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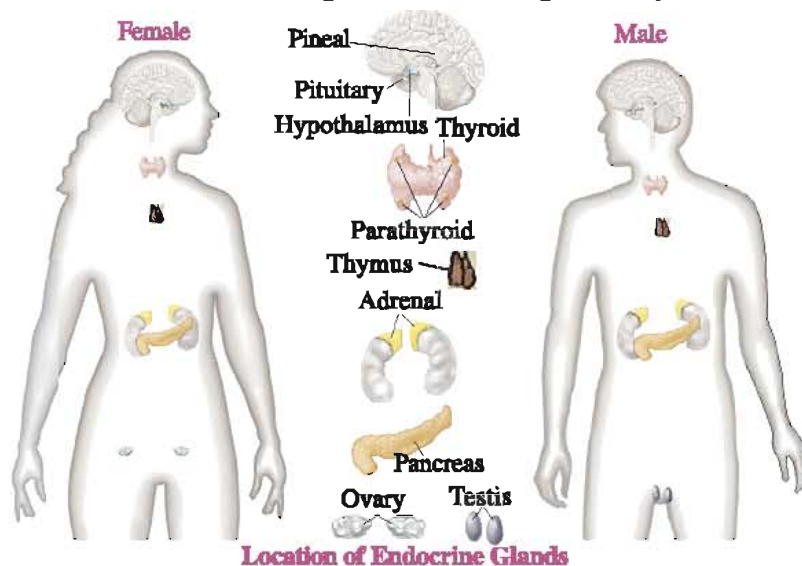
Chemical Coordination and Control

In the previous chapter, we have studied that the nervous system provides rapid coordination among organs. The nervous system controls speedily but its effects are very short lived. For example the nerve impulse transmits rapidly in milliseconds along the nerves to skeletal muscles, which respond immediately. But for the regulation of continuous cellular functions, control and coordination are done by endocrine system. Endocrine system is meant for internal regulation and communication of the human body. In this chapter we will study about human endocrine glands and their hormones and mechanism of hormones.

Endocrine Glands and Hormones

Endocrine glands are ductless and secrete the chemicals termed as hormones into the surrounding blood, which are then transported to the site of action, located away from the site of secretion. Hormones are special types of chemical messengers secreted by endocrine cells in one part of the body and influence the activity of various organs of another part of the body. They are effective in minute quantities to stimulate or inhibit specific physiological processes of the body. Hypothalamus, pituitary, pineal, thyroid, parathyroid, thymus, adrenal, pancreas, testis and ovary are the organised endocrine glands. In addition to these, hormones are secreted by some other organs, like heart, kidney and gastrointestinal tract.

Hypothalamus is the base of the diencephalon, a part of the forebrain. The hypothalamus is composed of nervous tissue and it regulates a wide range of body functions. Hypothalamus is connected with the



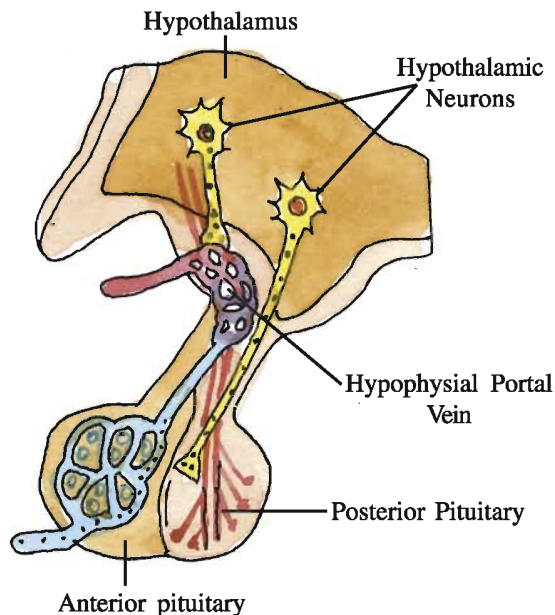
Location of Endocrine Glands

anterior lobe of the pituitary gland by hypophysial portal vessels and with the posterior lobe of the gland by axon of its neurons. It contains several groups of neurosecretory cells which when stimulated, release hormones termed as neurohormones. These hormones regulate the synthesis and secretion of the pituitary hormones. Hypothalamus produces two types of hormones.

The releasing hormones (RH) stimulate secretion of pituitary hormones and the inhibiting hormones (IH) inhibit secretion of pituitary hormones. Growth hormones releasing hormone or somatotrophic releasing hormone (GH.RH or STH.RH), stimulate the anterior pituitary to release growth hormone (GH) or somatotropin. Growth hormone releasing inhibiting hormone (GH-RIH), inhibits the secretion of growth hormone from the anterior pituitary.

Pituitary Gland

The pituitary gland is located just below the hypothalamus. It is situated in a depression of the sphenoid bone of the skull called *sella turcica* and attached to hypothalamus by stalk or *infundibulum*. Pituitary gland is divided anatomically into adenohypophysis and neurohypophysis (posterior lobe). Adenohypophysis consists of two parts, commonly known as anterior pituitary and pars intermedia. The anterior pituitary gland produces following hormones. (1) Growth Hormone (GH) or somatotrophic hormone (STH) stimulates growth and development of all tissues by increasing cell division and protein synthesis. Dwarfism is caused by low secretion of GH. While Gigantism caused by over secretion of GH. It stimulates excess growth and abnormal height in childhood. In adult stage due of excess secretion of growth hormone, bones of lower jaw and limbs becomes abnormally large which develops Acromegaly.



Pituitary and its Relationship with Hypothalamus

(2) Prolactin (PH) stimulates the growth of mammary gland and the secretion of milk after delivery. (3) Thyroid Stimulating Hormone (TSH) stimulates the thyroid and production of thyroid hormones. (4) Adrenocortico Trophic Hormone (ACTH) stimulates adrenal cortex to secrete glucocorticoid and mineralocorticoid hormones. (5) Leuteinising Hormone (LH) in male induces sex hormones-androgens (testosterone) which make the male reproductive system fully grown and functional. The (6) Follicle Stimulating Hormone (FSH) and androgen in male regulate spermatogenesis. In female LH causes ovulation of fully mature follicle (graafin follicles) and forms corpus luteum in the empty ovarian follicle.

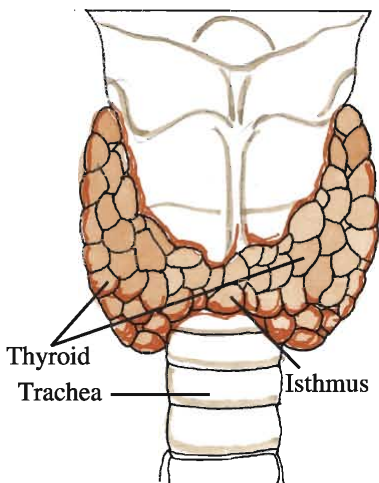
Follicle stimulating hormone (FSH) and Luteinising hormone are together termed as Gonadotrophic Hormones (GTHs). Intermediate lobe of pituitary secretes a hormones named Melanocyte Stimulating Hormone (MSH) which stimulates the melanocytes (black pigments in skin) and regulates pigmentation in skin. Posterior lobe of pituitary releases oxytocin and vasopressin. Oxytocin stimulates the contraction of smooth muscles of our body. In females, it stimulates a widening of uterus at the time of child birth and milk secretion from the mammary glands. Vasopressin stimulates the reabsorption of water and electrolytes by the distal tubules of kidney and reduces loss of water through urine (diuresis). It is also called anti-diuretic hormone (ADH). The deficiency of ADH reduces reabsorption of water and increases urine output. This disorder is known as diabetes incipidus.

Pineal Gland

The pineal gland is located under the corpus callosum between the two cerebral hemispheres of the brain. It is a very small, solid, vascular, reddish grey and conical body. Pineal secretes a hormone called melatonin, which plays a very important role in the regulation of a 24-hour rhythm of our body. Hence it functions as a biological clock. Pineal gland helps in maintaining the normal rhythm of body temperature, and sleep-wake cycle. The melatonin regulates metabolism, menstrual cycle, pigmentation and self defense capability.

Thyroid Gland

The Thyroid gland is bilobed, and located on either side of the upper part of the trachea. The two lobes are connected by a narrow connective tissue band called **isthmus**. The thyroid gland is composed



Thyroid Gland (Dorsal Side)

of rounded follicles, which has a wall of cuboidal epithelium, and is filled with a gelatinous colloid secreted by epithelium. The thyroid gland secretes three hormones : **Thyroxine (T₄)**, **Triiodothyronine (T₃)** and **Thyrocalcitonin**. Iodine is essential for the hormone of thyroid gland. Deficiency of iodine in our diet causes the enlargement of the thyroid gland, commonly known as **Goiter**. Hypothyroidism is caused by under secretion of thyroid gland. During pregnancy, it causes defective development and maturation of the infants leading to cretinism. A person with cretinism has stunted growth, mental retardation, abnormal skin and deaf-mutism. Hyperthyroidism in adult women may cause irregular menstrual cycle. In adult women the deficiency of hormone causes **myxedema** characterized by puffy appearance due to accumulation of fat in the subcutaneous tissue.

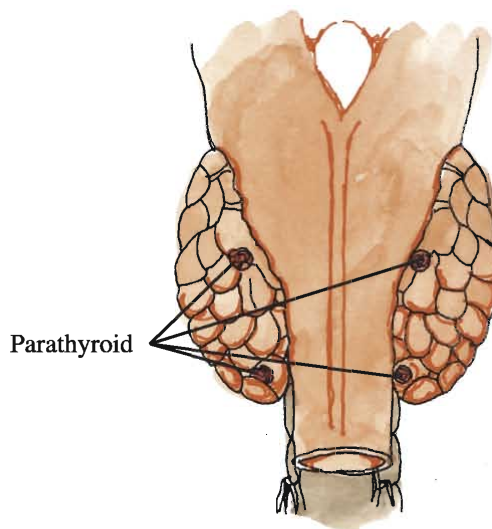
Over secretion of Thyroxine hormone causes **Exophthalmic Goitre**, in which bulging of eyeballs, quick heart beat, rise in blood pressure and body temperature occur. Thyroid hormone plays an important role to control the general metabolism of carbohydrate by regulating the oxidation and ATP production. It maintains the **basal metabolic rate (BMR)** of the body. Thyroid hormone stimulates the process of RBC formation. Thyroid hormone also maintains water and electrolyte balance. Thyroid gland secretes hormone **Thyrocalcitonin (TCT)** which acts upon osteoblast of bones and decreases the calcium level in blood.

Parathyroid

The four lobes of parathyroid glands are located on the ventral surface of the thyroid gland. The parathyroid secretes only one hormone called **Parathyroid hormone** or **Parathormone (PTH)**. PTH increases the Ca^{2+} level in blood. PTH acts on bone and activates the process of bone resorption. PTH increases Ca^{2+} absorption from the digested food and also activates reabsorption of Ca^{2+} by renal tubules. PTH along with TCT plays a significant role in maintenance of calcium balance in the body.

Thymus

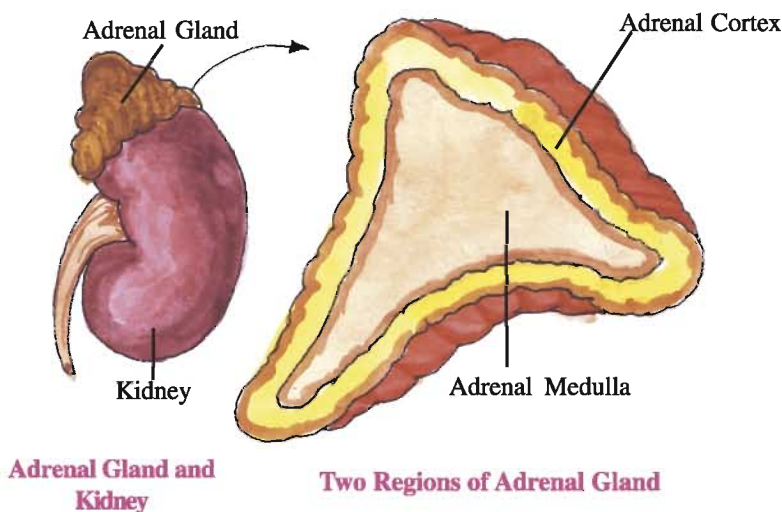
It is located in upper dorsal side of the heart and aorta. The thymus is a soft, bilobed mass of lymphoid tissue. Thymus secretes hormone **Thymosin**. The thymus plays a major role in the development of the immune system. Thymosin stimulates the development and differentiation of T - lymphocytes which provide cell-mediated immunity. Beside this, thymosin stimulates the production of antibodies to provide humoral immunity. In children it is a prominent gland, but it gradually degenerates in the adult, resulting in a decreased secretion of thymosin. Due to this, the immune responses of old persons become weak.



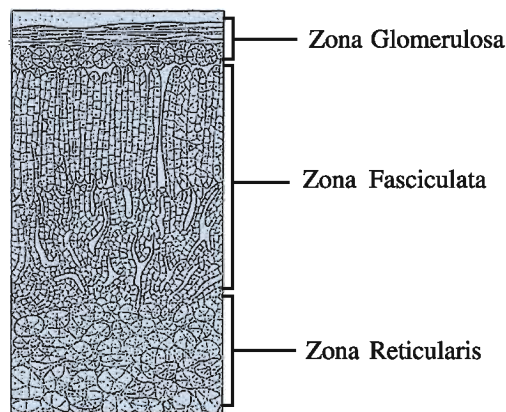
Diagrammatic View of the Position of Thyroid and Parathyroid Ventral Side

Adrenal Gland

A pair of adrenal glands is present, one on the anterior part of each kidney. The adrenal gland is yellowish and conical in shape. Each gland has two distinct regions known as outer adrenal cortex and inner adrenal medulla. The adrenal medulla is a soft, dark reddish brown part. The adrenal medulla secretes two hormones known as adrenaline or epinephrine and noradrenaline or norepinephrine. They are placed in group called catecholamines. At the time of danger or stress or emergency, the CNS stimulates the medulla to secrete adrenaline and nor adrenaline. These hormones play an important role to overcome 'flight or fight' situation hence they are called emergency hormones. Due to these hormones increase alertness and warm red face, pupillary dilation, raising of hairs, faster heart beats and sweating like symptoms are often noticeable. Catecholamine also activates the breakdown of glycogen resulting in an increased level of glucose in blood. They also stimulate the breakdown of protein and lipid.



The adrenal cortex is divided into three layers : the inner layer Zona reticularis, middle layer, Zona fasciculata and the outer layer Zona glomerulosa. Each layer produces its own set of steroid hormones called corticoids. The adrenal cortex is important for life, because its destruction or removal causes death. Mineralocorticoids are secreted by outer layer. They regulate mineral metabolism and the balance of water and Na^+ . Glucocorticoids hormones are secreted by middle region of adrenal cortex. They regulate carbohydrate, protein and fat metabolism. They have antiallergic and anti-inflammatory effects and suppress the immune responses. The main glucocorticoid is cortisol. Sexcorticoids are hormones secreted by both, middle and inner parts of the cortex, which include male and female sex hormones. The male sex hormone, **testosterone**, stimulates the development of male secondary sexual characters such as deepening of voice and distribution of hairs on body. The female sex hormones are **estrogen** and **progesterone**. The estrogen stimulates secondary sexual characters such as enlargement of breast and menstruation.



Adrenal L.S.

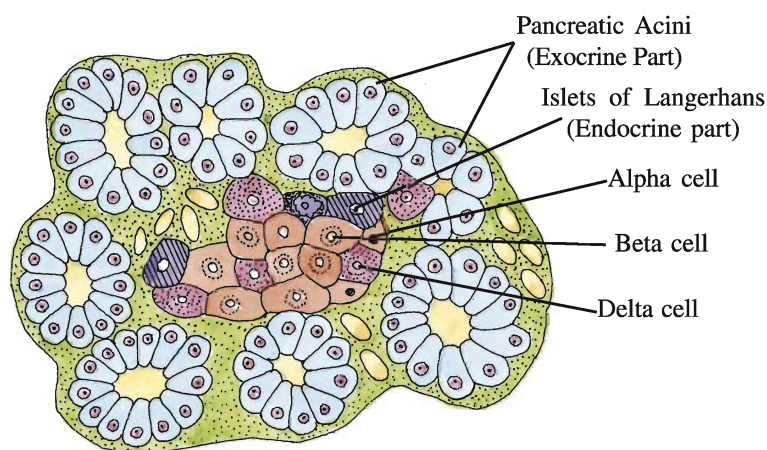
Disorders of Adrenal Gland

Addison Disease : It is caused by deficiency of mineralocorticoid, characterized by ion imbalance. The symptoms include weakness, weight loss, vomiting, nausea and diarrhoea.

Cushing's syndrome is caused by excess secretion of cortisol. The symptoms include high blood sugar, obesity and rise in blood pressure and blood volume.

Pancreas

The pancreas is an elongated yellowish and lobulated gland. Pancreas acts as both exocrine as well as endocrine gland. The endocrine part of pancreas consists of about 1 to 2 million islets of Langerhans.



A Part of T.S. of Pancreas

The three main types of cells present in the islets of Langerhans are α -cells, β -cells and delta cells. The β -cells secrete a hormone called insulin which decreases blood glucose level. The α -cells secrete a hormone called glucagon which increases blood glucose level. Glucagon is a peptide hormone and is secreted in response to a fall in the blood glucose level. Glucagon acts mainly on liver cells and stimulates glycogenolysis resulting in an increased blood sugar (hyperglycemia). Glucagon also stimulates the process of gluconeogenesis which results in rise of blood glucose level. Thus Glucagon is a hyperglycemic hormone. Secretion

of **insulin** from β -cells is stimulated by increased blood glucose level. Insulin acts mainly on liver cells and adipose tissue and increases cellular glucose uptake and utilisation. As a result there is a transfer of glucose from blood to liver cells and adipose tissue resulting in decreased blood glucose level (hypoglycemia). Insulin stimulates conversion of glucose to glycogen (glycogenesis). The glucose level is thus maintained by opposite effect of above both the hormones. Deficiency of insulin causes diabetes mellitus. Diabetes can cause damage to kidney, blood circulation and vision. The symptoms of diabetes are excessive urination, excessive thirst, greater hunger etc. This disease can be controlled by proper diet-control, physical exercise and external introduction of insulin. Delta cells are about 5% and secrete **somatostatin**, which inhibits growth hormone (GH).

Testis

Testis are situated in the scrotum (outside abdomen) of male. They secrete male sex hormones known as **androgens**, mainly testosterone is secreted from the group of Leydig's cells. Testosterone stimulates the development, maturation and functions of the male accessory sex organs like epididymis, vas deference, seminal vesicle, prostate gland and urethra. These hormones stimulate the development of male accessory sex characters like beard and moustaches, muscular growth, axillary hair, low pitch of voice, aggressiveness and broadening of shoulders. Androgens play a main stimulatory role in the process of maturation spermatogenesis. It also acts on the CNS and influences the male sexual behaviour and sex urge.

Ovary

A pair of ovary lie in the abdomen. Ovary secretes three steroid female sex hormones : **estrogen**, **progesterone** and **relaxin**. Ovary is composed of ovarian follicle and stromal tissues. Growing ovarian follicles secrete estrogen and after ovulation, the ruptured follicle is converted to corpus luteum which secretes progesterone.

Estrogen stimulates the female reproductive system to grow to full size and becomes functional. It also stimulates the secondary sex characters (e. g. enlargement of breast, broadening of pelvis, growing axillary hair). It also stimulates development of ovarian follicles in the ovary.

Progesterone supports embryo and foetal development and suspends ovulation, implantation of the foetus in the uterine wall, and helps in placental formation. Progesterone also acts on the mammary glands to stimulate milk secretion and storage of milk. Relaxin is secreted by corpus luteum at the end of the gestation period. It relax the cervix of the uterus for easy birth of the young one.

Hormones of Heart, Kidney and Gastrointestinal Tract

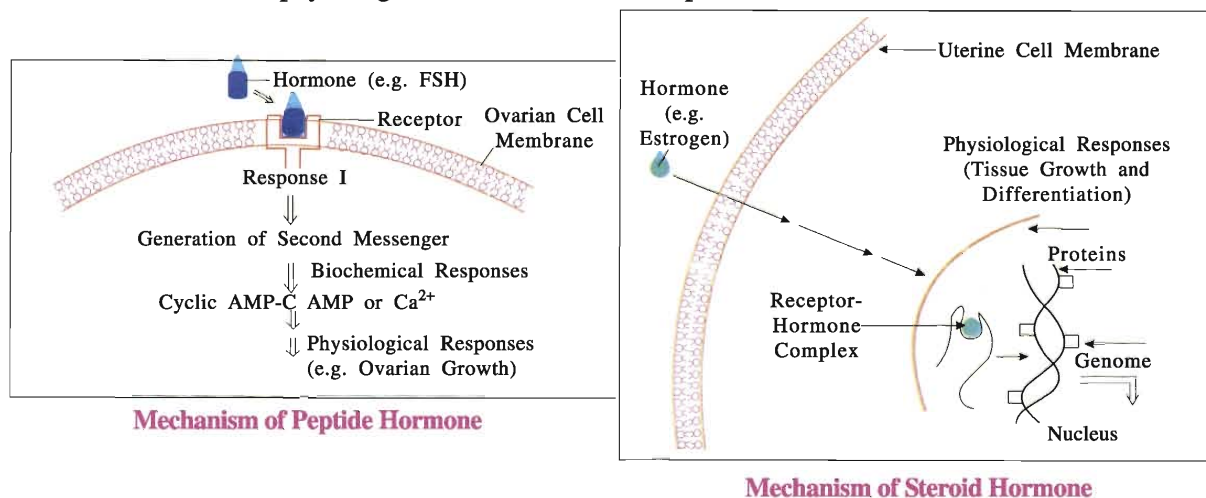
Hormones are also secreted by some tissues which are not endocrine glands. The atrial wall of heart secretes peptide hormone known as **Atrial Natriuretic Factor (ANF)** which decreases blood pressure, when blood pressure is increased. ANF causes dilation of the blood vessels, which reduces the blood pressure. The juxtaglomerular cells of kidney secrete erythropoietin which stimulates formation of RBCs (erythropoiesis). In different parts of gastro intestinal tract endocrine cells are present which secrete peptide hormones namely gastrin, secretin, cholecystokinin (CCK) and Gastric Inhibitory Peptide (GIP). Gastrin stimulates gastric glands to secrete pepsinogen and HCl. Secretin acts on the exocrine gland of pancreas and stimulates the secretion of bicarbonate ions and water. CCK acts on pancreas and gall bladder and stimulates them to secrete pancreatic enzyme and bile respectively. GIP inhibits gastric secretion. Many non endocrine tissues secrete hormones known as **growth factors**, which are important for normal growth of tissues and their repairing and regeneration.

Mechanism of Hormone Action

Hormones exhibit their effects on target cells by binding to specific proteins known as **hormone receptors proteins**, found only in the target cells. These hormone receptors, found on the cell membrane of the target cells, are known as **membrane-bound receptors**. Receptors found inside the target cells are known as **intracellular receptors**. Binding of a hormone to its receptors leads to formation of **hormone receptors complex**. Each receptor is specific to one specific hormone only and hence receptors are specific. Formation of hormone receptor complex creates certain biochemical changes in the target cells. Metabolic processes and physiological processes in target cells are regulated by hormones. On the basis of their chemical nature, hormones can be divided into following groups.

(i) peptide, polypeptide, protein hormones (e.g. insulin, glucagon, pituitary hormones, hypothalamus hormones). (ii) steroid (eg. cortisol, testosterone and progesterone) (iii) iodothyronines (thyroid hormones) (iv) amino acid derivatives (epinephrine).

Hormones which interact with membrane-bound receptor generally do not enter the target cell and generate second messengers (eg. cyclic AMP, Ca^{2+} IP_3 (Inositol tri phosphate) which in turn regulate cellular metabolism. Hormones which bind with intracellular receptors such as steroid, mostly regulate gene expression by the interaction of hormone-receptor complex with the genome. As a result of many biochemical reactions, physiological reactions and development are affected.



SUMMARY

The nervous system controls speedily, but its effects are of very short period. Continuous regulation of cellular functions is necessary. This control and coordination is done by endocrine system. Endocrine is ductless gland and mainly secretes the chemicals termed hormones. Hormones are effective in minute quantity to stimulate or inhibit specific physiological processes of the body. The endocrine system consists of hypothalamus, pituitary, pineal, thyroid, adrenal, pancreas, parathyroid, thymus testis and ovary. In addition to these endocrine glands, some other organs. eg. gastrointestinal tract, heart and kidney also secrete hormones.

The hypothalamus contains several groups of neurosecretory cells, which produce releasing hormones (RH) and inhibiting hormones (IH). The pituitary gland is divided into three parts, anterior pituitary, intermediate lobe and posterior lobe. The anterior pituitary secretes six hormones, intermediate lobe secretes only one hormone and posterior lobe secretes two hormone. The pituitary hormones regulates the growth, and induce secretion of sex hormones. Pineal gland secretes melatonin which regulates 24 hour rhythm of body temperature.

The thyroid hormone plays an important role in the control of general metabolism and maintains BMR of the body. The parathyroid gland secretes parathyroid hormone (PTH) which increases the Ca^+ level in blood. Thymus secretes hormone thymosins which stimulates development of T-lymphocytes and provide cell-mediated immunity. It also stimulates the production of antibodies to provide humoral immunity.

Adrenal gland have two regions known as adrenal cortex and adrenal medulla. The adrenal medulla secretes adrenaline and noradrenaline. The role of these hormones is often called flight or fight reaction. The hormones increase alertness, and cause warm red face, pupillary dilation and faster heart beat. The adrenal cortex secretes mineralocorticoids which regulate mineral metabolism, and the balance of water and Na^+ . Glucocorticoids hormone regulates carbohydrate, protein and fat metabolism.

The main glucocorticoids is sex corticoids, which includes male and female sex hormones. Testosterone is a male sex hormone while oestrogen and progesterone are female sex hormones. The pancreas secretes hormones glucagon and insulin. Glucagon stimulates glycogenolysis and gluconeogenesis resulting in hyperglycemia. Insulin stimulates cellular glucose uptake and glycogenesis resulting in hypoglycemia. Insulin deficiency results in a disease called diabetes mellitus.

Testis secretes sex hormone mainly testosterone which stimulates development, maturation and functions of the male accessory sex organs. The ovary secretes estrogen which stimulates growth and development of female reproductive system and secondary sex characters. Progesterone plays an important role during delivery and prevents ovulation. Relaxin relaxes the cervix of the uterus for easy birth of the young one. The atrial wall of the heart secretes ANF which decreases blood pressure. The kidney produces erythropoietin which stimulates formation of RBC. The gastrointestinal tract secretes gastrin, secretin, cholecystokinin and gastric inhibitory peptide(GIP). These hormones regulate the digestive enzyme secretion and help in digestion.

EXERCISE

1. Put a dark colour in a given circle for correct answer :

- (1) Which of the following does not secrete any hormone?
(a) Spleen (b) Ovary (c) Testes (d) Pancreas
- (2) The number of hormones secreted by anterior pituitary is
(a) 3 (b) 4 (c) 6 (d) 8
- (3) The disease caused by hypo secretion of thyroxine is
(a) Goiter (b) Cretinism
(c) Acromegaly (d) Addison's disease

- (4) Gigantism and acromegaly result from hypersecretion of
 (a) ADH (b) GH (c) TSH (d) ACTH
- (5) Emergency gland of body is
 (a) Thymus (b) Testis (c) Adrenal (d) Pituitary
- (6) Progesterone hormone is secreted by
 (a) Corpus callosum (b) Corpus luteum
 (c) Corpus albicans (d) Thymus
- (7) To whom secretin stimulates ?
 (a) Lungs (b) Gall bladder
 (c) Pancreas (d) Gastric glands
- (8) Which of the following is not a steroid hormone?
 (a) Aldosterone (b) Androgen
 (c) Estrogen (d) Thyroxine

2. Answer the following questions in short :

- (1) Which are the two main types of glands in our body ?
- (2) Define Hormone.
- (3) What is the location of hypothalamus ?
- (4) Name the gland which acts as an exocrine as well as an endocrine gland.
- (5) Name the cells which secrete testosterone.
- (6) Name the cells which secrete estrogen.
- (7) Name the hormones secreted by thymus gland.

3. Do as directed :

- (1) Differentiate between exocrine and endocrine glands.
- (2) What is acromegaly ?
- (3) Why is an injection of oxytocin hormone given at the time of childbirth ?
- (4) State the differences between cretinism and myxoedema.

4. Answer the following questions in detail :

- (1) What is hormone ? Describe thyroid gland in detail.
- (2) Give an account of adrenal gland.
- (3) Give an account of pancreas as a gland.