Chemical Coordination and Integration - Part 1

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Introduction

Human body is a complex system but it is highly coordinated and regulated. We have seen in the previous chapter that the neural system provides signals for rapid coordination between various organs. The flow of signals through neurons is very fast but it is short-lived. The nerve cells do not reach every cell but the cellular functions need to be regulated. This regulation is provided by special chemicals called ***hormones*** which are secreted mostly from ***endocrine glands***. Thus, endocrine glands secrete hormones which, along with the neural system, coordinate and regulate various cellular functions that are essential for the normal physiological functions.

What are Endocrine Glands?

A group of cells, organized into a structure, that secrete certain chemicals (*hormones*) which perform some essential functions in our body are called **glands.** The glands are of two types: exocrine glands and endocrine glands. **Exocrine glands** (*exo* = outside; -*crine* = secretion) secrete their products into ducts from where the product is taken to respective target organs like skin, small intestine etc. The glands secreting mucus, wax, sweat, oil, earwax, saliva and digestive enzymes are examples of exocrine glands. On the other hand, **endocrine glands** (*endo* = inside) secrete their products (hormones) that diffuse into blood and through blood circulation reach their target organs. Some examples of endocrine glands are pituitary gland at the base of the brain, pineal gland, thyroid gland, parathyroid gland and adrenal gland. Endocrine glands are also known as ***ductless glands***. However, in addition to well defined endocrine glands there are certain organs and tissues which are not exclusively classified as endocrine glands but contain specialized cells that secrete hormones. Examples include hypothalamus, thymus, pancreas, kidneys, stomach, small intestine, skin, liver, ovaries, testes, heart, adipose tissue and placenta. Thus, all the endocrine glands and hormone secreting tissues/cells form part of the **human endocrine system**.

What are Hormones?

A hormone (*hormon* = to excite) is a molecule that is released in one part of the body and regulates the functions of the cells in other parts of the body. However, the scientific definition of hormones is: ***Hormones are non-nutrient chemicals which act as intracellular messengers and are produced in trace amounts***.

Most hormones are released by the cells, enter the interstitial fluid and diffuse into the blood to be circulated in the body to reach their target cells. A hormone exerts its effects by binding to specific receptors on target cells. The responses of endocrine system are comparatively slower than the nervous system; the effects of endocrine system are longer than effects of neural system and while nervous system acts on muscles and glands, the endocrine system is much broader in its actions and acts on virtually all types of cells in the body. Invertebrates possess a very simple endocrine system and secrete few hormones whereas vertebrates secrete many hormones which coordinate various functions inside the body. Examples of hormones include insulin, melatonin, thyroxin, cortisol, catecholamines etc.

Hormones can be classified into two broad groups based on their chemical structure i.e. **lipid soluble hormones** and **water soluble hormones**. The *lipid soluble hormones* include **steroid hormones** which are synthesized from cholesterol (Example, estrogen, progesterone, glucocorticoids etc.), **thyroid hormones** (T_3 and T_4) synthesized by attaching iodine to the amino acid tyrosine and **nitric oxide** (NO) which can act as hormone as well as neurotransmitter.

Water soluble hormones include **amine hormones** (derived from amino acids; example, epinephrine, norepinephrine and dopamine derived from tyrosine; histamine, derived from histidine; serotonin and melatonin derived from tryptophan etc.), **peptide and protein hormones** (peptide hormones consist of 3 to 49 amino acids while protein hormones have 50 to 200 amino acids; example, oxytocin, growth hormone, insulin), **glycoprotein hormones** (proteins to which a carbohydrate group is attached; example, thyroid stimulating hormone, luteinizing hormone etc.) and **eicosanoid hormones** (hormones derived from arachidonic acid; examples, prostaglandins and leukotrienes).

Human Endocrine System

As stated in the previous section, the endocrine glands and the tissues/cells producing hormones constitute the endocrine system. The organized endocrine glands in our body are pituitary, pineal, thyroid, parathyroid, adrenal, pancreas, thymus, ovaries in females and testes in males (Figure 1). However, endocrine glands secrete hormones only after getting a suitable stimulus. In most of the endocrine glands, the stimulation is provided by signals from the hypothalamus via pituitary

The Hypothalamus

The hypothalamus is located on the under surface of the diencephalon, the forebrain. It lies just below the thalamus and above the pituitary gland to which it is attached by an infundibular stalk. The hypothalamus consists of several neurosecretory cells that form **nuclei** (an aggregation of cell bodies of neurons) and secrete hormones that indirectly control autonomic functions. The hormones secreted by hypothalamus regulate the synthesis and secretion of hormones from the pituitary gland. The hormones produced by hypothalamus are of two types: releasing hormones and inhibitory hormones. The releasing hormones of hypothalamus stimulate the pituitary to secrete hormones while inhibitory hormones inhibit the secretion of hormones from the pituitary, thereby regulating the production of hormones in the body. Some releasing and inhibitory hormones are summarized in Table 1.

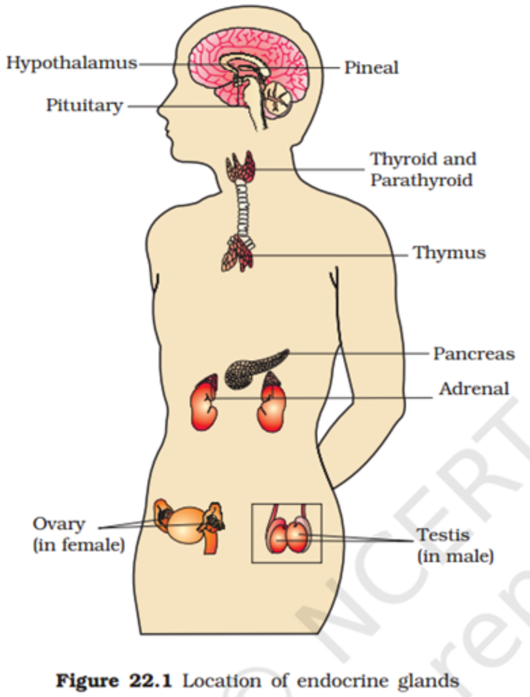


Figure 1: Endocrine glands in humans

Source: NCERT

For example, a releasing hormone from hypothalamus known as gonadotropin releasing hormone (GnRH) stimulates the pituitary to synthesize and secrete gonadotropins i.e. Luteinizing Hormone (LH) and Follicle Stimulating Hormone (FSH). Similarly, Growth Hormone Releasing Hormone (GHRH) stimulates pituitary to secrete Growth Hormone (GH) while Growth Hormone Inhibiting Hormone (GHIH) or somatostatin inhibits the secretion of GH from pituitary. The releasing and inhibiting hormones from hypothalamus are released by nerve endings or axon terminals into the capillaries in the median eminence, which form a portal circulatory system, from where the hormones are carried to the anterior pituitary. This system of transport of hormones from hypothalamus to anterior pituitary, through a network of capillaries or blood vessels is known as **hypothalamic-hypophyseal portal system** (hypophysis = pituitary gland) or **brain-pituitary portal system**. However, the posterior pituitary receives the hormones (oxytocin and vasopressin) directly from the hypothalamus as the axons of these neurons are very long and release the hormones directly into the posterior pituitary (Figure 2).

The Pituitary Gland

The pituitary gland is a pea-shaped structure that lies in the bony cavity called **sella turcica** and is attached to the hypothalamus by a stalk known as **infundibulum** (meaning *funnel*). The pituitary is divided anatomically and functionally into two parts: **anterior pituitary** or **adenohypophysis** (constitutes 75% of the total weight of the gland) and **posterior pituitary** or **neurohypophysis**. In adults, anterior pituitary consists of two parts- **pars distalis** (the larger portion) and **pars tuberalis** which forms a sheath around the infundibulum. The posterior pituitary consists of two parts- **pars nervosa** (the larger portion) and the infundibulum. Another region of the pituitary gland known as *pars intermedia* atrophies during development and is almost merged with pars distalis in adults.

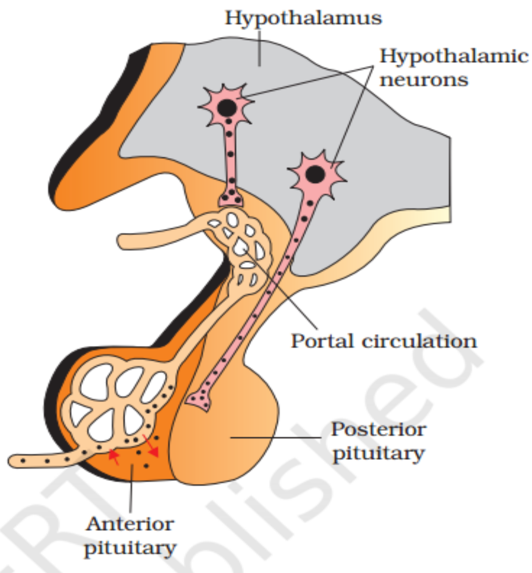


Figure 2: The Pituitary Gland

Source: NCERT

The pars distalis produces several hormones, after getting stimulated by hormones from hypothalamus, examples include Growth Hormone (GH), prolactin (PRL), thyroid stimulating hormone (TSH) etc. (Table 1). Pars intermedia secretes only one hormone known as **melanocyte stimulating hormone (MSH).** Pars nervosa or neurohypophysis stores and secretes two hormones – antidiuretic hormone (ADH) or vasopressin and oxytocin (OT). These hormones are synthesized by neurons in the hypothalamus and are transported to neurohypophysis for storage via long axons.

Table 1: Various hormones secreted by pituitary gland and their functions

Releasing/Inhibitory Hormones (Hypothalamus)	**Hormones secreted by Pituitary/Specialized cells**	**Target organ/Effects**
	Anterior Pituitary	
GnRH (Gonadotropin releasing hormone)	LH (Luteinizing Hormone); secreted by gonadotrophs FSH(Follicle stimulating hormone); secreted by gonadotrophs	Reproductive system; production of sex hormones from gonads Reproductive system; stimulates production of eggs and sperms
TRH (Thyrotropin releasing Hormone)	TSH (Thyroid stimulating hormone); secreted by thyrotrophs	Thyroid gland; stimulates release of thyroid hormone which regulates metabolism
PRH (Prolactin releasing Hormone)	PRL (Prolactin); secreted by lactotrophs	Mammary glands; production of milk
PIH (Prolactin inhibiting hormone) or dopamine	Inhibits secretion of prolactin	-
GHRH (Growth hormone releasing Hormone)	GH (Growth hormone); secreted by somatotrophs	Liver, bone, muscles; body growth and higher metabolic rate
GHIH (Growth hormone inhibiting hormone)	Inhibits release of GH	-
CRH (Corticotropin releasing hormone)	ACTH (Adrenocorticotropic hormone); secreted by corticotrophs	Adrenal glands; stimulates production of glucocorticoids
	Posterior Pituitary	
ADH (Antidiuretic hormone)	Stores ADH	Kidneys, sweat glands, circulatory system; balance of water in body

-	OT (Oxytocin)	Female reproductive system; stimulates uterine contractions during childbirth

Over-secretion and under-secretion of hormones can lead to several abnormalities in the body. For example, over secretion of growth hormone stimulates abnormal growth of the body and causes gigantism whereas low secretion of GH causes stunted growth or dwarfism during childhood. In adults, excessive secretion of GH can cause severe disfigurement, a condition known as **Acromegaly** (Figure 3), which may cause serious complications and premature death if it remains unchecked. Acromegaly usually affects middle-aged people and often goes unnoticed unless changes in external features become noticeable.

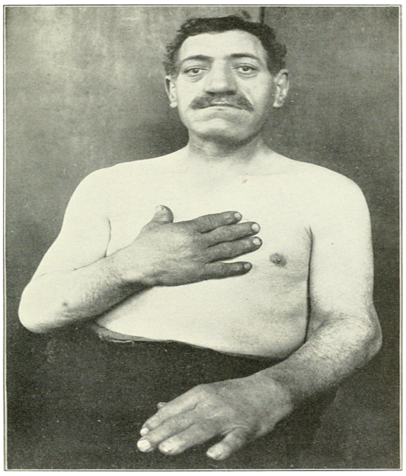


Figure 3: Male acromegaly

Source: https://commons.wikimedia.org/wiki/File:Male_acromegaly_patient_(1904).jpg

Prolactin regulates the growth of mammary glands and production of milk in them. TSH stimulates the synthesis and release of thyroid hormones from thyroid glands. ACTH stimulates the synthesis and release of glucocorticoids (steroid hormones) from adrenal cortex. LH and FSH stimulate gonads, hence they are also known as **gonadotropins**. LH stimulates the Leydig cells in testes to secrete androgens (testosterone) and together with FSH regulate the process of spermatogenesis. In females, LH stimulates the ovulation of fully mature ovarian follicles (**graafian follicles**) and maintains the corpus luteum. LH also prepares the uterus for implantation of the fertilized ovum. FSH regulates the growth and development of ovarian follicles. MSH acts on the melanocytes (cells containing the pigment melanin) and regulates the pigmentation of the skin. Oxytocin acts on the smooth muscles and stimulates their contraction. In females, oxytocin stimulates vigorous uterine contraction during childbirth and release of milk from the mammary glands. Vasopressin (*vaso* = blood; -*pressus* = to press) acts on the kidney and stimulates reabsorption of water and electrolytes by distal tubules and thus reduces loss of water through urine (diuresis). Hence, vasopressin is also known as antidiuretic hormone (ADH) (*anti* = against, -*diuretic* = increased urine production). If the synthesis and release of ADH is impaired, the kidney fails to conserve water leading to loss of water and dehydration. This condition is known as **Diabetes Insipidus**.

Pineal Gland

The pineal gland is about the size of a small pea and is located on the dorsal side of the forebrain. The pineal is considered an endocrine gland as it secretes the hormone **melatonin**. Melatonin sets the body's biological clock or 24-hour (day-night) rhythm of our body. Melatonin is secreted more during darkness or night, hence it is thought to promote sleep. In addition to this, it also helps in maintaining normal body temperature, influences pigmentation, metabolism, menstrual cycle as well as our defense mechanism (it is a strong antioxidant agent).

Thyroid Gland

Thyroid gland is butterfly-shaped and is located just inferior to the larynx. It consists of two lateral lobes which are located on either side of the trachea (Figure 4a and 4b). Both the lobes are connected by a thin flap of connective tissue known as **isthmus**. The thyroid gland is composed of several spherical sacs known as **thyroid follicles** located in **stromal tissue**. Each thyroid follicle consists of follicular cells which enclose a cavity at the center.

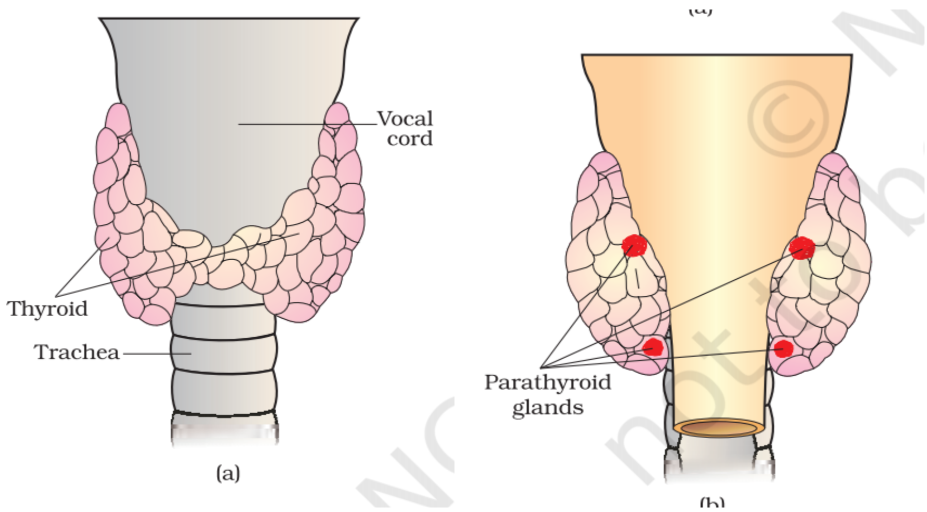


Figure 4: Position of thyroid and parathyroid glands. (a) Ventral view; (b) Dorsal view
Source: NCERT

Follicular cells synthesize two hormones – **tetraiodothyronine** (T_4; it contains four atoms of iodine) or **thyroxine** and **triiodothyronine** (T_3; it contains three atoms of iodine). Thyroid hormones increase the **basal metabolic rate (BMR)** as a result of which cellular metabolism of carbohydrates, lipids and proteins increases. They also maintain normal body temperature. Normal mammals can survive in subzero temperatures but if their thyroid glands are removed, they can not survive. Thyroid hormones also reduce blood cholesterol levels. Thyroid hormones increase some actions of the catecholamines (epinephrine and norepinephrine) and thus in case of hyperthyroidism, symptoms such as increased heart rate, forceful heartbeat and high blood pressure are observed. Thyroid hormones, along with insulin and growth hormone, accelerate body growth, particularly growth of the nervous system and bones. Thus during fetal development, infancy or childhood, deficiency of thyroid hormones results in mental retardation and stunted bone growth. Water and electrolyte balance is also influenced by thyroid hormones. A few cells called parafollicular **cells** or **C cells** lie in between the follicles in the stroma. C cells secrete a hormone known as **calcitonin (CT)** which regulates the calcium levels.

Iodine is essential for the synthesis of both the thyroid hormones. The deficiency of iodine in diet results in **hypothyroidism** and enlargement of thyroid gland (a condition known as **goiter**). Hypothyroidism during pregnancy leads to defective development and maturation of the growing baby which results in stunted growth (cretinism), mental retardation, low intelligence quotient (IQ), deaf-mutism, abnormal skin etc. In adult women, hypothyroidism may be the cause of irregular menstrual cycles. Another condition associated with the abnormal functioning of thyroid gland is **hyperthyroidism** (excessive production of thyroid hormones). Hyperthyroidism may result due to cancer of the thyroid gland or due to development of nodules in thyroid gland due to which there is more production of thyroid hormones than the body needs. Hyperthyroidism affects the body physiology and can be identified by symptoms such as nervousness, fatigue, weakness, rapid or irregular heart-beat, weight loss, mood swings and goiter.

Another condition, known as **Graves' Disease,** can arise due to hyperthyroidism. Actually, Graves' disease is an autoimmune disorder that causes thyroid gland to become overactive. It is also known as **exophthalmic goiter** and is characterized by enlargement of thyroid gland, protrusion of eyeballs, increased basal metabolic rate (BMR) and weight loss.

Parathyroid Gland

Humans have four parathyroid glands present on the back side of the thyroid gland, one pair each in the two thyroid lobes (Figure 4b). Parathyroid gland produces a peptide hormone known as **parathyroid hormone (PTH)** or **parathormone**. The secretion of parathormone is regulated by circulating levels of calcium ions (Ca^{2+}). PTH increases the calcium levels in blood. PTH increases the activity of osteoclasts (cells that degrade bone) resulting in bone resorption (dissolution/demineralization) which releases calcium and phosphate ions into blood. PTH stimulates reabsorption of the Ca^{2+} by the renal tubules and also increases calcium absorption from the digested food. Thus, PTH is a hypercalcemic hormone i.e. it increases blood calcium levels.

Thymus

Thymus is a bilobed endocrine gland located between lungs behind the sternum on the ventral side of the aorta (Figure 5). Thymus is largest in size in infancy (weighing 70 g approximately) and after puberty its size starts to decrease and later it is replaced by adipose and areolar connective tissue. In adults, thymus atrophies significantly but it still produces new T lymphocytes for immune response. In old age, thymus weighs only 3 g. Hence, the immune response of old people becomes weaker.

The hormones produced by thymus are **thymosin**, **thymic humoral factor (THF)**, **thymic factor (TF)** and **thymopoietin**. All these hormones promote maturation of T lymphocytes (involved in adaptive immunity) and may retard the process of aging. Thymosin is the major hormone secreted by thymus and plays a role in differentiation of T-lymphocytes during cell-mediated immunity. Thymosins also promote production of antibodies during humoral immune response.

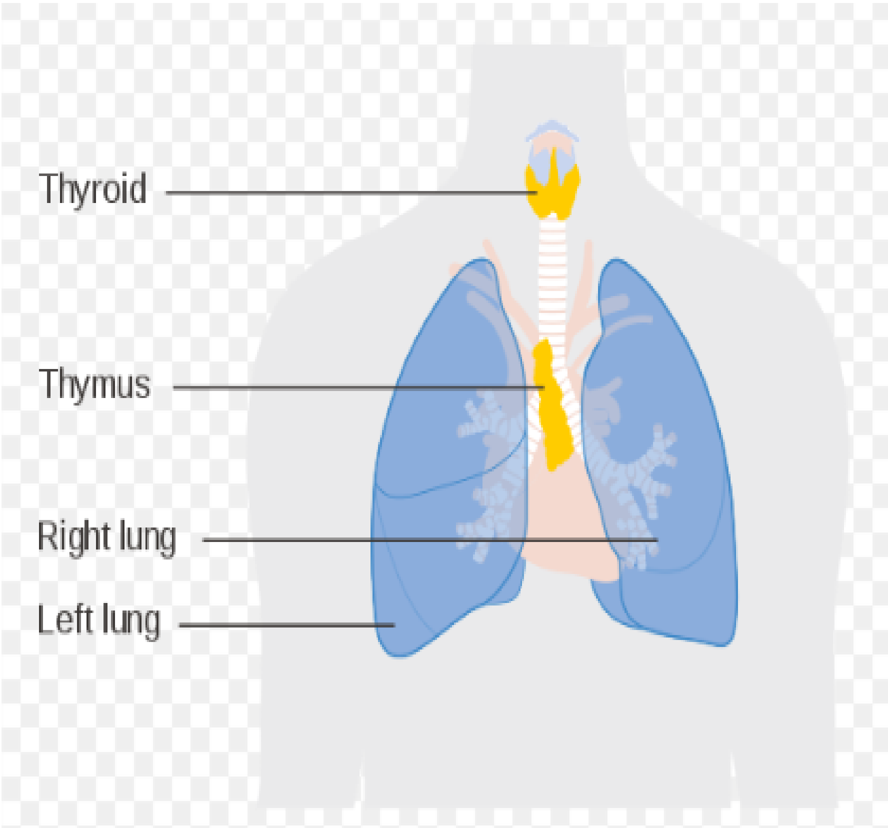


Figure 5: Location of thymus gland

Source:https://commons.wikimedia.org/wiki/File:Diagram_showing_the_position_of_the_thymus_gland_CRUK_362.svg

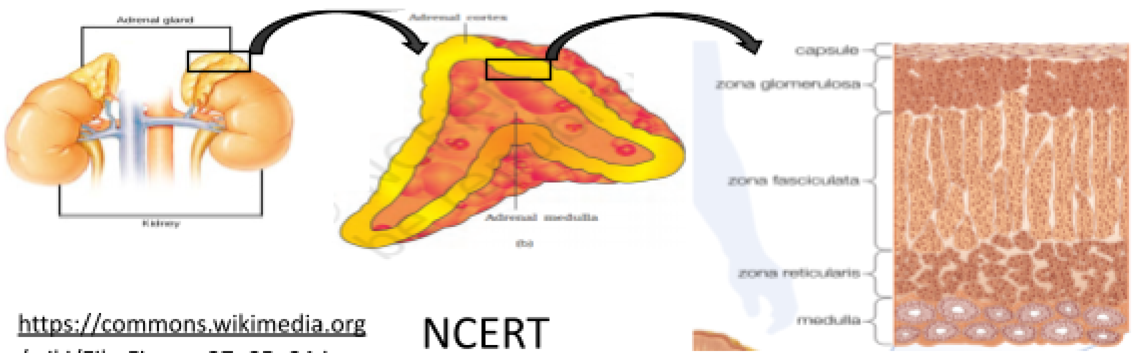
Adrenal Gland

Adrenal glands, also known as **suprarenal glands** (*supra* = above; -*renal*= kidney), are paired glands located superior to each kidney in retroperitoneal space. They have a flattened pyramidal shape. Structurally and functionally, they are divided into two distinct regions: **adrenal cortex** (comprising peripheral 80-90% of the gland) and a smaller **adrenal medulla** at the center (Figure 6).

Adrenal cortex

The adrenal cortex is subdivided into three layers and each layer secretes different hormones. The outer layer is known as **zona glomerulosa** (zona= belt; glomerul- = little ball) which secretes **mineralocorticoids** (hormones that maintain mineral homeostasis); the middle layer is known as **zona fasciculata,** it is widest layer and secrets **glucocorticoids** (hormones that maintain glucose homeostasis) and the innermost layer of cells is known as **zona reticularis**, they appear as branching cords and synthesize weak androgens in small quantities. The major mineralocorticoid is **aldosterone** which maintains the homeostasis of sodium (Na^+) and potassium (K^+) ions and helps in maintaining blood pressure and blood volume. The examples of glucocorticoids are **cortisol, corticosterone and cortisone**. Cortisol is sometimes called a '***stress hormone***'. It is called so as it helps the body to handle stressful situations and is stimulated to be released in response to various types of stresses. Cortisol accounts for 95% activity of glucocorticoids. Glucocorticoids increase protein breakdown, stimulate gluconeogenesis (conversion of amino acids or lactic acid to glucose), stimulate lipolysis (breakdown of fats to release fatty acids), provide resistance to stress, have anti-inflammatory effects and high doses suppress immune response. Cortisol also maintains cardio-vascular system and regulates kidney functions.

In males and females, the adrenal cortex produces small amounts of weak androgens. The major androgen produced by adrenal cortex is **dehydroepiandrosterone (DHEA)**. Males produce testosterone in large quantities, so the effects of adrenal androgens become less significant. However, in females adrenal androgens play significant roles. For example, they promote libido (sex drive) and are converted to estrogens in other tissues. After menopause, when ovaries stop secretion of estrogens, the androgens from adrenal are converted to estrogens and provide minimal supply of estrogens. Adrenal androgens stimulate growth of axillary and pubic hair in boys and girls.



https://commons.wikimedia.org/wiki/File:Figure_37_05_04.jpg

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https://www.britannica.com/science/zona-reticularis

Figure 6: Structure of adrenal gland

Source: as mentioned with picture

Adrenal Medulla

Adrenal medulla secretes two major hormones: epinephrine (E) or adrenaline and norepinephrine (NE) or noradrenaline. These hormones are commonly called

catecholamines. They are secreted to initiate flight or fight response, thus helping us to handle the physical and emotional stress. Epinephrine increases heart rate due to which blood rushes to muscles and brain as well as increases the blood sugar levels by ***glycogenolysis*** (breakdown of glycogen to release glucose) and thus helps the body to respond to stress. Norepinephrine works with epinephrine and helps the body to deal with the stress. NE causes vasoconstriction (narrowing of blood vessels) resulting in high blood pressure. In addition to these, the catecholamines increase alertness, dilate pupils, cause piloerection (raising of hairs), sweating and increase rate of respiration.

The production of abnormal levels of hormones by the adrenal cortex results in some diseases. For example, when the adrenal gland does not produce enough cortisol, it causes **adrenal insufficiency** resulting in acute weakness and fatigue, a condition known as Addison's disease. Other symptoms of Addison's disease are loss of appetite, weight loss, increased thirst and abdominal pain. The causes of adrenal insufficiency include autoimmune disorders, some infections, sometimes cancer and genetic factors. The adrenal insufficiency due to genetic factors is known as **congenital adrenal hyperplasia**. In contrast to adrenal

insufficiency, when the adrenal overproduces cortisol, it result in **Cushing syndrome** which is characterized by gain in weight, deposition of fat in certain areas in body such as face and abdomen; thinning of limbs, fatigue, muscle weakness, hypertension, diabetes etc. the causes of Cushing syndrome include tumor in pituitary or anywhere which results in overproduction of ACTH; excessive and chronic consumption of external steroids,

Pancreas

Pancreas is a composite gland which is elongated and tapered. It can be called exocrine (primarily) as well as endocrine gland. The exocrine part of the pancreas secretes **digestive enzymes**, for breaking down carbohydrates, fats and proteins, into a duct that joins the main pancreatic duct.

The endocrine part in the pancreas is the '**Islets of Langerhans**' which secretes the hormones. There are about 1-2 million islets of Langerhans in humans accounting for 1-2% of the pancreatic tissue. The islets of Langerhans consist of four types of cells –

a) **Alpha cells** (α cells; 20% of the cells of islets of Langerhans):

These cells secrete glucagon and maintain normal levels of glucose in blood. These cells are stimulated to secrete glucagon when the blood glucose levels are low.

b) **Beta cells** (β cells; 75% of the cells of islets of Langerhans):

These cells secrete insulin. High blood glucose levels stimulate these cells to synthesize and release insulin.

c) **Delta cells** (δ cells; 4% of the cells of islets of Langerhans):

These cells secrete the hormone somatostatin which inhibits the release of insulin and glucagon. Somatostatin is also secreted by hypothalamus [as Growth Hormone Inhibitory Hormone (GHIH)], stomach and intestine.

d) **PP cells** (1% of the cells of islets of Langerhans):

These cells secrete pancreatic polypeptide (PP) which plays a role in appetite and also regulates pancreatic exocrine and endocrine functions.

Glucagon is a peptide hormone. It mainly acts on the hepatocytes (liver cells) and stimulates **glycogenolysis** (breakdown of glycogen to produce glucose) to increase blood glucose levels (hyperglycemia). It also stimulates gluconeogenesis (synthesis of glucose from sources other than carbohydrates) to increase blood sugar levels. Glucagon retards the uptake of glucose by cells which also contributes to hyperglycemia. Thus, glucagon is also known as a **hyperglycemic hormone**.

Insulin is also a peptide hormone and like glucagon, it helps in maintaining glucose homeostasis. Insulin acts on hepatocytes and adipocytes (cells of adipose tissue) and stimulates cells to take up glucose and utilize it. Due to this movement of glucose from blood to hepatocytes and adipocytes, the blood glucose levels reduce. This is known as **hypoglycemia** (low blood glucose levels). Insulin stimulates **glycogenesis** (synthesis of glycogen from glucose) in the target cells.

Sustained and chronic high levels of glucose in the blood (hyperglycemia) results in **diabetes mellitus**. Diabetes mellitus is of two types:

(i) **Type I Diabetes**: It is also known as **insulin-dependent diabetes mellitus (IDDM)** or **'juvenile diabetes'** and is an autoimmune condition where the cells producing insulin are damaged, so there is no or very little production of insulin in the body. It is not as common as Type II. It generally develops at a younger age but it can develop at any age. The common symptoms of Type I diabetes are excessive thirst, unusually high urination, fatigue, weight loss and muscle weakness. It also causes diabetic retinopathy (damage to tiny blood vessels in eyes), diabetic neuropathy (damage to nerves) and diabetic nephropathy (damage to kidneys).

(ii) **Type II Diabetes**: It is more common and generally affects older people. Type II is generally associated with excessive weight. It is also known as **non-insulin dependent diabetes mellitus (NIDDM)** or **'adult-onset diabetes'**. In Type II diabetes pancreas produces some insulin but it is not enough or the body does not use it properly i.e. body develops ***insulin resistance***. This results in an increase in the blood sugar level. The symptoms include frequent urination, increased thirst, always feeling hungry, fatigue, weight loss, blurry vision, infections or sores that don't heal etc.

Summary

Endocrine glands produce chemical mediators known as hormones to coordinate and regulate various physiological functions. The structured endocrine glands in the human body are pituitary, pineal, thyroid, parathyroid, adrenal, pancreas, thymus, ovaries in females and testes in males. However, endocrine glands secrete hormones only after getting a suitable stimulus. In most of the endocrine glands, the stimulation is provided by signals from the hypothalamus via pituitary. The hormones secreted by hypothalamus regulate the synthesis and secretion of hormones from the pituitary gland. The hormones produced by hypothalamus are of two types: releasing hormones and inhibitory hormones. The releasing hormones of hypothalamus stimulate the pituitary to secrete hormones while inhibitory hormones inhibit the secretion of hormones from the pituitary, thereby regulating the production of hormones in the body. The pituitary is divided into two parts: anterior pituitary or adenohypophysis (which secretes most of the hormones like TSH, GH, ACTH, LH, FSH etc.) and posterior pituitary or neurohypophysis (which secretes two hormones – oxytocin and vasopressin). Oversecretion of GH can result in gigantism in children and acromegaly in adults while under secretion can result in dwarfism. Similarly low ADH levels in the body can cause loss of water and dehydration resulting in diabetes insipidus. Melatonin, secreted by pineal, sets the body's biological clock or 24-hour (day-night) rhythm of our body. Thyroid gland secretes two hormones- T_3 and T_4, which increase the basal metabolic rate (BMR). Some cells of thyroid also secrete **calcitonin (CT)** which regulates the calcium levels. Hypothyroidism can result in enlargement of the thyroid gland or goiter while hyperthyroidism causes Grave's disease. Parathormone secreted by parathyroid gland increases calcium levels in the blood by increasing activity of osteoclasts. Thymosin secreted by thymus helps in maturation of T lymphocytes. Adrenal gland is divided into two compartments- adrenal cortex and adrenal medulla. Adrenal cortex is further arranged into three major layers of cells, each layer secreting different hormones: outermost layer is zona glomerulosa (secretes mineralocorticoids like aldosterone which maintains mineral homeostasis), zona fasciculata (secretes glucocorticoids like cortisol which maintain glucose homeostasis) and zona reticularis (secretes weak androgens). Adrenal medulla secretes catecholamines *viz.* epinephrine or adrenaline and norepinephrine or noradrenaline. These hormones initiate fight or flight response. When the adrenal overproduces cortisol, it results in Cushing syndrome. Pancreas is an endocrine as well as exocrine gland. The exocrine part is the acini which secrete digestive enzymes and are secreted into ducts while the endocrine part includes the Islets of Langerhans. The islets of Langerhans are made up of many types of cells like alpha cells which secrete glucagon, beta cells which secrete insulin, delta cells which secrete somatostatin and PP cells which secrete pancreatic polypeptide. Glucagon is secreted when blood glucose levels are low and increases the blood glucose levels by glycogenolysis and gluconeogenesis. Insulin is secreted when blood glucose levels are high. It stimulates the cells to take up glucose from blood and thus regulates the blood glucose levels. Somatostatin inhibits the release of glucagon and insulin while pancreatic polypeptide plays a role in appetite and also regulates pancreatic exocrine and endocrine functions. Prolonged high state of hyperglycemia can result in diabetes mellitus which is of two types – Diabetes Type I (also known as insulin-dependent diabetes mellitus (IDDM) or 'juvenile diabetes') and Diabetes Type II (Non insulin-dependent diabetes mellitus (NIDDM) or 'adult-onset diabetes'.