Chapter 45

Endocrine System

- **Endocrine system** are those systems which generally control long term activities of target organs as well as physiological process such as digestion, metabolism, growth, development and reproduction in contrast to more rapid activities under the control of nervous system either directly or indirectly.
- The endocrine system carries out a wide variety of physiological processes through chemical messengers called "**hormones**."
- Endocrine system **comprise endocrine glands and their hormones**.
- **Gland** is an organ, tissue or cell that secretes a chemical for performing a particular function.
- **Types of glands** are - exocrine, endocrine and heterocrine.
- **Exocrine gland** is a gland whose secretions perform metabolic activity on the surface or into a particular region by means of ducts. Eg. sebaceous gland, salivary gland, liver etc.
- **Endocrine gland** is an isolated gland that pour their secretion directly into venous blood or lymph for passage to different organs in order to control their growth, function, metabolism etc.
- Endocrine gland is also called as **ductless gland**.
- **Heterocrine gland** (mixed gland) consists of both exocrine and endocrine region.
- **Endocrinology** is the study of endocrine glands, hormones and their effect.
- Father of endocrinology was **Thomas Addison**.
- The major glands that make up the human endocrine system are the pineal body, hypothalamus, pituitary, thyroid, parathyroids, adrenals and the reproductive glands (the ovaries and testes).
- The pancreas is also part of this hormone secreting system, even though it is also associated with the digestive system because the exocrine part of the pancreas also produces and secretes digestive enzymes into the intestine.
- Although the endocrine glands are the body's main hormone producers, some non-endocrine organs - such as the brain, heart, lungs, kidneys, liver, thymus, skin, and placenta - also produce and release hormone.
- **Hormones** are chemical regulators or chemical messenger of the body which are secreted in response to changes in the environment inside or outside the body.
- **Lag period** is a period between the secretion of hormone from endocrine gland and biological response from target organ.
- **First hormone** discovered in 1902 **by Bayliss and Starling** was **secretin**.
- Hormones may be **excitatory** or **inhibitory** in their effects.
- **On the basis of their chemical composition**, hormones may be **divided into three categories** – amine hormones, steroids and proteinaceous and peptide hormones.
- **Amine hormones** are derived from tyrosine amino acids and have amino group, eg. thyroxine, epinephrine and nor-epinephrine.
- **Steroids** are fat soluble and have sterol group. They are derived from cholesterol, eg. hormones of adrenal cortex, testis and ovaries.
- **Proteinaceous and peptide hormone** are water soluble and includes hormones of hypothalamus, pancreas and pituitary.
- Hormones can be divided into **lipophilic** (lipid soluble) and **hydrophilic** (water soluble).
- The **lipophilic hormones**, all of the steroid hormones and thyroxine as well as other lipophilic regulatory molecules (including the retinoids, or vitamin A) can easily enter cells. This is because

the lipid portion of the cell membranes does not present a barrier to the entry of lipophilic regulators.

- **Water soluble hormones** in contrast can not pass through cell membranes. They must regulate their target cells through different mechanisms.
- **Hormone action at the cellular level** begins with the association of the hormone and its specific receptor.
- Hormones can be **classified by the location of the receptor** and **by the nature of the signal or second messenger** used to mediate hormone action within the cell.
- **Hormone receptors are found** either exposed **on the surface of the cell** or **within the cell (cytoplasm)**, depending on the type of hormone.
- **Peptide hormones** usually **act at a specific receptor on the plasma membrane**. The signal is then communicated to the cytoplasm by one of the signal transduction pathways (e.g., *via* a receptor, G proteins, adenylyl cyclase, AMP, and kinase).
- **Steroids**, produced by endocrine glands of mesodermal origin, easily **pass through both the plasma and nuclear membranes**.
- Steroid bind with a specific Hormone Response Element (HRE) in the nucleus to activate DNA transcription.
- The thyroid hormone's mechanism of action resembles that of the steroid hormones.
- Hormone action is **usually short-lasting** because hormones are **catabolised by the liver**.
- Hormones which control activity of other endocrine glands and/or growth are called **trophic hormones**.
- When two hormones work together it is called **synergistic hormone**. Eg. FSH & LH.
- **Moulting hormone** (ecdysone) and **juvenile hormone** (corpora allata) are important in insect development.
- **Local hormones** (also called **tissue hormone**, **para hormone** or **paracrine**) are those hormone which do not pass into blood but diffuses to the target and work upon adjacent tissue.
- **Types of local hormones** are neurohormones, prostaglandin and pheromones.
- **Neurohormones** are secreted by nerve cells and released into tissue fluid at synapses by the synaptic vesicles of axon, eg. - acetylcholine and nor-epinephrine.
- **Prostaglandin** are fatty acid derivatives and secreted by many organs (kidney, gonads, seminal vesicle, thymus etc.) into their tissue fluid.
- Prostaglandin **controls either contraction/ relaxation of smooth muscles** or **dilation/ contraction of blood capillaries**.
- Prostaglandin were **first reported** in semen of man and produced by prostate gland.
- **Kinin or bradykinins** are polypeptides that causes contraction of smooth muscles and dilation of blood vessels.
- The gaseous hormone, **nitric oxide** (also an air pollutant) is also a local hormone.
- New researches demonstrated that the NO linked to haemoglobin allow **blood vessels to expand or contract**, depending on how much of the molecule is present. This principle is used in **'viagra' medicine**.
- **Pheromones** are the chemicals used for communication amongst individuals of the same species.
- Pheromones are also known as **ectohormones** or **sex attractants** or **sanio-chemicals**.
- Pheromones are **volatile** in nature and travel with air.
- It invoke a specific response in other members like **recognition**, **warning** and **attraction**.
- **Bombykol** is a sex attractant pheromone produced by female silkworm moth.
- A deer produces **seven different types of pheromones**, all from different sites and with different functions.

PINEAL GLAND

- The **pineal gland** (or **epiphysis**) is a stalked, small rounded organ. It is located on the midline, attached to the posterior end of the roof of the third ventricle in the brain.
- The pineal body is located above the superior colliculus and behind and beneath the stria medullaris, between the laterally positioned thalamic bodies.
- The pineal body is **part of the epithalamus**.
- The pineal gland consists mainly of **pinealocytes**, but four other cell types have been identified: interstitial cells, perivascular phagocyte, pineal neurons and peptidergic neuron-like cells.
- It **secretes two biogenic hormones – melatonin** and **serotonin**.

- The **pineal gland calcifies with age** and melatonin production correspondingly decreases. This decline in melatonin has been suggested to be a trigger for the ageing process.
- **Also called epiphysis cerebri**, the pineal gland is important because it is the centre for the production of the hormone melatonin and it contains magnetic material in birds and other animals. It is a **centre for navigation**.
- **Melatonin**, or 5-methoxy-N-acetyltryptamine, is a hormone produced by pinealocytes in the pineal gland, and a derivative of the amino acid tryptophan.
- The **production of melatonin** by the pineal gland is **stimulated by darkness** and **inhibited by light**.

There is a pathway from the retinas to the hypothalamus called the retinohypothalamic tract. It brings information about light and dark cycles to a region of the hypothalamus called the suprachiasmatic nucleus (SCN). From the SCN, nerve impulses travel *via* the pineal nerve (sympathetic nervous system) to the pineal gland. These impulses inhibit the production of melatonin. When these impulses stop (at night, when light no longer stimulates the hypothalamus), pineal inhibition ceases and melatonin is released. The **pineal gland is therefore a photosensitive organ and an important timekeeper for the human body**.

- To synthesize melatonin, serotonin is converted to N-acetylserotonin by the enzyme 5-HT N-acetyltransferase. N-acetylserotonin is then converted to melatonin by the enzyme 5-hydroxyindole-O-methyltransferase.
- **Melatonin has important effects** in integrating photoperiod and affecting circadian rhythms. Consequently, it has been reported to **have significant effects on reproduction, sleep-wake cycles and other phenomena showing circadian rhythm**.
- Melatonin **delays sexual development** and **inhibit ovarian functions,** hence referred as **antigonadotrophic hormone**.
- **Brain sands** (also called acervuli), found in pineal body, are particles of calcium salts ($CaCO_3$ & Ca_3PO_4).

Nobel Prize Laurate **Julius Axelrod** performed many of the seminal experiments elucidating the role of melatonin and the pineal gland in circadian rhythms.

HYPOTHALAMUS

- The **hypothalamus**, a region of the brain that controls an immense number of bodily functions, is located in the middle of the base of the brain, and encapsulates the ventral portion of the third ventricle.
- The hypothalamus is the **main link between the endocrine and nervous systems**.
- Nerve cells in the hypothalamus control the pituitary gland by producing chemicals that either stimulate or suppress hormone secretions from the pituitary.
- **Herring bodies** formed in hypothalamus store neurosecretory substance.
- The hypothalamus **regulates homeostasis**. It **has regulatory areas** for thirst, hunger, body temperature, water balance, and blood pressure.
- In addition to secreting neuromodulators, the hypothalamus synthesizes and secretes a number of neurohormones.
- These neurohormones are known as **releasing hormones** because the major function generally is to stimulate the secretion of hormones originating in the anterior pituitary gland.
- The **hypothalamo-pitiutary axis** is the unit formed by the hypothalamus and pituitary gland, which exerts control over many parts of the endocrine system.
- This unit functions by means of interaction of the nervous and endocrine system whereby the nervous regulates the endocrine system and endocrine activity modulates the activity of the CNS.
- Neurohormones were first discovered by **Guillemin** and **Schally** (Nobel Prize 1977).
- **Types of neurohormones** are – TRH or TSH-RH; GnRH; ACTH-RH or CRH; SRH or GH-RH; GIH; PRH or LTH-RH; PIH or LTH-RH; MSH-RH or MRH and MSH-IH or MIH.
- **Thyrotropin releasing horomone (TRH)** is the simplest of the hypothalamic neuropeptides.
- It is also called thyrotropin releasing factor (TRF), thyroliberin or protirelin.

The **sequence of TRH was first determined** and the hormone synthesized by **Roger Guillemin** and **Andrew V. Schally** in 1969.

- TRH is involved in the **control of body temperature** and that it has psychological and behavioural effects.
- The TRH-secreting cells are subject to stimulatory and inhibitory influences from higher centres in the brain and they also are inhibited by circulating thyroid hormone. In this way TRH **forms the topmost segment of the hypothalamic-pituitary-thyroid axis**.
- **GnRH (gonadotrophins releasing hormone)** stimulates the synthesis and release of the two pituitary gonadotrophins – **luteinizing hormone (LH)** and **follicle-stimulating hormone (FSH)**.
- There may be two distinct releasing hormones – **FSH-RH** and **LH-RH in female** and one **ICSH-RH in male**.
- Neurons that secrete GnRH have connections to an area of the brain known as the limbic system, which is heavily involved in the control of emotions and sexual activity.
- Some individuals have **hypogonadism** (in which the functional activity of the gonads is decreased and sexual development is inhibited) due to a **congenital deficiency of GnRH**.
- **Abnormalities in the GnRH secretion** result in subnormal fertility, abnormal or absent menstruation, and possibly cystic disease of the ovary or even ovarian cancer.
- **Adrenocorticotropin-releasing hormone (CRH) stimulates** not only **secretion of corticotropin or adrenocorticotropin (ACTH) hormone in the pituitary gland** but also the synthesis of corticotropin in the corticotropin-producing cells (corticotrophs) of the anterior lobe of the pituitary gland.
- CRH, also called **corticoliberin,** is a polypeptide hormone and neurotransmitter involved in the stress response.
- **Excessive secretion of CRH** leads to an increase in the size and number of corticotrophs in the pituitary gland, often **resulting in a pituitary tumor**. This, in turn, leads to excessive stimulation of the adrenal cortex, resulting in high circulating levels of adrenocortical hormones.
- Like CRH, **growth hormone-releasing hormone (GH-RH)** is a large peptide and stimulate anterior pituitary to produce and secrete growth hormone.
- GH-RH secretion is **stimulated by stresses**, including physical exercise, and **secretion is blocked by a powerful inhibitor** called **somatostatin**.
- GH releasing hormone (GH-RH) is also known as **somatotropin releasing hormone (SRH) or somatocrinin**.
- Negative feedback control of GH-RH secretion is mediated largely through compounds called **somatomedins**. Somatomedins is a growth-promoting hormone that are generated when tissues are exposed to growth hormone itself.
- **Growth inhibiting hormone (GIH) or somatostatin** inhibits adenohypophysis to secrete growth hormone.

Somatostatin is also secreted by delta cells of stomach, intestine, and pancreas. It binds to somatostatin receptors.

- Somatostatin is **also a powerful inhibitor of pituitary TSH secretion**.
- Somatostatin, like TRH, is **widely distributed** in **the central nervous system** and in other tissues. It **serves an important paracrine function** in the islets of Langerhans, by blocking the secretion of both insulin and glucagon from adjacent cells.
- Somatostatin has emerged **not only as a powerful blocker of the secretion of GH, insulin, glucagon**, and other hormones **but also as a potent inhibitor of many functions of the gastrointestinal tract**, including the secretion of stomach acid, the secretion of pancreatic enzymes, and the process of intestinal absorption.
- **Prolactin releasing hormone (PRL-RH)** stimulate anterior pituitary to secrete prolactin (PRL or LTH).
- **Prolactin inhibiting hormone (PRL-IH)**, also called **dopamine,** stops synthesis of LTH by anterior pituitary.
- **In brain**, dopamine **functions as a neurotransmitter,** activating dopamine receptors. Its (dopamine) chemical name is 4-(2-aminoethyl) benzene-1, 2-diol and it is abbreviated as DA.
- Dopamine can be supplied as a medication that acts on the sympathetic nervous system, producing effects such as increased heart rate and blood pressure.

- Deficits in dopamine levels are implicated as one of several possible causes for Adult attention-deficit disorder (AADD), and some types of medications used to treat Attention-deficit hperactivity disorder (ADHD/ADD) will help to stimulate dopaminergic systems, leading to potentially heightened sensation, for those afflicted by it and receiving treatment for it.
- **Melanocyte stimulating hormone (MSH-RH)** induces intermediate lobe of pituitary to secrete MSH.
- **Melanocyte stimulating hormone inhibiting hormone (MSH-IH)** stops synthesis of MSH.

PITUITARY GLAND

- **Pituitary** is the **smallest, pea shaped endocrine gland** which is connected to hypothalamus by an infundibular stalk formed of connective tissue with blood capillaries and nerves.
- It lies in the cavity called **sella turcica** of sphenoid bone of skull.
- It is also called as **hypophysis** or **hypothalamus cerebri**.
- Pituitary gland is **cranio-epithelial in origin**.
- Removal of pituitary is known as **hypophysectomy**.
- The pituitary gland is sometimes called the "**master**" **gland of the endocrine system**, because it controls the functions of the other endocrine glands.
- The pituitary gland itself consists of **three lobes**: the **anterior lobe**, the **intermediate lobe** and the **posterior lobe**.
- Each lobe of the pituitary gland produces certain hormones.
- Pituitary is a **composite gland** comprising anterior lobe (adenohypophysis) and posterior lobe (neurohypophysis) on the basis of anatomy and embryology.
- **Adenohypophysis** (makes 75% of total weight) develops as an outgrowth of pharynx called **Rathke's pouch**.
- The adenohypophysis **consists of three principal types of hormones secreting parenchymal cells** according to the pattern of staining : **acidophils** (which stains with acidic dyes), **basophils** (which stain with basic dyes), and **chromophobes** (which have only pale staining).
- **Acidophils** are subdivided into two classes – **lactotropes** (mammotropes) and **somatotropes**. Lactotropes produce prolactin and somatotropes produce GH.
- **Basophils** are subdivided into three classes – **corticotropes, thyrotropes,** and **gonadotropes**. Corticotropes produce ACTH and lipotropic hormones (LPH); thyrotropes produce TSH; and gonadotropes produce LH and FSH.
- **Chromophobes** probably are acidophile or basophile that have lost their specific staining properties after releasing their hormone-containing granules.
- Adenohypophysis is formed of three parts - **pars distalis** (largest), **pars tuberalis** (highly vascular region) and **pars intermedia** (also called intermediate lobe of pituitary gland).
- Pars distalis and pars tuberalis are collectively known as **anterior lobe of pituitary or adenohypophysis**.
- Hormones of anterior pituitary are called **trophic hormones or tropins**.
- Secretion of the trophic hormones is **controlled by neurohormones of hypothalamus** through a feedback mechanism which operates either at gene level or at enzyme level.
- **Hormones of adenohypophysis** are :
  - **GH** (growth hormone, somatotropin or somatotrophic hormone, STH)
  - **TSH** (thyroid stimulating hormone)
  - **ACTH** (adrenocorticotrophic hormone)
  - **GnTH** (gonadotrophic hormones)
  - **PRL or LTH** (prolactin or lactogenic or luteotrophic hormone).
- **GH** (or **STH**) is a proteinaceous hormone whose effects on the tissues of the body can generally be described as anabolic (building up).
- Growth hormone is **also called somatropin and somatotropin**. The **genes for human growth hormone are localized in the q22-24 region of chromosome 17** and are closely related to human chorionic somatomammotropin (hCS, also known as placental lactogen) genes.

GH, hCS, and PRL are a group of homologous hormones with growth-promoting and lactogenic activity.

- GH **stimulates** growth of body by synthesis and deposition of protein in tissue, increased glucose

level in blood by decreased secretion of insulin, increased cell division and increased growth of bones by increased absorption of calcium from intestine.

- GH **promotes body growth** by:
  - binding to receptors on the surface of liver cells
  - this stimulates them to release insulin-like growth factor-1 (IGF-1; also known as somatomedin-C)
  - IGF-1 acts directly on the ends of the long bones promoting their growth
- In childhood, **hyposecretion of GH** produces the stunted growth of a **dwarf**. Dwarfism is characterised by retarded physical growth but normal alertness and intelligence.
- The dwarf are called **midgets**.
- **Simmond's disease** in a adult is a rare condition in which patient becomes thin and show sign of premature ageing. It is caused due to **hyposecretion of growth hormone**.
- **Hypersecretion of GH leads to gigantism** in **childhood** before the closure of epiphyseal plates at the end of bones and **in adults it leads to acromegaly**.
- **Gigantism** is characterised by extra ordinary growth in height (7-8 feet) caused by abnormal elongation of long bones. And **acromegaly** is characterised by abnormal growth of hand, feet, face, especially lower jaw. Appearence may be ape like.
- Gigantism is also called **pituitary giant**.
- Secretion of **thyroid stimulating hormone (TSH)** is **controlled by feedback mechanism from thyroid hormone**.
- TSH **consists of two subunits** – the **alpha** and the **beta subunit**. The α (alpha) subunit is identical to that of human chorionic gonadotrophin (hCG), luteinising hormone (LH), follicle-stimulating hormone (FSH). The β (beta) subunit is unique to TSH, and therefore determines its function.
- TSH **control structure and functioning of thyroid gland to synthesize** and **release of its hormones** thyroxine and triiodothyronine.
- TSH is a proteinaceous hormone, secreted by pars distalis.
- **Hyposecretion of TSH** leads to thyroid atrophy while **hyperactivity** produces symptoms similar to Grave's disease.

Table : Effects of TSH deficiency

Metabolic	Body weight increases Oxygen consumption decreases Heat production decreases Basal metabolic rate decreases
CNS	Impaired mentally Poor memory and concentration Drowsiness
Motor nervous system	Activity decreases
Sympathetic nervous system	Activity decreases
Cardiovascular	Bradycardia Reduced output and blood pressure
Gl tract	Activity decreased Constipation

- **ACTH** is a peptide hormone which **controls the structure and functioning of adrenal cortex especially secretion of glucocorticoids and sex corticoids**.
- **Hypersecretion of ACTH** leads to **rheumatoid arthritis** while **hyposecretion** leads to **excessive growth of adrenal cortex**.
- **Gonadotrophins** or **gonadotrophic hormone (GTH)** regulates the growth and function of gonads.
- The two main gonadotrophins are – **FSH** and **LH/ ICSH**.
- **FSH** or follicle stimulating hormone are also called **gametokinetic factor**.
- FSH is a **proteinaceous hormone** which **stimulates spermatogenesis and growth of seminiferous tubules in testes**; **maturation of Graafian follicle** and **secretion of estrogen** (by the cells of ovarian follicle) and **progesterone** (from the corpus luteum).
- **LH (luteinizing hormone)** is known as **gamete releasing factor**.
- In **sexually-matured females**, LH
  - **Stimulates the follicle to secrete estrogen** in the first half of the menstrual cycle
  - Surge **triggers the completion of meiosis I** of the egg and its release (process called ovulation) in the middle of the cycle

- Stimulates the now-empty follicle to develop into the **corpus luteum**,which secretes progesterone during the latter half of the menstrual cycle.

- **In males** LH **acts on the interstitial cells of the testes** stimulating them to synthesize and secrete the male sex hormone, testosterone and other androgens for the development of secondary sex organs and secondary sexual characters.
- LH in males is also known as **interstitial cell stimulating hormone (ICSH).**
- **Hyposecretion of ICSH** results in impaired development of external genitalia and **LH** results in sterility in females.
- **PRL (prolactin)** acts to **initiate and maintain milk secretion by the mammary glands**, hence it is also known as **hormone of maternity**.
- PRL **works with other hormones such as oxytocin**, which actually causes milk ejection, and **oestradiol, progesterone, glucocorticoids, GH, thyroxine and insulin**, which prepare the mammary gland for milk production.
- The hormone prolactin is **downregulated by dopamine** and is **upregulated by estrogen**.
- PRL **secretion is under inhibitory control of dopamine**. This means that if the link between the hypothalamus and pituitary is severed PRL secretion increases, unlike all other pituitary hormones, where production would decrease without stimulatory control of the hypothalamus.
- TSH has a **stimulatory affect on PRL secretion**. Oestradiol **increases** PRL production and **levels of PRL rise during pregnancy** and **remain high during lactation**.

  During pregnancy, prolactin levels rise as rising estrogen promotes prolactin release, causing further maturing of mammary glands, preparing them for lactation. After childbirth, prolactin levels fall as the internal stimulus for them is removed. Sucking by the baby on the nipple promotes further prolactin release, maintaining the ability to lactate.

- **Hyperprolactinaemia** is a **common cause of menstrual problems** in women, and high levels of prolactin can cause gynaecomastia (breast enlargement) in men. It can also cause inappropriate galactorrhoea (milk production) in males and females.
- Usually, in the absence of galactorrhea, lactation will cease within one or two weeks of the end of demand breastfeeding.
- **High prolactin levels** also tend to **suppress the ovulatory cycle by inhibiting both FSH and GnRH**.
- Prolactin is **also called luteotrophic hormone** (LTH) because it also stimulates the corpus luteum of the ovary to secrete progesterone hormone.

  Sometimes, newborn babies (males as well as females) secrete a milky substance from their nipples. This substance is commonly known as **Witch's milk**. This is caused by the foetus being affected by prolactin circulating in the mother just before birth, and usually stops soon after birth.

- **MSH** (also called **intermedin**), a polypeptide hormone is produced by pars intermedia so called intermediate lobe of pituitary.
- It stimulates **synthesis and dispersal of melanin** pigment present in skin of fish, amphibia and some reptiles.
- It is **non-functional in man**.
- **Neurohypophysis** develops as a downgrowth of hypothalamus.
- The neurohypophysis has three main components – **pars nervosa** (infundibular process), **media eminence** and **infundibular stalk**.
- **Pars nervosa,** also called the posterior lobe, does not actually produce hormones, but stores and secretes hormones made by the hypothalamus. Therefore posterior lobe is also called **storage organ**.
- **Pituicyte cells** formed in neurohypophysis, secrete two octapeptide hormones – **vasopressin** and **oxytocin** from supraoptic and paraventricular nuclei respectively.
- Vasopressin is also called **antidiuretic hormone (ADH) or pitressin** or **arginine vasopressin (AVP)**.
- **Antidiuretic hormone (ADH)** is a peptide hormone and **acts on the kidneys**, concentrating the urine by promoting the reabsorption of water and salt into the cortical collecting duct.
- ADH is **activated by "water receptors"** in both the extracellular fluid volume and the intracellular fluid volume.
- In the extracellular fluid the activators are mainly

baroreceptors in the veins, atria, and arterioles. In the intracellular fluid the activators are mainly osmoreceptors in the hypothalamus.

- **Ethanol and caffeine block the release of ADH** from the posterior pituitary gland. This decrease in water reabsorption **leads to a higher volume of urine output**.
- **ADH is under negative feedback control**. A fall in blood volume stimulates release of ADH. Also, a fall in the arterial partial pressure of oxygen and a rise in partial pressure of carbon dioxide stimulate ADH release.
- Secretion of ADH is **also affected by the angiotensin II, adrenaline, cortisol and sex steroids**. At the level of the hypothalamus, pain, trauma, nausea and vomiting, and a rise in external temperature increase AVP secretion, and psychological and emotional stimuli also affect its release.
- **Overproduction of ADH** can occur due to brain trauma. It leads to water retention, serum hypo-osmolality, hyponatraemia and high urine osmolality.These effects cause symptoms of headache, apathy, nausea and vomiting, impaired conciousness and can be fatal in extreme cases.
- **Underproduction of ADH** results in the condition of **diabetes insipidus**. Clinical signs are excretion of large volumes of urine (diuresis, 10 litre urine/day) leading to dehydration and thirst (polydipsia), as well as increased plasma osmolality.
- **Oxytocin** secretion occurs in response to nervous stimulation of the hypothalamus.
- Oxytocin **causes** contraction of the smooth muscle of the uterus (hence called **birth hormone**) and also of the myoepithelial cells lining the duct of the mammary gland (hence called **milk ejection hormone**).

Synthetic oxytocin is also called as **pitocin and syntocinon**. Oxytocin is destroyed in the gastrointestinal tract, and therefore must be administered by injection or as nasal spray. Oxytocin has a half-life of typically about three minutes in the blood. Oxytocin given intravenously does not enter the brain in significant quantities - it is excluded from the brain by the blood-brain barrier. Drugs administered by nasal spray are thought to have better access to the CNS. An oxytocin nasal spray has been used to stimulate breastfeeding.

- **Release of oxytocin is under positive feedback control**. Stimulation of mechanoreceptors in the uterus and vagina during parturition cause a rise in oxytocin levels up to a maximum until the stimulus is no longer present and the action of the hormone is no longer needed.
- **Negative feedback** is an important factor in controlling the hypothalamic pituitary-target organ axis function. Once hypothalamic hormones stimulates the release or inhibition of the pituitary hormone, this may then act as a target gland, such as the thyroid, causing release of further hormones of causing metabolic effects.
- The action of hypothalamic hormones may be inhibited by **long feedback loops** from the target gland hormone or **by short feedback loops** from the pituitary hormone. There may also be direct feedback from the target gland hormone to the pituitary gland.
- Positive feedback also plays a part in certain systems. For example, in the situation where high levels of oestradiol in the blood cause a surge in LH levels during the menstrual cycle.

THYROID GLAND

- The **thyroid gland** is located in the front of the neck, below the larynx (voice box).
- The small, two-inch thyroid gland **consists of two lobes**, one on each side of the windpipe, **connected by tissue** called the **isthmus**.
- The thyroid tissue is made up of two types of cells: **follicular cells** and **parafollicular cells (G-cells).**
- **G-cells or parafollicular cells** are group of endocrine cells scattered in connective tissue and between the thyroid follicles.
- Thyroid follicles contains **thyroglobulin.**
- **Thyroglobulin**, a glycoprotein in colloidal suspension, is a stored formed of thyroxine and an exocrine secretion product of follicular epithelial cells.
- **Follicular cells**, secrete iodine-containing hormones called **thyroxine or tetraiodothyronin (T_4)** and **triiodothyronine (T_3)**.
- Thyroglobulin contains multiple copies of one amino acid **tyrosine**.
- The level of thyroglobulin present in the body can be measured with blood tests.

Table : Physiological effects of thyroid hormones.

Target tissue	Effect	Mechanism
Heart	Chronotropic	Increase number and affinity of β-adrenergic receptors.
	Inotropic	Enhance responses to circulating catecholamines. Increase proportion of α myosin heavy chain (with higher ATPase activity).
Adipose tissue	Catabolic	Stimulate lipolysis
Muscle	Catabolic	Increase protein breakdown.
Bone	Developmental	Promote normal growth and skeletal development.
Nervous system	Developmental	Promote normal brain development.
Gut	Metabolic	Increase rate of carbohydrate absorption.
Lipoprotein	Metabolic	Stimulate formation of LDL receptors.
Other	Calorigenic	Stimulate oxygen consumption by metabolically active tissues (exceptions : testes, uterus, lymph nodes, spleen, anterior pituitary). Increase metabolic rate.

- Thyroglobulin **serves a useful readout for the presence or absence of thyroid cells**, particularly in patients with thyroid cancer where it serves as a "tumor marker".
- The thyroid **needs iodine** to produce the hormones.
- The thyroid plays an **important role in regulating the body's metabolism and calcium balance**.
- The **T_4 and T_3 hormones** stimulate every tissue in the body to produce proteins and increase the amount of oxygen used by cells.
- **T_3 is 3 - 4 times more potent** than T_4.
- T_4 and T_3 are **deiodinated** in the liver, kidneys and many other tissue.
- The level of T_4 circulating in the blood controls its release from the thyroid gland **by negative feedback mechanism involving the hypothalamus and anterior pituitary.**
- **If excess T_4 is present in the blood** it switches off its own production by **switching off production of TRH** (thyrotropin releasing hormone) by the hypothalamus and **TSH** (thyroid stimulating hormone) by the anterior pituitary.
- Thyroxine **control BMR** (basal metabolic rate) of the body.
- The BMR of a normal adult man is **40 cal/m^2** and **37.5 cal/m^2** in woman.
- Apart from carrying out metabolic and regulatory function, thyroxine **also controls some developmental process** like metamorphosis. Eg. amphibia & teleost fish.
- It **controls urine output**, **maintains nervous and muscular tonus**, **increase the oxidation of glucose** in tissue and **also acts on SA node & maintains the normal heart beat** and also **reduce the formation of ketone bodies** etc.
- In its (thyroxine) absence or presence of thiourea (antithyroid substance), **tadpoles remains in larva stage indefinitely**. They stimulate tissue differentiation, therefore they affect metamorphosis of a tadpole into an adult frog.
- **Hypothyroidism** results in **cretinism**, **myxoedema**, **endemic or simple goitre or colloid goitre** and **Hashimoto's disease**.
- **Hypothyroidism** is the condition in which the thyroid is underactive (*i.e.*, it is producing an insufficient amount of thyroid hormones).
- Hypothyroidism is the **most common thyroid disorder.**
- The **most common cause of hypothyroidism** is an autoimmune reaction, where the body produces antibodies against the thyroid gland.
- Severe hypothyroidism can lead to a condition called **myxoedema.**
- Myxoedema is also called **Gull's disease** developing in adult life, **most commonly in middle-aged women**.
- Myxoedema is **characterized** by **puffy appearance**

due to subcutaneous accumulation of fat, low BMR, low heart rate and body temperature, retarded sexuality.

- **Cretinism** is a **condition produced in infants and children** due to lack of thyroid hormone.
- Children who are hypothyroid from birth or before are called **cretins.**
- Cretinism **usually results** from a congenital defect. However, it can develop later if there is a lack of iodine in the diet, or if the thyroid is diseased or surgically removed.
- The **main cause of congenital hypothyroidism** are - maternal iodine deficiency, inborn errors of thyroid hormone synthesis, maternal antithyroid antibodies that cross the placenta etc.
- Cretinism **causes** very serious retardation of physical and mental development; if the condition is left untreated, growth is stunted and the physical stature attained is that of a dwarf. In addition, the skin is thick, flabby, and waxy in colour, the nose is flattened, the abdomen protrudes, and there is a general slowness of movement and speech.
- If the condition commences after adulthood is reached it is called myxoedema (*described earlier*).
- **Goitre** is a non-specific term describing enlargement of the thyroid gland.
- **Symptoms of goitre** are feeling of pressure; increased neck size; a feeling of narrowness, as if there's a lump in the neck region; difficulty in swallowing and hoarseness.
- When the dietary iodine intake falls below 50μg/dL, thyroid hormone synthesis is inadequate and secretion declines.
- **Endemic goitres** are those which occur at high incidence in certain geographic regions. They are **associated with iodine deficiency** but other factors must be involved as the prevalence varies in areas with similar low levels of iodine. Factors such as the intake of goitrogens or metabolic defects in thyroxine synthesis may be important.
- **Simple goitres** arise from compensatory hyperplasia in an attempt to maintain thyroid hormone levels. Once a state of euthyroidism is reached, colloid accumulates - hence, the term **colloid goitre**.
- **Hashimoto's thyroiditis** is a type of autoimmune thyroid disease in which the immune system attacks and destroys the thyroid gland. Hashimoto's prevents the gland from producing enough thyroid hormones for the body to work correctly. It is the **most common form of hypothyroidism**.
- Hashimoto's disease is **also known as suicide of thyroid gland.**
- **Hyperthyroidism** means **overactivity of the thyroid gland**, resulting in too much thyroid hormone in the bloodstream which **leads to overactivity of the body's metabolism**.
- **Symptoms** may include: nervousness, irritability increased perspiration, thinning of the skin; fine, brittle hair; weak muscles, especially in the upper arms and thighs; shaky hands; fast heartbeat; high blood pressure; increased bowel movements; weight loss; sleeping difficulty; eye sensitivity to light; staring; confusion, irregular menstrual cycle.
- **Grave's disease** is most often **associated with hyperthyroidism**.
- Grave's disease is **categorized as an autoimmune disorder** (in which circulating antibodies formed against the TSH receptor activate the receptor, making the gland hyperactive). The disease is **most common in young to middle-aged women** and tends to run in families.
- **Symptoms of Graves' disease** are identical to hyperthyroidism, with the addition of three other symptoms – **goitre** (enlarged thyroid which may cause a bulge in the neck), **bulging eyes** (**exophthalmos** due to swelling of extraocular muscle), **thickened skin over the shin area.**
- **Thyroiditis** (the inflammation of the thyroid gland) causes temporary hyperthyroidism, usually followed with hypothyroidism.
- **Calcitonin** (non–iodinated polypeptide hormone) **is secreted from the parafollicular or C cells** in the thyroid gland, but it is also synthesized in a wide variety of other tissues, including the lung and intestinal tract.
- Calcitonin is **also called thyrocalcitonin** (TCT).
- Calcitonin plays a **role in calcium and phosphorous metabolism**. In particular, calcitonin has the ability to decrease blood calcium levels at least in part by effects on two well-studied target organs : bone and kidney.

Bone : Calcitonin suppresses resorption of bone by inhibiting the activity of osteoclasts, a cell type that "digests" bone matrix, releasing calcium and phosphorous into blood.

Kidney : Calcium and phosphorous are prevented from being lost in urine by reabsorption in the kidney tubules. Calcitonin inhibits tubular reabsorption of these two ions, leading to increased rates of their loss in urine.

- The most prominent factor controlling calcitonin secretion is the **extracellular concentration of ionized calcium.**
- **Elevated blood calcium levels** strongly stimulate calcitonin secretion, and secretion is suppressed when **calcium concentration falls below normal.**
- When serum calcium levels rise, calcitonin secretion occurs, bone resorption decreases and serum calcium level falls again.
- The calcitonin hormone **works together with the parathyroid hormone** to regulate calcium levels in the body.
- Calcitonin is **used to treat hypercalcemia** resulting from a number of causes, and **has been a valuable therapy for Paget disease**, which is a disorder in bone remodeling.
- Calcitonin **also appears to be a valuable aid in the management of certain types of osteoporosis and loss of bone density** (due to dissolution of PTH).
- In birds, fish and amphibians, calcitonin is secreted from the **ultimobrachial glands.**

PARATHYROID GLANDS

- **Parathyroid glands** are small glands which are located in the neck behind the thyroid.
- There are usually **4 parathyroid glands** which are normally a little smaller than a pea, 2 in the left lobe of the thyroid and 2 in the right lobe.
- The **normal role of the parathyroid glands** is to control the blood calcium **by secreting parathyroid hormone (PTH).**
- The levels of blood calcium are constantly monitored by a protein expressed by parathyroid cells, designated the calcium sensing receptor.
- **Parathyroid hormone** (secreted by **chief cells**) is also called **parathormone** (PTH) or **Collip's hormone**.
- The **parathyroid hormone stimulates the following functions** –
  - Release of calcium by bones into the bloodstream
  - Absorption of food by the intestines
  - Conservation of calcium by the kidneys.
- PTH has an effect that **opposes the effect of calcitonin.**
- PTH affects the synthesis of 1, 25 dihydroxy-cholecalciferol (a metabolite of vitamin D), which indirectly affects serum calcium by increasing the efficiency with which dietary calcium is absorbed in the gastrointestinal tract.
- Persistent excess production of PTH may lead to the development of a high level of blood calcium, referred to as **hyperparathyroidism**.
- **Hyperparathyroidism may be associated with** the development of **osteoporosis** (destruction of bone with increased incidence of fractures), **kidney stones**, **impaired kidney function**, **increased thirst** or increased frequency of urination, **osteitis fibrosa cystica** (means normal bone is replaced by cysts and fibrous tissue) and sometimes, stomach upset and ulcers.
- **Hyposecretion of PTH** leads to **tetany** characterised by decreased serum Ca^{2+} and increased serum phosphate, and decreased urinary phosphate, muscle spasm, twitching, increasing neuroexcitation etc.

THYMUS

- The **thymus** (throne of immunity) is a **ductless gland** which lies in the upper part of the mediastinum behind the sternum and extends upwards into the root of the neck.
- The **thymus reaches its greatest size at puberty**, after which it undergoes slow involution and both cortical and T lymphocytes are reduced in peripheral blood.
- The thymus is the **first developing lymphoid organ.**
- The main function of the thymus is to **develop immature T-cells into immunocompetent T-cells**.
- The thymus is divided into two distinct compartments– the **outer cortex** and the **inner medulla.**
- Both regions are **densely populated with lymphocytes** (or thymocytes while in the thymus).

- The **maturation of the thymus and other lymphoid tissue** is stimulated by **thymosine**.
- **Thymosine**, a polypeptide hormone secreted by reticular epithelial cells, increases the rate of growth, accelerates cell division, helps in maturation of genital organs and produces lymphocytes and antibodies.
- **Thymic or Hassal's corpuscles** made of concentrically arranged epithelioreticular cells become more common into adulthood. They **act as phagocytes**.
- The thymus **plays an important role in the development of the immune system in early life**, and its cells form a part of the body's normal immune system.
- **Thymopoietin**, also called **thymin**, depresses neuromuscular transmission, induces T-cell markers, and has a role in the generation of cytotoxic T cells and prevention of autoimmunity.
- The human thymus, especially in the foetus, **supports erythropoiesis** and **granulopoiesis**.
- The thymus is also present in many other animals. When animal thymus tissue is sold in a butcher shop or at a meat counter, thymus is known as **sweetbread.**
- **Hypersecretion of thymosine hormone** may lead to **Myasthenia gravis**, characterised by abnormal muscular excitation.

ADRENAL GLAND

- The adrenal gland is called **supra renal gland** because it is situated on the anteriosuperior aspect of the kidney and receives its blood supply from the adrenal arteries.
- Adrenal gland is separated into two distinct structures – the **adrenal medulla** (10–20% and **ectodermal in origin**) and the **adrenal cortex** (80–90% and **mesodermal in origin**), both of which receive regulatory input from the nervous system.
- The **adrenal medulla** is the body's **main source of the catecholamine hormones like epinephrine (adrenaline) and norepinephrine (nor-adrenaline)**.
- Adrenal medulla is composed of masses of catecholamines secreting cells surrounded by complex network of blood vessels.
- Catecholamines secreting cells are sometimes called **chromaffin cells** because their granules stain a brownish colour when exposed to solutions containing dichromate ions.
- The **release of epinephrine and nor-epinephrine is controlled by the central nervous system through the preganglionic sympathetic fibres in the medulla**.
- These hormones are **derived from aminoacid tyrosine**.
- **Dopamine** is an intermediate in the biosynthesis of adrenaline and nor-adrenaline from the tyrosine and phenylalanine.
- A deficiency of dopamine results in **Parkinson's disease**.
- **Secretion of adrenaline** is **5-10 times higher** than nor-adrenaline.
- These hormones are secreted for **meeting an emergency** as in cold, emotional stress, pain, anger, fear etc.
- Adrenaline is also known as **emergency hormone**.
- It **increases** blood pressure, basal metabolic rate, lipolysis in adipose tissue to increase level of fatty acids in blood, acts as vasodilator, increase respiration rate as it dilates trachea, increases sugar level in blood by stimulating glycogenolysis in liver and skeletal muscle and slows down peristalsis.
- **Nor-adrenaline** more or less resembles adrenaline in its biological effects except that **it operates during normal state, exercises, lesser effect on cardiac activity and produces greater constriction of blood vessels in muscles**.
- **Hypersecretion of adrenaline** causes hypertension, high level of sugar in blood and urine, high metabolic rate, nervousness and sweating etc.
- **Adrenal cortex,** composed of cortical cells, secretes 40 different steroid hormones which are collectively called as **corticoids**.
- Corticoids are divided into **mineralocorticoids, glucocorticoids** and **sexcorticoids**.
- The adrenal cortex can be divided into **three distinct layers of tissue based on cell type and function –**
  - **Zona glomerulosa** (outer) - mineralocorticoid production, primarily aldosterone
  - **Zona fasciculata** (middle) - glucocorticoid production, mainly cortisol (roughly 95%)
  - **Zona reticularis** (inner) - sex corticoids, androgen production, including testosterone

- Two common mineralocorticoids (secreted by zona glomerulosa) are **aldosterone** and **deoxycorticosterone**.
- Aldosterone is also called as **salt-retaining hormone**.
- **In response to increased potassium levels or decreased blood flow and sodium to the kidneys**, cells of the **zona glomerulosa secrete the aldosterone** into the blood as part of the renin-angiotensin system.
- **Aldosterone** regulates the body's concentration of electrolytes, primarily sodium and potassium, by acting on the distal convoluted tubule of kidney nephrons to increase potassium excretion; increase sodium reabsorption; and increase water reabsorption through osmosis.
- **Zona fasciculata responsible for the production of glucocorticoids** are the **primary effectors of adrenocorticotropic hormone (ACTH)**.
- **ACTH** stimulates cortical cells to secrete glucocorticoids.
- **Important glucocorticoids** are **cortisol and corticosterone**.
- The **primary glucocorticoid** released by the adrenal gland is **cortisol.**
- Cortisol **enhances metabolism in several ways:**
  - Stimulating the release of amino acids from the body
  - Stimulating lipolysis, the breakdown of fat
  - Stimulating gluconeogenesis, the production of glucose from newly-released amino acids and lipids conserving glucose by inhibiting uptake into muscle and fat cells.
- Glucocorticoids are **used maximum in medicine for allergic condition, rheumatoid arthritis, skin disease and asthma** etc.
- Cells of the zona reticularis **provide a secondary source of androgens** such as testosterone, dihydrotestosterone (DHT), androstenedione, and dehydroepiandrosterone (DHEA). These enhance muscle mass, stimulate cell growth, and aid in the development of the secondary sexual characteristics.
- **Addison's disease** usually results due to **deficient secretion of aldosterone and cortisol**.
- During **addison's disease**, excessive loss of Na^+, Cl^- and HCO_3^- takes place and level of K^+ ion increases in blood. Imbalance in sodium potassium ratio's alter muscle and nerve functions.
- **Hypersecretion of aldosterone** due to adrenal cortical tumor causes **aldosteronism** or **Conn's syndrome**.
- **Conn's syndrome** is characterised by rise in blood volume & blood pressure, muscular weakness, high plasma Na^+ (due to decreased renal excretion) resulting in kidney damage and polyuria, tetany, hypokalemic alkalosis.
- **Excessive loss of sodium ion** is known as **acidosis**.
- Acidosis **means decrease in pH of blood from 7.4 to 6.8**.
- **Over secretion of cortisol** causes **cushing syndrome**, characterised by high sugar level in blood, loss of sugar in urine, loss of weight, high Na^+ & low K^+ concentration in plasma, rise in blood volume and blood pressure etc.
- Cushing syndrome is also produced by **tumors of non–endocrine** tissues that secretes substances with CRH activity or more commonly ACTH.
- **Cushing disease**, same as cushing syndrome is **caused by oversecretion of cortisol due to excessive hormone stimulation by adrenal cortex by tumor/hyperplasia** (due to increased cell mass) of **anterior pituitary**.
- Cushing disease mainly **occurs in females** and causes obesity, hypertension, glycosuria (sugar in urine), virilism.
- **Excessive secretion of sex corticoids** results in **virilism** or appearance of male secondary characters like male voice, beard, moustaches in females.
- **Hirsutism** is the **presence of facial and excess body hair in females** due to adrenal virilism, while it causes **gynaecomastia** in males characterised by enlarged breast.
- Secretion of glucocorticoids and sexcorticoids are **regulated by ACTH of pituitary**.
- Mineralocorticoid release is stimulated by the **activity of renin and angiotensin**.
- Adrenal gland is also called **4 S gland** (= sugar metabolism, salt retaining, sex hormones, source of energy) and **3 F gland** (fright, fight and flight.)

PANCREAS

- The **pancreas** is a **retroperitoneal organ**.
- Pancreas is the **second largest gland** located in the loop of duodenum.
- It is an **heterocrine gland** in which exocrine part occurs as **acini** while the endocrine part (2-3%) is represented by **islets of Langerhans** or **pancreatic islets**.

- **Control of the exocrine function of the pancreas** occurs by the enzymes gastrin, cholecystokinin and secretin, which are secreted by cells in the stomach and duodenum, in response to distension and/or food and which cause secretion of pancreatic juices.
- The acinar cells are **specialized to secrete the proteins in the digestive process.**
- Hormones of pancreas, secreted by different types of endocrine cells present in islet of Langerhans, are - **α cell** (secretes glucagon); **β cell** (secretes insulin); **γ cell** (secretes gastrin); **δ cell** (secretes somatostatin); and **F cell** (secretes pancreatic polypeptides).
- Islets **have fenestrated capillaries** (typical of all endocrine tissues) **which facilitate hormone transport.**
- **Insulin** and the **glucagon** are the **chief hormones** produced in the islet tissue.
- **Glucagon** (secreted by α cells of pancreas), is a proteinaceous hormone whose **secretion is stimulated by low blood sugar level**.
- Glucagon **stimulates glycogen breakdown and glucose synthesis** in the liver thereby increasing the blood glucose concentration.
- **Excess of glucagon** may cause **glycosuria** due to presence of sugar in urine.
- Glucagon is **antagonistic to insulin**.
- **Insulin** (secreted by β-cells of pancreas), is **also called hypoglycaemic or antidiabetic factor**.
- **Rising blood glucose levels** stimulates insulin secretion and **falling blood glucose levels** stimulate glucagon synthesis.
- Insulin is **anabolic hormone** whereas glucagon is **catabolic hormone**.
- **Normal range of blood sugar is 80-120 mg/ 100 ml** of blood (80 mg/100 ml before fasting & 120 mg/100 ml after meal).
- **Deficiency of insulin** causes **diabetes mellitus**.
- **Diabetes** is **characterised** by **polyuria**, **polydipsia**, weight loss inspite of **polyphagia** (increased appetite), **hyperglycemia**, **glycosuria**, **ketosis** (increased ketone bodies in blood), **acidosis** (increased H^+ ions in blood) & **coma**.
- **Polyuria** or excessive urination is due to increase in water content of urine.
- **Polydipsia** means excessive thirst inspite of drinking more and more water.
- Indication of diabetes start when blood sugar level increases about **3 times** and is **more than 150 mg/100 ml of blood** due to regular supply from alimentary canal and failure of cells to absorb glucose.
- Diabetes mellitus are of **two types – type I diabetes** and **type II diabetes**.
- **Type I diabetes** usually **develops before age 40** and it is **characterised** by loss of β-cells with eventual absence of insulin in the circulation.
- Type I diabetes is also called **juvenile diabetes and insulin-dependent diabetes mellitus** (IDDM). It is **ketosis prone diabetes** means that fatal high level of ketone bodies increase in the blood due to severe non-availability of insulin. Insulin is a metabolic hormone which prevents ketone body formation.
- **Type II diabetes** usually **develops after age 40** and is **not** associated with total loss of the ability to secrete insulin.
- Type II diabetes is also called **maturity-onset diabetes** and **non-insulin dependent diabetes mellitus**. It is **ketosis-resistant diabetes**.
- **Somatostatin** (secreted by δ cell) is a local hormone which controls functioning of α and β cells.
- Somatostatin **inhibits the secretion of insulin and glucagon**.
- **Pancreatic polypeptide** (secreted by F-cells) check secretory activity of digestive glands.
- **Gastrin** (secreted by γ cells) is similar to the one produced by pyloric stomach.
- **Hypokalaemia** means low level of potassium in blood and **ketonaemia** refers to presence of ketone bodies in blood due to increased oxidation of fats.

GONADAL HORMONES

- **Gonads** (testes in male and ovary in female) are both exocrine and endocrine in function.
- Secretion of gonadal hormones are **stimulated** by **GnTH of pituitary**.
- Endocrine part of testes is formed of group of cells called **interstitial cells** or **leydig cells.**
- Leydig cells are the most important functional cells in the interstitium (the space between the seminiferous tubules of testis).
- Leyding cells synthesize and secrete male sex steroids called **androgens.**
- **Testosterone (**steroid hormone) is the **most abundant androgen** released by leydig cells.
- Testosterone is responsible for the growth and

development of male secondary sex organs (like epididymis, seminal vesicle etc.) and male secondary characteristics (like beard, moustaches etc.)

- It **stimulates** spermatogenesis & erythropoiesis.
- The surgical removal of testes is called **castration or orchidectomy**. **Cryptorchidism** is non descent of testis from its abdominal origin to testicular sac.
- Castrated human male are called **eunuch or neuter** and **oxen** (instead of bulls) in case of cattle.
- **Eunochoidism** is a hormonal disorder due to non secretion of testosterone in a genetically male individual.
- Just like testes, the ovaries are **cytogenic** as well as **endocrine in function**.
- Ovaries secrete **3 types of female hormones – estrogen**, **progesterone** and **relaxin**.
- **Estrogen**, group of steroid hormone is mainly **secreted by follicular epithelial cells of membrana granulosa of Graafian follicles**.
- **Secretion of estrogen** is **stimulated by LH** of anterior lobe of pituitary gland.
- Estrogen includes **estradiol**, **estriol** and **estrone**.
- **Principle estrogen** is **estradiol**.
- Estrogen stimulates the growth and development of female secondary sex organs and female secondary sexual characteristics.
- Estrogen **decreases** the secretion of FSH while **increases** the secretion of LH during menstrual cycle.
- During pregnancy, estradiol is secreted by **placenta**.
- **Progesterone** is a steroid hormone secreted by corpus luteum.
- Small amount of progesterone is also secreted by **adrenal cortex** and **placenta**.
- Progesterone is **responsible for the maintenance of pregnancy,** hence called as **pregnancy hormone**.
- During pregnancy **progesterone** helps in attaching embryo to uterine wall, development of placenta & growth of secretory alveoli in mammary glands.
- Progesterone is **thermogenic** and is probably responsible for the rise in basal body temperature at the time of ovulation.
- **Hyposecretion of progesterone** results in **abortion** and **misconception**.
- Progesterone is also called as **antiabortion hormone**.
- **Relaxin** is a proteinaceous hormone, **secreted by corpus albicans** which is formed from the corpus luteum at the end of gestation period.
- Relaxin **softens the pubic symphysis so helps in parturition (child birth) in rats and guinea pig**. In women, this role is played by **estrogens & progesterone**.

PLACENTAL HORMONES

- **Placenta** is the connection between foetus and uterine wall for physiological exchange like respiration, excretion, nutrition etc.
- During **pregnancy**, placenta also **acts as an endocrine gland**.
- The **chorionic villi of placenta** secretes **two steroids** (estradiol & progesterone) and **two proteins** (human chorionic gonadotrophin, HCG and placental lactogen, PL) hormones.
- **HCG** is a glycoproteinaceous hormone that maintains the corpus luteum for continued secretion of progesterone so as to maintain the pregnancy.
- Pregnancy test is confirmed by the **presence of HCG in urine**.
- **HPL** (human placental lactogenic hormone) prepares the mammary glands to secrete milk.
- **Inhibin** hormone is **produced by corpus luteum, placenta & testes**.
- It supplements the effect of excess sex hormones for depressing gonadotrophic activity (FSH, CH, ICSH) of pituitary.

OTHER HORMONES

- **Juxta glomerular region of kidney** produces two hormones – **erythropoietin** (regulates erythrocyte production) and **renin** (changes angiotensinogen of liver into angiotensin.)
- **Heart** produces a peptide hormone, **atrial natriuretic factor** (ANF) in case of hypertension.
- This hormone inhibits **renin** (in kidney) and **ADH secretion** (in pituitary).
- **Salivary gland** produces a proteinaceous hormone, **parotin** for calcification of teeth.
- **Gastrointestinal hormones** are proteinaceous in nature. These are of following types – gastrin, secretin, enterogastrone cholecystokinin, pancreozymin, enterocrinin, duocrinin and villikinin.

  [*For the functions of these hormones refer chapter Nutrition and Digestive System*].

HORMONES AND GLANDS AT A GLANCE

Hormone of maternity	–	Prolactin
Birth hormone and milk ejecting hormone	–	Oxytocin
Milk production hormone	–	Prolactin
Emergency hormone	–	Adrenaline
Antiabortion hormone	–	Progesterone
Hormones of metabolism	–	Insulin, glucagon, calcitonin, corticoids.
Hormones of reproduction	–	FSH, LH (ICSH in male), oxytocin, sex hormones
Hormones of growth and development	–	GH (somatotropin), thyroxine.
Salt-retaining hormone	–	Aldosterone
Antidiuretic hormone	–	Vasopressin
Prolactin inhibiting hormone.	–	Dopamine
Anti-gonadotrophic hormone	–	Melatonin
Hormones helps in parturition	–	Relaxin and oxytocin
Hormone responsible for maintaining pregnancy	–	Progesterone
Sex hormones	–	Steroid hormones except hCG and relaxin
Hormone associated with immune system	–	Thymus
Pregnancy test hormone	–	HCG (Human chorionic gonadotropin)
Anti-ageing hormone	–	Thymus, melatonin
Largest endocrine gland.	–	Thyroid.
Largest endocrine organ.	–	Gut.
Temporary endocrine gland.	–	Corpus luteum, placenta.
Receding endocrine gland.	–	Thymus, shrinks after puberty.
Smallest endocrine gland.	–	Pituitary (0.5-1.0 gm).
Triple 'F' & Four 'S' gland	–	Adrenal gland

End of the Chapter