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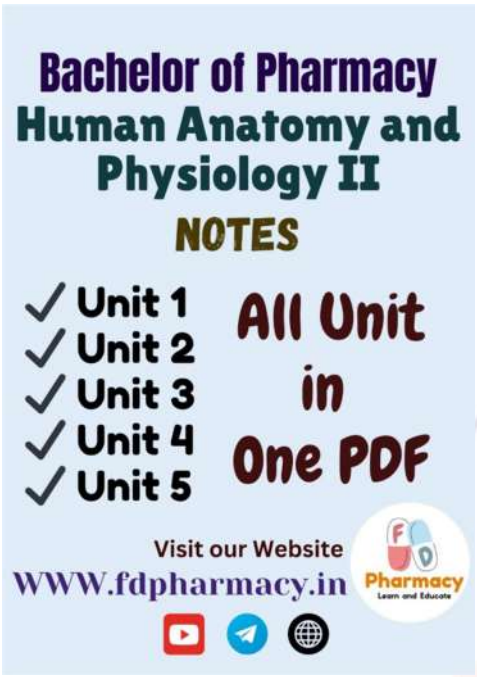
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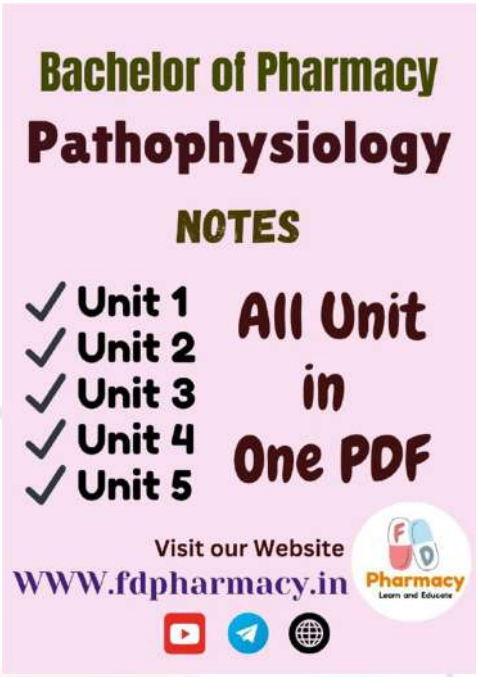
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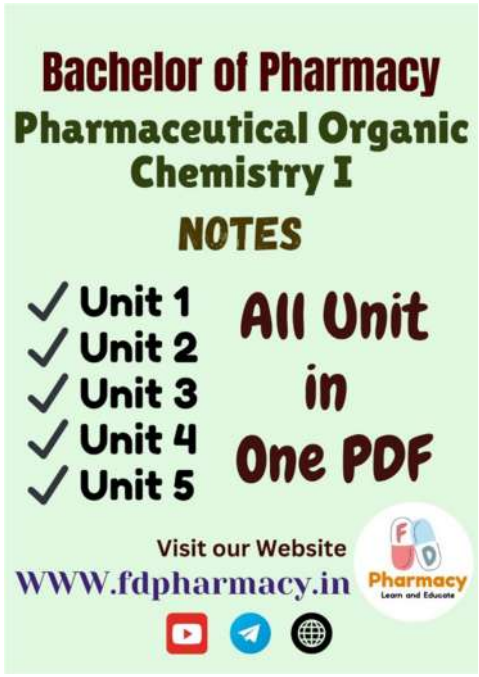
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HUMAN ANATOMY AND PHYSIOLOGY – II

UNIT 4

TOPIC :

- **Endocrine system**

  Classification of hormones, mechanism of hormone action, structure and functions of pituitary gland, thyroid gland, parathyroid gland, adrenal gland, pancreas, pineal gland, thymus and their disorders.

Endocrine System

→ The endocrine system consists of glands secreting hormones essential for maintenance of homeostasis throughout the body.

→ Hormones are chemical messengers that act to control and coordinate different functions of tissues and organs.

→ Various body activities like growth and development and metabolism are also regulated by hormones.

→ Each hormone is secreted from a particular gland and is distributed to the target tissues via blood.

→ Endocrine glands are ductless glands, thus release their products directly into the bloodstream, and are carried to their target cells.

→ On the other hand, exocrine glands secrete their products (excluding hormones and other chemical messengers) into the ducts, which are then transported to the bloodstream.

→ The endocrine system comprises of all the endocrine glands of the body.

→ Pituitary, pineal, thyroid, and adrenal, pancreas, parathyroid, thymus, and gonads (testis in males and ovary in females) are the endocrine glands found in humans .

→ These glands work in conjunction with the nervous system, and therefore this complex of two systems is referred to as the neuroendocrine system.

→ This system controls and coordinates various functions of the body, maintaining homeostasis (constancy of body fluids) within the body. The term neuroendocrinology defines the study of endocrine system in combination with the nervous system.

CLASSIFICATION OF HORMONES

→ Based on Source (Gland of Origin)

Endocrine Gland	Hormones Secreted
Pituitary gland	GH, ACTH, TSH, FSH, LH, Prolactin, ADH, Oxytocin
Thyroid gland	T_3 (Triiodothyronine), T_4 (Thyroxine), Calcitonin
Parathyroid gland	Parathyroid hormone (PTH)
Adrenal gland	Cortisol, Aldosterone, Adrenaline, Noradrenaline
Pancreas	Insulin, Glucagon, Somatostatin
Gonads (Testes/Ovaries)	Testosterone, Estrogen, Progesterone
Pineal gland	Melatonin
Thymus	Thymosin

Mechanism of Hormone Action

- Hormones act as chemical messengers that bind to specific receptors on or inside target cells to regulate physiological processes like metabolism, growth, reproduction, and homeostasis.

Two Main Types of Hormone Action

1. Mechanism of Action of Lipid-Soluble Hormones (Intracellular Receptors)

→ Lipid-soluble hormones (like steroids and thyroid hormones) can freely cross the cell membrane and bind to intracellular receptors (present in the cytoplasm or nucleus) to regulate gene expression directly.

→ Examples: Steroid hormones (Cortisol, Estrogen, Testosterone), Thyroxine (T_4)

Steps:

- Hormone diffuses through plasma membrane (because it is lipid-soluble).
- Binds to intracellular receptor in cytoplasm or nucleus.
- Hormone-receptor complex binds to specific DNA sites.
- Activates or represses gene transcription.
- New proteins/enzymes are synthesized.
- These proteins bring about the desired physiological response.

Time of action: Slower, but effects are long-lasting.

2. Mechanism of Action of Water-Soluble Hormones (Membrane Receptors)

→ Water-soluble hormones cannot cross the lipid bilayer of the plasma membrane. Instead, they bind to specific receptors on the cell membrane, triggering a cascade of intracellular events using second messengers to produce a physiological response.

→ Examples: Insulin, Adrenaline, Glucagon, FSH, LH

→ These cannot pass through the lipid membrane, so they use second messengers.

Steps:

- Hormone binds to receptor on cell membrane.
- Activates G-protein inside the cell.
- G-protein activates second messengers like:
  - cAMP (cyclic AMP)
  - IP_3 / DAG
  - Ca^{2+} ions
- These second messengers amplify the signal.
- Activate intracellular enzymes (e.g., protein kinases).
- Leads to metabolic changes or cellular response.

Time of action: Fast, but short-lived.

PITUITARY GLAND

- An endocrine gland, pituitary (hypophysis), is of the size of a pea and weighs nearly 0.5gm. Its diameter is 1 1.5cm (0.5 inch). A stalk, the infundibulum, and a funnel attach it to the hypothalamus.
- Since pituitary gland secretes hormones which control the other endocrine glands, it was named the master endocrine gland.

Location and Structure

- Pituitary gland lies within the pituitary (hypophyseal) fossa located at the base of the brain in the sphenoid bone (in the middle cranial fossa).
- From the inferior surface of the hypothalamus, it is seen as a protrusion resting on a small, bony cavity, known as sella tursica.
- The hypothalamic hormones are produced in the cell bodies or axons and move to the cells of anterior pituitary gland via the hypophyseal portal system.
- The posterior pituitary is under the direct neural regulation of hypothalamus.

Hormones

The pituitary gland secretes different hormones:

1) **Anterior Pituitary:** The hormones secreted by this part are:
   i) Growth Hormone (GH),
   ii) Thyroid Stimulating Hormone (TSH),
   iii) Adrenocorticotropic Hormone (ACTH).
   iv) Prolactin (PRL).
   v) Gonadotropins:
   (a) Follicle-Stimulating Hormone (FSH), and
   b) Luteinising Hormone (LH).
   (c) Melanocyte Stimulating Hormone (MSH))

2) **Posterior Pituitary:** The hormones secreted by this part are:

(i) Antidiuretic Hormone (ADH, or vasopressin), and
(ii) Oxytocin.

Function

1. ANTERIOR PITUITARY (ADENOHYPOPHYSIS)

Hormone	Full Name	Main Function
GH	Growth Hormone	Stimulates body growth, protein synthesis, bone/muscle development
TSH	Thyroid Stimulating Hormone	Stimulates the thyroid gland to produce T_3 and T_4 hormones
ACTH	Adrenocorticotropic Hormone	Stimulates adrenal cortex to secrete cortisol
FSH	Follicle Stimulating Hormone	In females: stimulates ovarian follicle growth
In males: stimulates sperm production		
LH	Luteinizing Hormone	In females: triggers ovulation
In males: stimulates testosterone production		
PRL	Prolactin	Promotes **milk production** in females after childbirth

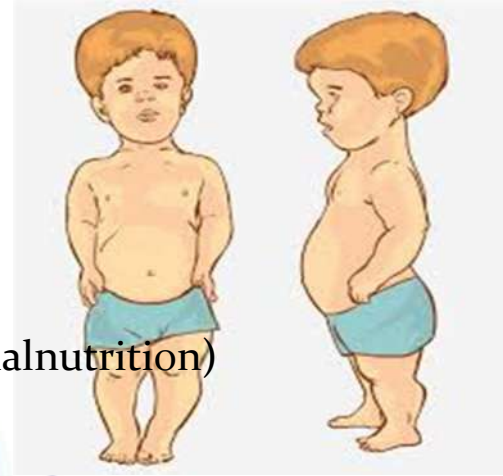
2. POSTERIOR PITUITARY (NEUROHYPOPHYSIS)

Hormone	Full Name	Main Function
ADH	Antidiuretic Hormone (Vasopressin)	Increases water reabsorption in kidneys, helps regulate blood pressure
Oxytocin	—	Stimulates **uterine contractions during childbirth** and **milk ejection** during breastfeeding

Disorder of Pituitary Gland

1. Dwarfism

- A growth disorder characterized by short stature due to deficient secretion or action of Growth Hormone (GH) during childhood, leading to reduced bone and body growth.



Cause:

- Growth Hormone (GH) deficiency
- Genetic disorders (e.g., Achondroplasia)
- Pituitary gland damage or tumor
- Radiation or head trauma
- Chronic diseases (e.g., kidney disease, malnutrition)

Symptoms:

- Short stature (height significantly below average for age)
- Normal body proportions in GH deficiency (disproportionate in genetic forms)
- Delayed physical development
- Immature facial features
- Delayed puberty or sexual development
- In some cases, normal intelligence (in GH-related cases)

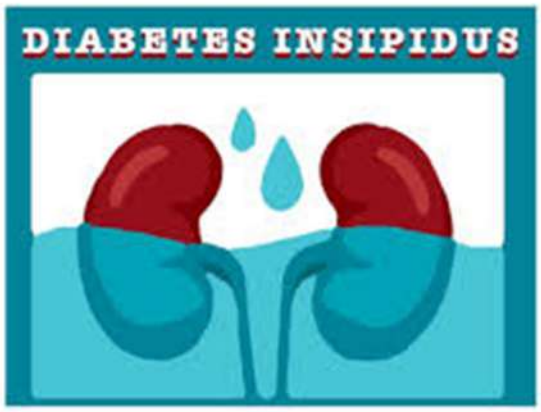
2. Diabetes Insipidus

- A disorder caused by a deficiency of Antidiuretic Hormone (ADH) or the kidney's inability to respond to ADH, leading to excessive loss of water through urine and intense thirst.

Cause:

Central (Neurogenic) DI – Decreased ADH secretion due to:

- Head injury
- Brain tumor
- Pituitary surgery
- Infections (e.g., meningitis)



Nephrogenic DI – Kidneys do not respond to ADH due to:

- Genetic mutation
- Kidney disease
- Certain medications (e.g., lithium)

Symptoms:

- Polyuria (excessive urination)
- Polydipsia (excessive thirst)
- Dehydration
- Dry skin and mouth
- Fatigue and weakness
- No glucose in urine (unlike diabetes mellitus)

THYROID GLAND

- Thyroid is the largest endocrine gland (5×3cm), weighing 25gm in a healthy adult.
- It is brownish red in colour.
- It is immensely vascularised and receives 80-120ml of blood per minute.

Location and Structure

- Thyroid gland lies on the anterolateral side of the cervical trachea, extending from the level of the 5th cervical vertebra to the 1st thoracic vertebra. It comprises of two lobes (bilobed) interconnected by a transverse glandular band (isthmus) and appearing as a butterfly. It is therefore described as an H-shaped organ .

Hormone

Thyroxine

Thyrocalcitonin (TCT)

Functions

Thyroid gland performs the following functions:

1) It controls the body's metabolic activities (the body's ability of converting food into energy).

2) It secretes hormones which regulate the vital organs and maintain the internal homeostasis.

3) It controls the breathing and heart rate.

4) It monitors the body weight, thus defective thyroid gland in an individual result in severe weight variation.

5) lts wings or lobes produce thyroid hormone.

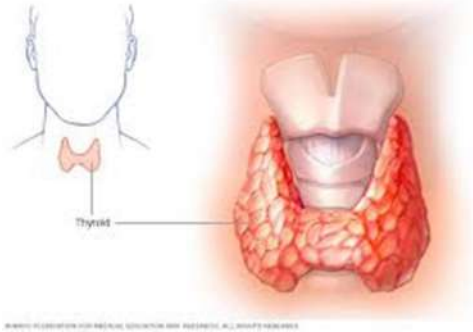
6). It secretes a hormone which controls the internal body temperature and cholesterol levels.

7) The hormones it secretes also increase cellular metabolic activity, thus influencing the metabolic rate and protein synthesis, which in turn facilitates normal development (since development relies on protein synthesis).

Disorder of Thyroid Gland

1. Hypothyroidism

→ A condition where the thyroid gland produces insufficient thyroid hormones (T_3 and T_4), leading to a slowing of metabolism and body functions.



Cause:

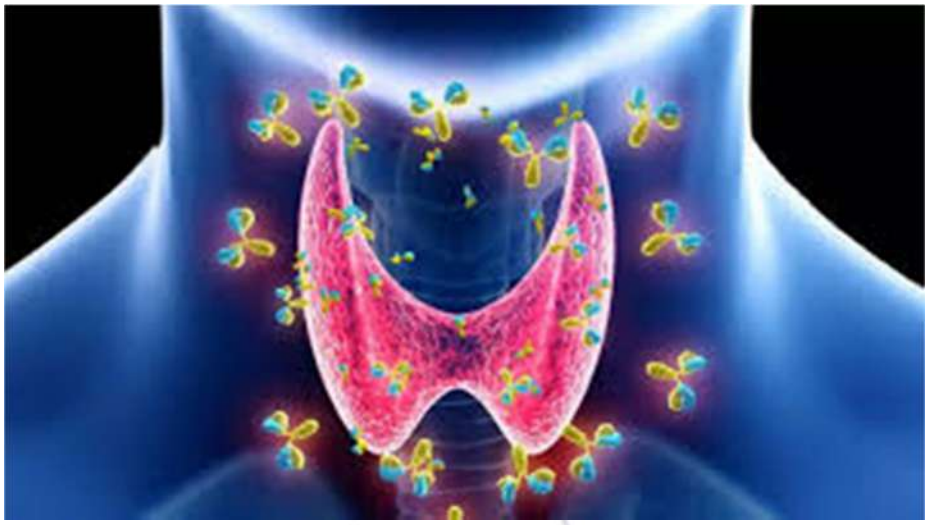
- Autoimmune disease (e.g., Hashimoto's thyroiditis)
- Iodine deficiency
- Post-thyroid surgery or radiation
- Congenital hypothyroidism (present at birth)
- Pituitary or hypothalamic disorders (secondary/tertiary hypothyroidism)
- Certain medications (e.g., lithium, amiodarone)

Symptoms:

- Fatigue
- Weight gain (despite poor appetite)
- Cold intolerance
- Constipation
- Dry skin, hair loss
- Depression or poor memory

2. Hyperthyroidism

→ A condition in which the thyroid gland produces excessive thyroid hormones (T_3 and T_4), resulting in an increased metabolic rate and overactive body functions.



Cause :

- Graves' disease (autoimmune – most common)
- Toxic multinodular goiter
- Thyroid adenoma (benign tumor)
- Thyroiditis (inflammation of thyroid)
- Excessive intake of thyroid hormone (overmedication)
- Iodine excess

Symptoms :

- Weight loss (despite increased appetite)
- Increased sweating
- Heat intolerance
- Palpitations, rapid heart rate (tachycardia)
- Tremors (shaky hands)

PARATHYROID GLAND

- Parathyroid glands are small endocrine glands located in the neck and produce parathyroid hormone.
- Four parathyroid glands are positioned behind the thyroid gland, or within the thyroid gland (in rare cases) or in the chest.
- These glands regulate the calcium levels in blood and bones.

Structure

- Four pea-shaped parathyroid glands are either completely or partially embedded in the dorsal surface of thyroid gland; each lobe of thyroid has two oval-shaped, small sized (5 x 5mm) and yellow coloured parathyroid glands, Masses of polygonal cells (known as chief and oxyphil cells) arranged in cords make up the histological structure of a parathyroid gland.

Hormone

Parathyroid Hormone (PTH)

Functions

Parathyroid gland produces and releases PTH to maintain the blood calcium level (whenever its level declines) by:

1) Breakdown of bone to release calcium, as bone stores: maximum amount of calcium,

2) Facilitating calcium absorption from food, and

3) Limiting calcium loss via urine.)

Disorder of Parathyroid Gland

1. Hyperparathyroidism

- A condition caused by excessive secretion of parathyroid hormone (PTH) by one or more of the parathyroid glands, leading to increased calcium levels in the blood (hypercalcemia) and bone resorption.

Cause:

Primary Hyperparathyroidism – Overactive gland(s), usually due to:

- Parathyroid adenoma (benign tumor)
- Parathyroid hyperplasia
- Parathyroid carcinoma (rare)

Secondary Hyperparathyroidism – Response to low calcium levels, due to:

- Chronic kidney disease (**CKD**)
- Vitamin D deficiency
- Malabsorption

Tertiary Hyperparathyroidism – Long-standing secondary form becomes **autonomous** (glands continue to secrete PTH despite normal calcium)

Symptoms:

"Bones, Stones, Groans, and Psychic Moans"

- Bone pain, fractures (due to calcium loss from bones)
- Kidney stones (due to high calcium in urine)
- Abdominal pain, constipation
- Fatigue, muscle weakness
- Depression, confusion, memory issues
- Polyuria and polydipsia

2. Hypoparathyroidism

- A condition characterized by deficient secretion of parathyroid hormone (PTH) from the parathyroid glands, leading to low blood calcium levels (hypocalcemia) and high phosphate levels (hyperphosphatemia).

Cause:

- Accidental removal or damage to parathyroid glands during thyroid or neck surgery (most common)
- Autoimmune destruction of parathyroid tissue
- Genetic disorders (congenital absence of glands – DiGeorge syndrome)
- Radiation to neck
- Magnesium deficiency (needed for PTH secretion)
- Hereditary hypoparathyroidism

Symptoms:

All due to hypocalcemia (low calcium)

- Muscle cramps and spasms (tetany)
- Numbness or tingling in fingers, toes, lips
- Twitching of facial muscles (Chvostek's sign)
- Carpal spasm with BP cuff (Trousseau's sign)
- Seizures (in severe cases)
- Irritability, anxiety, depression

ADRENAL GLAND

- ♠ Adrenal glands (or suprarenal glands) are star-shaped endocrine glands.
- ♠ The term adrenal indicates its position (ad means near or at; -renes means kidneys; and supra- means above).
- ♠ These glands mainly regulate the stress response by producing corticosteroids and catecholamines, including cortisol and adrenaline (epinephrine), respectively.

Location and Structure

- ♦ Adrenal glands are positioned on the anterior portion of kidneys.
- ♦ It is divided into outer and inner zones, i.e., adrenal cortex and adrenal medulla, respectively.
- ♦ These two zones differ in structure, functions, and origin.
- ♦ The adrenal glands are highly vascularised.

Hormones

- Cortisol (glucocorticoid)
- Aldosterone (mineralocorticoid)
- Androgens
- Epinephrine, Norepinephrine

Functions

The adrenal gland performs the following functions:

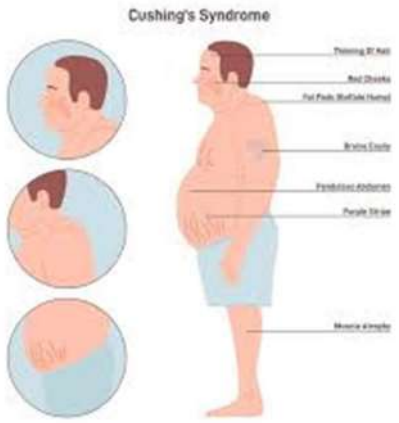
1. It allows the body to deal with stress related to injury disease, work, or personal life.
2. It determines the energy released when the body responds to the changes in internal and external environment.
3. It secretes hormones which allow the body to mobilise its resources to escape or fight off danger (stress) and survive.

Disorder of Adrenal Gland

1. Cushing's Syndrome

➢ A hormonal disorder caused by prolonged exposure to high levels of cortisol (a glucocorticoid), either due to endogenous overproduction or exogenous administration.

Cause:



- **Adrenal tumor** → cortisol overproduction
- **Ectopic ACTH production** (e.g., lung tumors)

Symptoms:

- **Moon face** (round, puffy face)
- **Buffalo hump** (fat pad on upper back)
- **Central (truncal) obesity** with **thin limbs**
- **Purple striae (stretch marks)** on abdomen and thighs
- **Muscle weakness**
- **Osteoporosis**

2. Addison's Disease

➢ A chronic endocrine disorder caused by destruction or dysfunction of the adrenal cortex, resulting in deficiency of glucocorticoids (cortisol) and often mineralocorticoids (aldosterone).

Cause:

- Tuberculosis
- Fungal infections (histoplasmosis)
- Adrenal metastasis or hemorrhage
- Genetic/congenital adrenal hyperplasia

Symptoms:

- Fatigue and weakness
- Weight loss and decreased appetite
- Hyperpigmentation (bronze skin, gums – only in primary)
- Low blood pressure (hypotension)
- Salt craving
- Nausea, vomiting, abdominal pain

PANCREAS

- Pancreas is a large gland located near the duodenum and stomach.
- It lies obliquely on the posterior abdominal wall, partially to the right and to the left of the median plane.
- The right end of pancreas is large and is called the bead; then comes the short and constricted part the neck, which is continuous with the main part of the gland, the body; and the thin left end of the pancreas is the tail.

Location and Structure

- Pancreas is a retroperitoneal gland which is 12-15cm (5-6 inches) long and 2.5cm (1 inch) thick It is present on the posterior of the greater curvature of stomach.
- It is divided into a head, neck, body, and a tail; and is connected to the duodenum via two ducts.
- It is positioned such that it remains in a close association with the duodenum, stomach, spleen, inferior vena cava, abdominal aorta, and the left kidney.
- Head is the expanded portion fitted in the C-shaped duodenum curve; neck lies just behind the pylorus; body lies behind the stomach body; and tip of the tail comes in contact with the spleen.

- Exocrine cells release pancreatic juices into small ducts which combine to form the two larger ducts. i.e., the pan creatic and the accessory duct.
- These ducts transfer the juices into the small intestine.
- The pancreatic duct (or duct of Wirsung) and the common bile duct (from the liver and gallbladder) unites form the hepatopancreatic ampulla (or ampulla of Vater) which enters the duodenum on an elevation of its mucosa (called major duodenal papilla lying about 10cm inferior to the pyloric sphincter of stomach.

Hormones

- Glucagon
- Insulin

Functions

Since pancreas an exocrine as well as an endocrine gland, its functions are follows:

I. Functions of Exocrine Part: The exocrine part of pancreas are involved in:
   i) Digestion of Proteins: The inactive enzyme precursors (trypsinogen and chymotrypsinogen) are activated by enterokinase enzyme microvilli to yield active proteolytic enzymes (trypsin and chymotrypsin). These enzymes convert polypeptides to tripeptides, dipeptides; and amino acids.
   ii) Digestion of Carbohydrates: Pancreatic amylase converts the digestible polysaccharides (starches) to disaccharides by salivary amylase,
   iii) Digestion of Fats: Fats are converted to fatty acids and glycerol by lipase. Bile salts emulsify fats, ie, reduce the globule size to increase the surface area

2) Function of Endocrine Part: The endocrine part of pancreas secrete insulin and glucagon, which control. the blood glucose levels.

Disorder of Pancreas

1. Diabetes Mellitus Type I

➢ A chronic autoimmune disorder where the pancreatic β-cells of the Islets of Langerhans are destroyed, leading to an absolute deficiency of insulin. This causes high blood glucose levels (hyperglycemia) and an inability to regulate carbohydrate, fat, and protein metabolism.

Cause:

- Autoimmune destruction of insulin-producing β-cells (most common)
- Genetic predisposition (HLA-DR3, HLA-DR4 genes)
- Environmental triggers (e.g., viral infections such as coxsackievirus, rubella)
- Family history of Type I diabetes
- Toxins or early exposure to cow's milk proteins (hypothetical)

Symptoms:

- Polyuria (frequent urination)
- Polydipsia (excessive thirst)
- Polyphagia (increased hunger)
- Unexplained weight loss
- Fatigue and weakness
- Blurred vision
- Slow wound healing

2. Hypoglycemia

- A condition characterized by abnormally low blood glucose levels, usually below 70 mg/dL, resulting in inadequate glucose supply to the brain and other tissues, causing both autonomic (adrenergic) and neuroglycopenic symptoms.

Cause:

- Excessive insulin administration (common in Type I diabetes)
- Skipping meals or delayed eating after insulin dose
- Intense or prolonged physical activity without adjusting food or insulin
- Alcohol consumption (especially without food – inhibits gluconeogenesis)
- Certain medications (e.g., sulfonylureas in diabetics)
- Insulinoma (rare insulin-secreting pancreatic tumor)

Symptoms:

Adrenergic Symptoms (early):

- Sweating
- Tremors
- Palpitations
- Anxiety or nervousness
- Hunger

Neuroglycopenic Symptoms (later/severe):

- Headache
- Confusion
- Slurred speech
- Drowsiness
- Dizziness or blurred vision

PINEAL GLAND

- The pineal gland is a small endocrine gland located in the brain. It is best known for regulating the biological clock and the sleep-wake cycle through its hormone secretion.

Location and Structure

Feature	Description
Location	Deep in the center of the brain, between the two cerebral hemispheres, near the roof of the third ventricle
Shape	Small, pine-cone shaped (hence the name 'pineal')
Size	About 5–8 mm in length; weighs around 100–150 mg
Composition	Made up of pinealocytes (hormone-secreting cells) and neuroglial cells
Control	Activity is influenced by the hypothalamus and light signals via the retina and sympathetic nervous system

Hormone

- Melatonin

Functions

- ✓ Regulation of Circadian Rhythms : Melatonin controls the biological clock, including sleep-wake cycles, body temperature, and hormone release
- ✓ Promotion of Sleep : Increases melatonin levels at night → induces drowsiness and helps maintain deep sleep
- ✓ Antioxidant Role : Melatonin is a powerful antioxidant, protecting cells from free radical damage
- ✓ Regulation of Reproductive Hormones : Inhibits secretion of GnRH (Gonadotropin-Releasing Hormone) in children → delays puberty onset
- ✓ Mood Regulation : Linked to serotonin pathways → helps regulate mood and emotional balance

Disorders of Pineal Gland

1. Melatonin Deficiency

- Melatonin deficiency is a condition where the pineal gland fails to produce sufficient melatonin, leading to disruption of the sleep–wake cycle (circadian rhythm), along with mood, immune, and hormonal imbalances.
- Melatonin is a hormone secreted at night in darkness by the pineal gland, and plays a critical role in inducing and maintaining sleep.

Causes:

- Aging (natural decline in melatonin with age)
- Pineal gland damage or tumor
- Pineal gland calcification
- Shift work or irregular sleep schedules
- Excessive exposure to artificial light at night
- Jet lag
- Certain medications (e.g., beta-blockers)

Symptoms:

- Insomnia or difficulty falling asleep
- Frequent night awakenings
- Daytime fatigue or drowsiness
- Depression or mood disturbances
- Poor immune function

THYMUS GLAND

- The thymus gland is a primary lymphoid organ essential for the development of the immune system, especially during early life. It is responsible for the maturation of T-lymphocytes (T-cells), which are vital for cell-mediated immunity.

Location and Structure

Feature	Details
Location	Behind the sternum (breastbone), in the **upper anterior part of the chest** (mediastinum), between the lungs.
Size	Largest in children; **atrophies after puberty** (shrinks in adults)
Structure	Bilobed organ enclosed in a capsule; each lobe has an **outer cortex** and **inner medulla**
Composition	Made of **epithelial cells**, **thymocytes** (immature T-cells), and **macrophages**

Hormones

- Thymosin

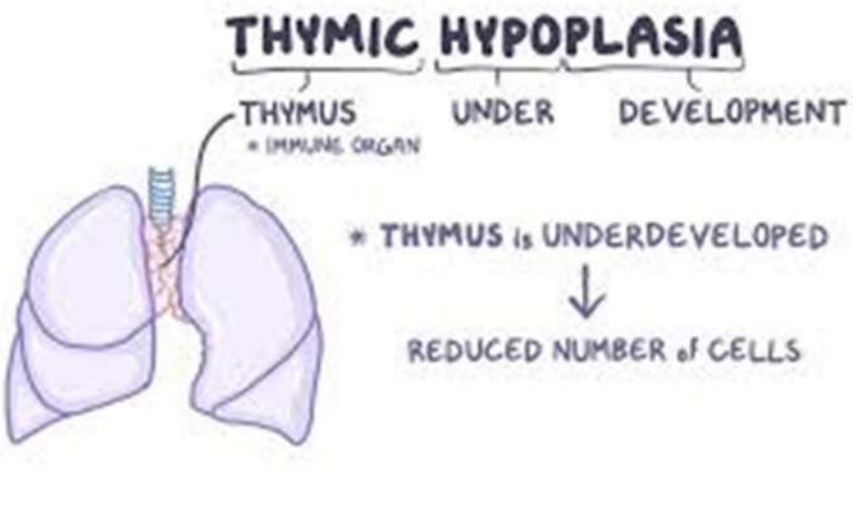
Functions

- ✓ Maturation of T-cells : Immature T-cells from bone marrow migrate to the thymus and differentiate into mature, functional T-cells (helper, cytotoxic, and regulatory T-cells)
- ✓ Development of Immune Tolerance : The thymus helps eliminate T-cells that would react against the body's own cells, thus preventing autoimmune diseases
- ✓ Secretion of Thymic Hormones : Hormones like thymosin promote immune cell development and maintenance
- ✓ Regulation of Adaptive Immunity : T-cells produced in the thymus play a central role in adaptive immune responses (cell-mediated immunity)

Disorder of Thymus Gland

1. Thymic Hypoplasia

- Thymic hypoplasia is a condition where the thymus gland is underdeveloped or absent, leading to a reduction or deficiency in T-lymphocyte (T-cell) production. This results in weakened cell-mediated immunity, making the body more vulnerable to infections.
- The thymus gland, located behind the sternum, is essential in early life for the maturation of T-cells, which are critical for immune defense.



Causes:

- DiGeorge Syndrome (22q11.2 deletion – most common cause)
- Congenital genetic disorders (e.g., CHARGE syndrome, ataxia-telangiectasia)
- Infections during pregnancy (e.g., rubella, CMV)
- Surgical removal or accidental damage (especially in infants during heart surgery)
- Radiation exposure during pregnancy
- Pineal or thymic developmental defects

Symptoms:

- Recurrent infections (especially viral and fungal)
- Chronic diarrhea
- Failure to thrive (poor growth in infants)
- Absent thymic shadow on chest X-ray
- Hypocalcemia (low calcium levels, common in DiGeorge syndrome)
- Congenital heart defects
- Facial abnormalities (e.g., cleft palate, low-set ears)
- Delayed or impaired immune responses