THE NERVOUS SYSTEM

Nervous System

Functions of the Nervous System

1. Permits sensory input

    Receptors in PNS respond to both external and internal stimuli

2. Performs integration

    CNS sums all the input and “decides” what (if anything) to do about it

    If a response is needed the CNS “figures out” how to carry out that response

3. Stimulates motor output

    CNS sends signal through the PNS to the effectors

    The signal is the “instruction set” to respond to the sensory input

    Effectors are muscles and glands, execute the planned response

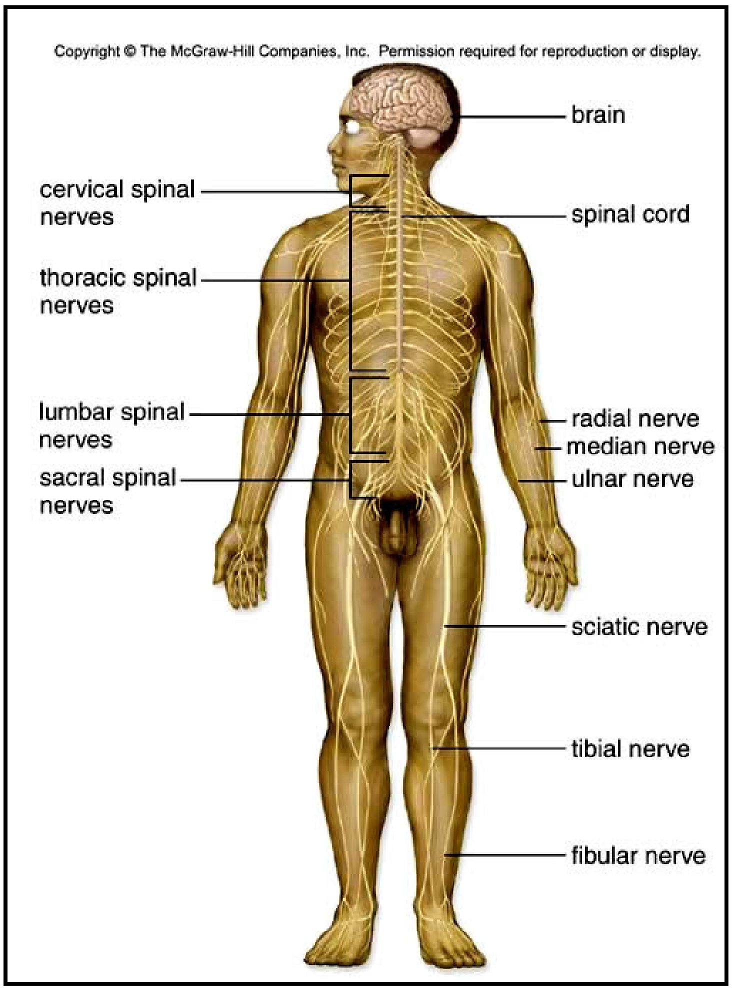
Divisions of the Nervous System

CNS

    Brain

    Spinal cord

PNS – cranial and spinal nerves; projections from the CNS to the rest of the body and inputs from the rest of the body back to the CNS



Motor - efferent, nerves from CNS deliver motor information to effectors

Somatic - motor nerves to skeletal muscle (voluntary)

Autonomic - motor nerves to smooth and cardiac muscle and glands

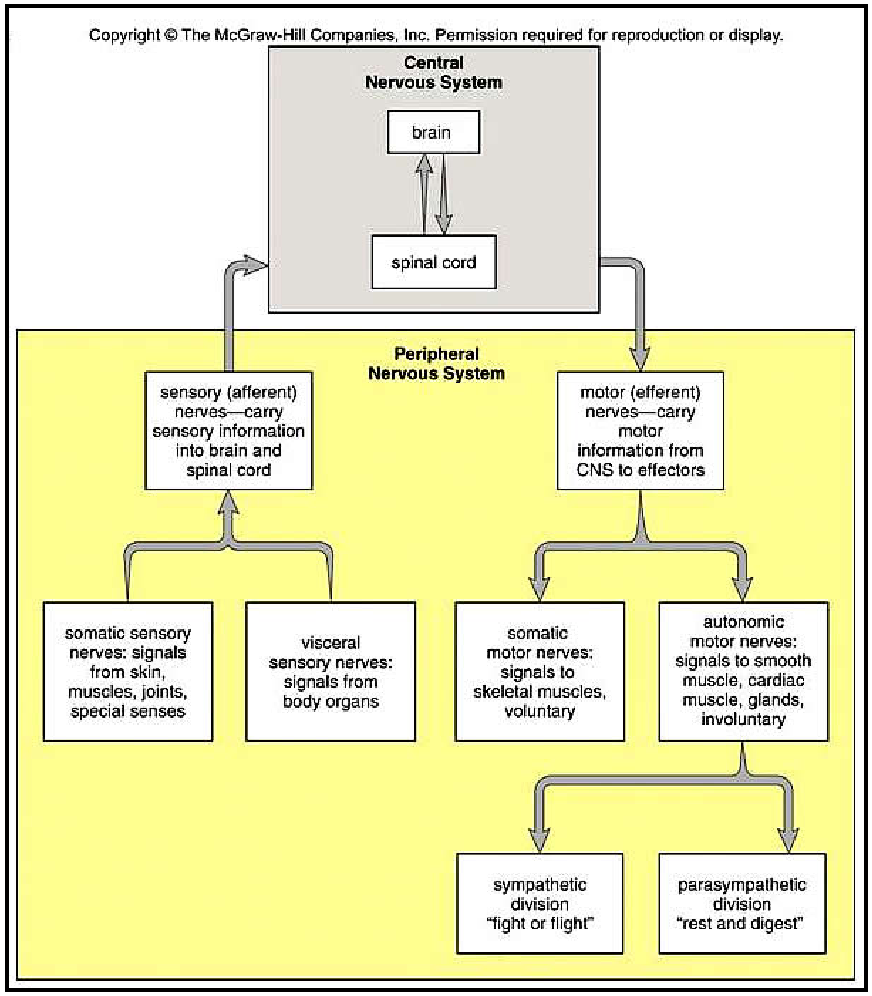
Sympathetic division - "fight or flight"

Parasympathetic division - "resting and digesting"

Sensory - afferent; nerves from structures outside the CNS deliver sensory input to the CNS

Somatic - input to CNS from skin, muscles, joints, and special senses

Visceral - input to CNS from body organs



Nervous Tissue

Neurons, transmit nerve impulses

Neuroglial cells - support the function of neurons

Neuron Structure

Dendrites – receive input and conduct impulses toward cell body (usually)

Cell bodies – contains nucleus and other organelles

Bundles of neuron cell bodies in the CNS are *nuclei*; bundles of neuron cell bodies in the PNS are *ganglia*

Axons – conduct impulses away from the cell body

Axons and dendrites may also be called processes or fibers

Bundles of parallel axons in the PNS are *nerves*; bundles of parallel axons in the CNS are tracts

Myelin sheath – a covering of lipid material often found on axons, insulates axons and speeds nerve impulse transmission

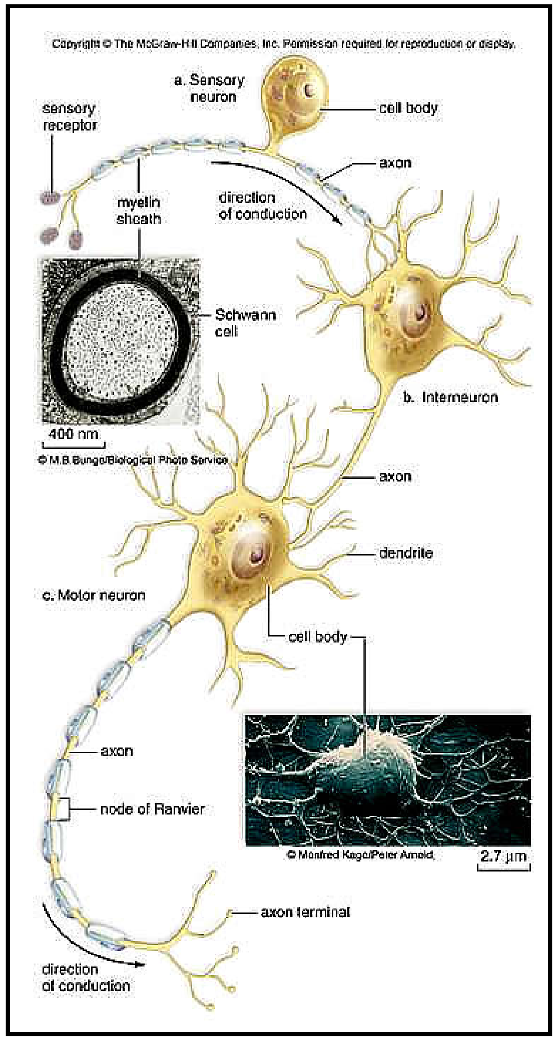
Produced in the CNS by neuroglial cells called oligodendroglia, in the PNS by neuroglial cells called Schwann cells

Neurilemma = Schwann cell cytoplasm and nucleus within plasma membrane

Myelin sheath is the inner part where the cytoplasm has been squeezed out

Nodes of Ranvier – gaps between Schwann cells, important in nerve impulse conduction

Multiple Sclerosis (MS) disease of the myelin sheath, lesions become fibrotic, interfere with normal nerve impulse conduction



Types of Neurons

Sensory neurons (afferents) – conduct impulses from periphery to CNS

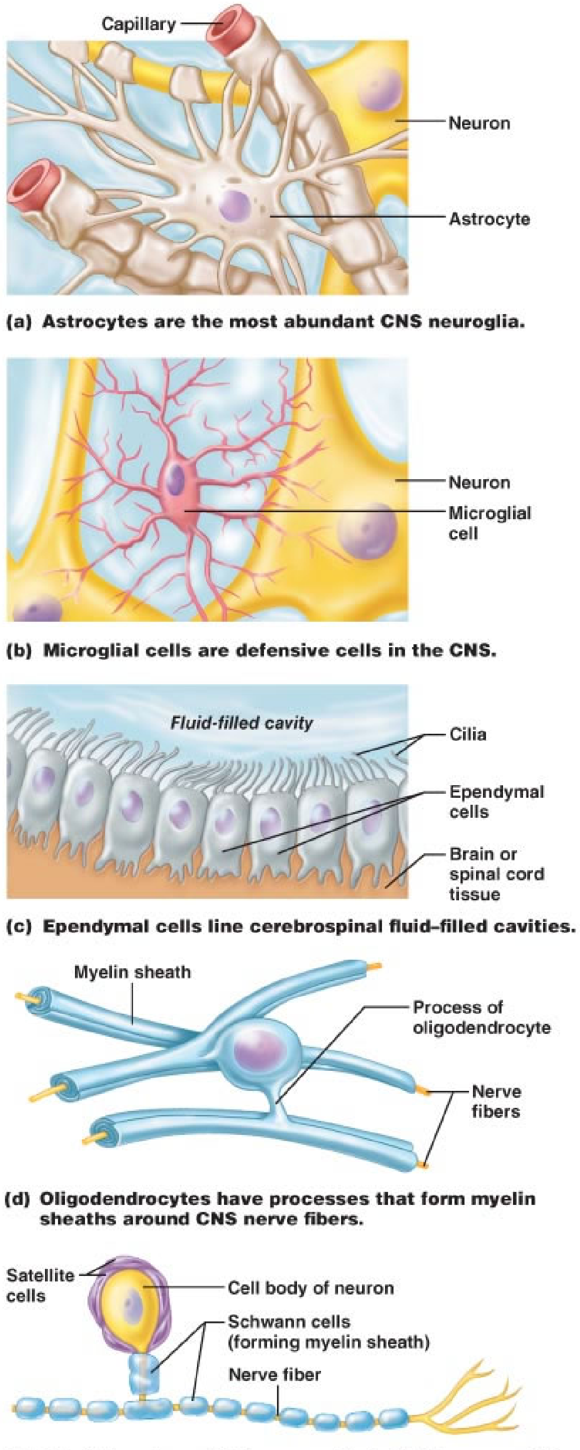
Motor neurons (efferents) – conduct impulses from CNS to periphery

Interneurons (association neurons) conduct impulses within CNS

Neuroglial cells

Supporting cells

Astrocytes – CNS, star shaped, provide support between neurons an capillaries Microglial cells – CNS, phagocytic, macrophage like Ependymal cells – line cavities in CNS, produce and help circulate CSF Oligodendroglial cells – CNS, produce myelin sheaths in CNS	Satellite cells - PNS, surround neuron cell bodies, help regulate chemical environment Schwann cells – PNS, produce myelin sheaths in PNS



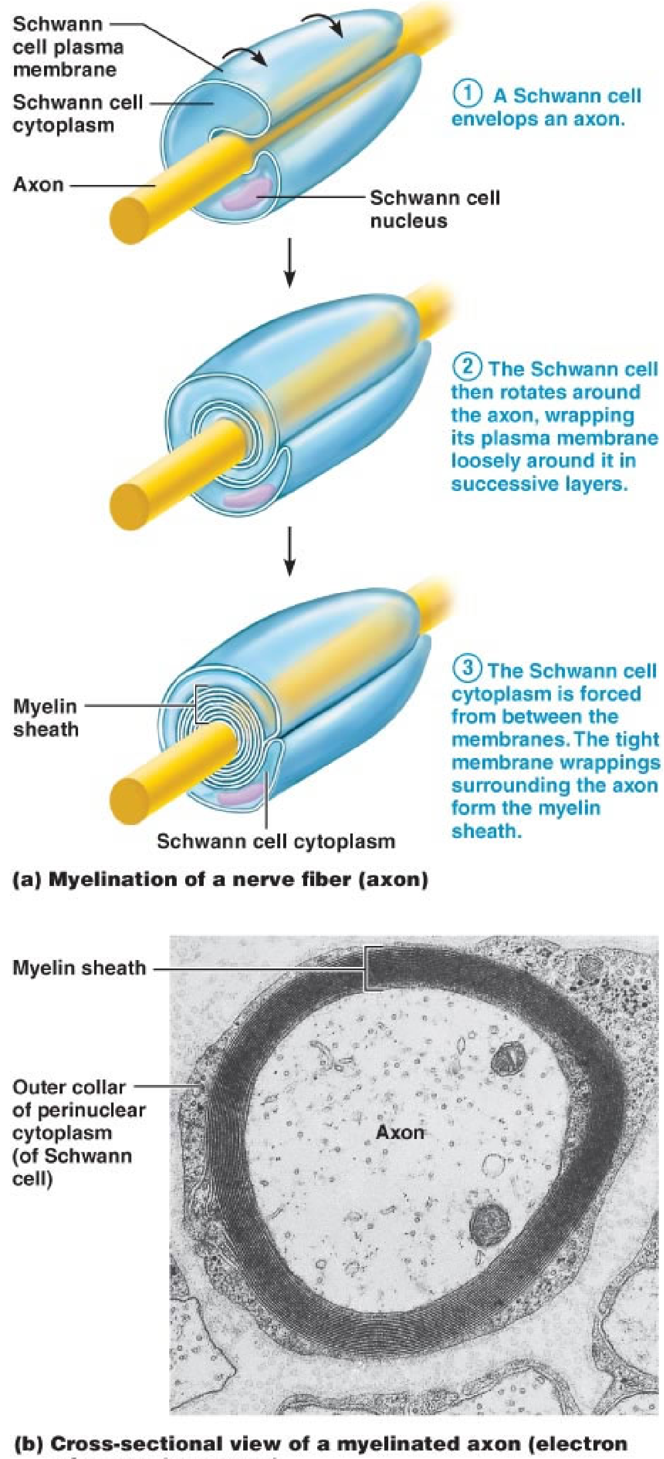
(a) Astrocytes are the most abundant CNS neuroglia.

(b) Microglial cells are defensive cells in the CNS.

(c) Ependymal cells line cerebrospinal fluid–filled cavities.

(d) Oligodendrocytes have processes that form myelin sheaths around CNS nerve fibers.

(e) Satellite cells and Schwann cells (which form myelin) surround neurons in the PNS.



(a) Myelination of a nerve fiber (axon)

(b) Cross-sectional view of a myelinated axon (electron micrograph 24,000×)

Nerve Signal Conduction

Resting Membrane Potential

There is more Na^+ outside the cell than inside, and more K^+ inside the cell than outside.

Na^+ diffuses in through leakage channels, K^+ diffuses out through leakage channels.

K^+ diffuses out faster than Na^+ diffuses in, so more positive charges end up on the outside of the cell.

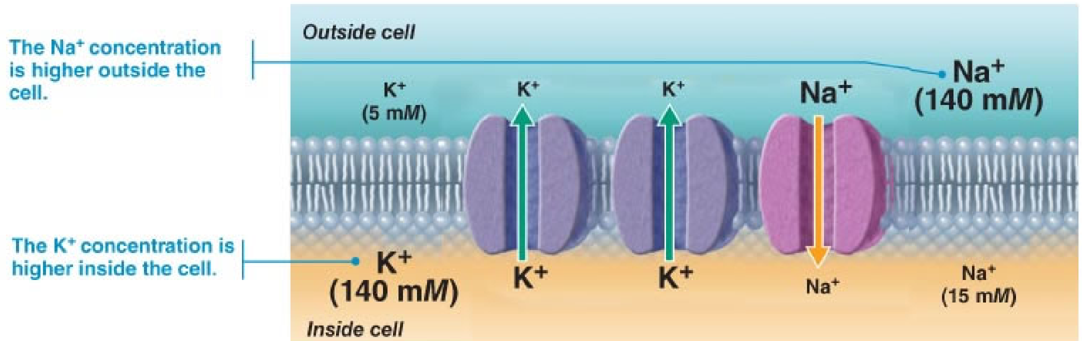
The negatively charged internal proteins and the unequal Na^+ and K^+ distribution across the membrane contribute to making the cell membrane kind of like a battery, with a positive pole on the outside and a negative pole on the inside.

The membrane is said to be “polarized”.

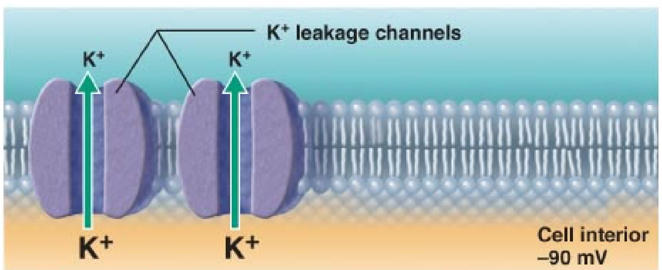
The difference between the positively charged outside part of the membrane and the negatively charged inside of the membrane represents potential energy – since opposite charges attract and like charges repel a positively charged particle would shoot straight through the membrane from outside to inside if it could get through.

> This potential energy can be measured: It is called a membrane potential and the amount of potential energy (the difference in charge between the inside and outside of the plasma membrane) is measured in volts (or millivolts at the level of a cell).
>
> At equilibrium the membrane potential is called a *resting* membrane potential.
>
> The Na^+ and K^+ distributions are maintained by the Na^+ - K^+ pump; this protein pumps Na^+ back out of the cell and K^+ back into the cell to maintain the uneven charge distribution; this is the equilibrium that produces the resting membrane potential.
>
> If Na^+ and K^+ diffused until the concentration of each was the same on both sides of the membrane they would be in equilibrium with regard to distribution but then the cell wouldn't have a resting membrane potential, which turns out to be pretty useful.

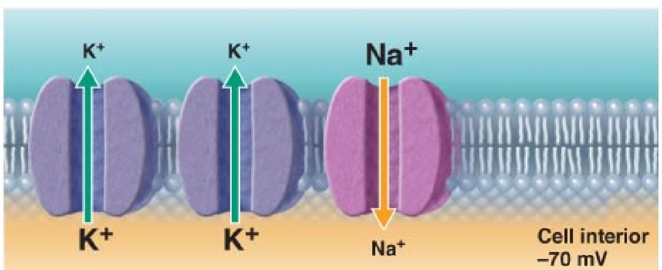
The concentrations of Na^+ and K^+ on each side of the membrane are different.



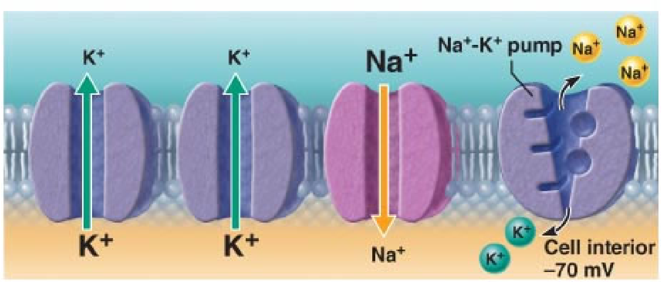
The permeabilities of Na^+ and K^+ across the membrane are different.



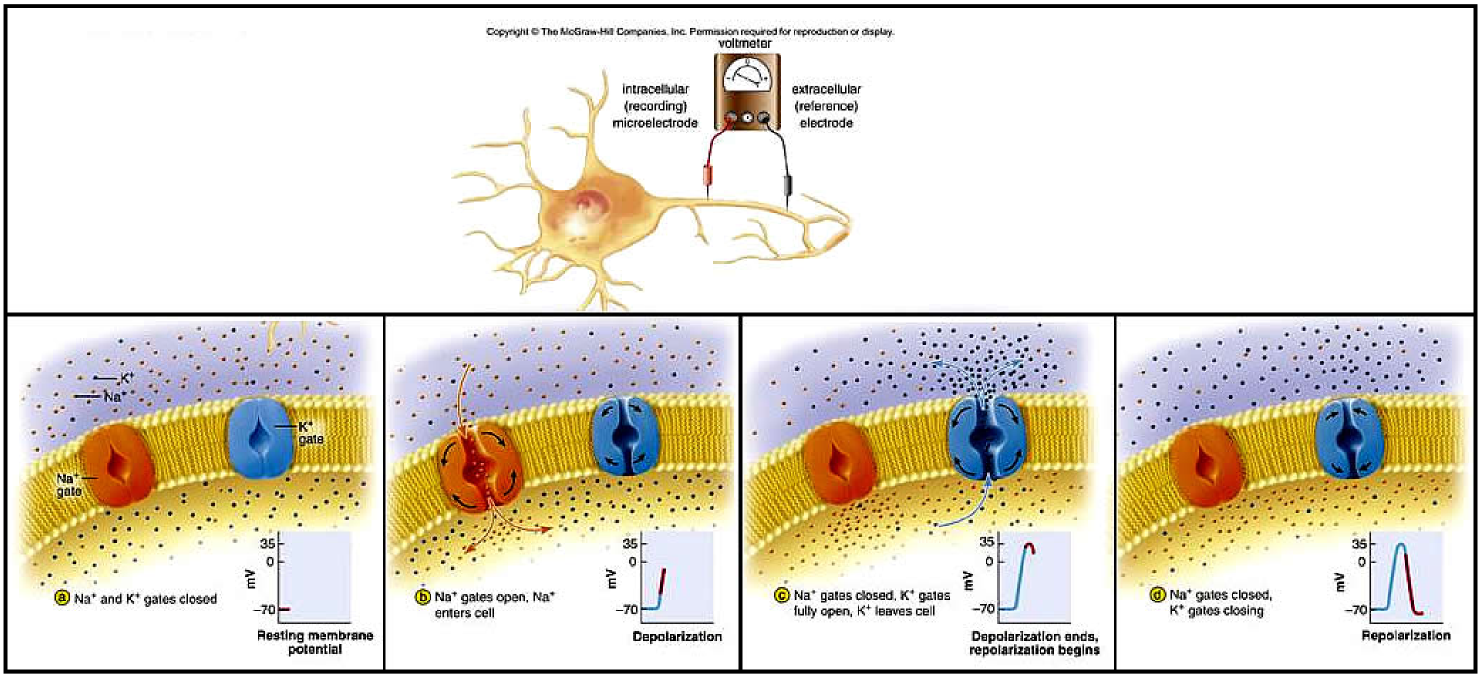
K^+ loss through abundant leakage channels establishes a negative membrane potential.



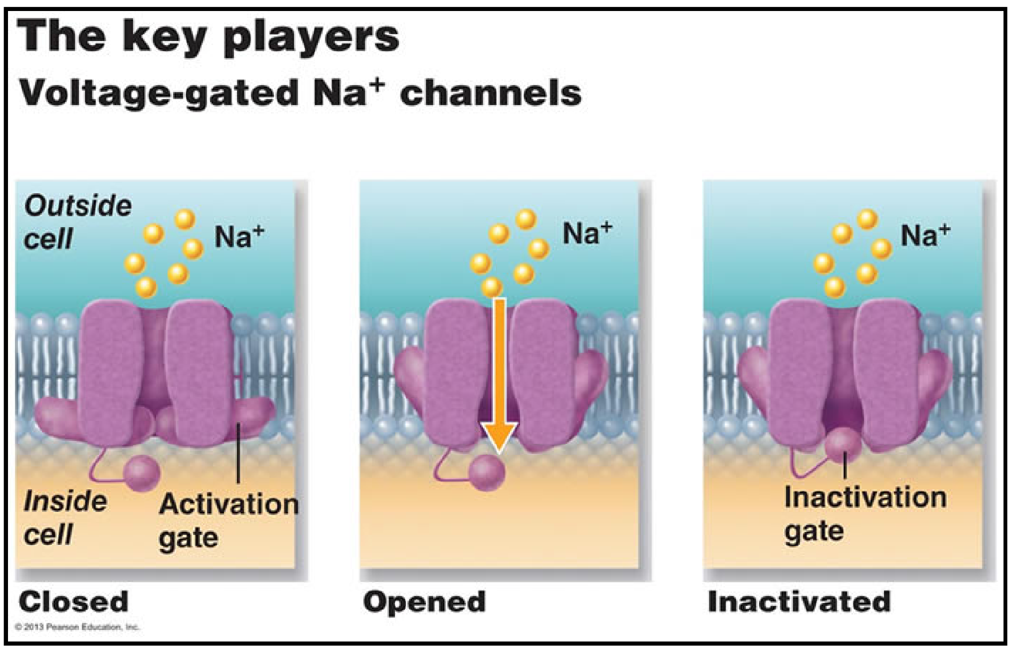
Na^+ entry through leakage channels reduces the negative membrane potential slightly.

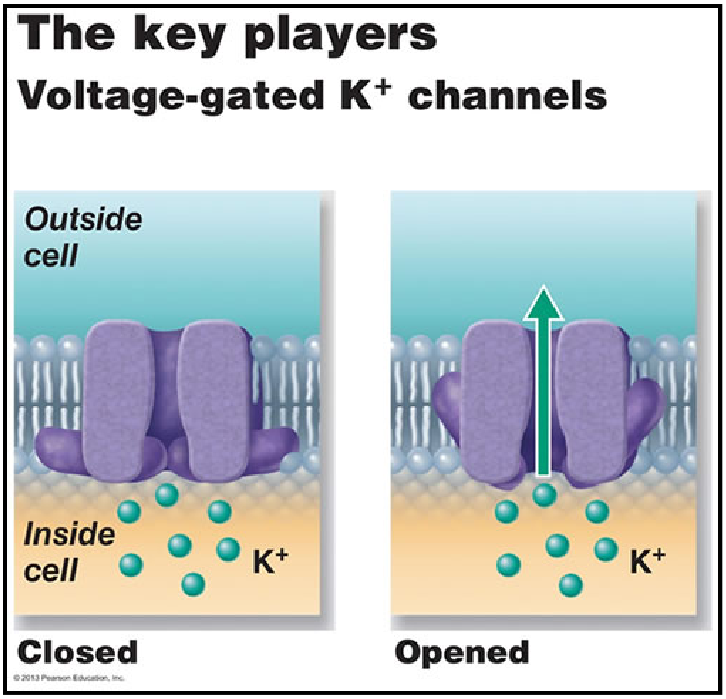


Na^+-K^+ ATPases (Pumps) maintain the concentration gradients, resulting in the resting membrane potential.



Action potential

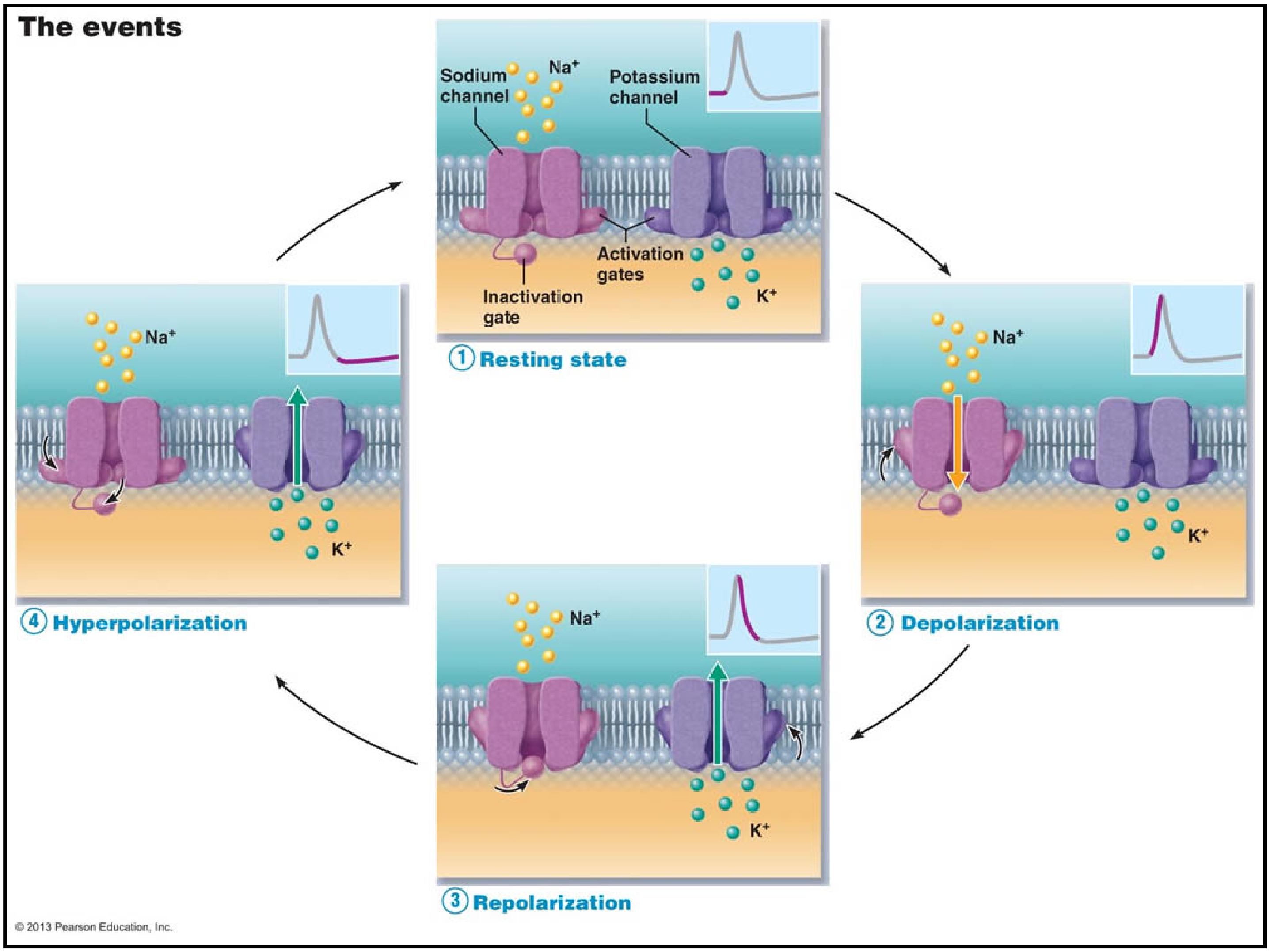




A stimulus to a neuron can cause rapid influx of large amounts of Na^+ through voltage-regulated Na^+ channels, which causes a large change in polarity - a depolarization as the inside becomes less negative until the polarity is reversed and the inside becomes positive compared to the outside.

After depolarization the voltage-regulated Na^+ channels close and voltage-regulated K^+ channels open, allowing K^+ to diffuse out of the cell and reverse the depolarization (this is called repolarization).

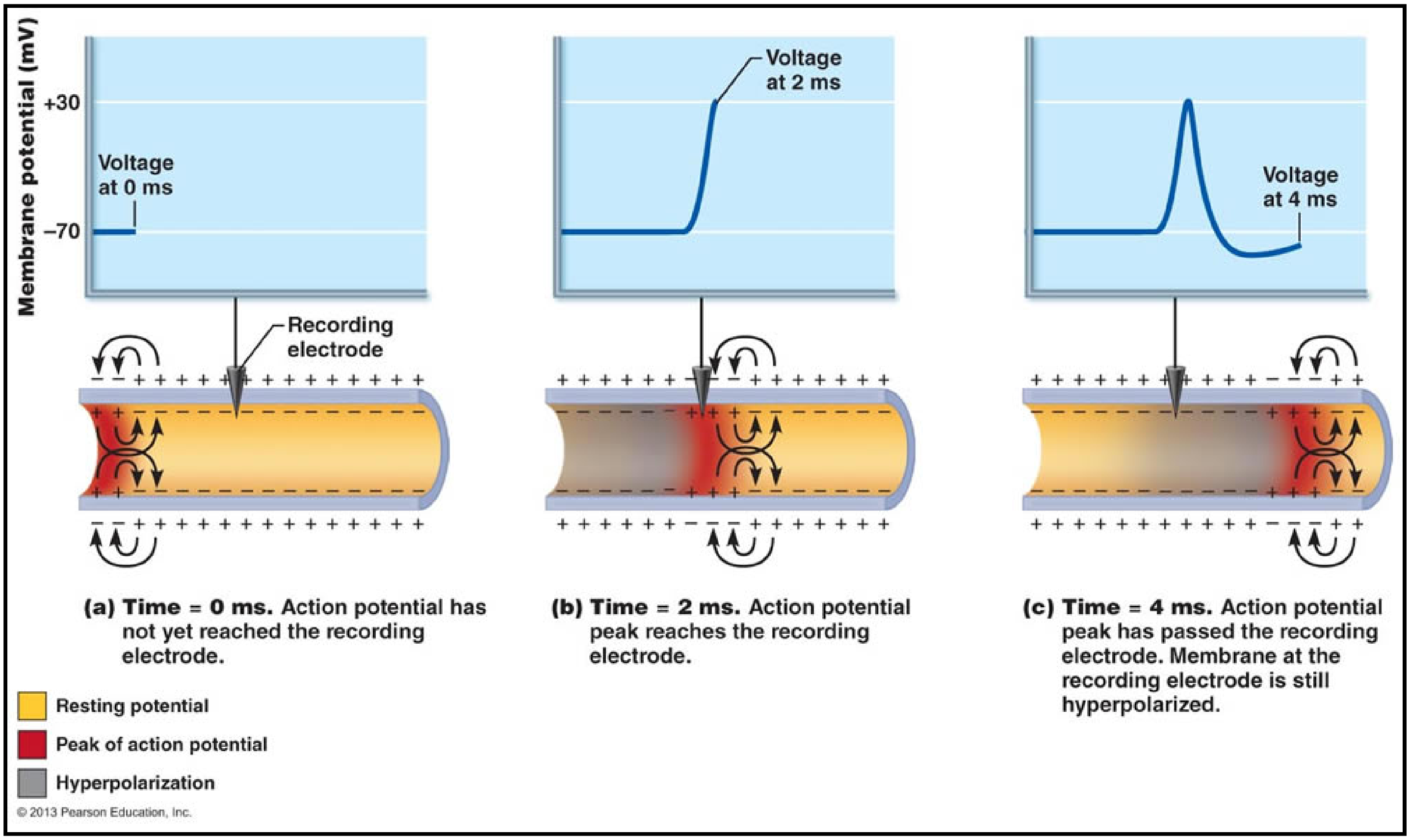
The time required for repolarization to occur is the *refractory period*, during which the cell can't be restimulated.



Another problem you may run into is this: Having all that Na^+ inside the cell and all that K^+ outside the cell eventually will lead to ionic imbalance; however the proper distribution of Na^+ and K^+ is restored by the Na^+ - K^+ pump.

Conduction of Action Potentials

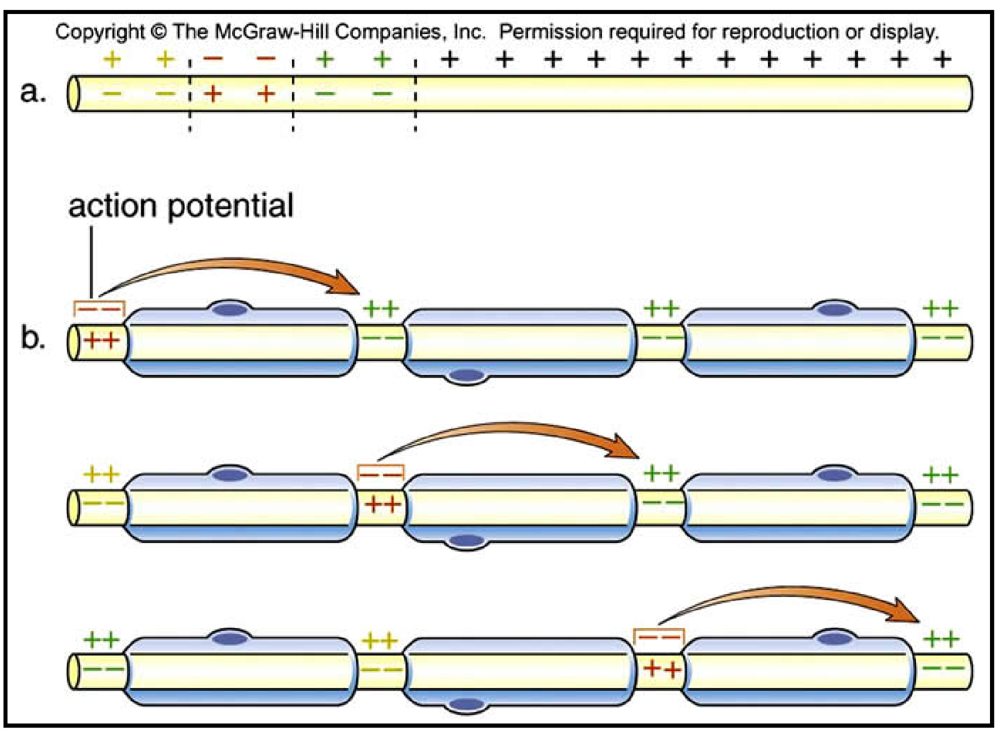
As this change in polarity moves down the membrane a nerve impulse is transmitted along the cell - the wave of depolarization coming down the axon opens more voltage-regulated Na^+ channels which reinforce the action potential and insures that it will reach the axon terminal.



As the wave of depolarization moves down the axon the degree of depolarization is decreased by the presence of leakage channels, allowing Na^+ and K^+ to move freely across the membrane.

Myelinated axons conduct action potentials much more quickly than unmyelinated axons because in myelinate axons the leakage channels are only found at the nodes of Ranvier – which is also where the voltage regulated Na^+ channels are located. The depolarization wave can open the cluster of voltage regulated Na^+ channels located here and overcome the effects of ion leakage.

Conduction is slow in small unmyelinated fibers, fast in thick myelinated fibers.



Transmission Across a Synapse

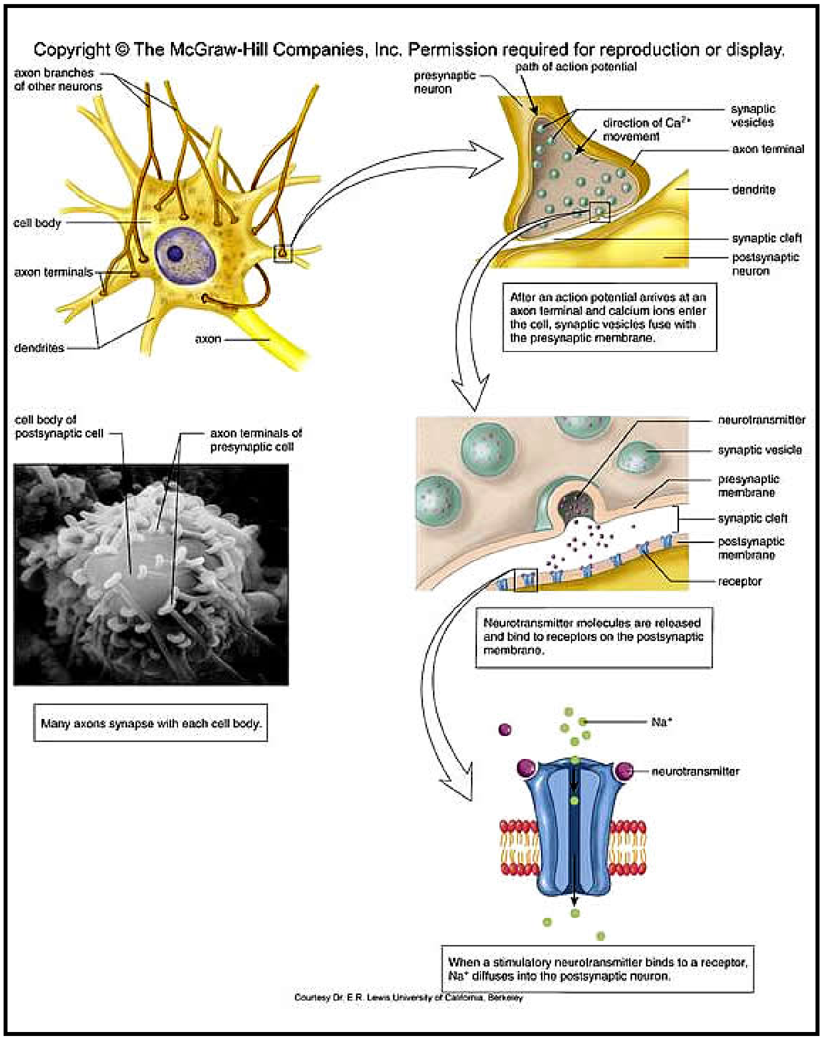
A synapse is where the axon terminal (synaptic knob) of a neuron meets a dendrite on another neuron (or cell membrane of effector).

There is no physical contact, they are separated by a small space (the synaptic cleft).

Presynaptic membrane vs. postsynaptic membrane – well, the plasma membrane of the axon terminal before the synapse would be the presynaptic membrane and the plasma membrane of the cell on the other side of the synaptic cleft would be the postsynaptic membrane.

When the action potential reaches the axon terminal voltage-regulated calcium channels open, calcium floods into the axon terminal, and causes the synaptic vesicles to fuse with the presynaptic axon plasma membrane and release neurotransmitters into the synaptic cleft.

Depending on the neurotransmitter and the type of receptor on the postsynaptic membrane the result of binding can be excitatory or inhibitory.



Graded Potentials and Synaptic Integration

When neurotransmitters are released from the presynaptic membrane they transmit the stimulus across the synaptic cleft to receptors on the postsynaptic membrane.

The receptors are linked to (or part of) chemically regulated ion channels; binding causes the channels to open and a graded local potential is generated.

These receptors may be excitatory, like those linked to Na^+ channels – when NT binds the channels open, Na^+ floods in, and a graded local potential called an excitatory postsynaptic potential is generated.

Some receptors are inhibitory, that is, they let negatively charged ions like Cl^- in to the cell (which hyperpolarizes the membrane) or they may let positively charged ions like K^+ out of the cell (which also hyperpolarizes the membrane), generating an inhibitory postsynaptic potential.

The sum of all the graded local potentials must reach threshold (depolarization of 15 - 20 mV or so less negative than the resting membrane potential) when they reach a voltage-regulated Na^+ channel to generate an action potential.

Neurotransmitter Molecules

Acetylcholine – active in all parts of the nervous system

- Acetylcholine esterase - breaks acetylcholine down to remove from synapse

Norepinephrine – adrenergic; can be stimulatory or inhibitory depending on receptor type present on postsynaptic cell

Serotonin and dopamine – behavioral states; mood, tension, learning, memory

Neurotransmitters and neurological disorders

- Parkinson's disease
  - Imbalance in dopamine (probably some serotonin too)
  - Wide-eyed, unblinking expression
  - Involuntary tremor of fingers an thumbs
  - Muscular rigidity
  - Shuffling gait
- Huntington's disease (chorea)
  - Progressive deterioration of nervous system leading to constant thrashing and writhing (thus "chorea")
  - Onset is usually mid-30's to early 40's, prognosis is insanity and death. The cause is genetic and is one of the few genetic diseases caused by a dominant mutation. The tragedy is that an affected parent has a 50% chance of passing the gene to their children but they don't show signs of the disease until after they've given birth (assuming childbirth occurs before mid-30's).
  - Possible malfunction of GABA (another NT)
- Alzheimer disease
  - Gradual loss of reason, including memory, personality changes, ability to perform simple tasks, confusion
  - Pathological differences:
    - AD neurons exhibit neurofibrillary tangles surrounding the nucleus
    - Amyloid plaques surround axon branches
    - Acetylcholine appears diminished in AD-affected brains
    - Neural abnormalities seen primarily in frontal lobes and limbic system

Susceptibility

16% liklihood in people with no family history

24% in people with first degree relative

May be linked to a genetic defect on chromosome 21

People with Down’s syndrome (3 copies of chromosome 21) are more likely to develop AD

The defect on chromosome 21 affects normal production of amyloid precursor protein, which is though to be the cause of amyloid plaques

Treatments

Drugs: cholinesterase inhibitors allow acetylcholine accumulation; memantine, blocks excitotoxicity (diseased neurons self destruct and cause death of nearby neurons

Future possibilities: autologous induced pluripotent stem cell transplants, gene therapy where applicable

Central Nervous System
Meninges and Cerebrospinal Fluid

Meninges – protective membranes

Dura mater – outer layer

Tough, fibrous CT

Lies next to skull and vertebrae

Forms channels (splits into 2 layers; actually consists of 2 fused layers in most places) called dural sinuses that collect and return venous blood and CSF to circulation.

Epidural hematoma – bleeding between dura and bone.

Subdural hematoma – bleeding below dura, into space between dura mater and arachnoid.

Arachnoid membrane

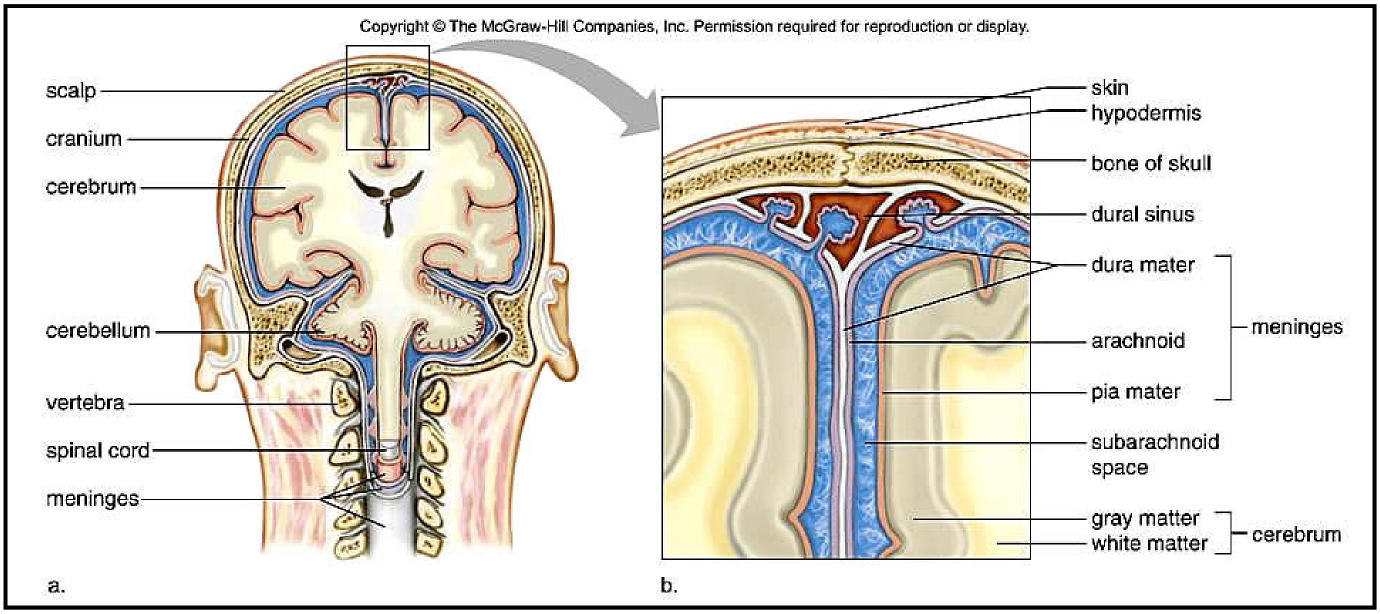
Delicate, web-like CT

Attaches to pia mater

Subarachnoid space contains Cerebrospinal fluid (CSF)

Pia mater

Thin, fine follows contours of brain closely



Cerebrospinal Fluid

A clear fluid derived from plasma that forms protective cushion around CNS, provides nutrients, and collects wastes.

CSF is produced at choroid plexuses, specialized capillary networks where ependymal cells filter plasma (and circulate the CSF).

CSF circulates through the ventricles, into the central canal of spinal cord, into the subarachnoid spaces, and returns to veins of the brain where it drains into the dural sinuses and returns to blood.

Production and drainage are balanced; blockage produces hydrocephalus.

In infants the cranial sutures haven't fused so the head can enlarge to accommodate the fluid.

In adults the brain gets mashed against the skull.

The Spinal Cord
Structure of the Spinal Cord

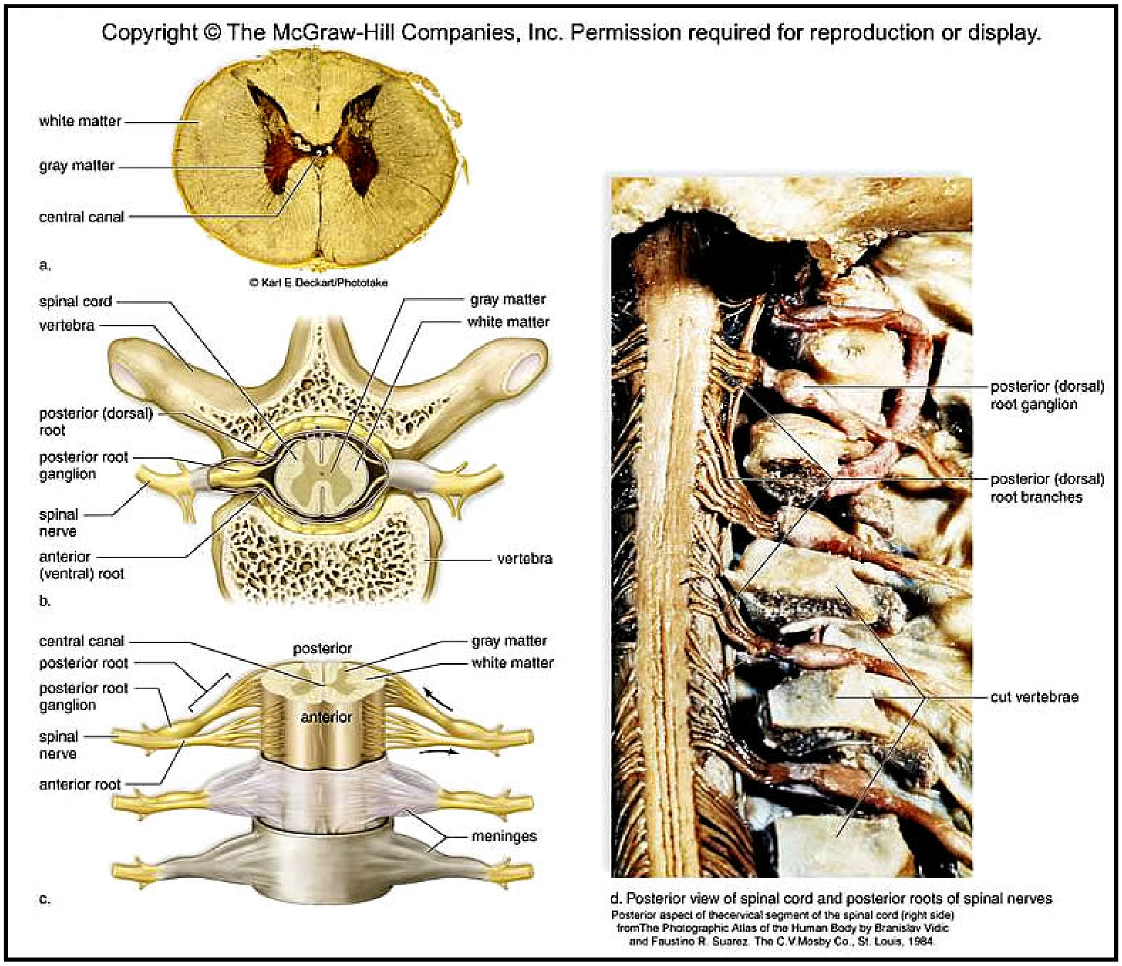
Extends from the base of the brain through the foramen magnum, down the vertebral canal (middle of vertebrae) and ends between 1st and 2nd lumbar vertebrae

External white matter surrounding butterfly shaped gray matter with a central canal

Gray matter is described as anterior or ventral horns and posterior or dorsal horns

Gray matter contains cell bodies and short unmyelinated fibers

Sensory neurons enter through the dorsal roots, motor neurons exit through the ventral roots, roots join to form spinal nerves



White matter contains bundles of myelinated fibers or tracts that form columns running up and down the spinal cord

Ascending tracts take sensory nerve impulses up to the brain

Descending tracts take motor nerve impulses down and out to effectors

Tracts crossover in the medulla; right side of brain controls left side of body and vice versa

Cauda equina (distal portion of spinal cord - "horse's tail"), spinal nerves “chase” exit point because vertebral column grows more quickly than cord

Functions of the Spinal Cord

Center for reflex arcs

Communication between brain and peripheral nerves

Epidural anesthesia – inject it in the epidural space and numb everything below the level of injection

Spinal Cord Injuries

Partial section or transection of cord

Location and severity of injury determines what part of body is affected

Betwween T1 ad L2 – paralysis of lower body and legs – paraplegia

Between C4 and T1 – entire body and 4 limbs – quadriplegia

Unilateral hemisection (half cut) motor loss on same side as injury (crossover occurs in medulla)

The Brain

Ventricles

The two lateral ventricles are associated with the cerebrum and are connected to 3rd ventricle by the interventricular foramen.

The third ventricle is associated with the diencephalon and is connected to the 4th ventricle by the cerebral aqueduct

The the fourth ventricle is associated with the brain stem and cerebellum. It is continuous with central canal of spinal cord inferiorly and connected to the subarachnoid space by 2 lateral apertures and median aperature.

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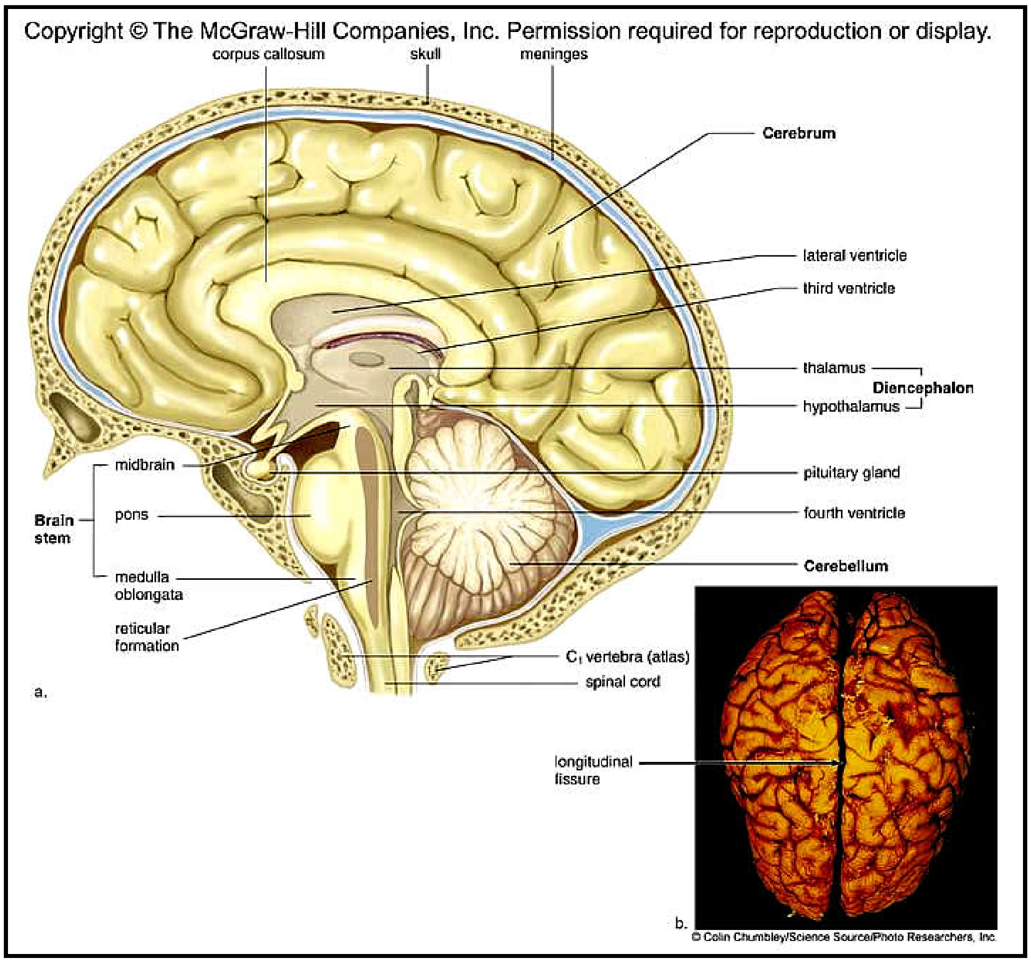


EEG

Measures electrical activity of the brain

Good diagnostic tool – irregular brain patterns can indicate pathologic conditions (epilepsy to brain death for example; although functional MRI studies show blood flow and have helped elucidate areas of the brain active during specific tasks.)

Waking subjects have 2 types of brain waves

Alpha waves – predominate when eyes are closed; calm, relaxed state of wakefulness

Beta waves – predominate when eyes are open, indicate mental alertness, concentration

Sleeping subjects

Theta waves – light sleep, not seen normally in awake adults (although common in children)

Delta waves – deep sleep

REM sleep – EEG pattern looks like alph waves, eyes move rapidly beneath eyelids, dreaming occurs

The Cerebrum

Largest and most superior part of brain

Outer cortex of gray matter

Contains cell bodies and short fibers

Convolutions known as gyri

Shallow grooves known as sulci

Deep grooves known as fissures

Accounts for sensation, voluntary movement, and consciousness

The Cerebral Hemispheres

The right and left cerebral hemispheres are divided by the longitudinal fissure and joined by a bridge of myelinated fibers, the corpus callosum.

Each hemisphere contains a lateral ventricle

Each hemisphere has 4 lobes

Frontal lobe - deep to the frontal bone, anterior to the parietal lobe

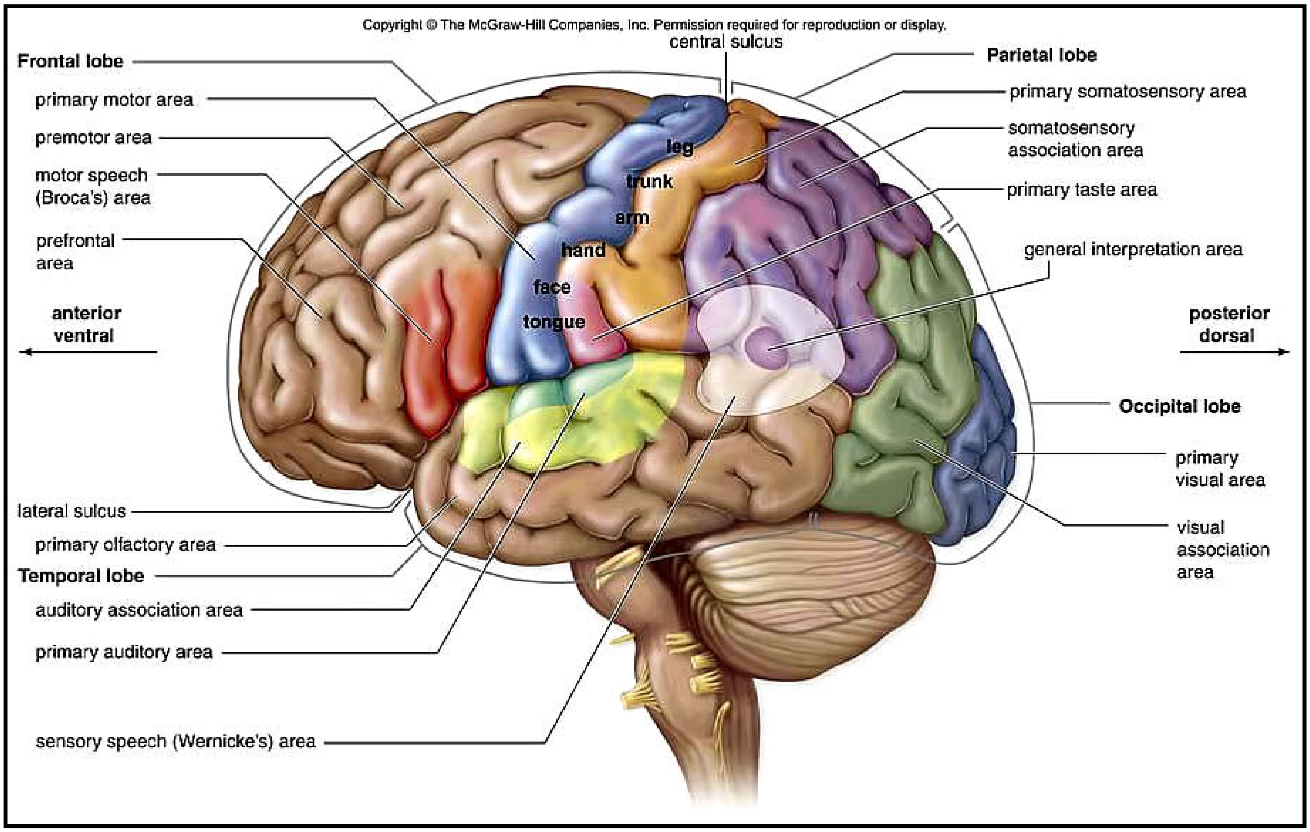
Central sulcus – divides frontal lobe from parietal lobe

Parietal lobe - deep to the parietal bone, posterior to the frontal lobe

Occipital lobe - deep to the occipital bone in the most posterior area of the cranial vault

Temporal lobe - deep to the temporal bone, separated from the frontal lobe and parietal lobe by the lateral sulcus

Insula - the fifth lobe, the insula, lies deep to the lateral sulcus



Motor and Sensory Areas of the Cortex

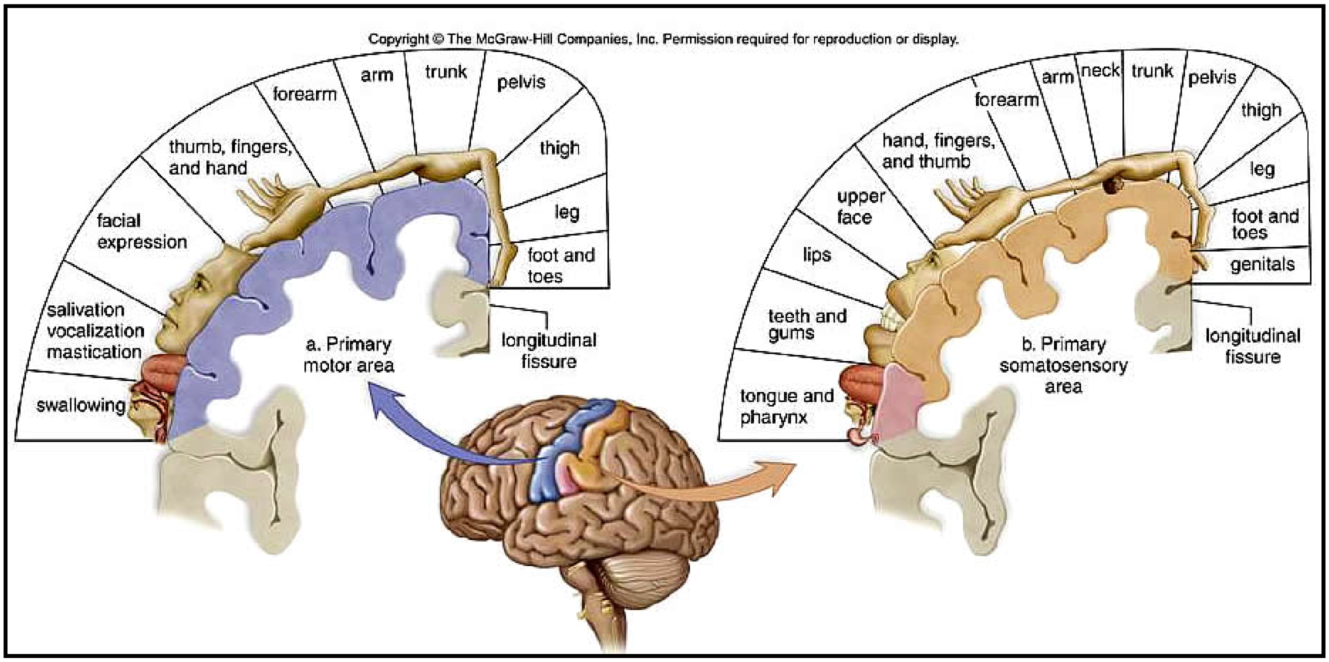
Primary Motor Area: in the frontal lobe just anterior to the precentral gyrus; responsible for movement of skeletal muscle

> Somatic motor neurons cross over after leaving the primary motor area so the right primary motor area controls the left side of the body and the left primary motor area controls the right side.

Primary Somatosensory Area: in the parietal lobe just posterior to the precentral gyrus; receives input from temperature, touch, pressure, and pain receptors in the skin.

> Like the motor areas, the left hemisphere recieves somatosensory input from the right side of the body and the right hemisphere recieves input from the left side of the body.

The figure below, depicting the areas of the cortex that exert voluntary motor control and recieve sensory input, illustrates that areas with the greatest amount of control or sensitivity have the greatest amount of cortex devoted to them.



Primary taste area (gustatory cortex) - located in the insula just deep to the parietal lobe

Primary visual area - located in the occipital lobe

Primary auditory area - located in the temporal lobe

Olfactory cortex - located on the medial aspect of the temporal lobe, part of the rhinencephalon, link to the limbic system

Visceral sensory area - located just posterior tot he gustatory cortex in the insula, involved in conscious perception of visceral sensation

Vestibular (equilibrium) cortex - conscious awareness of balance, located in the posterior part of the insula and adjacent parietal cortex

Association Areas

Association areas integrate sensory input and store memories - interpret sensory experiences and remember visual scenes, music, and other complex sensory patterns

Premotor area - organizes motor functions for skilled motor activities and communicates with the primary motor cortex. The primary motor cortex sends signals to the cerebellum and basal nuclei, which integrate the information.

Somatosensory association area - posterior to the primary somatosensory area, process and integrates sensory information from skin and muscles

Visual association area - combines new visual images with memories of older visual information

Auditory association area - combines new auditory data with memories of previously encountered auditory stimuli

Processing Areas

Prefrontal area (cortex) – recieves input from other association areas, is used for concentration, planning, complex problem solving, judging the consequences of behavior.

Damage to these areas can completely change personality traits.

Broca's area – motor area for speech

Located at the base of the precentral gyrus in the frontal lobe

Usually located in left hemisphere

Wernicke's area - general interpretive area, recieves inputs from all other sensory association areas, works with Broca's area in understanding speech and the use of language to express thoughts and feelings.

Usually located in the left hemisphere

The Left and Right Brain

Sperry and Gazzaniga’s experiments - severed corpus callosum in epileptic patients

Found that the hemispheres are pretty much structurally the same but functionally different

Dominant hemisphere is defined as the hemisphere containing language abilities (Broca’s area, Wernicke’s area)

90% of people have dominant left hemispheres

Left brain (usually) controls language, logic, math skills

Right brain controls spatial discrimination, musical and artistic ability, intuition and emotion

Central White Matter

Projection Fibers (vertical): Myelinated axons carry information from CNS to the body (descending tracts), from the body and lower brain centers to the CNS (ascending tracts)

Horizontal Fibers: Association fibers carry information between different areas of the cerebrum within the same hemisphere and commissural fibers link corresponding areas in opposite hemispheres (corpus callosum, anterior commissure).

Basal Nuclei

Masses of gray matter deep within the white matter of the cerebrum

Part of limbic system – not really, this statement reflects the fact that the caudate nucleus is usually included with the basal nuclei and is really a part (functionally) of the limbic system

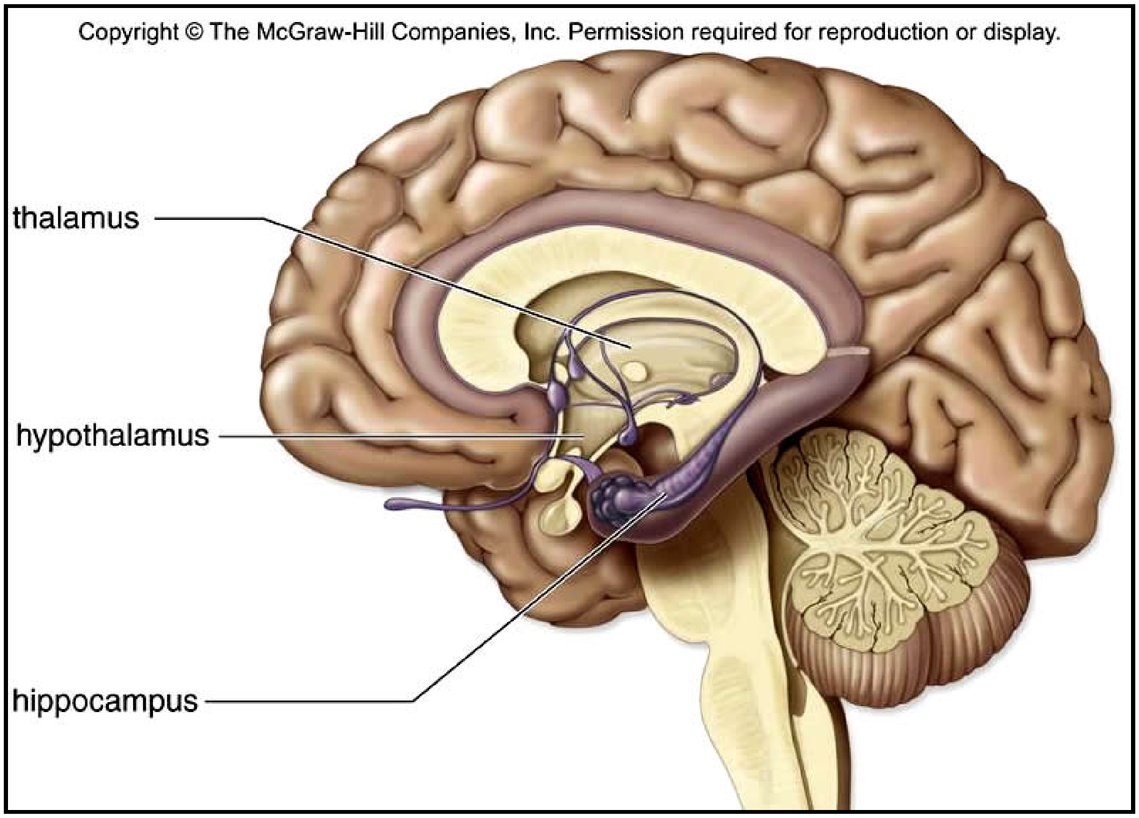
Receive inputs from entire cerebral cortex, other nuclei, and each other

Project to the premotor and prefrontal cortices through thalamic relays, influence voluntary muscle movements directed by the primary motor cortex

No direct involvement in motor pathways

Impairment results in disturbances in posture, muscle tone, involuntary movements including tremors and abnormal slowness of movement as seen in Parkinson’s disease

The Diencephalon



Thalamus

- Central relay station for sensory impulses traveling from everywhere else to the cerebrum
- Receives all sensory impulses except smell and sends them to the correct region of the cerebral cortex to be interpreted

Hypothalamus

- Maintains homeostasis
- Contains centers for regulating hunger, sleep, thirst, body temperature, water balance, and blood pressure
- Controls pituitary gland – links nervous system with endocrine system

Epithalamus - contains the pineal gland, which secretes the hormone melatonin.

- Melatonin regulates sleep-wake patterns (daily rhythyms)

Limbic System

System of pathways connecting parts of the frontal lobes, temporal lobes, thalamus, and hypothalamus

The emotional brain – responsible for feelings of anger, fear, sorrow, pleasure, affection, sexual interest

Involved in learning and memory, links emotion to stored memories

Arose from the ancient rhinencephalon or “smell brain”

- Our sense of smell has diminished and those structures have evolved to deal with emotions, memory, and learning
- Responsible for the strong link between smell and emotionally charged memories

Cerebellum

Lies below posterior portion of cerebrum

Two hemispheres joined by narrow medial bridge

Cortex of gray matter

Deeper white matter (some nuclei in white matter)

Functions:

- Muscle coordination – integrates impulses from higher centers to produce smooth and graceful motion
- Maintains normal muscle tone and posture
- Receives information about body position from inner ear and sends impulses to muscles to maintain or restore balance

Brain stem

Medulla oblongata

- Centers for regulating heartbeat, breathing, and blood pressure
- Reflex centers for vomiting, coughing, sneezing, hiccoughing, and swallowing
- Ascending and descending tracts between higher brain centers and spinal cord

Pons

- Bridge; tracts running between cerebellum and the rest of the CNS
- Coordinates with medulla to regulate breathing
- Reflex centers for head movements in response to visual and auditory stimuli

Midbrain

- Encloses cerebral aqueduct
- Relay station for tracts that run between cerebrum and spinal cord and cerebellum
- Reflex centers for visual, auditory, and tactile responses

Reticular formation

- System of loosely clustered neurons extending through brainstem with projections (all over) to hypothalamus, thalamus, cerebellum, spinal cord
- Functions: Arousal of brain
  - Reticular Activating System
    - Receives sensory inputs from all ascending sensory tracts and sends impulses to cerebral cortex through thalamic relays
    - Maintains cortex in alert conscious state, enhances excitability
    - Filters out repetitive, familiar or weak signals
    - Brings attention to unusual, significant, or strong impulses
    - Role in learning and memory; part of “reward pathway”

Depressed by alcohol, sleep-inducing drugs, tranquilizers; severe injury results in unconsciousness (permanent = coma)

Damped by sleep centers of hypothalamus, etc.; damping removed by LSD and other hallucinogens

Motor arm projects to spinal cord

Helps control skeletal muscles during coarse movement of limbs

Autonomic functions

Include vasomotor, cardiac, and respiratory centers of the medulla

Peripheral Nervous System

Afferent, or sensory system

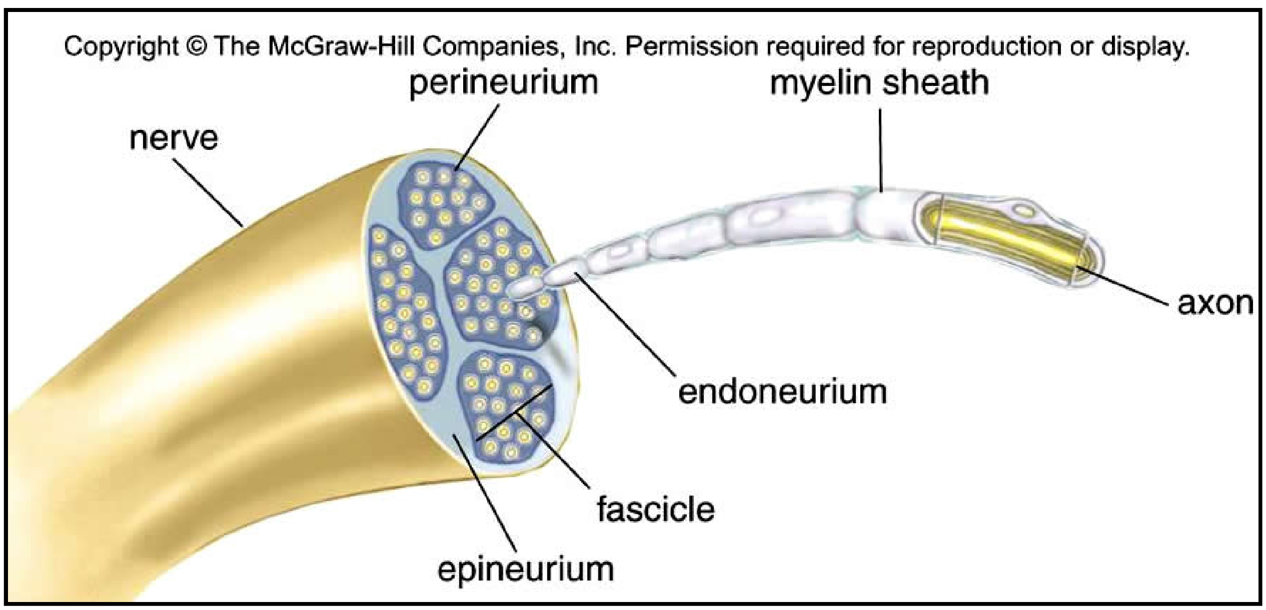
Somatic sensory system includes all the fibers that innervate the musculoskeletal system, including skin, joints, and tendons (in addition to skeletal muscles); the special senses are also part of the somatic sensory system.

Visceral sensory system supplies internal organs.

Efferent, or motor system

Somatic motor system innervates skeletal muscles.

Autonomic motor system innervates smooth and cardiac muscle and glands.



Types of Nerves

Cranial nerves are attached to the brain, spinal nerves are attached to the spinal cord.

Cranial Nerves

Twelve pairs attached to the brain

Consist of motor, sensory, and mixed nerves

Innervate head, neck and facial regions, except the vagus nerve (internal organs)

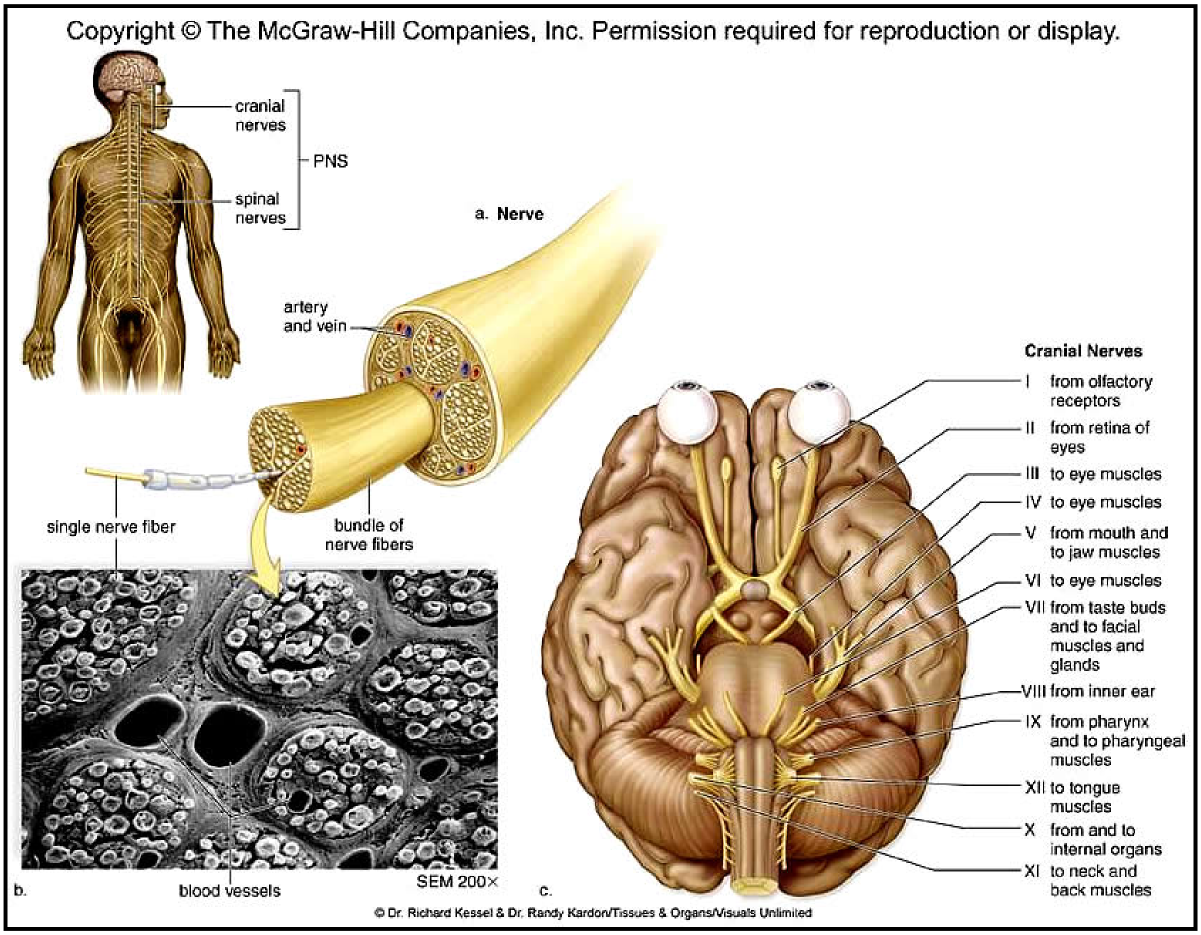


TABLE 8.1 Cranial Nerves

Nerve	Type	Brain Pathway	Transmits Nerve Impulses to (Motor) or from (Sensory)
Olfactory (I)	Sensory	I: Mucous membrane of nose to olfactory bulbs	Olfactory receptors for sense of smell
Optic (II)	Sensory	II: Retina → optic nerve → thalamus → occipital lobe	Retina for sense of sight
Oculomotor (III)	Motor	III: Midbrain → eye and eyelid	Eye muscles (including eyelids and lens); pupil (parasympathetic division)
Trochlear (IV)	Motor	IV: Midbrain → eye	Eye muscles
Trigeminal (V)	Mixed: Sensory	V: Sensory: Teeth, eye, skin, Tongue → pons	Teeth, eyes, skin, and tongue
	Mixed: Motor	Motor: Pons → jaw muscles	Jaw muscles (chewing)
Abducens (VI)	Motor	VI: Pons → eye	Eye muscles
Facial (VII)	Mixed: Sensory	VII: Sensory: Tongue → pons	Taste buds of anterior tongue
	Mixed: Motor	Motor: Pons → facial muscles, Salivary glands, tear glands	Facial muscles (facial expression) and glands (tear and salivary)
Vestibulocochlear (VIII) (also called auditory; acoustic)	Sensory	VIII: Inner ear → pons and medulla	Inner ear for sense of balance and hearing
Glossopharyngeal (IX)	Mixed: Sensory	IX: Sensory: Tongue, throat → pons	Pharynx
	Mixed: Motor	Motor: Pons → Salivary gland, Throat muscles	Pharyngeal muscles (swallowing), salivary glands
Vagus (X)	Sensory Motor	X: Sensory: Eardrum, ear canal, throat, heart, lungs, abdominal organs → medulla	Internal organs, external ear canal, eardrum, back of throat
		Motor: Medulla → throat and larynx, heart, lungs, abdominal organs	Internal organs (parasympathetic division), throat muscles (somatic motor division)
Spinal accessory (XI)	Motor	XI: Medulla → muscles of throat, neck, shoulder	Neck and back muscles
Hypoglossal (XII)	Motor	XII: Medulla → tongue muscles	Tongue muscles

Spinal Nerves

Thirty one pairs

8 cervical, 12 thoracic, 5 lumbar, 5 saccral, 1 coccygeal

Dorsal and ventral roots leave cord, fuse to form spinal nerves just before exiting the vertebral column

Dorsal roots contain sensory neurons

Dorsal roots have enlargements that contain the cell bodies of the sensory neurons (dorsal root ganglia)

Ventral roots contain axons of motor neurons

Spinal nerves contain sensory “dendrites” and motor axons; they are mixed nerves

Dermatomes – segments of skin supplied by a particular spinal nerve

Knowledge of which spinal innervates a particular dermatome allows interpretation of sensory aberrations in a dermatome as an indicator of damage to that particular spinal nerve

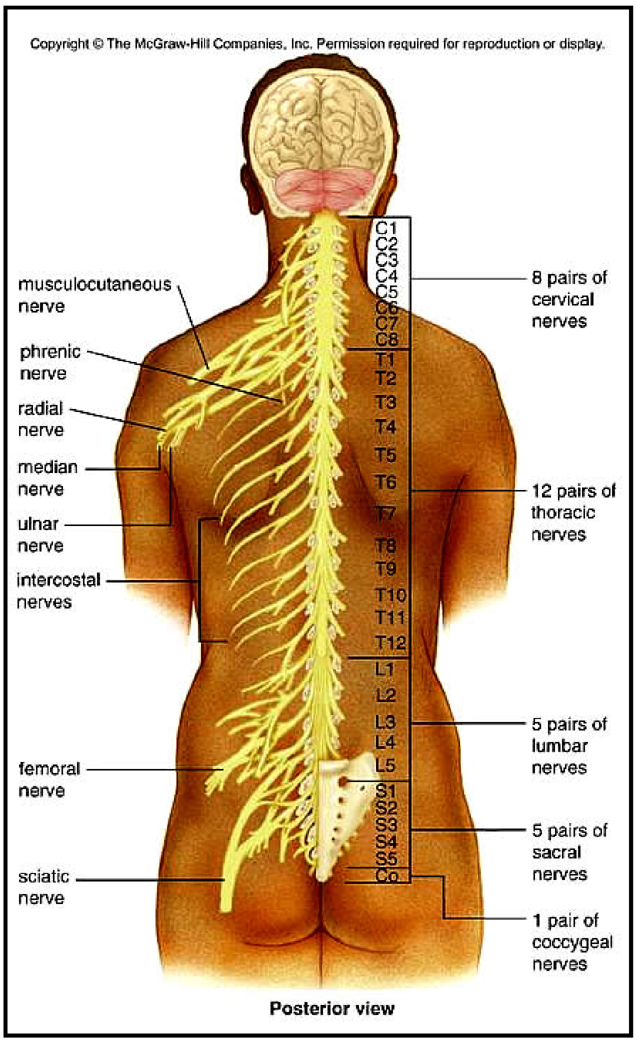


TABLE 8.2 Spinal Nerves

Name	Spinal Nerves Involved*	Function
Musculocutaneous nerves	C_5–T_1	Supply muscles of the arms on the anterior sides, and skin of the forearms
Radial nerves	C_5–T_1	Supply muscles of the arms on the posterior sides, and skin of the forearms and hands
Median nerves	C_5–T_1	Supply muscles of the forearms, and muscles and skin of the hands
Ulnar nerves	C_5–T_1	Supply muscles of the forearms and hands, and skin of the hands
Phrenic nerves	C_3–C_5	Supply the diaphragm
Intercostal nerves	T_2–T_{12}	Supply intercostal muscles, abdominal muscles, and skin of the trunk
Femoral nerves	L_2–L_4	Supply muscles and skin of the anterior thighs and legs
Sciatic nerves	L_4–S_3	Supply muscles and skin of the posterior thighs, legs, and feet

*C = cervical; T = thoracic; L = lumbar

Somatic Motor Nerves and Reflexes

Reflexes and the Reflex Arc

Automatic, involuntary responses to changes occuring either inside or outside the body

Cranial reflexes involve the brain, spinal reflexes involve only the spinal cord although the brain is usually notified

Reflex Arc

Structure

Receptor

Receives sensory input and transduces that information into a nerve impulse

Impulses are transmitted to the sensory neuron dendrites

Receptors may be just free dendritic endings of the sensory neuron

Sensory neuron fiber

Unipolar – dendritic ending, long axon on both sides of cell body– draw it and explain it

Axon located in a spinal nerve

Cell bodies of sensory neurons are located in the dorsal-root ganglion (ganglia – groups of cells bodies in the PNS)

Axon continues into the gray matter of the dorsal horn where they form synapses with interneurons

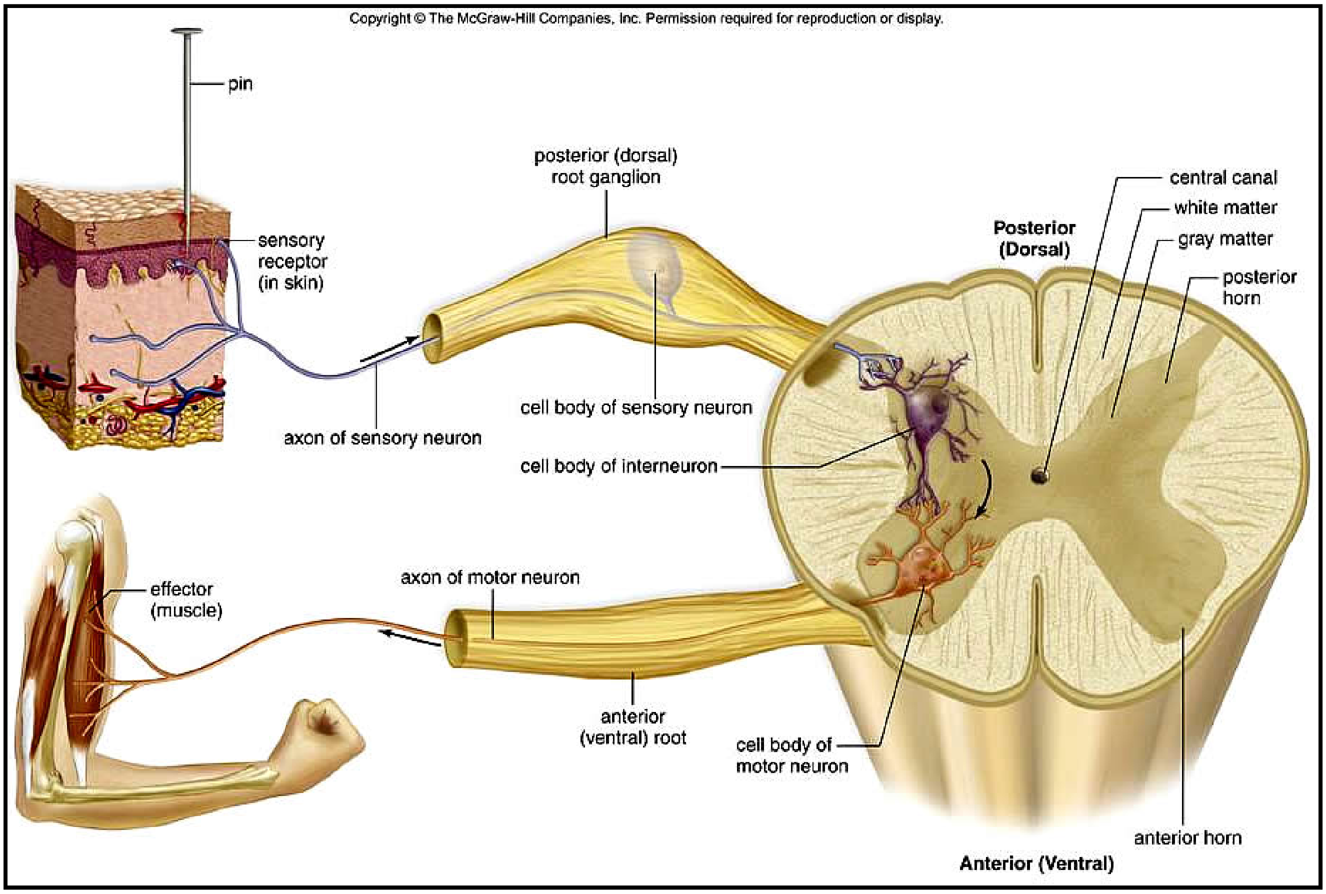
Interneuron

Located completely within the gray matter of the spinal cord

Motor neuron

Dendrites and cell body located within the gray matter's ventral horn

Axon located in the spinal nerve



Function

Information travels along the sensory neuron to the interneuron and back through the motor neuron to elicit a response

In the case of skeletal muscle the muscle contracts and moves the body part out of harm's way or moves to maintain posture

Knee-jerk reflex

Ankle-jerk reflex

Autonomic Motor Nervous System and Visceral Reflexes

Innervates smooth and cardiac muscle and glands (all internal organs)

Involuntary – doesn't require voluntary control; automatic

Utilizes 2 motor neurons and one ganglion for each impulse

First neuron has cell body in CNS and preganglionic axon

Second neuron has its cell body within the ganglion and its axon is postganglionic

Visceral reflexes

Occur in response to normal physiological fluctuations

Breathing

Heart rate

Body temperature

Food digestion and waste elimination

Swallowing, coughing, sneezing, vomiting

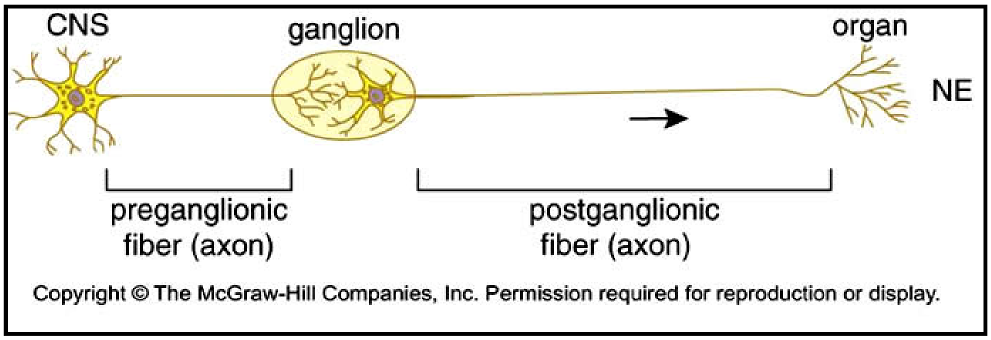
Sympathetic Division

Fight or flight division

Fibers arise from thoracic and lumbar regions of the spinal cord (also called the thoracolumbar division)

Ganglia lie very near the spinal cord; short preganglionic fibers, long post ganglionic fibers

Postganglionic axons release NE



Parasympathetic Division

Resting and digesting division

Fibers arise from cranial and sacral nerves (craniosacral division)

Ganglia lie near the organ that is innervated; long preganglionic fibers, short post ganglionic fibers

Postganglionic axons release acetylcholine

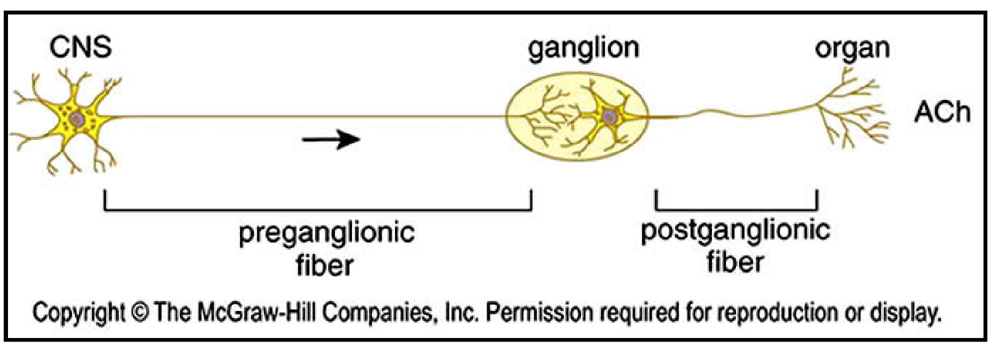
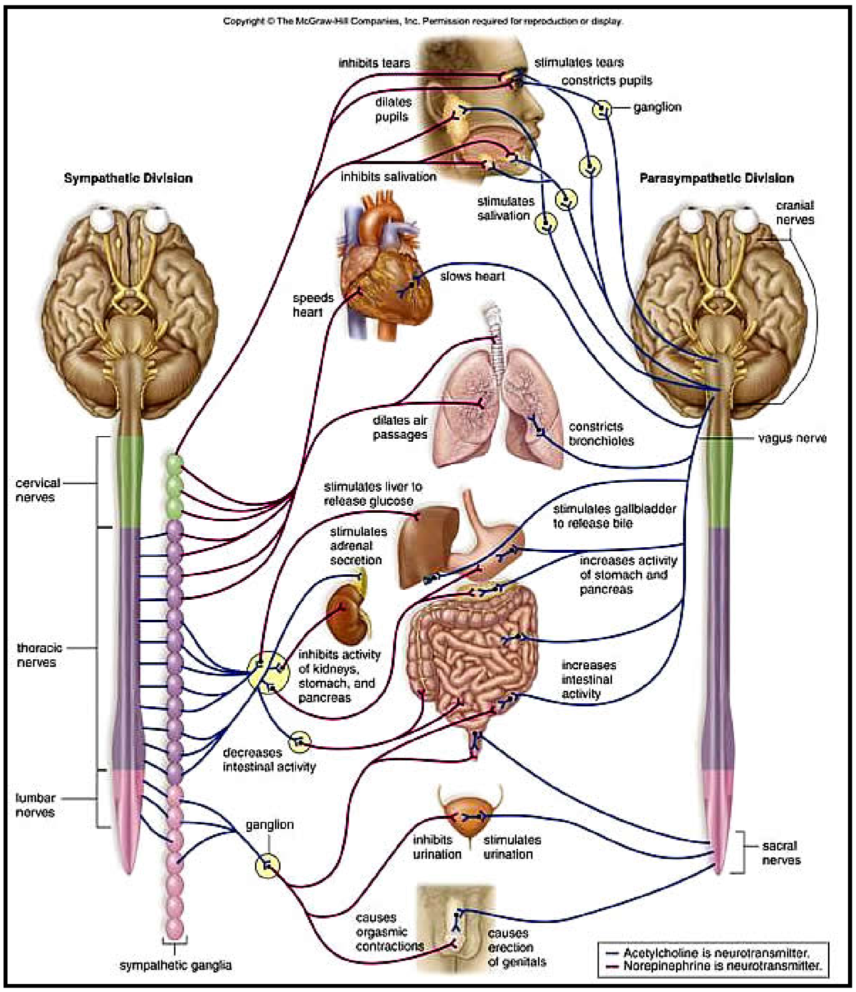


TABLE 8.3 Autonomic Motor Pathways

	Sympathetic	Parasympathetic
Type of control	Involuntary	Involuntary
Number of neurons per message	Two (preganglionic *shorter* than postganglionic)	Two (preganglionic *longer* than postganglionic)
Location of motor fiber	Thoracolumbar spinal nerves	Cranial (e.g., vagus) and sacral spinal nerves
Neurotransmitter	Norepinephrine	Acetylcholine
Effectors	Smooth and cardiac muscle, glands	Smooth and cardiac muscle, glands



Effects Of Aging

Begin to lose thousands of neurons a day after age 60

By age 80 brain weighs about 10% less

Cerebral cortex loses as much as 45% of its cells

Learning, memory, and reasoning decline

Homeostasis