

# Neuroanatomy

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# Nervous System

- Master controller and communicating system in the body
- Every thought, action and emotion reflects its activity.
- It signals the body through electrical impulses that communicate with the body cells.
- Its signaling and responding abilities are highly specific and rapid.



# Functions of the Nervous System

## 1. **Sensory input** – gathering information

- To monitor changes occurring inside and outside the body
- Changes = are called stimuli

## 2. **Integration**

- Nervous System is able to integrate this information
- Process and interpret sensory input and decide if action is needed

## 3. **Motor output**

- A response to the integrated stimuli
- The response activates muscles or glands



# Nervous Tissue

- Comprise of 2 types of cells
  - **Neuroglia**= supporting cells
    - The insulators, adhesive, protectors and nourishers
  - **Neurons** = nerve cells that transmit impulses. Nerves are cable-like bundles of axons.



# Classification of Neurons

- Neurons can be classified based on function or by structure.
- Structure:
  - (1) Multipolar
    - Many processes arising from cell body
    - Brain or spinal cord
  - (2) Bipolar
    - 2 processes (1 from each end of cell body)
    - Ear, eyes, nose
  - (3) Unipolar
    - Single process extends from cell body
    - Outside of brain & spinal cord



## Classification of Neurons (by function)

Sensory Neurons – (afferent) have specialized receptor ends that sense stimuli and then carry impulses from peripheral body parts to brain or spinal cord.

Can be unipolar or bipolar.



## Interneurons (association neurons)

- Found in neural pathways in the central nervous system
  - **Connect sensory and motor neurons**

Motor Neurons – (efferent) carry impulses out of the brain or spinal cord to effectors (muscles, glands).

Interneurons and motor neurons are multipolar.

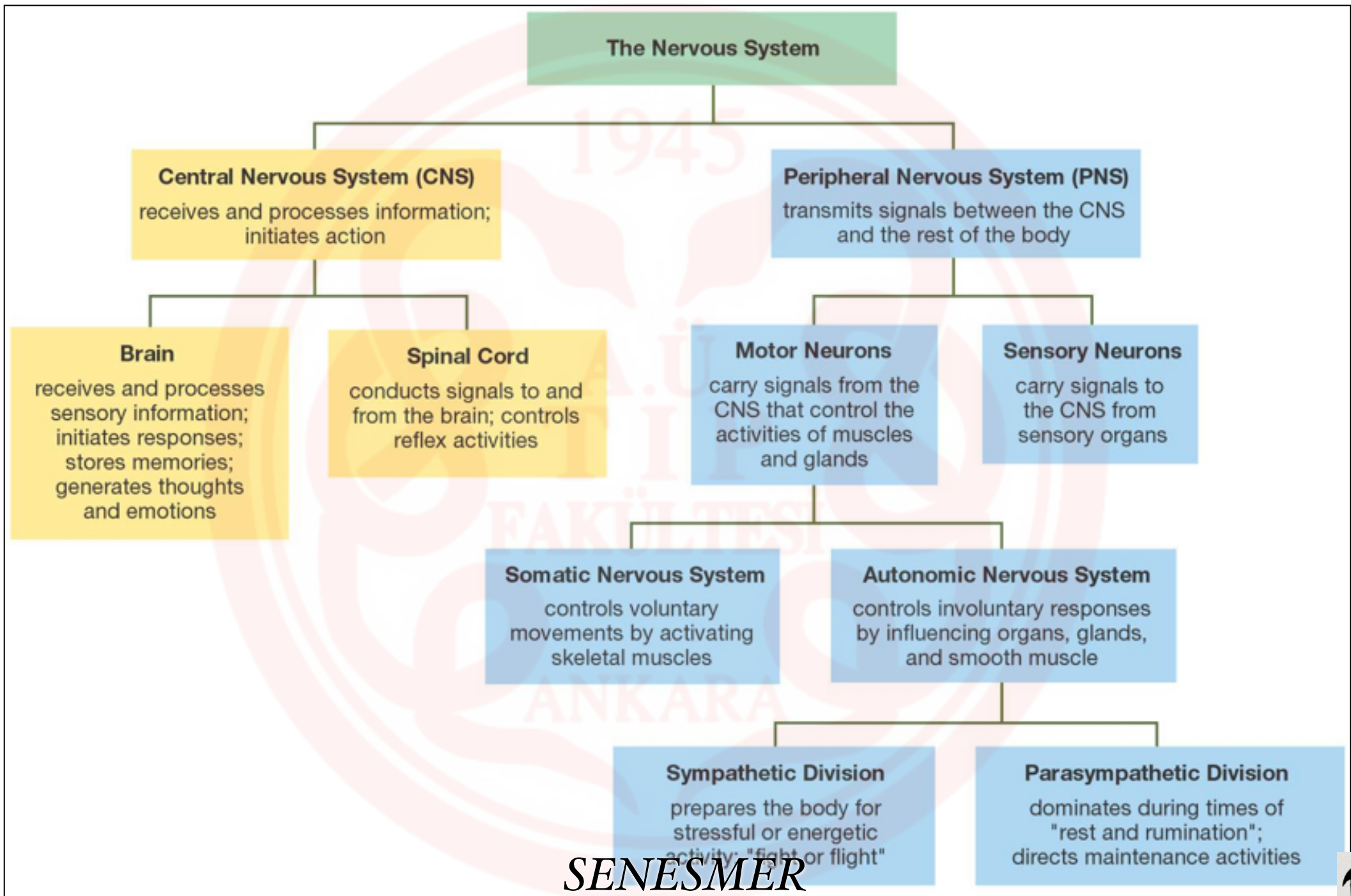


# Structural Classification of the Nervous System

- Central nervous system (CNS)
  - Brain
  - Spinal cord
- Peripheral nervous system (PNS)
  - Nerve outside the brain and spinal cord







# Brain: Structure

- **Hindbrain** carries out the most basic functions.
- **Midbrain** coordinates signals.
- **Forebrain** processes signals, stores memories, creates thought.



- Cerebral hemispheres
- Diencephalon
- Brain stem
- Cerebellum



# Layers of the Cerebrum

- **Gray matter**
  - Outer layer
  - Composed mostly of neuron cell bodies
- **White matter**
  - Fiber tracts inside the gray matter
  - Example: corpus callosum connects hemispheres
- **Basal nuclei**
  - internal islands of gray matter



# Cerebral Hemispheres (Cerebrum)

- Paired (left and right) superior parts of the brain
- Include more than half of the brain mass
- The surface is made of ridges (**gyri**) and grooves, (fissure)(**sulci**)



# Lobes of the Cerebrum

- Fissures (deep grooves) divide the cerebrum into lobes
- Surface lobes of the cerebrum
  - Frontal lobe
  - Parietal lobe
  - Occipital lobe
  - Temporal lobe
  - (Insula)



# Specialized Areas of the Cerebrum

- **Somatic sensory area** – receives impulses from the body's sensory receptors
- **Primary motor area** – sends impulses to skeletal muscles
- **Broca's area** – involved in our ability to speak
- Gustatory area (taste)
- Visual area
- Auditory area
- Olfactory area

Interpretation areas of the cerebrum

- Speech/language region
- Language comprehension region
- General interpretation area



# Diencephalon

- Sits on top of the brain stem
- Enclosed by the cerebral hemispheres
- Made of four parts
  - Thalamus
  - Hypothalamus
  - Epithalamus
  - Subthalamus





# Thalamus

- The relay station for sensory impulses
- Transfers impulses to the correct part of the cortex for localization and interpretation

# Hypothalamus

- Under the thalamus
- Important autonomic nervous system center
  - Helps regulate body temperature
  - Controls water balance
  - Regulates metabolism
- An important part of the limbic system (emotions)

# Epithalamus

# Subthalamus



# Brain Stem

- Attaches to the spinal cord
- Parts of the brain stem
  - Midbrain
  - Pons
  - Medulla oblongata



# Midbrain

- Mostly composed of tracts of nerve fibers
- Has four rounded protrusions – corpora quadrigemina
  - Reflex centers for vision and hearing

# Pons

- The bulging center part of the brain stem
- Mostly composed of fiber tracts



# Medulla Oblongata

- The lowest part of the brain stem
- Merges into the spinal cord
- Includes important fiber tracts
- Contains important control centers
  - Heart rate control
  - Blood pressure regulation
  - Breathing
  - Swallowing
  - Vomiting



# Cerebellum

- Responsible for:
  - coordination of muscles, balance, posture, & muscle tone



# Meninges

- Consists of 3 membranes
- Covers and protects the brain and spinal cord
- Dura mater
  - thick, tough outer layer
- Arachnoid membrane
  - middle delicate weblike layer
- Pia mater
  - inner most layer with blood vessels to nourish the nerves

## ❖ Spaces

➤ **Epidural**

➤ **Subdural**

➤ **Subarachnoid**: Contains CSF and blood vessels within web-like strands of arachnoid tissue



# Cerebrospinal Fluid

- Circulates continuously
- Serves as shock absorber to protect brain and spinal cord
- Carries nutrients to parts of brain and spinal cord
- Helps remove metabolic products & wastes
- After circulation, absorbed into the blood vessels of the dura mater.



➤ **The brain ventricles** are four cavities located within the brain that contain [cerebral spinal fluid \(CSF\)](#).

➤ The system comprises four ventricles:

[lateral ventricles](#) right and left (one for each hemisphere)

[third ventricle](#)

[fourth ventricle](#)

➤ The ventricles are **interconnected with each other**, and also with the **central canal of the spinal cord** and **with the subarachnoid space**.

➤ CSF is produced by the lining of the ventricles. The CSF then circulates throughout the ventricular system and is eventually reabsorbed in the subarachnoid space.





# Spinal Cord

- ❖ Elongated, cylindrical, suspended in the vertebral canal
- ❖ Surrounded by the meninges and cerebrospinal fluid (CSF).
- ❖ Extends from foramen magnum to second lumbar vertebra.
- ❖ Continuous above with the *medulla oblongata*.
- ❖ The tapered inferior end forms *conus medullaris*.
- ❖ Gives rise to 31 pairs of spinal nerves
- ❖ Segmented
  - ✓ Cervical
  - ✓ Thoracic
  - ✓ Lumbar
  - ✓ Sacral



# Spinal Meninges

❖ Connective tissue membranes surrounding spinal cord and brain

- **Dura mater**: continuous with epineurium of the spinal nerves
- **Arachnoid mater**: thin and wispy
- **Pia mater**: bound tightly to surface of brain and spinal cord.

❖ Spaces

- **Epidural**
- **Subdural**
- **Subarachnoid**: Contains CSF and blood vessels within web-like strands of arachnoid tissue



## Cross Section of Spinal Cord

- ❖ Composed of **grey matter** in the center surrounded by **white matter** supported by neuroglia.
- ❖ **Roots**: spinal nerves arise as rootlets then combine to form roots
  - Dorsal (posterior) root has a ganglion
  - Ventral (anterior)
  - Two roots merge laterally and form the **spinal nerve**



# Spine: structure

- The spinal cord is protected by the vertebrae.
- Gray matter contains cell bodies; white matter contains myelinated fibers.
- PNS nerves extend outside of the vertebrae.



# Functional Classification of the Peripheral Nervous System

- Sensory (afferent) division - carrying toward a center
  - Nerve fibers that carry information to the central nervous system
  - Somatic sensory  
(skin, skeletal muscle)
  - Visceral sensory  
(visceral organs)



# Functional Classification of the Peripheral Nervous System

- Motor (efferent) division
  - Nerve fibers that carry impulses away from the central nervous system
  - Activate (effect) muscles or glands to bring about a response.



# Functional Classification of the Peripheral Nervous System

- Motor (efferent) = 2 division
  - Somatic nervous system = voluntary (skeletal muscles)
  - Autonomic nervous system = involuntary (smooth and cardiac muscles, glands)



# Peripheral Nervous System

- PNS can be subdivided into 2 divisions:
- (1) Autonomic
  - Cranial & spinal nerves connecting CNS to heart, stomach, intestines, glands
  - Controls unconscious activities
- (2) Somatic
  - Cranial & spinal nerves connecting CNS to skin & skeletal muscles
  - Oversees conscious activities





- The peripheral nervous system (PNS) is made up of peripheral nerves that connect the CNS to the rest of the body.
- 31 pairs of spinal nerves
- 12 pairs of cranial nerves



# Spinal Nerves

- There are 31 pairs of nerves exiting the spinal column: **Thirty-one pairs** of spinal nerves
- First pair exit vertebral column between skull and atlas.
- **Eight pair cervical, twelve pair thoracic, five pair lumbar, five pair sacral, one pair coccygeal**
- Each spinal nerve arises as rootlets which then combine to form **dorsal (posterior) & ventral (anterior) roots.**
- Two roots merge laterally and form the **spinal nerve.**
- Dorsal (posterior) root has a ganglion (**dorsal root/sensory ganglion**) that contains the **cell bodies of the sensory neurons**
- Each spinal nerve then divides into a **smaller dorsal** and a **larger ventral ramus**



# Branches of Spinal Nerves

- ❖ **Dorsal Ramus:** innervate deep muscles of the trunk responsible for movements of the vertebral column and skin near the midline of the back.
- ❖ **Ventral Ramus:** what they innervate depends upon which part of the spinal cord is considered.
  - **Thoracic region:** form **intercostal nerves** that innervate the intercostal muscles and the skin over the thorax
  - **Remaining spinal nerve ventral rami (roots of the plexus):** form five plexuses (intermingling of nerves).

- Ventral rami of C1-C4= **cervical plexus**
- Ventral rami of C5-T1= **brachial plexus**
- Ventral rami of L1-L5= **lumbar plexus**
- Ventral rami of L4-S4= **sacral plexus**
- Ventral rami of S4 & S5= **coccygeal plexus**



# 31 Pairs of Spinal Nerves

- 8 cervical
  - Cervical plexus
  - Brachial plexus
- 12 thoracic
  - Intercostal nerves & enlargements
- 5 lumbar
  - Lumbar plexus
- 5 sacral
  - Sacral plexus
- 1 coccygeal
  - Tailbone & perineum



# Cervical Plexus

1. The cervical plexus and innervation of the neck- formed by C1-C4 nerves, most branches are cutaneous nerves and anterior neck muscles and diaphragm.
  2. The **phrenic nerve** innervates the respiratory diaphragm
- " C<sub>3,4,5</sub> keeps the diaphragm alive!



# Brachial Plexus

The brachial plexus and innervation of the upper limb- formed by C5-C8 nerves, it supplies the upper limbs.



# Lumbar Plexus

The lumbar plexus and innervation of the lower limb- formed by L1-L4 nerves the main branches innervate the anterior thigh via the **femoral nerve**. Medial thigh and adductor muscles are innervated by the **obturator nerve**.



# Sacral Plexus

The sacral plexus and innervation on the lower limb- formed by L4-S4 nerves, its many branches innervate the buttock, lower limb, pelvis, and perineum. The largest branch is the **sciatic nerve** that supplies lateral and posterior limb regions.





# Cranial Nerves

- 12 pairs & their branches
- 1<sup>st</sup> 2 pairs attach to forebrain
- Remainders originate on brainstem



III. **Cranial Nerves**- These nerves serve the head and neck; they originate in the brain and most of them exit the skull through cranial foramina not vertebral foramina. They are numbered I – XII rostrally to caudally.

- **A. Olfactory nerve I**- sensory nerve for smell, it runs below the frontal lobe, purely sensory, cerebrum
- **B. Optic nerve II**- a brain tract exiting through the optic chiasma, it sends signals of images to the brain, purely sensory, cerebrum
- **C. Oculomotor nerve III**- caudal to optic chiasma it innervates internal eye muscles to move the eye (superior, inferior, lateral, medial rectus) and eyelids. It adjust the pupil and lens. Motor nerve, visceral motor, midbrain



D. Trochlear nerves IV- (pulley) it innervates the superior oblique muscles of the eye. Motor nerve, midbrain

E. Trigeminal nerves V - (three fold)- it has three branches that carry sensory information from the face and motor information for chewing muscles. Motor, sensory, pons

F. Abducens nerves VI- innervates a muscle that abducts the eye ( lateral rectus), motor nerve, pons

G. Facial nerves VII- innervates muscles of facial expression, activates facial glands, conveys sensory from taste buds. Mixed (visceral motor), pons

H. Vestibulocochlear nerves VIII- sensory nerve for hearing and equilibrium, purely sensory, medulla oblongata



I. Glossopharyngeal nerves IX. innervates the tongue and pharynx, controls a muscle used for swallowing, activates salivary gland, conducts taste, and other facial sensory. Mixed (visceral motor), medulla oblongata

J. Vagus Nerves X- (wanders) controls muscles of swallowing extends beyond the face and neck into the thorax and abdomen to innervate internal organs for motor and sensory impulses, some sensory near ear area. Mixed (visceral motor), medulla oblongata.

K. Accessory nerves XI- accessory for the vagus nerve- (it joins it, and controls muscles that moves the head and some of the same as the vagus.) Motor, medulla oblongata.

L. Hypoglossal nerves XII- (below the tongue) runs below the tongue and innervates the tongue muscles, motor nerves, medulla oblongata.



# Cranial Nerves

**Table 9-1: The Cranial Nerves**

NUMBER	NAME	TYPE	FUNCTION
I	Olfactory	Sensory	Olfactory (smell) information from nose
II	Optic	Sensory	Visual information from eyes
III	Oculomotor	Motor <b>Visceral motor</b>	Eye movement, pupil constriction, lens shape
IV	Trochlear	Motor	Eye movement
V	Trigeminal	<b>Motor, sensory</b>	Sensory information from face, mouth; motor signals for chewing
VI	Abducens	Motor	Eye movement
VII	Facial	Mixed	Sensory for taste; efferent signals for tear and salivary glands, facial expression
VIII	Vestibulocochlear	Sensory	Hearing and equilibrium
IX	Glossopharyngeal	Mixed	Sensory from oral cavity, baro- and chemoreceptors in blood vessels; efferent for swallowing, parotid salivary gland secretion
X	Vagus	Mixed	Sensory and efferents to many internal organs, muscles, and glands
XI	Spinal accessory	Motor	Muscles of oral cavity, some muscles in neck and shoulder
XII	Hypoglossal	Motor	Tongue muscles



# The Nervous System

## Central Nervous System (CNS)

- brain and spinal cord
- receives sensory input via PNS sensory nerves
- processes/interprets sensory input (interneurons)
- sends response to effectors (muscles and glands) via motor nerves

## Peripheral Nervous System (PNS)

- cranial and spinal nerves extending from brain and spinal cord
- connects CNS to entire body

### Autonomic

- cranial and spinal nerves connecting CNS to heart, stomach, intestines, and glands
- controls unconscious activities

### Somatic

- cranial and spinal nerves connecting CNS to skin and skeletal muscles
- oversees conscious activities

### Parasympathetic

- decreases heart rate, bronchiole dilation, blood glucose, blood to skeletal muscle, bladder
- increases digestion, pupil size, urinary output
- “rest and digest”

### Sympathetic

- decreases digestion, pupil size, urinary output
- increases heart rate, bronchiole dilation, blood glucose, blood to skeletal muscle, pupil size
- “fight or flight”



# Autonomic Nervous System

- The involuntary branch of the nervous system
- Helps maintain a balance in involuntary functions of the body. But allows the body to react in times of emergency.
- Regulate activity of smooth muscle, cardiac muscle & certain glands
- Consists of only motor nerves
- Divided into two divisions
  - Sympathetic division
  - Parasympathetic division
- **Dual innervation**
  - one speeds up organ
  - one slows down organ
  - Sympathetic NS increases heart rate
  - Parasympathetic NS decreases heart rate



# Differences Between Somatic and Autonomic Nervous Systems

- Effector organs
  - Somatic – skeletal muscle
  - Autonomic – smooth muscle, cardiac muscle, and glands





# Autonomic Functioning

- **Sympathetic – “fight-or-flight”**
  - Response to unusual stimulus
  - Takes over to increase activities
  - Remember as the “E” division = exercise, excitement, emergency, and embarrassment
- **Parasympathetic – housekeeping activities**
  - Conserves energy
  - Maintains daily necessary body functions
  - Remember as the “D” division - digestion, defecation, and diuresis



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