids and tyrosine derivatives.

**Protein hormones:** These protein hormones are large or small proteins. Receptors of protein hormones are situated in the cell membrane of target cell. These are secreted by pituitary gland, thyroid gland (Calcitonin), parathyroid gland and pancreas.

**Steroid hormones:** These are hormones formed from cholesterol or its derivatives. Receptors of these hormones are situated in cytoplasm of target cell. Steroid hormones are secreted by adrenal cortex, gonads and placenta.

**Tyrosine derivatives:** There are two groups of hormones which are derived from tyrosine, those are thyroid hormones and adrenal medullary hormones (catacholamines). Receptors of thyroid hormones are in the nucleus of the cell, where as the receptors of catacholamines are present in cell membrane.

<table>
<thead>
<tr>
<th>Protein hormones</th>
<th>Steroidal hormones</th>
<th>Tyrosine derivatives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growth hormone</td>
<td>Aldosterone</td>
<td>Thyroxine (T₄)</td>
</tr>
<tr>
<td>Thyroid stimulating hormone</td>
<td>Cortisol</td>
<td>Tri-iodo thyronine (T₃)</td>
</tr>
<tr>
<td>Adreno corticotrophic hormone</td>
<td>Corticosterone</td>
<td>Adrenaline</td>
</tr>
<tr>
<td>Follicle stimulating hormone</td>
<td>Testosterone</td>
<td>Noradrenaline</td>
</tr>
<tr>
<td>Leutinising hormone</td>
<td>Dehydroepiandrosterone</td>
<td>Dopamine</td>
</tr>
<tr>
<td>Prolactin</td>
<td>Estrogen</td>
<td></td>
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<tr>
<td>Anti-diuretic hormone</td>
<td>Progesterone</td>
<td></td>
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<tr>
<td>Oxytocin</td>
<td>11-Deoxy corticosterone</td>
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<tr>
<td>Parathormone</td>
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<tr>
<td>Calcitonin</td>
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<tr>
<td>Insulin</td>
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<tr>
<td>Glucagon</td>
<td></td>
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<tr>
<td>Somatostatin</td>
<td></td>
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<tr>
<td>Human chorionic gonadotrophic hormone</td>
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Regulation of hormone receptors:

Receptor proteins are not static components of the cell. Their number increase or decrease in various conditions.

Generally, when a hormone is secreted in excess, the number of receptors of that hormone decreases. This process called down regulation. During the deficiency of the hormone, the number of receptors increases which is called up regulation. When a hormone binds with the receptor, a hormone-receptor complex is formed. This complex enters the target cell by means of endocytosis and executes the actions. The whole process is called internalization.

After internalization, some receptors are recycled, where as many of them are degraded and replaced by newly formed receptors in the cell, which takes a long time. So the number of receptors decreases when the hormone level increases.

Mechanism of hormonal action:

On the target cell, the hormone-receptor complex acts by any one of the following mechanisms:

1. **By altering the permeability of the cell membrane**- neurotransmitters act by this mechanism.
2. **By activating the intracellular enzymes**- protein hormones and catacholamines act by this mechanism.
3. **By activating the gene**- thyroid hormones and steroid hormones act by this mechanism.

PITUITARY GLAND

Pituitary gland is ectodermal in origin. Pituitary gland or hypophysis was called the master endocrine gland because it secretes several hormones that control other endocrine glands. It is a small oval shaped or pea shaped reddish-grey colored gland with diameter of 1-1.5 cm and weigh about 0.5-1gm. It is situated at the base of the brain, in the sella turcica of the sphenoid bone. It increases in size through the fourth decade of life, and then slowly decreases. It also enlarges in pregnancy. It is connected with the hypothalamus by the pituitary stalk or hypophysial stalk or infundebulum.
On the basis of physiology, the pituitary gland is divided into two portions:

- Anterior pituitary or adenohypophysis
- Posterior pituitary or neurohypophysis

Even though anterior pituitary and posterior pituitary are situated in such close approximation, both are entirely different in their development, structure and function.

**Anterior pituitary**

Anterior pituitary arises from the pharyngeal epithelium as an upward growth. It accounts for about 75% of the total weight of the pituitary gland. Hypothalamo-pituitary portal circulation is the relationship between hypothalamus and anterior pituitary. The hormones secreted by hypothalamus are transported to anterior pituitary through this circulation. They are:

1. Growth hormone releasing hormone (GHRH)
2. Growth hormone release inhibitory hormone (GHRIH)
3. Thyrotropic releasing hormone (TRH)
4. Corticotropin releasing hormone (CRH)
5. Gonadotropin releasing hormone (GnRH)
6. Prolactin release inhibitory hormone (PRIH)
7. Prolactin releasing hormone (PRH)

Release of anterior pituitary hormone is stimulated *releasing hormones* and suppressed by *inhibitory hormones* of hypothalamus. By this way, the above mentioned hormones are an important link between the nervous system and endocrine system.

Depending upon the staining property, the cells of anterior pituitary are classified into two types. They are:

1. Chromophobe cells
2. Chromophil cells
   1. **Chromophobe cells**: These cells do not possess granules and stains poorly. These constitute 50% of total cells of adenohypophysis. These cells are not secretory in nature but are believed to be the precursors of chromophil cells.
   2. **Chromophil cells**: These cells take up stain and having granules in cytoplasm. Based on nature of stain taking these cells are of two types. Those are:
      a. Acidophilic cells or α- cells
      b. Basophilic cells or β- cells

The acidophilic cells are about 35% and basophilic cells about 15%. Based on secretory nature again these cells are divided into several types.
Hormones secreted by anterior pituitary are:

1. Growth hormone or somatotropic hormone (GH)
2. Thyroid stimulating hormone (TSH)
3. Adrenocortico tropic hormone (ACTH)
4. Follicle stimulating hormone (FSH)
5. Luteinizing hormone (LH)
6. Prolactin (PRL)
The first five hormones stimulate the other endocrine glands. Therefore, these five hormones are called *tropic hormones*. Prolactin is concerned with milk secretion.

1. **Growth hormone:**

   It is secreted by somatotropes of anterior pituitary. Chemically it is a protein. Its daily output in adults is 0.5-1.0mg. Blood concentrations of GH in adults are up to 300ng/dl and in children it is up to 500ng/dl. GH is responsible for the growth of almost all tissues of the body, by increasing the size and number of cells. Thus, GH is responsible for the general growth of the body. After release, GH is active only for 20 minutes.

   **Regulation of GH regulation:**

   The secretion of GH is regulated by two hormones from the hypothalamus. Those are GHRH and GHRIH. GH secretion is under negative feedback control. Hypothalamus releases GHRH which intern promote release of GH from anterior pituitary. GH acts on various tissues. It also activates the liver cells to secrete somatomedin-C or also known as insulin like growth factor–I (IGH-I). Now, the somatomedin-C increases the release of GHRIH from hypothalamus. It acts on pituitary directly and inhibits the secretion of GH.

2. **Thyroid stimulating hormone (TSH):** It secretes from the basophilic cells, thyrotropes. Chemically it is glycoprotein. Its target organ is the thyroid gland. TSH stimulates the normal growth of the
thyroid and the secretion of thyroxine (T$_4$) and tri-iodothyronine (T$_3$). The secretion of TSH is stimulated by TRH. Release of TRH internally depends on levels of T$_3$ and T$_4$. High levels of T$_3$ and T$_4$ inhibit secretion of TRH and vice versa.

3. **Adreno corticotrophic hormone (ACTH):**

   It is releasing from corticotropic cells. ACTH secretion is under negative feedback control. Its target organ is adrenal cortex. It is necessary for the structural integrity and the secretory activity of adrenal cortex. It controls the production and secretion of cortisol and other glucocorticoids from adrenal cortex of adrenal gland. Corticotrophin releasing hormone (CRH) from the hypothalamus stimulates secretion of ACTH. Stress related stimuli, such as low blood glucose or physical trauma & interleukin-I also stimulate the release of ACTH. ACTH is responsible for life-long maintenance of circadian rhythm and sleep pattern.

4. **Follicle stimulating hormone:**
   - FSH and LH are known as gonadotropic hormones because of their actions on gonads.
   - FSH is releasing from gonadotropes.
   - In females, ovaries are the targets for FSH. Each month it initiates several ovarian follicles and prepares them for ovulation. FSH also stimulates secretion of estrogens from follicular cells.
   - In males, FSH stimulates sperm production in the testes.
   - GnRH from the hypothalamus stimulate the release of FSH
   - GnRH & FSH release is suppressed by estrogens in females & testosterone in males through negative feedback control.

5. **Luteinising Hormone (LH)**
   - It releases from luteotropic cells.
   - In females, it triggers ovulation, and it is necessary for the formation of corpus luteum (structure formed after ovulation) in the ovary and the secretion of progesterone by the corpus luteum.
   - In males, it is known as interstitial cell stimulating hormone (ICSH) because it stimulates interstitial cells of testes for the secretion of testosterone.
   - Secretion of LH is controlled by GnRH.

6. **Prolactin (Leuteotropic Hormone):**

   Its main target is the mammary glands to initiate milk secretion and ejection (Lactation) after childbirth. The hypothalamus secretes both inhibitory and releasing hormones that regulate prolactin secretion. Prolactin Inhibitory Hormone (PIH), which is dopamine inhibits the release of prolactin from anterior pituitary most of the time. During pregnancy, prolactin releasing hormone of the hypothalamus releases and stimulates the anterior pituitary to release prolactin. The sucking action of a baby causes a reduction in hypothalamic secretion of PIH.
The function of prolactin is not known in males, but its hyper secretion causes erectile dysfunction. In females, Hypersecretion of prolactin causes galactorrhea (inappropriate lactation) and amenorrhea (absence of menstrual cycles).

**Posterior Pituitary (Neurohypophysis)**

The posterior pituitary arises from the base of the brain or hypothalamus as a down ward extension. Communication between the hypothalamus and the posterior pituitary occurs through neurosecretory cells that span the short distance between the hypothalamus and the posterior pituitary. Hormones produced by the cell bodies of the neurons of hypothalamus, are packed in vesicles and transported through the axon and stored in the axon terminals that lie in the posterior pituitary. When the neurosecretory cells are stimulated, the action potential, the action potential generated triggers the release of the stored hormones from the axon terminals to a capillary network within the posterior pituitary. Two hormones, oxytocin and antidiuretic hormone (ADH) are produced and released this way.

**Anti Diuretic Hormone (ADH):**

Chemically it is a polypeptide. Its half-life is 18 – 20 minutes. Osmoreceptors are the receptors situated in the hypothalamus and give response to change in the osmolar concentration of the blood. When osmolar concentration of blood increases, osmoreceptors stimulate hypothalamus which sends motor impulses to posterior pituitary and results in release of ADH. ADH causes reabsorption of water
from the renal tubules. This increases the volume of extra cellular fluid and restores normal osmolarity. In large amounts, the ADH shows vasoconstrictor action on arteries and results in increase in BP.

**Regulation of secretion of ADH:** The secretion of ADH depends upon the volume of body fluid and the osmolarity of the body fluids. The stimulants are decrease in ECF volume, increase in osmolar concentration in ECF, dehydration, stressful conditions, anxiety, acetylcholine and nicotine. The inhibitor is alcohol.

**Oxytocin:**
- It secretes from posterior pituitary. Chemically it is a polypeptide. It is released by positive feedback mechanism
- In females, oxytocin acts on mammary glands and uterus
  - On mammary glands it causes ejection of milk by causing contraction of the myoepithelial cells of mammary glands.
  - On uterus it causes contraction of pregnant uterus and helps in expulsions of fetus.
  - The action of oxytocin on non pregnant uterus is to facilitate the transport of sperms through female genital tract up to fallopian tube by producing the uterine contraction during sexual intercourse.
- In males, oxytocin increases during ejaculation and facilitates release of sperm into urethra.

**Gigantism:** It is the pituitary disorder characterized by excess growth of the body. The subjects look like the giants with average height of about 7 – 8 feet.

**Acromegaly:** It is the disorder characterized by the enlargement, thickening and broadening of bones, particularly in the extremities of the body.

**Cushing’s disease:** It is due to over secretion of ACTH, characterized by obesity because of over secretion of cortisol from adrenal cortex.

The disorder due to the pituitary cause is called *caushing’s disease*, and when it is the adrenal cause, it is called *caushing’s syndrome*.

**Dwarfism:** It is a pituitary disorder in children characterized by the stunted growth.

**Acromicria:** It is a rare disease in adults characterized by atrophy of the extremities of the body (i.e. hands and feet).

**Simmond’s disease (Pituitary Ca Chexia):** It is a rare pituitary disease characterized by rapidly developed senile decay. Thus, a 30 years old person looks like a 60 years old person, loss of hair over the body and teeth. The skin on face becomes dry and wrinkled.

**Diabetes insipidus:** It is pituitary disorder characterized by polyuria, polydipsia and dehydration.

Polyuria – Excretion of large quantity of dilute urine (4 – 12 lit per day)
Polydipsia – Intake of excess water
Dehydration – Loss of water.

Gigantism

Acromegaly

Acromegaly

THYROID GLAND

Thyroid gland situated at the root of the neck on either side of the trachea, just below the larynx, at the 5th, 6th, 7th cervical and 1st thoracic vertebrae. Anatomically it has two lobes, which are connected in middle by an isthmus. It is reddish brown in color, each lobe is cone shaped, measured about 5cm in height and 3cm in breadth and 2cm thickness. It weighs about 20 – 40 gms in adults. Apex is narrow and the base is flat in shape. Right lobe is larger in size than the left lobe. Thyroid is larger in females than in males. Thyroid gland starts functioning in the fetal life itself. However, the maximum activity of the
gland is achieved only after puberty. Superior thyroid artery and subclavian artery supplies arterial blood to gland. Venous blood is drained by thyroid vein into the internal jugular vein. Continuous proliferation of thyroid gland requires adequate supply of iodine from diet.

**Microscopic structure of thyroid gland:** Upon microscopic examination, the thyroid gland is composed of follicles or vesicles. The follicles are lined with cuboidal epithelial cells, which are called follicular cells. The follicular cavity is filled with a protein known as thyroglobulin which is secreted by the follicular cells. Follicular cells secrete tetra iodothyroxine (TA) or thyroxine and tri-iodothyroxine(T3). In between the follicles, the para-follicular cells are present. These cells secrete calcitonin.

**Synthesis of thyroid hormones:**
- These follicular cells having ability to extract the iodide molecules from blood capillaries and then concentrate in the colloid. This process is known as “iodine trapping mechanism”.

![Diagram of thyroid gland with microscopic structure and blood supply](image)

![Diagram of blood supply to thyroid gland](image)
The trapped iodide (I) converted into idodine (I₂) in presence of peroxidase enzyme in thyroid follicles.

These iodine molecules binds with an amino acid tyrosine to form monoiodo tyrosine and diiodothyrosine which further undergo oxidative condensation to form tyroxine (T₄) and T₃.

For the synthesis of normal quantities of thyroid hormone approximately 1 mg of iodine is required per week or about 50 mg per year. To prevent iodine deficiency, common table salt is iodized with one part of sodium iodide to every 1,00,000 parts of sodium chloride.

After synthesis, the thyroid hormones remain in the form of vesicles within thyroglobulin. There is 1: 10 ratio between T₃ & T₄ respectively. Thyroid gland is unique in this, as it is the only endocrine gland that can store its hormones for a long period of about 4 months. So, when the synthesis of thyroid hormones stops, the signs and symptoms of deficiency do not appear for about 4 months.

**Control of thyroid hormone secretion:** Low blood levels of T₃ and T₄ or low metabolic rte stimulate the hypothalamus to secrete TRH. TRH enters the hypothalamo-pituitary portal circulation and flows to the anterior pituitary to secrete TSH.

TSH stimulates Iodine trapping, hormone synthesis, and secretion and growth of the follicular cells. T3 and T4 release into the blood until the metabolic rate return to normal. An elevated level of T3 inhibits release of TRH and TSH through negative feedback inhibition.

<table>
<thead>
<tr>
<th>Hormone</th>
<th>Normal plasma level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total T₃</td>
<td>0.12µg/dl</td>
</tr>
<tr>
<td>Total T₄</td>
<td>8µg/dl</td>
</tr>
<tr>
<td>TSH</td>
<td>2U/ml</td>
</tr>
</tbody>
</table>
Functions:
- To increase overall metabolic rate in the body.
- To stimulate growth in children.

On Basal Metabolic Rate:
- Thyroxine increases the metabolic activities of almost all tissues of the body except brain, retina, spleen, testes and lungs.
- It increases the BMR by increasing the oxygen consumption and utilization of nutrients in the peripheral cells.
- **On protein Metabolism:** Thyroid hormones increase the synthesis of proteins in the cells.
- **On Carbohydrate Metabolism:**
  - Thyroxine increases the absorption of glucose from GIT.
  - Enhances the glucose uptake by the cells.
  - Enhances the glycogenolysis and gluconeogenesis.
- **On Fat Metabolism:** Thyroxine mobilizes fats from adipose tissues and converts into free fatty acids, which are useful for production of energy.
- Thyroid hormone accelerates the growth of the body especially in growing children.
- Thyroxine is more important to promote growth and development of brain during fetal life and the first few years of postnatal life.
• On Body Weight: Thyroxine is essential for maintaining the weight.
  ▪ Increase in thyroxine secretion – Decrease in body weight.
  ▪ Decrease in thyroxine secretion – Increase in body weight. **Miscellaneous:**

Accelerate the process of erythropoiesis. Increase in HR, FOC, vasodilation, BP, rate and depth of respiration, appetite, motility and secretion of enzymes.

**Disorders:**

**Hyper thyroidism:** It leads to Grave’s disease (autoimmune disorder) BMR increased by about 60 – 100% above normal.

In Graves disease the B-lymphocytes (Plasma cells) produce autoimmune antibodies called thyroid stimulating auto antibodies, these antibodies acts like TSH and results in hyper secretion of thyroid hormones.
  ▪ Thyroid adenoma
  ▪ Exophthalmia – protrusion of eye balls.

Protrusion of eye balls stretches and damages the optic nerve resulting in blindness. Eyelids can’t be closed completely while blinking or during sleep.

**Hypothyroidism:** In hypothyroidism BMR falls by 20 – 40% below normal level.

<table>
<thead>
<tr>
<th>Hypothyroidism in</th>
<th>Disorder</th>
<th>Characterized by</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adults</td>
<td>Myxedema</td>
<td>Edematous appearance</td>
</tr>
<tr>
<td>Children</td>
<td>Cretinism</td>
<td>Stunted growth</td>
</tr>
</tbody>
</table>

Along with T3 & T4 thyroid gland also secretes another hormone that is “calcitonin” by parafollicular cells which are found in between the follicles either singly or in groups. It will release when the blood calcium levels raised than the normal (8 – 10mg/dl). It acts by inhibiting the absorption of Ca^{2+} from intestine, reabsorption at kidneys and stimulate movement of calcium into the bone.

**Calcium level increases by:** Parathormone acts on bones & makes release of calcium. 1, 25- Dihydroxy cholecalciferol (calcitrol) by acting on intestine and increases the absorption of calcium.

**Iodine Deficiency Disorders**

Myxedema before treatment (left) & after treatment (right)
**PARATHYROID GLANDS**

There are four parathyroid glands. They are embedded in the posterior surface of the lobes of the thyroid gland. Usually one superior and another inferior. Parathyroid glands are attached to each thyroid lobe. These are small, round masses weight about 40mg each. Parathyroid gland secretes a hormone known as *parathyroid hormone* (PTH), also known as *parathormone* from the chief cells of parathyroid gland.

- Parathormone play role in regulation of the levels of Calcium (Ca\(^{2+}\)), Magnesium (Mg\(^{2+}\)) and Phosphate (HPO\(_4\)^{2-}\) ions in the blood. PTH increases the number and activity of osteoclasts and results in release of ionic calcium and phosphates into the blood.

- PTH also acts on kidney to increase the reabsorption of calcium and magnesium ions.

- PTH promotes formation of the hormone “Calcitriol” (i.e. active form of vitamin D) from kidneys which increase the absorption of Calcium, Magnesium and Phosphate ions from GIT into blood.

- The blood calcium level directly controls the secretion of both calcitonin and parathormone via negative feed back loops.

Deficiency of PTH can lead to tetany, muscle weakness and hemostasis (blood clotting).
PANCREAS

It is a pale grey colored gland weighing about 60gms. It is about 12-15cm long and situated in posterior part of abdomen. It consists of broad head, body and a narrow tail. It is both endocrine and exocrine gland. Exocrine cells of pancreas are known as “acini”. Endocrine cells of pancreas are known as islets of “langerhans“. There are three types of islets are there. Those are:

- $\alpha$ – islets of langerhans which secrete Glucagon.
- $\beta$ – islets of langerhans which secrete Insulin.
- $\gamma$ – islets of langerhans which secrete somatostatin.

Glucagon: It releases from $\alpha$ – islets of langerhans. Chemically it is a polypeptide. Its release was initiated when blood glucose levels are below than the normal (100 – 120 mg/dl).

Functions:
- It increases the blood glucose level by glycogenolysis, gluconeogenesis.
- It increases peripheral utilization of lipids and facilitates the conversion of proteins into glucose.

Insulin: It is secreted by $\beta$ – islets of langerhans. Chemically it is a polypeptide. It is the only hormone in the body that reduces blood sugar level. It reduces blood glucose levels by:
  - Promoting the entry of glucose into cells
  - Enhancing the conversion of glucose into glycogen and fats (Glucogenesis).
  - Promotes peripheral utilization of glucose for energy.
  - It facilitates the synthesis and storage of proteins and inhibits the cellular utilization of proteins.
  - It stimulates the synthesis and storage of fat in adipose tissue.
  - Along with GH, insulin promotes growth of the body.

Somatostatin: It secretes from hypothalamus (i.e. GHRIH) and $\gamma$ – islets of langerhans of pancreas. Chemically it is a polypeptide. Somatostatin acts within islets of langerhans and inhibits both $\alpha$ and $\beta$ cells i.e. inhibit the secretion of both glucose and insulin. It decreases the motility of GIT. It reduces the secretion of GIT hormones gastrin, CCK.

Disorders:

Diabetes Mellitus: It is characterized by high blood glucose level. In most cases it develops due to deficiency of insulin.

Type I Diabetes Mellitus (IDDM): Characterized by dysfunction or absence of $\beta$ – islets of langerhans and not associated with obesity.

Type II Diabetes Mellitus (NIDDM): Due to the absence or reduced number of insulin receptors in the cells of the body.
There are two adrenal glands. Each gland is situated on the upper pole of each kidney because of this adrenal glands are also known as “supra renal glands”. Each gland weighs about 4gm. The adrenal gland is made of two distinct parts. The adrenal cortex and adrenal medulla. Adrenal medulla is the central portion of the gland constituting 20%. Adrenal cortex is the outer portion constituting 80% of the gland. These two parts are different from each other in development, structure and functions. Adrenal medulla secretions and functions resembles that of sympathetic nervous system. Adrenal cortex secretes a different group of hormones known as ‘corticosteroids’.

Adrenal cortex is formed by three layers of structures known as:

- **Zona glomerulosa**- Outer layer – Mineralocorticoid and little amount of glucocorticoids androgens.
- **Zona fasciculata**- Middle layer – Glucocorticoids
- **Zona reticularis** - Inner layer – Sex hormones.

Corticosteroids based on their functions they are classified into three groups. They are:

- Mineralocorticoids - Aldosterone
- Glucocorticoids – Cortisol, cortisone and corticosterone
- Sex hormones.

Total loss of corticoids usually causes death with in 3 – 12 weeks. During mineralocorticoids deficiency K⁺ levels increase Na⁺ and Cl⁻ levels decrease. That is why, it is known as life saving hormone.

**Mineralocorticoids**: Aldosterone

- It increases the reabsorption of sodium from renal tubules.
- It increases the excretion of potassium through renal tubules.
- It increases the secretion of hydrogen ions into renal tubules.
Regulation of release: It releases when there is increase in potassium ion concentration in ECF, decrease in sodium ion concentration in ECF, decrease in ECF volume. Increase in the concentration of K⁺ is the most effective stimulant for aldosterone secretion.

Glucocorticoids: There are the corticoids, as the name indicates these acts mainly on glucose metabolism. Glucocorticoids secreted mainly from Zona fasciculata of adrenal cortex. Glucocorticoids are cortisol, corticosterone and cortisone. Cortisol is more potent and it has 95% of glucocorticoid activity, Corticosterone – 4% and corticosterone – 1%.

Functions:
- Increases blood glucose levels by promoting gluconeogenesis and inhibiting glucose uptake and utilization by body cells.
- Glucocorticoids promote catabolism of proteins.
- Glucocorticoids mobilize fats and make the fatty acids available for utilization by which energy is liberated.
- In large amounts produce anti inflammatory effects and immune suppressive effects.

Regulation of secretion: Anterior pituitary regulates glucocorticoid secretion by secreting ACTH. ACTH secretion is regulated by hypothalamus through corticotrophin releasing hormone (CRH). It follows negative feedback mechanism.
**Sex Hormones:** These are secreted by zona reticularis and small quantities from z.fasciculata. Most of the hormones are male sex hormones (androgens). But small quantity of estrogen and progesterone are also secreted but when compared to the quantity secreted by female gonads it is insignificant. The androgens secreted by adrenal cortex are:

- Dehydroepiandrosterone (most active androgen)
- Androstenedione
- Testosterone

**Disorders:**

**Cushing’s syndrome:** It is characterized by obesity, pot belly with people strives and fat deposition in upper abdomen thorax and face (moon face) with thin hands. It is due to hypersecretion of glucocorticoids.

- Pituitary origin - Cushing’s disease
- Adrenal origin - Cushing’s syndrome

**Hyper aldosteronism:** It is characterized by increase in ECF volume and blood volume. It is due to increased secretion of aldosterone.

**Addison’s disease:** It is characterized by pigmentation of skin and mucous membrane due to excess secretion ACTH secretion because of cortisol deficiency. ACTH causes pigmentation by its melanocyte stimulating action.

**Adrenal Medulla:** Adrenal medullary hormones are the amines derived from catechol and so these are called ‘catecholamines’. These catecholamines are secreted by medulla. They are:

- Adrenaline or epinephrine
- Nor adrenaline or norepinephrine
- Dopamine

**Functions (like sympathetic actions):**

- Increases oxygen consumption and CO₂ removal, increase BMR. Increase blood glucose level, mobilization of fats. Decrease blood coagulation time and increase RBC count. Increase in heart rate, force of contraction, Conductivity in heart muscle and blood pressure. Constriction of blood vessels, increase rate and depth of respiration, increase in secretion of sweat.
The Gonads

In males, the interstitial cells of the testes produce the male hormones known as **androgens**. **Testosterone** is the most important androgen. During embryonic development, the production of testosterone affects the development of CNS structures, including hypothalamic nuclei, which will later influence sexual behaviors. **Nurse cells** in the testes support the differentiation and physical maturation of sperm. Under FSH stimulation, these cells secrete the hormone **inhibin**. It inhibits the secretion of FSH at the anterior lobe of the pituitary gland and perhaps suppresses GnRH release at the hypothalamus.

In females, steroid hormones called **estrogens** are produced in the ovaries under FSH and LH stimulation. Estradiol is the principal estrogen. Circulating FSH stimulates the secretion of inhibin by ovarian cells, and inhibin suppresses FSH release through a feedback mechanism comparable to that in males.

At ovulation, follicles in the ovary release an immature gamete, or oocyte. The remaining follicle cells then reorganize into a corpus luteum, that releases a mixture of estrogens and progestins. **Progesterone** is the principal progestin. During pregnancy, the placenta and uterus produce additional hormones that interact with those produced by the ovaries and the pituitary gland to promote normal fetal development and delivery.