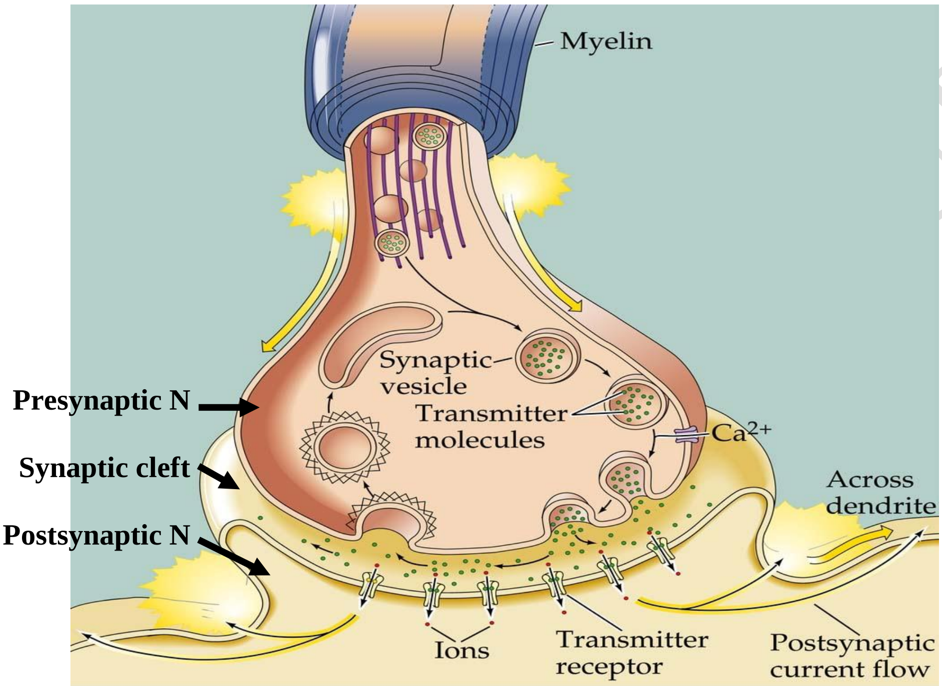
Lecture 18-20

PHYSIOLOGY OF NERVOUS SYSTEM

Synaptic and junctional transmission



Synaptic transmission resembles the junctional transmission of neuromuscular junction. Synapse is a junction between two neurons. The first is called presynaptic neuron and the other is postsynaptic neuron. Between them is the synaptic cleft. Chemical synapses are the predominant type of synapses where chemical substances called neurotransmitters are synthesized and stored in synaptic vesicles.

When AP arrives at the axon terminal, it opens voltage gated Ca^{2+} channels (channels that are opened or closed electrically) and Ca^{2+} influx will increase intracellular Ca^{2+} concentrations which attract the synaptic vesicles (full of neurotransmitter substance) to the presynaptic membrane and signals the neurotransmitter to be released to the synaptic cleft by exocytosis.

Vesicles fuse with the active zones of presynaptic membrane. Neurotransmitter diffuses across the synaptic cleft to bind its specific receptor on the postsynaptic membrane. Several types of neurotransmitters are available and each may have several types and subtypes of receptors. Postsynaptic action depends on the nature of the receptor.

After that, neurotransmitter must be inactivated by degradation, reuptake, diffusion, or bioconversion.

Properties of synapses:

1- One-way conduction from pre- to post-synaptic neurons because post synaptic membrane contains no synaptic vesicles.
2- Synapse is a site of neurotransduction (from electrical to chemical signal).
3- Intercellular chemical messages converted into intracellular signal.
4- Synaptic potentials are either excitatory (EPSP) or inhibitory (IPSP). EPSP causes depolarization while IPSP causes hyperpolarization.
5- EPSP and IPSP are present simultaneously in synaptic cleft.
6- Synaptic potentials are not all-or-none potentials.
7- A period of time (about 0.5 ms) is required for the signal to travel from pre- to post-synaptic neurons which is called synaptic delay.

Transmitter substance: There are two groups of synaptic transmitters

A. Small molecule, rapidly acting transmitters:

Class I: Acetylcholine

Class II: The amines (adrenaline "epinephrine", noradrenaline "norepinephrine", dopamine, serotonine and histamine).

Class III: Amino acids (γ-aminobutyric acid "GABA", glycine, glutamate and aspartate).

Class IV: Nitric oxide "NO".

B. Neuropeptide, slowly acting transmitters:

a- Hypothalamic-releasing hormones.
b- Pituitary peptides.
c- Peptides that act on gut and brain.
d- Peptides from other tissues.

Excitatory and inhibitory transmitters

Excitatory and inhibitory synaptic transmissions use different neurotransmitters and receptors. L-glutamate is the major excitatory and GABA is the major inhibitory neurotransmitters found in CNS. Whether the result of synaptic transmission will be excitatory or inhibitory depends on the type of neurotransmitter used and the ion channel receptors they interact with. L-glutamate receptors are Na^+ channels cause depolarization. GABA receptors are Cl^- channels cause hyperpolarization.

Acetylcholine, dopamine, serotonin and many others also perform vital functions in the central nervous system, some of which are excitatory and others are inhibitory.

Organization of the nervous system

Nervous system is, functionally, organized into two divisions:

1- Central nervous system which involves brain and spinal cord. The brain involves cerebrum, cerebellum and brain stem. Cerebrum is composed of cerebral cortex and subcortical structures (basal ganglia, diencephalon, …etc)

2- Peripheral nervous system which is subdivided into somatic nervous system and autonomic nervous system.

Central nervous system

Within the brain; gray matter is organized on the surface in lamina while white matter is organized centrally and constitutes the majority of brain mass. In the spinal cord; gray matter is centrally located and white matter is organized on the surface

Cerebral Hemispheres

1. Cerebral hemispheres are organized into functional areas:
   a. Motor: Voluntary control of movement
   b. Sensory: Conscious awareness of sensation
   c. Association: Integration and emergent properties
2. The body is controlled contralaterally, i.e. each hemisphere is concerned with the opposite of the body.
3. Functions are lateralized, i.e. each hemisphere has unique functions.
4. Function arises from concerted activity, i.e. multiple inputs and outputs.
5. Cortical lobes are:
   a. Frontal
   b. Parietal
   c. Temporal
   d. Occipital

Cerebral cortex

Most of the cerebral cortex is neocortex. However, there are phylogenetically older areas of cortex termed the allocortex. Allocorteices are more primitive areas located in the medial temporal lobes and are involved with olfaction and survival functions such as visceral and emotional reactions. In turn, the allocortex has two components: the paleocortex and archicortex. Common features of all cortices are:

- They are sheets (layers) of cell bodies parallel to surface of brain
- Layer I lacks cell bodies (molecular layer)
- At least one layer has pyramidal cells that emit large apical dendrites which extend up to layer I

Neocortical layers

Layer I (molecular layer)
Layer II (outer granular layer)
Layer III (outer pyramidal layer)
Layer IV (inner granular layer) is composed of stellate cells
Layers V (inner pyramidal layer)
Layer VI (multiform layer, or fusiform layer)

Each cortical layer contains different neuronal shapes, sizes and density as well as different organizations of nerve fibers. Functionally, the layers of the cerebral cortex can be divided into three parts. The supragranular layers consist of layers I to III. The supragranular layers are the primary origin and termination of intracortical connections, which are either associational (i.e., with other areas of the same hemisphere), or commissural (i.e., connections to the opposite hemisphere, primarily through the corpus callosum). The supragranular portion of the cortex is highly developed in humans and permits communication between one portion of the cortex and other regions.

The internal granular layer, layer IV, receives thalamocortical connections, especially from the specific thalamic nuclei. This is most prominent in the primary sensory cortices.

The infragranular layers, layers V and VI, primarily connect the cerebral cortex with subcortical regions. These layers are most developed in motor cortical areas. The motor areas have extremely small or non-existent granular layers and are often called "agranular cortex". Layer V gives rise to all of the principal cortical efferent projections to basal ganglia, brain stem and spinal cord. Layer VI, the multiform or fusiform layer, projects primarily to the thalamus.

Motor areas

a. Primary motor cortex
b. Premotor cortex
c. Broca's area
d. Frontal eye field

Primary motor cortex (Brodmann 4) is located in the precentral gyrus of frontal lobe. It functions in: conscious control of motor execution. Pyramidal cells give rise to the corticospinal tracts. Body is mapped on that area (motor homunculus). Representation is proportionate to level of motor control (somatotopy). Innervation is primarily contralateral.

Premotor cortex (Brodmann 6). Functions in learned motor skills which are patterned or repetitious.

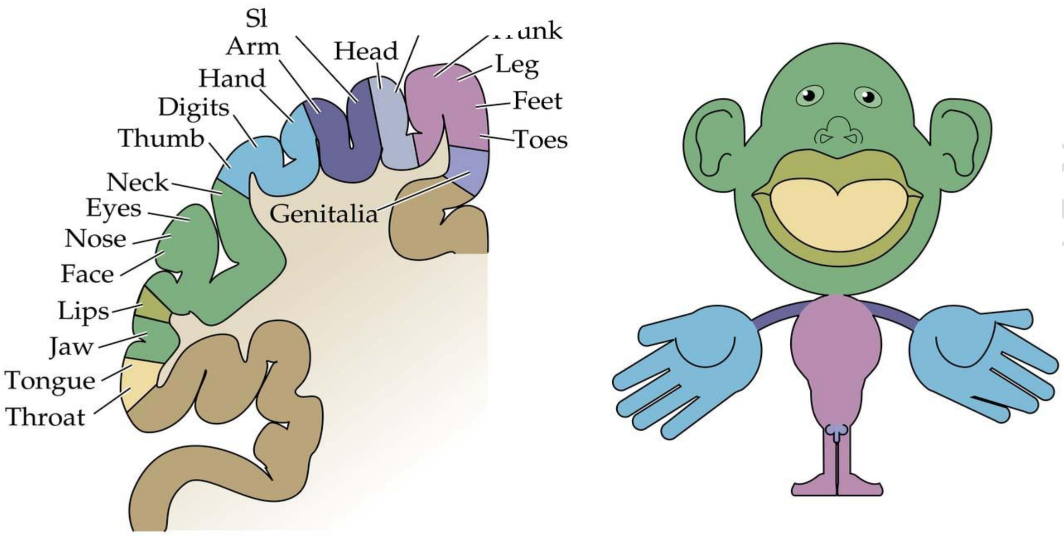
Broca's area (Brodmann 44/45): Directs muscles of the tongue, throat and lips. So it functions in motor planning for speech related activity.

Frontal eye field (Brodmann 8). Functions in voluntary movement of the eyes.

Sensory areas

a. Primary somatosensory cortex
b. Somatosensory association area
c. Visual cortex
d. Auditory cortex
e. Olfactory cortex
f. Gustatory cortex
g. Other association areas

Primary somatosensory cortex (Brodmann 1, 2 & 3) is located in postcentral gyrus of parietal lobe. It concerns somatic senses (pain, temperature, touch and proprioception). Again, somatotopy draws the somatosensory homunculus in which the body is mapped. Representation is proportionate to number of sensory receptors and innervation is primarily contralateral.



Somatosensory association area (Brodmann 5 & 7). It integrate various somatic sensory inputs

Visual areas

i. Primary visual cortex (Brodmann 17): Located primarily in the calcarine sulcus of occipital lobe. It represents the sensory function with the largest cortical representation. Its innervation is primarily contralateral.

ii. Visual association areas (Brodmann 18 & 19): For interpretation of visual stimuli and past visual experiences

Auditory areas

i. Primary auditory cortices (Brodmann 41): Located on the superior margin of temporal lobe. Concerns pitch, rhythm and loudness of sounds.

ii. Auditory association area (Brodmann 42 & 43): Functions in recognition of stimuli as specific auditory experiences (e.g., speech).

Olfactory cortex

Olfactory cortex is located on the piriform lobe (uncus) occupying the medial aspects of temporal lobe.

Gustatory cortex

Gustatory cortex (Brodmann 43): Located on parietal lobe deep to the temporal lobe.

Other association areas

Association areas, generally, analyze, recognize and act on sensory inputs. They have multiple inputs and outputs. In addition to those association areas discussed above; there are:

i. Prefrontal cortex
ii. Gnostic area
iii. Language areas

Prefrontal cortex (Brodmann 11 & 47): Located on the anterior portion of frontal lobe. It concerns intelligence, complex learned behavior, personality, understanding written and spoken language.

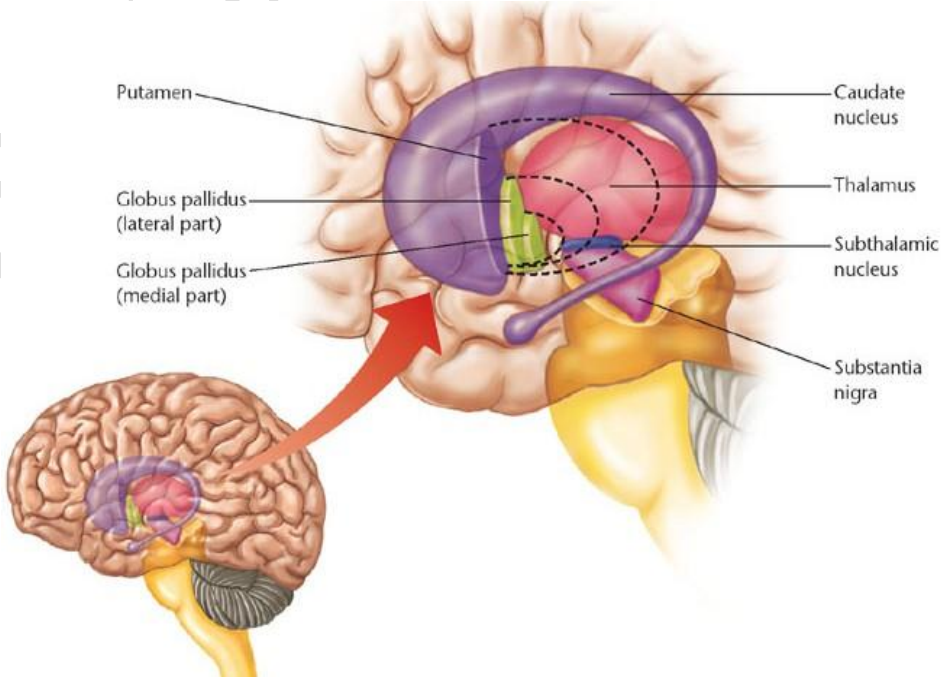
Gnostic (General interpretation) area: Encompasses parts of temporal, parietal and occipital lobes. Generally found on the left side. It functions in the storage of complex sensory memories.

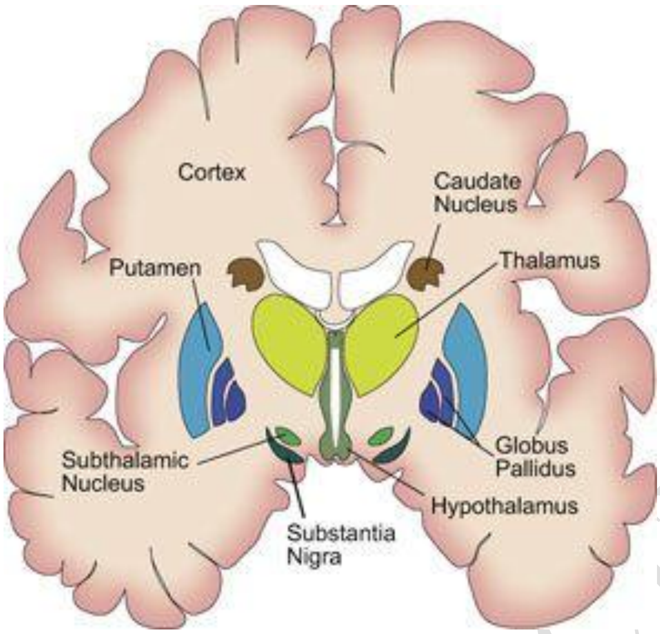
Language areas are Broca's area, Wernicke's area and affective language areas. Broca's area, as mentioned before, functions in motor planning for speech related activity. Wernicke's area lies on posterior temporal lobe on left side and functions in sounding out unfamiliar words. Affective language areas are located contralateral to Broca's and Wernicke's areas and concerns nonverbal and emotional components of language.

Basal nuclei (ganglia):

a. Caudate
b. Putamen
c. Globus pallidus
d. Substantia nigra
e. Subthalamic nucleus.

They receive inputs from most cortical structures and project to motor cortex via the thalamus. The function in motor control. They control starting, stopping and monitoring movement and they inhibit unnecessary movement.





Diencephalon

Diencephalon structures are located in the core of forebrain and surrounded by cerebral hemispheres. It is composed of three bilateral structures:

i. Thalamus
ii. Hypothalamus
iii. Epithalamus

Thalamus is comprised of multiple nuclei. Each nucleus receives specific afferent projections. Nuclei interconnect and project (relay) processed information to particular cortical areas. Functions of thalamus are to process and relay information

Hypothalamus is located below thalamus between optic chiasm and mammillary bodies. It is connected to the pituitary gland via infundibulum. It is the visceral control center of the body.

Functions of hypothalamus::

i. Autonomic control (e.g., blood pressure and heart rate).
ii. Emotional response (e.g., fear and sex drive).
iii. Regulation of body temperature.
iv. Regulation of feeding.
v. Regulation of thirst.
vi. Regulation of circadian rhythm.
vii. Control of endocrine function.

Epithalamus

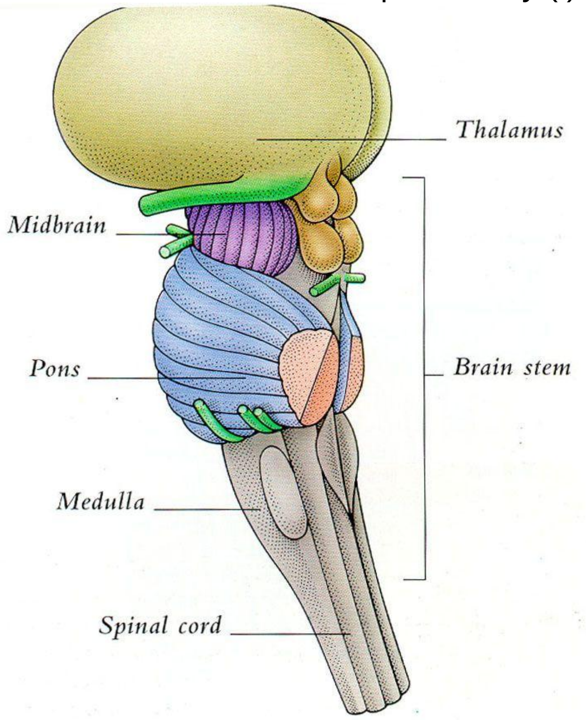
Epithalamus is composed of pineal body and choroid plexus:

a. Pineal body provides control of sleep-cycle
b. Choroid plexus functions in production of cerebral spinal fluid (CSF)

Brain Stem

a. Midbrain
b. Pons
c. Medulla oblongata

Brain stem functions in autonomic behavior and as a pathway for fiber tracts. All cranial nerves arise from the brain stem except olfactory (I) and optic (II) nerves.



Midbrain

a. Cerebral peduncles are fiber tracts connecting cerebrum with inferior structures
b. Corpora quadrigemina are superior and inferior colliculi
c. Substantia nigra (black substance): Nucleus of dopamine neurons. The color is due to melanin pigment (which is the dopamine precursor).
d. Red nucleus Functions in motor reflex
e. Reticular formation (some of its nuclei are found here)

Pons

Pons lies between midbrain and medulla. It is comprised, mostly, of conducting fibers (longitudinal projections connecting between higher brain areas and spinal cord). Pontine nuclei relay information between motor cortex and cerebellum. Pons contains nuclei for several cranial nerves: trigeminal (V), abducens (VI) and facial (VII)

Medulla oblongata

Medulla oblongata lies between pons and spinal cord with no obvious demarcation between medulla and spinal cord. Medullary pyramids represent descending corticospinal tracts which decussate (cross from one side to the other).

Medulla oblongata contains nuclei for several cranial nerves: Hypoglossal (XII), glossopharyngeal (IX), vagus (X), accessory (XI) and vestibulocochlear (VIII). It also functions in control of visceral motor function

a. Cardiovascular center
   i. Cardiac center
   ii. Vasomotor center
b. Respiratory center
   i. Control rate and depth of breathing
c. Reflex
   i. Vomit
   ii. Hiccup
   iii. Swallowing
   iv. Coughing
   v. Sneezing

Cerebellum

Cerebellum consists of bilateral cerebellar hemispheres connected by vermis. Hemispheres consist of lobes (posterior, anterior and flocolonodular). Gray and white matter is organized like cerebrum. (gray outside and white inside). Cerebellum is connected via cerebellar peduncles which are fiber tracts connecting brain stem and sensory cortices with cerebellum. Cerebellum functions in precise timing of skeletal contraction where sensory and motor information is integrated.

Brain Systems

Limbic system
Reticular formation

Limbic system

Limbic system is a group of cortical structures located on medial aspect of the cerebral hemisphere and diencephalon with complex connectivity function in emotional and affective state.

Reticular formation

Reticular formation is a complex of nuclei and white matter with disperse and widespread connectivity located in the central core of medulla, pons and midbrain and function to:

a. Maintain wakefulness and attention by coordination of all afferent sensory information

b. Coordination of muscle activity by modulation of efferent motor information

Spinal Cord

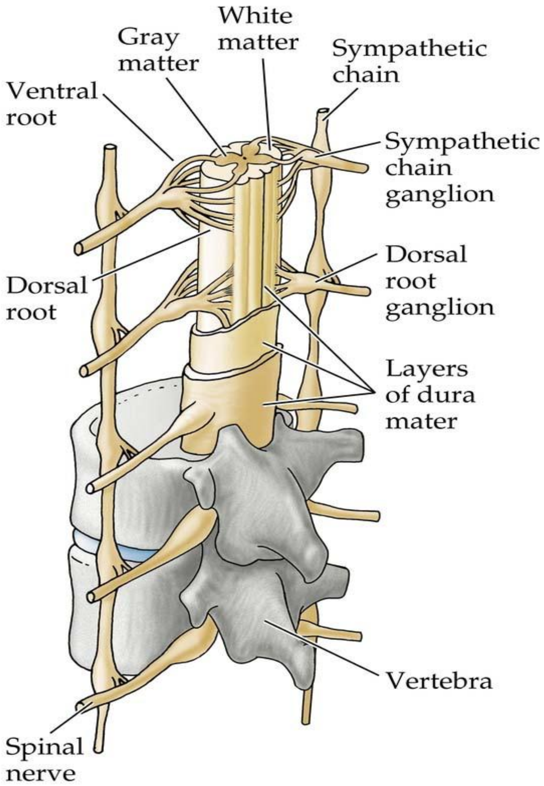
Gray matter in spinal cord is organized like a butterfly with a bridge (gray commissure) connecting the two wings. Gray matter columns are:

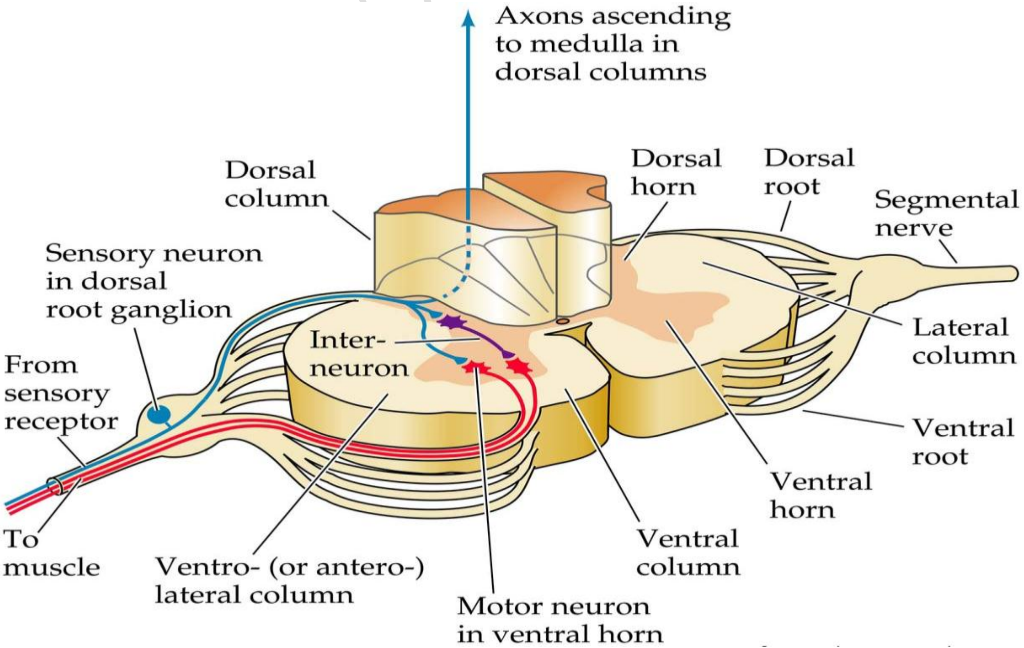
i. Posterior (dorsal) horn

ii. Anterior (ventral) horn

iii. Lateral horn (in thoracic and superior lumbar regions only)

Anterior horn contains cell bodies of somatic motor neurons and sends axons via ventral root. Lateral horn contains cell bodies for autonomic motor neurons and sends axons via ventral root. Dorsal root ganglion contains cell bodies of sensory neurons and the axons project to cord via dorsal root. Some of these axons enter white matter tracks and ascend. The others synapse with interneuron located in posterior horn. Spinal nerves are formed by lateral fusion of ventral and dorsal roots. They are parts of peripheral nervous system.





Spinal pathways

Characteristics of spinal pathways are:

a. Most pathways decussate.
b. Most are poly-synaptic (two or three neurons).
c. Most are mapped (position in cord reflects location on body).
d. All pathways are paired.

The spinal pathways are either ascending or descending:

Ascending (sensory) pathways:

Sensory pathways use three different neurons to get information from sensory receptors at the periphery to the cerebral cortex. These neurons are designated primary, secondary and tertiary sensory neurons. Primary sensory neuron cell bodies are found in the dorsal root ganglia, and their central axons project into the spinal cord. Ascending (sensory) pathways are:

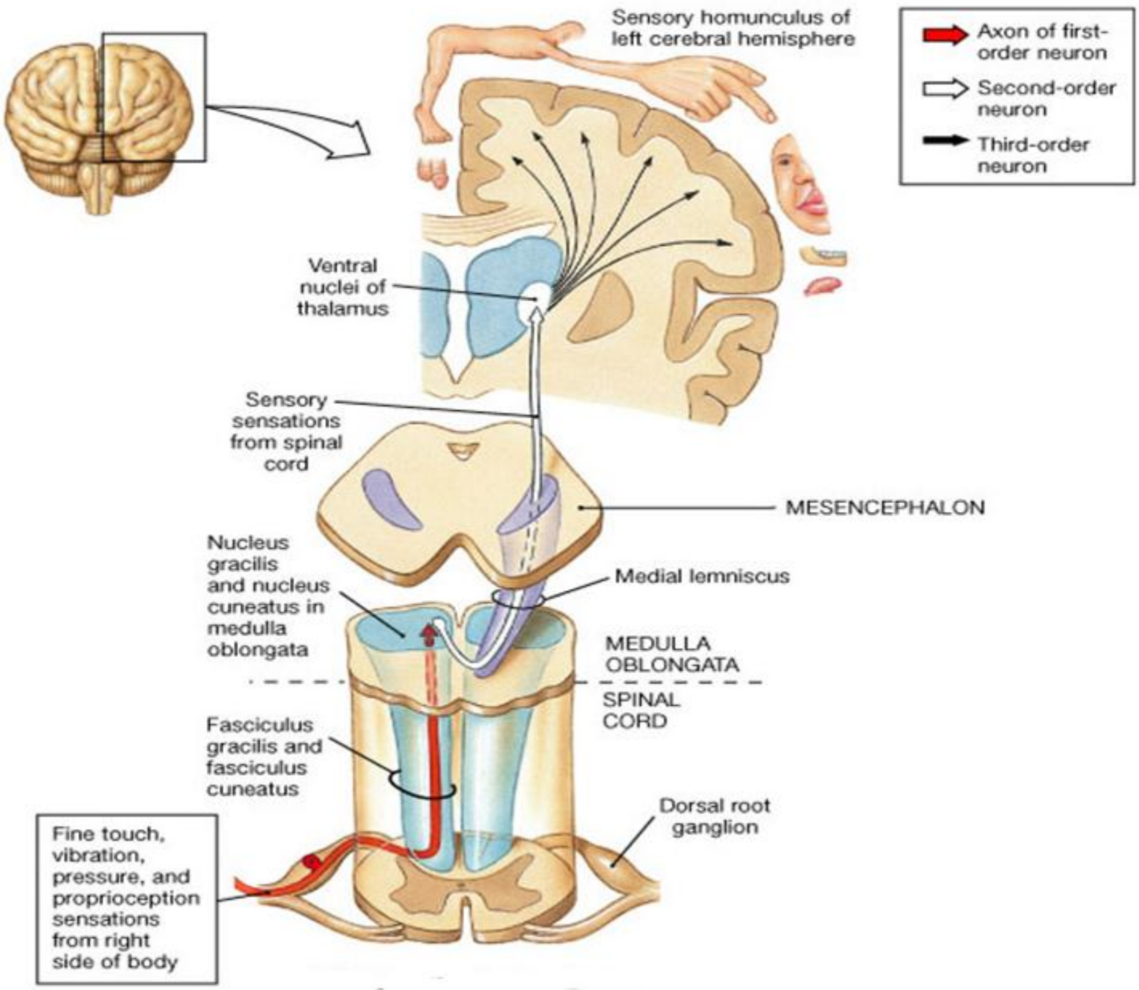
a. **Dorsal column-medial lemniscus tract** (for touch, pressure, vibration and conscious proprioception) in which the primary neuron's axon enters the spinal cord and then enters the dorsal column.

If the primary axon enters below spinal level T6, the axon travels in the fasciculus gracilis (the medial part of the column) and if the axon enters above level T6, then it travels in the fasciculus cuneatus, which is lateral to the fasciculus gracilis. Both primary axons ascend to the lower medulla, where they leave their fasciculi and synapse with a secondary neurons in one of the dorsal column nuclei: either the nucleus gracilis or the nucleus cuneatus, depending on the pathway they took.

At this point, the secondary axon leaves its nucleus and passes anteriorly and medially. The collection of secondary axons that do this are known as internal arcuate fibers. The internal arcuate fibers decussate and continue ascending as the contralateral medial lemniscus.

Secondary axons from the medial lemniscus, finally, terminate in the ventral posterolateral nucleus (VPLN) of the thalamus, where they synapse with tertiary neurons.

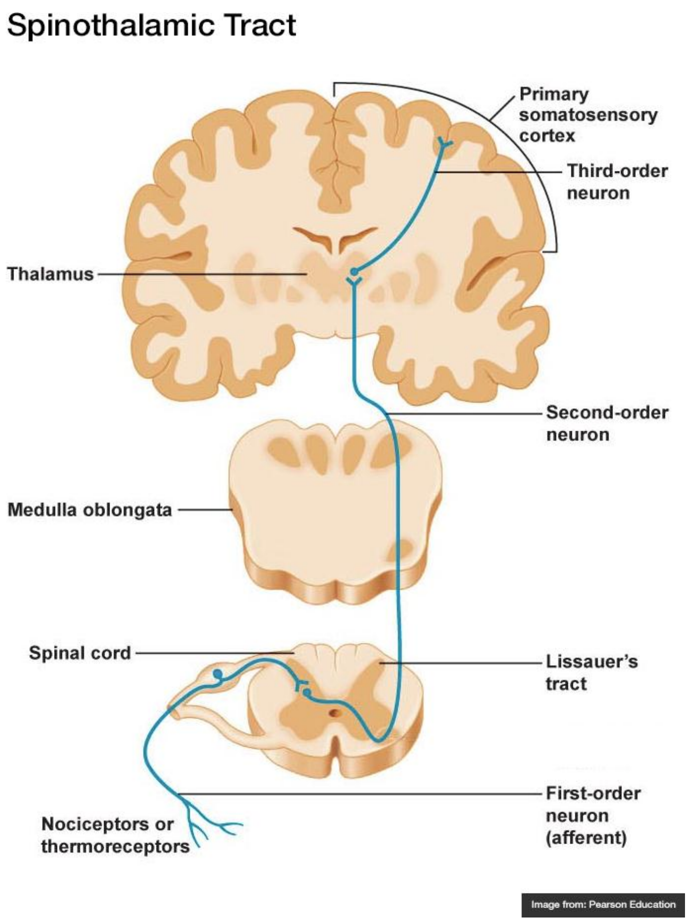
From there, tertiary neurons ascend via the posterior limb of the internal capsule and end in the primary sensory cortex.



The proprioception of the lower limbs differs from the upper limbs and upper trunk. There is a four-neuron pathway for lower limb proprioception. This pathway initially follows the dorsal spinocerebellar pathway. It ascends via Clarke's column as the secondary neuron to the medulla oblongata where the tertiary neuron projects to the VPLN of thalamus. The quaternary neuron arises from VPLN and runs through the posterior limb of internal capsule and then through corona radiata to reach the sensory area of cerebrum.

b. Anterior and lateral spinothalamic tracts (ALS) for pain and temperature. Its primary neurons axons enter the spinal cord and then ascend one to two levels before synapsing in the substantia gelatinosa. The tract that ascends before synapsing is known as Lissauer's tract. After synapsing, secondary axons decussate and ascend in the anterior lateral portion of the spinal cord as the spinothalamic tract. This tract ascends all the way to the VPLN, where it synapses on tertiary neurons. Tertiary neuronal axons then travel via the posterior limb of the internal capsule to the primary sensory cortex.

Collaterals from pain fibers in the ALS travel towards the reticular formation in the midbrain. The reticular formation then projects to a number of places including the hippocampus (to create memories about the pain), the centromedian nucleus (to cause diffuse, non-specific pain) and various parts of the cortex. Additionally, some ALS axons project to the periaqueductal gray in the pons, and the axons forming the periaqueductal gray then project to the nucleus raphe magnus, which projects back down to where the pain signal is coming from and inhibits it. This helps control the sensation of pain to some degree.



c. The spinoolivary tract (historically Helweg's tract) is located in the anterior funiculus of the spinal cord and provides transmission of unconscious proprioception and is involved in balance. This tract carries proprioception information from muscles and tendons as well as cutaneous impulses to the olivary bodies.

Descending (motor) pathways

Motor information travels from the brain down the spinal cord via descending tracts. Descending tracts involve two neurons: the upper motor neurons (UMN) which have their cell bodies in the brain and lower motor neurons (LMN) which have their cell bodies in the anterior horn of spinal cord.

A nerve signal travels down the upper motor neuron until it synapses with the lower motor neuron in the spinal cord. Then, the lower motor neuron conducts the nerve signal to the spinal root where efferent nerve fibers carry the motor signal toward the target muscle. There are several descending tracts serving different functions.

-Direct corticospinal (or pyramidal) tracts tracts (lateral and anterior) are responsible for coordinated limb movements.

-Indirect tracts like rubrospinal tract, vestibulospinal tract, reticulospinal tract and tectospinal tract...

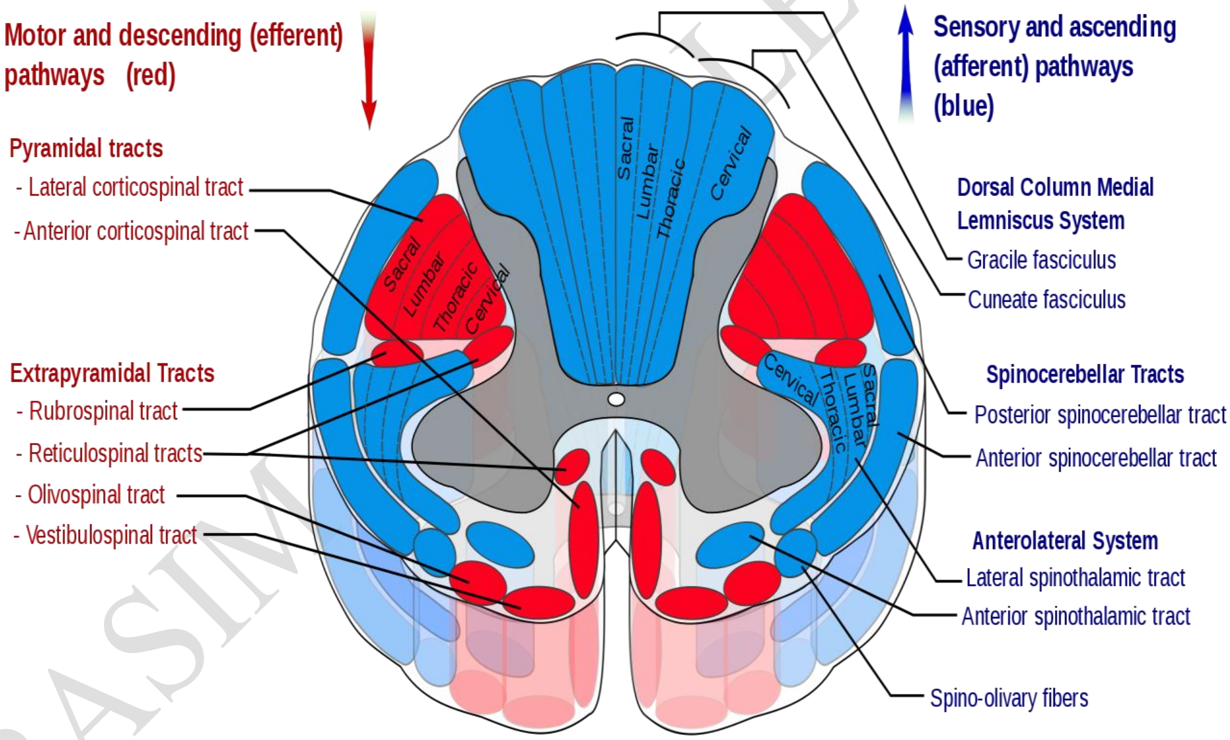
The corticospinal tracts originate from Brodmann areas 1, 2, 3, 4, and 6 and then descend in the posterior limb of the internal capsule, through the crus cerebri, down through the pons, and to the medullary pyramids, where about 90% of the axons cross to the contralateral side at the decussation of the pyramids. They then descend as the lateral corticospinal tract. The remaining 10% of axons descend on the ipsilateral side as the ventral (or anterior) corticospinal tract. These axons synapse with lower motor neurons in the ventral horns. Most of them will cross to the contralateral side of the cord (via the anterior white commissure) right before synapsing.

The rubrospinal tract descends with the lateral corticospinal tract, while the vestibulospinal, reticulospinal and tectospinal tracts descend with the anterior corticospinal tract.

The neuronal axons of lateral upper motor tract synapse on dorsal lateral (DL) lower motor neurons which are involved in distal limb control. There is no decussation in the lateral corticospinal tract after the decussation at the medullary pyramids.

The neuronal axons of anterior upper motor tract descend ipsilaterally in the anterior column. They either synapse on ventromedial (VM) lower motor neurons in the ventral horn ipsilaterally or descussate at the anterior white commissure where they synapse on VM lower motor neurons contralaterally .

The tectospinal, vestibulospinal and reticulospinal descend ipsilaterally in the anterior column and synapse only on VM lower motor neurons but they do not synapse across the anterior white commissure. The VM lower motor neurons control the large, postural muscles of the axial skeleton.



Peripheral nervous system

Peripheral nervous system connects the brain with outside world. It is either somatic or autonomic. Somatic nervous system controls conscious sensory and voluntary motor activities while autonomic nervous system controls involuntary motor activities.

Peripheral nervous system has structural components which are:

a. Sensory receptors
b. Peripheral nerves and ganglia
c. Efferent motor endings

Sensory receptors

Sensory receptors are classified according to the nature of stimulus detected into:

a. Mechanoreceptors (touch, vibration, pressure, stretch)
b. Thermoreceptors (temperature changes)
c. Photoreceptors (light energy present exclusively in the retina of eye)
d. Chemoreceptors (chemical in solution)
e. Nociceptors (pain)

Sensory receptors are, also, classified according to location into:

a. Exteroceptors (surface of skin)
b. Interoceptors or visceroceptors (visceral organs and blood vessels)
c. Proprioceptors (musculoskeletal organs)

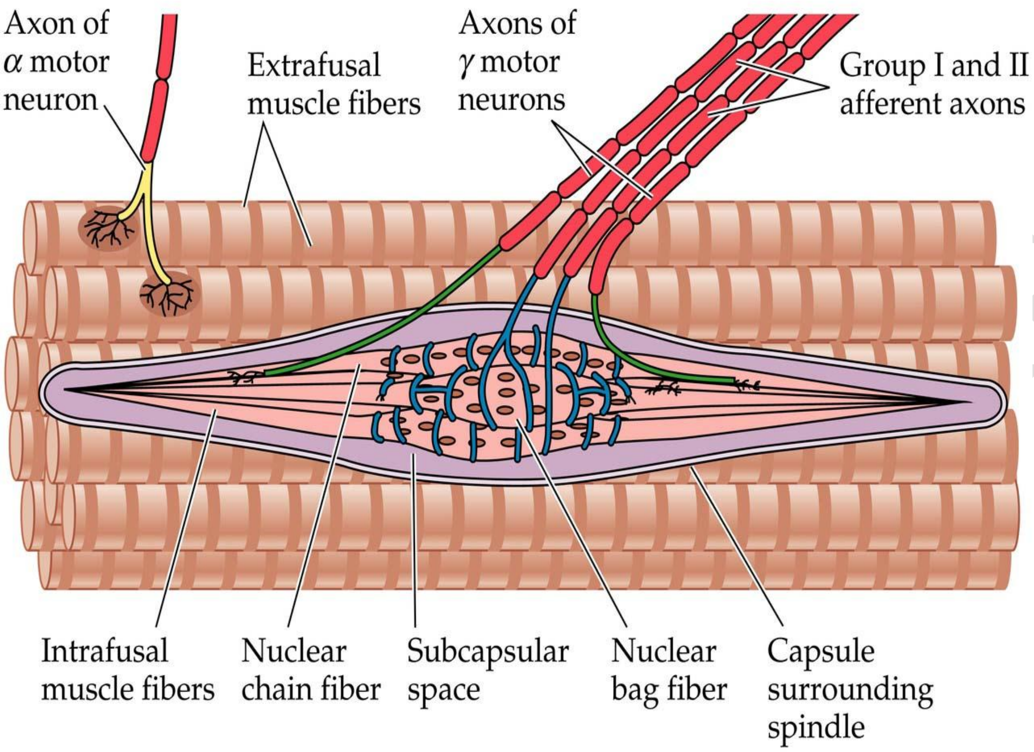
Sensory receptors are classified according to complexity into:

a. Simple or generalized senses (most sensory receptors)
b. Complex or special senses (vision, audition, olfaction, gustation).

Generalized sensory receptors are further classified into:

a. Free dendritic endings (unencapsulated)
    i. Free nerve endings
    ii. Merkel discs
    iii. Root hair plexus
b. Encapsulated
    i. Meisner's corpuscles (detect low frequency vibration)
    ii. Pacinian corpuscles (detect high frequency vibrations)
    iii. Ruffini's corpuscles (detect deep pressure)
    iv. Muscle spindles (detect muscle stretch)
    v. Golgi tendon organs (detect tendon stretch)

Muscle spindle



Muscle spindle is an example of encapsulated simple sensory receptors. It is composed of contractile region innervated by gamma (γ) efferent (motor) fibers that maintain spindle sensitivity. Nuclear bag and nuclear chain fibers are sensory components wrapped by afferent sensory endings types Ia and II fibers to conduct information about the state of muscle stretch. Extrafusal muscle fibers are skeletal muscle fibers innervated by alpha (α) motor neurons. Sequence of events involves:

a. Stretching muscle activates muscle spindle
b. Impulse carried by primary sensory fiber to spinal cord
c. Activates alpha motor neuron which sends efferent signal to muscle
d. Stretched muscle contracts
e. Antagonist muscle is reciprocally inhibited

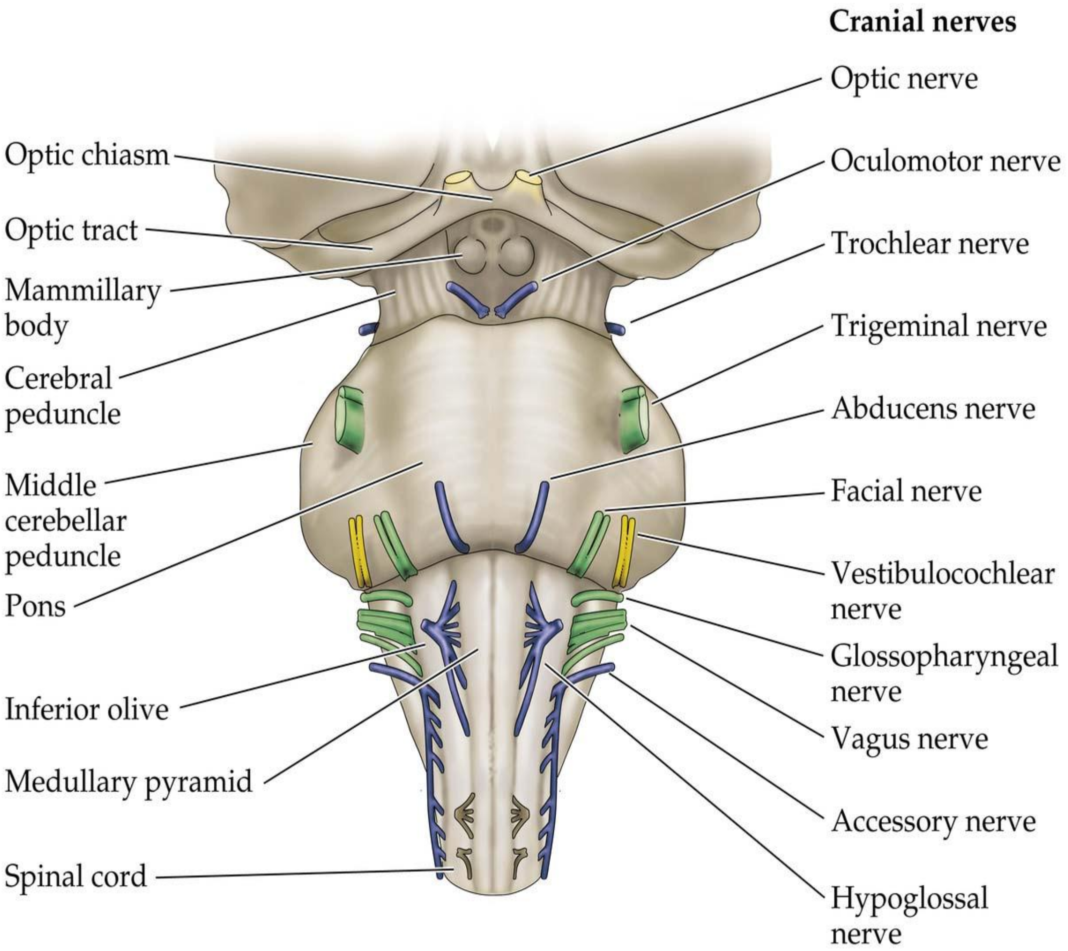
Nerves

Nerves are parallel bundles of peripheral axons enclosed by connective tissue and some may be myelinated. They are classified according to the nature of information into sensory (afferent), motor (efferent) and mixed nerves. They are also classified based on site of origin into cranial and spinal nerves.

Motor endings

Motor endings activate effectors by releasing neurotransmitters. Neuromuscular junction is the contact between motor neuron and muscle. It releases Ach. Varicosities are contacts between autonomic motor endings and visceral effectors and organs, smooth and cardiac muscle.

Cranial nerves



	Cranial Nerve	Sensory	Motor
I	Olfactory	YES—smell	NO
II	Optic	YES—vision	NO
III	Oculomotor	NO	YES—eye muscles
IV	Trochlear	NO	YES—eye muscle
V	Trigeminal	YES—general	YES—chewing
VI	Abducens	NO	YES—abducts eye
VII	Facial	YES—taste	YES—facial expression
VIII	Vestibulocochlear	YES—audition; balance	NO
IX	Glossopharyngeal	YES—taste	YES—tongue and pharynx
X	Vagus	YES—taste	YES—pharynx and larynx
XI	Accessory	NO	YES—head and neck movement
XII	Hypoglossal	NO	YES—tongue

Spinal nerves

Spinal nerves are 31 pairs.

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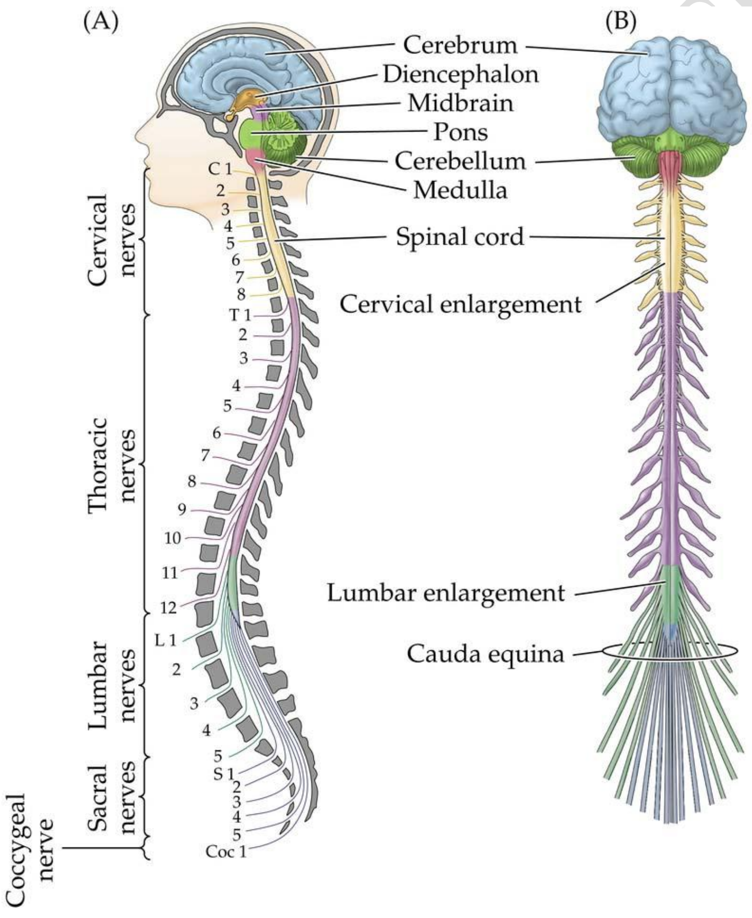
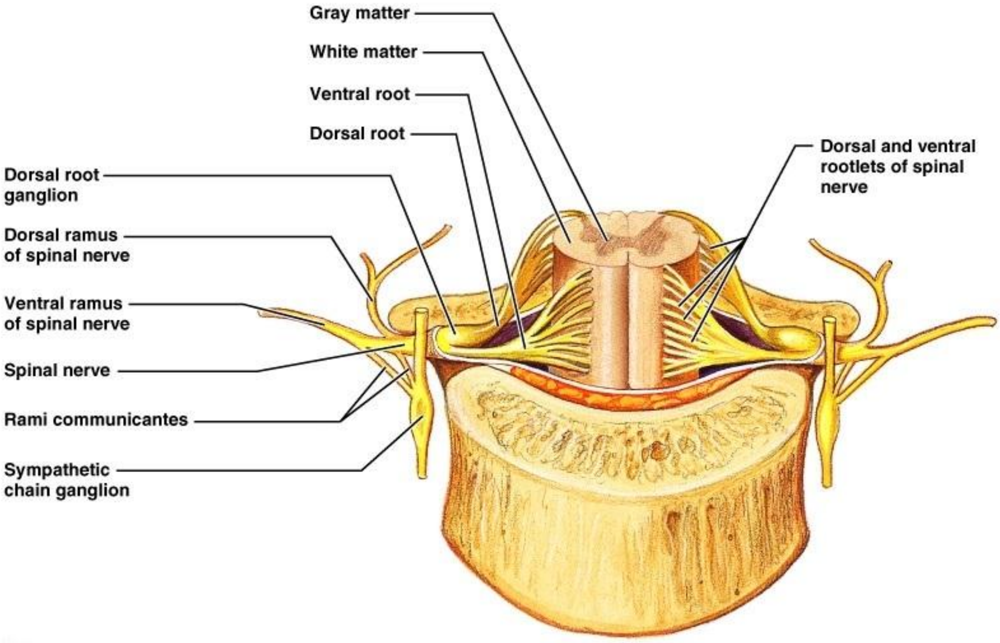
a. Eight cervical ($C_1 – C_8$)
b. Twelve thoracic ($T_1 – T_{12}$)
c. Five lumbar ($L_1 – L_5$)
d Five sacral ($S_1 – S_5$)
e. One coccygeal (C_0)

The spinal nerve emerges through intervertebral foramen between adjacent vertebrae. The cervical nerves are numbered by the vertebra below, except C8, which exists below C7 and above T1. The thoracic, lumbar, and sacral nerves are then numbered by the vertebra above.



Dorsal and ventral rootlets project from the spinal cord and unite to form dorsal and ventral roots of the spinal nerve. The dorsal roots carry afferent sensory axons, while the ventral roots carry efferent motor axons. Dorsal root ganglia represent the cell bodies of somatic sensory neurons.

As it leaves the vertebral column, the spinal nerve divides into dorsal and ventral rami. The dorsal ramus innervates the skin and muscles of the back. The ventral ramus innervates the ventral parts of the trunk and the upper and lower limbs. The rami communicantes are autonomic fibers connecting the spinal nerves with the sympathetic chain ganglia in thoracolumbar region.



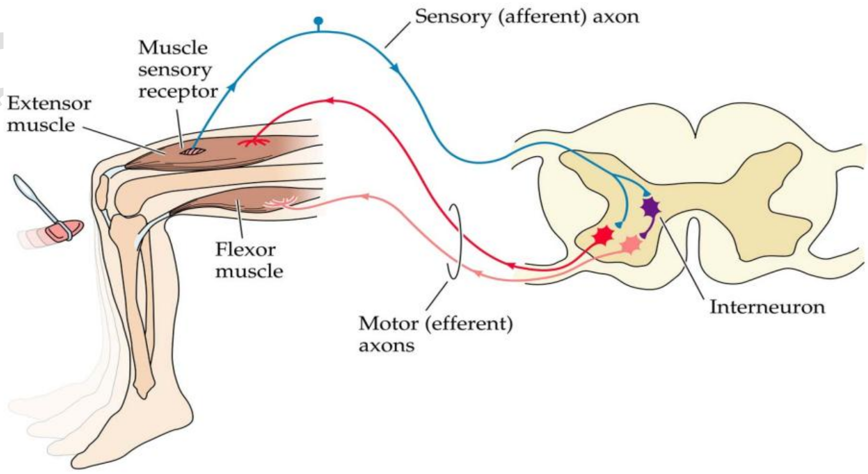
Dermatomes

An area of skin innervated by the cutaneous branch of a single spinal nerve is called dermatome. All spinal nerves (except C_1) have dermatomes. Dermatomes always overlap. They are of great clinical medical and surgical importance.

Reflex Activity

Reflex is a stimulus-response sequence that is unlearned, unpremeditated and involuntary. It is mediated by spinal cord circuits but information may ultimately relay to the brain. Components of a reflex arc are:

1. Receptor which is a site of stimulus action
2. Sensory neuron to transmit the afferent impulse to the CNS
3. Integration center which is either
    a. Monosynaptic reflex (single synapse) or
    b. Polysynaptic (multiple synapses with chains of interneurons)
4. Motor neuron to conduct efferent impulse from integration center to effector
5. Effector which is muscle fiber or gland



Autonomic Nervous System

Somatic nervous system is voluntary, sensory information is relayed to the CNS, cell bodies lie within spinal cord or brainstem and targets are controlled monosynaptically. In comparison; autonomic nervous system (ANS) is involuntary, cell bodies of all lower autonomic motor neurons lie outside the CNS within autonomic ganglia, the autonomic neurons are postganglionic driven by preganglionic neurons whose cell bodies are in the spinal cord or brainstem. Divisions of ANS are sympathetic and parasympathetic which differ based on:

a. Neurotransmitter type
b. Fiber length
c. Location of ganglia
d. Function

Neurotransmitter

Division	Preganglionic	Postganglionic
Sympathetic	Acetyl choline	Norepinephrine
Parasympathetic	Acetyl choline	Acetyl choline

Acetylcholine acts locally and usually has a stimulatory effect. Norepinephrine has alpha and beta adrenergic receptors. Alpha is stimulatory while beta is inhibitory (except in the heart when it is excitatory).

Fiber length

a. Parasympathetic has long preganglionic and short postganglionic
b. Sympathetic has short preganglionic and long postganglionic

Location of ganglion

a. Parasympathetic ganglion is located in visceral organ
b.Sympathetic ganglia lie close to spinal cord (sympathetic chain ganglia)

Function of sympathetic and parasympathetic divisions:

Divisions work in concert. Parasympathetic division generally functions in maintenance of function and energy conservation (to feed and breed or to rest and digest) while sympathetic division functions in emergence and intense muscular activity (to fight or flight).

Sympathetic response

a. Pupil dilated
b. Secretory responses inhibited
c. Stimulates sweating
d. Heart function
i. Increases rate
ii. Dilates coronary vessels
e. Increased blood pressure (constricts most vessels)
f. Bronchioles dilate
g. Decreased activity of digestive system
h. Piloerection
i. Increase metabolic rate
i. Glucose is released into blood
ii. Lipolysis
j. Increased alertness
h. Causes ejaculation or vaginal reverse peristalsis

Parasympathetic response

a. Pupils constrict
b. Stimulates secretory activity (salivation)
c. Heart function
  i. Decreases rate
  ii. Constricts coronary vessels
d. Constricts bronchioles
e. Increases activity of digestive system
f. Causes erection (penis and clitoris) due to vasodilation