

## CHAPTER 11: NERVOUS SYSTEM II: DIVISIONS OF THE NERVOUS SYSTEM

### OBJECTIVES:

1. Outline the major divisions of the nervous system.
2. Discuss how the organs of the central nervous system (CNS) are protected in terms of bones, membranes and fluid.
3. Name the three meninges and discuss the differences between how they are structured around the brain and spinal cord.
4. Name the space that lies between two of the meninges surrounding both the brain and spinal cord, and name the fluid that fills this space.
5. Name the additional space that is found around the spinal cord, and name the fluid that fills this space.
6. Define the term *meningitis*.
7. Discuss the external structure of the spinal cord in terms of its length, start, end, number of segments, and enlarged areas.
8. Name the terminal point of the spinal cord, the term used for how the remaining spinal nerves appear, and the point at which they terminate.
9. Fully discuss the cross-sectional anatomy of the spinal cord.
10. Name the cells that line the central canal and identify the fluid that fills the central canal.
11. Distinguish between a "horn" and a "column" in the spinal cord.
12. Explain which portion of the spinal cord is the location for the major nerve tracts, and discuss their significance.
13. Compare and contrast ascending and descending tracts.
14. Discuss the general characteristics of nerve tracts.
15. Discuss the features located on the periphery of the spinal cord in cross-section.
16. Define the term *ganglion* and discuss the specificities of a dorsal root ganglion.
17. Define the term *nerve pathway*.
18. List and discuss the components in a reflex arc.
19. Discuss the significance of reflex arcs.

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20. Fully discuss the three-fold function of the nervous system.
  - A. In the first sentence, name the three functions of the nervous system.
  - B. Then write a paragraph discussing how and where a nerve impulse begins and name the components of a nerve pathway.
  - C. Then draw a simple nerve pathway that involves three neurons (with cell parts labeled), and track (on your diagram) the transmission of a nerve impulse throughout this pathway.
  - D. Finally, fully discuss how the nerve impulse begins, how it travels through each neuron, how it is transmitted between neurons, and finally, how it is transmitted to the effector.
21. Name and locate the three major regions of the brain.
22. Discuss the structure of the cerebrum in terms of its size, two major divisions, surface appearance, major grooves, and lobal divisions.
23. Identify the composition of the bulk of the cerebrum.
24. Define the term *cerebral cortex* and discuss its composition and significance.
25. Compare the major functional areas (sensory and motor) of the cerebral cortex in terms of location and function (a diagram may help here).
26. Explain what is meant by an association area of the cerebral cortex and name a few association traits.
27. Name the term referring to the measurement of brain activity.
28. Explain what is meant by hemisphere dominance, and name the hemisphere that is dominant in most people.
29. Define the term basal ganglia and explain their location and function.
30. Name the interconnected cavities within the cerebrum and brain stem and identify the fluid that fills these spaces and name the cells that line these spaces.
31. Name the specialized capillaries that secrete CSF and denote their location on a diagram.
32. Trace a drop of CSF from where it is secreted to where it is reabsorbed back into the blood stream.
33. Define the terms *arachnoid granulations* and *dural sinuses*.
34. Discuss the functions of CSF.

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35. Discuss the two important areas of gray matter within the diencephalon, in terms of location and function.
36. Identify the three major parts of the brain stem.
37. Discuss the midbrain in terms of its location, composition and function.
38. Name the location of the pneumotaxic area of the respiratory center.
39. Discuss the importance of the medulla (oblongata).
40. Briefly explain the significance of the limbic system and reticular formation.
41. Locate the cerebellum on a diagram, and discuss its structure and function.
42. Discuss the general structure of a nerve.
43. Distinguish between a mixed, sensory, and motor nerve.
44. Name the twelve pairs of cranial nerves, designate them by Roman numeral, discuss their function, and designate them as sensory, motor, or mixed.
45. Discuss the characteristics of spinal nerves in terms of number, coverings, and composition.
46. Discuss how a spinal nerve is distributed.
47. Define the term *nerve plexus* and explain its significance.
48. Name the four major nerve plexuses and briefly discuss the areas that each innervates.
49. Compare the somatic and autonomic divisions of the NS in terms of motor neurons involved, the presence or absence of ganglia, neurotransmitter type, and effector type.
50. Describe the general function of the ANS.
51. Name the two major divisions of the ANS, and describe their general function.
52. Compare the length of a preganglionic and postganglionic neuron in the sympathetic and parasympathetic division of the ANS.
53. Define the term *ganglion*, and compare the location of sympathetic and parasympathetic ganglia.
54. Explain why sympathetic ganglia are called chain ganglia.

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55. Compare the origin of a sympathetic preganglionic neuron with a parasympathetic preganglionic neuron.
56. Describe the structures around the spinal cord (i.e. dorsal root, ventral root, spinal nerve, white ramus communicans, gray ramus communicans, paravertebral (chain) ganglia, and prevertebral ganglia.)
57. Explain the general preganglionic sympathetic pathway traveled by a nerve impulse to the paravertebral (chain) ganglia.
58. Explain the three different routes that a nerve impulse above may take from the paravertebral ganglia (i.e. It may synapse with the postganglionic neuron either ...)
59. Distinguish between cholinergic and adrenergic fibers (axons).
60. Define the term *receptor*.
61. Describe the two types of cholinergic and adrenergic receptors.
62. Compare and contrast the two divisions of the ANS in terms of their name, general function, origin of preganglionic fiber, length of preganglionic fiber, location of ganglia, and type of neurotransmitter secreted by the postganglionic fiber.

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### Central Nervous System (CNS)

#### I. PROTECTION OF THE CNS

The brain and spinal cord are protected (surrounded) by bones, membranes, and fluid.

##### A. Bones

1. The brain is encased by eight **skull bones** (i.e. cranium; name the eight bones);
2. The spinal cord is encased by 26 bones that make up the vertebral column

##### B. Meninges

The membranes around the brain and spinal cord are called "**meninges**"; three distinct layers.

###### 1. Brain:

###### a. Dura mater

- outermost membrane that is attached to the inner periosteum of the skull;
- tough, white fibrous CT;
- contains many blood vessels & nerves;
- Note: DM splits into two layers where it encloses the dural sinuses (that collect venous blood from the brain).

###### b. Arachnoid Mater

- middle layer;
- thin net-like membrane.
- Beneath the arachnoid mater lies a wide space called the **sub-arachnoid space**.

This space is filled with **cerebrospinal fluid (CSF)** and serves as a cushion for the brain.

###### c. Pia Mater

- inner layer that clings to brain surface;
- very thin delicate CT;
- many nerves & blood vessels = nourishment;
- dips into grooves & contours.

###### 2. Spinal cord:

- a. Note that the dura mater is **not** attached to bone of the vertebra (as in the brain where it is attached to the skull).
- b. The space between the dura mater and the bone is called the **epidural space** and is filled with loose CT and fat.
- c. CSF fills the subarachnoid space and central canal.

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### Central Nervous System (CNS)

#### I. PROTECTION OF THE CNS

##### C. Ventricles and Cerebrospinal Fluid (CSF)

1. In addition to filling the subarachnoid space, CSF fills the **ventricles** (interconnected cavities) within the cerebral hemispheres and brain stem.
2. The Ventricles:
  - a. are continuous with central canal of spinal cord;
  - b. are filled with cerebrospinal fluid (CSF)
  - c. are lined by ependymal cells (remember this neuroglial cell in CNS?)
3. **Secretion and Circulation of CSF**
  - a. CSF is secreted by specialized capillaries in **choroid plexuses** into the lateral ventricles (**ventricles 1 & 2**);
  - b. CSF circulates down into the **3rd & then 4th ventricle** and then into either:
    - the **central canal** of spinal cord;
    - the **subarachnoid space** of meninges.
  - c. CSF is reabsorbed back into the bloodstream through **arachnoid granulations** that project into **dural sinuses**.
  - d. CSF movement is aided by cilia of ependymal cells.
4. **CSF**
  - a. **Total volume** in above spaces = 150 mL.
    - About 1 liter is secreted daily to replenish the circulating 150 ml every 3-4 hours.
  - b. **Functions:**
    - mechanical protection (i.e. cushion);
    - chemical protection (i.e. ions, hormones);

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### Central Nervous System (CNS)

#### II. THE SPINAL CORD

The **spinal cord** is a nerve column that passes downward from brain into the vertebral canal. Recall that it is part of the CNS. **Spinal nerves** extend to/from the spinal cord and are part of the PNS.

##### A. Structure of the Spinal Cord: Longitudinal

1. Length = about 17 inches;
  - a. Start = **foramen magnum**;
  - b. End = tapers to point (**conus medullaris**) and terminates near the intervertebral disc that separates the 1st - 2nd lumbar (**L<sub>1</sub>-L<sub>2</sub>**) vertebra.
2. Contains **31 segments** (and therefore gives rise to 31 pairs of spinal nerves).
3. Note cervical and lumbar enlargements.
4. Note **cauda equina** ("horse's tail") in which the lower lumbar and sacral nerves travel downward (i.e. lower spinal nerves must "chase" their points of exit).
5. Note **filum terminale** that represents distal portion of the tail (pia mater).

##### B. Structure of the Spinal Cord: Cross-Sectional

A cross-section of the spinal cord resembles a butterfly with its wings outspread (gray matter) surrounded by white matter.

1. **Gray matter** or "butterfly" = bundles of (interneuron) cell bodies:
  - a. **posterior (dorsal) horns**,
  - b. **lateral horns**, and
  - c. **anterior (ventral) horns**.
2. Note location of:
  - a. **central canal** (lined by ependymal cells),
  - b. **gray commissure**,
  - c. **anterior median fissure**,
  - d. **posterior median sulcus**.

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**Central Nervous System (CNS)**

**II. THE SPINAL CORD**

**B. Structure of the Spinal Cord: Cross-Sectional**

3. **White matter** = myelinated (interneuron) axons:
  - a. Locations:
    - **posterior** (dorsal) funiculi or **white column**,
    - **lateral** funiculi or **white column**, and
    - **anterior** (ventral) funiculi or **white column**.
  
4. Other Important Features:
  - a. ventral root;
  - b. dorsal root;
    - dorsal root ganglion (DRG).
      1. Ganglion = a bundle of cell bodies outside the CNS;
      2. DRG contains the cell bodies of sensory (afferent) neurons bringing impulses to the CNS.
  - c. The fusion of the dorsal and ventral roots designates the beginning of the spinal nerve which then passes through its intervertebral foramen.

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#### II. THE SPINAL CORD

##### C. Functions of the Spinal Cord

**Nerve Pathway** = the route traveled by a nerve impulse through the nervous system.

1. **Reflex arc** = the simplest demonstration of a nerve pathway
  - a. involves 2-3 neurons;
  - b. involuntary response;
  - c. does not involve the brain;
  - d. Examples include:
    - knee-jerk or patellar reflex
    - withdrawal
    - sneezing
    - blinking
2. Components of a Reflex arc:
  - a. A receptor, which reacts to a stimulus;
  - b. A sensory neuron, that conducts the afferent (sensory) impulses to the CNS;
  - c. The integration center, consisting of one to several synapses in the CNS;
  - d. A motor neuron, that conducts the efferent (motor) impulses from the CNS to an effector;
  - e. An effector, the muscle fibers or gland that respond to the motor impulse by contracting or secreting a hormone.
3. Uses of Reflexes:
  - a. to insure proper transmission of a NI from sensory receptor to effector;
  - b. to prevent tissue damage.

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### II. THE SPINAL CORD

#### D. Ascending and Descending Tracts

1. The white matter of the spinal cord represents the location of our major nerve pathways called "**nerve tracts**".
  - a. **provide a 2-way system of communication:**
    - In general, **ascending tracts** are located in the **posterior (dorsal) columns** and conduct **sensory (afferent) impulses** from body parts to brain;
    - In general, **descending tracts** are located in the **anterior (ventral) columns** and conduct **motor (efferent) impulses** from brain to effectors.
      - General characteristics of nerve tracts:
        1. Most cross over;
        2. Most consist of 2-3 successive neurons;
        3. Most exhibit somatotropy (i.e. tracts from/to upper body are located on outside, tracts from/to lower body on inside);
  - b. All pathways are paired (right and left).

#### E. Spinal Cord Injuries.

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#### III. BRAIN

##### A. Brain Development

1. Embryonic **neural tube** expands and hollows cranially.
2. Three **vesicles** develop that split and become four adult **ventricles**.
3. The walls of the three vesicles become certain adult brain areas
  - a. **Forebrain** = Cerebrum, basal nuclei, and diencephalons
  - b. **Midbrain** = Midbrain
  - c. **Hindbrain** = pons, medulla oblongata, and cerebellum

The brain is the largest and most complex portion of the nervous system. It occupies the cranial cavity and is composed of one hundred billion multipolar neurons. The brain oversees the function of the entire body and also provides characteristics like personality.

The brain is composed of **4 major portions, including the cerebrum, cerebellum, diencephalon and brain stem.**

##### B. Structure of the Cerebrum

1. **Cerebrum** = **the largest** portion of the brain, which is divided into **two cerebral hemispheres**.
  - a. Hemispheres are connected by a deep bridge of nerve fibers called the **corpus callosum**;
  - b. Surface ridges are called **convolutions (gyri)**;
  - c. Each hemisphere is divided into **lobes**, which are named for the bones that cover them including **frontal, parietal, temporal, and occipital lobes**.
  - d. Convolutions are separated by two types of grooves:
    - **sulci** = shallow groove;
      1. **central sulcus** (frontal/parietal)
      2. **lateral sulcus** (temporal/others)
    - **fissure** = deep groove;
      1. **longitudinal fissure** separates the two cerebral hemispheres.
      2. **transverse fissure** (cerebrum/cerebellum)

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#### III. BRAIN

##### B. Structure of the Cerebrum

###### 1. Cerebrum

###### e. Composition:

- Bulk of cerebrum is white matter.
  - \* bundles of myelinated nerve fibers (by oligodendrocyte);
- **Cerebral cortex** or the outer portion of cerebrum is composed of **gray matter**.
  - \* **bundles of neuron cell bodies.**

##### C. Functions of the Cerebrum

###### 1. Functional Regions of the Cerebral cortex

**Responsible for all conscious behavior** by containing three kinds of functional areas, which include **motor, sensory and association areas**:

###### a. **Motor Areas** are located in the **frontal cortex**:

- **Primary motor cortex**
  1. initiates all voluntary muscle movements;
  2. located in the gyrus just anterior to the central sulcus (precentral gyrus).
- **Broca's area**
  1. motor speech area;
  2. located in left frontal lobe, above temporal lobe;

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##### C. Functions of the Cerebrum

###### 1. Functional Regions of the Cerebral cortex

b. **Sensory Areas** are concerned with conscious awareness of sensations and are located in the parietal, occipital, and temporal cortex.

- **Primary somatosensory cortex**

1. receives information from general receptors (i.e. temperature, touch, pressure, & pain).
2. located in postcentral gyrus of parietal cortex;

- **Visual (Cortex) Area**

1. receives incoming information from vision receptors (in eye);
2. located in occipital cortex.

- **Auditory (Cortex) Area**

1. receives incoming information from hearing receptors (in ear);
2. located in temporal cortex.

- **Gustatory cortex**

1. receives incoming information from taste receptors in taste buds;
2. located in parietal cortex just above the temporal lobe.

c. **Association Areas** of cerebral cortex

- **General:**

1. include areas that are not directly involved in motor or sensory function.
2. are involved in many traits.
3. are usually interconnected.
4. involve all four lobes.

- **Association traits include:**

1. analyzing & interpreting sensory experiences;
2. help provide memory, reasoning, verbalizing, judgment and emotions.

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#### III. BRAIN

##### C. Functions of the Cerebrum

###### 1. Functional Regions of the Cerebral cortex

###### d. Hemisphere Dominance (Brain Lateralization)

- Most basic functions (sensory & motor) are equally controlled by both left & right hemispheres (remember communication exists through corpus callosum).
- However, for some association functions, one hemisphere has greater control over **language-related activities** including speech, writing, reading, mathematics and logic.
  1. This hemisphere is considered the "**dominant hemisphere**".
    - a. In most people, the **left hemisphere is dominant**.
    - b. The other hemisphere (non-dominant) controls orientation in space, art and musical appreciation and emotions.

###### e. Memory

Memory is the consequence of learning. Whereas learning is the acquisition of new knowledge, memory is the persistence of that learning, with the ability to access it at a later time.

- Two types of memory:
  1. **Short Term**
  2. **Long Term.**

###### 2. Basal Nuclei

- a. masses of gray matter located deep within the white matter of the cerebral hemispheres.
- b. **serve as relay stations for outgoing motor impulses from the brain.**  
(i.e. from primary motor cortex in frontal cortex to basal ganglia and then through brain stem, down spinal cord, etc.)
- c. Release **dopamine**, which inhibits excess movements

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#### III. BRAIN

##### D. Diencephalon:

1. includes two important areas of **gray matter**:
  - a. **Thalamus**  
central relay station for incoming sensory impulses (except smell), that directs the impulse to the appropriate area of the cerebral cortex for interpretation;
  - b. **Hypothalamus**
    - main visceral control center of the body (i.e. regulates homeostasis).
      - a. heart rate & blood pressure;
      - b. body temperature;
      - c. water & electrolyte balance;
      - d. control of hunger & body weight;
      - e. control of digestive movements & secretions;
      - f. regulation of sleep-wake cycles;
      - g. control of endocrine system functioning.
2. **Limbic System** = involved in **Emotional response**
  - a. also includes structures in the frontal and temporal cortex, basal nuclei, and deep nuclei;
  - b. controls emotional experience and expression;
  - c. can modify the way a person acts;
  - d. produces feelings of fear, anger, pleasure, and sorrow;
  - e. recognizes life threatening upsets in a person's physical or psychological condition and counters them;
  - f. involved in sense of smell.

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#### III. BRAIN

##### E. Brain Stem:

The brain stem is composed of **three major parts** that include the **midbrain, pons, and medulla oblongata**. The brain stem serves as a pathway for fiber tracts running to (sensory impulses) and from (motor impulses) the cerebrum and is the site where many cranial nerves (PNS) arise.

##### 1. Midbrain

- a. located between diencephalon and pons
- b. **Corpora quadrigemina** = 4 dome-like protrusions on the dorsal midbrain surface (remember you saw these in lab when you separated the cerebrum from cerebellum!);
- c. gray matter within white matter;
- d. acts in reflex actions (visual and auditory);
- e. also contains areas associated with reticular formation.

##### 2. Pons

- a. bulging portion of brain stem;
- b. "bridge" or pathway of conduction tracts;
- c. location of **pneumotaxic area** (regulation of breathing rate) of respiratory center;
- d. also contains areas associated with reticular formation.

##### 3. Medulla (Oblongata)

- a. inferior portion of brain stem, which blends into the spinal cord at its base;
- b. contains an autonomic reflex center involved in maintaining homeostasis of important visceral organs.
  - **Cardiac center** adjusts force and rate of heart contraction;
  - **Vasomotor center** regulates blood pressure by acting on smooth muscle in the walls of peripheral arterioles (i.e. vasoconstriction = bp increase; vasodilation = bp decrease)
  - **Respiratory center** = controls the depth and rhythm of breathing.
  - Additional centers regulate involuntary activities such as vomiting, hiccuping, swallowing, coughing, and sneezing.)

##### 4. Reticular Formation

controls brain's alertness; inhibited = sleep, alcohol, tranquilizers

##### 5. Types of Sleep

- a. **Slow wave** (90min) overall decrease in reticular formation activity
- b. Rapid eye movement sleep (**REM**) certain areas of brain are active
  - responsible for dreaming
  - lasts 15 minutes
  - alternates with slow wave

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**Central Nervous System (CNS)**

**III. THE BRAIN**

**F. Cerebellum**

1. large, cauliflower-like structure located dorsally to the pons and medulla and inferiorly to the occipital lobe of the cerebrum (separated by transverse fissure);
2. note pattern of white matter (within gray matter) = "**arbor vitae**";
3. **coordinates** all voluntary muscle movements (subconsciously); skilled movements, posture, equilibrium (i.e. balance).

**G. Brain Function Summary Table:**

<b>Brain Part</b>	<b>Specific Portion</b>	<b>Location/ Characteristics</b>	<b>Functions</b>
Cerebrum	Primary Motor Cortex		
	Broca's Area		
	Primary Somatosensory Cortex		
	Visual Cortex		
	Auditory Cortex		
	Gustatory Cortex		
	Association Areas		
Basal Nuclei			
Diencephalon	Thalamus		
	Hypothalamus		
Brain Stem	Midbrain		
	Pons		
	Medulla (Oblongata)		
Cerebellum			

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### Peripheral Nervous System (PNS)

#### I. PNS INTRODUCTION

The peripheral nervous system (PNS) consists of nerves that extend to and from the CNS organs. In other words, the PNS includes the cranial nerves and spinal nerves. The PNS connects all body parts to the brain and/or spinal cord.

The PNS is divided into a sensory and motor branch, and the motor branch of the PNS is further subdivided into a somatic nervous system (from CNS to skin and skeletal muscles) and autonomic nervous system (from CNS to smooth muscle, cardiac muscle and endocrine glands).

#### II. STRUCTURE OF PERIPHERAL NERVES

A. A nerve is a cord-like bundle of axons wrapped in CT.

B. **Structure of a Nerve:**

1. Three types of CT wrappings (similar to muscle):
  - a. **endoneurium** around each axon (and myelin);
  - b. **perineurium** around each fascicle (bundle) of axons;
  - c. **epineurium** around each nerve.

#### III. NERVE FIBER CLASSIFICATION

A. **Mixed Nerves**

1. Nerves that carry impulses both to and from the CNS;
2. contain both sensory and motor axons;
3. most common; 2-way communication.

B. **Sensory (afferent) Nerves**

1. Nerves that only carry sensory impulses toward the CNS;
2. rare (only three pairs of cranial nerves).

C. **Motor (efferent) Nerves**

1. Nerves that only carry motor impulses away from CNS;
2. rare (only five pairs of cranial nerves).

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**IV. CRANIAL NERVES**

- A. **12 pairs**
1. 2 pairs to/from forebrain,
  2. 10 pairs to/from brain stem;
- B. designated by Roman numerals:
- I. **Olfactory** = sense of smell; sensory only.
  - II. **Optic** = sense of vision; sensory only.
  - III. **Oculomotor** = innervates eye muscles; motor only.
  - IV. **Trochlear** = innervates eye muscles; motor only.
  - V. **Trigeminal** = largest; sensory from face; motor to chewing muscles; mixed.\*
  - VI. **Abducens** = innervates eye muscles; motor only.
  - VII. **Facial** = innervates muscles of facial expression; sensory taste; mixed.
  - VIII. **Vestibulocochlear** = sense of hearing and equilibrium; sensory only.
  - IX. **Glossopharyngeal** = moves tongue and pharynx muscles; mixed.
  - X. **Vagus** = innervates visceral smooth muscle; mixed; See Fig 11.28, page 401.
  - XI. **Accessory** = innervates neck muscles; motor only.
  - XII. **Hypoglossal** = moves tongue; motor only.
- C. Memorize by using one of many mnemonic devices:  
One example is: "**Oh, Oh, Oh, To Touch And Feel Very Good Velvet AH!**"  
See [www.medicalmnemonics.com](http://www.medicalmnemonics.com) for more.



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**Peripheral Nervous System (PNS)**

**V. SPINAL NERVES:**

**A. Introduction**

1. Recall that a spinal nerve is formed from the fusion of a dorsal and ventral root. Then the spinal nerve passes through its intervertebral foramen.
2. Spinal nerves are associated with the spinal cord and are named for the region of the spinal cord from which they arise.

**B. General Characteristics:**

1. **31 pairs:**
  - a. C<sub>1</sub> - C<sub>8</sub>
  - b. T<sub>1</sub> - T<sub>12</sub>
  - c. L<sub>1</sub> - L<sub>5</sub>
  - d. S<sub>1</sub> - S<sub>5</sub>
  - e. C<sub>0</sub>
2. Composition = all **mixed nerves**.

**C. Distribution of Spinal Nerves**

A short distance after passing through its **intervertebral foramen**, a spinal nerve branches into several branches:

1. **A posterior branch** (dorsal ramus)
2. **A large anterior branch** (i.e. ventral ramus)
3. Branches to paravertebral (autonomic) ganglia = **rami communicans**

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**V. SPINAL NERVES:**

**D. Nerve plexus**

1. Definition = **a branching network** (of the anterior branches) **of spinal nerves**.
  - a. The nerves do not extend directly to the body part they innervate, instead they form networks.
2. present in all spinal nerves except T<sub>2</sub> - T<sub>12</sub>:
  - a. cervical plexus; neck muscles and diaphragm (breathing)
  - b. brachial plexus; upper limb
  - c. lumbar plexus; anterior and medial thigh
  - d. sacral plexus; posterior lower limb, leg
3. Each resulting branch of the plexus contains the fibers from several spinal nerves;
4. Fibers from each spinal nerve are carried to the body periphery via several different routes or branches.

Therefore, damage to one spinal segment cannot completely paralyze any limb muscle.

**E. Intercostal Nerves**

1. Nerves T<sub>2</sub>-T<sub>11</sub> run in intercostal spaces
2. Supply skin (sensory) and muscles (motor) in the surrounding area

## CHAPTER 11: NERVOUS SYSTEM II: DIVISIONS OF THE NERVOUS SYSTEM

### Autonomic Nervous System (ANS)

#### I. GENERAL CHARACTERISTICS

The Autonomic Nervous System (ANS) regulates the action of smooth muscles, cardiac muscle, and some glands. In other words, the ANS regulates involuntary (automatic; unconscious) actions. There are two major divisions of the ANS. The parasympathetic division functions under normal conditions (to maintain homeostasis), and the sympathetic division of the ANS functions under stress.

#### II. AUTONOMIC NERVE FIBERS:

##### A. Somatic

1. one motor neuron;
2. no ganglia;
3. NT = acetylcholine (ACh); excitatory;
4. Effector = skeletal muscles.

##### B. ANS

1. **two motor neurons;**
2. synapse between neurons occur within a **ganglion;**
3. effectors = smooth muscle, cardiac muscle, glands.
4. Two Divisions:
  - a. **Parasympathetic:**
    - 1st neuron (preganglionic) = long;
    - 2nd neuron (postganglionic) = short.
    - NT of postganglionic fiber = ACh.
  - b. **Sympathetic:**
    - 1st neuron (preganglionic) = short;
    - 2nd neuron (postganglionic) = long.
    - NT of postganglionic fiber = norepinephrine..

##### C. LOCATION OF ANS GANGLIA:

1. Definition: A ganglion is a collection of neuron cell bodies outside the CNS.
2. **Parasympathetic ganglia** are located at or near the effector.
3. **Sympathetic ganglia** are located on either side of the spinal cord (chain ganglia; sympathetic trunk), and are far from their effector.
4. **Pre-ganglionic neuron**
  - a. Origination:
    - **Parasympathetic** arise from the **Craniosacral** regions of the brain & spinal cord.
    - **Sympathetic** arise from the **Thoracolumbar** regions of the spinal cord.
  - b. **Length** of axon (or **pre-ganglionic fiber**):
    - Parasympathetic = long.
    - Sympathetic = short.

**CHAPTER 11: NERVOUS SYSTEM II: DIVISIONS OF THE NERVOUS SYSTEM**  
**Autonomic Nervous System (ANS)**

**III. ANATOMY OF THE ANS:**

**A. Sympathetic (Thoracolumbar) Division**

1. T1 - L2;
2. General Pathway is complex!!!!
  - a. preganglionic neuron from spinal cord;
  - b. out through **white ramus communicans** to enter an adjoining
  - c. **paravertebral (chain) ganglion** forming part of the sympathetic trunk (chain).
3. Once a preganglionic axon reaches a paravertebral ganglion, **one of three things can happen:**
  - a. It can synapse with a postganglionic neuron within the same ganglion = **synapse in a paravertebral chain ganglion at same level.**

The postganglionic neuron passes through the **gray ramus communicans** and out the ventral ramus leading to its effector (blood vessel, skin).
  - b. It can ascend or descend within the sympathetic chain to synapse in another paravertebral ganglion = **synapse in a paravertebral chain ganglion at a different level.**

The postganglionic neuron passes through **gray ramus communicans.**
  - c. It can pass through the ganglion to **prevertebral (collateral) ganglion** (via Splanchnic Nerve)

Therefore synapse occurs within the prevertebral ganglion and the postsynaptic neuron extends to effector (abdominal organ).

**B. Parasympathetic ANS**

1. Long preganglionic fibers; much simpler.
2. Preganglionic fibers follow blood vessels to ganglia in or near wall of effector

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**IV. PHYSIOLOGY OF THE ANS**

**A. Autonomic Neurotransmitters**

1. ACh is released by cholinergic fibers (axons);
2. Norepinephrine is released by adrenergic fibers (axons).

**B. Actions of Autonomic Neurotransmitters**

A receptor is present in the cell membrane of an effector and recognizes its NT, allowing for a response to occur within the effector.

1. Cholinergic receptors bind ACh; two types:
  - a. nicotinic are always stimulatory.
  - b. muscarinic may be stimulatory or inhibitory.
2. Adrenergic receptors bind norepinephrine; two types:
  - a. alpha ( $\alpha$ ) are usually stimulatory.
  - b. beta ( $\beta$ ) are usually inhibitory.
3. Effects of Autonomic Stimulation on Various Effectors:

**C. Control of Autonomic Activity**

1. overall CNS controls ANS
  - a. medulla oblongata = cardiac, vasomotor, and respiratory functions
  - b. hypothalamus = visceral control including renal and digestive
  - c. limbic system = controls physiology of emotions

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V. **ANS Summary Table** (Keyed at the end of this outline)

Branch of ANS		
<b>General Function</b>		
<b>Origin of Preganglionic fiber</b>		
<b>Length of Preganglionic fiber</b>		
<b>Location of Ganglia</b>		
<b>NT secreted by post-ganglionic fiber</b>		

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**VI. LIFE SPAN CHANGES**

As the nervous system ages, cells are lost, which over time, lead to slowed functioning.

- A. Apoptosis of brain neurons begins before birth.
- B. Neuron loss among brain regions is not uniform.
- C. In adults, the number of cerebral cortex dendrites has declined, leading to slower neurotransmission.
- D. Risk of falling increases as balance decreases.
- E. Sleep problems are common in the elderly.

**CHAPTER 11: NERVOUS SYSTEM II: DIVISIONS OF THE NERVOUS SYSTEM**  
**Peripheral Nervous System (PNS)**

Summary Table for Cranial Nerves

Numeral	Name	Function	Sensory, Motor, or Mixed Nerve
I	OLFACTORY	OLFACTION/SMELL	SENSORY
II	OPTIC	VISION	SENSORY
III	OCULOMOTOR	MOVE EYE	MOTOR
IV	TROCHLEAR	MOVE EYE	MOTOR
V	TRIGEMINAL	CHEWING/MASTICATION AND SENSORY FROM FACE	MIXED
VI	ABDUCENS	MOVE EYE	MOTOR
VII	FACIAL	FACIAL EXPRESSION	MIXED
VIII	VESTIBULOCOCHLEAR	HEARING AND EQUILIBRIUM	SENSORY
IX	GLOSSOPHARYNGEAL	MOVE MUSCLES OF TONGUE AND PHARYNX	MIXED
X	VAGUS	INNERVATE VISCERAL SMOOTH MUSCLE	MIXED
XI	ACCESSORY	MOVE NECK MUSCLES	MOTOR
XII	HYPOGLOSSAL	MOVE TONGUE	MOTOR

**CHAPTER 11: NERVOUS SYSTEM II: DIVISIONS OF THE NERVOUS SYSTEM**  
**Autonomic Nervous System (ANS)**

ANS Summary Table

Branch of ANS	PARASYMPATHETIC	SYMPATHETIC
<b>General Function</b>	maintain homeostasis	to survive stressful or “fight or flight” situations
<b>Origin of Preganglionic fiber</b>	from cranial region of brain or sacral region of spinal cord	from thoracic or lumbar region of spinal cord
<b>Length of Preganglionic fiber</b>	Long	short
<b>Location of Ganglia</b>	at or near effector	alongside spinal cord
<b>NT secreted by post-ganglionic fiber</b>	acetylcholine	norepinephrine