Chapter 13 - **The Endocrine System**

The endocrine system is made up of the hormone producing glands and tissues of the body.

Hormones are chemicals which circulate through the blood (sometimes special ducts) and control the workings of organs and tissues in the body.

Organs which are affected by a hormone are called **target organs**. Each target organ is only affected by a particular hormone. This is because a target organ has specific receptors on its surface and only a certain hormone will fit into this receptor. This is commonly called the **lock - and - key hypothesis**.

Along with the nervous system, the endocrine plays a large role in helping the body control its homeostasis. Examples include...

1. Control of heart rate
2. Control of blood pressure
3. Controlling the immune response to infection
4. Control of reproduction
5. Control of emotional state
6. Controlling the overall growth and development of the body

Parts of the Endocrine System

The endocrine system consists of a number of glands and tissues.

It consists of the pituitary gland, thyroid gland, parathyroid gland, adrenal gland, thymus gland, and pineal glands. Also it contains the pancreas and reproductive tissues which include the ovaries and testes. { See Fig. 13.1, P. 422 }

Some other organs such as the liver, skin, kidney and parts of the digestive and circulatory systems produce hormones as well.

There are two types of glands in the human body ;

1. Endocrine glands
2. Exocrine glands

Endocrine glands are ductless glands which secrete their hormones directly into the bloodstream.

Exocrine glands release their secretions through ducts or tubes. Examples include sweat glands, salivary glands and tear glands.

Hormones are chemical messengers since they carry signals to one or more organs or tissues in the body.

Once received, the hormone causes a series of changes inside the target organ.

Although only very small quantities of hormone are produced and secreted into the blood, their impact in the target is huge.

Hormones which are secreted into the blood come into contact with virtually all cells and tissues as they circulate through the body. However, they trigger a response only in those cells which have specific receptor sites for the hormone.

Factors In Hormone Production & Function

The level of hormone production in the body can increase or decrease in response to changing metabolic needs in the body.

A number of factors can affect this level ;

1. Fluid level
2. Infection
3. Physical injury
4. Emotional stress

The impact of a specific hormone on a target tissue depends on a number of things ;

1. Hormone production and secretion
2. Hormone concentration in the blood
3. The rate of blood flow to a target organ
4. The half - life of the hormone

The half - life of a hormone refers to the length of time which a hormone remains viable in the blood before it is degraded by the liver or other tissues. It may range from several hours to several days.

Normal functioning of the endocrine system can be disrupted by various medical problems such as ;

1. Tumors
2. Infection
3. Autoimmune disease
4. Physical injury
5. Genetic disorders
6. Industrial pollutants
7. Food additives

Medical treatments for endocrine disorders include ;

1. Hormone replacement therapy
2. Medications which moderate endocrine activity
3. Changes in diet
4. Surgery to remove the affected tissue or organ.

Hormones which are produced by the endocrine system can also interact with each other. Such contrary hormonal substances are called **antagonistic hormones**.

The two types of hormones which are produced by the endocrine system are ;

1. Steroid hormones
2. Non - steroid hormones

Steroid hormones are made from cholesterol. Each type of steroid hormone is made of a central structure of four carbon rings attached to side rings of specific chemicals. { See Fig. 13.4, P. 424 }

Most steroid hormones are hydrophobic (do not mix with water) and are therefore carried throughout the bloodstream by a special protein carrier.

Steroid hormones are fat soluble. This allows them to pass through the membrane of a cell where they bind to a receptor protein inside the nucleus. The hormone - receptor structure then binds to DNA. This causes the activation of certain genes and protein synthesis.

An example of a steroid hormone is cortisol.

Non - steroid hormones are composed of either proteins, peptides, or amino acids. These substances are not fat soluble and thus do not enter cells. These hormones bind to receptors on the surface of target cells. This triggers a chain of chemical reactions within the cell.

Hormones are called the **first messenger** because they bring a message to the target cell when they bind to its membrane. After they bind with the cell's membrane, a special substance called **cyclic AMP** (cAMP) is produced, this is the **second messenger**. The second messenger is responsible for the chain of chemical reactions within the cell.

There are a number of hormones which use second messengers to affect cells. These include ;

1. Adrenaline
2. Adrenocorticotropic hormone (ACTH)

3. Glucagon
4. Luteinizing hormone (LH)
5. Follicle stimulating hormone (FSH)
6. Anti - diuretic hormone (ADH)

Substances such as calcium, caffeine and nicotine are considered to be stimulants and can have an effect on the endocrine system.

Section 13.2 - Endocrine Glands

Both the nervous system and the endocrine system are control systems which are used to help maintain homeostasis in the body.

The nervous system uses bioelectrical signals that travel along nerve cells while the endocrine system releases hormones into the bloodstream and these circulate throughout the body.

The nervous system acts by using a rapid, short - lived response while the endocrine system produces a slow, longer response.

These systems also work with each other. In fact the hypothalamus, a part of the nervous system, and the pituitary gland, a part of the endocrine system, control many critical physiological processes in the body. These include ;

1. Metabolism
2. Kidney function
3. Appetite
4. Mental alertness
5. Reproduction
6. Growth & development

The hypothalamus and the pituitary gland both release hormones which influence the activity of other hormone producing glands.

The Pituitary Gland

The hypothalamus is connected to the pituitary gland by a network of blood vessels called a portal system.

This allows the nervous system to exert its control over the hormones produced in the pituitary gland and other endocrine glands.

The pituitary gland is referred to as the **master gland** because it produces hormones which control the production of hormones in other endocrine glands. These hormones are called **tropic hormones**.

Example : The pituitary gland produces a hormone called the thyroid stimulating hormone (TSH) and this hormone stimulates the thyroid gland to produce the thyroid hormone.

The pituitary gland is made up of two glands ;

1. The anterior pituitary gland
2. The posterior pituitary gland

{ See Fig. 13.8, P. 428 }

The Anterior Pituitary

This lobe of the pituitary gland produces six types of endocrine hormones, human growth hormone and four tropic hormones.

Human growth hormone (HGH)

This hormone regulates growth and development of the body. It is also called somatotropin.

This hormone does a number of things to cause the body to grow and develop ;

1. Increases absorption of calcium from the intestines.
2. Increases cell division and development.
3. Stimulating protein synthesis and lipid metabolism.

The half life of HGH is only 20 hours.

HGH triggers the production of growth factors in the liver and other tissues.

The level of HGH in the body decreases with age. It is thought that the features of aging such as smaller muscle mass and wrinkles is due to the small amount of this hormone.

If the level of HGH is low during childhood, a condition called **pituitary dwarfism** may occur. People with this disorder have a short stature with normal length arms and legs.

Treatment of individuals involves...

1. Giving the dwarf child HGH which was extracted from cadavers.
2. Inserting sections of DNA which are responsible for HGH production into bacteria. These bacteria then produce HGH as a waste product. This HGH is then used to treat dwarfism.

If too much HGH is produced during childhood, a condition called **gigantism** results. Individuals with this disorder have abnormally long skeleton bones.

Treatment of this disorder includes ;

1. Surgical removal of a tumor from the pituitary gland
2. Irradiation of the gland tissue.

If an adult has too much HGH produced in their body, a condition called **acromegaly** can result. This is caused by the growth of a tumor in the pituitary gland. Symptoms of this condition may include ;

1. Thickening of bone tissue.
2. Abnormal growth of the head, hands and feet.
3. Spinal deformities.

Treatment of acromegaly includes ;

1. Surgical removal of the tumor.
2. Radiation therapy.
3. Injection of a growth hormone blocking drug.

Prolactin

This hormone, which is also produced by the anterior pituitary gland, stimulates the development of mammary gland tissue and milk production (lactogenesis).

The hypothalamus regulates the production of prolactin. The hypothalamus secretes a hormone called dopamine which inhibits the production of prolactin. In late pregnancy, an increase in the hormone estrogen will stimulate prolactin production. Also, after a child is born breast feeding stimulates nerve endings in the nipples which stimulates the hypothalamus to release prolactin secreting hormones.

The Posterior Pituitary

This gland is made up of secretory nerve cells which were produced in the hypothalamus.

The hypothalamus makes two hormones called anti-diuretic hormone (ADH) and oxytocin which are stored in the posterior pituitary gland until needed.

Anti-diuretic Hormone (ADH)

This hormone has two major roles in the human body ;

1. It regulates the levels of sodium in the bloodstream. Specialized cells in the hypothalamus, called osmoreceptor cells monitor the level of sodium in the blood. If the sodium level is too high, ADH is secreted from the posterior pituitary gland to bring it back to a normal level.

2. ADH is also secreted from the pituitary gland in response to decreased blood pressure which results from loss of blood due to torn or damaged blood vessels. ADH will cause a severed artery to constrict and reduce blood loss while increasing blood pressure.

There are a number of factors which can inhibit the secretion of ADH ;

1. Head trauma (head injury) which causes damage to the pituitary gland or hypothalamus.
2. The development of tumors in the pituitary gland.
3. Inflammation due to infection.

If the body does not produce enough ADH, a disorder called diabetes insipidus may result. Symptoms of this disorder include ;

1. Increased thirst and dehydration.
2. Frequent urination (dilute)
3. An enlarged urinary bladder

This disorder can be treated by giving the patient the ADH hormone.

If the body produces too much ADH, the kidneys will begin to retain more water and produce a concentrated urine. This will cause an increase in the volume of the blood and a decrease in the blood's sodium concentration. A low level of sodium can cause a twitchiness in both nerve fibers and muscle tissue.

Oxytocin

This hormone plays an important role both during and after childbirth in women.

It triggers muscle contractions during childbirth and stimulates the release of milk from the breasts after birth.

The action of this hormone during and after birth is what is known as a **positive feedback loop**.

A. Pressure from the baby's head against the walls of the uterus causes pressure receptors to send an impulse to the hypothalamus which triggers the release of oxytocin from the posterior pituitary. The oxytocin causes the uterine muscles to contract more forcefully and each contraction causes the release of more oxytocin.

B. A child suckling at the breast of its mother is also an example of a positive feedback loop. As the child feeds from the mother's breast, a suckling reflex is initiated. The reflex trigger's oxytocin secretion from the pituitary gland. The extra oxytocin stimulates contraction of smooth muscles of the mammary ducts which causes the expulsion of milk from the mammary glands (breasts). This induces the child to suckle at the breast.

It has been suggested that the secretion of oxytocin causes pleasure to the mother during contact with the newborn. This arouses feelings of strong affection which creates a mother - child bond.

The production of oxytocin is also a factor in erections and orgasm.

The Thyroid & Parathyroid Glands

The **thyroid gland** is located just above the trachea in the neck and has a butterfly shape. The thyroid gland contains four small glands called the **parathyroid glands**. The thyroid gland produces a hormone called **thyroxine**. This molecule contains four atoms of iodine. Thyroxine causes an increase in the metabolism and oxygen consumption of the heart, skeletal muscle, liver and kidney.

The anterior pituitary gland produces a hormone called **thyroid stimulating hormone** or TSH. This hormone stimulates the thyroid gland to produce thyroxine.

The thyroid gland uses about 30 % of the iodine in the blood to be used to make thyroxine.

Hyperthyroidism & Hypothyroidism

When an individual has too much or too little thyroxine produced by the thyroid gland, he / she can develop the following disorders called ;

1. Hyperthyroidism
2. Hypothyroidism

Hyperthyroidism occurs when the thyroid gland produces an excess of thyroxine. This disorder, also known as **Graves disease**, occurs when antibodies attach to TSH receptors on thyroid cells. This causes the cells of the thyroid gland to continually produce thyroxine. Excess thyroxine causes a number of problems ;

Enlargement of the thyroid gland
Muscle weakness
Increased metabolism
Excessive heat production
Sweating
Warm skin
Increased appetite, but weight loss.
Bulging or protruding eyes.

Treatments for hyperthyroidism include ;

Surgical removal of the thyroid gland.
Thyroid blocking drugs
Treatment with radioactive iodine
Injections of thyroid hormone

Hypothyroidism is a result of a deficiency of thyroxine. It is also called **myxedema**. A decrease in iodine levels in the body can cause hypothyroidism. Symptoms of hypothyroidism include ;

Reduced metabolism
Reduced tolerance to cold temperatures
Decreased heart rate
Decreased appetite, but weight gain
Decreased mental capacity
Weakness and fatigue
Poor physical development

Goiter

Goiter is a swelling of the thyroid gland caused by insufficient levels of iodine in an individual's diet.

Low levels of iodine in the diet causes an increase in cell division in the thyroid gland causing it to expand.

As the gland swells, a bulge occurs in the neck of the individual. { See Fig. 13.15, P. 433 }

Early treatment for goiter involved adding iodine to the diet of individuals and adding iodine to drinking water.

Today, iodine is a common addition to table salt, what we call “iodized salt”. This has eliminated most cases of goiter.

Calcitonin & Parathyroid Hormone

Calcium is a very important mineral in humans for a number of reasons ;

1. Healthy teeth
2. Normal skeletal development
3. Blood clotting
4. Formation of nerve impulses
5. Muscle contractions

The level of calcium in the blood is regulated by a hormone called **calcitonin** , a hormone which is produced by the thyroid gland and **parathyroid hormone** (PTH) which is made by the parathyroid gland.

Calcitonin and parathyroid hormone have opposite effects on the level of calcium in the blood. Thus, we call them **antagonistic hormones**.

1. Calcitonin production causes the level of calcium in the blood to become lower. This is due to the effect that more calcium is being deposited into bone tissue and into the skeletal system. The kidneys also excrete more calcium from the body in urine.

   Parathyroid hormone causes the level of calcium in the blood to increase. PTH stimulates bone tissue to release calcium into the blood and causes the blood stream to reabsorb calcium from the kidneys.

Vitamin D

Vitamin D is a steroid hormone which also helps to regulate the level of blood calcium.

Production of vitamin D is regulated by the parathyroid hormone (PTH).

The role of vitamin D is to maintain blood calcium levels.

It increases the release of calcium into the blood from bone tissue. It also increases the retention of calcium in the kidney.

In the small intestine it increases the rate of calcium absorption into the blood.

A lack of vitamin D will result in low levels of blood calcium and this problems such as osteomalcia (soft bones) in adults or rickets in infants. Symptoms of these disorders include ;

1. A lack of normal growth and development
2. Skeletal deformities
3. Susceptibility to bone fractures
4. Skeletal pain
5. Muscular weakness

The addition of vitamin D to foods such as dairy products has reduced the incidence of this disease.

The Pancreas

The pancreas is a small gland located near the small intestine.

It contains two types of tissues which act like endocrine and exocrine glands.

As an exocrine gland, the pancreas produces digestive enzymes which are secreted into the duodenum section of the small intestine.

As an endocrine gland, the pancreas produces two non-steroid hormones called **glucagon** and **insulin**.

These two hormones regulate how the body uses sugar and other carbohydrate molecules. They are produced by small groups of cells scattered through the pancreas called the **islets of Langerhans**.

Insulin is a hormone which forces the body to store excess nutrients. Examples of this include ; glycogen (starch) which is stored in the liver, fat which is stored in adipose tissue and protein which is stored in muscle tissue. Thus, we sometimes refer to insulin as the “hormone of abundance.”

Insulin also stimulates protein synthesis and tissue growth throughout the body. After it has performed its job, insulin is broken down by the liver and kidneys.

Glucagon has an opposite influence on the body. It triggers the release of glucose, fatty acids and amino acids from cells back into the bloodstream.

A problem which can arise in the pancreas is diabetes. There are two types of diabetes ;

A. Type 1 Diabetes
B. Type 2 Diabetes

Type 1 diabetes, also called **diabetes mellitus**, is an autoimmune disorder in which the body's own immune system attacks the pancreas because it no longer recognizes the pancreas as belonging to the body. Once the attack begins, the body loses its ability to produce insulin overnight.

Type 2 diabetes, also called **adult onset diabetes**, occurs in adults over the age of 40. Ninety percent of all diabetics have type 2 diabetes. In this case the body either produces too little insulin or the body fails to recognize the insulin which is produced. Treatments for this form of diabetes may include ;

1. Changes in diet and exercise (lifestyle change)
2. Medication or insulin shots to control blood sugar levels.

Both Type 1 and Type 2 diabetes can cause problems such as ;

A. Rapid weight loss
B. Blindness
C. Circulatory problems

The Pineal Gland

The pineal gland is a small, cone - shaped structure located in the center of the brain.

The pineal gland produces two hormones ; **cortisol** and **melatonin**.

The production of these hormones follows a daily 24 hour cycle which is referred to as a **circadian rhythm**.

Cortisol hormone production is greatest at night and peaks just before a person wakes. The level of this hormone decreases during the daytime.

Melatonin is also produced in high amounts during the nighttime and decreases during the day.

The Thymus Gland

The thymus gland is located in the upper chest cavity between the left and right lobes of the lungs.

This gland produces a hormone called **thymosin** which stimulates the production and maturation of lymphocytes to T cells. This gland disappears after puberty.

Seasonal Affective Disorder

This disorder, also known as SAD, is a condition that produces symptoms of depression and an overwhelming desire for sleep.
The symptoms for this disorder appear at the beginning of winter.
It affects 20 percent of the people in northern countries. It only affects a small population of the residents of southern countries.
When levels of melatonin are above normal, people can develop the symptoms of SAD.
Exposure to bright lights for 2 to 3 hours each day can lessen the symptoms of this disorder.

Section 13.3 - **The Adrenal Glands & Stress**

Humans have two adrenal glands which are located on top of each kidney.

The adrenal gland is made up of two layers ; an outer layer called the **adrenal cortex** and an inner layer called the **adrenal medulla**.

Each of these layers functions as an independent organ producing different hormones.

Both the cortex and medulla are regulated by the hypothalamus of the brain.

The adrenal gland has a major role to play in the body's response to stress.

The Adrenal Cortex

The adrenal cortex produces two types of steroid hormones ;
1. Cortisol (a type of glucocorticoid)
2. Aldosterone (a type of mineralcorticoid)

Cortisol is a hormone which stimulates the synthesis of carbohydrates.

Aldosterone regulates the body's salt and water balance.

The adrenal cortex also produces the male sex hormones called **androgens** and the female sex hormones called the **estrogens**.

The hypothalamus produces a substance called **corticotropin releasing factor** (CRF) which stimulates the anterior pituitary gland to produce a hormone called **adrenocorticotropic hormone** (ACTH) which regulates how much cortisol and aldosterone are produced by the adrenal gland.

Cortisol

Cortisol causes an increase in the process of **gluconeogenesis**. This is the process in which carbohydrates are made from amino acids and other substances in the liver. The carbohydrate is converted to glucose (simple sugar) when needed by the body. Cortisol also has other functions ;

1. It prompts the breakdown of lipids in fat tissue to be used for energy.
2. It inhibits metabolism.
3. It stops protein synthesis in most organs.

Medically, cortisol is used as an anti-inflammatory. It decreases the buildup of fluids in a region of inflammation. It suppresses the production of T-cells and antibodies from the immune system which can cause further inflammation.

It is used to treat inflammation in skin injuries, arthritis, and asthma.

Physiological Response To Stress

Any form of physical or emotional stress stimulates a response in the hypothalamus.

The response follows a particular pattern ;

1. The hypothalamus produces more CRF.
2. Next, the anterior pituitary gland produces ACTH hormone.
3. ACTH triggers the adrenal cortex to produce high levels of cortisol.
4. Extra cortisol helps relieve some of the negative effects of stress.

Increased levels of cortisol may also cause ;

A. An increase in gluconeogenesis which provides

additional energy for cells.

B. An increased interaction with insulin to increase food intake and redistribute stored energy from muscle to fat tissue.

C. A depressed immune function by reducing the availability of proteins needed to make antibodies and other immune system substances.

Aldosterone

Aldosterone has two main functions ;

1. Osmoregulation or the process of regulating the amounts of water and salts in the blood.

2. Regulation of blood pressure.

Aldosterone stimulates the reabsorption of sodium from the kidneys and colon (large intestine).

Sex Hormones

The adrenal cortex also produces small amounts of the sex hormones ;

Androgens (male sex hormones)
Estrogens (female sex hormones)

Although both hormones are found in each sex, males produce more androgens and females produce more estrogens.

Androgens promote muscle and skeletal development in both males and females.

Estrogens play a major role in the female reproductive system.

The Adrenal Medulla

This part of the adrenal gland secretes two hormones ;

1. Adrenaline (epinephrine)
2. Noradrenaline (norepinephrine)

Adrenaline is the major hormone which is secreted by the body in response to a stressful situation.

The adrenal medulla secretes 85% adrenaline and 15% noradrenaline.

These hormones affect the body in a variety of ways ;

1. Increase heart rate and blood pressure.
2. Cause widening of blood vessels in the heart and respiratory system.
3. Stimulate the liver to break down glycogen to glucose and releasing it into the blood.

Adrenaline & Anaphylactic Shock

Anaphylactic shock is a severe allergic reaction to antigens from sources such as ;

1. Bee stings
2. Peanuts & other foods
3. Sources of latex (rubber)
4. Intravenous medications such as penicillin

When these antigens (foreign particles) enter the bloodstream they trigger a chain reaction which we call **anaphylactic shock**.

When the antigen gets into the bloodstream, it triggers events such as ;

1. Release of an anti-inflammatory substance called histamine.
2. Histamine causes ;Widening of the arteries (vasodilation) in the cardiovascular system. Leakage of fluid and proteins from the capillaries. Decreased blood pressure. Reduction of blood flow to the body's organs and tissues.

Emergency treatment of this reaction involves injection of the adrenaline hormone (epinephrine) by a device called an Epi - Pen.

Without immediate treatment an individual could die within minutes.