

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.

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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.

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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:

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...

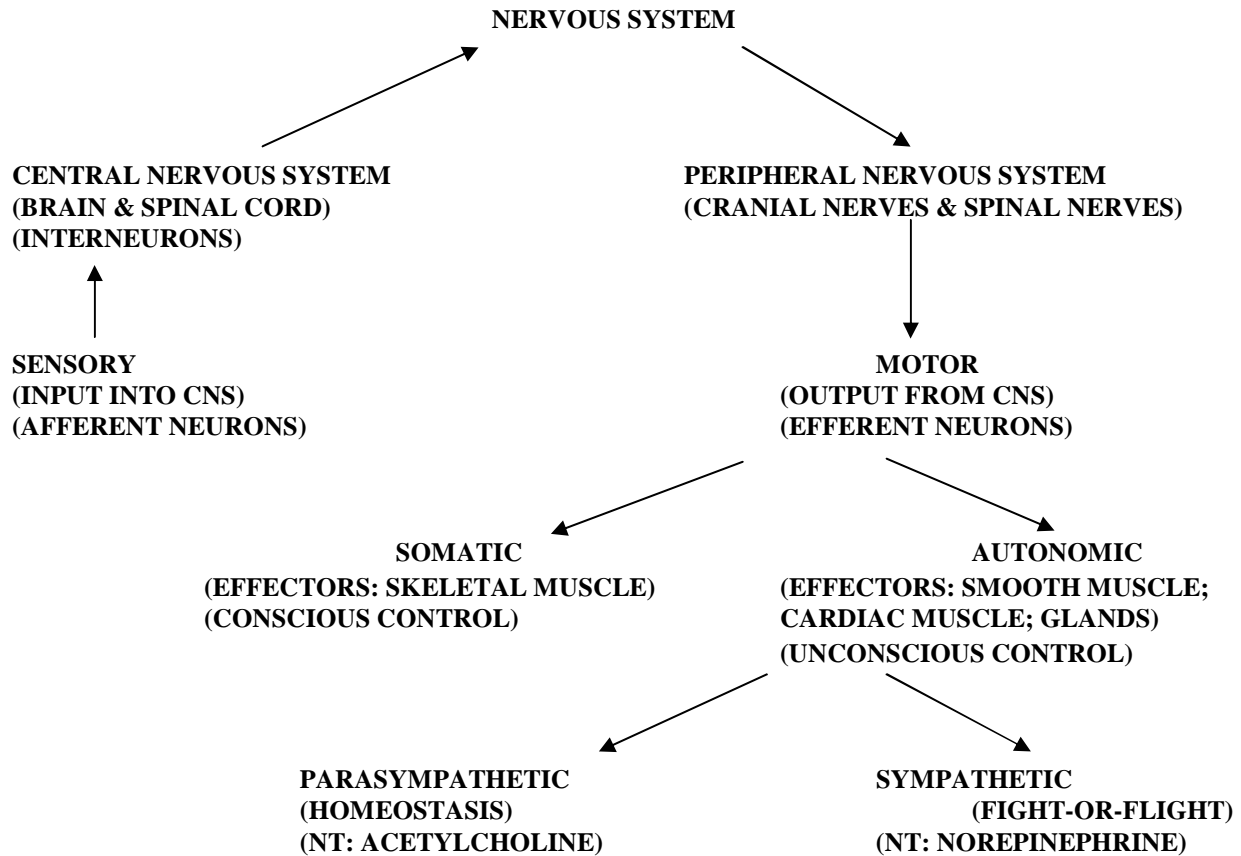
3. **Motor Function**

- 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).

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I. GENERAL FUNCTIONS OF THE NERVOUS SYSTEM

C. Levels of Organization of Nervous System (most will be discussed later)



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I. GENERAL FUNCTIONS OF THE NERVOUS SYSTEM

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

1. Neuron Structure

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:**
 - a. **Large axons** are surrounded by a **myelin sheath** produced by many layers of **Schwann Cells** (neuroglial cell).
 - "myelinated nerve fiber";
 - myelin = **lipoprotein**;
 - Interruptions in the myelin sheath between Schwann cells = **Nodes of Ranvier**.
 - b. **Small axons** do not have a myelin sheath.
 - "unmyelinated nerve fibers";
 - however all axons (in PNS) are associated with Schwann cells.

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I. GENERAL FUNCTIONS OF THE NERVOUS SYSTEM

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

1. Neuron Structure

b. Nerve Fibers

o Axons (continued)

6. Axons in CNS (i.e. in brain & spinal cord)

- 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:

A. Structural Classification: .

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.

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II. CLASSIFICATION OF NEURONS AND NEUROGLIAL CELLS:

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.

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

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.

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II. CLASSIFICATION OF NEURONS AND NEUROGLIAL CELLS:

D. Regeneration of Nerve Axons

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**.
 - 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)

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

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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:

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);
 - a. This event is called the **action potential**.
 - b. 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.

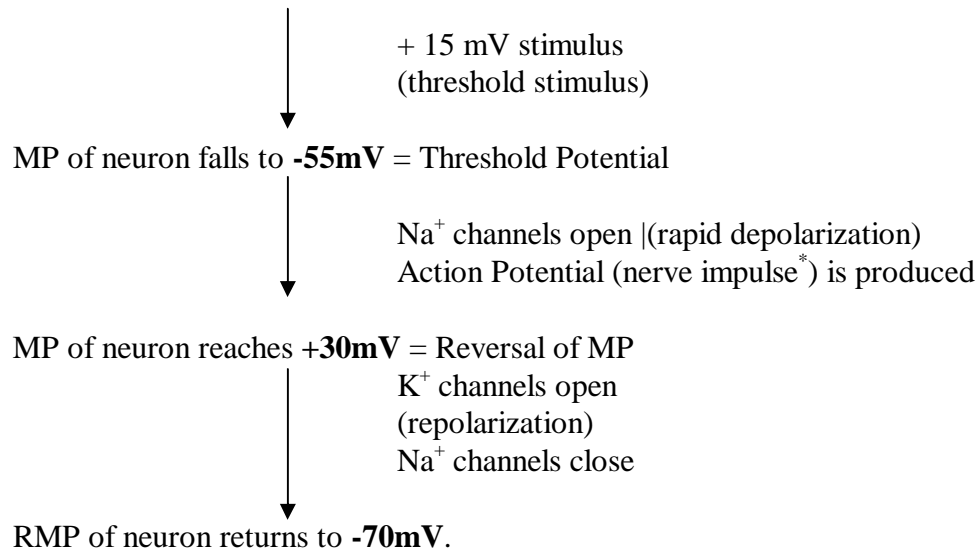
III. CELL MEMBRANE POTENTIAL

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D. Action Potential:

5. Summary: Nerve Impulse Conduction

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



* 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);

- 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

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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;

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;
 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

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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
(axon)

Post-synaptic Neuron
(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)

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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

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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 **endorphins**:
 - a. same as above, but with a more potent and longer lasting effect.

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. Disorders

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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

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

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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)			

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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 EFFECTOR)	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)

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