THE PERIPHERAL NERVOUS SYSTEM

The peripheral nervous system was introduced in plate 82. Here we focus on the peripheral nerves which communicate signals between the CNS and periphery, and may be associated with the brain (*cranial nerves) or* spinal cord (*spinal nerves).* Peripheral nerves may be sensory or motor, or mixed; many of them contain *autonomic fibers.*

CRANIAL AND SPINAL NERVES

Cranial nerves are associated with the brain & perform diverse functions—The 12 pairs of cranial nerves are referred to by names or by roman numerals and emerge from different brain sites. A summary of their functions is provided here:

No.	Name	Type	Specific Function
I	Olfactory	Sensory	Afferents to olfactory bulb.
II	Optic	Sensory	Visual afferents from eye to brain.
III	Oculomotor	Somatic motor Parasympathetic	Eye movements (up, down, medial). Lens accommodation, pupil constriction.
IV	Trochlear	Motor Sensory	Eye movements (down & lateral). Afferents from muscle receptors.
V	Trigeminal	Sensory Motor	Face, teeth, nasal mucosa and mouth. Mastication (chewing).
VI	Abducens	Motor	Eye movements (lateral).
VII	Facial	Sensory Motor Parasympathetic	Pressure, proprioception from face; taste signals from anterior 2/3 of tongue. Facial expression. Stimulates salivary and tear glands.
VIII	Vestibulo-cochlear	Sensory	Hearing & balance.
IX	Glosso-pharyngeal	Motor Sensory Parasympathetic	Swallowing muscles in pharynx. Taste from posterior 1/3 of tongue; blood pressure receptors. Stimulates salivary glands.
X	Vagus	Parasympathetic motor Visceral sensory	Soft palate, pharynx, heart and digestive organs. Sensation from ear canal, diaphragm, abdominal and chest visceral organs.
XI	Accessory	Motor	Muscles of palate, pharynx, larynx, and some neck and shoulder muscles.
XII	Hypoglossal	Motor	Tongue movement.

Spinal nerves are mixed & each is associated with one vertebrae—There are 31 pairs of *spinal nerves* , each formed from the union of fibers emerging from the spinal cord *dorsal roots (sensory fibers)* and *ventral roots (motor and autonomic fibers).* Like their corresponding vertebrae, the spinal nerves are divided into 8 cervical (neck), 12 thoracic (chest), 5 lumbar (loin, lower back), and 5 sacral (sacrum bone). There is also one coccygeal nerve. The cervical nerves innervate targets in the neck, shoulders, and arms; thoracic nerves innervate the trunk; lumbar nerves affect the legs; and sacral-coccygeal nerves supply the genitalia, pelvic, and groin areas. The largest spinal nerve, the sciatic nerve, is actually two nerves in one, and supplies the leg with both motor and sensory fibers. Some of the spinal nerves on their route to their targets form nerve plexuses: cervical plexus (C1–C5); brachial (C5–T1), and lumbosacral (T12–L4 & L4–S4).

Dermatomes & myotomes are supplied by corresponding spinal nerves—Careful nerve dissection, and examination of patients with neurological defects has revealed that each patch of the skin surface is innervated by a specific sensory nerve, with some overlap. This is best shown in the trunk where the upper trunk is supplied by thoracic nerves T2–T6 while the lower trunk by T7–T12, all in an orderly manner. These *dermatome maps* are not as orderly in the arms and legs areas due to changes in body configuration and rotation during the development of the body. In the embryo, the body is segmented into several somites, each receiving its nerve from the adjacent spinal cord segment. A dermatome is the portion of somite that becomes the skin. Similarly there are myotomes for muscles. The orderly correspondence of human dermatomes with spinal nerve supplies is best shown in the quadrupedal position. The dermatomes of the head are supplied in a similar fashion by the cranial nerves.

AUTONOMIC NERVES & GANGLIA

The autonomic nervous system (ANS) and the targets and functional effects of the autonomic nerves were introduced in plate 29 and in plates where specific systems and organs are controlled by the ANS. Autonomic regulation is carried out by two types of nerves: *sympathetic* and *parasympathetic.* Autonomic motor nerves regulate motility and secretion in skin, blood vessels, and visceral organs by stimulating smooth muscles and exocrine glands. This plate deals with anatomic organization, pathways and central control of autonomic nerves.

Sympathetic motor outflow via thoracic & lumbar spinal nerves—Sympathetic nerves innervate many visceral (heart, digestive organs) and peripheral (skin glands, blood vessels, and skeletal muscle arterioles) targets. Targets in the head (e.g., the iris of the eyes) receive sympathetic innervation by spinal nerves. Sympathetic nerves found within the spinal nerve trunks are usually unmyelinated, *postganglionic fibers*— their cell bodies are in the *sympathetic ganglia* chain, located on both sides of the vertebral column. The postganglionic sympathetic neurons are driven by the shorter myelinated *preganglionic sympathetic* neurons located in the spinal cord lateral horns with their axons terminating in the ganglia chain.

Sympathetic chain neurons are connected by interneurons which help in the generalized discharge characteristic of the sympathetic NS. Other sympathetic ganglia are found in the viscera, in relation to splanchnic nerves, innervating targets like the stomach and the adrenal medulla. In accord with the non-selective and diffuse function of the sympathetic NS, the sympathetic fibers innervate practically every visceral and peripheral organ in the body, particularly the blood vessels, thus controlling the blood flow in those organs.

Parasympathetic nerves emerge from the brainstem & sacral spinal cord—The parasympathetic nerves are associated with four cranial nerves: III, VII, IX, X, and with the sacral spinal nerves. A prominent parasympathetic nerve is the vagus "wanderer" (cranial nerve X), which innervates many visceral organs, including the lungs, heart, and digestive tract. The parasympathetic nerve fibers are basically preganglionic, with cell bodies in the brain stem motor nuclei and sacral spinal cord. The postganglionic neuron is short and emerges from a peripheral ganglia located near or in the target organ. Parasympathetic innervation of visceral organs is selective; profuse in heart and digestive organs but sparse in kidneys.

Hypothalamus & medulla serve in central ANS control—The ANS fibers are controlled by nerve centers in the brain stem, particularly the medulla and the hypothalamus. The medullary centers exert routine automatic control over cardiovascular, respiratory, and digestive systems. The sympathetic hypothalamic centers are involved in controlling body temperature and bodily responses to fear and excitement, fight and flight. Descending neurons from these hypothalamic and medullary centers terminate on, and stimulate the preganglionic autonomic neurons in the midbrain and spinal cord, which in turn stimulate the postganglionic neurons going to the peripheral effectors.

CN: Use dark colors for C and E.

1. Begin with the peripheral nerves. Note that the 12 cranial nerves contain various sensory, motor, and parasympathetic (autonomic) nerves. Spinal nerves contain all three, as seen in the enlarged cut nerve. Color all the peripheral nerves.
2. Color the large diagram of the spinal nerves. Begin with the anatomical portion to the left and include the directional arrows. Then color the cutaway drawing on the right side. Note that the title autonomic efferent motor, refers to both the sympathetic and parasympathetic nerves, and is colored gray. In this large illustration only the sympathetic system (F) is shown; the parasympathetic (G) is included in the bottom diagram.

The peripheral nervous system (PNS) consists of peripheral nervous structures and nerves that serve in the somatic and autonomic divisions. In the somatic division, sensory nerves connect the special (e.g., ear) and general (e.g., skin) sensory receptors to the spinal cord (SC) and brain, and motor nerves connect the central nervous system (CNS) to the skeletal muscles. In the autonomic division, visceral sensory fibers (inflow) and the sympathetic (S) and parasympathetic (PS) fibers (motor outflow) connect the visceral organs and effectors to the S and PS ganglia as well as to the SC and brain. Fibers within a nerve trunk vary in size and speed of conduction.

PERIPHERAL NERVES

Of the total of 43 pairs of peripheral nerves, 12 are associated with the brain (cranial nerves) and 31 with the SC (spinal nerves). Cranial nerves emerge directly from the brain, but the spinal nerves form by the merger of the dorsal and ventral roots of the SC. The cranial nerves are identified by names or roman numerals; spinal nerves by name and number of corresponding vertebrae. Some cranial nerves are purely sensory, others are motor or mixed. Some contain partly parasympathetic (autonomic) fibers; others are largely parasympathetic. Spinal nerves are generally mixed, containing sensory, motor, and autonomic fibers.

12 PR. CRANIAL, 31 PR. SPINAL NERVES$_A$

SPINAL NERVES (31 PAIR)$_A$

DORSAL ROOT & GANGLION$_B$

SOMATIC & VISCERAL AFFERENT SENSORY N.$_C$

VENTRAL ROOT, SOMATIC, EFFERENT MOTOR NERVE$_E$

AUTONOMIC EFFERENT MOTOR:*

SYMPATHETIC: PREGANGLIONIC F

POSTGANGLIONIC F' SYMPATHETIC CHAIN, F^2 GANGLION, F^3

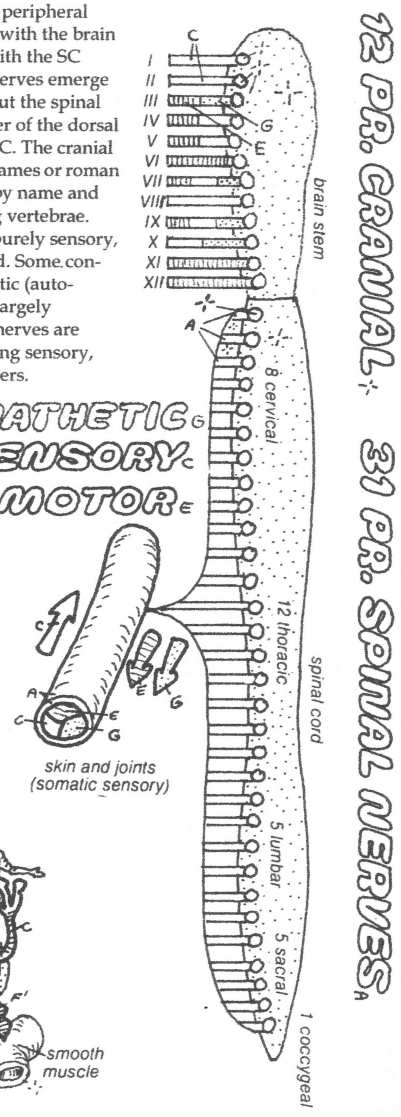
PARASYMPATHETIC: PREGANG. G

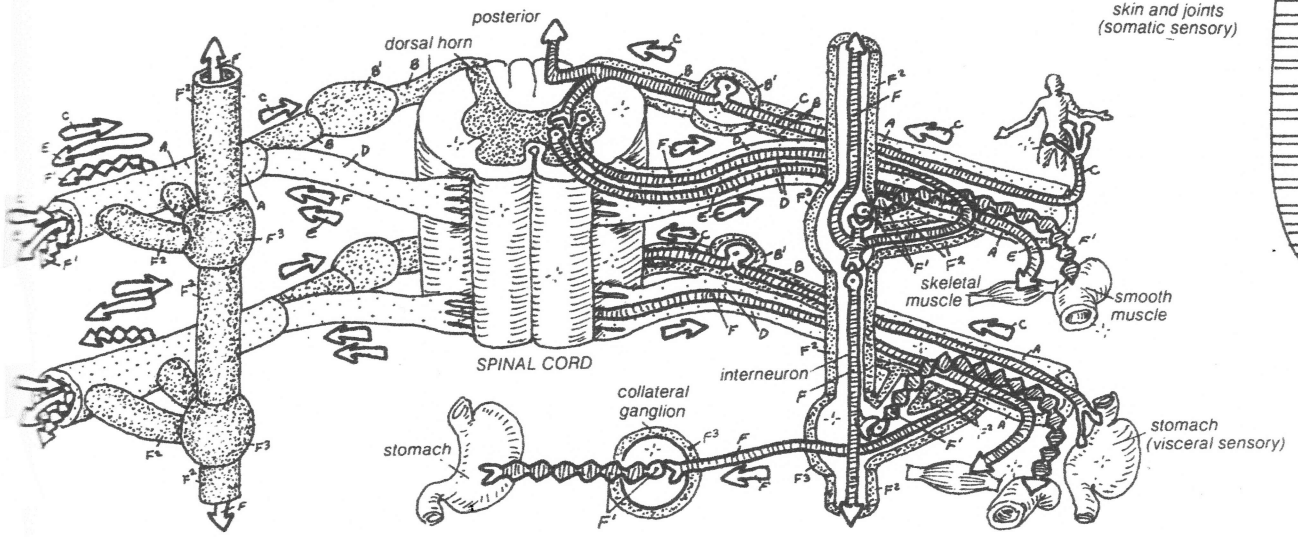
POSTGANGLIONIC G' GANGLION G^2

PARASYMPATHETIC$_G$

SENSORY$_C$

MOTOR$_E$





The sensory afferents from visceral organs enter the CNS via cranial or spinal nerves. Motor outflow to visceral effectors is via the S and PS motor fibers. PS fibers leave via the cranial and sacral nerves, the S outflow is via the thoracic and lumbar spinal nerves. Between the CNS and its visceral targets, both S and PS outflow consist of two neurons and a ganglion (G). The first neuron (pre-G) beginning in the brain or the SC, synapses with the second neuron (post-G) inside G. The G of the S system are located parallel to the SC, forming a chain. The G of the PS system are located near the target organs. Some targets (e.g., the stomach) contain complicated nervous networks (plexus) of their own that are innervated by the post-G fibers. The pre-G sympathetic fibers begin in the intermediate motor horns of the SC and terminate in the S ganglia. The post-G neurons leave the G and course along a spinal nerve to serve blood vessels and sweat glands of the somatic area served by that spinal nerve. Other post-G fibers in the S system leave the G to reach their target via an independent visceral nerve. The neurons in the S ganglia are connected by interneurons, allowing for simultaneous and generalized discharge from several S ganglia, even when only one G is activated from the brain or periphery. In contrast, the proximity of PS ganglia with their targets and lack of inter-G connections allow for discrete activation of specific targets by the PS system. Both S and PS pre-G neurons within the brain or SC are controlled by descending fibers from higher centers in the hypothalamus and medulla, enabling the hypothalamus and medullary centers to exert their control over internal bodily functions (digestion, blood flow, etc.). Also, via its connections with the limbic system, the hypothalamus controls internal bodily responses during arousal and emotional states.

SOMATIC & AUTONOMIC* MOTOR RESPONSE