
UNIT 2 BIOLOGICAL DEVELOPMENT (DEVELOPMENT OF THE BRAIN AND NERVOUS SYSTEM)

Structure

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2.0 INTRODUCTION

In the previous unit we tried to understand the theoretical perspectives of development in order to understand the meaning of development and growth. Now that you have a fair idea of it, we will, in this unit, try to understand the development of human brain and nervous system. The field draws on both neuroscience and developmental biology to provide insight into the cellular and molecular mechanisms by which complex nervous systems develop. Defects in neural development can lead to cognitive, motor, and intellectual disability, as well as neurological disorders such as autism, Rett syndrome, and mental retardation. It is not possible to understand human behaviour without having firsthand knowledge of the brain and its different structures and their functions. This unit tries to initiate you from the point of processes that generate, shape, and reshape the nervous system, from the earliest stages of embryogenesis to the final years of life.

2.1 OBJECTIVES

After going through this unit, you will be able to:

- Explain the development and stages of development of human brain;
- Describe cells, neurons, their structure and functions;
- Explain the nervous system and its parts;
- Enumerate the functions of different parts of the brain;
- Identify the differences between different parts of the brain; and
- Describe the relationship between brain and behaviour.

2.2 DEVELOPMENT OF THE BRAIN

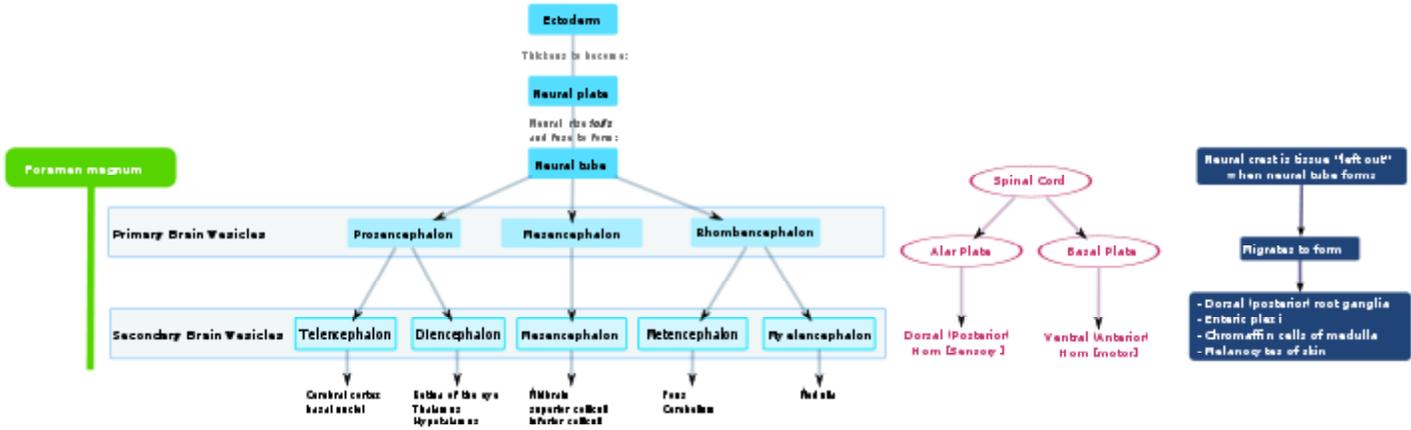
From the point of view of neuroscientists, development of brain can be divided into five stages or five parts, which are (i) Myelencephalon (ii) Metaencephalon (iii) Mesencephalon (iv) Diencephalon (v) Telencephalon

- 1) **Myelencephalon:** This is the first and oldest part of the brain. It extends from spinal cord. It has within it Medulla oblongata. The main function of this structure is to take care of the autonomic activities of breathing, respiration etc.
- 2) **Metaencephalon:** This is the next part of the brain which is old in terms of evolution. It has within it pons and cerebellum. The main function of this structure of the brain is to maintain balance between different physical activities, as for example rhythm and coordination between the movements of hands and legs and other parts of the body. To cite an example is swimming which requires high levels of coordination, balance and rhythmic movement.
- 3) **Mesencephalo:** This is the third in the sequence of development of the brain parts and structure. The two divisions under this include tectum and tegmentum. Tectum has structures termed as superior colliculi and inferior colliculi. As for their functions, the superior colliculi attends to the visual information and the inferior colliculi deals with auditory information. The Tegmentum is inner part of the mesencephalon.
- 4) **Diencephalon:** This is one of the most important parts of the brain. It is small in structure and contains within it the thalamus and the hypothalamus. Thalamus is the structure through which all sensory information from all parts of body are transmitted to different organs and it is called the great relay center. It contains hypothalamus which has as its main function to control homeostasis, emotions and motivations. It also has important role in sexual activities.
- 5) **Telencephalon:** This is the highest division of the brain and latest part to emerge on the scale of development. It encompasses forebrain, Limbic system and cerebral cortex. The forebrain is the largest part of the brain, most of which is made up of the cerebrum. The limbic system is a collective term referring to several brain parts, including the hippocampus and the amygdala. The limbic structures are important in the regulation of visceral motor activity and emotional expression. The hippocampus is important in the formation of memories and other higher functions. Amygdala is a structure whose function is to control autonomic, emotional and sexual behaviour.

Self Assessment Questions

- 1) State whether the following statements are true or false by putting a 'X' over the appropriate letter (T or F).
 - i.) Last portion of brain to develop was telencephalon. (T/F)
 - ii) Earliest part of brain on the scale of development is myelencephalon. (T/F)
 - iii) Diencephalon developed before telencephalon. (T/F)
 - iv.) Mesencephalon comes before diencephalon but after metencephalon. (T/F)

Schematic flowchart of human brain development is presented below the source of which is Wikipedia. It is clearly seen how the human brain develops and through which channels they move etc.



Highly schematic flowchart of human brain development.

Source: (http://en.wikipedia.org/wiki/Neural_development_in_humans)

2.3 CELLS

Physiological psychologists divide cell into three categories namely (i) the receptor cells (ii) effector cells (iii) Glands. Let us describe each of these below:

2.3.1 Receptor Cells

These are cells which receive stimulation from specific type of stimulus. In a normal organism these are affected by four types of stimuli, viz., thermal, mechanical, chemical, and light.

Thermal receptors are in the skin and they are both heat and cold receptors. Mechanical receptors include cells for hearing, balance, and touch sensation.

Chemical receptors comprise of cells for smell, taste and those responsible for sensitivity to chemicals. These receptors make us aware of the changes taking place within the body and the environment outside.

2.3.2 Effector Cells

These include cells that makes the organism to give a response to stimulus. These have specific functions and structures and are of two kinds- *muscles and glands*. Muscles are created out of different types of individual cells and muscle fibers and are of three types a) smooth muscles, found in visceral organs like intestines, abdomen and blood vessels; b) striped muscles, also called skeletal muscles characterised with stripes are found in muscles of arms, legs etc. ; c) cardiac muscles, as the name suggests they are found in the heart. these mke heart work through expansion and contraction.

Glands are another main effectors. These help maintain internal environment of the body through secretion of chemical elements known as hormones. They are of two types:

- endocrine glands, secreting hormones directly into the blood,
- exocrine glands, their secretion goes out of body via ducts, therefore, are also called duct glands like sweat gland, tear glands.

2.4 NEURONS

Neuron is the smallest unit of nervous system. Before proceeding to discuss the main nervous system, we must, first understand neuron, its types, structure and functions. It is neuron which converts stimulation from different stimuli into electrical impulse. On the basis of function they are divided into:

- i) Sensory neuron, responsible for carrying nerve impulse from sense organ to the brain and spinal cord
- ii) Motor neuron, which are responsible to carry nerve impulse from brain and spinal cord to effector muscles so that organism makes response to stimulus,
- iii) Association neuron, which are found only within the brain and spinal cord.

Now that you know neuron and its types, we will study the structure of neuron. Structurally a neuron is divided into three parts,

- i) Dendrite
- ii) Cell body
- iii) Axon

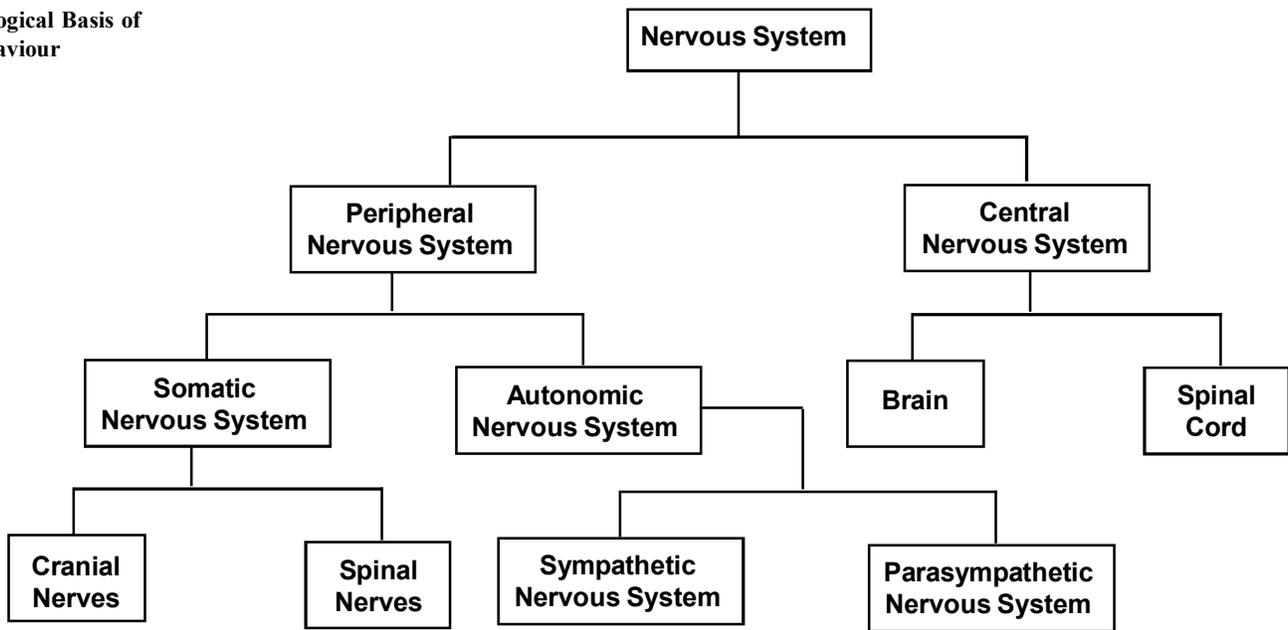
The Dendrite is a bushy structure. Its main function is to receive nerve impulses from other neurons and send to cell body. The cell body, also called as soma is the second main part of neuron. It is filled with a liquid called cytoplasm. In the center is nucleus. It sends nerve impulse to another neuron through axon and keeps the nerve cell alive and healthy. The axon it is a long structure having end buttons known as endbrush. Its function to receive nerve impulse coming from cell body and sends it to the endbrush.

2.5 NERVE IMPULSE

You must be wondering that I told you about cell, neurons, their types, structures and functions, but exactly how the brain functions? how it receives information and how it sends information? answer to your question is nerve impulse. A nerve impulse is an electrical event. When a neuron is in stable or resting condition, inside of the neuron has negative electrical charge and outside is having positive charge. Whenever some stimulation takes place it disturbs this electrical balance so that inside becomes positive and outside is negative. At this moment an impulse is generated aimed at restoring this balance. In this process electrical disbalance runs throughout the membrane. This impulse is then transmitted to another neuron via axon. This way a chain of reaction occurs till it reaches the concerned part of the brain where the meaning of this impulse is deciphered and brain sends directives for activity to the concerned parts of the body.

2.6 NERVOUS SYSTEM

Nervous system is a complex structure. It controls all our activities and functions as a whole in an integrated manner. Given below is the flow chart of human nervous system.



2.6.1 Central Nervous System

This comprises of two parts i.e. brain and spinal cord. *Spinal cord* runs from cervics to the end of waist. It is filled with fluid which is covered with **meninges**. It has thirty one divisions from which pairs of spinal nerves comes out at regular intervals. It is a great conductor of nerve impulses. All the sensory information from various parts of body are received here and then sent to higher parts of the brain. All motor information from brain first enters spinal cord and then sent to different parts of body for action. Besides this, the spinal cord also functions as center of reflex actions. Given its importance it also called the **automatic machine**.

Brain is located in the bony skull. Within the skull, the brain is protected by three layers of tissues called **meninges**. Outer most layer is called *dura matter* and inner most layer is called *pia matter*. Between these two layers is a soft membrane called arechnoid. Arechnoid is filled with CSF (cerebro spinal fluid). Brain is composed of white and grey matter. White matter is called so because it is covered with a sheath known as *mylin sheath*. From the view point of physiologists, the brain is divided into three parts, which is as given below.

- A) Fore brain (thalamus, hypothalamus and cerebrum).
- B) Mid brain (situated between forebrain and hind brain)
- C) Hind brain (medulla, pons, cerebellum and reticular formation)

We will start our journey of brain from the back i.e. **Hind brain**, because from evolutionary point of view it is the earliest part to develop. The first and foremost structure of Hind brain is **medulla**. Medulla connects higher parts of the brain with spinal cord. It also includes a portion of reticular formation, called the vital center of the brain. It is responsible for autonomic activities of respiration, heart rate, blood pressure etc. Destruction of this part of the brain can lead to instant death of the organism.

Pons, another important part of Hind brain, is located above the medulla. It contains different types of sensory and motor neurons. It receives sensory

information from some parts of face and head and sensations of touch, pain, and temperature. It also regulates motor activities related to facial expressions, muscular activities, eye balls and jaw movements. Besides it also acts as connection center between higher and lower parts of brain.

Cerebellum, located at the back of Hind brain, is a complex structure. Its outer structure is composed of grey matter while inner structure is made up of white matter. In appearance it resembles cerebral cortex. Its main function is to coordinate motor activities. Destruction of cerebellum leads to lack of coordination as for example, a person can walk but his gait would be disorganised.

B) **Midbrain** encompasses brain above the pons and acts as a bridge between forebrain and Hind brain. It has two subdivisions called **tectum** and **tegmentum**. Tectum has a pair of structures called **superior colliculi** and **inferior colliculi**. Superior colliculi is roof and concerned with visual information while inferior colliculi is on the floor and deals with auditory information. Tegmentum lies below tectum. It has some important structures like rostral, end of reticular formation and nuclei controlling the activities of eye movements. Sensory impulses from lower parts to higher parts of brain and motor impulses from higher parts to lower parts of brain pass through it.

Starting from medulla in the Hind brain and extending to midbrain and hypothalamus of forebrain, a net of fibers pass by and is called reticular formation. Since this structure regulates and controls the activities of sleep, arousal and attention it is also called reticular activating system. It has two subsystems (i) ascending reticular system and (ii) descending reticular system. Ascending system sends sensory impulses to cerebral cortex while descending system receives motor impulses from brain and sends them to spinal cord. Destruction of this system sends an animal into sleep and may even into coma. It acts as filter as for example, when we are concentrating on some task we receive no other sensation except the ones on which we are focused. It happens because RAS does not filter away all other sensations and do not allow them to reach the brain.

A) **Forebrain**: Now we will discuss the most important part of the brain i.e. forebrain. This portion of brain regulates and controls all higher and complex activities of human beings e.g. thinking, reasoning, memory etc.. Neuroscientists divide it into two parts-**telencephalon** and **diencephalon**. Telencephalon includes in it cerebral hemispheres, limbic system and basal ganglia. Diencephalon includes Thalamus and Hypothalamus. However psychologists have paid much attention on the structure and functions of thalamus and hypothalamus and cerebral hemispheres because almost all the activities are controlled and regulated by these parts.

Thalamus is an oval shaped structure is located right above the midbrain and between the two hemispheres. Thalamus contains three types of nuclei-sensory nuclei which receive sensory impulses relating to vision, hearing, pain, temperature, taste, and smell and sends them to appropriate parts of the cerebrum. Another type of nuclei receive nerve impulses from cerebellum, brain stem and reticular formation and send them to cerebrum. Third type of nuclei receive impulses from within the thalamus and sends them to cerebrum.

Hypothalamus is a small structure located below the thalamus. It is very important and functions to regulate and control – biological motives of hunger, thirst and sex. It also controls and regulates homeostatic mechanism of our body as for example, when we feel hot it causes us to sweat thereby reducing our body temperature and when we feel cold it causes us to shiver thereby raising our body temperature. Hypothalamus also regulates the activities of autonomic nervous system and endocrine gland. It regulates the functioning of pituitary gland which affects the functioning of all other glands. Hypothalamus plays an important role in the regulation and control of emotions like anger, fear and aggression.

Basal ganglia includes caudate nuclei, putamen, globus pallidus and some part of amygdala. It plays an important role in motor control. Destruction of this portion may lead to Parkinson's disease.

Limbic system has five main parts – olfactory bulb, septal area, hippocampus, amygdala and cingulate gyrus. Olfactory bulb receives smell sensations. Septal area, cingulate gyrus and amygdala play important role in the regulation of emotions. Hippocampus plays an important role in memory.

B) **The Cerebrum** largest portion of the brain is divided into two hemisphere by the longitudinal fissure. Both right and left hemispheres are composed of gray matter. In layman's language it is said that larger the gray matter the more intelligent a person will be. The two hemispheres are connected through corpus callosum, a bundle of nerve fibers. Each hemisphere has two deep fissures known as fissure of Rolando and central sulcus or lateral fissure. These fissures together divide each hemisphere into four parts or lobes:

- *Frontal lobe* is located in front of the central sulcus and above the lateral fissure. It plays important role in motor activities and higher mental processes. It has motor cortex, Broca's area and frontal association area.
- *Parietal lobe* located behind central sulcus and above the Sylvian fissure it is primarily responsible for bodily sensations and knowledge of direction.
- *Temporal lobe* located below central sulcus in the temple it has Wernicke's area and temporal association area.
- *Occipital lobe* is located at the back of each hemisphere and it is the primary area for visual sensation.

2.6.2 Peripheral Nervous System

This comprises of all those neurons which lie outside the brain and spinal cord and connect these two with receptors, effectors and glands. It is divided into two parts i.e. somatic and autonomic nervous system.

- **Somatic nervous system** is primarily related to voluntary activities. Central nervous system sends impulses to voluntary muscles through somatic nervous system. It is further divided into cranial nerves and spinal nerves.

Cranial nerves originate from the bony skull and are found in pairs of twelve nerves. These are motor, sensory and association nerves. **Spinal nerves** originate at regular intervals from the spinal cord and there are 31 pairs and are divided into five parts:

Name	Number	Position
Servical	8	Neck
Thoracic	12	Chest
Lumbar	5	Coin/waist
Sacral	5	End of spinal column
Coccygeal	1	End of spinal column

- ***Autonomic nervous system***

This is rather important portion of peripheral nervous system. It comprises those neurons or nerve cells which are connected and regulate and control involuntary muscles, glands like kidneys, cardiac muscles, endocrine glands etc. Although connected with brain and spinal cord it acts in an independent manner. Autonomic nervous system is further subdivided into- **sympathetic nervous system** and **parasympathetic nervous system**.

Sympathetic system is located in the thoracic and lumbar region of spinal cord and is therefore known as thoraciclumbar system. It acts in integrated manner. It prepares our body for emergency situations e.g. when faced with danger it activates adrenal gland and pancreas thereby increasing the quantity of blood sugar in blood and also increases the rate of metabolism. All these changes in the body give us extra energy to meet the emergency situation.

Parasympathetic system is located in the cranial and sacral regions of the spinal cord hence called craniosacral system. It functions to restore our bodily processes to normalcy. In other words it is the opposite of sympathetic system. It lowers metabolic rate, heart beat and quantity of blood sugar in the blood.

Although the two systems are antagonistic they tend to act in a coordinated manner e.g. in situations of fear or anger adrenal gland, pancreas are activated by the sympathetic system to generate more energy. The parasympathetic system suspends digestive activity and other functional systems so that energy freed from these is available for use to meet the emergency situation.

2.7 LET US SUM UP

We have discussed the evolution and development of brain. We discussed neuron the smallest and basic unit of brain. Now we know how the neuron functions. We discussed how the brain receives information from environment. We also discussed broad outlines of the brain. While discussing the brain we acquainted ourselves with different parts of the brain like central nervous system, peripheral nervous system and their subdivisions. We also talked about how the different systems and subsystems of nervous system function and affect our body and behaviour as for example, our behaviour in emergency situation is different from normal situation and this is caused by activation of sympathetic and parasympathetic systems. Now we know what the absence or destruction of different parts of brain affect our body functioning and our behaviour in turn e.g. destruction of basal ganglia can lead to Parkinson's disease. Thus now you know all about the basics of brain and nervous system and can apply this knowledge with modification if necessary.

2.8 UNIT END QUESTIONS

- 1) Discuss the development of brain.
- 2) What are cells? and what are their different types?
- 3) Discuss the structure and functioning of neuron?
- 4) Write detailed description of central nervous system.
- 5) Discuss sympathetic and parasympathetic nervous system and how they function in integrated manner?

2.9 SUGGESTED READINGS

Inderbir Singh (2008). *Anatomy and Physiology for Nurses*. Jaypee Brothers, New Delhi

Marieb, Wilhelm (2010). *Essentials of Human Anatomy & Physiology*, Ninth Edition Companion Website Pearson Education. New York.