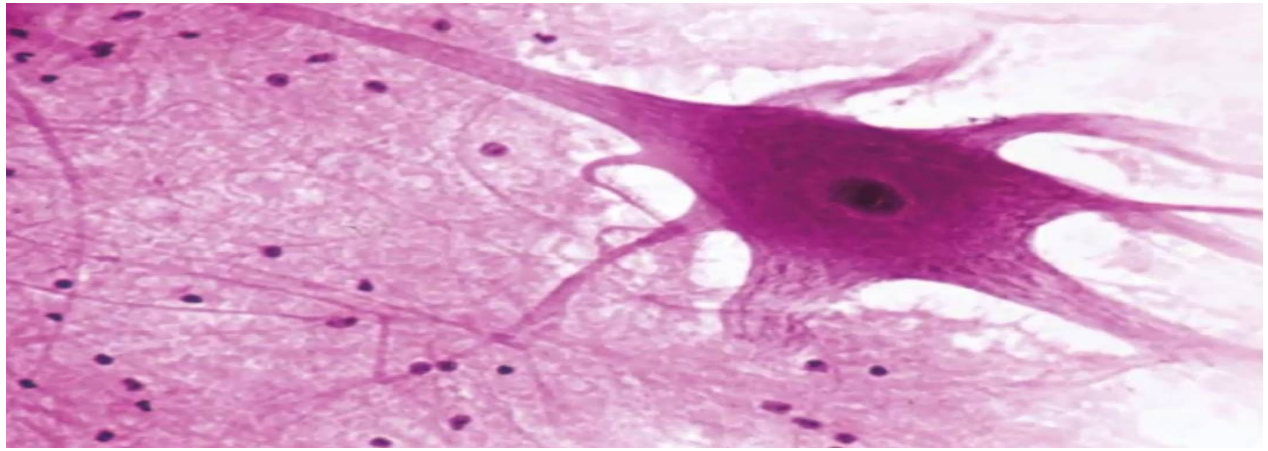
THE NERVOUS SYSTEM

OVERVIEW

detects environmental changes that impact the body, works with the endocrine system to respond

Responsible for all our behaviors, memories, and movement

Able to accomplish all these functions because of the excitable characteristic of nervous tissue, allows for the generation of action potentials



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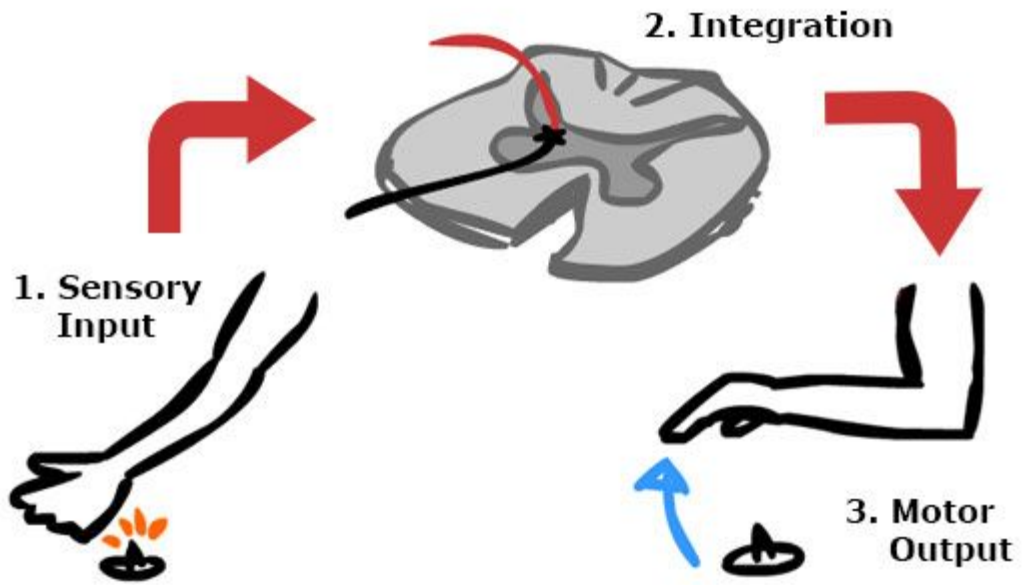
Everything done in the nervous system involves 3 fundamental steps:

- A sensory function detects internal and external stimuli
- An interpretation is made (analysis)
- A motor response occurs (reaction)



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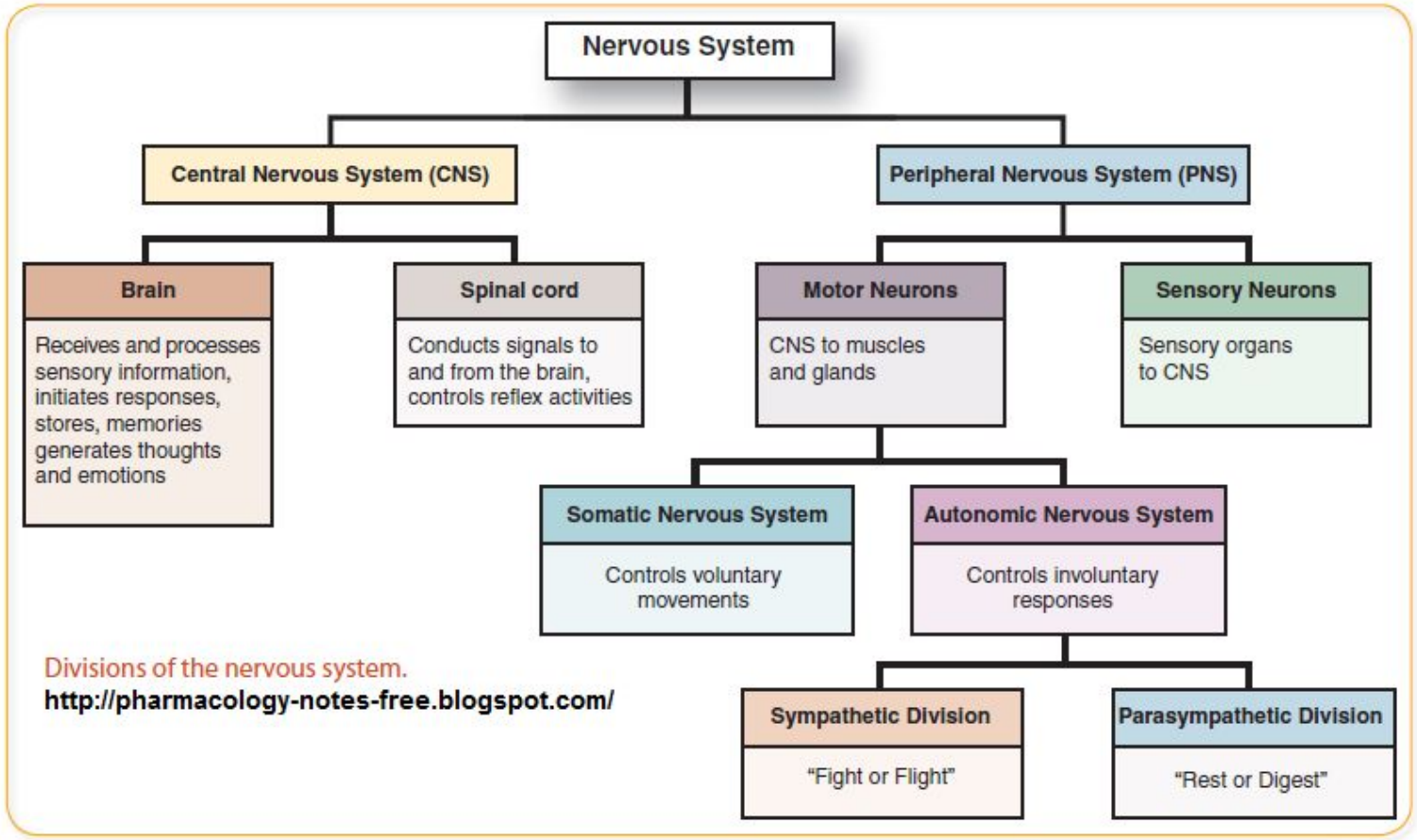
Over 100 billion neurons and 10–50 times that number of neuroglia

Glial cells play a major role in support and nutrition of the brain, do not manipulate information. They maintain the internal environment so that neurons can do their jobs

Nerve cells are organized into two main subdivisions:

- CNS
- PNS

NERVOUS SYSTEM DIVISONS



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- CNS - brain and spinal cord
  - Most signals that stimulate muscles to contract and glands to secrete originate in the CNS
- PNS - all nervous tissue outside the CNS
  - Includes nerves, ganglia, enteric plexuses, and sensory receptors

FURTHER DIVISION OF THE PNS

somatic nervous system (SNS)

- innervates skeletal muscles.

autonomic nervous system (ANS)

- innervates lungs, heart, urinary system and vessels.

enteric nervous system (ENS)

- innervates digestive organs.

FURTHER DIVISION OF THE SNS

(SNS)consists of:

Somatic sensory (afferent) neurons

convey information from sensory receptors in the head, body wall and limbs towards the CNS.

Somatic motor (efferent) neurons

conduct impulses away from the CNS towards the skeletal muscles under voluntary control in the periphery.

Interneurons are any neurons that conduct impulses between afferent and efferent neurons within the CNS.

FURTHER DIVISION OF THE ANS

Sensory neurons

- convey information from autonomic sensory receptors located primarily in visceral organs like the stomach or lungs to the CNS.

Motor neurons

- involuntary control conduct nerve impulses from the CNS to smooth muscle, cardiac muscle, and glands
- The motor part of the ANS consists of two branches which usually have opposing actions:
  - sympathetic division (F or F)
  - parasympathetic division (R & D)

ENTERIC NERVOUS SYSTEM

ENS

involuntarily controls GI propulsion, and acid and hormonal secretions.

Once considered part of the ANS, the ENS consists of over 100 million neurons in enteric plexuses that extend most of the length of the GI tract

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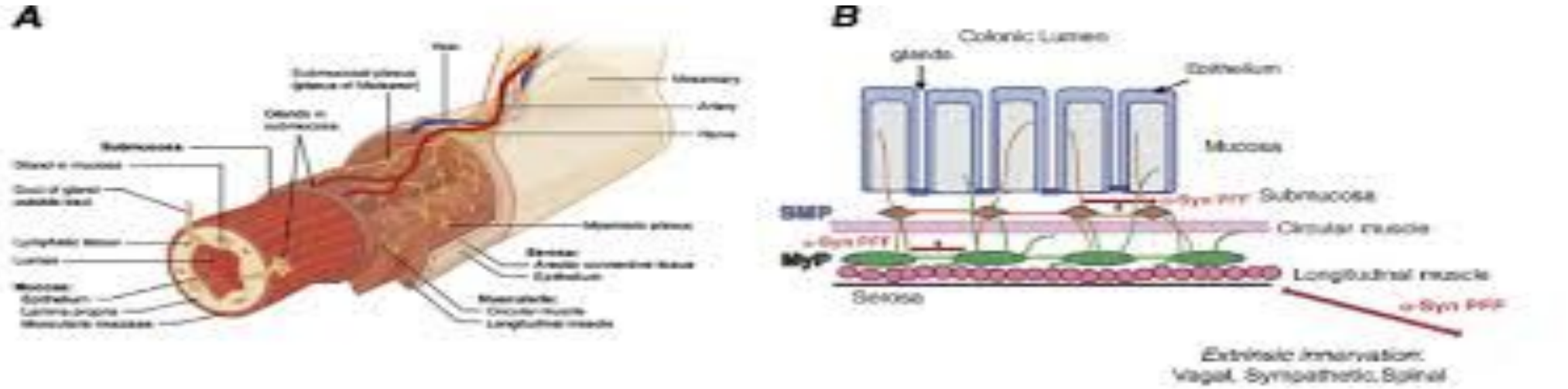


NEURONS & NEUROGLIA

Neurons and neuroglia combine in a variety of ways in different regions of the nervous system.

Neurons are the “functional unit”

- form complex processing networks within the brain and spinal cord that bring all regions of the body under CNS control

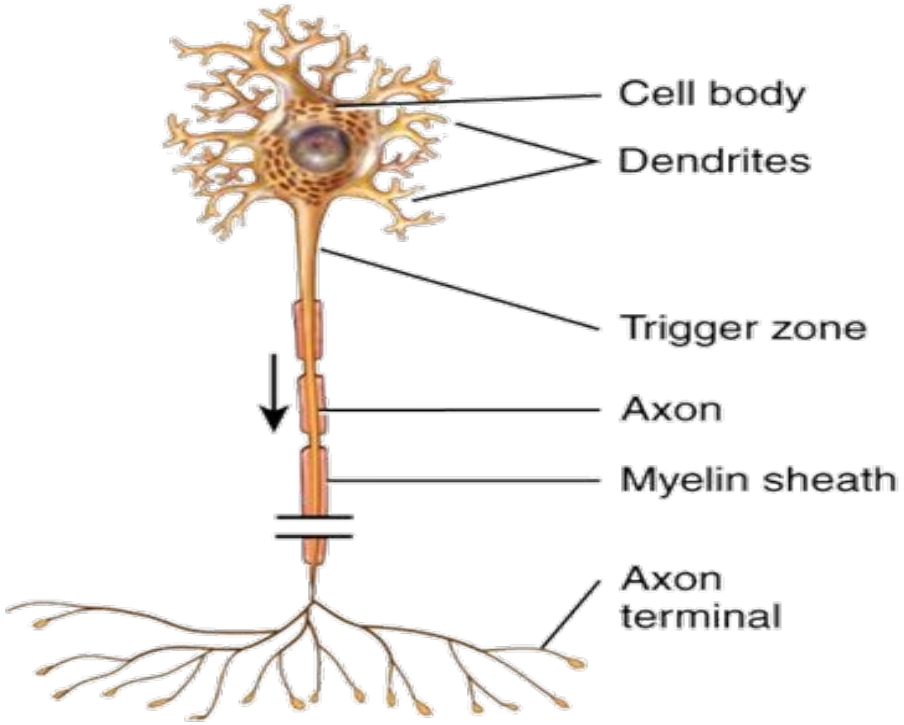
Neuroglia, though smaller than neurons, greatly outnumbers them

- support and maintain the neuronal networks

NEURONS

Though there are several different types of neurons, most have:

- A cell body
- An axon
- Dendrites
- Axon terminals



(a) Multipolar neuron

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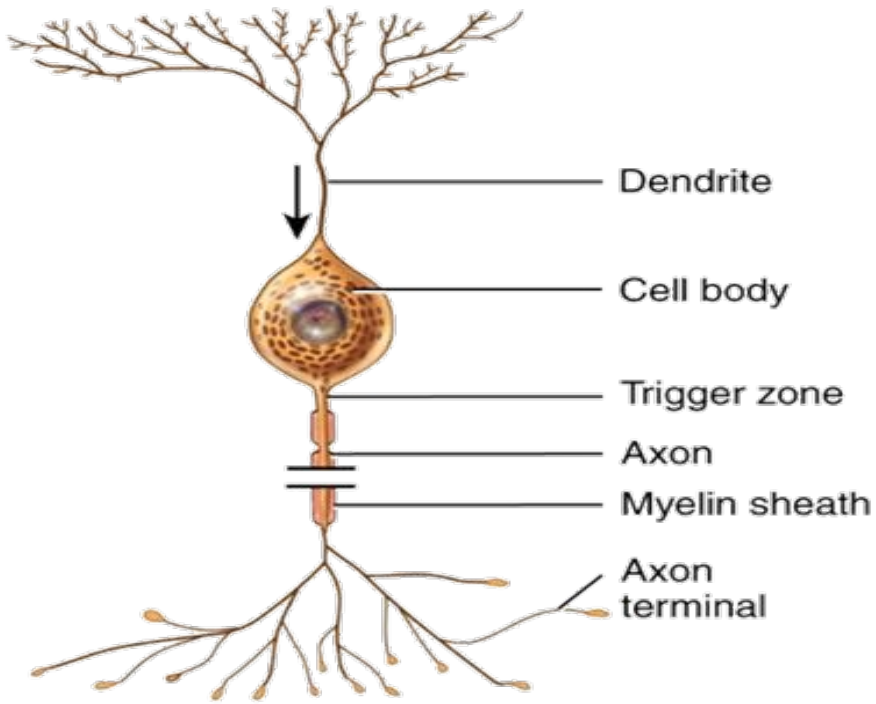
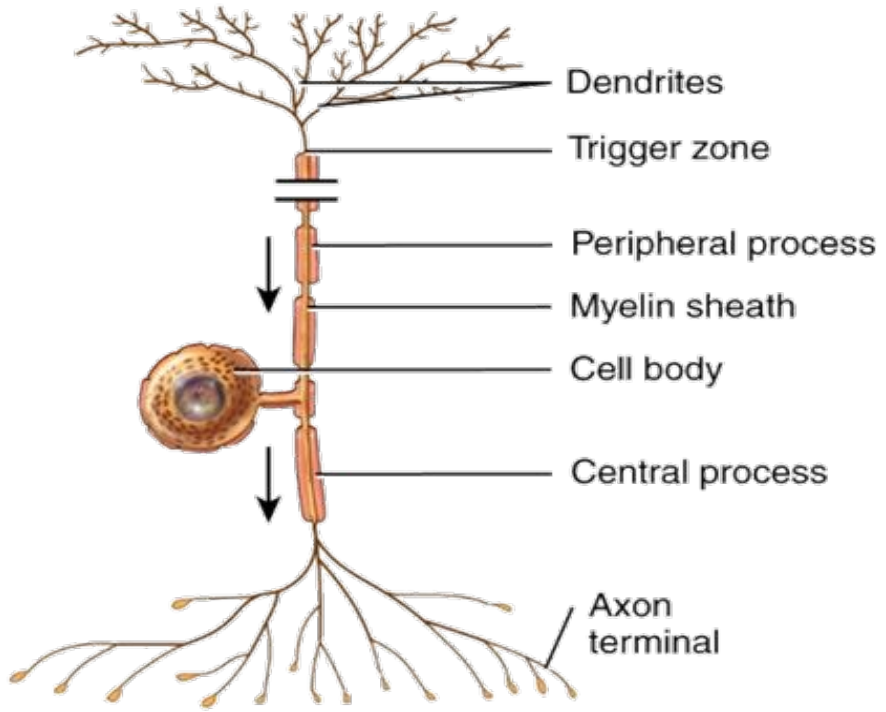


(b) Bipolar neuron



(c) Unipolar neuron

PARTS OF A NEURON

Neurons gather information at dendrites and process it in the dendritic tree and cell body Then they transmit the information down their axon to the axon terminals.

Dendrites (little trees) are the receiving end of the neuron.

- They are short, highly branched structures that conduct impulses toward the cell body.
- They also contain organelles.

cell body has a nucleus surrounded by cytoplasm.

- contain organelles such as lysosomes, mitochondria, Golgi complexes, and rough ER for protein production (in neurons, RER is called Nissl bodies), No mitotic apparatus is present

CONTINUED

Axons conduct impulses away from the cell body toward another neuron or effector cell.

- The “axon hillock” is where the axon joins the cell body.
- The “initial segment” is the beginning of the axon.
- The “trigger zone” is the junction between the axon hillock and the initial segment.

The axon and its collaterals end by dividing into many fine processes called axon terminals. The tips of some axon terminals swell into bulb-shaped structures called synaptic end bulbs

The site of communication between two neurons or between a neuron and another effector cell is called a synapse.

SYNAPTIC CLEFT

Gap between the pre and post-synaptic cells.

Synaptic end bulbs and other varicosities on the axon terminals of presynaptic neurons contain many tiny membrane-enclosed sacs called synaptic vesicles that store packets of neurotransmitter chemicals. Many neurons contain two or even three types of neuro-transmitters, each with different effects on the postsynaptic cell

Electrical impulses or action potentials (AP) cannot propagate across a synaptic cleft. Instead, neurotransmitters are used to communicate at the synapse, and re-establish the AP in the postsynaptic cell.

Substances synthesized or recycled in the neuron cell body are needed in the axon or at the axon terminals

CONTINUED

Two types of transport systems carry materials from the cell body to the axon terminals and back

- Slow axonal transport conveys axoplasm(the cytoplasm in axons) in one direction only – from the cell body toward the axon terminals.
- Fast axonal transport moves materials in both directions. that occurs in an anterograde (forward) direction moves organelles and synaptic vesicles from the cell body to the axon terminals. Fast axonal transport that occurs in a retrograde (backward) direction moves membrane vesicles and other cellular materials from the axon terminals to the cell body to be degraded or recycled.

CONTINUED

Substances that enter the neuron at the axon terminals are also moved to the cell body by fast retrograde transport. These substances include trophic chemicals such as nerve growth factor, as well as harmful agents such as tetanus toxin and the viruses that cause rabies and polio.

NEURON SIZE & SHAPE

The longest nerve in your body is the **sciatic nerve**- whose roots start at the level of your lumbar vertebrae and stretch all the way to the tips of your toes.
The longest axons of neurons in your body are found in the **dorsal root ganglion**, which carries information from your skin to the brain. Some axons could stretch all the way from the tips of your toes to the brain stem.

The pattern of dendritic branching is varied and distinctive for neurons in different parts of the NS. Some have very short axons or lack axons altogether, such as **interneurons in the spinal cord.**

NEURON STRUCTURE AND CLASSIFICATION

Can be structural or functional

Structural – based on number of processes (axons or dendrites) extending from the cell body

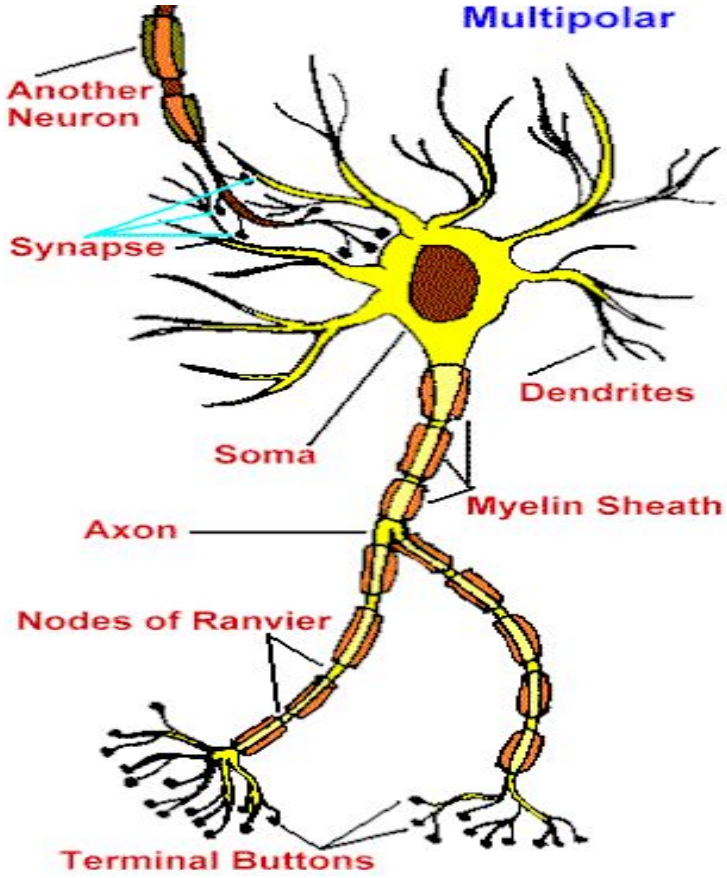
- Multipolar
- Unipolar
- bipolar

MULTIPOLAR NEURON

several dendrites and only one axon

located throughout the brain and spinal cord

majority of the neurons in the human body are multipolar.



BIPOLAR NEURON

have one main dendrite and one axon

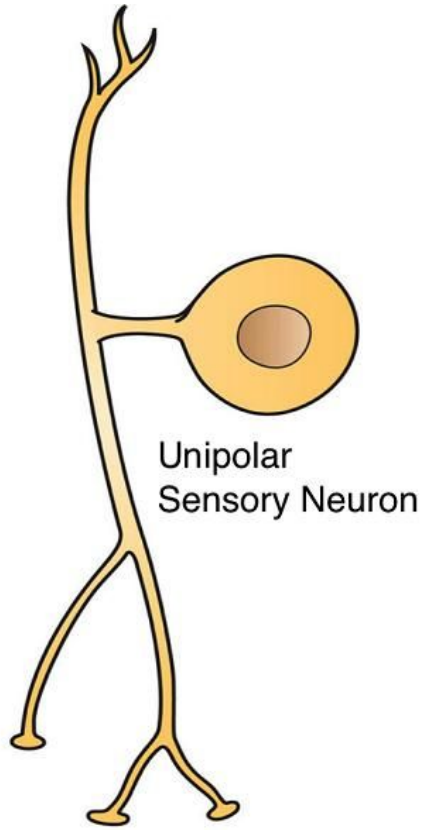
convey the special senses of sight, smell, hearing and balance

found in the retina of the eye, the inner ear, and the olfactory area of the brain

UNIPOLAR NEURON

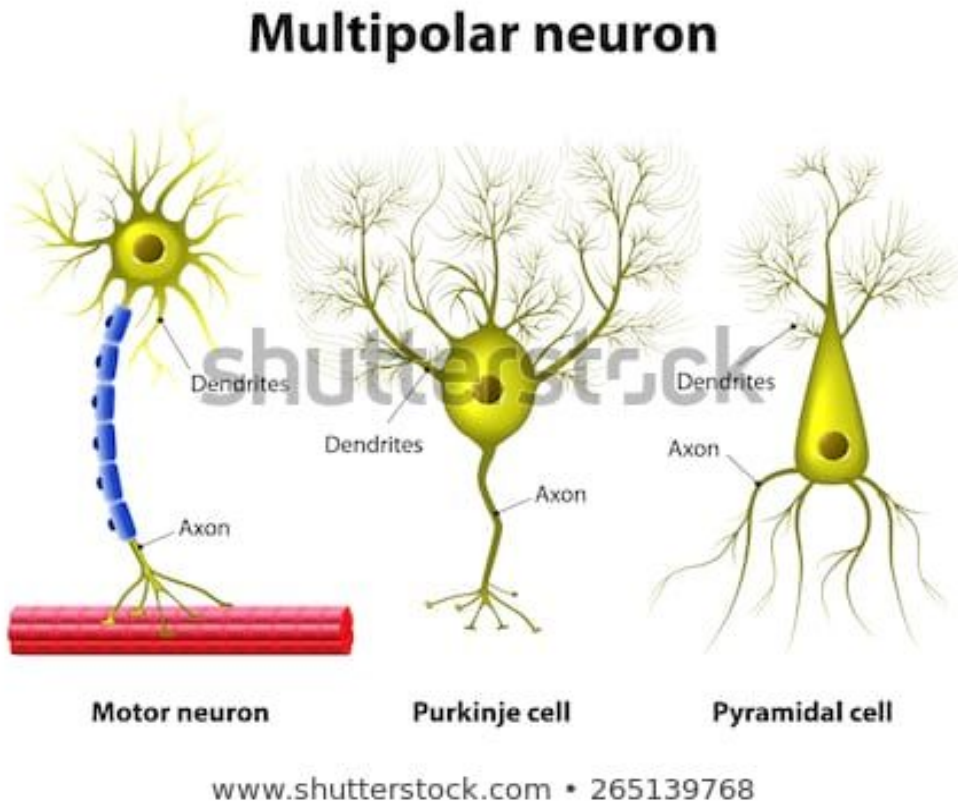
one process which extends from the body and divides into a central branch that functions as an axon and as a dendritic root

Used for sensory neurons that convey touch and stretching information from the extremities



FUNCTIONAL CLASSIFICATION

based on electrophysiological properties (excitatory or inhibitory) and the direction in which the AP is conveyed with respect to the CNS



FUNCTIONAL - CONTINUED

Sensory (afferent) neurons

APs into the CNS through cranial or spinal nerves. Most are unipolar.

Motor (efferent) neurons

APs away from the CNS to effectors (muscles and glands) in the periphery through cranial or spinal nerves. Most are multipolar.

Interneurons (association) neurons

mainly located within the CNS between sensory and motor neurons. Interneurons integrate (process) incoming sensory information and then elicit a motor response by activating the appropriate motor neurons. Most interneurons are multipolar in structure.

NEUROGLIA

Does not generate or conduct nerve impulses.They support neurons by:

- Forming the Blood Brain Barrier (BBB)
- Forming the myelin sheath around neuronal axons
- Making the CSF that circulates around the brain and spinal cord
- Participating in phagocytosis

TYPES OF NEUROGLIA IN THE CNS

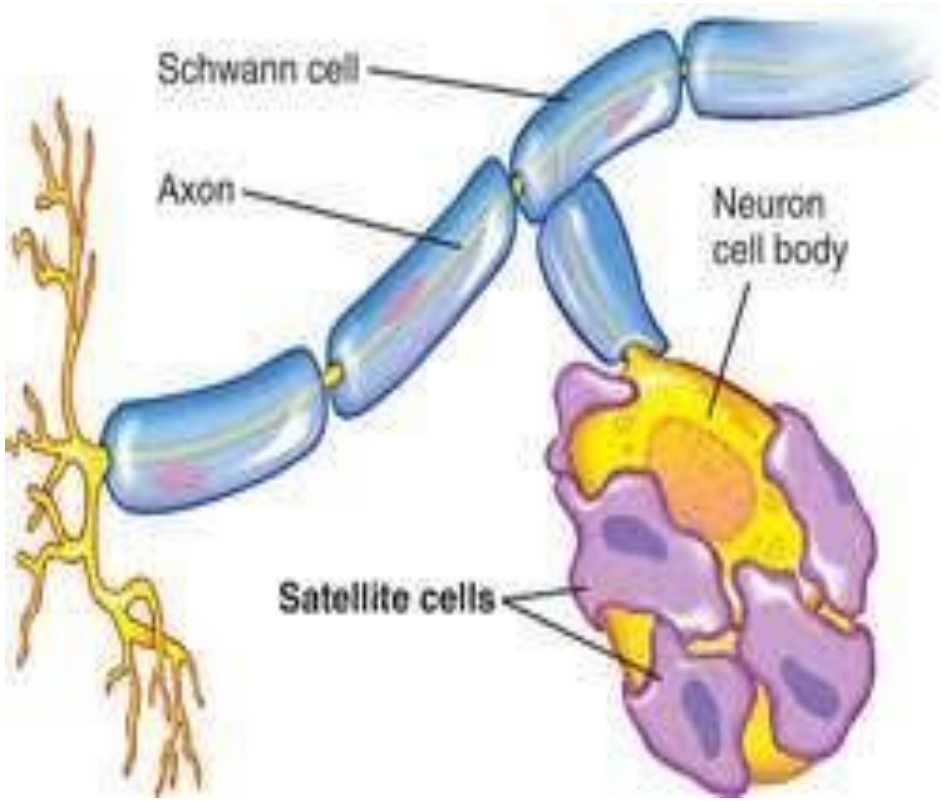
- Astrocytes - structural support for neurons in the CNS; Blood Brain Barrier
  - Maintain the chemical environment (Ca2+ & K+)
- Oligodendrocytes - produce myelin in CNS
- Microglia - participate in phagocytosis
- Ependymal cells - form and circulate CSF

https://youtu.be/7k5ca2UeLqI

TYPES OF NEUROGLIA IN THE PNS

Satellite cells - support neurons in PNS

Schwann cells - produce myelin in PNS



MYELENATION

Process of forming a myelin sheath which insulates and increases nerve impulse speed

Formed by Oligodendrocytes in the CNS and by Schwann cells in the PNS

amount of myelin increases from birth to maturity

Diseases like Multiple Sclerosis result from autoimmune destruction of myelin.

https://youtu.be/eoVQ09W_Qlo

NERVE REGENERATION & MYELENATION

neurons lose their mitotic features at birth and can only be repaired through regeneration after an injury

Nerve tissue regeneration is largely dependent on the Schwann cells in the PNS and essentially doesn't occur at all in the CNS where astrocytes form scar tissue

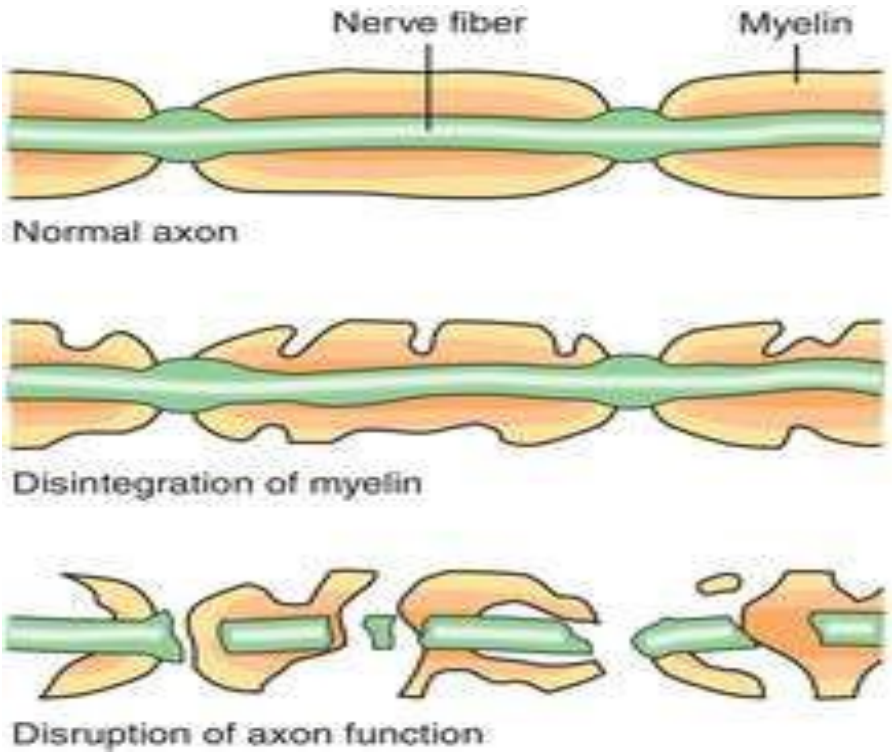
The outer nucleated cytoplasmic layer of the Schwann cell, which encloses the myelin sheath, is the neurolemma (sheath of Schwann).When an axon is injured, the neurolemma aids regeneration by forming a regeneration tube that guides and stimulates regrowth of the axon. To do any regeneration, neurons must be located in the PNS, have an intact cell body, and be myelinated by functional Schwann cells having a neurolemma.

DEMYELINATION

refers to the loss or destruction of myelin sheaths around axons

may result from disease or medical treatments such as radiation therapy and chemotherapy

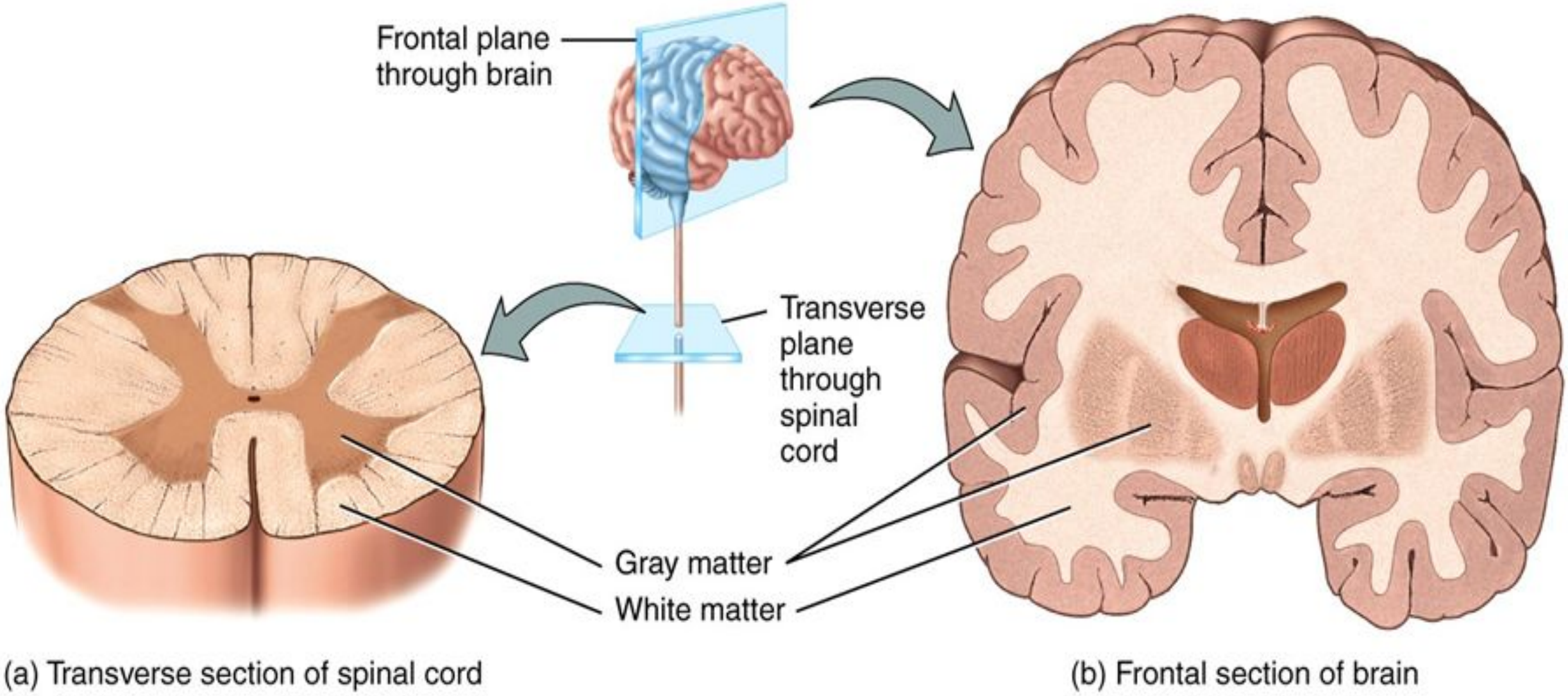
Any single episode of demyelination may cause deterioration of affected nerves.



GRAY & WHITE MATTER

White matter of the brain and spinal cord is formed from aggregations of myelinated axons from many neurons. The lipid part of myelin imparts the white appearance.

Gray matter (gray because it lacks myelin) of the brain and spinal cord is formed from neuronal cell bodies and dendrites.


Frontal plane through brain
Transverse plane through spinal cord
Gray matter
White matter
(a) Transverse section of spinal cord
(b) Frontal section of brain

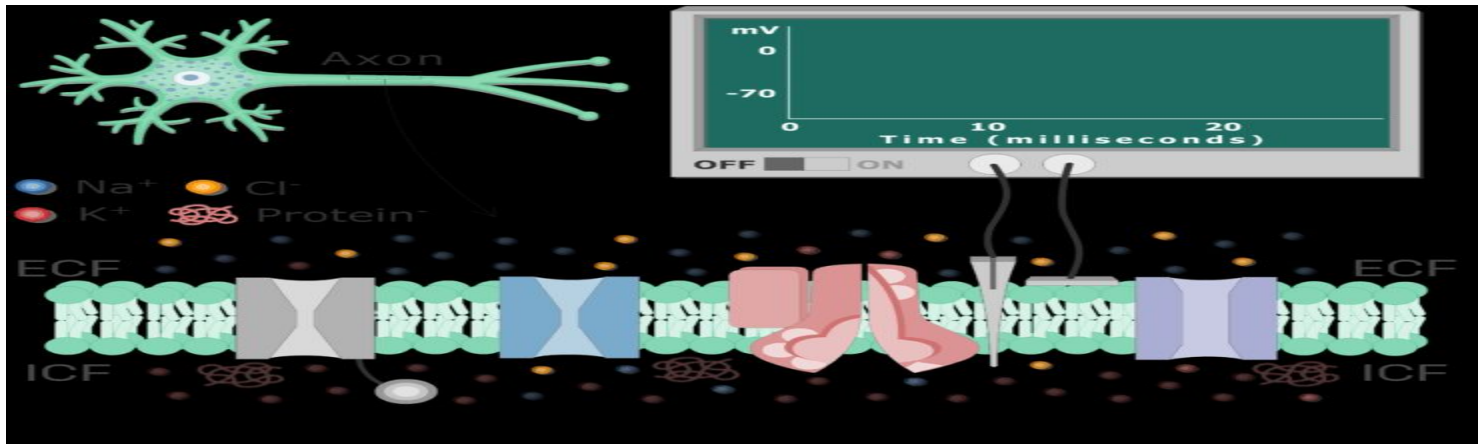
potential

ELECTRICAL SIGNALS IN NEURONS

Like muscle fibers, neurons are electrically excitable. They communicate with one another using two types of electrical signals:

- Graded potentials are used for short-distance communication only.
- Action potentials allow communication over long distances within the body.

Producing electrical signals in neurons depends on the existence of a resting membrane potential (RMP)



RMP

A cell’s RMP is created using ion gradients and a variety of ion channels that open or close in response to specific stimuli.

Because the lipid bilayer of the plasma membrane is a good insulator, ions must flow through these channels.

ION CHANNELS

present in the plasma membrane of all cells in the body, but they are an especially prominent component of the nervous system.

energy expended by all cells of the body, is used to create a net negative charge in the inside of the cell as compared to the outside of the cell.

When ion channels are open, they allow specific ions to move across the plasma membrane, down their electrochemical gradient.

> Ions move from areas of higher concentration to areas of lower concentration - the “chemical” (concentration) part of the gradient. Positively charged cations move toward a negatively charged area, and negatively charged anions move toward a positively charged area - the electrical aspect of the gradient.

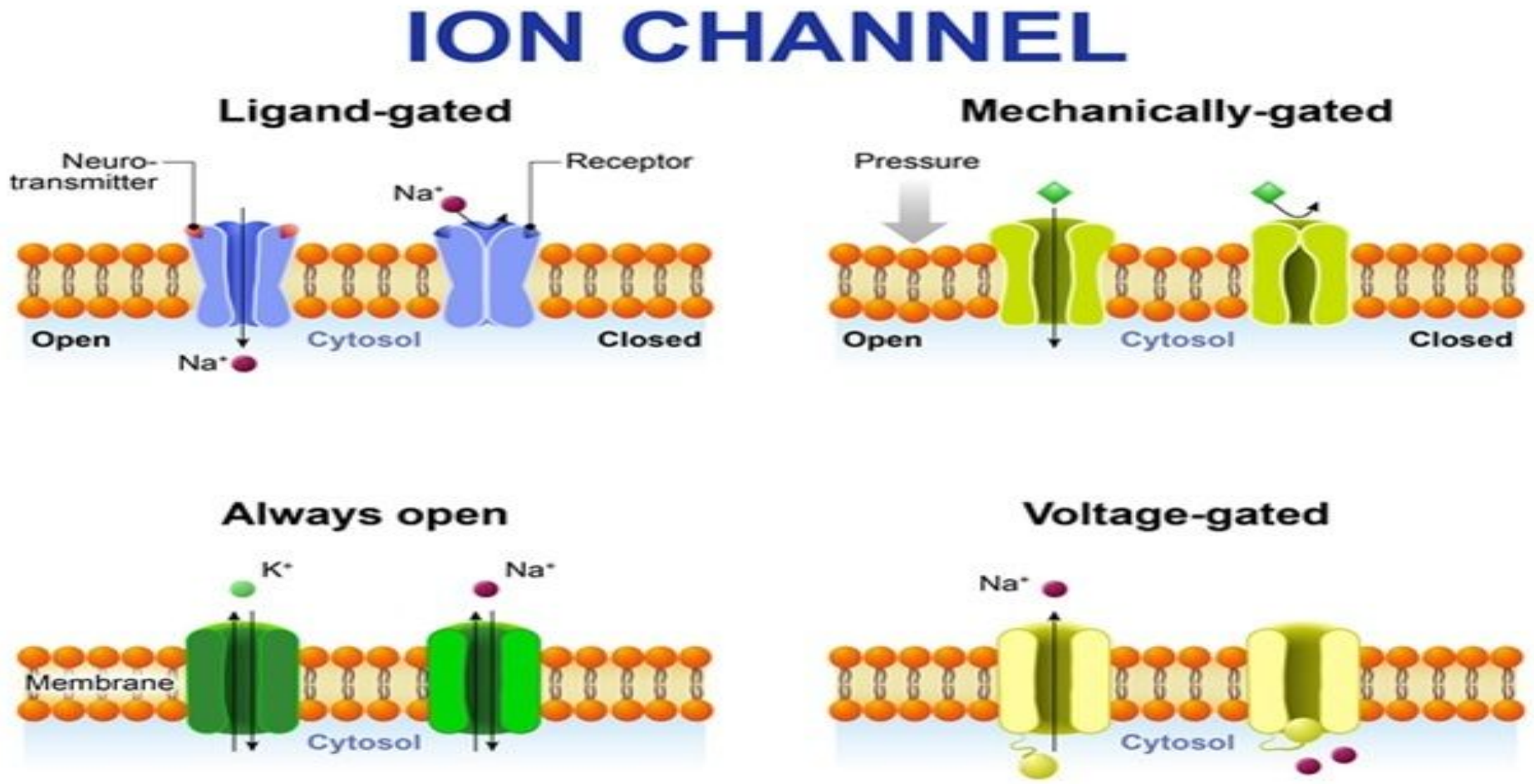
ACTIVE GATED CHANNELS

Active channels open in response to a stimulus (they are “gated”). There are 3 types of active, gated channels:

- Ligand-gated channels respond to a neurotransmitter and are mainly concentrated at the synapse.
- Voltage-gated channels respond to changes in the transmembrane electrical potential and are mainly located along the neuronal axon.
- Mechanically-gated channels respond to mechanical deformation (applying pressure to a receptor).

“Leakage” channels are also gated but they are not active, and they open and close randomly

GATED CHANNELS



MAINTAINING RESTING MEMBRANE POTENTIAL

A neuron's RMP is measured at rest (not conducting a nerve impulse)

The RMP exists because of a small buildup of negative ions in the cytosol along the inside of the membrane, and an equal buildup of positive ions in the extracellular fluid along the outside surface of the membrane. The buildup of charge occurs only very close to the membrane – the cytosol elsewhere in the cell is electrically neutral. The RMP is slightly negative because leakage channels favor a gradient where more K+ leaks out, than Na+ leaks in (there are more K+ channels than Na+ channels.)

In neurons, a typical value for the RMP is **–70 mV** (the minus sign indicates that the inside of the cell is negative relative to the outside.)

A cell that exhibits an RMP is said to be polarized.

CONTINUED

In this state, the cell is “primed” - it is ready to produce an action potential. In order to do so, graded potentials must first be produced in order to depolarize the cell to threshold.

A graded potential occurs whenever ion flow in mechanically gated or ligand-gated channels produce a current that is localized – it spreads to adjacent regions for a short distance and then dies out within a few millimeters of its point of origin.

From the RMP, a stimulus that causes the cell to be less negatively charged with respect to the extracellular fluid is a depolarizing graded potential, and a stimulus that causes the cell to be more negatively charged is a hyperpolarizing graded potential.

https://youtu.be/HYLyhXRp298

ACTION POTENTIAL

In contrast to graded potentials, an action potential (AP) is a signal which travels the length of the neuron. During an AP, the membrane potential reverses and then eventually is restored to its resting state.

If a neuron receives a threshold stimulus, a full strength nerve impulse is produced and spreads down the axon of the neuron to the axon terminals.

If the stimulus is not strong enough (subthreshold), no nerve impulse will result.

An AP has two main phases:

- a depolarizing phase and
- a repolarizing phase

Graded potentials that result in depolarization of the neuron from –70mV to threshold (about –55 mV in many neurons) will cause a sequence of events to rapidly unfold.

CONTINUED

Voltage-gated Na+ channels open during the steep depolarization phase allowing Na+ to rush into the cell and making the inside of the cell progressively more positive.

Only a total of 20,000 Na+ actually enter the cell in each little area of the membrane, but they change the potential considerably (up to +30mV).During the repolarization, phase K+ channels open and K+ rushes outward. The cell returns to a progressively more negative state until the RMP of –70mV is once again restored.

A stronger stimulus will not cause a larger impulse.

After initiating an action potential, there is a period of time called the absolute refractory period during which a cell cannot generate another AP, no matter how strong the stimulus.

The relative refractory period is the period of time during which a second action potential can be initiated, but only by a larger-than-normal stimulus.

https://youtu.be/oa6rvUJlg7o

SPEED OF AN ACTION POTENTIAL

The speed of an AP is also affected by:

- The axon diameter
- The amount of myelination
- The temperature

Fiber Types

- A fibers are large, fast (130 m/sec), myelinated neurons that carry touch and pressure sensations; many motor neurons are also of this type.
- B fibers are of medium size and speed (15 m/sec) and comprise myelinated visceral sensory & autonomic preganglionic neurons.
- C fibers are the smallest and slowest (2 m/sec) and comprise unmyelinated sensory and autonomic motor neurons.

SYNAPTIC TRANSMISSION

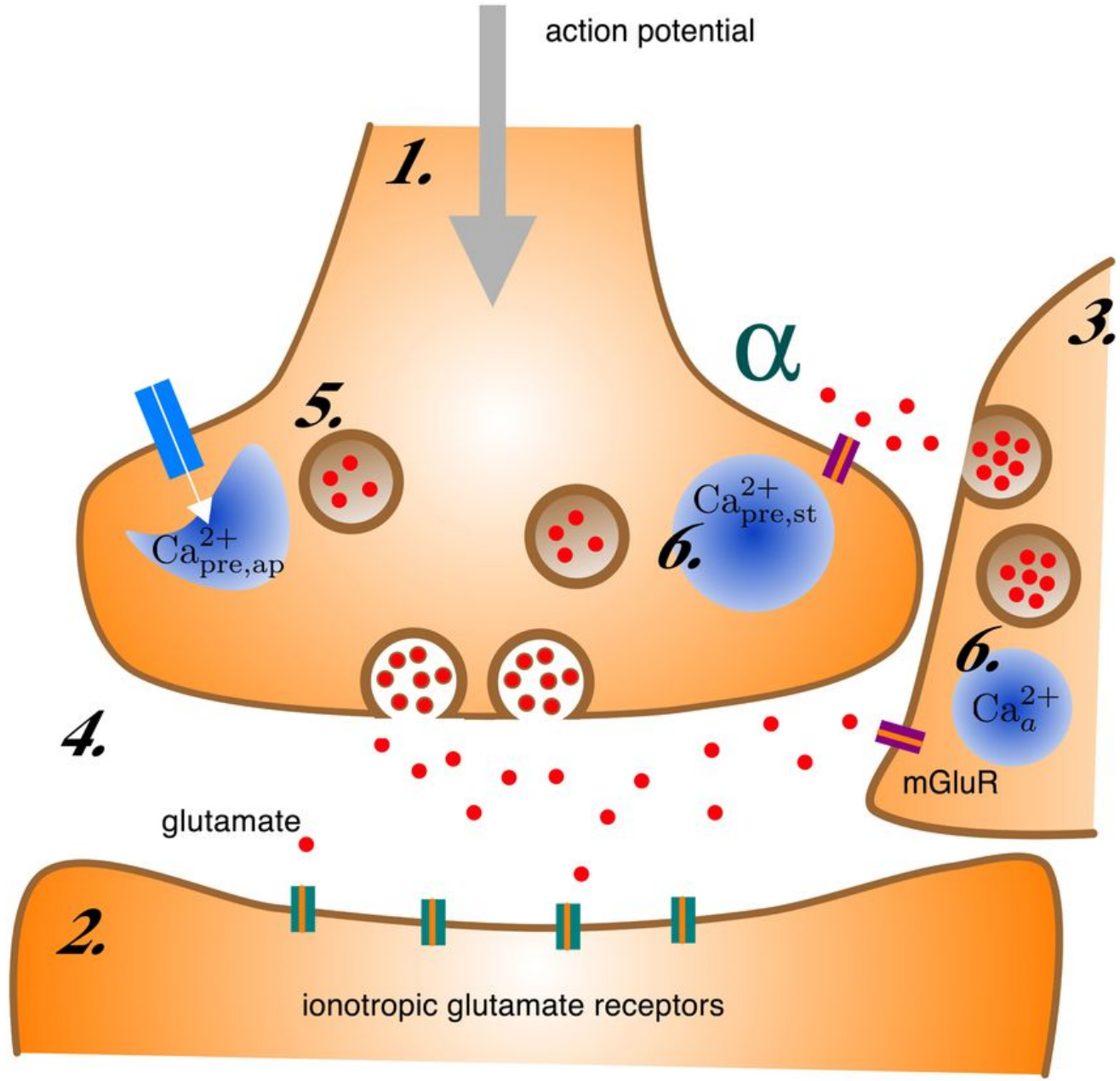
Signal transmission at the synapse is a one-way transfer from a presynaptic neuron to a postsynaptic neuron. When an AP reaches the end bulb of axon terminals, voltage-gated Ca2+ channels open and Ca2+ flows inward, triggering release of the neurotransmitter.

The neurotransmitter crosses the synaptic cleft and binds to ligand-gated receptors on the postsynaptic membrane. The more neurotransmitter released, the greater the number and intensity of graded potentials in the postsynaptic cell.

CONTINUED

In this way, the presynaptic neuron converts an electrical signal (nerve impulse) into a chemical signal (released neurotransmitter). The postsynaptic neuron receives the chemical signal and in turn generates an electrical signal (postsynaptic potential).

The time required for these processes at a chemical synapse produces a synaptic delay of about 0.5 msec.


action potential
1.
α
3.
5.
$Ca^{2+}_{pre,ap}$
$Ca^{2+}_{pre,st}$
6.
6.
Ca^{2+}_{a}
4.
mGluR
glutamate
2.
ionotropic glutamate receptors

NEUROTRANSMITTERS

Both excitatory and inhibitory neurotransmitters are present in the CNS and PNS.

The same neurotransmitter may be excitatory in some locations and inhibitory in others.

For example, acetylcholine (ACh) is a common neurotransmitter released by many PNS neurons (and some in the CNS). Ach is excitatory at the NMJ but inhibitory at other synapses.

Many amino acids act as neurotransmitters:

- Glutamate is released by nearly all excitatory neurons in the brain.
- GABA is an inhibitory neuro-transmitter for 1/3 of all brain synapses.
    - Valium is a GABA agonist that enhances GABA's depressive effects (causes sedation).

CONTINUED

Neurotransmitter effects can be modified in many ways:

- Synthesis can be stimulated or inhibited.
- Release can be blocked or enhanced.
- Removal can be stimulated or blocked.
- The receptor site can be blocked or activated.

An agonist is any chemical that enhances or stimulates the effects at a given receptor.

An antagonist is a chemical that blocks or diminishes the effects at a given receptor.

POSTSYNAPTIC POTENTIALS

A neurotransmitter causes either an excitatory or an inhibitory graded potential:

Excitatory postsynaptic potential (EPSP) causes a depolarization of the postsynaptic cell, bringing it closer to threshold. Although a single EPSP normally does not initiate a nerve impulse, the postsynaptic cell does become more excitable.

Inhibitory postsynaptic potential (IPSP) hyperpolarizes the postsynaptic cell taking it further from threshold.

NEURONAL CIRCUITS

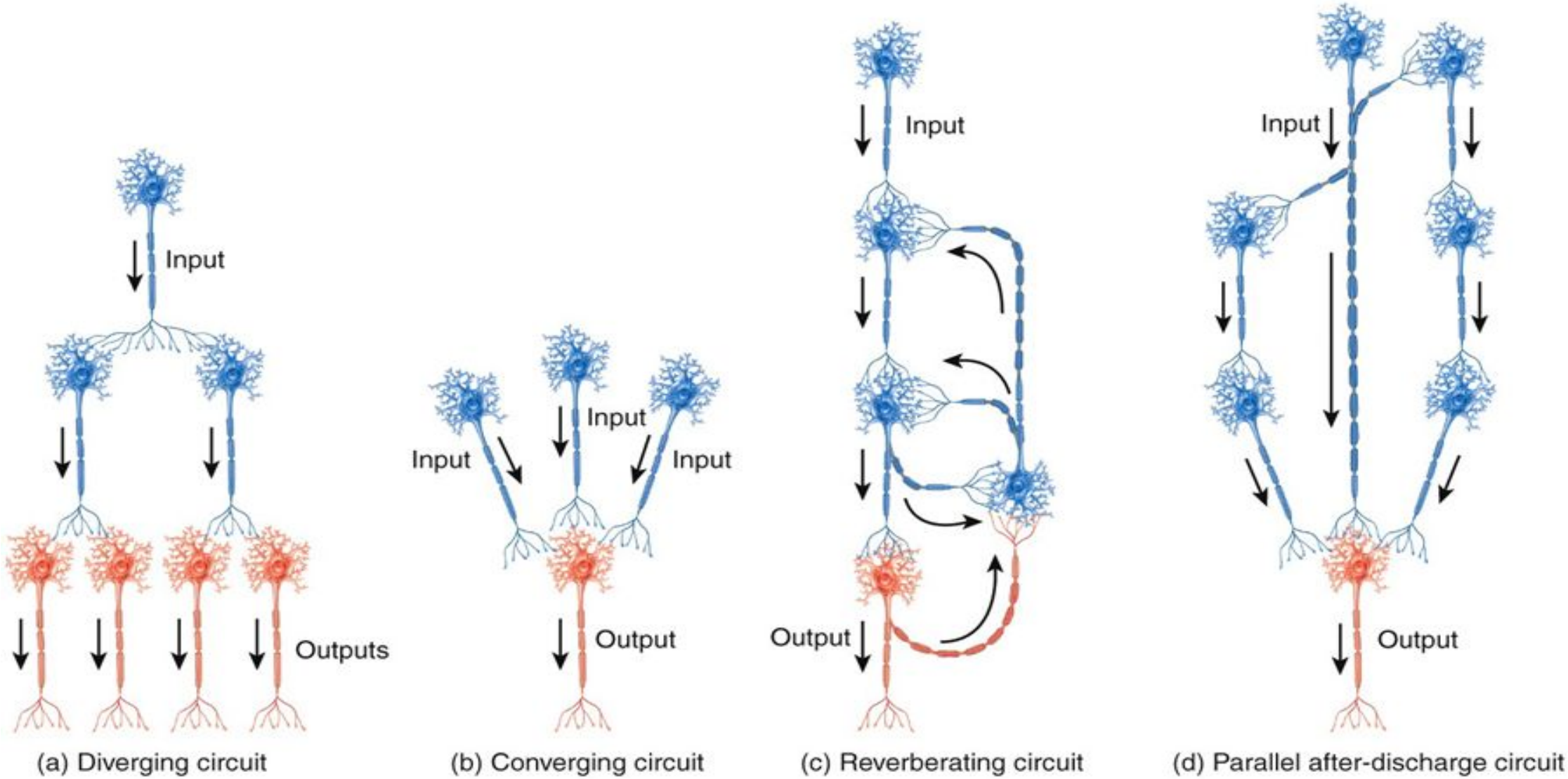
Integration is the process accomplished by the postsynaptic neuron when it combines all excitatory and inhibitory inputs and responds accordingly. This process occurs over and over as interneurons are activated in higher parts of the brain (such as the thalamus and cerebral cortex)

A neuronal network may contain thousands or even millions of neurons.

TYPES OF CIRCUITS

Types of circuits include diverging, converging, reverberating, and parallel after-discharge.

- In a diverging circuit, a small number of neurons in the brain stimulate a much larger number of neurons in the spinal cord. A converging circuit is the opposite.
- In a reverberating circuit, impulses are sent back through the circuit time and time again – used in breathing, coordinated muscular activities, waking up, and short-term memory.
- Parallel after-discharge circuits involve a single presynaptic cell that stimulates a group of neurons, which then synapse with a common postsynaptic cell – used in precise activities such as mathematical calculations.



(a) Diverging circuit (b) Converging circuit (c) Reverberating circuit (d) Parallel after-discharge circuit

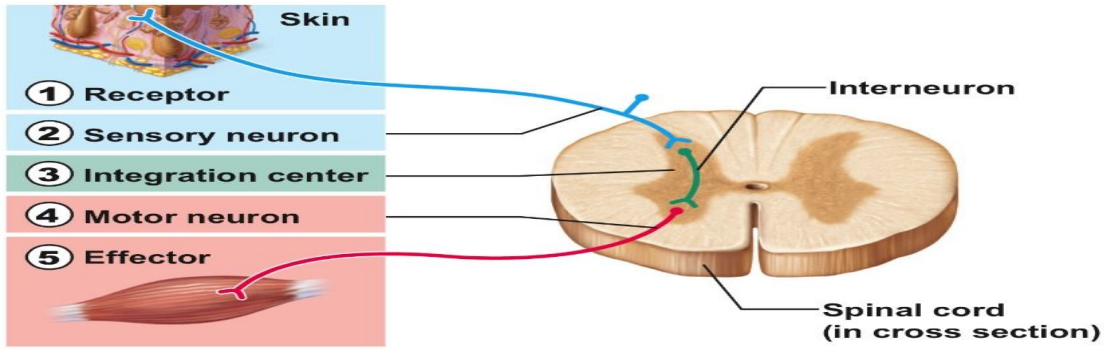
SPINAL CORD & SPINAL NERVES

OVERVIEW

About 100 million neurons and more neuroglia comprise the spinal cord

The spinal cord and its associated spinal nerves contain reflex circuits that control some of your most rapid reactions to environmental changes.

- The gray matter of the cord is a site for integration of postsynaptic potentials (IPSPs and EPSPs).
- The white matter of the cord contains major sensory and motor tracts to and from the brain.



EXTERNAL SPINAL CORD ANATOMY

The spinal cord begins as a continuation of the medulla oblongata (the most inferior portion of the brain stem) extending from the foramen magnum of the occipital bone to its termination as the conus medullaris between L1 - L2.

The spinal cord is oval in shape and slightly flattened anteriorly and posteriorly.

Two types of connective tissue coverings protect the cord and provide physical stability:

- The bony vertebral column provides the backbone.
- The spinal meninges surround the cord as a continuation of the cranial meninges that encircle the brain

MENINGES

These three membranes are labeled from superficial to deep as follows:

- The outermost dura mater (tough mother) forms a sac that encloses the entire cord.
- The middle meninx is a delicate avascular covering called the arachnoid mater. It is attached to the inside of the dura and forms the roof of the subarachnoid space (SAS) in which cerebral spinal fluid (CSF) circulates.
- The transparent pia mater is pressed-up against the cord and is filled with blood vessels that supply nutrients to it.

The epidural space runs between the dura mater and the more superficial ligamentum flavum (which lines the underside of the bony vertebral lamina).

The subdural space lies between the dura and the arachnoid. In the spinal column, the dura and arachnoid membranes are held firmly together so that the subdural space is often no more than a potential space.

CONTINUED

The pia mater has 21 pairs of denticulate ligaments which attach it to the arachnoid and dura maters. Named for their tooth-like appearance, the denticulate ligaments are traditionally believed to provide stability for the spinal cord against sudden shock and displacement within the vertebral column.

CERVICAL ENLARGEMENTS

- The spinal cord has two enlargements, one in the cervical area from C4–T1, and another in the lumbar area between T9–T12.
  - The cervical enlargement correlates with the sensory input and motor output to the upper extremities.
  - The lumbar enlargement handles motor output and sensory input to and from the legs.
- From superior to inferior, the spinal cord becomes progressively smaller.
  - There is less and less white matter as we descend because there are fewer sensory tracts going up, and there are fewer motor tracts going down.

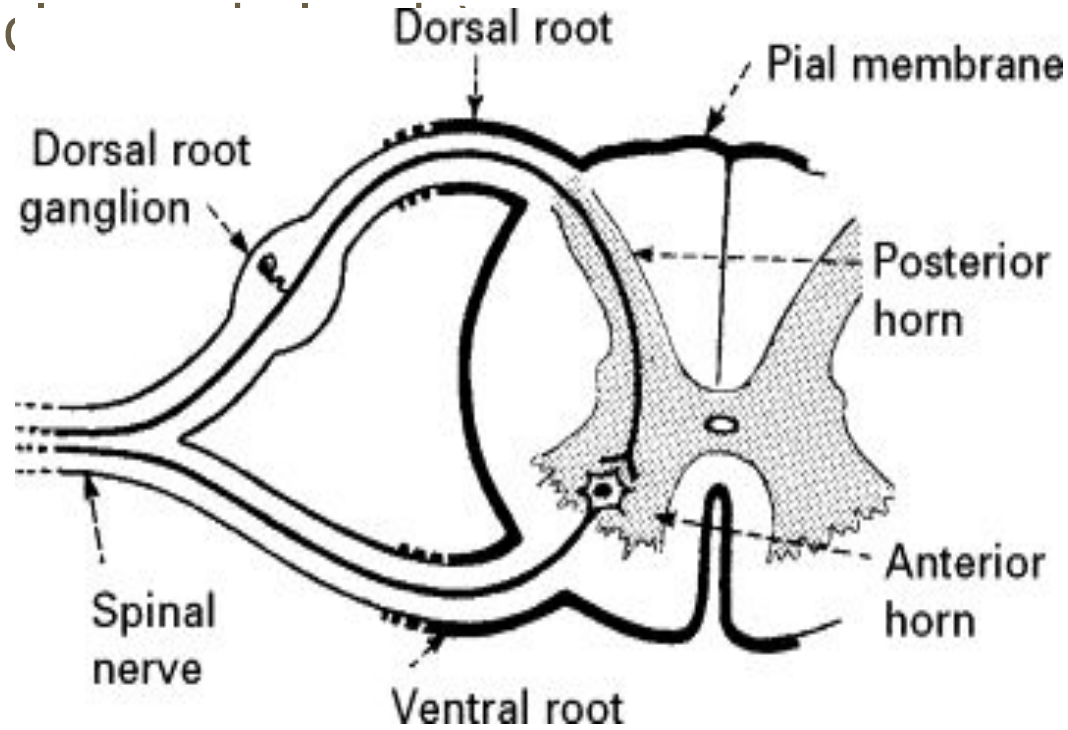
SPINAL NERVE ROOTS

Two bundles of axons, called roots, connect each spinal nerve to a segment of the cord by even smaller bundles of axons called rootlets.

The posterior (dorsal) root and rootlets contain only sensory axons, which conduct nerve impulses from sensory receptors in the skin, muscles, and internal organs into the central nervous system.

CONTINUED

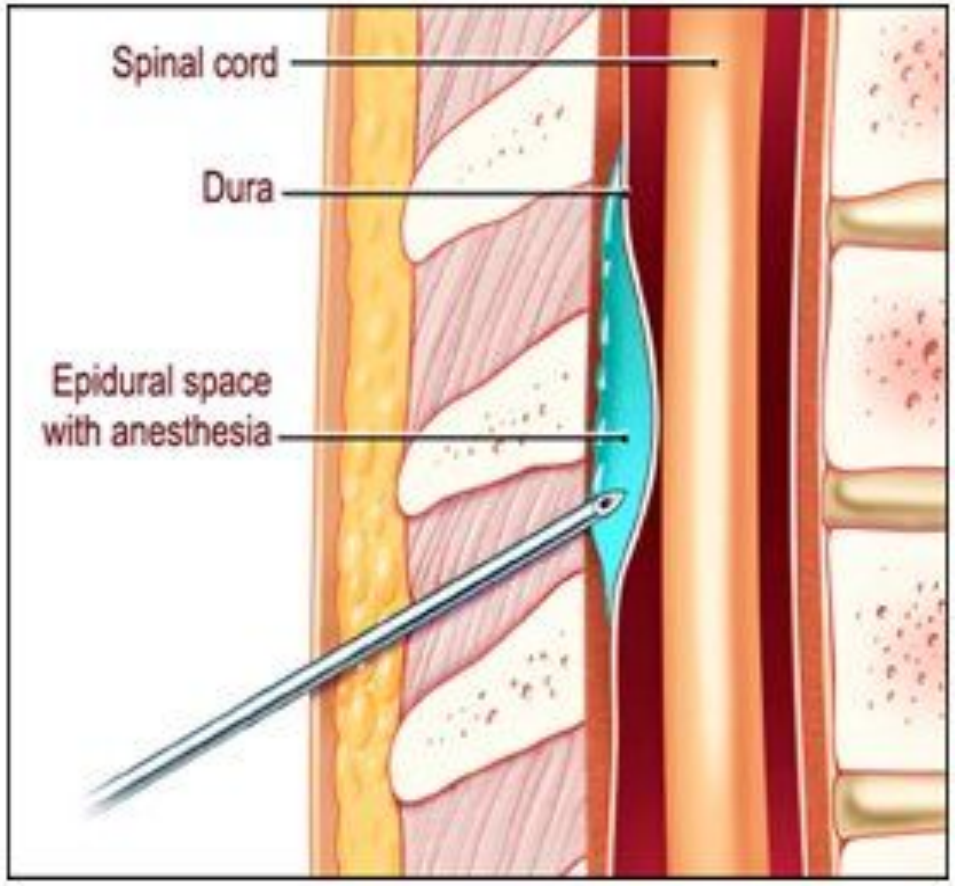
Each posterior root has a swelling, the posterior (dorsal) root ganglion, which contains the cell bodies of sensory neurons. The anterior (ventral) root and rootlets contain axons of motor neurons, which conduct nerve impulses from the CNS to effectors (musc



EPIDURAL ANESTHESIA

Commonly administered to women about to go into labor. A needle is placed between the bones of the posterior spine until it just penetrates the ligamentum flavum yet remains superficial to the dura mater.

Local anesthetic is used to provide pain relief



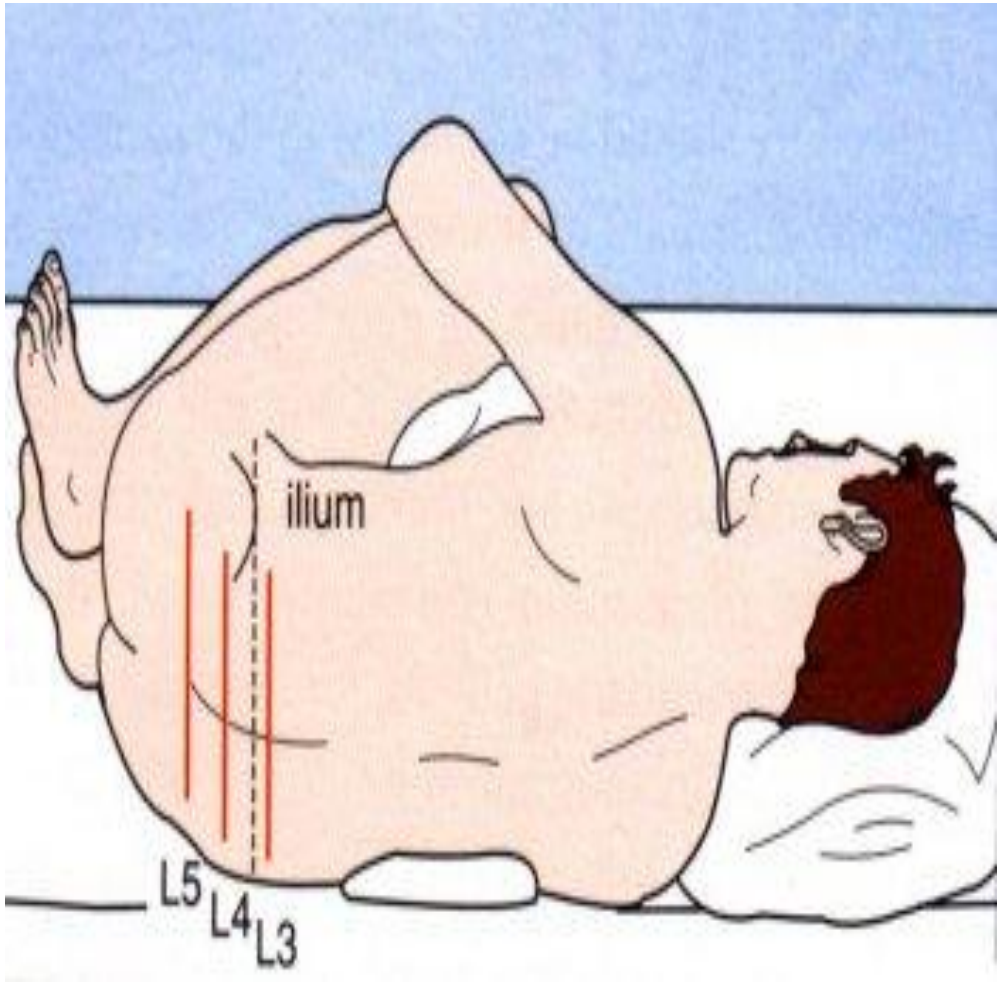
LUMBAR PUNCTURE

A needle inserted into the subarachnoid space for the purpose of withdrawing CSF (for diagnosis or to reduce pressure) or to introduce a drug or contrast agent is called a lumbar puncture.

- CSF is often collected to diagnose meningitis or some other disease of the CNS.
- Agents injected into the SAS include drugs such as antibiotics, chemotherapeutic agents, or analgesics, or contrast media for radiographic procedures.
- The pressure of CSF in the SAS can also be measured during a lumbar puncture

LUMBAR PUNCTURE LOCATION

The site used for most lumbar punctures is between the 3rd and 4th (or 4th and 5th) lumbar vertebrae - below the termination of the actual cord in the region of the cauda equina. With the needle in the SAS, CSF can be sampled



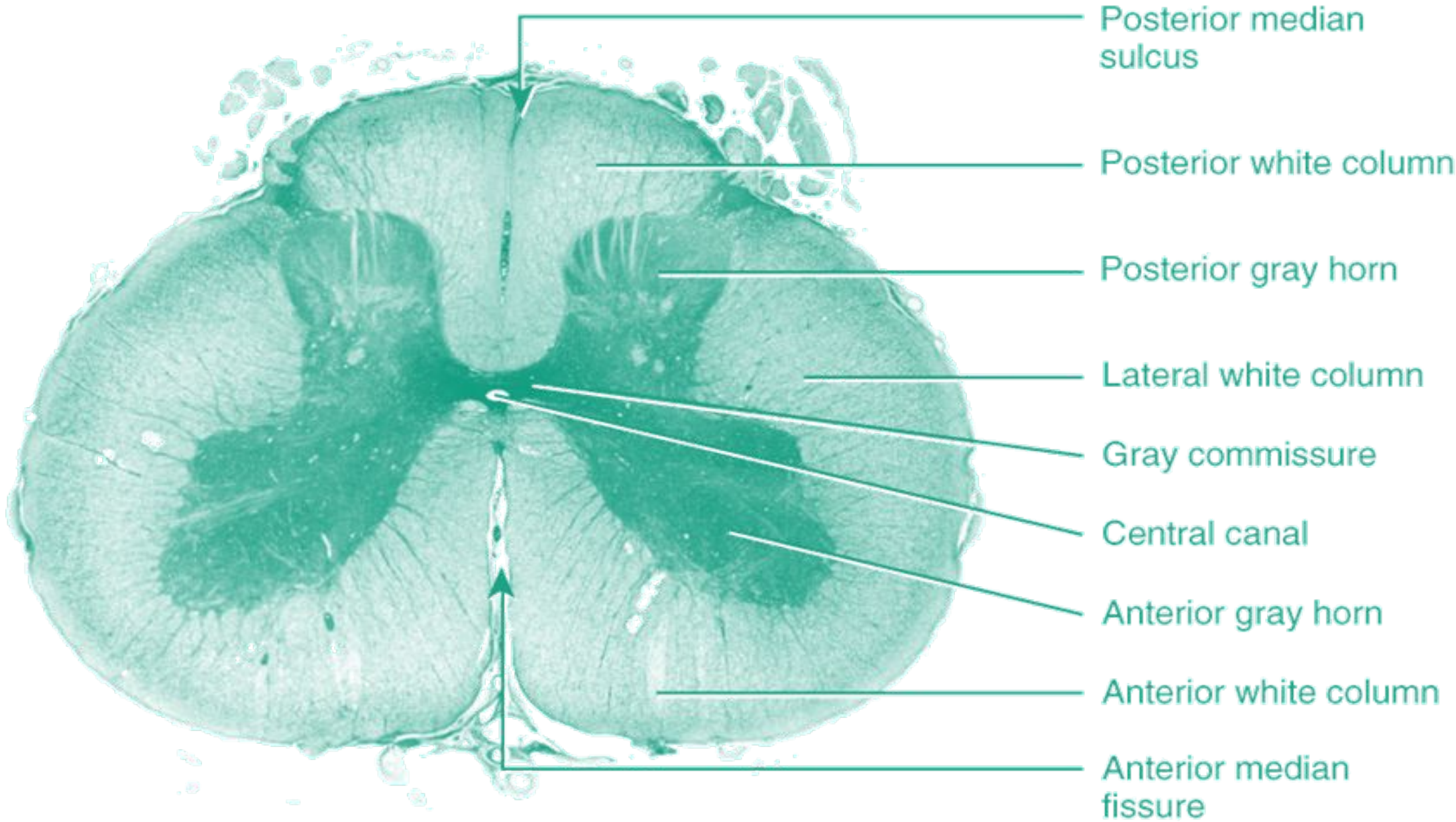
INTERNAL SPINAL CORD ANATOMY

In the spinal cord, the white matter is on the outside, and the gray matter is on the inside. In the brain the white matter is on the inside, and the gray matter is on the outside.

white matter of the cord consists of millions of nerve fibers which transmit electrical information between the limbs, trunk and organs of the body, and the brain.

Internal to this peripheral region, and surrounding the central canal, is the

butterfly-shaped central region made up of nerve cell bodies (gray matter).


Posterior median sulcus
Posterior white column
Posterior gray horn
Lateral white column
Gray commissure
Central canal
Anterior gray horn
Anterior white column
Anterior median fissure

GRAY HORNS

Anterior (ventral) gray horns consist of somatic motor neurons.

Posterior (dorsal) gray horns consist of somatic and autonomic sensory nuclei.

> The posterior gray horn is the site of synapse between first-order sensory neurons coming in from the periphery, and second-order neurons which either ascend in the cord or exit back out as parts of reflex arcs.

The lateral gray horns are found only in the thoracic, upper lumbar, and sacral segments of the cord. They contain cell bodies of autonomic motor neurons

Some of these fibers ascend outside the dura but close to the cord to supply sympathetic innervation to the head. Others travel in sympathetic trunks to the organs and glands of the thorax, abdomen, and pelvis.

TRACTS

The central canal extends the entire length of the spinal cord and is filled with CSF.

A tract is a bundle of neuronal axons that are all located in a specific area of the cord and all traveling to the same place (higher or lower in the brain or cord).

The white matter of the cord is divided into anterior, posterior, and lateral columns in which ascending sensory tracts are traveling to someplace in the brain and descending motor tracts are traveling to a location in the cord.

TRACTS CONT.

formed by using compound words that denote the origin of the tract, and the place where it ends

- The spinothalamic tract goes from the spinal cord to the brain – it is an afferent tract.
- The corticospinal tract goes from the cortex of the brain to the spinal cord – it is an efferent tract.
- The vestibulospinal tract originates from an area in the brain to the spine, and therefore deduce that it is a motor tract.

TRACTS CONTINUED

The posterior columns are afferent tracts that convey nerve impulses for discriminative touch, light pressure, vibration, and conscious proprioception (awareness of tendon and joint position in space and their relative movements).

The spinothalamic tract is an afferent tract that transmits sensations of pain, warmth, coolness, itching, tickling, deep pressure, and crude touch.

The lateral and anterior corticospinal tracts are major pathways for carrying signals from the cerebral cortex that result in voluntary movement of skeletal muscles.

Other motor tracts convey nerve impulses from the brainstem that coordinate visual stimuli with body movements, maintain posture and regulate skeletal muscle tone.

DERMATOMES

A dermatome is an area of skin that is innervated by a single spinal nerve, indicated by the letters and number of a particular segmental nerve.

Important dermatomes include:

C6/C7 - thumb and index finger.

T4 - nipple line

T10 - umbilicus

L1-L5 - lower extremities

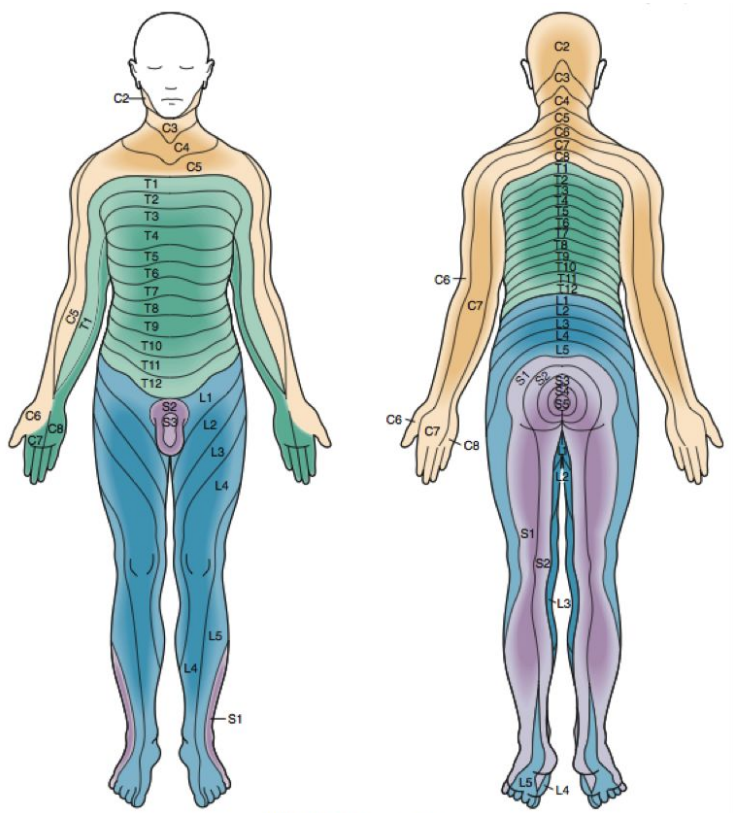


Figure 43-20. Sensory dermatomes.

DAMAGE TO THE CORD

Transection" of the spinal cord means that ascending and descending tracts are partially or completely severed.

If transection occurs, say in a motor vehicle or diving accident, paralysis will occur depending on the level of the injury. Transection:

- at the base of skull results in death by asphyxiation
- in the upper cervical area results in quadriplegia
- between the cord enlargements results in some form of paraplegia

PERIPHERAL NERVES

Spinal nerves are the paths of communication between the spinal cord and specific regions of the body. Nerves are arranged in fascicles surrounded by a perineurium, with the entire nerve sheathed by a CT epineurium.

31 left-right pairs of spinal nerves emerge from the cord at regular intervals (called segments). Except for the first cervical pair the spinal nerves leave the vertebral column from the intervertebral foramen between adjoining vertebrae – the first pair leaves between the skull and the first cervical vertebrae .

CONTINUED

The segmental (spinal) nerves exit the central nervous system into the peripheral nervous system and almost immediately split into 3 major branches: An anterior ramus, posterior ramus, and rami communicantes.(connections to sympathetic ganglia).

The anterior rami of the segmental nerves may travel alone (such as the intercostal nerves which run underneath each of the 12 ribs), or they can join together to form large plexus of nerves.

NERVE PLEXUSES

The cervical plexus, formed by the anterior rami of C1-C4, serves the head, neck, and diaphragm.

The phrenic nerves arise from the cervical plexus to supply the major muscle of respiration, the diaphragm (C3,4,5).

The brachial plexus is formed by the anterior rami of C5-C8 and T1. It is divided into roots → trunks → divisions → cords → nerves.

The nerves from the brachial plexus supply the shoulders and upper limbs.

COMMON BRACHIAL PLEXUS INJURY

Erb’s palsy is a paralysis of the arm that most often occurs as an infant's head and neck are pulled toward the side at the same time as the shoulders pass through the birth canal.

A similar injury may be observed at any age, including adults, following a traumatic fall or other trauma whereby the nerves of the plexus are violently stretched

Injuries to the brachial plexus or peripheral nerves:

- Median nerve injury, either at the plexus or occurring more distally, results in numbness, tingling and pain in the palm and fingers.

CONTINUED

Carpal tunnel syndrome is a common type of median nerve injury that is seen in people who perform repetitive motions of the hand and wrist like typing on a computer keyboard.

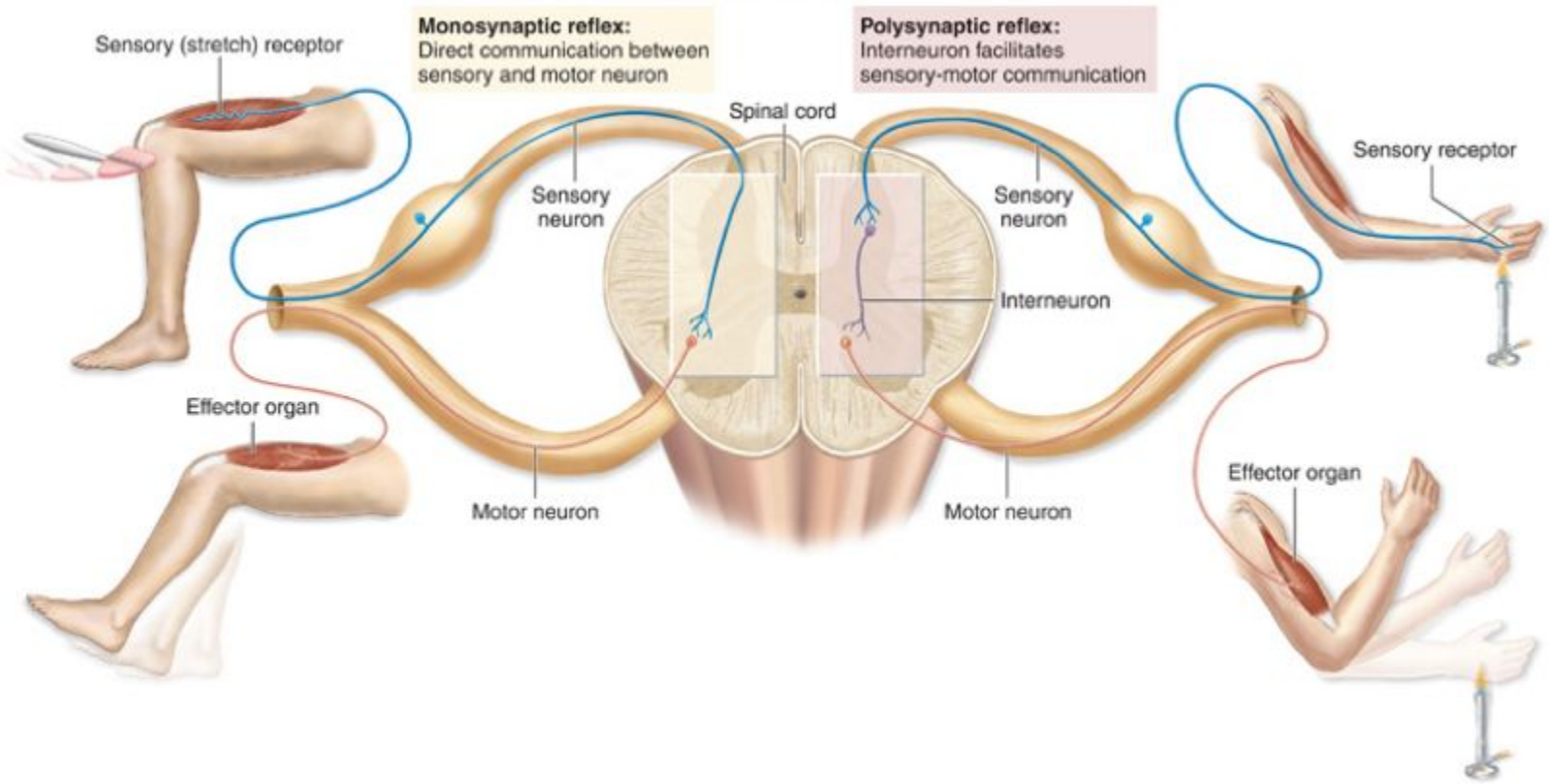
- The ulnar nerve is the largest unprotected (by muscle or bone) nerve in the human body. It emerges from the medial and lateral cords of the brachial plexus to supply the medial half of the hand. Damage to the nerve leads to abnormal sensations in the 4–5th fingers and an inability to abduct or adduct the little and ring fingers.
- The long thoracic nerve emerges from the cords of the brachial plexus to supply the serratus anterior muscle. Because of its long, relatively superficial course; it is susceptible to injury either through direct trauma or stretch of the plexus. Injury (resulting in a “winged scapula” in which thearm cannot be abducted beyond the horizontal position) has been reported in almost all sports

REFLEXES

A reflex is a fast, involuntary response to a stimulus. In a spinal reflex the integration takes place in the spinal cord, not the brain.

Spinal reflexes can be monosynaptic (sensory neuron with motor neuron) or polysynaptic (involving interneurons), and they can go in and out on the same, or on the opposite side of the cord.

MONO AND POLYSYNAPTIC REFLEX



REFLEX ARC

A reflex arc is a pathway that a nerve impulse follows to produce a reflex. Components of a reflex arc include a sensory receptor and a sensory neuron, an integrating center inside the cord, an exciting motor neuron, and an effector (which is usually some sort of muscle or a gland which makes something move or secrete involuntarily.

CONTINUED

Reflex arcs can be ipsilateral (all neurons and effectors on the same side of the body) or contralateral (the receptors and afferent neurons are on the opposite side of the body

The flexor (withdrawal) reflex is a good example of a contralateral reflex (Stepping on a tack).

IMPORTANT SPINAL REFLEXES

The **patellar reflex** in which the leg extends in response to stretch of the patellar tendon. This reflex can be blocked by damage in the corticospinal tracts from diabetes, neurosyphilis, or damage to the lumbar region of the spinal cord.

The **Achilles reflex** causes contraction of the calf when a force is applied to the Achilles tendon. It is absent after damage to the lower cord or lumbosacral plexus.

The **Babinski or plantar flexion reflex** is considered normal in adults if they flex (curl) the big toe when the sole of the foot is stimulated. If the sole of the foot is stimulated and the patient extends the big toe, it would indicate damage in the corticospinal tract. Infants normally extend their toes when stimulated in this way; so an abnormal Babinski does not indicate any disease or damage in this age group

THE BRAIN & CRANIAL NERVES

INTRODUCTION

The human brain, compared to all other animals' brains, is marked by the highest ratio of brain to body size - thought to directly correlate with our higher level of intelligence.

Most of the expansion is manifested in human's large cerebral cortex. Especially expanded are the frontal lobes which are associated with higher (executive) functions such as self-control, planning, reasoning, and abstract thought.

BRAIN DEVELOPMENT

During the first 3 weeks of gestation, the human embryo's neural tube flexes as it grows, forming the three primary brain vesicles called the forebrain, midbrain, and hindbrain. The 1st and 3rd vesicles further divide forming 5 secondary brain vesicles in a process called encephalization.

The major parts of the adult brain are directly derived from the 2 brain vesicles

The brain grows at an amazing rate during development; at times, as many as 50,000 neurons are added each second.

At birth, the neonatal brain looks very much like that of an adult and almost all the neurons the brain will ever have are already present.

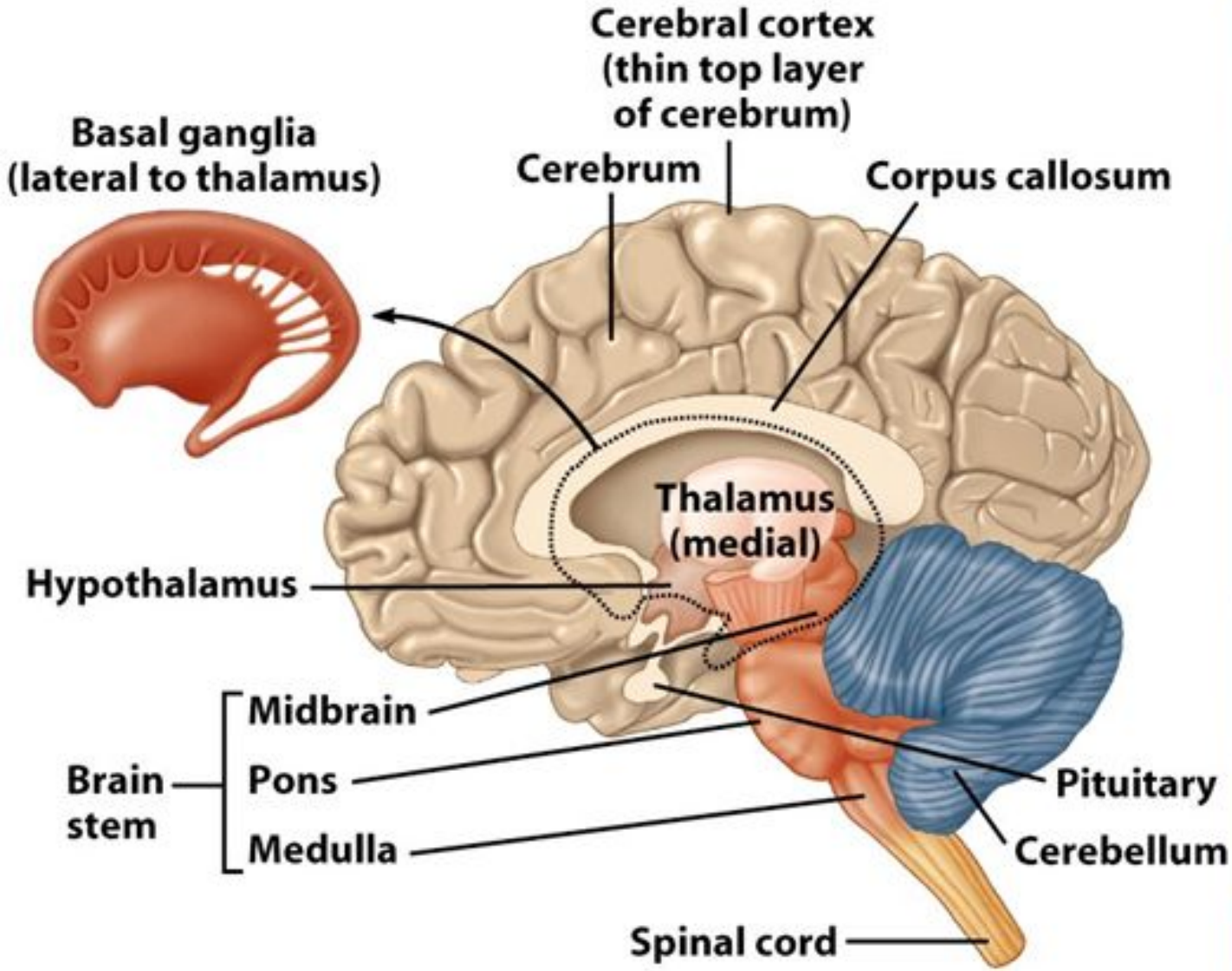
https://youtu.be/Tp25wrm-AoA?feature=shared

BRAIN ORGANIZATION

There are Four major regions of the brain:

- The **brain stem** is the continuation of the spinal cord and consists of the ***medulla oblongata, pons and midbrain.***
- The **cerebellum** is the second largest part of the brain.
- The **diencephalon** gives rise to the thalamus & hypothalamus.
- The **cerebrum** is the newest (evolutionarily) and largest part of the brain as a whole.

It is in the cerebral cortex (outer part of the cerebrum) that perception, thought, imagination, judgment, and decision making occur.



Cerebral cortex
- Receives sensory information
- Sends messages to move skeletal muscles
- Integrates incoming and outgoing nerve impulses
- Performs activities such as thinking, learning, and remembering

Basal ganglia
- Helps coordinate slow, sustained movements
- Suppresses useless patterns of movement

Thalamus
- Relays most sensory information from the spinal cord and certain parts of the brain to the cerebral cortex
- Interprets certain sensory messages such as those of pain, temperature, and pressure

Hypothalamus
- Controls various homeostatic functions such as body temperature, respiration, and heartbeat
- Directs hormone secretions of the pituitary

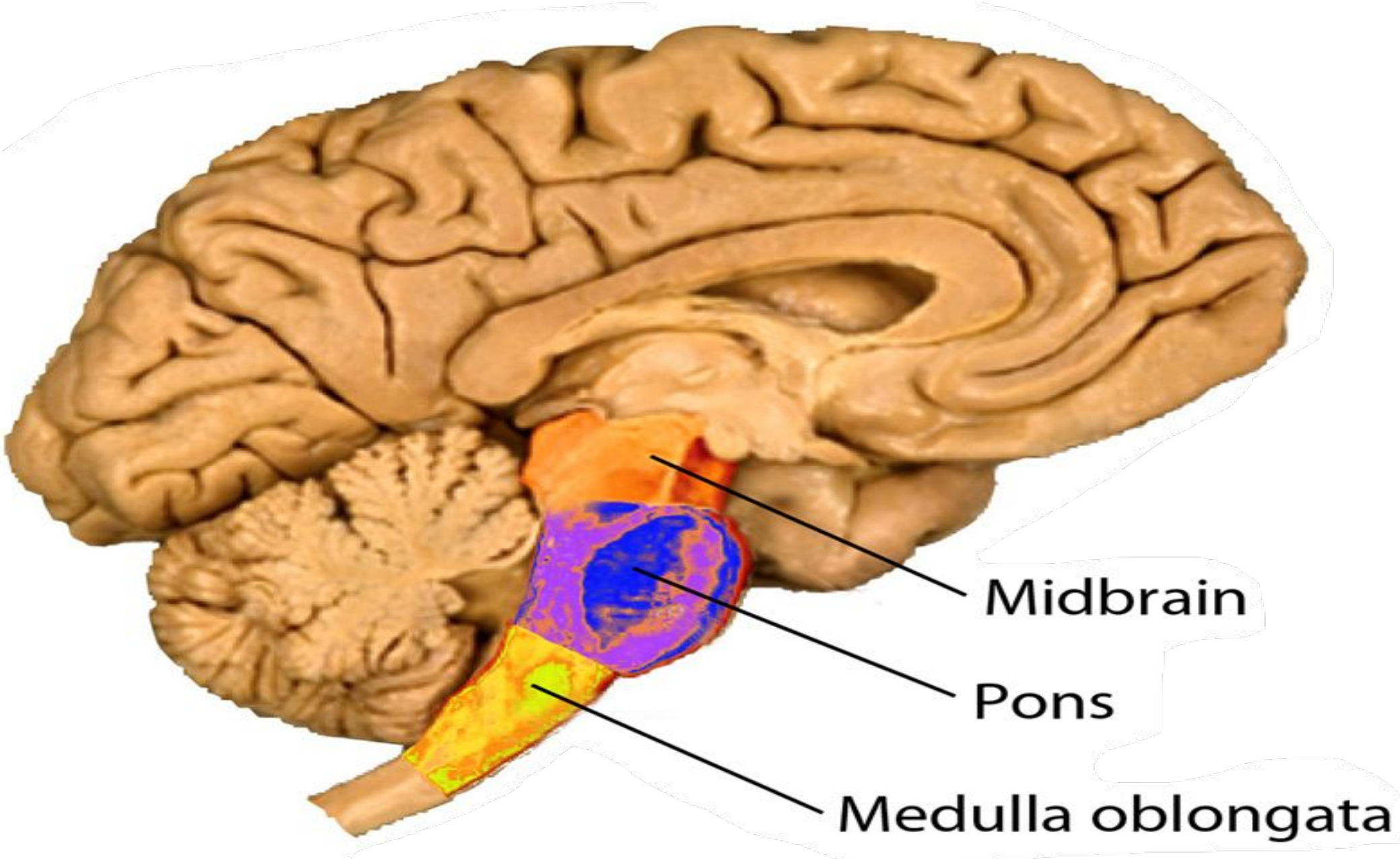
Cerebellum
- Coordinates subconscious movements
- Contributes to muscle tone, posture, and balance

Brain stem
- Origin of many cranial nerves
- Reflex center for movements of eyeballs, head, and trunk
- Regulates heartbeat and breathing
- Plays a role in consciousness
- Transmits impulses between brain and spinal cord

REGIONS OF THE BRAIN

The Brain Stem

The brain stem is superior to, but continuous with, the spinal cord. Developmentally, it does not represent a single structure, but rather a group of anatomical components considered collectively. It is made up of the midbrain, pons, and medulla oblongata


Midbrain
Pons
Medulla oblongata

BRAIN STEM : MEDULLA OBLANGATA

It has two external bulges called the pyramids formed by the largest motor tracts in the body.

Axons from the left pyramid cross over to the right and axons on the right ***cross over*** to the left (**decussation** of pyramids) – so that the left hemisphere of the brain controls the right side muscles, while the right hemisphere controls the left side.

VITAL FUNCTIONAL CENTRES OF MEDULA OBLONGATA

Vital functional centers regulated by the medulla include:

- The **cardiovascular center** – controls the rate and force of heartbeat, and the diameter of blood vessels
- The **respiratory rhythmicity center** – controls the rate and rhythm of breathing
- The **vomiting, coughing, and sneezing centers**

The nuclei associated with 5 of the 12 cranial nerves originate in the medulla (**CN VIII – XII**).

A portion of the 4th ventricle extends to the medulla.

BRAIN STEM: THE PONS

The pons lies directly above the medulla and anterior to the cerebellum (2.5 cm). It acts as a bridge connecting the spinal cord with the brain and parts of the brain with each other.

Together with the medulla, areas in the pons ***help control breathing***

The pons contains the nuclei associated with 4 pairs of **cranial nerves: V - VIII**

- Cranial nerve V emerges directly from the pons.
- VI, VII, and VIII emerge from the space between the pons and the medulla.

BRAIN STEM : MIDBRAIN

The midbrain extends from the pons to the diencephalon.

The cerebral aqueduct passes through the midbrain connecting the 3rd ventricle above with the 4th ventricles below (both locations of CSF formation and circulation.)On the anterior part of the midbrain are found the cerebral peduncles.

The peduncles contain axons of the corticospinal, corticobulbar, and corticopontine tracts which conduct nerve impulses from motor areas in the cerebral cortex to the spinal cord, medulla, and pons, respectively.

BRAIN STEM: MIDBRAIN

On the posterior part of the midbrain are four rounded elevations known as the superior and inferior colliculi which serve as **reflex centers** for certain **visual and auditory reflexes, and also the startle reflex.**

It is the origin of **cranial nerves III and IV.**

The midbrain contains several other nuclei, including the darkly pigmented ***substantia nigra***. Neurons that release ***dopamine***, extending from the substantia nigra, help control subconscious muscle activities; loss of these neurons is associated with ***Parkinson disease.***

Reticular Activating System (RAS)

Much of the brain stem consists of a netlike arrangement of neuronal cell bodies and small bundles of myelinated axons known as the reticular formation.

The ascending portion of this network is called the **reticular activating system (RAS)**, and consists of ***sensory*** axons that project to the cerebral cortex.The RAS functions to **maintain consciousness**, a state of wakefulness in which an individual is fully alert, aware, and oriented. ***Inactivation of the RAS produces sleep***, a state of partial consciousness from which an individual can be aroused.

It also prevents sensory overload by filtering out insignificant information.

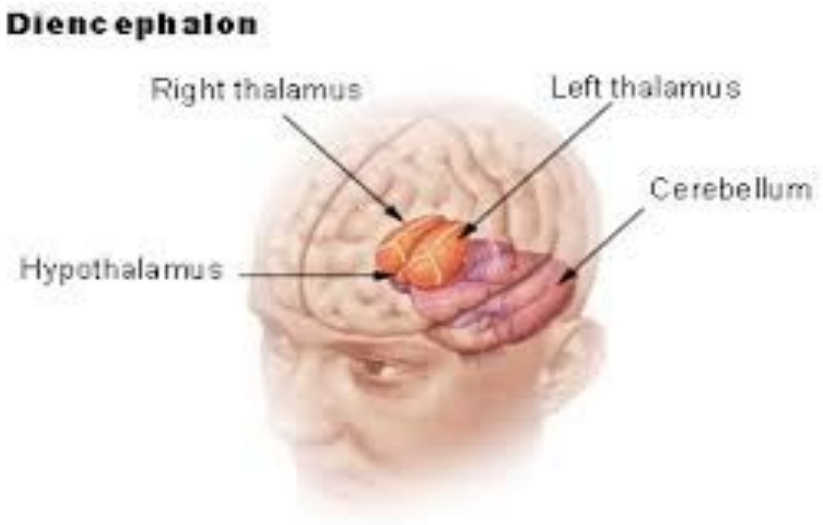
DIENCEPHALON

Located near the midline of the brain, above the midbrain

Develops from the forebrain vesicle

The diencephalon surrounds the 3rd ventricle and contains the thalamic structures

- Thalamus
- Epithalamus
- Hypothalamus



DIENCEPHALON: THALAMIC STRUCTURES

The thalamus:

functions as a **relay station for all sensory impulses** to the cerebral cortex (except smell, which belong to the hypothalamus). Pain, temp, touch, and pressure are all relayed to the thalamus en route to the higher centers of the cerebral cortex.

The epithalamus:

is superior and posterior to the thalamus

It consists of the **pineal gland (secretes melatonin) and habenular nuclei (emotional responses to odors)**

The hypothalamus:

controls many homeostatic functions

controls the ***Autonomic Nervous System (ANS)***.

coordinates between NS and ***endocrine systems***.(through direct communication with the pituitary gland)

controls body temperature (measured by blood flowing through it).

regulates hunger/thirst and feelings of satiety.

assists with the internal circadian clock by regulating biological activity.

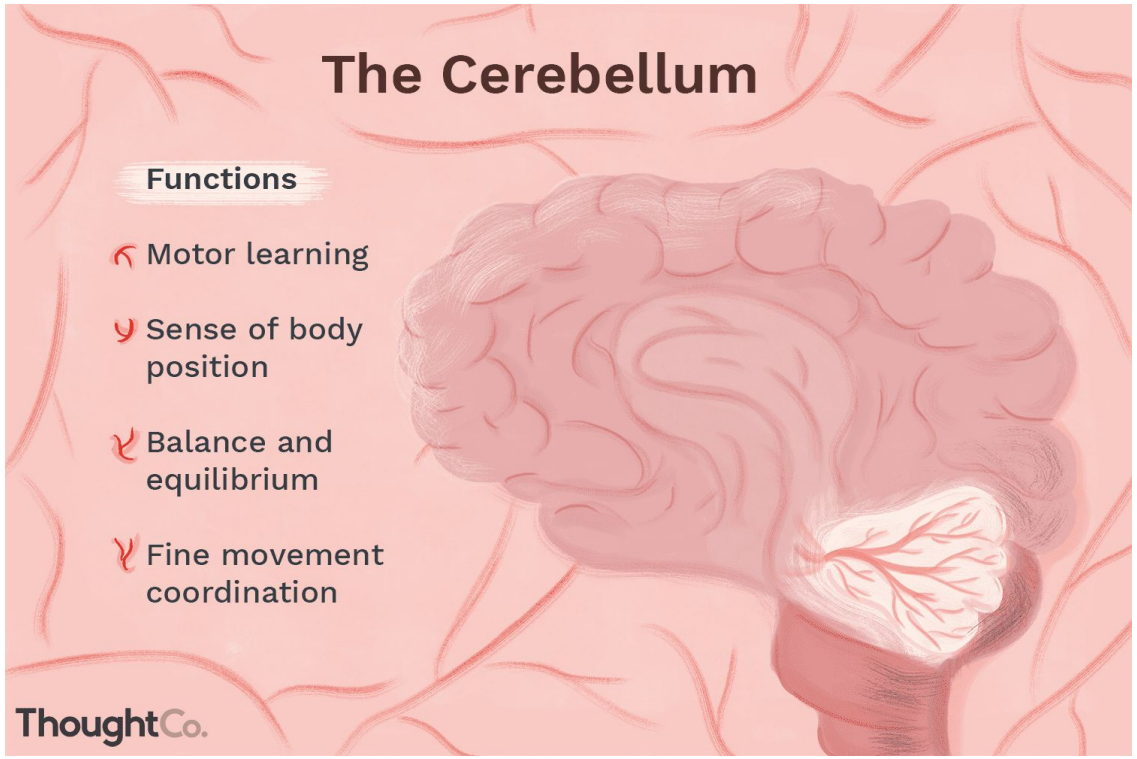
CEREBELLUM

The cerebellum, or “little brain”, is the ***second largest*** major region of the brain and lies inferior to the cerebrum and posterior to the brain stem. It is separated from the cerebrum by the transverse fissure (in which the tentorium cerebelli is located).

The cerebellum’s central constricted area is the vermis and the lateral “wings” or lobes are the cerebellar hemispheres.

The cerebellum compares intended movements with what is happening with skeletal muscles, and **regulates posture, equilibrium, and balance**.

CEREBELLUM



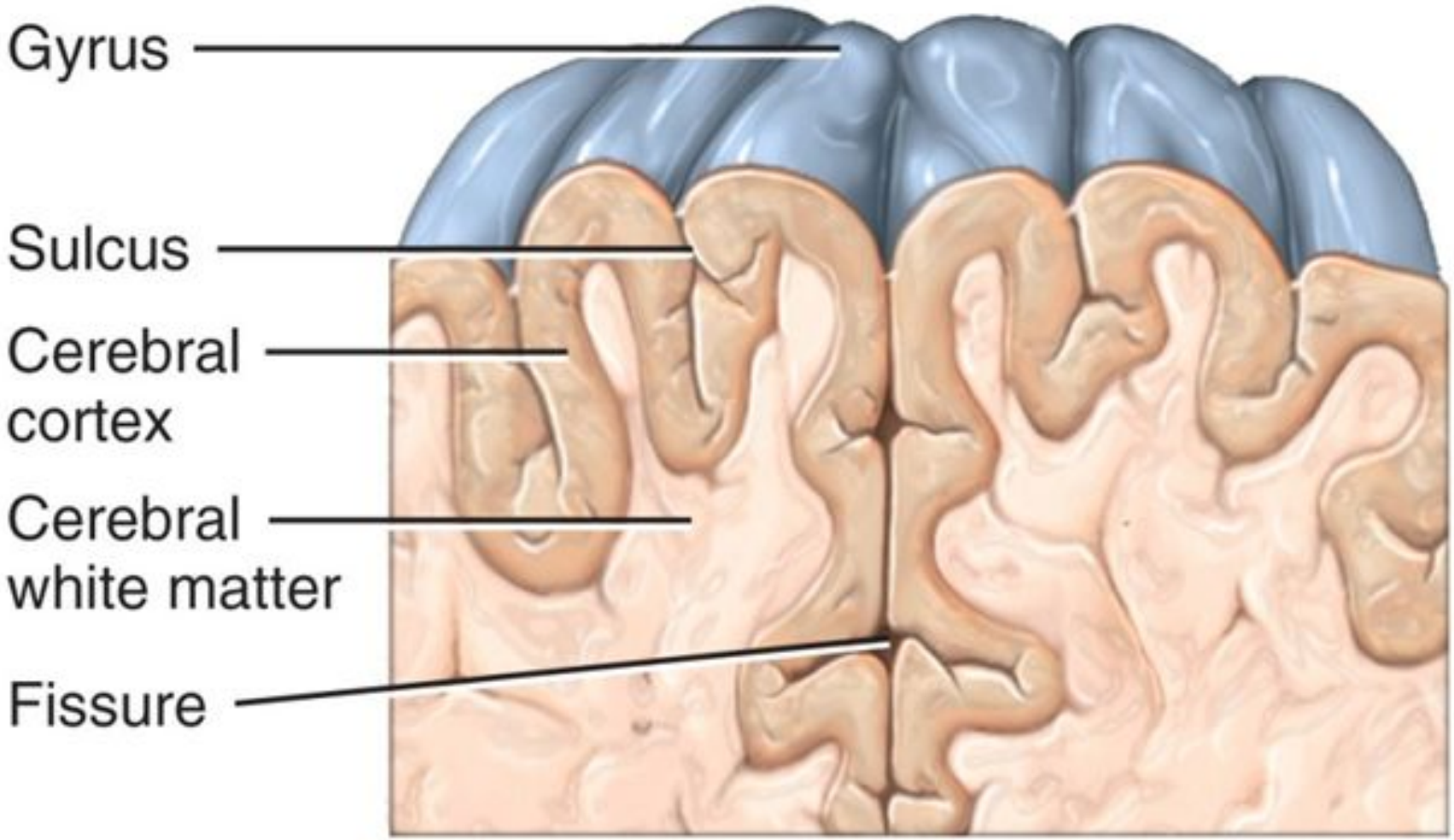
https://youtu.be/Fir-v6EoZNE?feature=shared

CEREBRUM

The cerebral cortex is the “seat of our intelligence”– it’s because of neurons in the cortex that we are able to read, write, speak, remember, and plan our life.The cerebrum consists of an **outer cerebral cortex**, an **internal region of cerebral white matter**, and **gray matter nuclei** deep within the white matter.

During embryonic development, the grey matter of the brain develops faster than the white matter - the cortical region rolls and folds on itself. Convolutions and grooves are created in the cortex during this growth process.

The folds or raised areas are called **gyri (gyrus).** The grooves between the gyri are called **sulci (sulcus),** with the deepest grooves referred to as **fissures.**



Details of a gyrus, sulcus, and fissure

CEREBRUM ANATOMY

The prominent. **longitudinal fissure separates the cerebrum into right and left cerebral hemispheres**

The **central sulcus further divides the anterior frontal lobe from the more posteriorly situated parietal lobe.**

The ***precentral gyrus*** - located immediately anterior to the central sulcus in the anterior lobe - contains the ***primary motor area*** of the cerebral cortex.

Another major gyrus, the ***postcentral gyrus***, which is located immediately posterior to the central sulcus in the parietal lobe, contains the ***primary somatosensory area*** of the cerebral cortex.

The parieto-occipital sulcus separates the parietal lobe from the posterior-most occipital lobe

The lateral cerebral sulcus (fissure) separates the frontal lobe from two laterally placed temporal lobes. The lobes of the cerebrum correspond to the bones of the braincase which bear the same names.

AREAS OF THE CEREBRUM

The **primary somatosensory area** located in the ***postcentral gyrus of each parietal lobe***, receives nerve impulses for, and consciously **perceives the somatic sensations** of touch, pressure, vibration, itch, tickle, temperature (coldness and warmth), pain, and proprioception (joint and muscle position).

The **primary motor area** located in the ***precentral gyrus of the frontal lobe***, **controls voluntary contractions** of specific muscles or groups of muscles

The **visual** area is located at the posterior tip of the **occipital** lobe mainly on the medial surface

The **gustatory** area is located just inferior to the somatosensory area in the **parietal** lobe

The **auditory area** is in the superior part of the **temporal** lobe

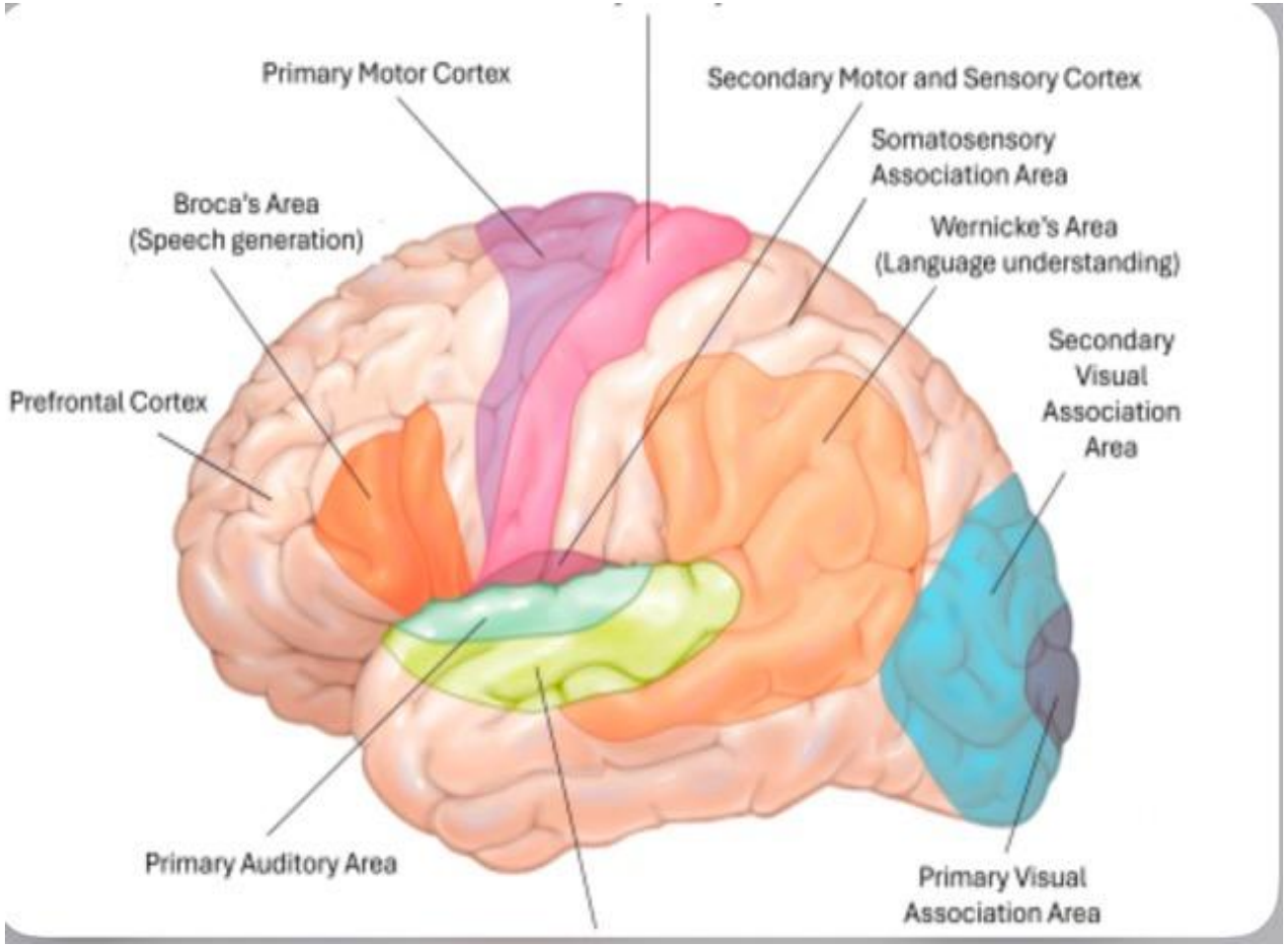
The **olfactory** area is in the inferomedial **temporal** lobe

SPECIAL AREAS OF THE CEREBRUM

Broca's area - located in the ***frontal lobe.*** It's an important area for language production. If damaged, people can develop Broca's aphasia, where they have trouble forming words and putting sentences together.

Wernicke's area- located in the ***temporal lobe***, involved in comprehension of spoken or written language comprehension.

Wernicke's aphasia patients have trouble understanding language, both spoken and written.



CEREBRAL WHITE MATTER

The cerebral white matter consists primarily of myelinated axons in three types of tracts.

Association tracts contain axons that conduct nerve impulses between gyri in the ***same hemisphere.***

Commissural tracts conduct nerve impulses between corresponding gyri ***from one hemisphere to another.***

Projection tracts *convey impulses to lower parts of the CNS* (thalamus, brain stem, or spinal cord) or vice versa.

CORPUS CALLOSUM

One of the three important groups of commissural tracts (the other two being the anterior and posterior commissures) – it is a **thick band of axons that connects corresponding areas of the two hemispheres**.

Through the corpus callosum, the left motor cortex (which controls the right body) is linked to the right motor cortex (which controls the left body).

In most people, the left hemisphere is more important for reasoning, numerical and scientific skills, spoken and written language, and the ability to use and understand sign language.

the right hemisphere is more specialized for musical and artistic awareness; spatial and pattern perception; recognition of faces and emotional content of language; discrimination of different smells; and generating mental images of sight, sound, touch, and taste.

LIMBIC SYSTEM

does not represent any one part of the brain – it is more a functional system composed of parts of the cerebral cortex, diencephalon, and midbrain.

sometimes called the “emotional brain” because it plays a primary role in promoting a range of emotions, including pleasure, pain, docility, affection, fear, and anger.

https://youtu.be/LNs9ruzoTmI?feature=shared

BASAL NUCLEI

The basal nuclei are conspicuous centers of cell bodies deep in the cortex. The 3 basal nuclei ***help initiate and terminate movements, suppress unwanted movements, and regulate muscle tone***. The basal nuclei also control subconscious contractions of skeletal muscles. Examples include automatic arm swings while walking.

Dysfunctions of the basal nuclei are implicated in Parkinson's disease.

Areas of the brain review:

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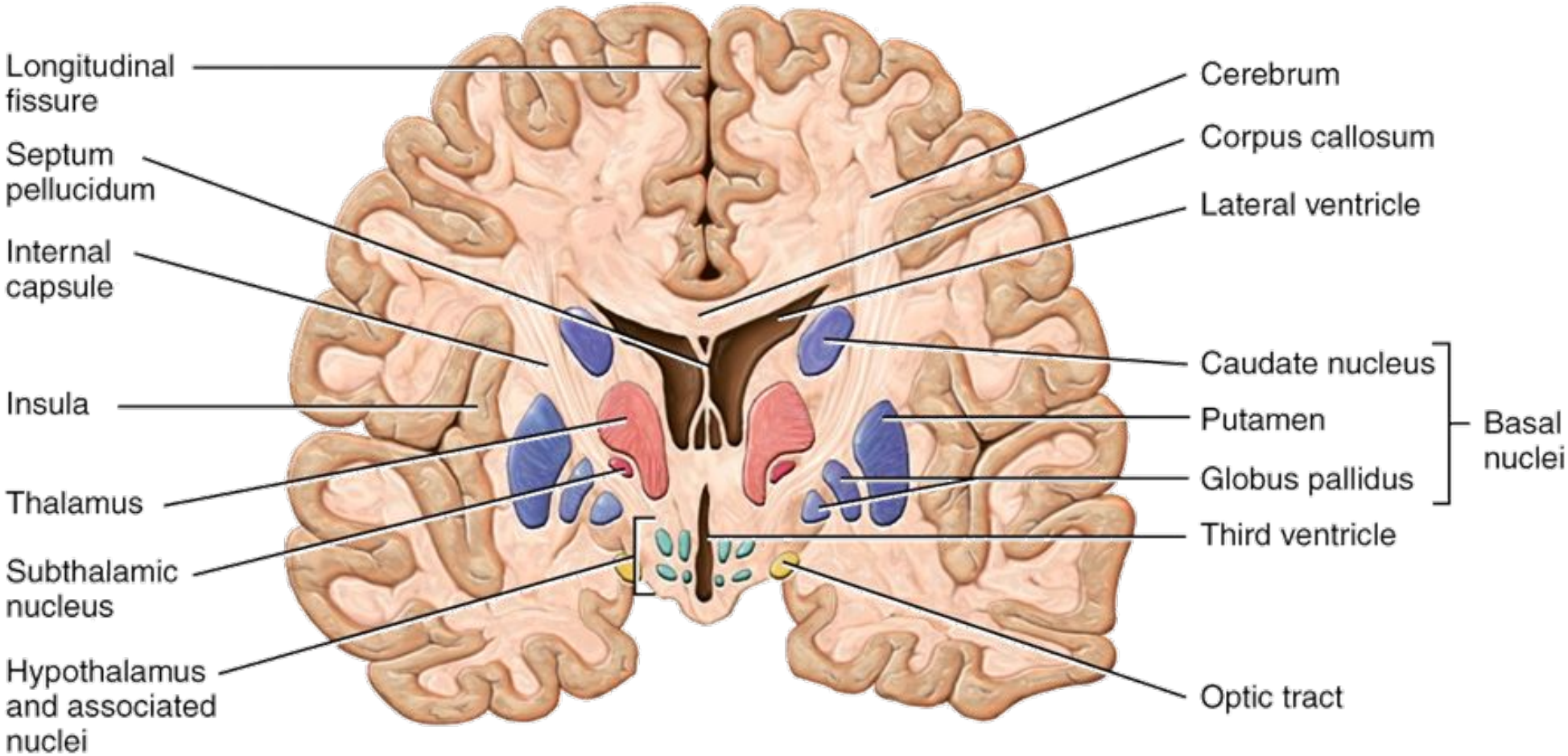


(b) Anterior view of frontal section

PROTECTIVE COATINGS - MENINGES

The cranial meninges are continuous with the spinal meninges and mirror their structure and function – they also bear the same names:

A tough outer **dura mater**, a spidery arachnoid mater and a thin, delicate pia mater.

The cranial dura mater has ***two layers*** – an external periosteal layer and an internal meningeal layer; the spinal dura mater has only one.

In the brain, extensions of the dura mater form hard, non-compliant membranes that divide the intracranial vault in various ways.

DURAL EXTENSIONS

In the brain, extensions of the dura mater form hard, non-compliant membranes that divide the intracranial vault in various ways.

The 3 important dural extensions:

The falx cerebri, the falx cerebelli, and the tentorium cerebelli.

The ***falx cerebri*** is a strong sickle-shaped fold of dura mater which descends vertically in the longitudinal fissure and ***separates the two cerebral hemispheres.***

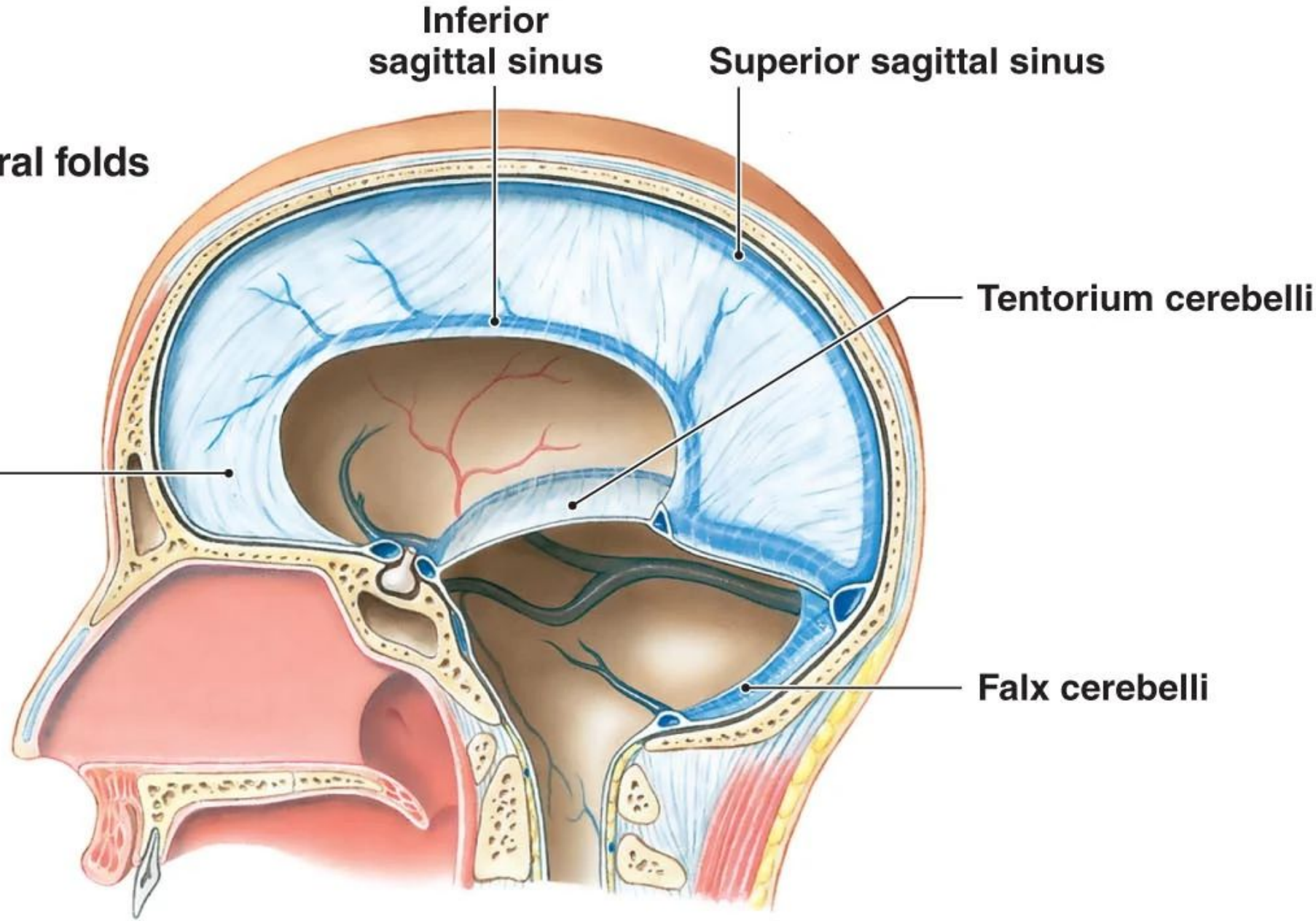
The ***falx cerebelli*** is a small triangular process that separates the ***two cerebellar hemispheres.***

DURAL EXTENSIONS

The ***tentorium cerebelli*** divides the cerebellum from the cerebrum. Clinically it is important because brain tumors are often characterized as supratentorial (above the tentorium) and infratentorial (below the tentorium). Most childhood tumors are infratentorial, while most adult tumors are supratentorial.

Since the tentorium is a hard structure, if there is any brain swelling the brain can get partly pushed down and herniate through the tentorium, which becomes a life-threatening event.

The dural sinuses and dural folds



BRAIN BLOOD FLOW

The brain represents only 2 percent of total body weight, but receives about 20% of the body's blood supply and consumes **20% of the O2 and glucose** (even when resting).

Anteriorly, the internal carotid arteries supply blood to the brain; the posterior blood supply is via the vertebral arteries.

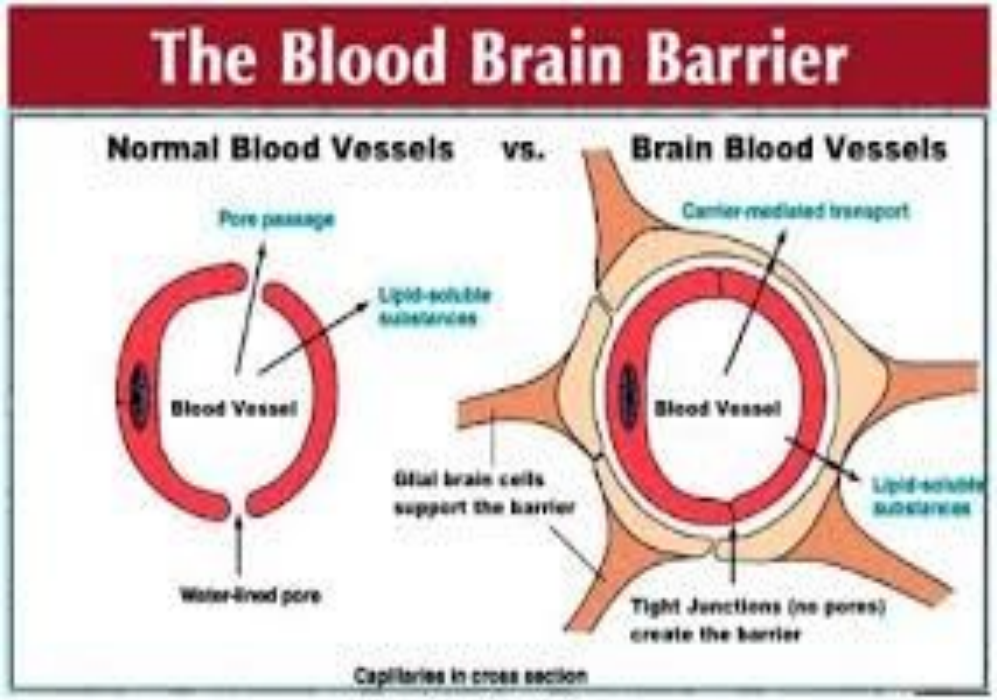
The internal jugular veins are the venous return

https://youtu.be/uMMMqkVZAhk?feature=shared

BLOOD BRAIN BARRIER (BBB)

The vascular endothelium around brain capillaries differs from most other organs of the body in that it forms tight junctions with the end-feet of nearby astrocytes.

As a result of this unusual architecture, a blood brain barrier (BBB) is formed that serves to isolate the parenchyma of the brain from many substances in the blood that would normally be able to gain access.



BLOOD BRAIN BARRIER

The BBB protects the brain from some harmful substances (like bacteria), but at a cost:

For one thing, certain molecules needed to meet metabolic needs (such as glucose) must be actively transported across the barrier using specific transport proteins and energy.

Another aspect of the BBB is that if a brain infection were to develop, antibiotics (and many other drugs) have difficulty crossing into the brain tissues and reaching therapeutic levels.

https://youtu.be/e9sN9gOEdG4?feature=shared

PRODUCTION & FLOW OF CEREBROSPINAL FLUID

Cerebral spinal fluid (CSF) is a clear fluid that circulates through the internal cavities in the brain (called ***brain ventricles***) and spinal cord (the ***central canal***) and also flows over and around the brain and cord in the ***subarachnoid space.*** In essence, the brain "floats" in it.

CSF absorbs shock and protects the brain and the cord. It also helps transport nutrients and wastes between blood and nervous tissues.

The majority of CSF production - ***80 to 150 mL*** at any given time in an adult - comes from ependymal cells in the choroid plexuses (networks of blood capillaries that line the ventricles).

CSF FLOW

The pathway CSF follows from the internal ventricles to the SAS is given in the following sequence:

Lateral ventricles - interventricular foramina - third ventricle- cerebral aqueduct-fourth ventricle-median aperture - lateral apertures - SubArachnoid Space.
https://youtu.be/9e9Lo0OPON4?feature=shared
https://youtu.be/444vP0Qzg_M?feature=shared

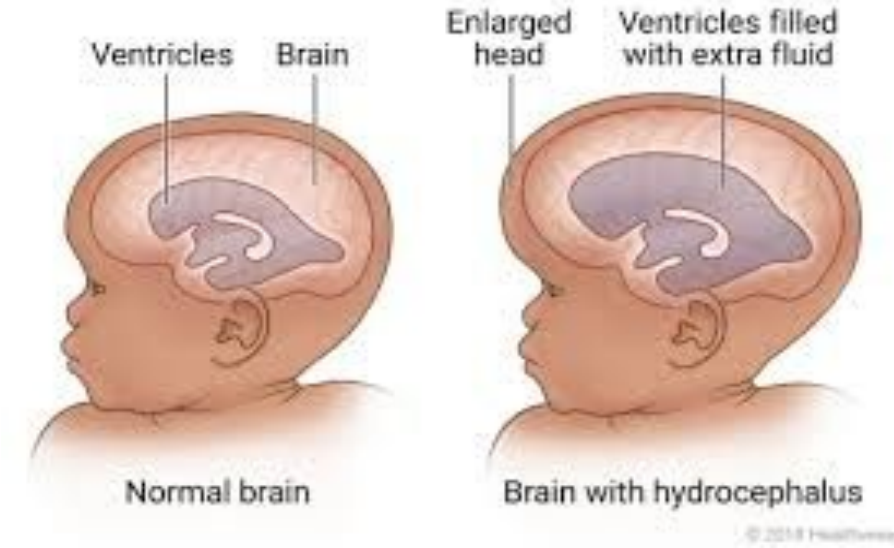
Pressure remains constant in the head because the rate of fluid reabsorption closely matches fluid formation at approx. 20 mL/h.

CSF is gradually reabsorbed back into the blood through the **arachnoid villi** (finger-like projections that extend into the dural sinuses).

CSF BUILDUP = HYDROCEPHALUS

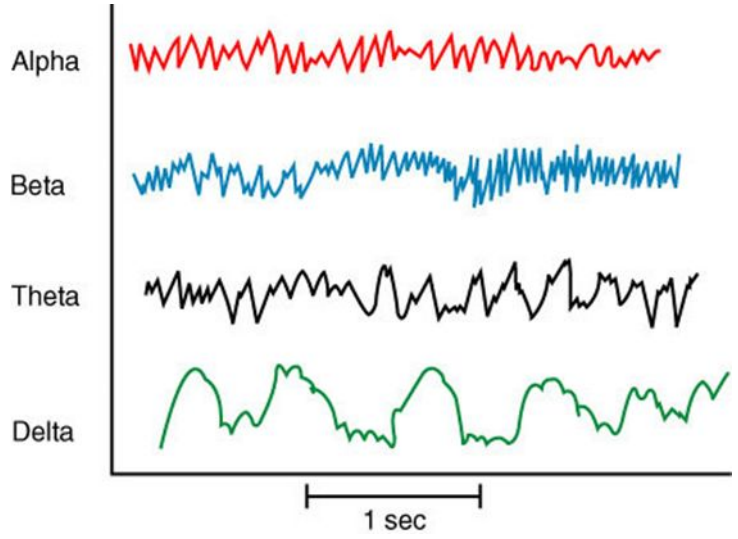
Failure of CSF to form and drain normally results in a buildup of pressure called hydrocephalus.

Hydrocephalus occurs with congenital abnormalities, head injury, meningitis, and episodes of bleeding into the brain.



BRAIN WAVES

Brain Waves: The billions of communicating brain neurons constantly generate detectable signals called brain waves. Those we can more easily measure are generated by neurons close to the brain surface, mainly neurons in the cerebral cortex. Electrodes placed on the forehead and scalp can be used to make a record called an electroencephalogram.



CONTINUED

Alpha (10–12 Hz (cycles/sec) waves are present when *awake* but disappear during sleep.

Beta (14–30 Hz) waves are present with sensory input and mental activity when the nervous system is active.

Theta (4–7 Hz) waves indicate emotional stress or a brain disorder.

Delta (1–5 Hz) waves appear only during *sleep* in adults but indicate brain damage in an awake adult.

Electroencephalograms are useful both in studying normal brain functions, such as changes that occur during sleep, and in diagnosing a variety of brain disorders, such as epilepsy, tumors, trauma, hematomas, metabolic abnormalities, sites of trauma, and degenerative diseases.

The EEG is also utilized to determine if “life” is present, that is, to establish or confirm that brain death has occurred.

https://youtu.be/tZcKT4l_JZk?feature=shared

Coma & Narcolepsy

Coma: When a person is in a coma, they look like they are asleep but they do not react to their environment or wake up for any reason, including pain. This state usually occurs as a result of either temporary or permanent injury to the brain. Some brain wave activity is detected on EEG.

Narcolepsy- A neurological disorder that affects sleep-wake cycles. Sufferers often experience persistent daytime drowsiness & may have periods of short, sudden sleep during daily activities. Strong emotion/stress can be a trigger.

Sleep apnea - A serious sleep disorder where your breathing can stop and start during sleep. We will discuss more in our cardiovascular section.

CRANIAL NERVES

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CRANIAL NERVES- SENSORY

Sensory Cranial Nerves:

CN I is the olfactory nerve (sense of smell).

CN II is the optic nerve (sense of sight).

CN VIII is the vestibulocochlear nerve. From the inner ear, the vestibular component carries information on balance, while the cochlear component enables hearing.

Damage of CN VIII causes vertigo, ringing in the ears, and/or deafness.

CRANIAL NERVES- MOTOR

CN III - Oculomotor Nerve - supplies motor input to our eyelid muscles and facilitates pupillary constriction. Moves the eyeballs in all directions not controlled by CN IV or CN XI

CN IV - Trochlear Nerve. Moves eyeballs down & inward (going cross-eyed)

CN VI - Abducens Nerve. Moves eyeballs to the left and right.

CN XI - **Spinal accessory nerve**. This nerve supplies somatic motor innervation to the Trapezius and Sternocleidomastoid muscles.

CN XII - Hypoglossal nerve. This is a very large nerve, it takes a lot more coordination than you might guess to chew, talk, and swallow without injuring our tongue.

CRANIAL NERVES - MIXED

CN V is the trigeminal nerve It has three large branches, each of which supplies an area of the face:Ophthalmic, maxillary & mandibular. It is the ***major sensory nerve*** of the face but also supplies some motor impulses to our chewing muscles.

CN VII - facial nerve. It has 5 large somatic branches & is the ***major motor nerve*** of the face. It also carries some ***taste sensations*** (anterior 2/3 of tongue).

Paralysis of CN VII is called ***Bell's palsy*** and leads to loss of ability to close the eyes and impairment of taste and salivation.

CN IX - glossopharyngeal nerve. This nerve carries ***some taste*** sensations(posterior ⅓ of tongue) as well as ANS impulses to salivary glands and the mechanoreceptors of the carotid body and carotid sinus (senses changes in BP).

CN X - vagus nerve ("the wanderer"), which carries most of the parasympathetic motor efferents to the organs of the thorax and abdomen

Cranial Nerve Graphic

Oh	I Olfactory	Sensory	Some
Once	II Optic	Sensory	Say
One	III Oculomotor	Motor	Marry
Takes	IV Trochlear	Motor	Money
Their	V Trigeminal	Both	But
Anatomy	VI Abducens	Motor	My
Final	VII Facial	Both	Brother
Very	VIII Vestibulocochlear	Sensory	Says
Good	IX Glossopharyngeal	Both	Big
Vacations	X Vagus	Both	Brains
Are	XI Spinal Accessory	Motor	Matter
Heavenly	XII Hypoglossal	Motor	More

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AUTONOMIC NERVOUS SYSTEM

HTTPS://YOUTU.BE/3A_ALSFVNWS

INTRODUCTION

ANS contributes to homeostasis by
- responding to subconscious visceral sensations
- exciting or inhibiting smooth muscle, cardiac muscle, and many glands

Made up of
- autonomic sensory neurons
- integrating centers in the CNS
- autonomic motor neurons

Enteric division
- specialized network of nerves and ganglia forming an independent nerve network within the wall of the GI tract

DISTINCTIVE FEATURES OF THE ANS

Usually operates without conscious control, though centers in the hypothalamus and brain stem do provide regulation for ANS reflexes

Sensory receptors(called ***interoceptors***) located in blood vessels, visceral organs, muscles, and the nervous system monitor conditions in the internal environment

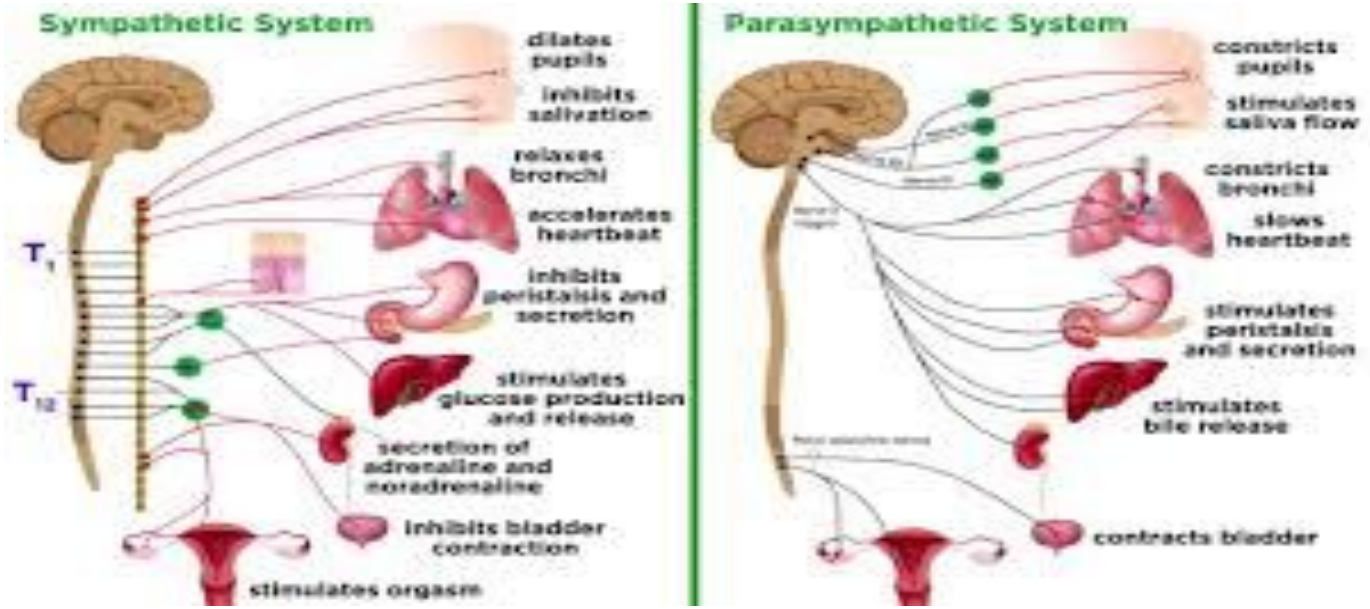
- **Chemoreceptors** – monitor blood CO2
- **Mechanoreceptors** - degree of stretch in organ walls or vessels

Autonomic motor neurons regulate visceral activities by either **increasing** (***exciting***) or **decreasing** ***(inhibiting***) ongoing activities in their effector tissues

DIVISIONS OF THE ANS

Most body organs have dual ANS innervation; that is, they receive impulses from both sympathetic and parasympathetic neurons.

Usually the nerve impulses from one division stimulate an organ, while impulses from the other division decrease activity.



SYMPATHETIC DIVISION

The cell bodies of neurons which participate in motor responses of the sympathetic nervous system are located in the lateral horns of the gray matter in the 12 thoracic segments and the first two lumbar segments of the cord.

Sympathetic preganglionic neurons exit the spinal cord only between levels T1-L2 , though sympathetic ganglia extend in the vicinity of the cord from the cervical to the sacral region.

MAJOR GROUPS OF SYMPATHETIC GANGLIA

The sympathetic trunk (vertebral chain) ganglia

The Prevertebral ganglia

The celiac, superior mesenteric, inferior mesenteric, aorticorenal and renal ganglia

EXITING THE SYMPATHETIC TRUNK

Axons leave the sympathetic trunk in four possible ways:

- They can enter and travel with spinal nerves.
- They can form fine networks of periarterial preganglionic traveling cephalad to synapse in the cervical ganglia.
- Postganglionic axons exiting the sympathetic trunk can form sympathetic nerves to the heart and lungs.
- Preganglionic axons can leave the sympathetic trunk without synapsing and form splanchnic nerves (affecting the organs)

CONTINUED

The postganglionic axons typically terminate in several different visceral effectors, making the effects of sympathetic stimulation a widespread massive response.

This is why anger can be hard to control – it is such a diffuse response.

PARASYMPATHETIC DIVISION

The cell bodies of preganglionic neurons which participate in motor responses of the parasympathetic nervous system are located in nuclei of 4 cranial nerves in the brainstem (III, VII, IX and X) and in the lateral gray matter of sacral areas of the spinal cord (S2-S4).

The vagus nerve (CN X) carries nearly 80% of the total parasympathetic flow to the organs of the thorax and upper abdomen. Lower abdominal and pelvic organs are innervated by the sacral output.

CONTINUED

Parasympathetic ganglia (terminal ganglia - located far from their origin, near the target organs

Four pairs of cranial parasympathetic ganglia innervate structures in the head: The ciliary, pterygopalatine, submandibular, and otic ganglia.

The cranial-sacral division also has the ganglia associated with the vagus (X) nerve and the sacral nerves.

The sacral preganglionic axons branch off of sacral spinal nerves to form pelvic splanchnic nerves which synapse with parasympathetic postganglionic neurons located in terminal ganglia in the walls of the innervated viscera. From the terminal ganglia, postganglionic axons innervate smooth muscle and glands in the walls of the colon, ureters, urinary bladder, and reproductive organs

CONTINUED

The parasympathetic response is more controlled than the sympathetic response.
Presynaptic parasympathetic neurons usually synapse with only 4–5 postsynaptic neurons, all of which supply a single visceral effector.
Parasympathetic stimulation leads to a narrow, focused action on specific organs.

ANS NEUROTRANSMITTERS

The total number of neurotransmitters used in the entire nervous system is not known, in the ANS, only 2, acetylcholine and norepinephrine, are used to any great degree.

- Synapses at which ACh is used are termed cholinergic.
- Synapses at which norepinephrine or epinephrine are used are termed adrenergic.

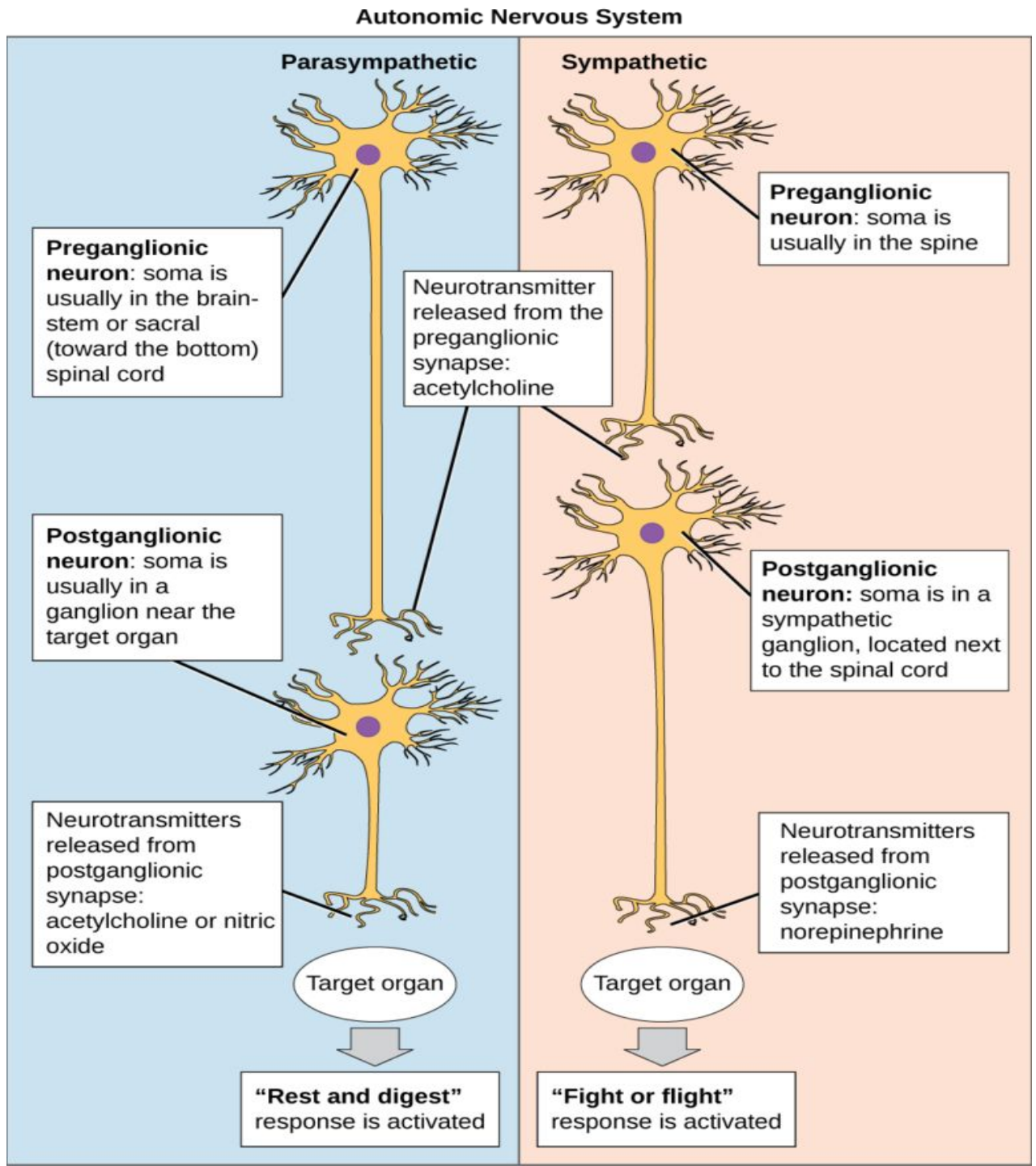
The neurotransmitter used in all of the synapses of sympathetic and parasympathetic ganglia (between the synapses of the preganglionic and postganglionic fibers) is acetylcholine.

ANS NEUROTRANSMITTERS

Receptors that respond to Ach released by these cholinergic neurons are called cholinergic receptors and there are 2 subtypes: nicotinic receptors (found in the ganglia) and muscarinic receptors (found in the synapses with the effector organs)

The neurotransmitter used at **most sympathetic postganglionic synapses is norepinephrine**

The neurotransmitter used at **all parasympathetic postganglionic synapses is Acetylcholine (ACh)**


Autonomic Nervous System
Parasympathetic
Sympathetic
Preganglionic neuron: soma is usually in the brain-stem or sacral (toward the bottom) spinal cord
Neurotransmitter released from the preganglionic synapse: acetylcholine
Preganglionic neuron: soma is usually in the spine
Postganglionic neuron: soma is usually in a ganglion near the target organ
Postganglionic neuron: soma is in a sympathetic ganglion, located next to the spinal cord
Neurotransmitters released from postganglionic synapse: acetylcholine or nitric oxide
Neurotransmitters released from postganglionic synapse: norepinephrine
Target organ
Target organ
"Rest and digest" response is activated
"Fight or flight" response is activated

PHYSIOLOGY OF THE ANS (SYMPATHETIC)

Sympathetic stimulation leads to secretion of norepinephrine by the adrenal glands, an increase in the rate and strength of the heartbeat, constriction of blood vessels of non-essential organs, dilation of vessels of essential organs (skeletal muscle and the cerebral cortex), an increase in the rate and depth of breathing, hepatic conversion of glycogen to glucose, and decrease in GI activity.

PHYSIOLOGY OF THE ANS (PARASYMPATHETIC)

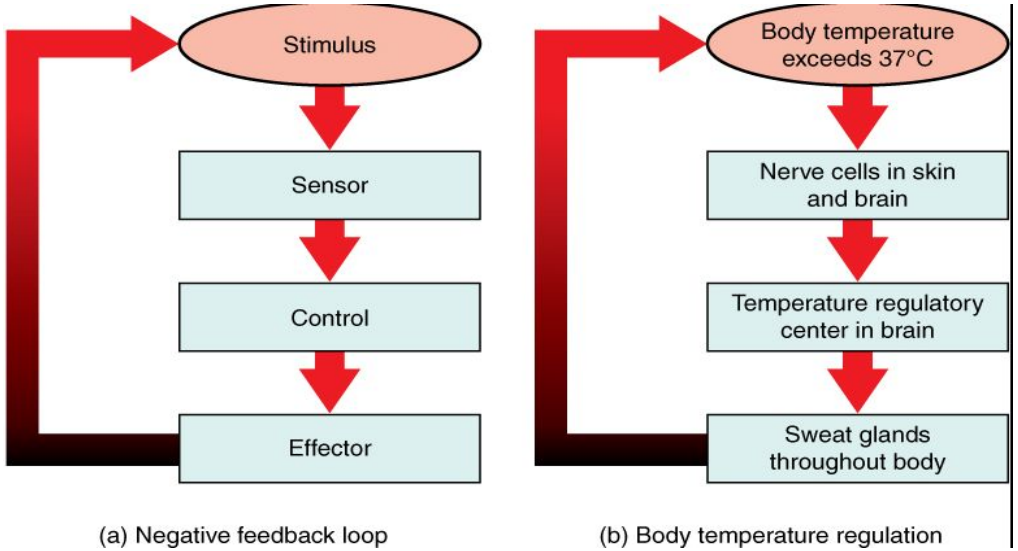
SLUDD is as an acronym used to describe the responses of the parasympathetic nervous system:

- Salivation (increased)
- Lacrimation (increased)
- Urination (increased)
- Digestion (increased)
- Defecation (increased)

decreases (in the rate and force of the heart beat, airway size and rate of breathing, and pupil size)

REGULATION

The balance of autonomic sympathetic-parasympathetic tone is regulated by feedback loops between the spinal cord and brainstem, with input from the limbic system and oversight by the hypothalamus.



SENSORY, MOTOR & INTEGRATIVE SYSTEMS

GENERAL SENSATIONS

As sensory impulses reach the CNS, they become part of a large pool of sensory input

not every sensory impulse will elicit a response

Each piece of incoming information is combined with other arriving and previously stored information in a process called integration

Integration occurs :

- along pathways in the spinal cord
- brain stem
- Cerebellum
- basal nuclei
- cerebral cortex

Sensations result in and evoke a conscious perception or subconscious awareness that changes have occurred in the external or internal environment. The motor responses are also modified at several of these levels.

Examples of complex integrative functions of the brain include wakefulness and sleep, and learning and memory

SENSORY MODALITIES

Each unique type of sensation is called a sensory modality, and a given sensory neuron carries information for only one modality, be it somatic, visceral, or “special”

- Somatic senses include tactile sensations (touch, pressure, vibration, itch, and tickle), thermal sensations (warm and cold), pain sensations, and proprioception
- Visceral senses provide information about conditions within internal organs

The process of sensation begins in a sensory receptor, which can be either a specialized cell or the dendrites of a sensory neuron

CONTINUED

A particular kind of stimulus activates certain sensory receptors, while other sensory receptors respond only weakly or not at all – a characteristic known as selectivity.

For a sensation to arise, four events typically occur:

1. Stimulation of the sensory receptor - an appropriate stimulus must occur within the receptor's receptive field
2. Transduction of the stimulus - a sensory receptor converts energy in a stimulus into a graded potential
3. Generation of nerve impulses – occurs when the sum of graded potentials reach threshold in first-order neurons
4. Integration of sensory input – occurs when a particular region of the CNS integrates a number (and even a variety) of sensory nerve impulses and results in a conscious sensations or perceptions

SENSORY RECEPTORS

Sensory receptors can be grouped into several classes based on structural and functional characteristics:

- Microscopic structure – free nerve endings vs encapsulated endings.

Location of the receptors and the origin of the stimuli that activate them

- The type of stimulus detected

Receptors named according to their location include:

- Exteroceptors - located at or near the external surface, respond to external stimuli
- Interoceptors (visceroceptors), which are located in blood vessels, organs, and muscles and produce impulses which usually are not consciously perceived
- Proprioceptors, which are located in muscles, tendons, joints, and the inner ear They provide information about body position and movement of joints

TYPES OF ENVIRONMENTAL STIMULUS

Mechanical	Thermal	Chemical	electromagnetic
• PRESSURE • TOUCH • MOTION • SOUND • VIBRATION • GRAVITY	▪ HEAT ▪ COLD ▪ INFRARED RADIATION	○ INDIVIDUAL TYPE OF MOLECULE	✳ VISIBLE LIGHT ✳ ELECTRECITY ✳ MAGNATISM

RECEPTORS NAMED ACCORDING TO MODE OF ACTIVATION

Mechanoreceptors, - sensitive to deformation

Thermoreceptors - changes in temperature

Nociceptors, - painful stimuli

Photoreceptors - photons of light

Chemoreceptors - chemicals in the mouth (taste), nose (smell) and body fluids

Osmoreceptors - osmotic pressure of body fluids

ADAPTATION

A characteristic feature of most sensory receptors is adaptation, in which the generator potential or receptor potential decreases in amplitude during a sustained or constant stimulus

Because there is an accommodation response at the receptor level, the frequency of nerve impulses traveling to the cerebral cortex decreases and the perception of the sensation fades even though the stimulus persists, receptors vary in how quickly they adapt (rapidly adapting and slowly adapting receptors)

NOCICEPTION & PAIN

Nociception: All of our sensory modalities are important, but pain serves a protective function and is indispensable for survival, Nociceptors are chemoreceptive free nerve endings activated by tissue damage from intense thermal, mechanical, or chemical stimuli - they're found in every tissue of the body except the brain

There are two types of pain: fast and slow

- The perception of fast pain (acute, well localized) occurs rapidly because the nerve impulses propagate along medium-diameter, myelinated A fibers
- By contrast, slow pain begins after a stimulus is applied and gradually increases in intensity over a period of several seconds or minutes. Impulses for slow pain conduct along small-diameter, unmyelinated C fibers. This type of pain may be excruciating and often has a burning, aching, or throbbing quality

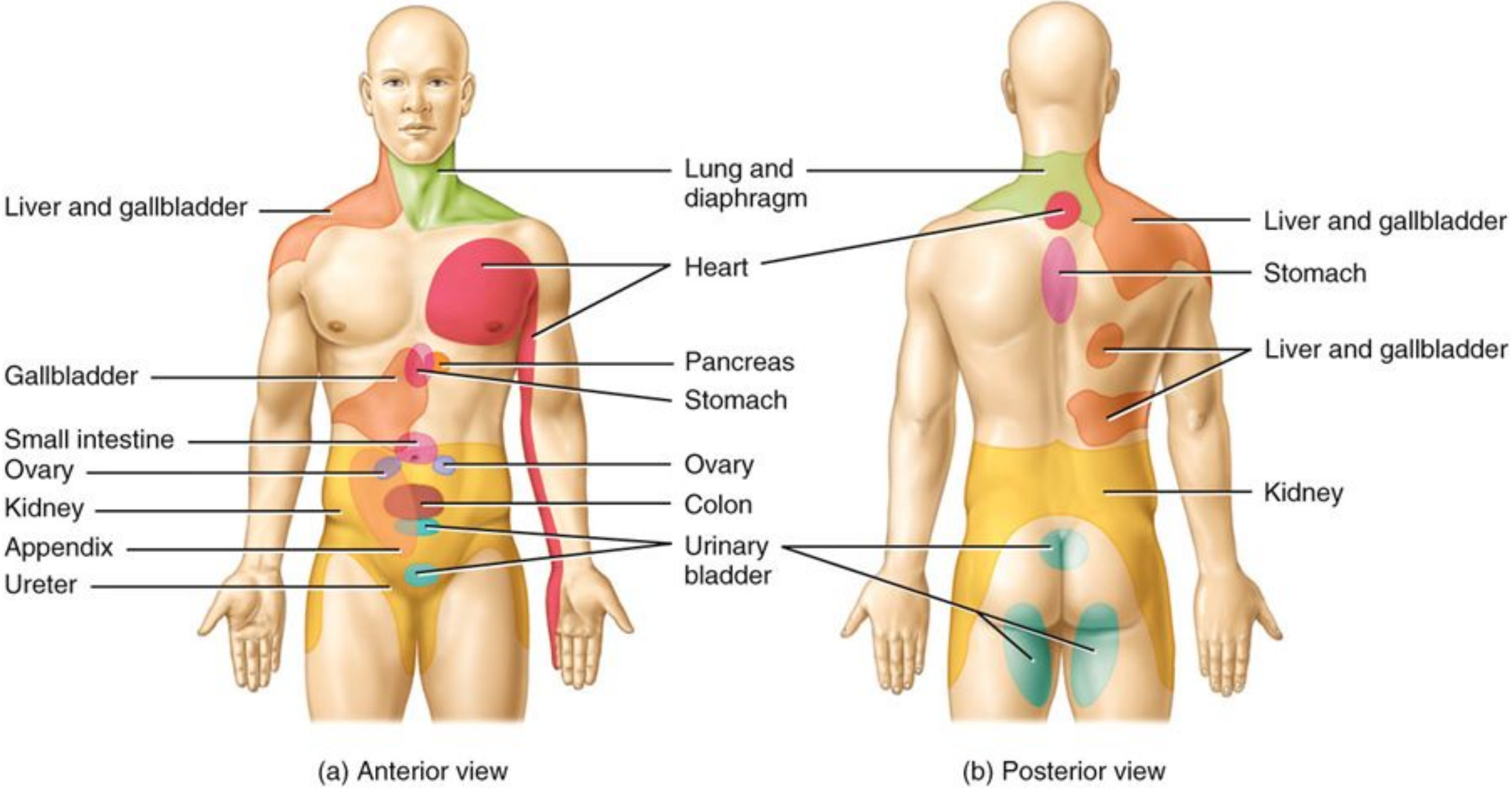
PAIN CONTINUED

Pain that arises from stimulation of receptors in the skin is called superficial somatic pain

stimulation of receptors in skeletal muscles, joints, tendons, and fascia causes deep somatic pain

Visceral pain results from stimulation of nociceptors in visceral organs

- In many instances of visceral pain, the pain is felt in or just deep to the skin that overlies the stimulated organ, or in a surface area far from the stimulated organ. This phenomenon is called referred pain


Liver and gallbladder
Gallbladder
Small intestine
Ovary
Kidney
Appendix
Ureter
Lung and diaphragm
Heart
Pancreas
Stomach
Ovary
Colon
Urinary bladder
Liver and gallbladder
Stomach
Liver and gallbladder
Kidney
(a) Anterior view
(b) Posterior view

PROPRIOCEPTION

Muscle spindles

- proprioceptors in skeletal muscles that monitor changes in the muscle length and participate in stretch reflexes, By adjusting how vigorously a muscle spindle responds to stretching of a skeletal muscle, the brain sets an overall level of muscle tone

Each muscle spindle consists of several slowly adapting sensory nerve endings that wrap around 3 to 10 specialized muscle fibers. A connective tissue capsule encloses the sensory nerve endings and anchors the spindle to the endomysium and perimysium

Muscle spindles are plentiful in muscles that control fine movements and much more sparse in those that control course or forceful movements

SOMATIC SENSORY PATHWAYS

First-order somatosensory neurons are unipolar in structure

- This means that their cell body is located in the dorsal root ganglia (DRG) just outside the CNS; their other end terminates nearby in the posterior gray horns of the cord, usually at the level where they enter

Second-order neurons conduct ascending impulses from the brain stem where their axons decussat before ascending to the thalamus

- all somatic sensory information from one side of the body reaches the thalamus on the opposite side.

Third-order neurons conduct impulses from the thalamus to the primary somatosensory area of the cortex on the same side.

Somatic sensory neurons (and their axons that convey somatic sensations) are not distributed evenly in the body. The peripheral areas with the highest density are represented in the brain with the largest amount of gray matter in the sensory homunculus. The most sensitive areas in the body are therefore the tip of the tongue, lips, and fingertips.

SPINOCEREBELLAR TRACTS

There are two major spinocerebellar tracts in the spinal cord that carry proprioceptive impulses to the cerebellum, although they are not consciously perceived, sensory impulses sent to the cerebellum along these two pathways are critical for posture, balance, and coordination of skilled movements

SOMATIC MOTOR PATHWAYS

Motor activity begins in the primary motor areas of the precentral gyrus and other cerebral integrative centers

any motor neuron that is not directly responsible for stimulating target muscles is called an upper motor neuron (UMN)

UMNs connect the brain to the appropriate level in the spinal cord

From there, all excitatory and inhibitory signals that control movement converge on second-order motor neurons known as lower motor neurons (LMNs) that descend to innervate skeletal muscle, Since only LMNs provide output from the CNS to skeletal muscle fibers they are also called the final common pathway

Axons of LMNs extend through cranial nerves to the skeletal muscles of the face and head, and through spinal nerves to innervate skeletal muscles of the limbs and trunk

Two of the major LMN tracts are the lateral and anterior corticospinal tracts.

SPECIAL SENSES

SPECIAL SENSES

sensation is the conscious or subconscious awareness of an internal or external stimulus

For the special senses only, “external stimulus” means light rays striking the retina of the eye, sound waves impinging on the tympanic membrane of the ear, molecules in the air and food transmitting smells and tastes to the chemical sensors in the nose and on the tongue, and the force of gravity acting on equilibrium receptors in the inner ear which sense changes in inertia.

Receptors for the special senses of smell, taste, vision, hearing, and equilibrium are anatomically distinct from one another and are concentrated in specific locations in the head, In addition to the stimuli and the receptors, there are specific afferent pathways and translation sites in the brain for information assembled from these special senses.

GENERAL SENSES VS SPECIAL SENSES

General Senses

- Include somatic sensations (tactile, thermal, pain, and proprioceptive) and visceral sensations
- scattered throughout the body
- relatively simple structures

Special Senses

- Include smell, taste, vision, hearing and equilibrium
- Are concentrated in specific locations in the head
- Are anatomically distinct structures
- Form complex neural pathways

OLFACTION

process of perceiving smells

Smell and taste are brought about through the interpretation of chemicals present in the environment

Olfactory and gustatory (taste) impulses travel not only to the cerebral cortex, but also to the limbic system, this is why we can have emotional responses and trigger strong memories to certain smells and tastes,

gustation and olfaction work together but olfaction is much stronger/more sensitive

- ie when someone has a cold it is difficult to taste food

OLFACTION CONTINUED

olfactory epithelium is located in the superior part of the nasal cavity covering the surface of the cribriform plate and extending along the superior nasal concha.

The olfactory epithelium consists of 3 kinds of cells:

- The olfactory receptor is a bipolar neuron with cilia (called olfactory hairs). There are 10-100 million of these receptors in the nose that respond to odorant molecules
- Supporting cells provide support and nourishment
- Basal cells are stem cells that replace olfactory receptors

CONTINUED

The olfactory apparatus can detect about 10,000 different odors, often in concentrations as low as 1/25 billionth of a milligram per milliliter of air,

When an odorant binds to the receptor of an olfactory hair it initiates a cascade of intracellular events through a G-protein and a 2nd messenger (production of cAMP → opening of Na+ channels → inflow of Na+ → generator potentials)

→ Once generated, nerve impulses travel through the two olfactory nerves to the olfactory bulbs , olfactory tract, primary olfactory area in the temporal lobe of the cortex

Olfaction is the only sensory system that has direct cortical projections without first going through relay stations in the thalamus

CONTINUED

Olfactory sensory pathways (centrally) are rapidly adapting, decreasing activity by 50% in the first second, and completely accommodating in 1–2 minutes

Olfactory supporting cells and glands are innervated by the facial (VII) nerve, a component of which provides parasympathetic motor innervation to lacrimal glands and the mucous membranes in the nasal cavity. This is why certain odors will make our nose run and cause us to produce tears

GUSTATION

Gustation, much simpler than olfaction in that only five primary tastes can be distinguished: sour, sweet, bitter, salty, and umami (“meaty” or “savory”)

Umami is believed to arise from taste receptors that are stimulated by monosodium glutamate, All other flavors, such as chocolate, pepper, and coffee, are combinations of the five primary tastes, plus accompanying olfactory and tactile (touch) sensations.

We have nearly 10,000 taste buds located on the tongue, soft palate, pharynx, and larynx (decreases with age)

Each taste bud is composed of about 50 gustatory receptor cells, surrounded by a number of supporting cells

CONTINUED

Basal cells located near the CT base multiply and differentiate, first to become the supporting cells around the bud, then the gustatory receptor cells inside the taste bud.

A single, long microvillus, called a gustatory hair, projects from each receptor cell to the surface through the taste pore, each gustatory receptor cell has a lifespan of about 10 days.

Taste buds are found in 3 different types of papillae (elevations on the tongue which provide a rough texture

- About 12 very large vallate papillae form a row at the back of the tongue (each houses 100–300 taste buds)
- Fungiform papillae are mushroom-shaped and are scattered over the entire surface of the tongue (containing about 5 taste buds each)
- Foliate papillae are located in small trenches on the lateral margins of the tongue, but most of their taste buds degenerate in early childhood

CONTINUED

In addition, the entire surface of the tongue has filiform papillae that contain tactile receptors but no taste buds; they increase friction between the tongue and food, making it easier to move food in the oral cavity

Three cranial nerves contain axons of the first-order gustatory neurons that innervate the taste buds

- The facial (VII) nerve serves taste buds in the anterior 2/3 of the tongue
- The glossopharyngeal (IX) nerve serves taste buds in the posterior 1/3 of the tongue
- The vagus (X) nerve serves taste buds in the throat and epiglottis

Nerve impulses propagate along these cranial nerves to the gustatory nucleus in the medulla oblongata. From there, axons carrying taste signals project to the hypothalamus, limbic system, and thalamus, Taste is perceived consciously as signals from the thalamus arrive at the primary gustatory area at the base of the somatosensory cortex in the parietal lobe.

CONTINUED

The threshold for taste varies for each of the primary tastes. We are most sensitive to bitter substances, such as quinine. Because poisonous substances are often bitter, this high sensitivity may have a protective function. The threshold for sour substances is somewhat higher, followed by salty and sweet substances.

Complete adaptation to a specific taste can occur in 1–5 minutes of continuous stimulation.

VISION

Our visual perception is dependent on the eye, its accessory structures, the optic tracts, and the visual cortex and it's association areas

The eyeball is about 2.5 cm in diameter, with only about 16% of it viewable by just looking at a person

The accessory structures of the eye are the extraocular muscles, palpebra, conjunctiva, and the lacrimal glands and ducts. The pupil is an opening for light to pass into the back of the eye.

ACCESSORY EYE STRUCTURES

The upper and lower palpebrae are the eyelids, with the fissure being the space between them

CN III supplies 4 of the 6 extraocular muscles, plus the levator palpebrae superioris muscles that raise the upper eyelid

The conjunctiva is a clear mucous membrane that covers the white (avascular) part of the eye

The lacrimal glands are each about the size an almond, situated superolateral to the eyeball. Leading from the lacrimal glands are 6 to 12 excretory lacrimal ducts

Tears (lacrimal fluid) run from the lacrimal glands, into the excretory lacrimal ducts, onto the surface of the conjunctiva, over the surface of the eyeball some lacrimal fluid also evaporates

TEARS

Tears (lacrimal fluid) run from the lacrimal glands, into the excretory lacrimal ducts, onto the surface of the conjunctiva, over the surface of the eyeball some lacrimal fluid also evaporates

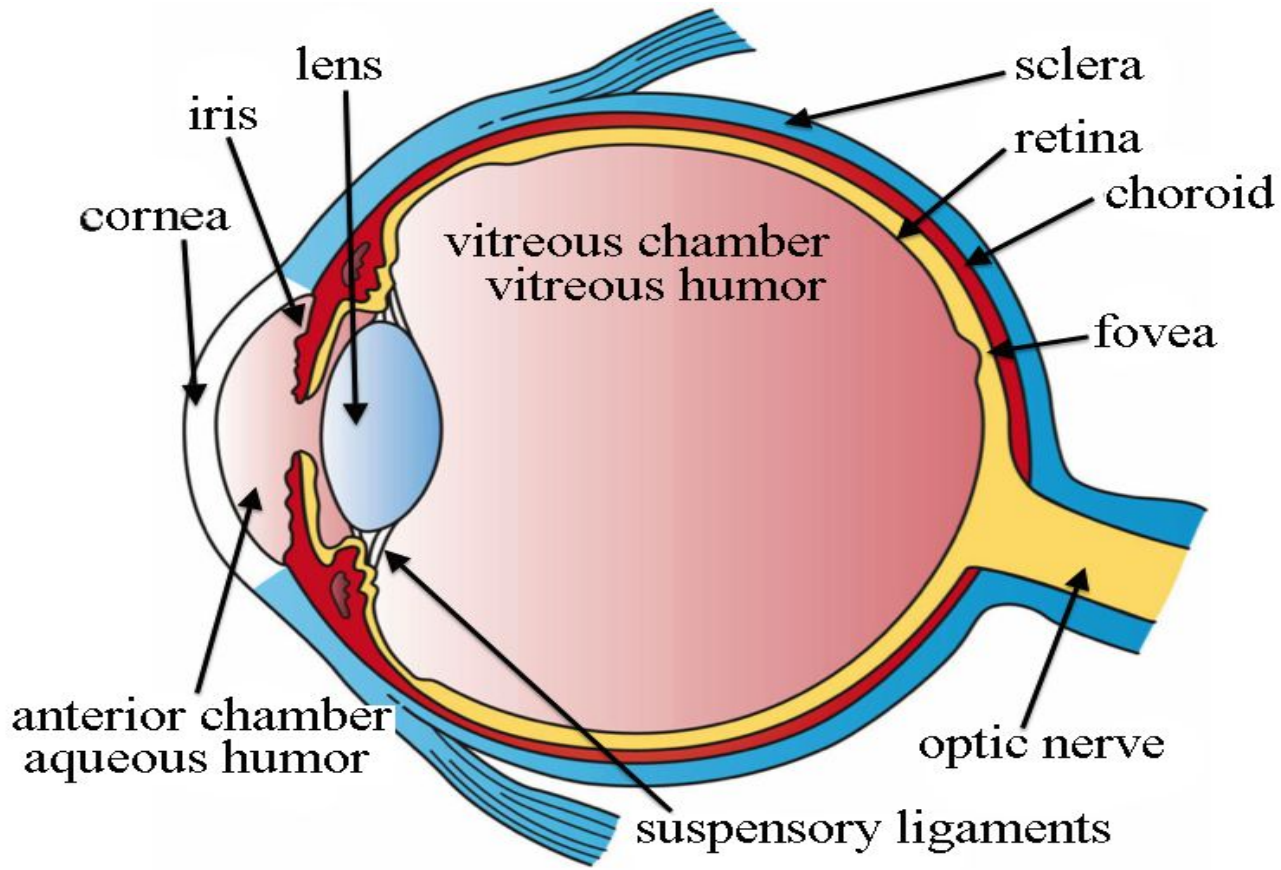
Tears drain into the lacrimal puncta, which are two openings on the nasal side of the extreme edge of the eyeball. Superior and inferior lacrimal canals empty the tears into the nasolacrimal sac and nasolacrimal duct

The right and left sided nasolacrimal ducts empty into each side of the nose

Watery eyes occur when lacrimal fluid builds up, as when something obstructs the nasolacrimal ducts for instance

Blocked nasolacrimal ducts can be caused by an inflammation of the nasal mucosa, such as a cold, Over production of lacrimal fluid occurs in response to parasympathetic stimulation, caused by an emotional response (crying), and tears spill over the edges of the eyelids and drain into the nasal cavity (causing nasal stuffiness)

ANATOMY OF THE EYE



ANATOMY OF THE EYE

The wall of the eyeball consists of three layers or tunics:

- The fibrous tunic is the outer layer and is composed of the sclera (“white” of the eye) and the cornea (the transparent epithelium the protects the front of the eye)
- The vascular tunic or uvea is the middle layer and is composed of the choroid, the ciliary body and the iris
- The nervous tunic is the inner retinal layer

The cornea is a very important structure in the outer avascular fibrous tunic

It’s composed of a transparent epithelium that covers the anterior eye and helps focus light onto the retina

CONTINUED

Because of the amount of collagen fibers in the sclera it forms the tough, white part of the eye, the sclera gives the eye it's shape and protects the inner anatomical parts

Of the 3 parts of the middle tunic the choroid forms the major vascular portion that lines the internal surface of the sclera

The ciliary body consists of two parts:

- The ciliary processes that secrete aqueous humor
- The ciliary muscle that changes the shape of the lens to adapt to near and far vision

The iris is the colored portion of the eyeball consisting of circular and radial smooth muscle fibers.

CONTINUED

The inner nervous tunic (retina) lines the posterior 2/3 of the eye

The retina consist of a layer of melanin pigmented epithelium that allows light to be absorbed rather than scattered. Without the melanin, scattered light in our eye would cause us to always be squinting, even in a moderately lit room

The exact center of the retina is called the macula lutea, and in its center is a small depression called the central fovea (or fovea centralis).

There are no rods or nerve cells in the fovea, only a high concentration of cones - this gives us the sharp central vision necessary in any activity where detail is of primary importance.

CONTINUED

The retina can be viewed through the pupil using an ophthalmoscope, allowing direct inspection of the retinal vessels for any pathological changes. This is the only place in the body where arterial vessels can be so viewed (without opening the body)

The optic disc is where the optic nerve and retinal vessels enter and exit the eyeball. Its existence creates a necessary defect on the retina – an area where there are no cones or rods. Bilateral vision and saccade (involuntary, quick) muscle movements allow our brain to correct for this "blind spot".

The retina consists of two types of photoreceptor cells, rods and cones

Rods are abundant in the periphery of the retina whereas cones are found more frequently in the central areas

CONTINUED

Each eye contains ≈ 120 million rod-shaped photoreceptors that are adapted for a low light threshold (high sensitivity) - they produce low resolution, black and white images

a loss of rods with age makes it difficult to drive at night.

Cone-shaped photoreceptors function in bright light to produce high resolution color images, they exist in three varieties, corresponding to the type of pigment they contain: red, green or blue.

The photopigments are concentrated in the outer segment of the receptor, while the inner segment contains the nucleus and organelles

EYE CAVITIES AND CHAMBERS

The lens is an avascular refractory structure situated posterior to the pupil and iris. It consists of a capsule with crystallin proteins arranged in layers, and like the cornea, the lens is transparent, it attaches to the ciliary muscle of the ciliary body by suspensory ligaments that fine tune the focusing of light on the retina

The lens divides the eyeball into two cavities: An anterior cavity anterior to the lens, and a posterior cavity (vitreous chamber) behind the lens

The anterior cavity is further divided at the level of the iris into anterior and posterior chambers (both filled with aqueous humor)

The much larger posterior cavity of the eyeball (vitreous chamber) lies between the lens and the retina

CONTINUED

Within the vitreous chamber is the vitreous body, a transparent jellylike substance that holds the retina flush against the choroid, giving the retina an even surface for the reception of clear images, occasionally, collections of debris called vitreal floaters cast shadows on the retina and create a spot in our field of vision (they are usually harmless and do not require treatment).

AQUEOUS HUMOR

The eye requires a constant bath in a nourishing fluid to deliver enough O2 to support the avascular lens and cornea. It also needs fluid to help “inflate” the walls of the eyeball (maintain a constant intraocular pressure – IOP) and support the vitreous body, this need is accomplished through the production of aqueous humor, which flows through the anterior cavity of the eye and is replaced every 90 minutes.

Aqueous humor is produced at the ciliary body and flows first through the posterior chamber (of the anterior cavity of the eye)

Traveling along the posterior surface of the iris it passes through the pupil to enter the anterior chamber.

It proceeds along the anterior surface of the iris until it is reabsorbed into the scleral venous sinus (canal of Schlemm) and returned to the venous system. Any sort of blockage to aqueous humor flow, or overproduction at the ciliary body may result in an increase of pressure inside the eye – a condition called glaucoma, If not treated, glaucoma can lead to a degeneration of eye function

RETINAL DETACHMENT

The vitreous body (humor) also contributes to maintain proper intraocular pressure as it holds the retina against the choroid. The vitreous humor, however, is only formed during embryological development and is not replaced. As we age, shrinkage of the vitreous body may lead to a detachment of the retina from the choroid

A retinal detachment is considered a medical emergency and needs immediate repair before vision loss becomes permanent.

THE PUPILLARY RESPONSE

The pupil is an opening in the center of the iris. It is composed of a radial muscle that “radiates” away from the center, and a circular muscle that is in the center, Contraction of the inner circular muscle fibers cause the pupil to constrict while contraction of the radial fibers cause it to dilate

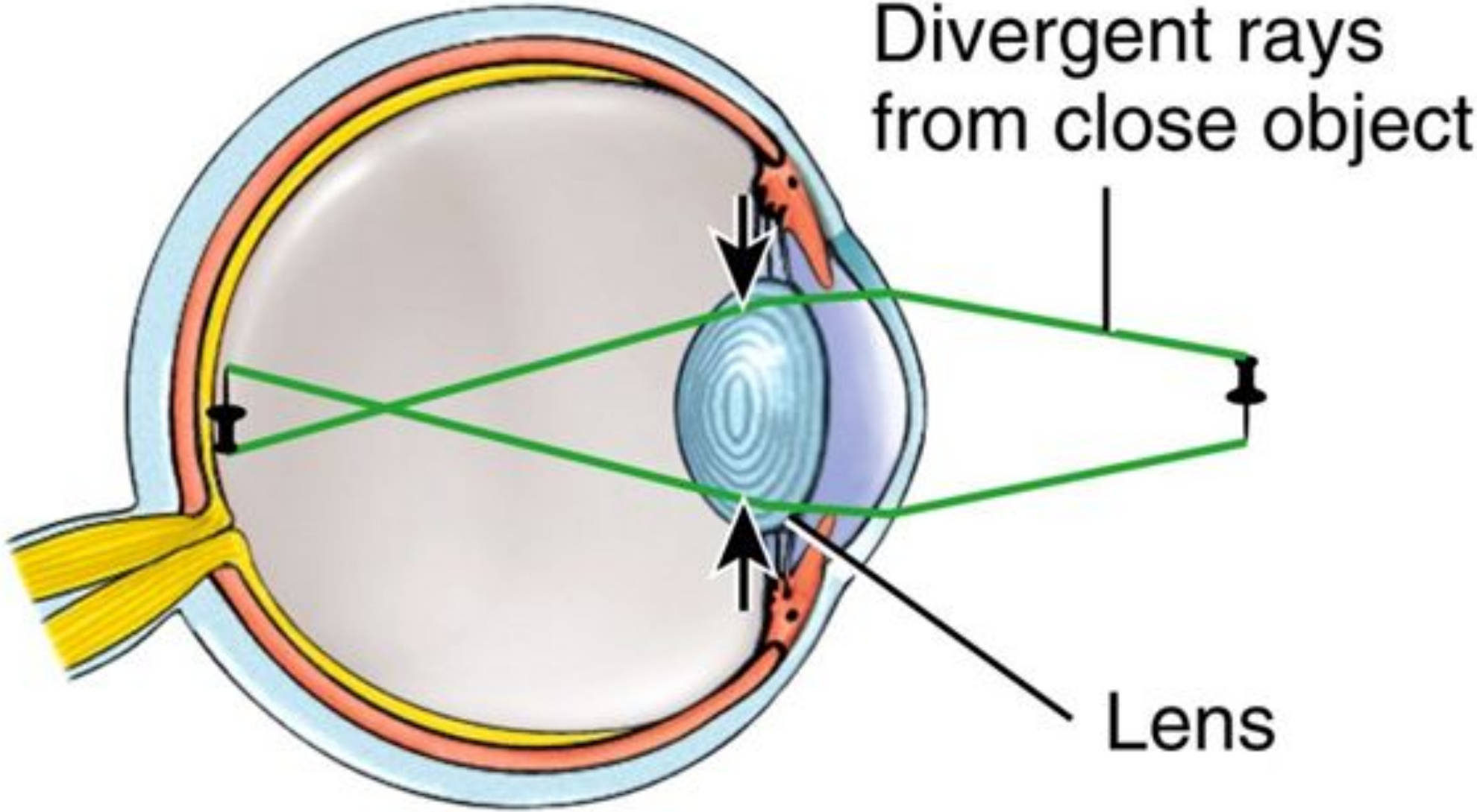
REFRACTION AND IMAGE

Normal image formation depends on refraction of light waves, accommodation of the lens, constriction of the pupil, and convergence of the two eyes

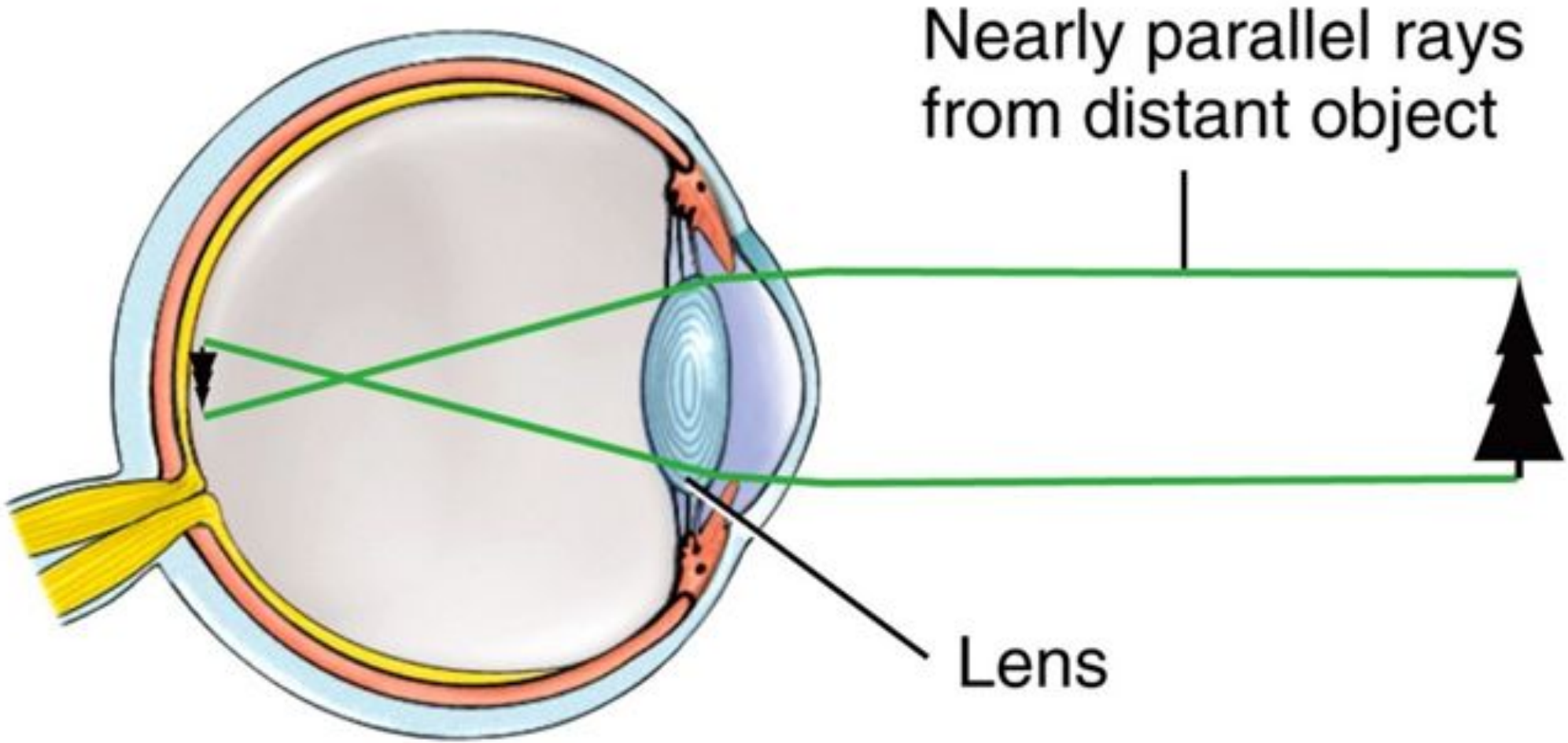
Refraction is the process of bending light rays. Both the cornea and the lens refract light rays, and both must be functioning in order to properly focus light onto the right spot on the retina to produce clear vision.

Since the cornea has a fixed shape, its “focal length” is also fixed; and its ability to refract light is likewise fixed

In order to focus light that has already been bent by the cornea the lens must change shape – the amount depending on the type of light rays we are trying to “see”.



Viewing objects up close



Viewing distant object

CONTINUED

An increase in the curvature of the lens for near vision is called accommodation

The near point of vision is the minimum distance from the eye that an object can be clearly focused - about 4 in (a distance that increases with age due to a loss of elasticity in the lens)

Convergence is the inward movement of the eyes so that both are directed at the object being viewed - becoming a little cross-eyed when viewing things close up.

The nearer the object, the greater the degree of convergence needed to maintain binocular vision, the coordinated action of the extrinsic eye muscles brings about convergence.

Convergence helps us maintain our binocular vision and see in three dimensions.

CONTINUED

With nearsightedness (myopia), only close objects can be seen clearly: Light rays coming in from distant objects are naturally focused in front of the retina and appear blurry

- Correction involves the use of a concave (negative) lens

With farsightedness (hyperopia), only distant objects can be seen clearly: Light rays coming in from nearer objects are naturally focused behind the retina

- Correction involves the use of a convex (positive) lens

Abnormal refractive capabilities of the eye are the result of a misshapen eyeball (usually too long or too short), or because the lens becomes stiff (usually with age). Corrections are accomplished using either a positive (convex) or negative (concave) lens (eyeglasses, contacts, or lens replacements).

THE VISUAL PATHWAY

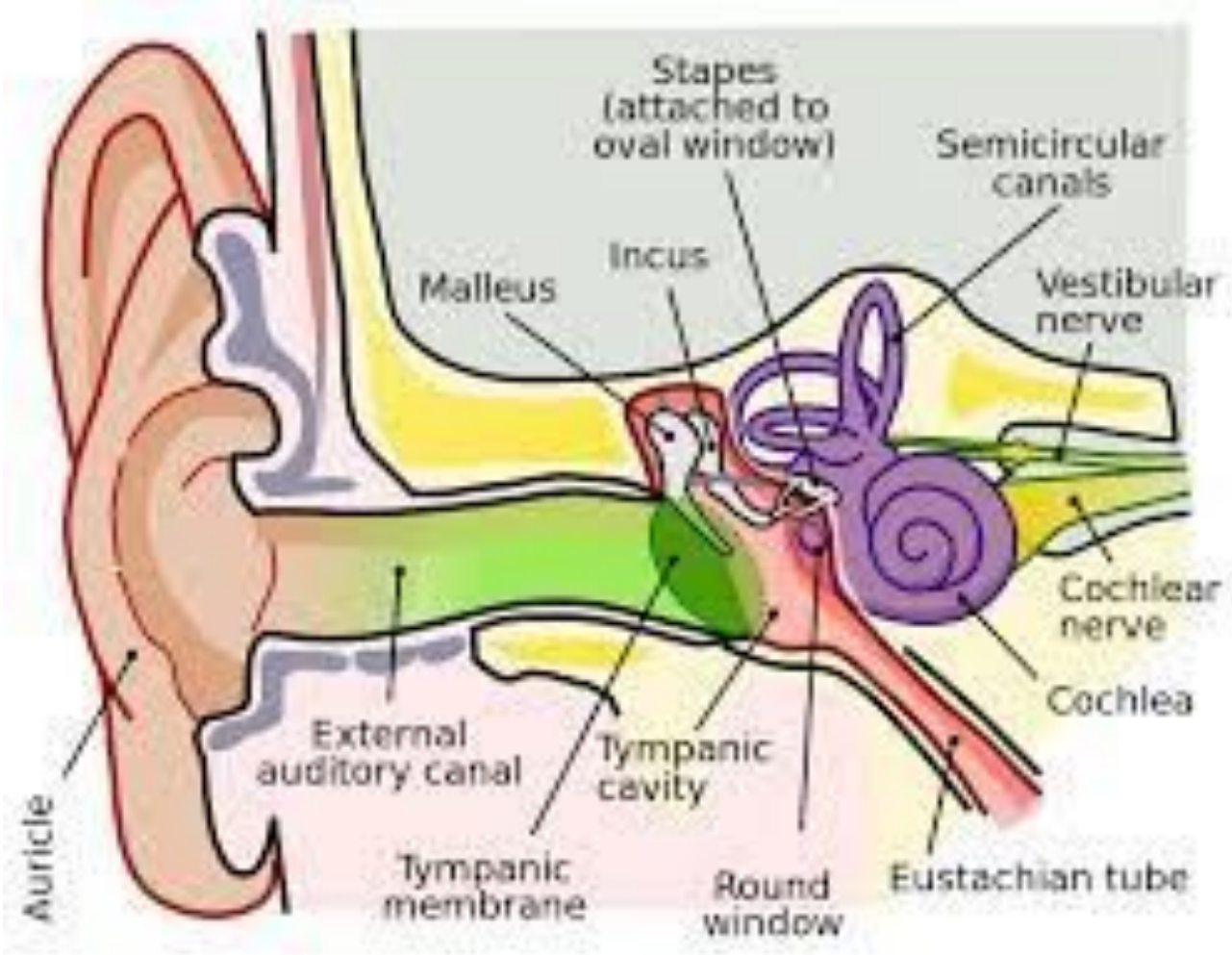
The graded potentials generated by the photoreceptors undergo considerable processing at synapses among the various types of neurons in the retina (horizontal cells, bipolar cells, and amacrine cells) - certain features of visual input are enhanced while others are discarded

Overall, convergence pre-dominates as 126 million photo-receptors impinge on only 1 million ganglion cells.

The axons of retinal ganglion cells provide output that travels back “towards the light”, exiting the eyeball as the optic nerve, which emerges from the vitreous surface of the retina, The axons then pass through a crossover point called the optic chiasm.

Some axons cross to the opposite side, while others remain uncrossed. Once through the optic chiasm the axons enter the brain matter as the optic tracts (most terminate in thalamus), here they synapse with neurons that project to the 1o visual cortex in the occipital lobes.

THE EAR


Stapes
(attached to
oval window)
Semicircular
canals
Incus
Malleus
Vestibular
nerve
Cochlear
nerve
Cochlea
External
auditory canal
Tympanic
cavity
Auricle
Tympanic
membrane
Round
window
Eustachian tube

AUDITION

The ear

the process of hearing, is accomplished by the organs of the ear. The ear is an engineering marvel because its sensory receptors can transduce sound vibrations with amplitudes as small as the diameter of an atom of gold into electrical signals 1000 times faster than the eye can respond to light; the ear also contains receptors for equilibrium

The ear has 3 principle regions

- The external ear, which uses air to collect and channel sound waves
- The middle ear, which uses a bony system to amplify sound vibrations
- The internal ear, which generates action potentials to transmit sound and balance information to the brain.

THE EXTERNAL EAR

The anatomy of the external ear includes:

- The auricle (pinna), a flap of elastic cartilage covered by skin and containing ceruminous glands
- A curved 1” long external auditory canal situated in the temporal bone leading from the meatus to the tympanic membrane (TM – or ear drum) which separates the outer ear from the cavity of the middle ear

THE MIDDLE EAR

The middle ear is an air-filled cavity in the temporal bone. It is lined with epithelium and contains 3 auditory ossicles (bones)

- The stapes (stirrup)
- The incus (anvil)
- The handle of the malleus (hammer) attaches to the TM

Two small skeletal muscles (the tensor tympani and stapedius) attach to the ossicle and dampen vibrations to prevent damage from sudden, loud sounds.

The Eustachian (auditory) tube connects the middle ear with the nasopharynx (upper portion of the throat), It consists of bone and hyaline cartilage and is normally passively collapsed. It opens to equalize pressures on each side of the TM(allowing it to vibrate freely).

THE INNER EAR

The internal ear (inner ear) is also called the labyrinth because of its complicated series of canals.

Structurally, it consists of two main divisions: an outer bony labyrinth that encloses an inner membranous labyrinth

The bony labyrinth is sculpted out of the petrous part of the temporal bone, and divided into three areas: (1) the semicircular canals, (2) the vestibule, and (3) the cochlea

- The vestibule is the middle part of the bony labyrinth . The membranous labyrinth in the vestibule consists of two sacs called the utricle and the saccule.
- The cochlea , located anterior to the vestibule.
- The three semicircular canals are above the vestibule, each ending in a swollen enlargement called the ampulla (for dynamic equilibrium)
- The snail shaped cochlea contains the hearing apparatus

FLUID IN THE EAR

Two types of fluid (perilymph and endolymph) fill its 3 different internal channels: The scala vestibuli, scala tympani, and cochlear duct.

Perilymph transmits the vibrations coming from the stapes in the oval window up and around the scala vestibuli, and then back down and around the scala tympani – causing the endolymph in the cochlear duct to vibrate.

Pressure waves in the endolymph cause the basilar membrane of the cochlear duct to vibrate, moving the hair cells of the spiral organ of Corti against an overhanging flexible gelatinous membrane called the tectorial membrane.

THE AUDITORY PATHWAYS

The cell bodies of the sensory neurons are located in the spiral ganglia. Nerve impulses pass along the axons of these neurons, which form the cochlear branch of the vestibulocochlear (VIII) nerve.

The nerve impulses follow CN VIII en route to the medulla, pons, midbrain, and thalamus and finally to the primary auditory cortex in the temporal lobe. Slight differences in the timing of nerve impulses arriving from the two ears at the superior olivary nuclei in the pons allow us to locate the source of a sound.

EQUILIBRIUM

Equilibrium is another function of the inner ear - controlled by the vestibular apparatus (the saccule and utricle of the vestibule, and the 3 semicircular canals)

- Static equilibrium refers to a state of balance relative to the force of gravity
- Dynamic equilibrium involves the maintenance of balance during sudden movements.

STATIC EQUILIBRIUM

Static equilibrium is controlled by the sensory hairs within the macula of the utricle and saccule.

An otolithic membrane, studded with dense calcium carbonate crystals (otoliths), responds to gravity when head position is changed

This movement opens transduction channels in the hair cells, producing local potentials which summate to form nerve AP.

DYNAMIC EQUILIBRIUM

Dynamic equilibrium is controlled by the sensory hairs within the ampulla of the semicircular canals.

Within each ampulla is a small elevation called the crista.

Each crista contains hair cells and supporting cells covered by gelatinous material called the cupula

With movement, the endolymph within the ampulla lags behind the moving cupola, causing a difference in the inertial forces – the hair bundle of the cupola bends and nerve impulses are generated.

EQUILIBRIUM PATHWAY

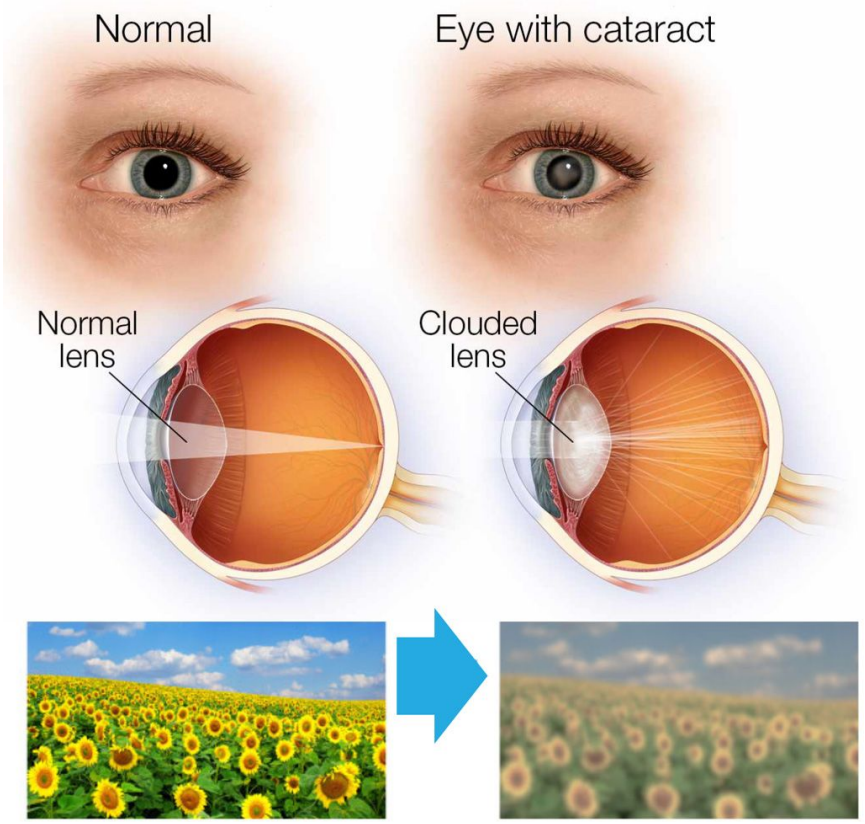
Once generated, nerve impulse travel up the vestibular branch of CN VIII. Most of these axons synapse in the major integrating centers for equilibrium, in the medulla and pons, which also receive input from the eyes and proprioceptors.

Ascending neurons continue primary auditory area in the parietal lobe to provide us with conscious awareness of the position and movements of the head and limbs.

conjunctiva

Eye Conditions

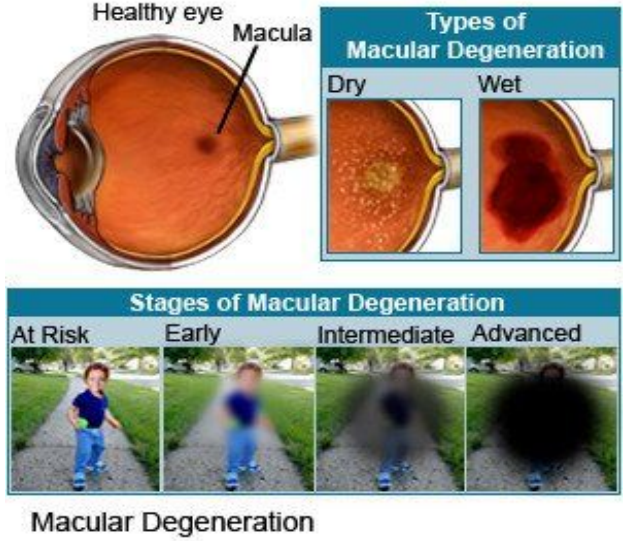
A **cataract** is an opaque defect in the cornea or lens of the eye – most cataracts are in the lens Cataracts caused by injury, medications, and diseases like diabetes. They are common in old age.



Eye Conditions

Conjunctivitis is an inflammation of the conjunctival membrane which covers part of the front of the eye. most frequently by viral infections (pink eye) and allergy. It can also result from bacterial infections and many other irritants

Age Related Macular Degeneration results in a loss of vision in the center of the visual field, because of damage to the retina. It is a major cause of visual impairment in older adults (>50 years). It can become impossible to recognize faces, yet enough peripheral vision remains to allow other activities of daily life



Macular Degeneration

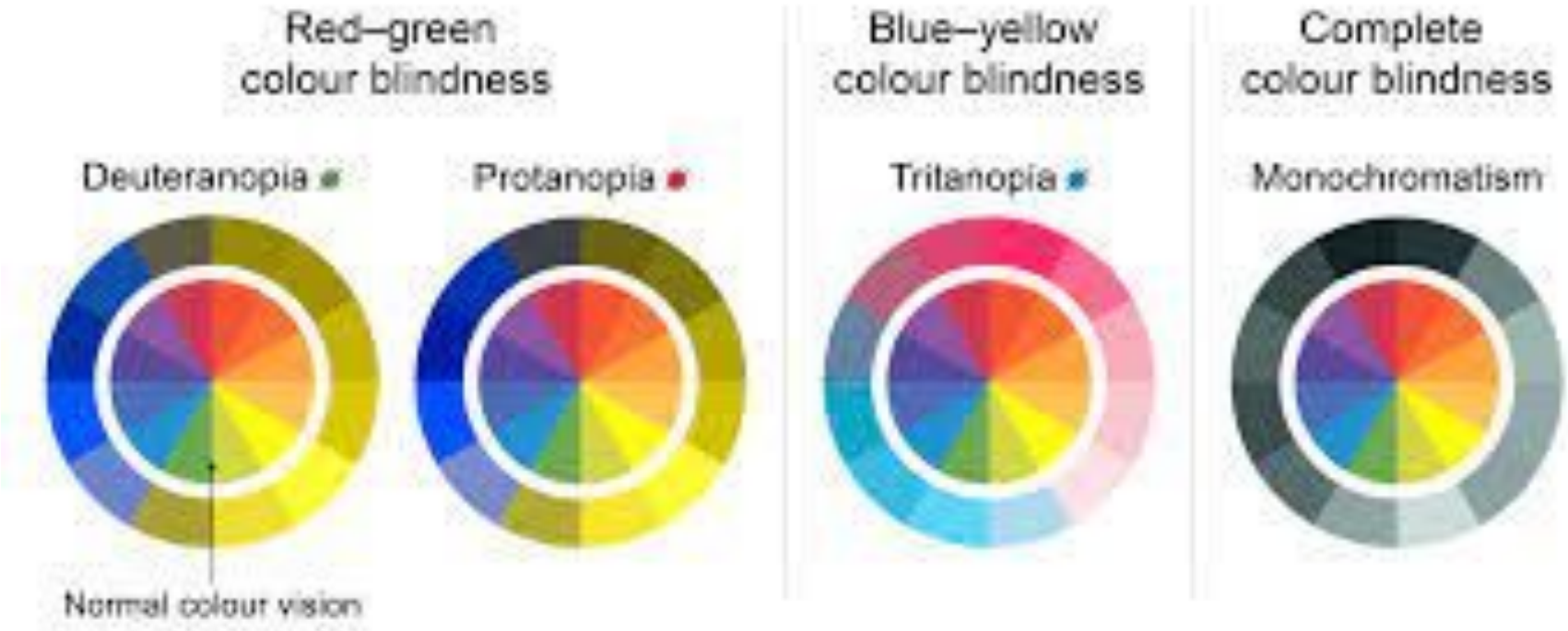
Colour Blindness

Colour Blindness is a decreased ability to differentiate between different colors. It is usually caused by an inherited defect in the genes, which affects one or more of the three types of cone photoreceptors in our eyes.

These genes are on the X chromosome, so males with only X chromosome are affected much more commonly than females, since they have two copies of the X chromosome. The most common form is red-green colorblindness, which affects 1 in 12 males and 1 in 200 females.

Colour blindness may also result from damage to the eye, optic nerve or visual cortex.

Colour Blindness



Ear Conditions

Myringitis is an inflammation of the eardrum.

Infections of the middle ear cavity **(otitis media)** are common in children between 6 mo. – 5 yrs. old, and usually presents with a crying child and a TM, that looks angry, red, and bulging

Otitis externa (commonly called “swimmer’s ear”) is a dermatitis of the epithelium of the outer ear (infectious and noninfectious). The chlorine, water, and ear plugs associated with swimming can result in irritated, inflamed tissues of the outer ear and ear canal

Meniere’s disease is a disorder of the inner ear that can affect hearing and balance, and is thought to be due to increased pressure in the cochlea and semicircular canals (extra endolymph). Episodes of *vertigo (the room spinning)* and *ringing in the ears (tinnitus)* can be a mild annoyance, or a chronic, disabling disability.