**CHAPTER 10: NERVOUS SYSTEM I, Basic Structure and Function**

**OBJECTIVES:**

1. Name the two major divisions of the nervous system and list the organs within each.

2. Fully discuss the three general functions of the nervous system, and draw a figure that summarizes them.

3. Construct a flow chart illustrating the relationship between the divisions of the nervous system.

4. Distinguish between sensory receptors and effectors.

5. Describe the structure of a neuron.

6. Identify Nissl bodies, and explain why neurons have no centrioles.

7. Identify the receptive portion of a neuron.

8. Define the terms *myelin sheath, Schwann cell, axonal terminal (synaptic knob)*, and *Node of Ranvier*.

9. Distinguish between the structure of a small axon and large axon in the PNS.

10. Distinguish between a Schwann cell and oligodendrocyte.

11. Describe how cell body damage differs from axonal damage.

12. Compare and contrast the structure of white matter and gray matter in the CNS.

13. List, and discuss the structure and function of the four types of neuroglial cells in the CNS.

14. Define the terms *ventricles* and *central canal* (in the CNS).

15. Classify neurons according to their function.

16. Classify neurons according to their structure, drawing an illustration of each.

17. Describe the characteristics of a resting membrane.

18. Define the terms *potential difference (PD)* and *resting membrane potential (RMP)*, and give the numerical value of the RMP in a neuron.

19. Illustrate how the RMP is maintained in a neuron.

20. Distinguish between hyperpolarization and depolarization and indicate which of these must occur in order to propagate a nerve impulse.

21. Define the terms *threshold potential, action potential, nerve impulse*, and *repolarization*.

22. List and explain the events involved in the propagation of an action potential in a neuron.

23. Explain how a nerve impulse is transmitted within a neuron.

24. List and discuss the characteristics of a nerve impulse.

25. Define the term *saltatory conduction*.

26. Define the terms *synapse* and *neurotransmitter (NT)*, and discuss the steps involved in the synaptic transmission of a nerve impulse from one neuron to another.

27. Name the most typical neurotransmitter and discuss its function.

28. Name two other classes of neurotransmitters and give examples of each.

29. Explain why the NTs discussed above do not continually stimulate the post-synaptic neuron's membrane.

30. List some typical diseases/disorders that result from NT imbalances.

31. List some drugs that alter neurotransmitter levels.

32. Name the two major neuropeptides in the CNS, discuss why (when) they are released and their effect in the brain and/or spinal cord.

33. Explain *convergence and divergence* and relate each as either sensory or motor.

I. **GENERAL FUNCTIONS OF THE NERVOUS SYSTEM**

The general function of the nervous system is to coordinate all body systems! This is accomplished by the transmission of (electrochemical) signals from body parts to the brain and back to the body parts.

A. The organs of the nervous system are divided into two major groups:

See Figure 10.2, page 339.

1. **Central Nervous System (CNS)** = brain & spinal cord

2. **Peripheral Nervous System (PNS)** = nerves that extend from the brain (cranial nerves) and spinal cord (spinal nerves)

B. **Three Major Functions**

1. **Sensory Input Function**

a. **PNS**;

b. **Sensory receptors** (located at the ends of peripheral neurons) detect changes (i.e. are stimulated) occurring in their surroundings;

c. Once stimulated, sensory receptors **transmit a sensory impulse to the CNS.**

d. A sensory impulse is carried on a **sensory neuron**.

2. **Integrative Function**

a. **CNS** (brain and/or spinal cord);

b. involves interpretation of an incoming sensory impulse (i.e. decision is made concerning what's going to happen next, based on sensory impulse).

c. Integration occurs in **interneurons**.

d. A motor impulse begins...

3. **Motor Function**

a. **PNS**;

b. involves the response of a body part;

c. **Motor impulses** are carried from CNS to responsive body parts called effectors;

d. A motor impulse is carried on a **motor neuron**;

e. **Effectors** = 2 types:

* **muscles** (that contract);
* **glands** (that secrete a hormone).

I. **GENERAL FUNCTIONS OF THE NERVOUS SYSTEM**

C. **Levels of Organization of Nervous System**

**(most will be discussed in Chapter 11)**

**NERVOUS SYSTEM**

**CENTRAL NERVOUS SYSTEM PERIPHERAL NERVOUS SYSTEM**

**(BRAIN & SPINAL CORD) (CRANIAL NERVES & SPINAL NERVES)**

**(INTERNEURONS)**

**SENSORY MOTOR**

**(INPUT INTO CNS) (OUTPUT FROM CNS)**

**(AFFERENT NEURONS) (EFFERENT NEURONS)**

**SOMATIC AUTONOMIC**

**(EFFECTORS: SKELETAL MUSCLE) (EFFECTORS: SMOOTH MUSCLE;**

**(CONSCIOUS CONTROL) CARDIAC MUSCLE; GLANDS)**

**(UNCONSCIOUS CONTROL)**

**PARASYMPATHETIC SYMPATHETIC**

**(HOMEOSTASIS) (FIGHT-OR-FLIGHT)**

**(NT: ACETYLCHOLINE) (NT: NOREPINEPHRINE)**

I. **GENERAL FUNCTIONS OF THE NERVOUS SYSTEM**

D. **Neuron** = the structural & functional unit of the nervous system; a nerve cell.

1. **Neuron Structure** See Fig 10.1, page 339 & Fig 10.3, page 341.

Each neuron is composed of a cell body and many extensions from the cell body called neuron processes or nerve fibers.

a. **Cell Body** = central portion of neuron; contains usual organelles, except centrioles;

* identify: nucleus, prominent nucleolus, and many **Nissl bodies** = RER.

b. **Neuron Processes/ Nerve Fibers** = extensions from cell body; two types:

* **Dendrites**:

1. **many** per neuron;

2. short and branched;

3. receptive portion of a neuron;

4. carry impulses toward cell body.

* **Axons**:

1. **one** per neuron;

2. long, thin process;

3. carry impulses away from cell body

4. Note terminations of axon branch = **axonal terminals**; synaptic knobs.

5. **Axons in PNS:**

See Fig 10.3, pg 341. a. **Large axons** are surrounded by a

See Fig 10.4, pg 342. **myelin sheath** produced by many

See Fig 10.5, pg 344. layers of **Schwann Cells** (neuroglial cell).

 "myelinated nerve fiber";

 myelin = **lipoprotein**;

 Interruptions in the myelin sheath between Schwann cells = **Nodes of Ranvier**.

See Fig 10.5, pg 344. b. **Small axons** do not have a myelin sheath.

 "unmyelinated nerve fibers";

 however all axons (in PNS) are associated with Schwann cells.

I. **GENERAL FUNCTIONS OF THE NERVOUS SYSTEM**

D. **Neuron** = the structural & functional unit of the nervous system; a nerve cell.

1. **Neuron Structure** See Fig 10.1, page 339 & Fig 10.3, page 341.

b. Nerve Fibers

* Axons (continued)

6. Axons in **CNS**

(i.e. in brain & spinal cord)

See Fig 10.8, page 346. a. Myelin is produced by an **oligodendrocyte** rather than Schwann Cells;

b. A bundle of myelinated nerve fibers = **"White Matter"**;

c. This is in contrast to CNS **"Gray Matter"** = A bundle of cell bodies (or unmyelinated nerve fibers).

II. **CLASSIFICATION OF NEURONS AND NEUROGLIAL CELLS**:

See Table 10.1, page 346.

A. **Structural Classification**: See Figure 10.6, page 344.

1. **Bipolar Neurons**

a. two extensions;

b. one fused dendrite leads toward cell body, one axon leads away from cell body;

2. **Unipolar Neurons**

a. one process from cell body;

b. forms central and peripheral processes;

c. only distal ends are dendrites.

3.  **Multipolar Neurons**

a. many extensions;

b. Many dendrites lead toward cell body, one axon leads away from cell body.

II. **CLASSIFICATION OF NEURONS AND NEUROGLIAL CELLS**:

See Table 10.1, page 346.

B. **Functional Classification**:

1.  **Sensory neurons**

a. PNS;

b. afferent neurons;

c. carry sensory impulses from sensory receptors to CNS;

d. input information to CNS;

e. Location of receptors = skin & sense organs.

2. **Interneurons (Association)**

a. CNS;

b. link other neurons together (i.e. sensory neuron to interneuron to motor neuron);

3.  **Motor Neurons**

a. PNS;

b. efferent neurons;

c. carry motor impulses away from CNS and to effectors;

d. output information from CNS;

e. Effectors = muscles & glands.

C. **Neuroglial Cells** = accessory cells of nervous system form supporting network for neurons; "nerve glue".

1. **PNS = Schwann cells** produces myelin. See Fig 10.4, page 342.

1. **CNS =4 types**; provide bulk of brain and spinal cord tissue:

See Table 10.2, page 347, and Figures 10.8, page 346 & figure 10.9, page 347.

a. **Astrocyte**

* star-shaped;
* Function: nourishes neurons.

b. **Oligodendrocyte**

* looks like eyeball;
* Function: produces myelin.

c. **Microglia**

* looks like spider;
* Function: phagocytosis.

d. **Ependyma**

* epithelial-like layer;
* Function: lines spaces in CNS.

1. brain = ventricles,

2. spinal cord = central canal.

II. **CLASSIFICATION OF NEURONS AND NEUROGLIAL CELLS**:

See Table 10.1, page 346.

D. **Regeneration of Nerve Axons**

See Fig 10.10, page 349.

1. Cell body injury = death of neuron;

2. Damage to an axon may allow for regeneration.

III. **CELL MEMBRANE POTENTIAL**

A. **Distribution of Ions**

1. A resting neuron's cell membrane is said to be **polarized = electrically charged** (i.e. the charge inside the cell is different than the charge outside):

Consequently, a potential difference (PD) exists across this resting cell membrane.

2. DEF: **Potential Difference (PD)** = the difference in electrical charge between 2 points (i.e. across a cell membrane).

3. The resting membrane potential (RMP) of a neuron results from the **distribution of ions across the cell membrane**. See Fig 10.12, page 351.

a. K+; high inside;

b. Na+; high outside;

c. Cl-; high outside;

d. Negatively charged proteins or Anions-; high inside.

Recall that these ion concentrations are maintained by active transport mechanisms (i.e. mainly the Na+K+-ATPase pump; Chapter 3)

B. **Resting Potential**

1. The RMP of a nerve cell is measured to be **-70 mV or millivolts** (inside / outside);

2. As long as the RMP in a nerve cell is undisturbed, it remains polarized. However, in order for a nerve impulse to be started or propagated in a nerve cell, this resting potential must be disturbed.

III. **CELL MEMBRANE POTENTIAL**

C. **Local Potential Changes (Graded Potentials)**

The RMP of - 70 mV can be disrupted or changed in one of two directions:

1. more negative = **"hyperpolarization"**

2. less negative (i.e. towards zero) = **"depolarization"**

a. The cell membrane of a neuron must be depolarized (to approximately -55mV) in order for certain ion channels to open and therefore start a nerve impulse.

D. **Action Potential:** See Fig 10.13-10.14, page 352 and Fig 10.15, page 353.

1. When the resting membrane potential (RMP) of a neuron is depolarized to -55mV, **threshold potential** is reached;

a. The threshold potential for a neuron is -55mV;

b. Therefore, a threshold stimulus = +15 mV;

2. When threshold potential is reached, the rapid opening of **Na+ channels results in rapid depolarization** (and even reversal of the membrane potential [MP] to +30mV);

1. This event is called the **action potential.**
2. The action potential represents the start of the nerve impulse on a neuron.

3. Then **K+ channels** open, (while Na+ channels close), and **repolarization** occurs = recovery of the RMP to -70mV.

4. This all occurs very quickly = 1/1000 sec.

III. **CELL MEMBRANE POTENTIAL**

D. **Action Potential:**

5. **Summary: Nerve Impulse Conduction** See Table 10.3, page 353.

RMP of neuron = **-70 mV**.

+ 15 mV stimulus

(threshold stimulus)

MP of neuron falls to **-55mV** = Threshold Potential

Na+ channels open |(rapid depolarization)

Action Potential (nerve impulse\*) is produced

MP of neuron reaches **+30mV** = Reversal of MP

K+ channels open

(repolarization)

Na+ channels close

RMP of neuron returns to **-70mV**.

\* An action potential represents the start of a **nerve impulse** in one small portion of the neuron's membrane.

\*\* How do you think it is transmitted throughout the entire neuron?

6. **Nerve Impulse (NI)** = the propagation of action potentials (AP) along a nerve fiber; (i.e. the entire length of the neuron); See Fig 10.15, page 353.

a. The NI is an **electrical impulse**;

b. An NI is similar to a row of dominos falling (i.e. once the first domino falls, the entire row will fall).

c. A nerve impulse begins on a dendrite (or cell body of a neuron), runs toward the cell body, through the cell body, and then down the axon.

III. **CELL MEMBRANE POTENTIAL**

E. **Characteristics of a Nerve Impulse** (NI)

1. **All or Nothing Response** = if a nerve cell responds at all, it responds completely.

a. subthreshold stimulus (5mV) = no AP; no NI;

b. threshold stimulus (15mV) = yes AP; yes NI;

c. > threshold stimulus (20mV) = yes AP; yes NI, but no greater

intensity than above.

2. **Refractory Period** = the period following a NI when a threshold stimulus cannot produce another NI;

a. The RMP has to be restored before it can be depolarized again; (i.e. dominos must be set up in order to be knocked down again);

3 . **Impulse Conduction** = the manner in which the NI runs down the neuron/nerve fiber;

a. **unmyelinated nerve fibers**: NI must travel the length of the nerve fiber; slow.

b. **myelinated nerve fiber: "Saltatory Conduction"**.

* NI jumps from node of Ranvier to node of Ranvier;
  + - * + Very fast transmission; See Fig 10.16, page 354.

VI. **THE SYNAPSE**

Nerve impulses are transferred from one neuron to the next through synaptic transmission.

A. **Synapse** = the junction between two neurons where a nerve impulse is transmitted; See Fig 10.17, page 355 and Fig 10.18a and b, page 356.

1. occurs between the axon of one neuron and dendrite or cell body of a second neuron.

2. Note that the two neurons do **not** touch. There is a gap between them = **synaptic cleft**.

VI. **THE SYNAPSE**

B. **Synaptic Transmission** Fig 10.18a & b, page 356.

1. NI reaches axonal terminal of pre-synaptic neuron causing **depolarization of synaptic knob**;

2. **Ca++ channels open** and calcium ions rush into axonal terminal causing;

3. synaptic vesicles (filled with neurotransmitter/NT) to **release NT via exocytosis into the synaptic cleft**;

4. NT diffuses across synaptic cleft and **depolarizes the post-synaptic neuron's membrane**.

5. An action potential **(AP) is triggered** and a **NI begins in the post-synaptic neuron**.

Pre-synaptic Neuron Post-synaptic Neuron

(axon) (cell body or dendrite)

C. **Synaptic Potentials**

1. Post-synaptic neurons response to neurotransmitter binding

2. May be depolarization = **Excitatory Post-Synaptic Potential** (EPSP)

3. May be hyperpolarization = **Inhibitory Post-Synaptic Potential** (IPSP)

4. **Summation** = many subthreshold stimuli received one after another may allow threshold potential to be reached, trigger an AP and begin a NI on a neuron.

a. +15 mV = threshold = AP = NI;

b. +5, +5, +5, = +15 mV = threshold = AP = NI.

D. **Neurotransmitters (NT)**

1. at least 30 different produced by CNS;

2. some neurons produce/release only one while release many;

3. Most typical NT is **Acetylcholine (ACh)**

a. ACh is released by

* all motor neurons (i.e. those that stimulate skeletal muscle)
* some CNS neurons.

VI. **THE SYNAPSE**

D. **Neurotransmitters (NT)**

4. Other NTs include:

a. monoamines (modified amino acids)

* are widely distributed in the brain where they play a role in:

1. emotional behavior and

2. circadian rhythm.

* are present in some motor neurons of the ANS.
* include:

1. epinephrine,

2. norepinephrine,

3. dopamine.

4. serotonin,

5. histamine.

b. unmodified amino acids;

* glutamate;
* aspartate;
* GABA (gamma aminobutyric acid)
* glycine.

5. **Fate of Neurotransmitter in Synaptic Cleft:**

a. **Destruction of Neurotransmitter**:

* Enzymes that are present in the synaptic cleft destroy NT.

1. For example, acetylcholinesterase destroys ACh;

b. **Reuptake of Neurotransmitter:**

* NT is transported back into pre-synaptic knob.

\* Both of the above processes prevent continual stimulation of the post-synaptic membrane!

VI. **THE SYNAPSE**

E. **Neuropeptides**

1. synthesized by CNS neurons;

2. act as NTs or neuromodulators that either:

a. alter a neuron's response to a NT;

b. block the release of a NT.

3. include **enkephalins**:

a. synthesis is increased during painful stress;

b. bind to the same receptors in the brain as the narcotic morphine;

c. relieve pain.

4. include **endorphines:**

a. same as above, but with a more potent and longer lasting effect.

See Clinical Application 10.4, page 359 concerning Opiates in pain relief.

V. **IMPULSE PROCESSING**

A. **Neuronal Pools** – neurons that synapse and work together

1. Working together results in **facilitation** – a general excitation that makes stimulation easier to achieve

B. **Convergence**

1. many neurons come together on fewer neurons **(summation occurs)**

2. typical of **motor** pathways

3. many inputs from brain, but usually only one motor response

C. **Divergence**

1. fewer neurons spread out to signal many neurons **(signal amplifies)**

2. typical of **sensory** pathways

3. reason that a stimulus (i.e. odor) can cause many responses

VI. **Disorders Associated With Neurotransmitter Imbalances**

A. **See Table 10.5, page 357.**

1. Alzheimer's = deficient ACh;

2. Clinical Depression = deficient norepinephrine/ serotonin;

3. Epilepsy = Excess GABA leads to excess norepinephrine & dopamine**;**

4. Huntington's Disease = deficient GABA;

5. Hypersomnia = excess serotonin;

6. Insomnia = deficient serotonin;

7. Mania = excess norepinephrine;

8. Myasthenia gravis = deficient ACh receptors at NMJs;

9. Parkinson's disease = deficient dopamine;

10. Schizophrenia = deficient GABA leads to excess dopamine;

11. SIDS = excess dopamine;

12. Tardive dyskinesia (uncontrollable movements of facial muscles) = deficient dopamine.

VI. **Disorders Associated With Neurotransmitter Imbalances**

B. **Drugs that Alter Neurotransmitter Levels**

**See Table 10.6, page 358.**

|  |  |  |  |
| --- | --- | --- | --- |
| DRUG | NT AFFECTED | MECHANISM OF ACTION | EFFECT |
| Tryptophan | Serotonin | Stimulates NT synthesis | sleepiness |
| Reserpine | Norepi | packages NT vesicles | limb tremors |
| Curare | Ach | decreases NT in NMJ | muscle paralysis |
| Valium | GABA | enhances receptor binding | decreased anxiety |
| Nicotine | Ach | stimulates synthesis of AChase | increased alertness |
| Cocaine | Norepi | blocks reuptake | euphoria |
| Tricyclic Anti  depressants | Norepi | blocks reuptake | mood elevation |
| Prozac | Serotonin | blocks reuptake | mood elevation |

VII.  **Nerve Pathway Summary (keyed at the end of this outline)**

|  |  |  |  |
| --- | --- | --- | --- |
| **NS**  **Division** |  |  |  |
| **CNS OR PNS?** |  |  |  |
| **TYPE OF NEURON?** |  |  |  |
| **RECEPTIVE PORTION OF NEURON** |  |  |  |
| **STIMULATED BY WHAT?** |  |  |  |
| **TRANSMISSION AND DIRECTION OF IMPULSE THROUGH NEURON** |  |  |  |
| **TRANSMISSION OF IMPULSE TO NEXT NEURON (OR EFFECT-OR)** |  |  |  |

VIII. **Other Interesting Notes**:

1. Clinical Application 10.1, page 340, on migraines.
2. Clinical Application 10.2, page 343, on Multiple Sclerosis (MS).
3. Neuroglial abnormalities. See blue box on page 348.
4. Clinical Application 10.3, page 355, on factors affecting impulse conduction.
5. Clinical Application 10.4, page 359, on Opiates.
6. Clinical Application 10.5, page 360-361, on Drug Addiction.

IX. **Innerconnections of the Nervous System on page 362.**

**Nerve Pathway Summary**

|  |  |  |  |
| --- | --- | --- | --- |
| **NS Division** | **sensory** | **integrative** | **motor** |
| **CNS OR PNS?** | **PNS** | **CNS** | **PNS** |
| **TYPE OF NEURON?** | **sensory (afferent) neuron** | **interneuron** | **motor (efferent) neuron** |
| **RECEPTIVE PORTION OF NEURON** | **sensory receptors at the ends of dendrites** | **dendritic ends (or cell body)** | **dendritic ends (or cell body)** |
| **STIMULATED BY WHAT?** | **A stimulus (i.e. light, temperature change, etc)** | **neurotransmitter (NT) released by sensory neuron** | **neurotransmitter released by interneuron** |
| **TRANSMISSION AND DIRECTION OF IMPULSE THROUGH NEURON** | **from sensory receptors of dendrites down dendrites through cell body down axon\* and into axonal terminal (synaptic knobs)**  **\*if axon is myelinated = saltatory conduction)** | **down dendrites through cell body down axon\* and into axonal terminal (synaptic knobs)**  **\*if axon is myelinated = saltatory conduction)** | **down dendrites through cell body down axon\* and into axonal terminal (synaptic knobs)**  **\*if axon is myelinated = saltatory conduction)** |
| **TRANSMISSION OF IMPULSE TO NEXT NEURON (OR EFFECT-OR)** | **from electrical within sensory neuron to chemical between neurons. NT released from axonal terminals of sensory neuron stimulates the dendrite (or cell body) of an interneuron** | **from electrical within interneuron to chemical between neurons. NT released from axonal terminals of interneuron stimulates the dendrite (or cell body) of a motor neuron** | **from electrical within motor neuron to chemical between motor neuron and effector. NT/Acetylcholine released from axonal terminals of motor neuron stimulates an effector to respond.**  **Effectors = muscle (contract) or glands (secretion of hormones)** |

## Chapter 10 Nervous System I: Basic Structure and Function

1. **Distinguish between neurons and neuroglial cells.**

**Neurons** are the structural and functional cells reacting to the physical and chemical changes in their environment. **Neuroglia** are the supporting cells necessary for nourishing and maintaining the neurons, among other functions.

1. **Explain the relationship between the central nervous system and the peripheral nervous system.**

The **central** **nervous** **system** (**CNS**) is composed of the brain and the spinal cord. The **peripheral** **nervous** **system** (**PNS**) is composed of all of the peripheral nerves that connect all of the parts of the body with the CNS.

1. **List three general functions of the nervous system.**

The nervous system functions in three ways:

**Sensory**—The sensory function is accomplished by means of sensory receptors that note changes in their environment.

**Integrative**—The CNS can take the impulses from all of the sensory receptors and combine them to make perceptions and sensations about the environment.

**Motor**—The CNS can send impulses along some peripheral nerves to effectors in the muscles and glands in response to changes in the internal and external environment.

1. **Describe the generalized structure of a neuron.**

All neurons have a cell body and nerve fibers that are responsible for nerve impulse conduction to and from the cell body. The cell body (soma or perikaryon) contains granular cytoplasm, mitochondria, lysosomes, a Golgi apparatus, and many microtubules. Neurofibrils extend in a network throughout the microtubules and support them. Also found in the cytoplasm are Nissl bodies, which are membranous sacks of rough endoplasmic reticulum. Cytoplasmic inclusions contain glycogen, lipids, or pigments. The nucleus is large and spherical with a conspicuous nucleolus. The two kinds of nerve fibers extending from the cell body are called dendrites and axons. The many dendrites are typically highly branched to provide receptive surfaces (dendritic spines) for other neurons to communicate. A neuron usually has only one axon arising from the axon hillock. It is a nearly smooth cylindrical process with uniform diameter. It is filled with cytoplasm containing many mitochondria, microtubules, and neurofibrils. It is specialized to conduct nerve impulses away from the cell body. The axon starts as a single fiber but may branch off into collaterals, which may end in presynaptic terminals.

1. **Define *myelin.***

Surrounding larger axons and dendrites of peripheral nerves are sheaths of neuroglial cells called Schwann cells. These cells are wound tightly around the fibers and, as a result, the cell membranes are layered closely together with little or no cytoplasm between them. The layers are composed of a lipoprotein called **myelin**, which forms a myelin sheath on the outside of the fibers. The outermost Schwann cells contain most of the cytoplasm and their nuclei remain outside the myelin sheath. This layer is known as neurolemma or neurolemmal sheath.

1. **Distinguish between myelinated and unmyelinated nerve fibers.**

A **myelinated nerve fiber** is one, which is bound by Schwann cells longitudinally along its length. The Schwann cells wrap tightly around the nerve fiber and form a myelin sheath. **Unmyelinated** **nerve** **fibers** lack these sheaths. In this case, these Schwann cells are not wound around the axons but simply for a grove or valley in which the axon sits. Myelinated (medullated) nerve fibers appear white. Unmyelinated nerve fibers appear gray.

1. **Explain how neurons are classified on the basis of their structure.**

Nerve fibers can be classified into three main groups:

**Bipolar**—Bipolar neurons have only two nerve fibers, one is the axon and one is the dendrite. They are from opposite sides of the cell body.

**Unipolar**—Unipolar neurons have a single nerve fiber extending from the cell body. From there it branches in two directions; one branch extends into a peripheral body part and serves as a dendrite. The other extends into the CNS and acts like an axon.

**Multipolar**—Multipolar neurons have one axon and many other extensions from the cell body that serve as dendrites.

1. **Explain how neurons are classified on the basis of their function.**

Nerve fibers can be classified into three groups:

**Sensory**—Sensory (afferent) neurons sense changes inside or outside the body by means of receptors ends or nearby receptor cells. They send impulses to the CNS in response to these changes. Most of these neurons are unipolar, with some bipolar.

**Interneurons**—Interneurons (association or internuncial neurons) are multipolar neurons found in the CNS. They link with other neurons and send impulses from one part of the CNS to another.

**Motor**—Motor (efferent) neurons are multipolar, and send impulses from the CNS to muscles or glands. There are two types of motor neurons that control smooth or cardiac muscle. Accelerator neurons increase muscle activity, while inhibitory neurons decrease muscle activity.

1. **Discuss the functions of each type of neuroglial cell.**

The PNS has only one type of neuroglial cell: the **Schwann** **cell**. The CNS has four different types of neuroglial cells. They are:

**Astrocyte**—Astrocytes are star-shaped cells located between neurons and blood vessels. They provide structural support and transport substances between the neurons and blood vessels. Astrocytes are joined together by gap junctions, providing a channel for circulating calcium ions. Other duties include metabolism of substances (such as glucose), keeping the synaptic clefts free of excess ions and neurotransmitters, and scar tissue formation after injury.

**Oligodendrocytes**—Oligodendrocytes function in myelin production. By extending numerous cellular processes, an oligodendroctye can provide myelin sheaths to several different axons. Because of this arrangement, no neurilemmal sheaths are formed.

**Microglia**—Microglia are small cells found throughout the CNS. They provide support and phagocytize bacteria and debris.

**Ependyma**—Ependyma are ciliated cuboidal or columnar cells found as the inner lining of the central canal and as a single-layered membrane covering the ventricles of the brain. They are joined together by gap and tight junctions, and provide a porous layer for substances to diffuse between the interstitial fluids of the brain and cerebrospinal fluid in the ventricles.

1. **Describe how an injured nerve fiber may regenerate.**

If the axon of a peripheral nerve is separated from the cell body, the distal portion deteriorates and the fragments are removed by macrophages. The proximal end then develops new sprouts, and nerve growth factors from surrounding neuroglia cause the sprouts to grow. At the same time, remaining Schwann cells proliferate and surround the new axon. If a sprout grows into the remaining basement membranes of the original tract, the new fiber may rejoin with its original connection. If the injured axon is from a neuron in the CNS, the lack of a myelin sheath prevents the new fiber from being guided to its original connection. Therefore, regeneration in the CNS is very unlikely. An injury to the cell body of a neuron usually causes death to the entire fiber, and no regeneration will occur.

1. **Explain how a membrane may become polarized.**

A cell, in its normal state, has a negatively charged interior with respect to the exterior. This is accomplished by transport mechanism channels that let potassium ions move easily in and out, and keep sodium and calcium ions under tight control.

1. **Define *resting potential.***

Because the movement of sodium ions into the cell is slower than the movement of potassium out of the cell, there are more positive ions (cations) outside and more negative ions (anaions) inside. The difference in the charges between the two sides of the cell’s membrane is about –70 millivolts (in relation to the interior charge). This difference in charge is defined as the **resting** **potential** because it shows a potential to do the work (send a message).

1. **Distinguish between depolarizing and hyperpolarizing.**

If, in response to a stimulus, the resting potential becomes more negative, the cell is said to be **hyperpolarizing**. If the stimulus causes the resting potential to become less negative, the cell is said to be **depolarizing**.

1. **List the changes that occur during an action potential.**

When enough stimuli have accumulated to cause the threshold potential to be released, the area stimulated opens its sodium channels. As the sodium ions rush in, the inside of the cell becomes momentarily positive. At the same time, potassium channels open to allow the potassium ions out. This causes the inside of the cell to return to a negative charge (repolarization). The entire sequence takes less than 1/1,000th of a second.

1. **Distinguish between action potentials and nerve impulses.**

An action potential occurs at a specific site. When an action potential occurs at the trigger zone of a nerve cell, it sends an electrical impulse to the adjacent membrane. This causes an action potential at the next site. This occurs in a wavelike sequence, without losing amplitude, from the beginning of the fiber to the end, and is known as a nerve impulse.

1. **Define refractory period.**

After an action potential passes, the fiber needs time to return to its resting potential. This time is called the **refractory** **period**. The refractory period has two parts. The first is the absolute refractory period. This lasts about 1/2,500th of a second, and is the period when no new impulses can be sent. The second is called the relative refractory period. During this time, the fiber still has not returned to its resting potential, but enough sodium and potassium ions have moved to allow an action potential to occur to very strong stimuli.

1. **Define *saltatory conduction.***

The Schwann cells surrounding a myelinated nerve fiber serve as an insulator and prevent most ions from passing through. Between adjacent Schwann cells is a small gap called a node of Ranvier, where the nerve fiber is exposed. When a nerve impulse is conducted along a myelinated fiber, it “jumps” from node to node. This type of conduction is called **saltatory conduction**.

1. **Define *synapse*.**

The ends of axons and dendrite are not directly connected to other neurons or effects. Instead, they terminate very close to them, leaving a space. The terminal end of the axon is called a presynaptic terminal and it communicates with a postsynaptic neuron. This “connection” is called a **synapse**.

1. **Explain how a nerve impulse is transmitted from one neuron to another.**

When a nerve impulse reaches the end of the presynaptic neuron, it enters several synaptic knobs that contain synaptic vesicles filled with neurotransmitters. The neurotransmitters are released into the synaptic cleft and trigger an action potential in the postsynaptic neuron.

1. **Explain the role of calcium in the release of neurotransmitters.**

An action potential moving across a synaptic knob’s membrane causes calcium channels to open and increases the membrane’s permeability. As the calcium ions move inward, some of the synaptic vesicles fuse with the presynaptic membrane and release their neurotransmitters. The number of vesicles that fuse to the membrane is directly related to the amount of calcium ions that move inward.

1. **Define *neuropeptide.***

**Neuropeptides** are chains of amino acids found in the CAN and/or PNS that act as neurotransmitters or *neuromodulators* (substances that block neurotransmitters or alter a neuron’s response). Among the neuropeptides are two found only in the CNS that are potent natural pain relievers (enkephalins and beta endorphin) and one found throughout both the CNS and PNS that transmits pain impulses (substance P).

1. **Distinguish between excitatory and inhibitory postsynaptic potentials.**

Different neurotransmitters cause distinctly different responses in the postsynaptic neuron. If a neurotransmitter binding to the postsynaptic neuron causes sodium ion channels to open, the ions move inward and depolarize the membrane, possibly causing an action potential. Because this reaction causes the membrane to be closer to the threshold potential, it is said to be an **excitatory** **postsynaptic** **potential** (**EPSP**). If the neurotransmitter causes the potassium receptors to open, the postsynaptic membrane becomes hyperpolarized in response to an influx of potassium ions. This reaction makes an action potential less likely and is called an **inhibitory** **postsynaptic** **potential** (**IPSP**).

1. **Describe the “trigger zone” of a neuron.**

A **trigger zone** is an area at the proximal end of an axon at the axonal hillock that starts a nerve impulse from the action potential.

1. **Describe the relationship between an input nerve fiber and its neuronal pool.**

A **neuronal pool** is a group of neurons in the CNS that has special characteristics. It responds to impulses from **input** (*afferent*) **nerve fibers**. These fibers branch many times upon entering the neuronal pool to form hundreds of synapses with dendrites and cell bodies in a certain region of the pool.

1. **Define *facilitation.***

Because a neuron in a region of a neuronal pool may receive excitatory and inhibitory impulses at the same time, the net effect may be either excitatory or inhibitory. If the net effect is excitatory enough to pass the threshold potential, an action potential will occur. If the net effect is excitatory but subthreshold, the neuron becomes more excitable and easier to push over the threshold. This state is called **facilitation**.

1. **Distinguish between convergence and divergence.**

When input nerve fibers from different areas of the body send impulses to the same neuron, they are said to **converge**. When a neuron sends impulses out on an output (*efferent*) nerve fiber, the impulse may stimulate others. These, in turn, may stimulate still others, and so on. **Divergence** works with input nerve fibers as well. For instance, the impulse form a sensory receptor may diverge and reach several different areas of the CNS for processing.

1. **Explain how nerve impulses are amplified.**

When a nerve impulse is diverged, it is carried on several nerve fibers. This amplifies its effect and causes a more forceful response.

## Chapter 10: Nervous System I

# I. General Functions of the Nervous System

A. The nervous system is composed predominately of nervous tissue but also includes some blood vessels and connective tissue.

B. Two cell types of nervous tissue are neurons and neuroglial cells.

C. Neurons are specialized to react to physical and chemical changes in their surroundings.

D. Dendrites are small cellular processes that receive input.

E. Axons are long cellular processes that carry information away from neurons.

F. Nerve impulses are bioelectric signals produced by neurons.

G. Bundles of axons are called nerves.

H. Small spaces between neurons are called synapses.

I. Neurotransmitters are biological messengers produced by neurons.

J. The central nervous system contains the brain and spinal cord.

K. The peripheral nervous system contains cranial and spinal nerves.

L. Three general functions of the nervous system are sensory, integrative, and motor.

M. Sensory receptors are located at the ends of peripheral neurons and provide the sensory function of the nervous system.

N. Receptors gather information.

O. Receptors convert their information into nerve impulses, which are then transmitted over peripheral nerves to the central nervous system.

P. In the central nervous system, the signals are integrated.

Q. Following integration, decisions are made and acted upon by means of motor functions.

R. The motor functions of the nervous system use neurons to carry impulses from the central nervous system to effectors.

S. Examples of effectors are muscles and glands.

T. The two divisions of the motor division are somatic and autonomic.

U. Somatic nervous system is involved in conscious activities.

V. The autonomic nervous system is involved in unconscious activities.

W. The nervous system can detect changes in the body, make decisions, and stimulate muscles or glands to respond.

X. The three parts all neurons have are cell body, axon, and dendrites.

Y. A neuron’s cell body contains granular cytoplasm, mitochondria, lysosomes, a Golgi apparatus, and many microtubules. It also contains a large nucleus, chromatophilic substance, and cytoplasmic inclusions.

Z. Neurofibrils are fine threads that extend into axons.

AA. Chromatophilic substance is membranous sacs that contain rough endoplasmic reticulum.

BB. Mature neurons generally do not divide but neural stem cells do.

CC. Dendrites are usually highly branched to provide receptive surfaces to which processes from other neurons communicate.

DD. Dendritic spines are tiny, thornlike spines on the surface of dendrites.

EE. A neuron may have many dendrites but will have only one axon.

FF. An axonal hillock is the initial portion of an axon closest to the cell body.

GG. An axon is specialized to carry nerve impulses away from the cell body.

HH. The cytoplasm of an axon includes mitochondria, microtubules, and neruofibrils.

II. Collaterals are branches of axons.

JJ. A synaptic knob is a specialized ending of an axon.

KK. A synaptic cleft is the space between a synaptic knob and the receptive surface of another cell.

LL. Axonal transport is the process an axon uses to convey biochemicals that are produced in the neuron cell body.

MM. Schwann cells produce myelin.

NN. Myelin is a lipid-rich substance.

OO. A myelin sheath is a coating produced by Schwann cells that is wrapped around an axon.

PP. A neurilemma is a portion of a Schwann cell outside of the myelin sheath.

QQ. A node of Ranvier is a narrow gap between myelin sheaths.

RR. Myelinated axons have myelin sheaths.

SS. Unmyelinated axons have no myelin sheaths.

TT. White matter is composed of myelinated axons.

UU. Gray matter is composed of unmyelinated axons, dendrites, and cell bodies of neurons.

# II. Classification of Neurons and Neuroglia

A. Classification of Neurons

1. The three major classifications of neurons based on structural differences are bipolar, multipolar, and unipolar.

2. Bipolar neurons have two processes; one process is a dendrite and the other an axon.

3. Bipolar neurons are found within the eyes, ears, and nose.

4. Unipolar neurons have one process which functions as an axon.

5. The peripheral process of a unipolar neuron is associated with dendrites near a peripheral body part and the central process enters the brain or spinal cord.

6. Unipolar neurons are located in ganglia.

7. Multipolar neurons have multiple dendrites and one axon.

8. Multipolar neurons are located in the brain and spinal cord.

9. The three classes of neurons based on functional differences are sensory, motor, and interneurons.

10. Sensory neurons carry impulses from peripheral body parts to the brain and spinal cord.

11. Sensory neurons have specialized receptors ends at the tips of their dendrites.

12. Most sensory neurons are unipolar but some are bipolar.

13. Interneurons are located in the brain and spinal cord.

14. Interneurons are multipolar and form links between other neurons.

15. Motor neurons carry nerve impulses from the brain and spinal cord to effectors.

16. Two specialized groups of motor neurons are accelerator neurons and inhibitory neurons.

17. Motor neurons that control skeletal muscle are under conscious control.

18. Motor neurons that control glands, smooth muscle and cardiac muscle are under involuntary control.

B. Classification of Neuroglial Cells

1. In the embryo, neuroglial cells guide neurons to their positions and may stimulate them to grow.

2. Neuroglial cells also produce growth factors that nourish neurons.

3. Schwann cells are the neuroglia of peripheral nervous system.

4. The four neuroglial cells of the central nervous system are astrocytes, oligodendrocytes, microglial cells, and ependymal cells.

5. Astrocytes are star shaped and are commonly found between neurons and blood vessels.

6. Astrocytes provide support and hold structures together.

7. Astrocytes aid metabolism of glucose.

8. Astrocytes respond to injury of brain tissue and form a special type of scar tissue.

9. Astrocytes play a role in the blood-brain barrier, which restricts movement of substances between the blood and CNS.

10. Oligodendrocytes occur in rows along myelinated axons and form myelin in the brain and spinal cord.

11. Unlike Schwann cells, oligodendrocytes do not form neurilemmal sheaths.

12. Microglia function to support neurons, and phagocytize bacterial cells and cellular debris.

13. Ependyma form the inner lining of the central canal of the spinal cord and ventricles of the brain.

14. Gap junctions join ependymal cells together.

15. Ependymal cells form a porous layer through which substances diffuse freely between the interstitial fluid of the brain tissues and the fluid within the ventricles.

16. Covering the choroids plexus, ependymal cells also regulate the composition of the cerebrospinal fluid.

C. Regeneration of Nerve Axons

1. Injury to a neuron cell body usually kills the neuron but damaged peripheral axons usually regenerate.

2. If a peripheral axon is separated from its cell body, the distal portion of the axon deteriorate but the proximal end of the axon develops sprouts shortly after injury.

3. Growth of a regenerating axon is slow but eventually the new axon may reestablish the former connection.

4. Axons within the central nervous system do not regenerate because there is no tube of sheath cells to guide it.

**III. Cell Membrane Potential**

A. Introduction

1. Polarized means electrically charged.

2. When a cell membrane is polarized, the inside is negatively charged with respect to the outside.

3. The polarization of a cell membrane is due to an unequal distribution of positive and negative ions on either side of the membrane.

B. Distribution of Ions

1. Potassium ions are the major intracellular positive ion and sodium ions are the major extracellular cation.

2. The distribution of potassium and sodium is largely created by the sodium-potassium pump.

3. The passage of potassium and sodium ions through the cell membrane depends on the presence of channels.

C. Resting Potential

1. A resting nerve cell is one that is not being stimulated to send a nerve impulse.

2. At rest, a cell membrane gets a slight surplus of positive charges outside, and inside reflects a slight negative surplus of impermeable negatively charged ions because the cell membrane is more permeable to potassium ions than sodium ions. Also the cell may contain anions and proteins that are negatively charged that cannot diffuse out of the cell.

3. The cell uses ATP to actively transport sodium and potassium ions in opposite directions.

4. Volts are the electrical differences between two points

5. A volt is called a potential difference because it represents stored electrical energy that can be used to do work

6. The membrane potential is the potential difference across the cell membrane and is measured in millivolts.

7. Resting potential is the membrane potential of a resting neuron and has a value of –70 millivolts.

8. The negative sign of a resting membrane potential is relative to the inside of the cell and is due to the excess negative charges on the inside of the cell membrane.

D. Local Potential Changes

1. Neurons are described as excitable because they can respond to the changes in their surroundings.

2. Stimuli on neurons usually affect the membrane potential in the region of the membranes exposed to the stimulus.

3. The stimulus affects the membrane potential of a neuron by opening a gated ion channel.

4. A membrane is hyperpolarized if the membrane potential becomes more negative than the resting potential.

5. A membrane is depolarized if the membrane becomes less negative that the resting potential.

6. Local potential changes are graded meaning that the amount of change in the membrane potential is directly proportional to the intensity of the stimulation.

7. A threshold potential is sufficient depolarization that triggers an action potential.

8. Summation is an additive phenomenon in which two or more depolarizing stimuli are added together.

9. At threshold, an axon potential is produced in an axon.

E. Action Potentials

1. The trigger zone of an axon is the initial portion of an axon.

2. The trigger zone contains a great number of voltage-gated sodium channels.

3. At the resting membrane potential, sodium channels are closed but when threshold is reached, sodium channels open.

4. As sodium ions rush into the cell, the membrane potential changes and temporarily becomes positive on the inside.

5. When sodium channels close and potassium channels open, potassium diffuses out across the membrane and the inside of the membrane becomes negatively charged again.

6. Repolarized means the membrane polar again or returned to its original resting state.

7. Axons are capable of action potentials but the cell body and dendrites are not.

8. A nerve impulse is the propagation of action potentials along an axon.

F. All-or-None Response

1. A nerve impulse is an all-or-nothing response, meaning if a neuron responds at all to a nerve impulse, it responds completely.

2. A greater intensity of stimulation on the neuron produces more impulses per second but not a stronger impulse.

G. Refractory Period

1. The refractory period is the period in which a threshold stimulus will not trigger another impulse on an axon.

2. An absolute refractory period is the period when an axon’s membrane cannot be stimulated and is the first part of the refractory period.

3. A relative refractory period is the period in which a stronger stimulus can trigger an impulse.

4. The refractory period limits how many action potentials may be generated in a neuron in a given amount of time.

H. Impulse Conduction

1. Myelin serves as an insulator.

2. Saltatory conduction is the type of nerve impulse conduction that occurs only at nodes.

3. Myelinated axons exhibit salutatory conduction.

4. Myelinated axons send nerve impulses faster than unmyelinated axons.

5. The diameter of an axon also affects the speed of a nerve impulse.

# IV. The Synapse

A. Introduction

1. Synapses are the places where impulses are passed from one neuron to another.

2. A presynaptic neuron is the neuron that brings the impulse to the synapse.

3. A postsynaptic neuron is the neuron that is stimulated by the presynaptic neuron.

4. Synaptic transmission is the process by which the impulse in the presynaptic neuron signals the postsynaptic neuron.

B. Synaptic Transmission

1. A nerve impulse travels along an axon to the axon terminals.

2. The synaptic knobs of axons contain sacs called synaptic vesicles.

3. Synaptic vesicles contain neurotransmitters.

4. When a nerve impulse reaches a synaptic knob, calcium diffuses inward from the extracellular fluid.

5. The calcium inside the synaptic knob initiates a series of events that causes the synaptic vesicles to fuse with the cell membrane, releasing the neurotransmitter by exocytosis.

6. Released neurotransmitters diffuse across the synaptic cleft and react with specific receptors on the postsynaptic neuron.

7. Some neurotransmitters cause ion channels to open, some cause ion channels to close.

8. Synaptic potentials are local potentials created by changes in chemically gated ion channels.

C. Synaptic Potentials

1. Synaptic potentials are graded and can depolarize or hyperpolarize the receiving cell membrane.

2. An excitatory postsynaptic potential is a type of membrane change in which the receiving cell membrane is depolarized.

3. An inhibitory postsynaptic potential is a type of membrane change in which the receiving cell membrane is hyperpolarized.

4. Within the brain and spinal cord, each neuron may receive the synaptic knobs of a thousand or more axons on its cell body and dendrites.

5. The integrated sum of EPSPs and IPSPs determines whether an action potential results.

D. Neurotransmitters

1. The nervous system produces at least thirty different kinds of neurotransmitters.

2. Acetylcholine stimulates skeletal muscle contractions.

3. Examples of monoamines are epinephrine, norepinephrine, dopamine, and serotonin.

4. Examples of unmodified amino acids that act as neurotransmitters are glycine, glutamic acid, aspartic acid, and GABA.

5. Examples of peptides are enkephalins and substance P.

6. Most neurotransmitters are synthesized in the cytoplasm of synaptic knobs and stored in synaptic vesicles.

7. The more calcium that enters the synaptic knob, the more neurotransmitters that are released.

8. After a vesicle releases its neurotransmitter, it becomes part of the cell membrane.

9. The enzyme acetlycholinesterase functions to break down acetylcholine.

10. The process of reuptake is when neurotransmitters are transported back into the synaptic knobs of the presynaptic neurons.

11. Monoamine oxidase functions to inactivate epinephrine and norepinephrine after reuptake.

E. Neuropeptides

1. Neuropeptides are substances that alter a neuron’s response to a neurotransmitter or block the release of a neurotransmitter.

2. Three examples of neuropeptides are enkephalins, beta endorphin, and substance P.

3. Enkephalins function to relieve pain sensations.

4. Endorphins function to relieve pain.

5. The function of substance P is to transmit pain impulses into the spinal cord and on to the brain.

# V. Impulse Processing

A. Neuronal Pools

1. Neuronal pools are groups of neurons that make synaptic connections with each other and work together to perform a common function.

2. Neuronal pools may have excitatory or inhibitory effects on other pools or on peripheral effectors.

3. Facilitation is a condition created in which a neuron is brought closer to threshold.

B. Convergence

1. Axons originating from different parts of the nervous system leading to the same neuron exhibit convergence.

2. Convergence allows the nervous system to collect, process, and respond to information.

C. Divergence

1. Axons may branch many times.

2. Impulses leaving a neuron of a neuronal pool may exhibit divergence by reaching several other neurons.

3. Diverging axons can amplify and impulse.