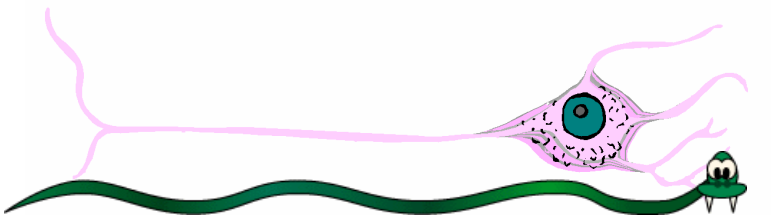


Chapt. 11: Fundamentals of the Nervous System and Nervous Tissue

Functions and Divisions of the Nervous System

• list and summarize the three overlapping functions of the nervous system (see Fig. 11.1):

• there are TWO MAIN DIVISIONS of the nervous system:

I. Central Nervous System (CNS)

• what does the CNS consist of?

II. Peripheral Nervous System (PNS)

• the PNS is the part of the nervous system outside of the CNS

• formed by: ✧ 31 pairs of **spinal nerves** that carry impulses to and from what?

✧ 12 pairs of **cranial nerves** that carry impulses to and from what?

✧ ganglia *(clusters of cell bodies of neurons in the PNS)*

✧ sensory receptors *(detect changes in the internal or external environment)*

FUNCTIONAL SUBDIVISIONS OF THE PNS:

A. Sensory (Afferent) Division

- this division consists of what?

1. ***somatic sensory (afferent) nerve fibers***

- convey impulses <u>to</u> the CNS from what?

2. ***visceral sensory (afferent) nerve fibers***
   - transmit impulses <u>to</u> the CNS from what?

   *(✰ The **visceral organs** are organs in the ventral body cavity, which includes the thoracic and abdominopelvic cavities.)*

B. Motor (Efferent) Division
- this division transmits impulses from what to what?

"**effectors**" are structures (muscle cells and gland cells) on which nerve impulses cause an effect!

1. ***somatic motor (efferent) nerve fibers***
   - conduct impulses <u>from</u> the CNS <u>to skeletal muscle cells only</u>
   - is the somatic nervous system voluntary or involuntary?

2. ***visceral efferent (motor) nerve fibers***
   - conduct impulses <u>from</u> the CNS to <u>smooth muscle cells, cardiac muscle cells, or gland cells</u>
   - form the **AUTONOMIC NERVOUS SYSTEM** (ANS)
   - is the autonomic nervous system voluntary or involuntary?
   - two divisions of the ANS: ✰ **sympathetic division** *(for "fight-or-flight" responses)*
     ✰ **parasympathetic division** *(for "rest-and-digest" activities)*
     (we will get back to these later, hope you can wait!)

Histology of Nervous Tissue

List and briefly describe the two principal types of cells of nervous tissue:

NEUROGLIA

- **neuroglia** (glial cells) are cells that support and protect neurons and perform other functions
- they do not generate or propagate action potentials
- observe the neuroglia in Figs. 11.3 *(you won't need to be able to recognize them, but they are pretty fancy, aren't they? ☺)*

Neuroglia in the CNS

- list the neuroglia in the CNS:

- are they more numerous than neurons?

ASTROCYTES

• describe the functions of astrocytes:

MICROGLIA

• phagocytic cells

EPENDYMAL CELLS

• what do these cells line?

• the beating of their cilia helps to circulate what?

OLIGODENDROCYTES

• what do oligodendrocytes produce?

Neuroglia in the PNS

SATELLITE CELLS

- what do satellite cells surround?

- they are thought to have many of the same functions as what?

SCHWANN CELLS

- what do Schwann cells surround and form?

- what are they vital to?

NEURONS

- what are neurons also called?
- neurons have the ability to conduct what?
  - list their three other special characteristics:

- although they all vary in structure, they all have what?

Neuron Cell Body

- **cell body** - what does it consist of?

- what are the clusters of rough endoplasmic reticula called?

- clusters of cell bodies of neurons in the CNS are called what?
- clusters of cell bodies of neurons in the PNS are called what?

Neuron Processes

- bundles of neuron processes in the CNS are called what?
- bundles of neuron processes in the PNS are called what?
- name the 2 types of **cytoplasmic processes** ("nerve fibers") that project from the cell body:

☆ **Dendrites** – short, branched
- dendrites are the main what?
- they provide enormous surface area for what?

- they convey what?
  - these electrical signals are usually not action potentials but are what?

☆ **The Axon**
- each neuron has how many axons?
- functionally, the axon is what?
- it generates nerve impulses and transmits them from the cell body, along the plasma membrane

☆ **Myelin Sheath**

- the axons of most neurons are <u>myelinated</u> (surrounded by a **myelin sheath** (myelin)
- myelin is rich in lipids; what color is it?
- what are the functions of the myelin?

Myelination in the PNS

- what cells form myelin sheaths in the PNS?

  - the cell membrane of these cells is rich in lipids and protein; it wraps around an axon many times like a jellyroll to form the myelin sheath (see Fig. 11.5)

- what are the gaps between Schwann cells where there is no myelin around the axon called?

Myelination in the CNS

- what cells form myelin sheaths in the CNS?
- define **white matter**:

- define **gray matter**:

Classification of Neurons

Structural Classification *(see Table. 11.1)*

Neurons are grouped structurally according to what?

• **Multipolar neurons**

✧ have many cytoplasmic processes, consisting of numerous dendrites and one axon
✧ e.g., neurosecretory cells of the hypothalamus; motor neurons; interneurons
✧ what percent of neurons belong to this class?

• **Bipolar neurons**

✧ have one axon and one dendrite
✧ give two examples of where bipolar neurons are present:

• **Unipolar neurons** (pseudounipolar neurons)

✧ have one short process that arises from the cell body and divides into two processes (central and peripheral) that together act as an axon; in place of dendrites, the unipolar neurons have <u>receptive endings</u> at the end of their peripheral process
✧ e.g., sensory neurons

Functional Classification

Neurons are grouped functionally according to what?

- **sensory (afferent) neurons** transmit impulses from what to what?

  - except for certain neurons in some special sense organs, virtually all sensory neurons are unipolar and their cell bodies are located where?

- **motor (efferent) neurons** carry impulses from what to what?

  - motor neurons are multipolar
  - except for some neurons of the autonomic nervous system, where are their cell bodies located?

Membrane Potentials

- when a neuron is adequately stimulated, what is generated and conducted along the length of its axon?
- what is this response called?
- the action potential is always the same, regardless of what?

Basic Principles of Electricity

Some Definitions: Voltage, Resistance, Current

- define **voltage**:
- define **potential difference**:
- define **current**:

Role of Membrane Ion Channels

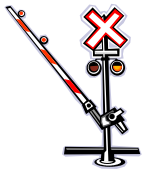
Cell membranes have a variety of ion channels made up of integral proteins through which ions flow into and out of cells:

✓ **LEAKAGE CHANNELS** (nongated channels) - they are always open (they have no "gates")

- the plasma membrane has more potassium ion leakage channels than sodium leakage channels
  - so, is the membrane more permeable to K^+ or Na^+?

✓ **GATED CHANNELS** - *the next 3 types are **gated channels***

- part of the integral protein forming the channel acts as a "gate" and can open or close in response to various signals:



- **chemically-gated channels** (ligand-gated channels) open when what binds?

- **voltage-gated channels** open and close in response to what?

- **mechanically-gated channels** open or close in response to what?

  - list examples of mechanically-gated channels:

✓ explain what it means to say that ions move along **chemical concentration gradients**:

✓ explain what it means to say that ions move along **electrical gradients**:

✓ define **electrochemical gradient**:

☞ ions flowing along electrochemical gradients underlie what?

TIME OUT FOR SOME ADVICE: Get up and stretch, take a walk outside, then take a deep breath and deal with this stuff! As with any material that you learn for the first time, it seems overwhelming at first. If you don't panic and keep an open mind as you study it, hopefully you will be happy with what you can figure out! Please do not turn off and think that you can't learn this because it has lots of big words and is more complex than other topics. Take your time and understand each part before you move on. Also, look at the Figures in the book as you read, try making your own sketches to show different steps, and write things out in your own words if it helps!

Ready...?!

The Resting Membrane Potential

✓ what is the potential difference in a resting neuron called?

- the membrane is said to be what?

✓ the resting membrane potential is approximately -70 mV; what does the minus sign indicate?

✓ the resting potential exists only across what?

✓ what is the resting membrane potential generated by?

➢ without panicking, read (don't write or memorize) the information on pages 397 to 406 and examine the Figures

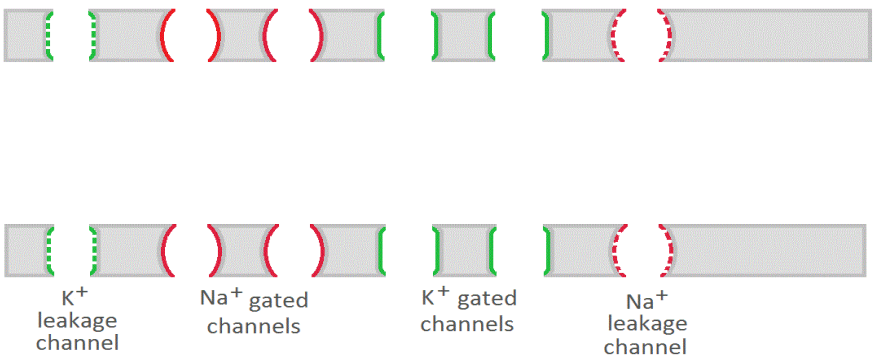
In a resting neuron:

(1) There is a higher concentration of sodium ions (Na^+) in the extracellular fluid along the outside surface of the plasma membrane than in the cytosol along the inside surface of the cell membrane.

(2) There is a higher concentration of potassium ions (K^+) in the cytosol along the inside surface of the cell membrane than in the extracellular fluid along the outside surface of the cell membrane.

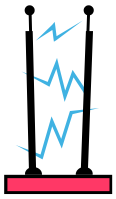
(3) The cell membrane is not permeable to various anions, such as proteins and phosphate ions, so that these negatively charged molecules can not diffuse out of the cell.

✯ *Examine Fig. 11.8 while reading this information! It is a magnified view of a cell membrane, showing the distribution of ions in the fluid on the inside and outside surfaces of the cell membrane of a resting neuron.*



So, now you are wondering why is there an unequal distribution of ions in a resting neuron? Here's the answer:

- Voltage-gated sodium ion channels and voltage-gated potassium ion channels in the cell membrane are closed.
- The cell membrane has some potassium ion leakage channels through which some potassium ions diffuse out of the cell
- The cell membrane has fewer sodium ion leakage channels through which fewer sodium ions diffuse into the cell
- the **sodium-potassium pump** *(formed by integral proteins in the cell membrane)* uses active transport to pump the ions against their concentration gradient. Sodium ions are transported out of the cell as potassium ions are pumped into the cell by the sodium-potassium pump.



The outside surface of the cell membrane of a resting neuron has a positive charge compared to the inside surface, which has a negative charge.

When one microelectrode is inserted into the resting neuron in the cytoplasm along the inner surface of the cell membrane and the other rests in the extracellular fluid along the outer surface of the cell membrane, a voltage of **-70 mV** is recorded.

The membrane is said to be **polarized**.

The difference in charges (**membrane potential**) across the cell membrane of a resting neuron is called the **resting membrane potential** and it equals -70 mV. *(The minus sign indicates that the cytoplasm side of the cell membrane is negatively charged relative to the outside surface of the cell membrane (i.e., the inside of the cell is 70 mV more negative than the outside).*

Note: The resting membrane potential exists only across the membrane.
The fluids inside and outside of the cell (cytoplasm and extracellular fluid, respectively) are each electrically neutral.

- with a sufficient stimulus (a **threshold stimulus)**, the axon generates an electrical signal due to the movement of certain ions into and out of the cell across the cell membrane due to concentration and electrical gradients

➢ the electrical signal that occurs in a neuron is called a **nerve action potential**

Membrane Potentials That Act as Signals

✓ changes in membrane potential can produce two types of signals; Name and describe the 2 types of signals:

✓ define **depolarization**:

✓ define **hyperpolarization**:

Graded Potentials

• what are **graded potentials**?

• graded potentials are triggered by some change (a stimulus) in the neuron's environment that causes gated ion channels to open; specifically either chemically gated (ligand-gated channels) or mechanically gated channels

• graded potentials occur most often in the dendrites and cell body of a neuron

Action Potentials

• only what cells can generate action potentials?

• define **action potential**:

• name the three phases of an action potential and indicate how long the whole event lasts:

• are the events of action potential generation and transmission identical or different in skeletal muscle cells and neurons?

• what is an action potential in a neuron also called?

• an action potential in a neuron is typically generated only in what?

• a neuron transmits a nerve impulse only when it is adequately stimulated. The stimulus changes what?

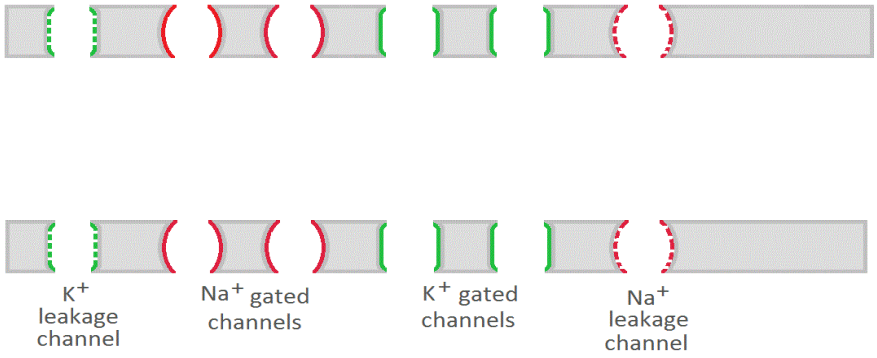
• these channels open and close in response to changes in the membrane potential and are activated by local currents (graded potentials) that spread toward the axon along the cell membranes of dendrites and the cell body

Generation of an Action Potential

✯ These phases (shown in Fig. 11.11) outline the electrical changes that occur in the same segment of the cell membrane of an axon during an action potential:

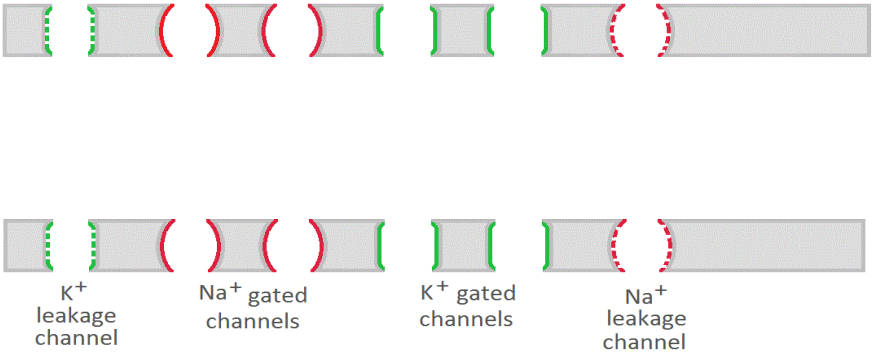
1. Resting State

- what channels in the cell membrane are closed?
- what channels are open?
- see the drawing that we did in class on page 7; you can redraw it here for practice!



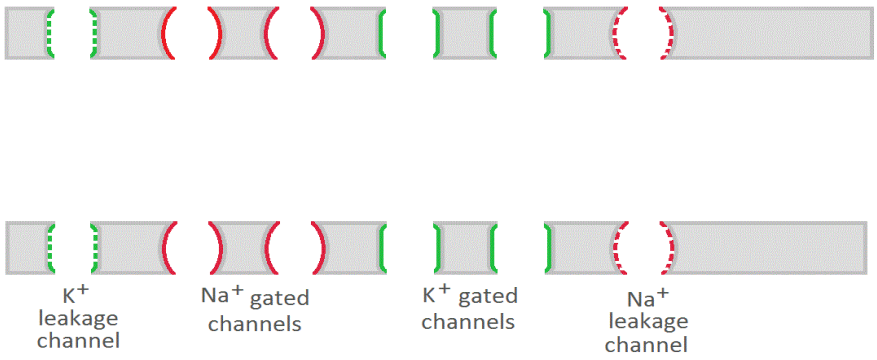
2. Depolarization

- as local currents depolarize the axon membrane, what happens?
- this influx of positive charges does what?
- The cytoplasm along the inner surface of the cell membrane is now more positive than the extracellular fluid along the outer surface of the cell membrane, and the potential difference reaches **+30 mV** at the end of depolarization.



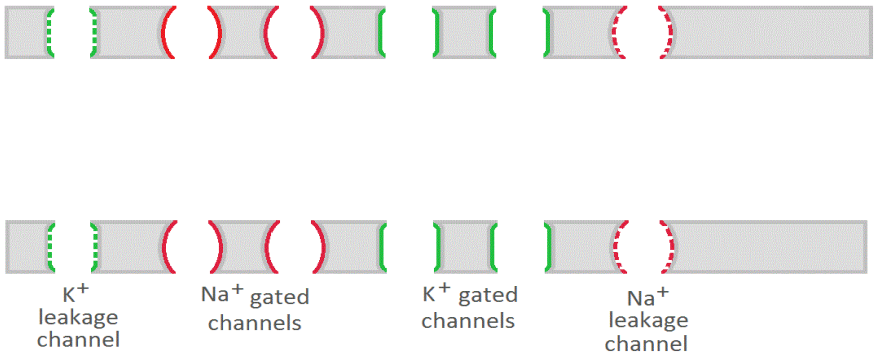
3. Repolariziation

- Voltage-gated sodium ion channels close and the influx of sodium ions stops.
- The slower voltage-gated potassium ion channels open and potassium ions diffuse out of the cell.
- With the outflow of positive ions, the cytoplasm along the inner surface of the cell membrane is now more negative than the extracellular fluid along the outer surface; the potential difference changes to **-70 mV** at the end of repolarization.



4. Hyperpolarization

- Voltage-gated potassium ion channels, which are slow to close, are still open and potassium ions continue to diffuse out of the cell.
- This net outflow of positive ions causes the cytoplasm along the inner surface of the cell membrane to become even more negative and the potential difference reaches **-85 mV**.



5. *Back To Resting Membrane Potential*

- Voltage-gated K^+ channels close and the **sodium-potassium pump** restores the Na and K ions to their original distribution.
- The membrane returns to its resting membrane potential of **-70 mV**.

✓ The chain of events just described is called an **action potential** or a **nerve impulse**.

✓ We will make a sketch in class (like on the top of on p. 402) that shows the electrical changes that occur over time at a given point inside an axon during an action potential.

Threshold and the All-or-None Phenomenon

☆ a **stimulus** is any condition in the environment that is capable of altering the resting membrane potential (e.g., temperature, pressure, electrical, chemical). A **threshold stimulus** is a stimulus that is sufficient to cause depolarization

☆ the ability of a neuron to respond to a stimulus and convert the stimulus into an action potential or nerve impulse is called **excitability**

☆ action potentials (impulses) is an **all-or-none phenomenon**. This means that once a threshold stimulus is reached, the action potential will proceed at a constant magnitude along the axon (i.e., it either happens completely or it doesn't happen at all!)

Propagation of an Action Potential

The phases of generation of an action potential reflect electrical changes that occur due to changes in distribution of ions at one segment of the cell membrane of an axon. So, now for how an impulse is conducted along the cell membrane of an axon (see Fig. 11.15):

✓ if it is to serve as the neuron's signal, an action potential must be what?

✓ the influx of sodium ions through a given area of the membrane establishes local currents that do what?

✓ once initiated, the action potential is self-propagating and does what?

✓ jump to page 405 and read about conduction velocity

· the rate of impulse propagation depends largely on what two factors?

Degree of myelination:

※ **continuous conduction**

· continuous conduction = step by step depolarization and repolarization of each adjacent segment of the plasma membrane; see Fig. 11.15(b)

· occurs in muscle cells and unmyelinated axons

※ **saltatory conduction**

· occurs in myelinated axons

· what does *"saltare"* mean?

· in saltatory conduction, only the regions of the cell membrane of the axon at the nodes of Ranvier (myelin sheath gaps) undergo depolarization and repolarization, so that the impulse appears to leap from node to node, bypassing the segments of cell membrane surrounded by the myelin sheath; see Fig. 11.15(c)

• which type of conduction is faster?

now, back to page 404...!

Coding for Stimulus Intensity

✓ are action potentials dependent on the stimulus strength?

✓ are all action potentials alike?

✓ how the CNS determines if a stimulus is intense or weak:
- strong stimuli cause what?

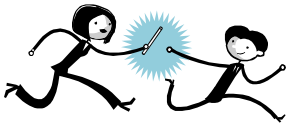
- stimulus intensity is coded for by what?

Refractory Periods

✓ when a patch of neuron membrane is generating an action potential and its voltage-gated sodium channels are open, can the neuron respond to another stimulus?

✓ **refractory period** = the period of time after an action potential begins during which the membrane cannot generate another axon potential

The Synapse



So far we have covered electrical changes that occur at one segment of the cell membrane of an axon and how an impulse is propagated along the cell membrane of an axon. That leaves how an impulse is **transmitted from a neuron to another neuron, to a muscle cell, or to a gland cell**:

✍ define **synapse**:

✍ define **presynaptic neuron**:

✍ define **postsynaptic neuron**:

- outside of the central nervous system, the postsynaptic cell may be what?

Electrical Synapses

- what do they consist of?
- they contain protein channels that intimately connect the cytoplasm of adjacent neurons and allow what?
- neurons joined in this way are said to be what?
- a key feature of electrical synapses between neurons is that what?

Chemical Synapses

- chemical synapses are specialized to allow what?
- name and describe the two parts of a typical chemical synapse:
- what are presynaptic and postsynaptic membranes always separated by?

Information Transfer Across Chemical Synapses

- we have already studied how an impulse is transmitted between a somatic motor neuron and a skeletal muscle cell with the Muscular System (remember the neuromuscular junction?!); synapses between neurons work in a similar way (see Fig. 11.17)
- list (and read about) the 6 numbered steps in bold print on page 408 and 410:

Neurotransmitters and Their Receptors

- neurotransmitters are released from synaptic vesicles of the axon terminal of the presynaptic neurons. They diffuse across the synaptic cleft and bind to the postsynaptic receptor (of another neuron, a muscle cell, or a gland cell).
- about how many neurotransmitters have been identified?
- flip through Table 11.3 on page 415 to page 416 and list some specific examples of neurotransmitters: ✯ be careful; don't list the chemical classes *(biogenic amines, amino acids, peptides, purines, or gases and lipids);* name specific neurotransmitters!

Note: neurotransmitters **may either excite or inhibit** the postsynaptic membrane, depending on how they affect the membrane potential of the postsynaptic receptor.

Basic Concepts of Neural Integration

- do neurons function in groups?
- **neuronal integration** is the interactions of groups of neurons that function, overall, to carry out activities of the nervous system
- define **neuronal pools**:

- define neuronal **circuits**: