• The nervous system is the system that keeps us in contact with the outside world. It tells us that we exist, and allows us to move and react to stimuli. Our thoughts and emotions reside in our nervous system.

• The nervous system is composed of nerve cells called neurons and many neurons together form a nerve.
Nervous system has **two major divisions**:

1. **Central Nervous System**: (CNS) - includes spinal cord and brain. In the "center" of the body.
2. **Peripheral Nervous System**: (PNS) - the rest of the nervous system (nerves)
Nerve Cells are called “Neurons” - what is their structure?

- All neurons have three parts:
  i) **DENDRITE(s)** - conduct nerve impulses **towards** the
  ii) **CELL BODY**
  iii) **AXON** (conducts impulses **away** from the cell body).

- Dendrites and axons are sometimes called **FIBERS**. Most long fibers are covered by a **MYELIN SHEATH**, a fatty substance for insulating the axons. The sheath has spaces in it exposing the axon called **NODES OF RANDIER**. The sheath is secreted by **SCHWANN CELLS**, each of which has a nucleus.
There are three types of neurons:

1. **SENSORY NEURON** (= *afferent* neuron) - takes a message from a sense organ to CNS. has **long** dendrite and **short** axon.
2. **MOTOR NEURON** (= *efferent* neuron) - takes message away from CNS to a muscle fiber or gland. **Short** dendrites, **long** axon.
3. **INTERNEURON** (= *association* neuron): completely contained within CNS. Conveys messages between parts of the system. Dendrites, axons, may be long or short.
Nerve Conduction is an **ELECTROCHEMICAL CHANGE** that moves in **one direction** along the length of a nerve fiber. It is electrochemical because it involves **changes in voltage** as a result of a change in the **concentrations of certain ions**.
• There are 3 phases in the generation of a nerve impulse along an axon: the RESTING phase, the ACTION phase and the RECOVERY phase.

• **RESTING POTENTIAL (VOLTAGE):** -60 mV. This negative polarity is caused by the presence of large organic negative ions in the axoplasm (the cytoplasm inside an axon).

• During the resting potential, Na+ ions are more concentrated on the outside of the membrane and K+ ions are more on the inside of the axon.

• This uneven distribution of K and Na ions is maintained by active transport across Na+/K+ pumps.
**ACTION POTENTIAL**: if nerve is stimulated a **nerve impulse** is generated. This nerve impulse is called the **ACTION POTENTIAL (AP)**.
- The AP can be broken into an **upswing** and **downswing**.
- During the **upswing** (-60 mV to +40 mV), membrane "depolarizes". Na⁺ ions move from outside to inside of axon.
- In the **downswing** (+40 mV to -60 mV), membrane “repolarizes”. K⁺ moves from outside to inside of axon.

**RECOVERY PHASE**: (Hyperpolarization) between nerve impulses, K⁺ ions are returned to inside of axon, Na⁺ to the outside **actively** by Na⁺/K⁺ pump. slowly.
Overview: The graph represents what occurs in during an action potential

The graph dips below resting potential because the K⁺ gates closes. This is known as hyperpolarization.
The speed of nerve impulses is quite rapid because of the MYELIN SHEATH, produced by the Schwann cells, and the gaps between the sheath called the NODES OF RANVIER. This sheath gives nerves their characteristic white appearance. The reason for the speed is that the nerve impulse "jumps" from node to node in myelinated fibers.
Transmission of Impulses across Synapses

- When a nerve impulse reaches the **end** of an axon, the impulse must travel across a region called a **SYNAPSE**.

- **Synapse**: the region between end of an axon and the cell body or dendrite to which it is attached.
- **Synaptic Endings**: knobs on the ends of axon.
- **Presynaptic Membrane**: the membrane of the axon synaptic ending (before synapse).
- **Postsynaptic Membrane**: the membrane of the next neuron after the synapse.
- **Synaptic Cleft**: the space between the presynaptic and the postsynaptic membranes.
- **Neurotransmitters**: chemicals that transmit the nerve impulses across a synaptic cleft.
- **Synaptic Vesicles**: contain the neurotransmitters.
- **Acetylcholine** (Ach), **Noradrenalin** (NA), **Serotonin**, **Adrenalin** (epinephrine) are some important neurotransmitters.
Transmission across a synapse is **one-way** because only the **ends of axons** have synaptic vesicles that release **neurotransmitters**.
• **STIMULATION** or **INHIBITION** of postsynaptic membranes can occur.

• **SUMMARY EFFECT:** If amount of excitatory neurotransmitters received is sufficient to overcome the amount of inhibitory neurotransmitters received, the neuron fires. If not, the impulse stops.

- **Excitatory transmitters** include ACETYLCHOLINE, ADRENALIN (epinephrine), NORADRENALIN, SEROTONIN, and DOPAMINE.
- **Inhibitory transmitters** include GABA, glycine, and Serotonin.
- The neurotransmitters include endorphins and enkephalins which function as a natural pain reliever in brain. Opium and heroin mimic these.
Step for the transmission of an impulse across the Synapse

Steps 3-7 are steps you need to know!!!!!

*Note that the neurotransmitters are either reabsorbed or broken down by enzymes in the synaptic cleft

Enzymes in cleft: Acetylcholinesterase and monoamine oxidase
THE PERIPHERAL NERVOUS SYSTEM: voluntary and involuntary control

- The **PERIPHERAL NERVOUS SYSTEM** consists of nerves that contain **long dendrites** and/or **long axons**. The cell bodies are found only in the brain, spinal chord, and **GANGLIA**.

- **Ganglia** are **collections of cell bodies** within the PNS.

*The dorsal root ganglion is a collection of cell bodies.*
- **SOMATIC NERVOUS SYSTEM**: includes *all the nerves that serve the musculoskeletal system and is the voluntary part of the nervous system.*

The Reflex Arc  
A reflex arc showing the path of a spinal reflex

- **Reflexes** are **automatic, involuntary responses to changes occurring inside or outside the body.** Can involve the brain (e.g. blinking) or not involve brain (e.g. withdraw hand from hot stove).
- The **Reflex arc** allows us to **react to internal and external stimuli.**
Path of a simple Reflex Arc:
1. **Receptor** - generates a nerve impulse
2. **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, into the spinal cord. Pass impulse to interneuron.
3. **Interneuron** - passes message to motor neuron
4. **Motor neuron** - takes message away from CNS to axon of spinal nerve
5. **Effector** - receives nerve impulses and reacts: glands secrete and muscles contract
THE AUTONOMIC NERVOUS SYSTEM

• is *part of the PNS* - made of motor neurons that control the internal organs **AUTOMATICALLY**.
• Autonomic nervous system is divided into **SYMPATHETIC** and **PARASYMPATHETIC** nervous systems. These two systems connect to the same organs by have **opposite effects**.
SYMPATHETIC NERVOUS SYSTEM:
- is especially important during EMERGENCY SITUATIONS and is associated with "FIGHT OR FLIGHT" reaction. For example, in an emergency, it causes the following:
  - energy directed **away from** digestion
  - pupils **dilate**
  - heart rate increases
  - breathing rate increases
  - perspiration rate increases
  - salivation decreases
- the **neurotransmitter** released Sympathetic nervous system is NORADRENALIN (which is closely related to adrenalin -- a known heart stimulant).
PARASYMPATHETIC NERVOUS SYSTEM

- The parasympathetic System promotes all the internal responses associated with a **RELAXED** state. For example:
  - causes the pupils to contract
  - energy diverted for digestion of food
  - heart rate slows
  - breathing rate slows
- Neurotransmitter in this system is **ACETYLCHOLINE**.
THE CENTRAL NERVOUS SYSTEM

- The CNS consists of the **BRAIN** and **SPINAL CORD**.
- In the CNS **sensory information is received** and **motor control is initiated**.
- **Protected** by **BONE** (skull, vertebrae). Cerebrospinal fluid is found within **central canal** of the spinal cord and **ventricle** of brain.

**Spinal Cord: the nervous system’s “superhighway”**

- contains **central canal** filled with **cerebrospinal fluid**
THE BRAIN

• The brain itself contains parts which function in the coordination of movement, sensing, & consciousness. The brain consists of hundreds of billions of neurons. You had the maximum number of neurons when you were born. Thousands are lost daily.
THE CONSCIOUS BRAIN: THE CEREBRUM OR THE CEREBRAL CORTEX

- **CEREBRUM** - largest, most prominent, most highly developed portion of the brain.
- **Consciousness** resides only in this part of the brain.
- **Intellect, learning, memory, sensations** are formed here.
- Divided into right and left **HEMISPHERES**, with **FOUR LOBES**:
  1. **FRONTAL** - movement, higher intellectual processes (e.g. problem solving, concentration, planning, judging the consequences of behavior, moving your tongue and mouth to speak.
  2. **PARIETAL** - sensations e.g. touch, temperature, pressure, pain. Understanding **speech**, using words
  3. **TEMPORAL** - hearing, smelling, **interpretation** of experiences, **memory** of visual scenes, music, and complex sensory patterns.
  4. **OCCIPITAL** - vision, combining visual experiences with other sensory experiences.
The Unconscious Brain

• **MEDULLA OBLONGATA** - Lies closest to spinal cord. Controls **heart rate, breathing, blood pressure, reflex reactions** like coughing, sneezing, vomiting, hiccupping, swallowing. An "ancient" part of brain.

The Limbic System is involved in **EMOTIONS, MEMORY, and LEARNING.**

• **Amygdala:** Long term memory, emotional memory
• **Hippocampus:** Memory
THALAMUS - receives sensory information from all parts of the body and relays them to the cerebrum. Serves as a CENTRAL RELAY STATION for sensory impulses coming up spinal cord and other parts of brain to the cerebrum. Receives all sensory impulses (except for smell) and sends them to opposite side from which they originated.

- sorts out incoming stimuli, passing on to the cerebrum only those that require immediate attention. i.e. it lets you ignore your teacher talking so you can do other things like text.
• **CEREBELLUM** - controls **balance** and **complex muscular movement**. It is the **second largest portion of the brain**. Functions in **muscle coordination** and makes sure **skeletal muscles work together smoothly**.

*Try the finger test!*
• **HYPOTHALAMUS**: for regulation of homeostasis. It maintains internal environment, contains centers for hunger, sleep, thirst, body temperature, water balance, blood pressure. Controls **PITUITARY GLAND** (serves as a link between the nervous system and the endocrine (hormone) systems). The hypothalamus plays a role in sexual response and mating behaviors, and the “fight-or-flight” response, and **pleasure**.
CORPUS CALLOSUM - horizontal connecting piece between the two hemispheres of the brain. Transmits information between the two cerebral hemispheres.
DRUG ACTION AND NEUROTRANSMITTERS

• There are many drugs that are used to alter the mood and/or emotional state of the user. In general, mood-altering drugs particularly affect the limbic system, and they either promote or decrease the action of a particular neurotransmitter.
• There are basically 5 ways a drug can act:
  1. drug stimulates release of neurotransmitter.
  2. drug blocks release of neurotransmitter
  3. drug combines with neurotransmitter preventing its breakdown
  4. drug mimics neurotransmitter
  5. drug blocks receptor so neurotransmitter can't be received

These drugs can be as common as the caffeine found in coffee, or Nicotine which enhances the action of acetylcholine.
THE ACTION OF DRUGS ON NERVOUS SYSTEM

- **AMPHETAMINES** - structurally similar to noradrenalin (NA), stimulates release of NA and dopamine in brain. e.g. cocaine blocks the uptake of dopamine so it is present in the synaptic cleft longer. As dopamine is an excitatory neurotransmitter, this causes the “rush” that cocaine users experience.

- **METHAMPHETAMINE** (Ice) has the same stimulatory effects as cocaine, but its effects last longer.

- **MARIJUANA** (*Cannabis sativa*) leaves contain a resin rich in THC (tetrahydrocannabinol), which is marijuana’s active ingredient. It causes in many people a mild euphoria along with alterations in vision and judgment, which result in distortions of space and time. Smokers will often have a very hard time speaking coherently and concentrating.

- **LSD** - (lysergic acid diethylamide) - affects the action of serotonin and dopamine involved in vision and emotion -> produces visual and auditory hallucinations and bizarre sensory sensations. LSD can cause permanent brain damage! **Never** take this drug.

- **CAFFEINE** - acts as a stimulant

- **NICOTINE** - enhances the action of acetylcholine. One of the most addictive compounds known.
• **ALCOHOL** - enhances the action of the inhibitory transmitter **GABA**. Therefore it acts as a **depressant**. Habitual use can also damage areas of the brain (especially the hippocampus, which can cause **memory impairment**).

<table>
<thead>
<tr>
<th># of drinks</th>
<th>Blood ROH Level</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.02-0.03%</td>
<td>Changes in behavior, coordination, and ability to think clearly</td>
</tr>
<tr>
<td>2</td>
<td>0.05%</td>
<td>Sedation or tranquilized feeling</td>
</tr>
<tr>
<td>3</td>
<td>0.08</td>
<td>Legal intoxication in B.C. (it is lower in some other provinces)</td>
</tr>
<tr>
<td>5</td>
<td>0.15-0.20%</td>
<td>Person is obviously intoxicated and may show signs of delirium</td>
</tr>
<tr>
<td>12</td>
<td>0.30-0.40%</td>
<td>Loss of consciousness</td>
</tr>
<tr>
<td>24</td>
<td>0.50%</td>
<td>Heart and respiration become so depressed that they cease to function and <strong>death</strong> occurs.</td>
</tr>
</tbody>
</table>

• **NARCOTICS** such as **HEROIN** and **MORPHINE** block the transmission of pain signals, as they bind to receptors meant for the body's natural **opioids** (endorphins and enkephalins). Opioids are believed to relieve pain by preventing the release of a neurotransmitter that causes the sensation of pain from certain neurons in the spinal chord. Heroin addicts become physically dependent on the drug. With time, the body’s production of endorphins decreases. **Tolerance** develops so that the user needs to take more of the drug just to prevent **withdrawal symptoms**.