| Subject | PSYCHOLOGY |
|---|---|
| **Paper No and Title** | **Paper No.1: Cognitive Science** |
| **Module No and Title** | **Module No.3: Cognitive Neuroscience** |
| **Module Tag** | **PSY_P1_M3** |


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## 1. Learning Outcomes

After studying this module, you shall be able to:

- Know the anatomy and functioning properties of Human brain
- Know about compartmentalisation and hemispheric lateralisation of the brain
- Know mind and body conceptions (past and present)
- Know about the new upcoming field of Cognitive Neuroscience
- Know about the functioning of the Nervous System.

## 2. Introduction

Its imperative that a student of psychology acquaints himself or herself with a thorough study and knowledge of the anatomy of human brain and its working. Human brain is the most complex machine ever produced with fascinating working tendencies. Its very flexible (one part takes over if another fails) and limiting as such in certain circumstances. Nevertheless, its very intriguing an experience to travel the 'brain' journey. In this module as we go further, we will touch upon mind and body issues. We will take a look at what our ancestors thought was the mind- body connection and what today we recognise as their relationship. Towards the end of this module, we will discuss briefly about the new emerging field of science - Cognitive Neuroscience - what it is and what other fields it draws from.

## 3. Introduction to brain

In an evolutionary sense, your brain is far older than you are, for it represents perhaps 500 million years of evolutionary development and fine-tuning. The human brain is like a living archaeological site, with the more recently developed structures built atop structures from the distant evolutionary past. The structures at the brain's core, which we share with all other vertebrates, govern the basic physiological functions that keep us alive, such as breathing and heart rate. Built upon these basic structures are newer systems that involve progressively more complex functions - sensing, emoting, wanting, thinking and reasoning. Evolutionary theorists believe that as genetic variation sculpted these newer structures over time, natural selection favoured their retention, because animals who had them were more likely to survive in changing environments The brain has traditionally been viewed as having three major subdivisions: the hindbrain; the midbrain; the forebrain. We will discuss here the 'Cerebral Cortex' of the forebrain in detail.

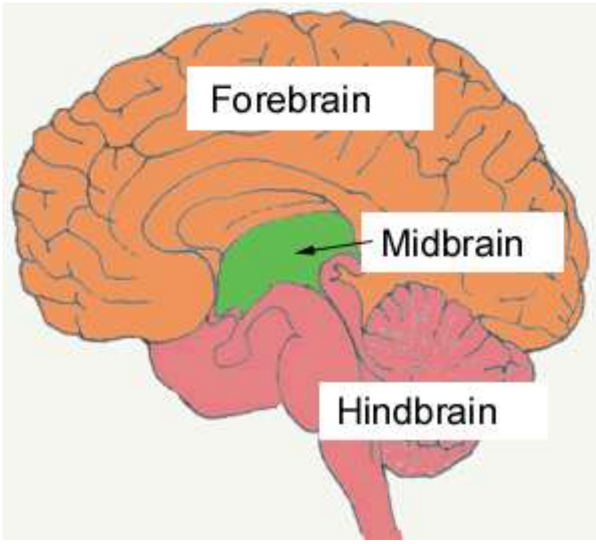
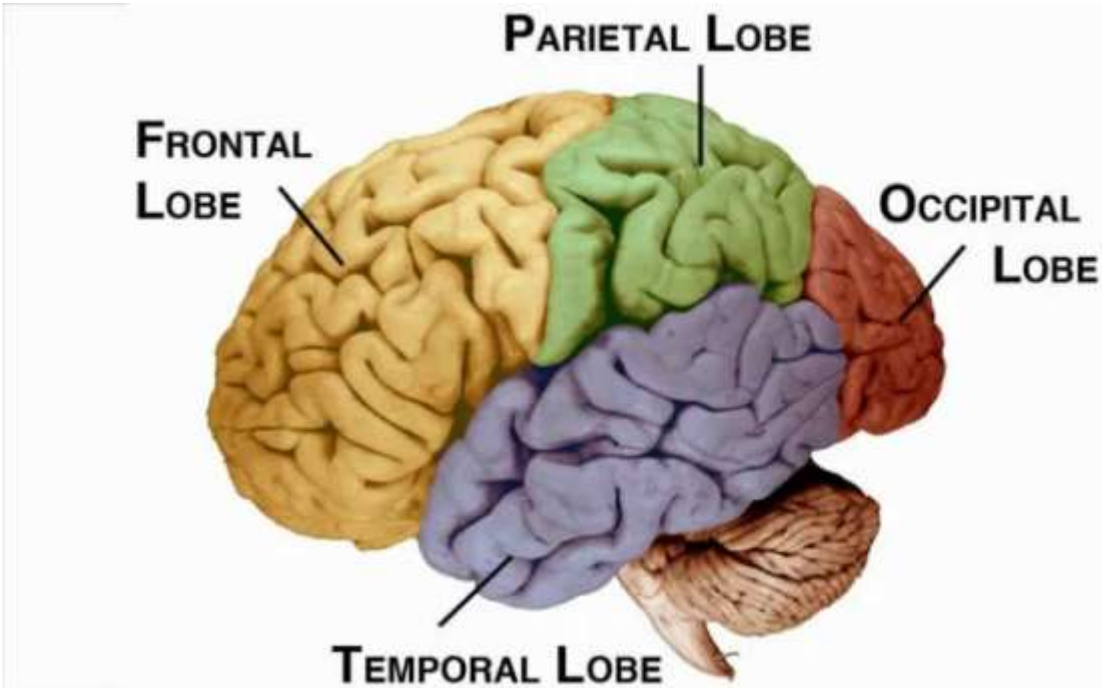


Figure 1: Forebrain, Midbrain, Hindbrain of the Human Brain.

### 3.1. Cerebral cortex

Benchmarkng evolutionary achievement in brain was the **Cerebral Cortex. It can be conceptualized a solid sheet of one forth of an inch thickness, constituting of gray cells (unmyelinated) that compose the external coating of the human brain.** Fish and amphibians have no cerebral cortex, and the progression from more primitive to more advanced mammals is marked by a dramatic increases in the proportion of cortical tissue. In humans however, nearly three fourth of the brain structure is constituted by cortex. The vitality of cerebral cortex lies more in the daily human functioning in comparison to brain stem structures which prove imperative for physical existence. Because the cortex is wrinkled and convoluted, like a wadded-up piece of paper, a great amount of cortical tissue occupies relatively less room in the brain structure. If we could remove the cortex and smooth it out, the tissue would cover an area roughly the size of a pillowcase. Perhaps 75 percent of the cortex's total surface area lies within its fissures, or canyon like folds. Three of these fissures are important landmarks. The right and left hemispheres of the brain are marked by one large fissure that extends vertically over the top of the brain. A central fissure dissects each hemisphere into front and rear halves and a third fissureruns horizontally over the brain. On the basis of these landmarks, neurologists have divided each hemisphere into four lobes: frontal, parietal, occipital, temporal. All cerebral lobes are associated with particular functions related to sensory inputs and motor movements, as well as with speech understanding and speech production. The large areas that do not link with sensory or motor functions constitute the association cortex, implicated in various cognitive functions such as attention, learing, memory, perception etc.




More than 600 muscles constituting our voluntary body movements are governed by **motor cortex**. If all of these muscles are activated at once, they would generate enough power to lift 11 tons. The motor cortex occupies place ahead of the frontal lobes next to the central fissure. Because the nerve tracts from the motor cortex cross over at the level of the medulla, therefore both hemispheres control the opposite movements of the body. Thus, severe lesion in the right motor cortex would produce paralysis in the left side of the body.

Sensory receptors transmit information to special areas of **sensory cortex**. With the exception of taste and smell, at least single unique area in the cortex is discerned for each of the five senses. The **somatic sensory cortex** receives sensory input that gives rise to our sensations of heat, touch, and cold and to our senses of balance and body movement (kinesthesis).
It lies at the front portion of the parietal lobe just behind the motor cortex, separated from it by the central fissure. The somatic sensory area is basically organised in an upside-down fashion, with the feet being represented near the top of the brain. Likewise, the amount of cortex devoted to each body area is directly proportional to that region's sensory sensitivity.

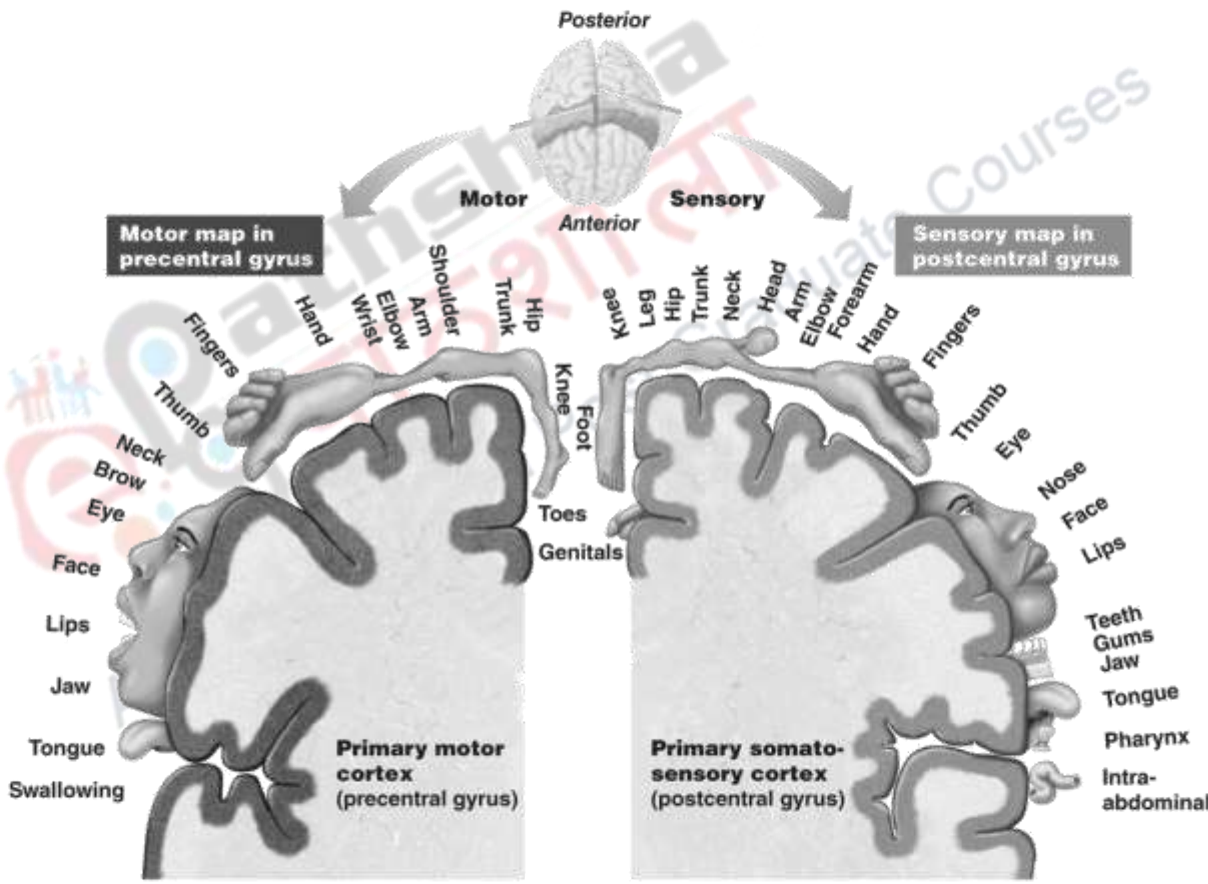



Figure 4: Brain areas corresponding body areas in motor and sensory cortex.

In each of the sensoriums, specific sensory inputs is responded by various neurons; which is associated with particular attributes of the environment. Thus, certain cells in the visual cortex fire only when sensations happen form particular stimulus, such as a vertical line or a corner. Nonetheless, the sensory cortex, like other parts of the brain, is also sensitive to experience. For example- when people learn to read Braille, the area in the sensory cortex that receives input from the fingertips increases in size, making the person more sensitive to the tiny sets of raised dots.

Two separate areas that control construction and comprehension of speech are also placed in separate lobes of the left hemisphere. Speech comprehension is fore mostly governed by **Wernicke's area** placed in the temporal lobe. Lesion to this cortical region leads to inability in understanding written or spoken speech. **Broca's area,** situated in the frontal lobe, is primarily implicated in the generation of speech in association with the motor cortex region that governs the muscles used in speed. Lesion to Broca's area leads to inability in expression of speech keeping the comprehension of speech intact. These two speech areas normally work in concert when you are conversing with another person. They allow you to comprehend what the other person is saying and to express your own thoughts.

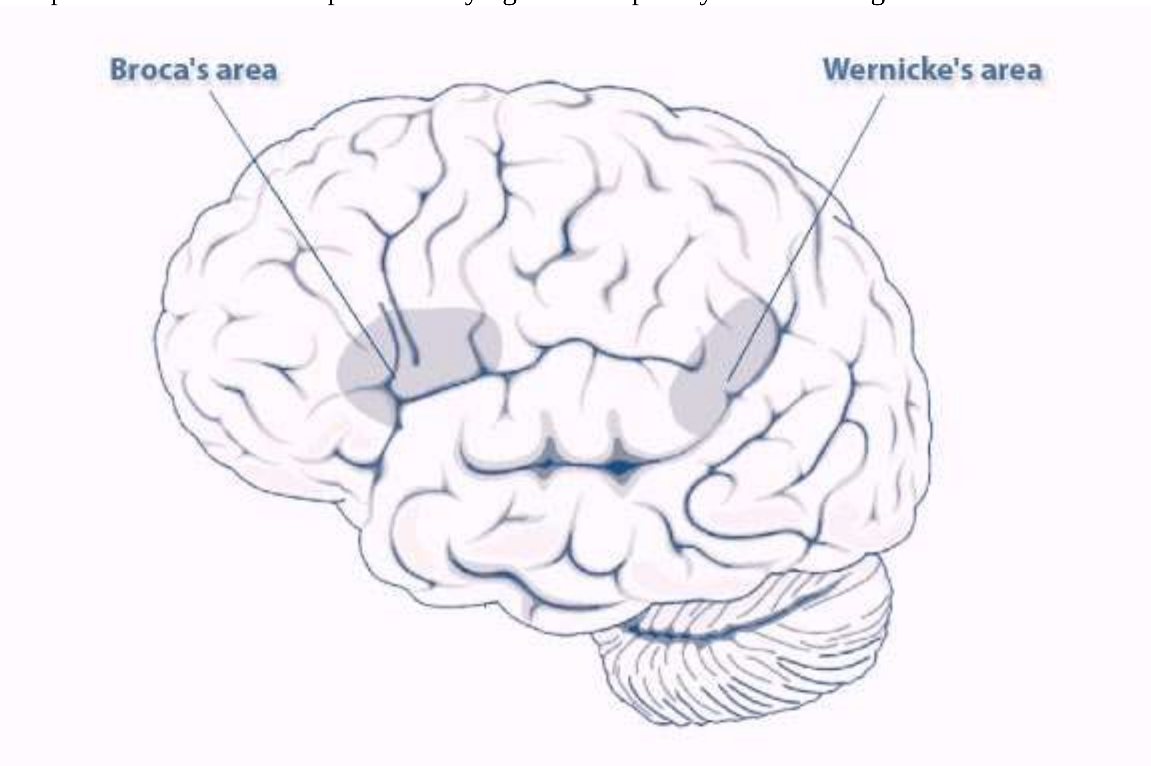



Figure 5: Broca's and Wernicke's area in the Brain.

The **Association Cortex** is implicated in various vital cognitive processes such as attention, perception, memory etc. The cortex is many times connoted as 'silent areas' since electrical stimulation of the area does not lead to any sensory or motor activity. Lesion to this imperative structure leads to aberrations in the areas of language, thought, decision making and problem solving. As we might expect, quantification of association cortex is far higher in human beings as compared to lower animals. It occupies three fourth room of the cerebral cortex in human species and assumes responsibility for people's superior cognitive capabilities.

### 3.2 Parallel Processing

Parallel Processing is the ability to carry out multiple operations or tasks simultaneously. The term is used in the contexts of both human cognition and computing by machines. In the human context, it refers to the ability of the brain to simultaneously process incoming stimuli in more than one way at a time. It is also called Parallel Distributed Processing (PDP) model. Let us learn about parallel processing through 'neural networks'.

Neural network models are computer models whose programming involves replication of assumptions governing the nervous system. Every neural network consists of interrelated nodes. Each node does not carry specific measure of information hence, there is no unique node for "red" or a unique node for "fire engine", and so on. Rather each node in itself is a like a complete information-processing unit. To explain it with an analogy, imagine each individual neuron in the brain as a separate node transferring information from one neuron to another but no unique node for any specific aspect is known. There is no specific neuron that connotes for red colour are for fire engine. Recall that in the brain, neurons have synaptic connections with many other neurons, receive and send signals that can be excitatory (increasing the likelihood that a neuron will fire) or inhibitory (decreasing the likelihood that a neuron will fire), and will fire if the overall input they receive moves their electrical potential to a certain threshold point. Similarly, nodes in neural network models have connections with many other nodes, are programmed to receive and transmit excitatory or inhibitory signals, and get aroused after stimulus strength moves beyond a particular threshold level. Just as learning experiences modify the brain's neural circuitry, in computer simulations neural networks gain proficiency variety of information's bits such as sounds or visual patterns. As they do, connections among various nodes increase or decrease (reflected by changes in the mathematical weight assigned to each connection) and the network acknowledges and differentiates between different kinds of stimuli (e.g. images of faces, spoken words, and so on).

In trying to model how memory operates, if concepts such as "red" and "fire engine" are not stored in their own individual nodes, then where are they preserved? In neural network models, each memory correspond to unique prototype of interconnected and simultaneously aroused nodes. When node 4 is activated parallel with nodes 95 and 423, the concept "red" emerges to mind. But, when b=node 4 is simultaneously activated with nodes 78 and 901, the concept of "fire engine" emerges in the mind. As we glance at the entire neural framework, various nodes distributed in neural fabric fire in parallel at each other and simultaneously spread their activation to their nodes. In this manner, priming of one node is done by other and information is received as a consequence.

### 3.3 Compartmentalisation of Brain

**Compartmentalisation of brain** refers to the tendency of the human brain to store two conflicting set of ideas in two different parts of the brain. Its a 'divide and conquer' process that separate thoughts that conflict one another. This often happens when there are different beliefs or values in an individual. In a nutshell, the individual is confused! For example- a person who is very religious and also a scientist holds the opposing beliefs in different cognitive compartments, such that when she is in church, she carries with herself blind faith towards god, and on the other hand, when she works in her laboratory, she questions everything. To some extent, we all compartmentalise in our lives. Are we not entirely different in front of guests, and when they are gone we are back to our original personality. We rationalize this by justifying "thats how it is!". To describe compartmentalisation in a more scientific manner, we can define it as- an unconscious psychological defence mechanism used to avoid cognitive dissonance or the mental discomfort, or anxiety caused by the person's conflicting values, cognitions, emotions, beliefs etc. within themselves.

Compartmentalisation may lead to hidden vulnerabilities in those who use it as a major defence mechanism. They may become highly confused in discussions and decisions making, become indifferent, lose self- confidence or use denial altogether against the conflict. To help someone become more integrated as an individual, one therapeutic technique is to take two chairs and have the person sit alternatively between the two seats as she/he has a conversation with herself/ himself, seeking to understand the other 'personality'. With time the walls will crumble and the person will develop a balanced understanding.

### 3.4 Hemispheres

Our brain anatomically can be divided into two halves- left brain or left hemisphere and right brain or right hemisphere. Both of them perform different functions in a human body. They together create human perception. At any given time, a human being uses both the hemispheres for his/ her functioning. However, at any given moment, one tends to dominate over the other. This tendency of hemispheres to dominate over each other has given rise to a theory called 'personality type'. The various experiments conducted have shown that the left brain aids logic, reasoning and is responsible for happy emotions, while the right brain aids/ creates creativity, imagination and sad emotions. This does not mean one is better than the other. It only emphasises the nature plan of segregating these two emotions in the human brain- giving one part one job. A PET scan can easily reveal which side of the brain a human uses more often - dominating hemisphere and accordingly is categorised as "logical or creative".

## 4. Mind and Body Issues

Humans have long sought to understand themselves, and for ages the **mind-body problem** has occupied the centre of this quest. Is the mind independent of body, an internal catalyst of consciousness and cognition or is it merged with body and is deeply influenced by body activities. Many earlier philosophers held a position of mind-body dualism, that mind and body are separate entities and independent of laws that govern each of the entities. But, if the mind is not composed of physical matter, how could it become aware of bodily sensations, and how could its thoughts exert control over bodily functions? French philosopher and scientist Rene Descartes (1596 - 1650) posited interaction of mind and body through brain's petite pineal gland. Although, Descartes placed the mind within the brain, he posited mind to be a spiritual, non-material entity. Dualism implied lack of evidences to ascertain established boundaries between mind and body.

Another view, **monism** (from the Greek word monos, meaning "one"), proposes unification of mind and body and rejects independent existence of either. To monists, mental events correspond to physical events in the brain, a position advocated by English philosopher Thomas Hobbes (1588 - 1679). Monism helped set the stage for psychology because it implied that the mind could be studies by measuring physical processes within the brain. Information philosophy today views mind as the immaterial information in the brain, a biological processor of information. Mind is seen as a software in the brain's hardware. The mind has an extensive control over the body and vice -versa. Body is seen as a physical entity, run and managed by the brain.

## 5. Cognitive Neurosciences

**Cognitive Neuroscience** concerns the scientific study of the neural mechanisms that underlie cognition. It is a branch of neuroscience and overlaps with cognitive psychology. Researchers within this discipline look at the psychological, computational and biological mechanisms that impact human thought or cognition. Cognitive neuroscience uses a good deal of technical know-how in its workings. Advanced brain imaging systems to gain in-depth knowledge of the working of the brain. The study of genetics also play an important role in this discipline as scientists attempt to track down any genetic roots to behaviour. Cognitive neuroscience is an interdisciplinary area emerging from many fields. Some of these are (prominent ones) psychology and computer science. Although historically speaking, the discipline has progressed from 'which areas of brain do what', today it has come to 'how the brain creates the mind'. Cognitive neuroscience is a very new field of science.

### 5.1 The Nervous System

The managerial hub of the body is the nervous system. The entire functioning of the system is carried out by three major variants of neurons. Sensory neurons transfer input stimulus from the sensoriums to the spinal cord and brain. On the other hand, motor neurons transfer messages from the brain and spinal cord to the muscles and body organs. Finally, there are neurons that link the input and output functions. These interneurons, which are far more than sensory and motor neurons, execute associative functions within the human nervous system. For example, interneurons would help in recognition of a friend by associating the sensory input from the visual field with the memory of that person's characteristics preserved in different region of the brain. The activity of interneurons makes possible the complexity of our cognitive, metacognitive, emotional and behavioural capacities. The nervous system can be broken down into several interrelated subsystems. The two major divisions are the peripheral and central nervous systems.

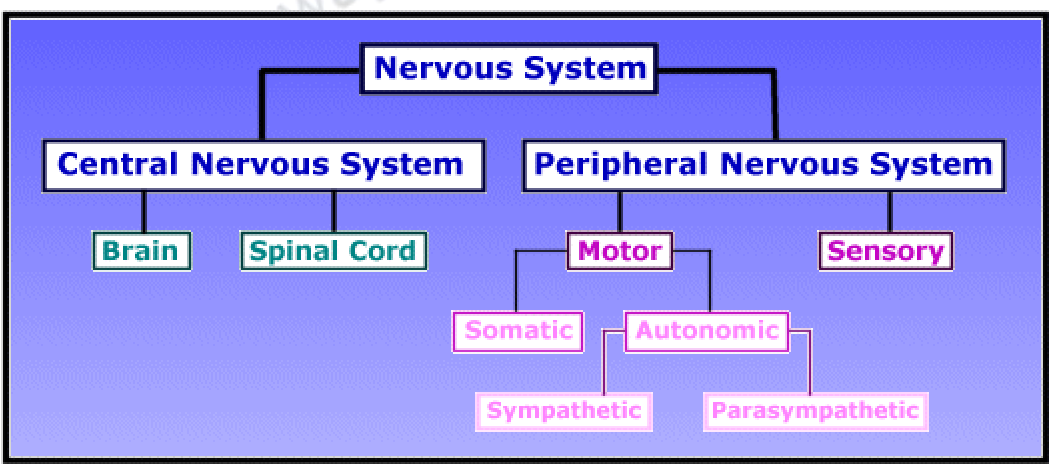



Figure 3 - Central and Peripheral nervous systems.

### 5.2 Peripheral nervous system

The **Peripheral Nervous System** contains all the neural structures that lie outside of the brain and spinal cord. Its specialised neurons assist in executing (1) the input functions that enable us to recognize the internal and external activities within the body (2) the output functions capacitate us to function with our muscles. The peripheral nervous system has two major divisions, the somatic nervous system and the autonomic nervous system.

### *5.2.1 Somatic nervous system*

The **Somatic Nervous System** comprises of sensory neurons that are dedicated to transfer input from sense organs, and motor neurons that transmit information from the brain and spinal cord to the muscles that govern intended actions. The axons of sensory neurons bunch together like many strands of a rope to compose sensory nerves, and motor-neuron axons unite to structure motor nerves. As you read this page, sensory neurons in your eyes are sending impulses into a complex network of specialised visual tracts that course through your brain (inside the brain and spinal cord, nerves are called tracts). At the same time, motor neurons are stimulating the eye movement that allow you to scan the lines and turn the pages. The somatic system thus allows you to sense and respond to your environment.

### *5.2.1 Autonomic nervous system*

The covert environment of the body is primarily regulated by the functioning of the **autonomic nervous system**, which governs the implicit functions of the body, controls the glands, the soft muscles that constitute the heart, the blood vessels, and the lining of the stomach and intestines. The autonomic system primarily deals with involuntary functions, such as respiration, circulation and digestion; it also plays a role in motivational, emotional responses and stress coping strategies. It consists of two subdivisions, the **sympathetic nervous system** and the **parasympathetic nervous system.** Typically, these two divisions affect the same organ or gland in opposing ways. The sympathetic nervous system bears an activation process and it tends to present as a holistic unit. For example- when you face a stressful situation, your sympathetic nervous system let you meet the stressor in several ways. It speeds up your heart rate so that it can pump extra blood to your muscles, dilates your pupils so that additional light can go into your eyes and improve your vision, slows down your digestive system so that blood can be transferred to the muscles, increases your rate of respiration so that your body can get more oxygen, and, in general, mobilizes your body. This is sometimes called the fight-or-flight response.

Compared with the sympathetic branch, which presents itself as unified element, the parasympathetic nervous system is way strong in its executions impacting mulitiple organs at a time. In general, it calms the functioning of the body and eventually maintains equilibrium. Thus, your sympathetic system races up your heart rate; your parasympathetic system calms it down. By working together to maintain equilibrium in your internal organs, the two divisions can maintain homeostasis, a delicately balanced or constant internal state. In addition, sympathetic and parasympathetic activities sometimes coordinate to enable us to perform certain behaviours. For example- sexual function in the male involves penile erection (through parasympathetic dilation of blood vessels) followed by ejaculation (a primarily sympathetic function).

### 5.3 Central nervous system

More than any other system in our body, the **central nervous system** contains the brain and the spinal cord, which connects most parts of the peripheral nervous system with the brain.

#### *5.3.1. Spinal cord*

Most nerves enter and leave the central nervous system by way of the spinal cord, a structure that is 16 to 18 inches long and about 1 inch in diameter in a human adult. The vertebrae (bones of the spine) protect the spinal cord's neurons. When the spinal cord is viewed in cross section , its central portion resembles an H or a butterfly. The H- shaped portion consists largely of grey coloured neuron cell bodies and their interrelated connections. At the periphery of the gray matter is white-coloured myelinated axons that connect intricate hierarchy of the spinal cord with each other and with the higher areas of the brain. Entering the backside of the spinal cord all through its length are sensory nerves. Motor nerves exit the spinal cord's front side. Some simple stimulus- response sequences known as spinal reflexes can be triggered at the level of the spinal cord without any involvement of the brain. For example- if you touch something hot, sensory receptors in your skin trigger nerve impulses in sensory nerves that flash into your spinal cord and synapse inside with interneurons. The interneurons then excite motor neurons that send impulses to your hand, so that it pulls away. Other interneurons simultaneously carry the "hot!" message up the spinal cord to your brain. But, its life saving that you do not have to wait for the brain to tell you what to do in such emergencies. Getting messages to and from the brain takes slightly longer, so the spinal cord reflex system significantly reduces reaction time and in this case potential tissue damage.

#### *5.3.2. Brain*

The three pounds of protein, fat and fluid that you carry around inside your skull which you call the real you. It's also the most complex structure in the known universe. Neuroscientists estimate that this three-pound powerhouse contains about 3 million miles of neural connections. If these lines form a neural trail, it would take you 5.7 years to drive an auto at 60mph, 24 hours a day, from one end to the other. As befits this biological marvel, brain emerges to be most vigorous energy consumer of all our body organs. Although your brain relates for just 2 percent of your total body weight, it utilizes about 25 percent of your body's oxygen and 70% of its glucose. Moreover, the brain never rests; its rate of energy metabolism is relatively constant day and night. In fact, when you dream, the brain's metabolic rate actually increases slightly. The brain commands the body to behave the way it behaves.

## 6. Summary

- The cerebral cortex is the crown of the head, present in advanced level species.

- Parallel Processing is the ability of the human brain to process effectively multiple sets of information.
- Compartmentalisation of the brain is the technique of separately storing and processing two or more conflicting ideas in the brain.
- Our brain is divided into - right and left hemispheres each performing different functions for our cognition and existence.
- Mind is an intangible, personal entity while Body is a tangible, physical entity. Both have an extensive impact over each other.
- Cognitive Neuroscience is a science in its nascent stages which studies neural activities underlying cognition.