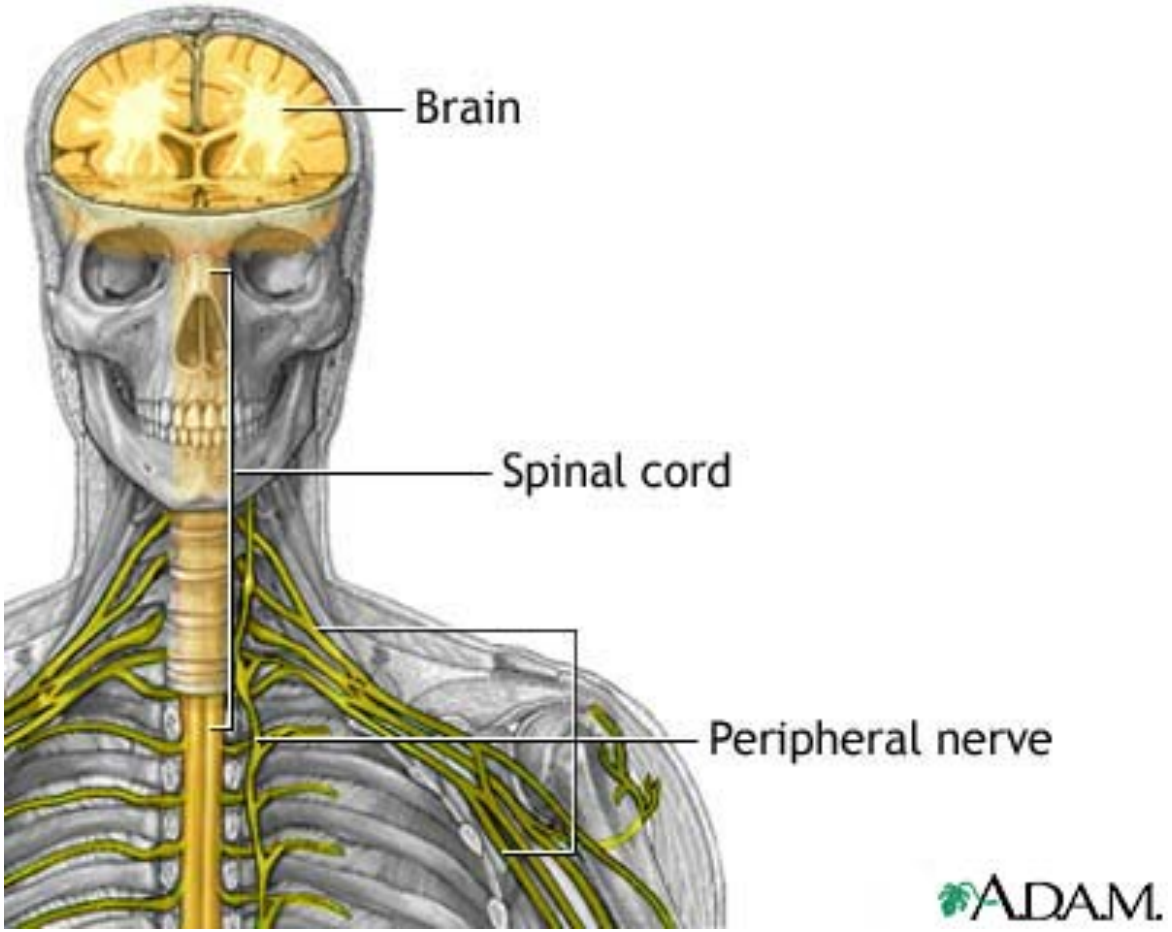
The Nervous System



I. Functions of the Nervous System

A. Nervous system is our processing system, and the system that keeps us in contact with the outside world. Intro Animation

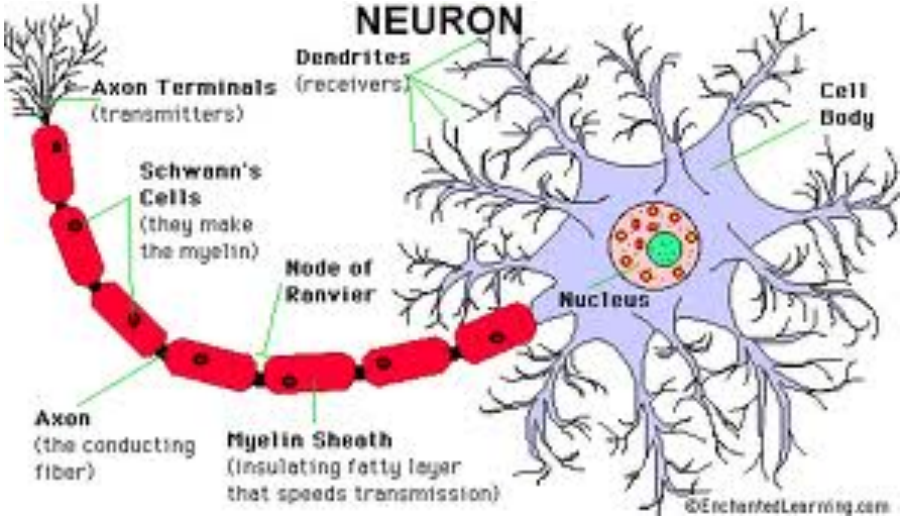
B. Roles of the nervous system:

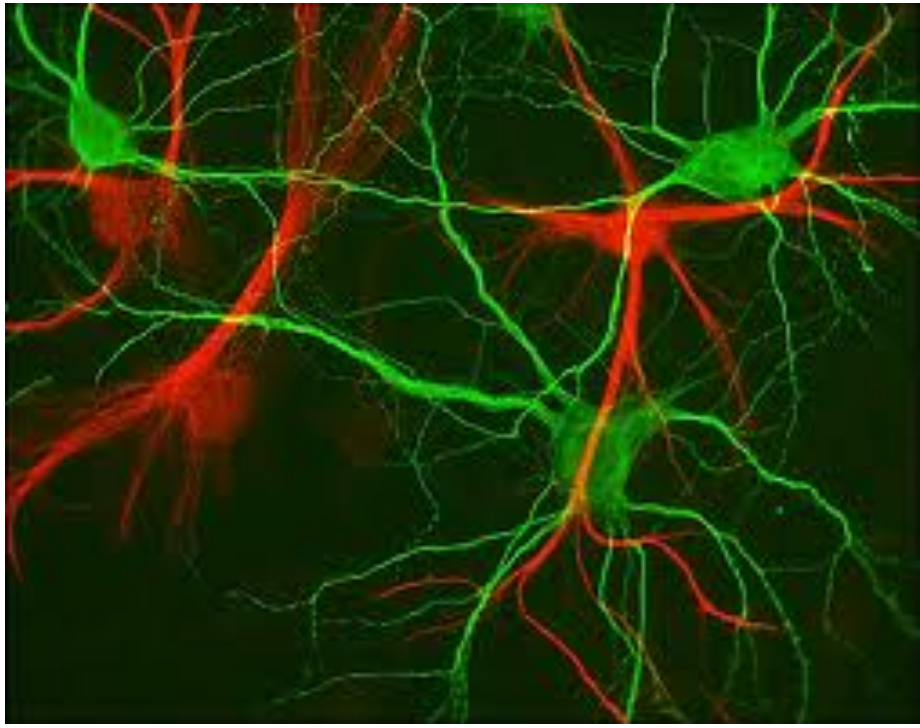
1. **Coordination of movement**
2. **Response to environmental stimuli**
3. **Intelligence**
4. **Self-awareness (consciousness)**
5. **Thoughts**
6. **Emotions**

II. Composition of the Nervous System

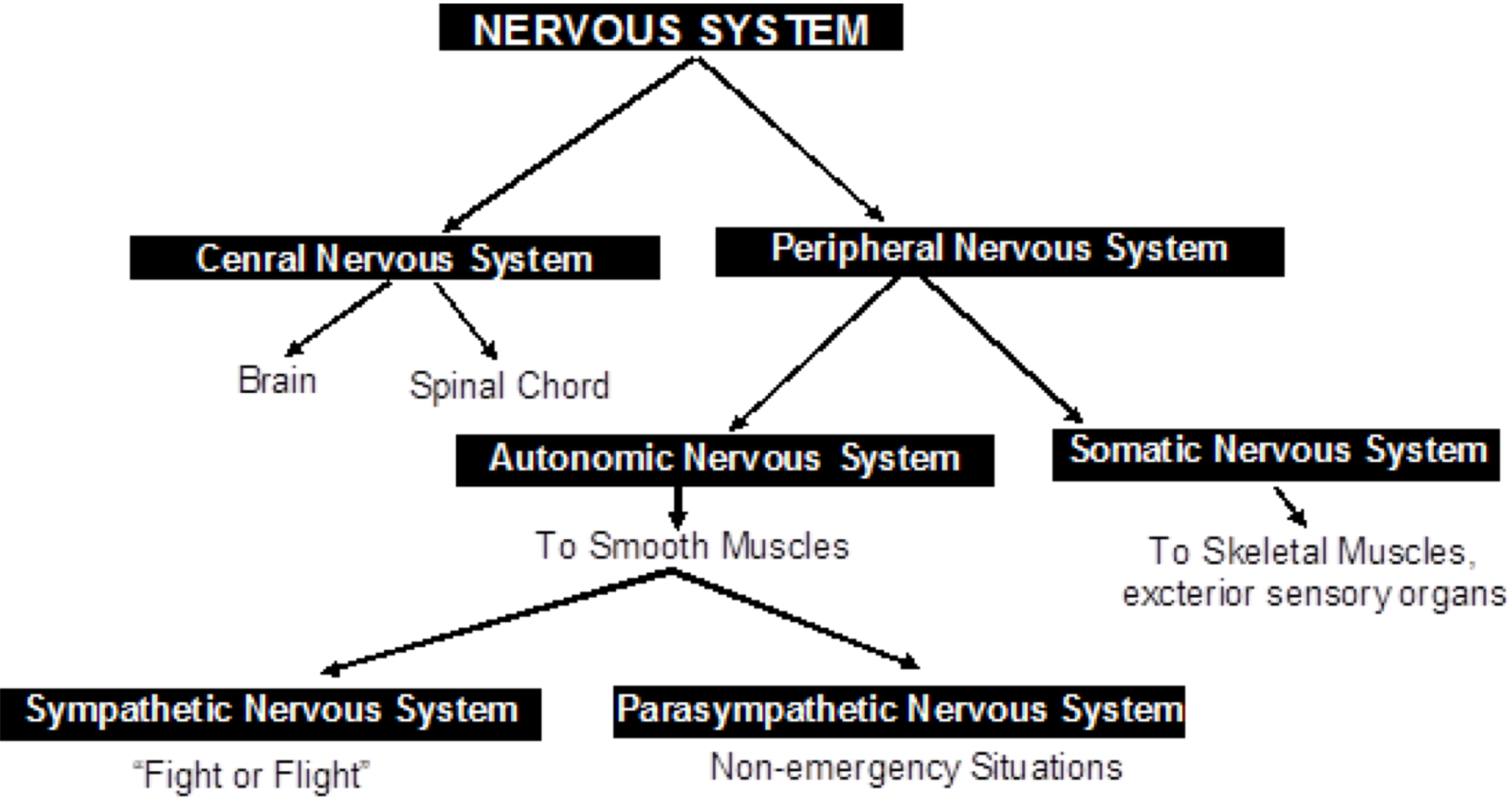
A. Made up of nerve cells called NEURONS

which are specialized to carry nerve impulses





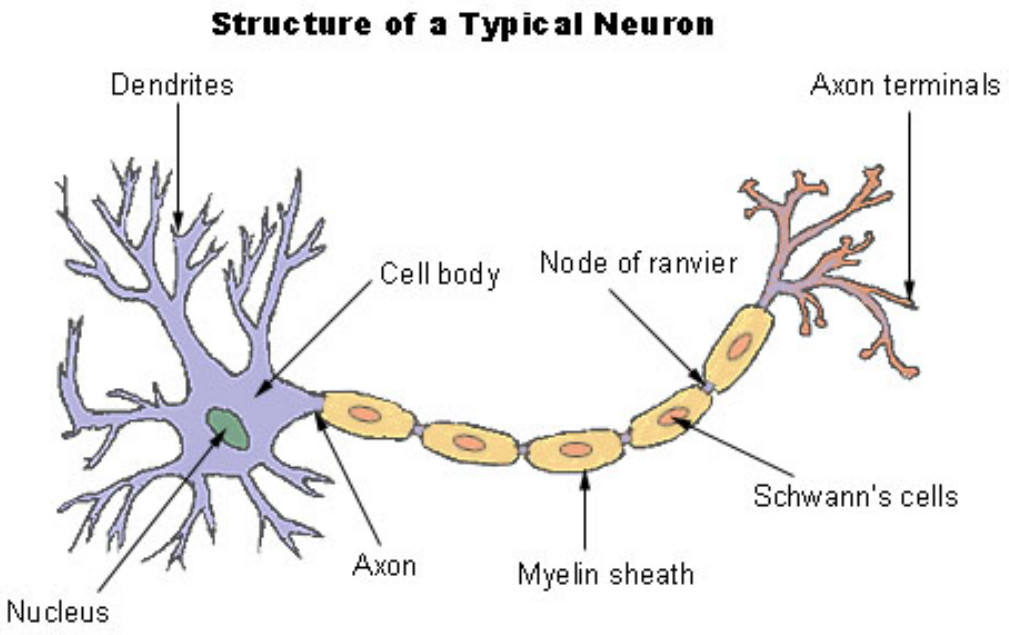
C. The nervous system is divided into branches



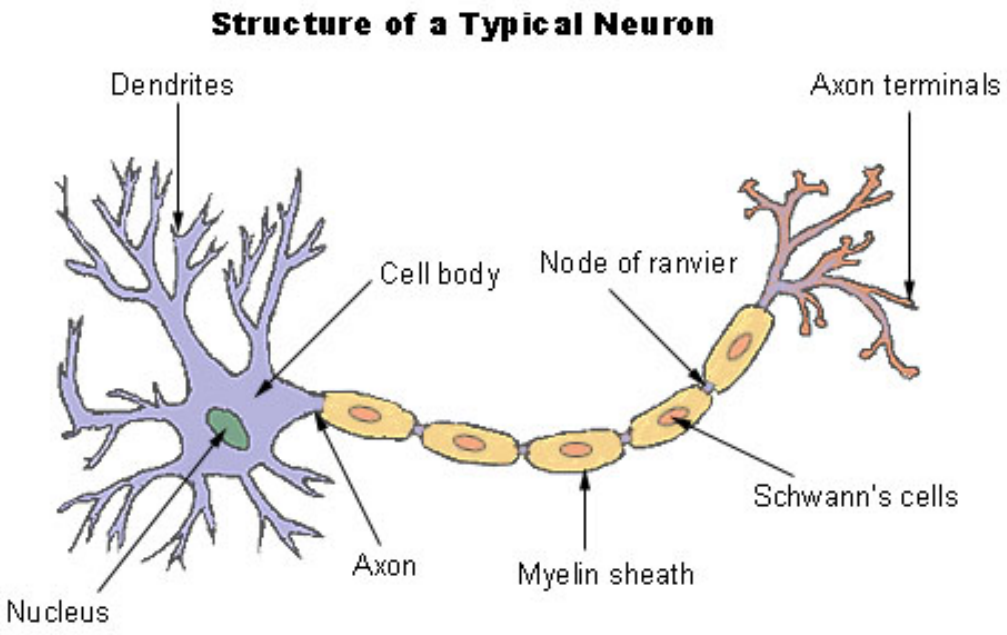
Neurons: Structure and Function

I. Parts of a Neuron

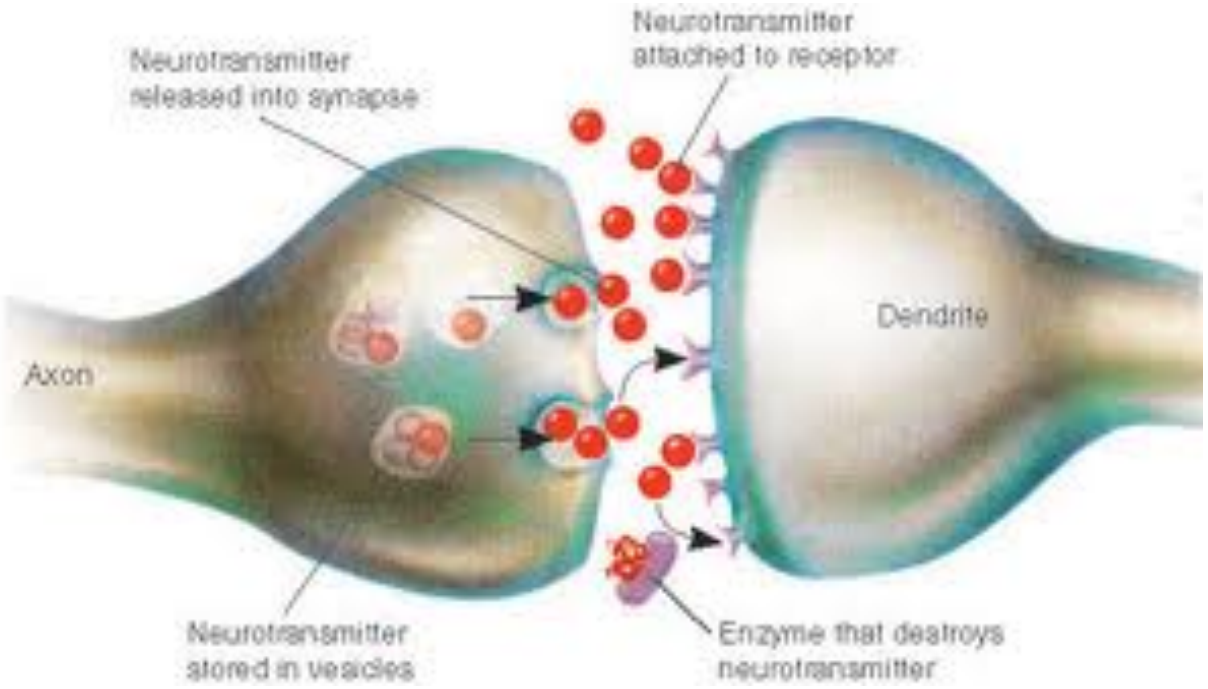
A. DENDRITE: conducts message towards the cell body. Animation



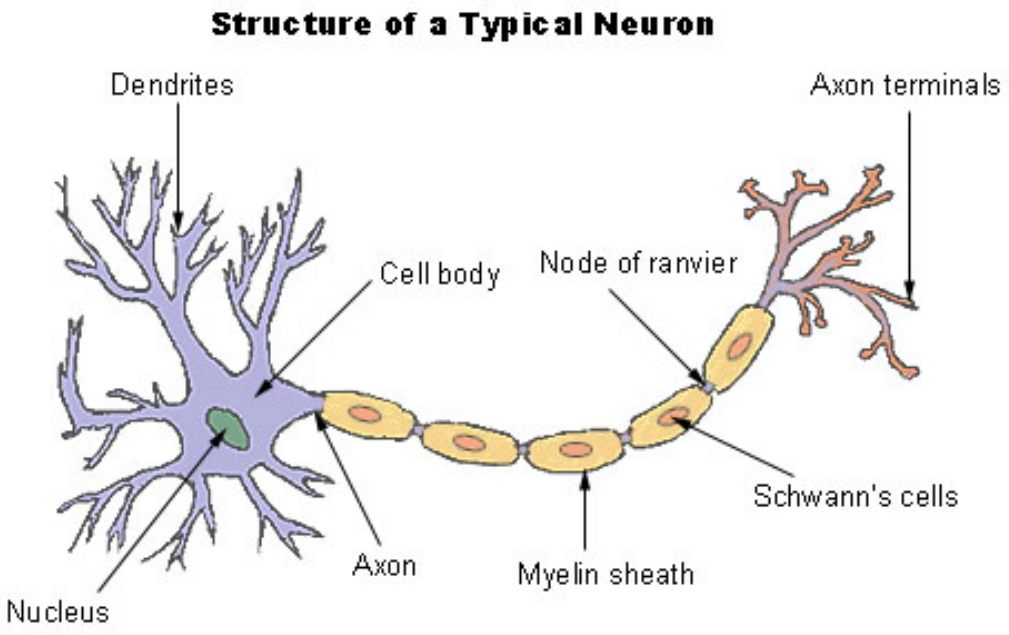
B. AXON: conducts message away from the cell body.



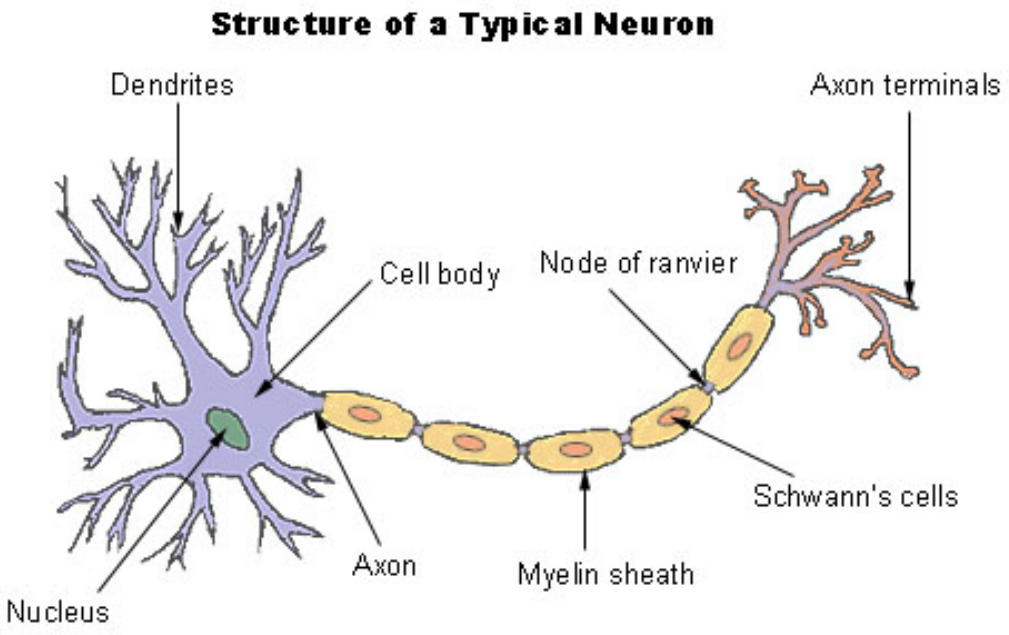
C. SYNAPSE: a junction between neurons; where message jumps from one neuron to another.



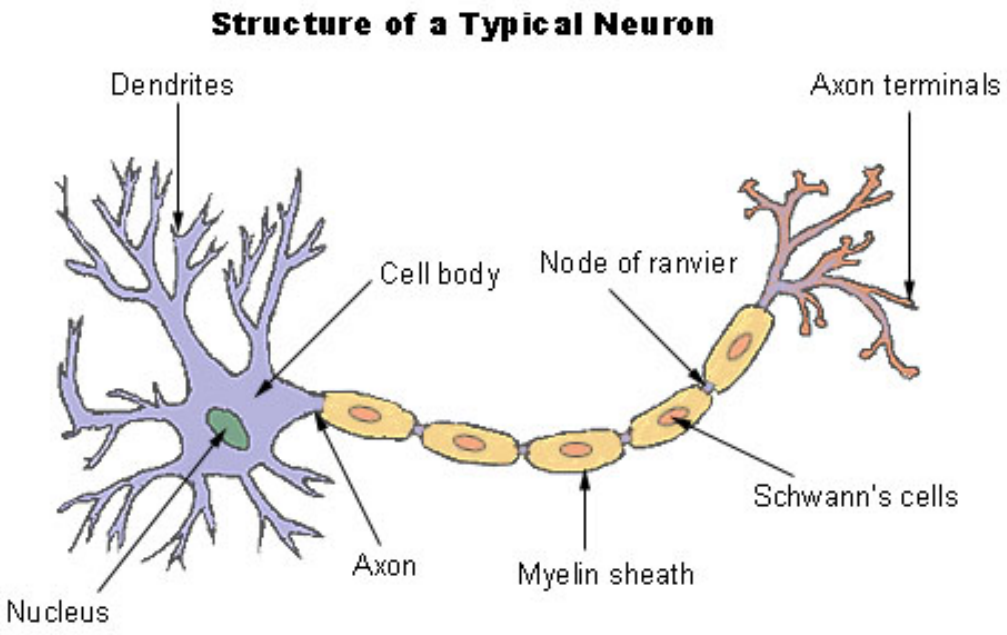
D. MYELIN SHEATH: insulates the nerve fibre electrically.



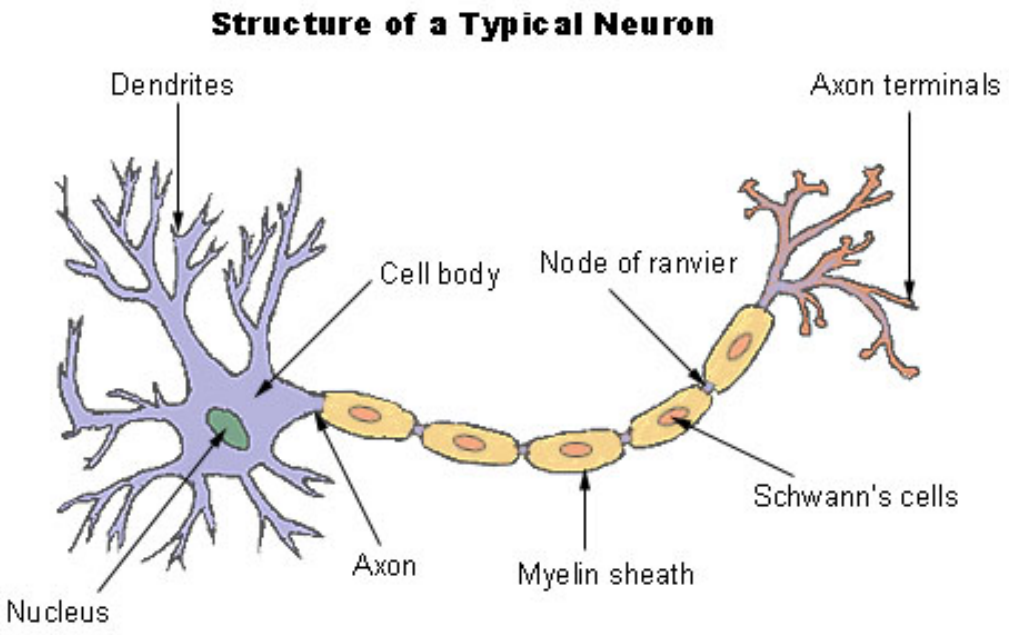
E. SCHWANN CELLS: cells that secrete the myelin sheath.



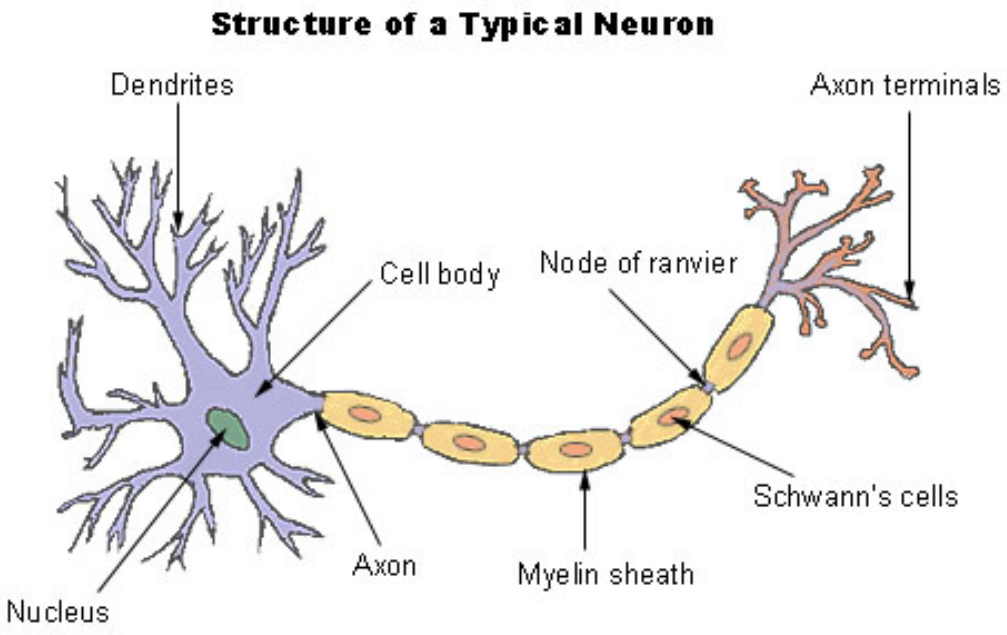
F. NODE OF RANVIER: gaps in the myelin sheath, they speed up transmission of nerve impulses.



G. CELL BODY: conducts the normal metabolic functions of the cell.



H. FIBERS: composed of dendrites and axons.



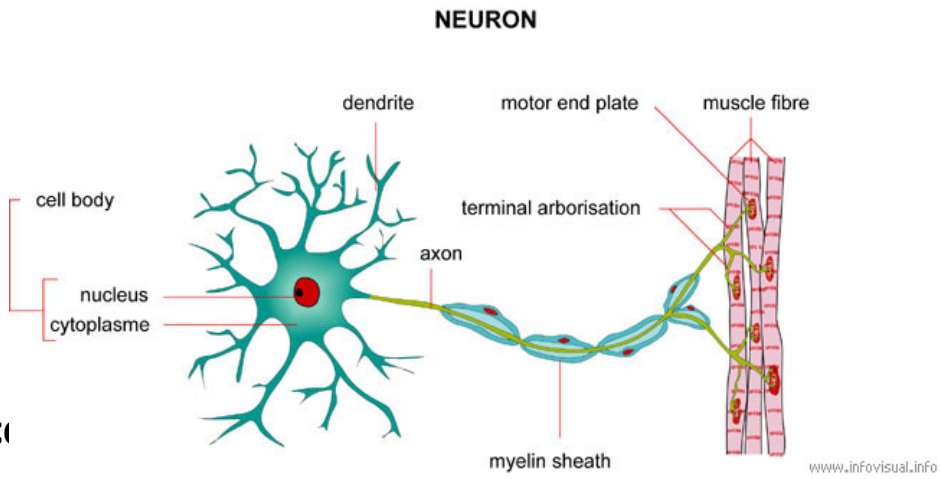
Types of Neurons: Structure and Function

I. Motor Neurons (Efferent Neuron)

A. Connected to an effector (muscle fibre or gland).

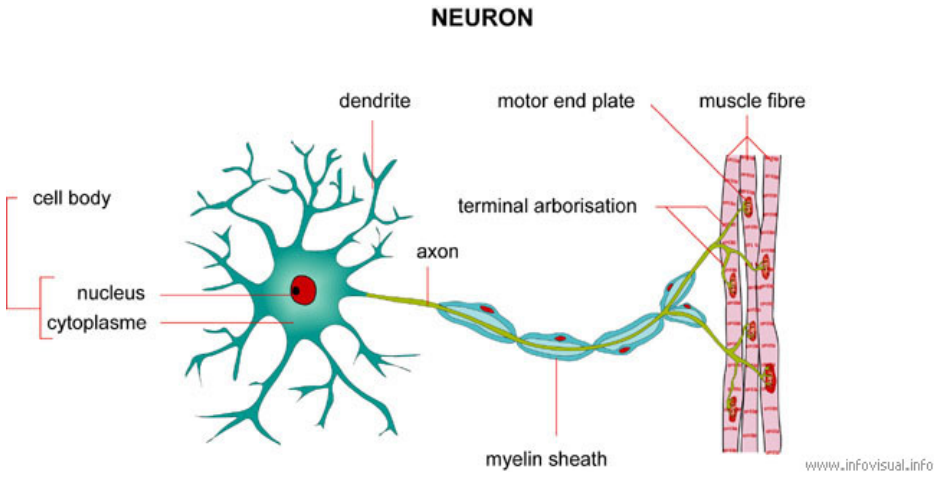
B. Appearance

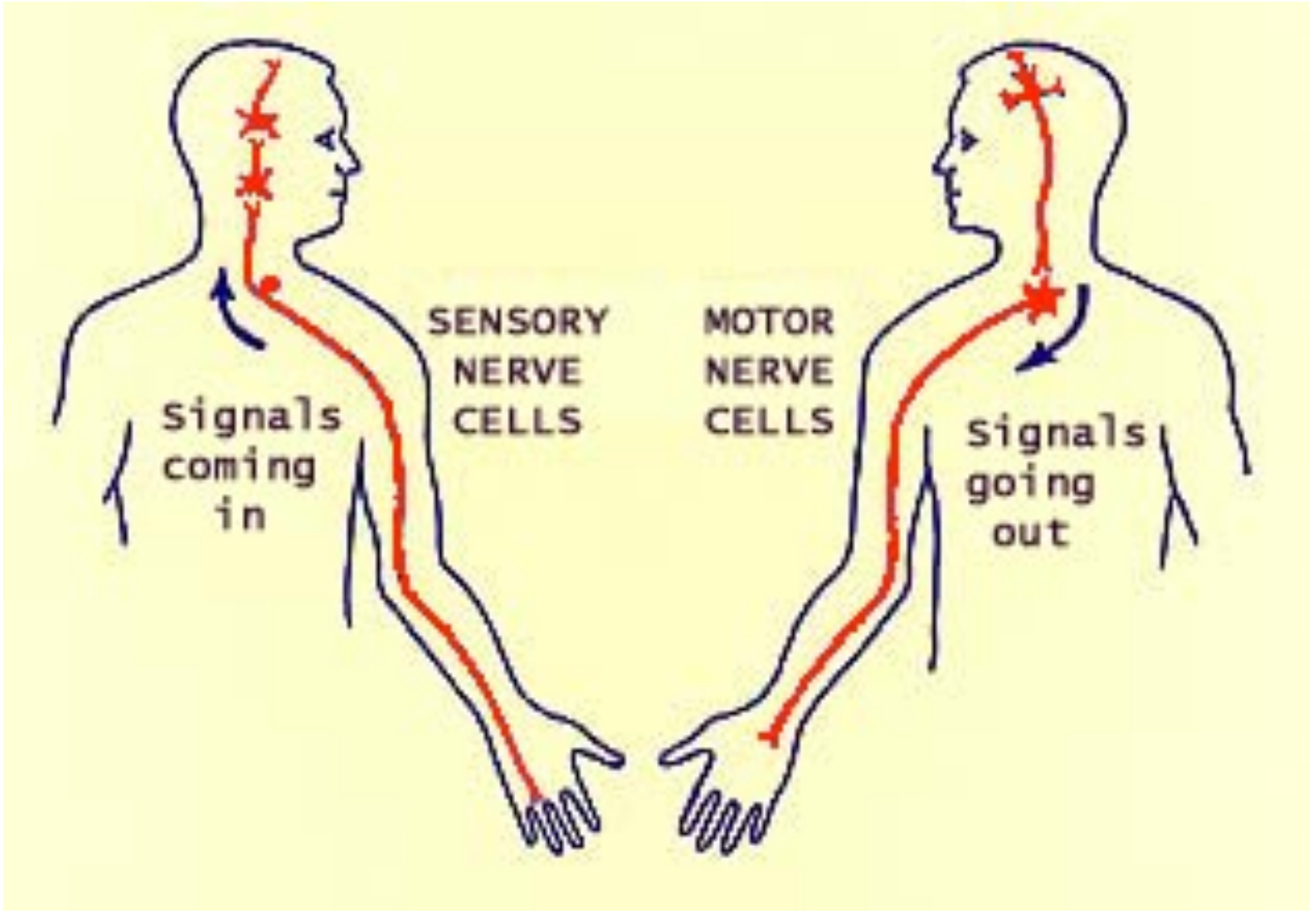
1. **Short dendrite**
2. **Long axon**
3. **Cell body positioned inside the c**



C. Transmitted impulses cause effector to react (eg. muscle to contract).

D. Message is traveling away from the brain



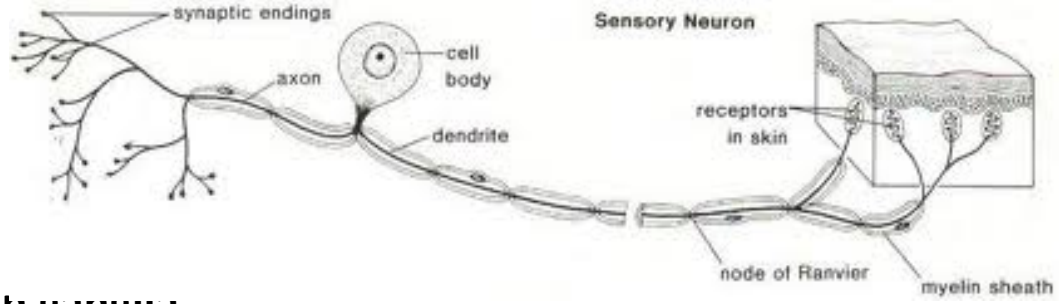

SENSORY
NERVE
CELLS
MOTOR
NERVE
CELLS
Signals
coming
in
Signals
going
out

II. Sensory Neuron (Afferent neuron)

A. Starts with a sensory receptor (pressure, heat, light, etc.).

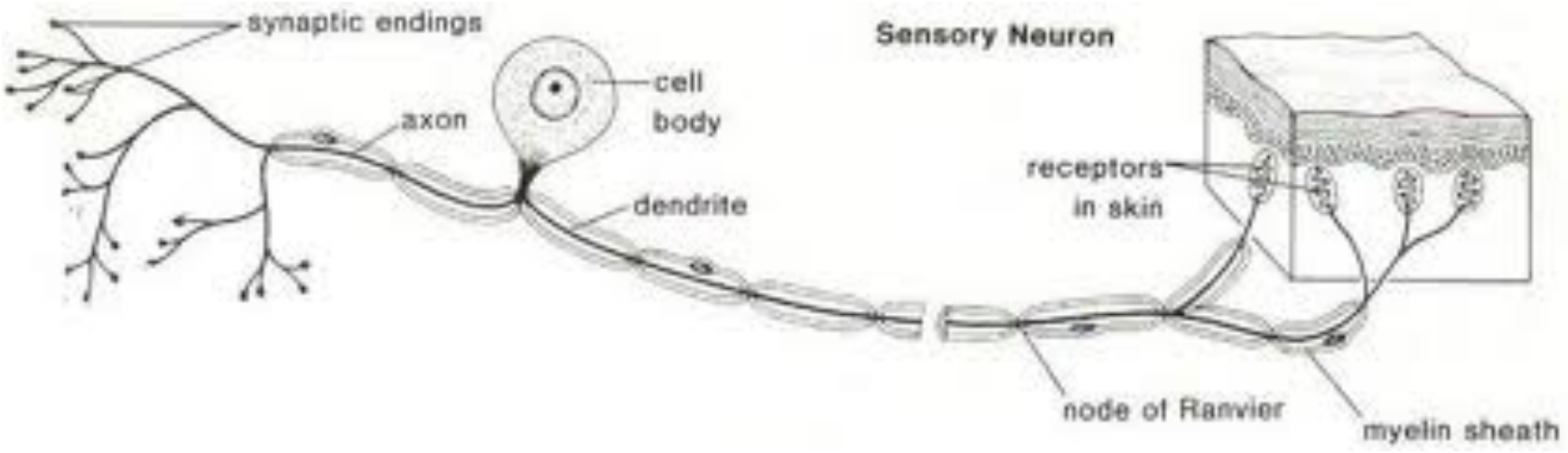
B. Appearance

1. Long dendrite
2. Short axon
3. Cell body is outside CNS in ganglia



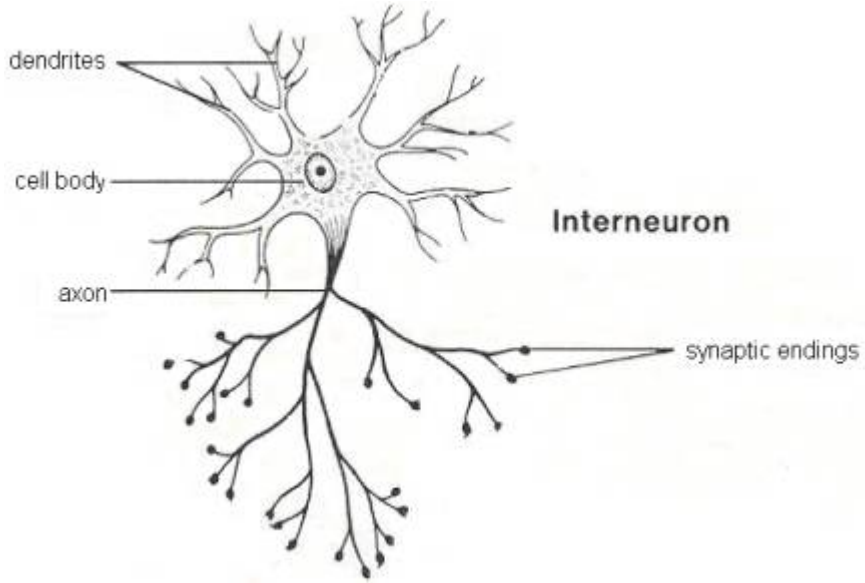
C. Transmitted impulses send information about the environment to the brain.

D. Message travels towards CNS. Animation



III. Interneuron (Association neuron)

A. Smaller than other two types of neurons.
B. Located entirely within CNS.
C. Usually, short dendrites.
D. Axons can be long or short.
E. Conveys messages between system parts in CNS.



Transmission of Nerve Impulses

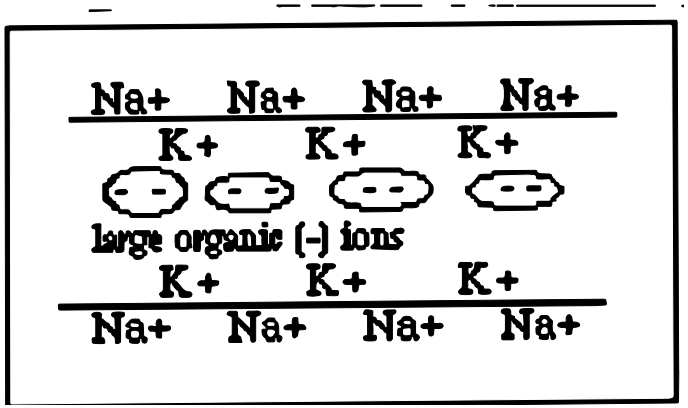
- **I. Nerve Conduction**

A. Occurs due to an electrochemical change that moves in one direction along the length of a nerve fiber.

B. It is electrochemical because it involves changes in voltage as well as in the concentrations of certain ions.

Three Phases of Nerve Impulse

- **A. Resting Potential**
- **1. Potential difference across the membrane of the axon when it is not conducting an impulse is -60 mV.**
- **2. This negative polarity is caused by the presence of large organic negative ions which are too large to cross the membrane.**



3. During the resting potential, Na^+ ions are more concentrated on the outside of the membrane than the inside.

4. K^+ ions are more concentrated on the inside of the axon.

5. This uneven distribution of K and Na ions is maintained by active transport across Na^+/K^+ pumps which operate whenever the neuron is not conducting an impulse.

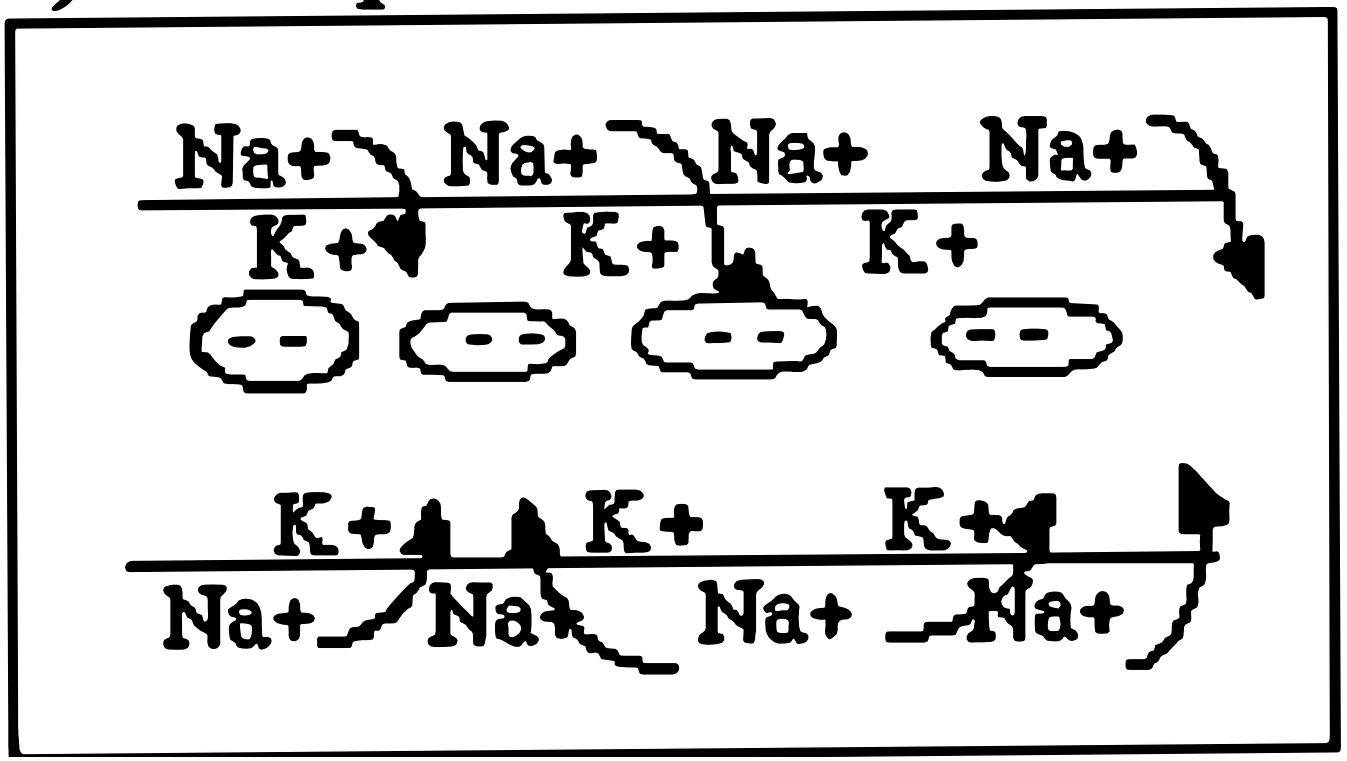
6. Must work all the time, because the membrane is partially permeable to these ions, and they tend to diffuse toward regions of lower concentration

B. Action potential

1. **If a nerve is stimulated by electric shock, pH change, mechanical stimulation, a nerve impulse is generated, and a change in potential can be seen.**

2. **This nerve impulse is called the ACTION POTENTIAL.**

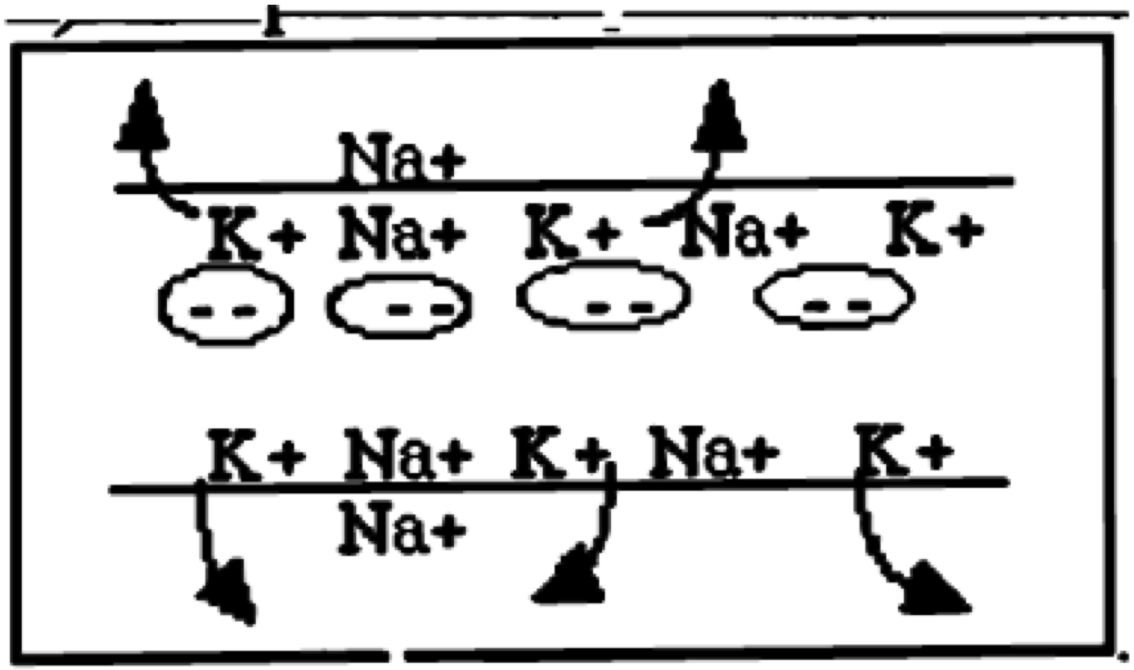
3. **Broken into an upswing and downswing.**
   a. **During the upswing (-60 mV to +40 mV), membrane becomes permeable to Na+ ions.**
      i. **Na+ ions move from outside to inside of axon due to opening of the sodium gates in the membrane.**
      ii. **Depolarization occurs because the inside of the axon becomes positive.**


Na+
Na+
Na+
Na+
K+
K+
K+
K+
K+
K+
Na+
Na+
Na+
Na+

b. In the downswing (+40 mV to -60 mV), membrane becomes permeable to K+ ions.

i. K+ ions moves from inside to outside of axon due to the opening of the potassium gates in the membrane.

ii. Repolarization occurs because the inside of axon becomes negative again.



- **C. Recovery Phase**

1. Occurs between transmissions, K+ ions are returned to inside of axon, Na+ to the outside.

2. This is done actively by the Na^+/K^+ pumps.

3. Neuron is now ready to send another impulse!

4. Multiple impulses can pass down a nerve in succession.

5. Only small amounts of the ions move, and the resting potential is quickly restored.

III. Summary of Nerve Impulse Transmission

A. The 3 phases of nerve impuls

1. **Resting potential**
2. **Action potential – depolarizatic**

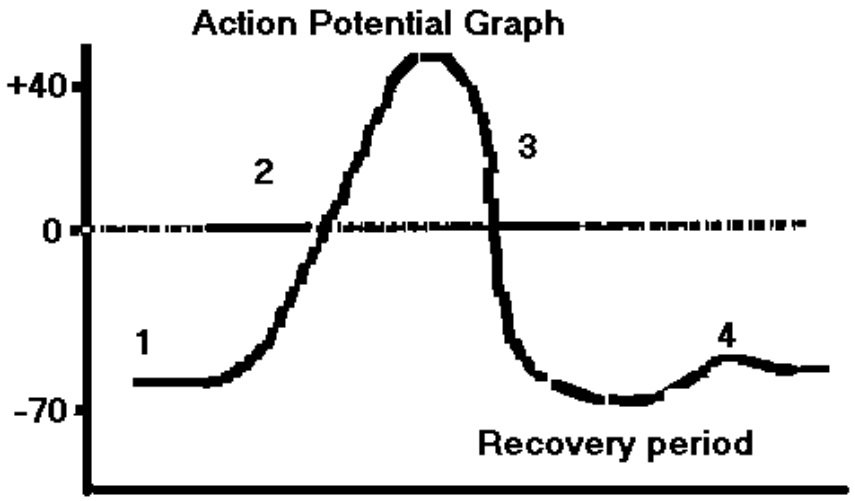
(Na⁺ gates opening, Na⁺ pouring in

3. **Action potential – repolarizatio**

(K ⁺ gates opening, K ⁺ pouring out

Animation 2

4. **Resting potential – neuron is re conduct again.**



B. Notes about transmission

1. **Impulse transmission is one way only.**

   a. As depolarization wave passes along, it stimulates the sodium gates to open at the very next point.

   b. Gates that have just opened and closed cannot be restimulated for a very brief period of time.

   c. This is called a REFRACTORY or Recovery Period.

   d. Makes it impossible for the impulse to travel "upstream".

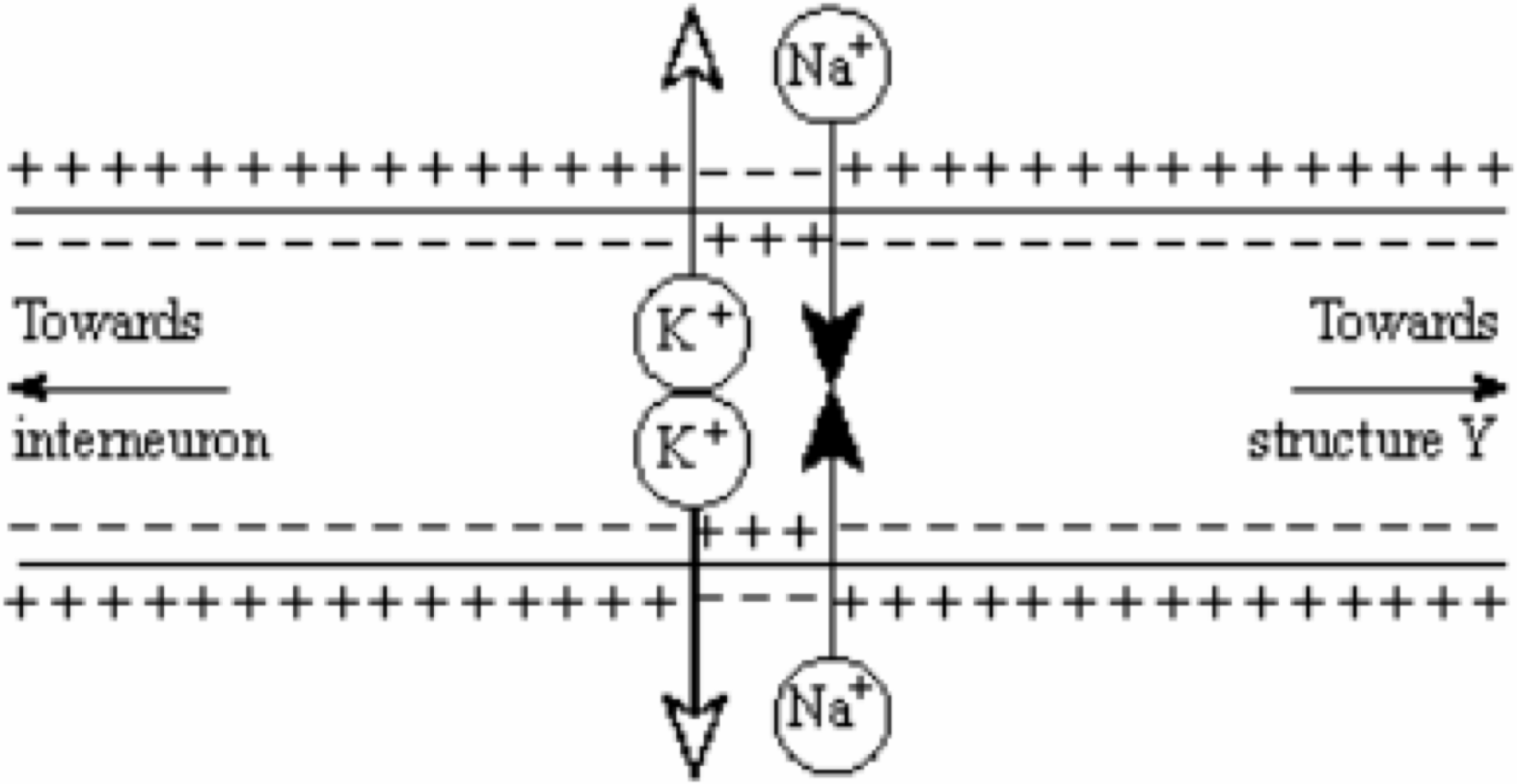
direction →

+- - - - - - - - - - - - - - -

- r r +- - - - - - - - - - - -

- - - - r r +- - - - - - - - -

- - - - - - - r r +- - - - - - **etc.**



Carefully examine this diagram that has appeared on several provincial exams. What do you think **structure Y** is? **Which direction is the impulse moving**?

2. Impulses travel from receptor (or dendrite) down the axon.

3. The impulse, once triggered, is the same each time, and in every neuron (-60 to +40 mV).

4. A neuron is either transmitting, or it is not.
   a. Often called the "ALL-OR-NONE" response.
   b. A stimulus must meet or exceed the neuron's THRESHOLD for triggering depolarization, or there is no impulse sent … but neurons do not distinguish between "meet" or "exceed."

Animation

Myelin Sheath

I. <u>Description</u>

A. Composed of lipids.

B. Composed of tightly packed spirals of the cell membrane of Schwann cells.

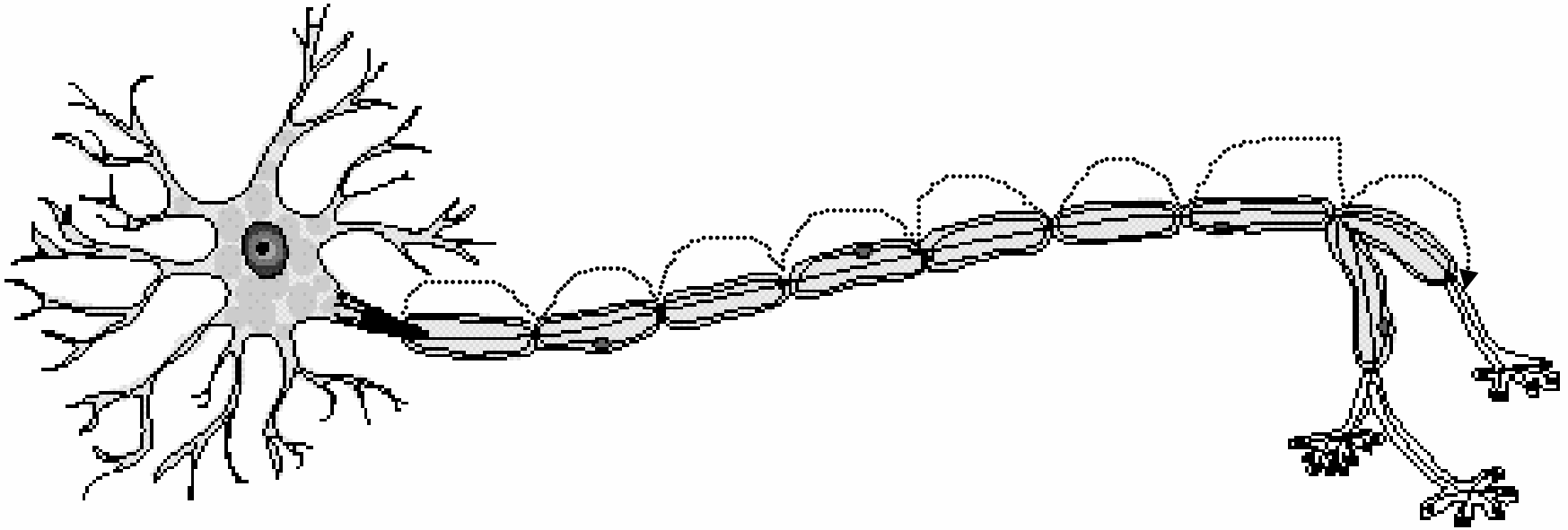
C. This sheath gives nerves their characteristic shiny white appearance.

II. Function

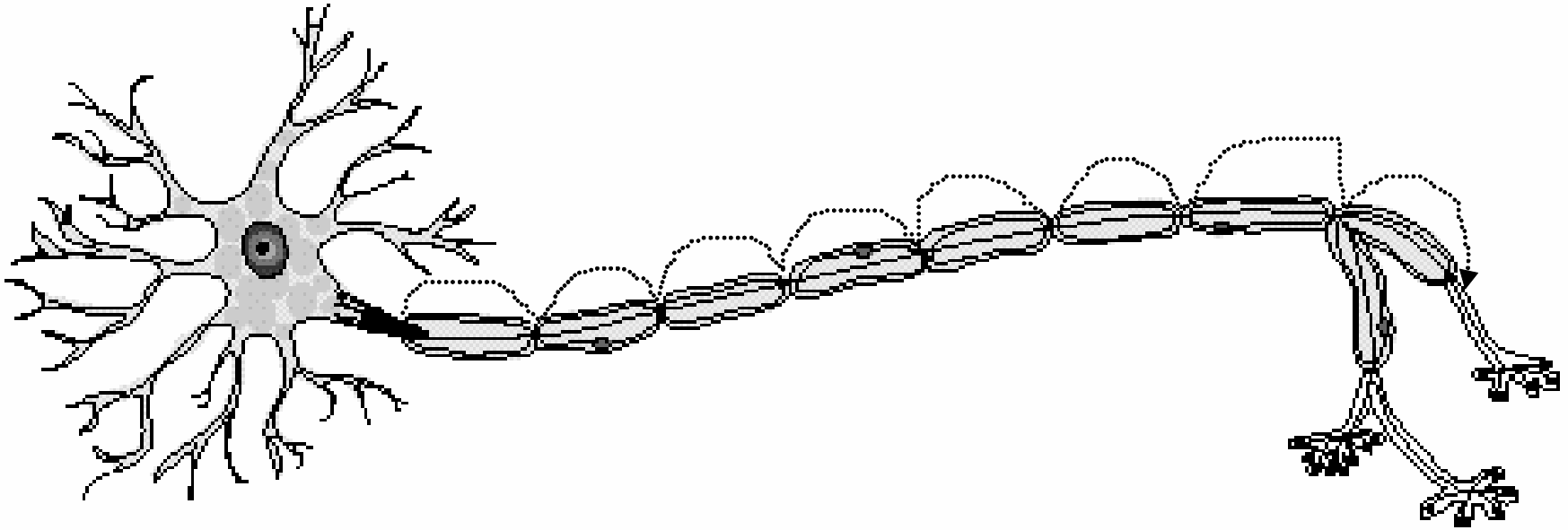
A. Acts as insulation

B. Speeds up impulse transmission

1. The speed of transmission is ~200 m/s in myelinated fibers, but only 0.5 m/s in non-myelinated fibers.
2. The reason is that the nerve impulse "jumps" from node to node in myelinated fibers (Saltatory conduction.)



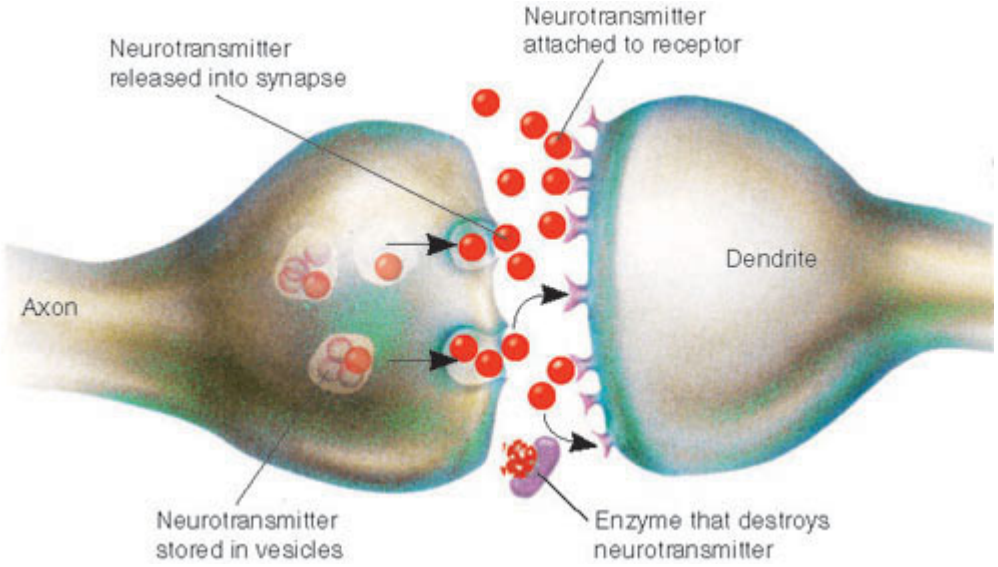
3. In non-myelinated fiber, the nerve impulse must depolarize and repolarize each point along the nerve fiber. Animation or Animation Ted-Ed Nerves



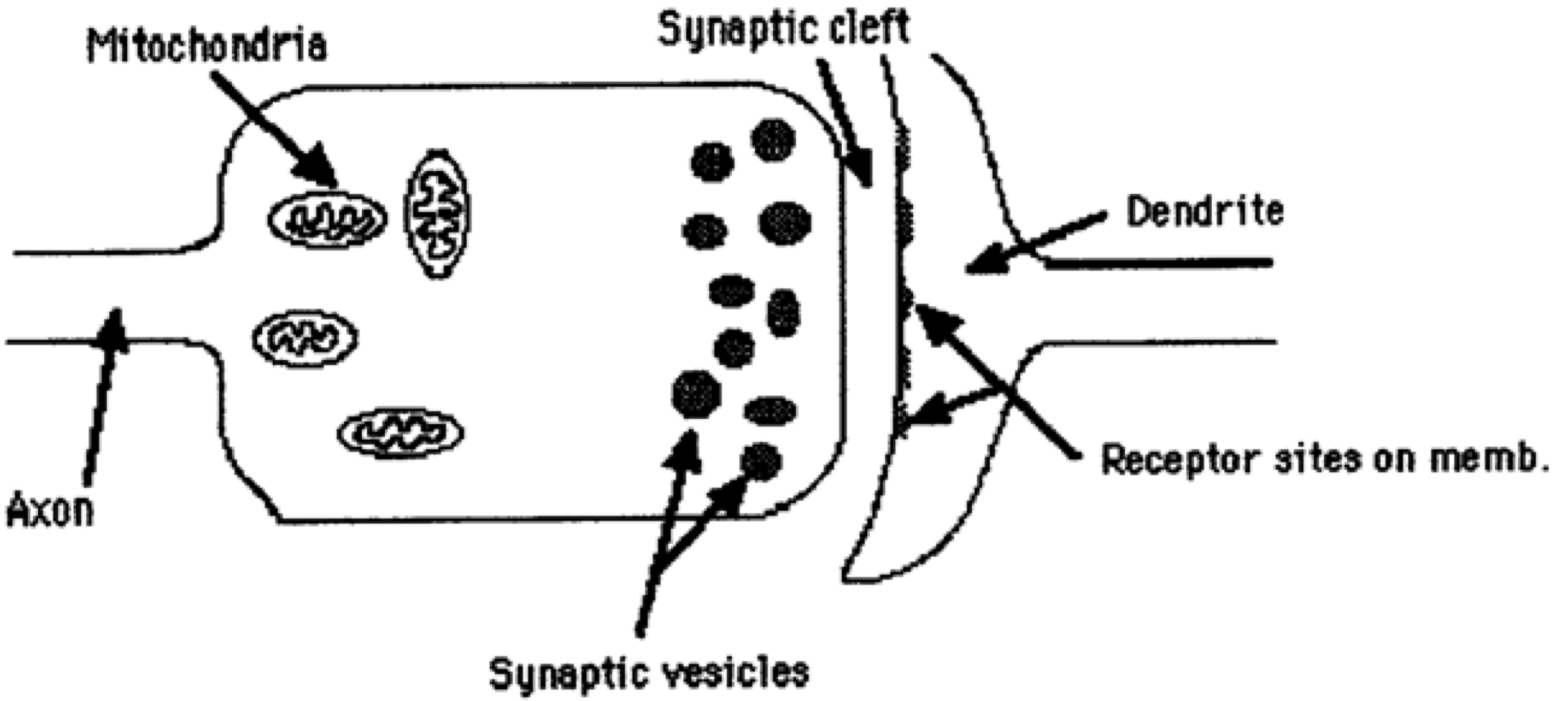
The Synapse

I. Why are Synapses Important?

A. A SYNAPSE is specialized region at the ends of axons called synapses allow one nerve cell to communicate and transmits an impulse across to another cell.



Synapse Anatomy



A. SYNAPSE: the region between end of an axon and the cell body or dendrite to which it is attached.

B. SYNAPTIC ENDINGS: swollen terminal knobs on the ends of axon terminal branches.

C. PRESYNAPTIC MEMBRANE: the membrane of the axon synaptic ending.

D. POSTSYNAPTIC MEMBRANE: the membrane of the next neuron just beyond the axon's synaptic membrane.

E. SYNAPTIC CLEFT: the space between the presynaptic and the postsynaptic membranes

F. NEUROTRANSMITTER SUBSTANCES (neurotransmitters): chemicals that transmit the nerve impulses across a synaptic cleft.

1. **Some important neurotransmitters**
   a. **Acetylcholine (Ach)**
   b. **Noradrenalin (NA)**
   c. **Serotonin**
   d. **Adrenalin (epinephrine)**

G. SYNAPTIC VESICLES: contain the neurotransmitters. Contained near surface of synaptic endings.

II. Transmission of Impulses across Synapses

A. An action potential reaches the axon bulb

B. Ca^{2+} gates in bulb membrane open.

C. Entry of Ca^{2+} bulb stimulates the

synaptic vesicles to move to the presynaptic membrane.

D. They fuse with the membrane, emptying

the neurotransmitter into the synaptic cleft by exocytosis

E. Neurotransmitters diffuses across the cleft to the receptors on the postsynaptic membrane of the next neuron's dendrite.

F. The action of binding the neurotransmitters initiates or suppresses an action potential in the postsynaptic neuron Animation

III. Notes about Impulses Across the synapse

A. Impulses can only go one way across the gap because only the axon has the vesicles and the dendrite only has the receptors.

B. Different nerve cells use different chemicals as neurotransmitters.

C. Most neurotransmitters are EXCITATORY –their binding opens Na^+ channels in the membrane, and creates or encourages action potentials.

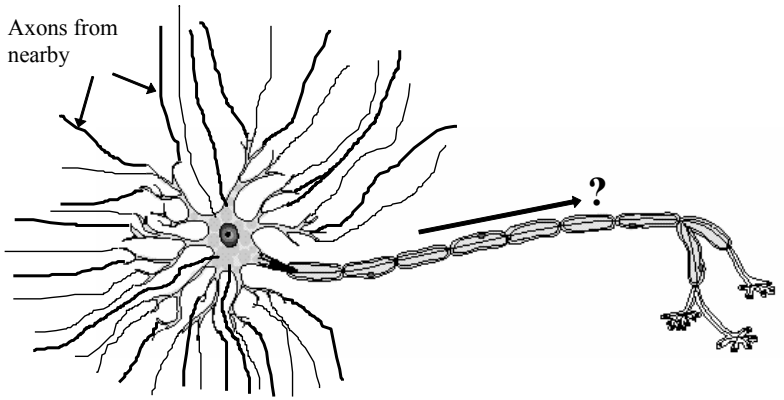
D. Some neurotransmitters are INHIBITORY – their binding stops action potentials.

E. Exact action depends more on the receptor than on the neurotransmitter.

a. **E.g. Serotonin can be excitatory or inhibitory in different circuits.**

F. A single neuron may receive information from thousands of neighbouring neuron through thousands of synapses.

1. **Some of the messages are excitatory (i.e. they tell the neuron to "fire") while others may be inhibitory (i.e. they tell the neuron not to fire).**
2. **Whether or not a neuron "fires" off an action potential at any particular instant depends on its ability to integrate these multiple positive and negative inputs.**
3. **This allows neurons to be fine-tuned to the environment**



Neurotransmitters

A. **Neurotransmitters take nerve impulses across synapses.**

B. **Neurotransmitters are small molecules.**

C. **They can be single amino acids, short chains of amino acids, or derivatives of protein.**

D. **Proper brain and nervous system function depends on the proper balance of excitatory and inhibitory synaptic transmitters.**

E. **Excitatory transmitters include**
   1. **Acetylcholine (ACh)**
   2. **Adrenalin (epinephrine)**
   3. **Noradrenalin (norepinephrine)**
   4. **Serotonin (derived from the amino acid tryptophan)**
   5. **Dopamine**

F. Inhibitory transmitters include

1. GABA (gamma aminobutyric acid - a type of amino acid)
2. Glycine (an amino acid)
3. Serotonin can also act as an inhibitory neurotransmitter.

G. Neurotransmitters include endorphins and enkephalins (a 5 amino-acid chain that functions as a natural pain reliever in brain).

H. Opium and heroin mimic the action of natural endorphins and enkephalins. Animation

TED-Ed Caffeine & Actual Caffeine Experiment

Neurotransmitters Breakdown

A. Inactivating neurotransmitters are important to clear the synaptic gap for the next signal from the presynaptic neuron.

B. Methods to remove neurotransmitters:

1. **Enzymes exist in the synaptic cleft to break apart the neurotransmitter (e.g. acetyolcholinesterase)**
2. **Reabsorption of neurotransmitters by axon bulb for breakdown or repackaging/reuse.**

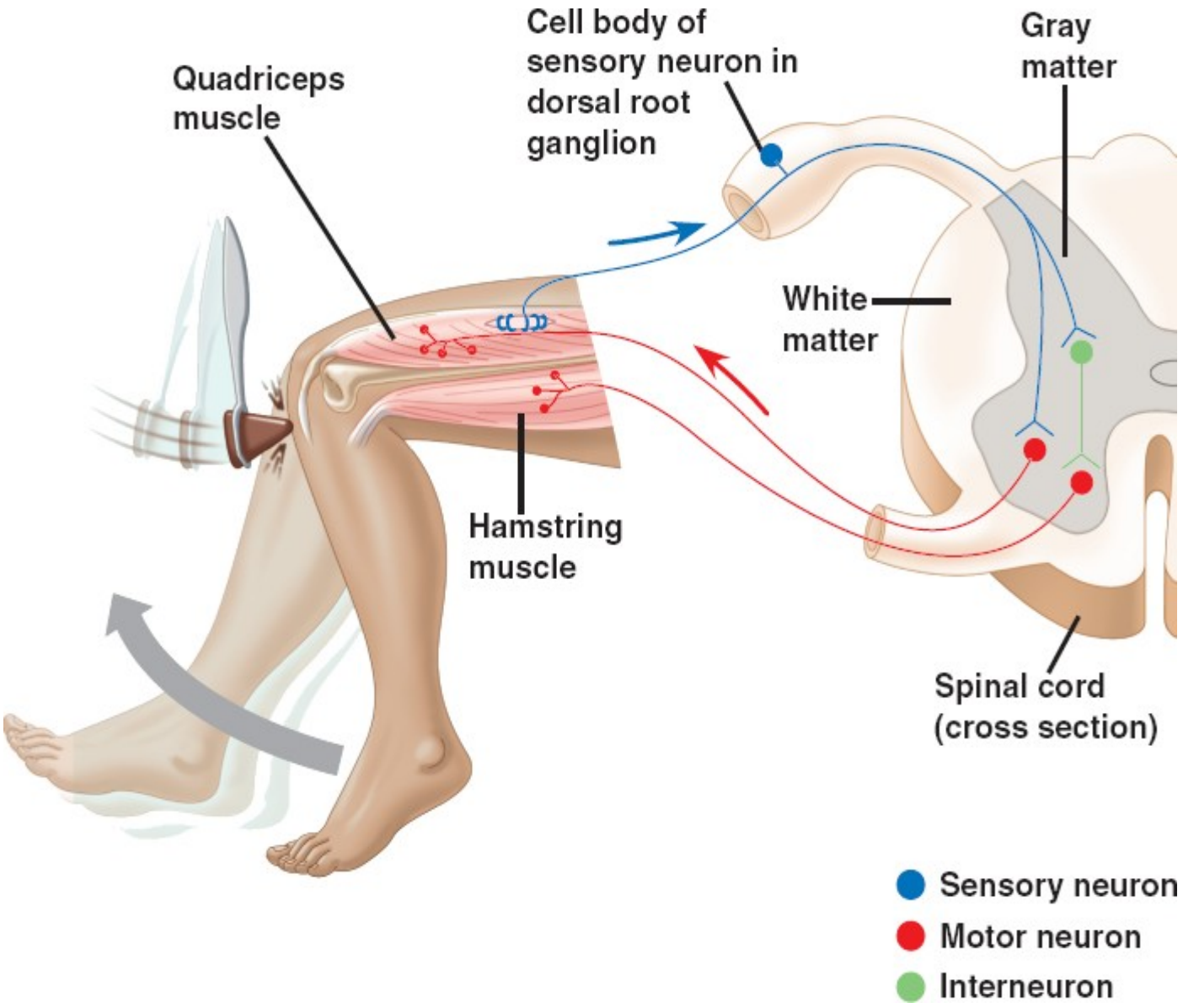
Reflex Arc

I. Reflex

A. Reflexes are automatic, involuntary responses to changes occurring inside or outside the body.

B. Can involve the brain (e.g. blinking) or not involve brain (e.g. withdraw hand from hot stove).

C. The reflex arc is the main functional unit of the nervous system and allows us to react to internal and external stimuli Animation Ted-ed Reflex

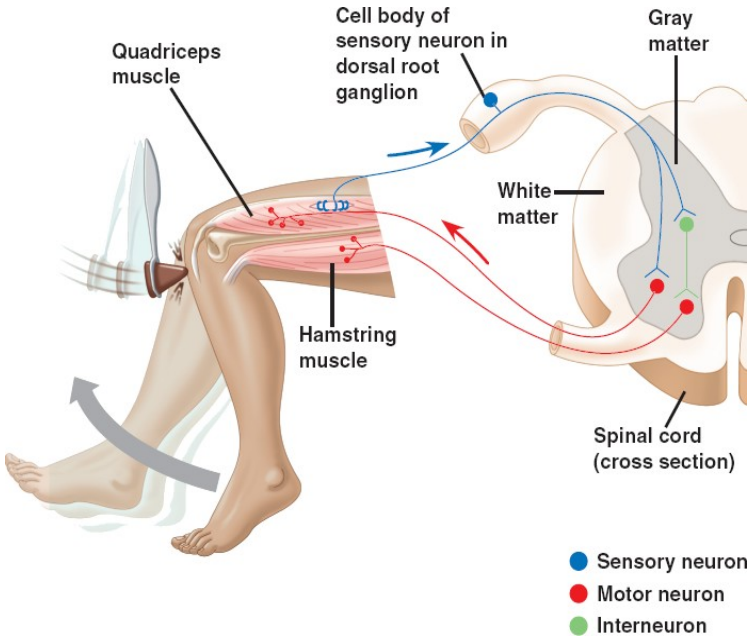

Quadriceps muscle
Cell body of sensory neuron in dorsal root ganglion
Gray matter
White matter
Hamstring muscle
Spinal cord (cross section)
Sensory neuron
Motor neuron
Interneuron

II. Parts of a Simple Reflex Arc

II. Parts of a Simple Reflex Arc Ted-Ed: 5 weird involuntary reflexes explained

A. RECEPTOR (e.g. in skin) - generates a nerve impulse.

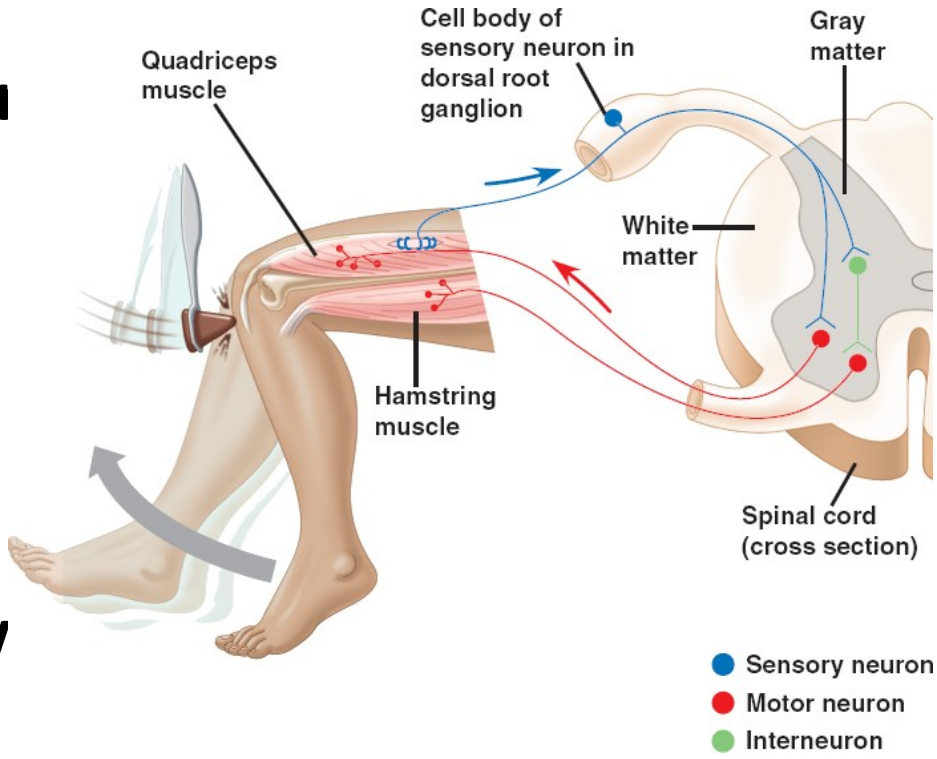
B. SENSORY NEURON - takes message to CNS. Impulses move along dendrite, proceed to cell body (in dorsal root ganglia) and then go from cell body to axon in gray matter of cord. Ted-Ed Hiccups



C. **INTERNEURON** - passes message to motor neuron

D. **MOTOR NEURON** - takes message away from CNS to axon of spinal nerve.

F. **EFFECTOR** - receives nerv impulses and reacts: glands secrete and muscles contract.



III. Parts of a Simple Reflex Arc

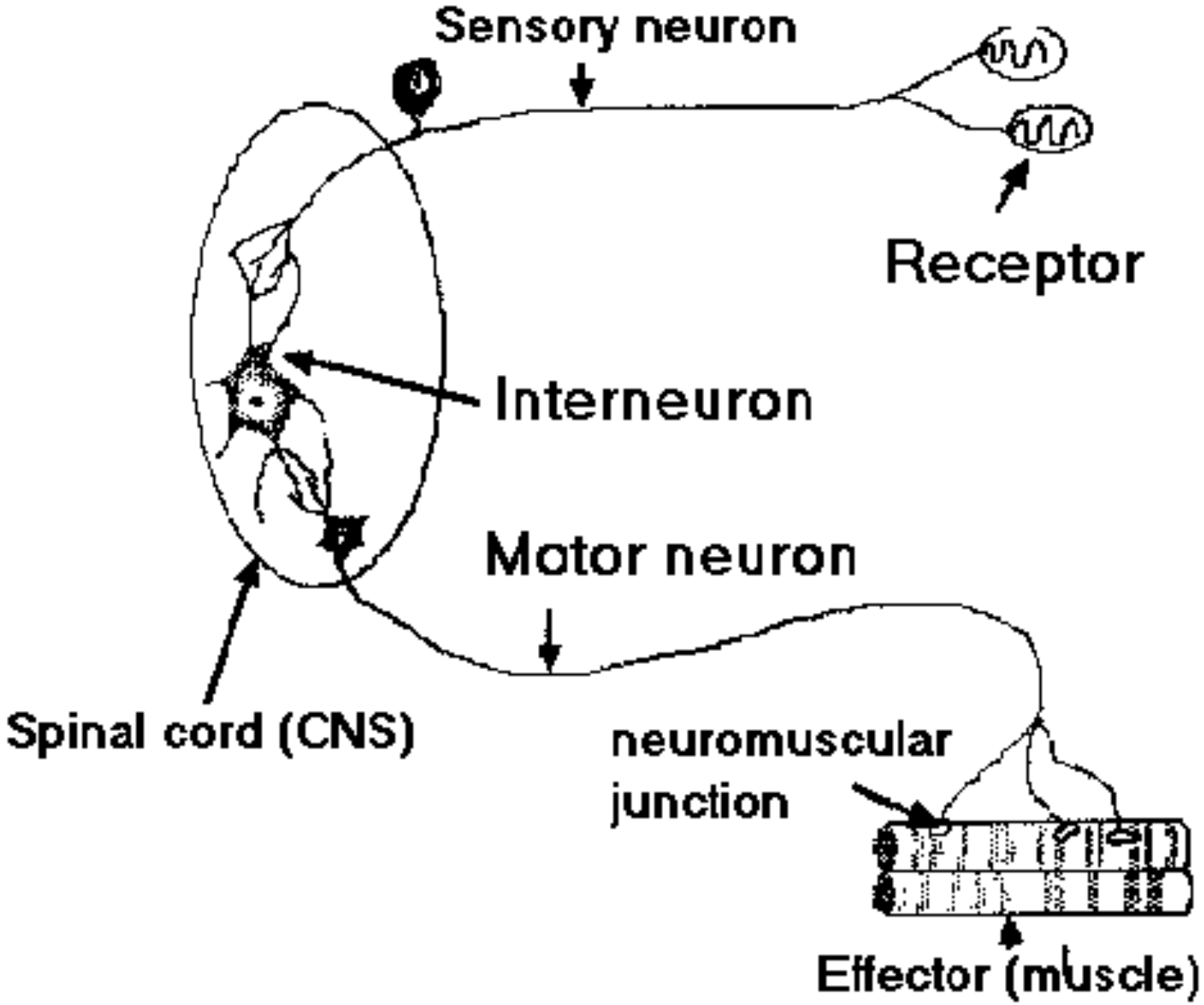
A. Receptor receives info from the environment, and initiates a nerve impulse.

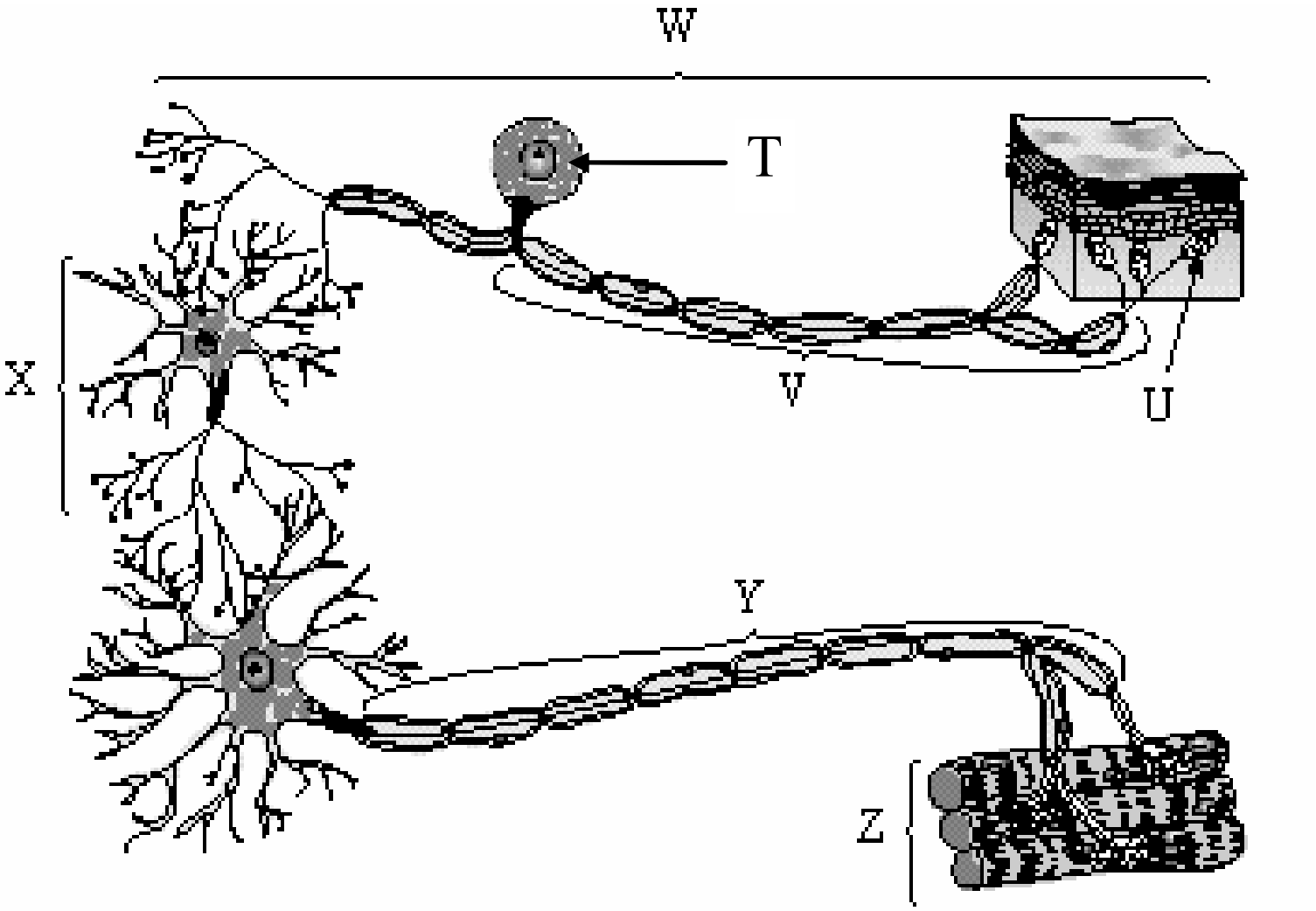
B. An interneuron in the spinal cord bypasses the brain and sends impulse directly to a motor neuron.

C. Motor neuron transmits impulse to an Effector. (e.g. muscle fibre)

D. Protective action initiated.

E. Interneuron does "notify" the brain of the stimulus but by the time the brain can respond, the reflexive action has already occurred!


Sensory neuron
Receptor
Interneuron
Motor neuron
Spinal cord (CNS)
neuromuscular
junction
Effector (muscle)


W
T
X
V
U
Y
Z

Different Parts of the Nervous System

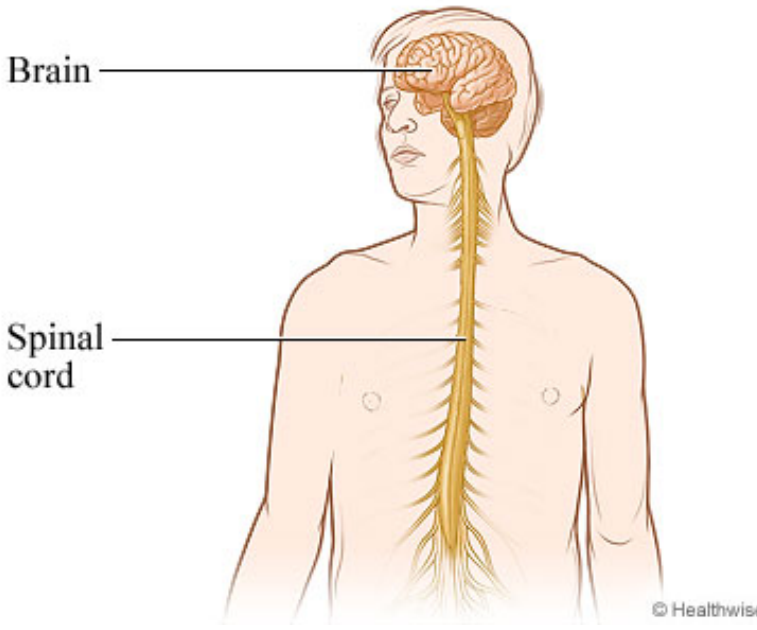
I. The Central Nervous System

A. Consists of the brain and spinal cord.

B. Lies in the mid-line of the body and is the place where sensory information is received and motor control is initiated.

C. Protected by the skull and vertebrae.

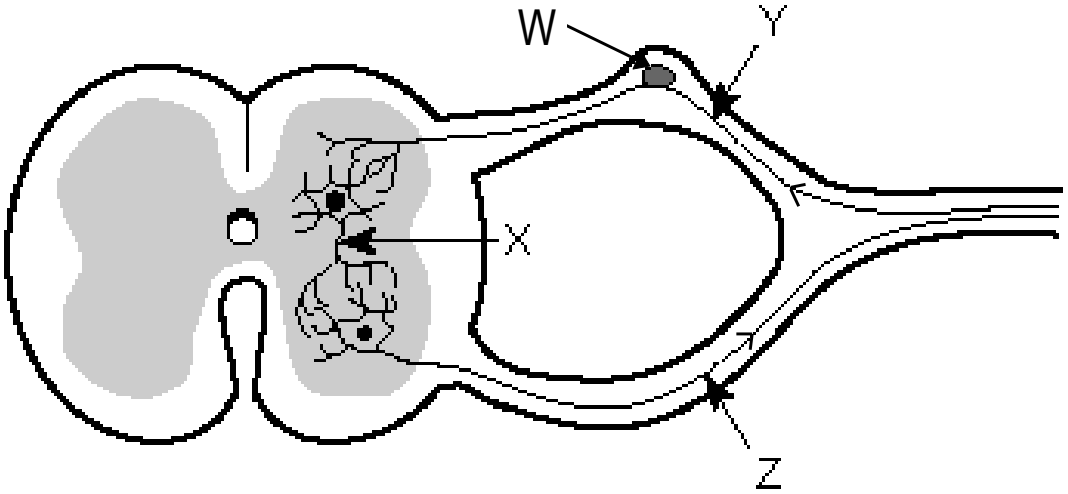
D. Wrapped up in three protective membranes called MENINGES. Ted-Ed Concussion



E. Cerebrospinal fluid for cushioning and protection fills the spaces between the meninges, the central canal of the spinal cord and ventricles of brain.

G. Spinal Cord

1. **Nervous system's "superhighway"**



Please label dorsal root ganglion (W), sensory nerve fiber, motor nerve fiber (Z), interneuron (X).

2. Gray matter (inner layer) contains cell bodies of neurons and short fibers.
    a. Looks kind of like a butterfly with open wings.
    b. Dorsal cell bodies function primarily in receiving sensory information.
    c. Ventral cell bodies send along primarily motor information.

3. White matter (outer layer) contains long fibers of interneurons that run together in bundles called tracts that connect the spinal cord to the brain.
    a. Ascending tracts take information to the brain.
    b. Descending tracts in the ventral part carry information down from the brain.

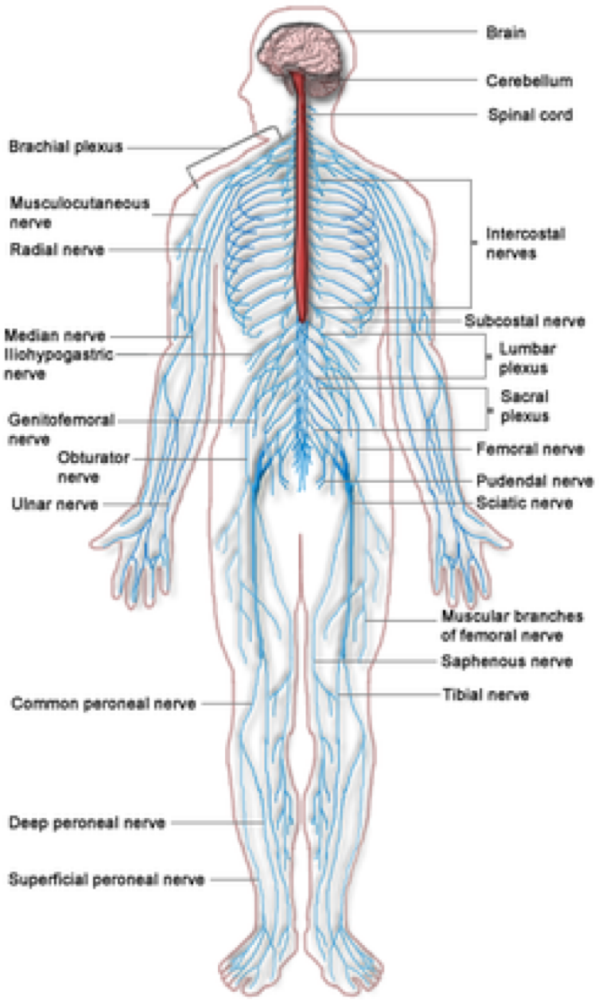
Peripheral Nervous System

A. Composed of nerves and ganglia that lie

outside the central nervous system (CNS).

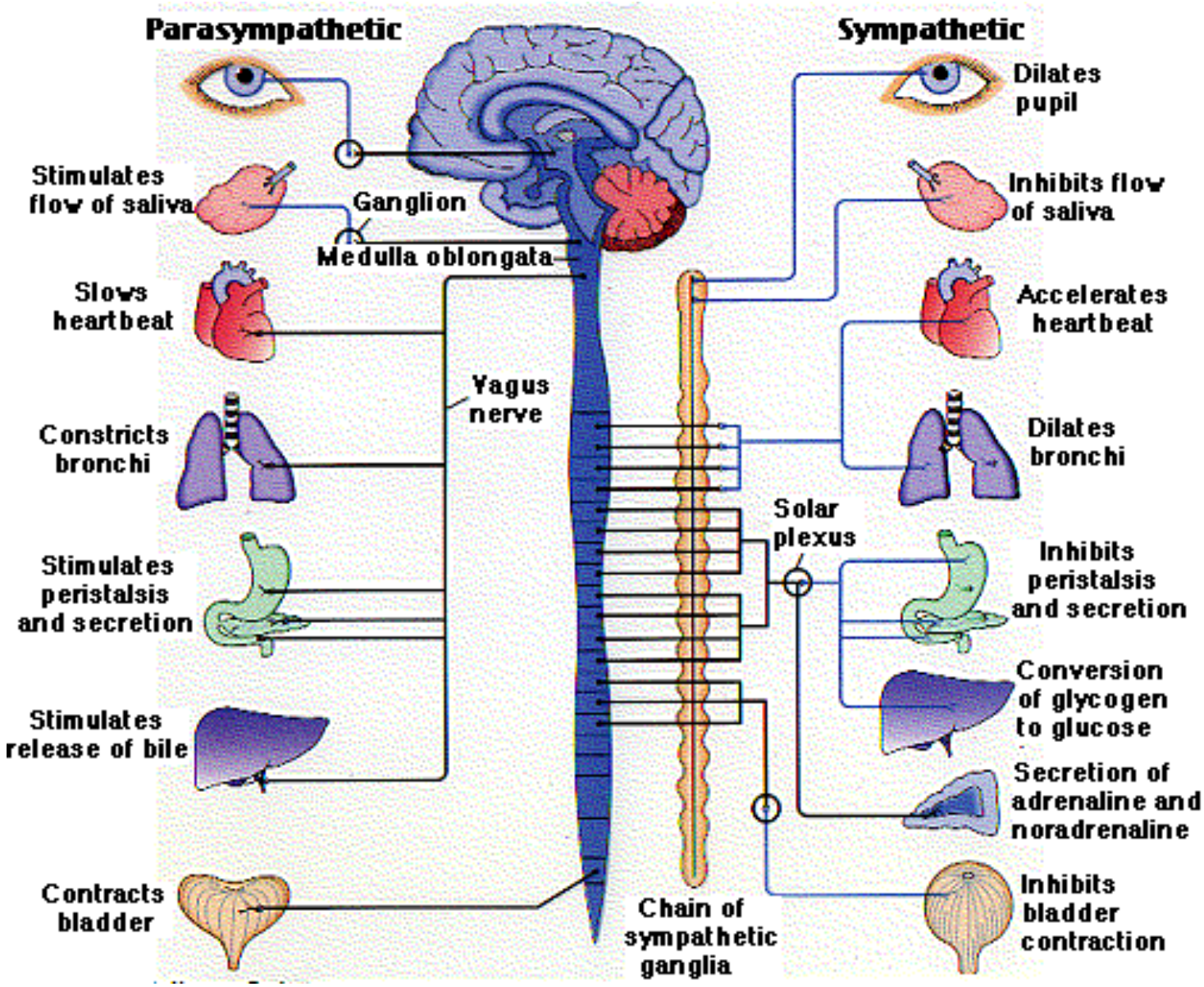
B. Carries information to and from the CNS.

C. Divided into two groups of nerves



1. **Somatic Nervous System (SNS)**
   a. **Nerves that serve the musculoskeletal system**
   b. **Nerves that serve the sense organs.**
   c. **Gives you information about the external environment and allows you to respond to it.**
2. **Autonomic Nervous System (ANS)**
   a. **Controls the internal organs automatically.**
   b. **No conscious control.**

Parasympathetic vs. Sympathetic Systems



I. Two parts of the Autonomic Nervous System

A. SYMPATHETIC and PARASYMPATHETIC nervous systems.
Animation

B. These two systems connect to the same organs but have opposite effects.

C. Each system functions unconsciously on internal organs and utilize two motor neurons and one ganglion for each nerve impulse.

II. Sympathetic Nervous System

A. Also known as "Fight or flight" system

(It comes into effect in life-threatening or exciting situations)

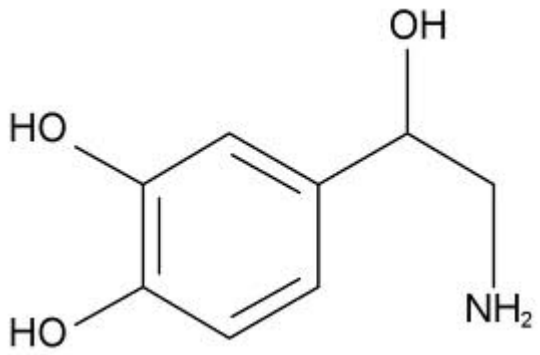
B. For example, in an emergency, it causes the following:

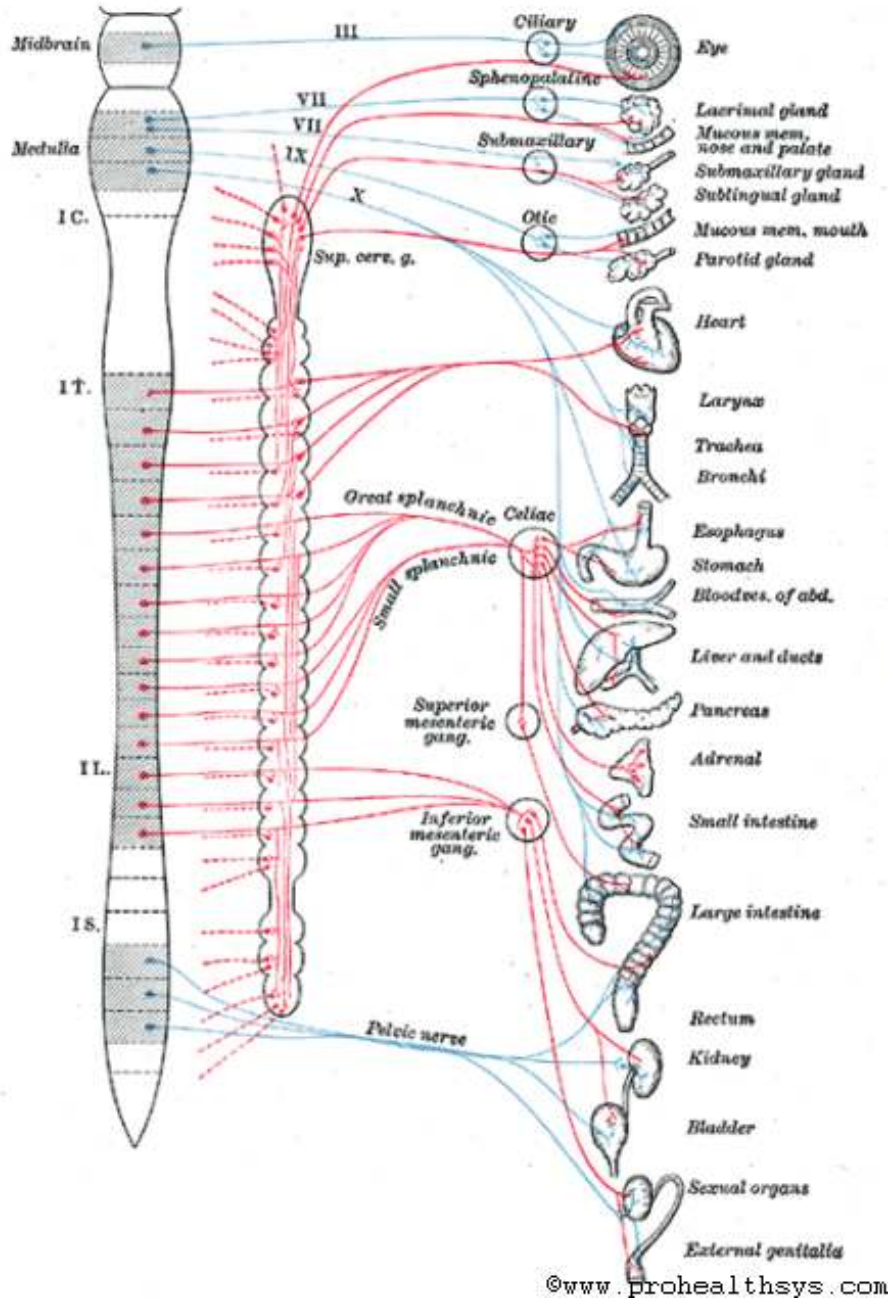
1. **Dilates pupils**
2. **Accelerates heartbeat**
3. **Increases breathing rate**
4. **Inhibits digestive tract: blood flow and peristalsis**
5. **Increases blood flow to skeletal muscle and CNS Animation**

C. Neurotransmitter released is NORADRENALIN.

1. Released by the postganglionic axon of the sympathetic nervous system.

2. Closely related to adrenalin





D. Fibers for this system arise from the thoracic-lumbar part of the spinal cord.

1. Preganglionic fiber is short.

2. Postganglionic fiber (which contacts the organ) is long.

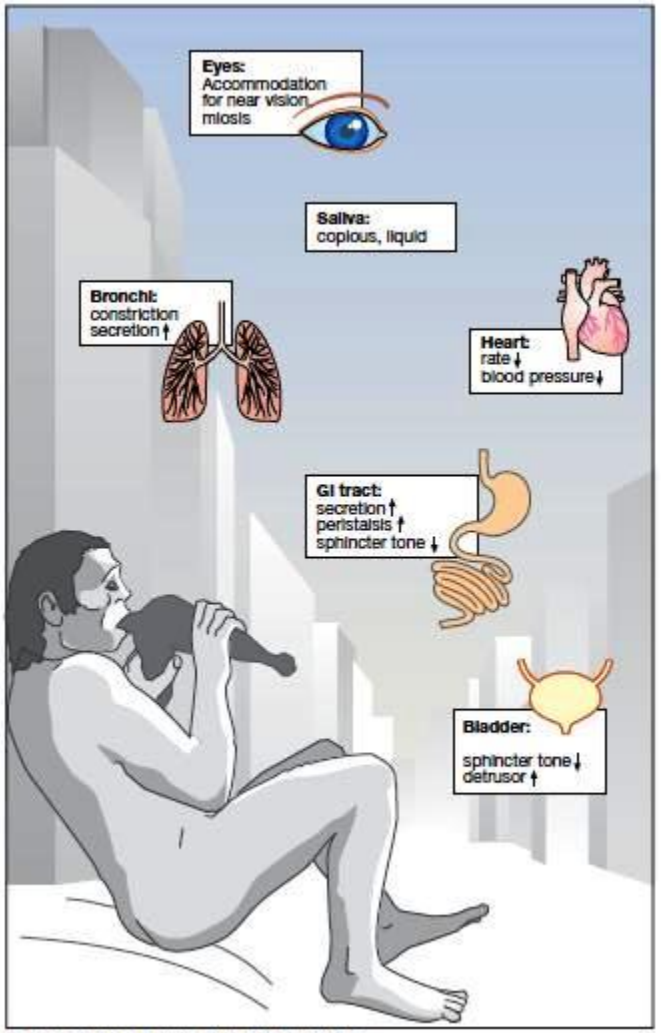
III. Parasympathetic Nervous System

A. Governs normal activity.

B. "Opposite" to Sympathetic system.

C. Promotes all the internal responses associated with a relaxed state.

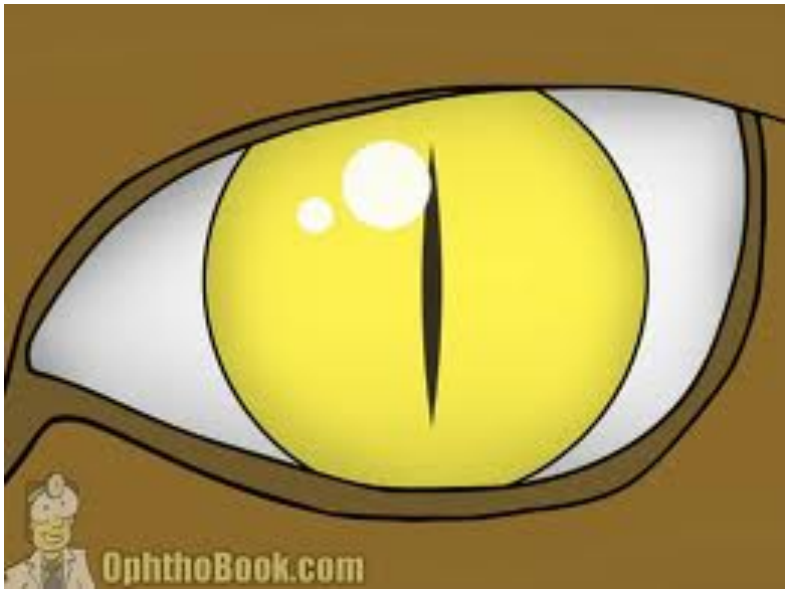
- Relax and Renew



A. Responses to parasympathetic activation

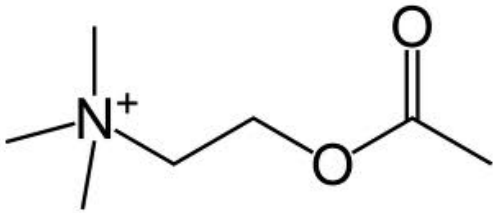
D. For example, it causes the following:

1. Contracts pupils
2. Diverts energy for digestion of food
3. Decreases heart rate



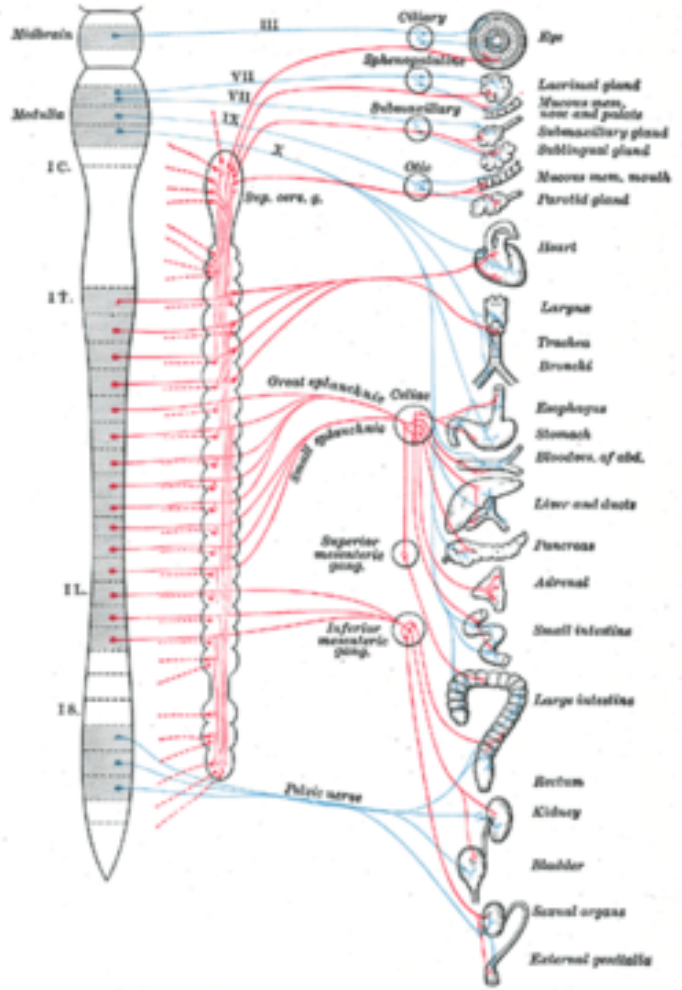
E. Neurotransmitter released is

ACETYLCHOLINE.

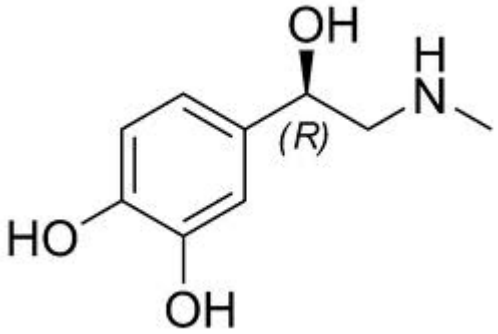


F. Fibers for this system arise from the cranial and sacral part of spinal cord.

1. **Preganglionic fiber is long.**
2. **Postganglionic fiber is short because the ganglia lie near or within the organ.**



Adrenalin



A. Hormone produced by the medulla (inner layer) of the adrenal glands:

1. **Adrenal glands are located on top of each kidney.**

B. Responsible for maintaining the "fight or flight" response.

C. Secreted in times of emergency or stress.