

Chemical Control & Coordination



Key Takeaway

Endocrine system

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Human endocrine system

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Hypothalamus

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Pituitary gland

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Pineal gland

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Hormones



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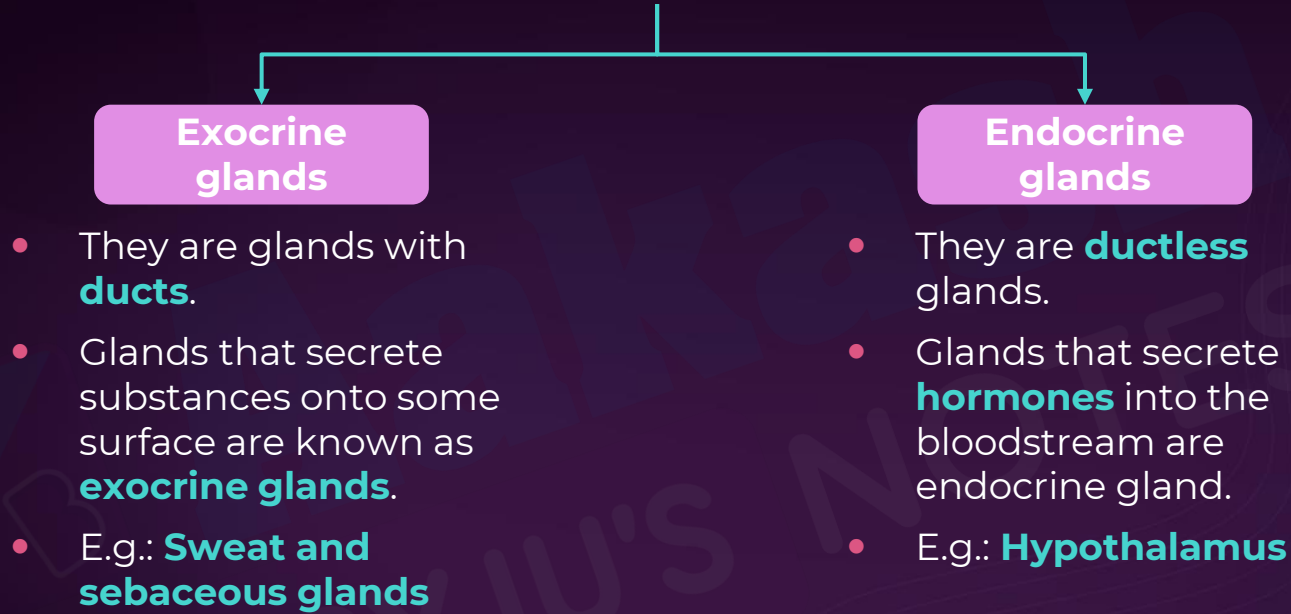
Hormone receptors

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Summary



Glands



Endocrine system

A system of endocrine glands along with hormone producing tissues or cells that are located in different parts of our body is referred to as endocrine system.

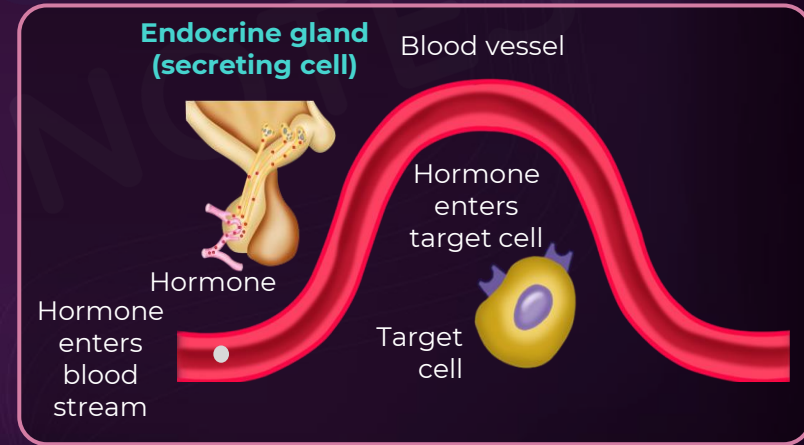
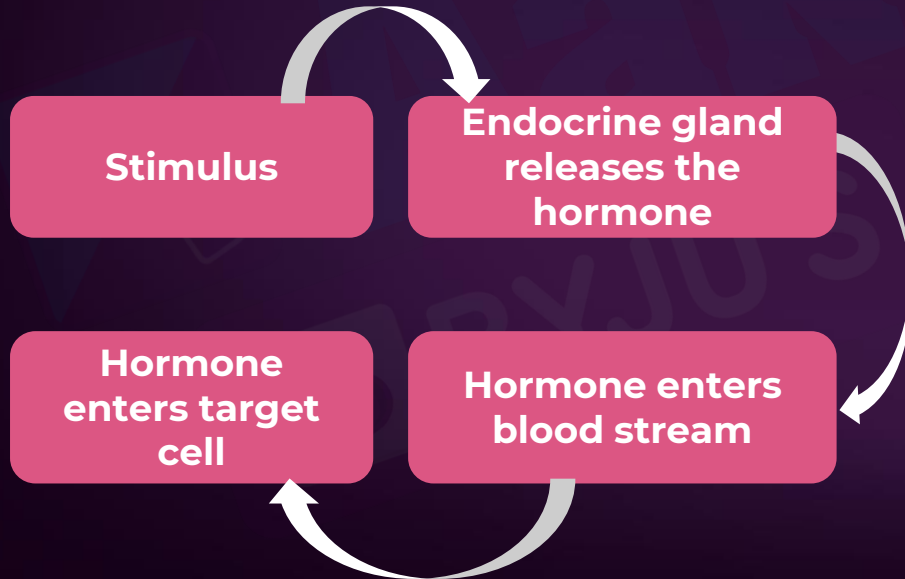
Endocrine system is responsible for **growth and development in our body**.



Endocrine System

Hormones

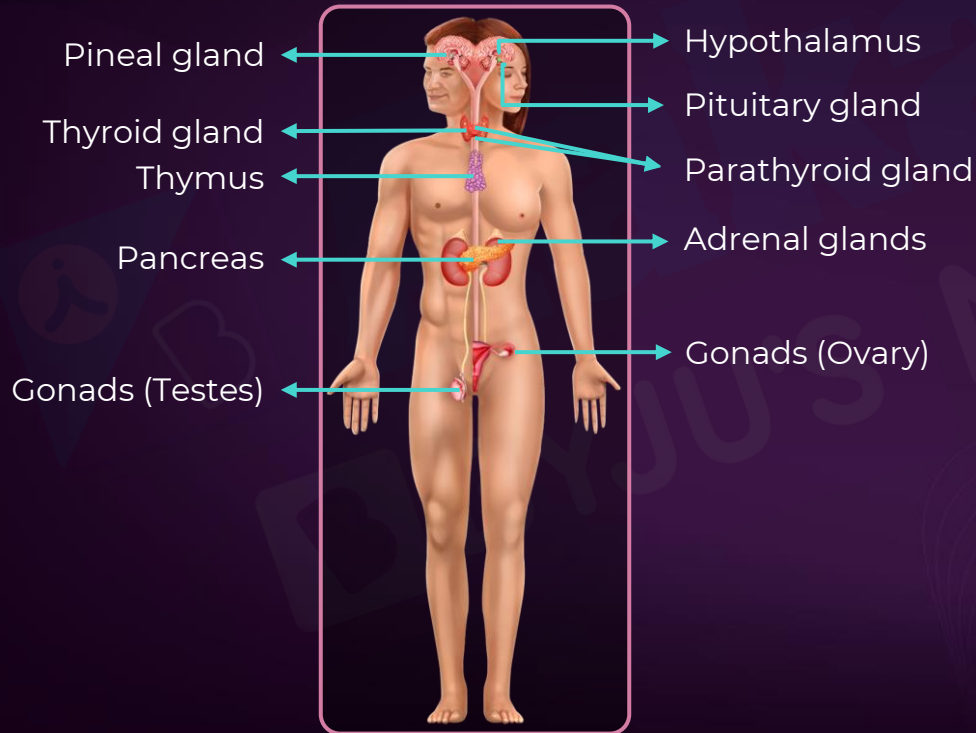
- They are **intercellular chemical messengers** produced in response to a specific **stimulus**.
- They are **non-nutrient** chemicals transported to target cells.
- They are produced in **trace amounts**.





Human Endocrine System

- The major endocrine glands present in the human endocrine system are as follows:



Pituitary gland: Master gland

It is called so because, it **directs the secretion of hormones of all the other glands** in the body.

Hypothalamus: Master control center

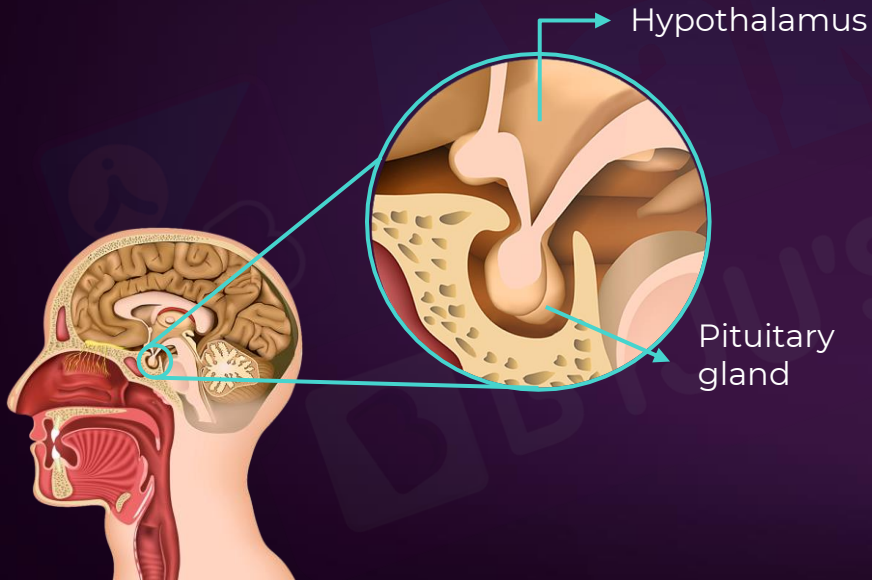
Hypothalamus is called so because, it **controls** and **provides necessary inputs to the pituitary**.



Hypothalamus

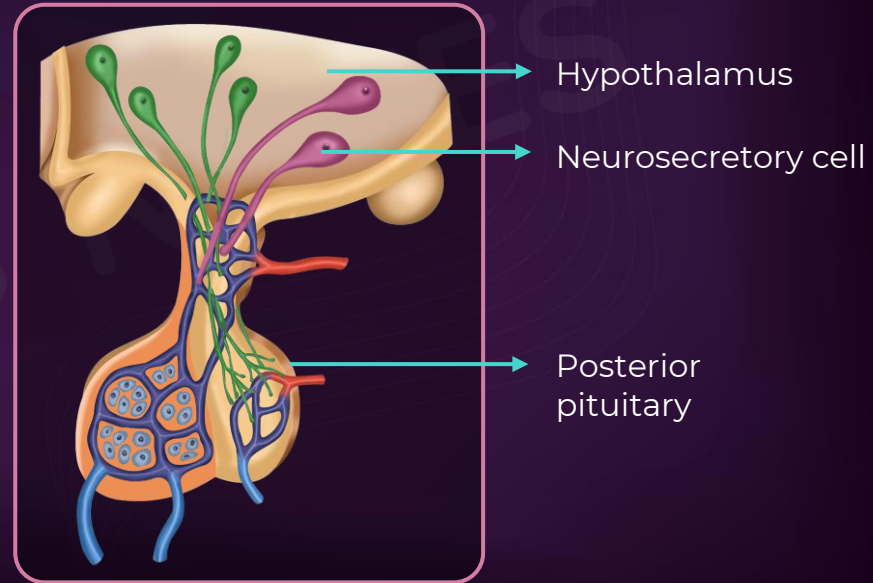
Location

- Hypothalamus is present in the **forebrain** at the **basal part of diencephalon**.



Structure

- Hypothalamus contains **neurosecretory cells**.
 - These cells are also known as nuclei.

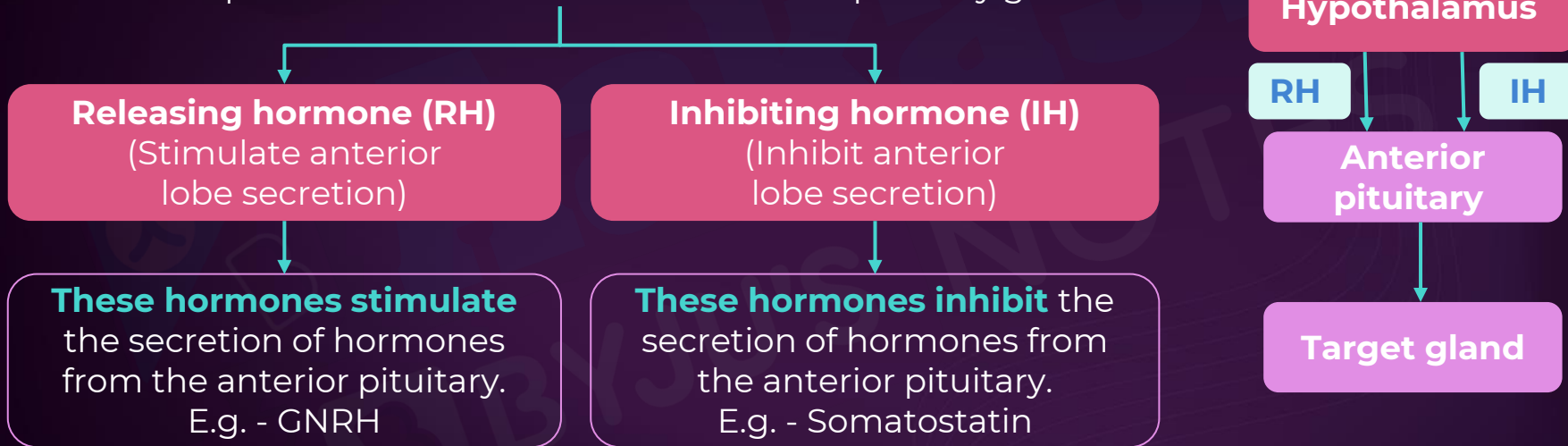




Hypothalamus

Hormones of hypothalamus

The hypothalamus produces hormones that **stimulate** or **inhibit** the hormone production in the anterior lobe of the pituitary gland.



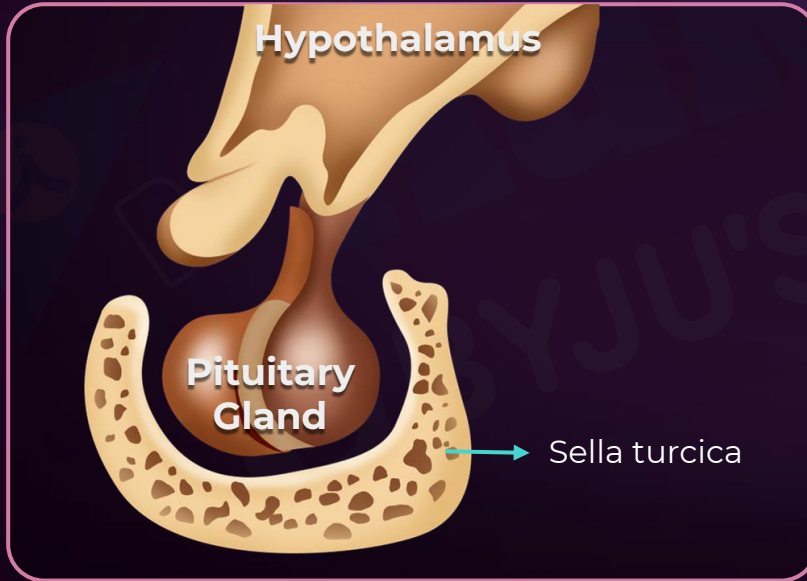
- The releasing and inhibiting hormones reach the pituitary gland through a portal circulatory system.
- The posterior pituitary is under the direct neural regulation of the hypothalamus.



Pituitary Gland

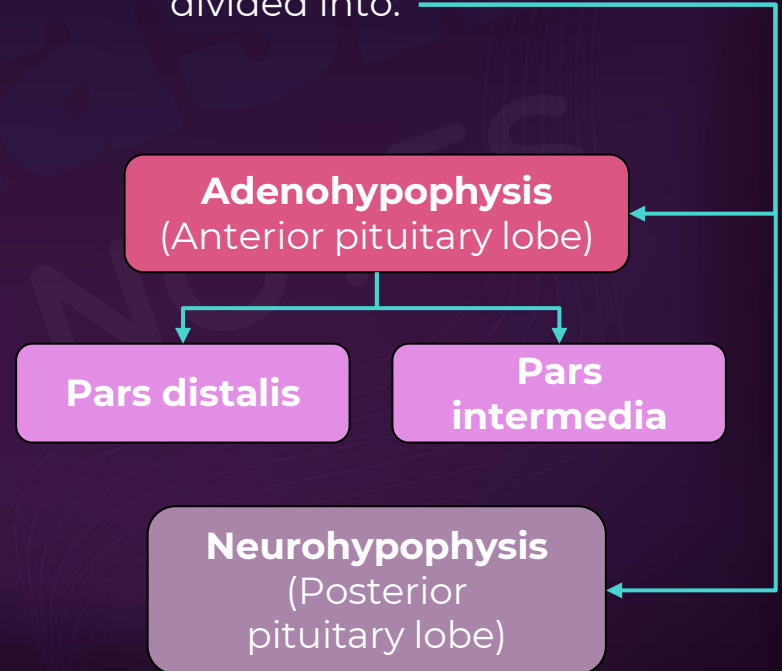
Location

- Pituitary gland is attached to the **hypothalamus by a stalk**.
- It is located inside a bony cavity known as **sella turcica**.



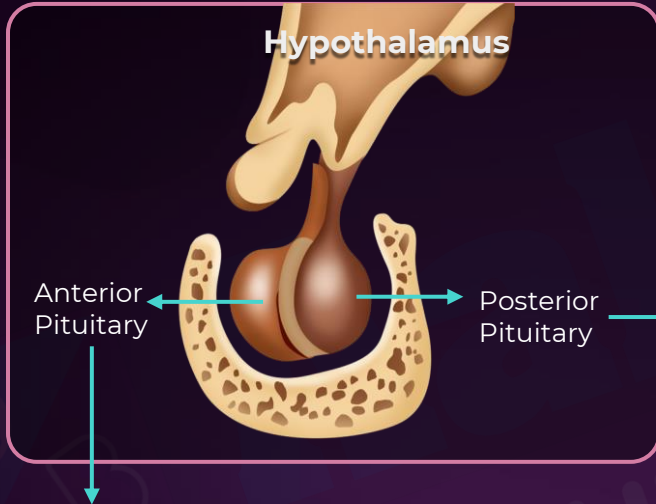
Structure

- Anatomically, pituitary is divided into:



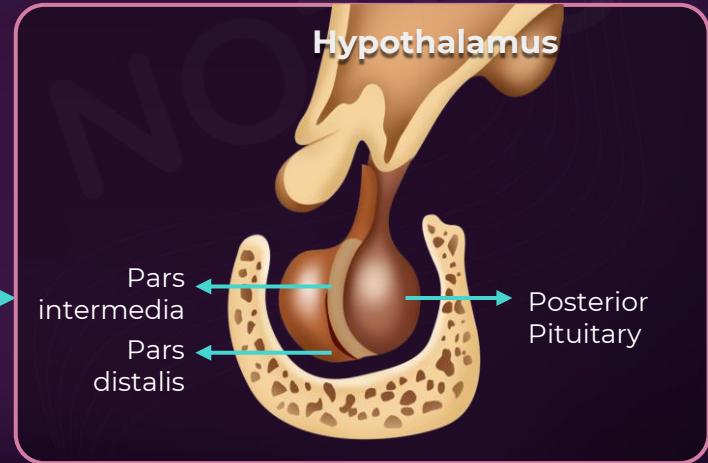


Pituitary Gland



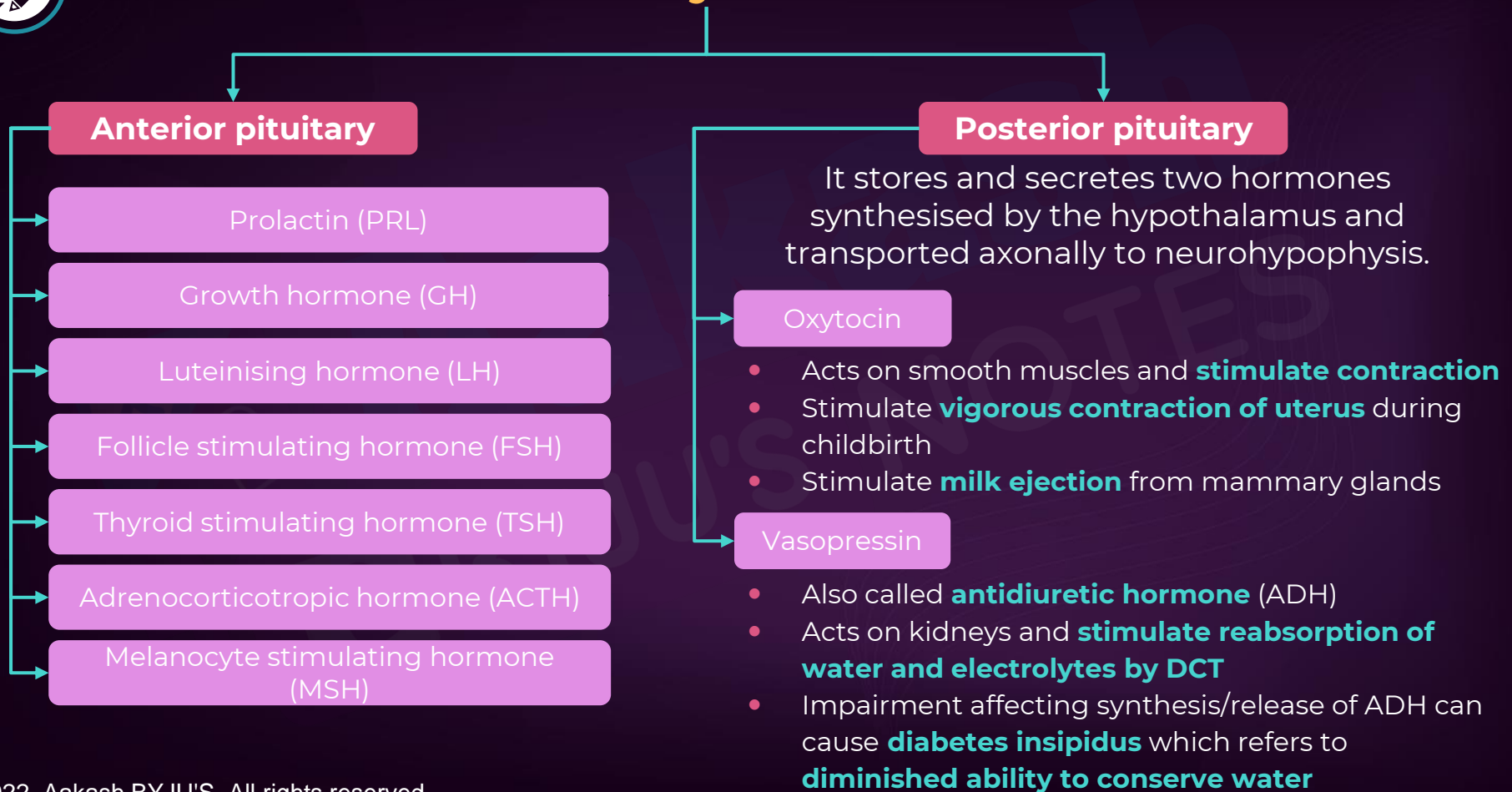
- It houses the axonal terminals of hypothalamic neurons.
- They store and release hormones.

- It consists of two portions, **pars distalis** and **pars intermedia**.
- **Pars distalis** is also known as anterior pituitary.
- In humans, the pars intermedia is almost merged with pars distalis.





Pituitary Hormones



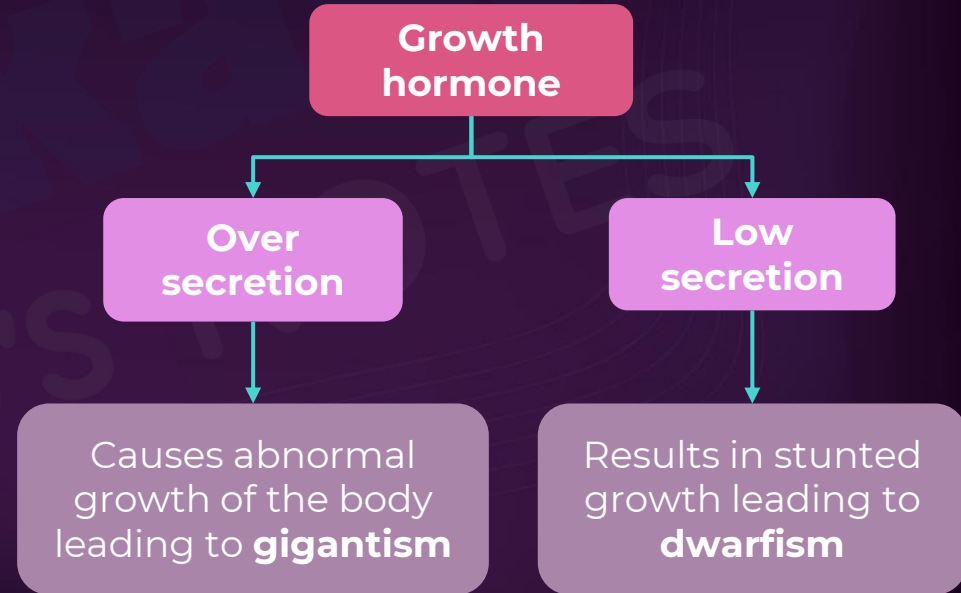


Pituitary Hormones

Anterior pituitary hormones

Growth hormone (GH)

- Growth hormone controls growth of the body.
- The release of growth hormone is controlled by hormones produced by the hypothalamus.
 - **Growth hormone-releasing hormone (GHRH)**
 - **Somatostatin/Growth hormone-inhibiting hormone (GHIH)**





Pituitary Hormones

Anterior pituitary hormones

Luteinising hormone (LH)

It is a gonadotropin
(stimulates gonadal activity)

Role in males

- Stimulates the synthesis and secretion of hormones called **androgens (testosterone)** from **testes**



Role in females

- Induces ovulation of fully mature follicles (Graafian follicles)
- Maintains the corpus luteum, formed after ovulation

Follicle stimulating hormone (FSH)

It is a gonadotropin
(stimulates gonadal activity)

Role in males

- FSH and androgens **regulate spermatogenesis** (process of origin and development of sperm cells).



Role in females

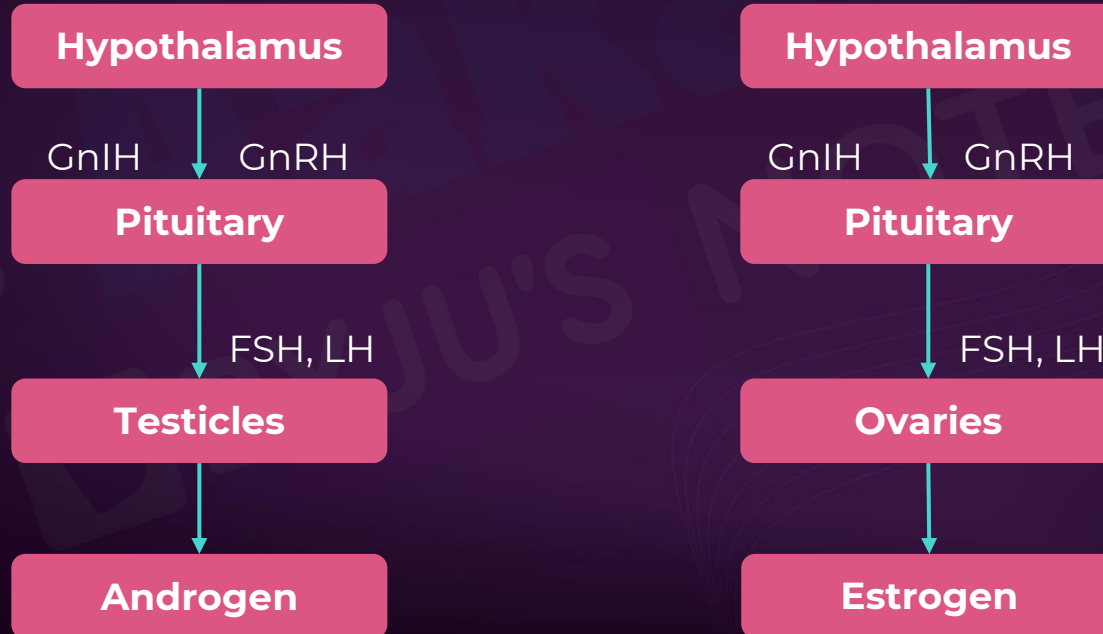
- It stimulates growth and **development of the ovarian follicles.**



Pituitary Hormones

Anterior pituitary hormones - LH & FSH regulation

LH and **FSH** production is controlled by the production of **GnRH** (gonadotropin-releasing hormone) and **GnIH** (gonadotropin-inhibiting hormone) from the hypothalamus.





Pituitary Hormones

Prolactin (PRL)

- It helps in the **production of milk** after childbirth.
- It regulates the **growth of the mammary glands**.
- The release of prolactin is controlled by the hypothalamus.

Melanocyte stimulating hormone (MSH)

- It acts on the **melanocytes** (melanin containing cells) and **regulates pigmentation** of the skin.

Thyroid stimulating hormone (TSH)

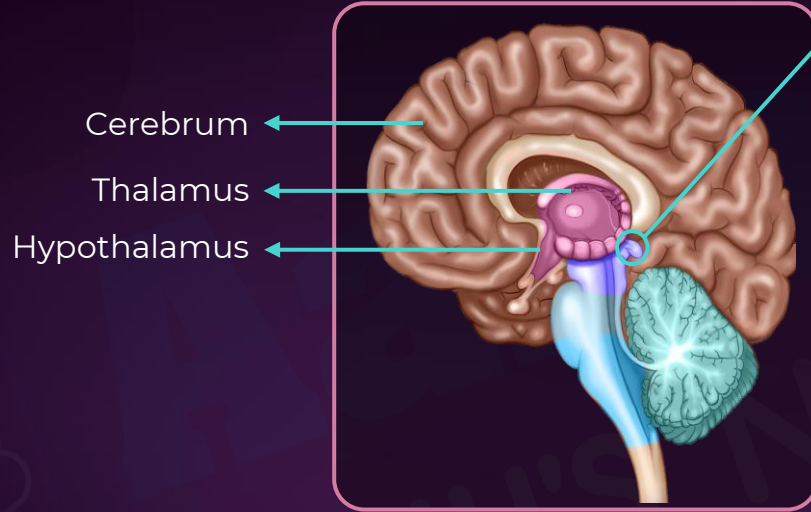
- It is triggered by the thyroid-releasing hormone of the hypothalamus.
- It stimulates the synthesis and **secretion of thyroid hormones**.

Adrenocorticotrophic hormone (ACTH)

- It stimulates synthesis and secretion of steroid hormone called **glucocorticoids**.
- It also stimulates the production of **cortisol**.



Pineal Gland



Pineal Gland

- 'Pineal' is derived from the Latin word '*Pinea*', which means pinecone
- Pea-sized gland
- Located on the dorsal side of the forebrain
- Secretes **melatonin**

- Light inhibits the **secretion of melatonin** from the **pineal gland**.



Pineal Gland

Functions of melatonin

Body clock and pigmentation

- Human **body maintains an internal clock** that responds to outside cues like light and eating habits.
- This clock is **regulated by melatonin**.

Menstrual cycle

- Melatonin also **keeps** the duration of the **menstrual cycle regular**.

Body defence

- Melatonin also **enhances immunity**.

Metabolism and body temperature

- Melatonin **increases metabolism**, which burns body fat.

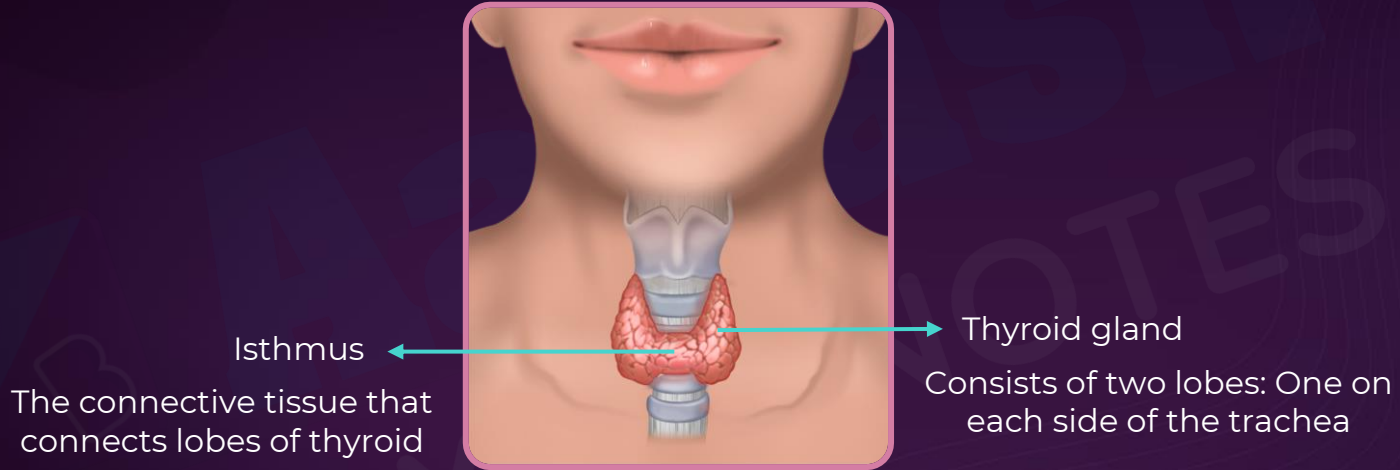
Diurnal rhythm

- The 24-hour sleep-wake cycle is the circadian rhythm.
- The circadian rhythm synced with day and night is the diurnal rhythm.
- **Melatonin maintains the diurnal rhythm**.



Thyroid Gland

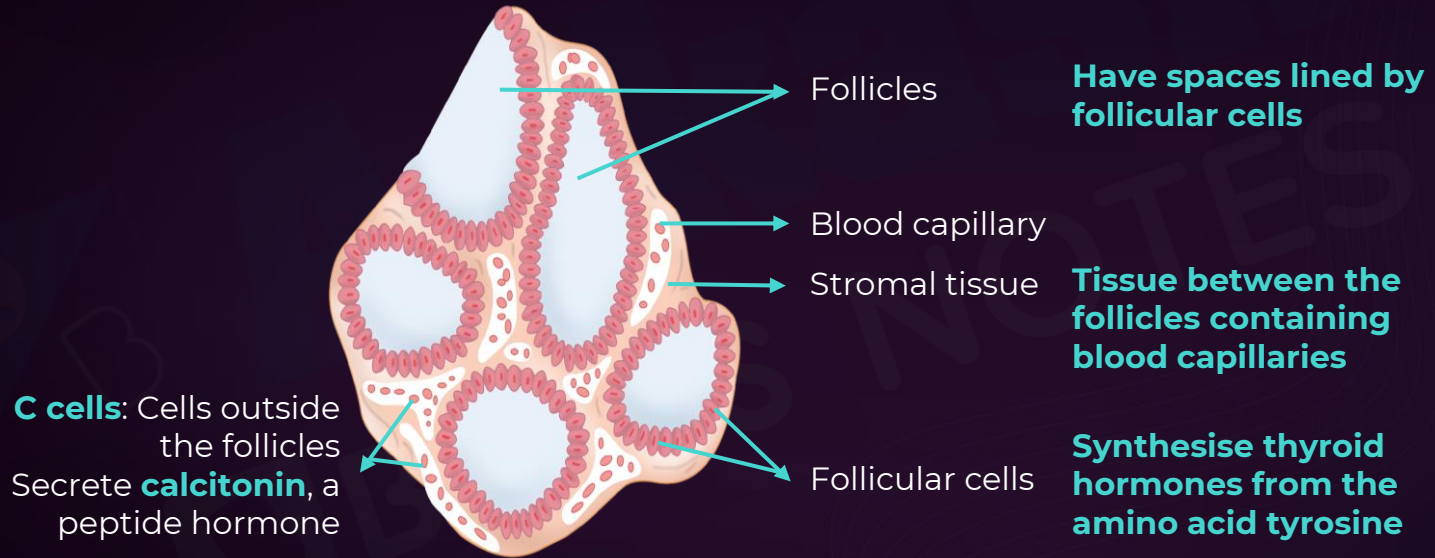
- It is present in the neck, in front of the trachea, or the windpipe.





Thyroid Gland

- It is made up of **follicles** and **stromal tissue**.



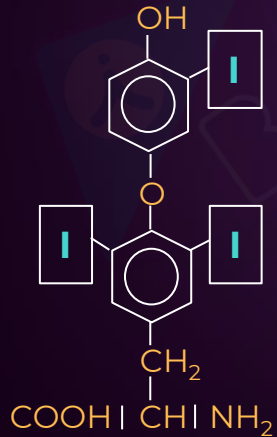


Thyroid Gland

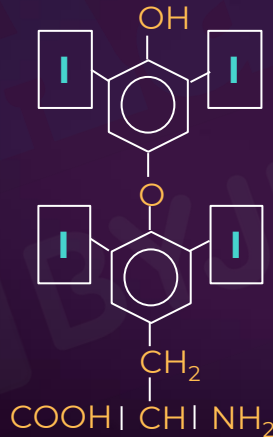
Thyroid hormones

Hormones produced by follicular cells

They are composed of tyrosine



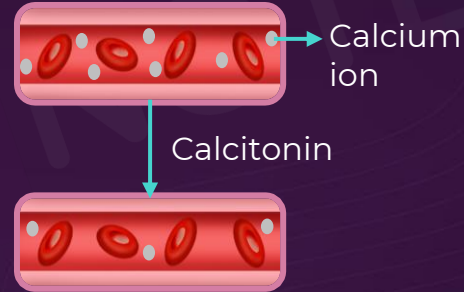
Triiodothyronine (T₃)
(3 iodine atoms)



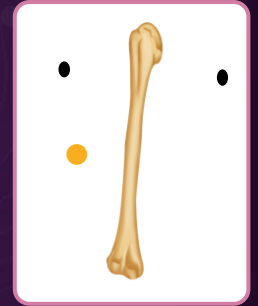
Tetraiodothyronine or thyroxine (T₄)
(4 iodine atoms)

Hormones produced by C-cells

Thyrocalcitonin



- Calcitonin promotes the removal of calcium ions from blood, so that the blood calcium levels fall.

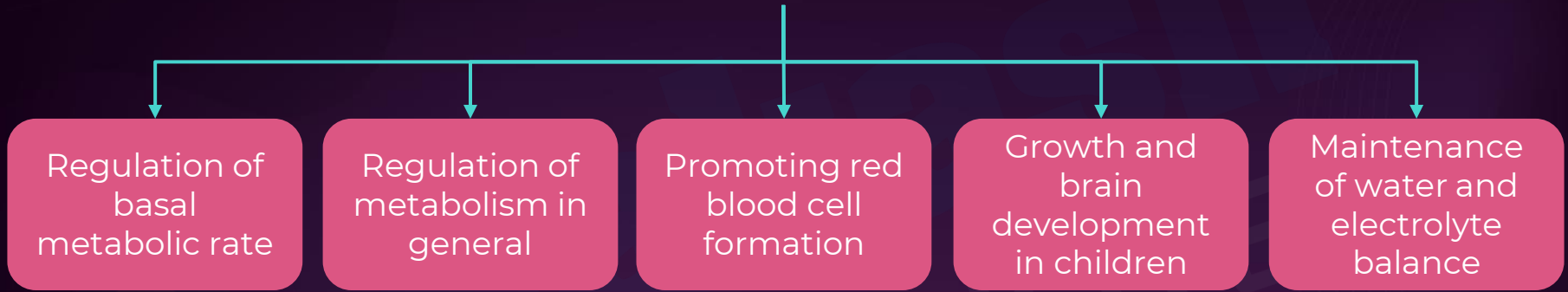


- Calcitonin also promotes the deposition of calcium ions into bones.



Thyroid Gland

Functions of thyroid hormones



Disorders



- Hypothyroidism: Thyroid hormones produced in less quantities than required

- Hyperthyroidism: Thyroid hormones are produced in higher quantities than required



Thyroid Gland

Hypothyroidism

Causes

- Low-iodine diet
- Underactive thyroid gland

Effects

Goitre

Decreased rate of metabolism Effects

- Enlargement of thyroid gland
- Fatigue and sluggishness
- Feeling cold
- Poor memory and concentration
- Constipation
- Weight gain
- Irregular menstrual cycle
- Myxoedema

Cretinism

Decreased growth and brain development of baby

Causes

- Deficiency of iodine in the diet of pregnant woman or the child
- Genetic/congenital defect

Effect

- Stunted growth
- Mental retardation
- Abnormal skin
- Deaf-mutism



Thyroid Gland

Hyperthyroidism

Causes

Graves' disease

- Also called exophthalmic goitre
- Characterised by enlargement of thyroid gland, protruding eyeballs, increased BMR, and weight loss

Thyroid nodule

- Lumps in thyroid, which produce excess thyroid hormones

Effects

- Hyperactivity
- Anxiety
- Weight loss



Parathyroid Gland

- **Location:** Four parathyroid glands are present on the backside or dorsal side and two on each lobe of the thyroid gland.
- **Function:** These glands secrete parathyroid hormone, **parathormone**, or PTH.
- **Chemical nature:** PTH is polypeptide in nature.
- It is a **hypercalcemic** hormone. It raises blood Ca^{2+} in the blood.

Effect of situations on parathyroid hormone

When calcium levels are low in blood

- Acts on **bones** and **stimulates resorption of Ca^{2+}**
- Also stimulates **reabsorption of Ca^{2+}** by the **renal tubules** and increases absorption from the **digested food**

When calcium levels are high in blood

- Production of **parathyroid hormone is reduced**
- Production of calcitonin increases



Thymus

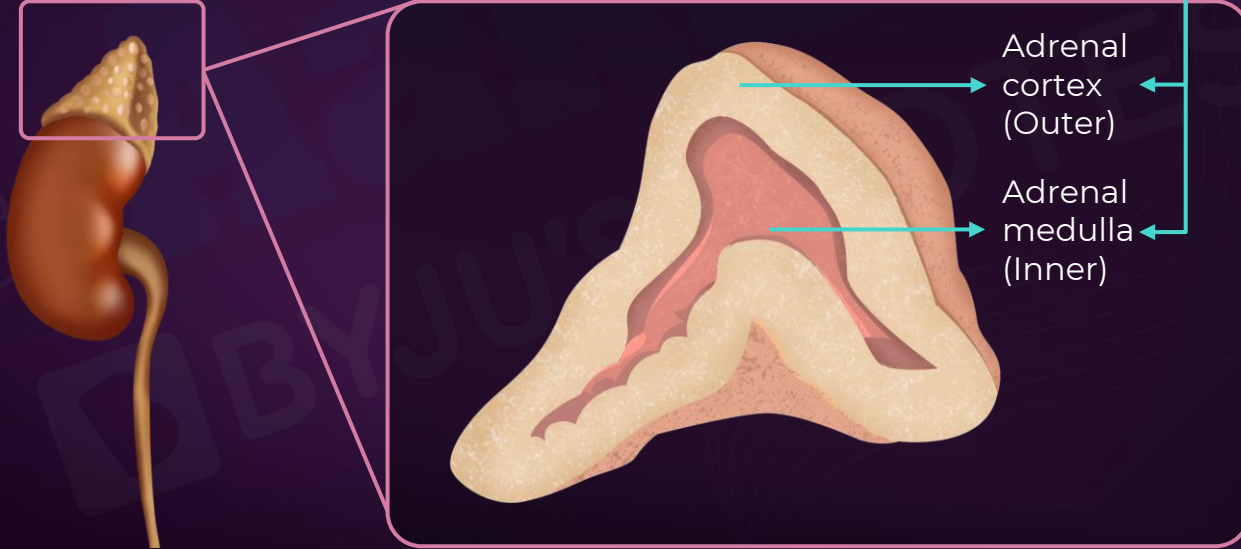
- **Location:** It is located in the chest, behind the sternum, between the lungs, and on the ventral (front) side of the aorta.
- It is not only an endocrine gland, but also plays a very important role in the development of immune system.
- It secretes small peptide hormones known as **thymosin**.
- **Function:** A major role of the thymus is the differentiation of T-lymphocytes.
 - Hence, it is involved in **cell-mediated immunity**.
 - It is also involved in **humoral immunity**, as it **produces antibodies**, though to a lesser extent.
- It gradually reduces in size as a person grows older, resulting in a weaker immune system.



Adrenal Glands

- **Location:** A pair of adrenal glands are located one above each kidney. They are also known as **suprarenal glands**.
- It is made of two regions: _____

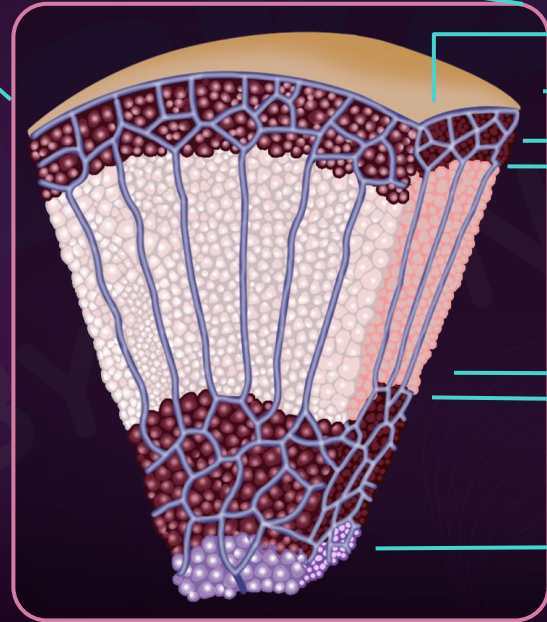
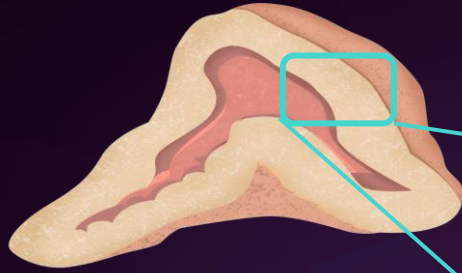
Adrenal glands





Adrenal Glands

Adrenal cortex



Capsule

Zona glomerulosa (Outer zone)
Secretes **mineralocorticoids**

Zona fasciculata (Middle zone)
Secretes **glucocorticoids**

Zona reticularis (Inner zone)
Secretes **gonadocorticoids**

Cortex



Adrenal Glands

Adrenal cortex

Cholesterol

All the hormones of adrenal cortex are synthesized from cholesterol.

Corticoids

Glucocorticoids

- Primarily involved in carbohydrate metabolism
- **Cortisol** - main and the **most abundant glucocorticoid**
- Other two **corticoids** are **cortisone** and **corticosterone**
- Known as a **stress hormone**, as it is released during stress
- Acts mainly on the **cells of the liver**

Mineralocorticoids

- Responsible for the **regulation of water and electrolyte balance**
- **Aldosterone**- principal and the **most abundant mineralocorticoid**
- Acts on the **cells of the kidney**

Gonadocorticoids

- Gonadocorticoids are also known as the sex hormones of **adrenal glands**



Adrenal Glands

Adrenal cortex

Functions of glucocorticoids

Gluconeogenesis

- Conversion of non-carbohydrates (like glycerol or amino acids) to carbohydrates

Proteolysis

- Breakdown of proteins into amino acids in blood
- Inhibits cellular uptake & utilisation of amino acids

Lipolysis

- Breakdown of fats in adipose tissue to fatty acids in bloodstream

Anti-inflammatory and immunosuppressant

- Suppresses immune response (Production of antibodies)
- Mostly produced by cortisol

Cortisol maintains cardiovascular and kidney functions

- Increases RBC production



Adrenal Glands

Adrenal cortex

Functions of mineralocorticoids (Aldosterone)

Maintenance of body fluid volume, osmotic and blood pressure:

- Expulsion of K^+ and phosphate ions
- Reabsorption of Na^+ and water

Functions of gonadocorticoids

Male sex corticoids (act on testes)

Androgens

Produced in large quantities

Female sex corticoids (act on ovaries)

Progesterone

Estrogen

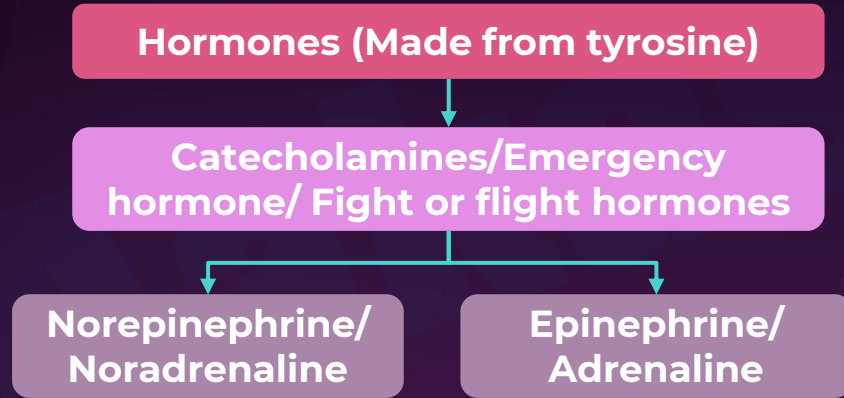
Produced in small quantities

- They also promote development of secondary sexual characters.



Adrenal Glands

Adrenal medulla

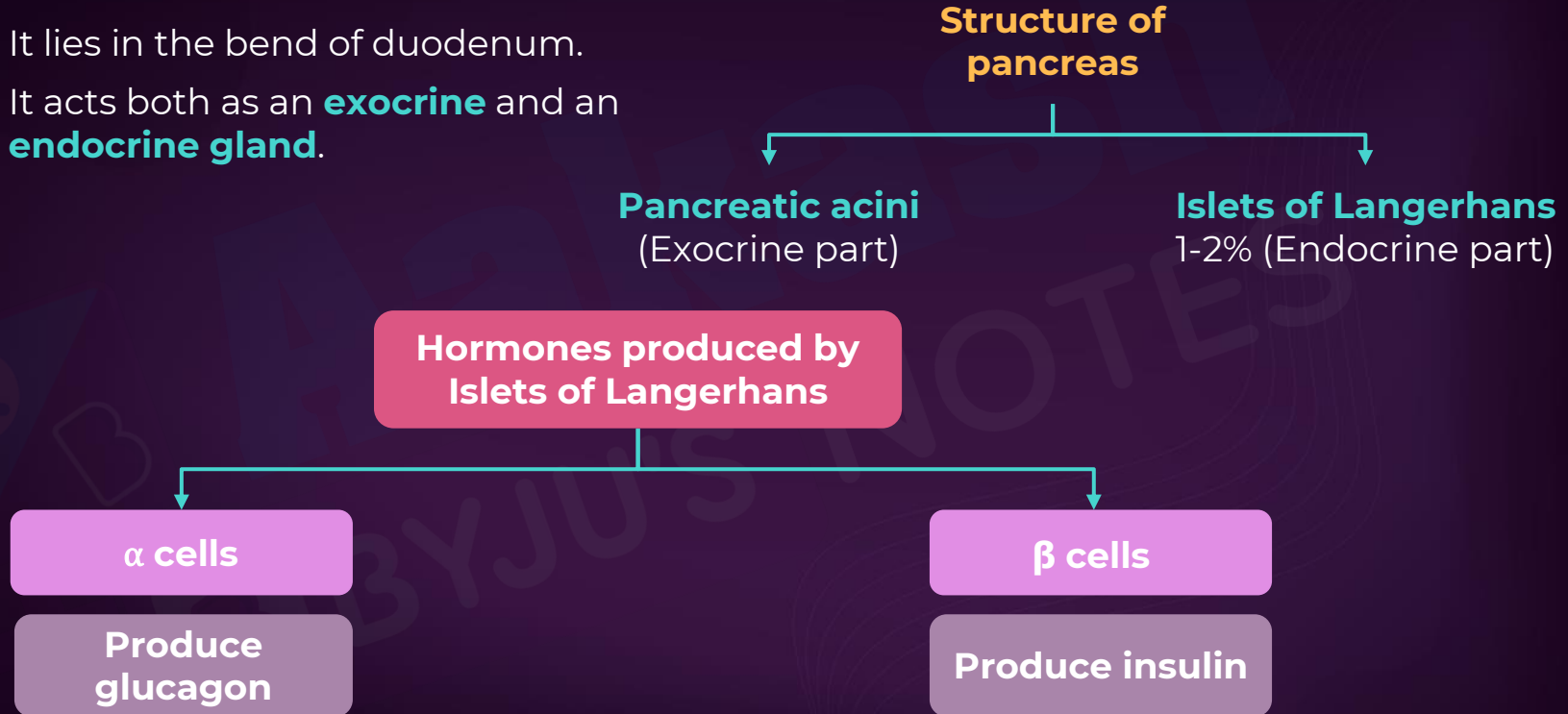


- Secreted during **stress and emergency situations**
- Breakdown glycogen and **increase blood sugar levels**
- Act on cells of skeletal, cardiac and smooth muscles, blood vessels and fat cells.
- Increase **alertness**, pupillary dilation, piloerection, **sweating**, heart rate and breathing
- Stimulate the breakdown of lipids and proteins.



Pancreas

- It lies in the bend of duodenum.
- It acts both as an **exocrine** and an **endocrine gland**.





Pancreas

Hormonal impact

Hyperglycemia (Diabetes mellitus)

- Prolonged hyperglycemia leads to a complex disorder known as **diabetes mellitus**.
- It leads to a **loss of glucose through urine** and the formation of harmful compounds known as **ketone bodies**.
- In diabetes, the body begins to uptake fatty acids from the blood to provide energy.
- Treatment: **Insulin therapy**

Hypoglycemia

- It leads to a **decrease in the blood glucose level** below normal.
- **Insulin** acts mainly on hepatocytes and adipocytes (cells of adipose tissue), and **enhances cellular glucose uptake** and utilisation.
- This can lead to glucose shortage in blood.



Pancreas



Glucagon

- **Acts** mainly on the **cells of the liver** (hepatocytes).
- Stimulates **glycogenolysis**, (**conversion of glycogen into glucose** in the liver).
- Stimulates **gluconeogenesis** (**formation of glucose** from non-carbohydrate precursors).
- Glycogenolysis and gluconeogenesis increase the blood sugar level, known as **hyperglycemia**.
- **Hyperglycemic hormone**

Insulin

- **Stimulates glycogenesis**, which is the **conversion of glucose into glycogen**.
- Insulin enhances the rapid movement of glucose from blood into hepatocytes and adipocytes.
- Decreases the blood glucose level, known as **hypoglycemia**.
- **Hypoglycemic hormone**



Testes

- A pair of testes are present in the scrotal sacs outside the abdominal cavity of males.
- It performs **dual functions** as the primary sex organ as well as an endocrine gland.

Structure of testes



Seminiferous tubules

- Seminiferous tubules contain epithelium consisting of **Sertoli cells** and **spermatogonia**.
- **Sertoli cells nourish sperms and spermatogonia produce sperms.**

Interstitial tissue

- The **Leydig cells** or interstitial cells are present in the interstitial/stromal tissue.
- Leydig cells are **responsible for the synthesis of androgens** (male sex hormones).



Testes



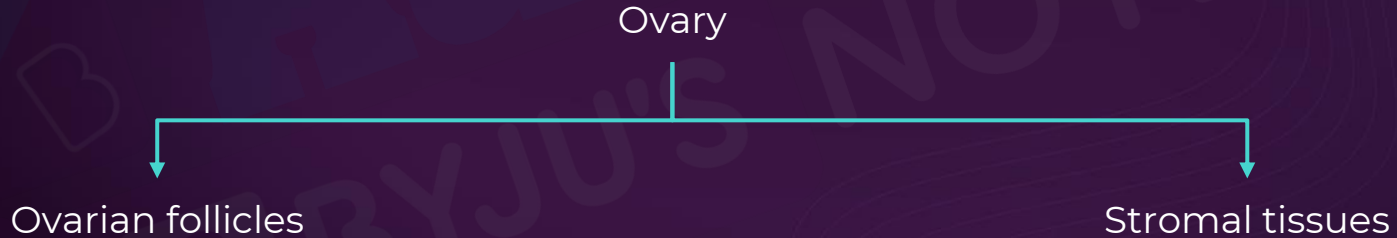
- **Role of androgens**

- They play a **stimulatory role** in the process of **spermatogenesis** (production of sperms).
- They act on the central neural system and **influence the male sexual behaviour** (libido).
- They **regulate** protein and carbohydrate **metabolism**.
- They regulate the development, maturation, and functions of the male accessory sex organs like epididymis, vas deferens, seminal vesicles, prostate gland, urethra, etc.
- They **promote growth of body tissues** like bones and muscles.
- They play a **vital role** in the development of **secondary sexual characters**.



Ovary

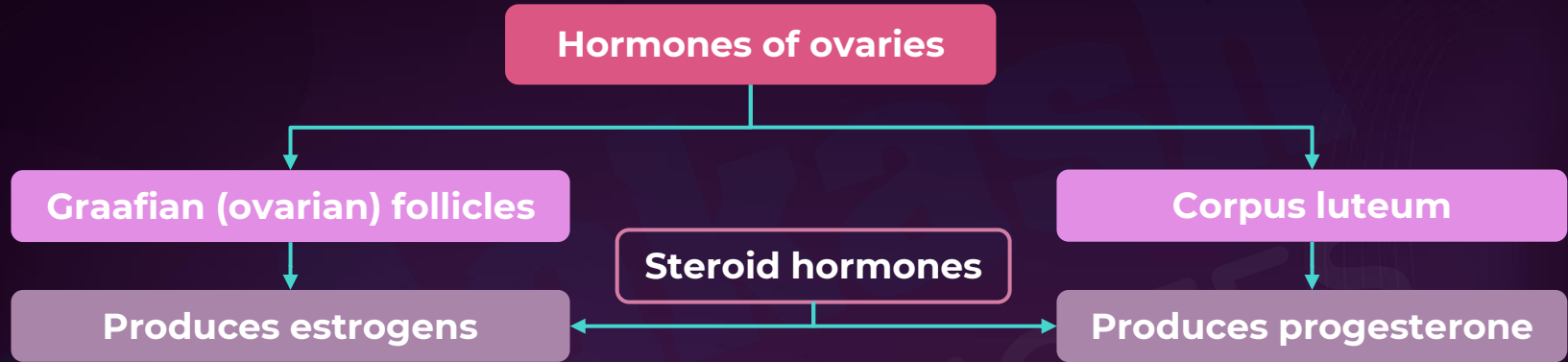
- Females have a **pair of ovaries** located in the **pelvic cavity**.
- It also has dual functions like the testes.
- Ovary is the primary female sex organ, which **produces** one **mature ovum** during each menstrual cycle.
- In addition to that, the ovary also **acts as an endocrine gland** and **produces hormones**.



- After ovulation (release of ovary), the **ruptured graafian follicle** is converted to a structure known as **corpus luteum**.



Ovary



- **Estradiol** is the principal estrogen.
- Functions of estrogen:
 - Stimulates **development** and **maturation** of growing **ovarian follicles**
 - Helps in **maturation of ova** in the ovaries
 - Controls **female sexual behaviour**
 - Helps in development of **female secondary sexual characters**
 - Stimulates **mammary gland development**

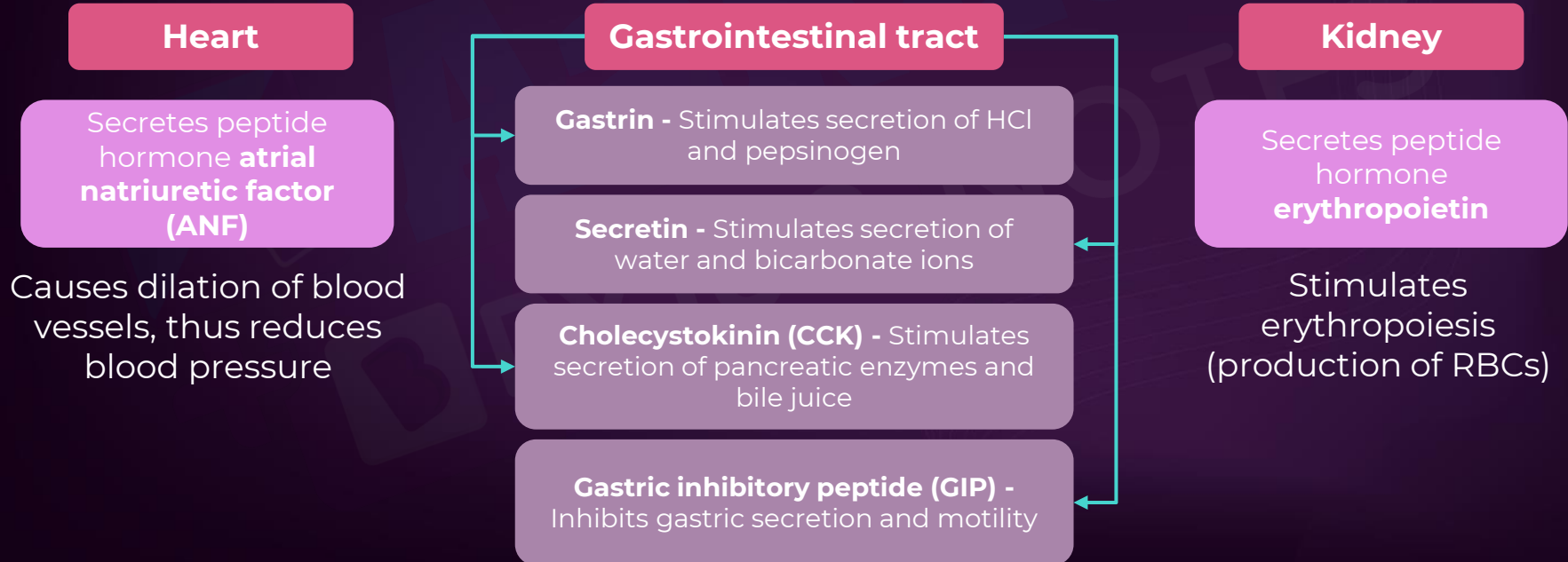
- Functions of progesterone:
 - Stimulates the **development** of **uterine endometrium**
 - Acts on the mammary glands and **stimulates** the **formation of alveoli** and **milk secretion**
 - Also secreted by the placenta during pregnancy



Hormones Secreted by Non-Endocrine Glands



- Hormones are secreted not only by endocrine glands.
- They are also produced by other organs such as the heart, kidney, and gastrointestinal tract.
- These organs have endocrine cells that secrete hormones.





Types of Hormones

Based on chemical nature

Peptide,
polypeptide,
and protein

Insulin,
glucagon,
pituitary
hormones,
hypothalamic
hormones,
etc.

Steroids

Cortisol,
testosterone,
estradiol,
progesterone,
etc.

Iodothyronines

Thyroid hormone

Amino acid
derivatives

Epinephrine

Based on solubility

Lipid
soluble

Steroids and
Iodothyronines

Water
soluble

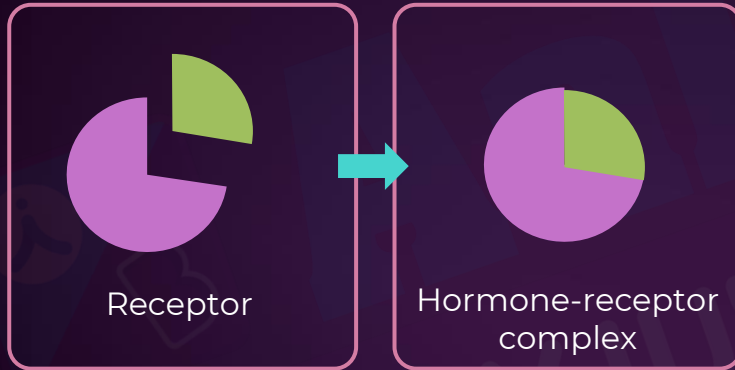
Peptides,
polypeptides,
protein
hormones,
amino acid
derivatives

Note: Several non-endocrine tissues secrete hormones called **growth factors**. These factors are essential for the normal growth of tissues and their **repairing/regeneration**.



Hormone Receptors

Hormones in our body act like **chemical messengers** that relay signals from the endocrine glands and deliver it to the target tissues by binding specifically to them.



Hormone

- Like a specific lock to the key, hormones have specific proteins called **receptors**.
- Hormones and receptors perfectly fit with each other.
- These receptors are present only on **target cells**.

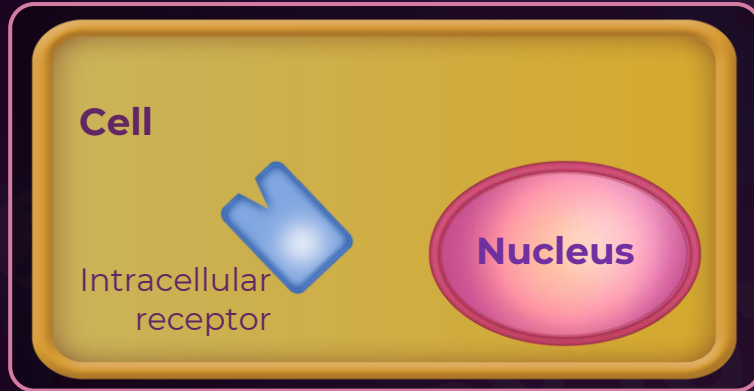


- When the hormone binds to a receptor protein, it forms a **hormone-receptor complex**.
- This complex leads to certain biochemical changes in target tissue.



Hormone Receptors - Types

Intracellular receptors



Intracellular receptors are present inside membrane of the target cell.

Membrane receptors



Membrane receptors are present on the cell membrane of the target cell. Membrane receptors are also called **extracellular receptors**. These act as first messengers.



Hormone Receptors

Types of hormones based on interaction with receptors

Hormones which interact with membrane-bound receptors

- They generate second messengers (e.g., cyclic AMP, IP_3 , Ca^{2+} etc) which in turn regulate cellular metabolism.
- They do not enter the target cell.
- E.g., protein hormones

Hormones which interact with intracellular receptors

- They mostly regulate gene expression or chromosome function by the interaction of hormone-receptor complex.
- They enter the target cell.
- E.g., steroid hormones



Summary

Endocrine system
(A system of endocrine glands along with hormone-producing tissues or cells)

Hypothalamus
(Master control centre)

Pituitary gland
(Master gland)

Pineal gland

Thyroid gland

Parathyroid gland

Thymus

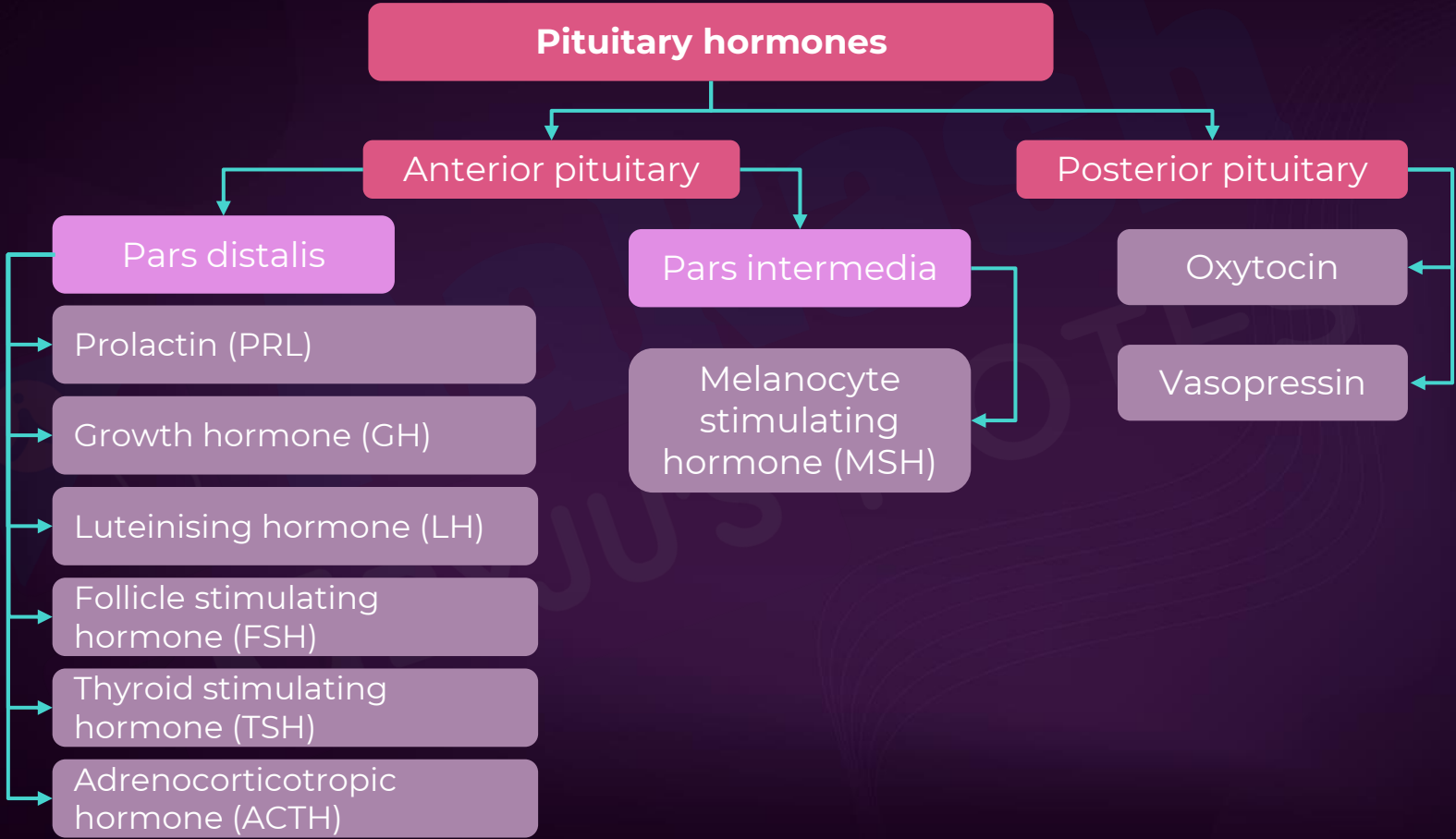
Pancreas

Adrenal gland

**Gonads- Testes
and ovaries**



Summary





Summary

Pineal gland

- Hormone: Melatonin
- Functions:
 - Maintains diurnal rhythm
 - Regulates body temperature, metabolism, menstrual cycle
 - Enhances immunity

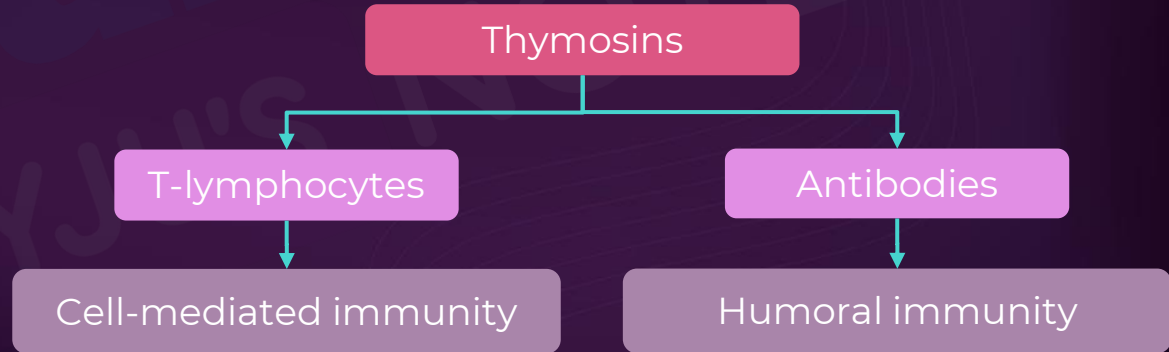
Thyroid gland

- Thyroid hormones
 - T_3 and T_4
 - Calcitonin
- Thyroid disorders
 - Hypothyroidism
 - Hyperthyroidism

Parathyroid gland

- Regulates blood calcium level by tackling deficiency of calcium in blood

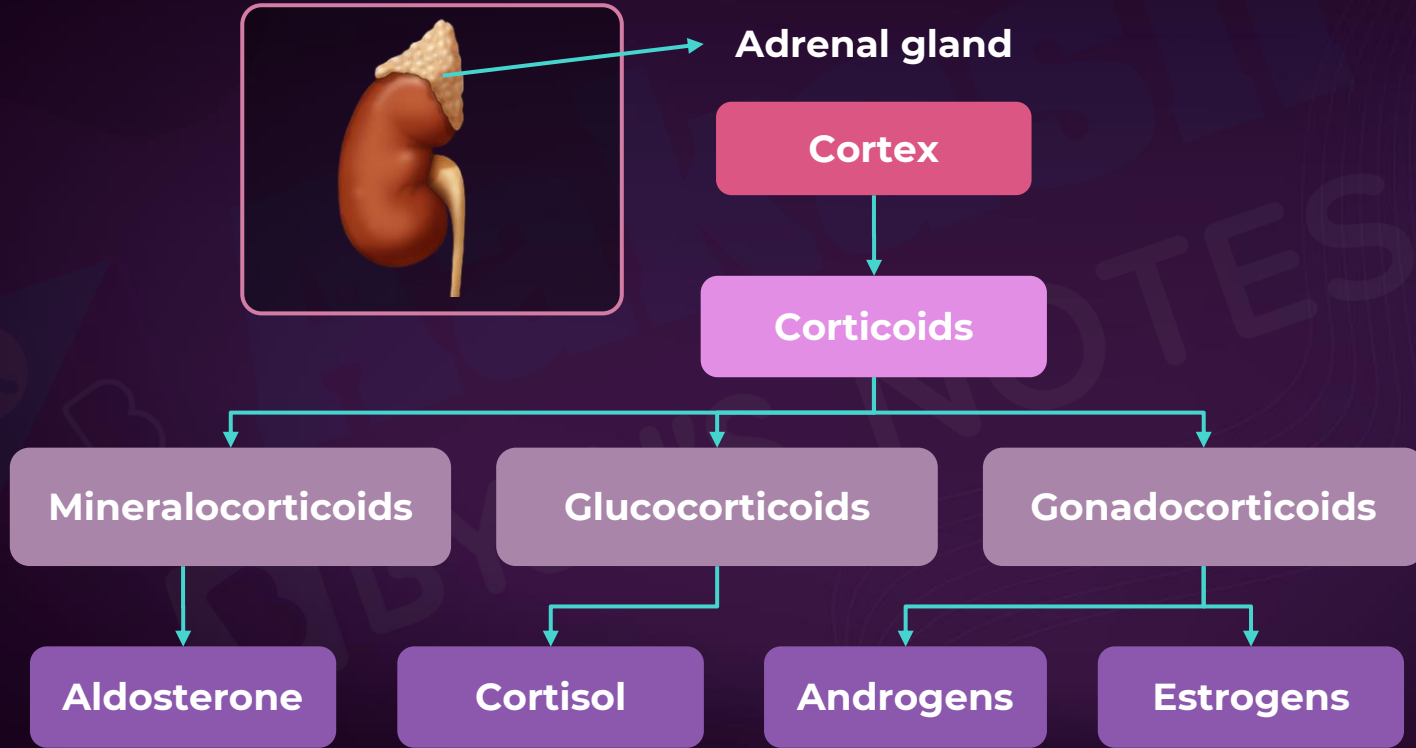
Thymus gland



Thymus gland plays a vital role in our immune system as the T-lymphocytes mature and differentiate in it.

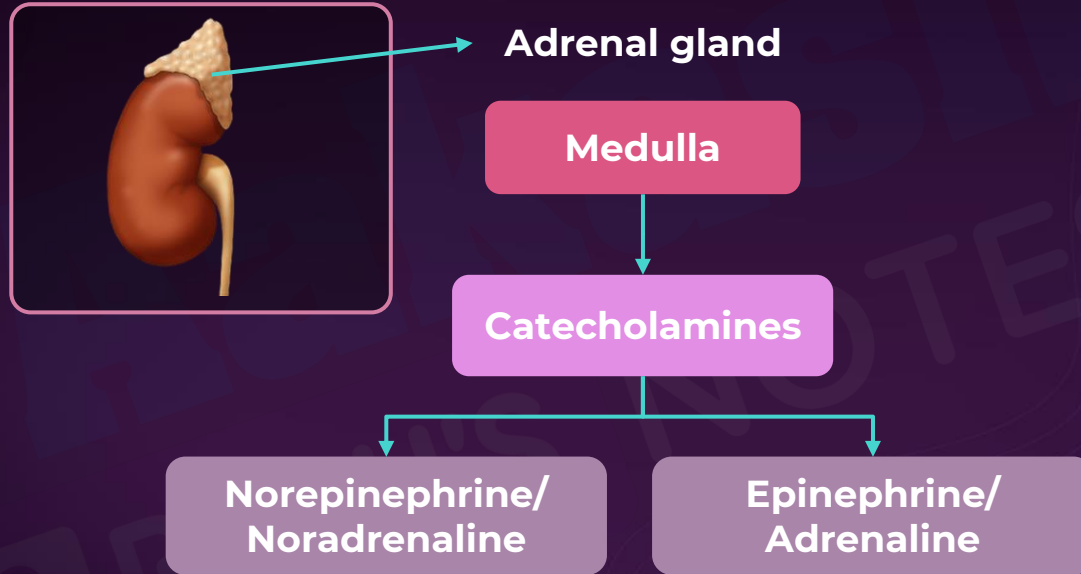


Summary





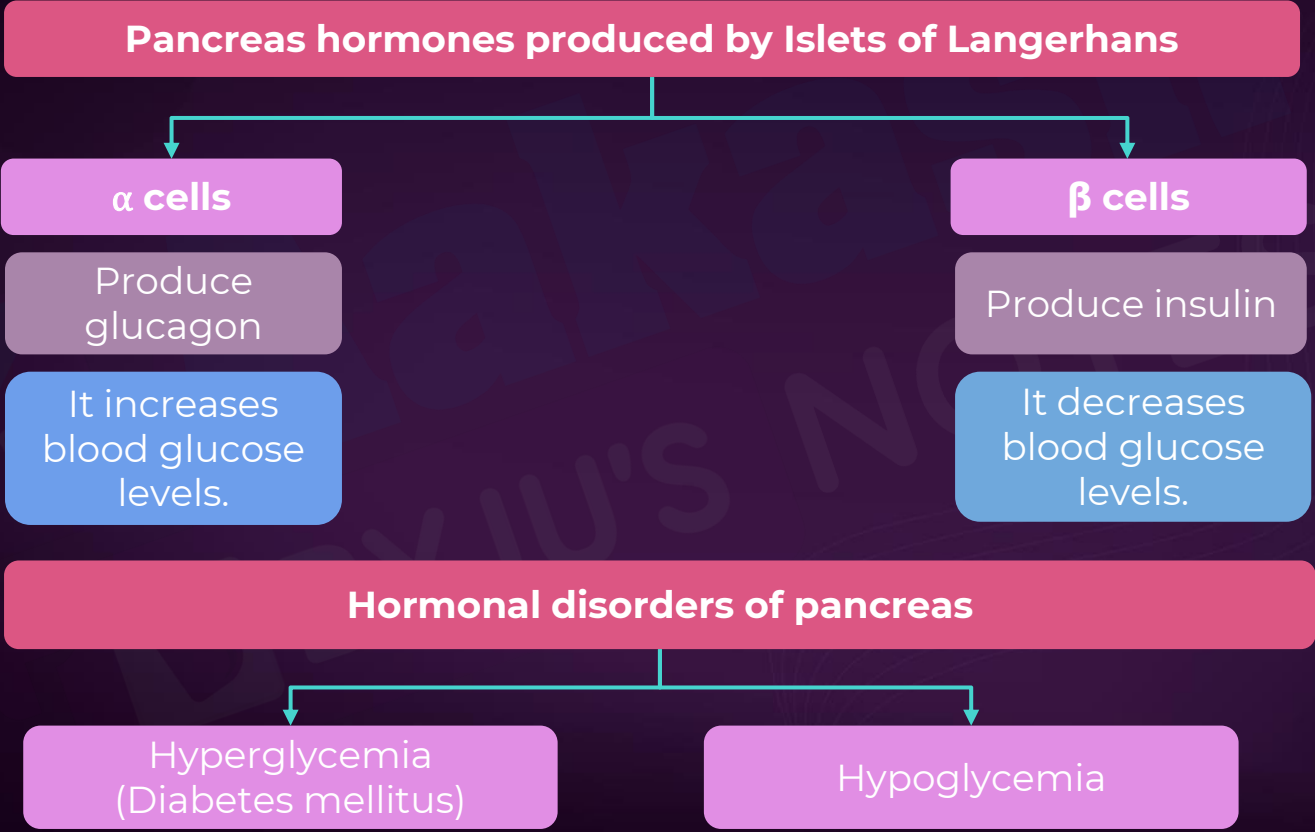
Summary



Emergency hormones or hormones of fight or flight

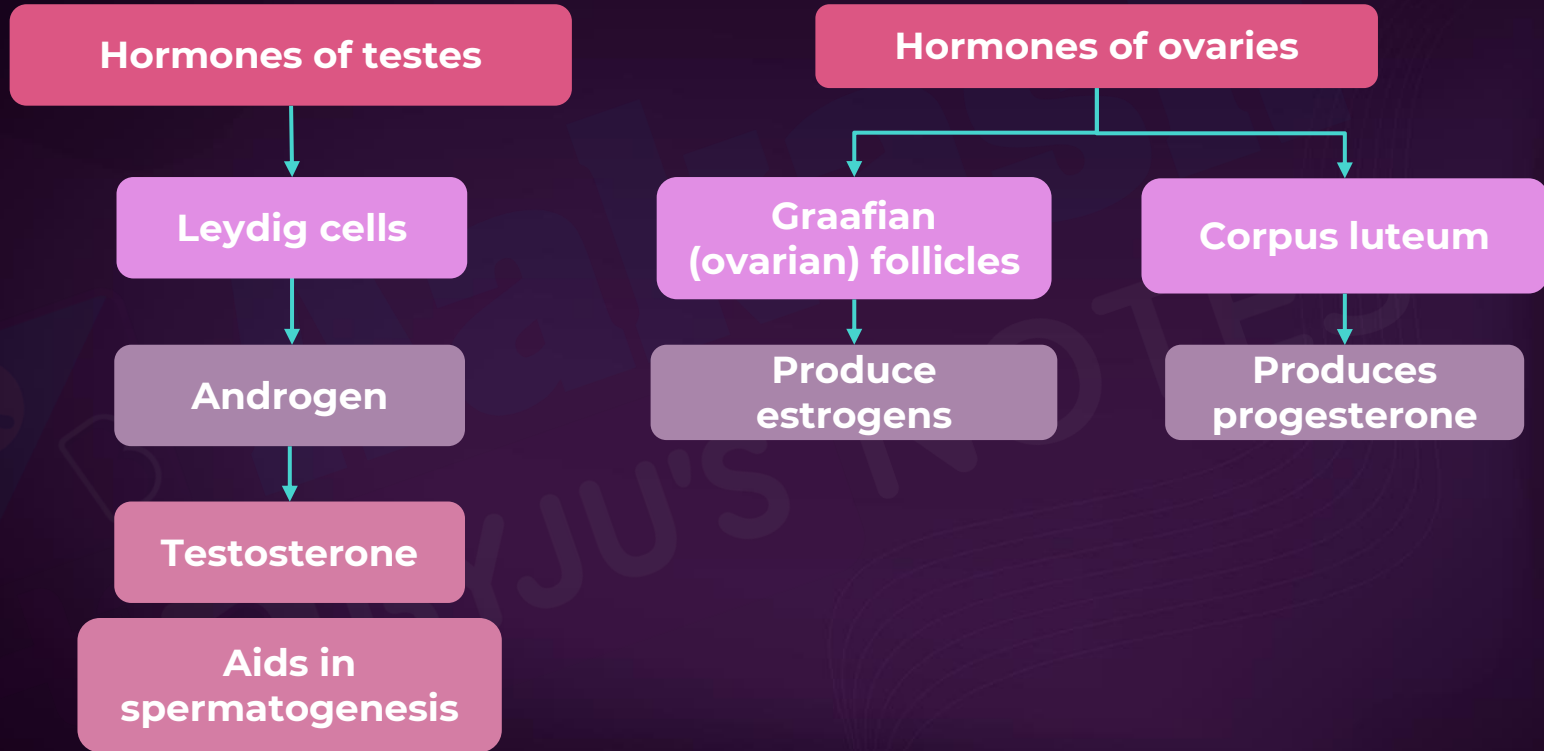


Summary





Summary





Summary

Hormones of heart, kidney and GI tract

Heart - ANF

**Gastrointestinal tract -
Gastrin, secretin, CCK, GIP**

**Kidney -
Erythropoietin**

Types of hormones

**Based on
chemical nature**

**Based on
solubility**

Peptide,
polypeptide,
and protein

Steroids

Iodothyronines

Amino acid
derivatives

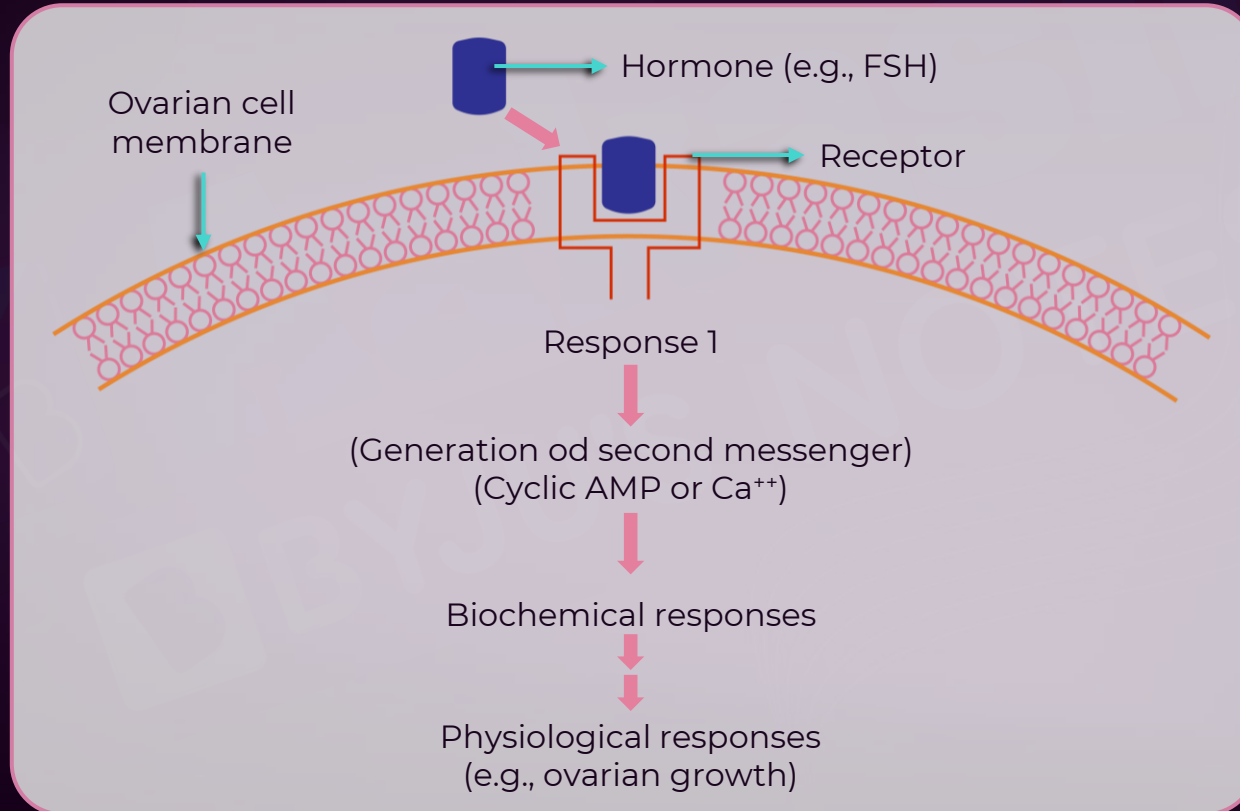
Lipid
soluble

Water
soluble



Summary

Mechanism of action for protein hormone





Summary

Mechanism of action for lipid hormone

