

NERVOUS SYSTEM GENERALITY – INTRODUCTION-HISTOLOGY part 2 D.HAMMOUDI.MD







Classification by action on other neurons

•Excitatory neurons evoke excitation of their target neurons. Excitatory neurons in the brain are often glutamatergic. Spinal motoneurons use acetylcholine as their neurotransmitter.

•Inhibitory neurons evoke inhibition of their target neurons. Inhibitory neurons are often interneurons. The output of some brain structures (neostriatum, globus pallidus, cerebellum) are inhibitory. The primary inhibitory neurotransmitters are GABA and glycine.

•<u>Modulatory neurons</u> evoke more complex effects termed neuromodulation. These neurons use such neurotransmitters as dopamine, acetylcholine, serotonin and others.

Classification by discharge patterns

Neurons can be classified according to their electrophysiological characteristics:

- Tonic or regular spiking. Some neurons are typically constantly (or tonically) active. Example: interneurons in neurostriatum.
 Phasic or bursting. Neurons that fire in bursts are called phasic[think M16].
- •Fast spiking. Some neurons are notable for their fast firing rates, for example some types of cortical inhibitory interneurons, cells in globus pallidus.
- •<u>Thin-spike.</u> Action potentials of some neurons are more narrow compared to the others. For example, interneurons in prefrontal cortex are thin-spike neurons.

Classification by neurotransmitter released

Some examples are cholinergic, GABA-ergic, glutamatergic and dopaminergic neurons.

Axons: Function

- Generate and transmit action potentials
- Secrete neurotransmitters from the axonal terminals
- Movement along axons occurs in two ways
 - Anterograde toward axonal terminal
 - Retrograde away from axonal terminal







Cell body (perikaryon)

- "Nutrition center"
- Cell bodies within CNS clustered into nuclei, and in PNS in ganglia

• Dendrites

- Provide receptive area
- Transmit electrical impulses to cell body

• Axon

- Conducts impulses away from cell body
- Axoplasmic flow:
- Proteins and other molecules are transported by rhythmic contractions to nerve endings

<u>– Axonal transport:</u>

- Employs microtubules for transport
- May occur in orthograde or retrograde direction







Axons

Dendrites

Take information away from the cell body
Smooth Surface
Generally only 1 axon per cell
No ribosomes
Can have myelin
Branch further from the cell body Bring information to the cell body
Rough Surface (dendritic spines)
Usually many dendrites per cell
Have ribosomes
No myelin insulation
Branch near the cell body

There are 4 classifications of neurons based on structure:

- 1. Anaxonic neurons:
- small
- all cell processes look alike
- found in brain and sense organs
- 2. Bipolar neurons:
- small
- one dendrite and one axon
- found in special sensory organs (sight, smell, hearing)
- 3. Unipolar neurons:
- very long axons
- dendrites and axon are fused, with cell body to one side
- found in sensory neurons of the peripheral nervous system
- 4. Multipolar neurons:
- very long axons
- 2 or more dendrites and 1 axon
- common in the CNS
- includes all motor neurons of skeletal muscles



- Sensory neurons:
- Interneurons
- Motor neurons

There are 3 classifications of neurons based on function:

1. <u>Sensory neurons or afferent neurons</u>, (the afferent division of the PNS):

- Cell bodies of sensory neurons are grouped in *sensory ganglia*.
- Sensory neurons collect information about our internal environment (visceral sensory neurons) and our relationship to the external environment (somatic sensory neurons).
- <u>Sensory neurons are unipolar.</u> Their processes, called afferent fibers, extend (deliver messages) from sensory receptors to the CNS.
- Sensory receptors are categorized as:

a. interoceptors:

- monitor digestive, respiratory, cardiovascular, urinary and reproductive systems
- provide internal senses of taste, deep pressure and pain

b. <u>exteroceptors:</u>

- external senses of touch, temperature, and pressure
- distance senses of sight, smell and hearing

c. proprioceptors:

- monitor position and movement of skeletal muscles and joints





- 2. <u>Motor neurons or *efferent neurons* (the efferent division of the PNS):</u>
- carry instructions from the CNS to peripheral effectors of tissues and organs via axons called efferent fibers.
- the 2 major efferent systems are:
- the somatic nervous system (SNS), including all the somatic motor neurons that innervate skeletal muscles.
- 2. <u>the autonomic nervous system (ANS)</u>, including the visceral motor neurons that innervate all other peripheral effectors (smooth muscle, cardiac muscle, glands and adipose tissue).
- signals from CNS motor neurons to visceral effectors pass through synapses at *autonomic ganglia*, dividing efferent axons into 2 groups:

1. preganglionic fibers 2. postganglionic fibers



Autonomic Nervous System



3. Interneurons or association neurons:

-located in the brain, spinal cord and some autonomic ganglia, between sensory neurons and motor neurons

-responsible for distribution of sensory information and coordination of motor activity

 involved in higher functions such as memory, planning and learning



Structural

Classification

- Multipolar many processes extend from cell body, all dendrites except one axon
- Bipolar Two processes extend from cell, one a fused dendrite, the other an axon
- Unipolar One process extends from the cell body and forms the peripheral and central process of the axon



Multipolar Neurons



The cell body









Bipolar Neurons

- Bipolar neurons are rare in the human body
- Found only in special sense organs where they function as receptor cells
- Examples include those found in the retina of the eye, inner ear, and in the olfactory mucosa
- They are primarily sensory neurons



Interneurons

- The Pyramidal cell is the large neuron found in the primary motor cortex of the cerebrum
- The Purkinje cell from the cerebellum



Unipolar Neuron

- Unipolar neurons have a single process that emerges from the cell body
- The central process (axon) is more proximal to the CNS and the peripheral is closer to the PNS
- Unipolar neurons are chiefly found in the ganglia of the peripheral nervous system
- Function as sensory neurons



Functional Classification



Sensory neurons

These run from the various types of stimulus receptors, e.g.,

touch
odor
taste
sound
vision

to the central nervous system (CNS), the brain and spinal cord.

The cell bodies of the sensory neurons leading to the spinal cord are located in clusters, called **ganglia**, next to the spinal cord.

The axons usually terminate at interneurons.

	Sensory neuron	Interneuron	Motor Neuron
Length of Fibers	Long dendrites and short axon	Short dendrites and short or long anxon	Short dendrites and long axons
Location	Cell body and dendrite are outside of the spinal cord; the cell body is located in a dorsal root ganglion	Entirely within the spinal cord or CNS	Dendrites and the cell body are located in the spinal cord; the axon is outside of the spinal cord
Function	Conduct impulse to the spinal cord	Interconnect the sensory neuron with appropriate motor neuron	Conduct impulse to an effector (muscle or gland)



Sensory Neurone:

- •Afferent Neuron Moving away from a central organ or point
- Relays messages from receptors to the brain or spinal cord
Interneurons

These are found exclusively within the spinal cord and brain.

They are stimulated by signals reaching them from •sensory neurons •other interneurons or •both. Interneurons are also called association neurons.







<u>NEUROGLIA OR GLIA</u>

- Glial cells, commonly called neuroglia or simply glia, are non-neuronal cells that provide
 - support and nutrition,
 - maintain homeostasis,
 - -form myelin,
 - participate in signal transmission in the nervous system.

TYPE OF NEUROGLIA

- <u>Microglia</u> [Microglia are specialized macrophages capable of phagocytosis that protect neurons of the CNS.]
- <u>Macroglia FOR CNS</u>
 - » Astrocytes: The most abundant type of glial cell, astrocytes (also called *astroglia*)
 - » Oligodendrocytes
 - » Ependymal cells
 - » Radial glia
- FOR PNS [PERIPHERIC NERVOUS SYSTEM
 - »Schwann cells
 - »Satellite cells

MICROGLIA CELL - GOLGI STAIN

Neuroglia

2. Microglia

- <u>Specialized immune cells that act as the</u> <u>macrophages of the CNS</u>
- Why is it important for the CNS to have its own army of immune cells? Microglia
- Microglia are small, with many fine-branched processes. They migrate
- through neural tissue, cleaning up cellular debris, waste products and
- pathogens.

B. Ependymal Cells

- Low columnar epithelial-esque cells that line the ventricles of the brain and the central canal of the spinal cord
- Some are ciliated which facilitates the movement of cerebrospinal fluid



The central nervous system has 4 types of neuroglia:

- 1. ependymal cells
- 2. astrocytes
- 3. oligodendrocytes
- 4. microglia

The cell bodies of neurons in the PNS are clustered in masses called ganglia, which are surrounded and protected by support cells called neuroglia.

Neuroglia of the Peripheral Nervous System,

- There are 2 types of neuroglia in the PNS: satellite cells and Schwann cells.
- 1. <u>Satellite cells (*amphicytes*)</u> surround ganglia and regulate the environment around the neuron.
- 2. <u>Schwann cells (*neurilemmacytes*)</u> form a myelin sheath called the neurilemma around peripheral axons.

One Schwann cell encloses only one segment of an axon, so it takes many Schwann cells to sheath an entire axon.

•Neurons perform all communication, information processing, and control functions of the nervous system.

 Neuroglia preserve the physical and biochemical structure of neural tissue, and are essential to the survival and function of neurons.

Neuroglia

- Outnumber neurons by about 10 to 1 (the guy on the right had an inordinate amount of them).
- 6 types of supporting cells
 - 4 are found in the CNS:
- 1. <u>Astrocytes</u>
 - Star-shaped, abundant, and versatile
 - Guide the migration of developing neurons
 - Act as K+ and NT buffers
 - Involved in the formation of the blood brain barrier
 - Function in nutrient transfer











Astrocytes

-Astrocytes are large and have many functions, including:

maintaining the blood-brain barrier that isolates the CNS

• creating a 3-dimensional framework for the CNS

- repairing damaged neural tissue
- <u>guiding neuron development</u>
- controlling the interstitial environment





A:ASTROCYT ES numerous processes (B), some astrocytic processes are in contact with nerve fibers.

Other astrocytic processes surround capillaries (D) forming perivascular end-feet (C).





Blood vessel

100 µm





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•Many glial cells do express neurotransmitter receptors, but <u>they do</u> <u>not form synapses with neurones</u>.

•Neuronal activity may regulate glial function by a spillover of transmitter from synaptic sites, which are typically surrounded by fine processes of glial cells.

•Glial cells may also communicate with each other via GAP junctions.



Microglia and Ependymal Cells





MICROGLIA STIMULATORS





1. Ependymal Cells

-The central canal of the spinal cord and ventricles of the brain, filled with circulating cerebrospinal fluid (CSF), are lined with ependymal cells which form an epithelium called the ependyma.

-Some ependymal cells secrete cerebrospinal fluid, and some have cilia or microvilli that help circulate CSF.

-Others monitor the CSF or contain stem cells for repair. Processes of ependymal cells are highly branched and contact neuroglia directly.



ependymal cells

cilia

central canal

•The ventricles of the brain and the central canal of the spinal cord are lined with <u>ependymal cells</u>.

•The cells are often cilated and form a simple cuboidal or low columnar epithelium.

•The lack of tight junctions between ependymal cells allows a free exchange between cerebrospinal fluid and nervous tissue.

•Ependymal cells can specialise into <u>tanycytes</u>, which are rarely ciliated and have long basal processes.

• Tanycytes form the ventricular lining over the few CNS regions in which the blood-brain barrier is incomplete.

•They do form tight junctions and control the exchange of substances between these regions and surrounding nervous tissue or cerebrospinal fluid.

Neuroglia

4. Oligodendrocytes

Produce the myelin sheath which provides the electrical insulation for certain neurons in the CNS



-Oligodendrocytes have smaller cell bodies and fewer processes than astrocytes.

-Processes may contact other neuron cell bodies, or wrap around axons to form insulating myelin sheaths.

-An axon covered with myelin (myelinated) increases the speed of action potentials.

-Myelinated segments of an axon are called internodes. The gaps between internodes, where axons may branch, are called nodes (nodes of Ranvier).

- Because myelin is white, regions of the CNS that have many myelinated nerves are called white matter, while unmyelinated areas are called gray matter.



several underlying axons Oligodendrocyte Nucleus Node of Ranvier

Electron micrograph showing branched oligodendrocytes with processes extending to

Oligodendrocytes, Schwann Cells, and Satellite Cells


• Most glial cells are much smaller than neurones.

• Their nuclei are generally much smaller than neuronal nuclei, and they rarely contain an easily visible nucleolus.

•Other aspects of their morphology are variable.

•The glial cytoplasm is, if visible at all, very weakly stained.

• Different types of glial cells cannot be easily distinguished by their appearance in this type of preparation.

•Most of the small nuclei located in the white matter of the CNS, where they may form short rows, are likely to represent oligodendrocytes.

Neuroglia

• 2 types of glia in the PNS

1. Satellite cells

- Surround clusters of neuronal cell bodies in the PNS
- Unknown function

2. Schwann cells

- Form myelin sheaths around the larger nerve fibers in the PNS.
- Vital to neuronal regeneration

Myelination in the Peripheral Nervous System





Myelin Sheath and Neurilemma: Formation

- Formed by Schwann cells in the PNS
- A Schwann cell:
 - Envelopes an axon in a trough
 - Encloses the axon with its plasma membrane
 - Has concentric layers of membrane that make up the myelin sheath
- Neurilemma remaining nucleus and cytoplasm of a Schwann cell

MYELIN SHEATH

1. Myelin Sheaths greatly increase the speed of impulse along an axon.

2. Myelin is composed of 80% lipid and 20% protein.

3. Myelin is made of special cells called Schwann Cells that forms an insulated sheath, or wrapping around the axon.

4. There are **SMALL NODES or GAPS** called the **Nodes of Ranvier** between adjacent myelin sheath cells along the axon.

5. As an impulse moves down a myelinated (covered with myelin) axon, the impulse JUMPS form Node to Node instead of moving along the membrane.

6. This jumping from Node to Node greatly increase the speed of the impulse.

7. Some myelinated axons conduct impulses as rapid as 200 meters per second.

8. The formation of myelin around axons can be thought of as a crucial event in evolution of vertebrates.

Destruction of large patches of Myelin characterize a disease called <u>Multiple</u>
 <u>Sclerosis</u>. In multiple sclerosis, small, hard plaques appear throughout the myelin. Normal nerve function is impaired, causing symptoms such as double vision, muscular weakness, loss of memory, and paralysis.





Myelin Sheath

A series of Schwann cells Sheath blocks ion movements Action potential must "jump" from node to node





The outer nucleated cytoplasmic layer of the neurolemmocyte, which encloses the myelin sheath, is called the neurolemma (sheath of Schwann). A neurolemma is found only around the axons in the PNS. When an axon is injured, the neurolemma aids in the regeneration by forming a regeneration tube that guides and stimulates regrowth of the axon. At intervals along an axon, the myelin sheath has gaps called neurofibral nodes (nodes of Ranvier).

Action Potential Leaps From Node of Ranvier to Node of Ranvier





Development of the myelin sheath of a peripheral axon, as seen in transverse section.



Neurilemma. The neurilemma is the nucleated cytoplasmic layer of the Schwann cell. The neurilemma allows damaged nerves to regenerate. Nerves in the brain and spinal cord DO **NOT have a neurilemma** and, therefore, DO NOT recover when damaged.

Regions of the Brain and Spinal Cord

- White matter dense collections of myelinated fibers
- Gray matter mostly soma and unmyelinated fibers

- A bundle of processes in the PNS is a nerve.
- Within a nerve, each axon is surrounded by an endoneurium (too small to see on the photomicrograph) – a layer of loose CT.
- Groups of fibers are bound together into bundles (fascicles) by a perineurium (red arrow).
- All the fascicles of a nerve are enclosed by a epineurium



Comparison of Structural Classes of Neurons

TABLE 11.1 Comparison of Structural Classes of Neurons NEURON TYPE MULTIPOLAR BIPOLAR

STRUCTURAL CLASS: NEURON TYPE ACCORDING TO THE NUMBER OF PROCESSES EXTENDING FROM THE CELL BODY



RELATIONSHIP OF ANATOMY TO THE THREE FUNCTIONAL REGIONS

= Receptive region (receives stimulus). Plasma membrane exhibits chemically gated ion channels.



= Conducting region (generates/ transmits action potential). Plasma membrane exhibits voltage-gated Na⁺ and K⁺ channels.



(Many bipolar neurons do not generate action potentials and, in those that do, the location of the trigger zone is not universal.) Secretory region (axon terminals release neurotransmitters). Plasma membrane exhibits voltage-gated Ca⁺ channels.



Comparison of Structural Classes of Neurons

TABLE 11.1 Comparison of Structural Classes of Neurons (continued)

BIPOLAR

NEURON TYPE

MULTIPOLAR

UNIPOLAR (PSEUDOUNIPOLAR)

RELATIVE ABUNDANCE AND LOCATION IN HUMAN BODY

Most abundant in body. Major neuron type in the CNS.

Rare. Found in some special sensory organs (olfactory mucosa, eye, ear).

Found mainly in the PNS. Common only in dorsal root ganglia of the spinal cord and sensory ganglia of cranial nerves.

STRUCTURAL VARIATIONS



Comparison of Structural Classes of Neurons

TABLE 11.1 Comparison of Structural Classes of Neurons (continued)

NEURON TYPE

MULTIPOLAR

BIPOLAR

UNIPOLAR (PSEUDOUNIPOLAR)

FUNCTIONAL CLASS: NEURON TYPE ACCORDING TO DIRECTION OF IMPULSE CONDUCTION

1. Most multipolar neurons are **interneurons (association neurons)** that conduct impulses within the CNS, integrating sensory input or motor output; may be one of a chain of CNS neurons, or a single neuron connecting sensory and motor neurons.

2. Some multipolar neurons are **motor neurons** that conduct impulses along the efferent pathways from the CNS to an effector (muscle/gland).

Essentially all bipolar neurons are sensory neurons that are located in some special sense organs. For example, bipolar cells of the retina are involved with the transmission of visual inputs from the eye to the brain (via an intermediate chain of neurons). Most unipolar neurons are **sensory neurons** that conduct impulses along afferent pathways to the CNS for interpretation. (These sensory neurons are called primary or first-order sensory neurons.)



In the PNS, peripheral nerves can regenerate after injury. ScHwann cells assist in a process called Wallerian degeneration.

As the axon distal to the injury site degenerates, Schwann cells form a line along the path of the original axon, and wrap the new axon as it grows.

• In the CNS, nerve regeneration is limited because astrocytes block growth by releasing chemicals and producing scar tissue.

Terms TO KNOW:

ganglion - a collection of cell bodies located outside the Central Nervous System. The spinal ganglia or dorsal root ganglia contain the cell bodies of sensory neurons entering the cord at that region.

nerve - a group of fibers (axons) *outside* the CNS. The spinal nerves contain the fibers of the sensory and motor neurons. A nerve does not contain cell bodies. They are located in the ganglion (sensory) or in the gray matter (motor).

tract - a group of fibers *inside* the CNS. The spinal tracts carry information up or down the spinal cord, to or from the brain. Tracts within the brain carry information from one place to another within the brain. Tracts are always part of white matter.

gray matter - an area of unmyelinated neurons where cell bodies and synapses occur. In the spinal cord the synapses between sensory and motor and interneurons occurs in the gray matter. The cell bodies of the interneurons and motor neurons also are found in the gray matter.

white matter - an area of myelinated fiber tracts. Myelination in the CNS differs from that in nerves.