Unit 1

Biological Aspects of Psychology

Learning outcomes
After studying this unit, you should be able to:

- Demonstrate knowledge of the human nervous system
- Demonstrate an understanding of the major structures of the brain
- Demonstrate an understanding of the genetic functions informing behaviour
- Demonstrate an understanding of stress and emotions.

1 Introduction

I want you to pause for a moment. What is happening now? The fact that you are reading this, means you are perusing your PYC1512 study material. Before this, you took a decision that, from a particular time in the day you would stop all other activities, sit at a designated place, and start working on your course material. Now you are seated in a chair at a table or desk, clicking your computer mouse or sliding a finger across a screen. You might glance out of a window every now and then and can probably hear the sound of a TV in the background, as your family watches a programme in another room. You might catch the aroma of the coffee you are sipping, and perhaps you have just reminded yourself to check what time your doctor's appointment is tomorrow … but that can wait a bit. You might feel an itch at the back of your neck, and gently scratch yourself with the fingers of one hand, while your eyes remain glued to the text on your screen. Then you might glance at the clock and realise it is close to midnight. You might decide to retire for the night, since you have to prepare to face a brand-new day in the morning. In your mind's eye you might consult your diary, trying to remember what events you have scheduled for tomorrow. This is an example of the experiences you could be going through right now, as you read this.

Everything that happened in the preceding paragraph, is an episode of your nervous system at work. Everything we do is a function of the messages being relayed by various sensory nerves – synaptic transfers of all those messages take place, and certain brain areas spring into action to enable you to perform whatever task you are busy with. What you will learn in this module, is how the organisation of the nervous system, and the constant interactions between different brain areas, always determine your everyday experience. As living organisms, we depend on the functioning of various biological systems in our bodies to function with precision, for us to experience a quality of life which ensures our survival. This part of the module will focus on the human nervous system – that part of our being that allows us to experience the world around us. At the end of the module, you will understand that behaviour has a physical component. Our understanding of psychology would not be complete without understanding the physiological processes involved in human behaviour.

1.1 Knowledge of the Human Nervous System

Some basics: The human nervous system is composed of two parts: The **central nervous system (CNS)** and the **peripheral nervous system (PNS).** The CNS consists of the brain and spinal cord. The PNS consists of all the nerves that exit the brain and spinal cord and carry sensory and motor messages to and from other parts of the body. Part of the PNS is the somatic nervous system, which consists of axons conveying messages from the sense organs to the CNS, and from the CNS to the muscles. Another part of the PNS is the **autonomic nervous system (ANS)** which controls the heart, intestines, and other organs. The ANS has some of its cell bodies within the brain and spinal cord, and some in the clusters along the sides of the spinal cord (Freberg, 2019; Kalat, 2019). The ANS is composed of the **sympathetic nervous system** and the **parasympathetic nervous system**. The sympathetic nervous system acts as an integrated whole in affecting smooth muscle systems to enable a "fight or flight" response when we perceive danger. Typical sympathetic responses are the dilation of the pupils to facilitate vision, the constriction of peripheral arteries to supply more blood to the arteries and the brain, the secretion of epinephrine to raise blood sugar levels and increase metabolism, and the reduction of stomach and intestinal activity so that energy can be redirected elsewhere. The parasympathetic nervous system controls rest, enjoyment, eating, sleep, and sexual activity. It stimulates the secretion of saliva and those responsible for digestion in the stomach, produces pupillary constriction, decreases the heart rate, and increases blood flow to the genitalia during sexual activity (VandenBos, 2007). (The autonomic nervous system is discussed in more detail later in the module.) Neither part of the nervous system is more important than the other – we need both parts of the system to work in a coordinated manner, for us to operate as fully functional human beings. For the purposes of this module, it makes logical sense to start understanding the PNS before we can understand the CNS.

1.2 Understanding the Major Structures of the Brain

1.2.1 The Peripheral Nervous System: Cells of the Nervous System

The nervous system is made up of two types of cells: **neurons** and **glia**. A neuron is the information processing and transmitting element of the central and peripheral nervous systems. Neurons receive information about the environment and transmit it to other cells. The glia (from the Greek word meaning *glue*) serve a variety of support functions for neurons. The adult human brain consists of approximately 86 million neurons and about 360 billion glial cells (Freberg, 2019; Kalat, 2019).

1.2.1.1 The Structure of a Neuron

Figure 1.1 is an illustration of a neuron – Figure 1.1a shows a **motor neuron** with all its components, while Figure 1b shows a **sensory neuron** with its components.

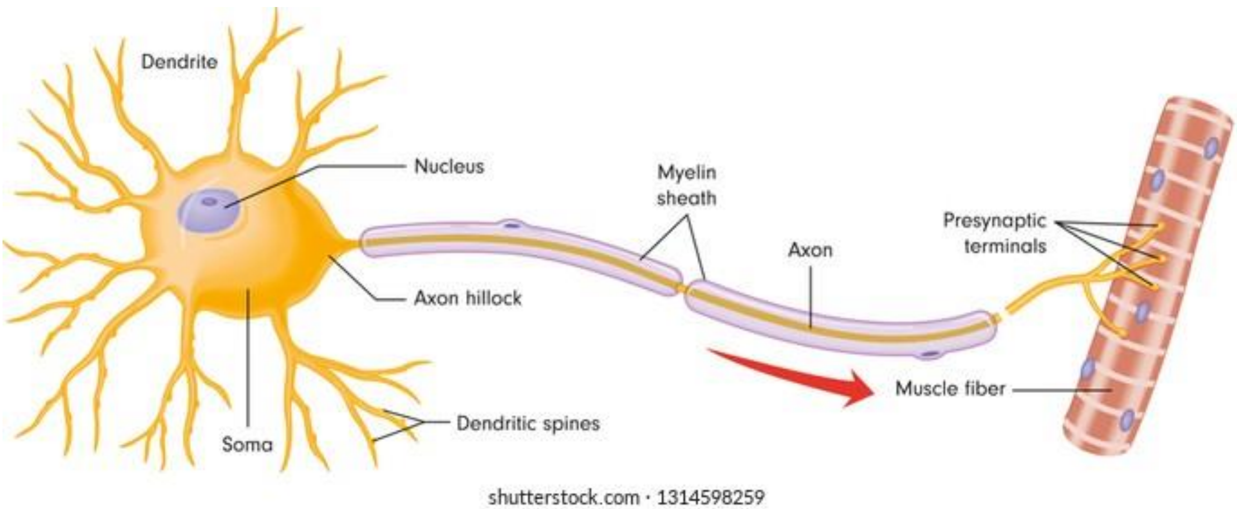


Figure 1.1a: Components of a Vertebrate Neuron

Source: www.shutterstock.com/search/neuron

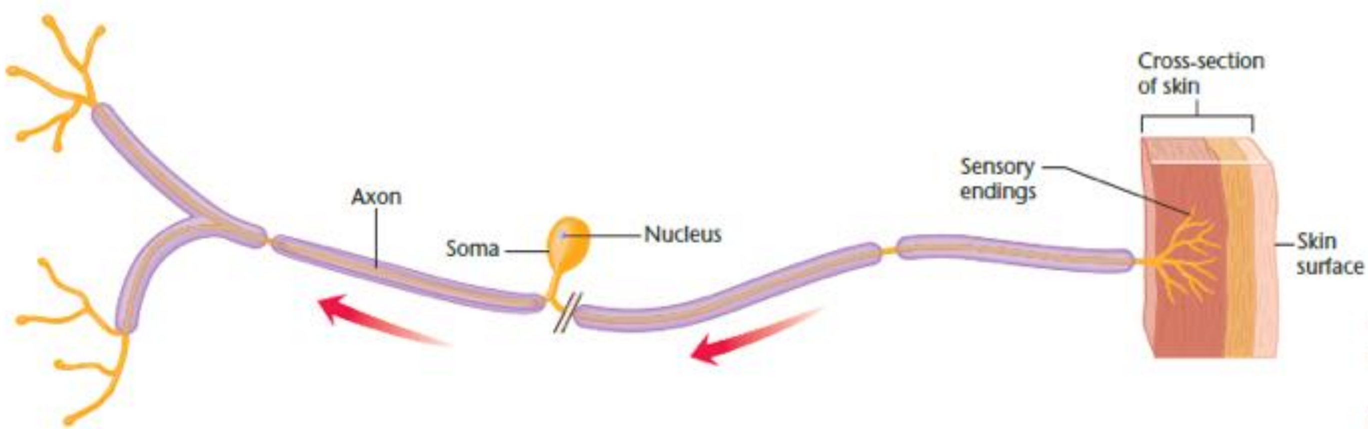
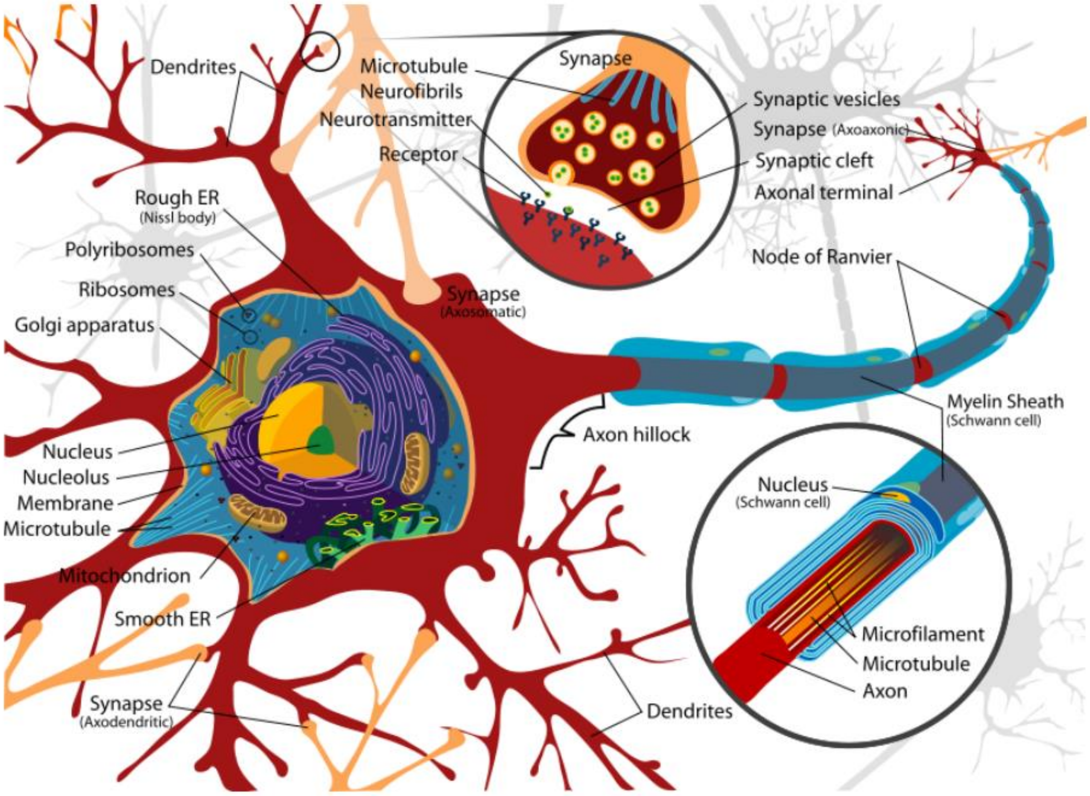


Figure 1.1b: A Vertebrate Sensory Neuron

Source: www.peace.saumag.edu)/faculty/kardas/Physio/kalatchapter1.html

As can be seen in Figure 1.1, the distinctive shape of a neuron is that it has a **soma** (cell body) and **dendrites** (from the Greek meaning *tree*), an **axon** (from the Greek meaning *axis*) and presynaptic terminals. The soma is the main mass of a neuron, as it contains the nucleus and its organelles. The dendrites and axons are the specialised branches that extend from the cell body and communicate with other cells. A motor neuron (Figure 1.1a), with its soma in the spinal cord, receives excitation through its dendrites, and conducts impulses through its body (soma) to a muscle. A sensory neuron (Figure 1.1b) is highly sensitive to particular kinds of stimuli such as light, sounds, or touch (Freberg, 2019; Kalat, 2019).

Dendrites, which become narrower near their ends, are lined with **synaptic receptors** which enable them to receive information from other neurons. Figure 1.2 illustrates a synapse. Most dendrites have short outgrowths known as **dendritic spines** that increase the surface area available for a synapse, thus heightening its ability to receive information. An example of synaptic activity is when a person takes medication – Aspirin, for instance – to treat a headache. After the Aspirin is taken, it reaches the neuron's terminal buttons (at the axon). The terminal button of this neuron containing Aspirin then "talks" to the dendritic membrane of the "receiving" cell, causing an alteration in the dendritic membrane of the receiving cell, to enable the transmission of Aspirin. The membranes of the two neurons are therefore "talking" to each other (the membrane of the transmitting neuron is the *pre-synaptic axon terminal* and that of the receiving neuron is the *post-synaptic dendrite membrane*). The space separating the pre-synaptic and post-synaptic membranes is known as the **synaptic cleft***.* The synaptic cleft contains cellular fluid containing neurochemicals through which the transmitter substance diffuses (Freberg, 2019). It is through synaptic activity between neurons that the Aspirin (or any medication) "travels" to the areas where its function is required.



Human Physiology Neurons The Nervous System

Figure 1.2: Axons and Dendrites

Source: www.slidesharenow.blogspot.com/2020/05/glial-cells-vs-neurons-psychology.html

The **soma** (cell body) contains the nucleus, ribosomes and mitochondria. This is where the neuron's metabolism takes place. Like dendrites, most neurons' cell bodies are covered by synapses (Kalat, 2019).

The **axon** is a thin fibre that conveys impulses towards other neurons, an organ, or a muscle. Many vertebrate axons are covered in an insulating material called myelin sheath, with interruptions known as nodes of Ranvier. Invertebrate axons do not have myelin sheaths (Kalat, 2019).

Other terms associated with neurons are "afferent", "efferent" and "intrinsic". An **afferent axon** ('a' for admit) brings information into a structure, while an **efferent axon** ('e' for exit) carries information away from a structure. Sensory neurons are afferent to the nervous system, while motor neurons are efferent to the nervous system. Where a cell's dendrites and axons are contained within a single structure, the cell is an **intrinsic neuron** or **interneuron** (Kalat, 2019).

Neurons vary in size, shape and function, depending on the location of the organs they are linked to, and the functions performed by those organs. For example, neurons in the eye would be different from those found on the skin's surface.

1.2.1.2 The Structure of Glia

Glia (also known as neuroglia) play the role of supporting neurons. As the Greek origin of the word (meaning *glue*) implies, glia are like the glue that holds neurons together. Glia are categorised according to their size: **macroglia** are large varieties of glial cells, and **microglia** are small cells.

Macroglia

There are four types of macroglia: astrocytes, ependymal cells, oligodendrocytes and Schwann cells.

- *Astrocytes:* Astrocytes are star-shaped cells located in the central nervous system. They serve to provide a structural matrix for neurons, so that the neurons do not just float haphazardly. Astrocytes provide nutrients to neurons by dilating blood vessels in areas of heightened neural activity. They also protect the blood-brain barrier, by preventing toxins circulating in the blood from entering the brain (Freberg, 2019; Kalat, 2019). Figure 1.3 illustrates the structure of an astrocyte.

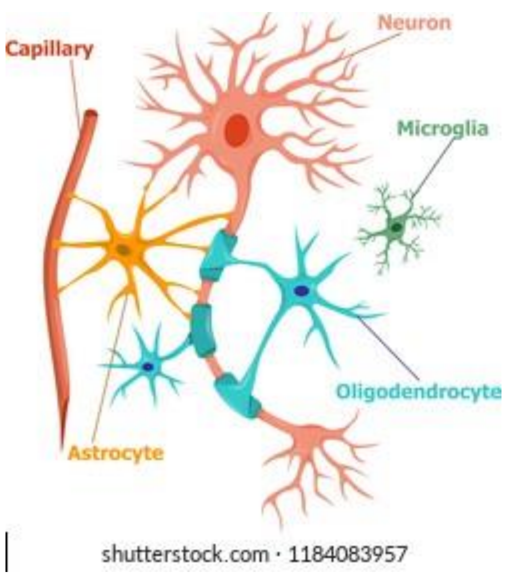


Figure 1.3: Structure of an Astrocyte
Source: www.shutterstock.com

- *Ependymal cells:* These are cube-shaped cells that line the ventricles of the brain and the central canal of the spinal cord. They act as a firewall against viruses that pose a threat to the CNS. Ependymal cells feature fine cilia (hairs) that project into the ventricle or spinal cord to facilitate the movement of cerebro-spinal fluid (CSF). In the process, they also monitor the quality of CSF and provide the underlying brain cells with proteins from the CSF (Freberg, 2019).
- *Oligodendrocytes and Schwann cells:* These cells build the myelin sheaths that surround and insulate vertebrate axons. Oligodendrocytes build myelin sheaths for axons in the brain and spinal cord, while Schwann cells provide the same function in the peripheral nervous system (PNS) (Kalat, 2019). Figure 1.4 shows oligodendrocytes and Schwann cells forming myelin sheaths around axons.

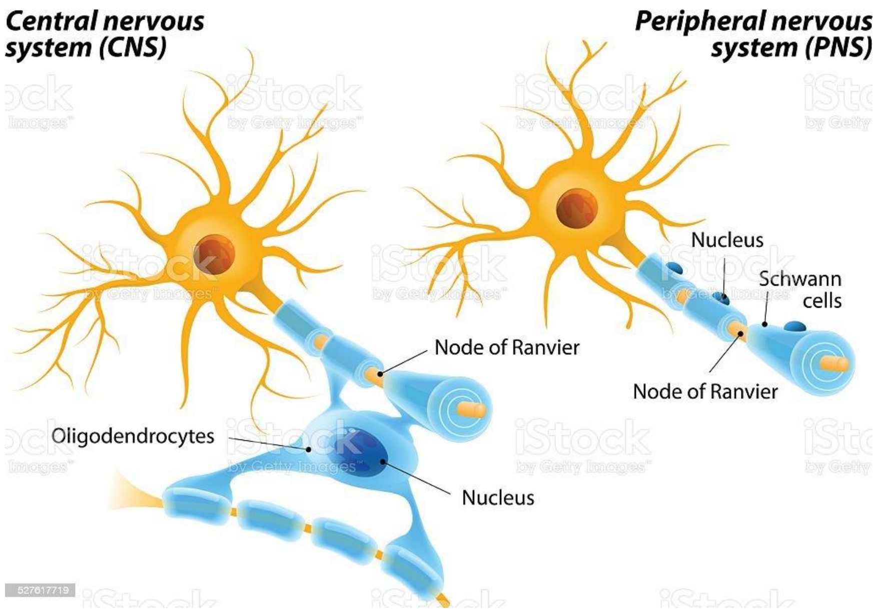


Figure 1.4a: In the Central Nervous System (CNS), Oligodendrocytes Send Out Branches that Form the Myelin Segments of Various Axons
Figure 1.4b: Schwann Cells Serve a Similar Purpose in the Peripheral Nervous System (PNS)
Source: www.shutterstock.com

Microglia

Microglia are tiny cells that act as part of the immune system. They remove viruses and fungi from the brain, and damaged and dead neurons following brain damage (Kalat, 2019). Freberg (2019) aptly names them the “clean-up crew” of the brain, the equivalent of white blood cells in the body.

Now that we know about the cells of the human nervous system and their physiological processes (that is, how they work), we turn to the two major components of the nervous system: the Central Nervous System (CNS) and the Peripheral Nervous System (PNS).

1.2.2 The Central Nervous System

For you to understand the rest of the biological psychology module from this point on, it is important to know the anatomical terms of the brain (this applies to the whole body as well) as you will encounter these terms in the lesson. Table 1.1, adapted from Kalat (2019), is a quick reference guide to body (brain, in this case) directions.

Table 1.1: Anatomical Terms Denoting Parts of the Brain from Varying Viewpoints (adapted from Kalat, 2019, p. 70).

Term	Definition
Dorsal	Towards the back, away from the ventral (stomach) side. (The top of the human brain is considered dorsal when compared to a four-legged animal.)
Ventral	Towards the front (stomach side), away from the dorsal (back) side
Anterior	Towards the front end
Posterior	Towards the rear end
Superior	Above another part
Inferior	Below is another part
Lateral	Towards the side, away from the midline
Medial	Towards the midline, away from the side
Proximal	Located close (approximate) to the point of origin or attachment
Distal	Located more distant (far) from the point of origin or attachment
Ipsilateral	On the same side of the body (e.g., your right arm and right leg)
Contralateral	On the opposite side of the body (e.g., your left arm and right arm)

Coronal plane (or frontal plane)	A plane that shows brain structures as seen from the front
Sagittal plane	A plane that shows brain structures as seen from the side
Horizontal plane (or transverse plane)	A plane that shows brain structures as seen from above
Rostral	Towards the front or anterior part
Caudal	Towards the tail end

The CNS includes the brain and spinal cord. The PNS contains all the nerves that enter the brain and spinal cord, carrying all sensory and motor messages to and from other parts of the body. The neurons and glia (discussed in the first part of the module) form part of the CNS. At this stage in the module, you must familiarise yourself with what the nervous system looks like. Turn to Figure 1.5 for a quick-reference illustration of how the nervous system is organised.

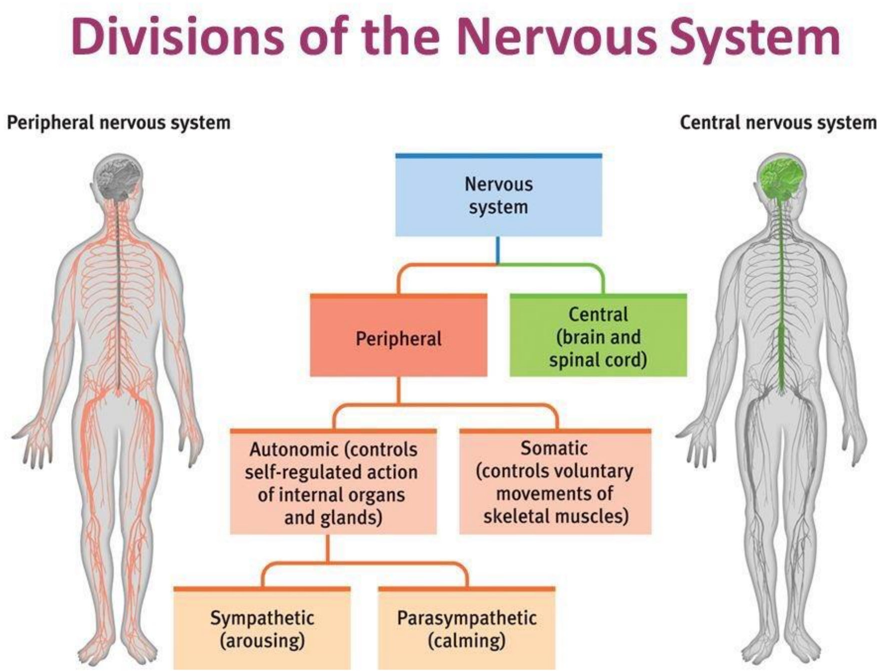


Figure 1.5: Divisions of the Nervous System
Source: www.humananatomy2013.weebly.com/nervous-system

1.2.2.1 The Spinal Cord

The spinal cord, which contains about one billion nerve cells and grows to about 45 cm in men and 43 cm in women, is the part of the CNS which is located inside the spinal column. The spinal cord communicates with all sense organs and muscles in the body, except those in the head. It is a segmented structure that contains sensory and motor nerves contralaterally. When cut in half and viewed dorsally, the spinal cord is made up of white matter, with gray matter infused internally in an H-shape. The white matter is made up of nerve fibres known as axons, the parts of neurons that carry signals to other neurons. It looks white because of the fatty material known as myelin which covers the axons, as explained at the beginning of the module. The gray matter is made up of cell bodies and dendrites that absorb some of the chemicals which preserve the tissue. Each segment of the spinal cord sends sensory information to the brain, and receives motor commands from the brain. All information is carried through tracts of axons located in the spinal cord. If the spinal cord is cut at any segment, the brain loses sensation from that segment and below it. The brain also loses motor control over the parts of the body served by that segment and below it (Freberg, 2019; Kalat, 2019).

1.2.2.2 The Brain

The brain is a soft tissue organ located inside the skull, and it is organised in three bulges: the hindbrain (rhombencephalon), midbrain (mesencephalon) and forebrain (prosencephalon). (Do not worry about remembering the terms in brackets; those are the original Greek terms that are no longer in use, but it is necessary to know them as they appear that way in some of the literature. By the way, *cephalon* means head.) The hindbrain and the midbrain make up what is often called the **brainstem**. Figure 1.6 shows the brainstem.

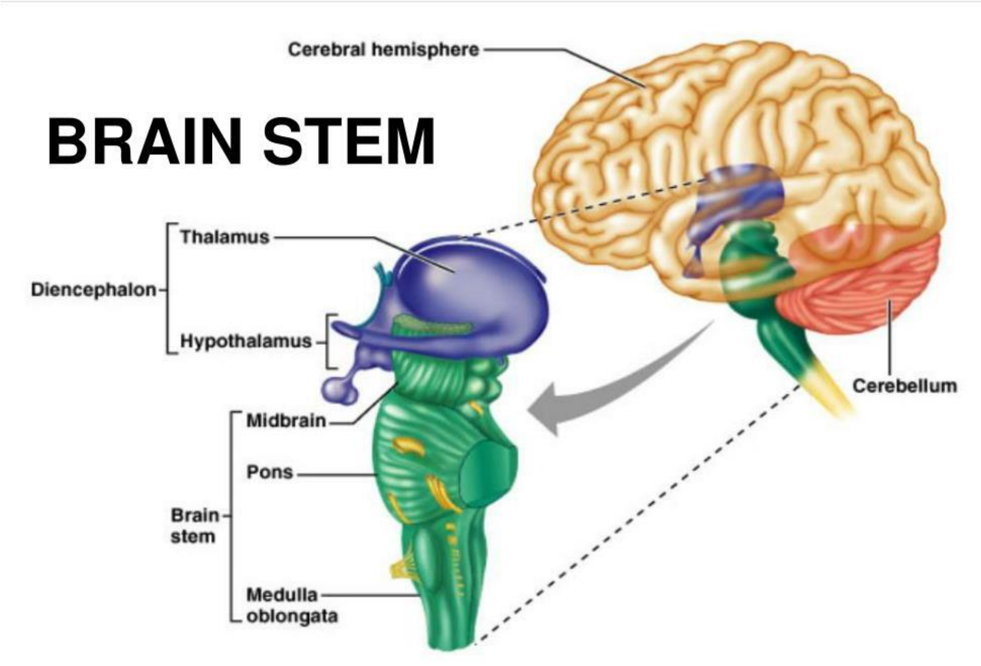


Figure 1.6: The Human Brain Stem
Source: www.slideserve.com/dympna/the-brain

a) The Hindbrain

The hindbrain is the posterior part of the brain located superior to the spinal cord, and it consists of three parts: the medulla, the pons and the cerebellum. The **medulla**, which is the most caudal part of the brain, could be considered an enlarged extension of the spinal cord. It contains large quantities of white matter, and serves as the nodal point where most of the information (passing to and from higher parts of the brain) passes. The head and organs connect to the medulla and adjacent areas via the contralateral cranial nerves. These cranial nerves control reflexes such as breathing, heart rate, salivation, coughing and sneezing (Freberg, 2019; Kalat, 2019).

The **pons** (‘bridge’ in Latin) lies posterior and ventral to the medulla, and contains nuclei from several cranial nerves. It is in the pons that axons from each half of the brain cross contralaterally, so that the left hemisphere controls the muscles on the right side of the body and vice versa (Freberg, 2019; Kalat, 2019).

The **cerebellum** is the large hindbrain structure with many deep folds. It controls movement and balance, and coordination as well as information processing. People with damage to the cerebellum are clumsy, and lose balance (Freberg, 2019; Kalat, 2019).

(Now you know why, in movies, people are immobilised by being struck hard on the back of the head.)

b) The Midbrain

The midbrain is the middle of the brain. As seen in Figure 1.7, the dorsal (roof) part of the midbrain is the tectum, while the ventral part is the tegmentum. CSF is contained in a small channel in the midline known as the cerebral aqueduct. A number of nuclei associated with cranial nerves are also located here, as is the most rostral part of the reticular formation, which is responsible for arousal. Also located in the midbrain is the superior colliculi, which receives input from the optic nerves leaving the eye and is responsible for guided eye movements. The inferior colliculi are responsible for hearing and regulating auditory reflexes, such as turning the head in the direction of a loud noise (Freberg, 2019).

c) The Forebrain

The forebrain, which is the most prominent and recognisable part of the brain, consists of two hemispheres – one on the right and the other on the left, divided by a membrane known as the **corpus callosum**. Each hemisphere is organised to receive sensory information from the contralateral (opposite) side of the body and control motor movements contralaterally. Figure 1.7 shows the forebrain.

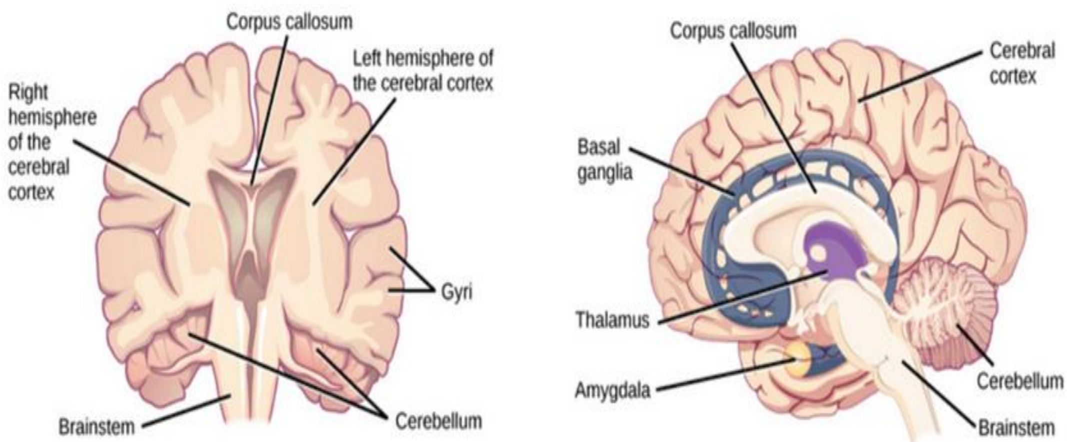


Figure 1.7: The Forebrain
Source: Openstax: https://openstax.org/books/biology/pages/35-3-the-central-nervous-system

The outer shell of the brain is the cerebral cortex (Latin for *bark*). The cerebral cortex is organised into four lobes named for the skull bones that lie over them: occipital, parietal, temporal and frontal lobes, as shown in Figure 1.8. Each lobe is described briefly below:

- *Frontal lobe*: The frontal lobe extends from the central sulcus to the anterior end of the brain. Its posterior portion, the precentral gyrus (also known as the *primary motor cortex),* specialises in the control of fine motor movements. Separate areas are responsible for parts of the body contralaterally and ipsilaterally. The most anterior part of the frontal lobe is the prefrontal cortex, which is responsible for executive functions such as paying attention, and planning. The frontal lobe controls important cognitive functions such as processing information relating to language, memory, decision making, and problem solving (Freberg, 2019; Kalat, 2019).
- *Parietal lobe*: The parietal lobe lies between the occipital lobe and the central sulcus, a deep groove in the surface of the cortex. The **parietal lobe** is primarily responsible for the whole body receiving inputs from the skin and muscles. This means that touching the skin activates the parietal lobe in the central nervous system.
- *Occipital lobe:* The occipital lobe is located at the posterior (caudal) end of the cortex. The occipital lobe contains the primary visual cortex. Images received in the retina of the eye activate this lobe, which activates vision.
- *Temporal lobe*: The temporal lobe is located along the temples of the head. It is responsible for auditory information. The left temporal lobe is essential for spoken language. It also contributes to complex aspects of vision, including the perception of movement and recognition of faces. Emotional and motivational behaviours are also regulated in the temporal lobe.

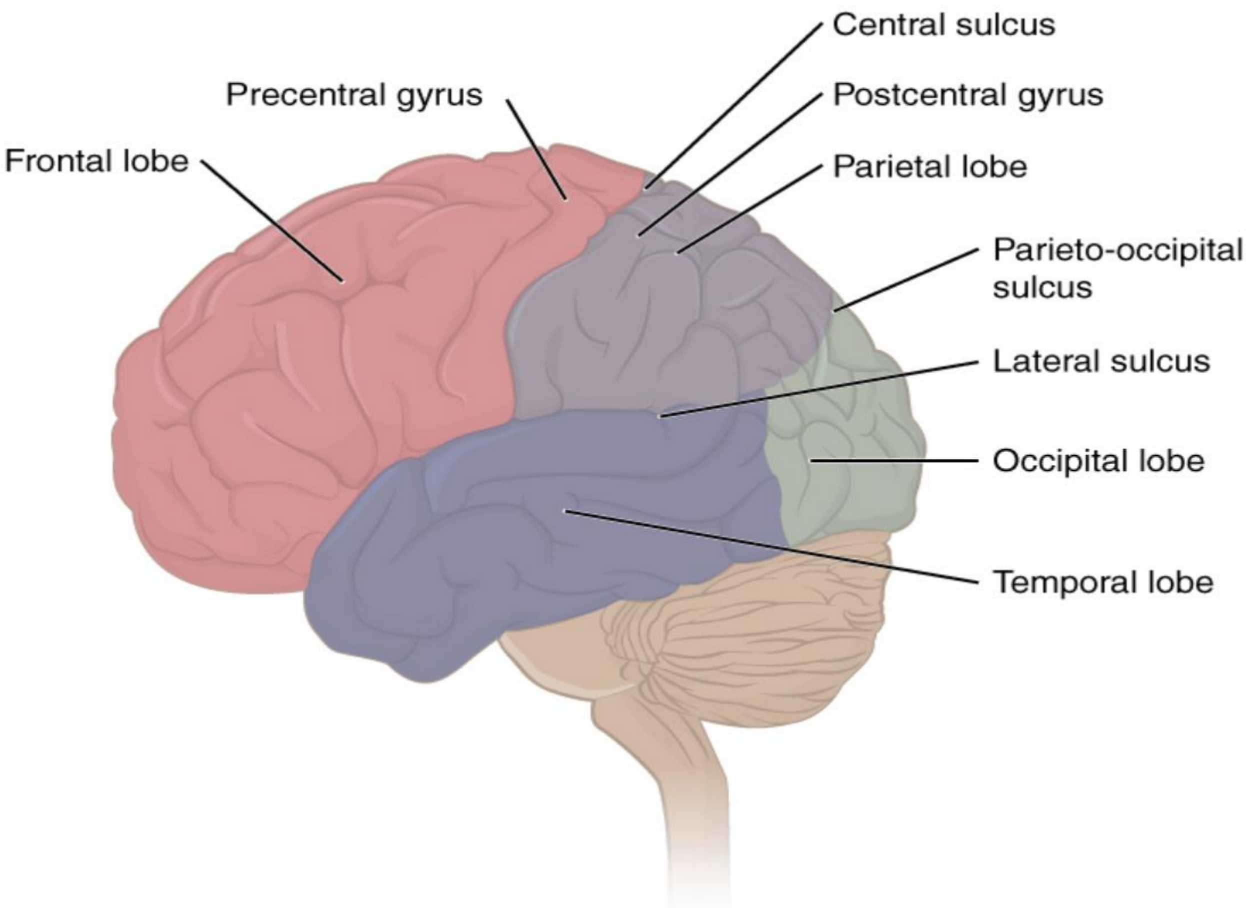


Figure 1.8: Lobes of the Cerebral Cortex
Source: Commons Open Educational Resources: https://www.oercommons.org/authoring/18534-brain/view

Located under the cerebral cortex are the following structures:

- *Thalamus:* This consists of a pair of structures at the centre of the brain. They are responsible for regulating and processing sensory information (except olfactory information) and sending output to the cerebral cortex.

- *Hypothalamus:* The hypothalamus, which is situated ventral to the thalamus, contains widespread connections to the rest of the brain that regulates functions such as eating, drinking, sex, biorhythms and temperature control. Through its connection with the **pituitary gland**, the hypothalamus also regulates the endocrine system through which hormones are released.

- *Limbic system:* The limbic system forms a border around the brain stem and includes the olfactory bulb, hypothalamus, hippocampus, amygdala, and cingulate gyrus of the cerebral cortex. The **hippocampus** plays a role in learning and memory. The **amygdala** is responsible for evaluating emotional information, especially fear. The **cingulate gyrus** is responsible for autonomic functions, decision making, cognitive control of emotion and anticipation of reward and pain (anterior part) and eye movements, spatial orientation and memory (posterior part) (see Figure 1.10).

- *Basal ganglia:* Situated laterally to the thalamus, basal ganglia are responsible for motor control, and learned skills and habits. Disorders involving impaired movement, such as Parkinson's Disease, are a result of damage to the basal ganglia.

What you have learned so far, is that the human nervous system is a well-integrated system that functions in a well-coordinated and systematic manner. To function effectively, the peripheral nervous system's network of nervous activity has to constantly interact with the central nervous system, to make behaviour (our actions) happen. So, it is evident that behaviour is dependent on physical processes happening in our bodies. The nervous system is that integral part of the human body, without which we cannot function.

Now that we understand the biological basis of our behaviour, we need to understand how we come to develop the biological system which is our nervous system. Yes, we have the nervous system that we have just learned about, because *we are born that way.* To understand how we have come to be who we are as *homo sapiens*, it is important that we grasp the basics of genetics and how, in interaction with the environment, our genes shape our behaviour. To that, we turn next.

1.3 The Genetic Basis of Human Behaviour

Start this part of the module by answering the following difficult question: *What makes you who you are?* As you grapple with that, let's complicate the issue a little. Let's suppose you discover today that you were adopted at birth. You are one of two identical twins, and you were adopted separately from your twin, who was adopted by different parents. So, it means you and your missing twin look exactly alike in terms of physical characteristics, although you were raised in different families. In other words, you and your twin share *nature* (genes), but you do not share *nurture* (environment). Does that mean you have the same intelligence, like the same fashions, prefer the same type of food, and enjoy the same recreational activities? Now, assuming your missing twin (who lives in a different part of the country and has not yet discovered that s/he has a missing twin) is also enrolled in this module right now … Let's go back to the original question

What makes you who you are? Let's say you and your missing twin are both answering this question at the same time, yet separately. We could also ask another question: If you were adopted by your twin's adoptive parents, and your twin by your adoptive parents, would you be the same persons you are today? The answer would be interesting, would it not? We will try to help you answer this question by the end of this part of the module.

1.3.1 The Basics of Mendelian Genetics

Genetics is a field of science fraught with controversy, as it has been perverted and employed as a political tool by people such as Adolf Hitler and Hendrik Verwoerd, who believed in the notion of racial purity and the hierarchy of races. We all know the consequences of the government policies that resulted from those views (refer to the History of Psychology in Module PYC1511 of this course, for details).

The field of genetics is attributed to a 19th-century monk, Gregor Mendel, who demonstrated that biological inheritance occurred through **genes**, units of heredity that maintain their structural identity from one generation to another. Genes come in pairs and are aligned along strands called **chromosomes**, which also come in pairs. A chromosome is a microscopic strand or filament composed of nucleic acid and proteins that carry individual hereditary traits. The normal/average human complement of chromosomes totals 46, or 23 pairs (44 autosomes, that is, chromosomes that are not sex chromosomes, and two sex chromosomes) which contain more than 30 000 genes. Each parent contributes one chromosome to each pair (Kalat, 2019; VandenBos, 2007).

The gene is the part of a chromosome composed of the double-stranded molecule called **deoxyribonucleic acid (DNA)** (Kalat, 2019). DNA is the principal carrier of genetic (heritable) information in chromosomes. Certain segments of DNA molecules constitute the organism's genes. Structurally, DNA consists of intertwined, helically coiled strands of nucleotides, called a double helix. The nucleotides each contain one of four bases: **adenine, guanine, cytosine** or **thymine**. Each base in a nucleotide forms hydrogen bonds with the adjacent base on the other sister strand, producing consecutive base pairs arranged like "rungs" on a helix (also written as helics) ladder. For example, adenine is always paired with thymine, and guanine with cytosine. DNS undergoes replication so that each strand serves as a template for assembling a matching complementary strand, resulting in two molecules exactly like the original pairing in the helix. The sequence of bases in the DNA of genes contains information according to the genetic code. The genetic code is the "instruction manual" that "tells" the cell how to make specific proteins. The base sequences of DNA make an organism (*homo sapiens*, in our case) reproduce themselves in a specific form, in accordance with an "instruction manual". So, the nervous system we studied in the previous section is reproduced in accordance with a DNA sequence. We inherited those sequences from our parents, and we will pass them on to our children (VandenBos, 2007).

A strand of DNA serves as a template for synthesising ribonucleic acid (RNA), a single-strand chemical (Kalat, 2019). RNA is a nucleic acid that directs the synthesis of protein molecules in living cells. The three main types of RNA are messenger RNA, which carries the genetic code from the cell nucleus to the cytoplasm; ribosomal RNA which is found in ribosomes (small particles where proteins are assembled from amino acids); and transfer RNA, which carries specific amino acids for protein synthesis. Just as DNA has four bases, so RNA also has four bases, except that uracil occurs instead of thymine (VandenBos, 2007). If a person has the same genes on two copies of a chromosome, s/he is homozygous for that gene. A person who has an unmatched pair of genes is heterozygous for that gene (Kalat, 2019).

Genes are dominant, recessive or intermediate. A dominant gene shows a strong effect in either the homozygous or the heterozygous condition. A recessive gene shows its effect only in the homozygous condition.

1.3.2 Sex-linked and Sex-limited Genes

Genes on the sex chromosomes (X for female and Y for male in mammals) are known as sex-linked genes. All other chromosomes are autosomal chromosomes, and their genes are known as autosomal genes. A female mammal has two X chromosomes, while the male has an X and a Y. During reproduction, the female contributes the X chromosome. In contrast, the male contributes either an X or a Y. If he contributes an X, the offspring will be female, and if he contributes a Y, the offspring will be male. Sex-linked genes are X-linked genes, because the Y chromosomes are too small to have genes of their own (Kalat, 2019).

In addition to sex-linked genes, there are sex-limited genes, which are present in both sexes but active only in one sex (for example, genes that are responsible for inducing/producing beard in men and breast size in women). These sex-limited genes show their effect during puberty (Kalat, 2019).

1.3.3 Gene Changes

Ordinarily, genes do not change. If they change, one of the ways in which they change is by mutation (Kalat, 2019). A mutation is a permanent change in the genetic material of an organism. It may consist of an alteration to the number or arrangement of chromosomes (a chromosomal mutation) or a change in the composition of DNA generally affecting one or a few bases in a particular gene (point mutation). Mutations can occur spontaneously, but many can occur due to exposure to extraneous agents such as X-rays or chemicals. A mutation occurring in a body cell (i.e., somatic mutation) cannot be inherited, whereas one occurring in a reproductive cell such as ova or spermatozoa (i.e., germ-line mutation) can be transmitted to offspring (VandenBos, 2007).

Another kind of mutation is a duplication (part of a chromosome appearing twice) or a deletion (a chromosome not appearing at all). When this happens to a tiny portion of a chromosome, it is called a microduplication or microdeletion. These duplications and deletions are responsible for several psychological, neurological, and psychiatric disorders (Kalat, 2019).

1.3.4 Epigenetics

While mutations cause permanent changes to genes, epigenetics is about changes in gene expression. So, epigenetics concerns the occurrence of a heritable change in gene function that is not the result of a change in the base sequence of the organism's DNA (*Epi* is Greek for 'over' or 'above'). Genes are switched on or off, depending on whether or not the experiences of a person require the activation of that gene. For example, a child who is stroked and loved consistently will have his/her "attachment" genes activated. In contrast, a child who was raised in a Rumanian orphanage during the rule of the dictator Ceauşescu, where there was no stimulation, would have his/her attachment genes "switched off", so s/he would be unresponsive to human interaction. Another example would be the people of Nepal (where Mount Everest is situated) who, over centuries, have adapted to living at high altitudes, which is why they are able to carry heavy loads up the mountain. A *nyaope* (i.e., low-grade heroin made from a mixture of substances) addict would have epigenetic changes to his/her brain functions. So, the experiences that people have – be it childhood trauma, living in a war zone for a long time, or a good life experience – produce epigenetic changes to the functioning of their genes. Epigenetic gene changes can be transmitted at least for a generation or two (Kalat, 2019).

1.3.5 Heredity and Environment

The jury is still out on whether observable differences between people are due to differences in heredity, or the environment. If variations in a characteristic are due to genetic differences, that characteristic is said to be high in heritability, which can range from zero (no heritability) to one (complete heritability).

Heritability is studied using twin studies, adoption studies, and the candidate gene approach. Twin studies use twins to assess the relative contributions of heredity and environment to some attribute – scholastic performance, for example. Twin studies involve comparing monozygotic and dizygotic twins, and comparing both types of twins reared together or apart. For example, monozygotic twins reared apart share the same genotype but different environments. Would differences between them be attributed to genes, or to the environment? Adoption studies have studied children reared apart from their biological parents. Like twin studies, adoption studies are inconclusive as, for example, the biological mother contributes not only her genes, but also the prenatal environment through factors such as nutrition, smoking and drinking habits – all of which influence brain development. Twin and adoption studies have shown high heritability in the various behavioural dimension studies (e.g., cognitive ability, loneliness, television watching habits, temperament, linguistic ability, and sociability). Interestingly, only religious affiliation did not show heritability (Kalat, 2019).

The candidate gene approach is used in attempts to identify specific genes linked to certain behaviour. This approach seeks to determine whether there is a single gene that accounts for a specific behaviour (e.g., alcohol abuse or criminality). Such studies have also been inconclusive.

The influence of the environment has not been overlooked. The environment can be manipulated to change a heritable condition (such as the prescription of a low-phenylalanine diet for children presenting with Phenylketonuria – a genetic inability to metabolise the amino acid phenylalanine, which impairs brain development). Most research concludes that no gene produces behaviour on its own but has to interact with specific environmental conditions to make the expression of behaviour favourable.

Thus, we can conclude by asking you to answer the question posed at the beginning of this part of the module: *What makes you who you are?* That is, is your behaviour a function of your genes (nature) or your environment (nurture)?

1.4 Emotions and Stress

Emotions are hard to define. VandenBos (2007, p. 325) defines emotion as "a complex reaction pattern, involving experiential, behavioural and physiological elements, by which an individual attempts to deal with a personally significant matter or event". What is most important in the definition is the "personally significant" part, as it denotes the importance which a person attaches to the event to which s/he is reacting. The significance of the event will determine how a person reacts. For example, if the event involves a threat to someone's life, s/he will react with fear; if it involves the achievement of a significant milestone, s/he will react with joy. Another all-encompassing definition of emotion is the one by Plutchik (1982, cited in Kalat, 2019, p. 352), which proposes that emotion involves "cognitive evaluations, subjective changes, autonomic and neural arousal and impulses to action". What is important to take from this definition, is that arousal happens because of a cognitive appraisal, and that a person will move into action as a result of that state of arousal which, as we shall learn, is activated by the autonomic nervous system. There is consensus in the literature that emotions involve cognitions (judging a situation as threatening), feelings (feeling frightened because of a situation judged to be a threat), actions (running away from the threatening situation that frightens you) and physiological changes (increased heart and breathing rates) (Kalat, 2019).

1.4.1 Emotions and Autonomic Arousal

Emotions arouse two branches of the autonomic nervous system: the sympathetic nervous system and the parasympathetic nervous system. Figure 1.9 illustrates the organisation of these two components of the ANS (see the beginning of this module, for a detailed description of these two branches of the ANS). Arousal is the state of alertness and readiness for action. During a state of arousal the sympathetic nervous system stimulates certain organs (such as the heart) while inhibiting others (such as the stomach and intestines, whose function is not required at that particular moment). The ANS stimulates the organs (regulated by the sympathetic system) whose role is required for "fight or flight" activities that are evoked during an emotionally stressful event, while inhibiting vegetative activities (regulated by the parasympathetic system), such as needing to eat, which can wait until later. Most "dangerous" situations evoke the combined action of both the sympathetic and parasympathetic systems of the ANS, which act in a complementary manner to enable the organism to cope with the immediate demands of the arousal-inducing situation (Kalat, 2019).

Much has been learned about emotions and arousal in research on aggression. Aggression is the intentional initiation of hostile and destructive acts towards another individual or other people. Predatory aggression (typical criminal behaviour) is premeditated, goal-directed and relatively unemotional. In contrast, impulsive aggression (self-defence, when attacked) occurs immediately in response to a provocative stimulus that produces anger or fear. The biological correlate of impulsive aggression is the activation of the amygdala in response to provocative stimuli, without any inhibition from the prefrontal cortex and anterior cingulate cortex (Freberg, 2019).

A prominent theory of emotion is the James-Lange theory, which proposes that awareness of our physical state leads to the identification of a subjective feeling; for example, trembling would result in a person feeling anxious. The theory proposes that all types of feelings have physical states associated with them, and that the presence of those physical states would result in the manifestations of feelings with which they are associated. For example, intense arousal of the sympathetic nervous system, as evidenced by intense heart palpitations, difficulty breathing, chest pain, choking sensations and excessive perspiration, result in a person having an emotional symptom called a **panic attack**. A variation of the James-Lange theory is the facial feedback hypothesis, which proposes that facial expressions affect how people feel. Detractors of the James-Lange theory have demonstrated that physiological responses are not always associated with feelings, and that the elements of emotion (cognition, feeling and action) can occur discretely, so that a person can experience a feeling without knowing why (cognition) or even doing anything about it (taking action). Further, no emotion has been found to correlate with a particular state of arousal.

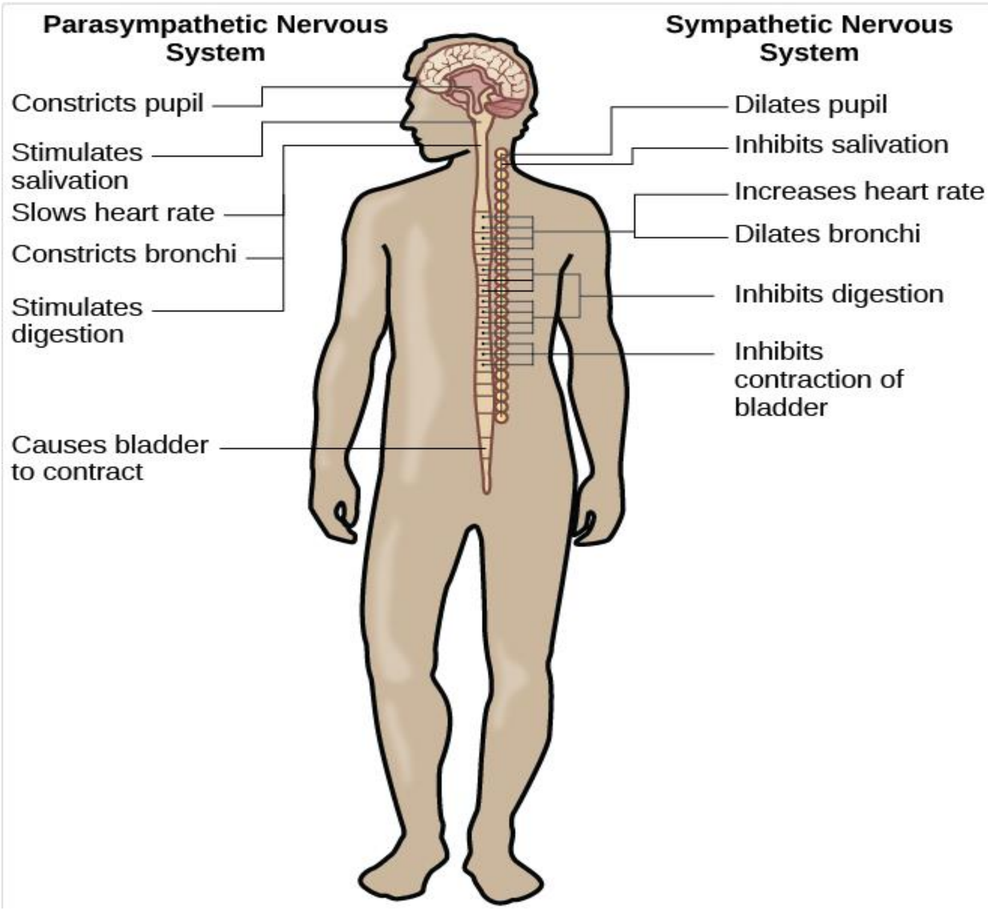


Figure 1.9: The Sympathetic and Parasympathetic Nervous System
Source: Commons Open Educational Resources: https://www.oercommons.org/courseware/lesson/71166

With the knowledge we have thus far covered on the nervous system, it is useful to know which areas of the brain are implicated in the activation of emotions.

1.4.2 Biological Correlates of Emotion

The brain is an active organ in our experiences of emotions. Emotional states are always accompanied by complex, interacting responses that combine the activation of the ANS, amygdala, insula, cingulate cortex, and cerebral cortex. Most of the autonomic activities associated with emotion are regulated in the limbic system. For a clearer understanding of the brain processes involved in emotions, it is necessary to remind ourselves of the structure of the limbic system, as most of the brain activity associated with emotions is regulated here. Figure 1.10 illustrates the limbic system.

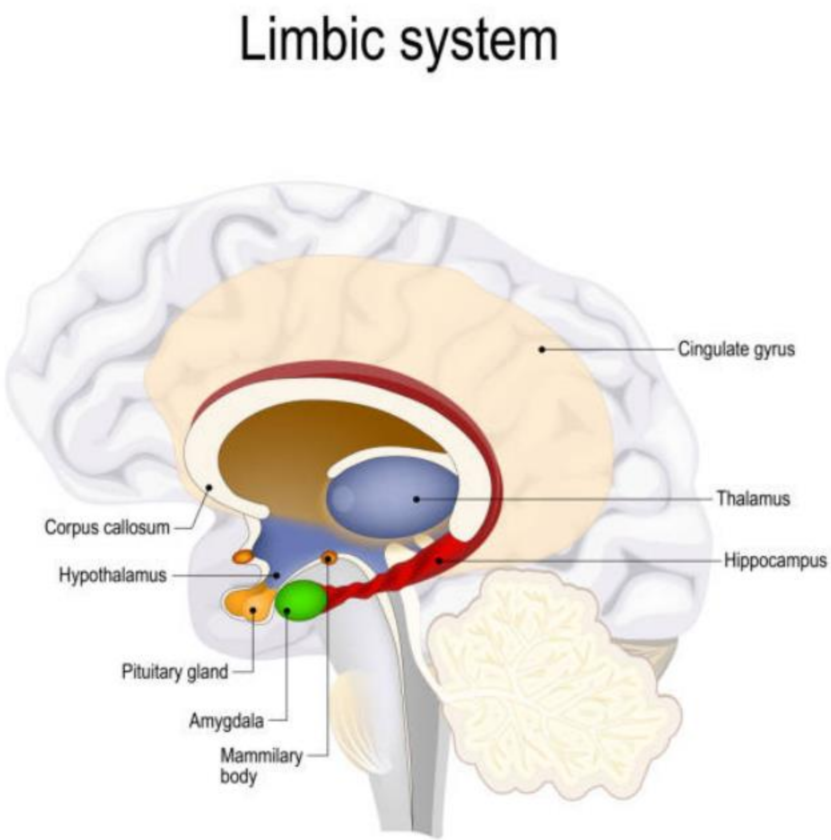


Figure 1.10: The Limbic System
Source: www.Pixabay.com

The Autonomic Nervous System

The ANS has a central role in the arousal associated with emotional states. The sympathetic division of the ANS prepares an organism for a fight response. At the same time, the parasympathetic system is responsible for more restful activities, such as the digestion of food and the repair of body tissue. The hypothalamus regulates the ANS via the nucleus of the solitary tract in the medulla, which receives inputs from the hypothalamus. Some measures of ANS activity (e.g., heart rate, the conductance of the skin, finger temperature and muscle activity) are associated with distinct emotional states. There is no conclusive evidence of a correlation between emotional activity and specific autonomic measures. There is, however, evidence of a stronger association between autonomic activity and negative emotions than positive emotions (Freberg, 2019).

The Amygdala and the Insula

The amygdala and the insula play a major role in identifying emotional stimuli and the arousal resulting from that identification. People with damage to the amygdala have diminished emotionality – specifically fear, anxiety and aggression. Individuals who have autism spectrum disorder, which involves an abnormality of the amygdala, are also known to have difficulty identifying emotions in other people (particularly fear). The amygdala also plays a role in impulsive acts of aggression, such as when a person reacts to provocative stimuli that induce fear or anger. The amygdala is part of a tightly connected circuit that includes the frontal lobes of the cortex, the cingulate cortex and the insula. The insula is important in making a distinction between positive and negative stimuli. Positive feelings are associated with activity in the rostral areas of the insula, while negative emotions are associated more with the caudal areas. The insula is most prominent in the experience of feelings of disgust. While the amygdala initiates arousal, especially in response to negative stimuli, the insula plays a role in discriminating between positive and negative stimuli (Freberg, 2019).

The Anterior Cingulate Cortex

The cingulate cortex acts as a gateway between the amygdala, other limbic structures and the frontal lobes of the cerebral cortex. The anterior cingulate cortex (ACC) plays a role in processing information about physical pain. It also cooperates with the orbitofrontal cortex in the inhibition of aggression. The anterior cingulate gyrus also plays a role in the more conscious cognitive appraisals of threat, compared to the less conscious signals arising from the amygdala. For example, when a person reacts with fright to seeing a snake, the amygdala perceives the situation as threatening. Still, the ACC would interpret it as less threatening if the snake were inside a Perspex enclosure (Freberg, 2019).

The Basal Ganglia

The basal ganglia play a role in voluntary movement in general, including the coordination of movement in response to emotional stimuli. The basal ganglia are especially active when people express feelings of disgust. People with Parkinson's Disease have challenges with movement coordination, because their basal ganglia are damaged (Freberg, 2019).

The Cerebral Cortex

The processing of emotion happens in the frontal lobes. This explains why people with frontal lobe damage have poor judgement and cannot regulate their emotions, particularly fear and anxiety. The two cerebral hemispheres have opposing roles in emotional regulation. The left hemisphere is associated with approach emotions, and the right hemisphere with avoidance emotions. For most people, the right hemisphere plays a greater role than the left in processing emotions (Davidson & Fox, 1982; Harmon-Jones et al., 2010). The right hemisphere processes emotional facial expressions faster and more accurately than the left hemisphere. Although language is localised in the left hemisphere, the meaningfulness of language is regulated in the left hemisphere, while the right hemisphere processes the emotional aspects of language.

1.4.3 Stress

No psychology lesson on emotion would be complete without touching on the phenomenon of stress. Stress is defined as "an unpleasant and disruptive state resulting from the perception of danger and threat" (Freberg, 2019, p. 513). A stressor is the source of stress. While Freberg's definition places emphasis on *perception*, thus implying a cognitive dimension, VandenBos' (2007) definition emphasises the physiological and psychological response to a stressor. According to the VandenBos definition, stress involves changes affecting nearly every system of the body, influencing how people feel and behave. The activation of the ANS can be inferred from the latter definition, blurring the distinction between a psychological (feeling and behaviour) state and a physiological process. To understand the psychology of stress, it is essential to know the physiology involved in the experience of stress.

Stress and the General Adaptation Syndrome

The concept of stress was popularised by physiologist Hans Selye's research on rats' physiological responses to environmental stimuli that included heat, cold, pain, confinement, and the sight of a cat. Selye observed a consistent, generalised response to stress that he named the **general adaptation syndrome (GAS)**, which was initiated in the adrenal glands (Freberg, 2019; Kalat, 2019). GAS consists of three stages: alarm, resistance and exhaustion. In the initial stage, *alarm*, the adrenal glands secrete the hormone *epinephrine* which stimulates the sympathetic nervous system to ready the body for emergency activity. The adrenal glands also release the hormone **cortisol** (generally referred to as the 'stress hormone'), which increases blood glucose, thus providing the body with extra energy. The hormone *aldosterone* is also released to maintain blood salt and blood volume. To maintain the energy required for the emergency response, the ANS (through the parasympathetic system) suppresses less urgent activities such as hunger and sexual arousal (Kalat, 2019).

During the second stage, resistance, the sympathetic responses decline, but the adrenal glands continue to secrete cortisol and other hormones to enable the body to maintain the fight or flight response. As the body continues to adapt, the parasympathetic system activities remain in abeyance, to allow the body to endure the period of stress and discomfort. After a prolonged period of intense stress the body enters the third phase, exhaustion. The individual is tired, inactive, and more vulnerable, because the nervous system and immune system no longer have the energy to sustain their required responses (Kalat, 2019).

Stress-related illnesses such as peptic ulcers, hypertension and migraines are a sign of prolonged activation of the GAS, until the body is depleted of its ability to continue the fight or flight response. If you think of the situation confronting the people of Syria, who have had to endure war and turmoil for a decade, it is not unlikely that incidences of stress-related illnesses among them would be more prevalent than in countries which are at peace. Even in our health system, incidences of stress-related illness are more prevalent among the poor who have to endure the stress of living in poverty and constantly being exposed to structural violence and crime.

Stress and the Hypothalamus-Pituitary-Adrenal Cortex (HPA) Axis

The GAS, which prepares the body for a fight or flight response, is the sympathetic nervous system in action when a person is experiencing stress. The other system that is activated is the HPA axis, which consists of the joint action of the hypothalamus, pituitary gland, and adrenal cortex. Figure 1.11 is a graphic representation of the HPA axis. It works as follows: activation of the hypothalamus induces the pituitary gland to secrete adrenocorticotropic hormone (ACTH), which in turn stimulates the adrenal cortex to secrete cortisol (the so-called stress hormone). Cortisol acts by enhancing metabolic activity, elevating blood sugar and increasing alertness, thus readying a person to deal with a stressful situation. An important difference to note between the GAS (sympathetic nervous system activity) and the activation of the HPA axis, is that the former acts when the stress is immediate (acute), such as when an intruder points a gun at you. The HPA axis is activated when the stress is prolonged (chronic), such as living in poverty or with an abusive spouse (Kalat, 2019).

The more cortisol is secreted, the greater the negative feedback system, which reduces an adaptive stress response, thereby shortening the duration of the stress response. For example, brief stress such as going for a driver's test would enhance performance and concentration. Brief stress can also enhance the immune system, as it enables the body to fight infections. However, the opposite effect is realised if the stress is prolonged (Kalat, 2019).

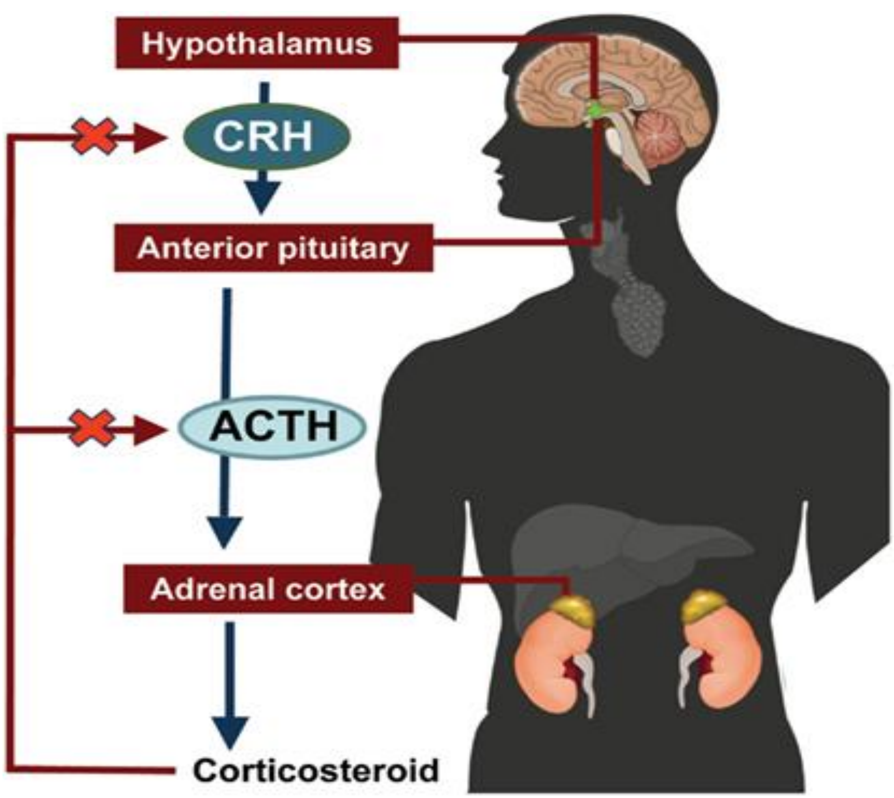


Figure 1.11: The Hypothalamus-Pituitary-Adrenal Cortex Axis

Stress and the Immune System

Psychoneuroimmunology (PNI) is the basic science of examining the structural and functional links between the behavioural, nervous, endocrine, and immune systems. It seeks to understand the neural and chemical pathways by which the immune system feeds information to the brain. The immune system refers to the vast system of cells, organs, lymphatic and other bodily structures and functions that participate in defending the body against viruses, bacteria, and other intruders that could cause disease (Florenza & Baum, 2004).

The primary components of the immune system are leukocytes, commonly known as white blood cells. The three types of leukocytes are B cells, T cells and natural killer cells. B cells, which are found in the bone marrow, secrete antibodies that attach to particular antigens (antibody-generator molecules). B cells recognise “self” antigens (antigens which are not considered a threat), and do not attack those. However, should they encounter an unfamiliar (therefore hostile) antigen, they will attack that antigen as a way to protect the body from invasive viruses and bacteria (the problem is that, in cases of organ transplants they could also attack the transplanted organ, causing the body to reject it). The immune system is strengthened when the body becomes familiar with, and recognises, particular antigens and does not attack them. T cells mature in the thymus gland and directly attack intruder antigens without the mediation of antibodies. Natural killer cells attack tumor cells and cells that are infected with viruses. Natural killer cells, unlike B cells and T cells, kill intruding antigens indiscriminately. In response to infections, leukocytes and other cells produce proteins called cytokines that combat infections (Kalat, 2019).

As people are exposed to chronic stress their immune systems are weakened, and they become highly susceptible to infections by viruses and other disease-causing bacteria. As these bodily threats multiply, the leukocytes in their bodies will trigger the activation of B cells and T cells to minimise the threat. The immune system has to cooperate with the nervous system to ensure that, when stress is experienced, the autonomic nervous system (the sympathetic part) is activated to help the person manage the stress. As the stress becomes prolonged, the HPA axis is activated. In turn, it activates the immune system to protect a person’s body against any diseases which the stressful situation could cause. This biological system is activated when a person is under stress. There are other psycho-social aspects of coping with stress that you will learn about as you proceed with your study of psychology.

1.5 Summary

In this part of the module, you learned about the biological system that forms the basis of human behaviour. By now you should realise that psychology has a strong physical basis. All our behaviour (an observable and external manifestation of actions) is regulated by a systematic biological system which has evolved since *homo sapiens* first developed. At a molecular level, we have systems of nervous activity that ensure communication between the different biological systems, to produce psychological processes: thoughts, feelings and actions. For these manifestations of human action to occur, we need to have a well-functioning brain and spinal cord that enable the nerves to do their work, enabling us to be fully human. From this point on, in everything you learn in psychology, remember one thing: all behaviour has a physical foundation. That foundation is the human nervous system.

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