NERVOUS SYSTEM

The **nervous system** is the part of an animal's body that coordinates its actions and transmits signals to and from different parts of its body.

In vertebrate species it consists of two main parts, the central nervous system (CNS) and the peripheral nervous system (PNS).

The CNS contains the brain and spinal cord. The PNS consists mainly of nerves, which are enclosed bundles of the long fibers or axons, that connect the CNS to every other part of the body.

Nerves that transmit signals from the brain are called *motor* or *efferent* nerves, while those nerves that transmit information from the body to the CNS are called *sensory* or *afferent.*

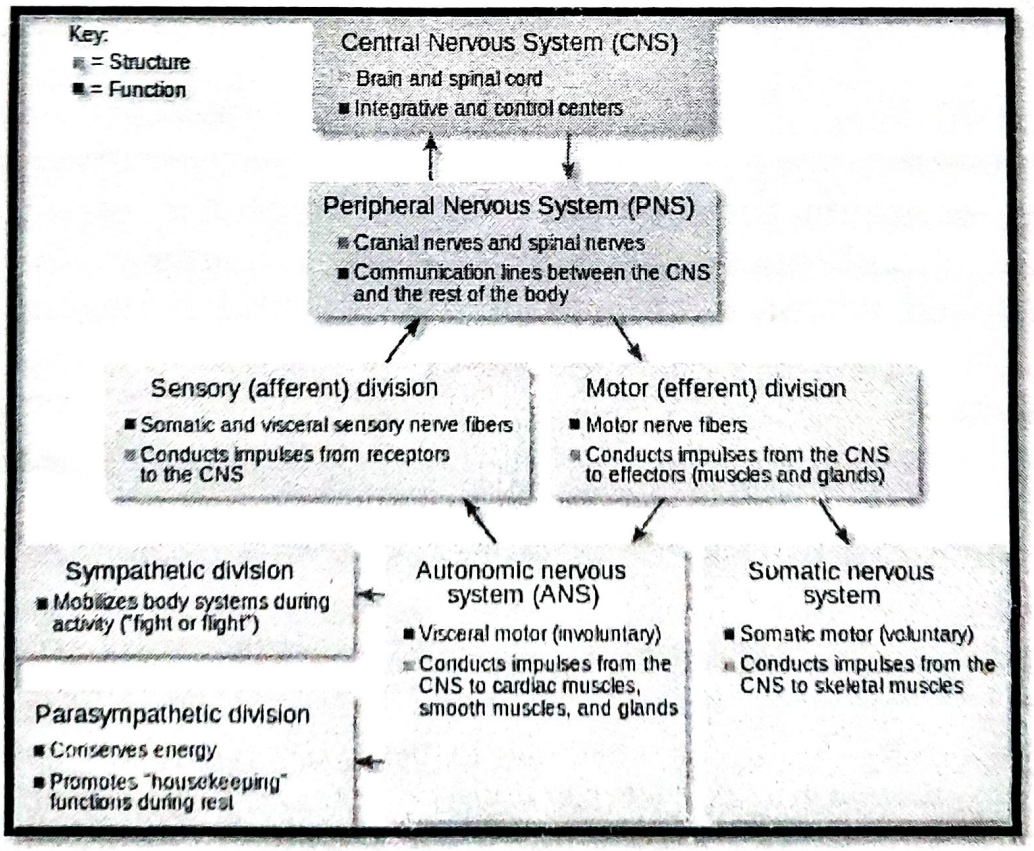
The PNS is divided into a) somatic and b) autonomic nervous system, and c) the enteric nervous system.

Somatic nerves mediate voluntary movement.

The autonomic nervous system is further subdivided into the sympathetic and the parasympathetic nervous systems.

The sympathetic nervous system is activated in cases of emergencies to mobilize energy, while the parasympathetic nervous system is activated when organisms are in a relaxed state.

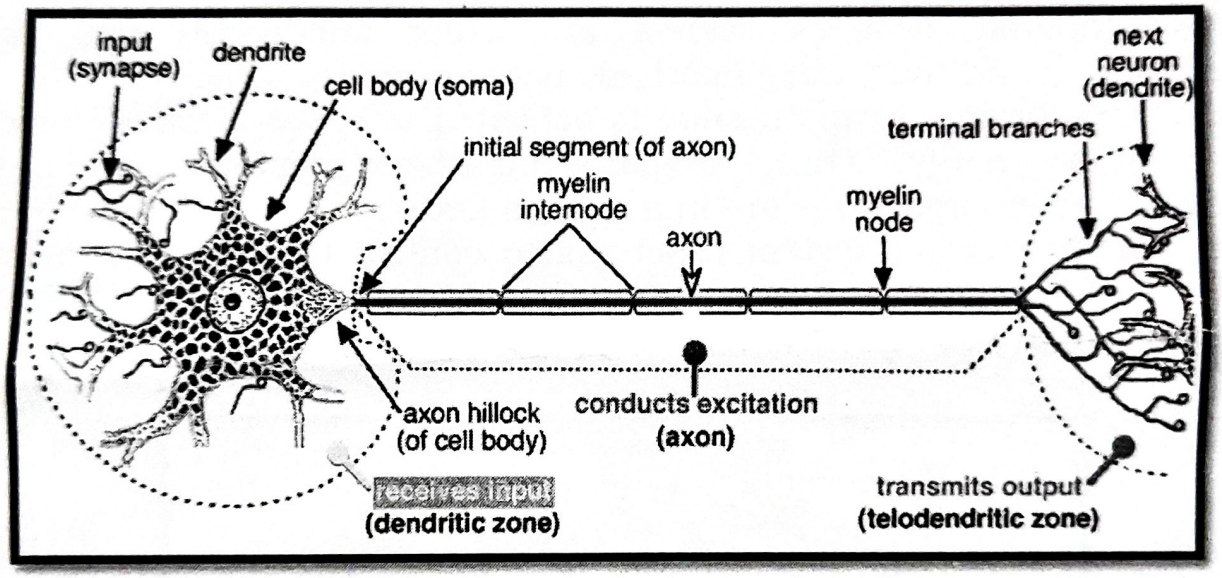
The enteric nervous system functions to control the gastrointestinal system. Both autonomic and enteric nervous systems function involuntarily.



At the cellular level, the nervous system is defined by the presence of a special type of cell, called the neuron, also known as a "nerve cell". Neurons have special structures that allow them to send signals rapidly and precisely to other cells. They send these signals in the form of electrochemical waves traveling along thin fibers called axons, which cause chemicals called neurotransmitters to be released at junctions called synapses.
A cell that receives a synaptic signal from a neuron may be excited, inhibited, or otherwise modulated.

Types of cells in the nervous system
It is made up of two types of cells
1. Neurons-Functional units
2.Glial cells

Structure of a multipolar neuron



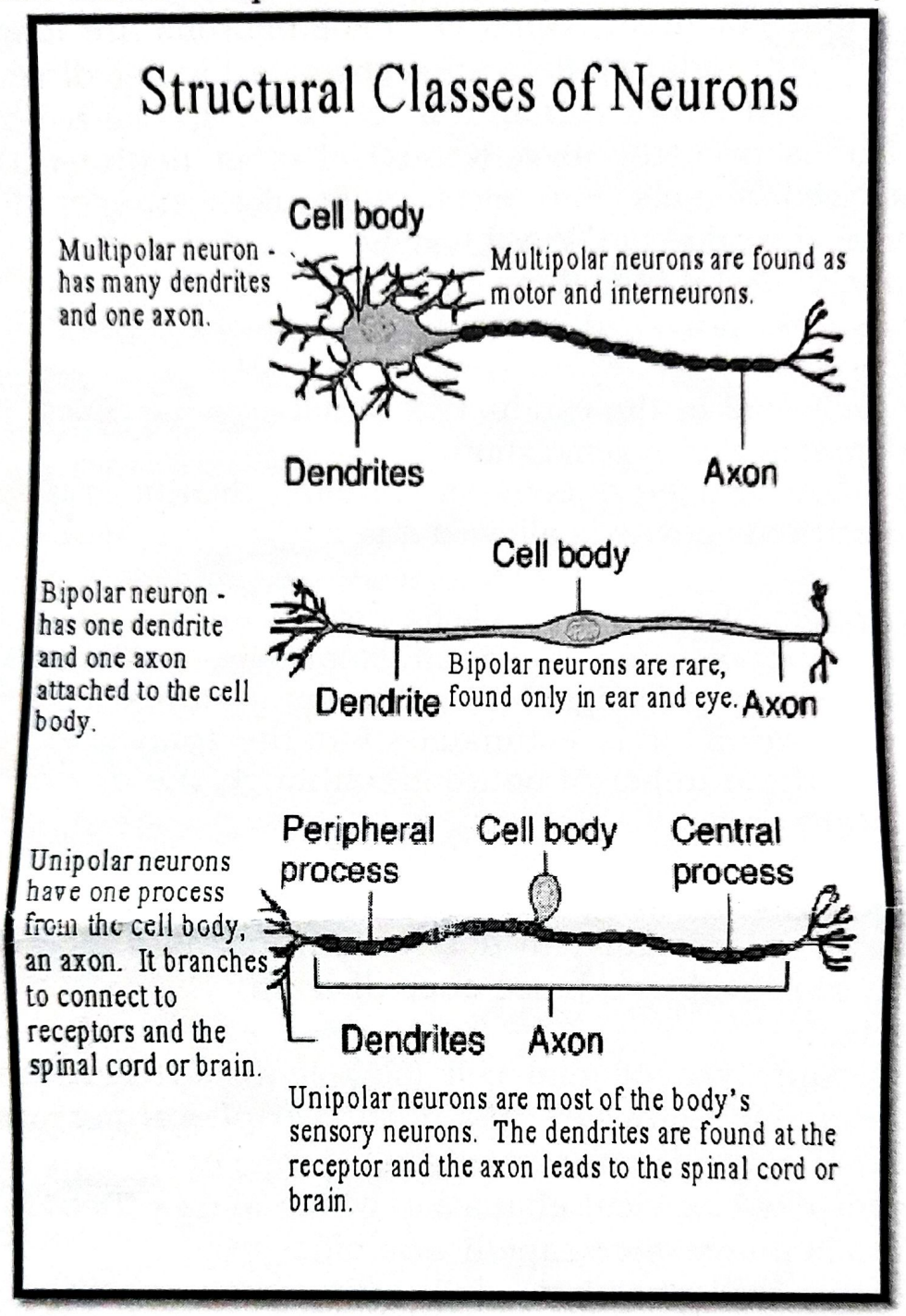
–Cell Body- contains the nucleus; site of synthesis of all neuronal proteins and membranes. Contains Lysosomes; aids in degradation. This is enclosed within a plasma membrane and contains a central nucleus.
–Axon- The **axon** is typically a long, slender process of the cell body that sends nerve impulses. It emerges from the cell body at the cone□shaped axon hillock. Nerve impulses arise in the trigger zone, generally located in the initial segment, an area just outside the axon hillock.
The cytoplasm of the axon, the **axoplasm,** is surrounded by its plasma membrane, the **axolemma.**
At its end, each axon or axon collateral usually forms numerous branches (**telodendria**), with most branches terminating in bulb□shaped structures called synaptic knobs (synaptic end bulbs, also called terminal boutons).

The synaptic knobs contain neurotransmitters, chemicals that transmit nerve impulses to a muscle or another neuron.
Axons are specialized for the conduction of a type of electrical impulse called an action potential. Axons of motor neurons are long and its terminal end branched. Impulses are transmitted in one direction.
-Dendrites- extend outward from the cell body; specialized to receive chemical signals from the axon termini of other neurons. Dendrites convert received signals into electric impulses transmitting them inwards in the direction of the cell body.
-Axon Terminal; Distal branching end
-Myelin Sheath- provides insulation; increases speed at which impulses travel
-Schwann Cells- aid in the conduction of nervous impulses; promotes nerve development and regeneration
-Nodes of Ranvier- gaps between myelin sheath; not insulated therefore, electrical activity is allowed and hence generated.

Glial cells (named from the Greek for "glue") are non-neuronal cells that provide support and nutrition, maintain homeostasis, form myelin, and participate in signal transmission in the nervous system.
In the human brain, it is estimated that the total number of glia roughly equals the number of neurons, although the proportions vary in different brain areas.
Among the most important functions of glial cells are to support neurons and hold them in place; to supply nutrients to neurons; to insulate neurons electrically; to destroy pathogens and remove dead neurons; and to provide guidance cues directing the axons of neurons to their targets.
A very important type of glial cell (oligodendrocytes in the central nervous system, and Schwann cells in the peripheral nervous system) generates layers of a fatty substance called myelin that wraps around axons and provides electrical insulation which allows them to transmit action potentials much more rapidly and efficiently.
Recent findings indicate that glial cells, such as microglia and astrocytes, serve as important resident immune cells within the central nervous system.

Types of neurons based on structure:
A**multipolar neuron**has many poles or processes, the dendrites and the axon. Multipolar neurons are found as *motor neurons* and *interneurons.*
There are also **bipolar neurons** with two processes, a dendrite and an axon, and **unipolar neurons**, which have only one process, classified as an axon.

Unipolar neurons are found as most of the body's *sensory neurons.* Their dendrites are the exposed branches connected to receptors, the axon carries the action potential in to the central nervous system.



Types of neurons based on function:

motor neurons - these carry a message to a muscle, gland, or other effector. They are said to be ***efferent***, i.e. they carry the message *away* from the central nervous system.

sensory neurons - these carry a message in to the CNS. They are ***afferent***, i.e. going *toward* the brain or spinal cord.

interneuron (a.k.a. association neuron, connecting neuron) - these neurons connect one neuron with another. For example in many reflexes interneurons connect the sensory neurons with the motor neurons.

Mechanism of Transmission of Nerve Impulse

All the nerve fibres carry information in the form of nerve impulse.

Nerve impulse is the sum total of physical and chemical disturbances created by a stimulus (electrical, chemical or mechanical) in a neuron or nerve fibre which result in the movement of a wave along the nerve fibre.

The nerve fibre or axon is like a cylinder, the interior of which is filled with axoplasm (i.e., the cytoplasm of the nerve cell) and the exterior of which is covered with a thin membrane, the axon membrane or axolemma.

The axon is immersed in the extracellular fluid (ECF). Through axolemma movement of solute takes place between the axoplasm and ECF.

Generally the solutes in ECF and axoplasm are in ionic form. In the axoplasm -vely charged protein molecules are present which are neutralized due to the presence of large amount of K^+ ions.

In the ECF (outside the axon) the -vely charged CI^- ions are neutralized by the presence of +vely charged Na^+ ions.

Conduction of nerve impulse is an electro-chemical process. Membrane of a non-conducting nerve cell or neuron is positive on the outside and negative inside. The difference in charge is about -70 to -90 millivolts which is called as resting potential and the membrane is said to be polarized. To maintain resting potential, sodium potassium metabolic pump operates.

This pump which is located on the axon membrane pump Na^+ from axoplasm to ECF and K^+ from ECF to axoplasm. It pumps more positive charges (3 Na^+) from axoplasm to ECF than in the reverse direction (2K^+), and is run by an enzyme called Sodium Potassium-ATPase. The concentration of sodium ions will be about 14 times more in ECF (outside) and concentration of potassium ions will be about 28-30 times more in axoplasm (inside).

When a stimulus (may be mechanical, electrical or chemical) is applied to the membrane of the nerve fibre, its permeability changes and sodium potassium pump stop operating. Sodium ions rush inside and potassium ions rush outside. This results in the positive charge inside and negative charge outside.The nerve fibre is said to be in action potential or depolarized.

The resting potential inside the membrane is about -70 mV and the action potential inside the membrane is about +30 mV.

An action potential is defined as the potential difference between the depolarized and resting regions of the neuron.

The travelling of action potential along the membrane is a nerve impulse.

After a period of action potential, at the site of stimulus the permeability of membrane to Na+ is very short lived and there is an increase in the permeability to K+ ions.
Again sodium pump operates and the potassium ions will diffuse from the axoplasm to the ECF and axon membrane will get back resting potential and the membrane is said to be repolarized.

After depolarization the membrane returns back to the polarized state at the point of stimulus and this phenomeneon is defined as repolarization.

Refractory period is the period of complete inexcitibility (restoration of nerve fibre) between deplorization and repolarization (1-6 milli seconds in mammals). During refractory period nerve fibre never transmits impulse.

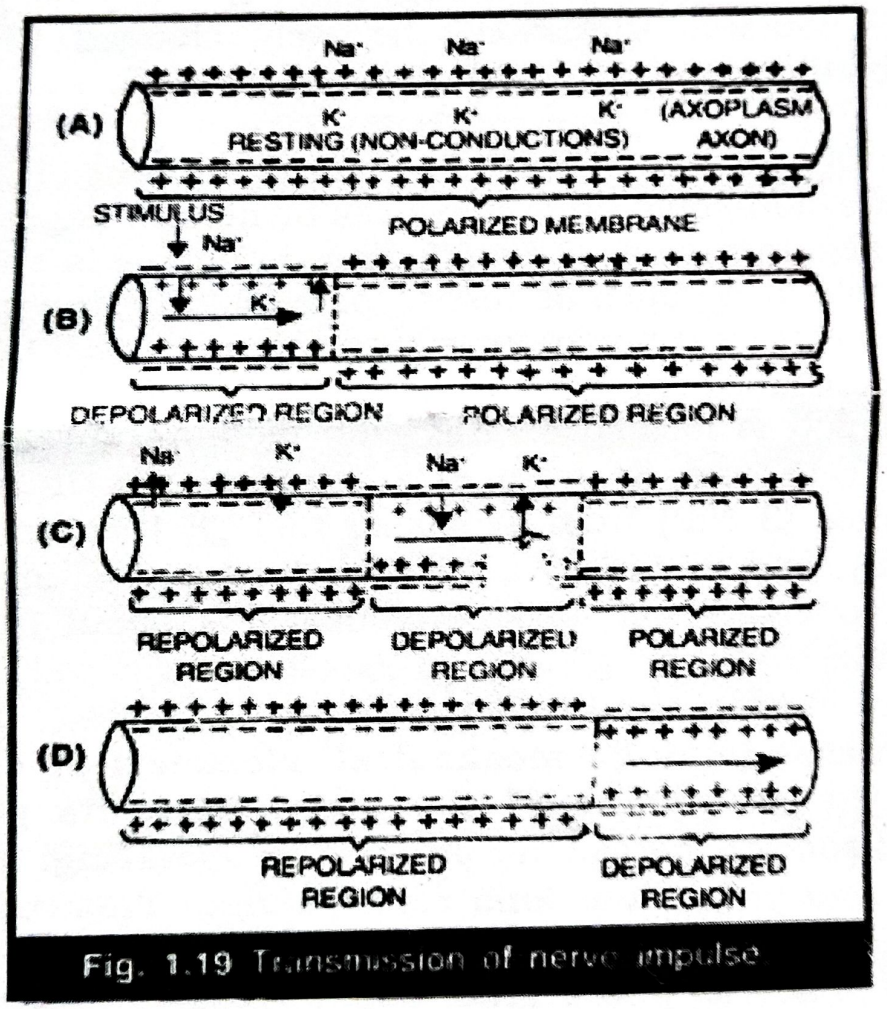


Fig. 1.19 Transmission of nerve impulse

Saltatory conduction

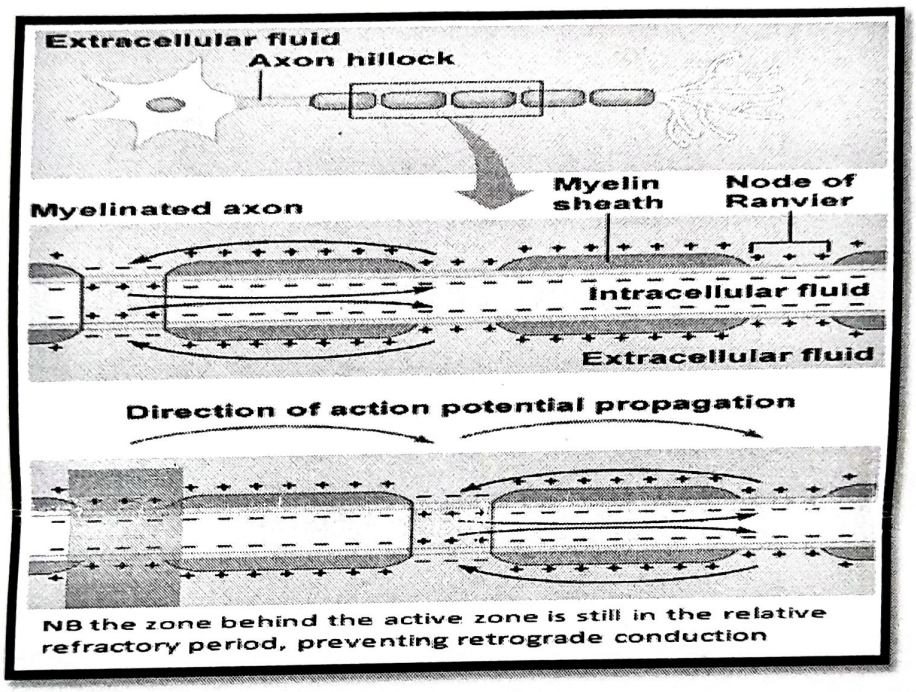
In medullated nerve fibres, the impulse jumps from node to node, it is called saltatory propagation. Myelin acts as an insulator, since ions are not able to cross its non-water barrier. Myelin is formed around the axon in sheaths, in between which are gaps known as *Nodes of Ranvier,* where the membrane is exposed to the ECF and the voltage gated channels are concentrated.

Saltatory conduction occurs, again, due to the movement of charge. However, the charge 'jumps' between the nodes of Ranvier (they are close enough to allow this to happen, but far enough away to maximise the distance of conduction).

It increases the speed of nerve impulse which is about 20 times faster in medulated than in non-medullated nerve fibres.

The speed of transmission of nerve impulse also depends upon the diameter of the fibre. Fibres with larger diameter conduct impulse faster.

The velocity of conduction of nerve impulse of mammal is 120 metres per second. The threshold value of any nerve fibre is the minimum strength of stimulus which initiates action potential in that nerve fibre.



Synaptic Transmission

A synapse is the functional junction between two neurons presynaptic and post synaptic or between a neuron and a cell.

There are two types of synapses

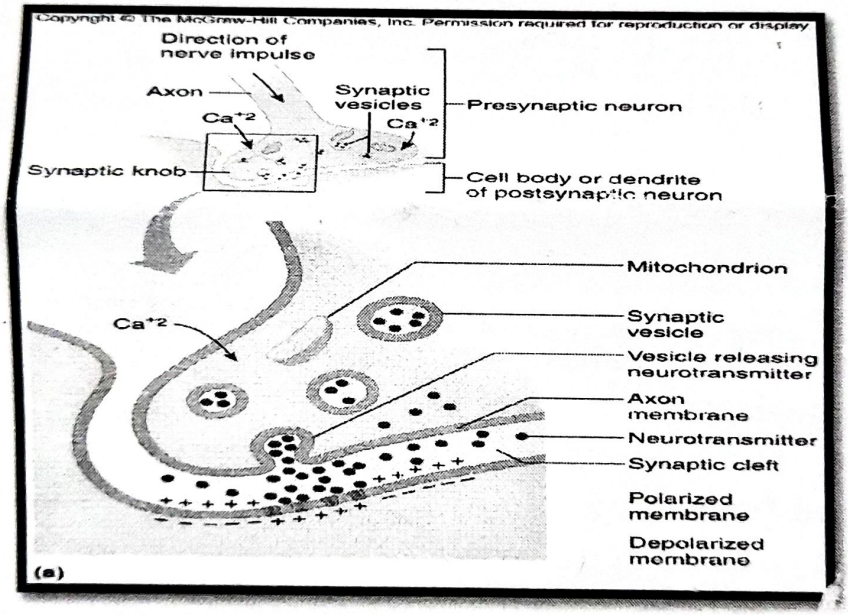
1. **Electrical synapse**
2. **Chemical synapse**

Electrical synapse	**Chemical synapse**
1. The membrane of presynaptic and post synaptic neurons are in close proximity there is no synaptic cleft	1. The membrane of presynaptic and post synaptic neurons are separated by a fluid filled synaptic cleft
2. Electric current can flow directly from one neuron to the next neuron	2. Transmissioninvolves chemicals called neurotransmitters

3. Impulse conduction is faster	3. Impulse conduction is slower
4. Electrical synapses are very rare in human body	4. Most common type of synapses in human bosy

Synaptic transmission is the mechanism that transmits a signal from the **pre-synaptic** neuron to the **post-synaptic** neuron.
An action potential causes the release of **neurotransmitters** from the presynaptic cell that diffuse across the synapse and bind to the postsynaptic cell.
Steps involved in Synaptic Transmission

1. A nerve impulse (action potential) travels down the axon to the axon terminal.
2. The action potential opens calcium channels causing calcium to diffuse into the synaptic knob.
3. The calcium influx triggers the release of neurotransmitters from synaptic vesicles into the synapse.
4. The neurotransmitters diffuse across the synapse and bind to receptors on the post-synaptic cell



Neurotransmitters are the chemicals which allow the transmission of signals from one neuron to the next across synapses. They are also found at the axon endings of motor neurons, where they stimulate the muscle fibers.Some neurotransmitters are inhibitory whereas others are excitatory, so the post-synaptic cell may be stimulated or it may be inhibited depending on the neurotransmitter.

Serotonin

Serotonin is an inhibitory neurotransmitter that has been found to be intimately involved in emotion and mood. Too little serotonin has been shown to lead to depression, problems with anger control, obsessive-compulsive disorder, and suicide. Too little also leads to an

increased appetite for carbohydrates (starchy foods) and trouble sleeping, which are also associated with depression and other emotional disorders.
serotonin also plays a role in perception. Hallucinogens such as LSD, mescaline, psilocybin, and ecstasy work by attaching to seratoninreceptor sites and thereby blocking transmissions in perceptual pathways.

GABA (gamma aminobutyric acid), which is also usually an inhibitory neurotransmitter. GABA acts like a brake to the excitatory neurotransmitters that lead to anxiety. People with too little GABA tend to suffer from anxiety disorders, and drugs like Valium work by enhancing the effects of GABA. Lots of other drugs influence GABA receptors, including alcohol and barbituates. If GABA is lacking in certain parts of the brain, epilepsy results.

Endorphin

Endorphin is short for "endogenous morphine." It is structurally very similar to the opioids (opium, morphine, heroin, etc.) and has similar functions: Inhibitory, it is involved in pain reduction and pleasure, and the opioid drugs work by attaching to endorphin's receptor sites. It is also the neurotransmitter that allows bears and other animals to hibernate.

The main excitatory neurotransmitters in the body are acetyl choline dopamine, norepinephrine, epinephrine glutamate.

Acetylcholine

Acetylcholine was the first neurotransmitter to be discovered.Acetylcholine has many functions: It is responsible for much of the stimulation of muscles, including the muscles of the gastro-intestinal system. It is also found in sensory neurons and in the autonomic nervous system, and has a part in scheduling REM (dream) sleep.

There is a link between acetylcholine and Alzheimer's disease: There is something on the order of a 90% loss of acetylcholine in the brains of people suffering from Alzheimer's, which is a major cause of senility.

Dopamine plays a number of important functions in the brain. It is very important in the reward system whereby we feel pleasure, achieve heightened arousal and do much of our learning. Every type of reward that has been studied increases the level of dopamine transmission in the brain. A wide variety of highly addictive drugs, including cocaine and amphetamines (i.e., methamphetamine, "speed", Adderall, Vyvanse, Dexedrine) act directly on the dopamine system. Dopamine also helps with focus, concentration and memory as well as motivation. Several important diseases are associated with

dysfunctions in the dopamine system, including Parkinson's disease, schizophrenia, restless leg syndrome and ADD/ADHD.

Norepinephrine is made from dopamine and plays many roles it the body. It along with epinephrine are responsible for the "fight-or-flight" response to stress, which increases your heart-rate, increases blood sugar and increases blood flow to the muscles to allow you to act or react to stressors. Norepinephrine also affects blood pressure and heart rate, although it's most widely known impact is on alertness, arousal, decision making, attention and focus.

Epinephrine (also known as adrenaline) is released in reaction to stress and is partially responsible for the "fight-or-flight" response. It affects a number of important functions, including heart rate, breathing and blood pressure. Imbalances in epinephrine can lead to "adrenaline junkies", a term that is often used to describe people that seem to enjoy stress and stressful activities. Unfortunately, they also usually suffer from constant need for urgency, have trouble relaxing or sleeping and keep 'the pedal to the medal' as they race through life.

Glutamate is the most abundant excitatory neurotransmitter in the human brain. It plays key roles in cognitive functions like learning and memory. Imbalances in glutamate levels are associated with Alzheimer's disease, seizures and forms of autism.