**ENDOCRINE SYSTEM**

The endocrine system **includes** all of the glands of the body and the hormones produced by those glands. The glands are controlled directly by stimulation from the nervous system as well as by chemical receptors in the blood and hormones produced by other glands. By regulating the functions of organs in the body, these glands help to maintain the body’s homeostasis. Cellular metabolism, reproduction, sexual development, sugar and mineral homeostasis, heart rate, and digestion are among the many processes regulated by the actions of hormones.

**Anatomy of the Endocrine System**

**Hypothalamus**
The [**hypothalamus**](http://www.innerbody.com/image_endo01/endo03.html) is a part of the [**brain**](http://www.innerbody.com/image/nerv02.html) located superior and anterior to the brain stem and inferior to the [**thalamus**](http://www.innerbody.com/image_nerv01/nerv142.html). It **serves many different functions** in the [**nervous system**](http://www.innerbody.com/image/nervov.html), and is also **responsible for** the direct control of the endocrine system through the pituitary gland. The hypothalamus **contains** special cells called neurosecretory cells—neurons that secrete hormones:

* Thyrotropin-releasing hormone (TRH)
* Growth hormone-**releasing** hormone (GHRH)
* Growth hormone-**inhibiting** hormone (GHIH)
* Gonadotropin-releasing hormone (GnRH)
* Corticotropin-releasing hormone (CRH)
* Oxytocin
* Antidiuretic hormone (ADH)

All of the releasing and inhibiting hormones affect the function of the anterior pituitary gland. TRH stimulates the anterior pituitary gland to release thyroid-stimulating hormone. GHRH and GHIH work to regulate the release of growth hormone—GHRH stimulates growth hormone release, GHIH inhibits its release. GnRH stimulates the release of follicle stimulating hormone and luteinizing hormone while CRH stimulates the release of adrenocorticotropic hormone. The last two hormones—oxytocin and antidiuretic hormone—are produced by the hypothalamus and transported to the posterior pituitary, where they are stored and later released.

**Pituitary Gland**
The [**pituitary gland**](http://www.innerbody.com/image/endo01.html), also known as the hypophysis, is a small pea-sized lump of tissue connected to the inferior portion of the hypothalamus of the brain. Many [**blood vessels**](http://www.innerbody.com/image/card05.html) **surround** the pituitary gland to carry the hormones it releases throughout the body. Situated in a small depression in the [**sphenoid bone**](http://www.innerbody.com/image_skel01/skel44_new_skull.html) called the sella turcica, the pituitary gland is actually made of 2 completely separate structures: the posterior and anterior pituitary glands.

1. *Posterior Pituitary*: The posterior pituitary gland is actually not glandular tissue at all, but nervous tissue instead. The posterior pituitary is a small **extension** of the hypothalamus through which the axons of some of the neurosecretory cells of the hypothalamus **extend**. These neurosecretory cells create 2 hormones in the hypothalamus that are stored and released by the posterior pituitary:
	* Oxytocin **triggers** uterine contractions during childbirth and the release of milk during breastfeeding.
	* Antidiuretic hormone (ADH) **prevents** water loss in the body by **increasing** the re-uptake of water in the kidneys and **reducing** blood flow to sweat glands.
2. *Anterior Pituitary*: The anterior pituitary gland is the true glandular part of the pituitary gland. The function of the anterior pituitary gland is controlled by the releasing and inhibiting hormones of the hypothalamus. The anterior pituitary produces 6 important hormones:

	* Thyroid stimulating hormone (TSH), as its name **suggests**, is a tropic hormone responsible for the stimulation of the thyroid gland.
	* Adrenocorticotropic hormone (ACTH) stimulates the adrenal cortex, the outer part of the adrenal gland, to produce its hormones.
	* Follicle stimulating hormone (FSH) stimulates the follicle cells of the gonads to produce gametes—ova in females and sperm in males.
	* Luteinizing hormone (LH) stimulates the gonads to produce the sex hormones—estrogens in females and testosterone in males.
	* Human growth hormone (HGH) affects many target cells throughout the body by stimulating their growth, repair, and reproduction.
	* Prolactin (PRL) has many effects on the body, chief of which is that it stimulates the [**mammary glands**](http://www.innerbody.com/image_repo03/repo02-new.html) of the breast to produce milk.

**Pineal Gland**
The [**pineal gland**](http://www.innerbody.com/image_nerv02/nerv64-new.html) is a small pinecone-shaped mass of glandular tissue found just posterior to the thalamus of the brain. The pineal gland produces the hormone melatonin that helps to regulate the human sleep-wake cycle known as the circadian rhythm. The activity of the pineal gland is inhibited by stimulation from the photoreceptors of the retina. This light sensitivity causes melatonin to be produced only in low light or darkness. Increased melatonin production causes humans **to feel drowsy** at nighttime when the pineal gland is active.

**Thyroid Gland**
The [**thyroid gland**](http://www.innerbody.com/image/endo04.html) is a butterfly-shaped gland located at the base of the neck and wrapped around the lateral sides of the trachea. The thyroid gland produces 3 major hormones:

* Calcitonin
* Triiodothyronine (T3)
* Thyroxine (T4)

Calcitonin is released when calcium ion levels in the blood rise above a certain set point. Calcitonin functions to reduce the concentration of calcium ions in the blood by aiding the absorption of calcium into the matrix of bones. The hormones T3 and T4 work together to regulate the body’s metabolic rate. Increased levels of T3 and T4 lead to increased cellular activity and energy usage in the body.

**Parathyroid Glands**
The [**parathyroid glands**](http://www.innerbody.com/image/endo04.html) are 4 small masses of glandular tissue found on the posterior side of the thyroid gland. The parathyroid glands produce the hormone parathyroid hormone (PTH), which is **involved** in calcium ion homeostasis. PTH is released from the parathyroid glands when calcium ion levels in the blood drop below a set point. PTH stimulates the osteoclasts to **break down** the calcium containing bone matrix to release free calcium ions into the bloodstream. PTH also triggers the kidneys to return calcium ions filtered out of the blood back to the bloodstream so that it is conserved.

**Adrenal Glands**
The [**adrenal glands**](http://www.innerbody.com/image/endo02.html) are a pair of roughly triangular glands found immediately superior to the kidneys. The adrenal glands are each made of 2 distinct layers, each with their own unique functions: the outer adrenal cortex and inner adrenal medulla.

* *Adrenal cortex*: The adrenal cortex produces many cortical hormones in 3 classes: glucocorticoids, mineralocorticoids, and androgens.

	1. Glucocorticoids have many diverse functions, including the breakdown of proteins and lipids to produce glucose. Glucocorticoids also function to reduce inflammation and immune response.
	2. Mineralocorticoids, as their name suggests, are a group of hormones that help to regulate the concentration of mineral ions in the body.
	3. Androgens, such as testosterone, are produced at low levels in the adrenal cortex to regulate the growth and activity of cells that are receptive to male hormones. In adult males, the amount of androgens produced by the testes is many times greater than the amount produced by the adrenal cortex, leading to the appearance of male secondary sex characteristics.
* *Adrenal medulla*: The adrenal medulla produces the hormones epinephrine and norepinephrine under stimulation by the sympathetic division of the autonomic nervous system. Both of these hormones help to increase the flow of blood to the brain and muscles to improve the “fight-or-flight” response to stress. These hormones also work to increase heart rate, breathing rate, and blood pressure while decreasing the flow of blood to and function of organs that are not involved in responding to emergencies.

**Pancreas**
The [**pancreas**](http://www.innerbody.com/image/endo03.html) is a large gland located in the abdominal cavity just inferior and posterior to the [**stomach**](http://www.innerbody.com/image/dige02.html). The pancreas is considered to be a heterocrine gland as it contains both endocrine and exocrine tissue. The endocrine cells of the pancreas make up just about 1% of the total mass of the pancreas and are found in small groups throughout the pancreas called islets of Langerhans. Within these islets are 2 types of cells—alpha and beta cells. The alpha cells produce the hormone glucagon, which is responsible for raising blood glucose levels. Glucagon triggers muscle and liver cells to break down the polysaccharide glycogen to release glucose into the bloodstream. The beta cells produce the hormone insulin, which is responsible for lowering blood glucose levels after a meal. Insulin triggers the absorption of glucose from the blood into cells, where it is added to glycogen molecules for storage.

**Gonads**
The gonads—ovaries in females and testes in males—are responsible for producing the sex hormones of the body. These sex hormones determine the secondary sex characteristics of adult females and adult males.

* *Testes*: The [**testes**](http://www.innerbody.com/image_endoov/repo10-new2.html) are a pair of ellipsoid organs found in **the scrotum** of males that produce the androgen testosterone in males after the start of puberty. Testosterone has effects on many parts of the body, including the muscles, bones, sex organs, and hair follicles. This hormone causes growth and increases in strength of the bones and muscles, including the accelerated growth of long bones during adolescence. During puberty, testosterone controls the growth and development of the sex organs and body hair of males, including pubic, chest, and facial hair. In men who have **inherited** genes for baldness testosterone triggers the onset of androgenic alopecia, commonly known as male pattern baldness.
* *Ovaries*: The [**ovaries**](http://www.innerbody.com/image_endoov/repo07-new2.html) are a pair of almond-shaped glands located in the pelvic body cavity lateral and superior to the uterus in females. The ovaries produce the female sex hormones progesterone and estrogens. Progesterone is most active in females during ovulation and pregnancy where it maintains appropriate conditions in the human body **to support** a developing fetus. Estrogens are a group of related hormones that function as the primary female sex hormones. The release of estrogen during puberty triggers the development of female secondary sex characteristics such as uterine development, breast development, and the growth of pubic hair. Estrogen also triggers the increased growth of bones during adolescence that lead to adult height and proportions.

**Thymus**
The [**thymus**](http://www.innerbody.com/image_endoov/lymp04-new.html) is a soft, triangular-shaped organ found in the chest posterior to the sternum. The thymus produces hormones called thymosins that help to train and develop T-lymphocytes during fetal development and childhood. The T-lymphocytes produced in the thymus go on to protect the body from pathogens throughout a person’s entire life. The thymus becomes inactive during puberty and is slowly **replaced** by adipose tissue throughout a person’s life.

**Other Hormone Producing Organs**
In addition to the glands of the endocrine system, many other non-glandular organs and tissues in the body produce hormones as well.

* *Heart*: The cardiac muscle tissue of the [**heart**](http://www.innerbody.com/image/card01.html) **is capable of** producing the hormone atrial natriuretic peptide (ANP) in response to [**high blood pressure**](http://www.innerbody.com/diseases-conditions/hypertension) levels. ANP works to reduce blood pressure by triggering vasodilation to provide more space for the blood to travel through. ANP also reduces blood volume and pressure by causing water and salt to be excreted out of the blood by the kidneys.
* *Kidneys*: The [**kidneys**](http://www.innerbody.com/image_urinov/dige05-new.html) produce the hormone erythropoietin (EPO) in response to low levels of oxygen in the blood. EPO released by the kidneys travels to the red bone marrow where it stimulates an increased production of red blood cells. The number of red blood cells increases the oxygen carrying capacity of the blood, eventually ending the production of EPO.
* *Digestive System*: The hormones cholecystokinin (CCK), secretin, and gastrin are all produced by the organs of the gastrointestinal tract. CCK, secretin, and gastrin all help to regulate the secretion of pancreatic juice, bile, and gastric juice in response to the presence of food in the stomach. CCK is also instrumental in the sensation of satiety or “fullness” after eating a meal.
* *Adipose*: Adipose tissue produces the hormone leptin that is involved in the management of appetite and energy usage by the body. Leptin is produced at levels relative to the amount of adipose tissue in the body, allowing the brain to monitor the body’s energy storage condition. When the body contains a **sufficient** level of adipose for energy storage, the level of leptin in the blood tells the brain that the body is not starving and may work normally. If the level of adipose or leptin decreases below a certain threshold, the body enters starvation mode and attempts to conserve energy through increased hunger and food intake and decreased energy usage. Adipose tissue also produces very low levels of estrogens in both men and women. In obese people the large volume of adipose tissue may lead to abnormal estrogen levels.
* *Placenta*: In pregnant women, the placenta produces several hormones that help to maintain pregnancy. Progesterone is produced to relax the uterus, protect the fetus from the mother’s [**immune system**](http://www.innerbody.com/image/lympov.html), and prevent premature delivery of the fetus. Human chorionic gonadotropin (HCG) assists progesterone by signaling the ovaries to maintain the production of estrogen and progesterone throughout pregnancy.
* *Local Hormones*: Prostaglandins and leukotrienes are produced by every tissue in the body (except for blood tissue) in response to damaging stimuli. These two hormones mainly **affect** the cells that are local to the source of damage, leaving the rest of the body free to function normally.

	1. Prostaglandins cause **swelling, inflammation, increased pain sensitivity**, and increased local body temperature to help block damaged regions of the body from infection or further damage. They act as the body’s natural bandages to keep pathogens out and **swell** around damaged joints like a natural cast to limit movement.
	2. Leukotrienes help the body heal after prostaglandins have taken effect by reducing inflammation while helping white blood cells to move into the region to clean up pathogens and damaged tissues.

**Physiology of the Endocrine System**

**Endocrine System vs. Nervous System Function**
The endocrine system works alongside of the nervous system to form the control systems of the body. The nervous system provides a very fast and narrowly targeted system to turn on specific glands and muscles throughout the body. The endocrine system, on the other hand, is much slower acting, but has very widespread, long lasting, and powerful effects. Hormones are distributed by glands through the bloodstream to the entire body, affecting any cell with a receptor for a particular hormone. Most hormones affect cells in several organs or throughout the entire body, leading to many diverse and powerful responses.

**Hormone Properties**
Once hormones have been produced by glands, they are distributed through the body via the bloodstream. As hormones travel through the body, they pass through cells or along the plasma membranes of cells until they **encounter** a receptor for that particular hormone. Hormones can only affect target cells that have the appropriate receptors. This property of hormones is known as specificity. Hormone specificity explains how each hormone can have specific effects in widespread parts of the body.

Many hormones produced by the endocrine system are classified as tropic hormones. A tropic hormone is a hormone that is able to trigger the release of another hormone in another gland. Tropic hormones provide a pathway of control for hormone production as well as a way for glands to be controlled in distant regions of the body. Many of the hormones produced by the pituitary gland, such as TSH, ACTH, and FSH are tropic hormones.

**Hormonal Regulation**
The levels of hormones in the body can be regulated by several factors. The nervous system can control hormone levels through the action of the hypothalamus and its releasing and inhibiting hormones. For example, TRH produced by the hypothalamus stimulates the anterior pituitary to produce TSH. Tropic hormones provide another level of control for the release of hormones. For example, TSH is a tropic hormone that stimulates the thyroid gland to produce T3 and T4. Nutrition can also control the levels of hormones in the body. For example, the thyroid hormones T3 and T4 require 3 or 4 iodine atoms, respectively, to be produced. In people lacking iodine in their diet, they will fail to produce sufficient levels of thyroid hormones **to maintain** a healthy metabolic rate. Finally, the number of receptors present in cells can be varied by cells in response to hormones. Cells that are exposed to high levels of hormones for extended periods of time can begin to reduce the number of receptors that they produce, leading to reduced hormonal control of the cell.

**Classes of Hormones**
Hormones are classified into 2 categories depending on their chemical make-up and solubility: water-soluble and lipid-soluble hormones. Each of these classes of hormones has specific mechanisms for their function that dictate how they affect their target cells.

* *Water-soluble hormones*: Water-soluble hormones include the peptide and amino-acid hormones such as insulin, epinephrine, HGH, and oxytocin. As their name indicates, these hormones are soluble in water. Water-soluble hormones are unable to pass through the phospholipid bilayer of the plasma membrane and are therefore dependent upon receptor molecules on the surface of cells. When a water-soluble hormone **binds to** a receptor molecule on the surface of a cell, it triggers a reaction inside of the cell. This reaction may change a factor inside of the cell such as the **permeability of the membrane** or the activation of another molecule. A common reaction is to cause molecules of cyclic adenosine monophosphate (cAMP) to be synthesized from adenosine triphosphate (ATP) present in the cell. cAMP acts as a second messenger within the cell where it binds to a second receptor to change the function of the cell’s physiology.
* *Lipid-soluble hormones*: Lipid-soluble hormones include the steroid hormones such as testosterone, estrogens, glucocorticoids, and mineralocorticoids. Because they are  **soluble** in lipids, these hormones are able to pass directly through the phospholipid bilayer of the plasma membrane and bind directly to receptors inside the cell nucleus. Lipid-soluble hormones are able to directly control the function of a cell from these receptors, often triggering the transcription of particular genes in the DNA to produce "messenger RNAs (mRNAs)" that are used to make proteins that affect the cell’s growth and function.

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**TASKS**

* 1. Write out all the terms and their definitions
	2. Find all the examples of the Passive Voice use; underline them and translate the sentences
	3. Create an outline for each meaningful part of the text
	4. Make up 10 questions based on the contents of the text: start your questions with “How”, “Why” and “What”. However, **focus on the relationships between the concepts** rather than the definitions.