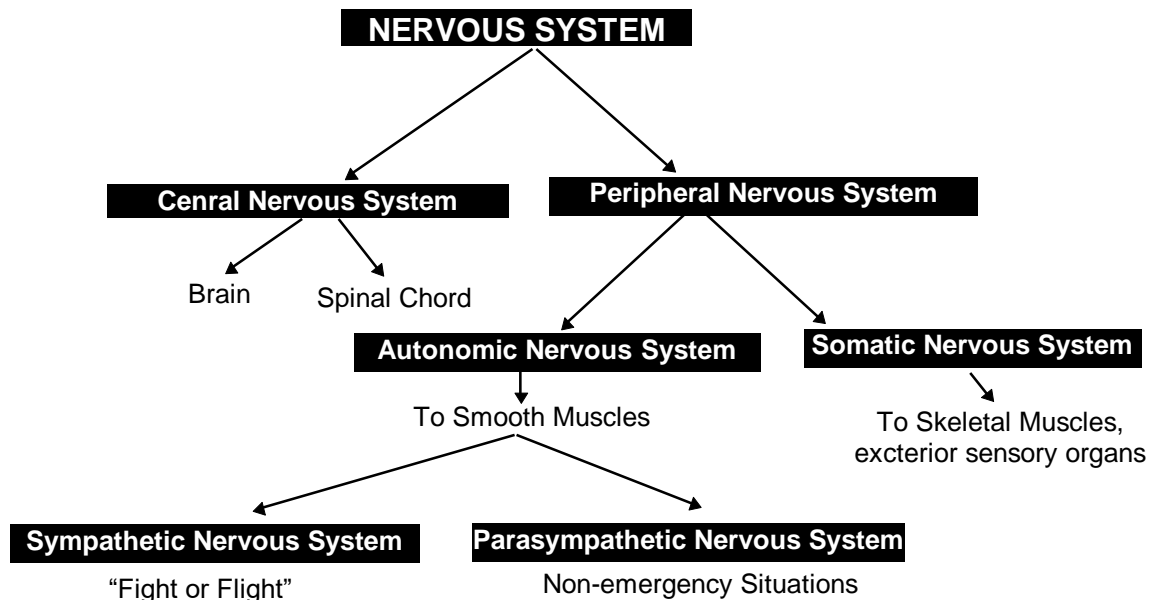
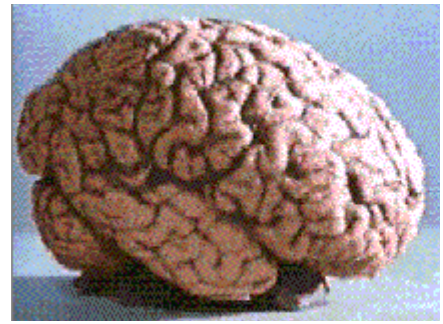


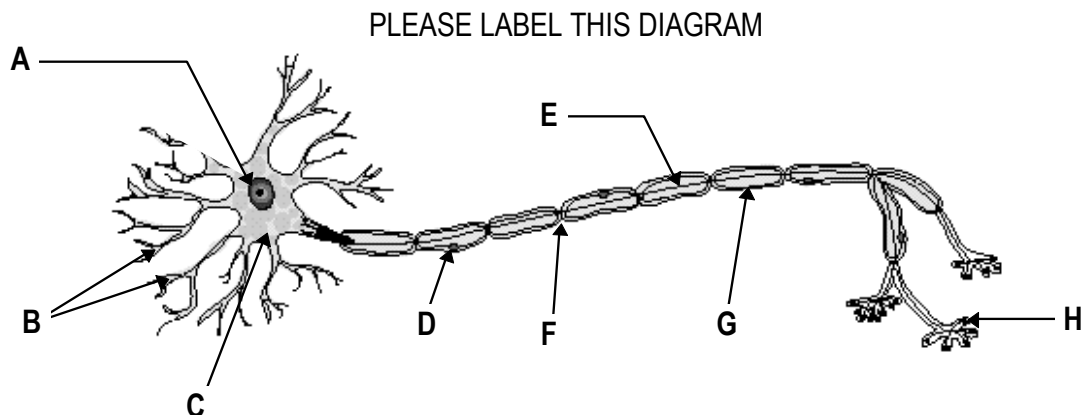
- The nervous system is our **processing system**, and the system that keeps us in contact with the outside world. It tells us that we exist, and along with the muscles allows us to move and react to stimuli. Our **consciousness** resides in our nervous systems, as do our thoughts and emotions.
- In short, the roles of the nervous system are: responsible for coordination of movement, response to environmental stimuli, intelligence, **self-awareness**, **thought**, **emotion**.
- **Composed** of nerve cells called **neurons**, which are specialized to carry nerve impulses.
- Nervous system has **two major divisions**: (the division is arbitrary; the two systems work together and are connected to one another). The two systems are:
  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: PNS is further divided into the **Somatic Nervous System** (connects to skeletal muscle) and **Autonomic Nervous System** (connects to smooth (involuntary) muscles). The Autonomic Nervous System is further divided into the **Sympathetic Nervous System** (usually causes effects associated with emergency situations) and the **Parasympathetic Nervous System** (promotes activities associated with a normal state).



**Nerve Cells** are called "**Neurons**" - what is their structure?

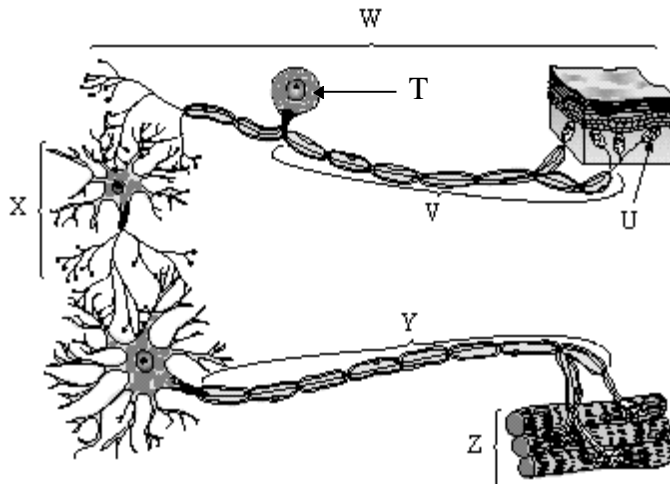
All neurons have three parts: i) **DENDRITE(s)** - conduct nerve impulses **towards** the ii) **CELL BODY** and **AXON** (conducts nerve impulses **away** from the cell body). Dendrites and axons are sometimes called **FIBERS**. Most

long fibers are covered by a **MYELIN SHEATH**. The sheath has spaces in it exposing the axon called **NODES OF RANVIER**. The sheath is secreted by **SCHWANN CELLS**, each of which has a nucleus.



There are three types of neurons:

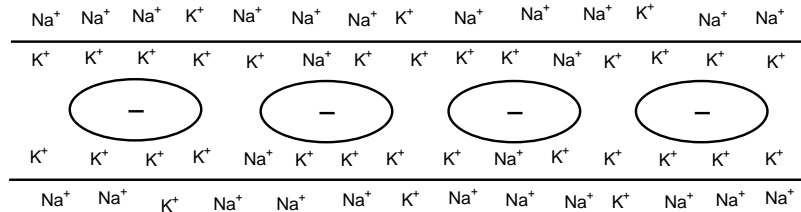
PLEASE LABEL



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 or connector neuron): completely contained within CNS. Conveys messages between parts of the system. Dendrites, axons, may be long or short.

### Generation and Transmission of Nerve Impulses

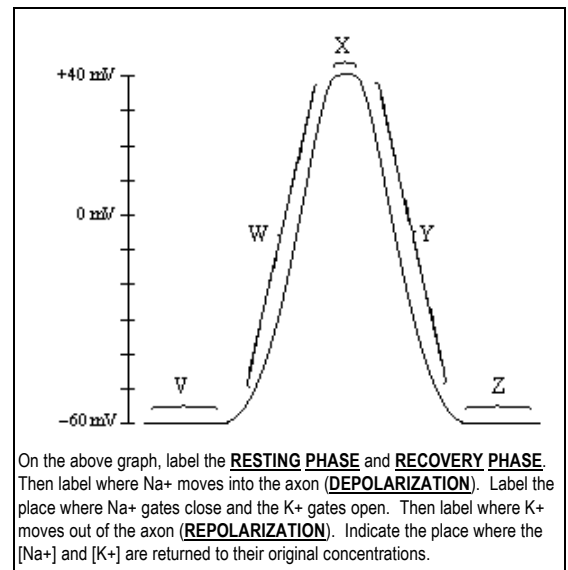
- Scientists used **giant axons in squids** to figure out how nerve impulses are generated.
- Nerve Conduction is an **ELECTROCHEMICAL CHANGE** that moves in **one direction** along the length of a nerve fiber. It is electrochemical because it involves **changes in voltage** as well as in the **concentrations of certain ions**. Since it is electric, we can use an **oscilloscope** (a type of voltmeter that shows a graph of voltage changes) to measure potential differences (voltages).



### Resting Potential

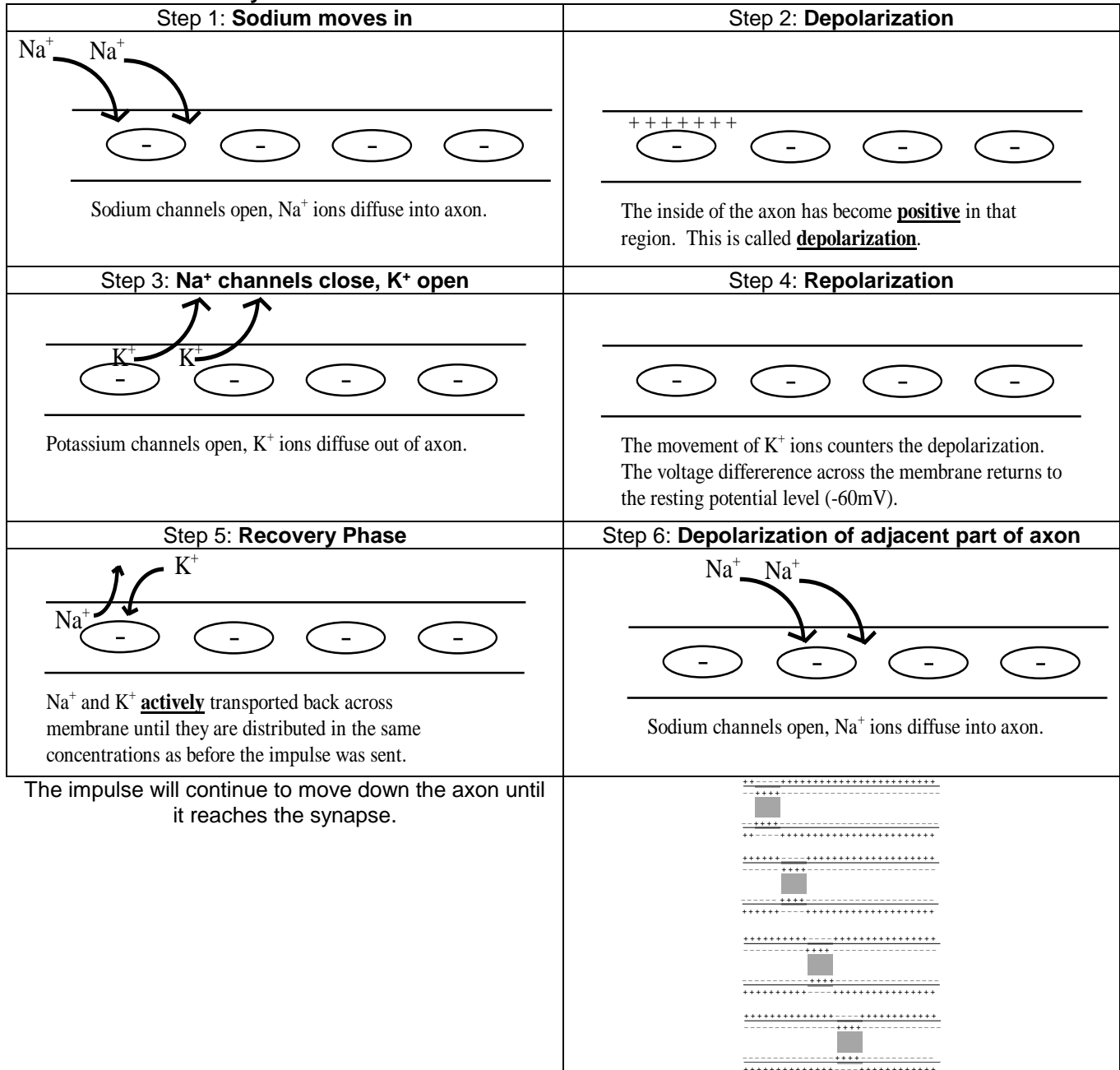
When **not** conducting impulses, there is a voltage difference across the membrane of the axon of about **-60 mV**. The negative charge on the inside of the axon is due to the presence of large negative ions. There are more sodium ions on the outside of the axon compared to the inside of the axon, and more potassium ions on the inside compared to the outside.

- We talk about **three distinct phases** in the generation of a nerve impulse along an axon: the **RESTING phase** and the **ACTION phase**, followed by a **RECOVERY phase**.
- **RESTING POTENTIAL:** the potential difference across the membrane of the axon when it is **NOT** conducting an impulse. equals **-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<sup>+</sup> ions** are **more concentrated on the outside** of the membrane than the **inside**.
- **K<sup>+</sup> ions** are **more concentrated on the inside of the axon**
- This **uneven distribution** of K and Na ions is maintained by **active transport** across **Na<sup>+</sup>/K<sup>+</sup> pumps** which operate whenever the neuron is not conducting an impulse.
- **ACTION POTENTIAL:** if nerve is stimulated by electric shock, pH change, mechanical stimulation, a nerve impulse is generated, and a **change in potential** can be

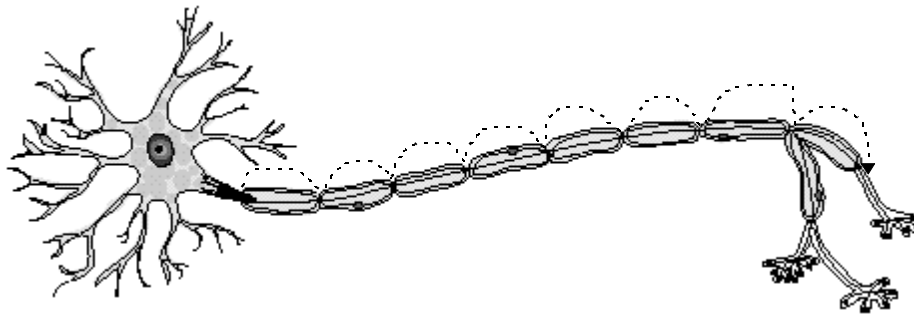


seen on the oscilloscope. This nerve impulse is called the **ACTION POTENTIAL**.

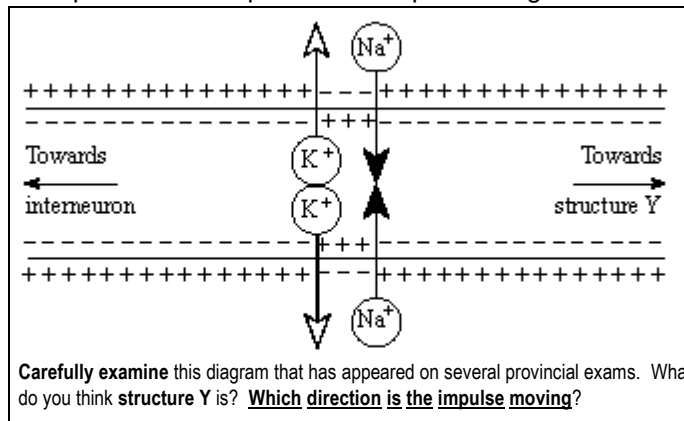
- On the oscilloscope, can be broken into an **upswing** and **downswing**.
- During the **upswing** (-60 mV to +40 mV), **membrane becomes permeable to Na<sup>+</sup> ions**. Na<sup>+</sup> ions move from outside to inside of axon (i.e. "**depolarization**" occurs -- the inside of the axon becomes **positive**).
- In the **downswing** (+40 mV to -60 mV), **membrane becomes permeable to K<sup>+</sup>**. K<sup>+</sup> moves from inside to outside of axon. This is called **repolarization** (since the inside of axon becomes **negative** again).
- **RECOVERY PHASE**: between transmissions, K<sup>+</sup> ions are returned to inside of axon, Na<sup>+</sup> to the outside. This is done **actively**.



- The speed of nerve impulses is **quite rapid**. This is due to the structure of the nerves. Specifically, the **MYELIN SHEATH** of most nerve fibers (this sheath is formed by tightly packed spirals of the cell membrane of **Schwann cells**) and the interruptions or gaps of the sheath called the **NODES OF RANVIER**. This sheath gives nerves their **characteristic white appearance**.



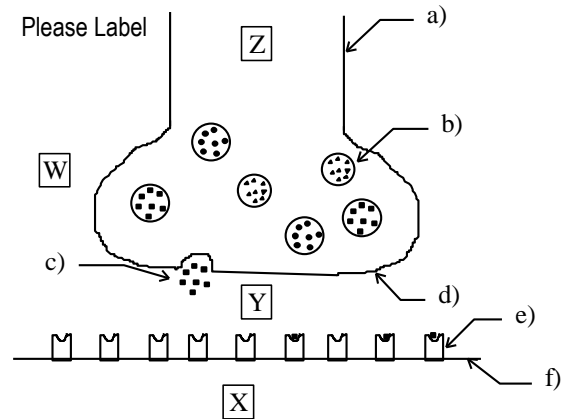
- The speed of transmission is **~200 m/s** in myelinated fibers, but only **0.5 m/s** in non-myelinated fibers.
- The reason is that the nerve impulse "**jumps**" **from node to node** in myelinated fibers. In non-myelinated fiber, the nerve impulse must depolarize and repolarize each point along the nerve fiber.

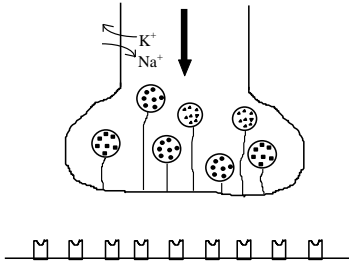
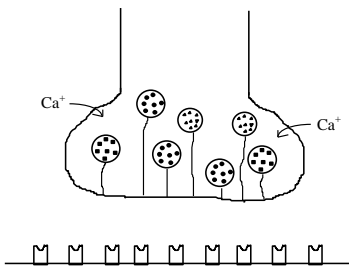
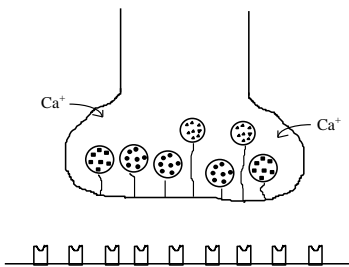
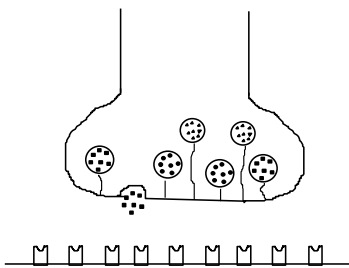
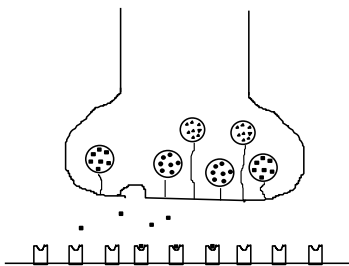
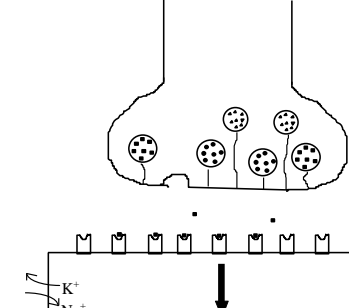


### Transmission of Impulses across Synapses

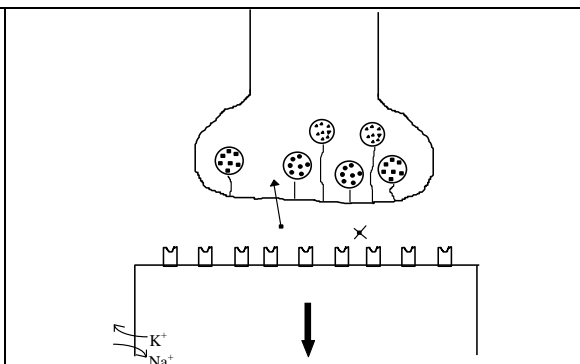
- *What happens to a nerve impulse once it reaches the **end** of an axon? How does one nerve communicate with another?* The answer lies in the specialized regions at the ends of axons called **SYNAPSES**.
- **Synapse**: the region between end of an axon and the cell body or dendrite to which it is attached.
- **Synaptic Endings**: swollen terminal knobs on the ends of axon terminal branches.
- **Presynaptic Membrane**: the membrane of the axon synaptic ending.
- **Postsynaptic Membrane**: the membrane of the next neuron just beyond the axon's synaptic membrane.
- **Synaptic Cleft**: the space between the presynaptic and the postsynaptic membranes
- **Neurotransmitter Substances** (neurotransmitters): chemicals that transmit the nerve impulses across a synaptic cleft.
- **Synaptic Vesicles**: contain the neurotransmitters. Contained near surface of synaptic endings.
- **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 are able to release **neurotransmitters** to affect the potential of the next neurons.
- **STIMULATION** or **INHIBITION** of **postsynaptic membranes** can occur.
- A neuron is on the receiving end of **many synapses** -- some may be giving inhibitory and some may give stimulatory impulses. Whether or not the neuron they are attached to fires depends on the **SUMMARY EFFECT** of all the excitatory neurotransmitters received.
- If amount of excitatory neurotransmitters received is sufficient to overcome the amount of inhibitory neurotransmitters received, the neuron fires. If not, only **local excitation** occurs. The total process allows neurons to **fine-tune to the environment**.

### Sequence of events:



<p>1. Nerve impulse travel along axon, reach a synaptic ending.</p>	
<p>2. Arrival of nerve impulse at synaptic ending changes membrane ----&gt; <b>Ca<sup>++</sup></b> flows into ending</p>	
<p>3. Ca<sup>++</sup> ions cause <b>contractile proteins to pull synaptic vesicles to inner surface</b> of the presynaptic membrane.</p>	
<p>4. <b>Vesicle fuses</b> with presynaptic membrane, <b>releasing neurotransmitters</b> into synapse.</p>	
<p>5. <b>Neurotransmitters diffuse across synaptic cleft to receptors</b> on postsynaptic membrane. The receptors control selective <b>ion channels</b>; binding of a neurotransmitter to its specific receptors <b>opens</b> the ion channels.</p>	
<p>6. The resulting ion flux (not shown on diagram) changes the voltage of the postsynaptic membrane. This either moves the membrane voltage closer to the <b>'threshold voltage'</b> required for an action potential (an excitatory synapse), or hyperpolarizes the membrane (an inhibitory synapse). In this case, the neurotransmitters binding to receptors on the dendrite causes the <b>nerve impulse to be transmitted down the dendrite of the second neuron</b>. The nerve impulse has now been transmitted from the first neuron to the second neuron.</p>	

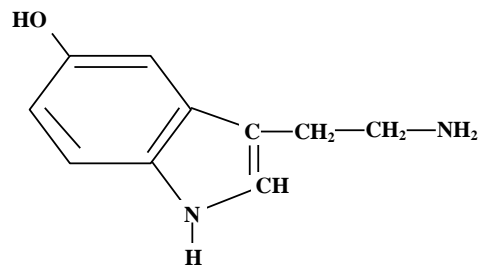
7. Neurotransmitters are quickly **deactivated** to prevent them from continually acting on postsynaptic membrane. This can occur by:
- neurotransmitter is **degraded** by **enzymes** (e.g., **acetylcholinesterase** (= "cholinesterase") breaks down acetylcholine).
  - synaptic ending **reabsorbs** the neurotransmitter. e.g. this is what happens to **Serotonin**.
    - e.g. **Monoamine oxidase** breaks down **noradrenalin** after it is absorbed.



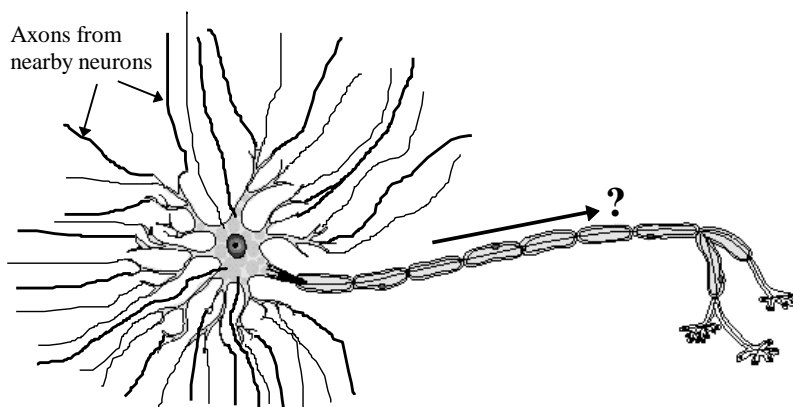
- neurotransmitters **take nerve impulses across synapses**. Neurotransmitters are small molecules. They can be single amino acids, short chains of amino acids, or derivatives of protein.
- proper brain and nervous system function depends on the **proper balance** of excitatory and inhibitory synaptic transmitters.
 

**Excitatory transmitters:** include **ACETYLCHOLINE** (ACh), **ADRENALIN** (epinephrine), **NORADRENALIN** (norepinephrine), **SEROTONIN** (derived from the amino acid tryptophan), and **DOPAMINE**.

**Inhibitory transmitters:** include **GABA** (gamma aminobutyric acid - a type of amino acid), **glycine** (an amino acid). Serotonin can also act as an inhibitory neurotransmitter.
- neurotransmitters include **endorphins** and **enkephalins** (a 5 amino-acid chain that functions as a natural pain reliever in brain). **Opium** and **heroin** mimic the action of natural endorphins and enkephalins.



Structure of Serotonin



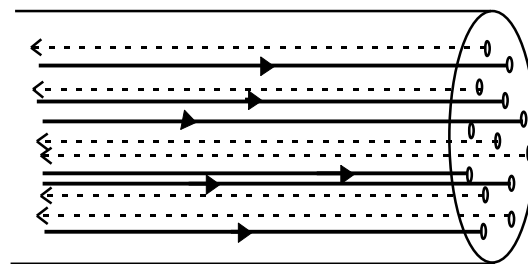
- A single neuron may receive information from **thousands** of neighbouring neuron through thousands of synapse. Some of the messages are **excitatory** (i.e. they tell the neuron to "fire") while others may be **inhibitory** (i.e. they tell the neuron **not** to fire).
- Whether or not a neuron "fires" off an action potential at any particular instant depends on its ability to integrate these multiple positive and negative inputs.

### THE PERIPHERAL NERVOUS SYSTEM: voluntary and involuntary control

- The **PERIPHERAL NERVOUS SYSTEM** consists of nerves that contain only **long dendrites** and/or **long axons**. This is because neuron cell bodies are found only in the brain, spinal chord, and **GANGLIA**.
- Ganglia** are **collections of cell bodies** within the PNS.

There are 3 types of nerves:

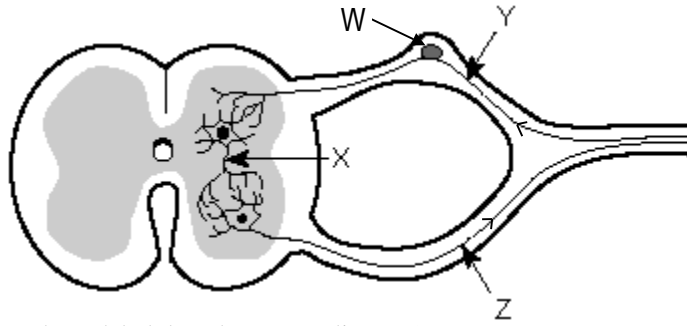
- Sensory nerves:** contain only **long dendrites of sensory neurons**.
- Motor nerves:** contain only the **long axons of motor neurons**.
- Mixed nerves:** contain both the **long dendrites of sensory neurons and the long axons of motor neurons**.



A mixed nerve

- Humans have **12 pairs of cranial nerves** attached to the brain. Some are **sensory**, some are **motor**, others are **mixed**. The cranial nerves are a part of the **PNS**.

The cranial nerves serve the **head, neck, and face** regions except for the **VAGUS** nerve, which branches to serve internal organs.



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

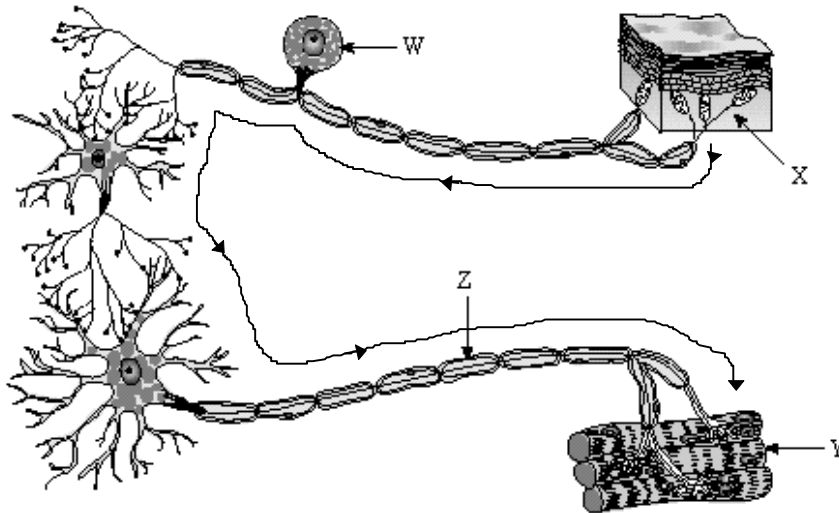
- Humans have **31 pairs of Spinal Nerves**. Spinal nerves are **mixed nerves** leaving the spinal cord by **two short branches** (called **ROOTS**) which lie **within the vertebral column**. Of these, the **DORSAL ROOT** (Y) can be identified by the presence of an **enlargement** called the **DORSAL ROOT GANGLION** (W), which contains the **cell bodies** of the **sensory neurons** whose dendrites conduct impulses toward the cord. The **VENTRAL ROOT** (Z) of each spinal nerve contains axons of **motor neurons** that conduct impulses away from the cord.

- The two roots **join just before the spinal nerve leaves the vertebral column**.
- SOMATIC NERVOUS SYSTEM**: includes **all the nerves that serve the musculoskeletal system and the exterior sense organs** (including skin). Exterior sense organs are **RECEPTORS** (receive environmental stimuli and begin nerve impulses). Muscle fibers are **EFFECTORS** that react to the stimulus.

### The Reflex Arc

- 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** is the **main functional unit** of the nervous system. It allows us to **react to internal and external stimuli**.

### Path of a simple Reflex Arc:



- Receptor** (e.g. in skin) - generates a **nerve impulse**
  - 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.
  - Interneuron** - passes message to motor neuron
  - Motor neuron** - takes message away from CNS to axon of spinal nerve
  - Effector** - receives nerve impulses and **reacts**: glands secrete and muscles contract
- LABEL ALL THESE**

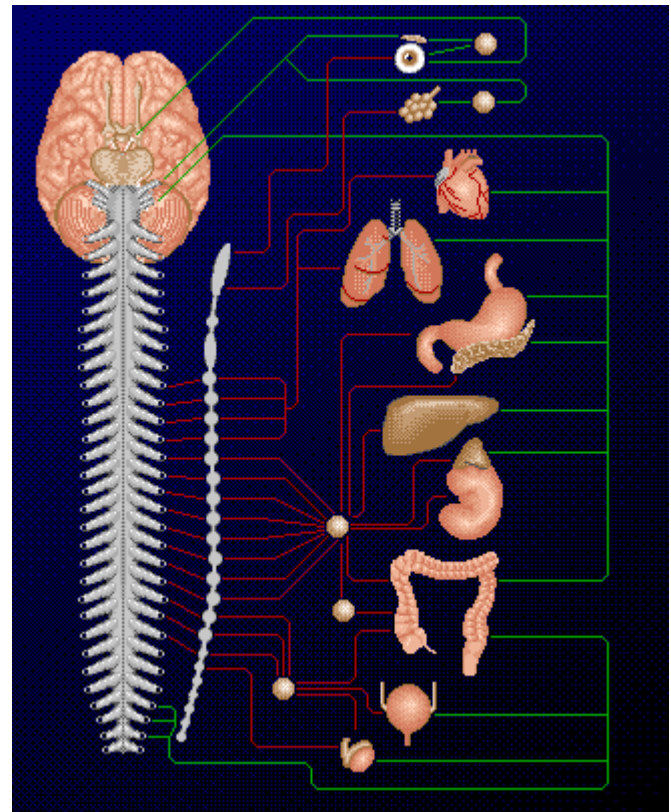
### PARTS AND THE DIRECTION ON THIS DIAGRAM

### THE AUTONOMIC NERVOUS SYSTEM

- is **part of the PNS** - made of **motor neurons** that control the internal organs **AUTOMATICALLY** (usually **unconsciously**).
- Autonomic nervous system is divided into **SYMPATHETIC** and **PARASYMPATHETIC** nervous systems. These two systems connect to the same organs by have **opposite effects**.
- Each system functions **unconsciously** on internal organs and utilize **two motor neurons** and **one ganglion** for each nerve impulse.

## 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**
  - **perspiration increases**
  - **salivation decreases**
- breathing rate increases
- the **neurotransmitter** released by the postganglionic axon of the Sympathetic nervous system is **NORADRENALIN** (which is closely related to adrenalin -- a known heart stimulant). **Noradrenalin** is released by postganglionic axon - --> heart rate accelerates
- fibers for this system arise from **middle part (thoracic-lumbar) of the spinal cord**. Preganglionic fiber is **short**, postganglionic fiber (which contacts the organ) is **long**.



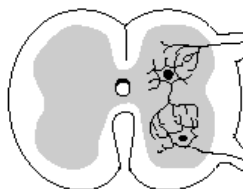
## PARASYMPATHETIC NERVOUS SYSTEM

- 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
- Important neurotransmitter in this system is **ACETYLCHOLINE**.
- fibers for this system arise from **upper and lower part of spinal cord** (cranial and sacral nerves).
- Preganglionic fiber is **long**, postganglionic fiber is **short** because the ganglia lie near or within the organ.

## THE CENTRAL NERVOUS SYSTEM

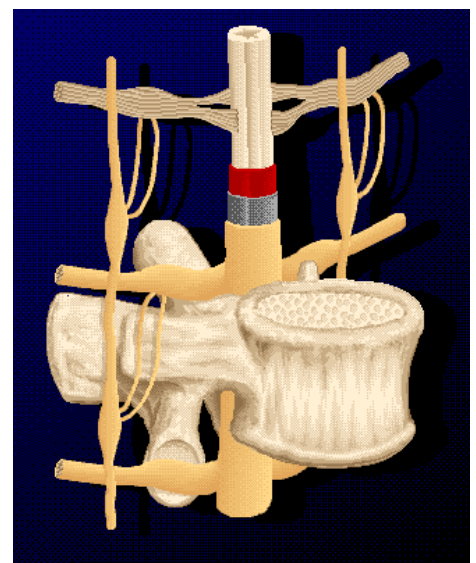
- The CNS consists of the **BRAIN** and **SPINAL CORD**.
- The CNS lies in the **mid-line** of the body and is the place where **sensory information is received** and **motor control is initiated**.
- **Protected** by **BONE** (skull, vertebrae). They are also wrapped up in **three protective membranes** called **MENINGES** (*spinal meningitis* is infection of these membranes). Spaces between meninges filled with **cerebrospinal fluid** for **cushioning and protection**. This fluid also 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**,
- **GRAY MATTER** (inner layer) containing **cell bodies** of neurons and **short fibers**. Looks kind of like the a butterfly with open wings.
- in **grey matter**, dorsal cell bodies function primarily in **receiving sensory information**, and ventral cell bodies send along primarily motor information.

- **WHITE MATTER** (outer layer) containing **long fibers of**





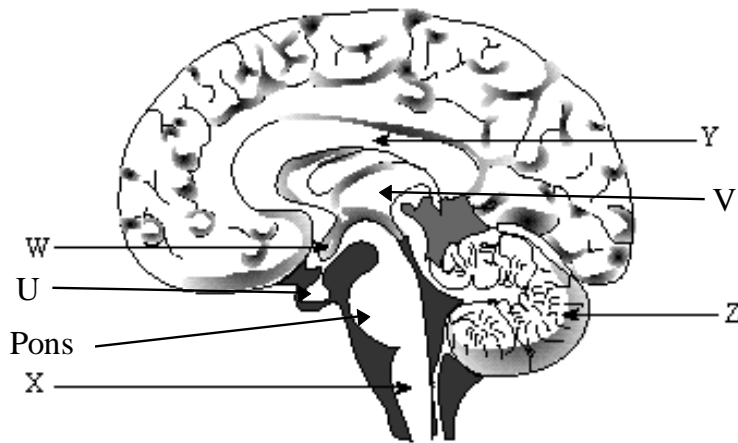
**interneurons** that run together in bundles called **tracts** that connect the cord to the brain.

- within white matter, **ascending tracts** take information to the brain, **descending tracts** in the ventral part carry information down from the brain.

## THE BRAIN

- The brain itself contains parts which function in the coordination of movement, sensing, & **consciousness** (and all that entails), as well as areas that are **below** the level of conscious control. The brain has a volume, on average, or **1,370 cubic centimeters** (with a normal range of 950 to 2,200 cm<sup>3</sup>). It weighs about **1.35 kg** (or **3 pounds**), and consists of hundreds of billions of neurons and glial cells. You had the maximum number of neurons when you were born. Thousands are lost daily, never to be replaced and apparently not missed, until the cumulative loss builds up in very old age. The brain is vastly complex, and is certainly not thoroughly understood. There are many ways of looking at the brain functionally and structurally. The simplest first way of looking at it is dividing it up into parts that run “automatically” (the unconscious brain) and the parts in which our consciousness resides (the conscious brain).

### The Unconscious Brain



- **MEDULLA OBLONGATA** (X)- 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 Pons also participates in some of these activities, having ganglia that regulate the breathing centers in the medulla, for example.
- **THALAMUS** (V)- receives sensory information from all parts of the body and **channels** them to the cerebrum. It is the last portion of the brain for sensory input before 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 appropriate regions of the cortex for interpretation.

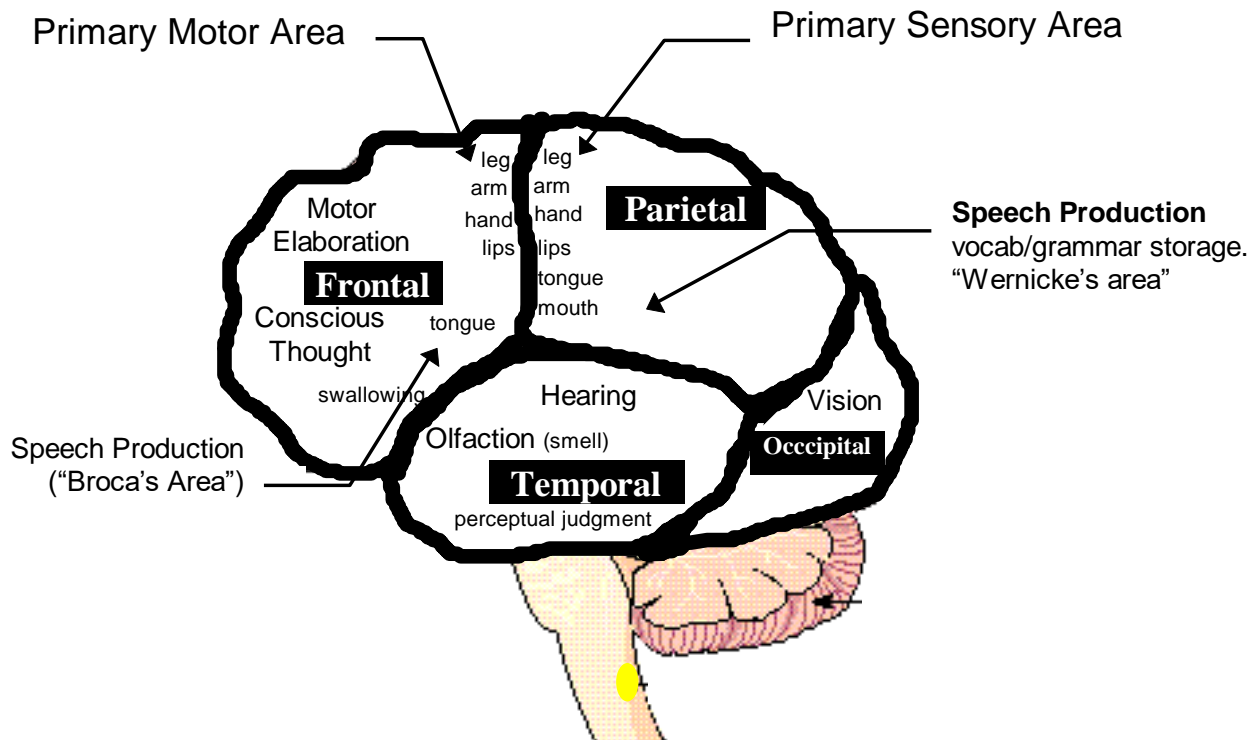
- The thalamus has connections to various parts of the brain, and is part of the **RAS** (the **reticular activating system**), which **sorts out incoming stimuli**, passing on to the cerebrum only those that require **immediate attention**. i.e. it lets you ignore input (like your teacher talking) so you can do other things (yak to your friends about Grad). The RAS extends from the medulla oblongata to the thalamus.
- **CEREBELLUM** (Z)- controls **balance** and **complex muscular movement**. It is the *second largest portion of the brain*. **Butterfly-shaped**. Functions in **muscle coordination** and makes sure **skeletal muscles work together smoothly**. Responsible for **maintaining normal muscle tone, posture, balance**. It receives sensory information from the inner ear (which senses balance).
- **HYPOTHALAMUS** (W) one of the most important sites for the regulation of homeostasis. It **maintains internal environment**, contains centers for **hunger, sleep, thirst, body temperature, water balance, blood pressure**. Controls **PITUITARY GLAND** (U) (serves as a **link** between the **nervous system** and the **endocrine systems**). The hypothalamus plays a role in **sexual response** and mating behaviors, and the “fight-or-flight” response, and **pleasure**. Yes, there are *pleasure centers* in the hypothalamus (these have been stimulated experimentally with electrodes in studies using rats).
- **CORPUS CALLOSUM** (Y)- horizontal connecting piece between the two hemispheres of the brain. **Transmits information between the two cerebral hemispheres**. It has been noted that severing the corpus callosum can control severe **epilepsy** (which is thought to be caused by a disturbance of the normal communication between the RAS and the cortex), but also means the two halves of brain don't communicate with each other normally and will function **separately**. Each half has its own memories and “style” of thinking. Sometimes you'll hear this discussed as “right brain” versus “left brain” thinking.
- The **right hemisphere** of the brain controls the **left side** of the body (except for smell), and vice versa. Thus, an image viewed with the right eye is actually “seen” with the left occipital lobe. The left hand is controlled by the right frontal lobe, and so on.

- A person with a severed corpus callosum may appear normal in most situations, but careful experiments reveal much about **lateralization** of the brain. For example, a patient holding a key in the left hand, with both eyes open, will readily name it as a “key.” If blindfolded, though, the subject will recognize the key by touch and use it to open a lock, but will be completely unable to name it. The center for speech is in the left hemisphere, but sensory information from the left hand crosses (normally) the corpus callosum and enters the right side of the brain. In this patient, sensory input and spoken response are dissociated.

**Right Brain/Left Brain: Different Qualities and an Uneasy Alliance?**

The Left Hemisphere the “logical side”	The Right Hemisphere The “intuitive side”
<ul style="list-style-type: none"> <li>• speaks</li> <li>• processes data</li> <li>• evaluates</li> <li>• analyzes differences</li> <li>• is factual</li> <li>• is structured</li> <li>• has time and measures</li> <li>• “speaks but cannot know”</li> </ul>	<ul style="list-style-type: none"> <li>• creates images</li> <li>• processes senses</li> <li>• symbolizes</li> <li>• seeks similarities</li> <li>• is spiritual</li> <li>• is spontaneous</li> <li>• has no time and measures</li> <li>• “knows but cannot speak”</li> </ul>
<b>You use the LEFT side of the brain when you know what you’re looking for</b>	<b>You use the RIGHT side of the brain when you “know it when you see it”</b>
<ul style="list-style-type: none"> <li>• talking</li> <li>• setting goals</li> <li>• planning</li> <li>• measuring</li> <li>• seeing differences</li> </ul>	<ul style="list-style-type: none"> <li>• feeling</li> <li>• speculating</li> <li>• visualizing</li> <li>• empathizing</li> <li>• sensing similarities</li> </ul>

**THE CONSCIOUS BRAIN = THE CEREBRUM**

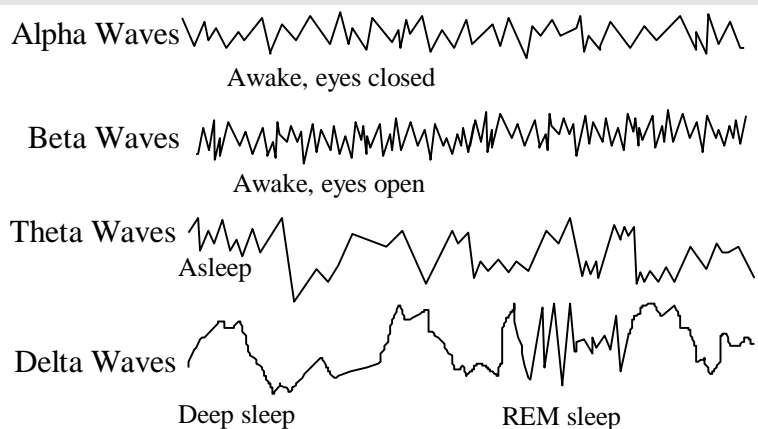


- **CEREBRUM** - largest, most prominent, most highly developed portion of the brain.
- **Consciousness** resides only in this part of the brain.

- **Intellect, learning, memory, sensations** are formed here.
  - Outer layer is the **CORTEX** (gray in colour). It is the largest and most complex part of the human brain, and the part that has changed the most during vertebrate evolution. The highly folded human cortex has a surface area of about 0.5 m<sup>2</sup>.
  - Divided into right and left **CEREBRAL HEMISPHERES**, each consisting of **FOUR LOBES: FRONTAL, PARIETAL, TEMPORAL, and OCCIPITAL** lobes. The a fifth lobe called the **INSULA**, that lies below the surface. Its function is poorly understood. The cerebral cortex has been “mapped” in some detail. All the lobes have **association areas** that receive information from other lobes and integrate it into higher, more complex levels of consciousness. Association areas are concerned with intellect, artistic, and creative abilities, learning, and memory.
1. **FRONTAL** - **movement, higher intellectual** processes (e.g. problem solving, concentration, planning, judging the consequences of behavior, moving your tongue and mouth to speak (left side only).
  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.

### Electroencephalogram (EEG) NOT ON PROVINCIAL

- An EEG is a **record of the electrical activity of the brain**, derived from a machine called an **electroencephalograph**, which receives information from the brain through **electrodes** attached to the scalp. The EEG can be **used to diagnose epilepsy and brain tumors**, as well as **brain death**. The average brain produces about 20 Watts of electrical power (barely enough to power a compact fluorescent light bulb).
- when people are awake, usually see two types of waves: **alpha waves** and **beta waves**. Alpha wave predominate when eyes are **closed**. Beta waves, which have higher frequencies but lower voltages, appear when eyes are open.
- **REM** (rapid eye movement): in this period of sleep, brain waves are **slower** and **larger**, and eyes move back and forth **irregularly**. This is the state, usually occurring **5 times per night**, that corresponds with the act of **dreaming**. REM sleep is **needed for normal brain function**.



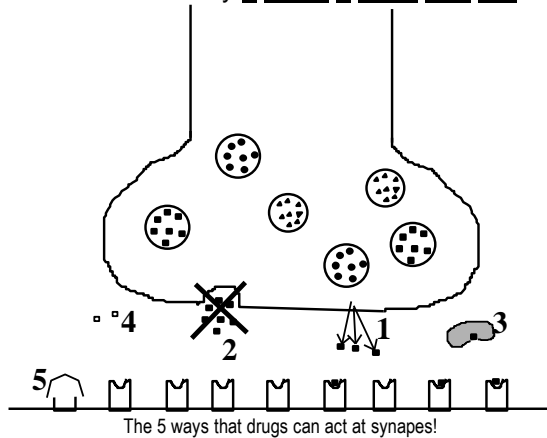
### The Extrapyrarnidal and Limbic Systems: movement and Emotion NOT ON PROVINCIAL

- Masses of white matter that belong to the descending tracts are called the **EXTRAPYRAMIDAL SYSTEM** (includes parts of the cerebrum, cerebellum, and pons).
- The extrapyramidal system controls **BODY MOVEMENT AND POSTURE**.
- The extrapyramidal system passes into the **basal nuclei** (masses of grey matter that lie deep within each hemisphere of the cerebrum). These basal nuclei are part of the **LIMBIC SYSTEM**, which connects portions of the **frontal lobes, temporal lobes, thalamus, amygdala, and hypothalamus**.
- The limbic system is involved in **EMOTIONS, MEMORY, and LEARNING**.
- It is sometimes called the emotional brain because it seems to control emotions: **Pain, Pleasure, Rage, Affection, Sexual interest, Fear, Sorrow**.
- Memories can be stored all over the brain, but seem to be **concentrated in the limbic system**.
- The limbic system is also essential for **short-term** and **long-term memory**. An example of a short-term memory is the ability to remember a phone number long enough to dial it. An example of long-term memory is the ability recall what you did yesterday.
- Long-term memory involves **protein synthesis** and may include the **formation of new connections** between neurons (this also occurs in learning).
- It is believed that at first, impulses move only within the limbic circuit, but eventually the basal nuclei transmit the neurotransmitter Ach to the sensory areas where memories are stored. The involvement of the limbic system explains why emotionally-charged events result in the most vivid memories. The fact that the limbic

system communicates with the sensory areas for touch, smell, vision, hearing, and taste accounts for the ability of any particular sensory stimulus to awaken a complex memory.

## 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 RAS and 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, **theophylline** in tea (both block the action of adenosine, a chemical that inhibits the release of neurotransmitters).
  - **Nicotine** enhances the action of **acetylcholine**. Some drugs (e.g. *Thorazine*) also affect cognitive or thinking processes. Mood-altering drugs particularly affect the RAS.

- Drugs either **promote** or **decrease** the action of neurotransmitters, either **stimulating** or **inhibiting** the action of excitatory transmitters or inhibitory transmitters. **Stimulants** either **enhance** excitatory transmitters or **block** the action of inhibitory transmitters. **Depressants** either **enhance** the action of an inhibitory transmitter or **block** the action of an excitatory transmitter.

Drug Action	Type of Neurotransmitter	Result
Blocks neurotransmitter	Excitatory	Depression
Enhances neurotransmitter	Excitatory	Stimulation
Blocks neurotransmitter	Inhibitory	Stimulation
Enhances neurotransmitter	Inhibitory	Depression

## THE ACTION OF DRUGS ON NERVOUS SYSTEM (NOT ON PROVINCIAL)

- **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. Overuse can lead to hallucinations and other neurological effects (e.g. extreme addicts can lose the ability to feel pleasure).
- **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. Like LSD, it is classified as a hallucinogen. It can be psychologically addicting. Marijuana may act on the neurotransmitter serotonin.
- **TRANQUILIZERS** - e.g. Valium, Ativan, barbiturates, alcohol **enhance the action of the inhibitory transmitter GABA**. **Dependency** develops when the body begins to produce less GABA on its own. Overall, tranquilizers **depress brain function**, and **overdoses can cause death** due to this.
- **LSD** - (lysergic acid diethylamide) - affects the action of **serotonin** and **dopamine** on RAS cells 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** - **blocks** the action of **adenosine**, a chemical that inhibits the release of neurotransmitters. Therefore, it 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**. Dependency develops when the body begins to produce less GABA. Death can occur from over consumption because of its depressing effect on brain functions. Habitual use can also damage areas of the brain (especially the hippocampus, which can cause **memory impairment**). Also leads to **cirrhosis** of the liver.

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

- **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 (lets call it "P") 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**. The euphoria originally experienced upon injection is no longer felt. Heroin withdrawal symptoms include perspiration, dilation of pupils, tremors, restlessness, cramps, goose-flesh, involuntary defecation, vomiting, and increase in blood pressure and heart rate.

#### A Few Disorders of the Nervous System NOT ON PROVINCIAL

- **HUNTINGTON'S CHOREA** - causes a progressive deterioration of nervous system culminating in insanity and death. Thought to be due to GABA malfunctions. A genetic disorder -- children have a 50% chance of developing Huntington's chorea if one of their parent has it. No cure yet.
- **ALZHEIMER'S DISEASE** - a severe form of senility marked by advanced memory loss. Affects 5 to 10% of people over 65. Is a disorder of the limbic system, as it affects both emotion and memory. Protein plaques build up in the brain and destroy brain cells. Ach secretion is considerably below normal in the brains of Alzheimer's patients. Some drugs show limited success in forestalling advancement of disease in some patients. No cure yet.
- **PARKINSON'S DISEASE** - characterized by tremors of limbs (especially hands), muscular rigidity. Thought to be due to a lack of **dopamine**. Some modern medicines are symptomatically effective. No cure yet.
- **EPILEPSY** - caused by disturbances of normal communication between RAS and cerebral cortex. Causes episodes of convulsions known as seizures. There are "grand mal" and "petite mal" seizures. In a grand mal seizure, the cerebrum becomes extremely excited, the individual may lose consciousness. The seizure only stops when the neurons become fatigued. Medicines (like Dilantin) are effective in treating and preventing seizures. There is still no cure for this disease.
- **CEREBRAL PALSY** - characterized by spastic weakness of arms and legs. Caused by lack of oxygen during birth which damages motor areas of cerebral cortex.
- **SCHIZOPHRENIA**: severe mental illness is probably linked, in part, to a **surplus** of **dopamine**.
- **DEPRESSION** is thought to be linked to deficiencies in the neurotransmitter **serotonin** and/or norepinephrine. Drugs such as imipramine and Prozac work by increase the concentrations of these substances in limbic system synapses. Depression is a serious medical disorder that affects more one person in 10 during their lifetime.