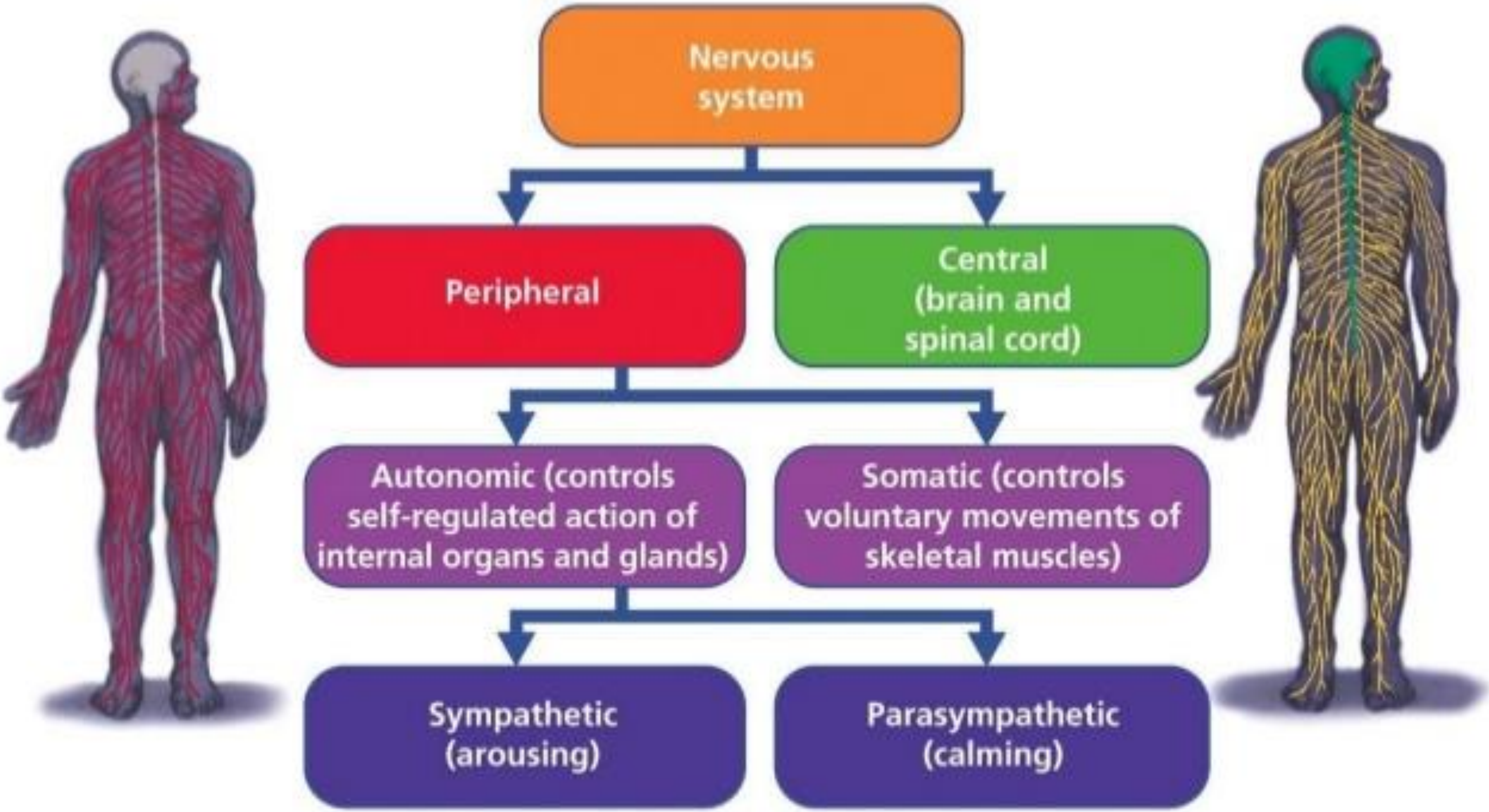
Nervous Coordination

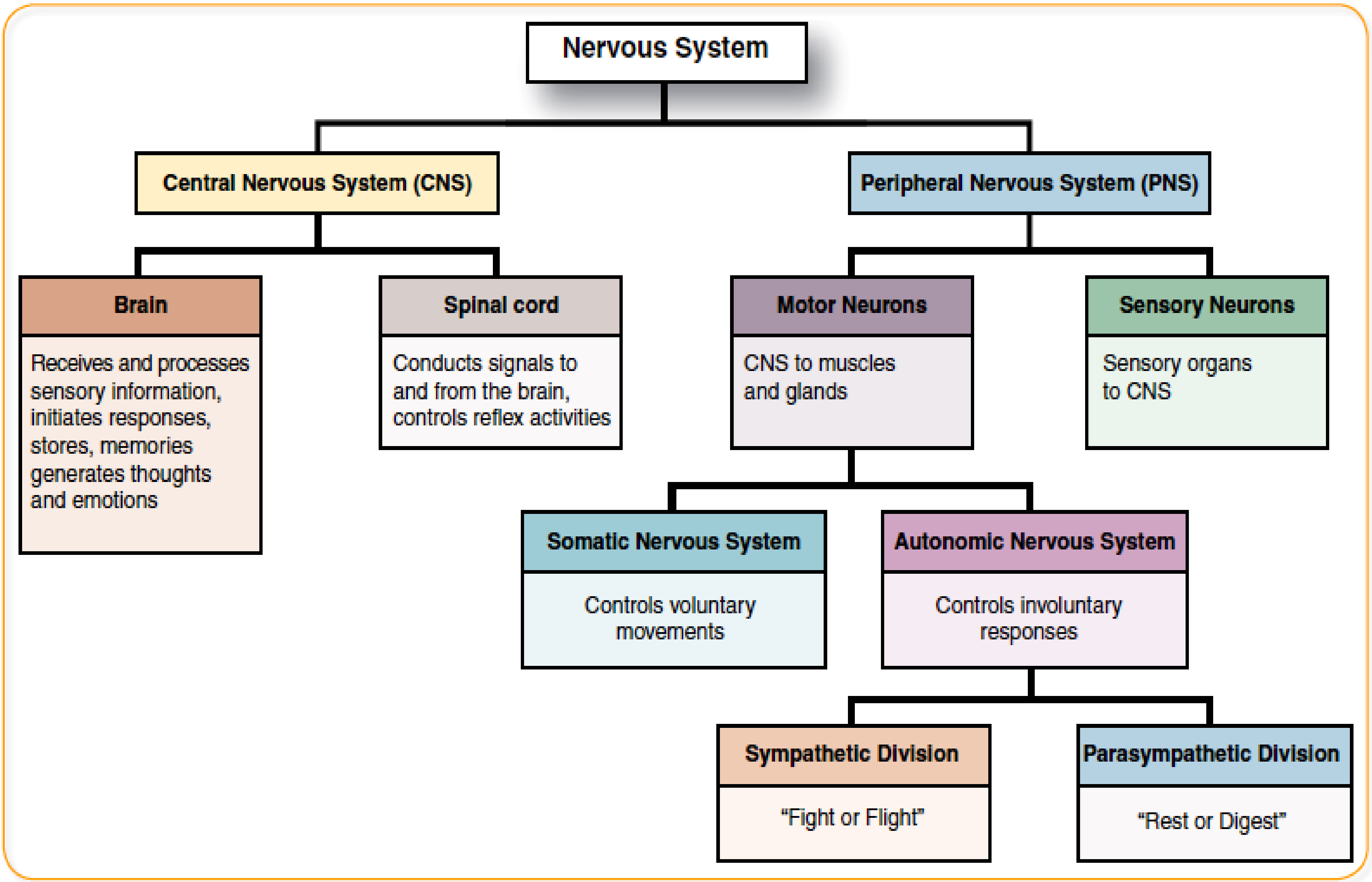
The Nervous system is an essential organ system in every organism, it plays a key role in controlling all bodily functions.

Functions of the Nervous System

1. **Gathers information** from both inside and outside the body - **Sensory Function**
2. **Transmits information** to the processing areas of the brain and spine
3. **Processes the information** in the brain and spine – **Integration Function**
4. **Sends information** to the muscles, glands, and organs so they can respond appropriately – **Motor Function**
5. It **controls and coordinates** all essential functions of the body including all other body systems allowing the body to maintain homeostasis or its delicate balance.
6. The Nervous System is divided into Two Main Divisions: **Central Nervous System (CNS) and** the **Peripheral Nervous System (PNS)**

Divisions of the Nervous System



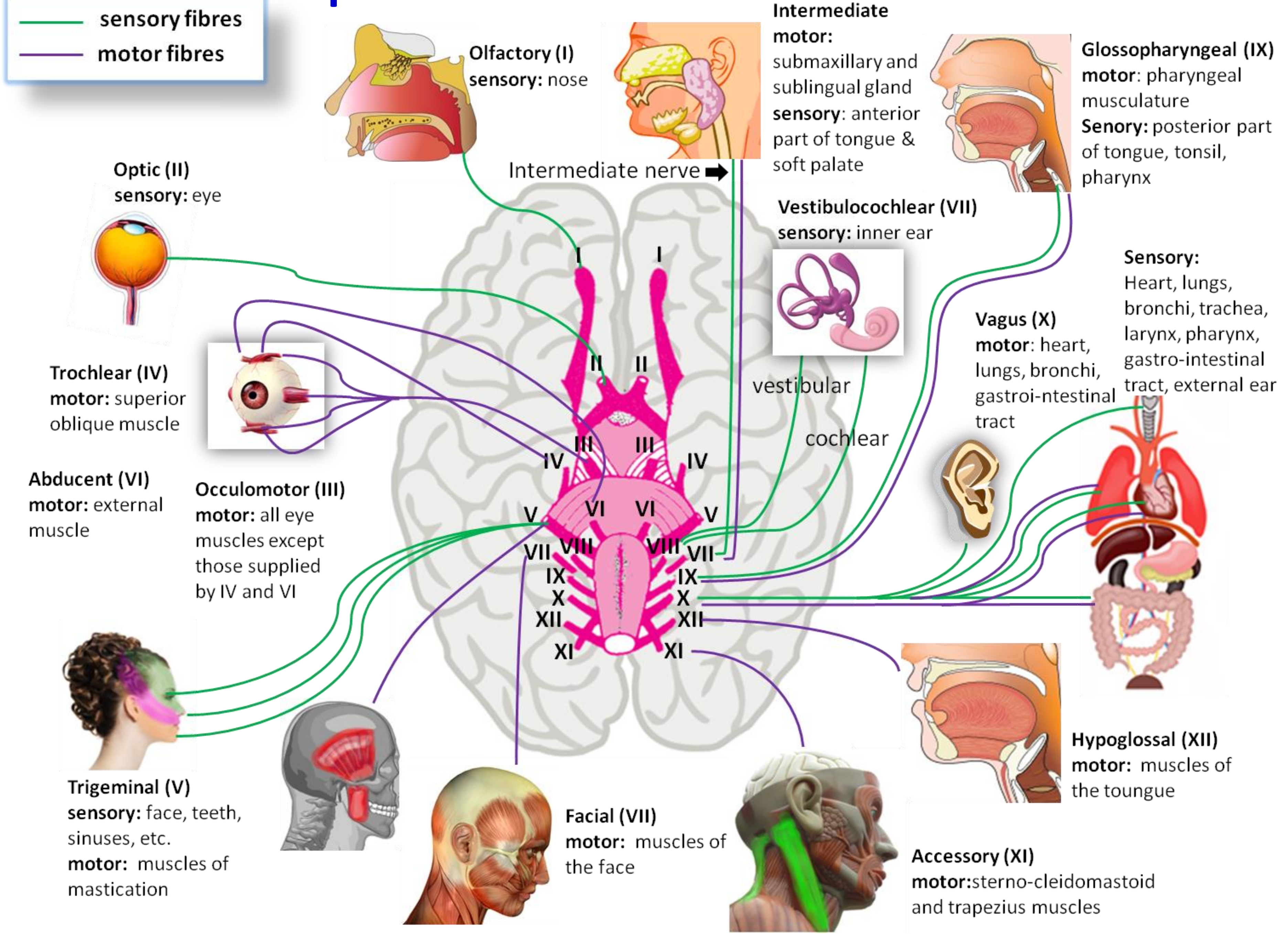


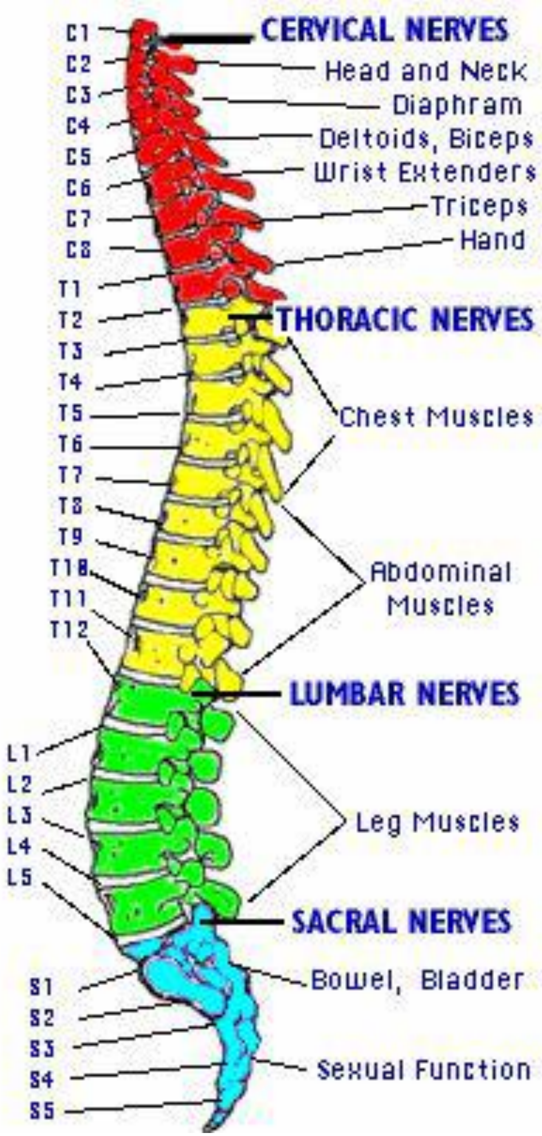
Nervous System
Central Nervous System (CNS)
Peripheral Nervous System (PNS)
Brain
Receives and processes sensory information, initiates responses, stores, memories generates thoughts and emotions
Spinal cord
Conducts signals to and from the brain, controls reflex activities
Motor Neurons
CNS to muscles and glands
Sensory Neurons
Sensory organs to CNS
Somatic Nervous System
Controls voluntary movements
Autonomic Nervous System
Controls involuntary responses
Sympathetic Division
"Fight or Flight"
Parasympathetic Division
"Rest or Digest"

Peripheral Nervous System

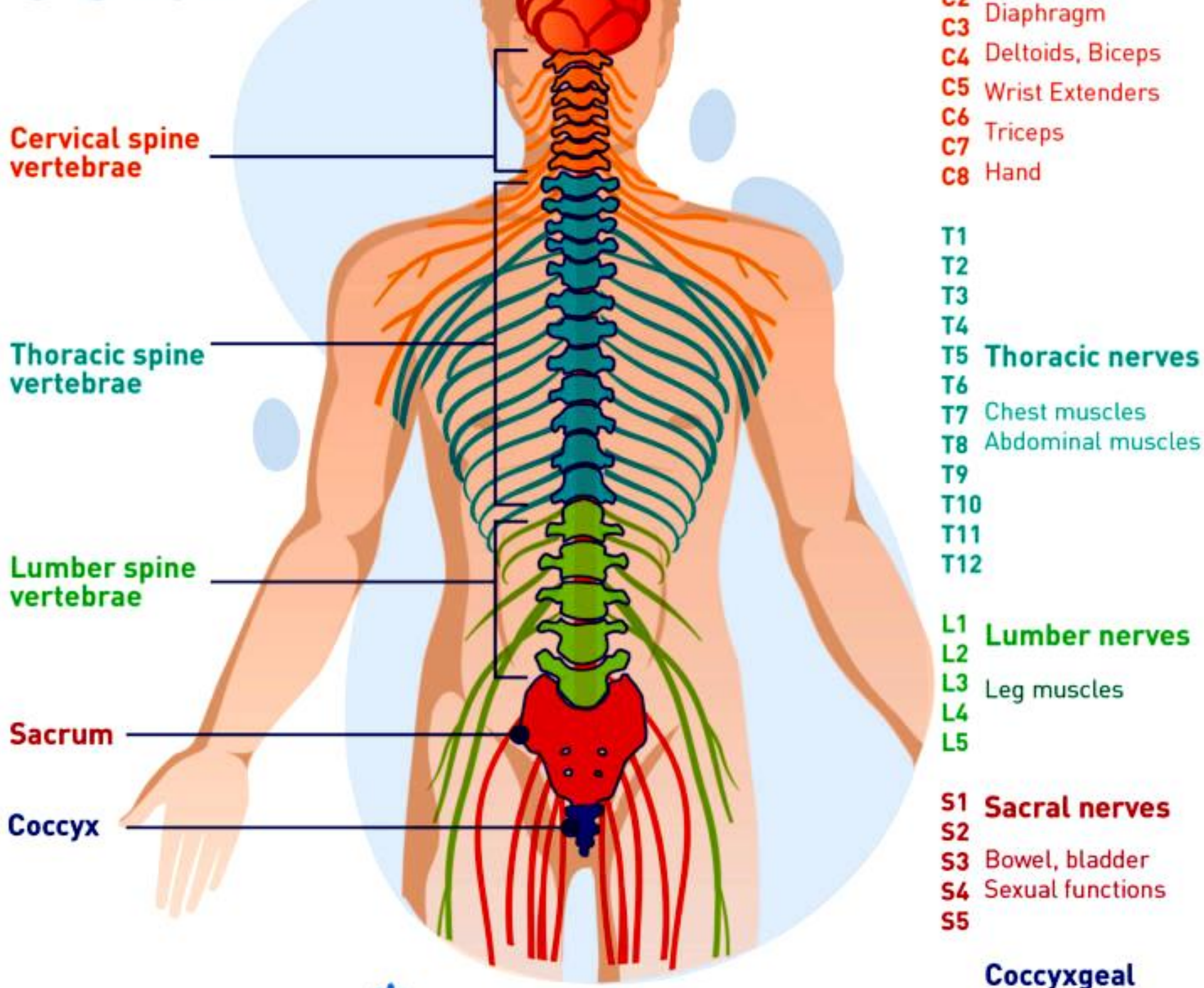
- **Cranial nerves**
  - 12 pairs—attached to under surface of the brain
  - Connect brain with the neck and structures in the thorax and abdomen
- **Spinal nerves**
  - 31 pairs—contain dendrites of sensory neurons and axons of motor neurons
  - Conduct impulses necessary for sensations and voluntary movements
  - Skin surface area supplied by a single nerve is called a *dermatome*

12 pair of Cranial nerves arise from brain




CERVICAL NERVES
C1
C2
C3
C4
C5
C6
C7
C8
Head and Neck
Diaphram
Deltoids, Biceps
Wrist Extenders
Triceps
Hand
THORACIC NERVES
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
T11
T12
Chest Muscles
Abdominal Muscles
LUMBAR NERVES
L1
L2
L3
L4
L5
Leg Muscles
SACRAL NERVES
S1
S2
S3
S4
S5
Bowel, Bladder
Sexual Function

SPINAL CORD


Cervical spine vertebrae
Thoracic spine vertebrae
Lumber spine vertebrae
Sacrum
Coccyx
Cervical nerves
C1 Head and neck
C2
C3 Diaphragm
C4 Deltoids, Biceps
C5 Wrist Extenders
C6 Triceps
C7
C8 Hand
T1
T2
T3
T4
T5 Thoracic nerves
T6
T7 Chest muscles
T8 Abdominal muscles
T9
T10
T11
T12
L1 Lumber nerves
L2
L3 Leg muscles
L4
L5
S1 Sacral nerves
S2
S3 Bowel, bladder
S4 Sexual functions
S5
Coccyxgeal

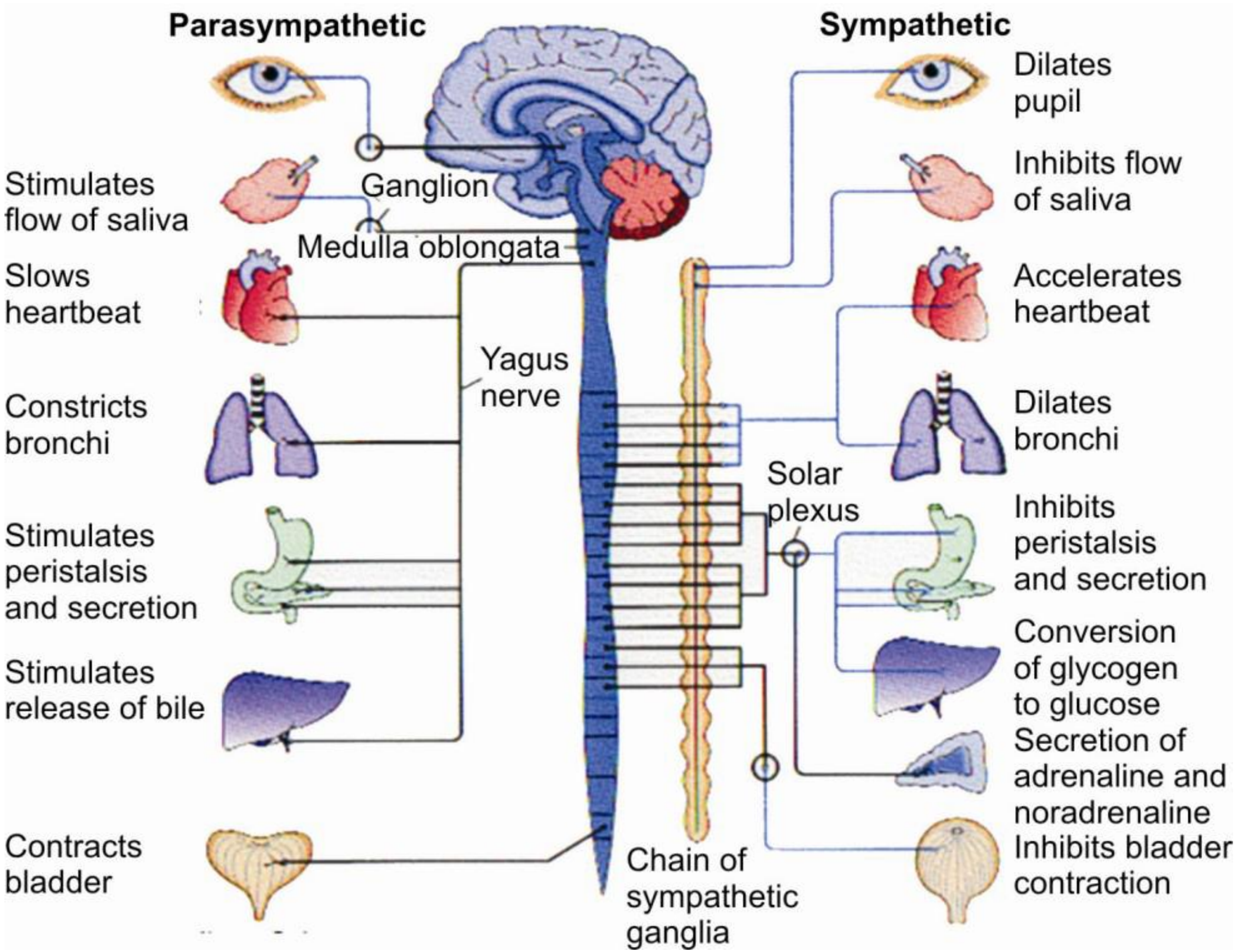
Somatic Nervous System (voluntary)

- Relays information from skin, sense organs & skeletal muscles to CNS
- Brings responses back to skeletal muscles for voluntary Responses

Autonomic Nervous System (involuntary)

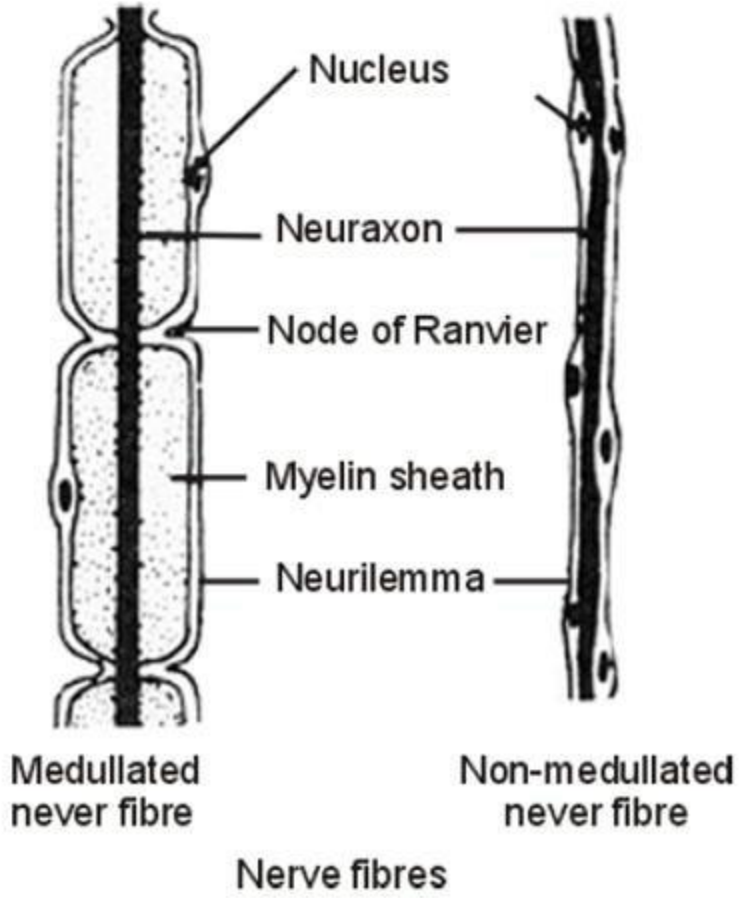
- Regulates bodies involuntary responses
- Relays information to internal organs
- Two divisions

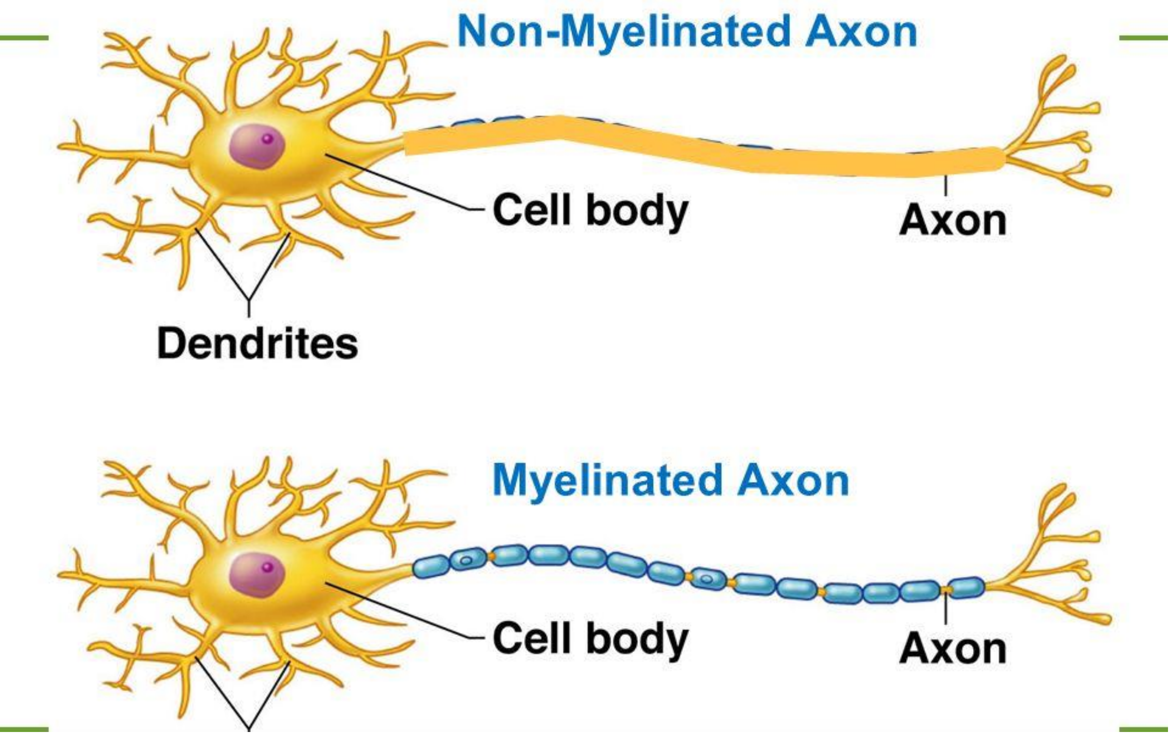
1. **Sympathetic nervous system** – in times of stress
    - Emergency response
    - "Fight or flight"
2. **Parasympathetic nervous system** – when body is at rest or with normal functions
    - Normal everyday conditions
    - "Rest & Digest"


Parasympathetic
Sympathetic
Dilates pupil
Ganglion
Stimulates flow of saliva
Inhibits flow of saliva
Medulla oblongata
Slows heartbeat
Accelerates heartbeat
Yagus nerve
Constricts bronchi
Dilates bronchi
Solar plexus
Stimulates peristalsis and secretion
Inhibits peristalsis and secretion
Conversion of glycogen to glucose
Stimulates release of bile
Secretion of adrenaline and noradrenaline
Inhibits bladder contraction
Contracts bladder
Chain of sympathetic ganglia

Nervous tissue consists of two types of cells:

1. Neurons
2. Neuroglia (glial cells)





Parts of a Neuron

- **Dendrite –** receive stimulus and carries impulses toward the cell body
- **Cell Body with nucleus –** nucleus & most of cytoplasm
- **Axon –** fiber which carries impulses away from cell body
- **Schwann Cells-** cells which produce myelin or fat layer in the Peripheral Nervous System
- **Myelin sheath –** dense lipid layer which insulates the axon – makes the axon look gray
- **Node of Ranvier –** gaps or nodes in the myelin sheath
- **Neurilemma –** outermost layer of neuron, surrounds the axon in PNS.

Cell body

The cell body is called neuron cell body. It contains a mass of granular cytoplasm, and cell membrane. The single large nucleus is centrally placed with a prominent nucleolus. Golgi apparatus, mitochondria and other organelles are present. The cytoplasm is characterised by the presence of Nissl's bodies and neurofibrils. Nissl's bodies are group of ribosomes and rough ER associated with protein synthesis.

Dendrites

Dendrites are short and thin, often highly branched cytoplasmic extensions that are gradually tapered from their bases to their tips. Axons of other neurons form synapses (sin-apse) with the dendrites. The function of the dendrite is to receive stimuli and conduct impulses to the cell body.

Axon

An axon is comparatively a long and thick nerve fibre which has a constant diameter and can vary in size from a few mm to more than a metre length. It is may be branched or un-branched. The cytoplasm of the axon is called axoplasm and its cell membrane is called axolemma (Greek, *lemma, sheath). Axons terminate by branching to form small extensions with enlarged ends called presynaptic terminals. Functionally, axons conduct action potentials from the neuron cell body to the presynaptic terminals.*

Myelin sheath and Schwann cells

Beside neuron, nervous system also consists of neuroglia or glial cells, which support, protect and nourish the neurons. Schwann cells are neuroglial cells in peripheral nervous system. Usually axons are covered by Schwann cells which are strip like cells wrap around axon fibres. These cells are also covered by a fatty substance called myelin sheath that acts as an insulator. This is why axons are called myelinated fibres. A non myelinated part of axon between two Schwann cells is called node of Ranvier. Conduction of action potentials from one node of Ranvier to another in myelinated neurons is called saltatory conduction.

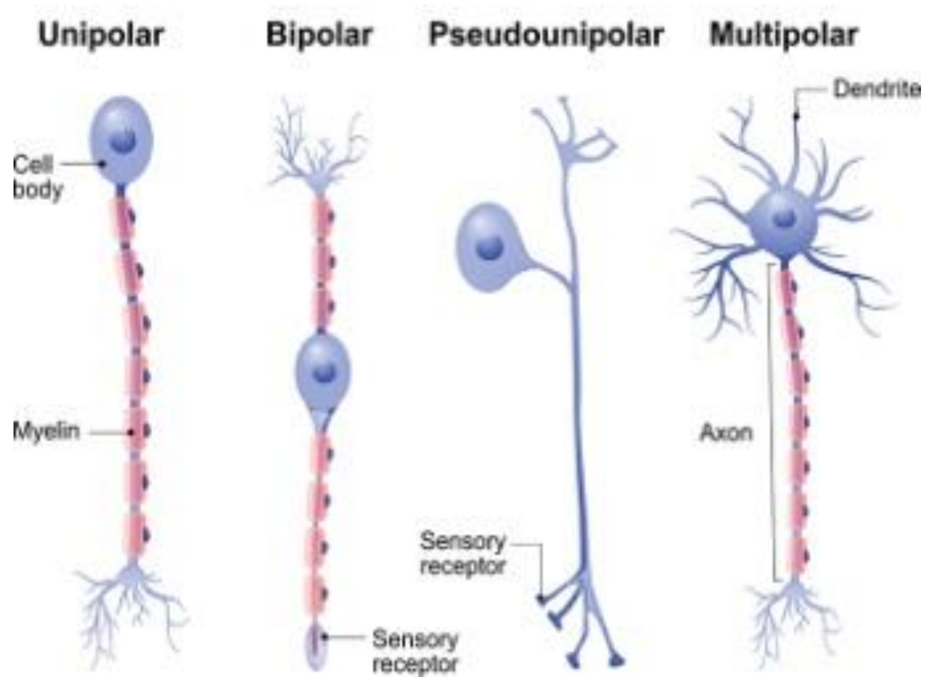
Classification of Neurons

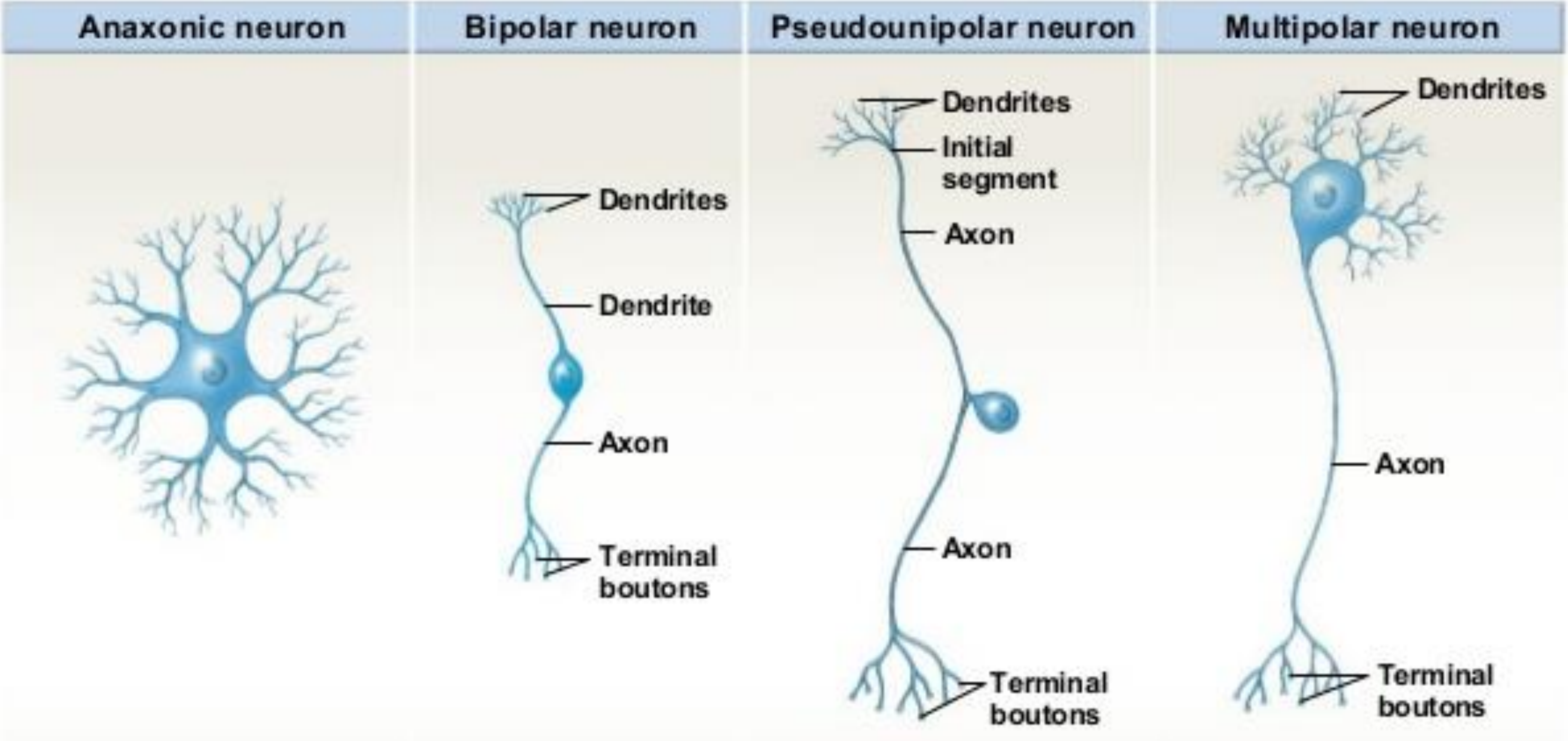
1. Based on Number of Process

A) Unipolarneuron -a single nerve fiber is extended from the soma, and it divides into a dendrite and an axon (sensory neurons that conduct reflexes or detect various stimuli).

B) Bipolar neuron -a dendrite and an axon extend from the soma independently (sensory neurons involved in special senses such as vision, olfaction, and hearing).

C) Multiple neuron -one axon and many dendrites extend from the soma (interneurons located inside the brain and spinal cord).





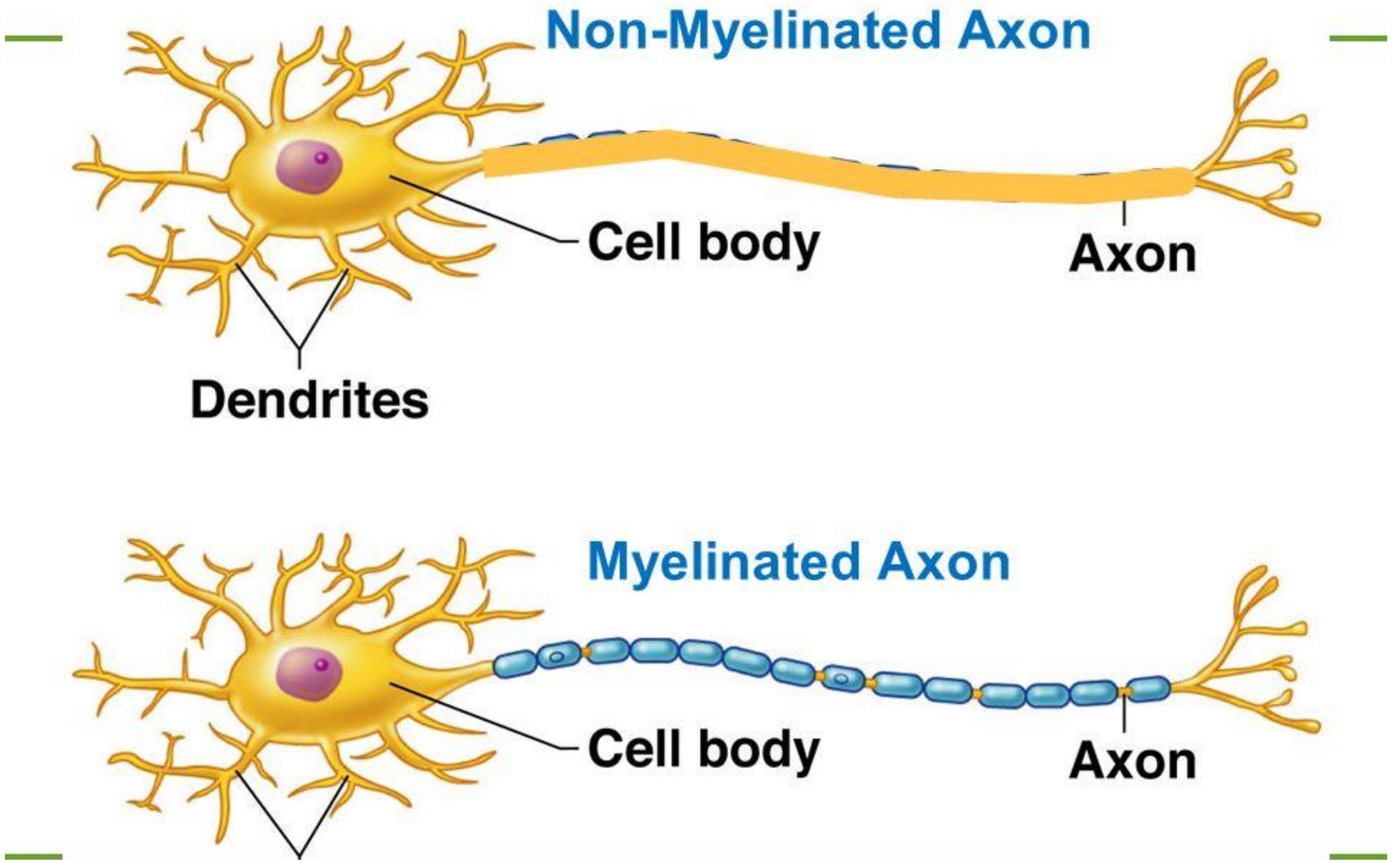
a Anaxonic neurons have more than two processes, but axons cannot be distinguished from dendrites.

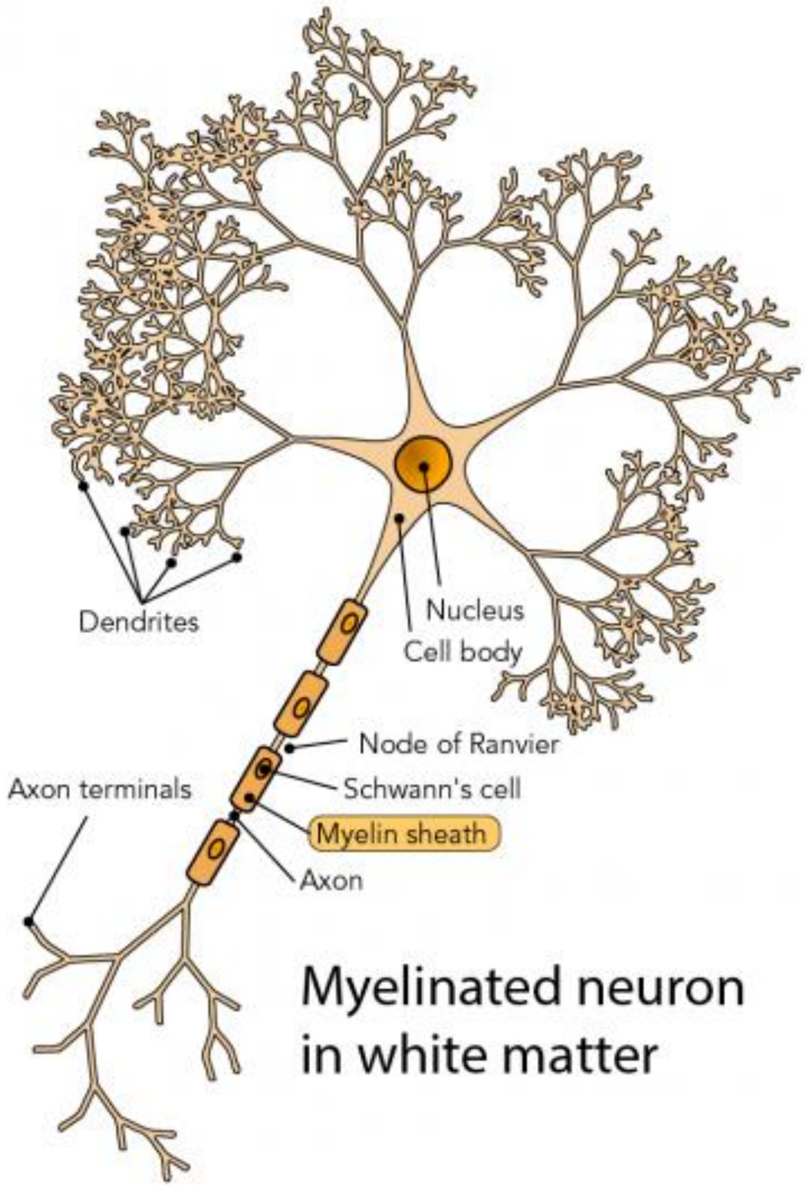
b Bipolar neurons have two processes separated by the cell body.

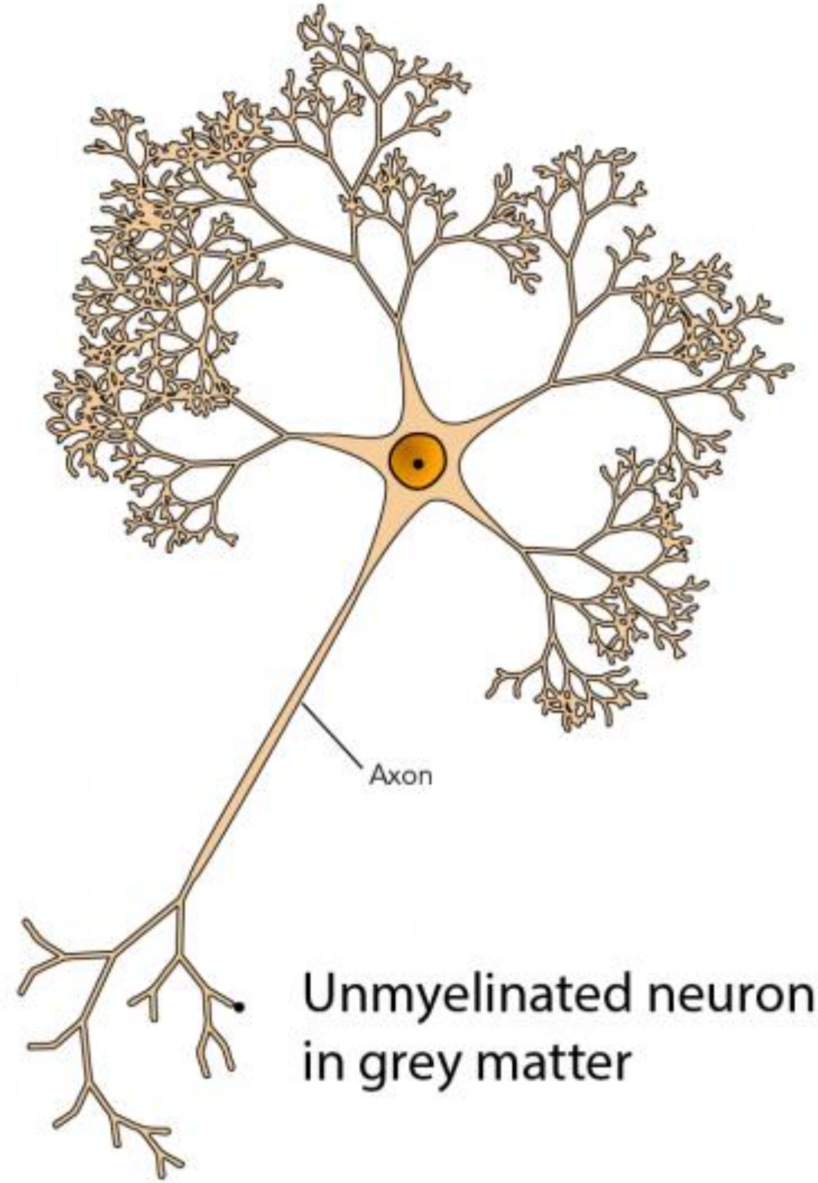
c Pseudounipolar neurons have a single elongate process with the cell body situated to one side.

d Multipolar neurons have more than two processes; there is a single axon and multiple dendrites.

2. Based on Presence or Absence of Myelin sheeth







Also called as Medulated and Non-medulated Neurons

Medullated neurons	Non Medullated neurons
• It includes those neurons which are covered with the myelin sheath.	• It includes those neurons which are not covered with the myelin sheath.
• In this the conduction of the action potential is fast.	• In this, the conduction of action potential is quite slow as compared to medullated neurons.
• In this, there is no leakage of current as axon remains insulated as it has the myelin sheath around it.	• In this, there is leakage of current as there is no insulation of axons as there is no myelin sheath.
• Nodes of Ranvier are present which are junctions where myelin sheath is not present and ion channels are present.	• Nodes of Ranvier are absent.
• In this conduction takes place through jumping where impulse jumps from one node of Ranvier to another. This process is called Saltatory conduction.	• In this, there is no saltatory conduction. In this impulse travels through complete length of the neuron.

3. Based on their function or direction of impulse

- **Sensory neurons:**

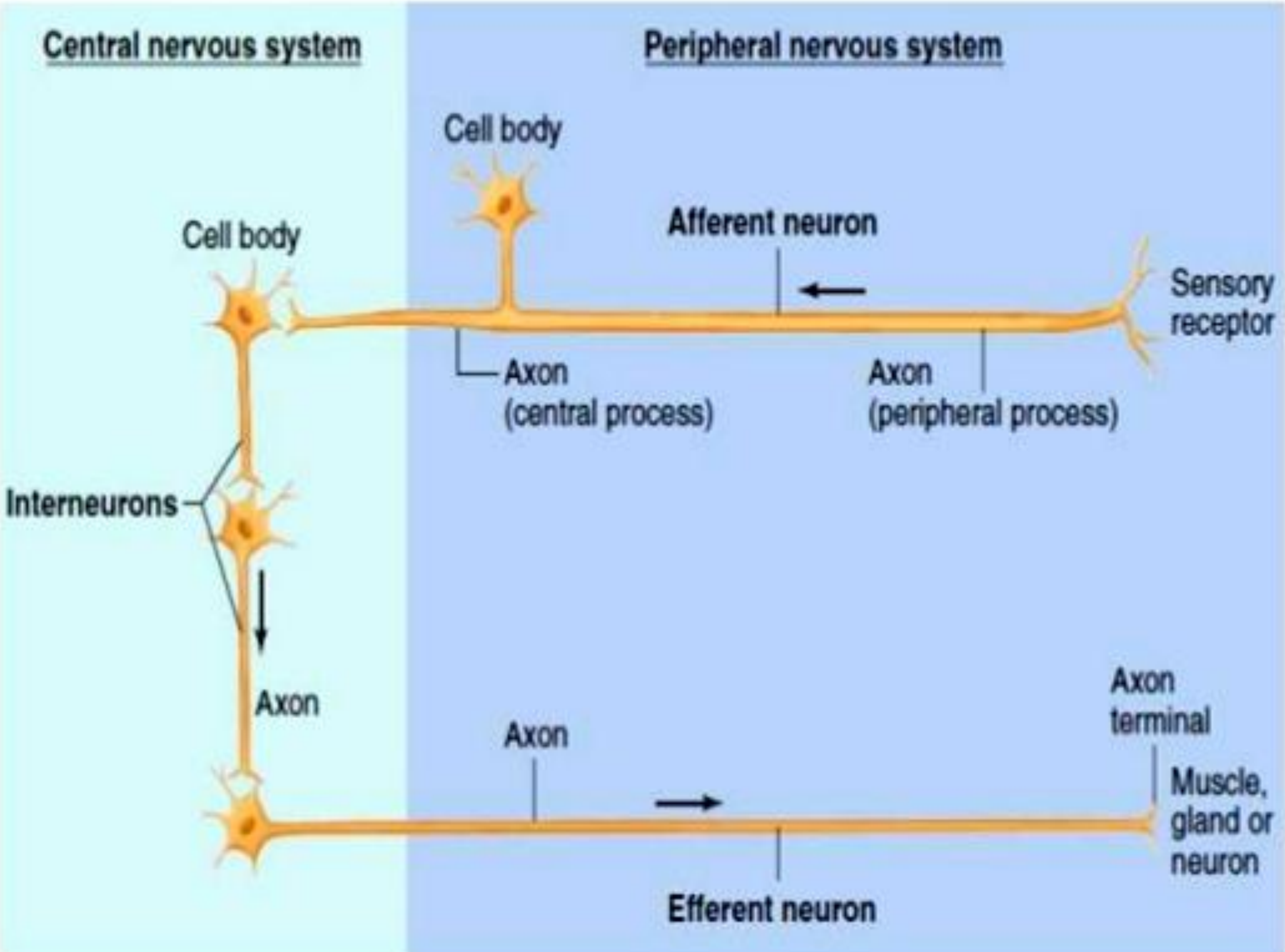
Occur in PNS and are unipolar conduct impulses to the spinal cord and brain; also called *afferent neurons*

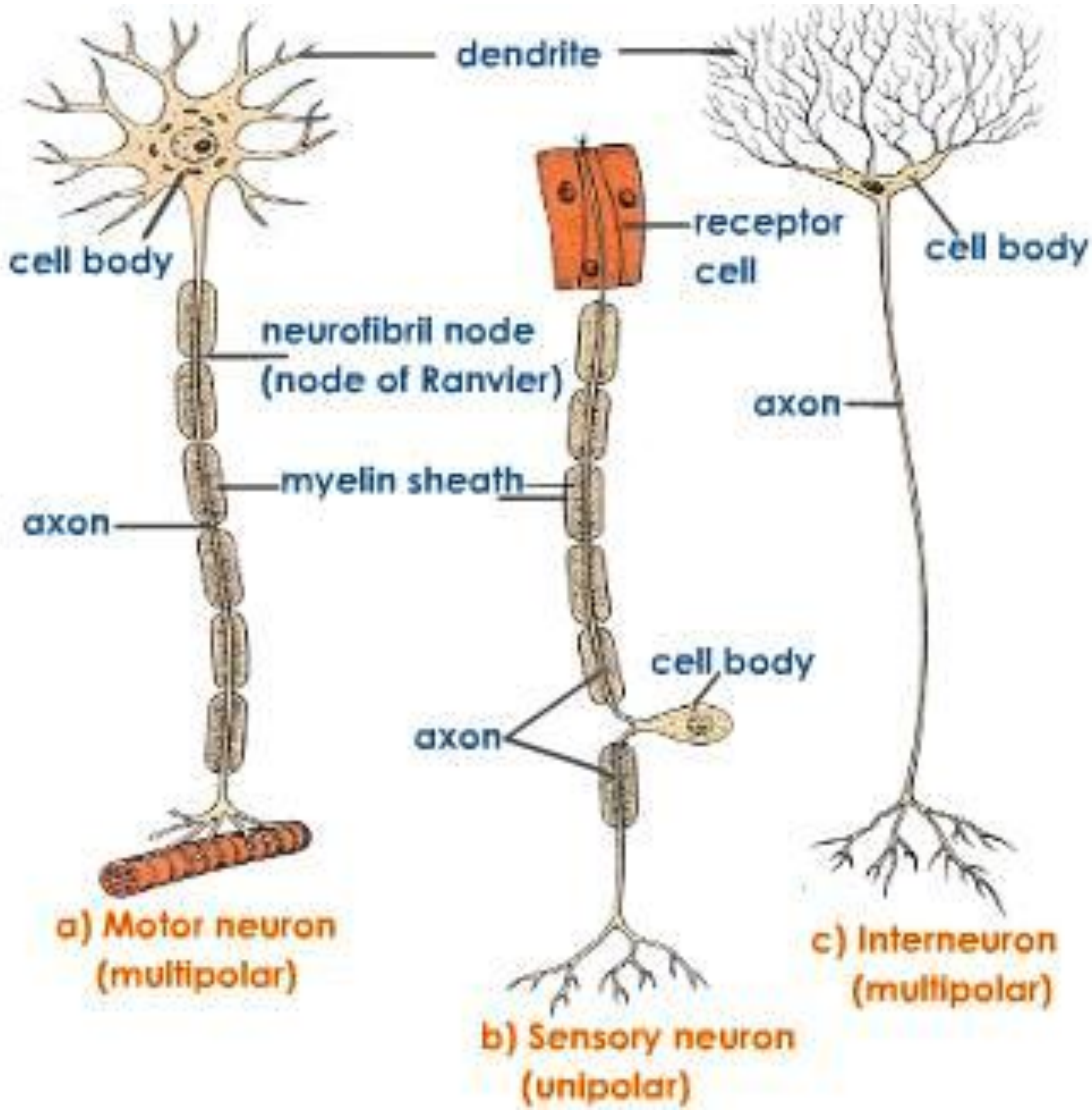
- **Motor neurons:**

Occur in PNS and are multipolar conduct impulses away from brain and spinal cord to muscles and glands; also called *efferent neurons*

- **Interneurons:**

Occur entirely within the CNS and are multipolar neuron. Conduct impulses from sensory neurons to motor neurons; also called *central or connecting neurons*


Central nervous system
Peripheral nervous system
Cell body
Afferent neuron
Cell body
Sensory receptor
Axon (central process)
Axon (peripheral process)
Interneurons
Axon
Axon
Axon terminal
Muscle, gland or neuron
Efferent neuron


dendrite
cell body
neurofibril node
(node of Ranvier)
myelin sheath
axon
receptor
cell
cell body
axon
cell body
axon
a) Motor neuron
(multipolar)
b) Sensory neuron
(unipolar)
c) Interneuron
(multipolar)

Classification of Neuroglia

Neuroglia are the supporting cells of the nervous system.

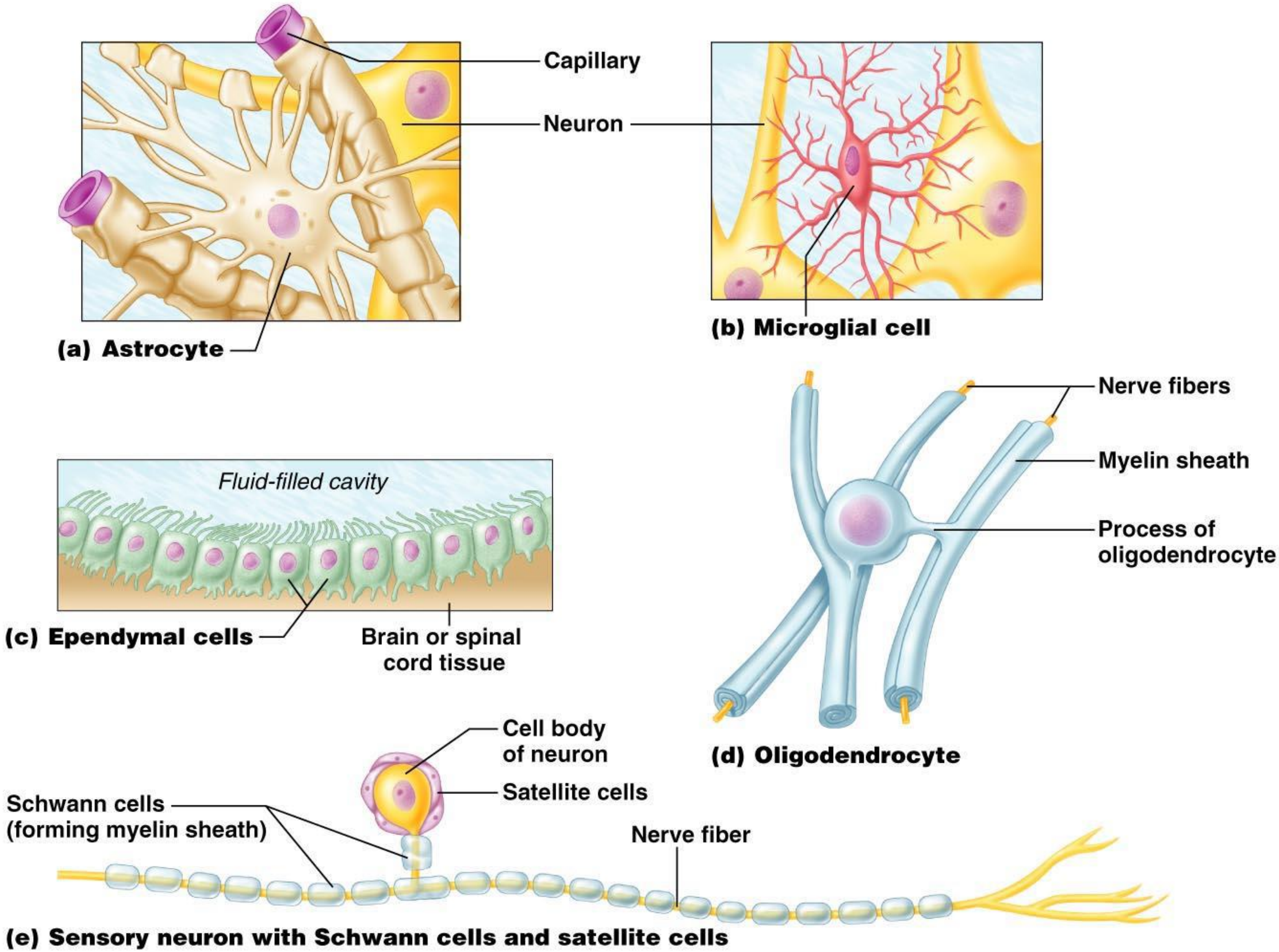
1. Astrocytes: star shaped cells found between neurons and blood vessels. They are the most abundant glial cells.
Function: structural support transport of substance between blood vessels and neurons, mop up excess ions (k) and neurotransmitters.

2. Microglial cells: small ovoid cells.
Function: structural support and phagocytosis (immune protection).

3. Ependymal cells: cuboidal or columnar shaped cells.
Function: form a porous layer through which substances diffuse between the interestitial fluid and the cerebrospinal fluid.

4. Oligodendrocytes: resemble astrocytes but have less processes and arranged in rows along nerve fibers.
Function: produce myelin sheet within the CNS (brain spinal cord) .

Neuroglia Cells



Structure of a Nerve

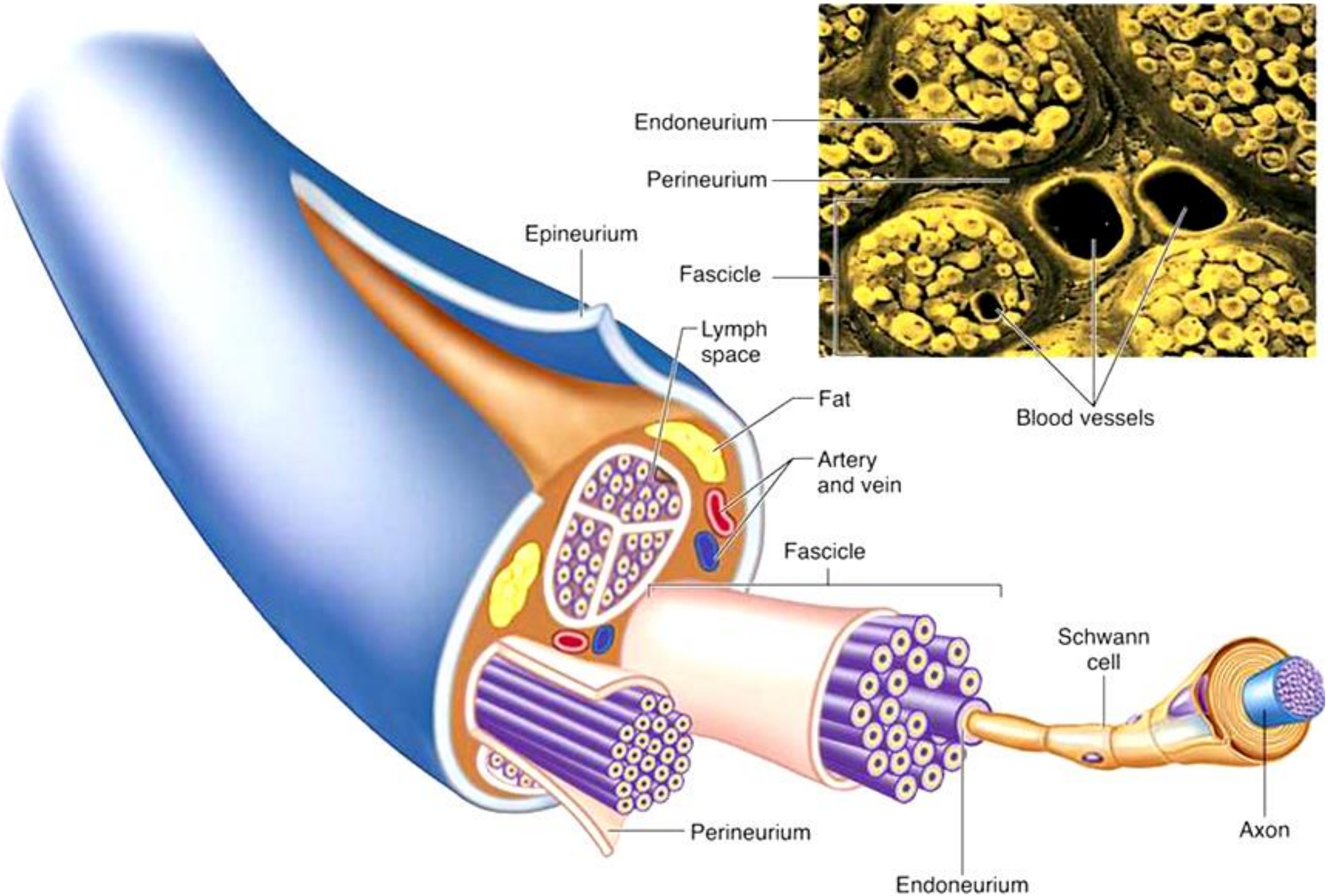
Nerve— it is the bundle of peripheral axons

- **Tract—** bundle of central axons
- **White matter—** brain or spinal cord tissue composed primarily of myelinated axons
- **Gray matter—** brain or spinal cord tissue composed primarily of cell bodies and unmyelinated fibers

**Nerve coverings - ** fibrous connective tissue

- **Endoneurium—** surrounds individual fibers within a nerve
- **Perineurium—** surrounds a group (fascicle) of nerve fibers
- **Epineurium—** surrounds the entire nerve

Structure of a Nerve



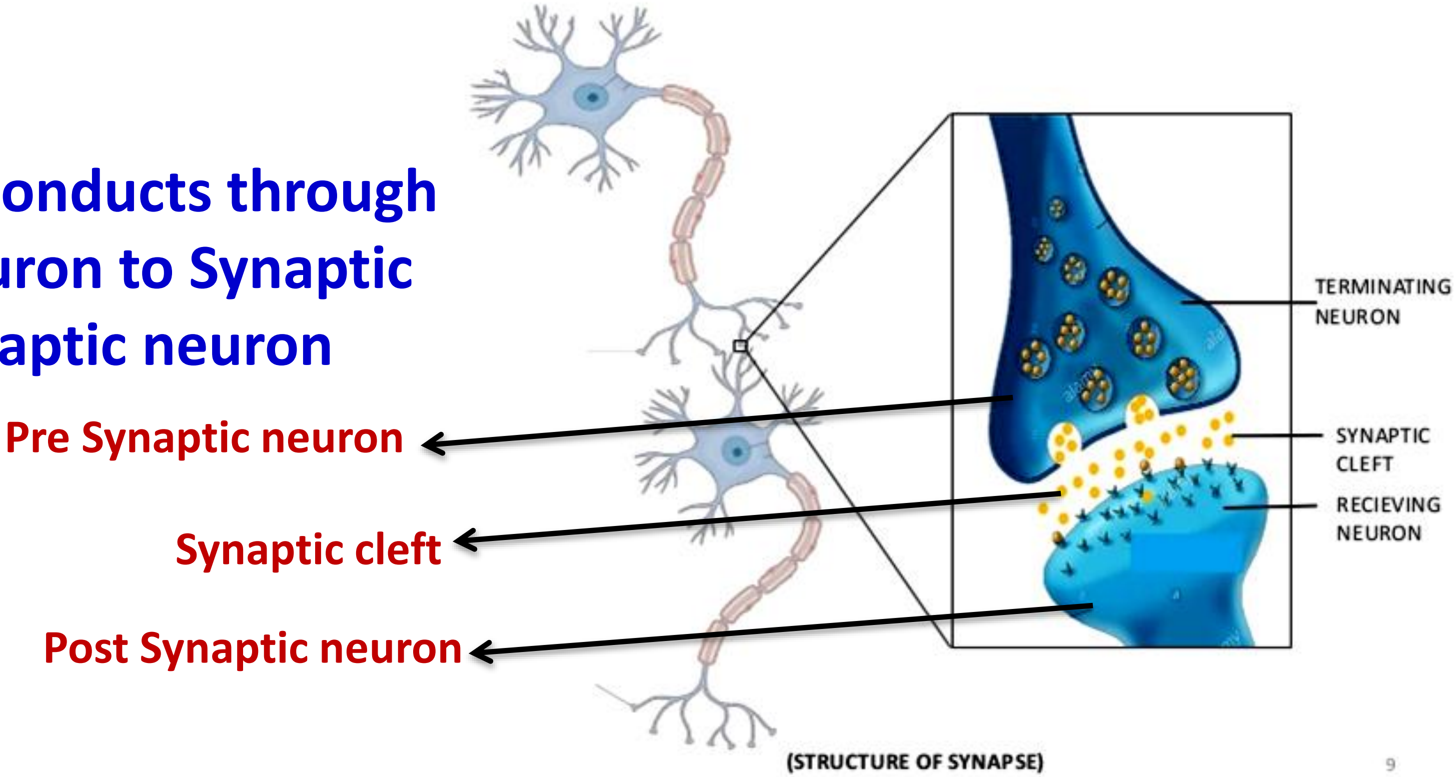
Conduction of Nerve Impulse

"Nerve Impulse is a wave of electrochemical changes which travels along the length of the neuron involving chemical reactions and movement of ions across the cell membrane."

or

"A nerve impulse is the physical and chemical events associated with the transmission of an electric signal along the axon"

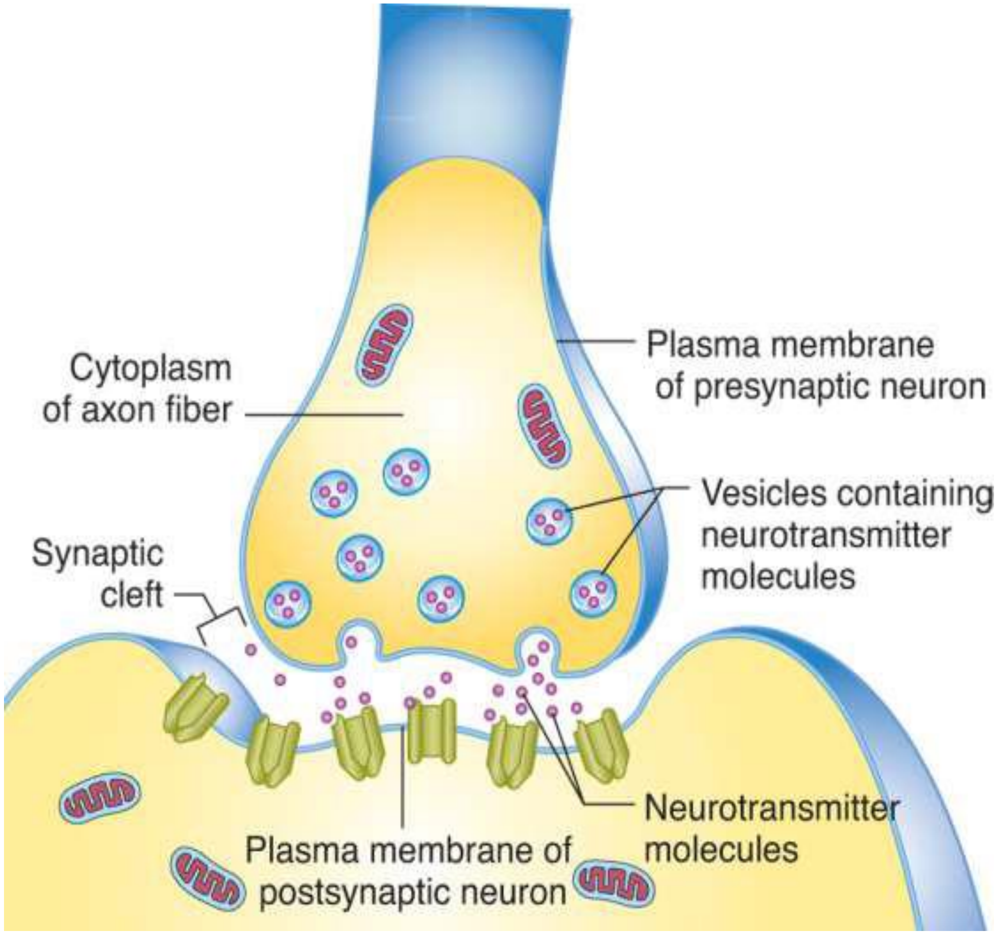
Nerve impulse conducts through Pre synaptic neuron to Synaptic cleft to post synaptic neuron



Synapse

- **Synapse –** the small gap or space between the axon of one neuron and the dendrite of another
- It is junction between neurons which uses neurotransmitters to start the impulse in the second neuron or an effector (muscle or gland)
- The synapse ensures one-way transmission of impulses

Neurotransmitters – the Chemicals in the junction which allow impulses to be started in the second neuron

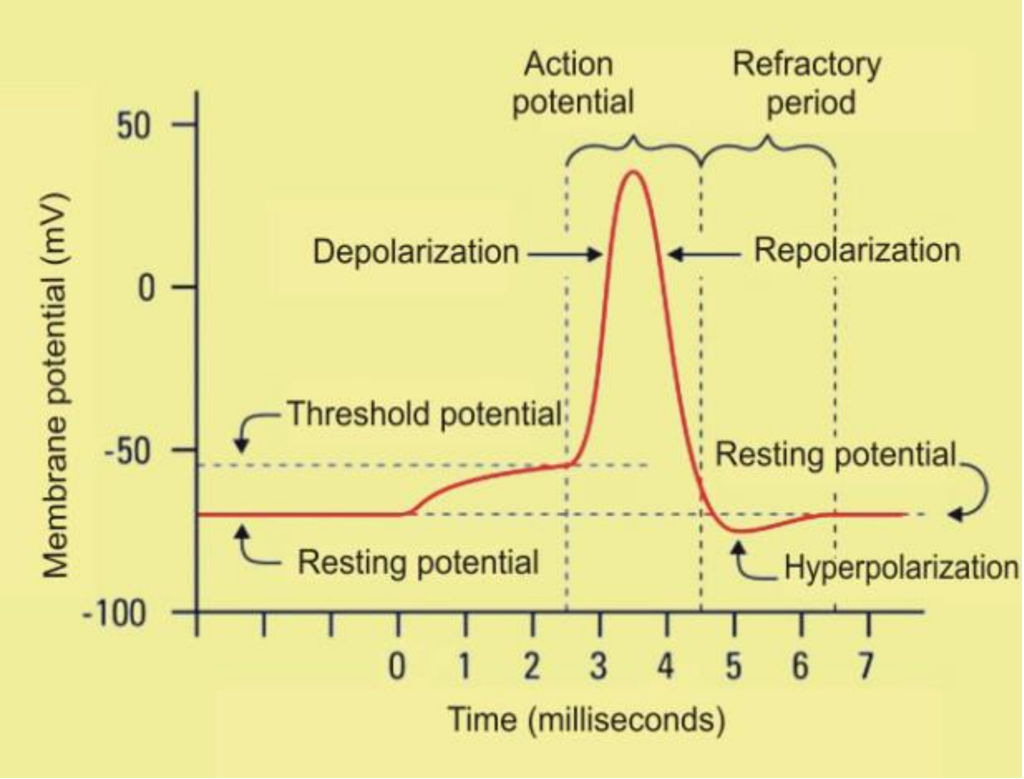


Three states of a neuron

1. **Resting potential –** The state during which no nerve impulse is being conducted, although the neuron is capable of doing so.

2. **Action potential –** The state during which the neuron is actively involved in conducting a nerve impulse.

3. **Recovery/Refractory potential –** The state during which the neuron is unable to conduct a nerve impulse since the neuron must " recover" following the last nerve impulse.



1. Resting Potential

- The state of the neuron when no nerve impulse is being conducted

- During resting potential there is an ion displacement between the inside and the outside of the neuron (i.e. on either side of the neuron cell membrane) as follows:
  - There are **more Na+** ions on the **outside** than on the inside
  - There are **more K+** ions on the **inside** than on the outside
  - There are many large organic anions (-ve charged ions) locked inside since they are too big to pass through the neuron's cell Membrane

- Due to this difference in ion displacement there is a NET CHARGE difference across the cell membrane = MEMBRANE POTENTIAL

- This membrane potential when the neuron is at rest is called the RESTING POTENTIAL= -70mV

- This difference in ion displacement is largely maintained by a protein channel called the Na+/K+ PUMP

- At rest, the inside of a neuron's membrane has a negative charge.
- As the figure shows, a Na+ / K+ pump in the cell membrane pumps sodium out of the cell and potassium into it.
- However, because the cell membrane is a bit leakier to potassium than it is to sodium, more potassium ions leak out of the cell.
- As a result, the inside of the membrane builds up a net negative charge relative to the outside.

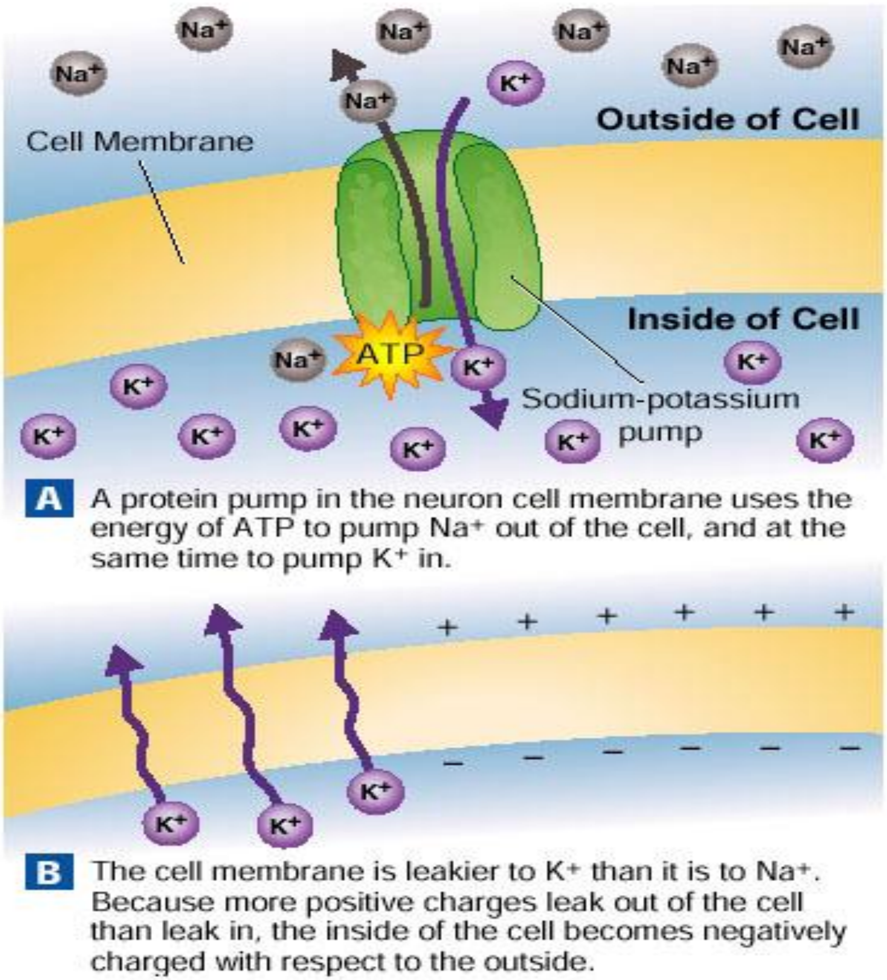


Table 17.1 Ion Concentration Inside and Outside a Typical Neural Membrane

	Concentration (mmol/L)	
	Inside	*Outside*
Na^+ ions	15	145
K^+ ions	150	5
Negative organic ions	156	30

Leakage of K+ ions

Cell membrane of neuron also has many channel proteins called gates. K+ ions are continuously moved out of the neuron through some non-voltage regulated gates. This also makes more positive outside of neuron than inside

Negative organic ions

There are many types of organic compounds in the neuron cytoplasm that also have negative charges. These ions include some amino acids, many proteins and RNA. Presence of these ions in the neuron cytoplasm makes inside of neuron more negative than outside.

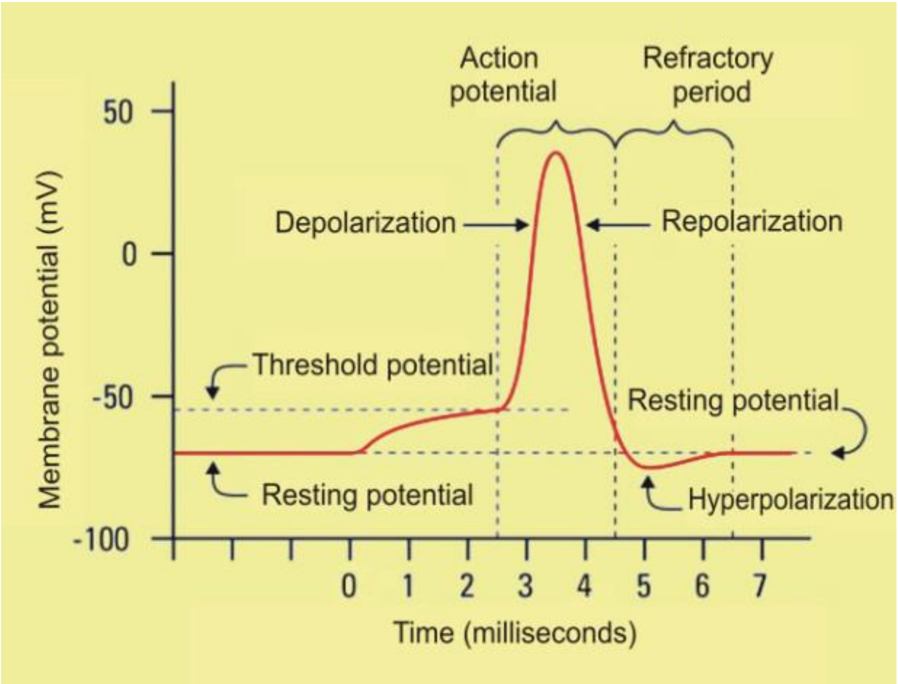
Table 17.1 Ion Concentration Inside and Outside a Typical Neural Membrane

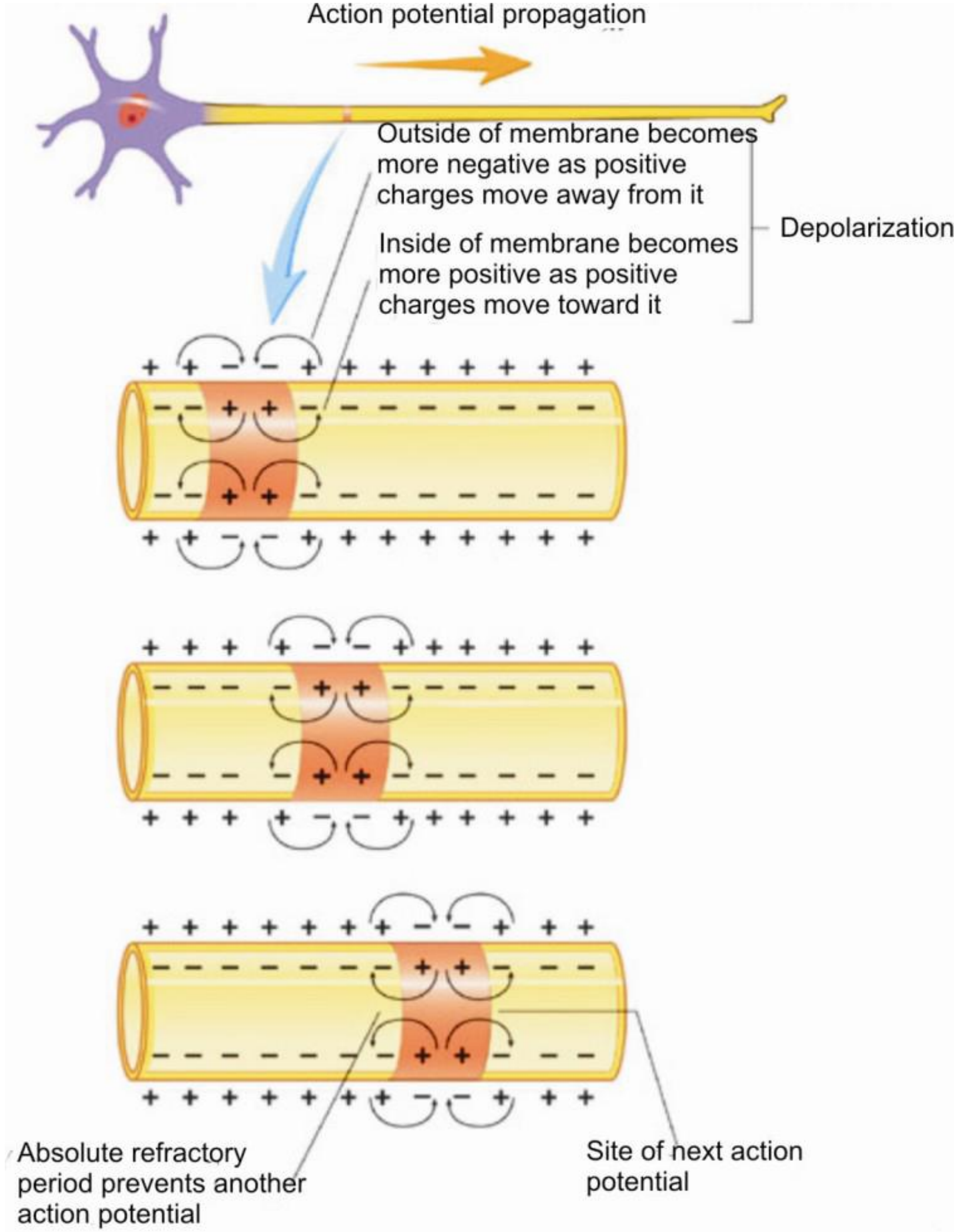
	Concentration (mmol/L)	
	Inside	*Outside*
Na^+ ions	15	145
K^+ ions	150	5
Negative organic ions	156	30

2. Action Potential

- An action potential occurs when a neuron is conducting a nerve impulse
- In order for an action potential to occur, the neuron must receive sufficient stimulation to open enough Na gates to reach the threshold level
- If sufficient Na gates are opened to reach the threshold level, other Na and K gates will be stimulated to open
- This results in a self-propagating wave of action potentials and Na and K gates opening along the entire length of the neuron and an action potental and nerve impulse occur
- Since an action potential will only occur if the membrane threshold level is reached, an action potential can also be described as an all or none response

- **Once an action potential is triggered, the membrane potential goes through a stereotypical sequence of changes which involves the following steps:**
  - ✓ **Depolarization**
  - ✓ **Repolarization**
  - ✓ **Hyper polarization**





MECHANISM OF ACTION POTENTIAL

Depolarization occurs first at the site of stimulation in the nerve fiber. It causes depolarization of the neighboring areas. Like this, depolarization travels throughout the nerve fiber. Depolarization is followed by repolarization.

Depolarization (upswing)

- If a neuron received sufficient stimulation to reach the membrane threshold (-50mV) , successive Na gates along the entire neuron membrane will open

- The opening of the Na gates allows Na ions to move into the neuron

- The movement of Na ions into the neruon causes the membrane potential to change from -70mV to +40mV

- As the membrane potential becomes more positive, Na gates begin to close. At the end of depolarization, the Na gates are all closed

Na+/K+ PUMP

- Powered by ATP this pump actively " pumps" Na+ ions out of the cell and K+ ions into the cell

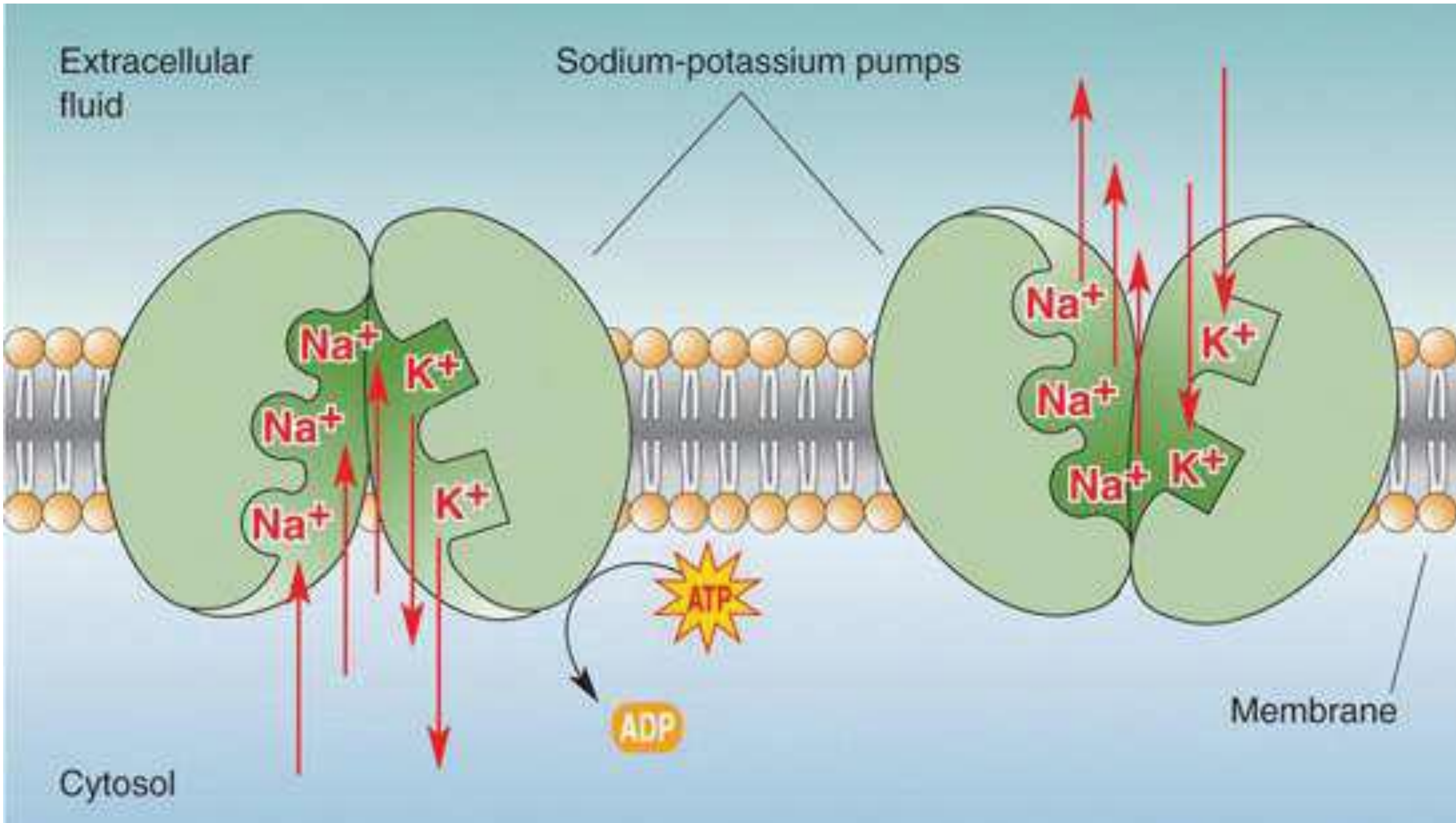
- As a result of this active transport, the cytoplasm of the neuron contains more K+ ions and fewer Na+ ions than the surrounding medium.

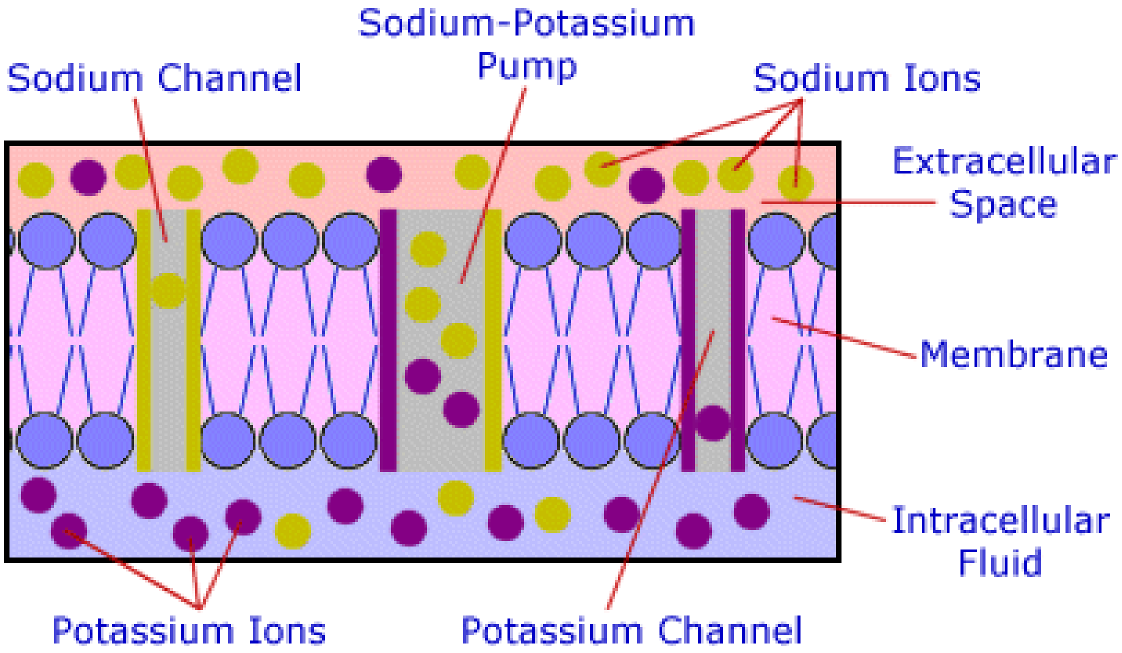
- The cell membrane also has 2 other separate protein channels, one that " leaks" K+ ions and one that " leaks" Na+ ions down their electrochemical gradient (combo of concentration and electrical).

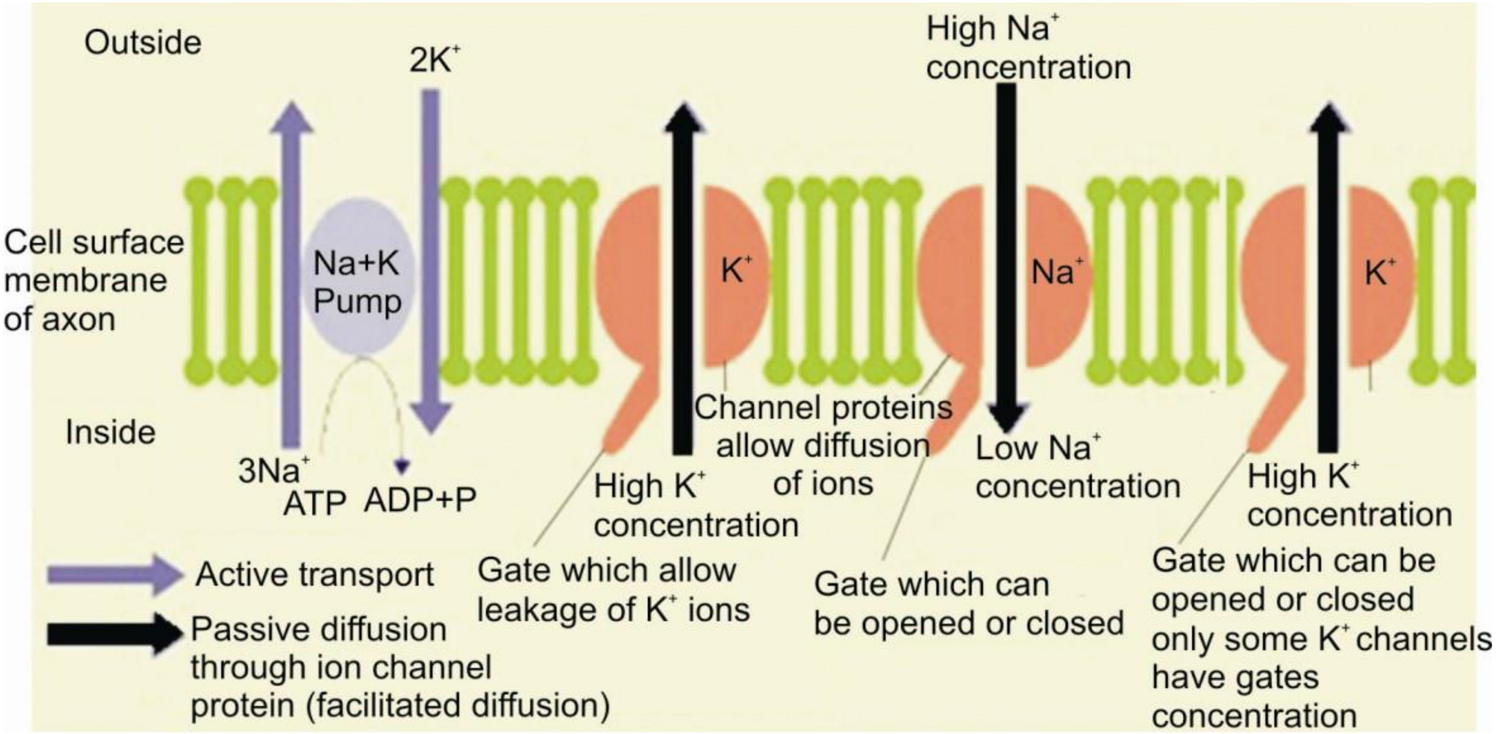
- There are more K+ channels than Na+ channels which means more K+ ions leak out of the cell as opposed to Na+ leaking into the cell

- As a result, K+ ions leak out of the cell to produce a negative charge on the inside of the membrane.

- This charge difference is known as the resting potential of the neuron. The neuron, of course, is not actually "resting" because it must produce a constant supply of ATP to fuel active transport.




Sodium-Potassium Pump
Sodium Channel
Sodium Ions
Extracellular Space
Membrane
Intracellular Fluid
Potassium Ions
Potassium Channel


Outside
2K+
High Na+ concentration
Cell surface membrane of axon
Na+K Pump
K+
Na+
K+
Inside
Channel proteins allow diffusion of ions
Low Na+ concentration
3Na+
ATP ADP+P
High K+ concentration
High K+ concentration
Active transport
Passive diffusion through ion channel protein (facilitated diffusion)
Gate which allow leakage of K+ ions
Gate which can be opened or closed
Gate which can be opened or closed only some K+ channels have gates concentration

Repolarization (Down-swing)

- At the end of the depolarization phase, K gates begin to open, allowing K to leave the neuron

- These K gates are activated at the +ve membrane potential value of about +40mV

- The movement of K ions out of the neuron produces a change in membrane potential such that the potential becomes more –ve

- Following repolarization, the K gates close slowly

- During the conduction of a nerve impulse, each successive section of a neuron's membrane will undergo an action potential consisting of depolarization followed by repolarization

- **Thus the nerve impulse is the movement of the action potential along the neuron cell membrane**

Recovery/Refractory Potential

- Immediately following an action potential, a neuron is unable to conduct a nerve impulse until it has recovered because its Na gates won’t open

- A neuron which is undergoing recovery is said to be refractory since it cannot conduct a nerve Impulse

- During the recovery phase the following events are occurring:
  - The K gates are closing
  - The Na/K pump is returning the Na ions to the outside and K ions to the inside of the neuron
  - The membrane potential is returning to its resting value of -70mV

- Once the recovery phase is complete, the neuron is no longer in its refractory period and is ready to conduct another nerve impulse

Hyperpolarization

- The continuous outflow of K+ ions makes the membrane potential more negative i.e. hyperpolarize it.

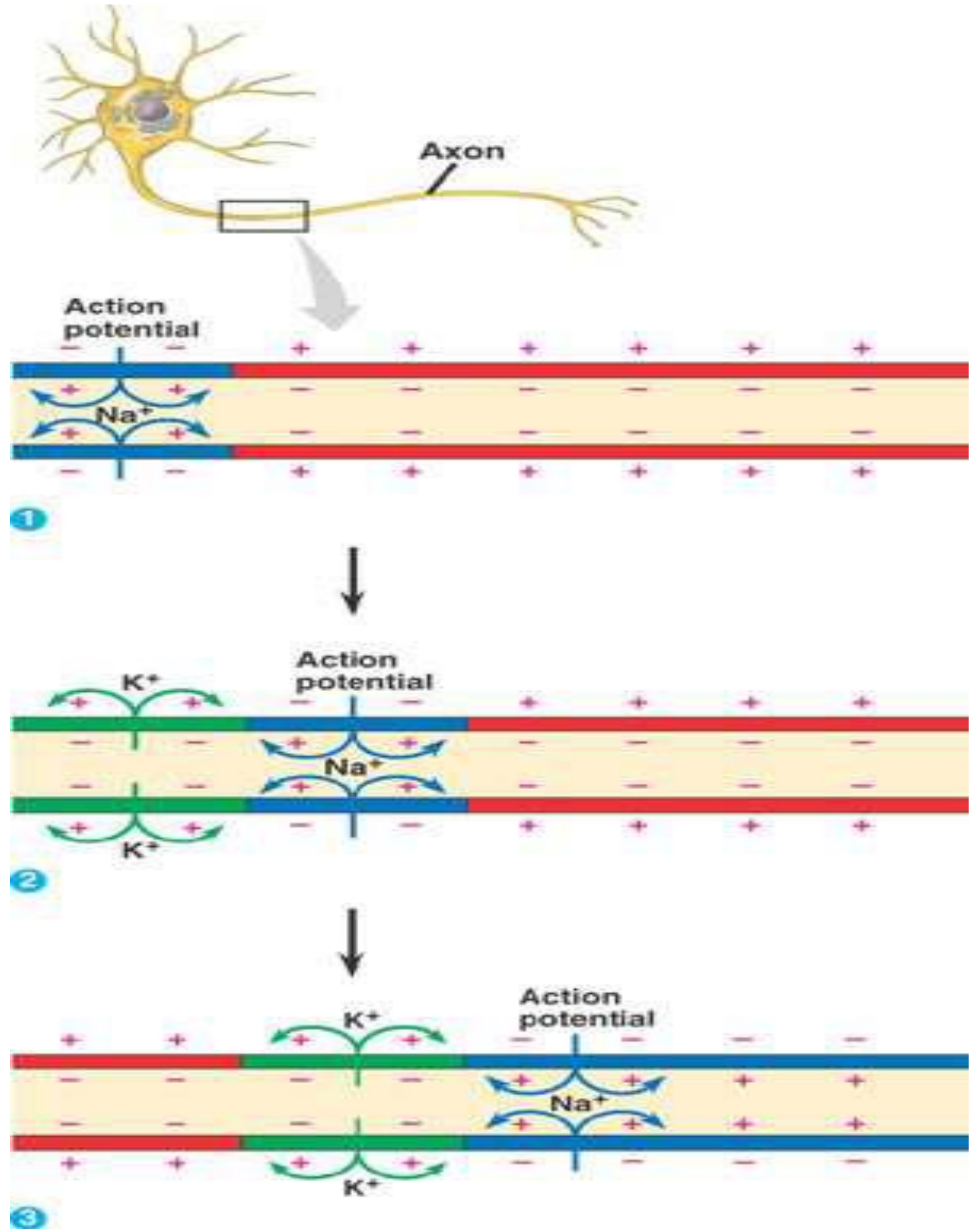
- During this phase, also called as **undershoot,** both the activation and inactivation gates of Sodium channel are closed.

- If a second depolarizing stimulus arrives during this phase, it will be unable to trigger an action potential.

- This period when a neuron is insensitive to depolarization is called "**refractory period.**"

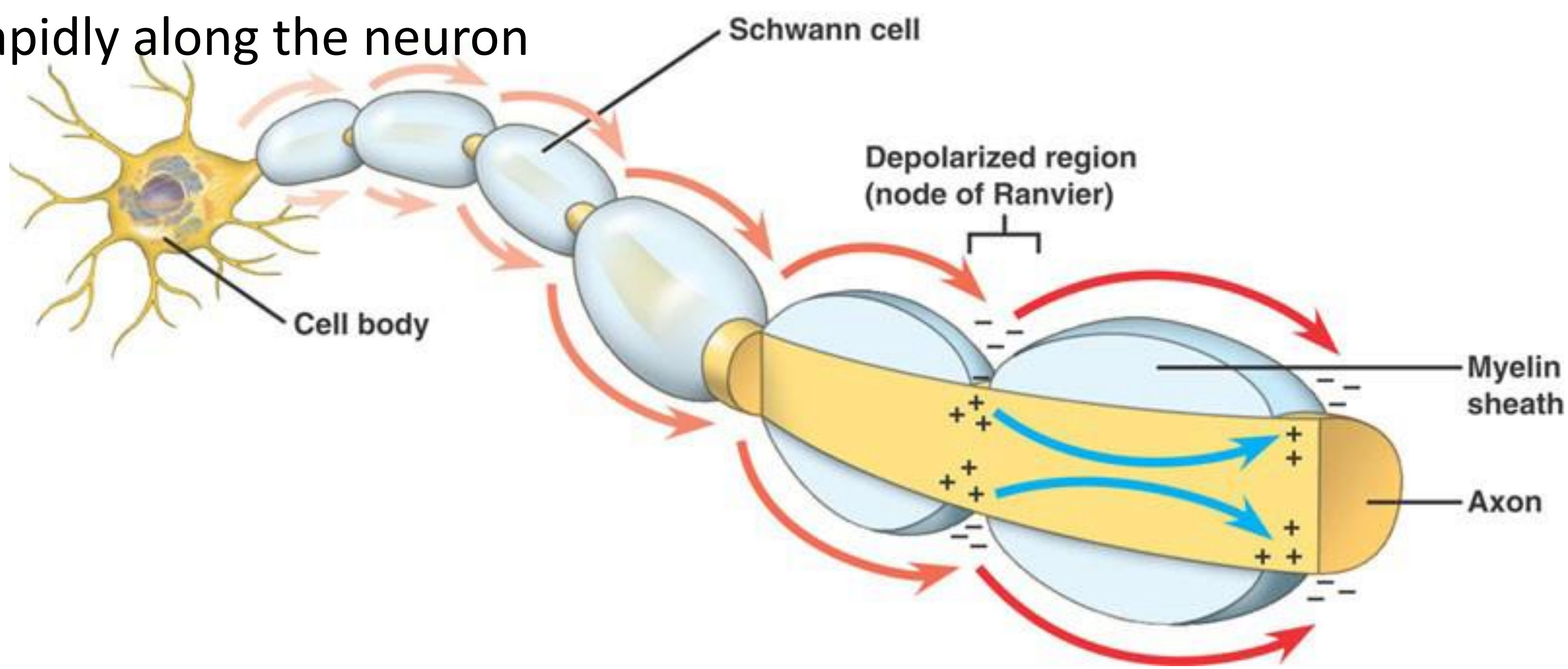
Continuous Conduction

- Some neurons have no myelin coating and are described as nonmyelinated
- In nonmyelinated neurons, an action potential must pass through each point along the neuron cell membrane which makes the conduction of the nerve impulse relatively slow

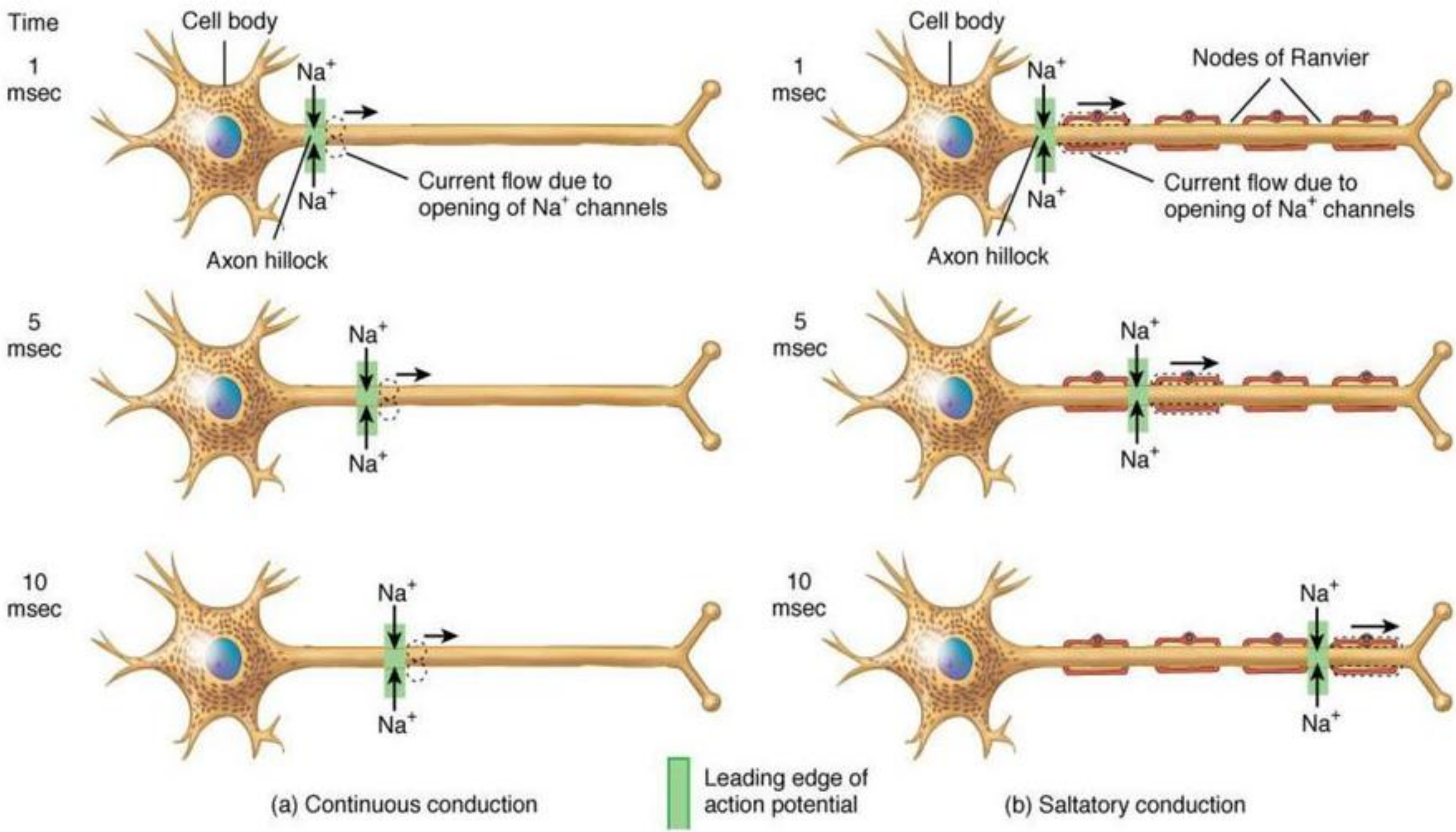


Salatory Conduction

- In myelinated neurons, an action potential does not occur along sections of the neuron which are wrapped in myelin
- Ions are unable to cross the nerve cell membrane in these sections
- The gaps in myelin are called Nodes of Ranvier. These gaps are the site of an action potential
- Thus, in myelinated neurons, the action potential jumps from one node of Ranvier to the next in a process called **salatory conduction**
- Salatory conduction is very rapid, allowing the nerve impulse to travel very rapidly along the neuron



Conduction of impulse in
Myelinated & Non- Myelinated neurons



Synapse

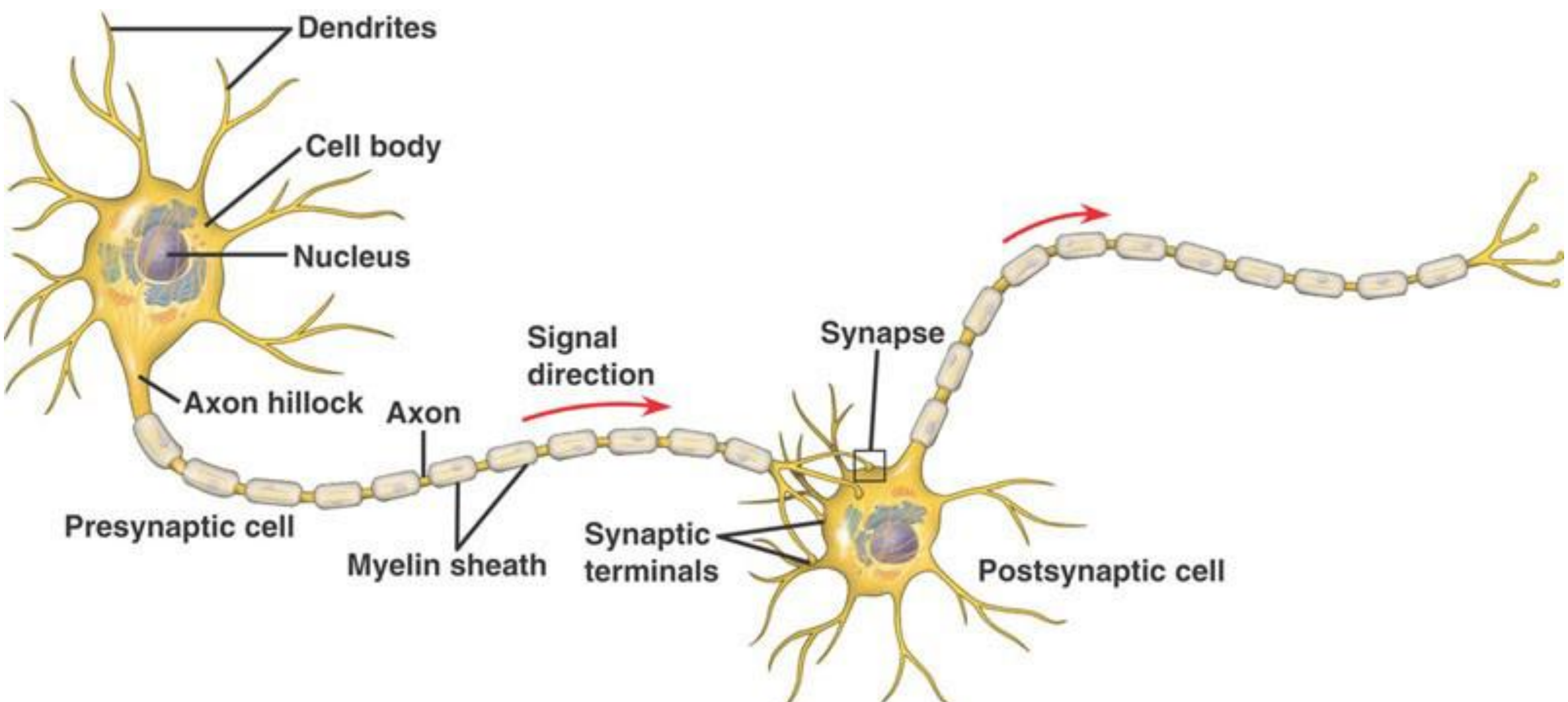
- Synapse is a unique junction that controls communication between neurons.
- The junction between axon terminal of one neuron and the dendrite of another neuron, where information from one neuron is transmitted or relayed (handed over) to another neuron is called **synapse.**
- Consecutive neurons are so arranged that the axon endings of one neuron are connected to the dendrites or cell body of the other neuron.
- There is no cytoplasmic connections in between but there are microscopic gaps at these contact points which are called as **Synapse.**
- Chemical messengers called **Neurotransmitters** (*Acetylcholine, Dopamine, Serotonin) help in* communication between the neurons.

- Synapse is a junction that mediates information transfer from one neuron:

  -To another neuron (neuro-synapses or just synapse)
  -To an effector cell
    - Neuromuscular synapse if muscle involved
    - Neuroglandular synapse if gland involve

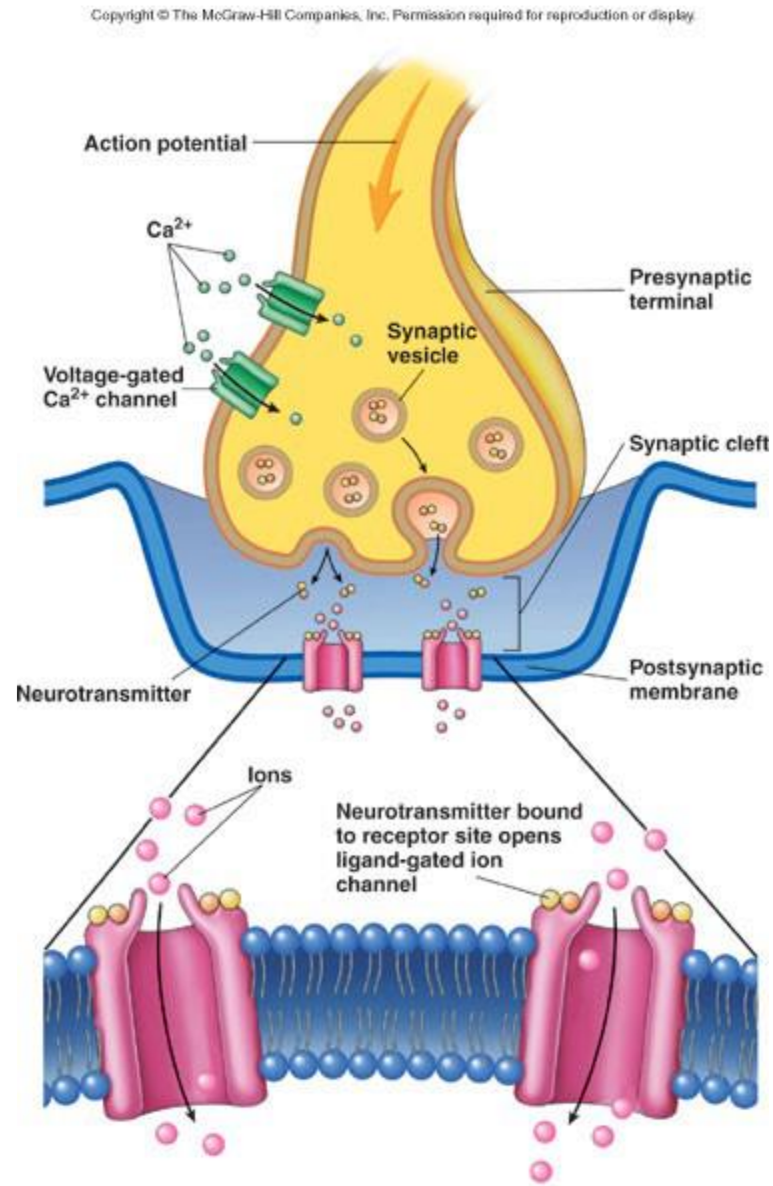
- Presynaptic neuron – conducts impulses toward the synapse

- Postsynaptic neuron – transmits impulses away from the synapse



Structure of a Synapse

- The neurons are not in direct contact at a synapse. There is a gap, called a synaptic cleft between them.
- A neuron which carries an impulse toward a synapse is called presynaptic neuron (transmitting neuron).
- A neuron which receives the impulse after it crosses the synapse is a post synaptic neuron.
- A single neuron may form synapses with many incoming fibres of different neurons.



Mechanism of synaptic transmission

1. Arrival of action potential on presynaptic neuron opens volage-gated Ca++ channels.

2. Ca2+ influx into presynaptic terminal.

3. Ca2+ acts as intracellular messenger stimulating synaptic vesicles to fuse with membrane and release Neurotransmitter (NT) via exocytosis.

4. NT diffuses across synaptic cleft and binds to receptor on postsynaptic membrane.

5. Receptor changes shape of ion channel opening it and changing membrane potential.

6. Opening of all types of ion channels causes a localized depolarization of the membrane and produces an **excitatory postsynaptic potential (EPSP).**

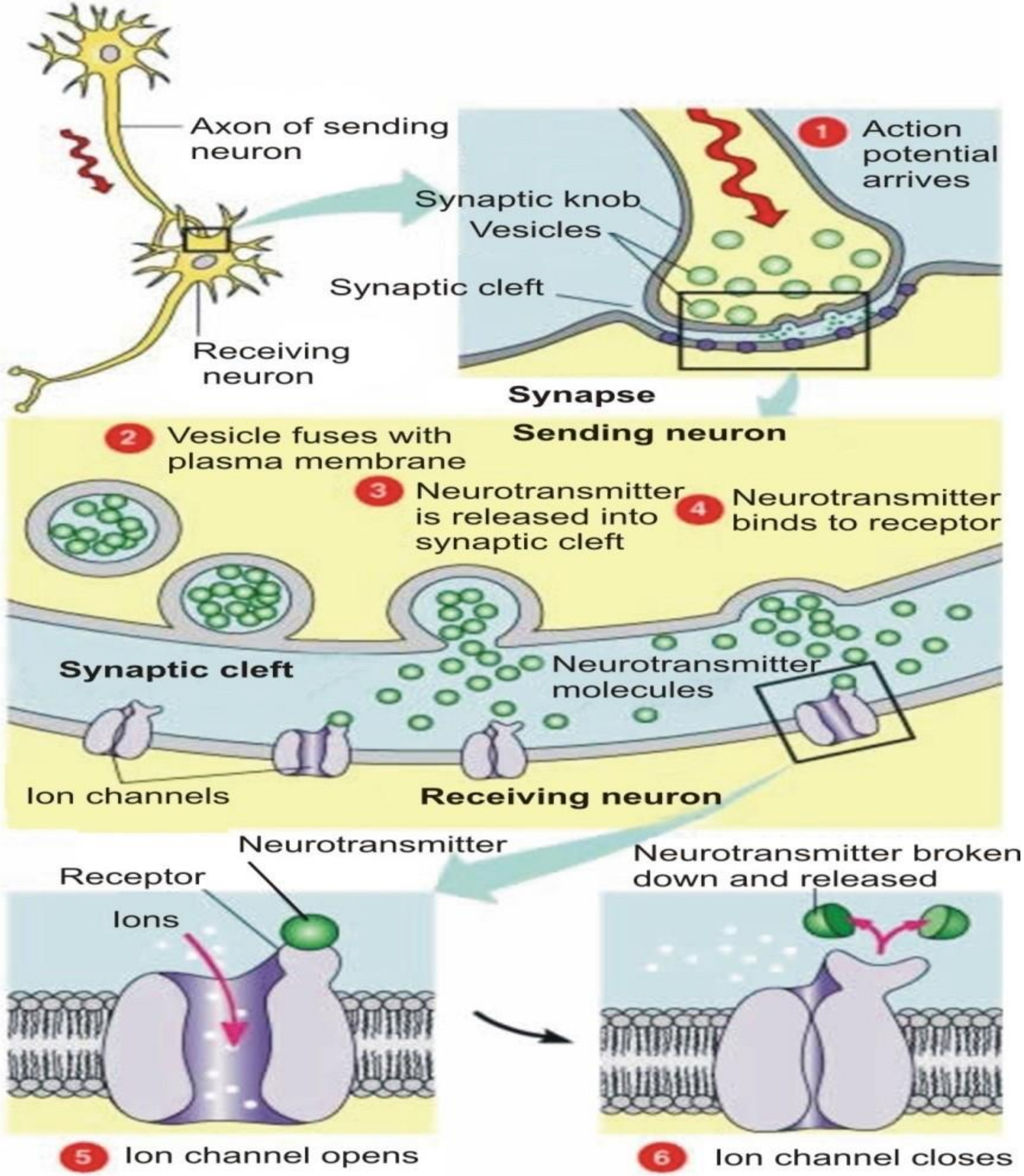
7. Selective opening of only the smaller ions like K+ and Chloride ions, causing hyperpolarization of the membrane and that constitutes the inhibitory postsynaptic potential (IPSP).

8. If the EPSP exceeds threshold value, it initiates the propagated action potential in the postsynaptic neuron or muscle action potential (MAP) in most skeletal and cardiac muscle.

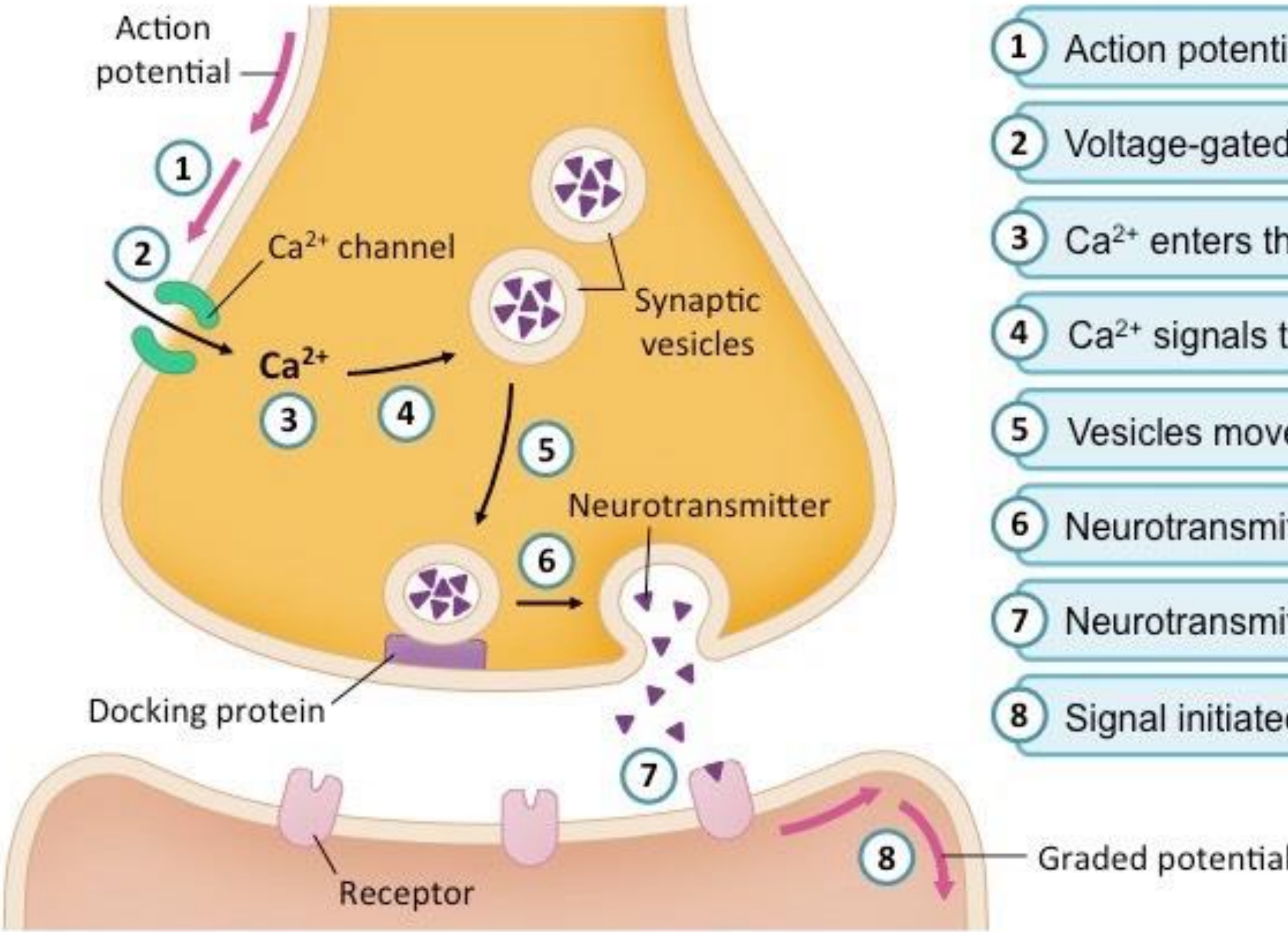
9. During the development of the EPSP, simultaneously IPSP may be developed at the same site by incoming action potential from r othesources. The propagation of nerve impulse by EPSP is dependent upon the intensity of the postsynaptic potential.

10. NT is quickly destroyed by enzymes or taken back up by *astrocytes* or presynaptic membrane.

Mechanism of synaptic transmission



Mechanism of synaptic transmission



1. Action potential arrives at axon terminal
2. Voltage-gated Ca^{2+} channels open
3. Ca^{2+} enters the presynaptic neuron
4. Ca^{2+} signals to neurotransmitter vesicles
5. Vesicles move to the membrane and dock
6. Neurotransmitters released via exocytosis
7. Neurotransmitters bind to receptors
8. Signal initiated in postsynaptic cell

Velocities of Nerve Impulse

- Velocities of nerve impulse in the axon membrane and in the synaptic cleft are variable.
- In human Non myelinated fibres, nerve impulses travel at 1 to 3 metres per second. Myelinated fibres conduct at speeds of up to 120 meters per second.
- The velocity of nerve impulse is faster in myelinated neuron fibre due to saltatory conduction. Another reason that myelinated fibres conduct faster impulse is that myelin sheath acts as an insulating sheath and prevents loss of energy, so myelinated neuron fibres require less energy.
- Velocity of nerve impulse also depends upon diameter of neuron fibres. Thick neuron fibres conduct faster impulse than thin fibres because resistance to electrical current flow is inversely proportional to the cross sectional area of the conductor (such as wire or a neuron fibre), so with the increase in thickness of neuron fibres there is decrease in resistance of fibre to nerve impulse.
- The short journey across the synapse takes about a millisecond, longer than a electrical signal takes to travel the same distance. This time is therefore called **synaptic delay.**

Neurotransmitters

- **“Neurotransmitters are chemical messengers released into the synaptic cleft by neurons”**

  or

  “Neurotransmitters are endogenous chemicals that transmit signals from a neuron to a target cell across a synapse”.

- They maintain signals in the nervous system by binding to receptors on post-synaptic neurons and triggering electrical impulses.

- They also activate responses by effector organs (such as contraction in muscles or hormone release from endocrine glands)

- Neurotransmitters are packaged into synaptic vesicles clustered beneath the membrane on the presynaptic side of a synapse, and are released into the synaptic cleft, where they bind to receptors in the membrane on the postsynaptic side of the synapse.

- Neurotransmitters are an essential part of our everyday functioning. While it is not known exactly how many neurotransmitters exist, scientists have identified more than 100 of these chemical messengers.

- Release of neurotransmitters usually follows arrival of an action potential at the synapse.

Types of neurotransmitter

(A) According to the nature (chemistry) of neurotransmitter

- **Amino acids:** Glutamic acid, γ-Aminobutyric acid (GABA), Aspartic acid, D-alanine, Glycine
- **Peptides:** Substance P
- **Monoamines and other biogenic amines:** Dopamine, Norepinephrine (noradrenaline), Epinephrine (adrenaline), Histamine, Serotonin (SE, 5-HT)
- **Fatty acid derivatives:** Prostaglandins
- **Others:** Acetylcholine (ACh), Adenosine

(B) Based on the activity on postsynaptic neuron

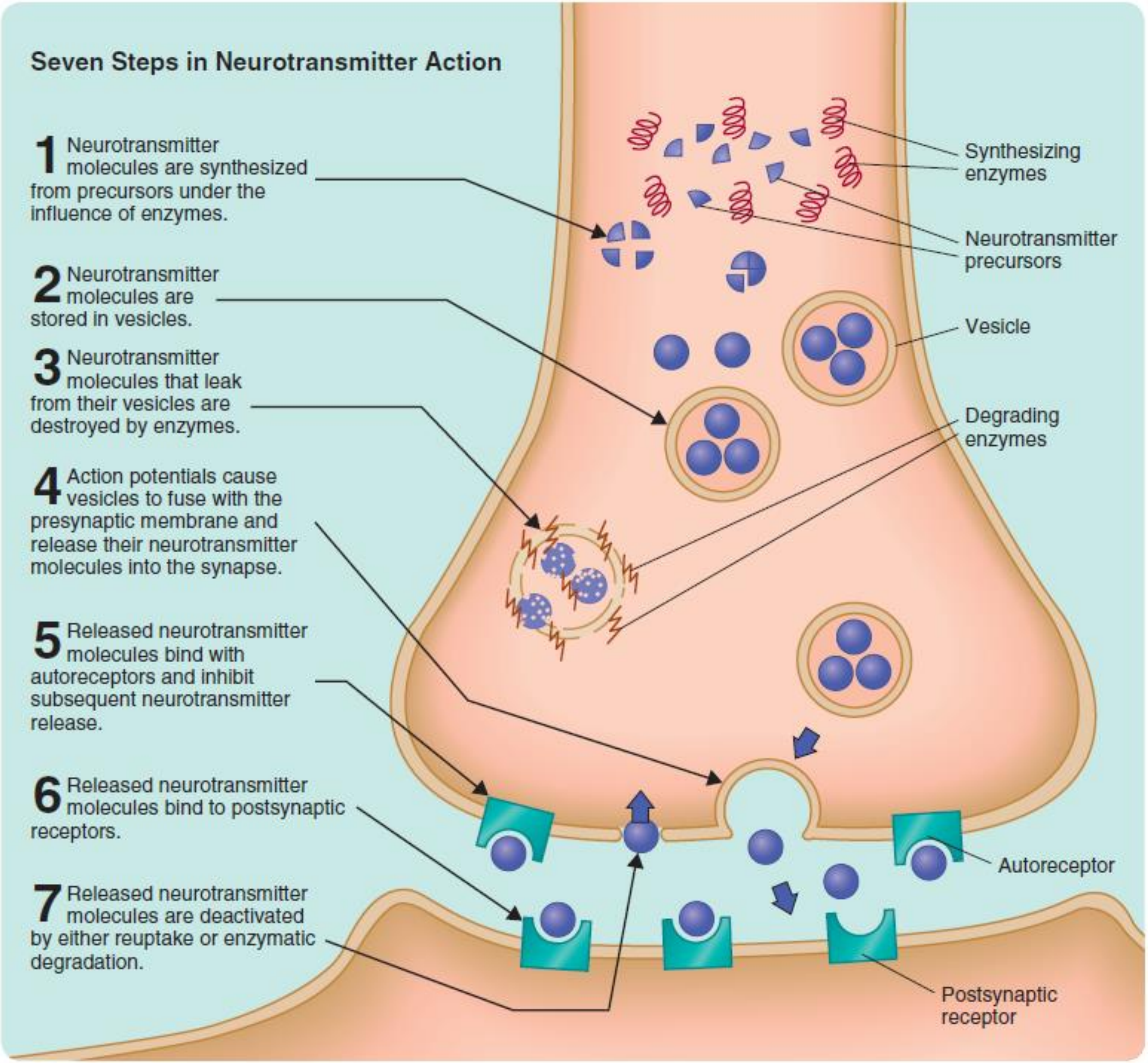
- **EXCITATORY (causes depolarization):**
  Examples: Acetylcholine, Aspartate, Dopamine, Histamine, Serotonin Norepinephrine, Epinephrine, Glutamate

- **INHIBITORY (causes hyperpolarization):**
  Examples: GABA, Glycine

Neurotransmitters may be either excitatory or inhibitory in their effect (some may be both depending on the receptor they bind to)

- Excitatory neurotransmitters trigger depolarisation, increasing the likelihood of a response

- Inhibitory neurotransmitters trigger hyperpolarisation, decreasing the likelihood of a response


Seven Steps in Neurotransmitter Action
1 Neurotransmitter molecules are synthesized from precursors under the influence of enzymes.
2 Neurotransmitter molecules are stored in vesicles.
3 Neurotransmitter molecules that leak from their vesicles are destroyed by enzymes.
4 Action potentials cause vesicles to fuse with the presynaptic membrane and release their neurotransmitter molecules into the synapse.
5 Released neurotransmitter molecules bind with autoreceptors and inhibit subsequent neurotransmitter release.
6 Released neurotransmitter molecules bind to postsynaptic receptors.
7 Released neurotransmitter molecules are deactivated by either reuptake or enzymatic degradation.
Synthesizing enzymes
Neurotransmitter precursors
Vesicle
Degrading enzymes
Autoreceptor
Postsynaptic receptor

Examples & Effects of Neurotransmitters

Adrenaline

- Adrenaline is primarily a hormone released by the adrenal gland, but some neurons may secrete it as a neurotransmitter
- It increases heart rate and blood flow, leading to a physical boost and heightened awareness
- It is produced during stressful or exciting situations

Noradrenaline

- In contrast to adrenaline, noradrenaline is predominantly a neurotransmitter that is occasionally released as a hormone
- It contracts blood vessels and increases blood flow, improving attention and the speed at which responsive actions occur

Serotonin

- Contributes to feelings of well-being and happiness
- Is affected by exercise and light exposure, and plays a role in the sleep cycle and digestive system regulation

Dopamine

- It is primarily responsible for feelings of pleasure, but is also involved in movement and motivation
- People tend to repeat behaviours that lead to dopamine release, leading to addictions
- Abnormal dopamine secretion is common in specific movement disorders, like Parkinson's disease

GABA

- Inhibits neuron firing in the CNS – high levels improve focus whereas low levels cause anxiety
- Also contributes to motor control and vision

Acetylcholine

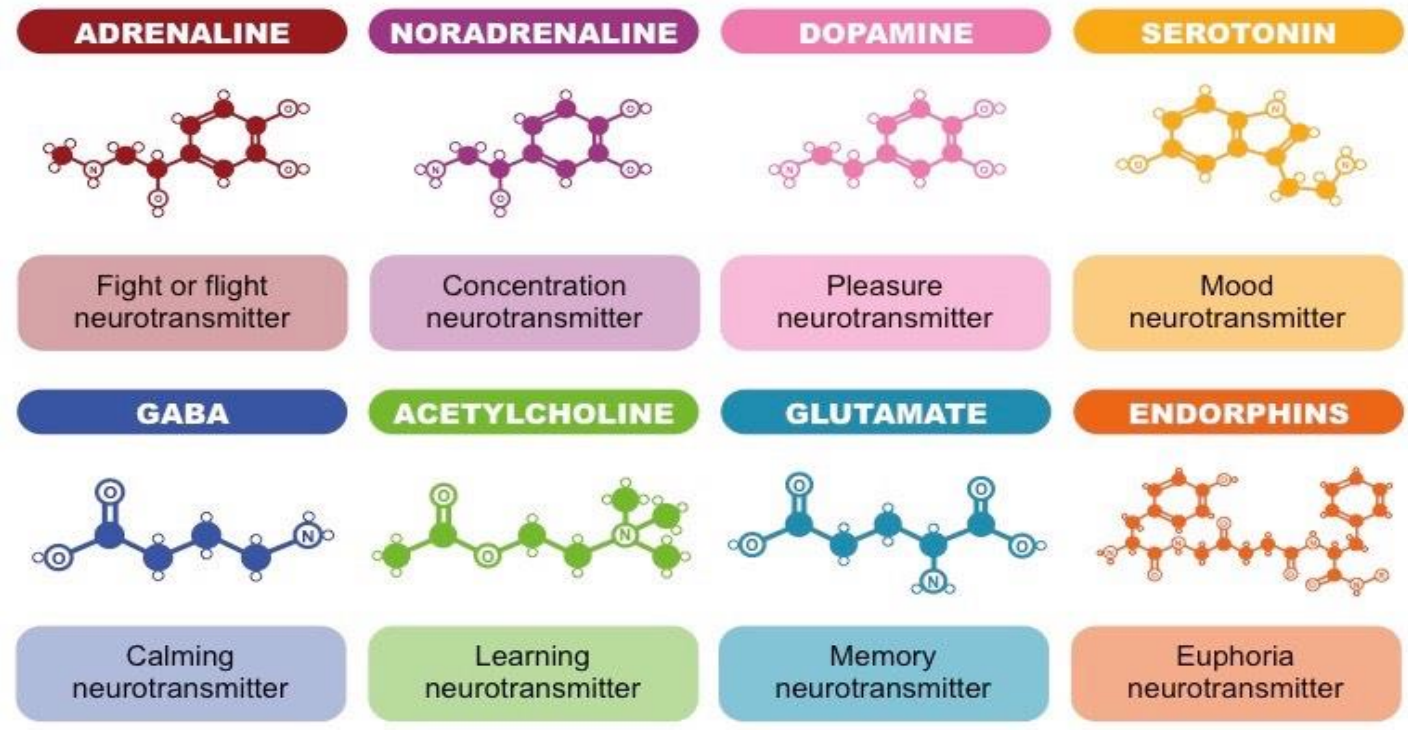
- Involved in thought, learning and memory within the brain
- Activates muscle contraction in the body and is also associated with attention and awakening

Glutamate

- Most common brain neurotransmitter
- Regulates development and creation of new nerve pathways and hence is involved in learning and memory

Endorphins

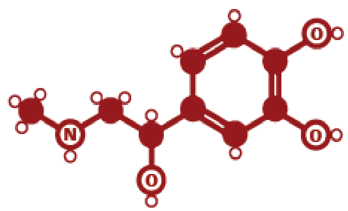
- Release is associated with feelings of euphoria and a reduction in pain (body's natural 'pain killers')
- Released during exercise, excitement and sex



THE STRUCTURES OF NEUROTRANSMITTERS

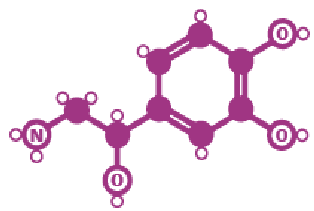
STRUCTURE KEY: Carbon atom · Hydrogen atom · (O) Oxygen atom · (N) Nitrogen atom · (R) Rest of molecule

ADRENALINE
Fight or flight neurotransmitter



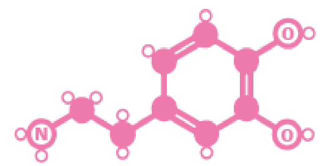
Produced in stressful or exciting situations. Increases heart rate & blood flow, leading to a physical boost & heightened awareness.

NORADRENALINE
Concentration neurotransmitter



Affects attention & responding actions in the brain, & involved in fight or flight response. Contracts blood vessels, increasing blood flow.

DOPAMINE
Pleasure neurotransmitter

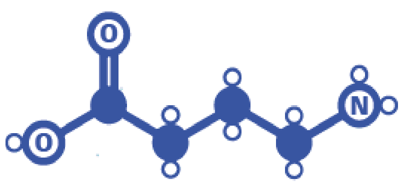


Feelings of pleasure, and also addiction, movement, and motivation. People repeat behaviours that lead to dopamine release.

SEROTONIN
Mood neurotransmitter

Contributes to well-being & happiness; helps sleep cycle & digestive system regulation. Affected by exercise & light exposure.

GABA
Calming neurotransmitter

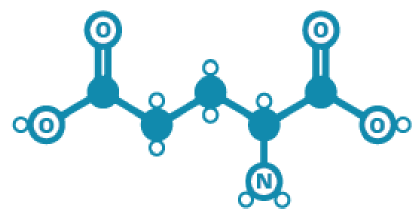


Calms firing nerves in CNS. High levels improve focus; low levels cause anxiety. Also contributes to motor control & vision.

ACETYLCHOLINE
Learning neurotransmitter

Involved in thought, learning, & memory. Activates muscle action in the body. Also associated with attention and awakening.

GLUTAMATE
Memory neurotransmitter

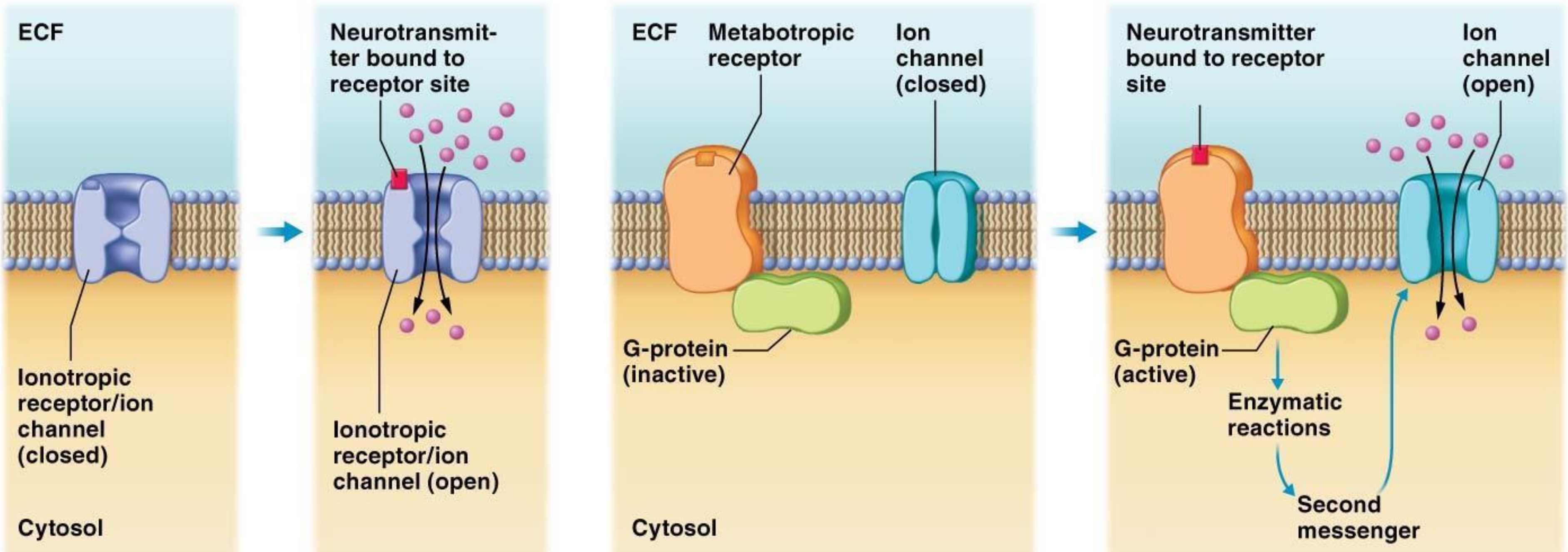


Most common brain neurotransmitter. Involved in learning & memory, regulates development & creation of nerve contacts.

ENDORPHINS
Euphoria neurotransmitters

Released during exercise, excitement, & sex, producing well-being & euphoria, reducing pain. Biologically active section shown.

Neurotransmitter Receptors



(a) Ionotropic receptor

(b) Metabotropic receptor

Effects of Drugs on the Nervous System

Alcohol

Central nervous system depressant – cell membranes are highly permeable to alcohol so once in the bloodstream it can diffuse into almost all body tissues. It is absorbed in the stomach so it gets into the blood stream quickly and slows down function of the nervous system

Nicotine

Small doses of nicotine have a stimulating action on the central nervous system – it is highly addictive nicotine's effects on the brain cause an increased release of neurotransmitters associated with pleasure. The brain quickly adjusts to repeated nicotine consumption by decreasing the amount of neurotransmitters released. The effect of this increased tolerance is that the smoker must continue to use nicotine in order to avoid the feelings of discomfort associated with withdrawal from the drug. Irritability and anxiety often ensue during nicotine withdrawal.

Caffeine

Acts as a central nervous system stimulant - caffeine suppresses melatonin for up to 10 hours and also promotes adrenalin. Melatonin is strongly associated with quality sleep, while adrenalin is the neurotransmitter associated with alertness.

Marijuana

THC, the main active ingredient in marijuana, binds to membranes of nerve cells in the central nervous system that have protein receptors. After binding to nerve cells, THC initiates a chemical reaction that produces the various effects of marijuana use. One of the effects is suppression of memory and learning centers (called the hippocampus) in the brain.

END