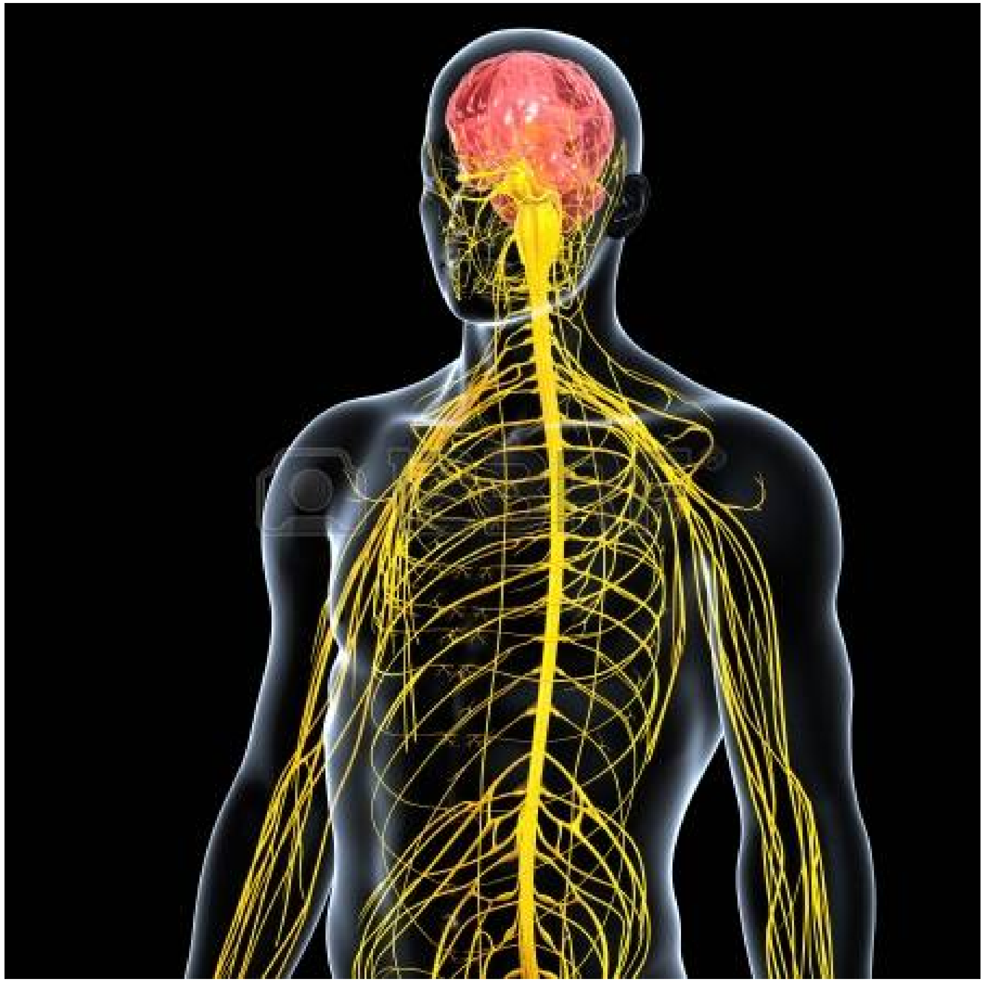
THE NERVOUS SYSTEM



Brain and spinal cord are integrating centers for homeostasis, movement, emotions, many other body functions. They are the control centers of nervous system.

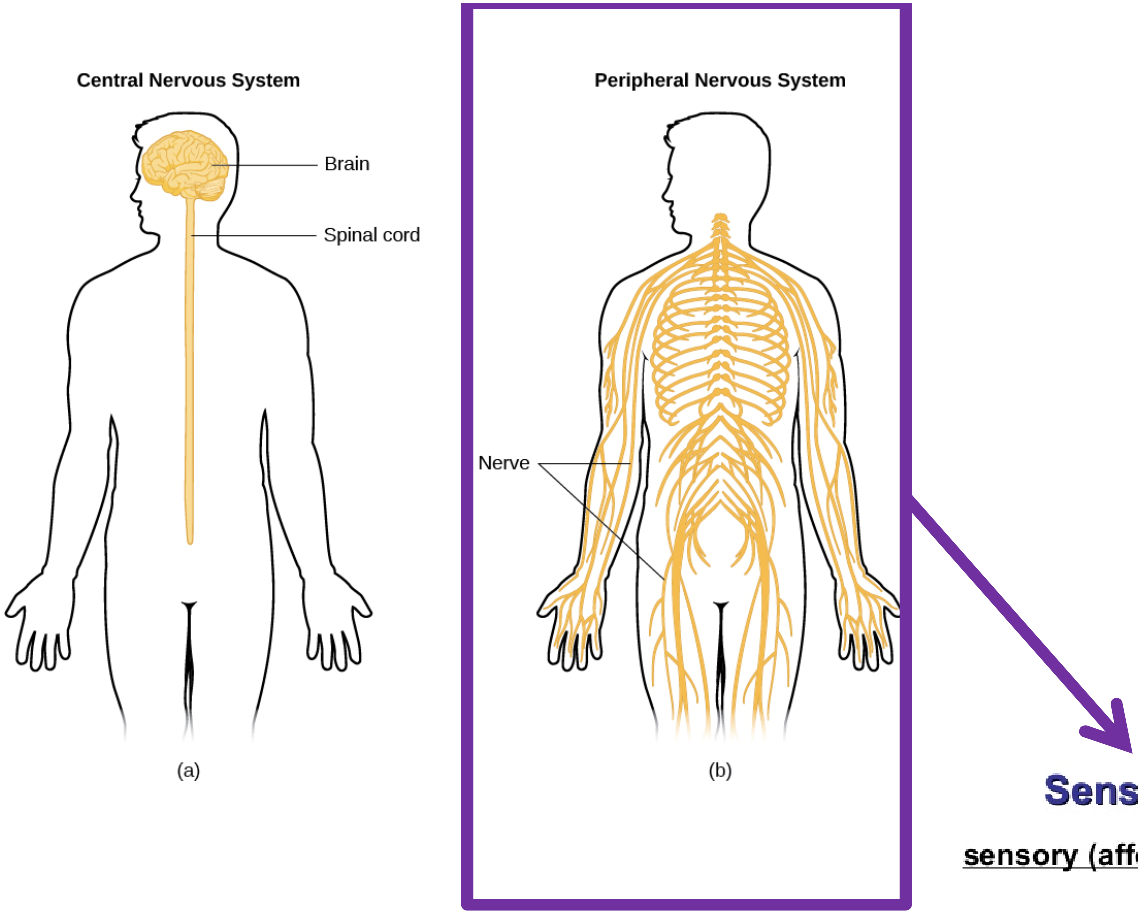
NERVE CELLS or NEURONS

Functional unit of nervous system

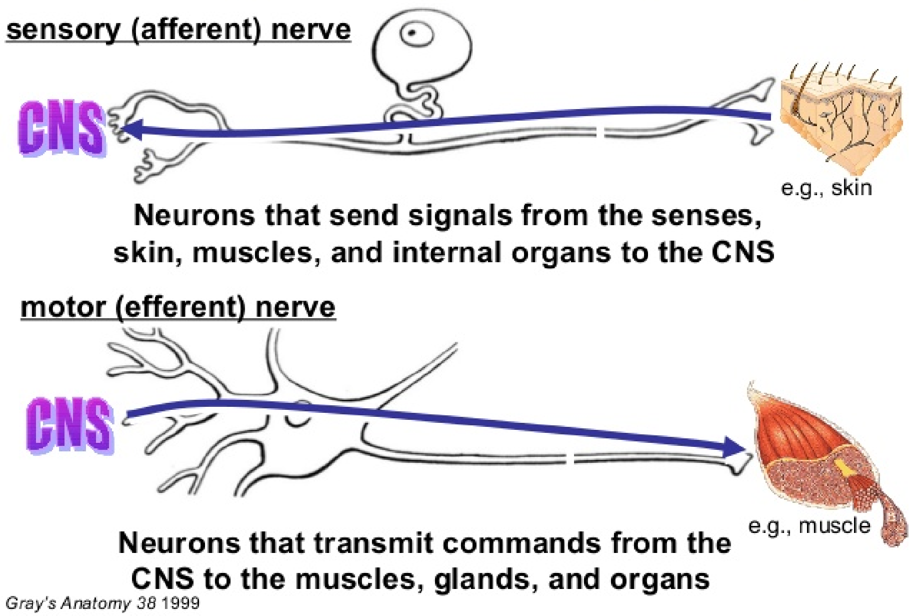
- carry electrical signals rapidly and over long distances.
- can extend up to a meter in length.
- excitable
- can generate & carry electrical signals

To communicate with neighboring cells,

- they release neurotransmitters into ECF or
- they are linked by gap junctions allowing electrical signal to pass directly.

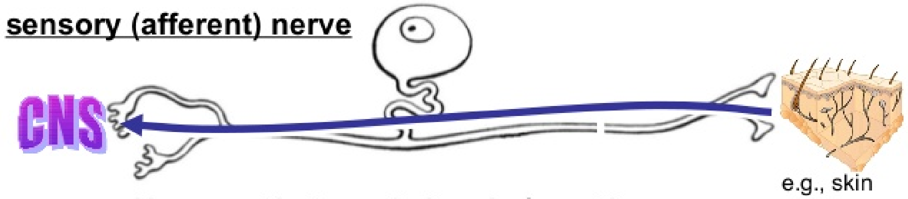


Sensory (Afferent) vs. Motor (Efferent)



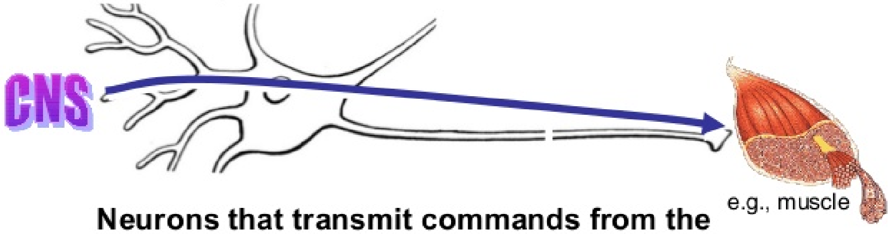
Sensory (Afferent) vs. Motor (Efferent)

sensory (afferent) nerve



Neurons that send signals from the senses, skin, muscles, and internal organs to the CNS

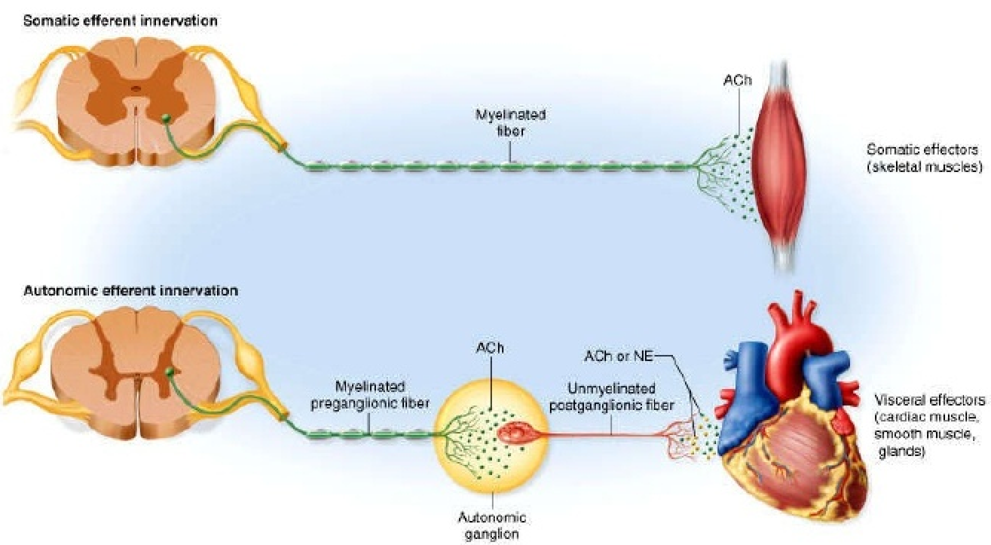
motor (efferent) nerve

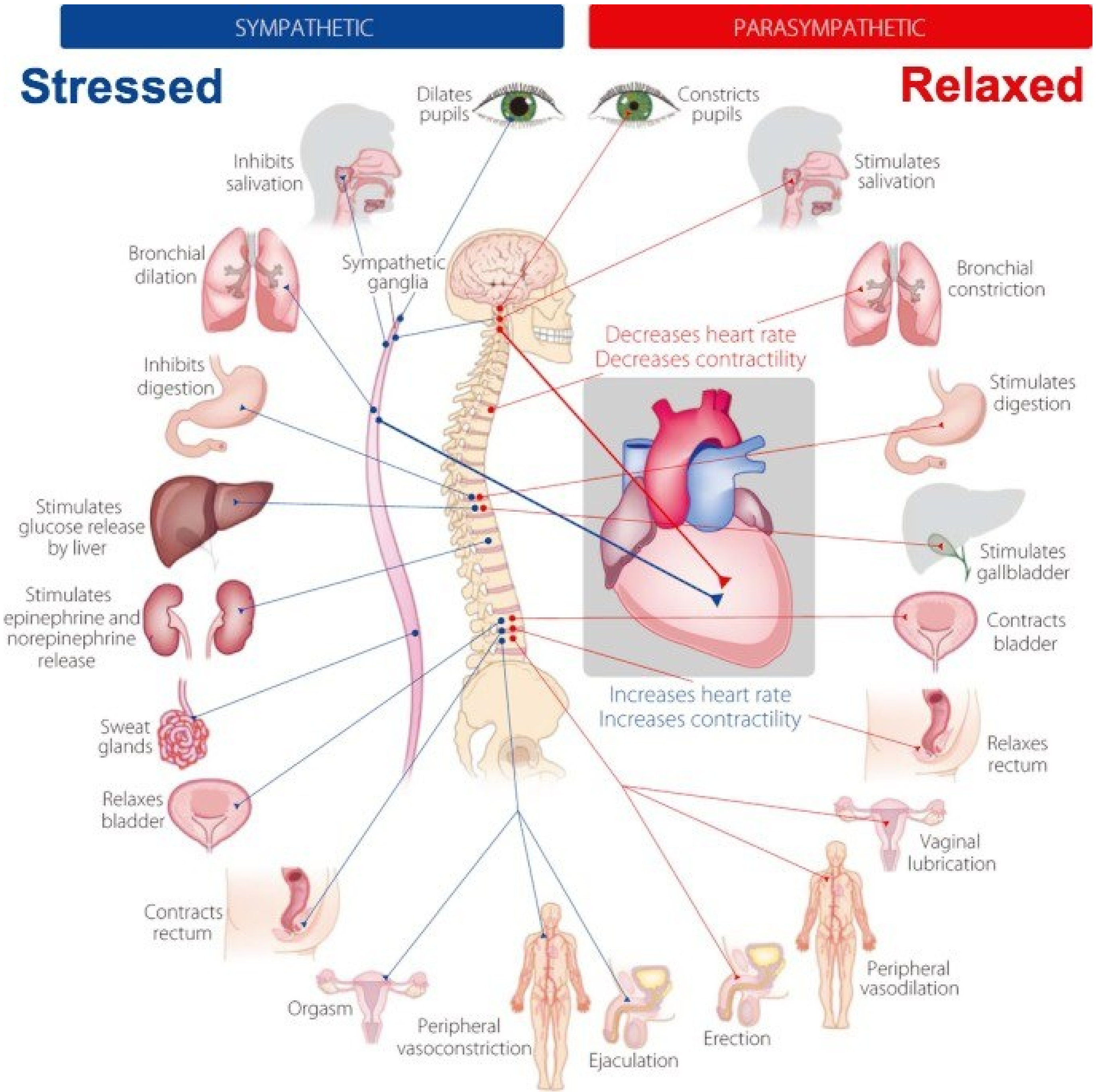


Neurons that transmit commands from the CNS to the muscles, glands, and organs

Gray's Anatomy 38 1999

Somatic vs. Autonomic

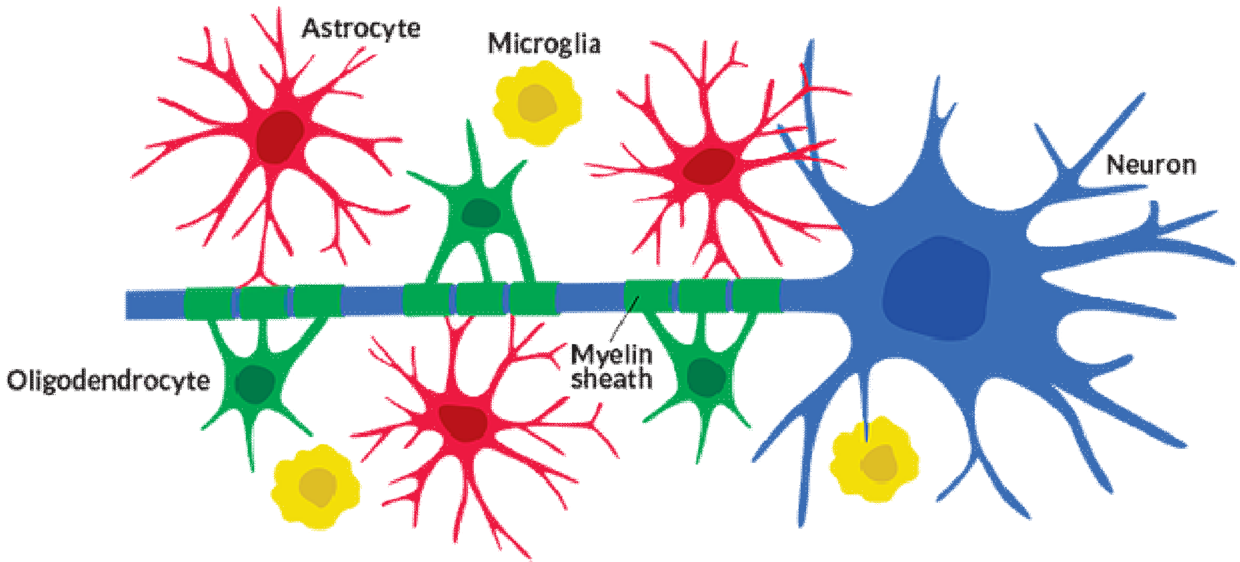




SYMPATHETIC
PARASYMPATHETIC
Stressed
Relaxed
Dilates pupils
Constricts pupils
Inhibits salivation
Stimulates salivation
Bronchial dilation
Sympathetic ganglia
Bronchial constriction
Decreases heart rate
Decreases contractility
Inhibits digestion
Stimulates digestion
Stimulates glucose release by liver
Stimulates gallbladder
Stimulates epinephrine and norepinephrine release
Contracts bladder
Increases heart rate
Increases contractility
Sweat glands
Relaxes rectum
Relaxes bladder
Vaginal lubrication
Contracts rectum
Peripheral vasodilation
Orgasm
Peripheral vasoconstriction
Ejaculation
Erection

Nervous system is composed of two cell types:

- 1. Neurons
- 2. Neuroglia = Support cells
  - Schwann Cells (PNS)
  - Oligodendrocytes (CNS)
  - Astrocytes
  - Microcytes
  - Ependymal Cells



- ✓ Neuron is the functional unit of the NS.
- ✓ Smallest structure that can carry out the functions.
- ✓ Dendrites which receive incoming signals;
- ✓ axons which carry outgoing information.

- ✓ Cell body, with a nucleus and organelles, is the control center.
- ✓ Dendrite receive incoming signals from neighboring cells
- ✓ Axons carry outgoing signals.
- ✓ axons originate from axon hillock.
- ✓ Vary in length. Electrical signal causes secretion of a chemical meesenger. .

Axons do not have ribosomes and golgi so proteins are synthesized in cell body and transferred to axons by axonal transport.

The region where axon terminal meets its target is called synapse.

Neuron that delivers a signal is presynaptic cell

Narrow space between two cells is synaptic cleft

the cell receives the signal is postsynaptic cell

Mostly presynaptic cell releases a chemical signal that diffuses across cleft an binds to a membrane on postsynaptic cell. Also human can contains electrical synapses where two cells are conncented by gap junction channels which allow electical current to flow.

Glial Cells,

provide structural stability by wrapping neurons around.

Nodes of Ranvier are tiny gaps in direct contact with ECF. They play a role in the transmission of electrical signals.

They generate electrical signals in response to a stimulus.

Membrane potential;
is the difference in electrical potential between interior and exterior of the cell.

Two factors influence membrane potential:

- the uneven distribution of ions across the cell membrane;
- differing membrane permeability to those ions.

NERNST EQUATION

describes the membrane potential that would result if the membrane were permeable to **only one ion**

Equilibrium potential;

is the membrane potential that exactly opposes a given concentration gradient.

Goldman-Hodgkin-Katz Equation

- Calculates the membrane potential that results from the contribution of all ions that can cross the membrane.
- For mammalian cells, we assume that Na+, K+ and Cl- are three ions that influence resting membrane potential.
- It can simplified as the membrane potential determined by the combined contributions of concentration gradient and membrane permeability for each ion.

- Resting membrane potential is determined primarily by the K+ concentration gradient and the cell's resting permeability to K+, Na+ and Cl-.
- A change in any of these, changes membrane potential.
- At rest, the cell membrane of a neuron is slightly permeable to Na+.
- If the membrane suddenly increases its Na+ permeability, Na+ enters the cell, moving down its electrochemical gradient.
- The addition of positive Na+ to the intracellular fluid depolarizes the cell membrane and creates an electrical signal.
- If cell become more permeable to K+, positive charge is lost from inside the cell, and the cell becomes more negative (hyperpolarizes).

Conductance is the ease with which ions flow through a channel.

Leak channels are the major determinant of resting membrane potential and spend most their time in an open state.

Ohm's Law

$$I = \frac{V}{R}$$

Electric current = Voltage / Resistance

Proportional to potential difference,
inversely proportional to resistance.

Current is the flow of electrical charge carried by an ion.
Direction depends on the electrochemical gradient.
Resistance is the force opposes flow.

Voltage changes across the membrane can be classified into two types of electrical signals:

- Graded potentials; travel over short distances and lose strength as they travel

- Action potentials; very brief, large depolarizations that travel for long distances without losing strength.

Graded potentials decrease in strength as they spread out from the point of origin.

Current is the net movement of positive electrical charge.

All-or-none

Strength of the stimulus has no influence on the amplitude.

There is no single action potential.

Ion channels open sequentially as electrical current passes, additional Na entering the cell reinforces the depolarization which is why an action potential does not lose its strength.

Action potential cannot be triggered for about 1-2 msec, no matter how large the stimulus.

Some but not all Na channel gates have reset, they need stronger stimuli and produce smaller amplitude.

Refractory period is a key characteristic for action potentials.

When a section of axon depolarizes, positive charges move by local current flow into adjacent sections of the cytoplasm. On the extracellular surface, current flows toward the depolarized region.

Conduction speed depends on

- Axon diameter
- Membrane resistance

- Larger neurons conduct action potentials faster.
- Conduction is faster in myelinated axons.

SALTATORY CONDUCTION

Action potentials appear to jump from one node of Ranvier to the next. Only the nodes have Na channels.

Demyelinating diseases reduce or block conduction when current leaks out of the previously insulated regions between the nodes.

Neurocrine chemicals   Paracrine/autocrine

Neurotransmitters; secreted by neurons that diffuse to the neighbor target cell

Neurohormones; secreted by neurons into the blood

Neurocrine receptors

ionotropic receptors
rapid response by altering ion flow

metabotropic receptors
slower response through a second messenger system

Termination of NTs

1. NTs can be returned to axon terminals

2. Enzymes inactivate NTs

3. NTs can diffuse out of the synaptic cleft

Neurons can use the **frequency** of AP to transmit info about the duration and strength of the stimuli.
A **stronger** stimulus causes **more AP** per second to arrive at the axon terminal, which in turn may result **in more neurotransmitter** release.
A **small** graded potential above threshold triggers a burst of APs.
As graded potentials increase in strength (amplitude), they trigger more frequent APs.

Electrical signal patterns are more variable.
Some neurons are tonically active firing regular APs.
They are created by ion channel variants that differ in their

- **activation and inactivation voltages**,
- **opening and closing speeds**, and
- **sensitivity to neuromodulators.**

The axon of a presynaptic neuron branches and its collaterals synapse on multiple target neurons. This pattern is known as **divergence.**

When a group of presynaptic neurons provide input to a smaller number of postsynaptic neurons, the pattern is known as **convergence.**

EPSP (excitatory depolarization) makes the cell more likely to fire an AP.
IPSP (inhibitory hyperpolarization) moves membrane potential away from threshold and the cell less likely to fire an AP.

Two subthreshold graded potential will not initiate an AP if they are far apart in time.

If two subthreshold potentials arrive at the trigger zone within a short period of time, they may sum amd initate an AP.

Spatial summation occures when the currents from nearly simultaneous graded potentials combine. They originate from different locations.

If summation prevents an AP in postsynaptic cell, it is called postsynaptic inhibition.

Global/selective

If modulation of a neuron decreases its neurotransmitter release, is called inhibition

Input from excitatory neuron increases neurotransmitter release by presynaptic cell.