BPCC-102

BIOPSYCHOLOGY

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Indira Gandhi National Open University

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PRINT PRODUCTION

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Tamal Basu
New Delhi

December, 2019

ISBN :

Printed and published on behalf of the Indira Gandhi National Open University, New Delhi by Director, School of Social Sciences.

Lasertypesetted at Graphic Printers, Mayur Vihar, Phase-I, Delhi-110091.

Printed at :

Course Contents

BIOPSYCHOLOGY: HOW TO PROCEED IN THE COURSE?

The course on BIOPSYCHOLOGY (BPCC-102) is the second core course offered in Ist Semester of BA Psychology Honours Programme, under Bachelors Degree Programme of IGNOU. The course is of 06 Credits, comprising Theory (04 Credits) and Tutorial (02 Credits). As per the credits, there will be 04 academic counseling sessions related to theory. 01 session will be of two hours. Similarly, for two credits tutorial, there will be 02 academic counseling sessions.

The course is divided into four blocks. Each of these blocks represents a specific theme which is discussed in one to two units. The units are arranged in a logical sequence so as to cover the main aspects of each theme. Each unit contains a brief introduction in the beginning and a list of references and further readings, as well as, online resources at the end. The list of online resources has been mentioned especially, since many of you would be having internet access. Therefore, for additional information on various topics, this section has been added. You are advised to read Course Introduction carefully, in order to know about the rationale and content of the course you have offered to read.

You have in your hands, all the four blocks and six units of this course. Before proceeding to read the units, you are advised to go through instructions about how to read the course material. Given below is the explanation of the organization and sequencing of the unit. We will tell you what is contained in various sections of a unit, and you should go about completing different tasks involved while reading the course material.

Organization and Sequencing of the Unit

The unit starts with,

1.0 Learning Objectives

1.1 Introduction

1.2 Section (Theme of the section)

1.2.1 Subsection of 1

…….

Check Your Progress

1.3 Section (Theme of the section)

1.3.1 Subsection of 2

…….

Check Your Progress

The numbering and length of each section and subsections may vary from one unit to the other unit, depending upon the depth of information in each unit. The last four sections in each unit with the following headings are also numbered. They are as follows,

- Review Questions
- References & Further Reading

- References for Figure
- Online Resources

As the scheme suggests, each unit is divided into sections for easy reading and better comprehension. Each section is indicated by **BOLD CAPITALS** and each sub-section by a **relatively smaller but bold typeface**. Divisions within the sub-sections are in **relatively smaller bold typeface** so as to make it easy for you to understand.

Let us now discuss each section of a unit.

Learning Objectives

We begin each unit with the section Learning Objectives. It tells you briefly what we expect from you once you complete working on the unit.

Introduction

In the section Introduction, we specify,

a) The relationship of the present unit to the previous unit.

b) The theme of the present unit

c) The order of presentation of all the sections in the unit from Introduction to Summary.

Summary

This section of each unit under the heading Summary, summarises the whole unit for the purpose of ready reference and recapitulation.

Box

Sometimes certain topics may deal with abstract ideas and related concepts, as well as some case studies. Thus, it becomes necessary to explain these related concepts in a separate enclosure, which is called Box, in our units. This is added information which is necessary to comprehend the main text. These boxes may include (i) explanatory notes regarding concepts, (ii) information about main works of scientists/ psychologists who have contributed to a particular topic, (iii) certain case-studies that are related to the concepts being discussed, etc.

Illustration

There are several illustrations in each unit in the form of pictures, figures, diagrams and images. The main purpose of these illustrations is to make the study comprehensive and interesting.

Check Your Progress

We have given self-check exercises under the caption Check Your Progress at the end of main sections. To answer the Check Your Progress questions, you should,

a) Write your answers using the space given below each question

b) Label the diagrams in the space provided.

You will be tempted to have a glance of the main text as soon as you come across an exercise. But we do hope that you will resist this temptation and turn to the main text only after completing the answers.

You should read each unit and note the important points in the margin provided in the course material. This will help in your study. It will also help you to answer the self-check exercises and the assignment questions, as well as help in revising your course before appearing for your Term End Examination.

Key Words

Each unit has key words at the end of the unit, to explain the basic ideas, technical terms and difficult words.

References & Further Reading

We have given a list of references at the end of each unit. There is a list of books and articles used by the course writers to prepare the units. This reflects that your course material is based on a wide spectrum of literature available on a particular theme, related to your course. This also informs you of the wide literature available in the particular area of study. If interested in widening your knowledge, you may look for the mentioned references. Each reference mentions the name of the author, year of publication, title of the book/article, name of publisher and place of publication.

Further readings help you to increase your level of understanding of a particular theme in each unit, though it is not a compulsory reading.

References for Figure

We have provided a list of references for the sources of images and pictures, in each unit, after the References & Further Readings section. The images and pictures in the units have been retrieved from online sources and hence, the URL for the figures has been mentioned. If interested, you may also look for the mentioned references.

Online Resources

We have given a list of online references, on various topics, in each unit after References for Figure section. Apart from the text material, if you are interested in learning more about the topic, then you may access the website as mentioned, for a particular topic.

Review Questions

Besides Check Your Progress, we have given Review Questions after summary section in each unit. You may practice these questions which will help you in answering assignments and Term End Examination Question Paper, though the pattern and style of questions asked may not be similar.

Audio and Video Aids

Some Units have been selected for the audio and video programmes to supplement the printed material. This will help you to understand the units with greater clarity.

Apart from this, you may also access IGNOU's FM radio channel, Gyanvani (105.6 FM)which is available across many cities in India, for regular programmes, related to themes on Psychology. You can listen to the live discussions by faculty and experts on the topic of the day and interact with them through telephone, email, and through chat mode.

You may also watch Gyandarshan TV channel (free to air educational channel), for programmes related to topics on Psychology. The schedule of Gyanvani and Gyandarshan is displayed on www.ignou.ac.in. The radio and TV channels may also be accessed on Gyandhara, webcast facility for Gyanvani and Gyandarshan, provided by the University.

Tutorial

The course on Biopsychology will include tutorials. These tutorials are compulsory and are of 02 Credits. It will be in form of activities and evaluated by your academic counsellor. You should carefully read the course material and apply the information. These activities are meant to develop your ability to relate your knowledge to day-to day life experiences.

Assignments

You will receive assignment for the whole course. This is a Tutor Marked Assignment, which is submitted to the respective Study Centre after completion. The assignment will be evaluated by academic counsellor from your Study Centre. Ensure that you complete the assignment because 30 percent weightage is given to the grades that you get in the assignment and is included in the final evaluation of your course. Before answering the assignment, read all the units and additional material (if available). While working on the assignment, kindly ensure the following points,

1) Clearly write your enrollment number
2) Answer them in your handwriting and in your own words
3) Write clearly and neatly so that it is easy to read your answers
4) Leave margins on one side of your answer-sheets so that evaluator may write his/ her comments on your performance
5) You will submit the assignments at your Study Centre on or before the date mentioned as per the admission cycle. Kindly check the dates from www.ignou.ac.in or your Regional Centre website.

Term End Examination

After reading and understanding the course material, as well as referring to the audio and video programmes, you will be writing the Term End Examination (TEE) for the course. Kindly consider the following points while answering for TEE.

1) Questions should be replied in one's own words and should be focused.
2) Answer questions keeping in mind the word limit.

Preparation of Course Material

The syllabus of course material BPCC-102 is designed by an Expert Committee (see page 2 of this course) and prepared by Course Preparation Team which comprises the author(s) of units, content editor(s), language editor, and the course coordinator. The expert committee selected the themes and sub-themes of the blocks and units, keeping in view the prescribed syllabi of UGC-Choice Based Credit Scheme. The authors of units have provided their expertise in elaborating them in the form of the main text of each unit. The content editor has carefully examined the course contents and has made an attempt to make the material clear and comprehendible.

For any query or feedback related to the course, you may kindly contact the course coordinator at,

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COURSE INTRODUCTION

You must be wondering why you have to learn about Biopsychology. With the remarkable advances in behavioural neuroscience, Biopsychology has emerged as a significant branch in Psychology. If we revisit the range and scope of Psychology, then it may be stated that Psychology is a science that studies behavior and mental functioning. The scientific study is carried out from both pure and applied perspectives. Thus, it tries to answer questions related to genetics, environmental influences, consciousness, mental disorders, working in groups, etc. from psychological perspective.

Biopsychology, as the name suggests, is a branch of Psychology that studies the relationship between brain and behavior. This also means that, brain and behavior are intrinsically associated. In order to understand behavior, Biopsychologist tries to understand the underlying neural mechanisms. It is an interdisciplinary branch that overlaps with other branches like cognitive psychology, cognitive neuroscience, neuropsychiatry, etc.

Biopsychology is the second Core Course in BA Psychology Honors Programme. It introduces you to the field of Biopsychology, underlying neural mechanisms, human brain structures, cognitive neuroscience techniques to study covert processes, localization of brain functions and the impact of endocrine system on human behavior.

BLOCK INTRODUCTION

There are four blocks in this course. Block 1 tells you about the field of biopsychology and the neuron and neural communication. Block 2 deals about the divisions of nervous system, namely the central nervous system and the peripheral nervous system. The Block 3 explains about localization of brain functions and the endocrine glands are discussed in Block 4.

Block 1 introduces you to the field of Biopsychology. This block will give you an idea about what will follow in other blocks as well. It comprises of two Units. Unit 1 describes about the emergence of the field of Biopsychology. It will further discuss the nature, scope and divisions of Biopsychology. Studying and conducting research in this area is highly scientific. Thus, major neurological techniques employed to study brain-behaviour relationship will be discussed followed by ethical considerations involved in neuropsychological research. Unit 2 will shed light on the basic cells of nervous system,that are neurons. The basic structure and functioning of neurons, neural conduction, synaptic transmission and neurotransmitters will be explained. This unit will also discuss about important neural responses like, neural degeneration, regeneration, reorganization and recovery.

Block 2 introduces you to the nervous system. This block consists of two units. The first unit (Unit 3) covers the divisions of nervous system and will focus on Central Nervous System(CNS) The main parts of CNS, that are spinal cord and brain will be discussed. It will also explain the brain processes related to consciousness as well as the major disorders caused as a result of any damage to the CNS. The second

unit (Unit 4) will describe the Peripheral Nervous System (PNS). An outline of cranial nerves and spinal nerves is given in this unit. PNS will further be explained with the help of its divisions like, somatic nervous system and autonomic nervous system. Finally, the functioning of sympathetic and parasympathetic divisions will be discussed.

Block 3 consists of one unit (Unit 5) that introduces you to hemispheric specialization. It will focus on the differences between the left hemisphere and the right hemisphere. The unit will also explain the techniques to study the mechanism of brain lateralization.

Block 4 consists of one unit (Unit 6) that gives a description of the endocrine system. Major endocrine glands that influence behavior will be explained in this unit.

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BLOCK 1

INTRODUCTION TO BIOPSYCHOLOGY

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UNIT 1 INTRODUCTION TO BIOPSYCHOLOGY*

Structure

1.0 LEARNING OBJECTIVES

After you have read this Unit, you will be able to:

- explain the nature and scope of biopsychology;
- describe the different divisions of biopsychology;
- discuss the research methods used in biopsychology;
- describe the neuropsychological assessment procedures; and
- explain the ethical considerations for research in biopsychology.

1.1 INTRODUCTION

Most of us are familiar with the image and pictures of human brain. Though not very attractive, it resembles a wrinkled walnut (see Figure 1.1). It is made up of tissue,

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weighing only about 1.3 kilograms, but consists of infinite neural connections (neurons) which control all our behaviours. The human brain is highly complicated. It is an organ that is responsible for so many varied tasks and activities ranging from simple to complex, and still, it is the least understood organ of our body.

(a) (b)

Figure 1.1(a) Dorsal view of human brain (b) Ventral view of human brain

The scientific study of the anatomy, biochemical processes and the physiology of nervous system is known as neuroscience. A closely related field of the neuroscience is *biopsychology*, which draws information from it to study human and animal behaviour. It is also known as *psychobiology*, *behavioural biology* or *behavioural neuroscience*. In this unit, we will discuss about this related branch of neuroscience, that is biopsychology. Major divisions of biopsychology and various methods employed to study it, will be described. Further, we will also discuss about the ethical issues involved in the field of biopsychology.

1.2 NATURE AND SCOPE OF BIOPSYCHOLOGY

Figure 1.2: Donald Olding Hebbs (1904-1985)
Image Source: https://can-acn.org

The biological approach to the study of human and animal behavior is known as biopsychology. The biopsychologists try to investigate scientifically how biological processes interact with cognition, emotions and other psychological processes.We can trace a long history of the study of biology of behavior. But biopsychology as a separate discipline of neuroscience, emerged in the 20th century. D. O. Hebbs' (Canadian psychologist) seminal publication, *The Organization of Behaviour* in 1949, in the field of psychology and neuroscience, paved the way for future investigation of neural foundations of behavior. What Hebb proposed in 1949, is being applied in the present times in the fields of engineering, robotics, psychology, neuroscience, and neurophysiology.

Biopsychology, thus, draws information from neurosciences and uses the information to study human and animal behavior. It may be better understood as that neuroscience is a team effort and biopsychologist is a part of this team. A biopsychologist may draw information from other disciplines of neuroscience and apply it to the study of behavior. Few of the disciplines of neuroscience that are of particular relevance for biopsychology are as follows:

- **Neuroanatomy:** It is the study of the structure of the nervous system
- **Neurochemistry:** It is the study of chemical aspects of nervous activity
- **Neuropathology:** It is the study of disorders of nervous system
- **Neuroendocrinology:** It is the study of interaction between the nervous system and endocrine system
- **Neuropharmacology:** It studies the impact of drugs on neural activity
- **Neurophysiology:** It studies the functions and activities of the nervous system

So, it may be rightly said that the field of biopsychology is diverse and it is one of the branches that contributes to neuroscience. The research conducted in biopsychology is also from varied perspectives. Biopsychological research is conducted on human or non-human participants. The most common non-human research participants are mice, rats, followed by cats, dogs and primates. There are three advantages in conducting research on non-human participants. The first being, that the brain and behavior of non-human participants is less complex as compared to human participants. Thus, the basic fundamental brain-behaviour interactions may be revealed. Secondly, conducting research on such a group leads to a comparative approach where biological processes of different species maybe compared. Thirdly, it is easy to conduct research on laboratory animals rather than human participants due to ethical reasons, that is there are fewer ethical constraints while we conduct research on animals. Though, the research in Psychology and its branches, are all governed by strict ethical guidelines framed by organizations, like American Psychological Association (Guidelines for Ethical Conduct in the Care and Use of Nonhuman Animals in Research), and Indian Council for Medical Research (ICMR Guidelines for Biomedical Research in India). Research in biopsychology may be a *pure research* or *applied research*, and the study is based on empirical investigations with applications for the society. The research can be done using an experimental approach or non-experimental approach or case studies. The scope is to understand the basis of behavior. Behaviour changes are primarily due to disruptions in various brain regions and neural circuits. This may happen because of head injury. Secondly, learning, exercise, etc, also changes the neural structures. So, how it produces a corresponding change in behavioral functions can be studied with the help of various research methods that are used to understand the functioning of the mental processes by examining the biological systems.

Biopsychology also aims to understand aspects like, the evolution of brain and its influence on behavior, the development of the nervous system across the life span, which areas of the brain are involved in sensation, perception, memory, movement, the role of brain in emotional expression and regulation, language and cognition, and how the behavioral change occurs after brain damage or trauma. It also seeks to understand the role of genetics and endocrine system in maintenance of homeostasis, and enhancing health and wellbeing of people suffering from various neurological disorders. There has been some very significant research related to brain-behaviour interactions that have been awarded Nobel Prize! You must have read about Ivan Pavlov, a Russian physiologist, in the course Introduction to Psychology(refer to Classical Conditioning). Pavlov was Nobel prize winner in 1904 for his research on physiology of digestion.

Box 1.1

Pure research: It is also known as basic or fundamental research. It is conducted without any prior aim or goal. It is exploratory in nature and driven by intuition and interest.

Applied research: It is conducted with a prior aim. Specifically, it starts with the aim to solve an existing problem. Thus, it is descriptive in nature and has practical implications. This type of research is mainly conducted in technology, medicine, agriculture etc.

1.3 DIVISIONS IN BIOPSYCHOLOGY

You have just learned about the nature and scope as well as how research is being conducted in different ways in the area of biopsychology. There are few approaches that gained prominence and consequently separate divisions of biopsychology emerged. Biopsychology has six main divisions such as: physiological psychology, psychopharmacology, neuropsychology, psychophysiology, cognitive neuroscience, and comparative psychology. These approaches are overlapping and many biopsychologists follow more than one approach.

Physiological psychology: Physiological psychology uses controlled experimental conditions to stimulate the brain and study its effects on behavior. It involves direct manipulation and recording of the brain by primarily using surgical or electrical stimulation on animals for research. Their aim is to develop theories about how neural mechanisms control behavior.

Psychopharmacology: Psychopharmacologists use drugs to stimulate neural systems and then observe their effects on behavior. The purpose is to study the interaction between brain and behavior, but majorly the experiments are applied in nature, focusing on developing therapeutic drugs and reduce drug use.

Neuropsychology: Neuropsychologists study the patients who have had some head injury or trauma and are suffering from brain damage. The neuropsychological tests help to diagnose the impairments and work out a suitable treatment for dealing with it. This sub-discipline specially uses case studies and quasi-experimental studies of patients with brain damage caused due to disease, accident or neurosurgery. The focus of these studies is cerebral cortex (you will learn more about this part in Unit 3), the most prominent part of mammalian brain which consists of cellular layers on the outer surface of cerebral hemispheres.

Psychophysiology: Psychophysiologists use non-invasive techniques (the physiological activity is recorded from the surface of the body) to examine the relationship between physiological activity and psychological processes as attention, learning, memory, emotions in human participants. Various measures that are used are like, scalp electroencephalogram (EEG), muscle tension, eye movement, galvanic skin response (GSR), heart rate, blood pressure, and pupil dilation.

Cognitive Neuroscience: Cognitive neuroscientists study the neural bases of cognition and higher order cognitive processes, like, thinking, memory, attention as well as perceptual processes. Hence, human participants are taken for research. The techniques used are non-invasive. Functional brain imaging is the main method of recording the brain activity.

Comparative Psychology: Comparative psychologists study the behavior of different species to understand their behavior from evolutionary, genetic and adaptation perspective. Behaviour is studied in either laboratory condition or it may be observed in its natural environment. The latter is known as *ethological research*.

Check Your Progress 1

1) Define biopsychology.

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2) List the main divisions of biopsychology.

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1.4 METHODS TO STUDY BIOPSYCHOLOGY

The preceding sections introduced you to the nature, scope and major divisions of biopsychology. This section deals with the methods employed to study human brain. The structure of the brain (see Figure1.1) is quite complex and understanding its working is all the more challenging for the researchers. With the discovery of Broca's area, it was concluded that different brain areas had different functions.In 1861, Paul Broca, French neurologist, found that one of his patients who had lost the ability to speak, had damage in left frontal cortex. More patients with loss of speech showed damage in and around this area, which is now known as Broca's area.

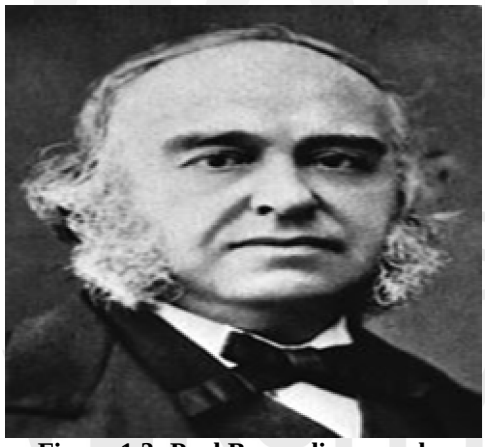

Figure 1.3: Paul Broca discovered a region of the brain responsible for language.
Image Source: https://www.nature.com

Thus, the research conducted in this area concludes that brain damage causes effects like increase or decrease in hunger, changes in emotional responses, to mention just a few. Let us see the main methods used in the study of brain.

1.4.1 Ablation Methods

Ablation means removal of a brain area, generally with a surgical knife.It is different from lesion. Both ablation and lesion methods are invasive and involve cutting a part of brain. Ablation method thus, involves the destruction of some tissue in the brain.This is followed by assessing the changes that occur in behavior due to the removal or destruction of the tissue. Any wound or injury thereby, is known as a lesion.But one has to be very careful as different parts of the brain are all connected to one another and work in conjunction with another. So if a lesion is created in one area, it may exert an influence on the neighbouring areas as well. Sometimes the animal also recovers from the brain damage either partially or the functions of the damaged part of the brain are covered up by another part of the brain.There are different ways to cause lesions.The main techniques discussed here are aspiration, radio frequency, knife cuts, cryogenic blockades and nerve poison.

- **Aspiration:** A fine thin needle is placed on the tissue (which can be seen by the surgeon and accessible by the instruments) that needs to be examined and it is

aspirated and the contents are then placed on the slide and examined for any diagnostic analysis.This is generally the preferred technique when a part of the cortical tissue has to be sucked to reveal the area that is under it for further investigation.

- **Radio-Frequency:** Radio frequency (RF) current is used to produce sub-cortical lesions. The wire is placed on the tissue which needs to be examined. Radio-frequency devices produce a high frequency current, that is alternating current. The heat that results from this current destroys the tissue in that area. The duration and intensity of the current will determine the size and shape of the lesion.

- **Knife Cuts:** Sectioning (Cutting) is used to make a cut on any area of the nerves or the brain. There is a special device that is used to make sub-cortical knife cuts very carefully by placing the brain using a stereotaxic apparatus. By using such a technique, extensive damage to the surrounding area is decreased.

- **Cryogenic Blockade:** This is a temporary way of inducing lesions. A cryoprobe is placed in the brain.Through this tube a coolant is sent to the area under study.The coolant reduces the temperatures at its tip to such an extent that the neurons stop sending impulses. Since the temperature is maintained at above freezing point there is no structural damage. Once the temperature is restored to the normal level, the neurons start functioning again.

- **Nerve poison:** Certain chemicals such askainic acid or ibotenic acid are used as nerve poisons to create lesions in a particular area in the brain. These chemicals are inserted through a glass tube known as cannula. The destruction is only partial, that is only the cell bodies are destroyed. So, if there is any change in behavior, then that can be attributed to the cell bodies.

1.4.2 Histological Methods

With the advent of technology in the present times, there are many techniques and methods to study anatomy and functioning of human brain. For studying minute details of tissue (microscopic investigation), histological methods are used for the purpose. In this method, the sample of the brain that is under investigation, needs to be prepared so that it can be mounted on a slide and observed under a light microscope. The neural tissue is very fragile and under normal conditions it may just disintegrate. Hence, the tissue needs to be fixed and stained inorder to be viewed on the slide. When it is taken out, the bacteria or moulds tend to decompose the neural tissue. Let us now look at the procedures in histological methods.

- **Fixation:** In this method, a fixative is used to fix the tissue.The tissue is cleaned and dipped in a fixative solution. The most commonly used fixative is formalin. This fixative prevents autolysis and makes the tissue hard. But still, the tissue is not so hard to be cut using a microtome (automatic slicing machine used in microscopy to produce thin sections of the fixed and embedded tissue for microscopic observations). Hence, the brain tissue is freezed so that the tissue becomes more hard. It is also used to stabilize neural tissue.

Box 1.2 : Autolysis

'Auto' means self. Thus, autolysis is the self-digestion or breakdown of cells in animal, plant or microorganism tissue by their own enzymes.

- **Freezing:** In freezing, the tissue needs to be frozen, in order to be sliced. To freeze the tissue, it is dipped in a sugar solution and then put in a freezer. The

temperature is regulated in a way so that the tissue is maintained at an appropriate temperature. Once the tissue is hard enough, it is to be placed on the microtome to be sliced.

- **Embedding:** Another way to make the brain tissue hard is by embedding and covering it by paraffin or nitrocellulose. Once the tissue is hard then it is cut using a microtome. These slices are then placed on a slide and mounted on it using albumin which is taken from the egg. The slide is dried, it is then dyed using different chemical solutions.
- **Staining:** It is done so that the structural details of the tissue become apparent under the microscope.This is done by darkening or colouring particular features of the tissue. Nissil stains or cell-body stains are most frequently used to dye the cell bodies. Myelin stains color the myelin sheath to study the nerve pathways. Membrane stains like golgi-cox stain, helps to color the cell body, dendrites and axon.

1.4.3 Psychophysiological Recording Methods

There are different psychophysiological methods that help to examine human participants in a non-invasive way. Such methods record from outside the skull (and other parts of the body) without inserting anything. The most widely used methods in this category are as follows:

- **Electroencephalography:** The electrical activity of the brain is recorded using Electroencephalograph (EEG) machine and the technique is known as electroencephalography. Electrodes are placed on the scalp of the patient and recording is done on the computer. Earlier a rolling paper was used where the readings were displayed, now a computer printout is taken. The EEG signals help in the diagnosis of various disorders of the brain, mild head injury, cerebral pathology, epilepsy, and speed of processing information or how the memory functions with an increase in age.

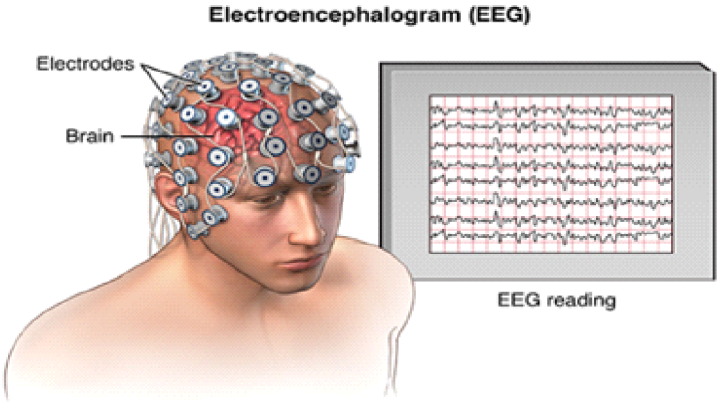

Figure 1.4: EEG and an example of the electrical waves that are read by each electrode

Image Source: https://hvmn.com

- **Magnetoencephalography:** Also referred as MEG, measures the changes in magnetic fields on the surface of the scalp, produced by changes in the basic patterns of the neural activity.
- **Electromyography:** The muscle tension is recorded with the help of electromyogram (EMG). The electrodes are attached to the skin over the muscle that is to be investigated. When the muscle contracts producing muscle tension, it is recorded.This information helps us to know about muscle tone.

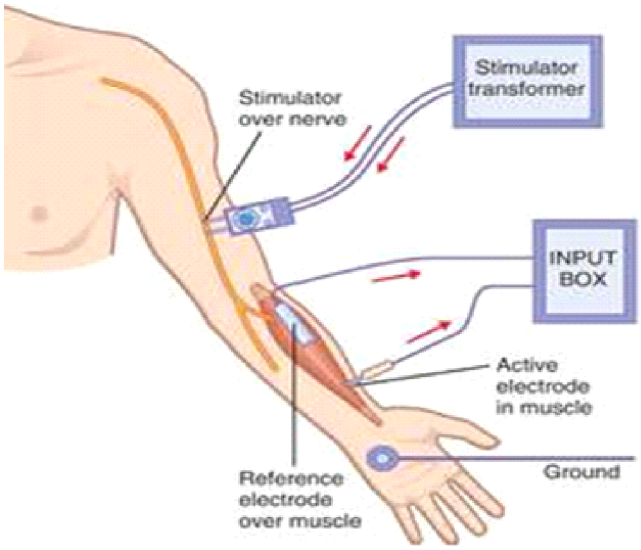

Figure1.5: Electromyogram

Image Source: https://medical-dictionary.thefreedictionary.com

- **Electrooculography:** The eye movements are recorded by using an electrooculogram (EOG).There is a slight difference in the electrical potential in the back and front portion of the eye ball.This difference in potentials is recorded with the help of electrodes that are placed near the eye.

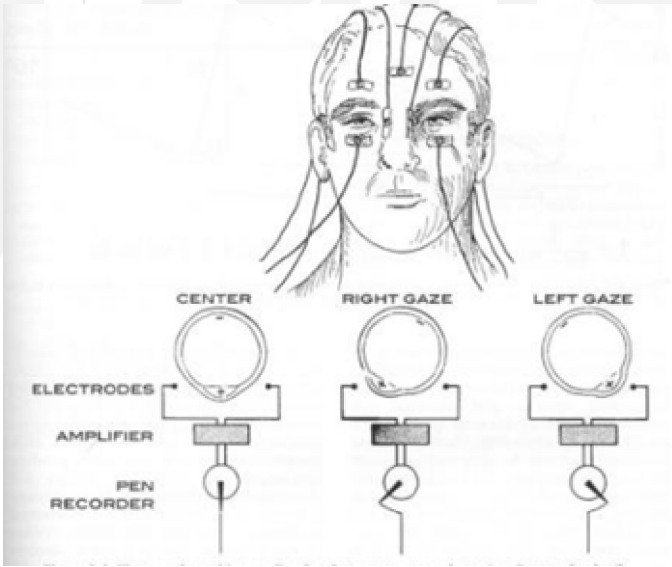

Figure 1.6: The EOG is captured by five electrodes placed around the eyes

Image Source: https://www.slideserve.com

- **Electro dermal activity:** Two main indices of electro dermal activity are Skin Conductance Level (SCL) and Skin Conductance Response (SCR).Electro dermal activity of the skin is recorded by attaching the electrodes on the fingers and recording the fluctuations in skin conductance. SCL measures the background level of skin conductance associated with a particular situation. SCR is the transient change in skin conductance associated with distinct experiences. When there are different kinds of emotional stimuli, variations are produced in the skin conductance level due to changes in the sweat gland activity.

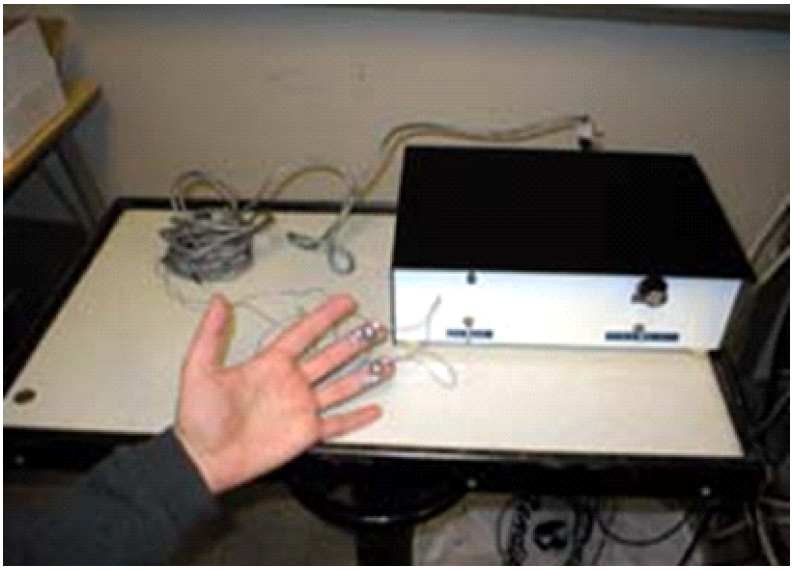

Figure 1.7: Skin Conductance Response

Image Source: http://www.shurilla.com

1.4.4 Electrical Stimulation

The brain can be stimulated electrically to gain information about the working of its various neural systems.When the brain is stimulated, there is a change in the resting membrane potential and an action potential is initiated. This causes behavioral changes depending upon which part of the area has been stimulated. For stimulating the brain electrically, electrodes are used. Microelectrodes are made of fine metal wires through which the nerves are electrically stimulated. Macro electrodes are made of steel wires and are placed either on top of the scalp or inside the brain to record the functioning of tracts, which are large number of neurons together.The electrical recordings can be made over a long period of time, such as when the animal is recovering from any surgery.This is known as chronic recording. If the scientist is focusing to study a particular nerve pathway or where the information is going, then acute recording is done. These recordings of the electrical signals are then displayed through an oscilloscope or ink writing oscilloscope.

- **Oscilloscope:** It helps to display the electrical recordings per unit time. It has a cathode ray tube on which the display is done. It is used to record the activity of one single neuron. When the action is detected,it is amplified and easily heard by the researcher.

- **Ink-writing oscilloscope:** This is also known as a polygraph.The evoked potentials are recorded with the help of the various electrodes that are attached to the scalp.There are needles/pen tips that record the neural activity on a rolling paper with ink. When the signal is detected, it is amplified and the pens move up and down writing the action in ink on a continuously rolling paper. These recordings of the brain are known as electroencephalogram (EEG). This helps to detect any tumor in the brain, epilepsy or study sleep and arousal pattern. Modern techniques use computer to record the information and display it on the screen.

- **Computer:** Helps to display, store and analyse the information that is collected by recording the electrical signals.

1.4.5 Chemical Stimulation

There are various ways to chemically stimulate the brain and make lesions. Drugs can

be given by injections or by inserting a tube into the stomach directly or into a vein or fatty tissue in the body. The chemical activity of the brain can be assessed by using various techniques. One is by using *2- deoxyglucose technique* (2-DG). 2-DG is a radioactive drug and when this drug is injected in the animal, the researcher waits till it is absorbed by the brain. Thereafter, the animal is killed and brain is removed and slices are made.Autoradiography is conducted, that is the slices are coated with photographic emulsion. These are then developed as a film. Neurons that have taken the drug appear like black spots on the slide.

Another useful technique is *cerebral dialysis*. A tube is inserted into the animal's brain. The animal is then engaged in an activity and the neuro-chemicals released while the animal is active, are collected and analyzed using the chromatograph. *In-vivo voltametry* is another technique that is used to record the neuro-chemicals released in the animals when they are actively involved in some activity. Immunocytochemistry is a process which helps to locate the presence of neuro-proteins in the brain. Each neurotransmitter responds to its specific receptors during a synapse. Microiontophoresis is a process that involves ejection of charged molecules used to apply drugs or chemical to nerve cells. It helps to locate the specific receptors to which the neurotransmitters respond.

1.4.6 Stereotaxic Lesion

When ablation is not possible for tiny structures located below the surface of the brain, researchers use sterotaxic techniques to damage a structure in the interior of the brain. First and foremost, it is important to identify which part of the brain needs to be investigated. The sterotaxic atlas helps to locate the exact point of the brain where the surgery has to be done. Once this is done, the animal's head is placed in the head holder of the sterotaxic apparatus. Once the head is firmly held in the apparatus, the electrode holder is used to insert the electrode or cannula into the brain. The electrode can be implanted permanently and when the animal comes out of the effect of anesthesia, behavior is monitored. When the study is over, the animal is given anesthesia again, the electrode is removed and the animal recovers from it.

1.4.7 Neuroimaging

Brain imaging is known as neuro-imaging. Structural imaging methods are used to image the structure of the brain.These procedures help to diagnose any injury or disease in the brain as tumors.Functioning imaging helps to understand the function of the brain. It also helps in diagnosing diseases related to metabolism, or brain disorder or disease.

- **X-ray technique:** Initially, this technique was used widely to explore the reason behind any neurological deficits. The conventional X-ray did not help much in observing the neural activity of a patient suffering from stroke or neurological disorders. It only provided information about the structures that absorbed the X-ray.The cerebral ventricular system and circulatory system within the brain is examined by using the contrast X- ray technique. In this technique, a substance is injected into one compartment of the body that absorbs X-rays either less than or more than the surrounding tissue. This creates a contrast during X-ray photography. Pneumoencephalography and cerebral angiography are two ways in which contrast X-rays are used. The former is a very old radiographic technique to examine the brain. Cerebral angiograms are most useful for localizing vascular damage and help to detect any tumor.

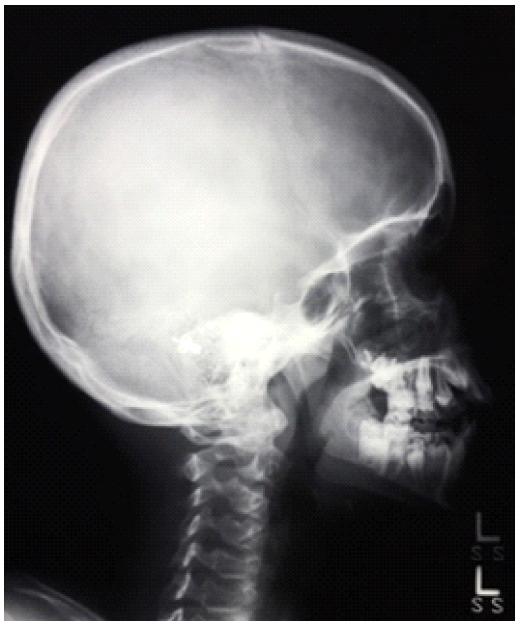

Figure 1.8: X-ray of a brain

Image Source: https://two-views.com

- **Computerized Tomography (CT scan):** This is an X-ray technique used along with the computer that helps to view the structures of the body and the brain. There is a huge cylindrical ring in which the person lies down. The X-ray is passed from one side and the X-ray detector is placed on the other side of the patient's head. Slowly the X-ray and the detector are rotated and the photographs are taken from all angles. All the photos are then collected by the computer and a CT scan of the brain is produced. A number of scans are taken and then they are combined to get a 3-D picture of the brain. Neurologists often use CT scans to diagnose blood clots, tumors, sclerosis or any internal injury, etc. and if surgery is to be carried out or not.

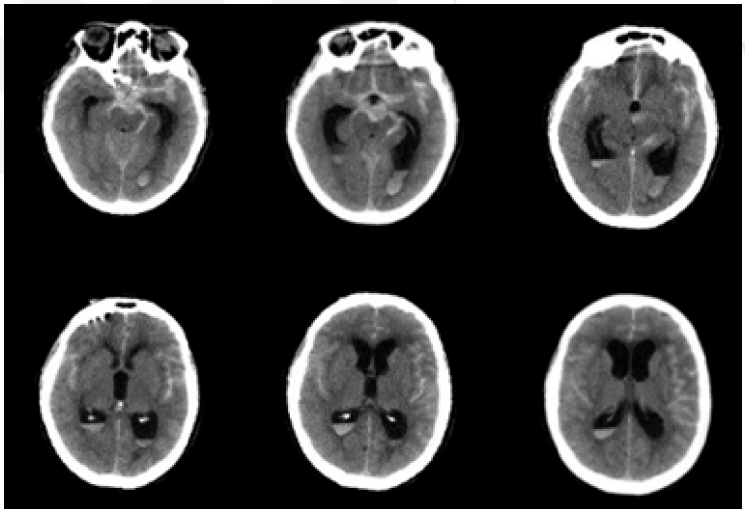

Figure 1.9: CT scan of brain

Image Source: https://www.slideshare.net

- **Magnetic Resonance Imaging (MRI):** This technique is used when detailed picture of the patient's brain is to be investigated. This technique uses a strong magnetic field to gather images of the brain in frontal and horizontal planes. Unlike CT scan, it provides more detailed and clearer picture of the brain.This technique helps to know the blood oxygen flow to the different areas of the brain that are active. The resolutions of the images are high and changes are recorded as they occur in real time. It is safe as no injection is given to the patient.

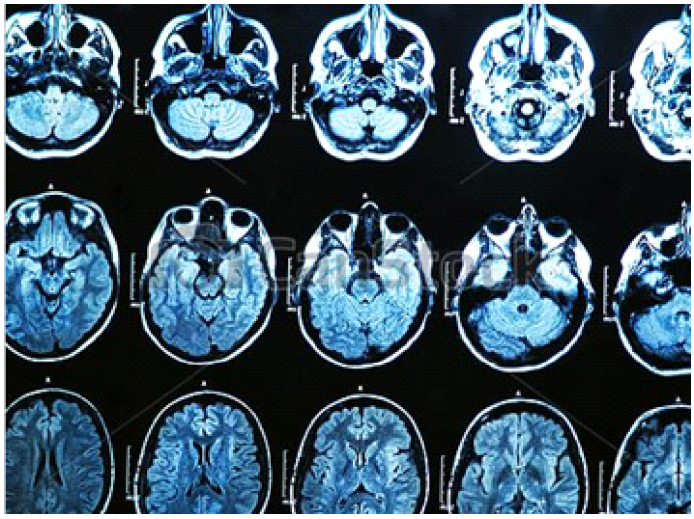

Figure 1.10: An MRI scan of the human brain provides different views

Image Source: http://www.openmrict.com

- **Positron Emission Tomography (PET):** PET scan helps to detect the changes in the metabolic activity taking place in the brain.It does not provide any structural information about the brain, rather it provides images of brain activity, that is, functional brain images. It is an invasive method where an injection of radioactive 2- deoxyglucose (2-DG) is given to the patient.When it is absorbed by the patient, the patient is given a task to do and while doing the task, recordings are made. The images recorded show which part of the brain was actively involved in the task. PET scans use radioactive chemicals with a short shelf-life, made in cyclotron (a device to accelerate charged atomic or subatomic particles). It is an expensive technique hence, it is mostly available in research hospitals.

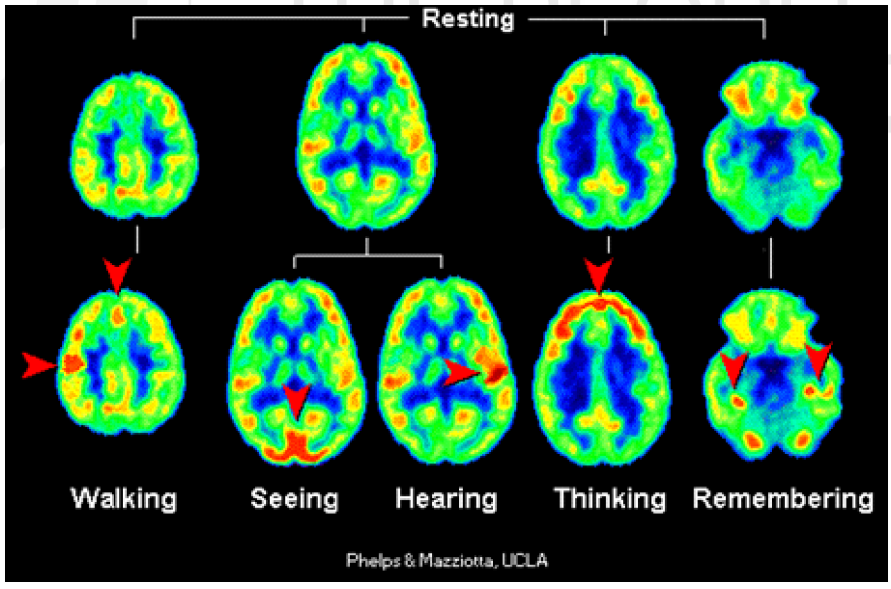

Figure 1.11: Brain PET scan

Image Source: https://steemit.com

- **Functional MRI (fMRI):** It is a less expensive and less risky technique than PET scan. fMRI primarily measures changes in blood flow (hemodynamic response).Currently, it is the most popular method to be used in cognitive neuroscience as well as for medical diagnosis.

- **Diffusion Tensor Imaging (DTI):** It is a method that identifies those pathways

along which water diffuses. Water diffuses in the tracts (bundles of axons), diffusion tensor imaging gives image of these major tracts. DTI determines the location and also the orientation of neural axons in the brain. This method gives an idea of how the different areas of brain are connected to each other. This is the particular advantage of this technique as compared to other techniques.

- **Transcranial Magnetic Stimulation (TMS):** It is a technique that turns off a part of cortex by creating a magnetic field. It temporarily inactivates the neurons below the magnet. Researchers use TMS as a mapping technique. For instance, when TMS coil is placed on motor cortex and stimulating different regions along this cortical strip, muscle movements and twitches will be observed on the contralateral side of the body. From this, it can be observed how different body parts map onto different parts of the cortex and also how much cortex is devoted to any particular body part. The main disadvantage of TMS is that it is not very effective in reaching the subcortical structures.

Check Your Progress 2

1) What are the different electrical and chemical methods of stimulation?

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2) List the main brain imaging techniques.

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1.4.8 Neuropsychological Assessment

When we have to assess the amount of impairment in behavior or cognitive capacities after brain injury or damage, we use neuropsychological assessment procedures.Various neuropsychological tests are employed to make an assessment of different cognitive functions such as, learning, memory, discrimination tasks, intelligence, language, perception, decision making, reasoning, etc. The tests are administered, scored and evaluated and a complete mental status of the patient is taken. The neuropsychological assessments include a comprehensive examination of behavioral, psychological, neurological assessment of the patient. These assessments help to get a clinical picture of the patient with respect to his/her cognitive strengths as well as any difficulties that may be there in any cognitive or psychological area. These evaluations help in treating the patient with appropriate medical or rehabilitative procedures. Apart from this, the neuropsychological assessments also provide valid information about the kinds of impairments that may result due to brain damage, injury or trauma

and how to take care of these deficits. What kind of interventions needed, can be planned to help the client cope with the impairments or how the patient can use other resources to deal with daily life problems. These assessments, thus not only help to diagnose a problem but also provide valuable information about the prospective treatment plan for the patient.The effectiveness of treatment procedures is also assessed so that these programs can be developed to benefit other patients too with similar symptoms. Hence, rehabilitative psychologists can be trained in devising intervention programs for alleviating or dealing with the cognitive impairments after brain injury, tumor, damage, stroke, etc. The psychologist gathers important information from the patient about the history of the illness, the occurrence, severity, developmental milestones, genetics or any other factor that may help in getting a more accurate picture of the patients' problem. Psychologists also use semi-structured interviews to know about the development of the problem.There are various diagnostic tests available for neuropsychological assessments. Few of the common neuropsychological tests used are as follows:

- **Wechsler Intelligence Scale:** The first version of this intelligence test was known as Wechsler-Bellevue Intelligence Scale. It was published in 1939 by David Wechsler to measure intellectual performance of adults. These scales have been subsequently been revised for adults and children. The Wechsler Adult Intelligence Scale III (WAIS III) is administered on adults. Wechsler Intelligence Scale for Children-III (WISC-III) is administered on children between the age 6 to 16 years. The Wechsler Preschool & Primary Scale of Intelligence-R (WPPSI-R) is designed for children between the age 4 to 6 ½ years.

- **The Halstead-Reitan Neuropsychological Test Battery:** The battery consists of a set of neuropsychological measures which are used by a trained psychologist or a clinical psychologist. The battery is designed to assess all major cognitive, sensory, expressive and motor functions (Reitan, 1986). The test battery is found to be reliable and valid for both younger and older age groups.

- **The Luria-Nebraska Neuropsychological Battery:** It is a standardized battery (1986) of neuropsychological tests found to be useful in diagnosing and treatment of brain damage or any brain dysfunction. The test battery is useful for adolescents, adults and older adults. A separate version for children between the ages 8-12 years of age is also available. The major areas covered in assessment are motor, perceptual (auditory, tactile, visual), language (receptive speech, expressive speech), academic (reading, recognition, spelling, writing, arithmetic), memory and intelligence functioning.

- **The Rey-Osterrieth Complex Figure Test:** The test was designed by Rey in 1941. It is used to assess visual perception and visual memory in brain damaged individual. It is one of the most used tools to assess constructional abilities and is also used as a non-verbal memory test. Osterrieth (1944) developed norms for children and adults with age range from 4 to 15 years and 16 to 60 years of age.

- **Delis-Kaplan Executive Function System:** It is a neuropsychological assessment for executive functions like thinking, inhibition, problem solving, planning, impulse control, concept formation, abstract thinking, and creativity (Delis, Kaplan, & Kramer, 2001). It maybe administered individually or on a group. It is a standardized measure to assess executive functions in children and adults between the age range 8 to 89 years.

- **Digit Span Test:** Initially, this test was part of WAIS. The aim of the test is to measure an individual's working memory and assess any impairment of the waking memory.
- **Wisconsin Card Sorting Test:** It is a neuropsychological test of 'set-shifting'. It is used to assess frontal lobe dysfunction in patients of brain injury, schizophrenia or any other mental illness. The participant has to sort 64 cards to match either with colour, form or number of figures (Kirby & Silvestri, 2015). The participant is not explicitly told the 'rule', but must refer it from the feedback received from the person administering the test.
- **Dichotic Listening Test:** Diachotic (di=2; otic=ear) test is non-invasive test. Initially used to investigate selective attention but later, used to assess hemispheric lateralization of language ability. In the standard dichotic listening task, a participant is simultaneously presented with two different auditory stimuli through earphones. Based on the instructions given by the experimenter, results are concluded for the test.

Figure 1.12: The dichotic listening task

Image Source: http://www.indiana.edu

1.5 RESEARCH ETHICS IN BIOPSYCHOLOGY

You learned in the first section of this unit, about the Ethical Guidelines to be followed by the researcher. These guidelines have been provided by American Psychological Association and Indian Council of Medical Research, for guidance to the researcher while conducting research with human and animal participants.

There are various ethical issues that need to be taken care of while doing research in biopsychology. There are many investigations when one has to explore the parts and functions of the brain, how an incision could influence a particular behavior, how damage to a particular part of the brain could have a psychophysiological impact and so on. For such studies, as well as for studies where there is harm to the person or where survival is at risk, animals are preferred for investigation.When human participants are selected, then the consent is taken from the participant, the doctor(s) treating him/her, therapist,and the caregivers. Whenever it is felt that the experiment is disturbing the participant, or negatively influencing his/her symptoms and aggravating the medical and psychological condition, then the experiment is immediately

discontinued.When the effects of chemicals, radiation, etc have to be examined on the body, then animals are considered for such studies. Hence, animals are used for those experiments where human beings cannot participate. There are several ethical considerations while doing such experiments. We need to take care of animals during and after the study is over. The conditions of doing an experiment must be well planned, the need for the surgical procedures and equipment must be appropriate.That is to say that animals must be used only when the research in question is of great importance to mankind. No unnecessary harm or pain must be inflicted to the animal. After the experiment is over the animal must be taken care of untill he/she recovers.

Check Your Progress 3

1) List the commonly used neuropsychological tests.

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2) Briefly explain the ethical issues involved in research in biopsychology.

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1.6 SUMMARY

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

- The biological approach to the study of human and animal behavior is known as biopsychology. The biopsychologists try to investigate scientifically how biological processes interact with cognition, emotions and other psychological processes.
- Some sub-disciplines of neuroscience are of particular relevance for biopsychology. List of these sub-disciplines include neuroanatomy, neurochemistry, neuropathology, neuroendocrinology,neuropharmacology and, neurophysiology.
- Research in biopsychology is done with the aim is to understand the basis of behavior and if there is any damage to the nervous system, and how it produces a corresponding change in behavioral functions.
- Various methods to record and understand brain-behaviour relationship, are ablation, psycho-physiological recordings, electrical and chemical stimulation, stereotaxic lesion, neuroimaging, and neuropsychological assessments.
- There are various ethical issues that need to be taken care of while doing research in biopsychology.

1.7 KEY WORDS

Biopsychology : The biological approach to the study of human and animal behavior is known as biopsychology.

Ablation : Ablation is a method to study the destruction of tissue in the brain and examining its effect on behavior due to the removal or destruction of tissue.

Histological methods : It is the method of scientifically examining the tissue for its structure, function, or pathology.

Brain imaging techniques : Also known as neuroimaging, it involves various techniques (such as EEG, PET, MRI, and fMRI scan) to study the structure, function, or pharmacology of the brain.

Magnetic Resonance Imaging (MRI) : This technique is used when detailed picture of the patient's brain is investigated. It uses a strong magnetic field to gather images of the brain in frontal and horizontal planes.

Physiological Psychology : It is a division/branch of biopsychology. It uses controlled experimental conditions to stimulate the brain and study its effects on behavior. It involves direct manipulation and recording of the brain by primarily using surgical or electrical stimulation on animals for research.

Electrooculography (EOG) : It is a method for recording eye movements. Here, the difference in the electrical potential in the back and front portion of the eye ball is recorded with the help of electrodes.

Embedding : It is a procedure to make the brain tissue hard by covering it with paraffin or nitrocellulose.

1.8 REVIEW QUESTIONS

1) A technique that uses magnetic fields and radio waves to produce computer-generated images that distinguishes among different types of soft tissue, allows us to see structures within the brain is ..... .

2) Method of analyzing brain structure by passing narrow X-ray beams through a person's head from several angles to produce measurements from which a computer can construct an image of the brain is known as ..... .

3) A synonym for experimental ablation is called ..... .

4) The procedure of ..... is done so that the structural details of the tissue become apparent under the microscope.

5) Which division of biopsychology relies on functional brain imaging as its major research method?

   a) psychophysiology

b) behavioral neuroscience

c) neuroimaging

d) physiological psychology

6) Why do we need to study biopsychology?

7) Discuss ablation as a method to study biopsychology.

8) How electrical stimulation and chemical stimulation techniques of biopsychology differ from each other?

9) Explain the need to take care of ethical issues while doing research in biopsychology.

1.9 REFERENCES AND FURTHER READING

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- The dichotic listening task. Retrieved September 10, 2018, fromhttp://www.indiana.edu/~p1013447/dictionary/dichot.htm

1.11 ONLINE RESOURCES

For more understanding on biopsychology as a subject visit:

– http://webs.wofford.edu/steinmetzkr/teaching/Psy230PDFs/Introduction.pdf

For information on brain imaging techniques, visit:

– https://www.st-andrews.ac.uk/psychology/research/brainimaging/

– https://dana.org/uploadedFiles/Pdfs/brainimagingtechnologies.pdf

For an overview on methods to study biopsychology, visit:

– http://www.d.umn.edu/~rlloyd/MySite/Physiological%20Psychology/Ch%205%20phy.PDF

– http://www.ecpdu.net/htmlfiles/uploads/2015/01/research-methods-in-biopsychology.pdf

For more on ethical issues in biopsychology, visit:

– https://www.apa.org/ethics/code/ethics-code-2017.pdf

– https://www.apa.org/science/leadership/care/guidelines.aspx

– https://www.icmr.nic.in/sites/default/files/guidelines/ICMR_Ethical_Guidelines_2017.pdf

For a demonstration on surgical implantation, visit:

– https://www.jove.com/video/3565/surgical-implantation-chronic-neural-electrodes-for-recording-single

Check your answers for Multiple Choice Questions

(1) MRI, (2) CT scan, (3) Lesion study, (4)Staining, (5) Neuroimaging

UNIT 2 NEURONS AND NERVE IMPULSE*

Structure

2.0 LEARNING OBJECTIVES

After reading this Unit, you will be able to:

- describe the structure and function of a neuron;
- explain the classification and types of neuron;
- explain the process of neural conduction;
- discuss the process of synaptic transmission;
- state the functions of neurotransmitters; and
- discuss neuroplasticity and the related concepts of neural degeneration, neural regeneration, neural reorganization and recovery.

2.1 INTRODUCTION

In the previous Unit, you have learned about the field of biopsychology, its various divisions, as well as how research is conducted in this area. The main purpose of this

* Dr. Meetu Khosla, Associate Professor of Psychology,Daulat Ram College, University of Delhi, New Delhi.

Unit is to help you to understand about the cells of nervous system, that are neurons, its structure, functions as well as its classification. This Unit will further explain how a synapse takes place and the functions of various neurotransmitters. The dynamic nature of brain, that is, neuroplasticity, neural degeneration, regeneration and reorganization will be discussed in the end. Now, let us first understand what a neuron is.

All organisms have cells. So, all organs within the human body also have cells, like heart cells, liver cells, brain cells, etc. Our behavior, actions and thoughts are also a product of interaction between complex system of cells, chemicals and organs. Nervous system is one such complex arrangement of cells. It contains millions of neurons and trillions of neural connections. The network of cells in the nervous system carries information to and from all parts of the body.There are two kinds of cells in the nervous system. They are neurons and glial cells. A neuron is the basic cell of the nervous system (nerve cell). It is responsible for transmitting information to and from the brain. For example, nerve cells carry information to the brain from our eyes, or ears. Nerve cells also carry back response from brain to the body, like muscle movements. It generates electrical impulses known as nerve impulse. In other words, neurons help us to feel, taste, see, move, feel emotions, remember and communicate. Also, each neuron has a different chemical makeup resulting in complex behaviours. It is very difficult to ascertain the exact number of neurons in a person and the number also differs from one person to the other. According to Williams & Harrup (1988) there are approximately 100 billion neurons in an adult human brain. There are 12 to 15 billion neurons in cerebral cortex and associated areas, 70 billion neurons in cerebellum, and nearly 1 billion neurons in spinal cord. Neurons are of varied shapes and sizes. Glial cells support and protect neurons.

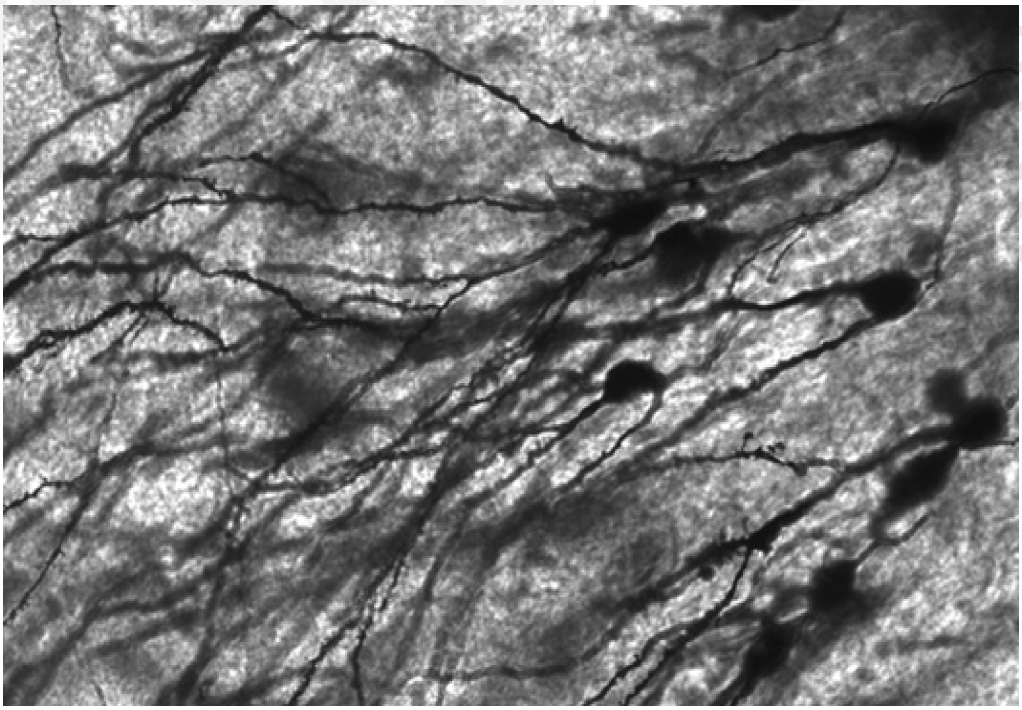


Figure 2.1: Image of Golgi stained neurons in the dentate gyrus of an epilepsy patient. 40 times magnification

Image source: https://commons.wikimedia.og

Box 2.1

Santiago Ramon Y Cajal (often called as father of neuroscience) first postulated (1887) that the nervous system was made up of individual cells.

He was awarded Noble prize in Medicine/ Physiology, in 1906 for 'work on the structure of nervous system'. He shared the award with Camilio Golgi.

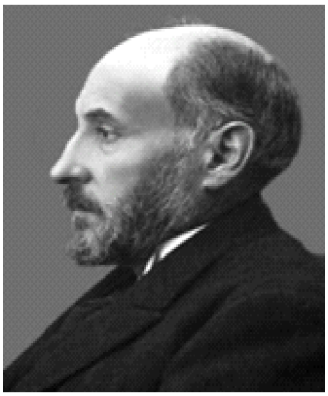


Image Source: https://www.nobelprize.org

2.2 NEURON: STRUCTURE AND FUNCTION

The cells of the nervous system that receive and send messages within that system are known as neurons. Neurons receive and process information to and from the brain. The electrical signal that the neuron conducts is known as a nerve impulse. They are in varying size and shapes having varied functions to perform. The neuron structure is related to its functions. Figure 2.2 is an illustration of external features of one type of a neuron.

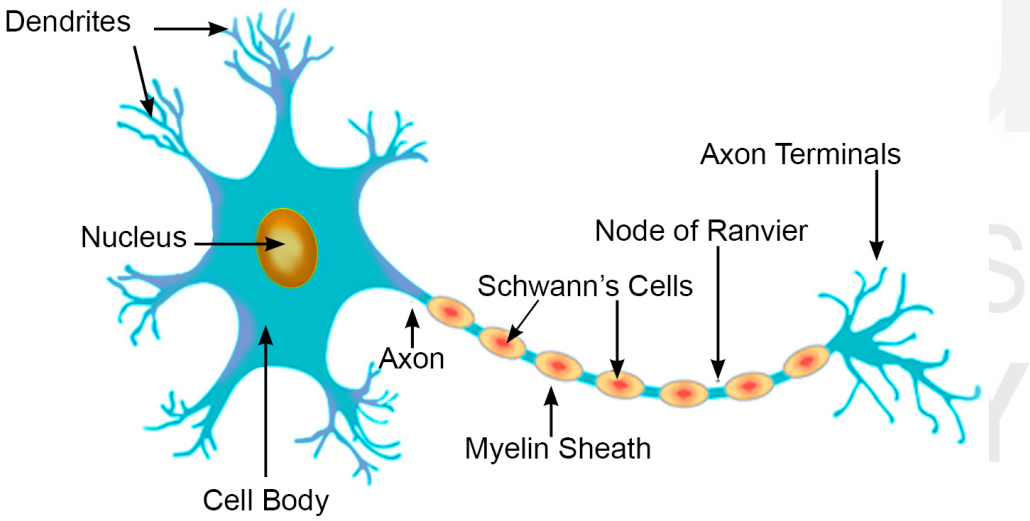


Figure 2.2: Structure of a typical Neuron

A typical neuron has the soma or the cell-body, axon, terminal buttons. The plasma membrane of the neuron is the double layer of phospho-lipid molecules that is semi-permeable to certain kinds of substances.The plasma membrane controls the movement of the substances through it, hence it is involved in the nerve impulse.It also provides sites for electrical activity that occurs during nerve impulse and for synaptic activity between two neurons.

The cell body is the largest part of the neuron that has number of organelles floating in its cytoplasm such as golgi body, nissl bodies, mitochondria, rough endoplasmic reticulum, smooth endoplasmic reticulum, etc. The cell body is the metabolic center of the neuron and is also called as the soma (the word soma means body). There is a nucleus in the centre. The dendrites (dendrite means 'tree-like') are the extensions from the cell-body which look like branches of a tree. The dendrite tips have sensory

receptors that receive the stimuli from other neurons and begin the process of nerve impulse by sending these impulses to the cell body. The axon is a long slender part of the neuron that extends from a portion of the cell-body known as axon hillock. Axon hillock is a cone-shaped region at the junction between axon and the cell-body. It is often covered by the myelin sheath and carries information from the cell body towards its distal ends known as terminal buttons. Myelin sheath is fatty insulation around many axons. The axons vary in length and diameter, with larger diameter indicating faster action potentials, influencing neural conduction. The axon may have branches known as axon collaterals.

A brief chemical or electrical message that begins from the cell-body, travels down the axon to the terminal buttons is known as an action potential. When the axons divide at the rear end, it branches profusely and each branch ends in a knob.These are known as terminal buttons.When the action potential travels down the axon it reaches the terminal buttons, where a chemical substance is released known as neurotransmitter. The function of the neurotransmitters is to either increase or reduce the activity of the receiving neuron.

Though, neurons are present in large numbers in the brain, there are other primary cells that provide support to the neurons, known as *neuroglia, glial cells or glia*. Glial cells also affect thinking, learning, memory, perception and help in maintaining a state of homeostasis of nervous system. Glial cells deliver nutrients to neurons, produce myelin to coat axons, clean up waste products and dead neurons, help in information processing and influence the generation of new neurons during prenatal development. The role of glial cells in neurodevelopmental disorders, like Autism Spectrum Disorder, degenerative disorder, like Alzeihmer Disorder and psychiatric disorders like major depressive disorder and schizophrenia, is being investigated by neuroscientists.There are four main types of glial cells. They are *oligodendrocytes, schwann cells, microglia,* and *astrocytes*. Oligodendrocytes produce myelin for neurons in the brain and spinal cord (the central nervous system) and Schwann Cells produce the myelin sheath around the neurons of the body (the peripheral nervous system). Myelin protects the shaft of the axon as well as it gives support. Such nerve fibers are known as myelinated fibers.There are certain gaps between the myelin sheath which are known as *Nodes of Ranvier*. Microglial cells are involved in inflammation response, that is protecting the brain from invading microorganisms. Astrocytes clean up the waste material of dying neurons.

2.2.1 Classification and Types of Neuron

There are different types of neurons. Each type has different functions to perform. We know that neurons vary in their size and shape. Neurons are also classified according to their structure and function.There are three kinds of neurons that are classified according to their structure namely, *unipolar neurons, bipolar neurons* and *multipolar neurons*.The classification is based on the number of processes (projections) emerging from the cell body. The types of neurons are illustrated in Figure 2.3.

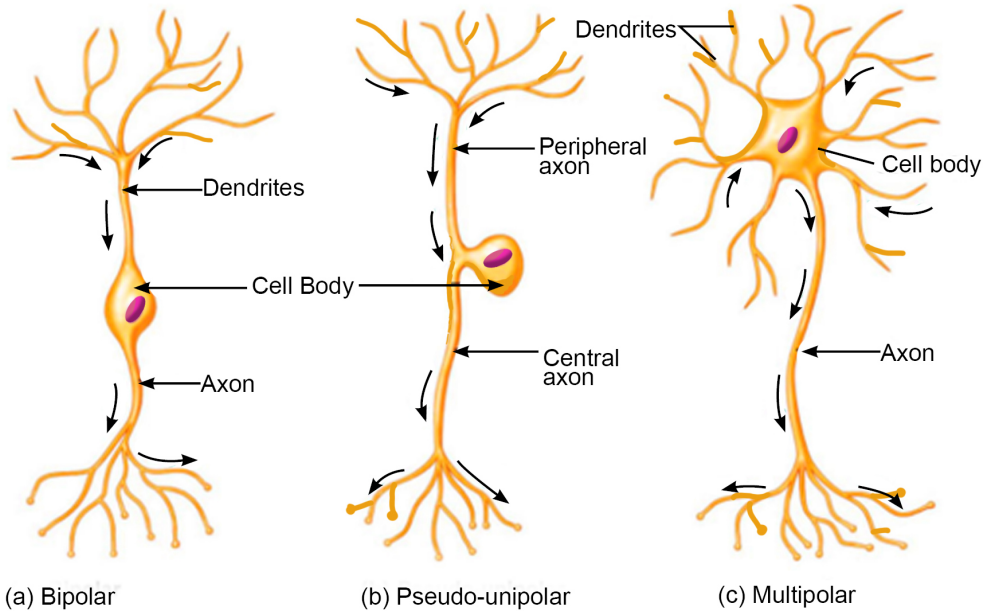


Figure 2.3: Classification of Neurons

The Pseudo-unipolar or Unipolar neurons have one axon that separates from the soma and branches into two. These neurons are involved in sensory functions. They send impulses received from the environment to the central nervous system.The bipolar neurons are sensory neurons.They have one axon and one dendrite which is profusely branched like a tree.The dendrite is placed at the opposite end of the soma.They are very few and are the kinds that are present in the retina of the eye, the inner ear and in the olfactory path. The multipolar neurons have only one axon but several dendrites. They are most commonly found in the brain and spinal cord.They are further classified as Golgi Type I and Golgi Type II neurons depending upon the length of their axons and how much they branch. Golgi Type I have very long axons and few branches and carry information further away as motor nerves. The Golgi Type II neurons have shorter axons and branch repeatedly.These neurons act mostly locally to nearby areas.

Neurons are also classified into types based on their functioning, namely, *afferent neurons*, *efferent neurons*, and *inter-neurons*. Afferent neurons are the sensory neurons that carry the nerve impulses to the Central Nervous System (CNS). They are affected by the changes in the environment. The efferent neurons take the impulses away from the brain or the spinal cord to the muscles or glands.They are also known as the motor neurons. The inter-neurons lie within the CNS.They carry information from the afferent neurons towards the efferent neurons (inside the spinal cord and much of the brain). Neurons are placed in the form of a reflex arc to conduct impulses to and from the brain and spinal cord.The most common reflex is the one that consists of an afferent neuron, an interneuron and an efferent neuron.

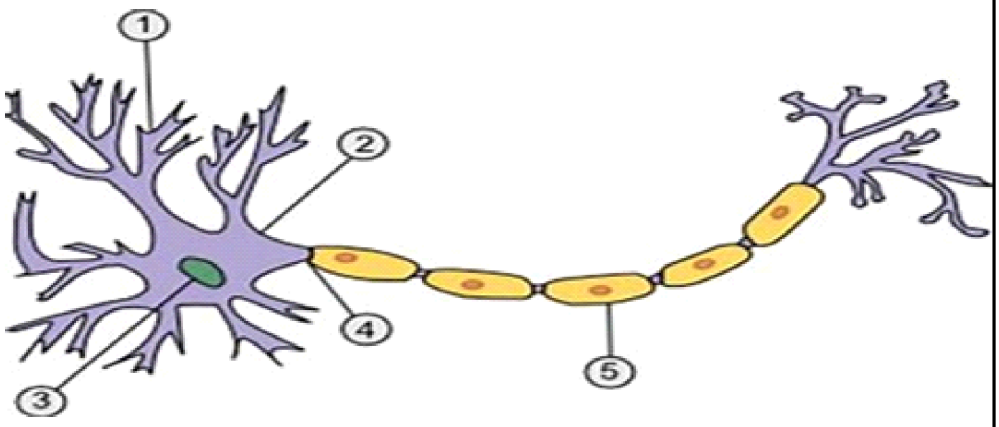
2.2.2 Functions of a Neuron

Neurons are involved in all reflex actions ranging from simple and complex problem solving to communication between sensory and motor neurons.Hence, no behavior is possible without the appropriate functioning of the neurons. For example, if we are able to see an object, it is possible because the receptors in the eye communicate this to the brain which helps us to perceive things clearly. Similarly, when we hold a glass in our hand, it is possible only because of the co-ordination of the sensory neuron with motor neuron which signals the muscles to hold the glass.There is an intricate network of connections between these neurons in the brain and spinal cord

that makes possible the proper functioning of the body. There are genetic as well as environmental factors that influence the development of the nervous system.

Check Your Progress 1

1) Label the external features of a neuron.



2) Discuss the classification of neurons.

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3) List types of glial cells.

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Check your answer of 1.1) Dendrites 2) Axon 3) Nucleus 4) Nodes of Ranvier 5) Myelin Sheath

2.3 NEURAL CONDUCTION

A neuron that is at rest, that is not firing a nerve impulse or a message, is actually electrically charged. There is a jelly-like solution inside and outside the cell which consists of charged particles known as *ions*.There are electrical charges across the neural membranes which constitute the positively charged ions, known as cations and negatively charged ions known as anions. Both positive and negative charged ions are present inside and outside the cell. There are mostly negatively charged ions inside the cell and positively charged ions outside the cell. This is because of diffusion (process of ions moving from areas of high concentration to areas of low concentration) and electrostatic pressure (the balance of electrical charges when the ions are at rest). The positively charged ions are sodium (Na+), Calcium (Ca2+),

Potassium (K+) and chloride (Cl-).There is relatively more positive charge next to the plasma membrane on the outside and a relatively more negative charge on the inside of the membrane. This difference in electrical charge across the membrane is known as the *membrane potential*. In an inactive state the neuron is said to be resting.It displays membrane potential or resting potential of -70mV. This is known as *resting membrane potential*. The magnitude of the potential difference is measured in volts (V) or millivolts (mV). The Resting Membrane Potential (RMP) is maintained with the help of principle of diffusion, electrostatic pressure, ion channels, and sodium potassium pump.

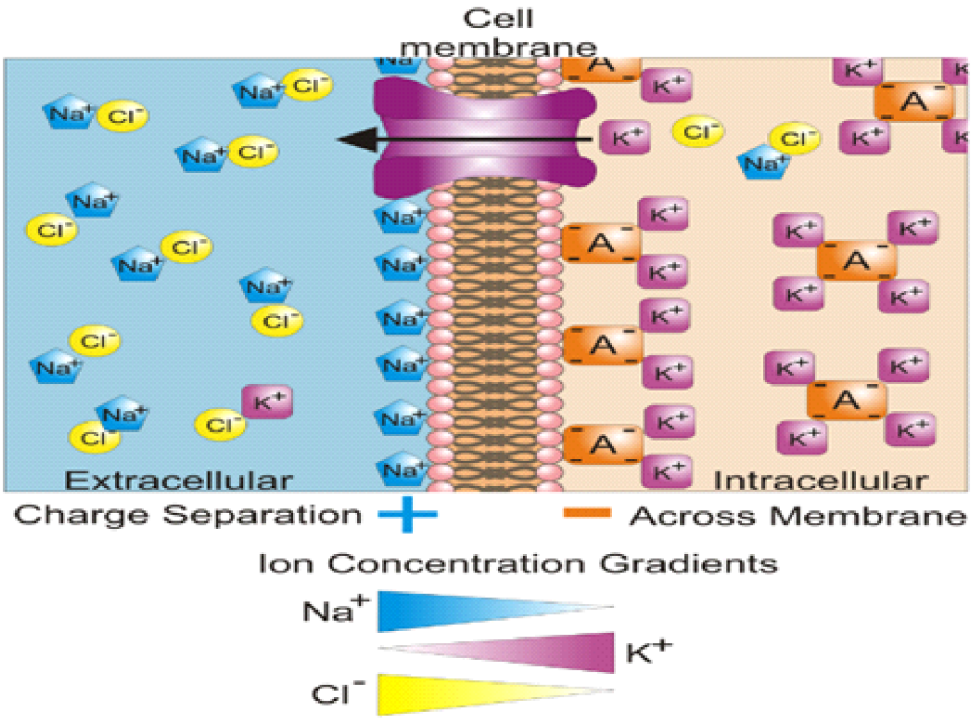

Figure 2.4: Diagram showing the ionic basis off resting potential

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

The nerve impulse is brief and it goes through the cell body to the axon to the terminal buttons.When there is a stimulus at the spike initiating region that reaches the threshold of excitation, it depolarizes the membrane.This leads the sodium ions to move into the cell with the help of forces of diffusion or via electrostatic pressure. This makes the inside of the membrane more positive with respect to outside for a temporary period of time from -70 mV to +50mV.The action potential (electrical charge reversal at a particular point along the axon) reaches its peak in about 1millisecond. No more sodium can enter the cell and potassium ions start leaving the cell. This causes the membrane potential to restore itself to its resting state.

Box 2.2

Ion channels: Ion channels are present in the membranes of all excitable cells. It can be defined as pore-forming membrane proteins that allow ions to pass through the channel pore. They are responsible for establishing a resting membrane potential, shaping action potentials and other electrical signals by gating the flow of ions across the cell membrane, controlling the flow of ions across secretory and epithelial cells (type of cells found near the surfaces of the body, eg. skin, organs, urinary tract and blood vessels), and regulating cell volume.

Sodium potassium pump: Also known as Na+/K+ pump. It is an enzyme found in the plasma membrane of all animal cells. In cellular physiology, it is responsible for maintaining the internal concentration of potassium ions [K+] higher than that in the surrounding medium (blood, body fluid, water) and maintains the internal concentration of sodium ions [Na+] lower than that of the surrounding medium.

The action potential is an all-or-none phenomenon, such that whenever it is initiated, it goes down the axon to its terminal buttons or it does not occur at all.Thus, information is sent down axons via small electrical impulses called as action potentials. The amplitude or the size of the nerve impulse depends upon the particular neuron as well as the rate at which the neuron conducts impulses. When the potassium ions begin leaving the cell it causes a state of depolarization of the membrane. Once enough positively charged potassium ions are released out of the cell, the membrane reaches its resting state. Sometimes too many potassium ions leave the cell, thus making the membrane slightly hyperpolarized, but then the potassium channels close making the membrane potential reach its normal resting state again.

Check Your Progress 2

1) What do you mean by membrane potential?

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2) Differentiate between resting membrane potential and action potential.

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3) What is all-or-none law?

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2.4 SYNAPTIC TRANSMISSION

The information passes from one neuron to another through the synapse. So, the action potential reaches the end of the axon, it reaches the terminal boutons.The point where the terminal button from one neuron contacts with the dendrite of another neuron is known as a *synapse*. Information passes at these junctions formed with the next neuron. Synapses occur at three places on the next neuron, mainly on the dendrites, soma or axons. Thus, synapses are known as axondendritic, axosomatic, and axoaxonic synapses. There are two kinds of synapses, electrical synapses and

chemical synapses.The electrical synapses are rare.In this case, the information from the transmitting neuron is sent to the next neuron via certain channels that come close to one another. By coming next to one another, the ions pass though the neurons easily and more efficiently. They are direct and operate more quickly sending information in either direction. Chemical synapses involve the transfer of neurotransmitters from one neuron to the other. When the membrane of the cell that sends the information (presynaptic membrane) comes in contact with the membrane of the cell that is receiving the information (postsynaptic membrane) there is a slight gap known as the *synaptic cleft*. Neurotransmitters are released by the vesicles in the terminal button of the presynaptic neuron and they go into the cleft.There they reach receptors that are located on the membrane of the postsynaptic neuron. This is a chemical synapse that is more commonly occurring.

There are certain steps involved in synaptic transmission, but let us first understand the structure of a synapse.

2.4.1 Structure of a Synapse

The synapse is made of three structures that we need to understand.These are,the synaptic knob, the synaptic cleft and the plasma membrane of the postsynaptic neuron.

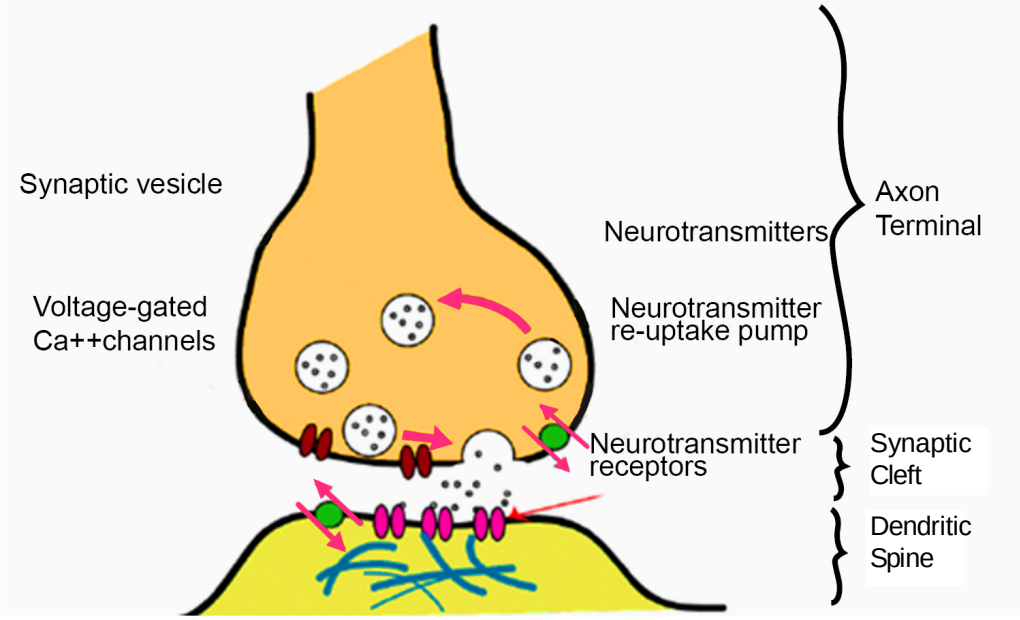

Figure 2.5: Illustration of a synapse

The *synaptic knob* is a tiny bulge that is there when the terminal buttons end. There are number of vesicles or sacs in the bulge which contain numerous neurotransmitters.The *synaptic cleft* is the space between neurons (between the axon terminal of the pre-synaptic neuron and the dendrite of the post-synaptic neuron). Information cannot pass directly from one neuron to the other. The information is transmitted by converting the electrical signal of the first neuron to a chemical signal that passes across the gap before it is converted back into an electrical signal in the second neuron. Presynaptic terminals consist of *synaptic vesicles* ("fluid-filled sac"). The chemical molecules, known as *neurotransmitters*, are released from the synaptic *vesicles* into the cleft and move about with the help of the extracellular fluid that is present in the cleft. The plasma membrane of the postsynaptic neuron is the membrane of the neuron where the information is going. Certain receptors are present on this membrane where the neurotransmitter molecules come and attach themselves.

2.4.2 Steps of Synaptic Transmission

When the nerve impulse reaches the terminal buttons of the presynaptic neuron,the calcium ions move inside the membrane very rapidly.This causes the vesicles to move about in the synaptic knob and merge with the walls of the presynaptic neuron membrane.When this happens, then the neurotransmitters are released from the vesicles.The neurotransmitters move across the synaptic cleft and try to reach the plasma membrane of the postsynaptic neuron.There they bind with the receptors placed on the membrane of the postsynaptic neuron.This causes a local postsynaptic potential. The excitatory neurotransmitters cause the sodium ions to come inside the membrane much faster than the potassium ions moving out from the membrane.This state is known as *excitatory postsynaptic potential* (EPSP).Once, the threshold point of EPSP is reached, the action potential is initiated in the postsynaptic membrane. The inhibitory neurotransmitters open the potassium channels causing the potassium ions to move inside.This makes the membrane much more negative than at resting position.This temporary state of hyper-polarization is known as inhibitory postsynaptic potential (IPSP). Neurotransmitters that do not bind to the receptors are then sent back to the synaptic knob.There they are either taken back into the synaptic vesicles to be used again in a process known as reuptake or are degraded using the synaptic enzymes. In this way, the synapse is cleared for the next release of neurotransmitters. (For instance, highly addictive stimulant drug like cocaine, when consumed affects the nervous system thereby blocking the reuptake process).

2.4.3 Importance of Synapse

Synapse plays an important part in the functioning of the nervous system.

- It helps to connect the neurons together via synapses and hence send information that mediates behavioral responses. If there is any dysfunction in the synaptic activity, then it may lead to change in behavior and cause depression, schizophrenia etc.
- Synapse makes sure that impulses traveling across neurons should follow one direction only. But how, neurons ensure one-directionality of impulses? Since, transmitters are present only in the pre-synaptic membrane and receptors molecules can be found only on the post-synaptic membrane. Due to this, impulses travel in one direction only.
- Synapse help in integrating the impulses travelling down from different neurons.
- It helps in filtering out unwanted and unnecessary stimuli. In order to cross a synaptic cleft, an impulse must reach an action potential of +40mV. If an impulse is weak i.e., less than +40mV, then it will not be able to generate enough neurotransmitters and thus no communication will occur between neurons. As a result of this, our body will not react to such stimuli and thus help in filtering out unnecessary stimuli.

2.4.4 Neurotransmitters

Neurotransmitter is a chemical found in the synaptic vesicles and when released has an effect on the next cell. As the name suggests, it is inside a neuron and they transmit a message. When neurons fire, neurotransmitters are released from their terminal buttons. More than 100 neurotransmitter substances have been identified. Neurotransmitters are classified in three classes of small-molecule neurotransmitters, namely, the amino acids, the monoamines, and acetylcholine. There is a fourth group in this category known as unconventional neurotransmitters. There is one-group of large-molecule neurotransmitters, namely the neuropeptides. Most often,

neurotransmitters produce either excitation or inhibition. But a few neurotransmitters produce excitation under one situation and inhibition in the other situation.

There are various kinds of neurotransmitters as excitatory neurotransmitters such as acetylcholine (ACh), catecholamines, glutamate, histamine, serotonin and some neuropeptides. ACh was the first neurotransmitter identified. ACh plays an important role in neuro-muscular function, sleep regulation, learning and memory. It also stimulates the skeletal muscles to contract but slows contraction in heart muscles. The inhibitory neurotransmitters include Gama-Aminobutyric Acid (GABA), glycine, and some peptides. Amine neurotransmitters are responsible for emotions, control of motor actions etc. Monoamines are like dopamine, nor-epinephrine, epinephrine, melatonin and serotonin. Epinephrine and nor-epinephrine are involved in motor functions. Dopamine (DA) is found in the brain. It helps to maintain body balance. When it is deficient, then it leads to tremors and over stimulation of the muscles, responsible for Parkinsonism. If too much DA is released, it may be a cause of Schizophrenia. Dopamine (DA) may have both excitatory and inhibitory effect depending on the synapse being affected. It is involved in regulating mood, emotions, sleep and appetite. Amino acids are most common neurotransmitters that are involved in protein synthesis. Any imbalance in the presence of the neurotransmitter GABA, may also predispose conditions for stroke when certain neurons are destroyed by glutamate. GABA is a major neurotransmitter with inhibitory effect. It helps in reducing anxiety. On the other hand, Glutamate is the major neurotransmitter with excitatory effect. An excess of glutamate may result in overactivation and neuronal damage. Neuropeptides have pain reducing effects on the body, called as endorphins.

Table 2.1: Important neurotransmitters and their functions

Neurotransmitters	Functions
Acetylcholine (ACh)	Affects movement, learning, memory, REM sleep
Gaba-Aminobutyric Acid (GABA)	Facilitates neural inhibition in the central nervous system (too much action potential)
Endorphins	Provide relief from pain and feelings of pleasure and well-being
Dopamine (DA)	Controls voluntary movements of the body and affects movement, attention, learning, reinforcement, pleasure
Norepihephrine (NE)	Affects eating, alertness, wakefulness
Epinephrine	Affects metabolism of glucose, energy release during exercise.
Serotonin (5HT)	Affects mood, sleep, appetite, impulsivity, aggression

The preceding account of neurotransmitters reflects on how the chemical substance may have an excitatory or inhibitory effect. This helps us to understand why certain drugs are prescribed by physicians to treat a disorder or drugs that are dangerous and should be avoided. Drugs may act as an *agonist* that is, the chemical substance may imitate or increase the effect of neurotransmitter on the receptor sites of the next cell, thereby increasing or decreasing the activity of the cell. For eg., anti-anxiety medication like Diazepam, is agonist for GABA. As you have learned that GABA is an inhibitory neurotransmitter, the inhibitory action is increased by the drug and the drug directly calms the specific brain areas that play a role in controlling anxiety. Drugs may also act as *antagonist*, that is the chemical substances that block or reduce a cell's response to the action of other chemicals or neurotransmitters. If the neurotransmitter that the antagonist affects is inhibitory, there will be actual increase

in activity of the cell, that would otherwise, would have been inhibited. There are some drugs that affect the reuptake or enzymatic degradation process. Drugs that are used to treat depression, like SSRIs (selective serotonin reuptake inhibitor), block the reuptake of serotonin, leaving more serotonin in the synapse to bind with the receptor sites, which over the period of time helps in improving the mood of the person.

Dopamine Hypothesis and the role of Glutamate in Schizophrenia

Abnormalities in dopamine transmission is one of the causes of psychotic disorder, such as schizophrenia. Dopamine hypothesis of schizophrenia states that schizophrenia is caused due to excess activity at dopamine synapses in certain brain areas. Researches have concluded that there is an increase in dopamine release in people showing the first symptoms of schizophrenia (hallucinations and delusions). Drugs that are most effective in treating schizophrenia, are the most effective at blocking dopamine receptors.This hypothesis is further supported by researches who have concluded that continuous use of drugs like amphetamine, cocaine, etc. also show psychotic symptoms and causes substance-induced psychotic disorder. These drugs increase the activity at dopamine synapses.

Apart from dopamine hypothesis, glutamate hypothesis also has a role in schizophrenia. Dopamine inhibits glutamate cells in many brain areas, and glutamate stimulates neurons that inhibit dopamine. Thus, the effects of increasing dopamine are similar to those of decreasing glutamate. So, the effect of anti-psychotic drugs that block dopamine are in consonance with either excess-dopamine hypothesis or deficient-glutamate hypothesis.

2.5 NEUROPLASTICITY: NEURAL DEGENERATION, NEURAL REGENERATION, NEURAL REORGANIZATION AND RECOVERY

In the first three sections of this Unit, you learned about the structure, types, and functions of neurons, neural conduction and synaptic transmission. This section will now focus on neuroplastic responses, namely neural degeneration, neural regeneration, neural reorganization and recovery.

It was earlier believed that any damage to the central nervous system (brain and the spinal cord) is permanent or more or less permanent. It was also hypothesized that the adult (mature) brain was incapable of any reorganization. But the recent advances in research by neuroscientists (1980s onwards) have concluded that the brain has the ability to constantly change the structure and functions of the cells in response to any experience, injury or any trauma. The mature brain is constantly changing and adapting. This ability of the brain is known as *neuroplasticity*. The brain keeps changing in the course of a persons' life, with changes in synaptic activity, genetic and environmental influences.There may be changes in the neuronal activity or more complex changes in cortical mapping in response to an injury or trauma.Throughout the lifespan, neurons continuously die out and it was assumed that old cells are lost without being replaced by the new ones. The recent evidence on *neurogenesis* (growth of new neurons) throws light on the capability of an adult brain to generate new nerve cells. The adult neurogenesis comes from hippocampus and olfactory bulb. Hippocampus is the unique structure located in the medial temporal lobe of the brain and is involved in memory, emotions and mood. Olfactory bulbs are the first cranial nerves, whose output goes primarily to amygdala and piriform cortex. Diet and enriched environment

play an important role in neurogenesis while as, sleep deprivation and stress impede neurogenesis.

Box 2.3 : Case Study of Henry Molaison (H.M.)

At the age of 29 years old, HM underwent a brain surgery to lessen the severity of epileptic seizures. In the surgery, a part of the brain, known as Hippocampus (both sides of medial temporal lobes were removed) and the surrounding cortical regions were removed. The surgery could control epileptic seizures and did not affect his intelligence and personality. But the surgery caused a serious deficit in his long-term memory (known as amnesia). Though, his working memory was intact. Thus, the results indicated that hippocampus and the surrounding cortical regions are critical for long-term memory. Hippocampus plays an important role in long-term memory encoding and long-term memory retrieval.

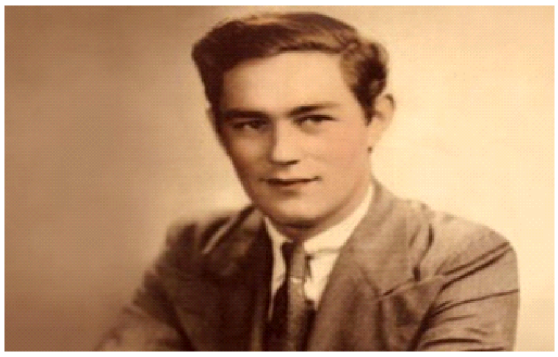

Figure 2.6: Henry Gustav Molaison
Image Source: https://en.wikipedia.org

Neural Degeneration

Neural degeneration is a result of brain development and disease. It is affected by nearby glial cells, degenerating neurons and any process or disease that triggers degeneration. When the axon of the neuron is cut, it causes two kinds of degeneration or deterioration.When the axon breaks from the point of cut towards the terminal button, it is known as anterograde degeneration and the distal end of the axon degenerates.When the neuron breaks from the centre of the axon including the cell body, it is known as retrograde degeneration. It is the degeneration of the segment that is proximal cut between the cut on the axon and the cell body.

Neural Regeneration

Neural regeneration is the regrowth of damaged neurons. Once the neurons are destroyed in the CNS in adult mammals, they do not recover. However, in the peripheral nervous system (PNS), they do try to regenerate, but the normal functions may not be possible.If the recovery process does take place then there are different ways. If the myelin sheath is intact, then the regenerating axons may grow through them to their desired target areas. If the nerve is severed and the ends of the myelin sheath moves apart, then no meaningful regeneration will take place. If the nerve is severed and the myelin sheath ends slightly gets separated from one another, then incorrect myelin sheaths develop that reaches out to undesired target areas. The PNS neurons have the inherent capability to regenerate, while as, CNS neurons cannot regenerate. Some CNS neurons are capable of regeneration if transplanted to the PNS, while some PNS neurons transplanted to CNS are not capable of regeneration. This clearly indicates the environment of PNS that promotes regeneration. When an axon degenerates, new axons branch out from adjacent healthy axons and synapse at the place vacated by degenerating axon. This is known as collateral sprouting. Collateral sprouts may grow from axon terminal branches or the nodes of Ranvier on adjacent neurons (refer to Fig. 2.2).

Neural Reorganization

Studies conducted on laboratory animals to study neural reorganization after brain

damage have primarily focused on sensory and motor cortex areas of the brain. The results of the studies by Kaas and Colleagues (1990), Pons and Colleagues (1991) and Sanes, Suner, and Donaghue (1990) clearly indicate cortical reorganization following damage in laboratory animals. Experiments conducted on adult mammalian brain also conclude that adult brain can reorganize its primary motor and sensory functions after gaining sufficient experience. Mechanisms like strengthening of existing connections, collateral sprouting, adult neurogenesis, etc. have a role to play in neural reorganization.

Recovery

Recovering the brain function after damage is very difficult. It is difficult to do cognitive experiments on brain damaged patients and hence it is poorly understood. But there is some evidence that education and intelligence create *cognitive* resources to help in recovery functions, referred to as *cognitive reserve*. Cognitive and physical exercise helps to recover from nervous system damage. Cognitive reserve has been used to explain that educated people are less vulnerable to the impact of ageing-related brain deterioration (Reuters-Lorenz & Cappell, 2008). With the discovery of neuroplasticity, neuroscientists are conducting studies on neurotransplantation (eg. to transplant human fetal dopamine cells to treat Parkinson's disease) as a treatment for CNS damage, as well as rehabilitative training to promote recovery from CNS damage.

Check Your Progress 3

1) Explain the structure of a synapse.

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2) Elucidate the steps of synaptic transmission.

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3) List the main neurotransmitters.

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4) What do you understand by neuroplasticity?

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2.6 SUMMARY

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

- Neuron is the cell of the nervous system that is specialized to convey the information to and from the nervous system.
- The main parts of a neuron are axon, dendrites, cell-body and terminal buttons.
- Though, neurons are present in large numbers in the brain, there are other primary cells that provide support to the neurons, known as neuroglia, glial cells or glia.
- There are different types of neurons. Neurons can be classified according to their structure and function. There are three kinds of neurons that are classified according to their structure namely, unipolar neurons, bipolar neurons and multipolar neurons. Neurons are also classified into types based on their functioning, namely, afferent neurons, efferent neurons, and inter-neurons.
- The information passes from one neuron to another through the synapse. The point where the terminal button from one neuron contacts with the dendrite of another neuron is known as a synapse. There are two kinds of synapses, electrical synapses and chemical synapses.
- The synapse is made of three structures, the synaptic knob, the synaptic cleft and the plasma membrane of the postsynaptic neuron.
- Chemical found in the synaptic vesicles is known as neurotransmitter.They are responsible for transmitting message across neurons. When neurons fire, neurotransmitters are released from their terminal buttons. Neurotransmitters can be classified into three types; the amino acids, the monoamines, and acetylcholine.
- The recent advances in research by neuroscientists (post 1980s) have concluded that the brain has the ability to constantly change the structure and functions of the cells in response to any experience, injury or any trauma and this is known as neuroplasticity. The brain keeps changing in the course of a persons' life, with changes in synaptic activity, because of genetic and environmental influences.

2.7 KEY WORDS

Axon : It is a long slender part of the neuron that extends from a portion of the cell body known as axon hillock. It is often covered by the myelin sheath and carries information from the cell body towards its distal ends known as terminal buttons.

Neuron : The cells of the nervous system are known as neurons. Neurons receive and process information to and from the brain.

Myelin sheath : It is an insulating cover that surrounds an axon with the layer of myelin (a mixture of protein and phospholipids).

Nodes of Ranvier : It is the gap between the myelin sheath.

Action Potential : When a cell gets activated by a stimulus, a momentary change in electrical potential occurs across plasma membrane of a neuron, known as action potential.

Membrane potential : Membrane potential of a neuron is the relative difference in electrical potential between inside of the cell and the surrounding extracellular fluid.

Synapse : The point where the terminal button from one neuron contacts with the dendrite of another neuron is known as a synapse.

2.8 REVIEW QUESTIONS

1) Which of the following are the parts of neurons?
   a) Brain, spinal cord, and vertebral column
   b) Dendrite, axon, and cell body
   c) Sensory and motor
   d) Cortex, medulla, and sheath
   e) Sympathetic and parasympathetic
2) A dendrite conducts nerve impulses _____ the cell body.
   a) Away from
   b) Towards
   c) Both away and towards
   d) Around bypassing
   e) Only inside
3) Schwann cells produce layers of membrane containing myelin, which provides nutrition for the dendrites.
   a) True
   b) False
4) The resting potential indicates that the inside of the neuron is _____ compared to the outside.
   a) Under ionic pressure
   b) Positive
   c) Negative
   d) All of the above

5) Why do nerve impulses move faster along myelinated neurons?

6) Explain the difference between depolarization of a neuron and an action potential.

7) Describe what is meant by "excitatory" and "inhibitory" when referring to the effects of neurotransmitters on the postsynaptic membrane.

8) Differentiate between: (i) postsynaptic potential, (ii) resting potential and, (iii) membrane potential.

9) Explain the terms; (i) neural degeneration, (ii) neural regeneration and (iii) neural reorganization.

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2.10 REFERENCES FOR FIGURE

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- Diagram showing the ionic basis off resting potential. Retrieved September 30, 2018, fromhttps://commons.wikimedia.org/wiki/File:Basis_of_Membrane_Potential2.png
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2.11 ONLINE RESOURCES

- For more information on neurons, visit;
  - web.mst.edu/~rhall/neuroscience/01_fundamentals/neuron.pdf
  - https://www.khanacademy.org/science/biology/human-biology/neuron-nervous-system/a/overview-of-neuron-structure-and-function
  - https://www.ncbi.nlm.nih.gov/books/NBK21535/
- For more understanding on neuron transplantation, visit;
  - www.ucdenver.edu/academics/colleges/medicalschool/departments/medicine/ClinicalPharmacologyToxicology/Pages/NeurotransplantationCenter.asp
  - www.neurosurgery.pitt.edu/centers-excellence/image-guided-neurosurgery/neuron-transplantation
- For more on Sodium-potassium pump, visit;
  - http://hyperphysics.phy-astr.gsu.edu/hbase/Biology/nakpump.html
- For more understanding on synapse, visit;
  - https://www.khanacademy.org/science/biology/human-biology/neuron-nervous-system/a/the-synapse
  - http://www.biologymad.com/nervoussystem/synapses.htm
  - https://faculty.washington.edu/chudler/synapse.html
  - https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3243741/
- For an article on HM, visit;
  - www.nytimes.com/2008/12/05/

Answers for Multiple Choice Questions

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