The Nervous System
The Basic Functions of the Nervous System

- **Sensation**
  - The ability of the nerves to detect stimuli, such as pressure, temperature changes, taste, smell or light, and send a message in the form of impulses to the brain and spinal cord.
The Basic Functions of the Nervous System

- Movement
  - The ability of the brain to send impulses to muscles to cause movement, or a change in position.
The Basic Functions of the Nervous System

- Coordination
- The nervous system controls and coordinates functions throughout the body and responds to internal and external stimuli.
The Two Divisions of the Nervous System

1. **The Central Nervous System:** is divided into two parts: the brain and the spinal cord.

2. **The Peripheral Nervous System:** is divided into two major parts: the somatic nervous system and the autonomic nervous system.
The Divisions of the Nervous System

Central Nervous System (CNS)
- Brain and spinal cord
- Integrative and control centers

Peripheral Nervous System (PNS)
- Cranial nerves and spinal nerves
- Communication lines between the CNS and the rest of the body

Sensory (afferent) division
- Somatic and visceral sensory nerve fibers
- Conducts impulses from receptors to the CNS

Motor (efferent) division
- Motor nerve fibers
- Conducts impulses from the CNS to effectors (muscles and glands)

Somatic nervous system
- Somatic motor (voluntary)
- Conducts impulses from the CNS to skeletal muscles

Autonomic nervous system (ANS)
- Visceral motor (involuntary)
- Conducts impulses from the CNS to cardiac muscles, smooth muscles, and glands

Sympathetic division
- Mobilizes body systems during activity (“fight or flight”)

Parasympathetic division
- Conserves energy
- Promotes “housekeeping” functions during rest
The brain contains approximately 100 billion neurons. The brain weighs about 3 pounds. About 20% of blood leaving the heart circulates through the brain.

The brain is responsible for analyzing information, processing information and relaying messages to the rest of the body. It is the main control center of the body.

Along with the spinal cord, it forms the body’s Central Nervous System or CNS.
The Central Nervous System: The Spinal Cord

• Along with the brain, it is part of the Central Nervous System.
• It is the major communication link between the brain and the rest of the body.
• It can process many reflexes – unconscious, automatic responses to stimuli.
• There are 31 pairs of spinal nerves which branch from the spinal cord to control such processes as breathing, arm movement, and leg movement.
The Peripheral Nervous System:
Somatic Nervous System

The somatic nervous system consists of peripheral nerve fibers that send sensory information to the central nervous system AND motor nerve fibers that project to and controls skeletal (voluntary) muscle.
The Peripheral Nervous System: The Autonomic Nervous System

The autonomic nervous system is divided into three parts: the sympathetic nervous system, the parasympathetic nervous system and the enteric nervous system. The autonomic nervous system controls smooth (involuntary) muscle of the viscera (internal organs) and glands.
Parts of the Brain

There are three major parts of the human brain:

• The Cerebrum
• The Cerebellum
• The Brain Stem

Each of these three parts has different regions with different functions.
The cerebrum or cortex is the largest part of the human brain, associated with higher brain function such as thought and action. The cerebral cortex is divided into four sections, called "lobes": the frontal lobe, parietal lobe, occipital lobe, and temporal lobe.

Note that the cerebral cortex is highly wrinkled. Essentially this makes the brain more efficient, because it can increase the surface area of the brain and the amount of neurons within it.
Parts of the Brain: The Cerebrum

What do each of these lobes do?

Frontal Lobe - associated with reasoning, planning, speech, movement, emotions, personality, ability to learn, think, concentrate, and problem solving, olfactory bulb = smell

Parietal Lobe - associated with movement, orientation, recognition, perception of stimuli (including taste, touch, temperature, and pain)

Occipital Lobe - associated with visual processing

Temporal Lobe - associated with perception and recognition of auditory stimuli, memory, and speech
A deep furrow (the longitudinal cerebral fissure) divides the cerebrum into two halves, known as the left and right hemispheres. The two hemispheres look mostly symmetrical yet it has been shown that each side functions slightly different than the other. The right hemisphere is associated with creativity, spatial abilities, face recognition, visual imagery, and music while the left hemisphere is associated with language, math, and logic abilities. The corpus callosum is a bundle of nerves which connects these two hemispheres.

Nerve cells make up the gray matter of the cerebrum which is a little thicker than your thumb. White nerve fibers (white matter) underneath carry signals between the nerve cells and other parts of the brain and body.
Parts of the Brain: The Cerebrum

The neocortex occupies the bulk of the cerebrum. This is a six-layered structure of the cerebral cortex which is only found in mammals. It is thought that the neocortex is a recently evolved structure, and is associated with "higher" information processing by more fully evolved animals (such as humans, primates, dolphins, etc).
The cerebellum, or "little brain", is similar to the cerebrum in that it has two hemispheres and has a highly folded surface or cortex. This structure is associated with regulation and coordination of skeletal muscle movement, posture, and balance.

The cerebellum is assumed to be much older than the cerebrum, evolutionarily. What do I mean by this? In other words, animals which scientists assume to have evolved prior to humans, for example reptiles, do have developed cerebellums. However, reptiles do not have neocortex (cerebrum).
Parts of the Brain: The Cerebellum
The thalamus: Almost all sensory information enters this structure where neurons send that information to the overlying cortex.

The hypothalamus: This structure is involved in functions including homeostasis, emotion, thirst, hunger, circadian rhythms, and control of the autonomic nervous system. In addition, it controls the pituitary.

The amygdala: Located in the temporal lobe; involved in memory, emotions such as fear, anger, and pleasure, and motivations that are related to survival.

The hippocampus: This part of the brain is important for learning and memory . . . for converting short term memory to more permanent memory, and for recalling spatial relationships in the world about us.
Underneath the limbic system is the brain stem. This structure is responsible for basic vital life functions such as breathing, heartbeat, and blood pressure. Scientists say that this is the "simplest" part of the human brain because animals' entire brains, such as reptiles (who appear early on the evolutionary scale) resemble our brain stem.

The brain stem is made of the midbrain, pons, and medulla.
Parts of the Brain: The Brain Stem

Figure AB-25: Brainstem

- Midbrain
- Pons
- Medulla
- To Spinal Cord
Parts of the Brain: The Brain Stem

- **The midbrain**: involved in vision, speech, eye and body movement.

- **The pons**: The pons is a small bulge above the medulla oblongata. It is important to help us regulate the rate and depth of breathing.

- **The medulla oblongata**: The medulla oblongata is continuous with the spinal cord and helps to regulate the heart beat, blood pressure, breathing, swallowing, hiccuppine, and vomiting.
Meninges

- A set of three layers of connective tissue that enclose the brain and spinal cord. They are located under the skull and attach directly to the brain.
- Meninges, along with the bones of the skull, help to provide protection to the brain and spinal cord.
- The meninges (from deep to superficial) are P.A.D. = Pia mater, Arachnoid mater, Dura mater
- Cerebrospinal fluid circulates between two layers of the meninges.
The Three Layers of Meninges and Fluid Spaces

1. **The dura mater** is the most superior of the meningeal layers. Its name means "hard mother" in Latin and it is tough and inflexible. This tissue forms several structures that separate the cranial cavity into compartments and protect the brain from displacement.

The **epidural space** is between the dura mater and the skull. If there is hemorrhaging in the brain, blood may collect here. Adults are more likely than children to bleed here as a result of closed head injury.

The **subdural space** is between the dura mater and the middle layer of the meninges, the arachnoid mater. When bleeding occurs in the cranium, blood may collect here and push down on the lower layers of the meninges. If bleeding continues, brain damage will result from this pressure. Children are especially likely to have bleeding in the subdural space in cases of head injury.
2. The arachnoid mater is the middle layer of the meninges. It provides a cushioning and protection for the central nervous system. The subarachnoid space lies between the arachnoid and pia mater. It is filled with cerebrospinal fluid. All blood vessels entering the brain, as well as cranial nerves pass through this space. The term arachnoid refers to the spider web like appearance of the blood vessels within the space.
3. The pia mater is the deepest layer of the meninges. It envelopes and firmly attaches to the surface of the brain and spinal cord. The pia mater contains blood vessels and capillaries that are responsible for nourishing the brain.
Cerebrospinal Fluid

- CSF is a clear, watery fluid which bathes the brain and the spinal cord to cushion and protect it by acting as a shock absorber.
- CSF also brings nutrients from the blood to the brain and removes waste products from the brain and sends them away in the blood.
- CSF circulates between the two layers of the meninges, through the center of the spinal cord, and through four hollow spaces in the brain (called ventricles). CSF is produced by special cells in the ventricles.
The spinal cord is the most important structure between the body and the brain. It is a vital link between the brain and the body, and from the body to the brain.

It is composed of gray matter in the shape of a butterfly on the inside with white matter on the outside.

The spinal cord is divided into four different regions: the cervical, thoracic, lumbar and sacral regions (Figure 3.1). The different cord regions can be visually distinguished from one another. Two enlargements of the spinal cord can be visualized: The cervical enlargement (gives off nerves to the arms), which extends between C3 to T1; and the lumbar enlargement (gives off nerves to the legs) which extends between L1 to S2 (Figure 3.1).

The cord is segmentally organized. There are 31 segments, defined by 31 pairs of nerves exiting the cord. These nerves are divided into 8 cervical, 12 thoracic, 5 lumbar, 5 sacral, and 1 coccygeal nerve (Figure 3.2). Dorsal and ventral roots enter and leave the vertebral column respectively through intervertebral foramen at the vertebral segments corresponding to the spinal segment.
The Spinal Cord

Bone notch at the base of the neck is C7.

C8 Sensation of C7 nerve is for the middle finger.

C8 and lower spinal nerve roots leave below the corresponding vertebral body.

T4 Sensation of T4 spinal nerve is approximately level with the nipple line.

T6 Sensation of T6 spinal nerve root is approximately level with the bottom of the sternum.

T10 Sensation of T10 spinal nerve root is approximately level with the abdomen.

T12 Sensation of T12 spinal nerve root is approximately level with the pubic bone.

The spinal cord ends approximately between L1 & L2.

Sacral cord segments (S1-S5 “Cauda Equina”) are level with T12-L1 Vertebrae.

The sacral vertebrae are fused to make up:

L5

S1

S3 Sensation of S3, S4 & S5 nerves is the
Neurons are the basic building blocks of the nervous system. They are highly specialized cells responsible for communicating information throughout the body in both electrical and chemical form.
Types of Nerves (neurons)

1. Sensory (afferent) nerves which detect changes in the environment and carry those messages to the brain and spinal cord from the sense organs.

2. Interneurons which are located between sensory and motor nerves and carry impulses between those nerves.

3. Motor (efferent) nerves which allow us to respond to our environment by carrying impulses away from the brain and spinal cord to muscles.
Cranial Nerves

There are twelve pair of cranial nerves. These nerves are continuous with the brain and are numbered from anterior to posterior, according to their attachments to the brain.

- CN-I is attached to the cerebral hemispheres.
- CN-II is attached to the central cerebrum via the optic chiasma (hypothalamus).
- CN-III and IV are attached to the midbrain.
- CN-V, VI, VII, and VIII are attached to the pons.
- CN-IX, X XI and XII are attached to the medulla oblongata.

Some cranial nerves are purely afferent (sensory); others are entirely efferent (motor); and some are mixed (both sensory and motor).
# Cranial Nerves

<table>
<thead>
<tr>
<th>Cranial Nerve</th>
<th>Major Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>I</strong> Olfactory</td>
<td>smell (sensory)</td>
</tr>
<tr>
<td><strong>II</strong> Optic</td>
<td>vision</td>
</tr>
<tr>
<td><strong>III</strong> Oculomotor</td>
<td>eyelid and eyeball movement (motor)</td>
</tr>
<tr>
<td><strong>IV</strong> Trochlear</td>
<td>innervates superior oblique turns eye downward and laterally (motor)</td>
</tr>
<tr>
<td><strong>V</strong> Trigeminal</td>
<td>chewing face &amp; mouth touch &amp; pain (mixed)</td>
</tr>
<tr>
<td><strong>VI</strong> Abducens</td>
<td>turns eye laterally (motor)</td>
</tr>
<tr>
<td><strong>VII</strong> Facial</td>
<td>controls most facial expressions secretion of tears &amp; saliva, taste (mixed)</td>
</tr>
<tr>
<td><strong>VIII</strong> Vestibulocochlear</td>
<td>hearing (sensory)equilibrium sensation  (auditory)</td>
</tr>
<tr>
<td><strong>IX</strong> Glossopharyngeal</td>
<td>taste (mixed) senses carotid blood pressure</td>
</tr>
<tr>
<td><strong>X</strong> Vagus</td>
<td>senses aortic blood pressure slows heart rate stimulates digestive organs taste (mixed)</td>
</tr>
<tr>
<td><strong>XI</strong> Spinal Accessory</td>
<td>controls trapezius &amp; sternocleidomastoid controls swallowing movements (motor)</td>
</tr>
<tr>
<td><strong>XII</strong> Hypoglossal</td>
<td>controls tongue movements (motor)</td>
</tr>
</tbody>
</table>

[Diagram of cranial nerves]
Cranial Nerves

To help memorize each, a mnemonic is often used by students such as . . .

"On Old Olympic Towering Tops
A Finn And German Viewed Some Hops"

Click below to learn more about the function and location of all twelve cranial nerves.

Introduction to Cranial Nerves
The autonomic nervous system is one division of the Peripheral Nervous System (PNS).

The autonomic nervous system (ANS) is an involuntary division of the nervous system that consists of motor neurons (efferent neurons) that conduct impulses from the brain stem or spinal cord to cardiac muscle, smooth muscle and glands. These motor neurons are responsible for regulating heart rate, regulating peristalsis (smooth muscle contraction of the digestive organs), and the release of secretions from certain glands, such as the salivary glands in the mouth.

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The Sympathetic Nervous System

- Controls the body in times of stress/distress (“Fight or Flight Response”).
- Increases heart rate and blood pressure
- Makes the pupils dilate
- Inhibits digestion
- Inhibits nasal secretions
- Inhibits production of saliva and mucus
- Inhibits the liver, kidneys, and gallbladder
- Stimulates sweating
- Causes piloerection (hair standing up)
- Makes the lungs dilate
- Increases muscle strength
- Is important for experiencing orgasm
The Parasympathetic Nervous System

- Promotes maintenance of the body at rest. ("Rest and Digest Response")
- Slows the heart rate down
- Decreases blood pressure
- Makes the pupils contract
- Stimulates digestion
- Stimulates production of saliva and mucus
- Causes nasal secretion
- Stimulates the liver, bladder, and kidneys
- Causes constriction inside the lungs
- Is important for sexual arousal
The Sympathetic vs. Parasympathetic Nervous Systems

Click to see the Flash Player video.
The sympathetic and parasympathetic nervous systems do not work only during times of “Fight or Flight” or “Rest and Digest”, but are constantly working together to help your body to maintain homeostasis.
The Enteric Nervous System

The enteric nervous system is a third division of the autonomic nervous system that you don’t hear much about. The enteric nervous system is a meshwork of nerve fibers that innervate the viscera (gastrointestinal tract, pancreas, and gall bladder).

The enteric nervous system is the digestive system’s own, local nervous system. The magnitude and complexity of the enteric nervous system is immense - it contains as many neurons as the spinal cord.

Enteric neurons secrete an intimidating array of neurotransmitters. One major neurotransmitter produced by enteric neurons is acetylcholine. In general, neurons that secrete acetylcholine are excitatory, stimulating smooth muscle contraction, increases in intestinal secretions, release of enteric hormones and dilation of blood vessels.
Norepinephrine is also used extensively for neurotransmission in the gastrointestinal tract, but it derives from extrinsic sympathetic neurons; the effect of norepinephrine is almost always inhibitory and opposite that of acetylcholine.

The enteric nervous system can and does function autonomously, but normal digestive function requires communication links between this intrinsic system and the central nervous system. These links take the form of parasympathetic and sympathetic fibers that connect either the central and enteric nervous systems or connect the central nervous system directly with the digestive tract.

Through these cross connections, the gut can provide sensory information to the CNS, and the CNS can affect gastrointestinal function. Connection to the central nervous system also means that signals from outside of the digestive system can be relayed to the digestive system: for instance, the sight of appealing food stimulates secretion in the stomach.