Overview of Spinal Nerves

Spinal nerves, a part of the PNS, generally refers to mixed nerves, with motor, sensory, and autonomic signals between the CNS and the body.

1. Spinal nerves arise from a combination of nerve fibers: the dorsal and ventral roots of the spinal cord.
   - Afferent sensory axons, bringing sensory information from the body to the spinal cord and brain, travel through the dorsal roots of the spinal cord, and efferent motor axons, bringing motor information from the brain to the body, travel through the ventral roots of the spinal cord.
   - All spinal nerves except the first pair emerge from the spinal column through an opening between vertebrae, called an intervertebral foramen.
   - The spinal nerves are typically labeled by their location in the body: thoracic, lumbar, or sacral.
   - **Dorsal Root**: Also known as the posterior root, the afferent sensory root of a spinal nerve.
   - **Autonomic**: Acting or occurring involuntarily, without conscious control.
   - **Intervertebral Foramen**: The foramen allows for the passage of the spinal nerve root, dorsal root ganglion, the spinal artery of the segmental artery, communicating veins between the internal and external plexuses, recurrent meningeal (sinu-vertebral) nerves, and transforaminal ligaments.
fig. 2 shows intervertebral foramina

Intervertebral foramina are indicated by arrows.

**Spinal Nerves**

The term spinal nerve generally refers to a mixed spinal nerve, which carries motor, sensory, and autonomic signals between the spinal cord and the body.

Humans have 31 left-right pairs of spinal nerves, each roughly corresponding to a segment of the vertebral column: eight cervical spinal nerve pairs (C1-C8), 12 thoracic pairs (T1-T12), five lumbar pairs (L1-L5), five sacral pairs (S1-S5), and one coccygeal pair. The spinal nerves are part of the peripheral nervous system (PNS).

**Location:**

Each spinal nerve is formed by the combination of nerve fibers from the dorsal and ventral roots of the spinal cord (Figure 0). The dorsal roots carry afferent sensory axons, while the ventral roots carry efferent motor axons. The spinal nerve emerges from the spinal column through an opening (intervertebral foramen) (Figure 1) between adjacent vertebrae. This is true for all spinal nerves except for the first spinal nerve pair, which emerges between the occipital bone and the atlas (the first vertebra). Thus the cervical nerves are numbered by the vertebra below, except C8, which exists below C7 and above T1. The thoracic, lumbar, and sacral nerves are then numbered by the vertebra above. In the case of a lumbarized S1 vertebra (aka L6) or a sacralized L5 vertebra, the nerves are typically still counted to L5 and the next nerve is S1.

**Targets:**

Outside the vertebral column, the nerve divides into branches. The dorsal ramus contains nerves that serve the dorsal portions of the trunk, carrying visceral motor, somatic motor, and somatic sensory information to and from the skin and muscles of the back (epaxial muscles). The ventral ramus contains nerves that serve the remaining ventral parts of the trunk and the upper and lower limbs (hypaxial muscles), carrying visceral motor, somatic motor, and sensory information to and from the ventrolateral body surface, structures in the body wall, and the limbs. The meningeal branches (recurrent meningeal or sinuvertebral nerves) branch from the spinal nerve and re-enter the intervertebral foramen to serve the ligaments, dura, blood vessels, intervertebral discs, facet joints, and periosteum of the vertebrae. The rami communicantes contain autonomic nerves that serve visceral functions carrying visceral motor and sensory information to and from the visceral organs.
Branches:

The spinal nerves branch into the dorsal ramus, ventral ramus, the meningeal branches, and the rami communicantes.

3.

fig. 3 shows the course and branches of thoracic spinal nerve

This diagram depicts the course and branches of a typical thoracic spinal nerve. The posterior division is labeled at the top right.

- The dorsal and ventral rami contain nerves that provide visceral motor, somatic motor, and sensory information, with the dorsal ramus feeding the dorsal trunk (skin and muscles of the back) and the ventral ramus feeding the ventral trunk and limbs, through the ventrolateral surface.
- The meningeal branches supply nerve function to the vertebrae themselves, including the ligaments, dura, blood vessels, intervertebral discs, facet joints, and periosteum, and the rami communicates contain autonomic nerves to serve the visceral organs.
- The vagus nerve is the 10th of 12 paired cranial nerves. Upon leaving the medulla between the medullary pyramid and the inferior cerebellar peduncle, it extends through the jugular foramen.
- **Meningeal Branches:** The meningeal branches of the spinal nerves (also known as recurrent meningeal nerves, sinuvertebral nerves, or recurrent nerves of Luschka) are a number of small nerves that branch from the spinal nerve (or the posterior ramus) near the origin of the anterior and posterior rami. They then re-enter the intervertebral foramen, and innervate the facet joints, the annulus fibrosus of the intervertebral disk, and the ligaments and periosteum of the spinal canal, carrying pain sensation.
- **Dorsal Ramus:** The posterior (or dorsal) branches (or divisions) of the spinal nerves are as a rule smaller than the anterior divisions. They are also referred to as the dorsal rami. They are directed backwards, and, with the exceptions of those of the first cervical, the fourth and fifth sacral, and the coccygeal, divide into medial and lateral branches for the supply of the muscles and skin of the posterior part of the trunk.
Outside the vertebral column, the spinal nerves divide into branches. The dorsal ramus contains nerves that serve the dorsal portions of the trunk carrying visceral motor, somatic motor, and sensory information to and from the skin and muscles of the back. The ventral ramus contains nerves that serve the remaining ventral parts of the trunk and the upper and lower limbs carrying visceral motor, somatic motor, and sensory information to and from the ventrolateral body surface, structures in the body wall, and the limbs. The meningeal branches (recurrent meningeal or sinuvertebral nerves) branch from the spinal nerve and re-enter the intervertebral foramen to serve the ligaments, dura, blood vessels, intervertebral discs, facet joints, and periosteum of the vertebrae. The rami communicants contain autonomic nerves that serve visceral functions carrying visceral motor and sensory information to and from the visceral organs.

Some ventral rami merge with adjacent ventral rami to form a nerve plexus, a network of interconnecting nerves. Nerves emerging from a plexus contain fibers from various spinal nerves, which are now carried together to some target location. Major plexuses include the cervical, brachial, lumbar, and sacral plexuses.

The vagus nerve is the 10th of 12 paired cranial nerves. Upon leaving the medulla between the medullary pyramid and the inferior cerebellar peduncle, it extends through the jugular foramen, then passes into the carotid sheath between the internal carotid artery and the internal jugular vein down below the head, to the neck, chest and abdomen, where it contributes to the innervation of the viscera. Besides output to the various organs in the body, the vagus nerve conveys sensory information about the state of the body's organs to the central nervous system. 80-90% of the nerve fibers in the vagus nerve are afferent (sensory) nerves communicating the state of the viscera to the brain.

**Plexuses:**

A nerve plexus is a network of intersecting nerve fibers consisting of nerves that serve the same part of the body.
The lumbar plexus is comprised of the ventral rami of the lumbar spinal nerves (L1-L5) and a contribution from the thoracic nerve (T12). The posterior (green) and anterior (yellow) divisions of the lumbar plexus are shown in the diagram.

- Nerve plexuses throughout the body tend to be named after the area in which the plexus occurs and the organs, limbs, and tissues it serves. Examples include the cervical, brachial, lumbar, sacral, celiac, and coccygeal plexuses.
- Auerbach’s plexus, which serves the gastrointestinal tract, is named after the first person to describe this plexus, Leopold Auerbach, rather than the area of the body it serves.
- The brachial plexus serves the chest, shoulders, arms and hands and is formed by the ventral rami of C5-C8-T1 spinal nerves, and lower and upper halves of C4 and T2 spinal nerves.
- **Coccygeal Plexus:** The coccygeal plexus is a plexus of nerves near the coccyx bone.
- **Nerve Plexus:** A nerve plexus is a network of intersecting nerves.
- **Brachial Plexus:** The brachial plexus is a network of nerve fibers, running from the spine, formed by the ventral rami of the lower four cervical and first thoracic nerve roots (C5-C8, T1). It proceeds through the neck, the axilla (armpit region), and into the arm. It is a bunch of nerves passing through the cervico-axillary canal to reach axilla and supplies the brachium, the antebrachium, and the hand.
5.

Cervical (C5-C8) and thoracic (T1) comprise the brachial plexus, which is a nerve plexus that provides sensory and motor function to the shoulders and upper limbs.

A nerve plexus is a network of intersecting nerves; multiple nerve plexuses exist in the body. Examples include: the cervical, brachial, lumbar, sacral, celiac, and coccygeal plexuses. The plexus is the characteristic form of nervous system in the coelenterates and persists with modifications in the flatworms. The nerves of the radially symmetric echinoderms also take this form, where a plexus underlies the ectoderm of these animals. Deeper in the body other nerve cells also form plexi of limited extent.

The cervical plexus serves the head, neck, and shoulders and is formed by the ventral rami of the upper four cervical nerves and the upper part of fifth cervical ventral ramus. The network of rami is located deep within the neck. The brachialplexus serves the chest, shoulders, arms and hands and is formed by the ventral rami of C5-C8-T1 spinal nerves, and lower and upper halves of C4 and T2 spinal nerves (Figure 1). The plexus extends toward the armpit (axilla). The lumbarplexus serves the back, abdomen, groin, thighs, knees, and calves and is formed by the ventral rami of L1-L5 spinal nerves with a contribution of T12 form lumbarplexus (Figure 0). This plexus lies within the psoas major muscle. The sacralplexus serves the pelvis, buttocks, genitals, thighs, calves, and feet and is formed by the ventral rami of L4-S3, with parts of L4 and S4 spinal nerves. It is located on the posterior wall of pelvic cavity.

The coccygeal plexus serves a small region over the coccyx and originates from S4, S5, and Co1 spinal nerves. It is interconnected with the lower part of sacral plexus. In addition, the celiac plexus serves the internal organs and Auerbach's plexusserves the gastrointestinal tract.

**Intercostal Nerves:**

The anterior divisions of the thoracic spinal nerves (T1-T11) are called the intercostal nerves.
fig. 5. Shows intercostal nerves

This diagram shows the intercostal nerves, in yellow, viewed with the superficial muscles removed.

- The intercostal nerves arise from the somatic nervous system. This enables them to control the contraction of muscles, as well as provide specific sensory information regarding the skin and parietal pleura.
- Intercostal nerves connect to the appropriate ganglion in the sympathetic trunk through rami communicans and serve the thoracic pleura and the abdominal peritoneum.
- Unlike most other anterior divisions of spinal nerves, the intercostal nerves do not form a plexus.
- **Thoracic Spinal Nerves**: The thoracic nerves are the spinal nerves emerging from the thoracic vertebrae. Branches also exit the spine and go directly to the sympathetic chain.
ganglia of the autonomic nervous system where they are involved in the functions of organs and glands in the head, neck, thorax, and abdomen.

- **Sympathetic Trunk:** The sympathetic trunks (sympathetic chain, gangliated cord) are a paired bundle of nerve fibers that run from the base of the skull to the coccyx.
- **Abdominal Peritoneum:** The peritoneum is the serous membrane that forms the lining of the abdominal cavity or the coelom—it covers most of the intra-abdominal (or coelomic) organs—in amniotes and some invertebrates (annelids, for instance). It is composed of a layer of mesothelium supported by a thin layer of connective tissue. The peritoneum both supports the abdominal organs and serves as a conduit for their blood and lymph vessels and nerves.

The intercostal nerves are part of the somatic nervous system, and arise from anterior divisions (rami anteriores; ventral divisions) of the thoracic spinal nerves from T1 to T11. The intercostal nerves are distributed chiefly to the thoracic pleura and abdominal peritoneum and differ from the anterior divisions of the other spinal nerves in that each pursues an independent course without plexus formation.

The first two nerves supply fibers to the upper limb in addition to their thoracic branches. The anterior division of the first thoracic nerve divides into two branches: one, the larger, leaves the thorax in front of the neck of the first rib, and enters the brachial plexus; the other smaller branch, the first intercostal nerve, runs along the first intercostal space, and ends on the front of the chest as the first anterior cutaneous branch of the thorax.

The next four are limited in their distribution to the parietes of the thorax; the lower five supply the parietes of the thorax and abdomen. The seventh intercostal nerve terminates at the xiphoid process, at the lower end of the sternum. The tenth intercostal nerve terminates at the umbilicus. The twelfth (subcostal) thoracic is distributed to the abdominal wall and groin.

Unlike the nerves from the autonomic nervous system that innervate the visceral pleura of the thoracic cavity, the intercostal nerves arise from the somatic nervous system. This enables them to control the contraction of muscles, as well as provide specific sensory information regarding the skin and parietal pleura. This explains why damage to the internal wall of the thoracic cavity can be felt as a sharp pain localized in the injured region. Damage to the visceral pleura is experienced as an un-localized ache.

**Dermatomes:**

A dermatome is an area of skin that is supplied by a single spinal nerve.
5.

Fig. 5. shows dermatomes

Dermatomes are areas of skin supplied by sensory neurons that arise from a spinal nerve ganglion. Dermatomes and the associated major cutaneous nerves are shown here in a ventral view.

- There are eight cervical nerves, twelve thoracic nerves, five lumbar nerves and five sacral nerves. Each of these nerves relays sensation, including pain, from a particular region of skin to the brain.
- Along the thorax and abdomen the dermatomes are like a stack of discs, with each section each supplied by a different spinal nerve. Along the arms and the legs, the pattern is different. The dermatomes run longitudinally along the limbs, so that each half of the limb has a different dermatome.
Dermatomes have clinical significance, especially in the diagnosis of certain diseases. Symptoms that follow a dermatome, such as pain or a rash, may indicate a pathology that involves the related nerve root. Examples include dysfunction of the spine or a viral infection.

**Chickenpox**: A common childhood disease caused by the varicella-zoster virus (VZV).

**Shingles**: Also known as herpes zoster, shingles is an acute viral inflammation of the sensory ganglia of spinal and cranial nerves associated with a vesicular eruption and neuralgic pains and caused by reactivation of the poxvirus causing chickenpox.

The shingles rash appears across a dermatome. In this patient, one of the dermatomes in the arm is affected, restricting the rash to the length of the back of the arm.

A dermatome is an area of skin that is supplied by a single spinal nerve (Figure 0). There are eight cervical nerves, twelve thoracic nerves, five lumbar nerves and five sacral nerves. Each of these nerves relays sensation, including pain, from a particular region of the skin to the brain. Along the thorax and abdomen, the dermatomes are like a stack of discs, with each section supplied by a different spinal nerve. Along the arms and the legs, the pattern is different. The dermatomes run longitudinally along the limbs, so that each half of the limb has a different dermatome. Although the general pattern is similar in all people, the precise areas of innervation are as unique to an individual as fingerprints.

Dermatomes have clinical significance, especially in the diagnosis of certain diseases. Symptoms that follow a dermatome, such as pain or a rash, may indicate a pathology that involves the related nerve root. Examples include dysfunction of the spine or a viral infection. Viruses that remain dormant in nerve ganglia, such as the Varicella zoster virus, which causes both chickenpox and shingles, often cause either pain, rash or both in a pattern defined by a dermatome (Figure 1). Shingles is one of the only diseases that causes a rash in a dermatomal pattern, and as such, this is its defining symptom. The rash of shingles is almost always restricted to a specific dermatome, such as on the chest, leg or arm, caused by the residual infection of the nerve that supplies that area of skin with the varicella zoster virus. Shingles typically appears years or decades after recovery from chickenpox.
Function and Physiology of the Spinal Nerves:

Spinal nerves connect the brain and spinal cord to the limbs and organs of the body.

7.

This diagram indicates the formation of a typical spinal nerve from the dorsal and ventral roots. Numbers indicate types of nerve fibers: 1 somatic efferent, 2 somatic afferent, 3-5 sympathetic efferent, 6-7 sympathetic afferent.

- Spinal nerves, considered part of the peripheral nervous system, generally refer to mixed spinal nerves, which carry motor, sensory, and autonomic information between the brain and spinal cord and the rest of the body.
- The cervical spinal nerves innervate the muscles and provide sensation for the head, neck, and diaphragm, as well as the upper limbs and back.
- The lumbar, sacral, and coccygeal nerves combine to form the lumbosacral plexus.
- **Peripheral Nervous System:** This system consists of the nerves and ganglia outside of the brain and spinal cord.
- **Mixed Spinal Nerve:** The term spinal nerve generally refers to a mixed spinal nerve, which carries motor, sensory, and autonomic signals between the spinal cord and the body.

The peripheral nervous system (PNS) consists of the nerves and ganglia outside of the brain and spinal cord. The main function of the PNS is to connect the central nervous system (CNS) to the limbs and organs. Unlike the CNS, the PNS is not protected by the bone of spine and skull, or by the blood–brain barrier, leaving it exposed to toxins and mechanical injuries. The peripheral nervous system is divided into the somatic nervous system and the autonomic nervous system.
The peripheral nervous system includes 12 cranial nerves and 31 pairs of spinal nerves, which provide communication from the CNS to the rest of the body by nerve impulses that regulate the functions of the human body. The term spinal nerve generally refers to a mixed spinal nerve, which carries motor, sensory, and autonomic signals between the spinal cord and the body. Humans have 31 left-right pairs of spinal nerves, each roughly corresponding to a segment of the vertebral column: 8 cervical spinal nerve pairs (C1-C8), 12 thoracic pairs (T1-T12), 5 lumbar pairs (L1-L5), 5 sacral pairs (S1-S5), and 1 coccygeal pair.

The first 4 cervical spinal nerves, C1 through C4, split and recombine to produce a variety of nerves that subserve the neck and back of the head. Spinal nerve C1 is called the suboccipital nerve, which provides motor innervation to muscles at the base of the skull. C2 and C3 form many of the nerves of the neck, providing both sensory and motor control. These include the greater occipital nerve which provides sensation to the back of the head, the lesser occipital nerve which provides sensation to the area behind the ears, the greater auricular nerve, and the lesser auricular nerve. The phrenic nerve arises from nerve roots C3, C4, and C5. It innervates the diaphragm, enabling breathing. If the spinal cord is transected above C3, then spontaneous breathing is not possible.

The last four cervical spinal nerves, C5 through C8, and the first thoracic spinal nerve, T1, combine to form the brachial plexus, or plexus brachialis, a tangled array of nerves, splitting, combining and recombining, to form the nerves that subserve the upper limb region and upper back. Although the brachial plexus may appear tangled, it is highly organized and predictable, with little variation between people.

The anterior divisions of the lumbar nerves, sacral nerves, and coccygeal nerve form the lumbosacral plexus, the first lumbar nerve being frequently joined by a branch from the twelfth thoracic. For descriptive purposes this plexus is usually divided into three parts: lumbar plexus, sacral plexus, and pudendal plexus.