ORGANIZATION

CN: Use very light colors for A and C. The numbers in parentheses following the titles under Spinal Nerves refer to the number of nerves in each of the regions listed. (1) In the central illustration, the spinal cord has been brought out of the vertebral column to show its regions in relation to the vertebrae. Spinal nerves, depicting regional limits, are shown with arrowheads pointing to the same spinal nerves emerging from the vertebral column. Avoid coloring the filum terminale—it is not a spinal nerve. (2) At upper right, color the cranial nerves. (3) At lower right, color over the lines representing the spinal nerves and their branches on the left side of the figure. Color the autonomic ganglia on the right side of the spinal cord.

CENTRAL NERVOUS SYSTEM (CNS)

- BRAIN
  - CEREBRUM A
  - BRAINSTEM B
  - CEREBELLUM C
- SPINAL CORD D
  - REGIONS D
    - CERV. G THOR. H LUM. I SAC. J COC. K

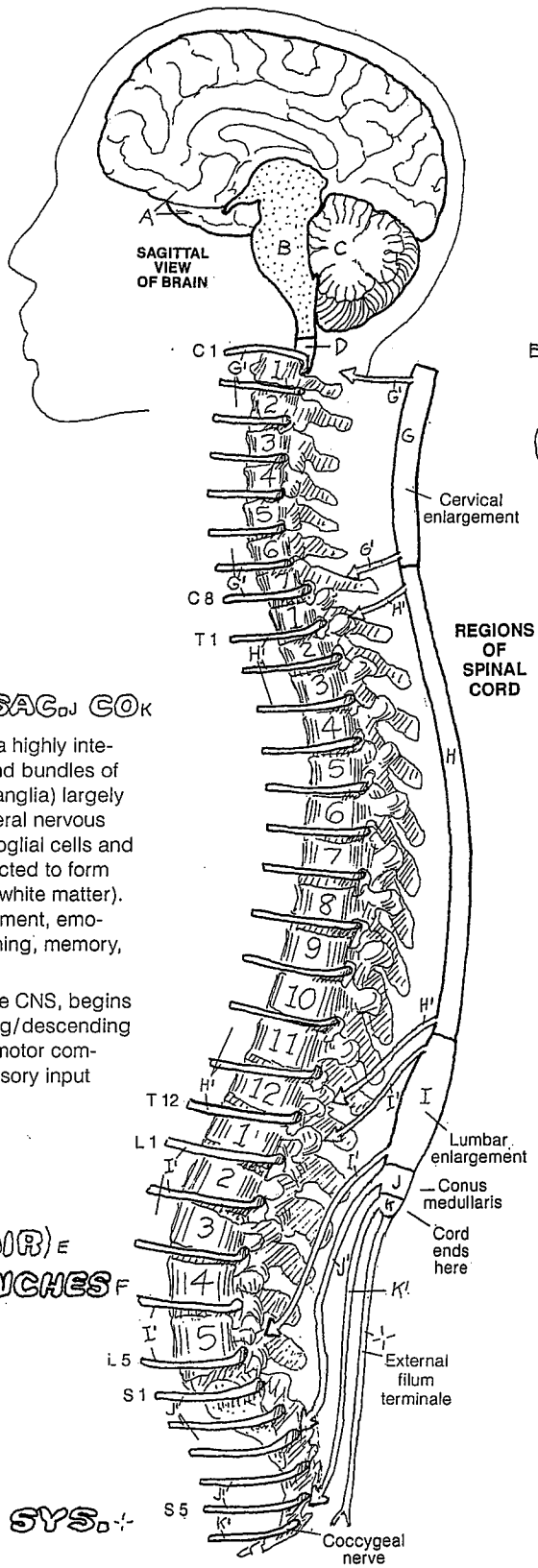
The nervous system consists of neurons arranged into a highly integrated central part (central nervous system, or CNS) and bundles of neuronal processes (nerves) and islands of neurons (ganglia) largely outside the CNS making up the peripheral part (peripheral nervous system, or PNS). These neurons are supported by neuroglial cells and a rich blood supply. Neurons of the CNS are interconnected to form centers (nuclei; gray matter) and axon bundles (tracts; white matter). The brain is the center of sensory awareness and movement, emotions, rational thought and behavior, foresight and planning, memory, speech, and language and interpretation of language.

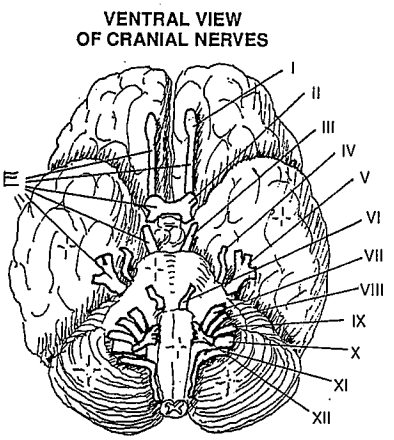
The spinal cord, an extension of the brain and part of the CNS, begins at the foramen magnum of the skull, traffics in ascending/descending impulses, and is a center for spinal reflexes, source of motor commands for muscles below the head, and receiver of sensory input below the head.

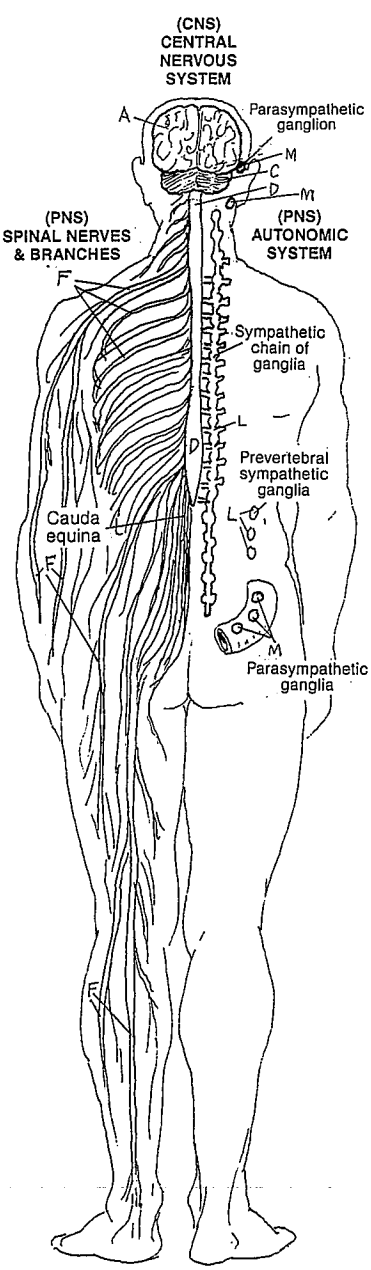
PERIPHERAL NERVOUS SYSTEM (PNS)

- CRANIAL NERVES (12 PAIR) E
- SPINAL NERVES & BRANCHES F
  - CERVICAL (8) G'
  - THORACIC (12) H'
  - LUMBAR (5) I'
  - SACRAL (5) J'
  - COCCYGEAL (1) K'
- AUTONOMIC NERVOUS SYS. D
  - SYMPATHETIC DIV. L
  - PARASYMPATHETIC DIV. M

The PNS consists largely of bundles of sensory and motor axons (nerves) radiating from the brain (*cranial nerves*) and spinal cord (*spinal nerves*) segmentally and bilaterally and reaching to all parts of the body (visceral and somatic) through a classic pattern of distribution. *Branches* of spinal nerves are often called peripheral nerves. Nerves conduct all sensations from the body to the brain and spinal cord; they conduct motor commands to all the skeletal muscles of the body. The *autonomic nervous system* (ANS) is a subset of ganglia and nerves in the PNS dedicated to visceral movement and glandular secretion and to the conduction of visceral sensations to the spinal cord and brain.



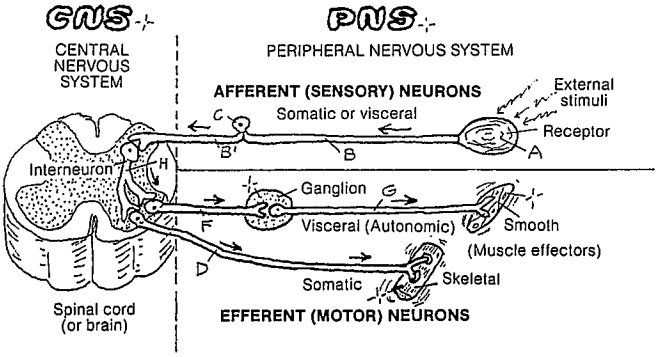




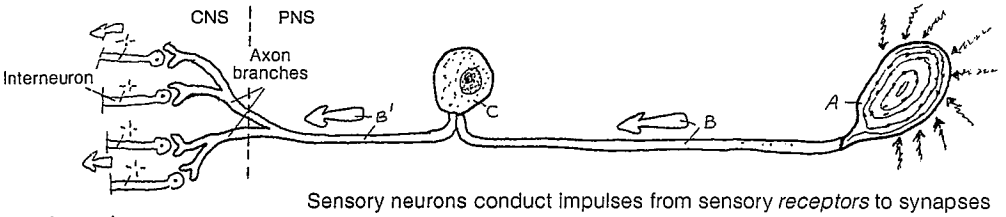
FUNCTIONAL CLASSIFICATION OF NEURONS

CN: Use light colors throughout the plate.
Do not color the summary diagram at the top of the page until completing the rest of the plate.

Neurons generally function in one of three modes: They conduct impulses from receptors in the body to the central nervous system or CNS (sensory or afferent neurons); they conduct motor command impulses from the CNS to muscles of the body (motor or efferent neurons); or they form a network of interconnecting neurons in the CNS between motor and sensory neurons (interneurons). If the sensory or motor neurons relate to musculoskeletal structures or the skin and fascia, the prefix "somatic" may be applied (somatic afferent/somatic efferent). If these neurons are related to organs with hollow cavities (viscera), the prefix "visceral" may be applied (visceral afferent/visceral efferent).

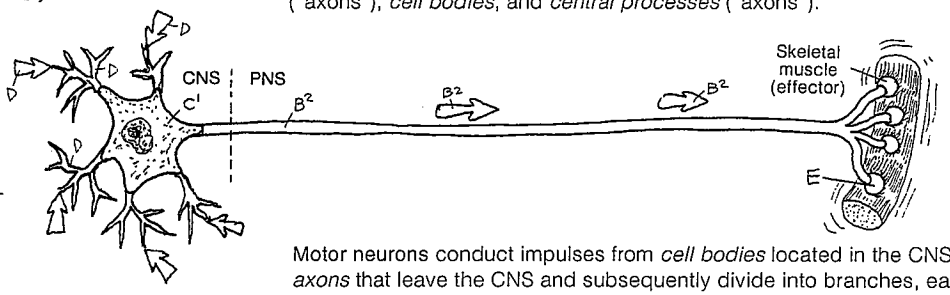


PNS:
SENSORY NEURON
- RECEPTOR A
- AXON (PERIPHERAL PROCESS) B
- CELL BODY C
- AXON (CENTRAL PROCESS) B'



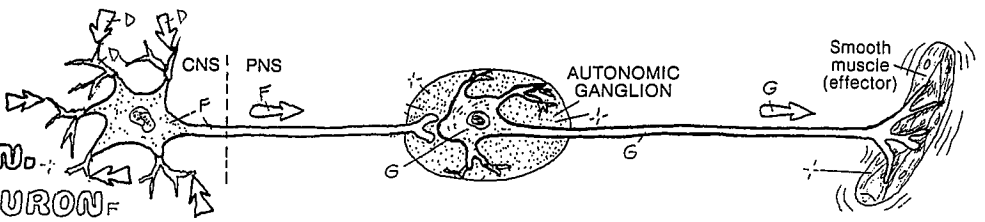
Sensory neurons conduct impulses from sensory *receptors* to synapses in the CNS. The receptors may be sensitive to touch, pressure, pain, joint position, muscle tension, chemical concentration, light, or other mechanical stimulus, basically providing information on the external or internal environment and related changes. Sensory neurons are unipolar neurons, with certain exceptions (bipolar neurons), and are characterized by *peripheral processes* ("axons"), *cell bodies*, and *central processes* ("axons").

PNS:
SOMATIC MOTOR NO.
- DENDRITE D
- CELL BODY C'
- AXON
- MOTOR END PLATE E

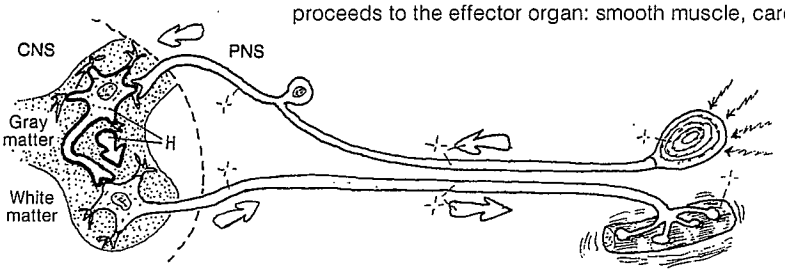


Motor neurons conduct impulses from *cell bodies* located in the CNS through *axons* that leave the CNS and subsequently divide into branches, each of which becomes incorporated into the cell membrane of a muscle cell (*motor end plate*). Here the neuron releases its neurotransmitter, which induces the muscle cell to shorten.

PNS:
AUTONOMIC MOTOR NO.
- PREGANGLIONIC NEURON F
- POSTGANGLIONIC NEURON G



Autonomic motor neurons function as paired units connected at a ganglion by a synapse. The first or *preganglionic neuron* arises in the CNS, and its axon embarks for a ganglion located some distance from the CNS. There it *synapses* with the cell body or dendrite of a *postganglionic neuron* whose axon proceeds to the effector organ: smooth muscle, cardiac muscle, or glands.



CNS:
INTERNEURON (ASSOCIATION NO.) H

Interneurons are found mostly in the CNS. They make up the bulk of the neurons of the brain and spinal cord. They come in a variety of shapes and sizes. Many of them are directly related to incoming (sensory) impulses and others to outgoing motor commands. Others serve to integrate sensory or ascending input with higher centers to effect an appropriate motor output.

SYNAPSES & NEUROTRANSMITTERS

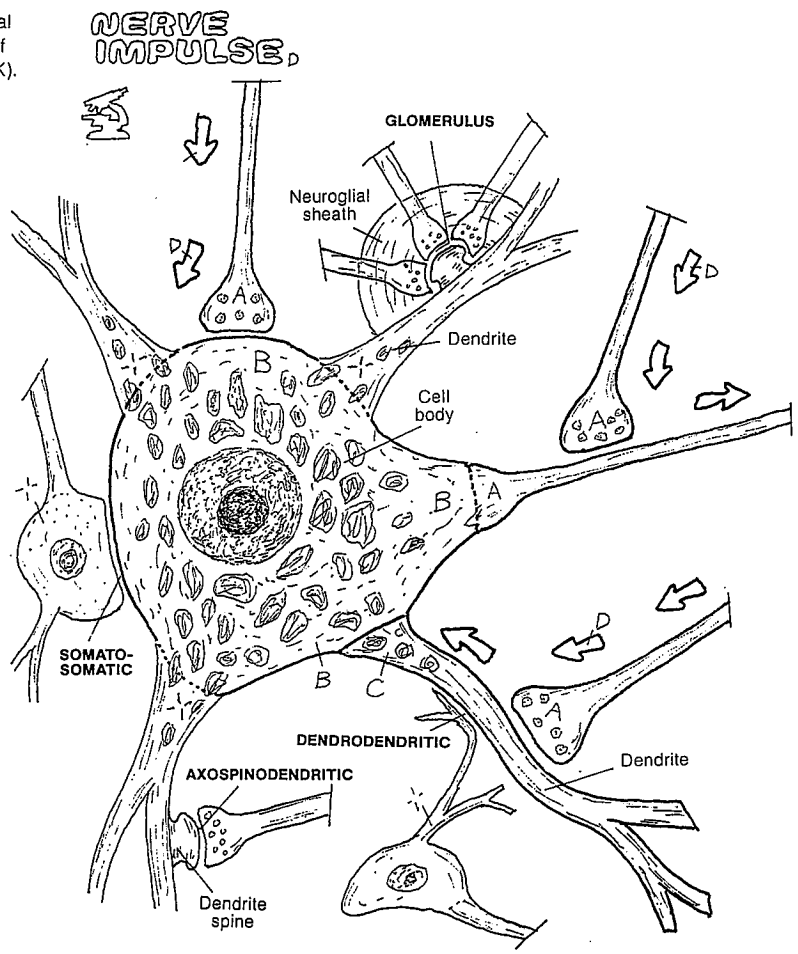
CN: Use light colors for A, B, and C. (1) In the upper drawing, each of the synapses shown has two parts. Color only the ones labeled with subscripts (A, B. C). Color the nerve impulse title (D, at the top) and the related directional arrows. (2) Color the numbered steps in the lower drawing. Note the change of color in the presynaptic membrane between exocytosis (H) and endocytosis (K).

BASIC TYPES OF SYNAPSES

- AXO$_A$ AXONIC$_A$
- AXO$_A$ SOMATIC$_B$
- AXO$_A$ DENDRITIC$_C$

Connections between and among neurons are called synapses. The great majority are non-contact connections in which chemical neurotransmitters carry the impulse from one neuron to another. Electrical synapses (where electrically charged atoms or ions pass from one neuron to another by way of protein channels; not shown) also exist in the brain and embryonic nervous tissue but are far less common. Most synapses are *axodendritic*; that is, the axon of one neuron synapses with the dendrite or dendritic spine of another neuron. The neuron in front of the synapse is said to be presynaptic. The second neuron is said to be postsynaptic. Another common synapse is *axosomatic*, where the axon of one neuron and the cell body (soma) of another neuron communicate by way of neurotransmitters. Other, more infrequently seen synapses are illustrated here as well. For example, note the complex of synapses (a glomerulus) between three axons and a dendritic spine, all surrounded by a neuroglial sheath.

Synapses permit the conduction of electrochemical impulses among myriad neurons almost instantly. Synapses vary from simple reflex arcs (see Plate 85) to polysynaptic pathways in the brain and spinal cord that involve millions of synapses. A single motor neuron of the spinal cord may have as many as 10,000 synapses on its body and dendrites! Multiple synapses greatly increase the available options of nervous activity. The ability to integrate, coordinate, associate, and modify sensory input and memory to achieve a desired motor command is directly related to the number of synapses in the pathway.



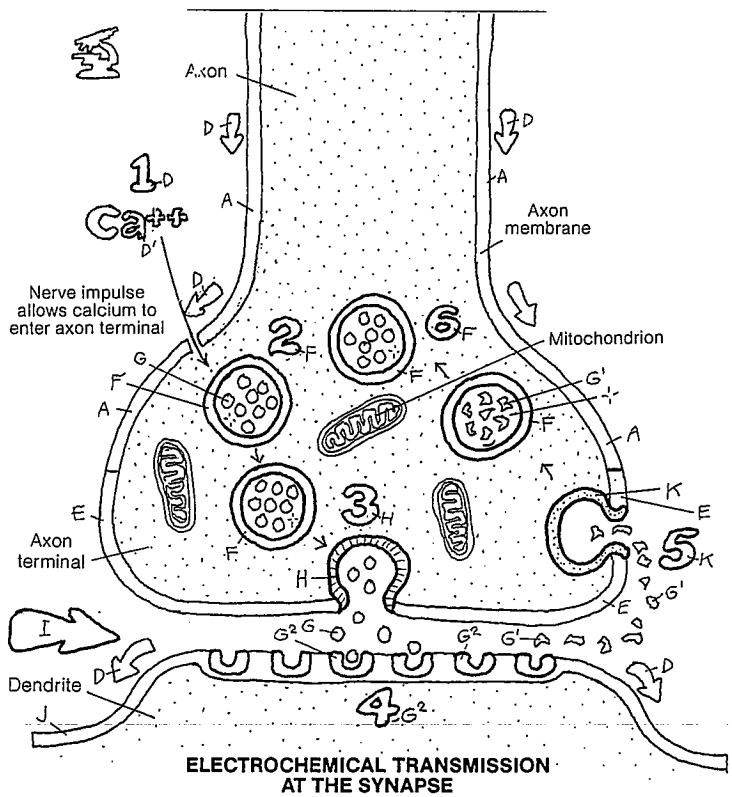
TYPES OF SYNAPSES

TYPICAL SYNAPSE

- PRESYNAPTIC AXON$_A$
  - PRESYNAPTIC MEMBRANE$_E$
- SYNAPTIC VESICLE$_F$
  - NEUROTRANSMITTER$_G$
    - FRAGMENT$_{G'}$
  - EXOCYTOSIS$_H$
- SYNAPTIC CLEFT$_I$
- POSTSYNAPTIC MEMBRANE$_J$
  - RECEPTOR$_{G'}$
- ENDOCYTOSIS$_K$

Here we show a typical axodendritic synapse. (1) The *presynaptic axon* transmits the electrochemical impulse toward the synapse. As the impulse reaches the axon terminal, calcium ion (Ca^{++}) channels/gates are opened in the cell membrane, and extracellular Ca^{++} pours into the axon terminal. (2) *Synaptic vesicles*, loaded with *neurotransmitter* (e.g., acetylcholine, norepinephrine), influenced by the incoming Ca^{++}, migrate toward the *presynaptic membrane* and fuse with it (3). Following fusion, neurotransmitter is spilled from the vesicles into the tiny synaptic cleft (*exocytosis*). Neurotransmitter molecules bind to receptor proteins on the *postsynaptic membrane* of the dendrite; ion channels are opened, and the altered membrane potential (impulse) is propagated along the dendrite (4). Inactivated neurotransmitter *fragments* are taken up by the presynaptic membrane (5; *endocytosis*), enclosed in a synaptic vesicle, and resynthesized (6).

The electrical activity of the postsynaptic membrane may be facilitated or inhibited by the neurotransmitter. If sufficiently excited by multiple facilitory synapses, the postsynaptic neuron will depolarize and transmit an impulse to the next neuron or effector (muscle cell, gland cell). Sufficiently depressed by multiple inhibitory synapses, the neuron will not depolarize and will not transmit an impulse.



ELECTROCHEMICAL TRANSMISSION AT THE SYNAPSE