NERVOUS TISSUE

Chapter 12

Anatomy and Physiology

NERVOUS TISSUE

The Nervous System is made up of the Brain, Spinal Cord, Nerves, and Sensory Receptors.

It is responsible for sensory perceptions, mental activities, and stimulating muscle movements and the secretions of many glands.

FUNCTIONS OF THE NERVOUS SYSTEM

1. Sensory input
2. Integration
3. Homeostasis
4. Mental activity
5. Control of muscle and glands

DIVISIONS OF THE NERVOUS SYSTME

Two Principal divisions of the Nervous System

1. **Central Nervous System (CNS)** - The control center for the entire nervous system.

   -Consists of the **Brain** and **Spinal Cord**.

   (Various sorts of incoming sensory information are integrated and correlated; thoughts and emotions are generated; and memories are formed and stored. Most nerve impulses that stimulate muscles to contract and glands to secrete originate here.)

2. **Peripheral Nervous System (PNS)** – Is external to the CNS.

Consists of:

a. **<u>Sensory Receptor</u>** – Ending of nerve cells or separate, specialized cells that detect temperature, pain, touch, pressure, light, sound, odors, and other stimuli.

   Location: Skin, muscles, joints, internal organs, eyes, and ears.

b. **<u>Nerve</u>** – Is a bundle of axons and their sheaths that connects the CNS to sensory receptors, muscles and glands.

   (i) **<u>12 Pairs of Cranial Nerves</u>** – Originate from the Brain.

   (ii) **<u>31 Pairs of Spinal Nerves</u>** – Originate from Spinal Cord.

c. **<u>Ganglion</u>** – Is a collection of neuron cell bodies located outside the CNS.

d. **<u>Plexus</u>** – Is an extensive network of axons and, in some cases, also neuron cell bodies located outside the CNS.

<u>Two Subcategories of PNS</u> :

1) **<u>Sensory (Afferent) Division</u>** – Transmits electric signals, called <u>action potentials</u>, from the sensory receptors to the CNS.

   -Called the Input Component.

2) **<u>Motor (Efferent) Division</u>** – Transmits action potentials from the CNS to effector organs, such as muscles and glands.

   -Called the Output component.

Motor (Efferent) Division is divided into:

1) **Somatic Nervous System (SNS)** – Transmits action potentials from the CNS to skeletal muscles.

   Skeletal muscles are voluntarily controlled through the somatic nervous system.

2) **Autonomic Nervous System (ANS)** – Transmits action potential from the CNS to smooth muscle, Cardiac muscle, and certain glands.

   Are subconsciously or involuntarily controlled by the ANS.

Autonomic Nervous System (ANS) is subdivide into:

1) **Sympathetic Division** – Prepares the body for physical activity.

2) **Parasympathetic Division** – Regulates resting or vegetative functions, such as digesting food or emptying the urinary bladder.

   Usually, the two divisions have opposing reactions.

CELLS OF THE NEERVOUS SYSTEM

Nervous System is made up of:

(1) **Neurons** - Receive stimuli and conduct action potential.

(2) **Nonneural (Neuroglia or Glial cell)** – Support and protect neurons and perform other functions.

NEURONS

-Are responsible for conducting nerve impulse from one part of the body to another.

-Do not normally undergo mitosis- (when injured, mature neurons have little capability to repair).

-Are the basic information-processing units of the nervous system.

Parts of a Neuron:

a. **Cell Body, Soma, or Perikaryon** - contains a well-defined nucleus and nucleolus surrounded by a granular cytoplasm.
Within Cytoplasm are organelles such as:

i) Lysosomes - contains powerful digestive enzymes
ii) Rough endoplasmic reticulum – Site of protein synthesis.
ii) Mitochondria - "Powerhouse" of the cell - production of ATP.
iii) Golgi complexes - Packaging of protein, lipid secretion, carbohydrate synthesis.

b. **Dendrites** - usually highly branched, thick extensions of the cytoplasm of the cell body.

-Contain chromatophilic substance, mitochondria, and other cytoplasmic organelles.

c. **Axon** - A single long, thin process that is highly specialized.

-Originates from the cell body as a small conical elevation called the axon hillock.

Function: Conducts nerve impulses away from the cell body to another neuron or muscular or glandular tissue.

Axoplasm - Axon cytoplasm.

Axolemma - a plasma membrane surrounding the axoplasm.

Axon Collaterals - side branches of axon.

Axon Terminals (Telodendria) - fine filaments in which Axon and Collaterals terminate.

Synaptic End Bulbs - bulblike structure at the distal end of axon terminal.
-Important in nerve impulse conduction from one neuron to another and from neuron to muscle or glandular tissue.

*Synaptic vesicles - membrane enclosed sacs in synaptic end bulbs, that store chemicals called neurotransmitter.

*Neurotransmitters determine whether or not impulses pass from one neuron to another or from a neuron to another tissue (muscle or gland).

*Cell Body - of a neuron is essential for the synthesis of many substances that sustain life of the nerve cell.

Axon Transport

Axon transport mechanism can move cytopskeletal proteins, organelles such as mitochondrial, and vesicles containing neurohormones to be secreted down the axon to the presynaptic terminals.

In addition, damaged organelles, recycled plasma membrane, and substances taken in by edocytosis can be transported up the axon to the neuron cell body.

He movement of material within the axon is necessary for its normal function, but it also provides a way for infectious agents and harmful substances to be transported from the periphery to the CNS.

<u>Types of Neurons</u>

Neurons in the body may be classified by <u>structure</u> and <u>function</u>.

I. **<u>Structural Classification</u>**

-Is based on the <u>number of processes</u> extending from the cell body

a. **<u>Multipolar Neurons</u>** - Have several dendrites and a single axon.

<u>Examples</u> : Most neurons in the CNS and Motor neurons are multipolar.

b. **<u>Bipolar Neurons</u>** - Have two processes: one dendrite and one axon.

Dendrite are specialized in to receive the stimulus, and axon conducts action potentials to the CNS.

<u>Examples</u>: In the <u>Retina of the Eye</u>, <u>Inner Ear</u>, and <u>Olfactory area</u> of the brain.

c. **<u>Unipolar Neurons (Pseudounipolar Neurons)</u>** - Have only one process extending from the cell body.

-The single process divides into <u>two</u> branches:

i) **<u>Central Branch</u>** - functions as an axon.

ii) **<u>Peripheral Branch</u>** - functions as a dendrite.

<u>Examples</u>: Unipolar neurons are found in

a) Posterior (sensory) root ganglia of spinal nerves; and
b) The ganglia of cranial nerves that carry general somatic sensory impulses

II. <u>**Functional Classification**</u>

Is based on the <u>direction</u> in which action potential is are conducted.

a) <u>**Sensory (Afferent) Neurons**</u> – Conduct action potential toward the CNS.

b) <u>**Motor (Efferent) Neurons**</u> – Conduct action potential away from the CNS toward muscles and glands.

c) <u>**Interneurons (Association) Neurons**</u> – Conduct action potentials from one neuron to another within the CNS.

NEUROGLIA OR GLIAL CELLS

<u>**Neuroglia**</u> - Serve as a special supporting and protective component of the nervous system.

Neuroglia support, nurture, and protect the neurons, maintaining homeostasis of the fluid that bathes neurons.

-Unlike neurons, can multiply and divide in the mature nervous system.

-Are believed to be derived from ectoderm.

-Are generally smaller than neurons and outnumber neurons by 50 to 50 times.

-<u>Gliomas</u> is a brain tumor involving neuroglia, are highly malignant.

<u>**Four Types of Neuroglia Found in the CNS**</u>:

a) <u>**Astrocytes**</u> - Star-shaped cells with numerous processes.

<u>Function</u>: Participate in the metabolism of Neurotransmitters;

maintain balance of K+; twine around nerve cells to form supporting network in CNS; attach neurons to their blood vessels; help form **blood-brain barrier**.

b) **Ependymal Cells** – Line the ventricles (cavities) of the brain and the central canal of the spinal cord.

Function: form a continuous epithelial lining for the ventricles of the brain (spaces that form and circulate cerebrospinal fluid) and the central canal of the spinal cord; probably assist in the circulation of cerebrospinal fluid (CSF) in these area.

c) **Microglia** - small cells with few processes; derived from monocytes; normally stationary but may migrate to site of injury, also called Brain Macrophages.

Function: Engulf and destroy microbes and cellular debris; may migrate to area of injured nervous tissue and function as small macrophages.

d) **Oligodendrocytes** - Resemble astrocytes in some ways, but processes are fewer and shorter.

Function: Give support by forming semirigid connective tissue rows between neurons in CNS; produce a phospholipid myelin sheath around axon of neurons of CNS.

Two Types of Neuroglia or Supporting Cells Found in PNS

1. **Schwann Cells or Neurolemmocytes** - Flattened cells arranged around axons in PNS.

   -Produce myelin sheath around axons of PNS neurons.

2. **Satellite Cells** - Flattened cells arranged around the cell bodies of neurons in ganglia (collections of neuronal cell bodies in the PNS)

   -Support neurons in ganglia of PNS.

MYELINATED AND UNMYELINATED AXONS

Cytoplasmic extensions of the Oligodendrocytes in the CNS and of the Schwann cells in the PNS surround axons to form either myelinated or unmyelinated axons.

Myelin protects and electrically insulates axon from one another.

Action potentials travel along myelinated axons more rapidly than along unmyelinated axons.

(1) **Myelinated Axons** – Extensions from oligodendrocytes or Schwann cells repeatedly wrap around a segment of an axon to form a series of tightly wrapped membrane rich in phospholipids with little cytoplasm sandwiched between the membrane layers.

Tightly wrapped membranes constitute the myelin sheath and give myelinated axons a white appearance because of the high lipid concentration.

Nodes of Ranvier – Are interruptions in the myelin sheath.

Internodes – The myelin covered area between the nodes.

(2) **Unmyelinated Axons** – Rest in invaginations of the oligodendrocytes or the Schwann cell. The cell's plasma membrane surrounds each axon, but does not wrap around them many times.

ORGANIZATION OF NERVOUS TISSUE

Gray and White Matter

(In a freshly dissected section of the brain or spinal cord, some regions look white and glistening whereas others appear gray.)

White Matter - refers to aggregation of myelinated processes from many neurons.

-Whitish color of myelin gives white matter its name.

Gray Matter of the nervous system contains either nerve cell bodies, dendrites, and axon terminal or bundles of unmyelinated axons and neuroglia.

ELECTRIC SIGNALS

(Communication by neurons depends on two basic properties of their plasma membrane)

1) Resting Membrane Potential (RMP) - an electrical voltage across the membrane

2) Ion Channels (Pores) that may be closed or open.

   -When they are open, specific ions in the intracellular fluid (cytosol) or extracellular fluid can flow across the membrane.

1. Resting Membrane Potential (RMP)

   Resting membrane potential (RMP) occurs because there is a small buildup of negative charges just inside the membrane and an equal buildup of positive charges on the outside.

   -A separation of positive and negative electric charges is a form of potential energy, measured in volts or millivolts (1mV = 1/1000 V).

   *In neurons, the RMP ranges from - 40 to 90 mV.

   *A typical value is - 70mV.

   *(The minus sign indicates that the inside is negative to the outside.)

*A cell that exhibits a membrane potential is said to be Polarized.

(Polarized - a membrane with differences in charge on either side.)

Two Main Factors Contribute to the Resting Membrane Potential

1) Distribution of ions across the plasma membrane.

-Extracellular fluid (outside cells) is rich in Na+ (sodium ions) and Cl- (chloride ions).

-Intracellular fluid (inside cells) is rich in K+ (potassium ions), organic phosphate and amino acids in proteins.

2) Relative permeability of the plasma membrane to Na+ and K+

-Permeability of the plasma membrane to K+ is 50 to 100 times greater than its permeability to Na+ in a resting neuron or muscle fiber.

First Consider what would happen if the Membrane were Permeable only to K+:

-These positive ions would tend to leak out of the cell into the extracellular fluid along the concentration gradient.

-But, as more and more exited, the interior of the membrane would become increasingly negative.
-The resulting electrical gradient (inside negative) would then start to pull K+ back into the cell.

*Eventually, just as many K+ would be entering due to the electrical gradient (+6 -) as would be exiting due to the concentration gradient (high concentration6 low concentration).

Potassium Equilibrium Potential is the membrane potential that balances the K+ concentration gradient (is -90 mV).

Actually, the membrane is moderately permeable to K+ and Cl- and Very slightly Permeable to Na+.

-One way to balance the electrical effect of K+ outflow might be Na+ inflow, in effect exchanging one positive particle for another.

-But inward leakage of Na+ is far too slow to keep pace with outward leakage of K+.

-Also, although positively charged ions leaving the cell should promote the tandem exit of anions (that is, negatives following positives by attractions), most anions in the cell are not free to leave.

*(They are attached either to large proteins or to other organic molecules, such as phosphates in ATP.)

-Inward leakage of Cl- along its concentration gradient cannot balance the electrical effect of K+ outflow.

(It will not happen because it would only make the inside more negative.)

In Summary

-The result of the low membrane permeability to Na+ and to anions inside the cell is that fluid just next to the inner surface of the plasma membrane becomes more and more negatively charged as K+ leaves.

Note:

-Both the Electrical and Concentration gradients promote Na+ inflow: the negative interior attracts these positive Na+ ions and the concentration of Na+is higher outside (should flow from area of high concentration to low concentration).

*Even though membrane permeability to Na+ is very low, a slow leak would eventually destroy the electrochemical gradient because there is no gradient to push Na+ back out.

*The small inward Na+ leak is taken care of by Na+/K+ Active Transport Pumps.

Na+/K+ Active Transport Pumps maintain the resting membrane potential by pumping out Na+ as fast as it leaks in; and brings in K+ that leaks out.

*The critical job of Na+/K+ pump is to export Na+.

-Some Na+/K+ pumps expel three Na+ for each two K+ imported.

*Such Na+/K+ pumps are said to be Electrogenic; which means they contribute to the negativity of the resting membrane potential.

2. **Ion Channels**

Two basic types:

a) Leakage (nongated) channels are always open.

b) Gated Channels open and close in response to some sort of stimulus.

Four Categories of Stimuli Operate gated Ion Channels

i) Voltage-gated (voltage-regulated) Ion Channel - opens in response to a direct change in membrane potential (voltage).

ii) Chemically gated ion channel - opens and closes in response to specific chemical stimulus.

iii) Mechanically gated ion channels open or close in response to mechanical vibration in pressure, such as sound waves or pressure of a touch.

iv) Light-gated ion channels close in response to light.

Action Potential (Impulse)

Two types of voltage-gated ion channels open and close during action potential:

1) Channels for Na+ 2) Channels for K+

Depolarization - rapid opening of voltage-gated Na+ channel, results to the loss and then reversal of membrane polarization.

*The slower opening of the voltage-gated K+ channels and closing of previously open Na+ channels lead to **Repolarization**.

Hyperpolarization is polarization more negative than the resting level.

*Electrical measurement of a polarized membrane indicate a voltage of about 70 millivolts (mV).

(1 mV = 1/1000 of a volt; 1.5 volt battery power a flashlight).

*Since positive charges predominate outside, the inside of the membrane is said to be 70 mV less positive than the outside - that is the Resting Membrane Potential is -70mV.

2. Excitability

Excitability - is the ability of nerve cells to respond to stimuli and convert them into nerve impulses.

Stimulus - is any condition in the environment capable of altering the resting membrane potential.

*If an excitatory stimulus of adequate strength, called a threshold stimulus, is applied to a polarized membrane, the membrane permeability to Na+ ion greatly increases at the point of stimulation.

What happens is that:

a) Voltage-sensitive sodium channels open and permit the influx of Na+ ions by diffusion. (The movement of Na+ inward also results from the attraction of positively charged Na+ ions to the negative ion on the inside of the membrane.)

b) Since there are more Na+ ion entering than leaving the resting membrane potential begins to change.

c) (At first, the potential inside the membrane shifts, from f<u>-70mV</u> toward <u>0</u>, and then to a positive value.

<u>Depolarization</u> - a movement toward less negative (more positive) voltages on the interior of the cell membrane.

-Moving away from the resting (polarized) state.

(Throughout depolarization, the Na+ ions continue to rush inside until the resting membrane potential is <u>reversed</u> - the inside of the membrane becomes positive and the outside negative.)

*Changes from -70mV to 0mV to +30mV.

<u>Voltage-sensitive (Gated) channels</u>

-Are ions channel composed of integral proteins in the plasma membrane, that contain one or more proteins that can undergo alterations in shape and thus function like gates by restricting or permitting the movement of ions in response to membranes voltage state (electric potential).

Two types of Voltage-Sensitive Channels:

1) Voltage-sensitive sodium channel - has two separate gates a) An activation gate near the exterior of the channel, and b) An inactivation gate near the interior of the channel.

-Activation gate is closed in a polarized (resting) membrane.

-Inactivation gate is open in a polarized (resting) membrane.

(As a result movement of sodium (Na+ ions to the interior of the cell is inhibited.)

*When a threshold stimulus is applied to a polarized membrane, the membrane starts to lose its polarity between -70 to -50mV, voltage-sensitive channels undergo a change from a resting to an activated state.

-At activated state both Activation and Inactivation gates are open and Na+ ions move inward in sufficient numbers so that the membrane voltage changes from -70 to 0 to +30mV.

*The inward movement of Na+ ion during depolarization is an example of a positive feedback system that is essential for homeostasis.

2. Voltage-Sensitive Potassium Channels - involves repolarization (back to resting potential).

-By the time the nerve impulse has traveled from one point on the membrane to the next, the previous, point becomes repolarized - Its resting potential is restored.

-When the membrane becomes depolarized, the voltage change causes a slow alteration that results in opening of the gate and rapid passage of K+ ions to the exterior by diffusion.

*In this state, the voltage-sensitive potassium channels are said to be activated.

-Repolarization period returns the cell to its resting membrane potential, from <u>+30mV to - 70mV.</u>

*The neuron is now ready to receive another stimulus, and go through the same process again.

*Until repolarization occurs, the neuron cannot conduct another nerve impulse.

<u>Refractory Period</u> - the period of time during which an excitable cell cannot generate another action potential.

<u>Absolute Refractory Period</u> - the time period during which a second action potential cannot be initiated, even with a very strong stimulus.

<u>Relative Refractory Period</u> - the period of time during which a second action potential can be initiated, but only by a suprathreshold (larger than threshold) stimulus.

3. **<u>All-or-None Principle</u>**

A single neuron, or a single muscle fiber, generates an action potential according to all-or-none principle.

Threshold (liminal) stimulus - any stimulus strong enough to initiate a nerve impulse.

Subthreshold (subliminal) stimulus - any stimulus weaker than a threshold stimulus.

4. **<u>Saltatory Conduction</u>**

<u>Continuous Conduction</u> - the step-by-step depolarization of each adjacent area of the axon or dendrite plasma membrane.

<u>Saltatory Conduction</u> - nerve impulse conduction in which the impulse jumps from neurofibral node to node.

5. **Speed of Impulse Propagation**

*The speed of a nerve impulse is independent of stimulus strength.

-Once a neuron reaches its threshold of stimulation, the speed of the nerve impulse is normally determined by temperature, the diameter of the fiber, and the presence or absence of myelin.

-Warmed nerve fibers conduct impulse at higher speeds.

-Cooled nerve fibers conduct impulse at lower speeds.

*Pain resulting from injured tissue can be reduced by the application of cold because the nerve fibers carrying the pain sensations are partially blocked.

*-Fibers with large diameters conduct impulses faster than those with small ones.

a) A fibers - fibers with the largest diameter, and are all myelinated with a brief absolute refractory period. - Split - second reaction, reaction may mean survival.

b) B fibers - have a middle sized diameter
-are myelinated and capable of saltatory conduction;
-have longer absolute refractory period than A fibers
*- conduct impulse more slowly and are generally found where instantaneous response is not a life-and-death matter.

c) C fibers - have the smallest diameter
-Have longest absolute refractory period
-Are unmyelinated
-Conduct impulse more slowly and are generally found where instantaneous response is not a life-and-death matter.

B. **Conduction Across Synapses**

(A nerve impulse is conducted not only along the length of a neuron but also from one neuron to another or to an effector such as a muscle or gland.)

a) <u>Neuromuscular (myoneural) Junction</u> - area through which impulses are conducted from a neuron to a muscular fiber (cell).

b) <u>Neuroglandular Junction</u> - area of contact between a neuron and glandular cell.

c) <u>Neuroeffector Junctions</u> - neuromuscular + neuroglandular junctions.

d) <u>Synapse</u> - a junction between two neurons.

Synapsis mean "connection".

<u>Synaptic Cleft</u> - a minute space, filled with extracellular fluid, about 20 mm across.

<u>Presynaptic Neuron</u> - a neuron located before a synapse.

<u>Postsynaptic neuron</u> - located after a synapse.

<u>Synaptic End bulbs</u>
A bulblike structure at the end of axon terminal neurons.

<u>Axodendritic</u> - when synaptic end bulb of a presynaptic neuron synapse with dendrites.

<u>Axosomatic</u> - when synaptic end bulb of a presynaptic neuron synapse with cell body.

<u>Axoaxonic</u> - when synaptic end bulb of a presynaptic neuron synapse with cell body.

<u>Divergence</u> - when synaptic end bulbs from a single presynaptic neuron synapse with several postsynaptic neurons.

<u>Convergence</u> - when synaptic end bulbs from several presynaptic neuronssynapsee with single postsynaptic neuron.

<u>Neuronal Circuits</u>

The CNS contains billions of neurons organized into complicated patterns called <u>neuronal pools</u>.

Neuronal pools in the CNS are arranged in patterns called <u>circuits</u>.

1. <u>Divergingn Circuit</u>, the nerve impulse from a single presynaptic neuron causes the stimulation of increasing numbers of cells along the circuit.

2. <u>Converging Circuit</u>, the postsynaptic neuron receives nerve impulse from several different sources.

3. <u>Reverberating (oscillatory) Circuit</u>, the incoming impulse stimulates the first neuron, which stimulates the second, which stimulates the third, and so on.

4. <u>Parallel After-discharge Circuit</u>, a single presynaptic cell stimulated a group of neurons, each of which synapses with a common postsynaptic cell.

   <u>Electrical Synapses</u> - a nerve impulse passes from one cell to another through small, protein, tubular structures called <u>gap junctions</u>.

   <u>Chemical Synapse</u> - a neuron secretes a chemical substance called a <u>neurotransmitter</u> (transmitter substance) that acts on receptors of the next neuron at a neuronal synapse, a muscle fiber at a neuromuscular junction, or a glandular cell at a neuroglandular junction.