The nervous system controls the functioning of the human body and is comprised of the brain, spinal cord, cranial nerves and spinal nerves. Along with the endocrine system, it is also responsible for regulating and maintaining body homeostasis. The nervous system uses millions of sensory receptors to monitor changes occurring both inside and outside the body. These changes or stimuli are considered sensory input. The nervous system processes and interprets the sensory input and makes decisions about what should be done at each moment (integration). The nervous system then causes a response by activating effector organs such as muscles or glands in a response called motor output.

Neurons, the functional cells of the nervous system, enable this process of sensory input, integration and motor output to occur seamlessly. Neurons and parts of neurons, within the brain and spinal cord constitute the central nervous system (CNS) and outside the brain and spinal cord constitute the peripheral nervous system (PNS). Functionally, neurons provide communication by means of electrical impulses conducted from one neuron to another to and from the tissues. The PNS, through sensory neurons, conducts sensory information from the tissues of the body to the CNS. The CNS integrates the sensory information to provide an appropriate response. Motor neurons conduct the response from the CNS to the body tissues.
Central Nervous System (CNS) - Spinal cord

The CNS is responsible for integrating and processing neuronal information such as sensory input and motor output (pp.62-63)

- The spinal cord is located in the vertebral column (spinal canal) and extends to L1-L2 in an adult … subarachnoid space extends to lower border of S2. Why is this distinction clinically important?
  - Lumbar puncture usually performed in L3-L4 or L4-L5 interspaces, at level of cauda equina; to keep the spinal cord alive, keep the spinal needle between L3 and L5
- Describe elements of the spinal cord such as the cervical and lumbar enlargements, conus medularis
- Note: We will focus on the spinal cord segment of the CNS as the brain will be covered in more detail during Unit #3; however, the brain will primarily be covered in the neuroscience block during your second year
Central Nervous System (CNS) - Meninges

The meninges are 3 membranous envelopes that surround the CNS; cerebrospinal fluid (CSF) fills the ventricles of the brain and subarachnoid space; function to protect the CNS (pp. 66-67); the three meninges are:

- **Dura mater** (tough mother) - the outermost layer; superficial to the dura mater is the epidural space which is filled with fat and veins; there is normally no space between the dura and arachnoid mater (subdural space) but a space can be created when bleeding occurs
  - The dural sac terminates caudally as does the subarachnoid space at the vertebral level of S2
- **Arachnoid mater** (spider web-like mother)
  - Subarachnoid space - space between the arachnoid and pia mater; filled with CSF
- **Pia mater** (soft mother) - the deepest layer and is fused with spinal cord and brain and cannot be separated from it with the exceptions of the dentate ligaments and filum terminale
Central Nervous System (CNS) - Spinal cord continued ...

In cross section the gray matter of the spinal cord looks like the letter H possessing a cross-bar of gray matter, called the gray commissure, which encloses the central canal. The two posterior projections of the gray matter are the posterior (dorsal) horns; the anterior pair is the anterior (ventral) horns. In addition, there are smaller lateral horns that are only present in the thoracic and upper lumber segments of the cord.

- **Anterior horns** - house neuronal cell bodies of somatic motor neurons. These send their axons out via the anterior roots of the spinal cord to skeletal muscles. The amount of anterior gray matter present at a given level of the spinal cord reflects the amount of skeletal muscle innervated at that particular level. Thus, the anterior horns are largest in the limb-innervating cervical and lumbar regions of the cord and are responsible for the enlargement seen in those regions.

- **Lateral horn** - house neuronal cell bodies of visceral (sympathetic division of autonomic NS) motor neurons that serve visceral organs. Their axons leave the cord via the ventral root along with those of the somatic motor neurons. Therefore, ventral roots can possess both somatic and visceral efferents.

- **Posterior horn** - sensory neurons conducting impulses from peripheral sensory receptors form the dorsal roots of the spinal cord. The neuronal cell bodies of the associated sensory neurons are found in an enlarged region of the posterior root called the posterior root ganglion or spinal ganglion. After entering the cord at the posterior horn, their axons may take a number of routes.
Peripheral Nervous System (PNS) - Spinal nerves

The PNS is responsible for relaying all sensory information from the body tissues to the CNS and all motor information from the CNS to the body tissues; the PNS consists of cranial nerves and spinal nerves (pp. 69-72)

- **Spinal nerve** - a collection of neurons. To be more specific, a spinal nerve consists primarily of the axons of neurons and these axons are oft times referred to as “nerve fibers”. To simplify the terminology from this point on the term “neuron” will be used.

The thousands of sensory neurons in the posterior root and motor neurons in the anterior root are organized into 31 pairs of spinal nerves. Each pair of spinal nerves is named according to their point of issue from the spinal cord within the vertebral canal. The vertebral canal is formed by the vertebral foramina of each individual vertebra, and as such the spinal nerves exit the canal between individual vertebrae in a segmental pattern to reach the peripheral tissues.

- The 31 pairs of spinal nerves are organized as follows
  - 8 **cervical spinal nerves**
  - 12 **thoracic spinal nerves**
  - 5 **lumbar spinal nerves**
  - 5 **sacral spinal nerves**
  - 1 **coccygeal spinal nerve**

Contrast the difference between:
- **Vertebral levels**
- **Spinal cord levels**
- **Spinal nerve levels**

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<th>Regions of the Spinal Cord and Verterbral Column</th>
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Peripheral Nervous System (PNS) - Sensory neurons

Sensory neurons - conduct sensory (afferent) information from the tissues of the body to the CNS; there are two modalities of sensory neurons that spinal nerves transmit to the posterior root from the body tissues:

- **General (somatic afferent) sensory neurons** - transmit sensations such as pain, temperature, touch and pressure to the spinal cord. Also included are proprioceptive sensory neurons that measure changes in joint position and tension of tendons and muscle fibers. General sensory neurons conduct impulses from tissues derived from somites are therefore considered “somatic” neurons. However, the term “general sensory” will be used from this point forward as the information conducted such as “pain” and “temperature” is not specialized to one tissue location such as the retina. These types of sensory neurons are found in all areas of the skin and other general parts of the body.

- **Visceral (visceral afferent) sensory neurons** – convey impulses from viscera such as glands, heart, blood vessels and other body organs and initiate reflex responses to smooth muscle. These neurons are responsible for the perception of hunger, nausea, sexual excitement, bladder distension, pulmonary airway irritation, blood pressure changes, blood oxygen content changes etc.
Peripheral Nervous System (PNS) - Motor neurons

Motor neurons - conduct motor (efferent) information from the CNS to tissues of the body; there are two modalities of motor neurons that spinal nerves transmit from the anterior root to the body tissues:

- **Somatic motor (efferent) neurons** - innervate skeletal muscles and other tissues derived embryologically from somites. Somatic motor neurons are voluntary and accompany general sensory neurons.

- **Visceral motor (efferent) neurons** - supply smooth muscle and glandular tissues. They are in-voluntary and belong to the ANS and can be classified as either sympathetic and parasympathetic visceral motor neurons. Visceral motor neurons accompany visceral sensory neurons.

**Note**: the terms “motor” and “efferent” are synonymous in the context of neurons as are “sensory” and “afferent”. From this point forward the term “motor” and “sensory” will be used instead of “efferent” and “afferent” as they are easier to differentiate during a lecture.
Peripheral Nervous System (PNS) - Rami

Each spinal nerve is quite short (1-2 cm) because almost immediately after emerging from the intervertebral foramen, it divides into a large **anterior ramus** and a smaller **posterior ramus** (pp. 75-76). Each ramus, like the spinal nerve itself is mixed.

- **Posterior rami** - mixed nerves and course sharply around the vertebral column to provide motor innervation to the deep muscles of the back (i.e., erector spinae muscles) and cutaneous/sensory innervation to the associated narrow strip of skin on the back. Posterior rami are distributed in a segmental fashion to the musculature and skin of the back, each nerve supplying a region centered below the center of distribution of the nerve arising above it. The posterior rami do not form plexuses like the anterior rami do.

- **Anterior rami** - mixed nerves as well and supply motor innervation to most other skeletal muscles including limbs and trunk and sensory innervation to most of the remaining skin except for parts of the head. The distribution of many of the anterior rami of the spinal nerves is complicated by the interchange of branches or by formation of **plexuses** in which the identities of the contributing nerves are lost.

![Diagram of Spinal Nerve Ramus](image-url)
Peripheral Nervous System (PNS) - Spinal nerves

- Review the following on a cross section of the spinal cord and identify their function:
  - Anterior root - contains motor neurons
  - Posterior root (posterior root ganglion) - contains sensory neurons
  - Anterior ramus - contains both motor and sensory neurons for the body (except back and head)
  - Posterior ramus - contains both motor and sensory neurons for the back
  - Sympathetic ganglion - location of synapse for pre and post ganglionic sympathetic neurons; examples include paravertebral and prevertebral ganglia
  - White ramus communicans - contains preganglionic sympathetic neurons
  - Gray ramus communicans - contains postganglionic sympathetic neurons
  - Spinal nerve - where sensory and motor neurons from roots and rami meet
Peripheral Nervous System (PNS) continued ...

- Spinal nerves are segmentally arranged, and the distribution of their fibers to skin and muscle through posterior rami and anterior rami is referred to as the segmental distribution of the spinal nerves.
- Understand the concept of a dermatome and the level for each of the following:
  - Posterior half of skull cap
  - Nipple
  - Xiphoid process
  - Umbilicus
  - Inguinal ligament
  - Patella
Overview of the Nervous System

- CNS
- PNS
- Sensory
- Motor
- General Afferent
- Somatic Efferent
- Skeletal muscle of the body wall
- Touch
- Pain
- Temperature
- Vibration
- Proprioception