UNIT 11 PHYSIOLOGY OF THE ENDOCRINE GLANDS

Structure

11.1 INTRODUCTION

The first section in this unit will deal with the hormones and the mechanism of hormone action in the body. In the next section, we will study the endocrine glands and their functions.

You have already learnt about different systems of human body in the previous units. It must be clear to you that each system has a distinct function. Functions of all the systems are coordinated by the endocrine system and the nervous system. We studied about the nervous system in Unit 9. Now let us get to know about the endocrine system.

The endocrine system consists of the glands that are widely distributed in the body having no connection with each other. These glands are the ductless glands. Secretions produced by these glands are called as *hormones,* which are directly secreted into the blood. Hormones are concerned with the long-term control of other systems and the metabolic functions of the body and the transport of substances through cell membrane or other aspects of cellular metabolism. The main abnormalities which occur in association with the endocrine glands are caused by either an oversecretion (hypersecretion) or an undersecretion (hyposecretion) of hormones.

What are these hormones? What is their classification and mechanism of action? The first section in this unit focuses on these aspects. Next, you will find a detailed discussion on the different endocrine glands and their role in the body.

Objectives

After studying this unit, you will be able to:

- illustrate the gross structure of endocrine glands,
- describe the role of various endocrine glands in the regulation of body functions, and
- discuss the effects of over secretion and under secretion of hormones.

11.2 HORMONES

What is a hormone? A hormone, as you may already know, can be described as *a chemical substance which having been formed in one particular organ or a gland is carried in the blood stream to another organ (target organ) where it has its effect, influencing its growth, nutrition and functions.*

In general, hormones are of two types – *local hormone* and *general hormone. Local hormones* affect cells in the vicinity of the organ secreting the hormone, what we call as *paracrine influence*. Examples of local hormones are gastrin and secretin etc. (These are the gastrointestinal hormones). *General hormones*, on the other hand, are emptied into the blood by specific endocrine glands and then flow throughout the entire circulation to affect cells and organs in far distant part of the body referred to as *endocrine influence*. Examples of general hormones are *thyroid hormone* and *adrenocortical hormone* etc. Some general hormones affect all cells almost equally, others affect specific cells. For example, growth hormone secreted from anterior pituitary gland affects all cells of the body, whereas, gonadotrophic hormone from the anterior pituitary gland affects the sex organs much more than the other.

Further, hormones are of two different chemical types – *protein hormone* and *steroid hormone*. Most of the hormones belong to the category of small proteins or derivatives of proteins such as polypeptides, polypeptide amines or chemical compounds derived from one or more amino acids. The adrenocortical and sex hormones are steroid hormones. They have a chemical structure similar to that of cholesterol. Next, let us learn how do these hormones act or function i.e. the mechanism of hormone action.

Mechanism of hormone action: Hormones affect cell function either by activating cyclic AMP (Adenosine monophosphate) mechanism or by activating genes. You may recall reading about the cyclic AMP mechanism in the Nutritional Biochemistry Course. If not, may we suggest you go back to Unit 6 and read it carefully. Here, you will find a brief explanation of the mechanism.

In the cyclic AMP mechanism, the activating hormone combines with a specific receptor substance on the surface of the cell membrane. This activates the enzyme adenyl cyclase in the membrane, which in turn converts some of the adenosine triphosphate (ATP) inside the cell into cyclic adenosine monophosphate (cyclic AMP). This substance has an activating effect on many intracellular reactions.

A second important way by which the hormone affects cell function is *gene activation*. This is the mechanism of hormonal control utilized by steroid hormones. In this case, the activating hormone reacts with a receptor substance in the cell cytoplasm and the combination of the hormone and the receptor then migrates into the nucleus where it activates one or more specific genes. These then promote specific functional effects within the cell. Thus, protein hormones (except thyroid hormones) act via cyclic AMP and steroid hormones including thyroid hormones act through cytoplasmic receptors before they migrate to nucleus. Through these two types of mode of action, the hormones can regulate growth, nutrition and metabolic activity of the cell. Hence, cellular nutrition and function are dependent on the hormonal action.

With this basic understanding of the mechanism of hormone action, we move on to learning about the different endocrine glands in our body.

11.3 ENDOCRINE GLANDS

What do you understand by the term endocrine glands and what is their role in our body? Well, those glands that manufacture one or more hormones and secrete them directly into the bloodstream are referred to as *endocrine glands*. These glands affect how the body uses food (i.e. metabolism). They also influence other body functions about which we shall learn in a little while from now.

First, let us get to know about the various endocrine glands. There are six very important endocrine glands in our body. These are:

1) The pituitary
2) The thyroid
3) The parathyroid
4) The pancreas
5) The adrenal, and
6) The gonads (ovary in female, testes in male)

Figure 11.1 gives a clear picture of these glands.

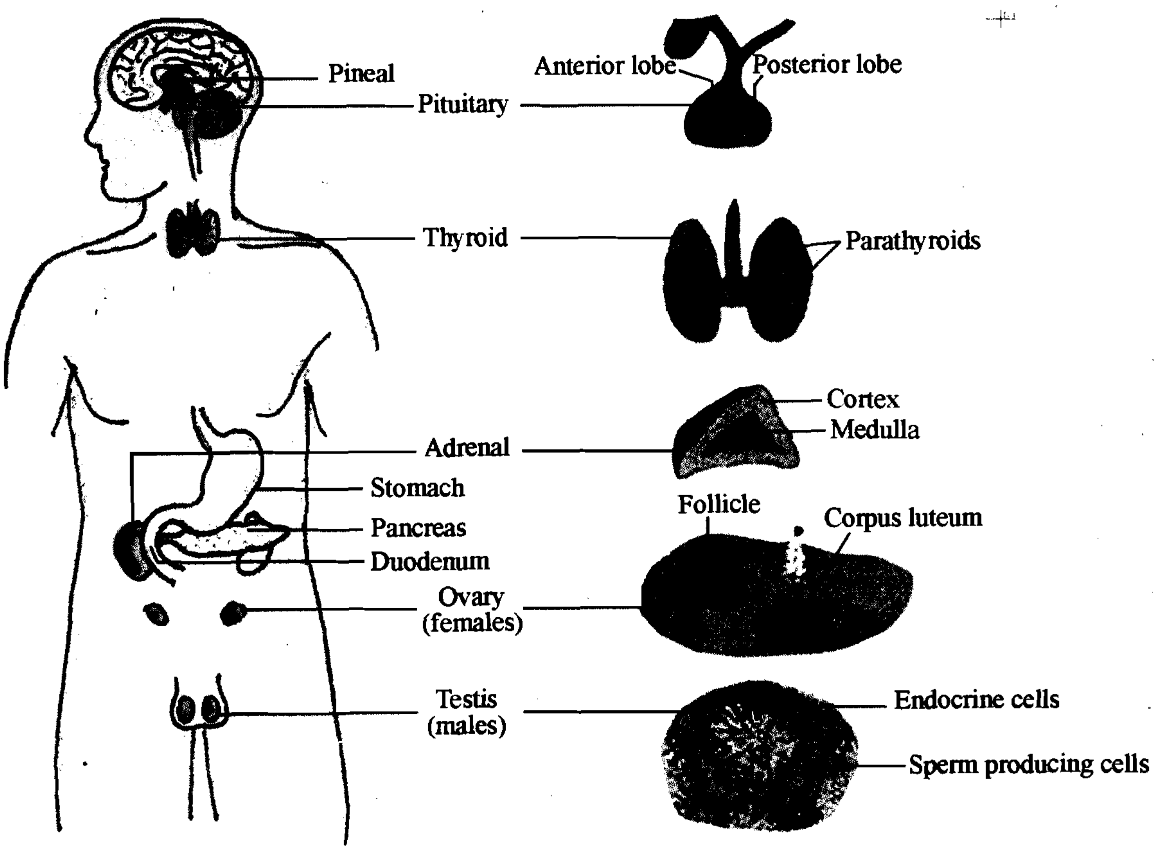

Figure 11.1: Flow diagram for endocrine glands

Let us now begin our discussion on endocrine glands. We shall start with the pituitary gland.

11.4 THE PITUITARY GLAND

The pituitary gland, also called as *hypophysis*, is a small gland that is attached to the underside or base of the brain, behind the nasal cavity as can be seen in Figure 11.2(a). It is approximately 1.5 cm long and 0.5 cm in diameter. In fact, it is no larger than the size of a pea. It lies in the saddle shaped boney depression at the base of skull, called *Sella turcica* (named after the turkish saddle) and is connected with the hypothalamus by the pituitary or hypophyseal stalk.

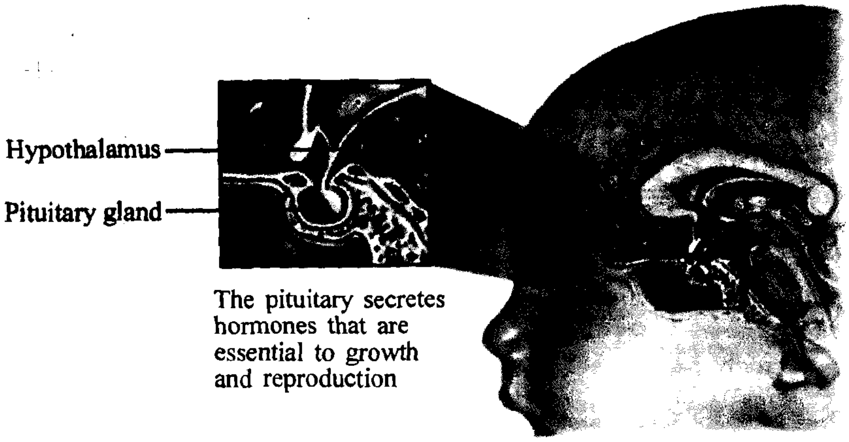

Figure 11.2(a): The pituitary gland

In man, the pituitary has two main compartments – *anterior (adenohypophysis)* and *posterior (neurohypophysis)* as illustrated in Figure 11.2 (b).

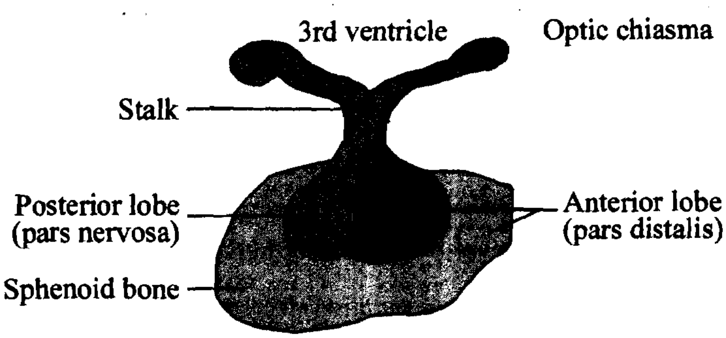

Figure 11.2(b): The anterior and posterior lobe of pituitary

Table 11.1 presents the major hormones synthesized and secreted by the two compartments of the pituitary gland, along with summary statements about their major target organs and physiological effects.

Table 11.1: Major hormones secreted by the pituitary gland

	Hormone	Major target organ(s)	Major physiological effects
Anterior Pituitary	Growth hormone	Liver, adipose tissue	Promotes growth (indirectly), control of protein, lipid and carbohydrate metabolism
	Thyroid-stimulating hormone	Thyroid gland	Stimulates secretion of thyroid hormones
	Adrenocorticotropic hormone	Adrenal gland (cortex)	Stimulates secretion of glucocorticoids
	Prolactin	Mammary gland	Milk production
	Luteinizing hormone	Ovary and testis	Control of reproductive function
	Follicle-stimulating hormone	Ovary and testis	Control of reproductive function
Posterior Pituitary	Antidiuretic hormone	Kidney	Conservation of body water
	Oxytocin	Ovary and testis	Stimulates milk ejection and uterine contractions

As seen in the table above, the anterior pituitary synthesizes and secretes 6 major hormones and the posterior pituitary 2.

Let us get to know about these two compartments of the pituitary in greater details. We shall begin our discussion with anterior pituitary.

11.4.1 Anterior Pituitary

The anterior pituitary gland or adenohypophysis consists of three types of cells – *acidophils, basophils* and *chromophores* according to their staining characteristics. The anterior pituitary, as already highlighted above, secretes six hormones: *growth hormone, thyroid stimulating hormone, adrenocorticotropic hormone, follicle stimulating hormone, luteinizing hormone* and *prolactin.* Since most of these are trophic hormones (controlling growth and nutrition of other glands), pituitary is also known as "master gland". Let us learn about these hormones secreted by anterior pituitary, one by one. We begin with growth hormone and its functions.

A) *Growth Hormone (GH):* It is a protein containing 191amino acids in a single chain. It is secreted by somatotrophs throughout life even though growth stops at adolescence. The main functions of GH are highlighted herewith. The growth hormone:

- promotes development and enlargement of all tissues during the growing phase of life,
- helps the bones to enlarge and lengthen and the skin thickens by the effect of growth hormone,
- increases transport of amino acids through cell membrane and protein synthesis. It promotes positive nitrogen balance and is a protein anabolic hormone, and
- increases blood glucose level by promoting hepatic output of glucose.

After adolescence, growth hormone secretion decreases. The growth of long bones stop by this time, short bones like lower jaw and nose continue to grow. Hence, before adolescence, growth of body depends on the proper action of growth hormone. Height of an individual depends on the proper action of this hormone.

Have you ever thought what would be the consequences of deficiency (hyposecretion) or on the other hand, an increased secretion (hypersecretion) of growth hormone during childhood and at adult stage? The discussion below describes both of these conditions.

Hyposecretion during childhood: Due to deficiency of growth hormone or its receptors, stunted growth of the skeleton and organs occur with resultant dwarfism.

Pituitary dwarfs are the individuals with stunted growth but normal physical and mental abilities. There is another type (Lorain type), where growth hormone level is normal but its receptors are deficient. Such dwarfs do not respond to growth hormone treatment.

Hyposecretion during adult life: It is only currently becoming recognized, the usual feature being low blood glucose level (hypoglycemia). Extended deficiency leads to negative protein balance, physical decline and lot of weight gain due to fat accumulation.

Hypersecretion during childhood: Due to an increased secretion of the growth hormone, gigantism occurs. There is an excessive skeletal growth and the individual may be more than 8 feet tall.

Hypersecretion during adult life: This results in a condition known as *acromegaly.* There is an excessive growth of the bones of the face specially the frontal bone, nose, ears and the mandible. The hands and feet become large (*acro* means extremity, *megaly* means enlargement). Also, there is a thickening of the skin on the face and hands.

From our discussion above, you would have got a fairly good idea that the growth hormone is very important for regulating cellular nutrition, protein metabolism and somatic growth. This is why it is also known as *Somatotrophic hormone.*

Next, let us get to know about the other important hormone i.e. thyroid stimulating hormone, secreted by the anterior pituitary.

B) *Thyroid Stimulating Hormone (TSH):* TSH, also known as *thyrotropin* is a glycoprotein and synthesized by thyrotroph cells of the anterior pituitary gland. Its functions are many and are listed as follows. The TSH:

- stimulates the secretion of thyroxine (T_4) and tri-iodothyronine (T_3) from the thyroid gland,
- increases the number and size of thyroid cells, and
- controls general metabolism of the body through its activity on thyroid.

The thyroid gland becomes inactive and secretes almost no hormone when the anterior pituitary gland fails to secrete TSH. We shall learn about the thyroid gland in the next section.

C) *Adrenocorticotropic Hormone (ACTH):* ACTH, also known as *corticotrophin,* is a polypeptide and is synthesized by corticotroph cells of the anterior pituitary gland. Its functions are to:

- increase both the number of cells in the adrenal cortex and their degree of activity, resulting in an increased output of adrenocortical hormones, and
- regulate mineral and glucose metabolism of the cells.

D) *Gonadotropic Hormones (GTH):* There are two gonadotropic hormones which regulate gonadal functions. They are follicle stimulating hormone (FSH) and luteinizing hormone (LH). Both of the hormones are secreted from gonadotrops of anterior pituitary gland.

FSH contains 204 amino acids and is a glycoprotein. It has distinct functions in case of males and females. In males, FSH stimulates growth of the germinal epithelium in the testes, thus promoting the development of sperm. While in case of females, it initiates growth of the follicles in the ovaries. It also helps to cause the ovaries to secrete oestrogen, one of the female sex hormones.

LH in females joins with FSH to cause oestrogen and progesterone secretion. It also causes the follicle to rupture, allowing the ovum to pass into abdominal cavity and then through a fallopian tube. LH also helps in the formation of corpus luteum (hence the name *luteinizing hormone*) which secretes progesterone. In the males, LH causes the leydig cells of testes to secrete testosterone, the male sex hormone. Hence, through its gonadotropic hormones, anterior pituitary controls the secretion of male and female sex hormones (gonadal hormones).

E) *Prolactin:* Prolactin is synthesized in lactotroph cells of anterior pituitary gland during pregnancy and during the entire period of milk production after the birth of the baby. Its role is to stimulate both breast growth and secretory functions of breasts.

With prolactin, we finish our discussion on the hormones secreted by the anterior pituitary. However, our discussion will be incomplete without a word about the hypothalamic control of anterior pituitary gland. How does the hypothalamus control the pituitary gland? Do you know? If not, read the following discussion and find out.

Hypothalamic control of anterior pituitary gland: The hypothalamus controls many of the automatic functions of the body. It secretes a series of different neurosecretory substances called *hypothalamic releasing* and *inhibitory factors*. These factors are secreted into the blood vessels connecting hypothalamus and pituitary called the *hypothalamic–hypophyseal portal system* and then to the anterior pituitary gland, where they regulate secretion of the various anterior pituitary hormones. These factors include:

- Thyrotropin Releasing Factor (TRF) which causes release of TSH.
- Corticotropin Releasing Factor (CRF) which causes release of ACTH.
- Growth Hormone Releasing Factor (GRF) which causes release of GH.
- Gonadotrophin Releasing Hormone (GnRH) which causes release of both LH and FSH.
- Prolactin Release Inhibiting Factor (PIF) which inhibits the secretion and release of prolactin.
- Prolactin Releasing Factor (PRF) which causes release of prolactin.
- Growth Hormone (GH) releases inhibiting hormone or somatostatin which inhibits the secretion and release of GH.

Now let's take a look at the posterior pituitary, its location, the hormones released from it and their functions in the body.

11.4.2 Posterior Pituitary

The posterior pituitary gland or neurohypophysis is located immediately behind the anterior pituitary gland, as you may have seen in Figure 11.2 (b). In a sense, the posterior pituitary is not a gland because hormones secreted from posterior pituitary are synthesized in the hypothalamus. Hormones from the posterior pituitary are *oxytocin* and *antidiuretic hormone* (ADH) or *vasopressin*. Let's get to know about them.

a) *Oxytocin:* Oxytocin is a polypeptide containing 9 amino acids. An 'oxytoxic' agent is a substance that causes the gravid uterus (uterus of a pregnant female) to contract and this is one of the primary effects of oxytocin. Oxytocin is secreted in moderate quantities during the latter part of the pregnancy and at the time of parturition (delivery). It promotes contraction of the uterine muscles and aids in the expulsion of the body (process of parturition or labor). Oxytocin also causes myoepithelial cells of the mammary gland to contract, therefore, squeezing the milk from the alveoli into the ducts so that the baby can suck it during breastfeeding.

b) *Antidiuretic Hormone:* Antidiuretic hormone or ADH, also known as vasopressin, is another polypeptide containing 9 amino acids. As the name of the hormone suggests, its major action is to prevent diuresis i.e., it reduces the rate of urine formation. This hormone acts on the distal tubules of the kidney controlling the reabsorption of water. When the osmotic pressure is high, the osmoreceptors respond by stimulating the secretion of antidiuretic hormone which increases the reabsorption of water by the renal tubules. ADH is often called *vasopressin* because under the influence of this hormone, the smooth muscles of the intestine and blood vessels contract. Contraction of the muscle layer in the blood vessel wall increases the blood pressure. Hence the name 'vasopressin'. Hence, in dehydrated or malabsorptive diseases, these hormones try to regulate the water and mineral balance of the body by adjusting the quantity of urine formation in the kidney.

Let us take a break here and revise what we have learnt so far. Try answering the questions given in the check your progress exercise 1.

Check Your Progress Exercise 1

1) Define the following terms:

a) Hormone

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b) Endocrine glands

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c) Endocrine influence

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d) Paracrine influence

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2) List the various endocrine glands in our body.

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3) Name two hormones involved in the regulation of water and electrolyte balance. Where are these secreted from?

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4) How are endocrine glands related to cell growth and nutrition?

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5) Match the following:

	A		B
a)	Dwarfism	i)	Hypersecretion of GH during adult life.
b)	Acromegaly	ii)	ACTH
c)	Regulation of mineral and glucose metabolism	iii)	Oxytocin
d)	Prevention of diuresis	iv)	Deficiency of GH
e)	Contraction of uterus	v)	Vasopressin

In the previous sections, you have learnt about the pituitary gland and its two lobes and the hormones secreted by them and their role in the body. Now we move on to the next endocrine gland, i.e. thyroid.

11.5 THE THYROID GLAND

The thyroid gland is situated in the neck in association with the larynx and trachea. It is of butterfly shape as can be seen in Figure 11.3. The gland is composed of acini having epithelial cells which vary from cubical to columnar, depending upon the activity of the gland. The cells are arranged in a single layer round a central space, *the acinus*. The space in the acinus contains a thick fluid known as *colloid.*

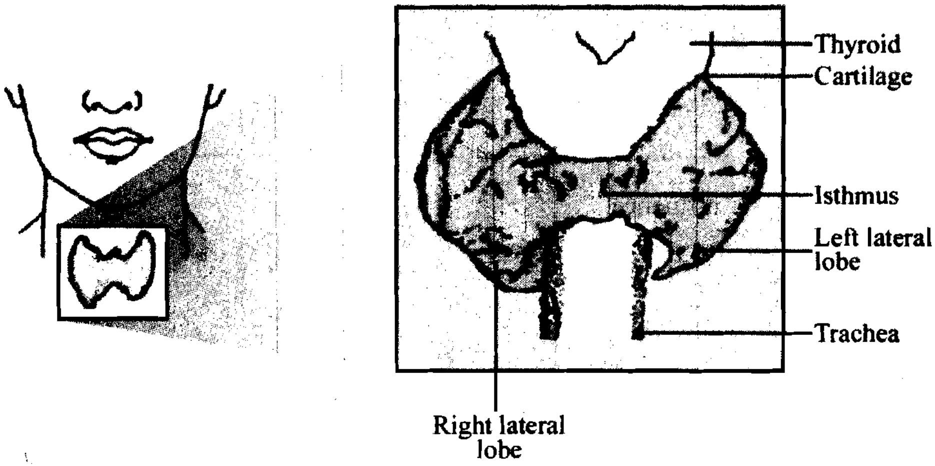

Figure 11.3: The thyroid gland

What is the role of thyroid and which are the hormones secreted by the thyroid? Let's learn. We shall start with the functions.

What are the functions of thyroid gland?

The thyroid gland:

- increases the metabolic activities of most tissues of the body,
- controls the utilization of oxygen in the body and hence, the Basal Metabolic Rate (BMR),
- controls the excitability of neurons and nerve fibres,
- stimulates the different aspects of carbohydrate and fat metabolism. Under the effects of these hormones, there is rapid uptake of glucose by the cells, enhanced glycolysis and gluconeogenesis and mobilization of lipid from adipose tissue, and
- makes the muscles react with vigor.

What are the hormones secreted from the thyroid gland?

Thyroxine (T_4) and tri-iodothyroxine (T_3) are the two hormones of thyroid gland. Iodine, as you may already know, is an essential nutrient required by our body. Why? Well, iodine present in the blood is taken up by the thyroid gland and the hormones thyroxine (T_4) and tri-iodothyroxine (T_3) are formed. These hormones are stored in the gland in the form of thyroglobulin and are released into the blood when required. Iodine ingested by the body is mostly utilized in the formation of tri-iodothyroxine (T_3) and thyroxine (T_4). The uptake of iodine from the blood, formation of the hormone and their release are stimulated by thyroid stimulating hormone (TSH) which you may recall reading above is secreted from the anterior pituitary gland. You should also note that the thyroid gland secretes the hormone calcitonin as well, which is involved with calcium metabolism.

Next, let us learn about the regulatory mechanism involved in the secretion of thyroid hormones.

Regulation of thyroid hormone secretion: TSH from the anterior pituitary gland controls the secretion of thyroid hormones. Thyrotropin Releasing Factor (TRF) from the hypothalamus stimulates TSH. When the level of thyroid hormones in the blood is increased, it inhibits the anterior pituitary secretion of TSH by a direct effect on the anterior pituitary itself (negative feedback) and by indirect effect acting throughout the hypothalamus. Of the various stimuli increasing TSH secretion, exposure to cold is one of them and is very important.

Do you know what the consequences of impaired regulatory mechanism are? What happens when there is either decreased secretion (hyposecretion) or increased secretion (hypersecretion) of the thyroid hormone ? Let's find out.

Hyposecretion (hypothyroidism) during infancy: Decreased secretion of thyroid hormone results in the development of the condition known as *cretinism.* There is a lack of skeletal development and stunted body growth. The child is mentally retarded due to lack of development of the nervous system. The skin is thick and dry, and the face is expressionless. Pulse and respiration rates are slow, there is a general sluggishness of all the body processes. Cretins are different from pituitary dwarfs as along with the stunted growth, they have mental retardation.

Hyposecretion (hypothyroidism) in adult life: Decreased secretion of thyroid hormone results in the development of *myxoedema.* There is a slowing of mental and physical activity. The basal metabolic rate is reduced and there is a considerable general oedema. The facial skin is coarse, thick and dry and there is a loss of hair especially from lateral regions of eyebrows.

Hypersecretion (hyperthyroidism) or thyrotoxicosis: This condition generally occurs in adult life. This is commonly caused by hyperplasia of the gland and is called 'Grave's Disease'. Anti-thyroid antibodies (one such antibody is LATS or long acting thyroid substance) interact with thyroid follicular cells to cause an over secretion of thyroid gland. There is an increased mental and physical activity in the patient. The body temperature is above normal. There may or may not be *exopthalmus*, that is, the protrusion of the eyeball. The patient is nervous, restless, provocative and ready to pick up quarrel on trivial issues. His handshake is warm but wet. Due to increased BMR, heart rate and BP is high with lots of sweating.

Goitre or the enlargement of thyroid gland is one of the critical manifestations of iodine deficiency. Iodine, as you must have realized by now, is an important micronutrient required by our body for the formation of thyroid hormone production. Only small amount, 1 mg per week is necessary for the formation of tri-iodothyroxine and thyroxine. If due to lack of iodine in water or soil or due to any reason, even this small amount of iodine is not supplied, goitre or enlargement of thyroid gland results. The actual swelling of the gland is due to the accumulation of colloid in the acini.

Sometimes, it could be possible that inspite of adequate iodine intake, there is a deficiency of iodine in our body. Now how does that happens? The answer to this is the presence of certain anti-thyroid substances in the body.

What are these 'anti-thyroid substances'? Well, *anti-thyroid substances* are those substances that suppress the thyroid activity. *Thiocyanate* and *propylthiouracil* are examples. Thiocyanate reduces the rate of uptake of iodine by thyroid cells. Propylthiouracil prevents the formation of thyroid hormones. These, along with other anti-thyroid drugs, can be used for the treatment of hyperthyroidism. Hence, by maintaining BMR, normal functioning of thyroid is essential to remain in a balanced state of metabolism.

Now let us move on to the next gland, i.e. the parathyroid gland.

11.6 THE PARATHYROID GLANDS

The parathyroid and thyroid glands are neighbours in the neck. You would realize that parathyroid glands are the small glands that lie behind the thyroid gland, arranged in two pairs – the superior and inferior parathyroids. In fact, there are four parathyroid glands, two behind each side of the thyroid, as can be seen in Figure 11.4. The glands are surrounded by the connective tissue capsules. The cells forming the glands are spherical in shape and are arranged in columns. These are known as the *principal cells*.

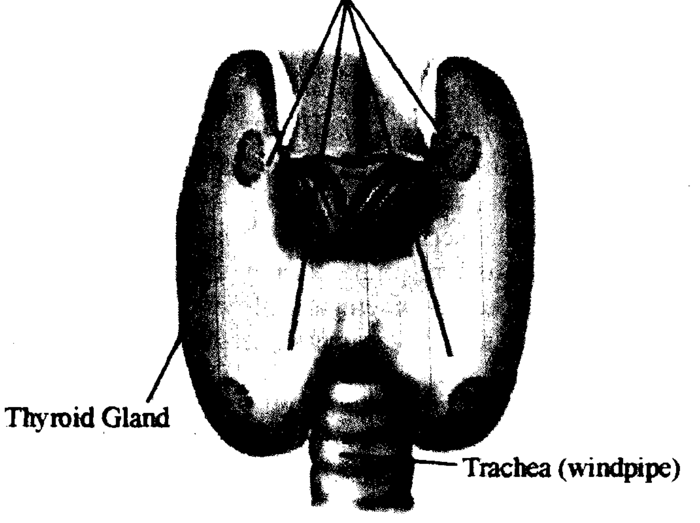

Figure 11.4: The parathyroid gland

What is the hormone secreted from the parathyroid gland?

The parathyroid gland secretes *parathormone*. The amount secreted is strongly influenced by the level of calcium in the blood. Calcitonin from the thyroid gland antagonizes the action of parathormone.

Let us look at the functions of parathyroid next.

What are the functions of parathyroid gland?

The main function of the parathyroid gland is to regulate the calcium levels in our body so that the nervous and muscular functions (where calcium has an important role) can function properly. Parathyroid hormone is mainly responsible for:

- maintaining the constancy of plasma calcium (9 to 11 mg%). It has a direct effect on bone from which calcium resorption occurs.
- promoting absorption of calcium from the small intestine. But this is brought about mainly by controlling the production of 1, 25-dihydroxycholecalciferol in the renal tubules.

How is the parathyroid hormone secretion regulated?

It is simple. An increase in parathyroid hormone causes an increase in calcium absorption from the intestine and renal tubules. When the bone is saturated with calcium salts, the slight excess of extracellular calcium ions reduces parathyroid hormone secretion.

But sometimes under certain conditions this regulation can become impaired. What are the consequences? These are enumerated next.

Hypoparathyroidism: Hypoparathyroidism or a decrease in the secretion of parathormone causes an upset in calcium metabolism. Hypocalcemia develops and the muscles go into a type of spasm known as *tetany.* Muscle spasms of the hands and feet are termed as *carpopedal spasm.* Also, there is twitching of the face and eye muscles. In infants and children, spasm of the muscles of the larynx (laryngismus strodulus) occurs accompanied by *cyanosis.* After a pause, without breathing, a sharp inspiration occurs accompanied by a high-pitched crowing sound.

Hypoparathyroidism occurs very rarely and may be due to the removal of the parathyroid gland in error during the operation of thyroid gland or removal of the parathyroid gland when the thyroid gland is malignant or some defects in the gland for which it is unable to secrete parathormone.

Hyperparathyroidism: Hyperparathyroidism may occur due to a tumour in one or more of the parathyroid glands. In this condition, the calcium level of the blood increases. There is an excessive demineralization of bones and non-utilization of calcium resulting in the softening of the bones. The bone becomes painful and fracture occurs frequently. Due to increased calcium in blood, there is a tendency of the formation of stones in the kidney. The disease is known as *osteitis fibrosa cystica.* Hence, parathormone along with thyroid calcitonin is essential for maintaining calcium balance in the body.

We move to the next gland i.e. the pancreas. You may be wondering why we are talking about pancreas here, when we have already studied about its structure and functions earlier in Unit 6 under the gastrointestinal and glucagon system. The reason being that pancreas is a gland which secretes the hormones insulin and glucagon. Read and find more information on this aspect in the next section.

11.7 THE PANCREAS

The pancreas is a gland that lies immediately below the stomach, surrounded by the loop of duodenum. You can look up the structure of pancreas illustrated in Figure 6.10 in Unit 6 and refresh your memory.

The bulk of the pancreas is composed of pancreatic exocrine cells, whose ducts are arranged in clusters called *acini* (singular *acinus).* The cells are filled with secretory granules containing the digestive enzymes. Embedded throughout the exocrine tissue are small clusters of cells called the *Islets of Langerhans*, which are the *endocrine* cells of the pancreas and secrete insulin, glucagon and several other hormones.

Here we shall focus on the endocrine cells which secrete the hormones. Let us learn about the hormones secreted from the endocrine cells of pancreas.

Hormones from the Islets of Langerhans

The cells which make up the Islets of Langerhans are found in clusters, distributed throughout the substance of the pancreas. There are many thousands of Islets of Langerhans in the pancreas and contain α and β types of cells. α-cells secrete glucagon whereas β-cells secrete insulin. Both influence the level of glucose in the blood. Let us get to know about the two hormones in greater details.

A) *Insulin*

Insulin is a hormone synthesized from the precursor called *preproinsulin.* Preproinsulin has four peptides. Insulin circulates in the blood in a free state. Plasma levels of insulin are from 20 microunits per ml during fasting to about 150 microunits per ml after food. The functions of insulin are listed next.

What are the functions of insulin?

The main function of insulin, as you may already know, is to maintain a steady level of blood sugar level in our body. Insulin, primarily:

- promotes glucose transport into all cells of the body except brain. Rapid transport of glucose into the cells decreases the blood glucose concentration. On the other hand, lack of insulin causes glucose to be accumulated in the blood.
- promotes glycogen storage in the liver and muscle. The glycogen concentration in liver cells sometimes increases to as high as 5 to 6 percent and in muscle cells to over 1 percent. After liver and muscle stores of glycogen have been filled, the rest of the glucose is stored in the fat tissue. Insulin helps in the transport of glucose in these cells.

  Besides these functions, insulin also:

- helps in the transport of most of the amino acids through the cell membrane, and
- increases the formation of protein and RNA in cells.

Having looked at the functions, let us next understand how insulin secretion is regulated.

How is the insulin secretion regulated?

It is interesting to note that blood sugar level itself controls insulin secretion. How? When blood sugar level rises, insulin secretion automatically increases and it helps excess glucose to be transported into the cells, to be used for energy and to be stored as glycogen. A fall in the blood glucose concentration decreases insulin secretion.

Next, we shall get to know the complications arising when the regulation of insulin secretion is effected.

Hyposecretion of insulin: You may already be aware that an insufficiency of insulin in the body leads to the development of *diabetes mellitus*. It is caused by the degeneration of β-cells of Langerhans, from where you learnt earlier that insulin is secreted. Inactivation of β-cells may be inherited from the parents or sometimes antibodies may develop against β-cells. Patients suffering from *diabetes mellitus* have a blood glucose level higher than normal. Sometimes it exceeds the renal threshold level and glucose is found in urine. If high concentration of glucose is present in urine, an excess amount of water is excreted leading to *polyuria* (excessive urination), *polydipsia* (excessive thirst), *polyphagia* (excessive hunger) and dehydration (water loss). Also excess amount of fats are metabolized to the stage of ketoacids. Insulin is not stored in the body. So it has to be given daily to a young diabetes mellitus patient, if required. In adults, diabetes mellitus develops if there is a lack of insulin receptors. Insulin is normal or high, but non-reactive. In such patients, anti-diabetic drugs and strict dietary regimen are essential to maintain blood glucose levels.

Next, let us see what happens when over secretion of insulin takes place.

Hyperinsulinism: Too much secretion of insulin or over treatment of a diabetic person with insulin may cause hyperinsulinism. In this condition, the blood glucose level is very low, resulting in reduced excitability of the brain and coma.

With this, we come to an end of our study on insulin. Next we shall learn about the other hormone produced by the pancreas i.e. glucagon.

B) *Glucagon*

Glucagon is secreted by α-cells of Islets of Langerhans. It is a hormone containing 29 amino acids. Its effects are opposite to that of insulin. Let us see how, by studying about its functions.

What are the functions of glucagon?

As you have just studied that the functions of glucagon are opposite to that of insulin. Hence glucagon:

- increases the breakdown of liver glycogen to glucose, thus making glucose available for transport into the blood, and
- increases gluconeogenesis (conversion of protein to glucose) by activating the liver cell enzymatic system.

So it is clear that glucagon makes glucose available in the body. Let us see how the glucagon secretion is regulated.

Regulation of glucagon secretion: It is simple, when the blood glucose concentration falls below normal, an increased quantity of glucagon is secreted. It helps to keep glucose concentration high enough in the blood and prevents hypoglycemic coma.

Thus, in this section we learnt that the hormones of endocrine pancreas regulate the blood glucose level. You should know that the glucose levels can also be regulated by dietary control of carbohydrates, exercise and anti-diabetic agents.

Check Your Progress Exercise 2

1) Where are the thyroid and parathyroid glands located in our body? What is their role in our body?

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2) How is pituitary dwarf different from thyroid dwarf or cretin?

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3) What are the different hormones secreted by the pancreas? State the functions of these hormones.

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....

4) Explain in 2-3 sentences only

   a) Grave's disease

   ....

   ....

   ....

b) Osteitis fibrosa cystica

....

....

c) Diabetes mellitus

....

....

11.8 THE ADRENAL GLANDS

Adrenal glands, also known as *suprarenal glands* are located on top of both kidneys as shown in Figure 11.5. Each gland is composed of two distinct parts – adrenal cortex (outer part) and adrenal medulla (inner part). These are shown in the Figure 11.6.

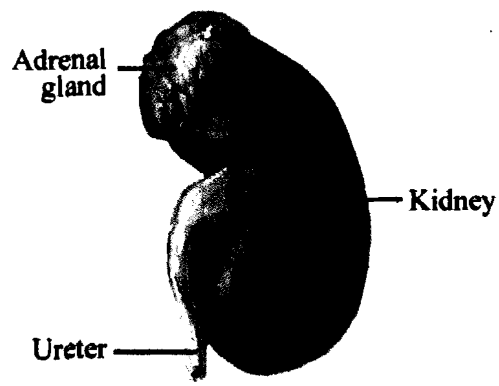

Figure 11.5: Adrenal gland

Let us get to know about the adrenal cortex and medulla in greater details.

11.8.1 Adrenal Cortex

The adrenal cortex is yellowish in colour and covered by a capsule. The cells are arranged in three layers as shown in Figure 11.6.

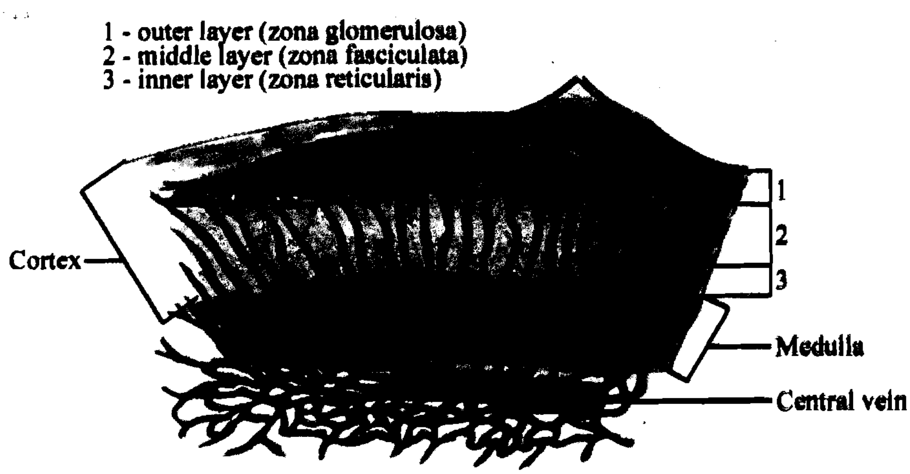

Figure 11.6: Structure of adrenal cortex

As you can see in Figure 11.6, the outer layer consists of groups of thickly set columnar cells called as *zona glomerulosa*. The middle layer consists of large polyhedral cells containing pigment called the *zona fasciculata*. The inner layer, where the cells become interlaced into a network is called the *zona reticularis*.

The zona glomerulosa secretes predominantly mineralocorticoids. The zona fasciculata secretes predominately glucocorticoids and the zona reticularis secretes predominantly sex hormones. Thus, the hormones produced by the adrenal cortex include:

- Glucocorticoid hormone, which includes the cortisol and corticosterone hormone
- Mineralocorticoid i.e. aldosterone hormone, and
- Sex hormones

Let us learn about the functions of these hormones next. We start with the mineralocorticoids i.e. aldosterone hormone.

a) *Functions of mineralocorticoids*

Aldosterone is the name given to the main physiological mineralocorticoid. As you go through the functions listed below, you will realize that aldosterone is associated with the maintenance of electrolyte balance in the body. Let us get to know about the functions of aldosterone.

- Aldosterone increases sodium reabsorption in the renal tubules, especially from the ascending limb of loop of Henle and Distal Convoluted Tubule (DCT) and the collecting tubule. You may recall reading about this earlier in Unit 7 under renal system. When the amount of sodium reabsorbed is increased, the amount of potassium excreted is increased. Thus aldosterone helps in the uptake and retention of sodium in all cells and the extrusion of potassium from them.

- Aldosterone tends to decrease the acidity of body fluids. Like potassium, the hydrogen ions are secreted into the tubules. Hydrogen ions originate from bicarbonic acid. When hydrogen ions are secreted, bicarbonate ions are left in the extra cellular fluid, resulting in alkalosis.

- Aldosterone causes an enhanced absorption of chloride ions. Sodium, chloride and bicarbonate ions are accumulated in the extra cellular fluid. As a result, there is an increased water re-absorption.

Functions of aldosterone are, thus, associated with the maintenance of electrolyte balance in the body. How is the aldosterone secretion regulated? Let's find out.

Regulation of aldosterone secretion: Increased potassium ion concentration and decreased sodium ion concentration increases the aldosterone secretion.

Renin-angiotensin system is also important for the regulation of aldosterone secretion. The juxtaglomerular cells of the kidney secrete renin. Once renin is released from the juxtaglomerular cells, it diffuses into the blood and circulates throughout the body. In the blood, it splits angiotensin I from renin substrate. Angiotensin I is further split to angiotensin II with the help of Angiotensin Converting Enzyme (ACE). Angiotensin II is a powerful vasoconstrictor and increases aldosterone secretion from zona glomerulosa. Hence, in hypertensive patients, advice of reduced salt intake is given along with anti-hypertensive drugs, including ACE inhibitors to reduce the aldosterone secretion.

A minimal amount of ACTH is also needed for the secretion of aldosterone.

The secretion of aldosterone is thus stimulated by:

- a drop in the level of sodium ions in the blood

- a rise in the level of potassium ions in the blood
- angiotensin II, and
- ACTH

b) *Functions of glucocorticoids*

Cortisol, cortisone and hydrocortisone are the names given to the glucocorticoids. What is their function in our body? They play a major role in the body's response to stress. For example, under the influence of cortisol, the blood sugar level is maintained and even raised in the times of stress. In fact, these hormones are responsible for converting glycogen to glucose. They stimulate gluconeogenesis by liver. The blood sugar level may be raised during stress by the process of gluconeogenesis.

Further, these reduce protein stores in essentially all body cells except those of the liver. Catabolism of proteins in the cells release amino acids from the already existing proteins and it hastens the conversion of amino acid to glucose to replenish the glucose supply.

Finally, these promote mobilization of fatty acids from the adipose tissues.

Infection, trauma, intense heat or cold or any type of stress causes an increase in cortisol level in the blood. Let us now see how the glucocorticoid secretion is regulated.

Regulation of glucocorticoid secretion: Glucocorticoid secretion is mainly controlled by ACTH or adrenocorticotropic hormone from the anterior pituitary gland. In any stress, ACTH secretion increases. It stimulates glucocorticoids. ACTH secretion is controlled by CRF or Corticotropin Releasing Factor from the hypothalamus. When the concentration of glucocorticoids is very high, the feedback mechanism automatically reduces ACTH towards a normal level. Glucocorticoids also directly inhibit the formation of CRF. During extreme stressful states, increased production of glucocorticoids cope with the enhanced energy/nutrition requirements of the cells and tissues. Minute stress is essential for the normal gearing up of the body tissues. Too much of stress will exhaust the adrenals to cause crisis.

Finally, let us look at the functions of the adrenal sex hormones.

c) *Functions of adrenal sex hormones*

Adrenal androgens have only weak effects in humans. Their functions are:

- It is possible that part of early development of the male sex organs results from childhood secretion of adrenal androgens.
- Most of the pubic and axillary hair in the female results from action of these hormones. Some amount of progesterone and oestrogens are also secreted by adrenals.

How is the adrenal sex hormone secretion regulated?

The secretion of adrenal androgens by the adrenal cortex is controlled by ACTH.

In the discussion above, we have seen how a fine tune mechanism works to regulate the hormone secretions of the adrenal cortex. An over secretion and under secretion can lead to complications as described herewith.

Hyposecretion of adrenocortical hormones: Hyposecretion of hormones from the adrenal cortex results in the development of the condition known as *Addison's disease.* There is muscular weakness, loss of weight due to loss of water, hypoglycemia, increased blood potassium and decreased blood sodium, pigmentation of the skin especially in the exposed parts of the body. There is a craving for salt. The first thing a patient picks up at the dining table is the salt. If not provided, due to some reason or the other (in diet or as table salt), craving is so great that the patient drinks his own urine.

Hypersecretion of adrenocortical hormones during childhood: Children suffering from hypersecretion of adrenocortical activity are described as *Infant Hercules*. There is too early development of sexual organs and secondary sex characteristics, unusual muscular development and obesity.

Hypersecretion of adrenocortical hormones in adult: This condition is known as *Cushing's syndrome*. It is characterized by *virilism* (hair growth above lips) in the females, that is, a tendency to develop male characteristics. In the males, *feminism* may develop, that is, a tendency to develop female sex characteristics. Besides this, there is wasting of muscles due to an excessive breakdown of proteins and hyperglycaemia develops due to an upset in carbohydrate metabolism.

Having studied about the adrenal cortex, next let us get to know about the medulla.

11.8.2 Adrenal Medulla

The adrenal medulla secretes epinephrine or *adrenaline* and norepinephrine or *noradrenaline*. The secretory cells of the medulla are modified postganglionic sympathetic neurons. Epinephrine and norepinephrine secreted from the adrenal medulla have similar stimulatory or inhibitory effects as the epinephrine and norepinephrine released from sympathetic nerves. Let us look at their functions next.

Functions of adrenomedullary hormones

The functions of the adrenal medulla hormones – adrenaline and noradrenaline – are to:

- prepare the body to deal with the abnormal conditions, so that it responds to fear and excitement,
- dilate coronary arteries and increase the blood supply to the heart muscles,
- dilate the pupil of the eye and allow increased quantity of light to enter,
- increase the activity of the sweat glands,
- dilate the bronchi and allow greater amount of air to enter the lungs at each inspiration,
- slow down peristalsis in the digestive tract and limit the flow of saliva,
- cause rapid breakdown of glycogen into glucose, thus ensuring sufficient glucose for sustained muscle contraction,
- cause intense vasoconstriction on the renal blood vessels and greatly decrease the output of urine, and
- contract the spleen thus increasing the volume of circulating blood.

Of all the endocrine glands, adrenals are essential for life. They prepare the individuals to cope up with the day-to-day stresses in life (General Adoption Syndrome) or make an individual to fight or flight from the enemy (3Fs – Fear, Fight and Flight).

With our understanding of the adrenal gland, we move on to study the pineal gland.

11.9 THE PINEAL GLAND

The pineal gland is a small body situated in the brain. It is reddish grey in colour as you can see in Figure 11.7. It is composed of epithelial cells arranged to form lobules, which are surrounded by a fine connective tissue. You would be interested to know that the pineal gland is about the size of a pea, and is in the center of the brain in a tiny cave behind and above the pituitary gland which lies a little behind the root of the nose. It is located directly behind the eyes.

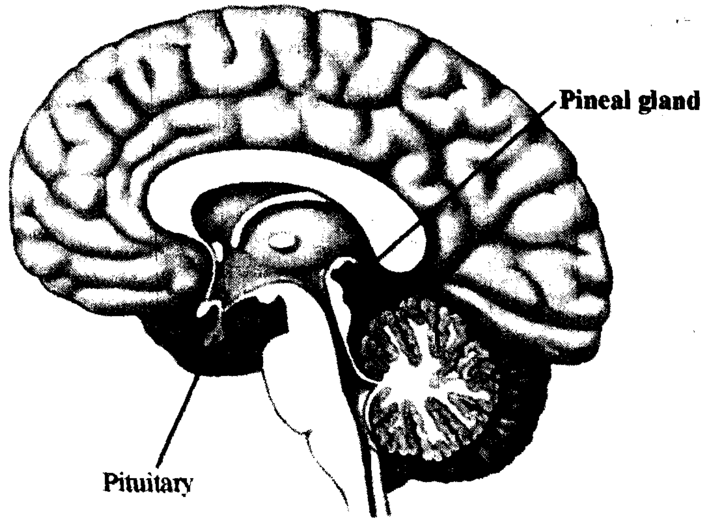

Figure 11.7: The pineal gland

The pineal gland secretes the hormone, *melatonin*. Melatonin acts as a conveyor of photoperiodic information. It has an influence on other endocrine glands. It inhibits the secretion of gonadotrophins. In the jet age, when day and night rhythms are upset due to long flights, melatonin and its derivatives are given to the subjects to overcome jetlags and improve upon their biological rhythms.

Next, a word about the thymus gland.

11.10 THE THYMUS GLAND

The thymus gland lies in the thoracic cavity immediately behind the sternum as shown in Figure 11.8. The gland varies in size depending on the age of the individual. During childhood, it is fairly large in size and in adults it is quite small. The gland is composed of a *cortex* and a *medulla*. A substance called *thymosin* has been isolated from the thymus which stimulates immunological activity in the lymphoid tissue, especially before puberty. In fact, of the two types of immuno competent lymphocytes i.e., B and T, the latter are so named because they are processed in thymus. The thymus, therefore, is responsible for many immune system functions including the production of T lymphocytes, a type of white blood cell responsible for "cell-mediated immunity." It is in fact the master gland of the immune system.

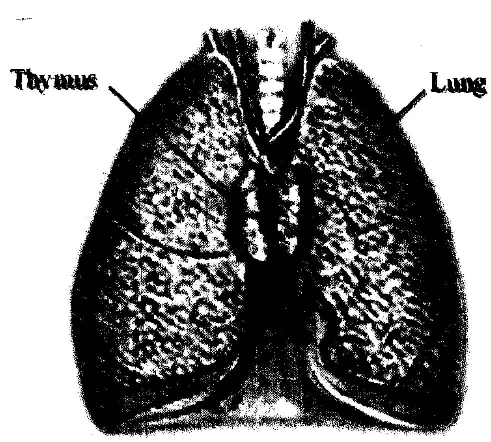

Figure 11.8: The thymus gland

Finally we shall study about the kidneys as an endocrine gland. We have already studied about kidney as an organ responsible for formation and secretion of urine earlier in Unit 7. So you are familiar with its structure. Let us look at the hormones secreted by the kidney.

11.11 KIDNEY AS AN ENDOCRINE GLAND

Besides its excretory function, the kidney secretes some hormones and acts as an endocrine gland. In response to hypoxia, the kidney secretes the hormone *erythropoietin*, which stimulates erythrocyte production. In kidney diseases, there can be anaemia due to deranged erythropoietin production.

Cholecalciferol or vitamin D_3 is taken in the diet from animal food sources. Cholecalciferol is converted into 25-hydroxycholecalciferol in the liver. This 25 hydroxycholecalciferol is transported in the blood stream to the kidneys as 1, 25 - dihydroxycholecalciferol, the active form of vitamin D.

Renin, secreted by the kidneys is responsible for the production of angiotensin in the plasma, which is essential for aldosterone production.

The discussion above highlighted the role of kidney as an endocrine gland.

With this, we come to an end of our study about endocrine glands. But we would like to highlight that *gonads* (ovary and testes) are also endocrine glands, functions of which will be dealt in the physiology of reproduction, in the next Unit.

Check Your Progress Exercise 3

1) Where are the adrenal glands found in our body? Why are they essential for life?

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2) What are the hormones secreted from the adrenal cortex and medulla?

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3) What is the role of glucocorticoids?

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....

....

4) Why does kidney disease produce anaemia?

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....

....

5) Match the following

	A		B
a)	Mineralocorticoid	i)	Cortisol
b)	Glucocorticoid	ii)	ACTH
c)	Adrenal Sex hormones	iii)	Melatonin
d)	Adrenal Medulla	iv)	Aldosterone
e)	Pineal gland	v)	Epinephrine

11.12 LET US SUM UP

In this unit, we learnt about endocrine glands and their functions, including hypo and hyper activity of the glands.

We learnt that there are some endocrine glands in our body which secrete specific substances called hormones into the circulatory system. These hormones influence metabolism and other physiological processes.

Pituitary, thyroid, parathyroid, pancreas, adrenals and pineal gland are the major endocrine glands in our body. We learnt that thyroid hormones affect overall metabolism. Calcitonin from thyroid gland and parathormone from parathyroid gland controls calcium metabolism. Mineralocorticoids from the adrenal gland and vasopressin from the posterior pituitary gland regulate water and electrolyte balance. Glucocorticoids and adrenal medullary hormones are helpful in stressful conditions of life.

11.13 GLOSSARY

Acromegaly : a chronic metabolic disorder in adults caused by the presence of too much growth hormone. It results in gradual enlargement of body tissues including the bones of the face, jaw, hands, feet and skull.

Addison's disease : bronzed skin disease, caused by the hyposecretion of adrenal cortex particularly mineralocorticoids.

Basal Metabolic Rate (BMR): the rate at which heat is produced by an individual in a resting state.

Calcitonin : a hormone produced by certain cells in the thyroid gland that lowers the levels of calcium and phosphate in the blood. It also inhibits the resorption of bone.

Cretinism : lack of thyroid secretion in childhood.

Cushing's syndrome : symptoms of excessive carbohydrate metabolism due to over activity of adrenal cortex.

Cyanosis : a bluish discolouration of skin and mucus membrane due to excessive reduction of haemoglobin in blood.

Diuresis : an increased output of urine by the kidneys.

Dwarf	:	a stunted individual due to the deficiency of growth hormone during childhood.
Exopthalamas	:	abnormal protrusion of the eyeball.
Gigantism	:	an excessive secretion of growth hormone during childhood before the closure of the bone growth plates, which causes overgrowth of the long bones and very tall stature.
Glycoprotein	:	a protein which has carbohydrate groups attached to the polypeptide chain.
Grave's disease	:	hyperactivity of the thyroid gland.
Hypophyseal stalk	:	the funnel-shaped stalk connecting the pituitary gland to the hypothalamus.
Melatonin	:	a hormone produced by the brain's pineal gland that regulates circadian rhythms (sleep/wakefulness cycle); helps induce sleep and acts as an antioxidant.
Myxoedema	:	accumulation of myxomatus fluid in the extra-cellular compartment due to lack of thyroid secretion in adults.
Osteitis fibrosa cystica	:	inflammation of the bones due to marked osteoclastic activity secondary to hyperparathyroidism.
Spasm	:	an involuntary and abnormal contraction of the muscles of hands, thumbs, feet, or toes that are sometimes seen with twitching and tetany. They can be severe and painful.
Steroid hormone	:	hormone derived from cholesterol, lipid soluble and not stored in the body (corticoids of adrenals)
Tetany	:	muscular spasms; a sudden, violent, uncontrollable contraction of a group of muscles, caused by low Ca^{++} in blood.
Thyrotoxicosis	:	a condition due to over-activity of thyroid gland.
Vasoconstrictor	:	a substance that constricts or narrows the blood vessels.

11.6 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1) a) A chemical substance which having been formed in one particular organ or a gland, is carried in the bloodstream to a target organ, where it has its effect, influencing its growth, nutrition and functions is referred to as hormone.

   b) The glands that manufacture one or more hormones and secrete them directly into the bloodstream are referred to as endocrine glands.

   c) General hormones are emptied into the blood by specific endocrine glands and then flow throughout the entire circulation to affect the cells and organs in far distant parts of the body. This is referred to as endocrine influence.

d) Local hormones affect cells in the vicinity of the organ secreting the hormone. This is referred to as paracrine influence.

2) The pituitary, the thyroid, the parathyroid, the pancreas, the adrenal and the gonads are the various endocrine glands in our body.

3) Antidiuretic Hormone (ADH) or vasopressin and aldosterone are the two hormones involved in the regulation of water and electrolyte balance. Antidiuretic Hormone (ADH) or vasopressin is secreted from the posterior pituitary and aldosterone is secreted from the adrenal cortex.

4) Endocrine glands manufacture one or more hormones and secrete them directly into the blood stream. These affect the body's metabolism and influence other body functions such as cell growth and nutrition. Growth hormone released by the anterior pituitary gland promotes development and enlargement of tissues, bones, amino acid transport and increase in blood glucose. TSH, another hormone released by the anterior pituitary increases the number and size of thyroid cells and controls general metabolism.

5) a) - (iv)

b) - (i)

c) - (ii)

d) - (v)

e) - (iii)

Check Your Progress Exercise 2

1) The thyroid gland is situated in the neck in association with the larynx and trachea while the parathyroid gland is located behind the thyroid gland, arranged in two pairs. Their functions are as follows:

Thyroid gland increases the metabolic activities of most tissues of the body, controls the utilization of oxygen in the body and control the excitability of nerve fibres, stimulates the different aspects of carbohydrate and fat metabolism, rapid uptake of glucose by the cells, enhanced glycolysis and gluconeogenesis and mobilization of lipid from adipose tissue, and make the muscles react with vigor.

Parathyroid gland maintains the constancy of plasma calcium (9 to 11 mg %) and promots absorption of calcium from the small intestine.

2) Hypothyriodism during infancy results in the development of the condition known as cretinism. In this, there is a lack of skeletal development, stunted body in growth accompanied by mental retardation, which is not seen in the pituitary dwarfs.

3) The different hormones secreted by the pancreas are insulin and glucagon. The functions of insulin are to promote glucose transport into all cells of the body and glycogen storage in liver and muscle; and glucose in the liver and muscle stores. The functions of glucagon are to increase the breakdown of liver glycogen to glucose and gluconeogenesis by activating the liver cell enzymatic system.

4) a) The hypersecretion of thyroid gland leads to the hyperplasia of the gland, which is called Grave's disease. There is an increased mental and physical activity in the patient, the body temperature is above normal. The patient is nervous, restless, provocative and ready to pick up quarrels on trivial issues.

b) Osteitis fibrosa cystica is a disease condition caused due to the hyperparathyroidism. The calcium level of the blood increases. There is an excessive demineralization of bone and non-utilization of calcium resulting in the softening of the bones.

c) Diabetes mellitus is an insufficiency of insulin in the body and caused by the degeneration of β-cells of Langerhans. The patients have a high blood glucose levels which sometimes exceeds the renal threshold level and glucose is found in urine.

Check Your Progress Exercise 3

1) Adrenal glands are located above the kidneys. Adrenal glands are essential for life as these prepare the individuals to cope up with the day-to-day stresses in life or make an individual to fight or flight from the enemy, maintenance of electrolyte balance and onset of puberty.

2) Adrenal cortex secretes aldosterone, cortisol, cortisone, hydrocortisone and oestrogens and androgens. While adrenal medulla secretes epinephrine and nor epinephrine.

3) Glucocorticoids play a major role in the body's response to stress, change glycogen to glucose. They stimulate gluconeogenesis by liver; reduce protein stores in essentially all body cells except those of the liver. Catabolism of proteins in the cells release amino acids from the already existing proteins and it hastens the conversion of amino acid to glucose to replenish the glucose supply. These promote mobilization of fatty acids from the adipose tissues.

4) Kidney is responsible for the secretion of the hormone erythropoietin which stimulates erythrocyte production. In kidney diseases, due to deranged erythropoietin production, anaemia can result.

5) a) - iv)

b) - i)

c) - ii)

d) - v)

e) - iii)