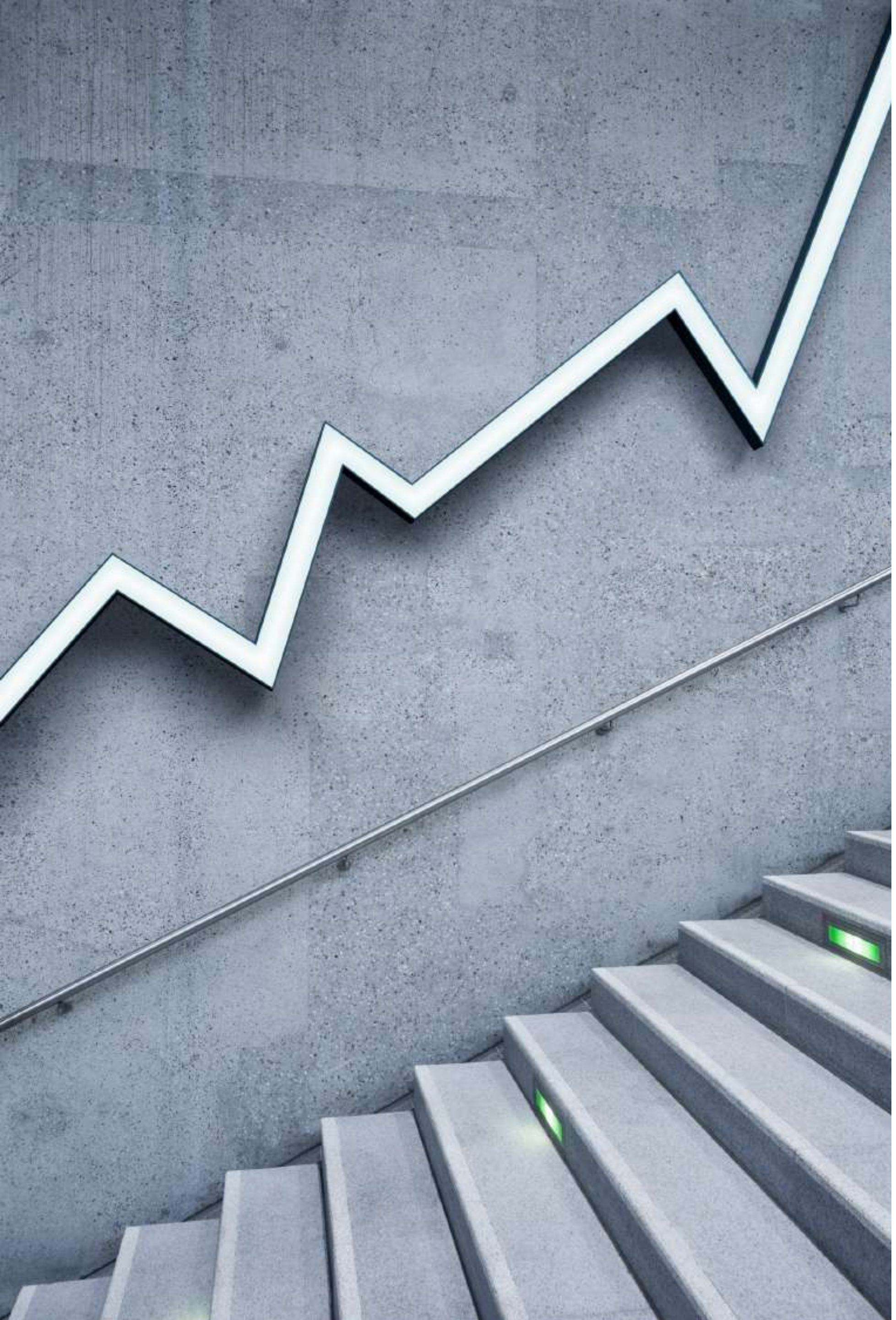


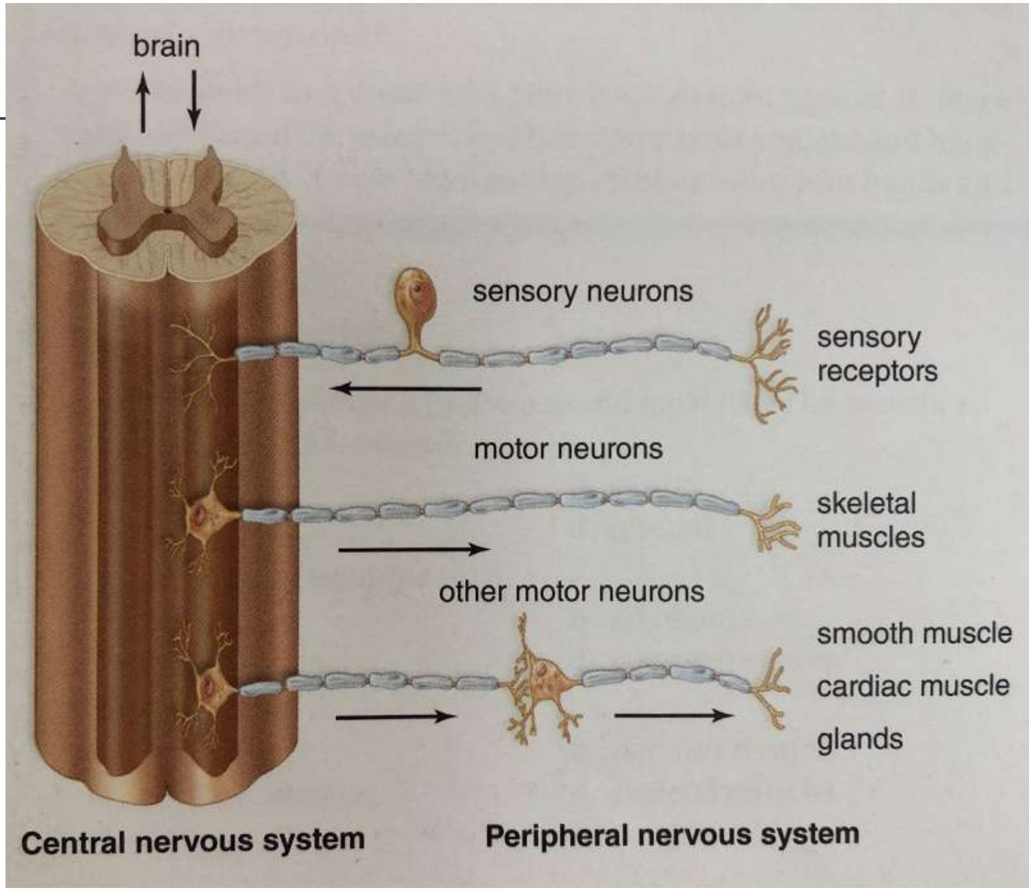
The Nervous System

MS. MARTEL

7.1 – NERVOUS TISSUE

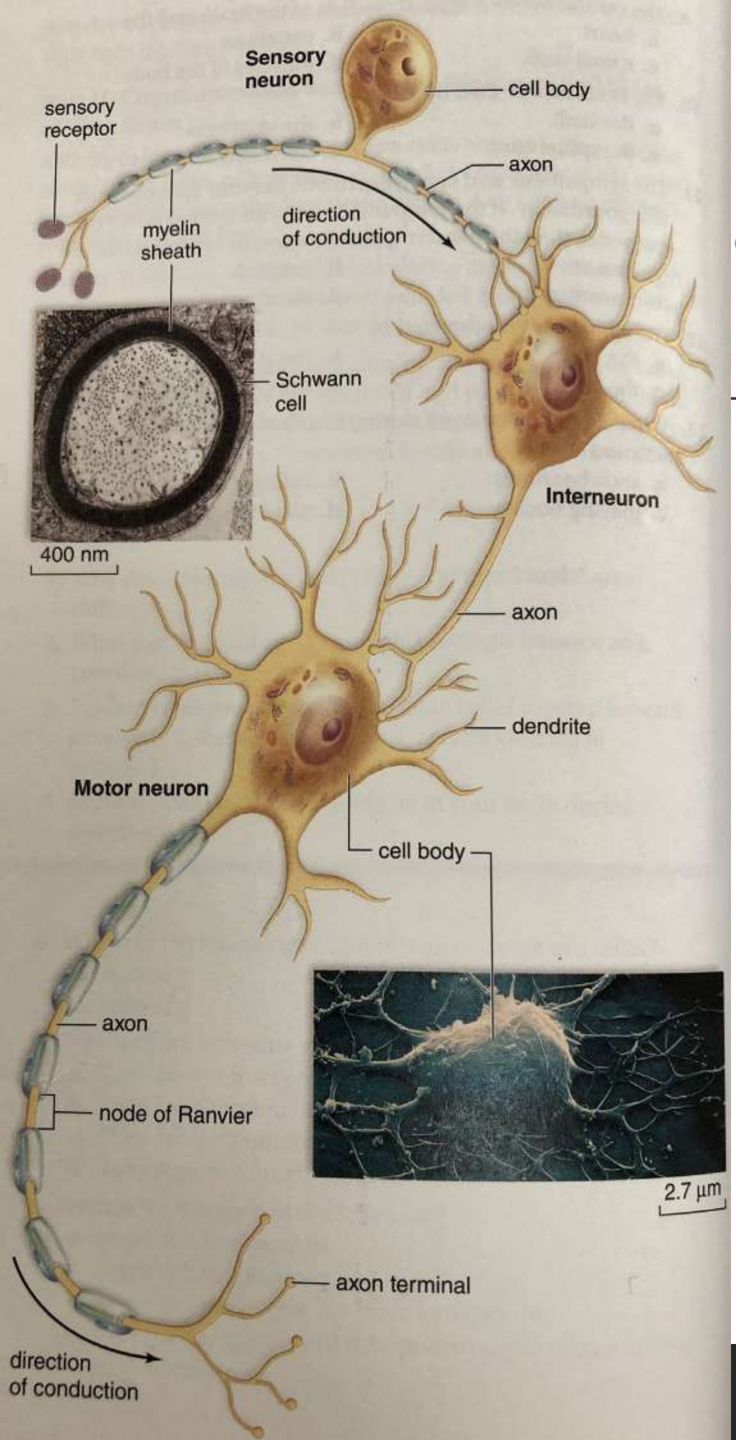
- The nervous system **coordinates and regulates the functioning** of the body's other systems.
- The nervous system has two major anatomical divisions:
  - **The central nervous system**(CNS) – consisting of the brain and spinal cord
  - **The peripheral nervous system**(PNS) – consisting of every other neuron in the body. These nerves carry **sensory messages to the CNS and motor commands from the CNS** to the muscles and glands.

- The nervous system contains two types of cells: **neurons and neuroglia.**
  - Neurons are the cells that **transmit nerve impulses between parts of the nervous system.**
  - Neuroglia support and nourish neurons, maintain homeostasis, **form myelin, and may aid in signal transmission.**



Types of Neurons & Neuron Structure

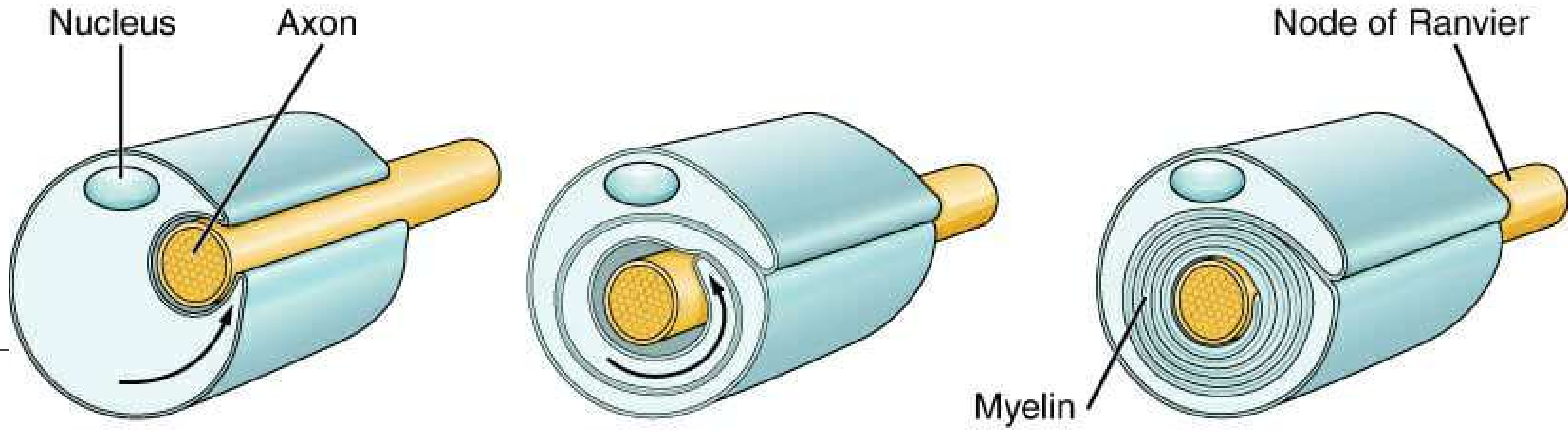
- There are three classes of neurons: **sensory neuron, interneurons, and motor neurons.**
- Their functions are best described in relation to the CNS.
  - **A sensory neuron takes messages to the CNS.** Sensory neurons may be equipped with specialized endings called sensory receptors that detect changes in the environment.
  - **An interneuron lies within the CNS.** They can receive information from sensory neurons and other interneurons in the CNS. They then communicate with motor neurons.
  - **A motor neuron takes messages away from the CNS to an effector**, which carries out responses to the environmental changes.



- Neurons vary in appearance, but most of them have 3 parts: **a cell body, dendrites, and an axon.**
  - The cell body contains the **nucleus as well as other organelles.**
  - Dendrites are extensions from the cell body that **receive signals.**
  - An axon conducts nerve impulses away from the cell body **toward other neurons or effectors.**

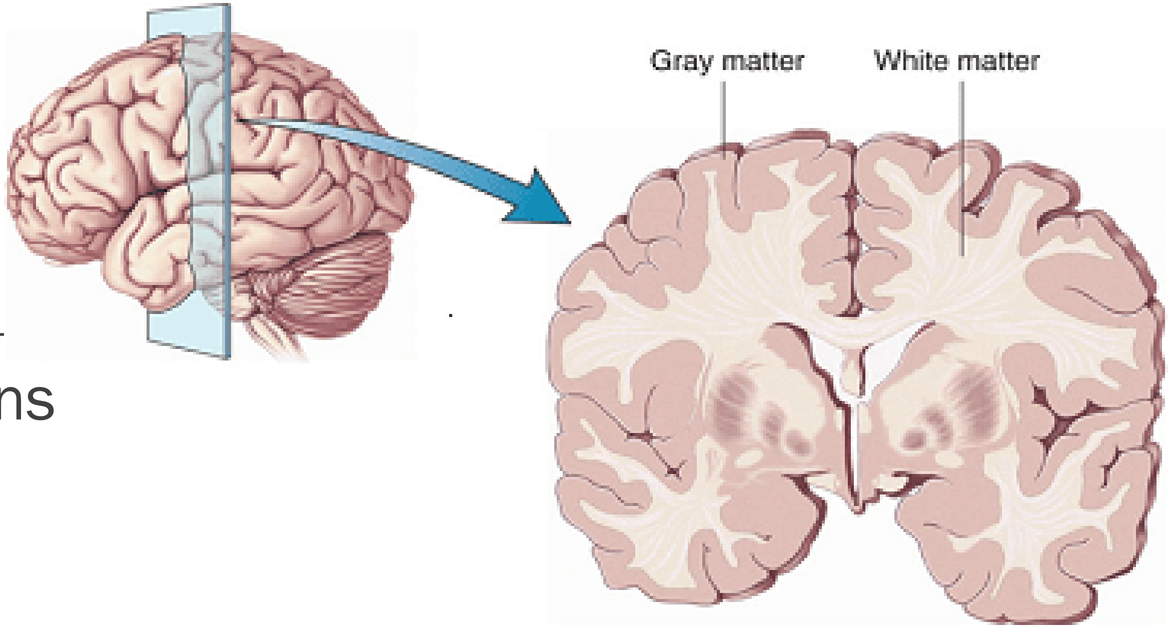
Myelin Sheath

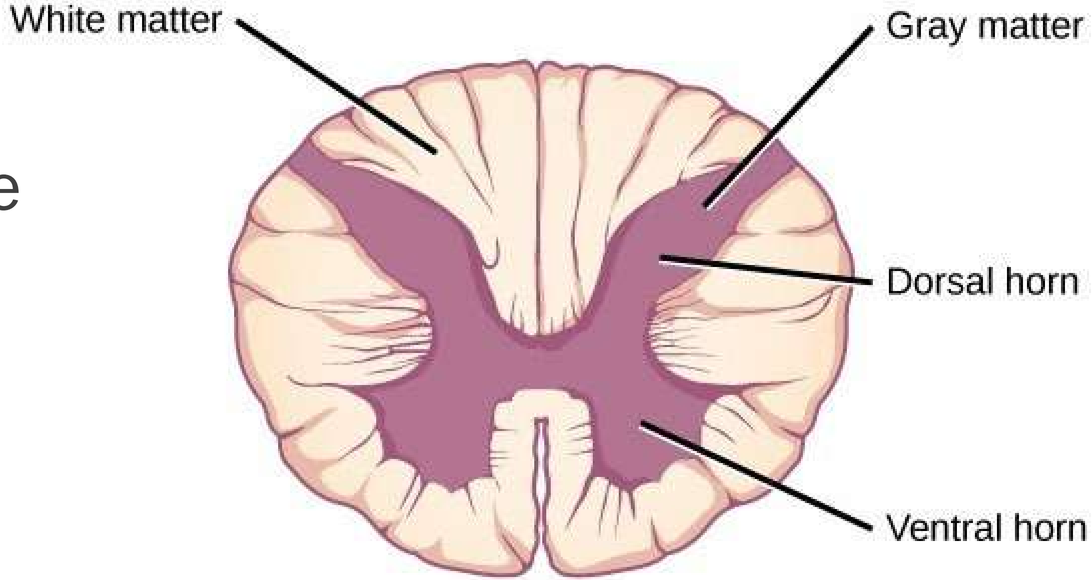
- Some axons are covered by a protective **myelin sheath.**
- In the PNS, this covering is formed by a type of neuroglia called **Schwann cells**, which contain myelin in their plasma membranes.
  - The myelin sheath develops when **Schwann cells wrap themselves around an axon.**
  - Each Schwann cell myelinates only **part of an axon.**
  - The gaps where there is no myelin sheath are called **nodes of Ranvier.**



- In the PNS, myelin gives nerve fibres their white glistening appearance.
  - The myelin sheath also plays an important role in **nerve regeneration within the PNS.**
  - In the CNS, myelin is produced by **a type of neuroglia called oligodendrocytes,**
  - Unlike in the PNS, **nerve regeneration does not occur to any significant degree in the CNS.**

- The CNS is composed of 2 types of nervous tissue – **grey matter & white matter.**
  - Grey matter is grey because it contains neurons with **short, nonmyelinated axons.**
  - White matter is white because it contains **myelinated axons that run together in bundles called tracts.**
- The surface layer of the brain is grey matter, the **white matter lies deep within the grey matter.**
- The central part of the spinal cord consists of grey matter, and is **surrounded by white matter.**





7.2 – TRANSMISSION OF NERVE IMPULSES

- The nervous system uses nerve impulses to **convey information.**
- Nerve impulses have been studied using a voltmeter which measures the millivolts (mV), which is a measure of the **electrical potential difference between two points.**
  - In the case of the neuron, the **two points are the inside and outside of the axon.**

Resting Potential

- When the axon is not conducting an impulse, the voltmeter records a **potential difference across the axonal membrane equal to -70mV.**
  - This means the inside of the axon is **negative compared to the outside.**
  - This is called the **resting potential.**

- This charge difference correlates with a **difference in ion distribution on either side of the axonal membrane.**
  - The concentration of sodium ions (Na+) is **greater outside the axon than inside.**
  - The concentration of potassium ions (K+) is **greater inside the axon than outside.**
  - The unequal distribution of these ions is maintained by the **sodium-potassium pumps.**
  - This actively transports **Na+ out of and K+ into the axon.**
  - Because the membrane is more permeable to K+ than to Na+, there are always more **positive ions outside the membrane than inside.**
  - This accounts for the **negative charge inside the axon.**

Action Potential

- An action potential is a **rapid change in polarity across an axonal membrane** as the nerve impulse occurs.
  - It is an **all-or-none phenomenon.**
  - A stimulus must cause the axonal membrane to **depolarize to the threshold**, otherwise an action potential will not occur.
  - The strength of an action potential does not change, but an intense stimulus can **cause an axon to fire more often than a weak stimulus.**
  - The action potential requires **two types of gated channel proteins in the membrane.**

1. Sodium Gates Open

- When an action potential begins, the **gates of sodium channels open first.**
  - Na+ flows down its concentration gradient **into the axon via a channel protein.**
  - As Na+ moves inside the axon, the **membrane potential change from -70mV to +35mV.**
  - This is called **depolarization.**

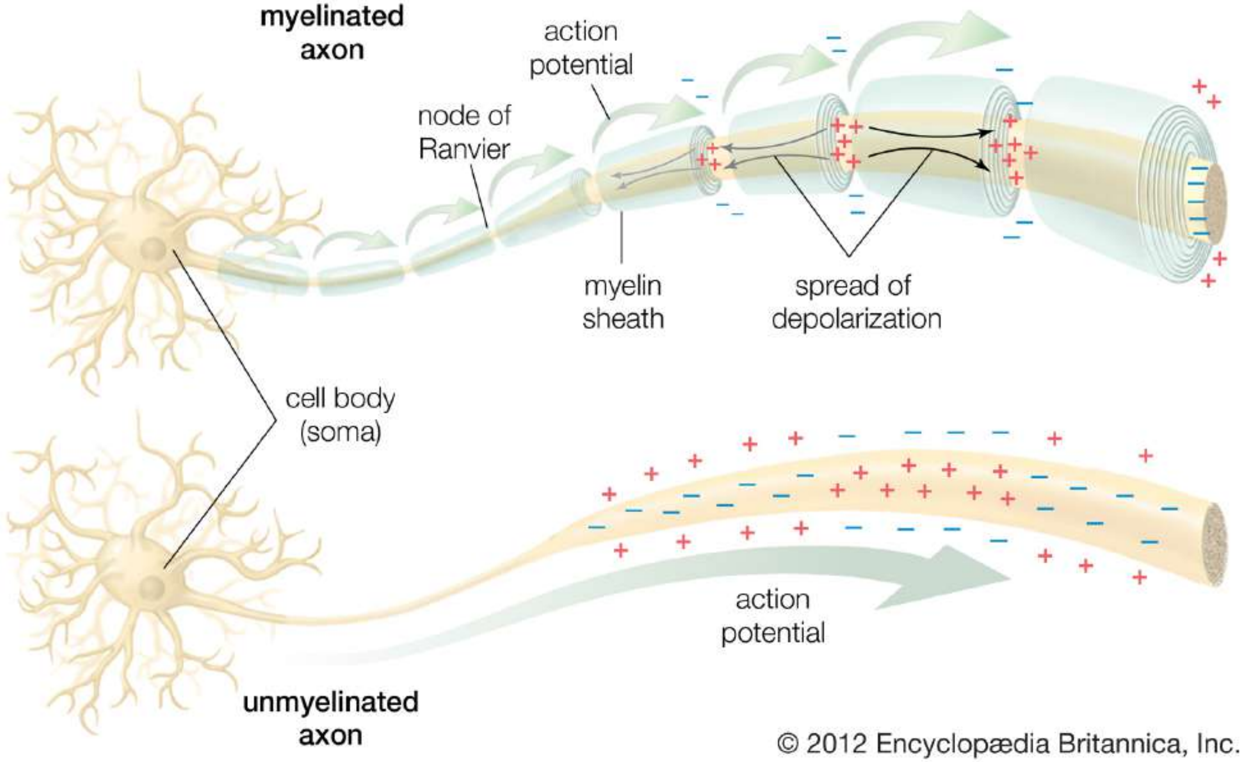
2. Potassium Gates Open

- Next, the gates of potassium channels open, and K+ flows down its concentration gradient **outside the axon via protein channels.**
  - As K+ moves outside, the **action potential becomes more negative again, -75mV.**
  - This is repolarization, because **inside the axon resumes a negative charge.**

Conduction of an Action Potential

- In nonmyelinated axons, the action potential travels down an axon **one small section at a time.**
  - As soon as an action potential has moved on, the previous section undergoes a refractory period. **Here sodium gates are unable to open.**
  - The sodium-potassium pump restores the **Na+ ions outside the axon and the K+ ions inside the axon.**

- In myelinated axons, the gated channels that produce an action potential are **concentrated at the nodes of Ranvier.**
  - The action potential travels faster than nonmyelinated axons.
  - This is called saltatory conduction, meaning the **action potential "jumps" from node to node.**

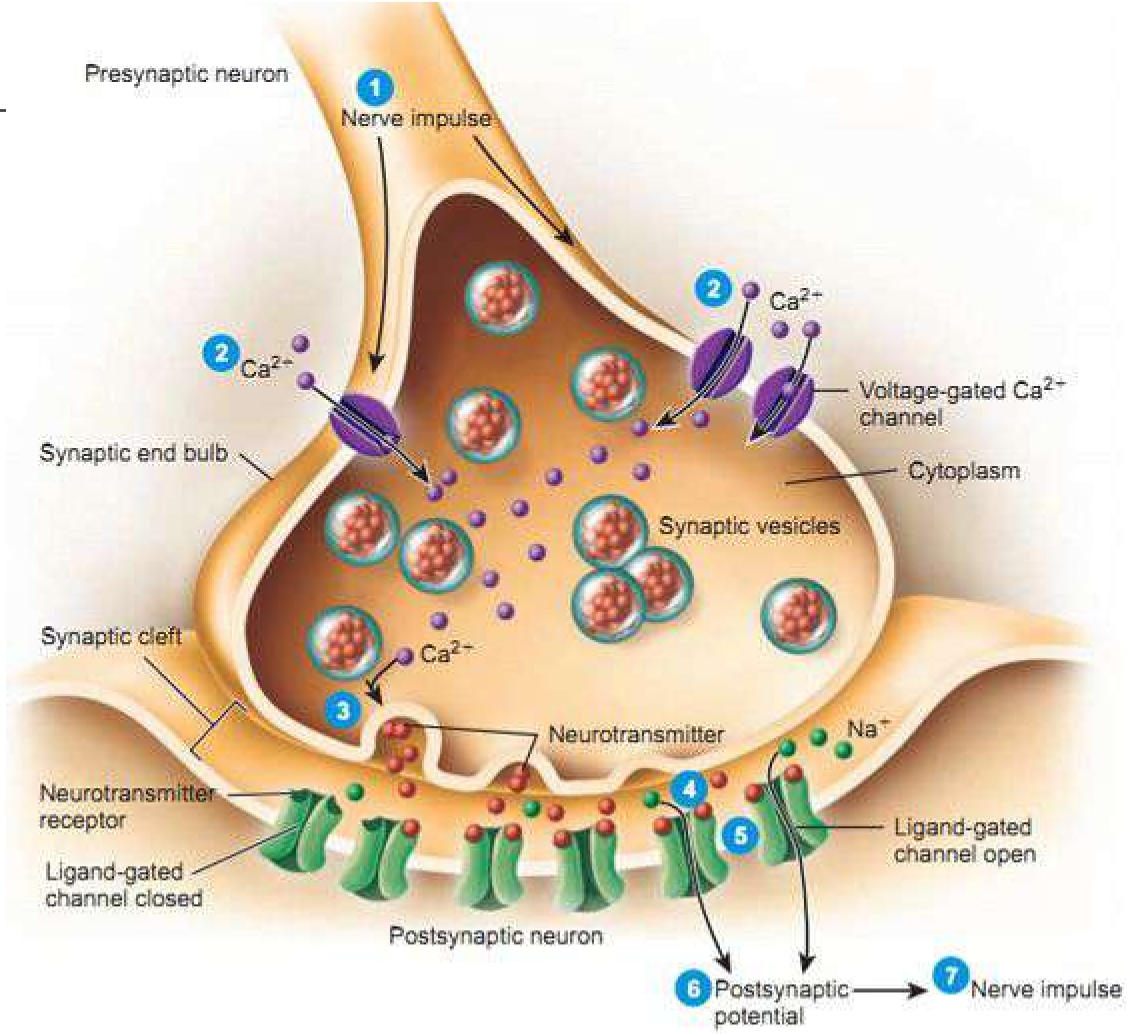


Transmission Across a Synapse

- Every axon has branches that are tipped with a **small swelling called an axon terminal.**
  - Each terminal lies very close to either the **dendrite or the cell body of another neuron, or a muscle cell.**
  - This region of close proximity is called the **synapse.**
  - The two neurons at a synapse never physically touch each other. They are separated by **a tiny gap called the synaptic cleft.**
  - The membrane of the first neuron is the **presynaptic membrane**, and the membrane of the next neuron is the **postsynaptic membrane.**

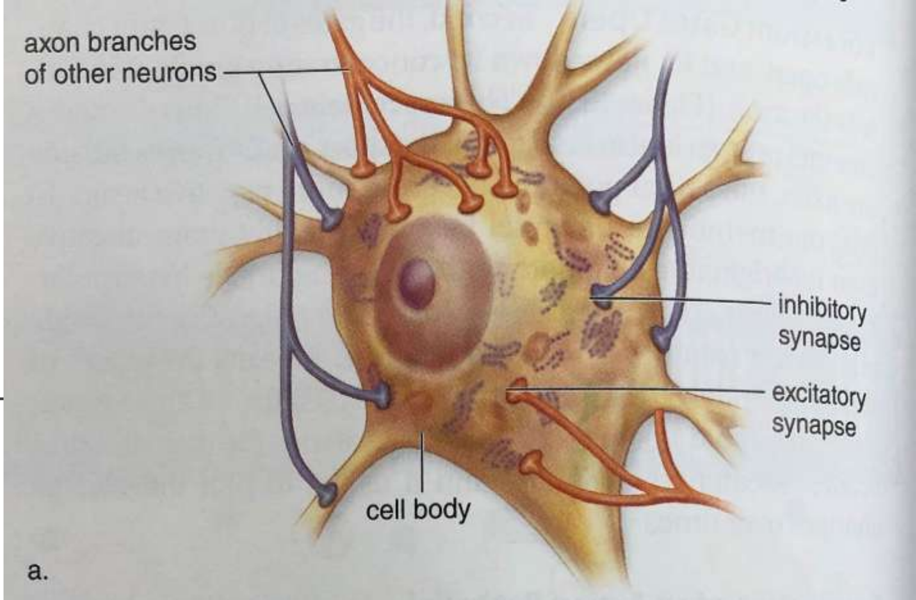
- An action potential **cannot cross a synapse.**
  - Communication between the two neurons at a **chemical synapse is carried out by neurotransmitters**(NT).
  - NT are stored in **synaptic vesicles.**
  - When nerve impulses reach an axon terminal, **Ca2+ channels open, and Ca2+ enters the terminal.**
  - The Ca2+ interact with the contractile proteins, and **pull the synaptic vesicles to the presynaptic membrane.**

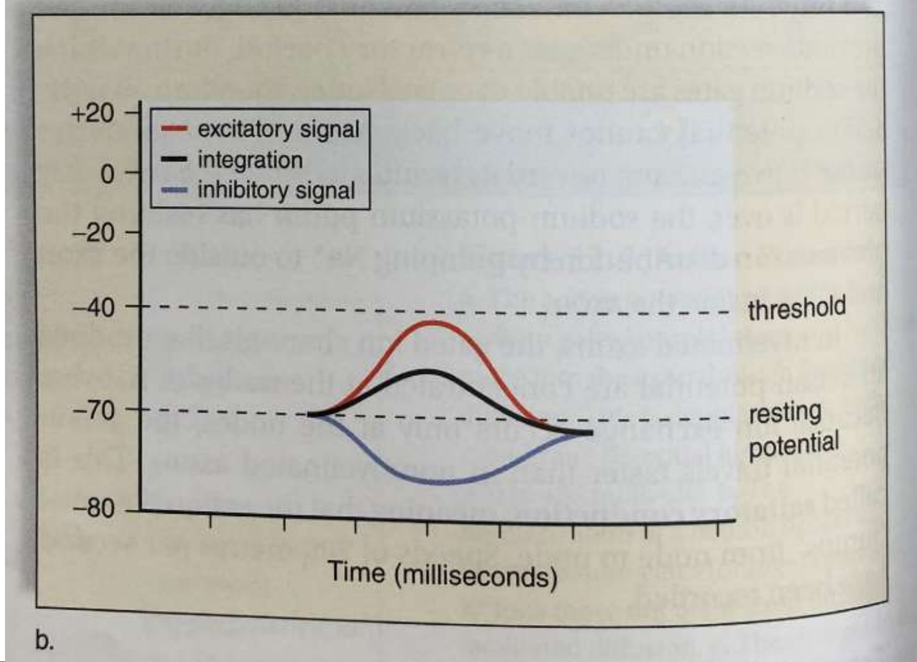
- The synaptic vesicles merge with the **presynaptic membrane resulting in exocytosis.**
- The NT, now in the synaptic cleft, **diffuse across the synapse to the postsynaptic membrane**, and bind to a specific receptor proteins.
- Depending on the type of NT and receptor, the response can be excitation (**causing an action potential to happen**) or inhibition (**stopping an action potential from happening**).



Synaptic Integration

- Dendrites and cell bodies of a neuron can have **synapses with many other neurons.**
  - Excitatory signals have a **depolarizing effect.**
  - Inhibitory signals have a **hyperpolarizing effect.**
- Integration is the **summing up of excitatory and inhibitory signals by a neuron.**
  - A neuron must receive many excitatory signals in order to **transmit an impulse**

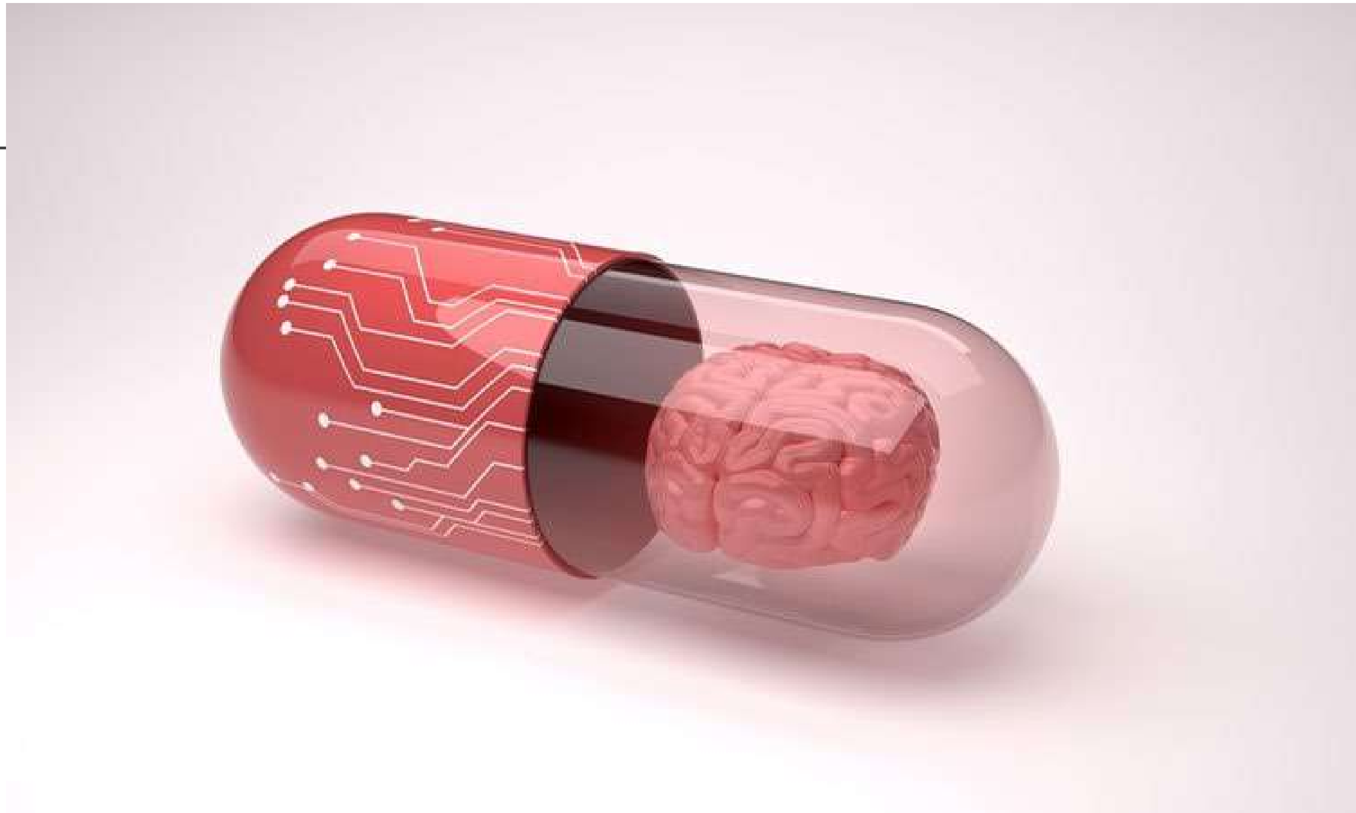


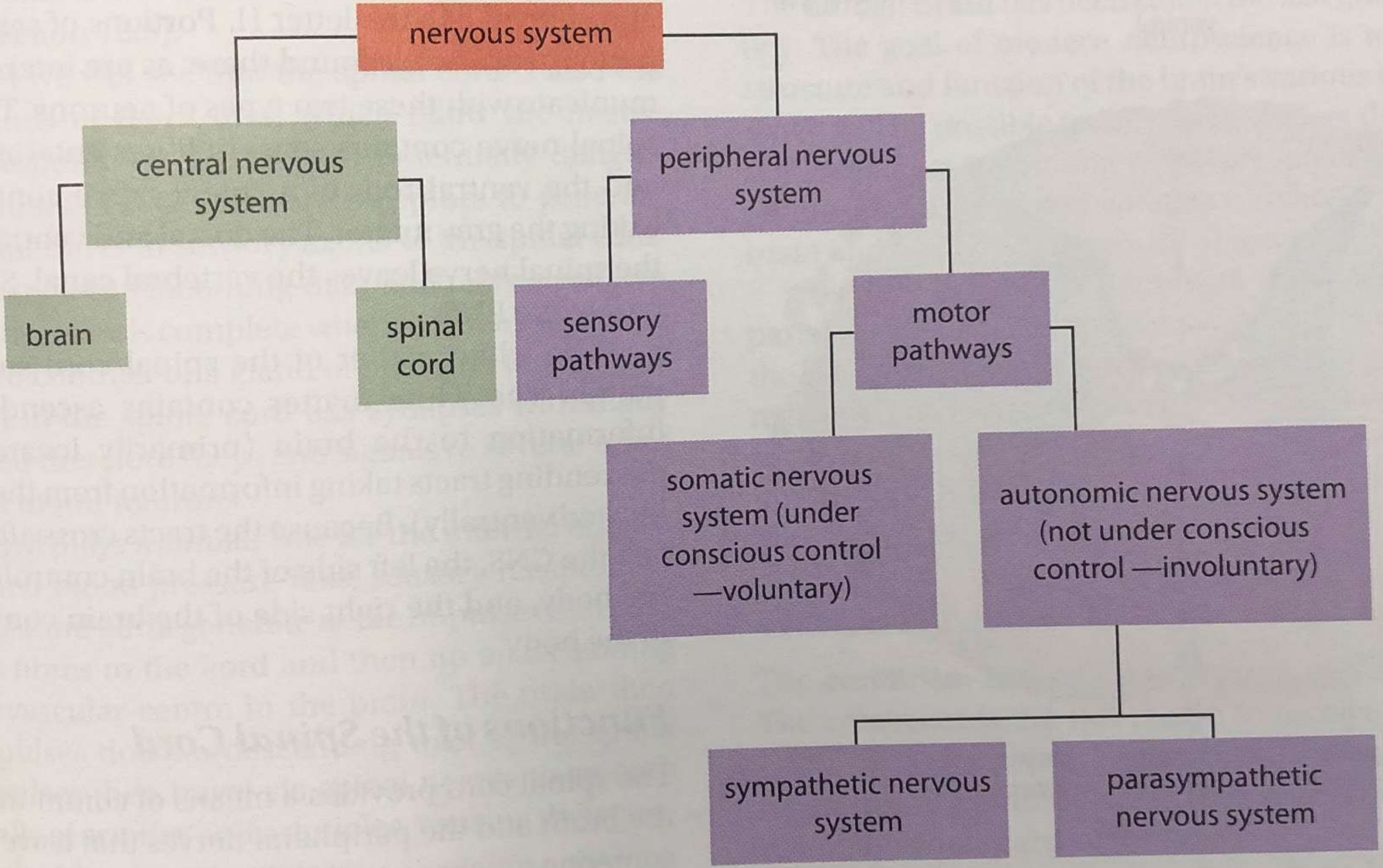


Neurotransmitters

- At least 25 different NT have been identified. The two most well-known ones are **acetylcholine (ACh) and norepinephrine (NE).**
- Once a NT has been released into the synaptic cleft, they are either **broken down by enzymes or reabsorbed by the presynaptic membrane.**
- Many drugs that affect the nervous system act by either **interfering with or enhancing the action of the NT.**

- Drugs can:
  - Enhance or block the release of a NT
  - Mimic the action of a NT or block a receptor
  - Interfere with the removal of a NT from the synaptic cleft.



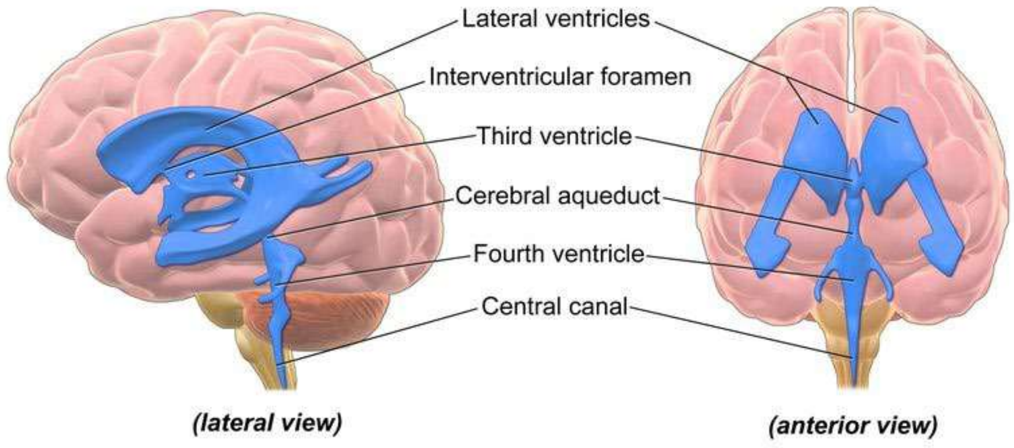

nervous system
central nervous system
peripheral nervous system
brain
spinal cord
sensory pathways
motor pathways
somatic nervous system (under conscious control —voluntary)
autonomic nervous system (not under conscious control —involuntary)
sympathetic nervous system
parasympathetic nervous system

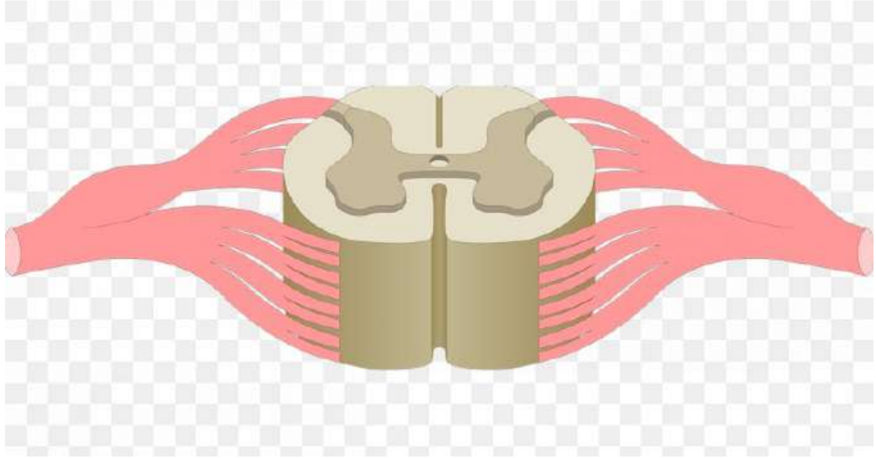
7.3 – THE CENTRAL NERVOUS SYSTEM

- The central nervous system is where sensory information is **received and motor control is initiated.**
  - The brain controls or influences many bodily functions such as **breathing, heart rate, temperature, and blood pressure.**
  - It is also the course of our emotions, and higher mental functions such as **reasoning, memory, and creativity.**

- Both the spinal cord and the brain are **protected by bone.**
  - They are also both wrapped in protective **membranes known as meninges.**
  - The spaces between the meninges are filled with **cerebrospinal fluid, which cushions and protects the CNS.**

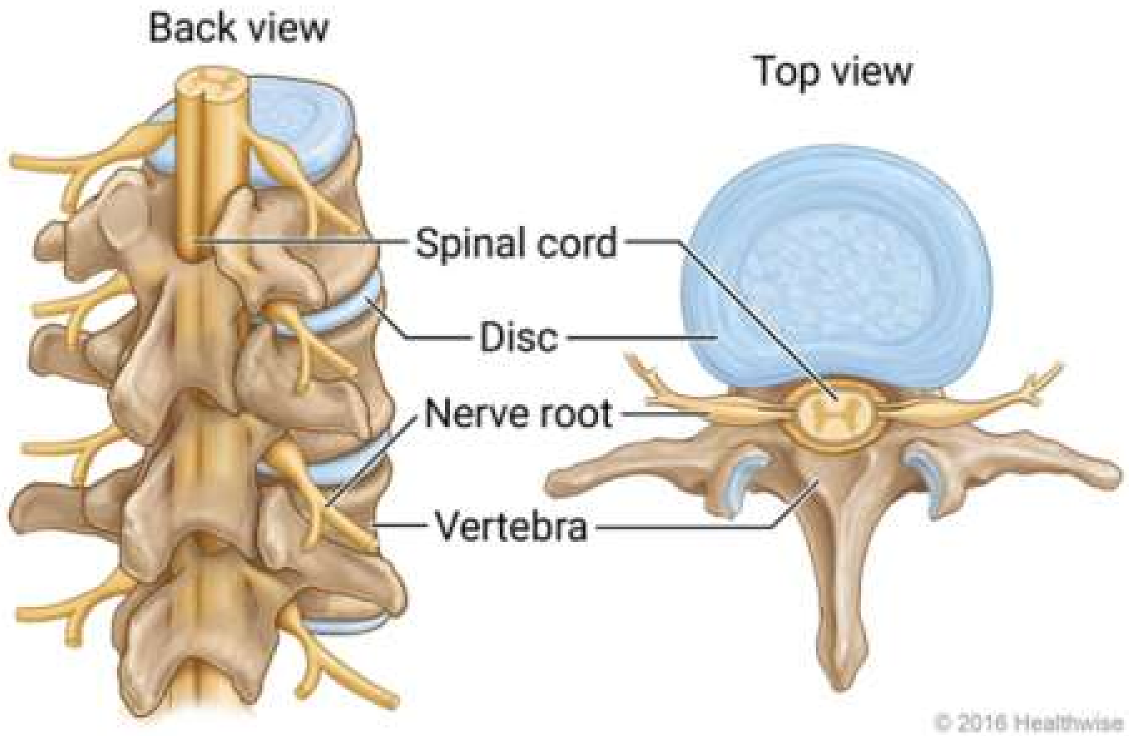
- The brain has hollow interconnecting cavities called ventricles, which also connects with the **hollow central canal of the spinal cord.**
    - The ventricles produce and serve as a **reservoir for cerebrospinal fluid, as does the central canals.**





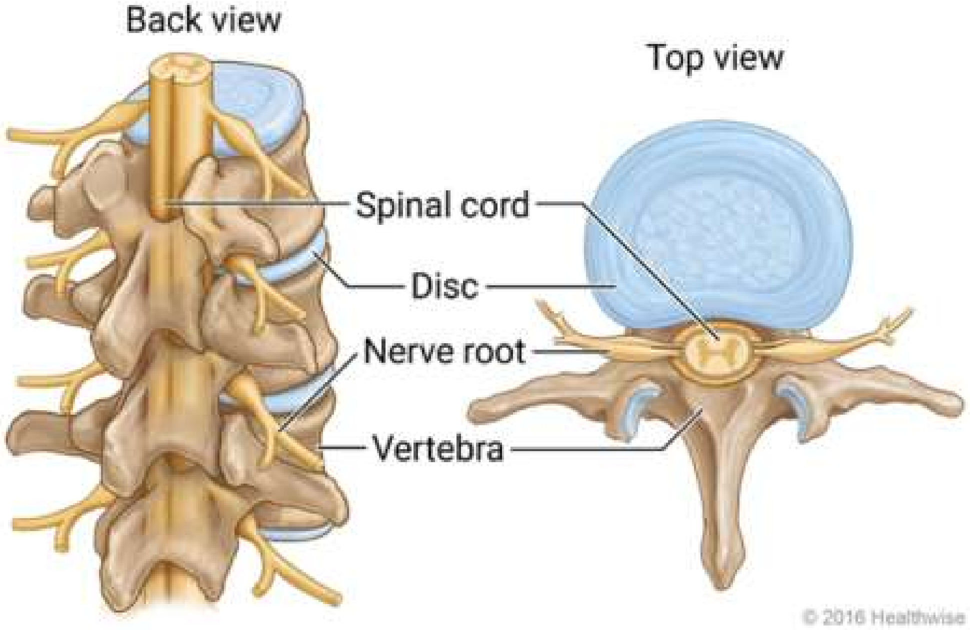
The Spinal Cord

- The spinal cord extends from the base of the brain through a large opening in the skull called the **foramen magnum, and into the vertebral canal.**



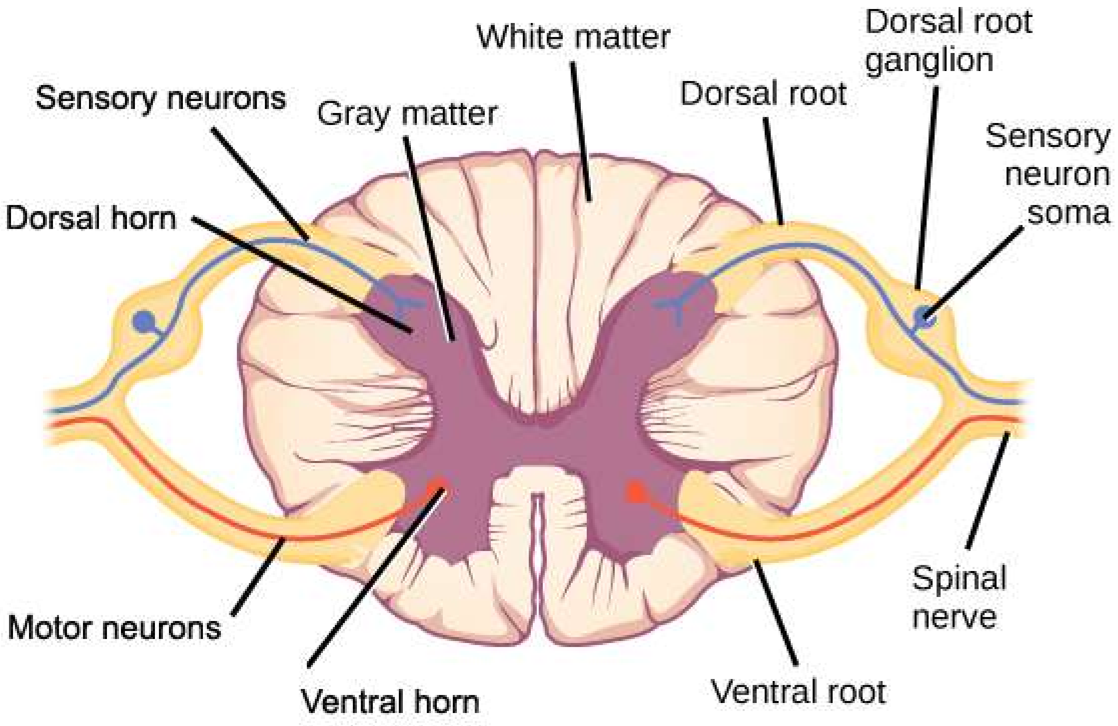
Structure of the Spinal Cord

- The spinal nerves project from the **cord between the vertebrae that make to vertebral column.**
- Fluid filled intervertebral disks **cushion and separate the vertebrae.**



- A cross section of the spinal cord shows a **central canal, grey matter, and white matter.**
  - The central canal contains **cerebrospinal fluid.**
  - Grey matter is in the center and shaped like an H. **Interneurons make up the majority of the grey matter.**
  - The dorsal root of a spinal nerve contains sensory neurons that enter the grey matter, and the **ventral root of a spinal nerve contains motor fibers that exit the grey matter.**
  - Spinal nerves are part of the **PNS**.

- The white matter of the **spinal cord surrounds the grey.**
  - The white matter contains ascending tracts that take information to the brain, and **descending tracts that take information from the brain.**
  - Because the tracts cross after they enter and exit the CNS, **the left side of the brain controls the right side of the body**, and the right side of the brain controls the left side of your body.



Cross Section of Spinal Cord

Function of the Spinal Cord

- The spinal cord provides a means of communication between the **brain and the PNS.**
  - When someone touches your hand, sensory receptors generate nerve impulses that pass through **sensory fibres to the spinal cord and up ascending tracts to the brain.**
  - When we voluntarily move our limbs, motor impulses originating in the brain pass down **descending tract to the spinal cord and out to our muscles through motor fibres.**

- The spinal cord is also the centre for thousands of reflex arcs, which allow the **nerves and muscles to respond very quickly to potentially dangerous stimuli.**
- It also helps to regulate and respond to our **internal organs.**

The Brain

- This section provides only a glimpse of what is known about the brain and the modern adventures of research.
- The brain has four major parts:
  - **The cerebrum**
  - **The diencephalon**
  - **The cerebellum**
  - **The brain stem**

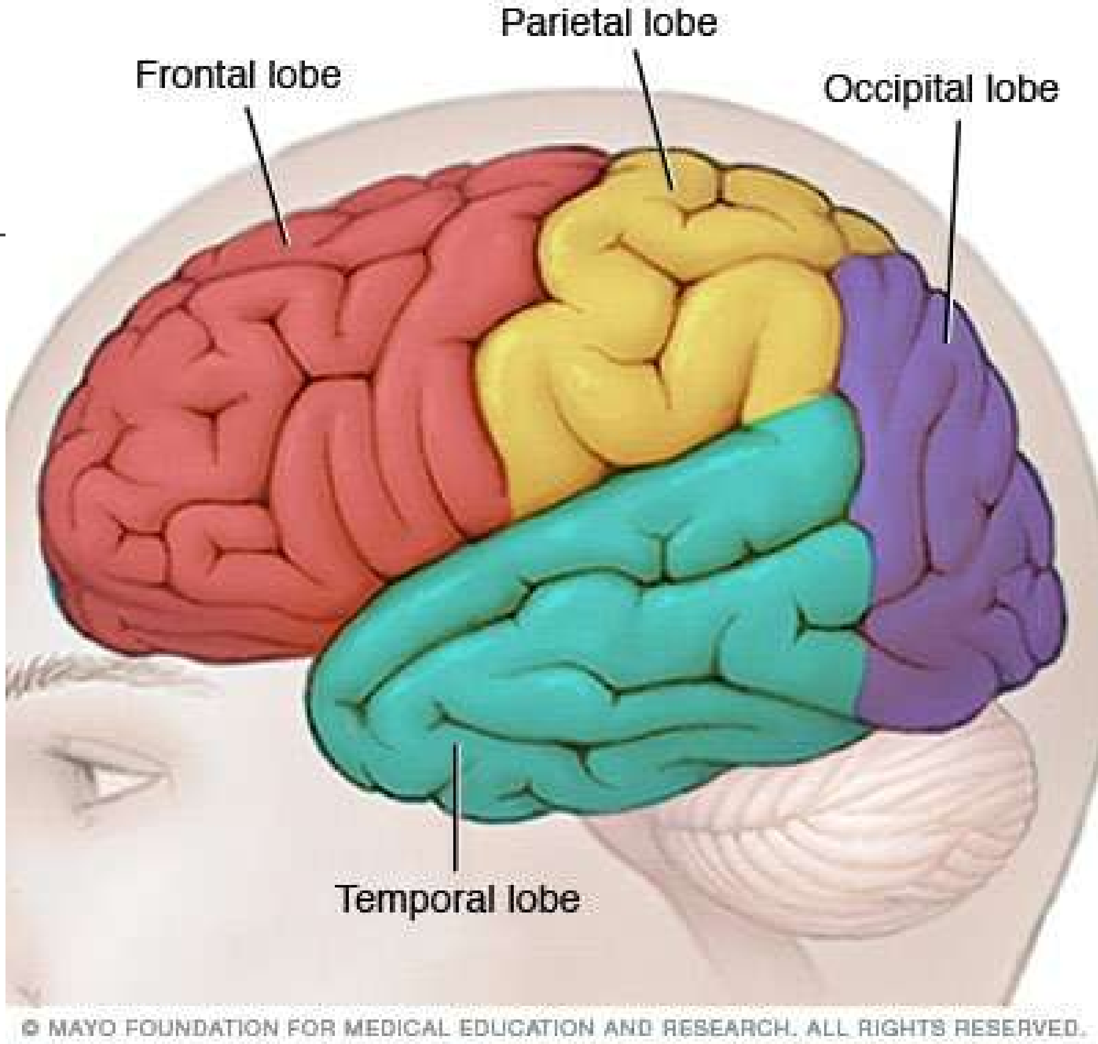
The Cerebrum

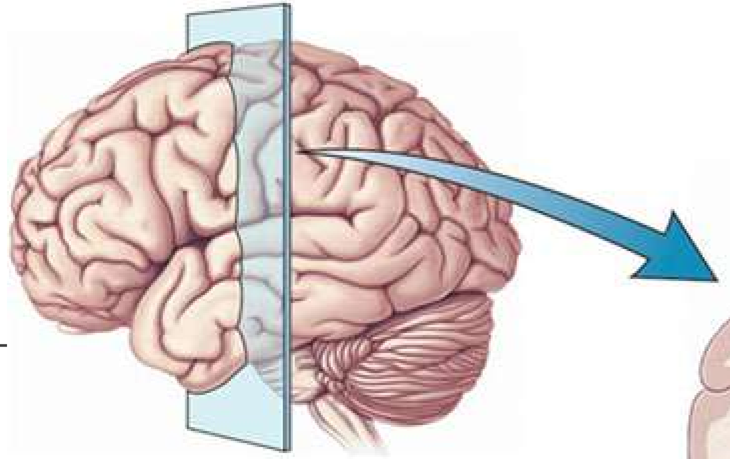
- The cerebrum is the **largest portion of the brain in humans**
- It receives sensory information, interprets it, and then **commands voluntary motor responses.**
- It communicates with, and **coordinates the activities of the other parts of the brain.**

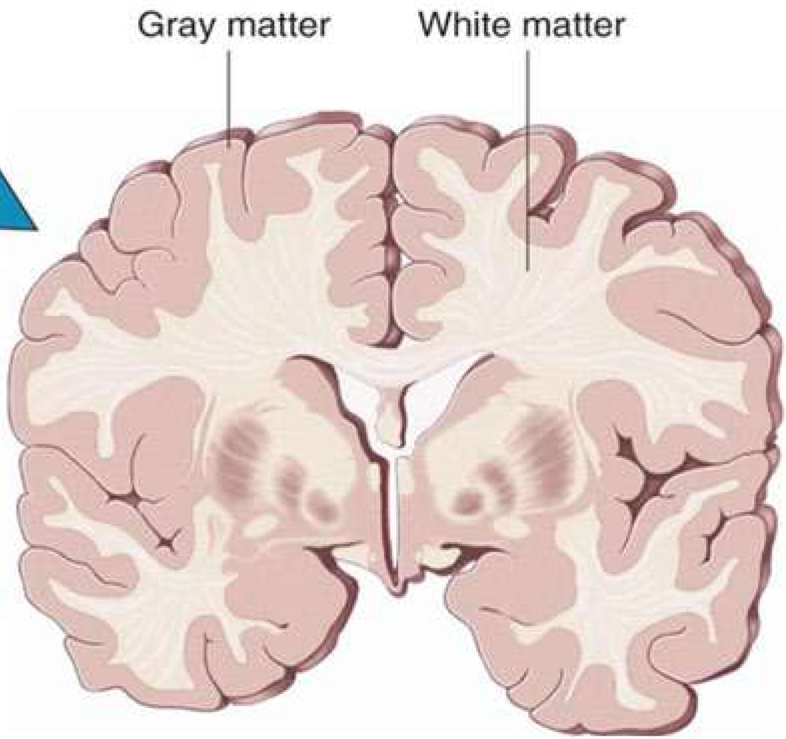
1. The Cerebral Hemispheres

- The brain has two cerebral hemispheres, the **right and left.**
- They are divided by the **longitudinal fissure.**
- The hemispheres communicate with each other via the corpus collosum, **this is an extensive bridge of nerve tracts.**

- **Shallow grooves called sulci** divide each hemisphere into lobes:
  - The frontal lobe is directly **behind the forehead.**
  - The parietal lobe is **posterior to the frontal lobe**
  - The occipital lobe is posterior to the parietal lobe at the **back of the head.**
  - The temporal lobe is found at the side of the head **near the temple and ear.**
- Each lobe is associated with a **particular function.**





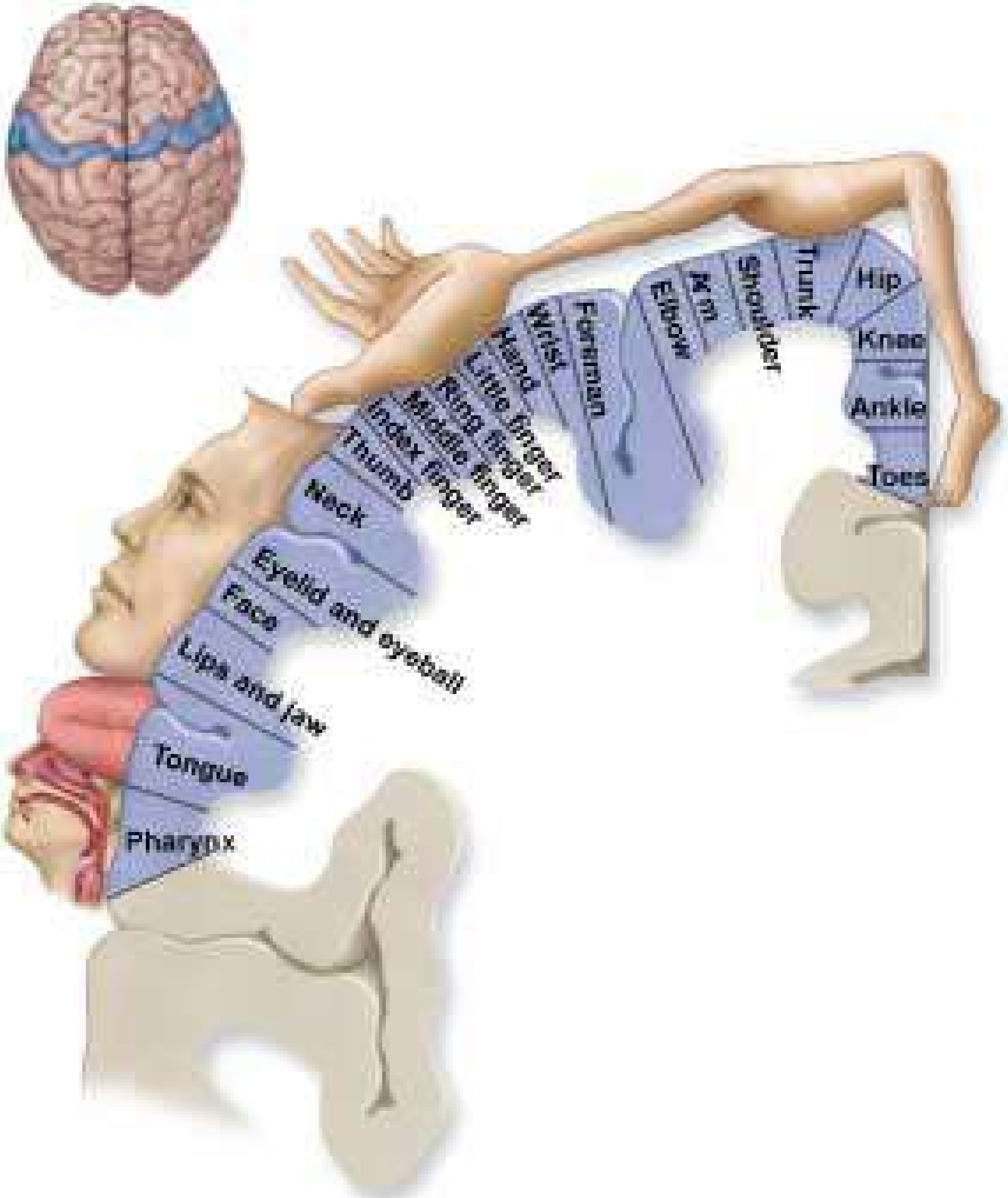


- The cerebral cortex is a thin, highly convoluted outer layer of **grey matter that covers the cerebral hemispheres.**
  - Each fold is called a **gyrus.**
  - The cerebral cortex is the region that accounts for sensation, voluntary movement, and **all thought processes we associate with consciousness.**

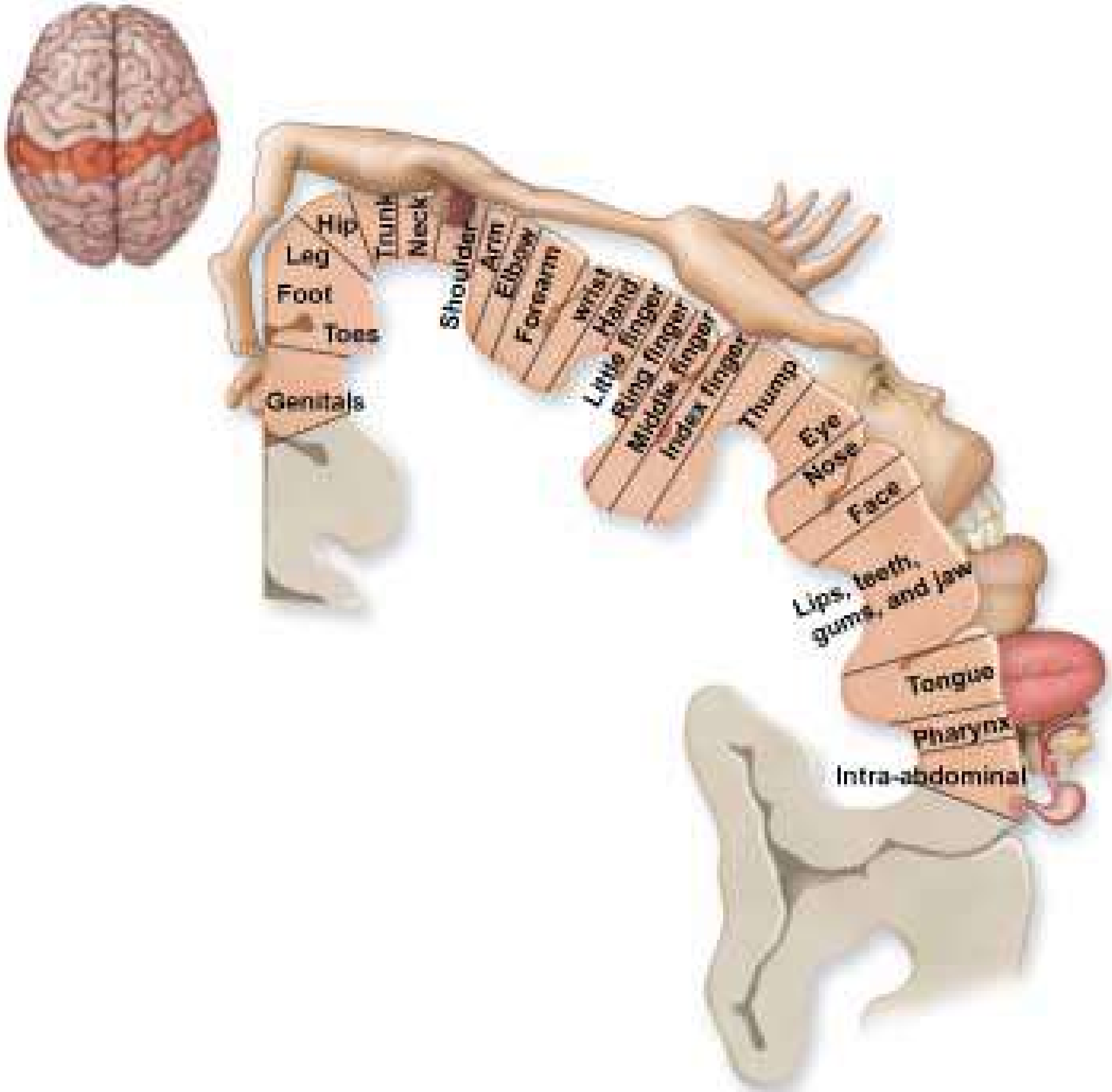
2. Primary Motor & Sensory Areas of the Cortex

- The primary motor area is in the **frontal lobe, anterior to the central sulcus.**
  - **Voluntary commands to skeletal muscles begin in the primary motor area**, each part of the body is controlled by a certain section.
  - Large areas are devoted to controlling structures that carry out very **fine, precise movements.**

- The primary somatosensory area is **posterior to the central sulcus in the parietal lobe.**
  - Sensory information from the **skin and skeletal muscles arrive here.**
  - Large areas of the primary visual area are dedicated to receiving information from areas that receive the **most sensory information such as the face and hands.**



a. Primary motor area



b . Primary somatosensory area

3. Association Areas

- Association areas are where integration occurs and where **memories are stored.**
  - The premotor area organizes motor functions for skilled motor activities, such as **walking and talking at the same time.**
  - The primary motor area then sends signals to the cerebellum, which **integrates them.**

- The somatosensory area, processes and analyzes sensory information from the **skin and muscles.**
  - The visual association area associates visual information with **previously received visual information.**
  - The auditory association area performs the **same for sound.**

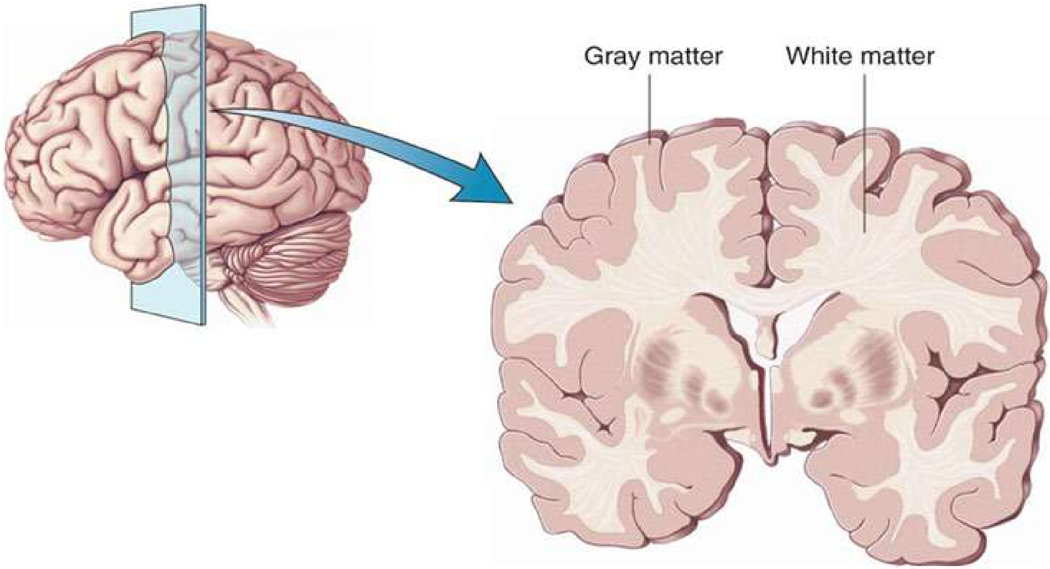
4. Processing Centres

- Processing centres receive information from other association areas and **perform higher-level functions.**
- The prefrontal area, a processing centre in the frontal lobe, receives information from other **association areas and uses it to reason and plan our actions.**

- Humans ability to speak is partially dependent upon two processing centres found in the **left cerebral cortex:**
  - Wernicke’s area – **helps us to understand both written and spoken word**, and sends information to Broca’s area.
  - Broca’s area – adds grammatical refinement and **directs the primary motor area to stimulate the appropriate muscles for speaking.**

5. Central White Matter

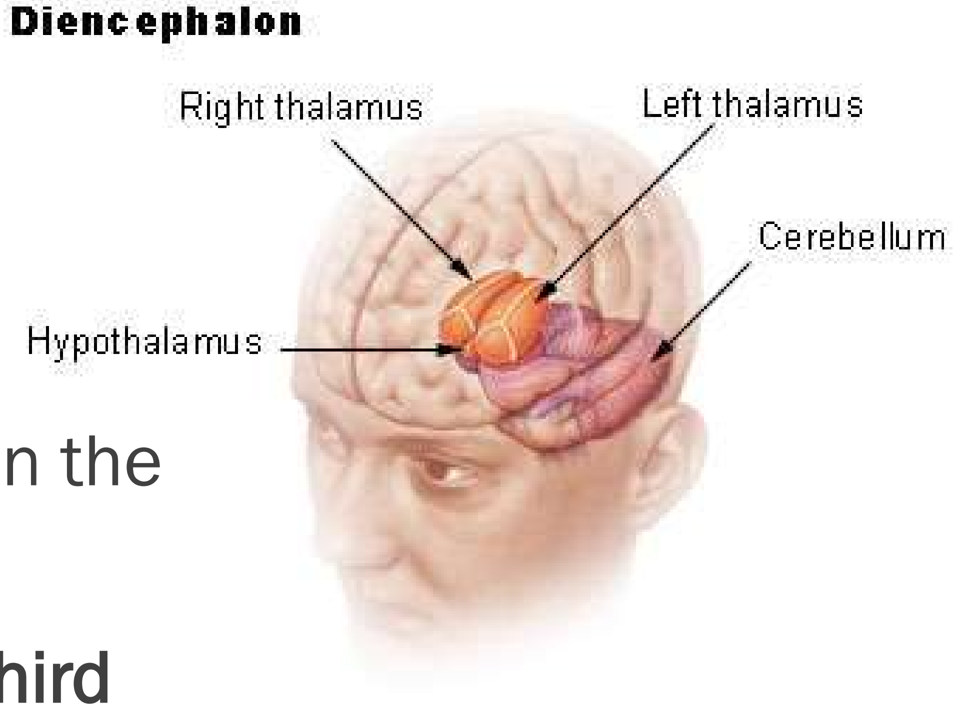
- Beneath the cerebral cortex is composed **primarily of white matter.**
  - Tracts within the cerebrum take information between different **sensory, motor, and association areas.**



6. Basal Nuclei

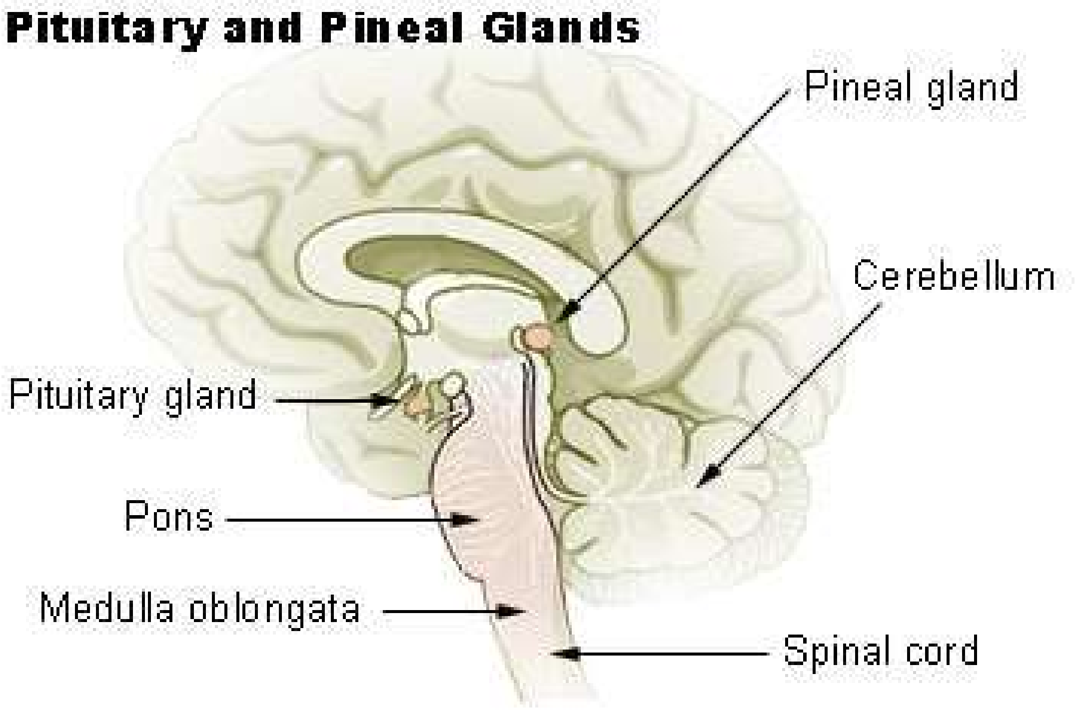
- The majority of the cerebrum is composed of tracts.
- However, there are masses of **grey matter located deep within the white matter.**
  - These basal nuclei integrate motor commands, **ensuring proper muscle groups are activated or inhibited.**

The Diencephalon



- The **hypothalamus and the thalamus** are in the diencephalon.
- The hypothalamus forms the **floor of the third ventricle.**
  - It is the integrating centre that helps **maintain homeostasis.**
  - It regulates **hunger, sleep, thirst, body temperature, and water balance.**
  - It also controls the **pituitary gland.**

- The thalamus consists of two masses of grey matter that form the **sides and roof of the 3rd ventricle.**
  - It receives all sensory information except for **smell.**
  - All other sensory information arrives at the thalamus via the **cranial nerves and tracts from the spinal cord.**
  - It integrates the information and sends it to the appropriate part of **the cerebrum.**
  - It also participates in higher mental functions such as **memory and emotion.**



- The pineal gland also located in the diencephalon, **secretes the hormone melatonin.**
  - This is involved in maintaining our normal **sleep-wake cycle.**

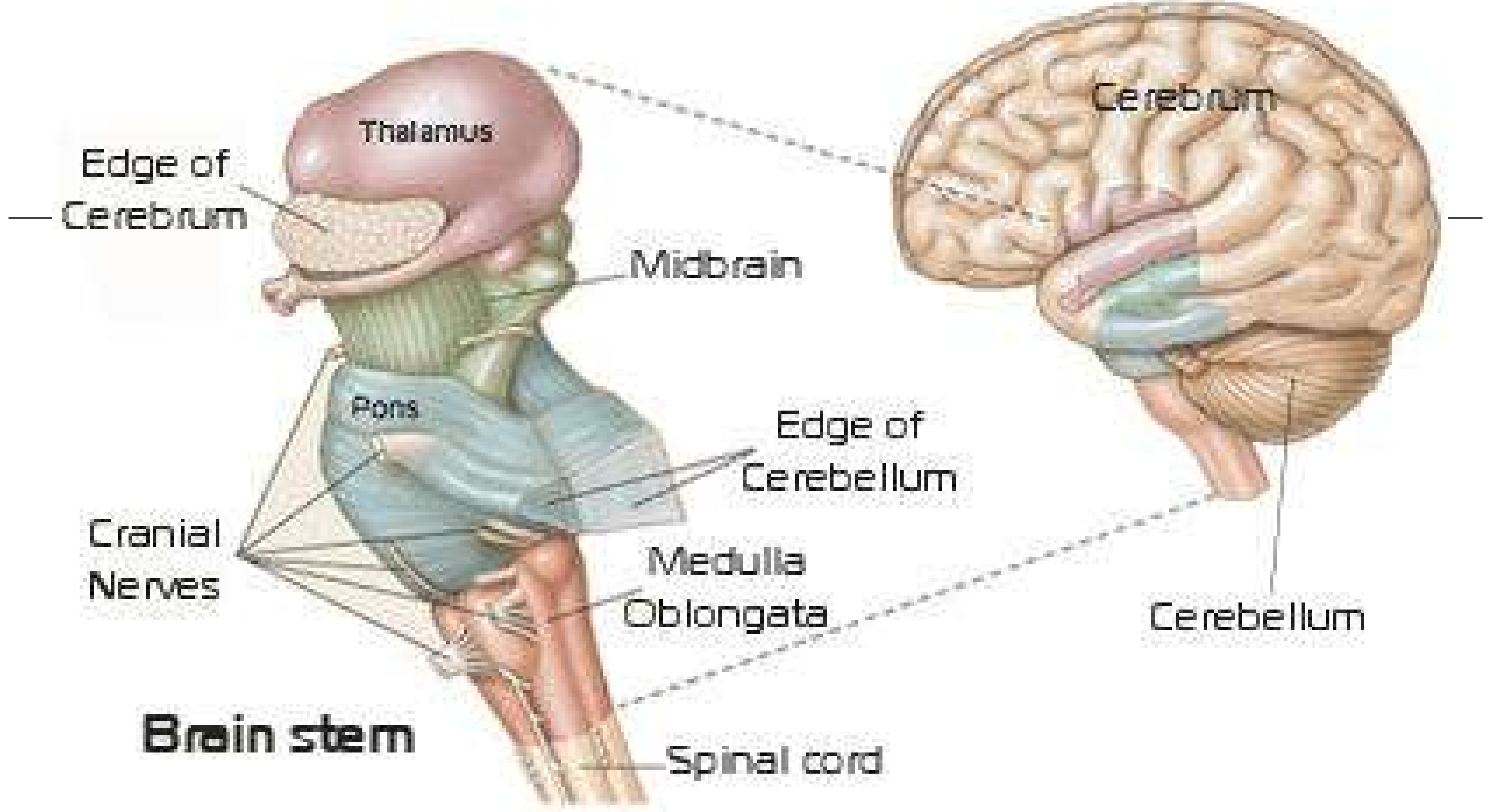
The Cerebellum

- The cerebellum lies under the occipital lobe, and is separated from the brain stem by the **4th ventricle.**
- It is divided into left and right portions, **primarily composed of white matter.**
  - There is a thin layer of **grey matter over the white matter.**

- The cerebellum receives sensory input from the joints, muscles, and other pathways about the **position of body parts.**
  - It also receives motor output from the **cerebral cortex about where the parts should be located.**
  - After integrating this information, it sends **motor signals by way of the brain stem to skeletal muscles.**

The Brain Stem

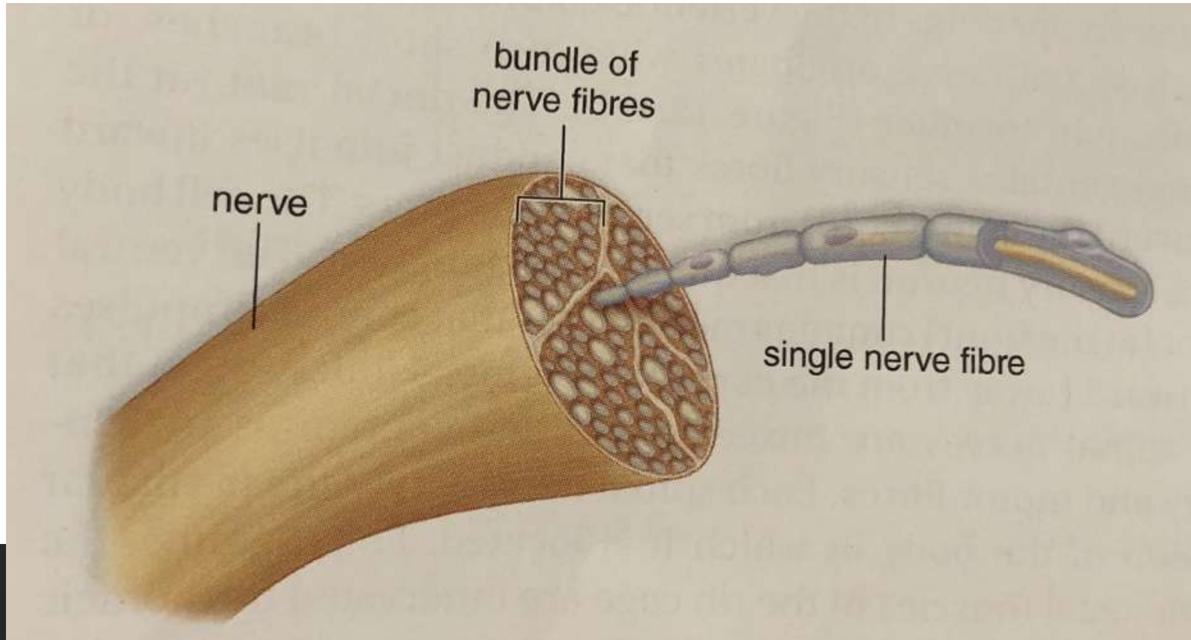
- The brain stem contains the **midbrain, pons, and the medulla oblongata.**
  - The midbrain acts as a relay station for **tracts passing between the cerebrum and spinal cord or cerebellum.** It also has reflex centres for visual, auditory, and tactile responses.
  - The pons contains bundles of axons travelling between the **cerebellum and the rest of the CNS.**
  - The medulla oblongata regulates **vital functions like heartbeat, breathing, and blood pressure.** It also contains reflex centres for vomiting, coughing, sneezing, hiccupping, and swallowing.


Thalamus
Edge of
Cerebrum
Midbrain
Pons
Edge of
Cerebellum
Cranial
Nerves
Medulla
Oblongata
Brain stem
Spinal cord
Cerebrum
Cerebellum

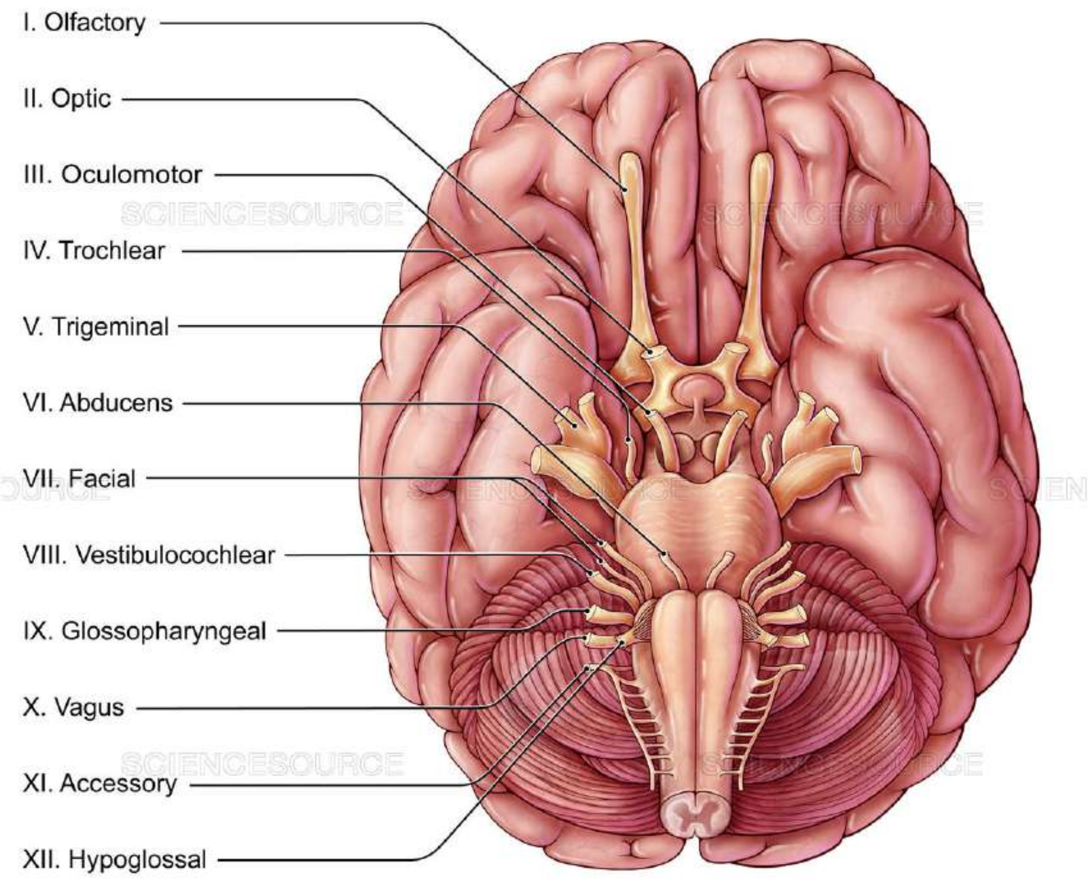
- The reticular activating system (RAS) contains reticular formation, a **complex network of nuclei and nerve fibres** that extend the length of the brain stem.
  - The RAS arouses the cerebrum via the thalamus and causes a **person to be alert.**
  - Apparently, the RAS can filter out **unnecessary sensory stimuli.**
  - A sever injury to the RAS can cause a person to become comatose, from which **recovery may be impossible.**

7.4 – THE PERIPHERAL NERVOUS SYSTEM

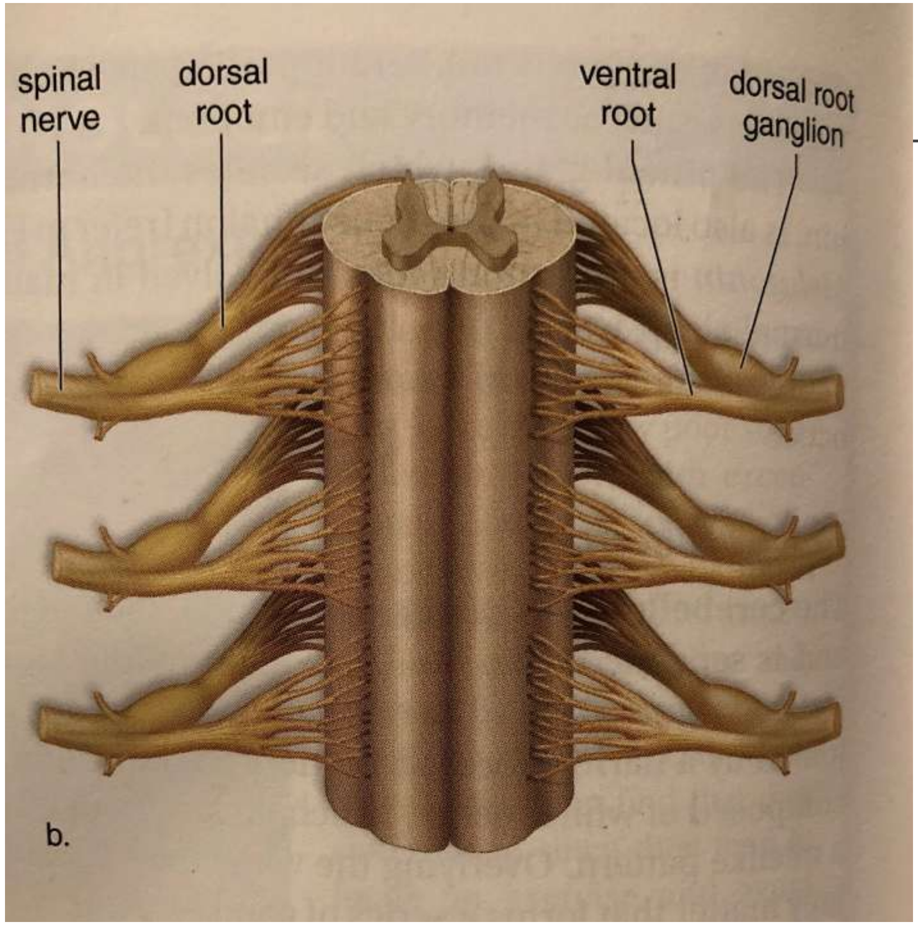
- The peripheral nervous system (PNS) lies outside the central nervous system, and is composed of **nerves and ganglia.**
  - In the PNS, nerves are **bundles of axons.**
  - The axons that occur in nerves are called **nerve fibres.**



- Sensory fibres **carry information to the CNS**, and motor fibres **carry information away from the CNS.**
- Ganglia are swellings associated with nerves that contain **collections of cell bodies.**



- Humans have 12 pairs of **cranial nerves attached to the brain.**
  - Some contain **only sensory input fibres, others contain only motor output fibres,** the remaining are mixed nerves.
  - Cranial nerves are largely concerned with the **head, neck, and facial regions of the body.**



- Humans have **31 pairs of spinal nerves.**

- Each spinal nerve originates when the **dorsal and ventral roots join together.**
  - The dorsal root contains sensory fibres that conduct impulses inward from the sensory receptors.
  - The cell body of a sensory neuron is in a **dorsal root ganglion.**
  - The ventral root contains motor fibres that conduct impulses **outward to effectors.**

Somatic System

- The PNS is subdivided into the **somatic system and the autonomic system.**
  - The somatic system serves the **skin, skeletal muscles, and tendons.**
  - It includes nerves that take sensory information from sensory receptors to the CNS, and **motor commands away from the CNS to the skeletal muscles.**
  - Some actions are due to reflex actions, which are **involuntary responses to a stimulus.**

The Reflex Arc

- This is a nerve pathway that **carries out a reflex.**
  - Reflexes are programmed, built-in circuits that allow for **protection and survival.**
  - They are present at birth and require **no conscious thought.**
- Ex) if your hand touches a sharp pin, sensory receptors generate nerve impulses that move along sensory fibres through the dorsal root ganglia **toward the spinal cord.**
  - The sensory neurons pass signals on to interneurons, which **synapse with a motor neuron, eventually reaching an effector.**
  - In this case it is the muscles in your arm/hand **withdrawing it from the pin.**

Reflex Arc Diagram

Autonomic System

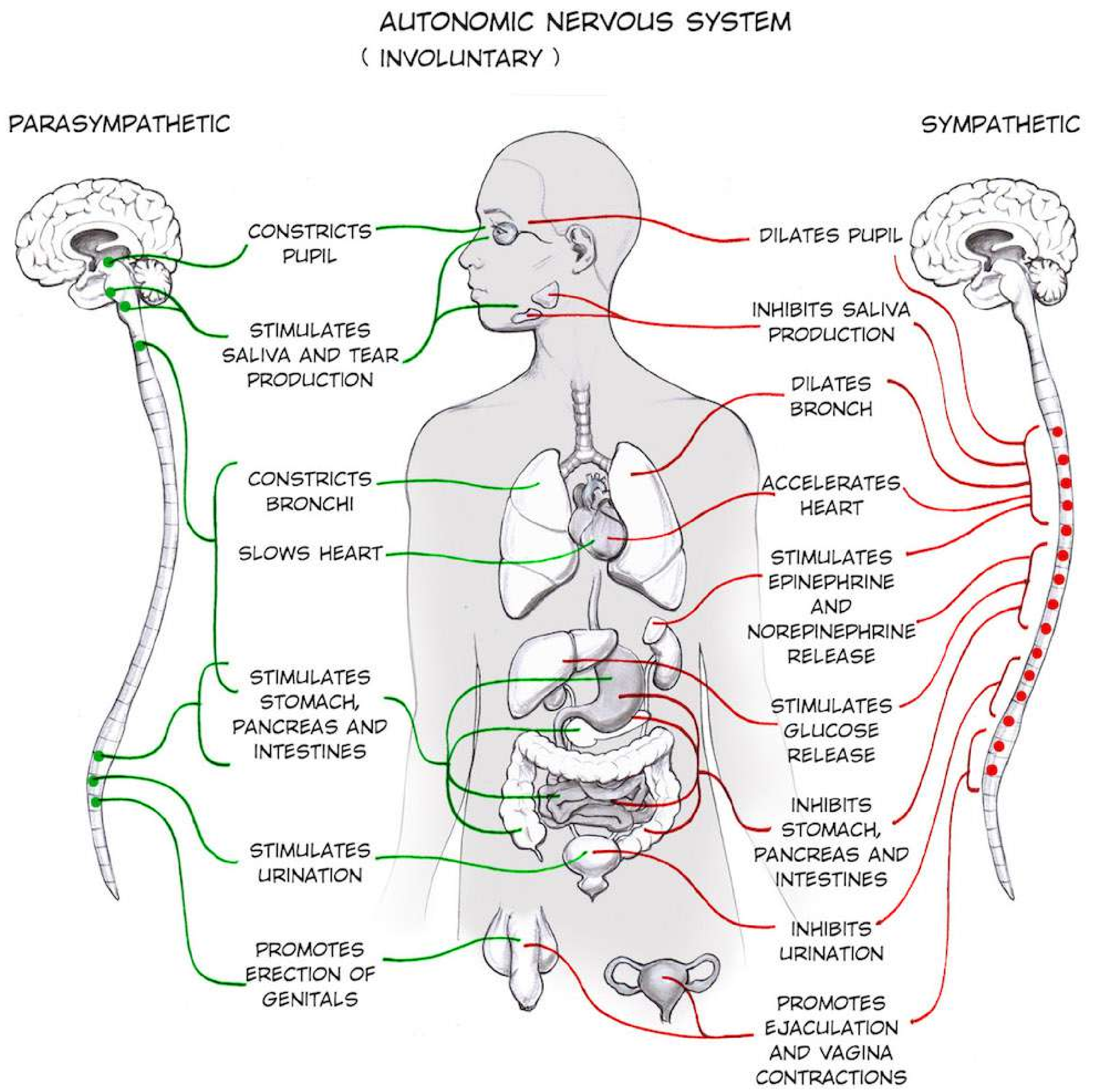
- The autonomic system regulates the activity of **cardiac and smooth muscle glands.**
  - It is broken into the **sympathetic, and parasympathetic divisions.**
  - These two division have several features in common:
    - They function automatically and **usually in an involuntary manner.**
    - They innervate all **internal organs.**
    - For each signal, they use **two motor neurons that synapse at a ganglion.**

- The first neuron has a **cell body in the CNS**
  - It’s axon is called the **preganglionic fibre.**
- The second neuron has a **cell body in the ganglion.**
  - It’s axon is called the **postganglionic fibre.**
- Reflex actions are especially important in **maintaining homestasis.**

Sympathetic Divisions

- The sympathetic division is important during emergency situations, ie) **the fight or flight response.**
  - It accelerates the **heartbeat and dilates the bronchi.**
  - Active muscles require a ready supply of **glucose & oxygen.**
  - However, it **inhibits digestion.**

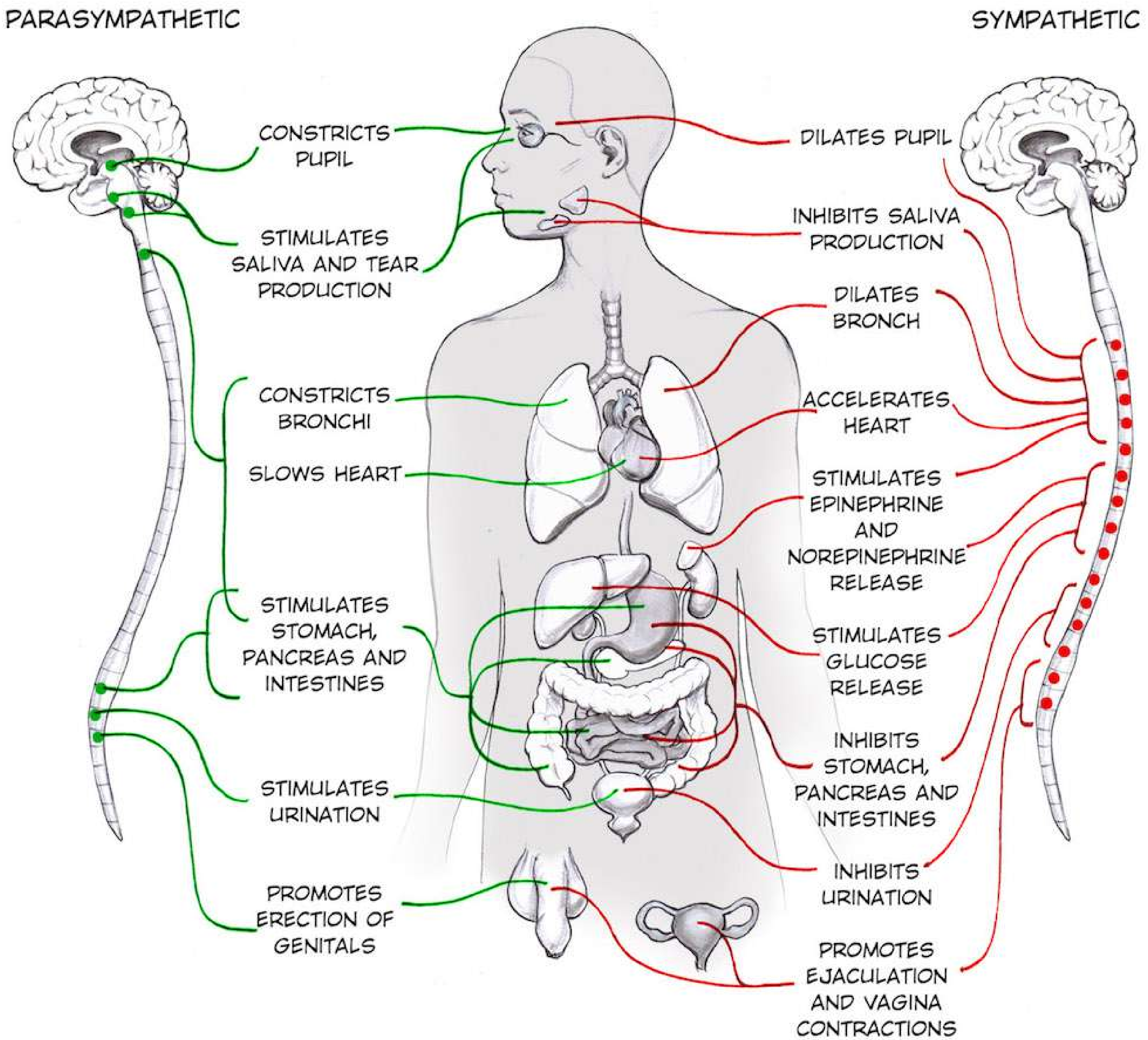
- The sympathetic division activates the adrenal medulla to secrete **epinephrine (adrenaline), and norepinephrine (NE) into the blood.**
  - These two hormones bind to receptors on various cell types, adding to the **fight or flight response.**
- Because they cause the heart to beat stronger and faster, and constrict certain blood vessels, they tend to **increase blood pressure.**


AUTONOMIC NERVOUS SYSTEM
(INVOLUNTARY)
PARASYMPATHETIC
SYMPATHETIC
CONSTRICTS PUPIL
STIMULATES SALIVA AND TEAR PRODUCTION
CONSTRICTS BRONCHI
SLOWS HEART
STIMULATES STOMACH, PANCREAS AND INTESTINES
STIMULATES URINATION
PROMOTES ERECTION OF GENITALS
DILATES PUPIL
INHIBITS SALIVA PRODUCTION
DILATES BRONCH
ACCELERATES HEART
STIMULATES EPINEPHRINE AND NOREPINEPHRINE RELEASE
STIMULATES GLUCOSE RELEASE
INHIBITS STOMACH, PANCREAS AND INTESTINES
INHIBITS URINATION
PROMOTES EJACULATION AND VAGINA CONTRACTIONS

Parasympathetic Division

- The parasympathetic division is sometimes called the **housekeeper division.**
  - It promotes all the internal responses we associate with **“rest and digest”**
  - It causes the **pupils to contract, digestion of food, and slows the heartbeat.**
  - The NT used by this division is called **acetylcholine** (Ach)

AUTONOMIC NERVOUS SYSTEM
(INVOLUNTARY)



7.5 – DISORDERS OF THE NERVOUS SYSTEM

- Disorders of the nervous system are broken into:
  - Disorders of the brain
  - Disorders of the spinal cord
  - Disorders of the peripheral nerves

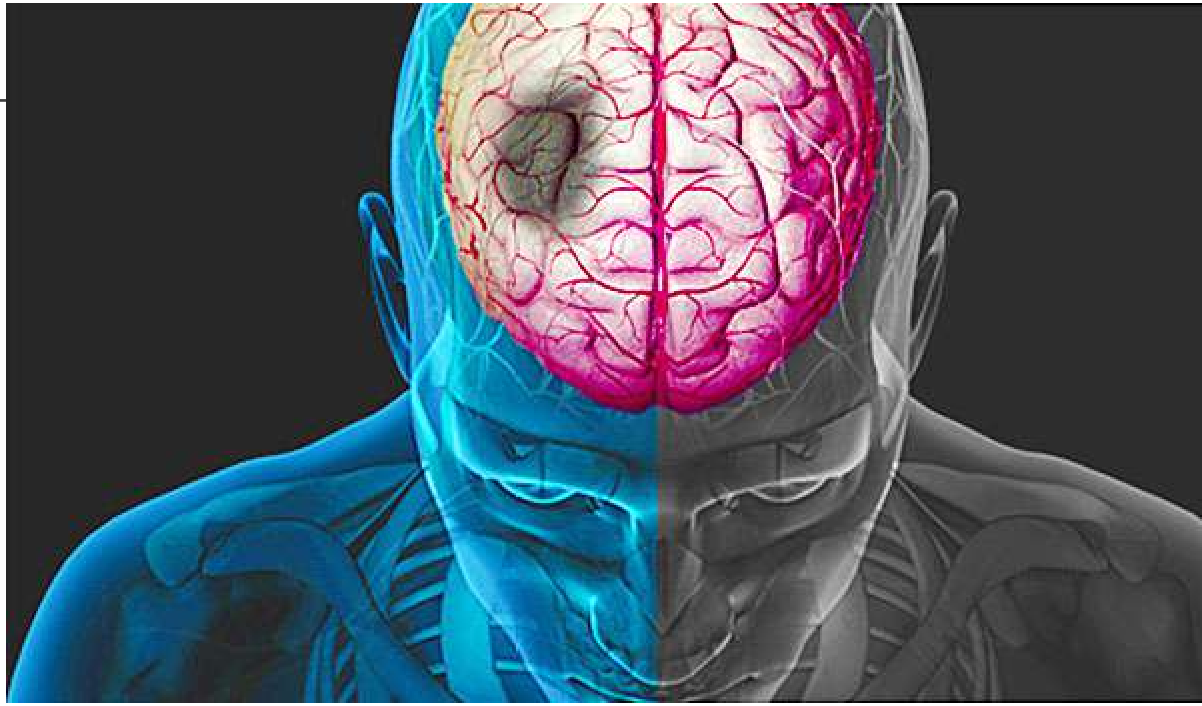
Disorders of the Brain

- Alzheimer's disease is the most common cause of dementia.
  - Signs of AD are usually seen after age 65.
  - One of the early symptoms is loss of **memory, particularly of recent events.**
  - Gradually, the person loses the ability to perform any type of daily activity and **becomes bedridden.**
  - Abnormal neurons are present especially in the hippocampus and amygdala. These neurons have two abnormalities:
    - **Plaques envelope the axons.**
    - **Neurofibrillary tangles are in the axons.**

- Parkinson’s disease is characterized by a **gradual loss of motor control.**
  - Eventually, the person develops a wide-eyed unblinking expression, **involuntary tremors, muscle rigidity, shuffling gait.**
  - Here the basal nuclei function improperly because of a degeneration of **neurons in the brain that release dopamine.**
  - Without dopamine, the excessive excitatory signals from the motor cortex result in the symptoms of PD.

- Multiple sclerosis (MS) is the most common neurological disease that **afflicts young adults.**
  - MS affects the myelin sheath of neurons in the **white matter of the brain.**
  - It is considered an autoimmune disease in which the persons own **WBC's attack the myelin.**
  - The most common symptoms include fatigue, vision problems, **limb weakness, and numbness and tingling.**
  - MS can also take several forms, from the milder relapsing-remitting form to more **relentlessly progressive forms.**

- A stroke results in a disruption of **blood supply to the brain.**
  - There are two major forms: **hemorrhagic and ischemic.**
  - In hemorrhagic, bleeding occurs in the brain due to **leakage from small arteries.**
  - Ischemic strokes occur when there is a sudden **loss of blood supply to an area of the brain** from a blot clot.
  - Some degree of paralysis and aphasia are common signs.



- Meningitis is an infection of the **meninges that surround the brain and spinal cord.**
  - Most cases are caused by **bacteria of viruses.**
  - Because cells of the immune system have somewhat limited access to the brain, infection may spread into the **brain tissue.**
  - Bacterial meningitis is especially serious, even life threatening.

Disorders of the Spinal Cord

- Spinal cord injuries may result from **car accidents or other trauma.**
- Because little or no nerve regeneration is possible in the CNS, any resulting disability is usually permanent.
  - The location and extent of the damage produce a variety of effects, depending on the **partial or complete stoppage of impulses passing up and down the spinal cord.**

- Amyotrophic lateral sclerosis is a rare but devastating condition that affects the **motor nerves of the spinal cord.**
  - It is incurable, and most people die within 5 years of being diagnosed, mainly due to **failure of the respiratory muscles.**
  - About 10% of patients survive for 10 or more years.

Disorders of the Peripheral Nerves

- Guillian-Barre syndrome (GBS) is an inflammatory disease that causes a **demyelination of peripheral nerve axons.**
  - It is thought to result from an **abnormal immune response to infectious agents.**
  - Symptoms usually begin with weakness or unsteadiness in the lower limbs, and may eventually **affect the respiratory muscles.**
  - Most patients make a full recovery in **6-12 months.**

- Myasthenia gravis (MG) is an autoimmune disorder in which antibodies are formed that react against the Ach receptor at the **neuromuscular junction of the skeletal muscles.**
  - In MG, antibodies bind to the Ach receptor and block binding of Ach, **preventing muscle stimulation.**
  - There is no cure, but MG patients often respond well to treatment with **immunosuppressive drugs.**