Neuron

Chapter 134

INTRODUCTION

Neuron or **nerve cell** is defined as the structural and functional unit of nervous system. Neuron is similar to any other cell in the body, having nucleus and all the organelles in cytoplasm. However, it is different from other cells by two ways:

1. Neuron has branches or processes called **axon** and **dendrites**
2. Neuron does not have centrosome. So, it cannot undergo division.

CLASSIFICATION OF NEURON

Neurons are classified by three different methods.

A. Depending upon the number of poles
B. Depending upon the function
C. Depending upon the length of axon.

DEPENDING UPON THE NUMBER OF POLES

Based on the number of poles from which the nerve fibers arise, neurons are divided into three types:

1. Unipolar neurons
2. Bipolar neurons
3. Multipolar neurons.

1. *Unipolar Neurons*

Unipolar neurons are the neurons that have only **one pole.** From a single pole, both axon and dendrite arise (Fig. 134.1). This type of nerve cells is present only in embryonic stage in human beings.

2. *Bipolar Neurons*

Neurons with **two poles** are known as bipolar neurons. Axon arises from one pole and dendrites arise from the other pole.

3. *Multipolar Neurons*

Multipolar neurons are the neurons which have **many poles.** One of the poles gives rise to axon and all other poles give rise to dendrites.

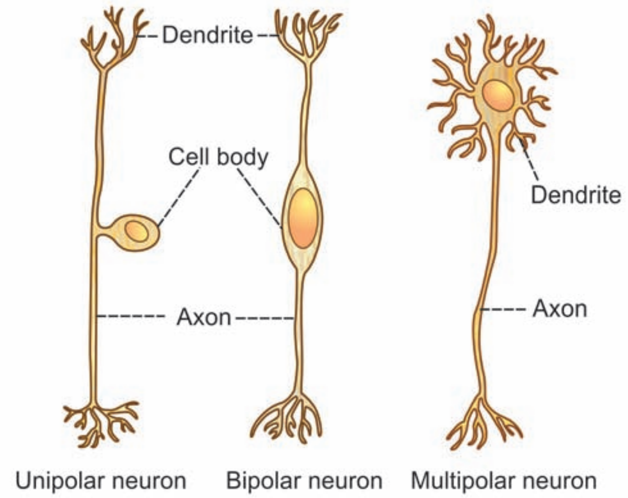

FIGURE 134.1: Types of neuron

DEPENDING UPON THE FUNCTION

On the basis of function, nerve cells are classified into two types:
1. Motor or efferent neurons
2. Sensory or afferent neurons.

1. *Motor or Efferent Neurons*

Motor or efferent neurons are the neurons which carry the **motor impulses** from central nervous system to peripheral effector organs like muscles, glands, blood vessels, etc. Generally, each motor neuron has a long axon and short dendrites.

2. *Sensory or Afferent Neurons*

Sensory or afferent neurons are the neurons which carry the **sensory impulses** from periphery to central nervous system. Generally, each sensory neuron has a short axon and long dendrites.

DEPENDING UPON THE LENGTH OF AXON

Depending upon the length of axon, neurons are divided into two types:
1. Golgi type I neurons
2. Golgi type II neurons.

1. *Golgi Type I Neurons*

Golgi type I neurons have **long axons.** Cell body of these neurons is in different parts of central nervous system and their axons reach the remote peripheral organs.

2. *Golgi Type II Neurons*

Neurons of this type have **short axons.** These neurons are present in cerebral cortex and spinal cord.

STRUCTURE OF NEURON

Neuron is made up of three parts:
1. Nerve cell body
2. Dendrite
3. Axon.

Dendrite and axon form the **processes** of neuron (Fig. 134.2). Dendrites are **short processes** and the axons are **long processes.** Dendrites and axons are usually called **nerve fibers.**

NERVE CELL BODY

Nerve cell body is also known as **soma** or **perikaryon.** It is irregular in shape. Like any other cell, it is constituted by a mass of cytoplasm called neuroplasm, which is covered by a cell membrane. The cytoplasm contains a large nucleus, Nissl bodies, neurofibrils, mitochondria and Golgi apparatus. Nissl bodies and neurofibrils are found only in nerve cell and not in other cells.

Nucleus

Each neuron has one nucleus, which is centrally placed in the nerve cell body. Nucleus has one or two prominent nucleoli. Nucleus does not contain centrosome. So, the nerve cell cannot multiply like other cells.

Nissl Bodies

Nissl bodies or **Nissl granules** are small basophilic granules found in cytoplasm of neurons and are named after the discoverer. These bodies are present in soma and dendrite but not in axon and **axon hillock.** Nissl bodies are called **tigroid substances,** since these bodies are responsible for tigroid or spotted appearance of soma after suitable staining. Dendrites are distinguished from axons by the presence of Nissl granules under microscope.

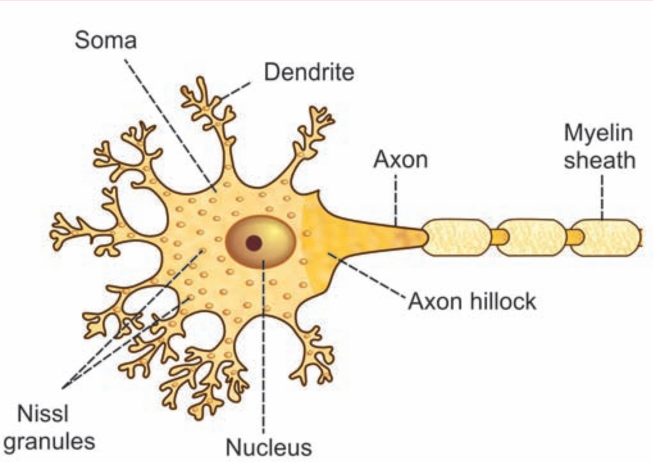

FIGURE 134.2: Structure of a neuron

Nissl bodies are membranous organelles containing ribosomes. So, these bodies are concerned with synthesis of proteins in the neurons. Proteins formed in soma are transported to the axon by axonal flow.

Number of Nissl bodies varies with the condition of the nerve. During fatigue or injury of the neuron, these bodies fragment and disappear by a process called **chromatolysis.** Granules reappear after recovery from fatigue or after regeneration of nerve fibers.

Neurofibrils

Neurofibrils are thread-like structures present in the form of network in the soma and the nerve processes. Presence of neurofibrils is another characteristic feature of the neurons. The neurofibrils consist of microfilaments and microtubules.

Mitochondria

Mitochondria are present in soma and in axon. As in other cells, here also mitochondria form the powerhouse of the nerve cell, where ATP is produced (Chapter 1).

Golgi Apparatus

Golgi apparatus of nerve cell body is similar to that of other cells. It is concerned with processing and packing of proteins into granules (Chapter 1).

■ DENDRITE

Dendrite is the **branched process** of neuron and it is branched repeatedly. Dendrite may be present or absent. If present, it may be one or many in number. Dendrite has Nissl granules and neurofibrils.

Dendrite transmits impulses towards the nerve cell body. Usually, the dendrite is shorter than axon.

■ AXON

Axon is the **longer process** of nerve cell. Each neuron has only one axon. Axon arises from axon hillock of the nerve cell body and it is devoid of Nissl granules. Axon extends for a long distance away from the nerve cell body. Length of longest axon is about 1 meter.

Axon transmits impulses away from the nerve cell body.

Organization of Nerve

Each nerve is formed by many bundles or groups of nerve fibers. Each bundle of nerve fibers is called a **fasciculus.**

Coverings of Nerve

The whole nerve is covered by tubular sheath, which is formed by a areolar membrane. This sheath is called **epineurium.** Each fasciculus is covered by **perineurium** and each nerve fiber (axon) is covered by **endoneurium** (Fig. 134.3).

Internal Structure of Axon – Axis Cylinder

Axon has a long central core of cytoplasm called **axoplasm.** Axoplasm is covered by the tubular sheath-like membrane called **axolemma.** Axolemma is the continuation of the cell membrane of nerve cell body. Axoplasm along with axolemma is called the **axis cylinder** of the nerve fiber (Fig. 134.4).

Axoplasm contains mitochondria, neurofibrils and axoplasmic vesicles. Because of the absence of Nissl bodies in the axon, proteins necessary for the nerve fibers are synthesized in the soma and not in axoplasm. After synthesis, the protein molecules are transported from soma to axon, by means of **axonal flow.** Some neurotransmitter substances are also transported by axonal flow from soma to axon.

Axis cylinder of the nerve fiber is covered by a membrane called **neurilemma** (see below).

Non-myelinated Nerve Fiber

Nerve fiber described above is the non-myelinated nerve fiber, which is not covered by myelin sheath.

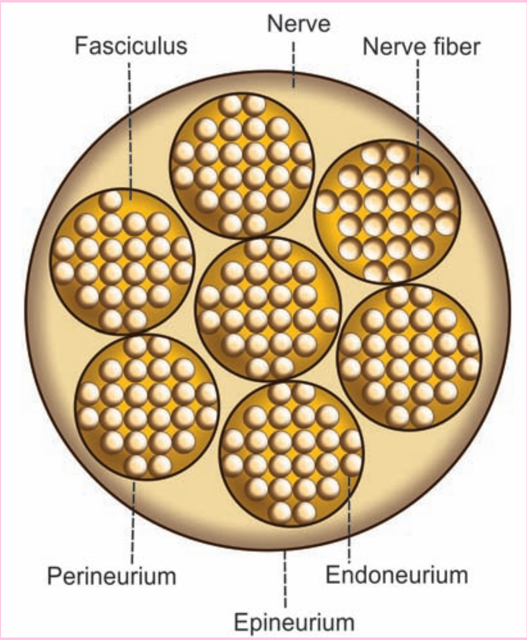

FIGURE 134.3: Cross section of a nerve

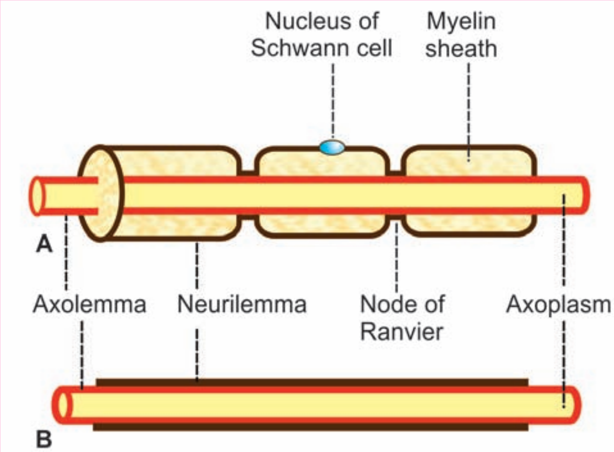

FIGURE 134.4: A. Myelinated nerve fiber;
B. Non-myelinated nerve fiber.

Myelinated Nerve Fiber

Nerve fiber which is insulated by myelin sheath is called myelinated nerve fibers.

■ MYELIN SHEATH

Myelin sheath is a thick lipoprotein sheath that insulates the myelinated nerve fiber. Myelin sheath is not a continuous sheath. It is absent at regular intervals. The area where myelin sheath is absent is called **node of Ranvier.** Segment of the nerve fiber between two nodes is called **internode.** Myelin sheath is responsible for white color of nerve fibers.

Chemistry of Myelin Sheath

Myelin sheath is formed by concentric layers of proteins, alternating with lipids. The lipids are cholesterol, lecithin and cerebroside (sphingomyelin).

Formation of Myelin Sheath – Myelinogenesis

Formation of myelin sheath around the axon is called the myelinogenesis. It is formed by **Schwann cells** in neurilemma. In the peripheral nerve, the myelinogenesis starts at 4th month of intrauterine life. It is completed only in the second year after birth.

Before myelinogenesis, Schwann cells of the neurilemma are very close to axolemma, as in the case of unmyelinated nerve fiber. The membrane of the Schwann cell is double layered.

Schwann cells wrap up and rotate around the axis cylinder in many concentric layers. The concentric layers fuse to produce myelin sheath but cytoplasm of the cells is not deposited. Outermost membrane of Schwann cell remains as neurilemma. Nucleus of these cells remains in between myelin sheath and neurilemma.

Functions of Myelin Sheath

1. *Faster conduction*

Myelin sheath is responsible for faster conduction of impulse through the nerve fibers. In myelinated nerve fibers, the impulses jump from one node to another node. This type of transmission of impulses is called **saltatory conduction** (Chapter 136).

2. *Insulating capacity*

Myelin sheath has a high insulating capacity. Because of this quality, myelin sheath restricts the nerve impulse within single nerve fiber and prevents the stimulation of neighboring nerve fibers.

■ NEURILEMMA

Neurilemma is a thin membrane, which surrounds the axis cylinder. It is also called **neurilemmal sheath** or **sheath of Schwann.** It contains Schwann cells, which have flattened and elongated nuclei. Cytoplasm is thin and modified to form the thin sheath of neurilemma.

One nucleus is present in each internode of the axon. Nucleus is situated between myelin sheath and neurilemma.

In non-myelinated nerve fiber, the neurilemma surrounds axolemma continuously. In myelinated nerve fiber, it covers the myelin sheath. At the node of Ranvier (where myelin sheath is absent), neurilemma invaginates and runs up to axolemma in the form of a finger-like process.

Functions of Neurilemma

In non-myelinated nerve fiber, the neurilemma serves as a covering membrane. In myelinated nerve fiber, it is necessary for the formation of myelin sheath (myelinogenesis). Neurilemma is absent in central nervous system. So, the neuroglial cells called **oligodendroglia** are responsible for myelinogenesis in central nervous system.

■ NEUROTROPHINS – NEUROTROPHIC FACTORS

Neurotrophins or neurotrophic factors are the protein substances, which play an important role in growth and functioning of nervous tissue.

Source of Secretion

Neurotrophins are secreted by many tissues in the body, particularly muscles, neuroglial cells called astrocytes and neurons.

Functions

Neurotrophins:

1. Facilitate initial growth and development of nerve cells in central and peripheral nervous system
2. Promote survival and repair of the nerve cells
3. Play an important role in the maintenance of nervous tissue and neural transmission.

Recently, it is found that neurotrophins are capable of making the damaged neurons regrow their processes *in vitro* and in animal models. This indicates the possibilities of reversing the devastating symptoms of nervous disorders like **Parkinson disease** and **Alzheimer disease.**

Commercial preparations of neurotrophins are used for the treatment of some neural diseases.

Mode of Action

Neurotrophins act via neurotrophin receptors, which are situated at the nerve terminals and nerve cell body. Neurotrophins bind with receptors and initiate the phosphorylation of tyrosine kinase.

Types

Nerve growth factor (NGF) was the first protein substance identified as neurotrophin. Now, many types of neurotophic factors are identified.

NERVE GROWTH FACTOR

Nerve growth factor (NGF) is a neurotrophin found in many peripheral tissues.

Chemistry

NGF is a peptide with 118 amino acids. Each molecule of NGF is made up of two α-subunits, two β-subunits and two γ-subunits. Only the β-subunits have nerve growth-stimulating activity.

Functions

1. NGF promotes early growth and development of neurons. Its major action is on sympathetic and sensory neurons, particularly the neurons concerned with pain. Because of its major action on sympathetic neurons, it is also called **sympathetic NGF.** NGF also promotes the growth of cholinergic neurons in cerebral hemispheres.
2. Commercial preparation of NGF extracted from snake venom and submaxillary glands of male mouse is used to treat sympathetic neuron diseases.
3. NGF plays an important role in treating many nervous disorders such as Alzheimer disease, neuron degeneration in aging and generation in spinal cord injury.

OTHER NEUROTROPHINS

1. *Brain-derived Neurotrophic Growth Factor*

Brain-derived neurotrophic growth factor (BDGF) was first discovered in the brain of pig. Now it is found in human brain and human sperm. BDGF promotes the survival of sensory and motor neurons, arising from embryonic neural crest. It also protects the sensory neurons in peripheral nervous system and motor neurons of pyramidal system. It enhances the growth of cholinergic, dopaminergic and optic nerves. It is suggested that BDGF may regulate synaptic transmission.

Commercial preparation is used to treat **motor neuron diseases.**

2. *Ciliary Neurotrophic Factor (CNTF)*

CNTF is secreted in peripheral nerves, ocular muscles and cardiac muscle. It protects neurons of ciliary ganglion and motor neurons.

3. *Glial Cell Line-derived Neurotrophic Factor (GNDF)*

GDNF is found in neuroglial cells. It has a potent protective action on dopaminergic neurons. It is used for the treatment of **Parkinson disease.**

4. *Fibroblast Growth Factor (FGF)*

FGF was first discovered as growth factor promoting the fibroblastic growth. It is also known to protect the neurons.

5. *Neurotrophin-3 (NT-3)*

Neurotrophin-3 (NT-3) acts on γ-motor neurons, sympathetic neurons and neurons from sensory organs. It also regulates the release of neurotransmitter from neuromuscular junction.

NT-3 is useful for the treatment of motor axonal neuropathy and diabetic neuropathy.

Recently, few more substances belonging to the neurotrophin family such as NT-4, NT-5 and leukemia-inhibiting factor are identified. NT-4 and NT-5 act on sympathetic neurons, sensory neurons and motor neurons.