CHAPTER-8

# The endocrine system

**Learning Outcomes:**
**The student should be able to:**


- Define an endocrine and exocrine gland
- Name the organs of the endocrine system
- Be able to locate these organs within the a diagram of the body
- Name the hormones secreted by the specific organs of the endocrine system

## Overview of the Endocrine System

The nervous and endocrine systems have a global and integrated effect on the body. The nervous system has structural continuity, which the endocrine system lacks. Its actions are rapid and its targets, precise. The endocrine system secretes hormones, which may take hours before having an effect, and are available to every cell in the body. Together, the nervous and endocrine systems function in co-ordinating homeostasis in the body.

The endocrine glands, which have ducts, release their secretions into body cavities or the outer surfaces of the body. These substances are either released directly into the blood or diffuse through the interstitial fluid into the capillaries to be delivered to its final destination via the circulatory system.

## Classification of hormones

Hormones are divided functionally, into two groups.

1) Endocrines or circulating hormones:
   These hormones are released into the circulation and affect tissues distant from the secretory cells. Inactivated by the liver, and excreted via the kidneys.
2) Local hormones:
   These hormones act locally, without first entering the bloodstream. Inactivated quickly (after a few minutes).
   Local hormones are further classified into:
   a) Paracrines: hormones acting on neighbouring cells.
   b) Autocrines: act on the same cell, which secreted it.

## Hormone Receptors

Hormones and their receptors work of a lock-and-key system; therefore, although hormones are available to almost every cell in the body, they only affect a few target cells. Hormones influence target cells through chemically binding to specific protein or glycoprotein receptors.
**Down and Up regulation:** When a certain hormone is present in excess, the number of target cells may decrease through lysosome degradation. In this way, the responsiveness of target cells is decreased. Up-regulation is the

opposite effect, when receptors are increased and the target tissue is more sensitive.

The control of hormonal secretion is usually the result of negative feedback

**Task**:
Make a note of the functions of hormones
Please note the three specific methods by which hormonal secretion is regulated

**The endocrine system is made up of the following glands:**

- The pituitary gland
- Thyroid glands
- Parathyroid glands
- Adrenal glands
- Pineal gland

**Other tissues and organs of the body secrete hormones, and are therefore part of the endocrine system, but are not exclusively endocrine glands:**

- Hypothalamus
- Thymus
- Pancreas
- Ovaries and testes
- Kidneys
- Stomach
- Liver
- Small intestine
- Skin
- Heart
- Adipose tissue
- Placenta.

The first thing you probably noticed was that the glandular organs of the system appears to be unconnected to each other. In one respect this is correct. Anatomically, they are quite remote from each other, and also appear to belong to other body systems. In fact, the endocrine system works by mainly negative feedback loops directly via the bloodstream. So the bloodstream might be considered the ‘stuff’ which holds this system together.

## The functions of the endocrine system

- Secretion of hormones.
- The functional integration of various tissues and organs – particularly those with metabolic processes.
- The development and growth of the body.
- The development, growth and regulation of the gonads and of the secondary sexual organs.
- The regulation of homeostasis

## The Hypothalamus and Pituitary Gland

These two glands act as a single organ, and might be compared to the conductor of the endocrine orchestra. The pituitary gland and hypothalamus are the integrating link, between the nervous and endocrine systems. They are located deep in the brain, and receive input from several regions of the brain e.g. the limbic system, cerebral cortex, thalamus, as well as from internal organs and the retina. Thus painful, stressful and emotional experiences are able to initiate change within the hypothalamic activity.
The hypothalamus has a role in regulation of the autonomic nervous system and thus controls activities such as body temperature, thirst, hunger sexual behaviour and defensive reactions.
As a unit, these glands influence the reproductive systems in the female and male bodies, the thyroid gland – which has an effect on our basal metabolic rate, adrenal output, growth and development, breast milk production, and kidney water excretion – thus contributing to the regulation of blood volume.

**The Pituitary Gland**:
This gland is a small pea shaped structure, attached to the hypothalamus via the infundibulum.
**It is divided anatomically and functionally into two portions:**
1) The anterior lobe – accounts for 75% of the weight of the gland.
2) The posterior lobe – contains axons and axon terminals of more than 10,000 neurons whose cell bodies are located in the supraoptic and paraventricular nuclei of the hypothalamus.

**The Anterior Pituitary Gland** (Adenohypophysis)**:**
The release and suppression of hormones is governed by releasing and inhibiting hormones derived from the hypothalamus.
Hypothalamic hormones reach the anterior pituitary gland through a portal system called the hypophyseal portal system. Blood flows from the median eminence of the hypothalamus into the infundibulum and anterior pituitary gland from several superior hypophyseal arteries. The superior hypophyseal arteries form the primary plexus of the hypophyseal portal system- a capillary network at the base of the hypothalamus.

Two groups of specialised neurons- neurosecretory cells, are found superior to the optic chiasm in the brain. These neurons secrete hypothalamic releasing and inhibiting hormones into the primary plexus. The hormones are synthesised in the neuronal cell bodies and packaged inside vesicles which reach the axon terminals via axonal transport. Nerve impulses stimulate the vesicles to undergo exocytosis, and the hormone diffuses into the primary plexus of the hypophyseal portal system.

From the primary plexus, blood drains into the hypophyseal portal veins, which pass down the infundibulum. In the anterior pituitary gland, the hypophyseal portal veins re-divide into another capillary network – the secondary plexus of the hypophyseal portal system.

This direct route between the hypothalamus and pituitary gland allows hormones to have a quick and undiminished effect. Hormones secreted by the anterior pituitary gland cells pass into the secondary plexus of the hypophyseal portal system, into the anterior hypophyseal veins for distribution to target tissues throughout the body.

**The seven hormones of the Anterior Pituitary Gland Cells:**

- Human growth hormone (hGH) or somatotropin
  Stimulates growth of the body tissues and regulates aspects of metabolism.

- Thyroid stimulating hormone (TSH) or thyrotropin
  Controls the secretions and activities of the thyroid gland

- Follicle-stimulating hormone (FSH) and luteinising hormone (LH)
  Secreted by the gonadotrophs. LH and FSH act on the gonads to secrete oestrogen and progesterone, testosterone and sperm production, stimulate the maturation of the oocytes.

- Prolactin (PRL)
  Initiates milk production in the mammary glands.

- Adrenocorticotropic hormone (ACTH) or corticotropin
  Stimulates the adrenal cortex to secrete glucocorticoids. Some corticotrophs also secrete Melanocyte Stimulating hormone (MSH)

**Note**– hormones influencing other endocrine glands are known as tropins or tropic hormones

**The Posterior Pituitary Gland** (Neurohypophysis)**:**
This part of the pituitary gland functions to store, but not synthesise hormones.
The gland is made up of pituicytes and axon terminals of the hypothalamic neurosecretory cells. The axons of the neurosecretory cells form the hypothalamohypophyseal tract running from the hypothalamus and ending near the blood capillaries of the posterior pituitary gland.

Neurosecretory cells produce oxytocin (OT) and antidiuretic hormone (vasopressin) (ADH). Oxytocin and antidiuretic hormone are packed into vesicles, which are transported by fast axonal transport to the axon terminals of the posterior pituitary gland. The nerve impulses trigger exocytosis.

Blood is supplied to the posterior pituitary gland by the inferior hypophyseal arteries. The blood and posterior pituitary hormones drain into the capillary plexus of the infundibular process, and on into the posterior hypophyseal veins for distribution to target cells in the tissues.

**The posterior pituitary gland hormones:**

- Oxytocin (OT)

Stimulates contraction of smooth muscle of the uterus during childbirth, and of the myoepithelial cells in the mammary glands to promote milk ejection.

- Antidiuretic Hormone/Vasopressin (ADH)
  Conserves water depletion by decreasing urine volume, perspiration loss. Raises blood pressure by constricting arterioles.

## The Thyroid Gland

A butterfly shaped gland located inferior to the larynx, with the right and left lobes on either side of the trachea. The gland is richly supplied with blood vessels.
The gland is made up primarily of thyroid follicles, which in turn, are made up of follicular cells. These follicular cells are influenced by Thyroid Stimulating Hormone (TSH) to produce the two thyroid hormones. A few other cells, known as parafollicular cells or C-cells are embedded between the follicles, and produce calcitonin.

Thyroid hormones:
1) Thyroxine or tetraiodothyronine (T4) – which contains four atoms of iodine.
2) Triiodothyronine (T3) – This contains three atoms of iodine.

**Actions of the Thyroid Hormones:**
Thyroid hormones
- Increases the basal metabolic rate
- Stimulates protein synthesis
- Increases lipolysis and enhances cholesterol excretion in bile
- Growth and development
- Contributes to the development of the nervous system

Calcitonin:
- Regulates calcium blood level homeostasis. Inhibits bone re-absorption and accelerating up take of calcium and phosphates into the bone matrix.

## The Parathyroid Glands

- These four little glands are attached to the lateral lobes of the thyroid gland.
- The parathyroid glands are made up of two kinds of cells –

1) The principal cells – which secrete parathyroid hormone (PTH) or parathormone
2) Oxyphil cells – their function is unknown at present.

**Actions of parathormone**:
- Increases blood calcium and magnesium levels.
- Decreases blood phosphate levels.
- Increases dietary calcium and magnesium absorption
- Increases osteoclastic activity

- Increases calcium reabsorption and phosphate excretion by the kidneys
- Promotes calcitriol (vitamin D)

## The Adrenal glands

The adrenals are a pair of glands, which lie superior to each kidney. The glands are divided functionally and structurally into two regions:

1) The adrenal cortex – makes up 80-90% of the gland. Produces the steroid hormones.
2) The adrenal medulla **–** produces two catecholamines hormones – norepinephrine (noradrenaline) and epinephrine (adrenaline).

**The adrenal cortex:**

This region is sub-divided into a further three zones:

a) The zona glomerulosa in the outer zone. These cells are arranged in spherical clusters and arched columns. Secrete mineralcorticoids, (aldosterone) which maintain homeostasis of sodium and potassium. Aldosterone is responsible for increasing blood levels of Na and water, and decreasing blood levels of potassium.

b) The zona fasiculata in the middle zone is made up of cells arranged in long straight cords. It secretes the glucocorticoids, (cortisol) affecting glucose homeostasis. Cortisol increases protein breakdown, stimulates gluconeogenisis and lipolysis. Provides resistance to stress, and reduces inflammation. Also has a depressing affect of the immune system – hence people under stress, or on steroidal drugs, often have a poor immune response.

c) The zona reticularis in the inner zone is made up of cells arranged in branching cords, and secretes small amounts of weak androgens (dehydroepiandosterone (DHEA)).
This male hormone is rather insignificant in males, but in females it contributes to the libido, and is converted to oestrogen in other tissues. After the menopause, this source of oestrogen is important. Contributes to axillary and pubic hair growth in both sexes.

**The adrenal medulla:**

This part of the adrenal gland is made up of chromaffin cells, which produce the catecholamine hormones. These cells surround large blood vessels and are in direct contact with pre-ganglionic neurons from the sympathetic ANS. Thus, they are said to be sympathetic post-ganglionic cells, specialised to secrete hormones instead of neurotransmitter. Catecholamines refer to substances produced by the body from the dietary amino-acids.
The two major hormones synthesised by the adrenal medulla are epinephrine (adrenaline), and norepinephrine (noradrenaline). These hormones are sympathomimetic and are responsible for the ‘flight and flight’ response.

The hormones function to:

1) Help to resist stress

2) Increase the cardiac rate and force of contraction – raised blood pressure, and increases blood flow to the heart and body.
3) Increase blood levels of glucose and fatty acids.

In stressful situations, during exercise and in response to hypoglycaemia, impulses received from the hypothalamus, are conveyed to the sympathetic preganglionic neurons, which release neurotransmitter – acetylcholine. Acetylcholine causes the chromaffin cells to increase their output of epinephrine and norepinephrine.

**The Pancreas**
(Also described in the gastrointestinal section)

The pancreas is made up of clusters called acini, which constitute approximately 99% of the weight of the gland, and produce digestive enzymes.
Scattered amongst the acini are pancreatic islets, or islets of Langerhans. These islets are made up of the following cells:

1) Alpha or A cells (20%) – secretes glucagon
   Glucagon: Breaks down glycogen to glucose in the liver - glycogenolysis
   Converts other nutrients into glucose in the liver – gluconeogenisis
   Releases glucose into the blood.

2) Beta or B cells (70%) – secretes insulin
   Insulin - Accelerates transport of glucose to cells, thereby lowering blood glucose.
   Converts glucose to glycogen - Glycogenesis
   Decreases glycogenolysis and gluconeogenesis
   Increases lipogenesis and protein synthesis.

3) Delta or D cells (5%) – secretes somatostatin
   Somatostatin - Inhibits the secretion of insulin and glucagon
   Slows the absorption of nutrients from the GI tract.

4) F cells (5%) – secretes pancreatic polypeptide.
   Pancreatic polypeptide Inhibits somatostatin secretion
   Inhibits gallbladder contraction
   Inhibits secretion of pancreatic digestive enzymes.

**The Pineal gland**

This is a small pea sized gland attached to the roof of the third ventricle of the brain. It is made up of a mass of neuroglia and secretory cells called pinealocytes.

- Sympathetic postganglionic fibres from the superior cervical ganglion terminate in the pineal gland.

- The gland secretes melatonin, a hormone derived from seratonin, and is influenced by light/darkness, which enters the eye and strikes the retina.

In bright light, norepinephrine released by the sympathetic fibres, inhibits secretion of melatonin, thus, lack of norepinephrine stimulates the secretion and results in sleepiness.
Thus, melatonin governs the circadian cycles. Melatonin also is a potent anti-oxidant, which may provide protection against free radicals.

## The Ovaries and Testes

The female gonads are called the ovaries, which produce the following female sex hormones:

1) Oestrogen and progesterone – which (together with the gonadotropic hormones of the anterior pituitary gland) regulate the menstrual cycle, maintain pregnancy, prepare the mammary glands for lactation, regulate oogenesis, promote and maintain the feminine secondary sex characteristics.
2) Inhibin – inhibits the secretion of FSH.
3) Relaxin – is produced during pregnancy to increase the flexibility of the symphysis pubis, and dilate the cervix during delivery.

The male gonads are called the testes and produce the following hormones:

1) Testosterone – This regulates spermatogenesis, and promotes the development of male secondary sex characteristics.
2) Inhibin – inhibits FSH secretion.

## Conclusion

Listed above, are the major tissues and hormones of the endocrine system. There are many more hormones, such as those associated with the heart, GI tract, and the kidneys, and no doubt, science is yet to discover more hormones in the body

It is important to realize that although we separate the body into systems for the convenience of study purposes, the body really functions as a whole unit. This is particularly true of the endocrine system, which is very strongly associated with the nervous system, and even the immune system. The relatively new science of psychoneuroimmunology has conclusively demonstrated how the nervous system (e.g. psychological stress) can affect the endocrine system (raised blood cortisol levels), which can impact (depress) on the immune system, and therefore lead to increased susceptibility to infection.

## The endocrine system

## SELF ASSESSMENT QUESTIONS

**Question 1:**
Define the following terms:
a) Hormone.
b) Homeostasis.

**Question 2:**
Describe the concept of the negative feedback system.

**Question 3:**
List the hormones secreted by the anterior and posterior pituitary gland, And note the tissues affected by these hormones.

**Question 4:**
True or False?
a) The thyroid gland requires iodine to develop?
b) Histamine contributes to the inflammatory response?
c) Epinephrine production will result in the conversion of glycogen to glucose?

**Question 5:**
Contract a flowchart showing the control mechanisms of:
a. Thyroxin
b. Calcitonin
c. Parathyroid hormone
d. Insulin
e. Glucagon
f. Cortisol
h. Aldosterone

**Please refer to your labelling supplement handbook and label any images associated with the above chapter.**