

# Chapter 8 Nervous System

## I. Functions

- A. **Sensory Input** – stimuli interpreted as touch, taste, temperature, smell, sound, blood pressure, and body position.
- B. **Integration** – CNS processes sensory input and initiates responses categorizing into immediate response, memory, or ignore
- C. **Homeostasis** – maintains through sensory input and integration by stimulating or inhibiting other systems
- D. **Mental Activity** – consciousness, memory, thinking
- E. **Control of Muscles & Glands** – controls skeletal muscle and helps control/regulate smooth muscle, cardiac muscle, and glands

## II. Divisions of the Nervous system – 2 anatomical/main divisions

- A. **CNS** (Central Nervous System) – consists of the brain and spinal cord
- B. **PNS** (Peripheral Nervous System) – consists of ganglia and nerves outside the brain and spinal cord – has 2 subdivisions
  - 1. **Sensory Division** (Afferent) – conducts action potentials **from PNS** toward the CNS (by way of the *sensory neurons*) for evaluation
  - 2. **Motor Division** (Efferent) – conducts action potentials **from CNS** toward the PNS (by way of the *motor neurons*) creating a response from an effector organ – has 2 subdivisions
    - a. **Somatic Motor System** – controls skeletal muscle only
    - b. **Autonomic System** – controls/effects smooth muscle, cardiac muscle, and glands – 2 branches
      - **Sympathetic** – accelerator “fight or flight”
      - **Parasympathetic** – brake “resting and digesting”

\* 4 Types of Effector Organs: **skeletal muscle, smooth muscle, cardiac muscle, and glands.**

## III. Cells of the Nervous System

- A. **Neurons** – receive stimuli and transmit action potentials to other neurons or effector organs – consist of a cell body (soma/perikarion), dendrites, and an axon – **no mitotic division**
  - 1. **Cell body** (soma) – contains a nucleus (source of information on protein synthesis/*how to make neurotransmitters*), Golgi apparatus (packages vesicles of *neurotransmitters*), mitochondria, large number of neurofilaments and microtubules (separate the ER into distinct areas called nissl bodies indicating large amount of protein synthesis as ribosomes are the work benches upon which protein synthesis takes place)
  - 2. **Dendrites** – short, often highly branching, cytoplasmic extensions of the soma – function as the receiver of action potentials and carry them **toward** the cell body
  - 3. **Axon** – a long cell process extending from the soma - carry the action potential **away** from the cell body – may vary in length from millimeters to more than a meter (spine to foot)
    - a. **axon hillock** – attachment site of the axon to the soma – devoid of nissl bodies – where *excitable postsynaptic potentials* (electrically charged ions) gather
- B. **Types of Neurons**
  - 1. **Multipolar** – have many dendrites and one axon – located mostly in the CNS as motor neurons

2. **Bipolar** – have one dendrite and one axon – located in some sensory organs (retina of the eye & nasal cavity)
  3. **Unipolar** – have a single axon which divides into two short branches – located mostly in the sensory division of the PNS
- C. **Neuroglia** (glial cells) – helper cells of the nervous system – **do not** conduct action potentials – function in support, nourishment, and protection of neurons – capable of mitotic division – is the most common cell in the nervous system – only cell in the nervous system prone to disease (diseases of the nervous system are associated with some form of damage to these cells, **not neurons**) – six types
1. **Astrocytes** – major support of the CNS – common site of CNS tumors – look like a star with some of their processes reaching out and wrapping around capillaries (create the blood brain barrier using tight junctions)
  2. **Ependymal** – line the fluid filled cavities of the CNS – produce and move the cerebral spinal fluid/CSF (clear blood filtrate) – are ciliated – form the coroid plexus (a joining of capillaries and ependymal cells)
  3. **Micrroglia** – phagocytes (macrophages/”janitor cells”) of the CNS
  4. **Oligodendrocytes** – have processes that reach out forming a mylinated sheath (multiple layers of phospholipid cell membrane) by wrapping around (as a covering) axons – found in the CNS
  5. **Schwan Cells** – form mylinated sheath (multiple layers of phospholipid cell membrane) around axons by wrapping themselves around axons – found in the PNS
    - a. **Nodes of Ranvier** – gaps where the schwan cells/oligodendrocytes meet but do not completely cover the axon – function in the conduction of action potentials causing faster (more rapid) conduction
  6. **Satellite Cells** – **PNS only** – support, nourish, and protect neurons in ganglion

#### IV. **Electrical Conduction**

- A. **Resting Membrane Potential** – when no more  $K^+$  can diffuse **out** of the cell because the negative ionic concentration within the cell won’t allow it – equilibrium
- B. **Local Current** – area where  $Na^+$  channels briefly open and allow  $Na^+$  to rush into the cell – start of depolarization
- C. **Depolarization** – inside of the cell membrane becomes more positive – leads to a local potential
- D. **Local Potential** – local area depolarization – can go one of 2 ways
  1. If threshold **is not** met repolarization occurs
  2. If threshold **is** met action potential occurs
- E. **Action Potential** – depolarization then repolarization of the **entire** cell in an **all-or-none** fashion – complete charge reversal across the cell membrane – in a nerve cell is non-detrimental (no loss in intensity from beginning to end)
  1. stronger stimulus will produce a greater frequency of action potentials **not** a greater amount (size of contraction)
  2. differentiation occurs because of frequency of depolarizations – graded response (light touch vs heavy touch)
  3. **Unmylinated axons** – conduct action potentials more slowly because depolarization and repolarization must move area by area (in a localized step-by-step way) across the entire cell (dendrite, soma, & axon) through the cytoplasm – refractory period (repolarization follows depolarization all the way down) – 2 meters per second
  4. **Mylinated axons** – conduct action potentials more quickly because the potentials can jump from node to node (Nodes of Ranvier) instead of

traveling the whole length of the axon – also called salutatory conduction – 120 meters per second

F. **Synapse** – junction where the axon of one neuron interacts with another neuron or effector organ – has several parts

1. **presynaptic terminal** – end of the axon
2. **synaptic cleft** – space between the axon and the next neuron or effector organ (5 thousandths of a mm small)
3. **postsynaptic membrane** – the membrane of the second neuron (at the dendrite) or the effector organ
4. **synaptic vesicles** – located in the presynaptic terminal – produced by the golgi apparatus – contain chemicals (neurotransmitters) responsible for inhibiting or causing action potentials
5. **neurotransmitters** – chemicals stored in the synaptic vesicles that when released across the synaptic cleft either inhibit or excite action potentials
  - a. **acetylcholine** – excitatory/ inhibitory
  - b. **norepinephrine** – excitatory/inhibitory
  - c. **others include:** serotonin – inhibitory, dopamine – excitatory, gamma-aminobutyric – inhibitory, glycine – inhibitory, and endorphins (widely used) – inhibitory

\*a & b are the 2 best known

G. **Reflexes** – involuntary reactions in response to a stimulus that's applied to a sensory organ and transmitted to the CNS (not necessarily the brain)

1. **Reflex Arc** – simplest neural pathway by which a reflex occurs – basic functional unit/smallest and simplest pathway capable of receiving a stimulus and yielding a response – consists of 5 components
  - a. **Sensory receptor** – initial stimulation happens here →
  - b. **Sensory neuron** – transports message →
  - c. **Interneuron** – located in the CNS (usually the spinal cord) **not part of all reflexes**
  - d. **Motor neuron** – transports response message →
  - e. **Effector organ** – effects a change (skeletal, cardiac, or smooth muscle **or** glands)
2. **Neural Pathways**
  - a. **Converging** – two or more neurons synapse with a single neuron
    - One or more may say “go” and/or one or more may say “stop” in either scenario *threshold* must be reached in order for it to fire and go
  - b. **Diverging** – one neuron with branching axon synapses with two or more neurons

V. **Spinal Cord** – located in the vertebral foramen – the cervical and lumbar areas are enlarged - extends from the foramen magnum to the second lumbar vertebra (end at L2 with the medulary cone) – inferior end of the spinal cord along with the nerves exiting there are called the cauda equine (horses tail) – consists of peripheral white matter and central grey matter – has 3 protective coverings called meninges (pia mater, arachnoid mater, and dura mater) with fluid between called cerebral spinal fluid (CSF) this fluid also circulates down through a narrow tube like structure in the center of the spinal cord through the grey matter called the central canal – the space between the wall of the vertebral foramen and the dura mater is filled with fat and is called the epidural space –

and the subarachnoid space between the dura mater and the arachnoid mater is where an *intrathecal* injection is given

- A. **White Matter** – consists of myelinated axons – if halved each half is organized into 3 columns: dorsal (posterior), ventral (anterior), and lateral – each containing nerve tracts – there are 2 types of nerve tracts
    1. **Ascending tracts** – consist of axons that conduct action potentials **toward the brain** – neurons of these axons located in the grey matter of the spinal cord
    2. **Descending tracts** – consist of axons that conduct action potentials **away from the brain** – neurons of these axons are usually in the primary motor cortex of the brain
  - B. **Gray Matter** – shaped like the letter **H** with posterior, anterior, and small lateral horns (only found from T1 thru L1 and are *only sympathetic neurons* which control visceral internal organs – motor to cardiac, smooth muscle and glands) – the middle line of the **H** is called the gray commissure which allows for communication between the horns
  - C. **Spinal Nerve** – mixed nerves (both afferent and efferent) formed by the joining of the ventral and dorsal roots laterally to the spinal cord – they exit from the vertebral column at the intravertebral foramen (lateral space between individual vertebrae)
    1. **Ventral root** – nerves protruding from the anterior horn – motor axons form *rootlets* that exit the spinal cord and bundle together to form the nerve – usually carry action potentials away from the CNS
    2. **Dorsal root** – nerves protruding from the posterior horn – sensory axons from a bundle separate into *rootlets* that enter the spinal cord carrying action potentials to the CNS – contain a swelling (knot) called a dorsal root ganglion which contain cell bodies of unipolar sensory neurons whose axons originate in the periphery of the body
  - D. **Spinal Cord Reflexes** – stretch reflexes are the simplest reflex, in which muscles contract in response to stretching force - classic example is the knee-jerk reflex (patellar reflex) – involves proprioceptors (sense receptors that know the position of your body at all times) (e.g. anyio spiral rings which wrap around muscle fibers and sense how much stretch (tension) is occurring)
  - E. **Withdrawal Reflex** – (flexor reflex) removes a body part from painful stimulus
- VI. **Spinal Nerves** – 31 pair categorized by region (8 cervical, 12 thoracic, 5 lumbar, 5 sacral, 1 coccygeal – which spit into dorsal and ventral rami after exiting the vertebral column at the intravertebral foramen, these then rejoin and are organized into 3 plexuses (switchboard; reorganization of spinal nerves)
- A. **Cervical Plexus** – originates from spinal nerves C1 thru C4 – branches of this plexus innervate muscles of the hyoid bone, neck skin, and posterior head skin – most important branch is the phrenic nerve which innervates the diaphragm
  - B. **Brachial Plexus** – originates from spinal nerves C5 thru T1 - controls the upper limbs – contains 5 major nerves
    1. **Axillary nerve** – innervates 2 shoulder muscles along with the skin covering them
    2. **Radial nerve** – innervates muscles of the posterior forearm along with the skin covering it and the hand
    3. **Musculocutaneous nerve** – innervates the anterior muscles of the arm and the skin covering the radial surface of the arm
    4. **Ulnar nerve** – innervates two anterior muscles, and most intrinsic hand muscles, and skin covering the ulnar side of hand – can be damaged easily

where it passes posterior to the medial side of the elbow (hitting your funny bone)

5. **Median nerve** – innervates most anterior forearm muscles, some intrinsic hand muscles, and skin covering the radial side of hand

C. **Lumbosacral Plexus** – originates from spinal nerves L1 thru S4 – controls lower limbs – 4 major nerves

1. **Obturator nerve** – innervates the muscles of the medial thigh and skin covering them
2. **Femoral nerve** – innervates the anterior thigh muscles and skin over anterior thigh *and* medial leg
3. **Tibial nerve** – innervates posterior thigh muscles, anterior and posterior leg muscles, most intrinsic foot muscles and skin covering the sole of the foot
4. **Common fibular nerve** – innervates lateral thigh and leg muscles, some intrinsic foot muscles, and skin covering the anterior and lateral leg as-well-as dorsal surface (top) of the foot

\***sciatic nerve** – tibial and common fibular nerves bound together in a connective tissue sheath

VII. **Brain** – 4 major regions

A. **Brainstem** – connection of spinal cord to brain – contains several nuclei which control vital functions like heart rate, blood pressure, breathing – damages to small areas can result in death – location of nuclei for all but the first two cranial nerves – 3 main parts

1. **Medulla Oblongata** – most inferior portion of the brainstem – located just inside the cranial vault at the *magnum foramen* – is continuous with the spinal cord (contains ascending and descending nerve tracts) – has discrete nuclei – specific functions: regulation of heart rate, blood vessel diameter, breathing, swallowing, vomiting, coughing, sneezing, balance and coordination – has two prominent enlargements on the anterior surface called *pyramids* which contain descending nerve tracts associated with voluntary skeletal muscle control
2. **Pons** – immediately superior to the medulla oblongata – also contains ascending and descending nerve tracts and several nuclei some of which also effect breathing, swallowing, and balance – others control chewing and salivating – also functions as a relay bridge between *cerebrum* and *cerebellum*
3. **Midbrain** – superior to the pons, is the smallest region of the brainstem – consists largely of ascending and descending tracts, however it also contains nuclei involved in coordination of eye movement, control of pupil diameter and lens shape – has 2 areas of interest
  - a. **Corpra quadrigemina** – four mounds on the posterior part of the midbrain called colliculi
    - **2 inferior colliculi** – major relay centers for auditory nerve pathways to CNS
    - **2 superior colliculi** – involved in visual reflexes like turning head toward; a tap on the shoulder, bright flash of light, or a sudden loud noise
  - b. **Substantianigra** – black nuclear mass which is part of the basil nuclei – involved in regulation of general body movements

B. **Reticular Formation** – group of nuclei scattered through out the brainstem – involved with regulating cyclical motor function like respiration, walking and chewing – major component to the reticular activating system which plays an important role in

arousing and maintaining consciousness and regulating sleep & wake cycle – if damaged can result in a coma – general anesthetics function to suppress it

- VIII. **Diencephalon** – region of the brain between the brainstem and the cerebrum – 3 main components
- A. **Thalamus** – the largest part of the diencephalon – consists of a cluster of nuclei – with two large lateral parts connected in the center by an intermediate mass called the interthalamic adhesion (yo-yo) – influences mood and registers as unlocalized, uncomfortable perception of pain
  - B. **Epithalamus** – small area superior and posterior to the thalamus – consists of a few small nuclei involved in emotional and visceral response to odors – also includes the pineal body which is an endocrine gland that may influence the onset of puberty and play a role in controlling long-term cycles that are influenced by light-and-dark cycle
  - C. **Hypothalamus** – most inferior part of the diencephalon – contains several small nuclei important to homeostasis – plays a central role in control of body temperature, hunger, and thirst – sexual pleasure, feeling relaxed “good” after a meal, rage, and fear are related to the hypothalamus which is related to the limbic system (primitive brain) – related to inappropriate emotional responses – controls secretion of hormones from the pituitary gland
    - 1. **Infundibulum** – funnel shaped stalk from the hypothalamus to the pituitary gland – *only connects them*
    - 2. **Mamillary bodies** – form the external visible swellings on the posterior portion of the hypothalamus – involved in the emotional response to odor and memory
- IX. **Cerebellum** – (little brain) attached to the brainstem by cerebellar peduncles at the pons and midbrain – consist of gray matter and white matter (looks like a tree) called the arbor vitae – has gyri and sulci only smaller and more compact than the cerebrum – involved in balance, muscle tone, and coordination of fine motor movement – major function: comparator – responsible for initiation of voluntary movement (skeletal muscle) by receiving information from proprioceptive neurons it then compares intended movement to real movement and makes adjustments necessary for smooth movement (coordination) – alcohol inhibits function – accelerator for movement (see Basal Nuclei)
- X. **Cerebrum** – largest part of the brain – has two hemispheres (right and left) separated by the longitudinal fissure connected at the base by the corpus callosum – gyri (raised fold) and sulci (intervening grooves) increase the surface-to-volume ratio – divided into 8 lobes
- A. **Frontal lobes** – (2, one for each hemisphere) – important in control of voluntary motor functions, motivation, aggression, mood, and olfactory reception – site of the primary motor cortex which is located directly anterior to the central sulcus (dividing line (sulci) of the frontal and parietal lobes) – also the site of Broca's Area (motor speech area) where the physical movement of speech is controlled (located in the inferior/posterior portion of the frontal lobe)
  - B. **Parietal lobes** – (again 2, one for each hemisphere) – principle center for reception and conscious perception of most sensory information (touch, pain, temperature, balance, and taste) – site of Wernicke's Area (sensory speech area) – if damaged speaks nonsense (no coherent sentences) located in the inferior portion of the parietal lobe – also the site of somatic sensory cortex directly posterior to the central sulcus
  - C. **Occipital lobes** – (2) – function in reception and perception of visual input

- D. **Temporal lobes** – (2) – involved in olfactory & auditory perception and in memory – also abstract thought and judgment
- XI. **Basil Nuclei** – group of functionally related nuclei – have two primary nuclei corpus striatum (located deep in the cerebrum) and substantia nigra (darkly pigmented cells in the midbrain) – important in planning, organizing, and coordinating motor movement and posture – brake for motor movement (see Cerebellum) – disorders (Parkinson's and Cerebral Palsy) result in difficulty rising from a sitting position and initiating walking, increased muscle tone and exaggerated, uncontrolled movements when at rest and/or resting tremors
- XII. **Limbic System** – olfactory cortex + deep cortical regions + nuclei of the cerebrum and diencephalon - make up the limbic system (primitive brain) – control responses necessary for survival (hunger, thirst, visceral responses to emotion, motivation, mood) – lesions in the limbic system cause voracious appetite, increased (often perverse) sexual activity, and docility (including loss of normal fear and anger responses)
- XIII. **Memory** – 3 types
- A. **Sensory** – brief retention of sensory input received by the brain for short evaluation then acted on
  - B. **Short-term** – within the temporal lobe – information retained for a few seconds to a few minutes – limited to about 7 bits of info (why phone numbers are 7 digits)
  - C. **Long-term** – involves physical change in neurons by reaching out and making new connections – these neurons are called memory engrams
- XIV. **Brain Waves** – recorded by an electroencephalogram (EEG) – different types of electrical activity of the brain - 4 types
- A. **Alpha** waves, often seen in a relaxed individual with eyes closed
  - B. **Beta** waves, typical of an alert individual
  - C. **Theta** waves, seen in the first stage of sleep
  - D. **Delta** waves, characteristic of deep sleep
- XV. **Meninges and Cerebrospinal Fluid**
- A. **Meninges** – connective tissue membranes covering and protecting the brain and spinal cord (CNS) – 3 layers
    - 1. **Dura mater** – (tough mother) – outer most covering
    - **Subdural space** – contains a small amount of serous fluid
    - 2. **Arachnoid mater** – very thin wispy and web like
    - **Subarachnoid space** – filled with cerebrospinal fluid (CSF)
    - 3. **Pia mater** – (affectionate mother) – tightly bound to the surface of the brain and spinal cord
  - B. **Ventricles** – (4) CNS fluid filled cavities
    - 1. **Lateral ventricles** – (2, one in each hemisphere) – formed by the corpus callosum and fornix – separated by a thin membrane called the septum pellucidum – lined by choroid plexus (small mass of capillaries in conjunction with ependymal cells) which produce the cerebrospinal fluid
    - **Foramen of Monro**
      - 2. **Third Ventricle** – small midline cavity located in the center of the diencephalon between the two halves of the thalamus
    - **Cerebral Aqueduct**

3. **Fourth Ventricles** – located at the base of the cerebellum – continuous with the *central canal* of the spinal cord (passes through an area called the Foramen of Magendie)
- C. **Cerebrospinal Fluid** – (CSF) is a clear blood filtrate that bathes the brain and spinal cord – helps create a protective cushion around the CNS – is produced by the *choroid plexus* (thin layer lining the ventricles of the brain – consist of capillaries and ependymal cells) that lines **all** ventricles of the brain – is returned to the blood by arachnoid granulations (small masses of arachnoid tissue (mater) that penetrates the superior sagittal sinus, which is a *dural venous sinus* located in the longitudinal fissure)

#### Δ Flow of CSF in the CNS

- Start at the **lateral ventricles** → flows down through the **foramen of Monro** → and into the **third ventricle** → then flows down through the **cerebral aqueduct** → and into the **fourth ventricle** → here it splits: some of the CSF flows down through the **foramen of Magendie** and into the **central canal** of the spinal cord; some of the CSF exits through small openings in the roof and walls of the *fourth ventricle* and into the **subarachnoid space** → where it washes over the spinal cord and up-and-around the brain until it reaches **arachnoid granulations** → where it is filtered back into venous blood through the **superior sagittal sinus**

#### XVI. Cranial Nerves (12)

Old	I	Olfactory	S - Smell
Opie	II	Optic	S - Vision
Occasionally	III	Oculomotor	M - 4 extrinsic eye muscles, upper eyelid; P - pupil, lens
Tries	IV	Trochlear	M - 1 extrinsic eye muscle
Trig	V	Trigeminal	S - face, teeth; M - muscles of mastication
And	VI	Abducens	M - 1 extrinsic eye muscle
Feels	VII	Facial	S - Taste; M - muscles of facial expression; P - salivary & tear glands
Very	VIII	Vestibulocochlear	S - Hearing and balance
Gloomy	IX	Glossopharyngeal	S - Taste & touch (back of tongue); M - pharyngeal muscles; P - salivary glands
Vague	X	Vagus	S - Pharynx, larynx, and viscera; M - palate, pharynx, and larynx; P - viscera of thorax and abdomen
And	XI	Accessory	M - 2 neck and upper back muscles (trapezius and sternocleidomastoid)
Hypoactive	XII	Hypoglossal	M - Tongue muscles

**S** = Sensory; **M** = Motor; **P** = Parasympathetic

\* Only cranial nerves III, VII, IX, and X have parasympathetic control.

- XVII. **Autonomic Nervous System** – unlike somatic motor neurons, which extent from the CNS all the way out to the effector (skeletal muscle), autonomic motor neurons only extend part way then synapse with another neuron, which carries the action potential the rest of the way to the effector (glands, smooth muscle or cardiac muscle), at a knotted area called a ganglion
- A. **Preganglionic neurons** – are the *first* neuron extending from the CNS to the ganglion
- B. **Postganglionic neurons** – are the *second* neuron extending form the ganglion to the effector
- C. **Divisions of Autonomic Nervous System**
1. **Sympathetic division** – prepares the body for “fight or flight”



2. **Parasympathetic division** – activates the vegetative or “resting and digesting” functions
  3. **Dual Innervation Exceptions** – most effectors receiving autonomic motor responses are innervated by *both* sympathetic and parasympathetic – the following are **exceptions**:
    - a. sweat glands and blood vessels – only sympathetic
    - b. smooth muscles associated with the lens of the eye – primarily parasympathetic
- D. **Preganglionic Neurons of the Sympathetic Division** – are located in the lateral horn of the spinal cord’s gray matter in the thoracolumbar region (T1 thru L1) – their axons exit through the ventral roots and project to either a sympathetic chain ganglion or collateral ganglion