BLOCK 2

THE NERVOUS SYSTEM

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UNIT 3 THE CENTRAL NERVOUS SYSTEM*

Structure

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3.0 LEARNING OBJECTIVES

After reading this Unit, you will be able to:

- explain the constitution of Central Nervous System (CNS);
- describe the structure and functions of the spinal cord;
- explain the structure and functions of the brain;
- discuss the relationship between brain and consciousness;
- describe different lobes and their functions; and
- discuss the impact of damage to the CNS.

3.1 INTRODUCTION

In the previous unit, we looked at neurons and how they communicate with each other. In this unit, we will look at the brain and spinal cord, which are the parts of central nervous system. The nervous system is responsible for all our behaviors and thought processes. The nervous system of the humans has two major divisions, namely, the Central Nervous System (CNS) and the Peripheral Nervous System (PNS). Figure 3.1 indicates the two major divisions.

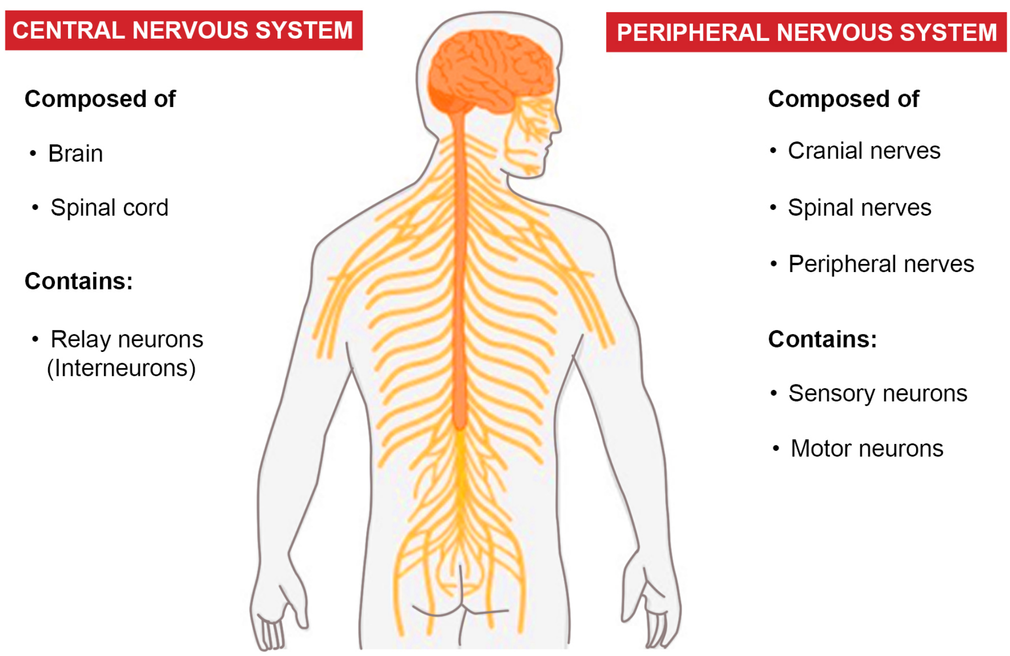

Figure 3.1: Main Components of the Human Nervous System

The central nervous system comprises of brain and the spinal cord that work together to make behavior possible.If there is any damage to any part of the spinal cord or the brain, then it causes different kinds of physiological and behavioral problems. The PNS is further subdivided into somatic nervous system (SNS) and autonomic nervous system (ANS). Figure 3.2 shows nervous system divisions and its functions.

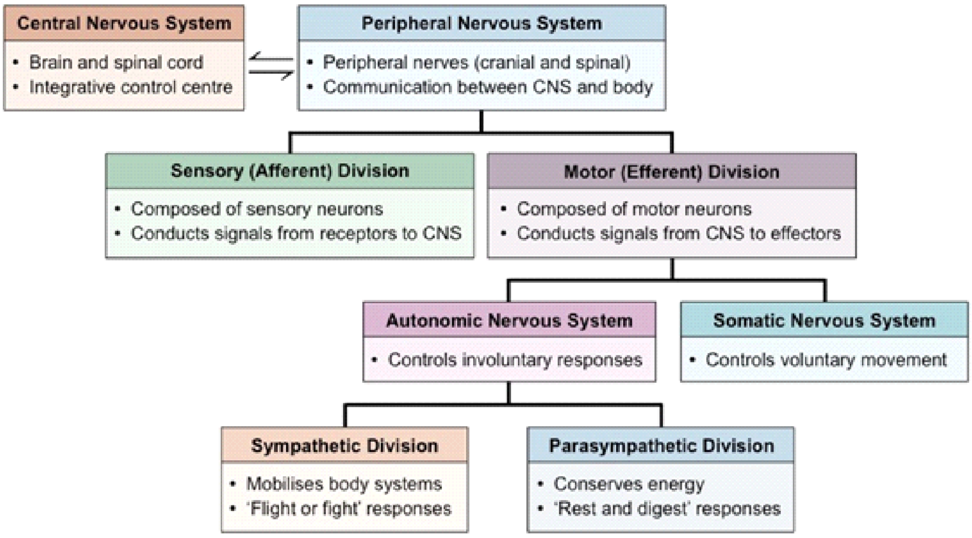

Figure 3.2: Schematic representation of Nervous System division and its function

Image Source: http://ib.bioninja.com.au

This Unit introduces you to the structure and functions of central nervous system. Further, we will discuss how damage to any part of CNS affects our behaviour. The other parts of the nervous system will be discussed in the next Unit.

Box 3.1 : Case of Phineas Gage

A famous case of brain injury is the case of Phineas Gage. He was a 25 year-old foreman crew in railroad construction company. In 1848, while blowing up rocks to clear the path for rail track, he met with a dangerous accident. A tamping iron rod pierced his left part of the brain, destroying his brain's frontal lobe. Even though he survived this accident miraculously, it had profound psychological consequences. From being a kind and hardworking Gage, he became rude and aggressive Gage. After few years (1860), he died of epilepsy.

Figure 3.3: Photograph of Phineas P. Gage (1823-1860) shown holding the tamping iron which injured him.

Image Source: https://commons.wikimedia.org/

3.2 CENTRAL NERVOUS SYSTEM

The Central Nervous System (CNS) consists of the brain and the spinal cord. It may thus, be said that the system is located within the skull and the spine. These are the most important parts of the human body.They are very delicate structures hence, are protected in bone and covered with the help of *meninges*. Meninges are three thin membranes or soft-tissue layers that protect the CNS called as the *dura mater, archnoid membrane and pia mater*. Another protective mechanism is the presence of colourless fluid known as *cerebrospinal fluid* that is found in the central canal of the spinal cord and cerebral ventricles (hollows) of the brain that provides a protective cushion to the brain and spinal cord. Patients whose cerebrospinal fluid is drained in some way, suffer from intense headaches and intense pain while jerking their heads. Also, in case of a tumour, the fluid accumulates in the ventricles and causes the walls of the ventricles as well as the brain to expand. This condition is known as *hydrocephalus*. It is cured by removing the tumour and draining out the excess fluid from the ventricles. Brain integrates the inputs from the sensory receptors and delivers the motor output to the effectors. It is also involved in complex functions as regulation of heart rate, breathing, consciousness, cognitive functions, etc. The spinal cord is placed within the spinal columns. The next sections will deal with the structure and functions of the spinal cord and brain in detail.

3.3 SPINAL CORD

In the first section, you learned about the major divisions of nervous system. You are also familiar with the cells of the nervous system. So now, we will focus on the structure and functions of the spinal cord.

3.3.1 Structure of the Spinal Cord

The shape of the spinal cord is oval, like a cylinder and about 45 cms in length in an average person. It is placed within the spinal column. The spinal cord is a very delicate structure hence it is protected by the cranial bones and the vertebrae that surround it. There is pair of spinal nerves attached to the spinal cord at 31 different levels of the spine. The pair of the nerves - one is attached to the left, and the other is attached to the right. It is also slightly tapered in the lower end (see Figure 3.4).

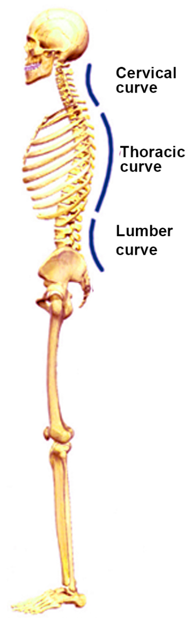

Figure 3.4 (a)

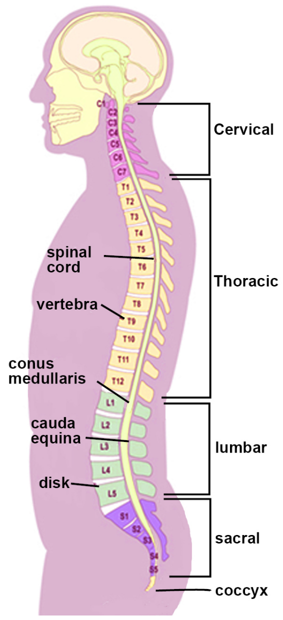

Figure 3.4 (b)

Figure 3.4 (a) Illustration of spine that forms an S-shape;
Figure 3.4 (b) The five regions of the spinal column.

There are two places where it bulges, at the cervical region and the other at the lumbar region. There are number of vertebrae that surround it. There are two deep groves in the spinal cord in the middle known as the *anterior median fissure* and the *posterior median sulcus*. There are nerve roots that enter and leave the spinal cord. The dorsal nerve root helps to send the information from the sensory receptors to the spinal cord and ventral nerve root carries motor information from the spinal cord to the parts of the body. From the cross-section of spinal cord, it is evident that it comprises of two different areas, namely the *gray matter* and the *white matter*. The inner core H-shaped area comprises of gray matter and mostly it constitutes of cell bodies and unmyelinated interneurons. The surrounding area comprises of white matter which constitutes myelinated axons.

3.3.2 Functions of the Spinal Cord

Spinal cord is responsible for the simple reflexes that take place in the body. The neurons of the spinal cord are responsible for sending information to the brain from the sensory receptors and to deliver the information received from the brain to the muscles and other glands of the body. Thus, it integrates the information coming to and going from the brain and other regions in the body. It also functions as the reflex center as it takes care of the ascending and descending tracts to and from the spinal cord. To say more clearly, the ascending tracts take the impulses towards the brain while the descending tracts carry impulses from the brain to the spinal cord to other muscles and glands in the body. Bundle of nerves together is known as a tract. Each tract serves one major function. *Spinothalamic tracts* include the axons that originate from the cell bodies of the neurons located in the spinal cord that end in the thalamus.These tracts are responsible for sensory functions including sensations of touch, pain and temperature.There are major ascending tracts of the spinal cord that serve important functions such as, *lateral spinothalamic tract* is responsible for pain, temperature, and touch; *anterior spinothalamic tract* is involved in crude touch and pressure; *fascicule gracilis* is involved in touch and conscious kinesthesia; and *anterior* and *posterior spino-cerebellar tract* is involved in subconscious kinesthesia. Major descending tracts of the spinal cord are *lateral* and *anterior corticospinal tract*, involved in voluntary movement, muscle contraction of hands and feet; *medial reticulospinal tracts* have inhibitory influence on motor functioning while *lateral reticulospinal tracts* have a facilitatory influence on the motor neurons going to the skeletal muscles and the *rubrospinal tract* helps in coordinating body movement and posture.

Spinal cord also serves as a reflex centre for many reflexes. It is the center of the reflex arc where in, the incoming sensory impulses are converted to outgoing motor impulses. Thus, it may be said that spinal cord plays an important role of being the integrator center in the brain, being responsible for gait, posture, reflexes, reaction to noxious stimuli, etc.

Check Your Progress 1

1) Illustrate the major divisions of nervous system.

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2) Explain the structure and function of the spinal cord.

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3.4 BRAIN

The brain is located at the top of the central nervous system (see Figure 3.1). It is protected by the skull and is interconnected with the body through the brain stem region to the spinal cord. The peripheral nervous system extends from the brain to the regions throughout the body and back again sends and receives neural signals that provide information related to pain, pressure, touch, movement, balance, and the senses of vision, audition, smell and taste. The cortex or neocortex is the seat of human cognition and sensory processing. We will explore the functional roles of the brain parts in the next section. But first let us see the "planes of the brain".

The brain is 'sliced' using three planes and these planes resemble to actual slicing done for instance at the time of post mortem examination or virtual slicing using magnetic resonance images of the brain. The three planes are shown in Figure 3.5. Slicing sideways across the brain so that the left and right hemispheres are exposed, is known as *axial slice*. It is also called *horizontal slice* because it is a horizontal cut across the brain. The second way to slice the brain is *sagittal slice*. The sagittal plane slices the brain vertically from left side to the right side, and the *coronal slice* is when the brain is sliced vertically from the front of the brain to the back. The other related terms are *dorsal*, indicating top of the brain, and *ventral*, meaning the bottom of the brain. The front of the brain is known as *anterior* and the back of the brain is known as the *posterior*. The middle part of the brain is referred as the *medial* section and the left and right outside edges are called *lateral*. These terms are used to denote where a region in the brain is located and once you are familiar with these terms, you will be able to identify the relative location of the brain areas. For instance, ventromedial prefrontal cortex or temporal lobe is posterior to the frontal lobe.

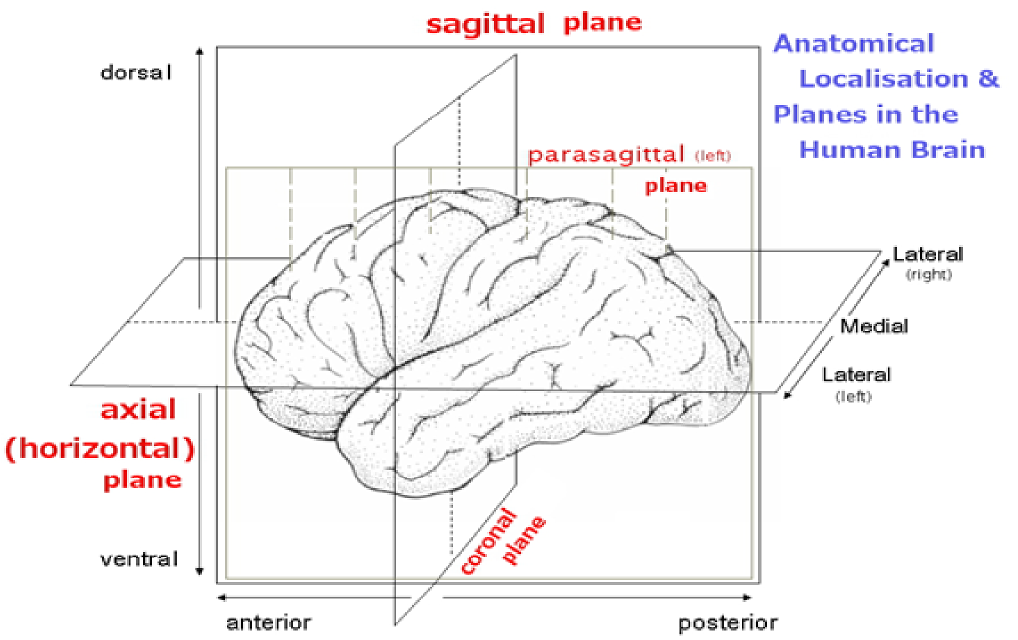


Figure 3.5: Side view of left hemisphere of brain.

Image Source: https://commons.wikimedia.org/wiki/User:JonRichfield (2014).

Now we will look what exactly is inside the brain. The adult brain is a large organ weighing approximately 1.5 Kg. It is very soft and jelly-like. The brain keeps growing till one reaches an age of 18 years. Hence, it is very important to have a proper nutrition in the body. Brain is a delicate organ and hence, it is protected firstly by a hard-bony structure, known as skull. The brain is enclosed in the skull that not only protects it but also retains its shape. Brain is also protected with the help of meninges, the soft-tissue layers that help in absorbing any kind of shock. The first layer under the skull is dura matter, which is thick and tough. The next layer is arachnoid membrane which is mesh-like, soft and spongy. Below this layer is cerebrospinal fluid (CSF) and the final layer is pia matter, which is a soft tissue layer. Meningitis is a potentially fatal disorder caused when these layers are inflamed because of any viral or bacterial infection. Brain is surrounded by CSF and it floats. There are four ventricles in the brain. Two large ventricles are present in the middle of the brain, one in each hemispheres and are known as lateral ventricles. Located below this is third ventricle and,fourth ventricle is located between cerebellum and the brain stem, at the base of the brain. The ventricles are filled with CSF. Figure 3.6 shows a lateral view (viewing brain from the side) of the human brain.

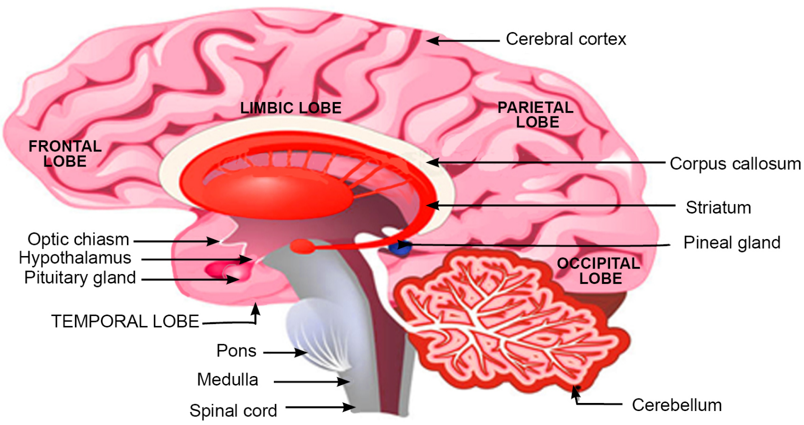


Figure 3.6: The Human Brain

As you can see that the surface of the brain is wrinkly, it has many parts. The brain has three major divisions as the fore brain, mid brain and the hind brain. Figure 3.7 illustrates the major divisions.

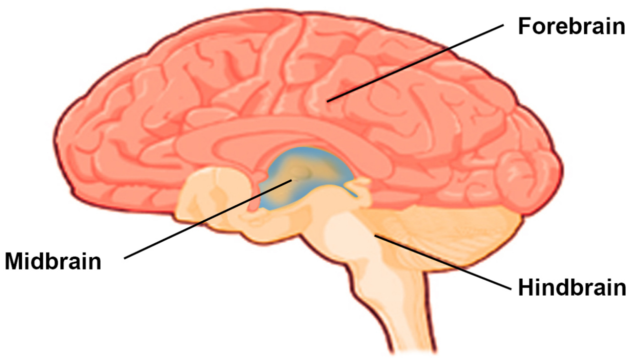


Figure 3.7: The brain and its parts: the forebrain, midbrain and hindbrain

The forebrain consists of structures as cerebral cortex, basal ganglia, limbic system, thalamus and hypothalamus.The Midbrain includes the tectum and tegmentum structures. While the hind brain consists of cerebellum, pons and medulla oblongata. The pons, medulla oblongata and cerebellum are also known as the brain stem. The cerebral hemispheres are situated on the brain stem.

3.4.1 Forebrain

Forebrain has two divisions known as the telencephalon and diencephalon. The telencephalon includes the cerebral cortex, basal ganglia and the limbic system. It is the largest division of the human brain. The cerebral cortex covers the two cerebral hemispheres while the basal ganglia is placed in the sub-cortical area in the brain. The diencephalon includes the thalamus and the hypothalamus, optic chiasma and pineal body. It is present between the cerebrum and the mid brain.

3.4.1.1 Telencephalon: Cerebral Cortex

The cerebral cortex is about 2 to 4 mm thick.It is on top of the cerebrum. It is outer, observable part of the brain. There are millions of dendrites that synapse here with the other neurons. The presence of small unmyelinated neurons in the cerebral cortex gives it a gray colour and thus, is also known as gray matter. The layer beneath the cortex constitutes of large myelinated axons which gives a white colour and hence is referred as the white matter.There are small and big bulges called as *convolution*. There are grooves between the bulges, the smaller ones are known as *sulci* and the larger grooves as *fissures*. There are many functions of the cerebral cortex. The post central gyrus functions as a general somatic sensory area.It receives sensations of touch, temperature and pressure. The precentral gyrus works as a somatic motor area which is involved in motor responses and maintaining body position. Hence, different areas of the cortex have important sensory functions to perform. The primary visual cortex helps in mapping the visual information and primary auditory cortex helps to map auditory information. Along with registering simple information, it also helps to compare and evaluate sensory information. Thus, it helps in integrating information pieces together into more meaningful perception. The motor functions help in regulating the motor movement. The primary somatic area is the precentral gyrus that is present in the frontal lobe. This helps in controlling individual muscles and the muscles of the feet, hands, toe for proper movement. Since the cortex receives sensory information, it integrates the information and sends out the motor responses, it functions as an integration center.This is responsible for consciousness and various other mental activities as language ability, emotions and memory. Cortex is also involved in other language functions, such as the ability to understand speech and written language. Cortex also helps in storing and retrieving information form short-term memory as well as long-term memory.

3.4.1.2 Telencephalon: Basal Ganglia

Basal Ganglia is present under the cerebral cortex. It is made up of white matter mostly which is composed of a number of tracts. There the gray matter is present deep inside the cortex unlike the white matter. The basal ganglia is made up of caudate nucleus, putamen, globus pallidus, and amagdaloid nucleus.Caudate nucleus and putamen have a stripped appearance and thus, are known as striatum. Being an important part of the cerebrum, the basal ganglia helps in regulating voluntary motor functions, as muscle contractions that are involved in maintaining the posture, walking or making other movements. If there is any damage to the blood vessels in this area, it causes a local interruption in the blood flow causing tissue damage or stroke locally. This causes a partial paralysis on one side of the body with problems in vision too. Parkinson's disease which is caused by the degeneration of certain neurons in the midbrain that sends its impulses to basal ganglia. This disease causes the person to experience weakness, tremors, poor balance, rigidity of limbs, and difficulty in initiating movements.

3.4.1.3 Telencephalon: Limbic System

The limbic (limbic means 'ring') system makes a border around the corpus callosum that connects the left hemisphere with the right one. It includes structures as cingulated gyrus and hippocampus which are connected to other areas of the brain as amygdala, septal, nucleus, hypothalamus and thalamus. Limbic system is also known as the ‘old brain’, performing functions related to emotional experience and expression and motivation. Since it is involved in the experience of different emotions such as fear, anger, sadness, feeding, sexual behaviour, fighting, etc., along with the cortex, it is also known as the emotional brain. If there is any damage in this area, it may lead to abnormal emotional reactions to situations. Since limbic system also plays an important role in learning and memory, any damage to the hippocampus causes deficits in memory.

3.4.1.4 Diencephalon: Thalamus

Thalamus is a large, two-lobed structure that is located on top of the brain stem. It is the central part of the forebrain that has important nuclei known as geniculate bodies and many neurons lie in the nuclei of the thalamus. The geniculate bodies play an important role in the processing of auditory and visual information. Hence, thalamus is responsible for sensation of pain, temperature and touch, and consciousness. The nuclei in the thalamus receive impulses form the brain stem and send it to the different regions of the cortex. The thalamic nuclei have an intermediate position are involved in relaying information from sensory receptors to motor effectors. Any damage to the thalamic region may be fatal or cause coma.

3.4.1.5 Diencephalon: Hypothalamus

Hypothalamus ('hypo' means below) is located below the anterior thalamus. It is a small part of the brain weighing about 7 grams only. Despite its small size, it is functionally very important. It has three important nuclei, known as *supraoptic nuclei*, the *paraventricular nuclei*, and the *mamillary bodies*. The mid-portion gives rise to a stalk known as infundibulum that is connected to the posterior pituitary gland. The hypothalamus is responsible for the survival as well as enjoyment of life. Since it links the nervous system to the endocrine system, it connects the mind (psyche) and the body (soma).The mamillary bodies are responsible for olfactory sensations. It also functions as pleasure centre, satisfying various drives as eating, hunger, sleep and sexual behaviour. Hypothalamus also regulates autonomic activities and integrates all responses made by the autonomic receptors. It regulates the release of hormones from the pituitary gland. It functions as the relay centre transferring information between the cerebral cortex and the autonomic centres. It also maintains water balance of the body and controls the functions of all body cells as it regulates the endocrine glands. Since hypothalamus regulates arousal or alerting mechanism, it helps to maintain the waking state. There is an appetite centre in the hypothalamus to regulate eating behaviour. If there is any damage to the hypothalamus, it causes a variation in the body temperature and it increases above the normal level.

3.4.2 Mid Brain

The middle portion of the brain is known as mid brain. Another name for it is mesencephalon.This has two parts known as tectum and tegmentum. The mid brain is composed of white tracts and reticular formation. Its function is to transmit impulses between the mid brain and the cerebrum.There is inferior colliculus which serves as an auditory centre while the superior colliculus functions as the visual centre.The mid brain is also responsible for certain nerve reflexes such as, papillary reflexes and eye movements.

3.4.2.1 Tectum

The top part of the mid brain is known as tectum. It has two colliculi on either side as superior colliculus and inferior colliculus. The function of the inferior colliculi is to relay auditory information. The function of the superior colliculi is to relay visual-motor system.

3.4.2.2 Tegmentum

Tegmentum lies in the middle of the midbrain. It includes some parts of the reticular formation, and some extensions that lie in the path between the fore brain and the hindbrain. It has two nuclei as *substantia nigra* and the *red nucleus*.

The red nucleus is involved in motor function while the substantia nigra (black substance) produces dopamine that prevents Parkinson's disease. Both are important components of the sensorimotor system. The reticular formation has number of neurons that are interconnected to one another. This network serves as a pathway to project the information to the cortex, thalamus and spinal cord. It is responsible for maintaining arousal, sleep, attention and muscle movements.

3.4.3 Hind Brain

The hind brain is the posterior part of the brain which consists of metencephalon and myelencephalon. Metencephalon contains the cerebellum and pons while myelencephalon includes the medulla oblongata.

3.4.3.1 Cerebellum

The cerebellum is the second largest part of the brain, also referred as 'little brain'. It is located at the base of the skull, behind the pons and below the main part of the brain and runs directly into the spinal cord. The internal white matter of the cerebellum looks like veins of a leaf. There are a number of grooves known as sulci and raised areas known as gyri.There are long and small tracts in the cerebellum that send impulses within and to the cerebellum.The cerebellum controls the movement of the skeletal muscles and enables in making smooth, efficient and coordinated movements than jerky ones. It helps in maintaining the body posture and equilibrium. Learned reflexes, habits and skills are also maintained by this area. If the cerebellum is damaged due to an injury, disease, tumor, etc then it causes cerebellar disease that is associated with typical symptoms. For example, in *ataxia* (means without coordination), the person faces problem in moving parts of the body the way one wants.Tremors become more frequent, gait and walking, is not stable and there are disturbances in the equilibrium.

3.4.3.2 Pons

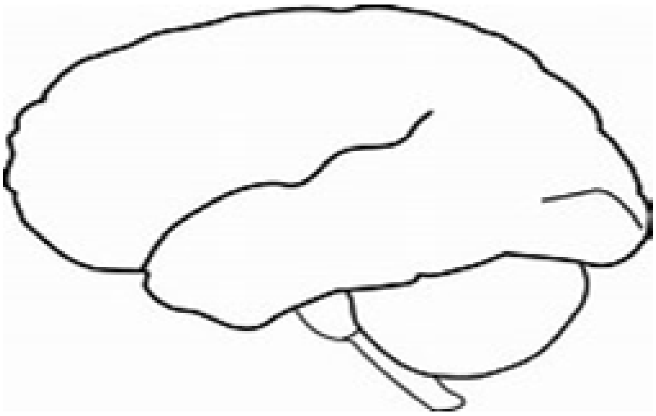
Pons consists of white matter and reticular formation. It lies just above the medulla. Pons means "bridge" and infact, it serves as the bridge between cerebellum and upper parts of the brain. Pons functions to control the reflexes of the body.It also helps in regulating respiration, and influences sleep, dream and arousal.

3.4.3.3 Medulla Oblongata

The medulla oblongata is about an inch in size.It is located at the top of spinal cord and is the lowest part of the brain.It contains projection tracts, reticular formation, and white matter.The nuclei in the reticular formation function as control centres such as cardiac, vasomotor or respiratory control centres, and thus, it controls life-sustaining functions. Medulla has other centres which take care of non-vital reflexes such as vomiting, coughing, sneezing, etc. It is also the place where the sensory nerves coming from the left and right sides of the body cross-over making the sensory information from left side of the body going to the right side of the brain and vice-versa.

Check Your Progress 2

1) Label the major parts of the brain in the figure given below.



2) Discuss the importance of hypothalamus.

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3) List two functions of the cerebellum.

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3.5 LOBES OF THE CEREBRAL CORTEX

The cortex is the outer covering of the brain that consists of tightly packed neurons. It is highly wrinkled, though initially (before birth), it is smooth but with the increase in size and complexity of the brain, it becomes more wrinkled. This process is known as *corticalization*. The cortex has two sections, known as *cerebral hemispheres*. It is covered by a thick and hard band of neural fibres known as *corpus callosum*. Corpus callosum enables the left and right hemispheres to exchange information with each other and communicate. If the corpus callosum is damaged, communication can be disrupted and each hemisphere acts independently, one side of the body does something without the other side knowing. This causes behavioural changes, common in 'split-brain patients'. The fissures or grooves in the cortex divide the cerebral hemispheres into five lobes (see Figure 3.7). These lobes are known as the temporal lobe, parietal lobe, frontal lobe, occipital lobe and insula. Insula is hidden from view though. Each of them will be explained in this section.

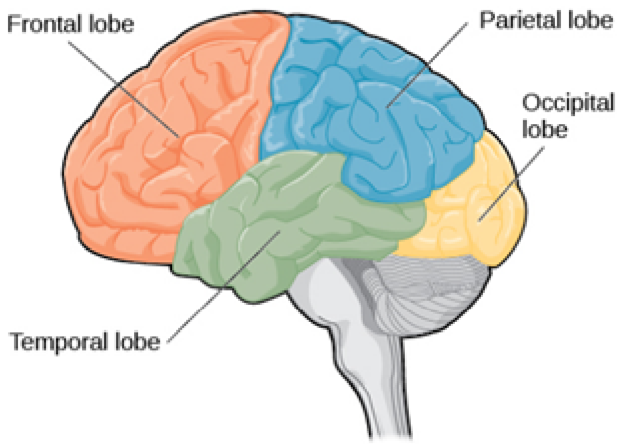

Figure 3.8: Illustration of the lobes of the brain.

3.5.1 Frontal Lobe

As the name indicates, frontal lobes (left and right) are present in front of the brain. The most anterior part of the frontal lobes is known as the pre-frontal cortex. The pre-frontal cortex helps to receive sensory information and project it to various portions around it. Frontal lobes are responsible for motor movements and fine movements, such as moving of a finger at a point of time, etc. There is the precentral gyrus that is involved in the motor functions. The rostral part of the frontal lobes is involved is higher order functions like, in cognition, complex decision-making and ideation. Since it is connected to limbic system, it also controls emotions. If you revisit the case of Phineas Gage, mentioned in the first section, he suffered damage in his left frontal lobe. Because of this damage, he could not control his emotions.

The frontal lobe is also involved in language functions (in most cases, the left frontal lobe).This area is known as Broca's area, named after French physician, Paul Broca. If there is any damage or lesion to the Broca's area, then it causes difficulties in producing and fluency in speech and sound, also called as Broca's aphasia.

Box 3.2: Aphasia

It is an impairment of language, affecting the production or comprehension of speech and the ability to read or write (National Aphasia Association, USA).

Box 3.3 : Paul Broca (1824-1880)

Paul Broca was one of the first to notice the localisation effect of brain while studying his patient who was only able to utter the word 'tan'. Broca observed this specific function when the patient died and he noted that the damage to the brain was confined to a small area in the frontal lobe in left hemisphere. Thus, Broca concluded that language production was a function of this specific brain area, which is now referred to as Broca's area.

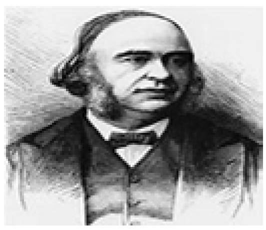

Image Source: www.britannica.com

3.5.2 Temporal Lobe

Temporal lobes lie on the either side of the brain, at the temples on the lateral sides. A deep groove known as lateral sulcus distinguishes the temporal lobe form the other lobes in the cortex. There is a gyrus known as transverse gyrus that serves as the primary auditory area and helps in the processing of language functions. This lobe is also involved in more complex functions as vision, movement perception and facial recognition. If there is any damage to the temporal lobe it may give rise to hallucinations that could be both auditory or visual. Temporal lobe is also involved in emotions and motivational behaviours. Hence, if there is any damage to temporal lobe it can lead to Kluver Bucy Syndrome. This is apparent in wild monkeys who do not display fear or anxiety responses.

Box 3.4 : Kluver Bucy Syndrome

"Kluver Bucy syndrome is a rare behavioral impairment characterized by inappropriate sexual behaviors and mouthing of objects. Other signs and symptoms, include a diminished ability to visually recognize objects, loss of normal fear and anger responses, memory loss, distractibility, seizures, and dementia. It is associated with damage to the anterior temporal lobes of the brain. Cases have been reported in association with herpes encephalitis and head trauma. Treatment is symptomatic and may include the use of psychotropic medications."

- National Institute of Health, U.S.

Also, located in the left temporal lobe, is the Wernicke's area, named after physiologist Carl Wernicke, a contemporary of Paul Broca. This area of the brain helps in speech comprehension. A person with Wernicke's aphasia will speak wrongly and will also not be able to understand what other people are saying to her/him, though there is no problem in fluency and articulation. Thus, any damage or lesion to this area might lead where the person can produce words and speak fluently but will be incorrect.

Box 3.5 : Carl Wernicke (1848- 1905)

Image Source: www.bing.com/images

Carl Wernicke, German physician noted very different language problems (comprehension difficulties) in patients who had brain damage. The specific brain regions identified for these problems were different to those identified by Broca. His understanding about aphasias, disorders interfering with the ability to communicate in speech or writing, helped in identifying nerve diseases to specific brain areas.

3.5.3 Parietal Lobe

The parietal lobes are located at the top and back of each hemisphere and lie between the occipital lobe and the central sulcus. There is a deep groove known as the post central gyrus that functions as the primary somatosensory cortex. This lobe is involved in sensation of touch and receives information from the muscle-stretch receptors. This knowledge of the touch and body sensations facilitates in the interpretation of visual and auditory information.

3.5.4 Occipital Lobe

Occipital lobes are located at the back and base of each cerebral hemisphere. It is responsible for processing of the visual information that is received from the eyes. The primary visual cortex area is Brodmann Area 17. It is involved in perceiving complex visual stimuli. Any damage to the occipital lobe leads to problems in vision when flashes of light are seen, visual hallucination or visual agnosia.

Box 3.6 : Brodmann Area

Korbinian Brodman, German neurologist divided the brain based on its functions. He was the first to describe the brain in this way and mapped cerebral cortex in 52 distinct areas based on different anatomic characteristics within each region such as cell shape, layering and density. Each Brodmann area (BA) might be associated with a particular cognitive process and used in describing discrete cortical subregions.

Box 3.7 : Visual hallucination

A type of sensory misperception. It refers to perception of people, colour, light or shapes in the absence of an external stimulus.

Box 3.8 : Visual Agnosia

"Visual agnosia is defined as a disorder of recognition confined to visual realm, in which a patient cannot arrive at a meaning of some or all categories of previously known nonverbal visual stimuli, despite normal or near normal visual perception and intact altertness, attention, intelligence, and language." International Encyclopedia of the Social & Behavioural Sciences (2001).

3.5.5 Insula

It is present under the temporal lobe and is hidden from view. This lobe is responsible for vision, so if there is any damage to this area then there could be cortical blindness. Extensive damage to this area, especially in the right hemisphere may damage the left visual field causing blindness in that area. The person having cortical blindness may not be able to perceive patterns or visual images (Sabo & Kirtley, 1982). It is known to be involved in consciousness, emotions and regulation of homeostasis. Other functions include self awareness, compassion, empathy etc.

3.6 BRAIN PROCESSES RELATED TO CONSCIOUSNESS

Various parts of the nervous system work together in co-ordination to make us aware of ourselves, our environment and other things and people surrounding us. The reticular activating system (RAS) conducts impulses to the cortex and arousal and human conscious excites it. RAS is a network of neurons that are involved in sensation and attention. It receives information from the spinal cord and relays it to the thalamus to cerebral cortex. The RAS functions as the arousing system that alerts the body hence maintaining consciousness. The three global brain states, awake, asleep and dreaming are controlled by RAS located in mesopons. These states develop and occur in a predictable manner depending upon the firing properties of neurons, synaptic connectivity and sensory inputs. Amphetamine is a drug that induces stimulatory influences on the cerebrum thus enhancing wakefulness and alertness.

Pineal body is placed little above the midbrain. Its main function is in regulating the biological clock and rhythm cycles. It regulates the circadian rhythms which are influenced by the dark and light cycle, especially important for birds, reptiles, fish and amphibians. Pineal gland produces *melatonin*, a hormone that helps in synchronizing the body functions with one another as well as regulating reproductive hormones. For humans and other mammals, it plays an important role in promoting sleep and regulating circadian rhythm.

3.7 DISORDERS OF THE CENTRAL NERVOUS SYSTEM

When the brain is damaged due to stroke, or injury, tumor, or nutritional problems,it causes various behavioral and cognitive changes. For example, when there is damage to the Broca's area, which is in the frontal part of the left hemisphere, then the person is unable to speak.This section presents an overview of main disorders of CNS.

3.7.1 Alzheimer's Disease

When there is degeneration process, it destroys many neurons in the brain. This influences the individual's memory, attention, and motor responses adversely. This degenerative disease is known as dementia. Alzheimer's disease is the most common cause of dementia. The cause identified is mostly genetic. People suffering from this have difficulty in memory, remembering names, people, places and have a very short attention span. They have great difficulty in maintaining personal hygiene and retaining their mental abilities. Acquired immune deficiency syndrome (AIDS) caused by the HIV virus may infect the neurons that lead to progressive degeneration of the brain causing dementia. Huntington's disease, a genetic disease that results in involuntary movements that are not desired, may also cause severe dementia and can be fatal.

3.7.2 Parkinson's Disease

It is a movement disorder, more prevalent in males and the onset is middle and old age. The most common symptom is tremor during inactivity, but not during voluntary movements, or sleeping. It is characterized by cognitive deficits.

3.7.3 Stroke

Sometimes an injury or a disease may destroy the tissue in the brain and neurons involved in motor movement. Strokes maybe caused because of cerebral hemorrahage (bleeding in the brain) or cerebral ischemia (interruption in the blood supply to an area of the brain). In cerebrovascular accident (CVA), the blood flow through the vessels is stopped due to haemorrhage. This causes lack of oxygen and if the neurons die then it leads to damage in motor neurons, thus leading to partial or complete paralysis. Apart from paralysis, the common result of a stroke can be amnesia, aphasia (language problems), and even coma.

3.7.4 Multiple Sclerosis

It is an autoimmune disorder and a progressive disorder that attacks the myelin sheath, the protective covering of the axons of the CNS. The usual onset of the disease is during young age. Common symptoms are visual disturbances, muscular weakness, tremors, and ataxia.

Box 3.9 : Autoimmune disorder

"Autoimmune diseases result from a dysfunction of the immune system. The immune system protects you from disease and infection. Sometimes, though, the immune system can produce auto antibodies that attack healthy cells, tissues, and organs. This can lead to autoimmune disease. Autoimmune diseases can affect any part of the body. More than 80 autoimmune diseases have been identified. Some are relatively well known, such as type 1 diabetes, multiple sclerosis, lupus, and rheumatoid arthritis, while others are rare and difficult to diagnose."

-National Institute of Environmental Health Sciences, U.S.A.

The causes of autoimmune diseases remain largely unknown. There is growing consensus that autoimmune diseases likely result from interactions between genetic and environmental factors.

3.7.5 Cerebral Palsy

This is a common disease that occurs during childhood when there is any damage to the brain tissue due to an infection, trauma, or reduced oxygen supply at birth. This causes permanent damage to the movement of body muscles. The voluntary muscle control is impaired and causes spastic paralysis that affects one side of the body.

3.7.6 Seizure Disorders

This is characterized by sudden bursts of seizures that cause a temporary change in the functioning of the brain, such as changes in consciousness, motor control or muscle contractions. Epilepsy is an example. The frequency and severity of seizures can be controlled with medication.

3.7.7 Amnesia

Amnesia is any major loss of memory while other mental functions are working. The cause can be infection, stroke, tumor, drugs, oxygen loss, epilepsy, and Alzheimer's disease. Amnesia can also be *psychogenic*, resulting from trauma or hypnotic suggestion (Nilsson &Markowitsch, 1999). In the classic case of HM (refer to Box 2.3, Unit 2), amnesia was due to bilateral damage to the medial temporal lobe, which includes hippocampus.The surviving functions are perception, cognition, intelligence, action, sometimes working memory is also sparred, remote memories, and nonconscious memories (implicit memory) that lack awareness of the previously experienced information. Amnesia can be of two types; *anterograde* amnesia refers to post damage memory deficit and *retrograde* amnesia refers to memory loss immediately before the damage.

Check Your Progress 3

1) Discuss the function of frontal lobe.

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2) Explain the role of brain in consciousness.

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3) List the main disorders of the central nervous system.

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3.8 SUMMARY

Now that we have come to the end of this unit, let us list all the major points that we have already learnt in this unit.

- The nervous system plays an important role in all off our behaviors and thought processes. The nervous system of the humans has two major divisions, namely Central Nervous System (CNS) and Peripheral Nervous System (PNS).
- The central nervous system that comprises brain and the spinal cord. Whereas, Peripheral Nervous System (PNS) is further subdivided into somatic nervous system (SNS) and autonomic nervous system (ANS).
- The spinal cord is a long cylindrical structure that is well encased in vertebrae. It is about 45 cms in length in an average person. It is protected by the cranial bones and the vertebrae that surround it. It bulges at two places namely, at the cervical region and the lumbar region.
- The brain is a large organ weighing about 1.5 Kg. It has three major divisions as the fore brain, mid brain and the hind brain.
- Forebrain consists of structures known as cerebral cortex, basal ganglia, limbic system, thalamus and hypothalamus. The Midbrain includes the tectum and tegmentum structures. Whereas the hind brain consists of cerebellum, pons and medulla oblongata.
- The cerebral cortex is the outer covering of the brain that consists of tightly packed neurons. The fissures or grooves in the cortex divide the cerebral hemispheres into five lobes namely, temporal lobe, parietal lobe, frontal lobe, occipital lobe and insula. Insula is hidden from view though.
- Reticular Activating System (RAS) is a network of neurons that are involved in sensation and attention. It plays important role in making us aware about ourselves and environment around us. It receives information from the spinal cord and relays it to the thalamus to cerebral cortex.
- Damage to the brain causes various kinds of disorders. For example, damage to Broca's region of brain leads to language disorder. Some of the main disorders of the CNS are Alzeihmer's Disease, Parkinson's Disease, stroke, multiple sclerosis, cerebral palsy, seizure disorders, and amnesia.

3.9 KEY WORDS

Central Nervous System : The central nervous system (CNS) consists of the brain and the spinal cord. It is responsible for combining information from our whole body and coordinates our behaviour.

Brain : Part of CNS, located within the skull. It consists of soft mass of grey and white matter that serves in to control and coordinate our behaviour.

Spinal cord : It is a thick bundle of nervous tissues, located inside our spines. It connects all parts of the body with the brain.

Aphasia : An impairment of language, affecting the production or comprehension of speech and the ability to read or write.

Cerebral palsy : Disease that occurs during childhood when there is any damage to the brain tissue due to an infection, trauma, or reduced oxygen supply at birth.

3.10 REVIEW QUESTIONS

1) The ________ is a sensory station where all sensory information, except for smell, goes before being sent to other areas of the brain for further processing:

   a) Amygdala

   b) Hippocampus

   c) Hypothalamus

   d) Thalamus

2) Damage to the ________disrupts one's ability to comprehend language, but it leaves one's ability to produce words intact:

   a) amygdala

   b) Broca's area

   c) Wernicke's area

   d) occipital lobe

3) Which of the following is not a structure of the forebrain?

   a) thalamus

   b) hippocampus

   c) amygdala

   d) substantia nigra

4) The visual cortex processes visual information. In which part of the cerebral cortex is it located?

   a) occipital lobe

   b) temporal lobe

   c) parietal lobe

   d) frontal lobe

5) Explain the structure and functions of the spinal cord.

6) Describe the two divisions of forebrain: telencephalon and diencephalon.

7) Describe the functions of cerebellum, pons and medulla oblongata.

8) What do you understand by aphasia? Differentiate between Broca and Wernicke's aphasia.

9) Discuss the different types of disorders caused by damage to CNS.

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- Image of Carl Wernicke, retrieved December 28, 2018, from https://www.bing.com/images
- Image of Paul Broca, retrieved December 28, 2018, from https://www.britannica.com

3.13 ONLINE RESOURCES

- For more understanding on central nervous system, visit
  - https://www.dartmouth.edu/~humananatomy/part_1/chapter_3.html
  - https://opentextbc.ca/anatomyandphysiology/chapter/13-2-the-central-nervous-system/

- For more understanding on lobes of brain, visit;
  - https://qbi.uq.edu.au/brain/brain-anatomy/lobes-brain
  - http://vpnl.stanford.edu/papers/grillspector_occipitallobe.pdf
  - https://courses.lumenlearning.com/waymaker-psychology/chapter/reading-parts-of-the-brain/
- To learn more about central nervous system, visit;
  - https://www.who.int/mental_health/neurology/neurological_disorders_report_web.pdf
  - https://web.duke.edu/pathology/siteParts/avaps/04.13.1_ Neurodegenerative_disorders_final.pdf
  - https://www.hopkinsmedicine.org/healthlibrary/conditions/nervous_system_disorders/overview_of_nervous_system_disorders_85,p00799
- For more on the region, Broadmann Area, visit;
  - http://dai.fmph.uniba.sk/courses/CCN/lectures/CCN-06-areas.pdf
  - http://braininfo.rprc.washington.edu/centraldirectory.aspx?ID=2102
- For an interesting article on Phineas Gage, visit;
  - https://thepsychologist.bps.org.uk<themythaboutphineusgage

Check your answer for Multiple Choice Questions

1(d), 2(c), 3(d), 4(a)

UNIT 4 THE PERIPHERAL NERVOUS SYSTEM*

Structure

4.0 LEARNING OBJECTIVES

After reading this Unit, you will be able to:

- describe the functions of cranial nerves and spinal nerves;
- explain peripheral nervous system;
- differentiate between somatic nervous system and autonomic nervous system; and
- compare the functions of sympathetic nervous system and parasympthetic nervous system.

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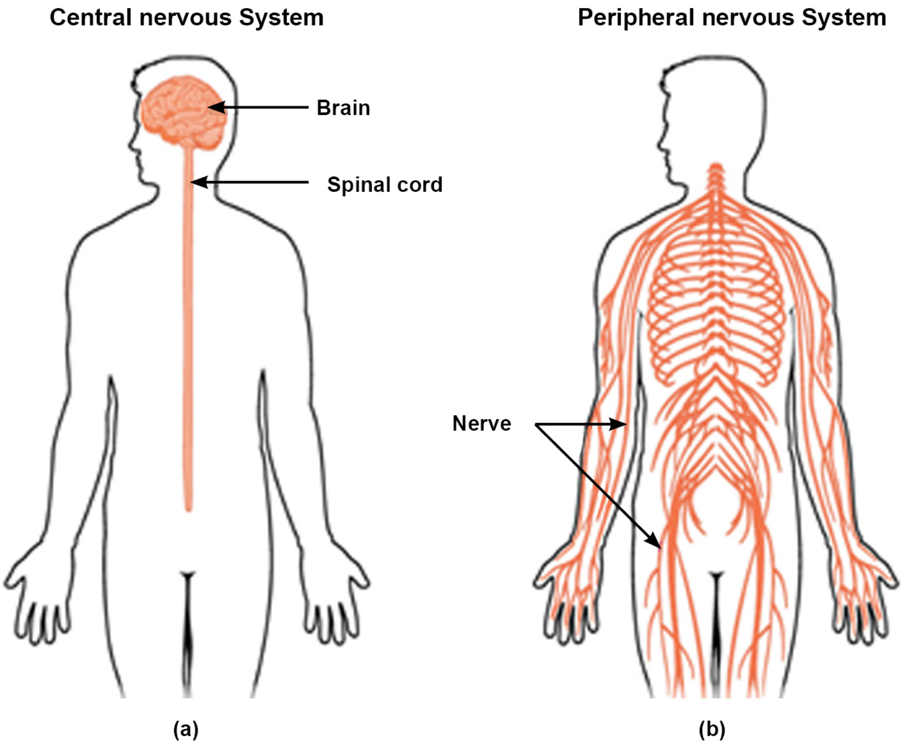
4.1 INTRODUCTION

Nervous system is a complex network of nerves and cells that carry information to and from various parts of the body. In Unit 3, you have learned about the main divisions of nervous system (see Figure 4.1) namely, the central nervous system (CNS) and the peripheral nervous system (PNS). We discussed in the last Unit, the parts of CNS consisting of brain and spinal cord. In this Unit, we will discuss the peripheral nervous system. Peripheral nervous system is responsible for connecting CNS with rest of our body. It is further divided into autonomic nervous system and somatic nervous system.



(a) (b)

Figure 4.1: The nervous system is divided into two major parts: (a) central nervous system and (b) peripheral nervous system

This Unit will explain cranial nerves and spinal nerves. The different types of cranial nerves and their functions will be described, followed by the spinal nerves and their functions. Thereafter, peripheral nervous system will be elucidated and the different kinds of reflexes. In the last part, the autonomic nervous system (ANS) and its divisions will be explained in detail.

4.2 CRANIAL NERVES

The cranial nerves are known by their number and name. There are 12 pairs (one of each pair is on the right side and one on the left) of cranial nerves that emerge out of the brain stem and reach out to the other areas of the body. Cranial nerves have bundles of axons. There are three types of cranial nerves depending upon their functions. The *sensory cranial nerves* have sensory axons and are involved in sensory functions, *motor cranial nerve* consists axons that are involved in motor functions and the *mixed cranial nerves* have both sensory and motor functions.The other nerves of the peripheral nervous system emerge from spinal cord.

Now let us have a look at the types of cranial nerves (see Figure 4.2). Cranial nerves I to IV are in the midbrain and the forebrain. The cranial nerves No. V to XII are in the medulla and pons.

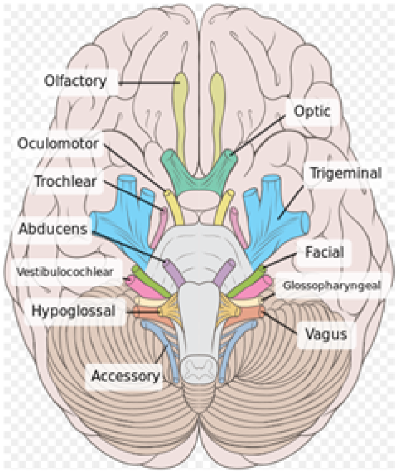


Figure 4.2: Inferior view of the human brain with labels showing cranial nerves

Image Source: https://commons.wikimedia.org

4.2.1 Olfactory Nerve (No.I)

Olfactory Nerves (I) have axons of neurons whose dendrites and cell bodies lie in the nasal mucosa. It is involved in the sensory function of smell.

4.2.2 Optic Nerve (No.II)

Optic Nerves (II) consist of the axons of sensory neurons that are present in the retina of the eye.These nerves are responsible for vision.

4.2.3 Oculomotor Nerve (No.III)

The Oculomotor Nerves (III) emerge from cells in the midbrain and reach out to the eye muscles. These nerves help in regulating the eye muscles do that the required amount of light only enters the eye. It is also involved in making eye movements, regulating the size of the pupil, and function of accommodation in the eye.

4.2.4 Trochlear Nerve (No.IV)

Trochlear Nerves (IV) emerge from the cells in the mid brain. The motor fibers extend from the trochlear nerve to the superior oblique muscles of the eye. This nerve is responsible for mediating the movements of the eyes and also making motor movements.

4.2.5 Trigeminal Nerve (No.V)

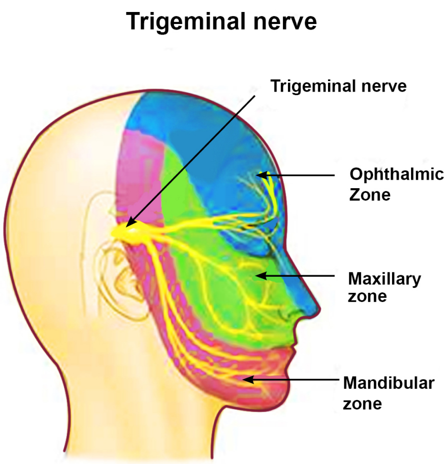


Figure 4.3: Illustration of Trigeminal Nerve

Trigeminal Nerves (V) divides into three kinds of nerves, known as the *opthalamic nerve, maxillary nerve and mandibular nerve* (see Figure 4.3). There are sensory neurons in these three kinds of nerves that help to carry impulses from the skin, mucosa of the head and the teeth to cell bodies in the trigeminal ganglion.They have mixed functions like sensation in the head, and face. It is also involved in chewing and propioception. It controls the movement of the muscles in the jaw.

Box 4.1 : Proprioception

Propioception is the sense through which the person perceives the position and movement of one's body. This includes the sense of equilibrium and balance.

Box 4.2 : Trigeminal nerves

Opthalamic nerve

It is the first branch of the trigeminal nerve. It transmits sensory information to the following structures: the eyes, nasal cavity, frontal sinus, falx cerebri upper eyelid, dorsum of the nose anterior part of the scalp. Further, some of the opthalamic nerves are also responsible for conveying information to parasympathetic nerves also.

Maxillary nerve

The maxillary nerve (V2) begins at the middle of the trigeminal ganglion and is intermediate (both in position and size) between the ophthalmic and mandibular nerves (Barral & Croibier, 2008).

Mandibular nerve

It is the third and last division of trigeminal nerve. Mandibular nerve contains both sensory and motor axons.

4.2.6 Abducens Nerve (No.VI)

Abducens (VI) is a motor nerve that originates from the pons. It is also involved in motor functions.

4.2.7 Facial Nerve (No.VII)

Facial Nerve (VII) has motor fibers. These fibers help to secrete saliva, and are involved in making facial expressions, tears and taste.

4.2.8 Vestibulocochlear Nerve (No.VIII)

The Vestibulocochlear nerve (VIII) is an auditory nerve. This is divided into two sensory nerves known as the vestibular nerve and the cochlear nerve. These nerves are involved in the function of hearing and maintaining balance in the body.

4.2.9 Glossopharyngeal Nerve (No. IX)

The Glossopharyngeal Nerve (IX) is made up of both the sensory and motor fibers.It sends impulses to the tongue, throat and is involved in swallowing, sensations of the tongue, secretion of saliva. It also helps in controlling the blood pressure and respiration.

4.2.10 Vagas Nerve (No. X)

The Vagus Nerve (X) is made up of both the sensory and motor fibres.The sensory fibres extend to several parts of the body and control the heart rate, voice production, swallowing and other visceral functions.

4.2.11 Accessory Nerve (No. XI)

This is a motor nerve. Some of its fibers originate in the medulla and extend to the thoracic and abdominal viscera, as well as the pharynx and larynx. Hence, this nerve is considered as an accessory to the vagus nerve. Since, it has spinal components, it was earlier also known as spinal accessory nerve. This nerve is responsible for shoulder movements, turning of the head, movements of the viscera, voice production, and proprioception.

4.2.12 Hypoglossal Nerve (No. XII)

Motor fibers in the Hypoglossal Nerve (XII) extend to the tongue muscles. This nerve is responsible for movements made by the tongue.

4.3 SPINAL NERVES

Spinal nerves are thirty-one in all. They do not have special names like the cranial nerves. These nerves emerge from the spinal cavity and are known according to the level of the vertebral column from which they emerge (see Figure 3.4 (b) in Unit 3). Those that arise from the cervical vertebrae are known as cervical nerve pairs. These are 8 in number and labeled as C1 through C8.The nerves arising from the vertebrae in the thoracic region are known as thoracic nerve pairs. These are 12 in number and are known as T1 through T12.There are 5 nerves that emerge from the vertebrae in the lumbar area, known as lumbar nerve pairs, L1 through L5. The nerves arising from the sacral vertebrae are 5 and known as sacral nerve pairs, S1 through S5. The last one is known as the coccygeal pair of spinal nerves in the coccyx region or tip of the spinal cord.

Check Your Progress 1

1) List the number, names and major functions of cranial nerves.

Number	Name	Major Function

2) Draw and label spinal nerves.

4.4 THE PERIPHERAL NERVOUS SYSTEM

The Peripheral Nervous System (PNS) consists of the nerves that lie in the peripheral region, outside the central nervous system. That is, it consists of all the nerves that branch out from the brain and spinal cord (not contained in the brain and spinal cord). From there it extends to other parts of the body as various muscles or organs. It is divided into somatic nervous system and the autonomic nervous system. The sensory information from the eyes, ears, skin and muscles is carried by the somatic nervous system to the CNS and the motor responses are mediated by the motor fibers from the CNS. The Autonomic Nervous system, another part of PNS, regulates emotional behavior, other organs and glands. The main role of the PNS is to connect the CNS with the limbs, and organs of the body.

4.4.1 Somatic Nervous System

The somatic nervous system conducts all sensory and motor information to and from the CNS. It is responsible for voluntary movement. This system consists of two major types of neurons such as sensory neurons and motor neurons. The sensory neurons are afferent neurons as they conduct impulses from the sensory organs to the central nervous system. The motor neurons are efferent neurons that convey information from the brain and spinal cord to muscle throughout the body. This is responsible for making voluntary movements. Thus, the somatic nervous system receives sensory information from the sensory organs and controls the movements of the skeletal muscles.

When a predictable response is given to a stimulus it is known as a *reflex*. In a reflex, the nerve impulse passes over a reflex arc.If the center of the reflex arc is in the brain, it is known as a cranial reflex, while if the center of the reflex arc is in the spinal cord, it is known as spinal reflex. Somatic reflexes involve the contraction of the skeletal muscles. Autonomic or visceral reflexes consist of contractions of smooth or cardiac muscles or glandular secretions. During any investigation, testing the reflexes is a very important diagnostic tool. If there is any deviation from the knee jerk, ankle jerk, corneal reflex, babinski reflex, and abdominal reflex then it is indicative of certain disease. The knee jerk reflex is also known as *patellar reflex.* It involves the muscles of the lower leg. Other examples of knee jerk reflex are spinal cord reflex when the centre of the reflex arc is in the spinal cord, segmental reflex when the nerve impulses emerge and end in the same segment of the spinal cord,ipsilateral reflex that occurs from the same side of the body or stretch reflex also known as myotatic reflex .The reflexes that are produced by the lower leg extensors are called as extensor reflex, and those produced by tapping of a tendon as the tendon reflex. The reflex that is produced when the Achilles tendon is tapped is known as the **ankle jerk** or the **Achilles tendon**. Corneal reflexes involve the blinking movement which occurs when the cornea is touched. When the side of the abdomen is touched the walls of the abdomen move producing an **abdominal reflex.**

Box 4.3 : Planter Reflex Vs. Babinski Reflex

The Babinski reflex was described by neurologist Joseph Babinski in 1899.

"Stroking the lateral part of the sole of the foot with a fairly sharp object produces plantar flexion of the big toe; often there is also flexion and adduction of the other toes. This normal response is termed the *flexor plantar reflex*."

In some patients, stroking the sole produces extension (dorsiflexion) of the big toe, often with extension and abduction ("fanning") of the other toes. This abnormal response is termed the *extensor plantar reflex*, or *Babinski reflex*" (Walker, 1990).

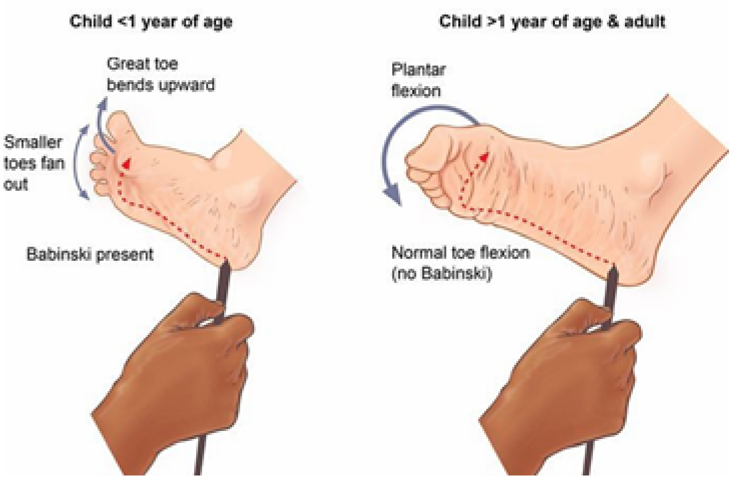


Figure 4.4 : Plantar reflex (the Babinski sign)

Image Source: http://canacopegdl.com/keyword/plantar-reflex.html

Babinski reflex abnormalities

Absent Babinski reflex

Babinski reflex gives stability to the infants' body, preparing their feet to take the first steps. It even ensures a proper coordination between the hips, lower limbs and spine.When newborns have no Babinski reflex, it suggests that their central nervous system has not matured properly, or there is some problem in *their spinal cord.*

Retained Babinski reflex

When children continue to have this infantile reflex even after reaching the age of two, they will have difficulty in placing their foot on the ground with ease. They may also face a problem in balancing themselves as their toes will always be extended outwards, making it problematic for them to walk around comfortably. Retained Babinski reflex may cause the following complications:

- Toe walking, flat feet, difficulty in paying attention or concentrating, weakened ankles, being inclined to extend or contract feet while walking, might have a claw or hammer toe.
- Children detected with cerebral palsy or hemiplegia (partial paralysis of the body) will retain their reflexes on the part that has been affected. Babies suffering from autism also have a prolonged Babinski reflex.

Source: https://www.pregmed.org/

The skeletal muscles are called the 'voluntary muscles', but can move when a reflex response occurs. They are called 'voluntary' because they can be moved at will and are not limited to that kind of movement.

4.4.2 Autonomic Nervous System

The Autonomic Nervous System (ANS) is that part of the peripheral nervous system that helps to transmit the efferent neurons to various autonomic or visceral effectors. As the name autonomic suggests that the functions are more or less automatic. It helps to regulate the effectors, like the cardiac muscles in the heart, smooth muscles on the skin, blood vessels and epithelial tissue in the glands. Thus, the somatic nervous system controls the senses and voluntary muscles, while as, the autonomic nervous system controls the organs, glands and involuntary muscles. The ANS functions involve regulating the heart rate, contraction of smooth muscles in the gall bladder and urinary bladder and maintain a state of homeostasis by regulating the glandular secretions. Hence, the ANS regulates the autonomic effectors that not only help to maintain homeostasis but also restores it.

ANS has two divisions, sympathetic division and parasympathetic division. These two divisions are very different from one another but work in conjunction with each other.Their functions are also very distinct. Though, many autonomic effectors involve both sympathetic and parasympathetic pathways. When the nerve fibers in the sympathetic system come out from the spinal cord, they immediately synapse with the ganglia that lie in sympathetic ganglionic chain. Both the sympathetic and parasympathetic divisions work antagonistically with one another such that when the sympathetic division works to enhance the heart rate and prepares the body to cope with the stressful situation, the parasympathetic division helps to relax it and bring the body back to a resting state or calm position (see Figure 4.5).

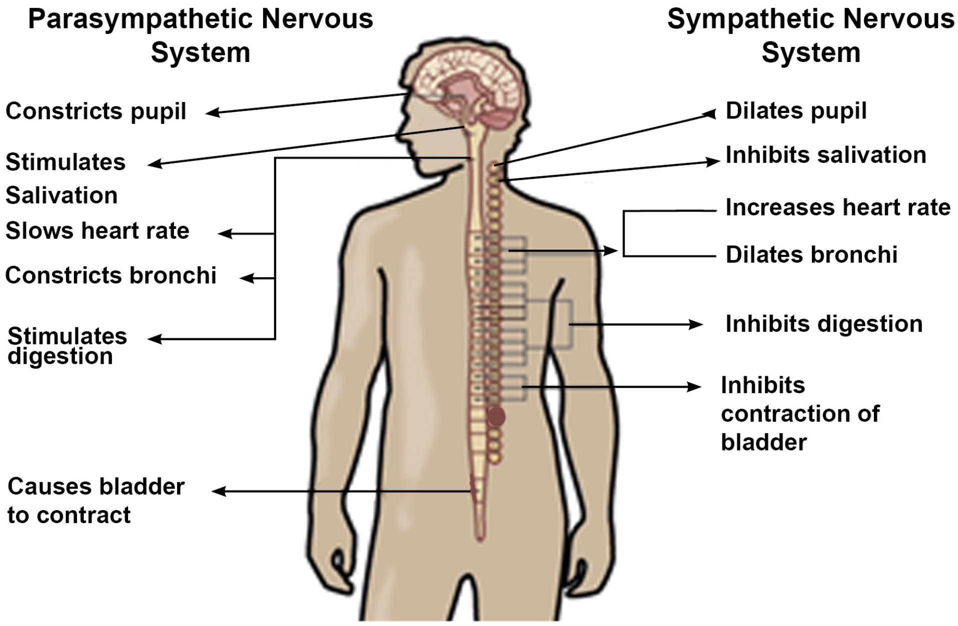


Figure 4.5: The sympathetic and parasympathetic divisions of the autonomic nervous system

Both sympathetic and parasympathetic divisions work *tonically* (continuous tension or contraction of muscles). This implies that they tend to conduct impulses to autonomic effectors continuously. Since they work on the principle of autonomic antagonism, they influence each other in opposite ways. In other words, if the sympathetic division stimulates an effector muscle or gland, then the parasympathetic tends to inhibit this stimulation. Sometimes the effectors are doubly innervated, which implies that both sympathetic and parasympathetic impulses are active simultaneously. Then in such a condition, the summation of these two opposing influences, determine which division will have a more dominating effect. If for example, the parasympathetic division helps to slow down the heart rate, it also enhances the working of the tear glands making them more active and also initiates the working of the digestive system. The heart rate is enhanced by the sympathetic division, which also diverts the blood from the organs in the digestive system to the muscles.

4.4.2.1 Functions of the Sympathetic Division

Sympathetic division is located primarily on the middle of the spinal column (top of the ribcage to the waist area that is thoracic and lumbar areas). The sympathetic division is responsible for "fight-or-flight" mechanism (fight : anger; flight : fear). You must have also experienced this kind of a moment at some point of time. Thus, it helps to maintain the normal functioning of the body under resting conditions.This means that when the parasympathetic division slows down the working of the autonomic effectors, it counteracts its functioning by regulating the heartbeat and keeping it at a normal pace. Thus, from Figure 4.5, it is clear how this division of autonomic nervous system, helps the body to react. It helps to maintain normal muscle tone and blood pressure under usual circumstances. However, when there is a change in the external environment, it serves as an emergency response to cope with the changes in the external environment and maintaining homeostasis. It helps the person or animal to deal with stressful situation (sympathy with one's emotions). In stress, the sympathetic division becomes very active, and starts sending its impulses very rapidly to defend the body. It also stimulates the adrenal gland to produce epinephrine and norepinephrine which help to enhance heart rate, blood sugar level, and increase the blood flow to the skeletal muscles to deal with stress. Most of the sympathetic nervous system use norepinephrine.

But not all organs are stimulated by sympathetic division. For example, digestion of food and eliminating waste products (excretion) from the body are not active during stressful situation. Infact, these systems tend to be stopped or inhibited in such a situation. But when there is excessive anxiety, then there is an urge to empty the bladder or bowels. When the arousal ends, the activities of sympathetic system are replaced by the activities of parasympathetic system. The sweat glands, the adrenal glands, the muscles that erect the hairs of the skin, and the muscles that constrict the blood vessels are only stimulated by sympathetic division.

4.4.2.2 Functions of the Parasympathetic Division

The neurons of this system are located top and bottom of the spinal column on both the sides of neurons of sympathetic division (para means 'beyond' or 'next to'). It is also known as *craniosacral system* because it consists of cranial nerves and nerves from sacral spinal cord.The parasympathetic division is active most of the time and controls various functions of the body in non-stressful situations or when everything is all right, that is in day-to-day functioning. The activities of sympathetic division are replaced by the parasympathetic division when the stress is over. It helps in repairing the body systems and bringing them back to a resting state and restoring the body to normal functioning after arousal. It produces acetylcholine that reduces the heart rate and brings it to a normal level and also tends to improve the digestion by stimulating the digestive glands. It enhances the activity of the gastric and intestinal system for smooth functioning of the body. Parasympathetic division restores the energy that is burned by the sympathetic division. Thus, it is also known as "eat-drink-and-rest system".

Check Your Progress 2

Fill in the blanks:

1) The peripheral nervous system (PNS) consists of the nerves that lie in the _______ region.
2) PNS is divided into ________ and _______.
3) The somatic nervous system is responsible for _______ movement.
4) When a predictable response is given to a stimulus it is known as a _______.
5) Autonomic nervous system has two divisions which are _____division and ______ division.

Answers: 1) Outside the central nervous system 2) Somatic nervous system; autonomice nervous system 3) Voluntary 4) reflex 5) sympathetic; parasympathetic

4.5 SUMMARY

Now that we have come to the end of this unit, let us recapitulate all the major points that we have covered.

- The cranial nerves are known by their number and name. There are 12 pairs (one of the each pair is on the right side and one on the left) of cranial nerves that emerge out of the brain stem and reach out to the other areas of the body.
- Based on function, cranial nerves can be of three types. The sensory cranial nerves have sensory axons and are involved in sensory functions, motor cranial nerve contains axons that are involved in motor functions and mixed cranial nerves which have both sensory and motor functions.
- There are 31 spinal nerves in our body. They do not have special names like the cranial nerves. These nerves emerge from the spinal cavity, and are known according to the level of the vertebral column from which they emerge.
- The peripheral nervous system consists of the nerves that lie in the peripheral region, outside the nervous system. That is, it consists of all the nerves that branch out from the brain and spinal cord (not contained in the brain and spinal cord). From there it extends to other parts of the body as various muscles or organs. It is further divided into somatic nervous system and the autonomic nervous system.
- The somatic nervous system conducts all sensory and motor information to and from the CNS. It is responsible for voluntary movement. This system consists of two major types of neurons, such as sensory neurons and motor neurons.
- The autonomic nervous system (ANS) is that part of the peripheral nervous system that helps to transmit the efferent neurons to various autonomic or visceral effectors. ANS can be further categorized as sympathetic division and parasympathetic division. These two divisions are very different from one another but work in conjunction with each other.

4.6 KEY WORDS

Peripheral nervous system : It is responsible for carrying information to and from the central nervous system to the whole body.

Cranial nerves : It carries information to the Peripheral nervous system.

Spinal Nerves : There are 31 pairs of spinal nerves in our body. They are responsible for carrying motor, sensory and autonomic information between the spinal cord and the body.

Reflex : When a predictable response is given to a stimulus it is known as a reflex.

Somatic nervous system : This system of PNS conducts all sensory and motor information to and from the CNS. Further, it is responsible for voluntary movement.

Autonomic nervous system : It is part of the peripheral nervous system. It helps to regulate the effectors, like the cardiac muscles in the heart, smooth muscles on the skin, blood vessels and epithelial tissue in the glands.

Sympathetic division : Part of autonomic nervous system, it is responsible for making body ready for stress related activities.

Parasympathetic division : It is another part of autonomic nervous system; it is responsible for making body ready for daily routine activities.

4.7 REVIEW QUESTIONS

1) Our ability to make our legs move as we walk across the room is controlled by the .... nervous system.
   a) autonomic nervous system
   b) somatic nervous system
   c) sympathetic nervous system
   d) parasympathetic nervous system
2) If your .... is activated, you will feel relatively at ease.
   a) somatic nervous system
   b) sympathetic nervous system
   c) parasympathetic nervous system
   d) spinal cord
3) Sympathetic nervous system is associated with ....
   a.) pupil dilation
   b) storage of glucose in the liver
   c) increased heart rate
   d) both A and C
4) The nervous system comprised of ....
   a) sympathetic and parasympathetic nervous system
   b) autonomic and somatic nervous system
   c) brain and spinal cord
   d) central nervous system and peripheral nervous system.
5) What do you understand by nervous system? Describe its classification.
6) What are cranial nerves? Write down its types and functions.
7) Differentiate between sympathetic and parasympathetic nervous system.
8) Explain the functions of somatic nervous system.

4.8 REFERENCES & FURTHER READING

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4.9 REFERENCES FOR FIGURE

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4.10 ONLINE RESOURCES

For more understanding on autonomic nervous system, visit;

– https://opentextbc.ca/anatomyandphysiology/chapter/15-1-divisions-of-the-autonomic-nervous-system/
– https://www.verywellmind.com/what-is-the-autonomic-nervous-system-2794823
– http://www.indiana.edu/~p1013447/dictionary/ans.htm

For more information on peripheral nervous system, visit:

– https://opentextbc.ca/anatomyandphysiology/chapter/13-4-the-peripheral-nervous-system/
– https://www.verywellmind.com/what-is-the-peripheral-nervous-system-2795465

Answers for Multiple Choice Questions

1) (b), 2) (c), 3) (d), 4) (d)