Definitions

Biopsychology	Scientific study of biological bases of behaviour and mental processes
Neuroscience	Scientific study of the nervous system
Nervous System	An extensive system of organs and nerves that are in charge of relaying information and signals between different parts of the body; composed primarily of specialized cells called neurons.
Cell Body	energy source of the neuron, produces nutrients and waste, contains nucleus and DNA
Dendrites	a branching, threadlike extension of the cell body that increases the receptive surface of a neuron. Receives chemical messages from other neurons and cells, sends messages along the neuron if important.
Axon	the long, thin, hollow, cylindrical extension of a neuron that normally carries a nerve impulse away from the cell body. Sends information through the neuron via the action potential.
Myelin Sheath	the insulating layer around many axons that increases the speed of conduction of nerve impulses. It consists of myelin and is laid down by glia, which wrap themselves around adjacent axons.
Axon Terminals	ending of an axon which releases neurotransmitters into a synaptic space near another neuron, muscle, or gland cell.
Synapse	the specialized junction through which neural signals are transmitted from one neuron (the presynaptic neuron) to another (the postsynaptic neuron).

Neurotransmitters

NAME	TYPE	RELEASED FROM	FUNCTION
Acetylcholine	Excitatory in all cases except in the heart (inhibitory)	Motor neurons, basal ganglia, preganglionic neurons of the autonomic nervous system, postganglionic neurons of the parasympathetic nervous system, and postganglionic neurons of the sympathetic nervous system that innervate the sweat glands	Regulates the sleep cycle, essential for muscle functioning
Norepinephrine	Excitatory	Brainstem, hypothalamus, and adrenal glands	Increases the level of alertness and wakefulness, stimulates various processes of the body

Neurotransmitters (cont)

Epinep-hrine	Excitatory	Chromaffin cells of the medulla of adrenal gland	The fight-or-flight response (increased heart rate, blood pressure, and glucose production)
Dopamine	Both excitatory and inhibitory	Substantia nigra	Inhibits unnecessary movements, inhibits the release of prolactin, and stimulates the secretion of growth hormone
GABA	Inhibitory	Neurons of the spinal cord, cerebellum, basal ganglia, and many areas of the cerebral cortex	Reduces neuronal excitability throughout the nervous system
Glutamate	Excitatory	Sensory neurons and cerebral cortex	Regulates central nervous system excitability, learning process, memory
Serotonin	Inhibitory	Neurons of the brainstem and gastroint-estinal tract, thrombocytes	Regulates body temperature, perception of pain, emotions, and sleep cycle
Histamine	Excitatory	Hypothalamus, cells of the stomach mucosa, mast cells, and basophils in the blood	Regulates wakefulness, blood pressure, pain, and sexual behavior; increases the acidity of the stomach; mediates inflammatory reactions

Electrical Communication

Two types of communication: one within the neuron, one between two or more neurons.

1. Communication within the neuron: Electrical communication.

Within the axon of the neuron is negatively charged potassium, surrounded by positively charged sodium when the neuron is at rest, or it is ready to fire.

When neuron gets ready to fire, the sodium floods into the neuron changing the charge and when it reaches the potential threshold and crosses it, the neuron fires.

Vocabulary

Ions	positively or negatively charged particles.
Resting State	Neuron has more negative ions inside than on the outside. This means that the neuron is polarized.
Active State	Neuron has more positive charge than the outside. This means neuron is depolarized.
Action Potential	Brief electrical impulse by which information is gathered by the dendrites and cell body are transmitted along the axon of a neuron until they hit the axon terminals. Follows the all or none law.

Myelin and Propagation of Action Potential

The speed of conduction of an action potential along an axon is influenced by both the diameter of the axon and the axon's resistance to current leak.

Myelin acts as an insulator that prevents current from leaving the axon; this increases the speed of action potential conduction.

The nodes of Ranvier are gaps in the myelin sheath along the axon. These unmyelinated spaces are about one micrometer long and contain voltage gated Na+ and K+ channels. Flow of ions through these channels, particularly the Na+ channels, regenerates the action potential over and over again along the axon. This 'jumping' of the action potential from one node to the next is called saltatory conduction.

Myelin and Propagation of Action Potential (cont)

If nodes of Ranvier were not present along an axon, the action potential would propagate very slowly since Na+ and K+ channels would have to continuously regenerate action potentials at every point along the axon instead of at specific points. Nodes of Ranvier also save energy for the neuron since the channels only need to be present at the nodes and not along the entire axon.

Chemical Synapse

When an action potential reaches the axon terminal it depolarizes the membrane and opens voltage-gated Na+ channels. Na+ ions enter the cell, further depolarizing the presynaptic membrane.

This depolarization causes voltage-gated Ca2+ channels to open. Calcium ions entering the cell initiate a signaling cascade that causes small membrane-bound vesicles, called synaptic vesicles, containing neurotransmitter molecules to fuse with the presynaptic membrane.

Fusion of a vesicle with the presynaptic membrane causes neurotransmitter to be released into the synaptic cleft, the extracellular space between the presynaptic and postsynaptic membranes.

The neurotransmitter diffuses across the synaptic cleft and binds to receptor proteins on the postsynaptic membrane.

Grey Matter and White Matter

Gray Matter	made up of clusters of neuronal bodies
	In the brain, the majority of gray matter is found superficially comprising the cerebral cortex. Smaller clusters of gray matter are found deep within the white matter comprising the subcortical structures, such as basal ganglia and diencephalon. Every unit of gray matter in the brain which is outside of the cortex is called the nucleus.
	the gray matter comprises its inner part and has a characteristic butterfly shape when observed on cross-section.
White Matter	composed of their myelinated axons
	The white matter, consisting of spinal cord pathways, is located externally surrounding the gray matter.

Grey Matter and White Matter (cont)

In the brain, the white matter composes its inner part.

Peripheral Nerves

Cranial Nerves	emerge from the cranium (brain/brain-stem)
	There are 12 pairs of cranial nerves
Spinal Nerves	leave the CNS via the spinal cord.
	31 spinal nerve pairs
Afferent or sensory neurons	carry information towards the CNS
Efferent or motor neurons	the ones transmitting impulses from the CNS

Peripheral Nervous System

Definition	A nervous system division composed of all the neural tissue found outside the cranial vault and vertebral canal.
Anatomical components	Peripheral nerves (spinal nerves, cranial nerves, autonomic nerves) Ganglia
Functional Components	**Autonomic nervous system (ANS)** - involuntary part in control of cardiac, smooth and glandular cells. It consists of sympathetic and parasympathetic divisions. **Somatic nervous system (SNS)** - voluntary part in control of skeletal muscles and processing of somatic sensation.
Function	Transmits motor and sensory information between the central nervous system and peripheral body tissues.

Parietal Lobe

Parietal Lobe	located just underneath the parietal bone, lying posterior to the frontal lobe and anterior and superior to the temporal and occipital lobes
	anterior border of the parietal lobe is demarcated by the central sulcus, and the posterior border is formed by an imaginary line that extends between the parietooccipital sulcus (superiorly) and the preoccipital notch (inferiorly)
	can be divided into three regions. The most anterior portion of the parietal lobe is the postcentral gyrus which runs parallel to the central sulcus
	Functionally, this area is known as the primary somato-sensory cortex
	This region receives sensory information from all sensory receptors that provide information related to temperature, pain (spinothalamic pathway), vibration, proprioception and fine touch (dorsal column pathway). Thus, the postce-ntral gyrus of the frontal lobe is mainly involved in processing various types of sensory information
	remainder of the parietal lobe can be divided into two main regions: the superior and inferior parietal lobules, which are separated anatomically by the intraparietal sulcus. The superior parietal lobule contributes to sensorimotor integration while the inferior parietal lobule contributes to auditory and language functions.

Temporal Lobe

Temporal Lobe	largely occupies the middle cranial fossa, and its name relates to its proximity to the temporal region/bone of the skull

Temporal Lobe (cont)

separated from the frontal and parietal lobes superiorly by the lateral sulcus (Sylvian fissure). It extends ventrally from this fissure to the inferior surface of the cerebral cortex. Dorsally, it extends to an arbitrary line running between the parietooccipital sulcus and the preoccipital notch

contains the cortical areas that process hearing, as well as sensory aspects of speech and memory

The primary auditory area, also known as the transverse gyri of Heschl, is located on the internal, superior part of the superior temporal gyrus. It is a specialized region of cortex primarily responsible for the reception of auditory information

Auditory information is further processed within the secondary auditory area. This lies posterior to the primary auditory area in the superior temporal gyrus, at the parietotemporal junction (Wernicke's region in the dominant hemisphere), and receives impulses from the primary auditory area and thalamus.

the middle and inferior temporal gyri are responsible for visual perception. The middle temporal gyrus is associated with the perception of movement within the visual field; whereas the inferior temporal gyrus contains the fusiform face area (FFA), which is necessary for face recognition

Testes/Ovaries

The male and female gonads are endocrine glands that produce sex hormones essential for the development of reproductive organs and the proper functioning of the process of reproduction.

Testes/Ovaries (cont)

Gonads secrete the same set of hormones secreted by the adrenal cortex in the form of androgens. The release of hormones by the gonads is regulated by the release of gonadotrophin stimulating hormone of the pituitary gland.

The male gonads are called testes, whereas the female gonads are called ovaries. The sex hormones secreted by the male and female gonads are different but perform more or less similar functions.

There is a pair of testis in men that secrete the hormone testosterone as the primary sex hormone. The hormone is responsible for the development of the male sex organs as well as the development of secondary sex characteristics in men.

The gonads occur in the form of ovaries in women. There are two ovaries in women that secrete two hormones, estrogen, and progesterone that are responsible for different processes like ovulation, menstrual cycle, and development of secondary sex characters in women.

The synthesis and release of sex hormones by the gonads are regulated by two hormones secreted by the pituitary; luteinizing hormone and follicle-stimulating hormone.

These hormones also work as sex hormones by helping in the formation of male and female gametes.

Pituitary Gland

The pituitary endocrine gland, which is located in the bony sella turcica, is attached to the base of the brain and has a unique connection with the hypothalamus. The pituitary gland consists of two anatomically and functionally distinct regions, the anterior lobe (adenohypophysis) and the posterior lobe (neurohypophysis). Between these lobes lies a small region called the intermediate lobe. The hypothalamus regulates the pituitary gland secretion.

The Anterior Pituitary (Adenohypophysis)

The anterior pituitary is derived from embryonic ectoderm. It secretes five endocrine hormones from five different types of epithelial endocrine cells. The release of anterior pituitary hormones is regulated by hypothalamic hormones (releasing or inhibitory), which are synthesized in the cell bodies of neurons located in several nuclei that surround the third ventricle.

Anterior Pituitary (AP) Hormones

Pituitary Gland (cont)

Growth hormone (GH) ***Other names:*** somatotropic hormone or somatotropin ***Precursor cells:*** somatotrophs in the AP ***Target cells:*** almost all tissues of the body

GH acts almost on every type of cell. Its principal targets are bones and skeletal muscles. It has direct metabolic effects on fats, proteins, and carbohydrates and indirect actions that result in skeletal growth. ***Direct Metabolic Functions:*** GH is anabolic. It stimulates the growth of almost all tissues of the body that are capable of growing (increase in the number of cells). GH also increases the rate of protein synthesis in most cells of the body and decreases the rate of glucose utilization throughout the body (diabetogenic action). Also, it increases the mobilization of fatty acids from adipose tissue and increases levels of free fatty acids in the blood. ***Indirect Actions on Skeletal Growth:*** GH stimulates the production of IGF-1 from hepatocytes. IGF-1 mediates the growth-promoting effects of GH on the skeleton. IGF-1 exerts direct actions on both cartilage and bone to stimulate growth and differentiation. These effects are crucial for growth during childhood to the end of adolescence.

Prolactin ***Precursor cells:*** mainly from lactotrophs in the AP ***Target cells:*** main target cells are mammary glands and gonads ***Mechanism of action:*** binds to peptide hormone receptor (single transmembrane domain) to activate the JAK2-STAT intracellular signaling pathway similar to that of GH Regulation: Like GH, dual hypothalamic inhibitory (from dopamine) and stimulatory hormones (PRH) regulate prolactin secretion. The predominant hypothalamic influence is inhibitory. ***Physiological Functions:*** The main functions of prolactin are stimulating mammary gland growth and development (mammographic effect) and milk production (lactogenic effect). It also has effects on the hypothalamic-pituitary-gonadal axis and can inhibit pulsatile GnRH secretion from the hypothalamus.

Pituitary Gland (cont)

Follicle-stimulating hormone (FSH) and luteinizing hormone (LH) ***Precursor cells:*** gonadotrophs in the AP ***Target cells:*** gonads (ovaries and testes) ***Mechanism of action:*** FSH and LH bind to G protein-coupled receptors to activate adenylyl cyclase enzyme, which in turn increases intracellular cAMP. cAMP activates protein kinase A (PKA) that phosphorylates intracellular proteins. These phosphorylated proteins then accomplish the final physiologic actions. ***Regulation:*** FSH and LH secretion are under the control of the hypothalamic gonadotropin-releasing hormone (GnRH). ***Physiological Functions:*** FSH and LH regulate the functions of the ovaries and the testes. In females, FSH stimulates growth and development of follicles in preparation for ovulation and secretion of estrogens by the mature Graafian follicle. LH triggers ovulation and stimulates the secretion of progesterone by the corpus luteum. In males, FSH is required for spermatogenesis, and LH stimulates testosterone secretion by Leydig cells.

Adrenocorticotrophic hormone (ACTH) ***Precursor cells:*** corticotrophs in the AP ***Target cells:*** cells in the cortex of the adrenal glands (adrenocortical cells) ***Mechanism of Action:*** ACTH binds to its G-protein coupled receptors on the adrenocortical cells. Similar to TSH, FSH, and LH, it activates adenylyl cyclase-PKA-cAMP system to phosphorylate several proteins, which in turn achieve the final physiologic functions. ***Regulation:*** ACTH secretion is under the control of the hypothalamic corticotropin-releasing hormone (CRH). It is subject to negative feedback regulation ***Physiological functions:*** the main function of ACTH is to stimulate the secretion of adrenal cortex hormones (mainly glucocorticoids) during stress.

The Posterior Pituitary (Neurohypophysis)

The posterior pituitary is neural in origin. Unlike the anterior pituitary, the posterior pituitary is connected directly to the hypothalamus via a nerve tract (hypothalamohypophyseal nerve tract). It secretes two hormones: oxytocin and antidiuretic hormone (ADH) or vasopressin. The hormones are synthesized by the magnocellular neurons located in the supraoptic and paraventricular nuclei of the hypothalamus. The hormones are transported in association with neurophysins proteins along the axons of these neurons to end in nerve terminals within the posterior pituitary.

Pituitary Gland (cont)

Oxytocin ***Precursor cells:*** paraventricular and supraoptic nuclei in the hypothalamus ***Target cells:*** myoepithelial cells of the mammary glands and the uterine muscles (myometrium) in women and myofibroblast cells in the seminiferous tubules in men. ***Mechanism of action:*** oxytocin acts on its target cells via a G-protein coupled receptor, which activates phospholipase C that in turn stimulates phosphoinositide turnover. This causes increased intracellular calcium concentration, which activates the contractile machinery of the cell. ***Regulation:*** oxytocin is released in response to an afferent neural input to the hypothalamic neurons that synthesize the hormone. Suckling and uterine stimulation by the baby’s head during delivery are the major stimuli for oxytocin release. It is subject to positive feedback regulation. ***Physiological Functions:*** oxytocin stimulates milk ejection from the breast in response to suckling (milk ejection reflex). It causes contraction of myoepithelial cells surrounding the ducts and alveoli of the gland and therefore milk ejection. Oxytocin also stimulates uterine contraction during labor to expel the fetus and placenta.

Antidiuretic Hormone (ADH) or Vasopressin ***Precursor cells:*** paraventricular and supraoptic nuclei of the hypothalamus. ***Target cells:*** renal distal convoluted tubules and collecting duct and vascular smooth muscle cells. ***Mechanism of action:*** similar to oxytocin, it acts on its target cells via a G-protein coupled receptor, which activates phospholipase C that in turn stimulates phosphoinositide turnover and causes an increase in intracellular calcium concentration which in turn achieves the final physiologic actions. ***Regulation:*** The main stimulus for ADH release is an increase in osmolality of circulating blood. Osmoreceptors located in the hypothalamus detect this increase and activate the paraventricular and supraoptic nuclei to release ADH. It also releases in response to hypovolemia. ***Physiological Functions:*** ADH binds to V2 receptors on the distal tubule and collecting ducts of the kidney to up-regulate aquaporin channel expression on the basolateral membrane and increase water reabsorption. It, as its name suggests, also acts as a vasoconstrictor upon binding to V1 receptors on the arteriolar smooth muscle.

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Anterior Pituitary (AP) Hormones

Growth hormone (GH) Other names: somatotropic hormone or somatotropin Precursor cells: somatotrophs in the AP Target cells: almost all tissues of the body Transport: 60% circulates free and 40% bound to specific GH-binding proteins (GHBPs)

Occipital Lobe

The occipital lobe lies just underneath the occipital bone. It forms the most posterior portion of the brain and is found behind both the parietal and temporal lobes.

The occipital lobe is separated superiorly from the parietal lobe by the parietoocccipital sulcus. Anteriorly, it is separated from the temporal lobe by an imaginary line called the lateral parietotemporal line, that extends from the termination of the parietooccipital sulcus superiorly, and to the preoccipital notch inferiorly.

The superolateral aspect of the occipital lobe presents with three notable gyri: the superior, middle and inferior occipital gyri. The superior occipital gyrus is the clearly defined gyrus on the lateral surface of the occipital lobe.

The intraoccipital sulcus, which is formed as an extension of the intraparietal sulcus, separates the superior and middle gyri (if present)

The lateral occipital sulcus (also known as the inferior occipital sulcus) separates the inferior occipital gyrus from the superior, or the middle occipital gyrus (if present).

Occipital Lobe (cont)

A fissure known as the calcarine sulcus begins slightly above the occipital pole just behind the parietooccipital sulcus. The calcarine sulcus divides the medial aspect of the occipital lobe into the cuneate gyrus (cuneus) superiorly and the lingual gyrus inferiorly.

The calcarine sulcus also marks the location of the primary visual cortex which is responsible for visual perception.

The occipital lobe is identified as the main visual processing centre. It is associated with color determination, facial recognition, depth perception, visuospatial processing and even plays a role in memory formation. The occipital lobe not only enables visual perception but allows us to process and interpret visual information.

Action Potential

Definition	An action potential is defined as a sudden, fast, transitory, and propagating change of the resting membrane potential.
Cells which can generate action potential	Muscle cells and Neurons
Steps	an action potential is generated when a stimulus changes the membrane potential to the values of threshold potential. The threshold potential is usually around -50 to -55 mV. This means that any subthreshold stimulus will cause nothing, while threshold and suprathreshold stimuli produce a full response of the excitable cell.

Phases

Hypopolarization	is the initial increase of the membrane potential to the value of the threshold potential. The threshold potential opens voltage-gated sodium channels and causes a large influx of sodium ions.

Phases (cont)

Depolarization	During depolarization, the inside of the cell becomes more and more electropositive, until the potential gets closer the electrochemical equilibrium for sodium of +61 mV.
Overshoot	This phase of extreme positivity is the overshoot phase
Repolarization	After the overshoot, the sodium permeability suddenly decreases due to the closing of its channels. The overshoot value of the cell potential opens voltage-gated potassium channels, which causes a large potassium efflux, decreasing the cell's electropositivity.
Hyperpolarization	Repolarization always leads first to hyperpolarization, a state in which the membrane potential is more negative than the default membrane potential. But soon after that, the membrane establishes again the values of membrane potential.

Synaptic Transmission

Synapse	is the place where information is transmitted from one neuron to another.
	usually form between axon terminals and dendritic spines. There are also axon-to-axon, dendrite-to-dendrite, and axon-to-cell body synapses.
Pre-synaptic neuron	The neuron transmitting the signal
Post-synaptic neuron	The neuron receiving the signal.
	These designations are relative to a particular synapse—most neurons are both presynaptic and postsynaptic.
Two Types	Chemical and Electrical

Central Nervous System

the CNS is the supreme command center of the body

consists of two organs which are continuous with each other; the brain and spinal cord.

are enveloped and protected by three layers of meninges, and encased within two bony structures; the skull and vertebral column, respectively.

brain consists of the cerebrum, subcortical structures, brainstem and cerebellum

spinal cord continues inferiorly from the brainstem and extends through the vertebral canal

Structures of The Brain

Cerebrum	is the largest part of the brain, divided into two hemispheres – a left and a right – by the falx cerebri along the longitudinal cerebral fissure.
	Each hemisphere can then be subdivided into lobes that are named according to the cranial bones under which they reside.
Cerebellum	It is an ovoid structure that resides in the posterior cranial fossa, inferior to the tentorium cerebelli. It has an outer grey matter cortex and white matter internally.
Brain Stem	is the distal part of the brain that is made up of the midbrain, pons, and medulla oblongata.
Parts of the Brain Stem	
Medulla oblongata	is the narrowest and most caudal part of the brainstem. It is a funnel-like structure.

Structures of The Brain (cont)

	The medulla develops from the myelencephalon, which is a secondary brain vesicle that arises from the rhombencephalon (the hindbrain). The other secondary brain vesicle to arise from the hindbrain is superior to the myelencephalon and gives rise to the pons.
Pons	resembles a dome-like structure with numerous striations across its surface. It is widest in the middle and tapers toward the lateral extremities.
	function: to house the pontine nuclei and to facilitate corticopontocerebellar communication. It also enables communication between the left and right hemispheres of the cerebellum.
Midbrain	is the shortest segment of the brainstem. It extends caudally from the base of the thalamus to the superior roof of the fourth ventricle.
Reticular formation	The reticular formation is a vast network of neurons that are involved in maintaining consciousness and initiating arousal. This neuronal tract extends from the spinal cord to the diencephalon and occupies different parts of the brainstem throughout.

Structures of The Brain (cont)

The nuclei of the reticular formation are situated deep within the brainstem along its vertical axis. On each half of the brainstem, there is a lateral, medial, and median group of nuclei. The combined effect of this collection of nuclei are related to the regulation of the circadian rhythm, coordinates the respiratory and antigravity muscles, modifies reflex activity, and also helps to coordinate the muscles of facial expression.

Frontal Lobe

Frontal Lobe	largest lobe of the brain comprising almost one-third of the hemispheric surface
	frontal lobe forms the most anterior portion of the cerebral hemisphere and is separated from the parietal lobe posteriorly by the central sulcus, and from the temporal lobe posteroinferiorly by the lateral sulcus
	The most anterior portion of the frontal lobe is known as the frontal pole
	is made up of three cortical surfaces: a lateral, medial and inferior surface
	lateral surface of the frontal lobe contains four principal gyri: the precentral, superior frontal, middle frontal, and the inferior frontal gyri
	medial (interhemispheric) surface extends down to the cingulate sulcus and consists mainly of the paracentral lobule (an extension of the precentral and postcentral gyri), and the medial extension of the superior frontal gyrus

Frontal Lobe (cont)

	nferior surface contains the olfactory tract and olfactory bulb, the straight gyrus and the four orbital gyri
	the entire frontal cortex of the frontal lobe is divided into three parts: the prefrontal cortex, motor cortex and Broca’s area
Prefrontal cortex	encompasses the superior, middle and inferior frontal gyri of the frontal lobe
	It plays a crucial role in the processing of intellectual and emotional information, including aggression, and facilitates judgement and decision-making
Motor cortex	corresponds to the precentral gyrus of the frontal lobe. The precentral gyrus contains the primary motor cortex
	which is responsible for integrating signals from different brain regions to modulate motor function. The primary motor cortex is where the corticospinal tract originates.
	Encompassing part of the middle and inferior frontal gyri, just rostral to the premotor region, is an area called the frontal eye fields
	which is responsible for voluntary control of conjugate (horizontal) eye movements
Broca's Area	inferior frontal gyrus is divided into three parts: i) the pars opercularis, ii) the pars triangularis, and iii) the pars orbitalis
	Pars opercularis refers to the most dorsal part of the gyrus
	pars triangularis is the middle triangularly-shaped part
	the pars orbitalis represents the most ventral part of the gyrus

Frontal Lobe (cont)

the pars opercularis and triangularis in the dominant hemisphere are referred to as Broca's speech area

Broca's area is responsible for producing the motor component of speech, which includes verbal fluency, phonological processing, grammar processing and attention during speech

Endocrine System

Endocrine System	consists of a series of glands that produce chemical substances known as hormones
	hormones are chemical messengers that must bind to a receptor in order to send their signal
	hormones are secreted into the bloodstream and travel throughout the body, affecting any cells that contain receptors for them
	Imbalances in hormones are related to a number of disorders.

Hypothalamus

The hypothalamus is the region in the ventral brain which coordinates the endocrine system. It receives many signals from various regions of the brain and in return, releases both releasing and inhibiting hormones, which then act on the pituitary gland to direct the functions of the thyroid gland, adrenal glands, and reproductive organs and to influence growth, fluid balance, and milk production.

The hypothalamus functions in conjunction with the pituitary gland through the hypothalamic-pituitary axis. The hypothalamus itself contains several types of neurons that release different hormones. The thyrotropin-releasing hormone (TRH), gonadotropin-releasing hormone (GnRH), growth hormone-releasing hormone (GHRH), corticotropin-releasing hormone (CRH), somatostatin, and dopamine are released from the hypothalamus into the blood and travel to the anterior pituitary.

Hypothalamus (cont)

The thyrotropin-releasing hormone is a tripeptide that stimulates the release of thyroid-stimulating hormone and prolactin from the anterior pituitary gland. The gonadotropin-releasing hormone triggers sexual development at the onset of puberty and maintains female and male physiology after that by controlling the release of follicle-stimulating hormone and luteinizing hormone. The growth hormone-releasing hormone stimulates the secretion of growth hormone by the anterior pituitary. The corticotropin-releasing hormone stimulates the release of adrenocorticotropic hormone from the anterior pituitary. Somatostatin inhibits the release of both growth hormone and thyroid-stimulating hormone, and various intestinal hormones. Dopamine inhibits the release of prolactin from the anterior pituitary, modulates motor-control centers, and activates the reward centers of the brain. Prolactin functions mainly to promote lactation but also helps regulate reproduction, metabolism, and the immune system.

Thyroid Gland

The thyroid is an endocrine gland. Its location is in the inferior, anterior neck, and it is responsible for the formation and secretion of the thyroid hormones as well as iodine homeostasis within the human body. The thyroid produces approximately 90% inactive thyroid hormone, or thyroxine (T4), and 10% active thyroid hormone, or triiodothyronine (T3). Inactive thyroid hormone is converted peripherally to either activated thyroid hormone or an alternative inactive thyroid hormone.

T3 is responsible for affecting many organs and tissues throughout the body, which can, in summary, is the effect of increasing metabolic rate and protein synthesis. Parafollicular cells, or C cells, are responsible for the production and secretion of calcitonin. Calcitonin opposes parathyroid hormone to decrease blood calcium levels and maintain calcium homeostasis.

The thyroid gland is responsible for the production of iodothyronines, of which there are three. The primary secretory product is inactive thyroxine, or T4, a prohormone of triiodothyronine, or T3. T4 is converted to T3 peripherally by type 1 deiodinase in tissues with high blood flow, such as the liver and kidneys. In the brain, T4 is converted to active T3 by type 2 deiodinase produced by glial cells. The third iodothyronine is called reverse T3, or rT3. rT3 is inactive and forms by type 3 deiodinase activity on T4.

Thyroid Gland (cont)

These iodothyronines are composed of thyroglobulin and iodine. Thyroglobulin is formed from amino acids in a basal to apical fashion within the thyroid cells themselves. Thyroglobulin is then secreted into the follicular lumen, where it is enzymatically combined with iodine to form iodinated thyroglobulin. Endosomes containing this iodinated thyroglobulin then fuse with lysosomes, which enzymatically release the thyroglobulin from the resultant thyroid hormone. The thyroid hormones are next released from the cell while the remaining thyroglobulin is deiodinated and recycled for further use.

Parathyroid Gland

In the blood, the sensitive process of calcium and phosphate homeostasis is maintained primarily by an appropriately functioning parathyroid gland. The parathyroid gland is comprised of 4 small glands located posteriorly to the thyroid in the middle aspect of the anterior neck. The parathyroid gland secretes parathyroid hormone (PTH), a polypeptide, in response to low calcium levels detected in the blood. PTH facilitates the synthesis of active vitamin D and calcitriol (1,25-dihydroxycholecalciferol) in the kidneys. In conjunction with calcitriol, PTH regulates calcium and phosphate. PTH effects are present in the bones, kidneys, and small intestines. As serum calcium levels drop, the secretion of PTH by the parathyroid gland increases. Increased calcium levels in the serum serve as a negative-feedback loop signaling the parathyroid glands to stop the release of PTH.

Pancreas

The pancreas is a composite organ, which has exocrine and endocrine functions. The endocrine portion is arranged as discrete islets of Langerhans, which are composed of five different endocrine cell types (alpha, beta, delta, epsilon, and upsilon) secreting at least five hormones including glucagon, insulin, somatostatin, ghrelin, and pancreatic polypeptide, respectively.

Insulin

Pancreas (cont)

Source: Beta cells of islets of the pancreas. ***Synthesis:*** Insulin is a peptide hormone. The insulin mRNA is translated as a single-chain precursor called preproinsulin, and removal of its signal peptide during insertion into the endoplasmic reticulum generates proinsulin. Within the endoplasmic reticulum, proinsulin is exposed to several specific endopeptidases, which excise the C peptide (one of three domains of proinsulin), thereby generating the mature form of insulin. Insulin is secreted from the cell by exocytosis and diffuses into islet capillary blood. C-peptide is also secreted into the blood in a 1:1 molar ratio with insulin. Although C-peptide has no established biological action, it is used as a useful marker for insulin secretion. ***Transport:*** insulin circulates entirely in unbound form (T1/2 = 6 min). ***Main Target cells:*** hepatic, muscle and adipocyte cells (i.e., cells specialized for energy storage). ***Mechanism of action:*** Insulin binds to a specific receptor tyrosine kinase on the plasma membrane and increases its activity to phosphorylate numerous regulatory enzymes and other protein substrates. ***Regulation of its secretion:*** Plasma glucose level is the main regulator of insulin secretion. The change in the concentration of plasma glucose that occurs in response to feeding or fasting is the main determinant of insulin secretion. Modest increases in plasma glucose level provoke a marked increase in plasma insulin concentration. Glucose is taken up by beta cells via glucose transporters (GLUT2). The subsequent metabolism of glucose increases cellular adenosine triphosphate (ATP) concentrations and closes ATP-dependent potassium (KATP) channels in the beta cell membrane, causing membrane depolarization and an influx of calcium. Increased calcium intracellular concentration results in an increase of insulin secretion. Increased plasma amino acid and free fatty acid concentrations induce insulin secretion as well. Glucagon is also known to be a strong insulin secretagogue. ***Physiological functions:*** Insulin plays an important role to keep plasma glucose value within a relatively narrow range throughout the day (glucose homeostasis). Insulin’s main actions are (1) In the liver, insulin promotes glycolysis and storage of glucose as glycogen (glycogenesis), as well as conversion of glucose to triglycerides, (2) In muscle, insulin promotes the uptake of glucose and its storage as glycogen, and (3) in adipose tissue, insulin promotes uptake of glucose and its conversion to triglycerides for storage.

Adrenal Gland

The adrenal gland is made up of the cortex and medulla. The cortex produces steroid hormones including glucocorticoids, mineralocorticoids, and adrenal androgens, and the medulla produces the catecholamines, epinephrine, and norepinephrine. This brief article reviews the physiology of the adrenal gland and highlights the relevance of understanding the clinical syndromes of excess and deficiency.

Adrenal Cortex

The adrenal cortex takes part in steroidogenesis, producing glucocorticoids, mineralocorticoids, and androgen precursors. It has 3 distinct functional and histological zones: the zona glomerulosa (outermost layer), the zona fasciculata (middle layer), and the zona reticularis (innermost layer).[1] Each layer produces steroid hormones from the precursor cholesterol. However, the specific steroid hormone produced differs in each layer because of zonal specific enzymes. The zona glomerulosa produces mineralocorticoids, the zona fasciculata produces glucocorticoids, and the zona reticularis produces androgen precursors (mostly DHEA with some androstenedione).

Hypothalamic-Pituitary-Adrenal (HPA) Axis

The hypothalamic-pituitary-adrenal (HPA) axis is involved in the production of glucocorticoids and adrenal androgens from the zona fasciculata and zona reticularis. In response to circadian rhythms or stressors, paraventricular neurons (PVN) in the hypothalamus make and secrete corticotropin-releasing hormone (CRH).

Adrenal Gland (cont)

CRH binds receptors on the anterior pituitary gland, which leads to the synthesis of ACTH (or corticotrophin) from pre-pro-opiomelanocortin (pre-POMC). Of note, cleavage of POMC also yields other hormones such as alpha-melanocyte-stimulating hormone (MSH). ACTH from the anterior pituitary is released into the circulation and engages the melanocortin type 2 receptors (MC2-R) in the zona fasciculata of the adrenal cortex predominantly to induce the synthesis of glucocorticoids. It is a GPCR and has an associated protein (MRAP) produced by the adrenal that appears to function as a chaperone to escort MC2-R to the cell surface to allow engagement by ACTH.Circulating glucocorticoids negatively feedback on the hypothalamus (long loop) and the anterior pituitary (short loop), suppressing the release of CRH and ACTH, respectively. This prevents the continued rise of glucocorticoid levels. ACTH is released from the anterior pituitary in a pulsatile pattern that parallels the fluctuating levels of cortisol. Both ACTH and cortisol levels rise to a peak in the morning (6:00 AM to 8:00 AM) and decline throughout the day, reaching their nadir at around midnight.

Adrenal Medulla and the Sympathetic Nervous System

The sympathetic nervous system regulates the secretion of epinephrine and norepinephrine from the adrenal medulla.