Introduction to the Nervous System.

Code: HMP 100/ UPC 103/ VNP 100. **Course: Medical Physiology**

Level 1 MBChB/BDS/BPharm

Lecture 1. The Organisation of the Nervous System

Lecture Outline

1.1 Introduction

In this lecture, we will go over basic aspects of the anatomy of the nervous system that is necessary to understand how the nervous system functions, i.e., its neurophysiology. In the lecture 2, we will discuss the parts of the nervous system involved in some of the functions of the nervous system. And in lecture 3, we will discuss the cells of the nervous system - neurons and glia - and look at a simple neural circuit. Once we have completed these 3 lectures, we will have the background to study in more detail how the nervous system carries out its many diverse functions.

1.3 Functions of the Nervous System

1.2 Learning Outcomes

At the end of this lecture, you should be able to:

1. State the function of the Nervous System
2. Name the divisions of the Nervous System
3. Draw and label the 7 divisions of the Central Nervous System
4. Draw and label the 5 lobes of the cerebral hemispheres
5. Draw the organisation of the spinal cord
6. Describe the organisation of the spinal cord

The nervous system is a complex organ with extraordinary functions, such as memory, learning, language, and movement. It also the organ of our body that sees, hears, tastes, creates emotions, controls our sleep/wake cycle as well as being creative and solving problem. It is the organ that makes us who we are. And we can imagine that an organ that carries out so many extraordinary

functions will be quite complex in its organisation. But let us do not panic, we do not need to know every single thing about the nervous system for this course. However, we do need to know the basic things about the nervous system and how in general how the nervous system functions.

What we will learn from these lectures on the nervous system will be useful in many different educational and professional areas. Some examples of the areas where understanding of the nervous system is useful are *neurology, psychiatry, behavioural science, neuropharmacology, psychology, physiotherapy, nursing science, dentistry, education and even economics.*

Our bodies contain 10 physiological systems: cardiovascular, respiratory, renal, gastrointestinal, endocrine, neuronal, integumentary, reproductive, musculoskeletal, and immune. Of these 10 physiological systems, 9 are necessary for survival and 1, the reproductive system, for the propagation of the species. From other lectures in physiology, we learnt that the overall function of our physiological systems is to maintain homeostasis, which the maintenance of the constancy of the chemical and physical composition of our internal environment. The internal environment is the fluid that surrounds all our cells and its chemical and physical properties need to be maintained within a range of values so our cells can function normally. For example, if there is change in the electrolytes ($Na+$, $K+$, Ca^{2+}, $Cl-$) concentrations, not only will signaling in the nervous system be affected but also our heart rhythm.

Because there are many variables that have to controlled for homeostasis, different physiological systems are necessary. But, how is the activity of these physiological systems controlled and how is their activity coordinated?

We have 2 physiological control systems: the endocrinal and the neuronal, that control and coordinate the activity of the other physiological systems. The endocrine system, which we will learn about in later lectures, operates slowly and its effects can last from mins to days to years. For example, at puberty hormones are released that cause change in our physical structure and these changes are not reversible and will remain with us for the rest of our lives. The neuronal system is faster than the endocrine system and its activity is turned on and off rapidly. (It works on a millisecond time scale). It is also the system through which information about the external and internal environment is received and processed. It has receptors and sensory organs (detectors) that respond to physical forces, energies, and chemicals that are present in our internal and external environment. For example, the retina, which is located at the back of the eye, contains special receptors that respond to electromagnetic radiation, which we call visible light, and the signals produced from these receptors are used to produce images of the external environment. Inside our body, there are also receptors that respond to changes in blood pressure, pH, temperature and other variables. So, for example, if our body pH goes down, i.e., becomes more acidic, the nervous system starts a compensation process which includes increase the rate and depth of our breathing so to increase the pH and bring back its value within the normal range, and hormonal changes to increase the excretion of hydrogen ions in the urine.

We will learn about the nervous system in at least 4 courses that you will take in level 1 and 2 course of studies for the degree MBChB/BPharm/BDS.

We will learn neuroanatomy in 1st year human anatomy, we will learn neurochemistry in our 1st and 2nd year of Biochemistry courses, and, of course, we will learn how the nervous system functions (neurophysiology) in our 1st and 2nd year medical physiology courses. So we will have several opportunities to learn about the many different aspects nervous system from its anatomical organization, to its chemistry and finally the mechanism of its function.

	Name the 10 physiological systems that are present in your body.

Before, we discuss how the nervous system functions, we will need to know some anatomy of the nervous system. As already mentioned, we will learn neuroanatomy in more detail in your human anatomy course. Here, our purpose is to know enough anatomical details of the nervous system to understand how the nervous system works.

	In which courses will we have opportunity to learn about the nervous system?

1.4 Divisions of the Nervous System

To study and learn about the nervous system, we first divide the nervous system into 2 major divisions: (1) **the central nervous system (CNS)** and **(2) the peripheral nervous system (PNS)**. Now, though these two divisions are part of the nervous system, they exist in different environment. The CNS is enclosed by bones of the vertebral column, skull, and membranes. This creates a separate environment for the CNS from the PNS. There is a blood-brain barrier, which we will learn about in later lectures. It is a physiological barrier that controls what substances can enter and leave our CNS. The boundary between our CNS and PNS is the tough leathery outer covering of the CNS called the dura mater.

We can further divide the CNS into two parts: the spinal cord which is located in the vertebral column, and the brain, which is located inside the skull. So the whole of the CNS is very well protected by being surrounded by thick bones.

This we can be see in figure 1, which shows the saggital section of person's head and neck. We can see how thick are the skull and vertebral bones

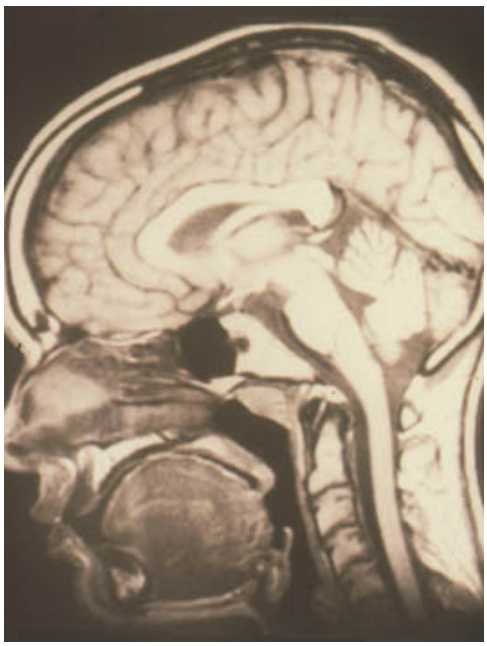

Figure 1.1 A Magnetic Resonance Image (MRI) of the sagittal section of human head and neck. (Neuroanatomy, Jack Martin)

Figure 1.2 is a diagram of the PNS. It is made up of 31 pairs of spinal nerves and cranial nerves, and the nerve fibers that go to all parts of the body.

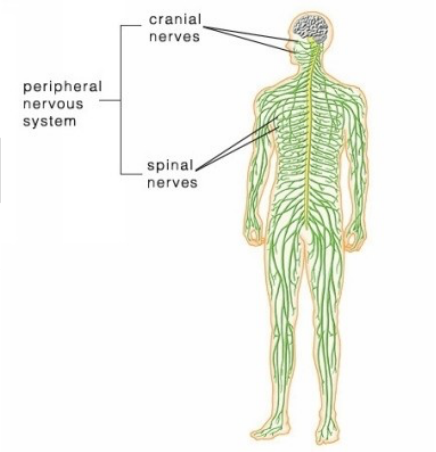

Figure 1.2 Diagram of the peripheral nervous system. (source: medcalterms.info)

Figure 1.3 shows the spinal cord. We can see that there is a darker region inside the spinal cord. This is called the **gray matter** and the spinal cord nerve cells are located here. Surrounding this gray matter is a lighter region called **the white**

matter, which consists of nerve fibres going up to and coming down from the brain.

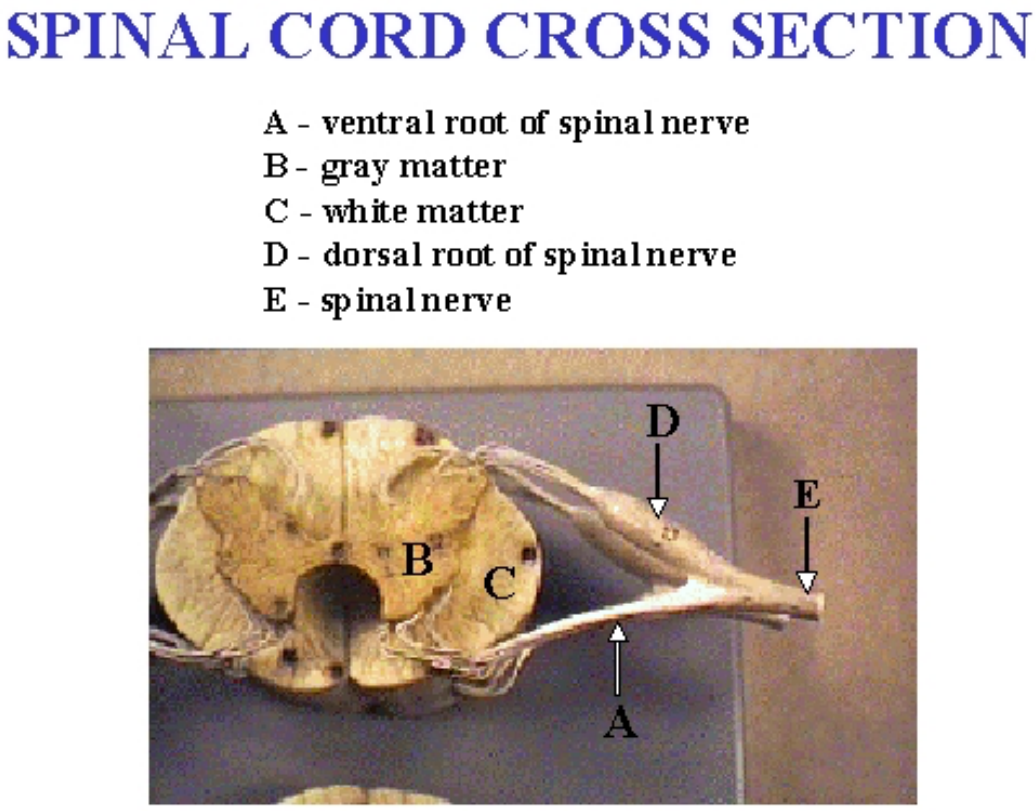

Figure 1.3 Spinal cord and the spinal nerves. (Source: facutly.ucc.edu)

The spinal nerve has two roots: (1) The **ventral root,** labelled A, through which nerve fibres of the nerve cells in the gray matter leave the spinal cord, and (2) the **dorsal root,** labelled D, through which nerve fibres enter the spinal cord. The nerve cells of the nerve fibres of the dorsal root are outside the spinal cord in swellings we can see in the dorsal root (Where the arrowhead of D is touching the dorsal spinal cord). These are called the **dorsal root ganglia** and run as chain along the length of the vertebral column - **the dorsal root ganglia chain**.

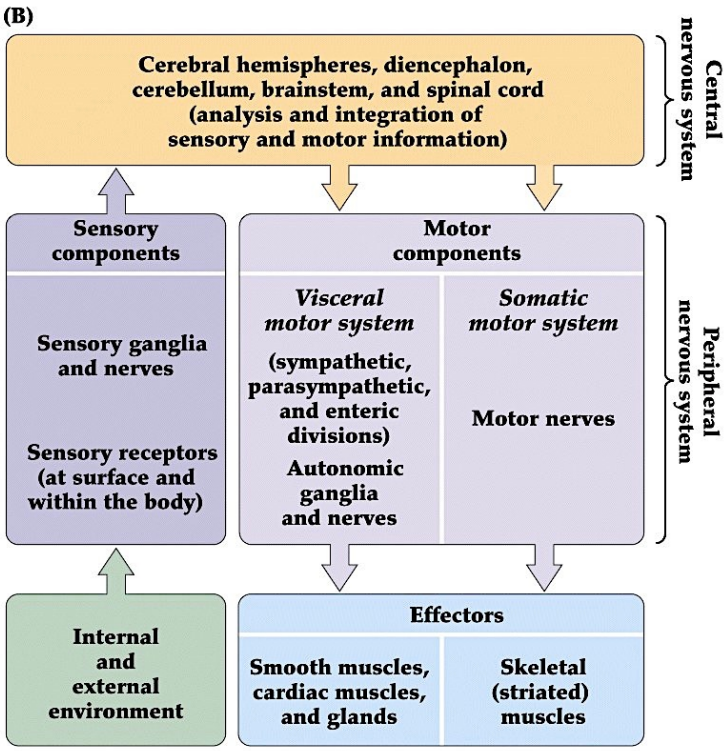

Figure 1.4 Organisation of the Nervous System. Source: Purves et al. Fig 10.1

Figure 1.4, shows the division of the nervous system into CNS (coloured yellow-brown) and PNS (purple coloured). Studying figure 1.4, we can see that the CNS communicates with the PNS and the PNS communicates with different tissues of our body. So the CNS controls the activities of these tissues through the PNS. There is the motor part of nervous system (the light purple color) and a sensory system (darker purple colour). The signals from the receptors on our skin and inside our bodies are send through the PNS to the CNS.
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1. What are the 2 divisions of the motor component of peripheral nervous system?
2. What tissues are controlled by these 2 divisions?
3. What are the 3 divisions of the visceral motor system?

So our PNS is sub-divided into 2 parts: a motor part and a sensory part and the motor part is further divided into (1) **somatic motor system**, which controls all our skeletal muscles, and (2) **visceral motor system** which controls the smooth muscles of internal organs, the cardiac muscle, and glandular activity inside our body.

The visceral motor system itself is further divided into the **sympathetic**, **parasympathetic,** and **enteric** divisions. The sympathetic and parasympathetic

together make up the **autonomic nervous system (ANS)**. The enteric nervous system is found within the walls of our gastrointestinal tract. In the lectures on gastrointestinal physiology, we will learn more about the enteric nervous system.

So in this section, we have learnt that the nervous system is divided into 2 major divisions: CNS and PNS, and the PNS is further sub-divided into two major divisions: somatic and visceral motor system, and the visceral motor system is further divided into 3 sub-divions. In the next section, we will look at sub-divisions of the CNS.

Study Aide*: A good study aide is to draw the diagrams and label them. We will find this reinforces our memory and having a clear mental picture of the nervous system will help us in learning about the nervous system easier.*

1.5 The Seven Divisions of the Central Nervous System

In section, we will identify and locate the 7 sub-divisions of the CNS. Figure 1.5 shows a saggital view of a person's head taken with the technique of magnetic resonance imaging (MRI). The MRI produces detailed images of living tissue that are used used a lot in the healthcare profession for diagnosis purposes.

Now, starting from bottom of the picture, we see the part of the CNS called the **spinal cord** located within the vertebral column (coloured in purple). The upper boundary of the spinal cord is at the base of the skull, and lower end in an adult is about the 2nd lumbar vertebra. Then as we move up through the hole in the base of the skull (foramen Magnum), we come to the **medulla oblongata** (coloured in yellow). This is a very important part of the CNS. It controls our breathing and heart rate. Damage to this area of our CNS will result in death. In fact, death is the dying of the nerve cells in the medulla oblongata.

Continuing to move up, we come to the third part of the CNS -**the pons (**shown in orange). And on top of the pons we come to the fourth part of the CNS – the **midbrain (**shown in green colour). Above the midbrain, the region coloured purple is the **diencephalon**. The medulla, pons, midbrain, and diencephalon are collectively called **the brainstem.**

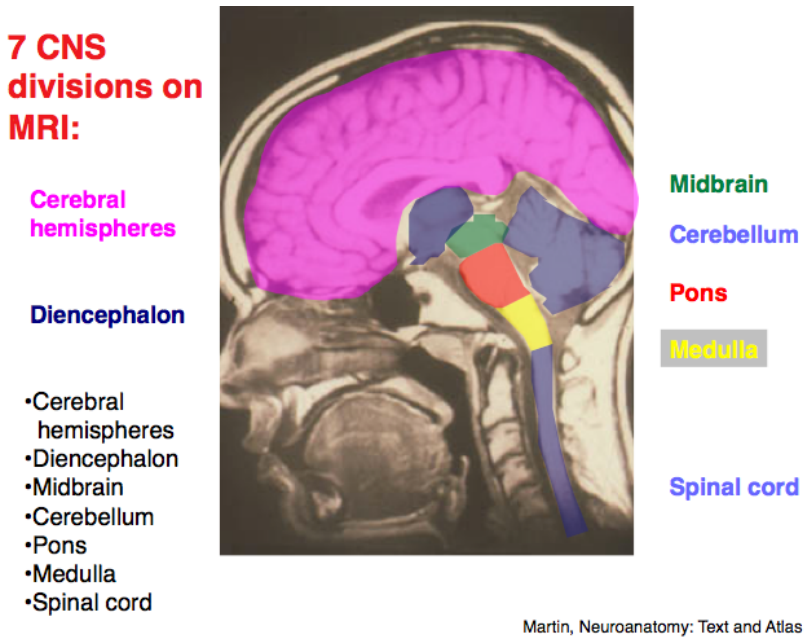


Figure 1.5 Sagittal section of the upper part of the spinal cord and the brain showing the 7 divisions of the nervous system. (Source: Jack Martin, Teaching Tools in Neuroscience, Ethiopia, 2015)

So we have now covered 5 divisions of the CNS. The final 2 are the **cerebellum** and the **cerebral hemispheres**. The cerebellum is shown in a purple colour jutting out from the brainstem. This part of the brain is very important in the control of movement. Sitting on top of the brainstem, shown in pink, are the huge cerebral hemispheres. They are called the hemispheres (half spheres) because we have two of them, one in the right side of our skull and the other in the left part of our skull.

In this section, we have learnt about the 7 sub-divisions of the CNS.

1. Draw a diagram of the brain in the saggital plane and label the 6 divisions of the CNS found inside the skull.
2. What does the word 'diencephalon' mean in plain English?

1.6 The 5 Lobes of the Cerebral Hemispheres

Now we continue to sub-divide the CNS. Here we will look at how the surface of the cerebral hemispheres is divided into 4 lobes: **frontal, parietal, temporal**, and **occipital**.

How were these divisions done? How on the surface of the cerebral hemispheres can these lobes be identified? These are questions that we will be looking at in the following part of the lecture.

Figure 1.6, shows a photograph of a human brain, in particular, the lateral view of the cerebral hemispheres. You can see that the surface of the cerebral hemisphere has folds or wrinkles. These folds or wrinkles are called the sulci (singular: sulcus) and the areas between the sulci are called the gyri (singular: gyrus). So the surface of the brain looks like a large piece of paper that has been crumpled to fit into a small space.

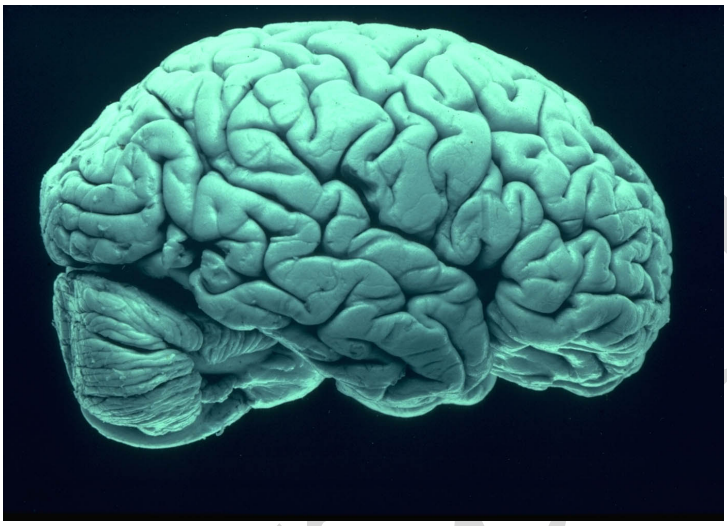


Figure 1.6. Lateral view of the left cerebral hemisphere. The front is towards the right.

If we take a dozen or so human brains and compare them, we start to notice that there is similarity of pattern in the sulci and gyri between the individual human brains. Each human brain has roughly similar pattern of sulci and gyri. We can use the regularity of the pattern of sulci and gyri as geographical markers on the surface of the cerebral hemispheres. While the surface of the brain looks very complicated, showing quite a number of sulci and gyri, there are not many sulci and gyri that we have to learn the names and location of.

Study Aide: *A very good exercise is to draw out the lateral (side) and sagittal (middle) view of the brain with all the sulci drawn. This way you will quickly learn the features of the surface of the cerebral hemispheres and the names of the major gyri that form the boundaries of the different lobes. On You Tube you can will find videos showing how to draw these views.*

Let us find the boundaries of the 4 lobes of the cerebral hemispheres. If we look down at the brain from the top, you see a deep division between the two cerebral hemispheres. This called the **medial longitudinal fissure**. Looking at the brain from the lateral side, we can see another deep space, running at an angle, from the front towards the back of the brain. This is the **lateral fissure** or the **Sylvan fissure**. (The difference between a sulcus and fissure is that a fissure is deeper

than a sulcus.) An important sulcus is the **central sulcus**. This runs all the way from the top of each cerebral hemisphere to the lateral fissure. This is nicely shown in figure 1.7 with the lateral fissure and the central sulcus marked in red.

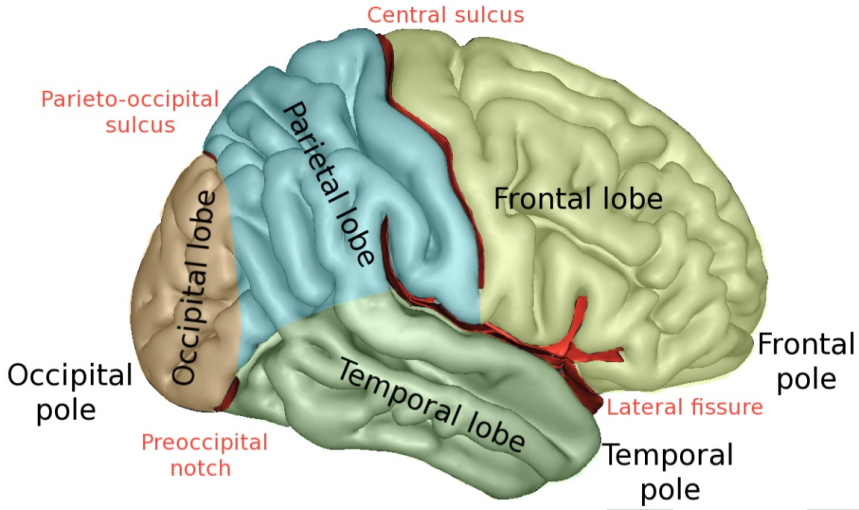


Figure 1.7 The lateral view of the brain surface. (The front of the brain is towards the right.) (Source: en.wikipedia.org)

So using the fissures and sulci as landmarks, the surface of the cerebral hemispheres can be divided into 4 major lobes. The area in front of the central sulcus going down to the lateral fissure is the **frontal lobe**. The area behind the central sulcus down to the lateral fissure and going back to the **parito-occipital sulcus** on the top of the cerebral hemisphere is the **parietal lobe**. The area going to the back of the cerebral hemisphere from the parito-occipital sulcus is the **occipital lobe**. The area of cortex below the lateral fissure is the **temporal lobe.** At the point where the parietal, temporal and occipital lobes meet, there is no physical boundary. It is an imagined boundary. If we look at the medial surface of the cerebral hemisphere in figure 1.8 we can see that lobes also extend onto the medial surface. Also, here in the medial surface, we can see the 5th lobe, which is called the **limbic lobe**. We will learn more about this lobe when we study the nervous system parts that are involved in producing emotion and motivation

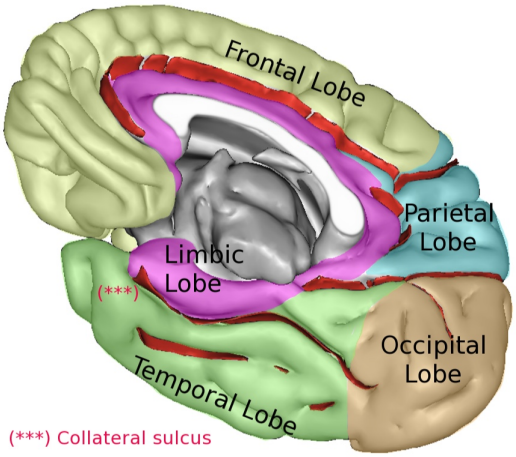


Figure 1.8. The medial surface of the cerebral hemispheres showing how far on the medial surface the frontal, parietal, occipital and temporal lobes extend. The the limbic lobe is also shown. (Source: en.wikipedia.org)

The lobes also extend round the base of the cerebral hemispheres. This is shown in figure 1.9. In the same figure of fixed human brain, we can see what the medulla oblongata and the pons look like. We can see a "white" cross in middle just in front of two ovalish swelling. This is the optic nerve carrying electrical signals from the retina in our eyes to the brain. We will more about these in the lectures on visual function.

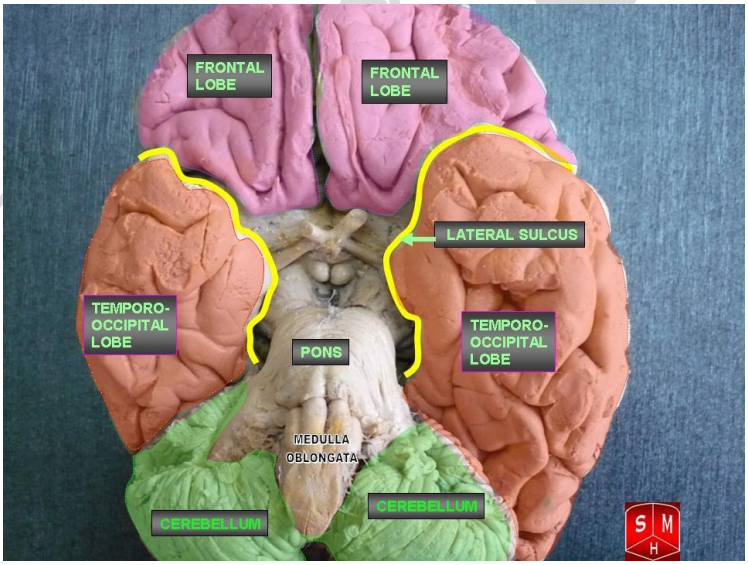
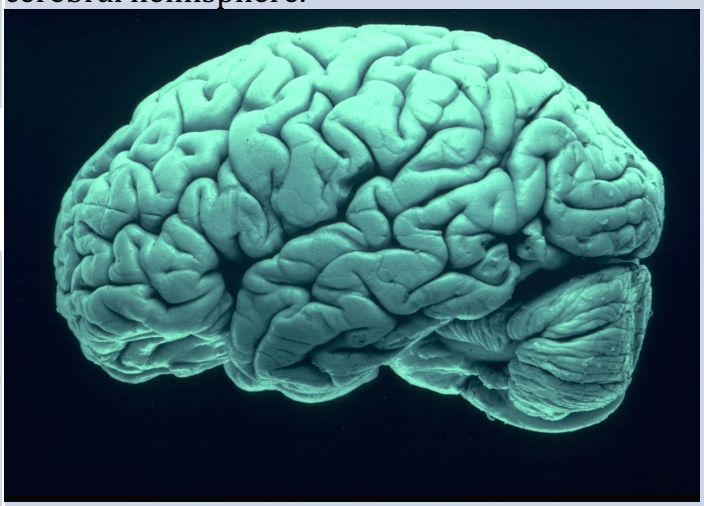


Figure 1.9. The lobes of the brain extend round the base of the cerebral hemispheres eye are send to the occipital lobe. In a living brain the cut ends would extend to your eyes. (Source: en.wikipedia.org)

The bones of the skull overlying the 4 lobes on the lateral surface of the cerebral hemispheres are also named by the lobes the bones lie over. So knowing the names of the bones of the skull, we also know the names of the lobes.

If we go back to the figure 1.8, showing the medial view of cerebral hemisphere, you can see a C-shaped structure, colored in white, in the middle. This is the **corpus callosum** because it is a large, hence callosum, nerve fiber tract through which the two cerebral hemispheres communicate with each other.

In the picture of the lateral surface of the cerebral hemispheres mark out and label the 4 lobes seen on the lateral surface of the cerebral hemisphere.



Brodmann's Classification

Before we leave the discussion on the method of deciding on sub-divisions of the cerebral hemispheres, we need to discuss another method that is used to mark out different areas of the surface of the cerebral hemisphere. It is important for you to know this classification method because it is also used in clinical studes to talk about specific areas of the cerebral hemispheres. This method, called **Brodmann's classification**, divides up the brain into 50 parts, and so it creates a more finer division than the method used for the lobe divisions.

The method is based on the organisation of the nerve cells (cytoarchitecture) in the different areas of the cortex of the cerebral hemispheres. In this classification, the different regions are labelled by numbers rather than letters or

A number of students when asked to draw a diagram of the neuronal circuitry involving the spinal cord put the nerve cell bodies in the white matter of the spinal cord. ***This is absolutely wrong and you will get a zero mark for making such a trivial mistake.***

words.

Confusing on which side of the spinal cord the sensory input comes in from which side the motor output leaves the spinal cord is another elementary mistake student make.
Input is dorsal; output is ventral.

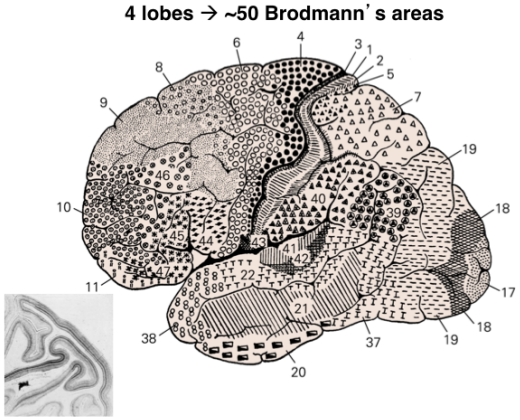


Figure 1.10. The surface of the cerebral hemisphere divided into different areas using the Brodmann's classification which is based on the cytoarchitecture in the different parts of the cerebral hemisphere surface.

A way to remember the difference between Afferent and Efferent is A is for arrival of neuronal signals to the spinal cord and E is for neuronal signals that exit the spinal cord.

Useful method to learn is to draw tree diagrams. So draw an upside down tree diagram starting with the nervous system at the top and all the divisions and subdivisions as you go down.

So in this section, we have discussed how the folds and wrinkles on the surface of the cerebral hemisphere are used to mark the 4 major lobes of the cerebral hemispheres and their anatomical location.

So now we have covered the basic organisation of the nervous system. In the next lecture we will look at the brain from the point of view of function. We will be asking the question: What parts of nervous system are involved in the different functions the nervous system, how they are organized, and how the function is carried out?

1.7 Summary

In this first lecture on the introduction to the Nervous System, we have learnt that the nervous system is divided into different divisions and than these division have sub-divisions. We have learnt of the 7 divisions of the CNS, the 3 divisions of the PNS and the organisation of the spinal cord.

1.8 Activity

1.9 Reading material

Sample Exam Questions

Multiple Choice Questions (MCQs)
Select for each question, the best correct answer.

1) The sulci or fissure dividing the frontal lobe from the parietal lobe.
   a) Medial longitudinal fissure
   b) Central sulcus
   c) Lateral fissure
   d) Parieto-occipital fissure
   e) Slyvian fissure
2) The auditory cortex is located on the
   a) Superior temporal gyrus
   b) Superior frontal gyrus
   c) Middle temporal gyrus
   d) Middle frontal gyrus
   e) Inferior temporal gyrus
3) The nerve fiber tract which the left and right cerebral hemispheres use to communicate with each other is
   a) Corticospinal tract
   b) Corpus callosum
   c) Spinothalamic tract
   d) Sensory tract
   e) Cerebral penduncles
4) The motor pathway cross the nervous system midline at
   a) Diencephalon
   b) Midbrain
   c) Pons
   d) Medulla
   e) Spinal cord
5) In sensory system the cross over of the nerve fibers to the other side takes place in the
   a) Diencephalon
   b) Midbrain
   c) Pons
   d) Medulla
   e) Spinal cord

Short Answer Questions (SAQs)
Note: SAQs have maximum of 5 marks. The answer to the question has to be precise giving all the key points required. If the SAQ requires a diagram or

illustration, we must provide the drawing otherwise we will immediately lose half the marks. We should practice drawing out key illustration or diagrams given in the lecture and in the textbooks.

1. Describe the divisions of the nervous system.

2. Draw a diagram of the lateral surface of the cerebral hemisphere showing the 4 lobes and the naming the main sulci and gyri that make up the boundaries.

3. With an illustration of the sagittal area of the central nervous system (CNS) label the 7 divisions of the CNS.

4. Draw the lateral surface of the left hemisphere and show the location of the primary motor cortex, the primary sensory cortex, the primary visual cortex, and the primary auditory cortex.