Nervous system physiology

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Introduction

- The human nervous system is highly complex. It is divided into the central nervous system, consisting of the brain and spinal cord; the peripheral nervous system, which includes nerves innervating the muscles and nerves sending sensory information from the skin, muscle, and joints to the brain; and the autonomic nervous system which controls the involuntary processes of the body.

Functions of the Nervous System

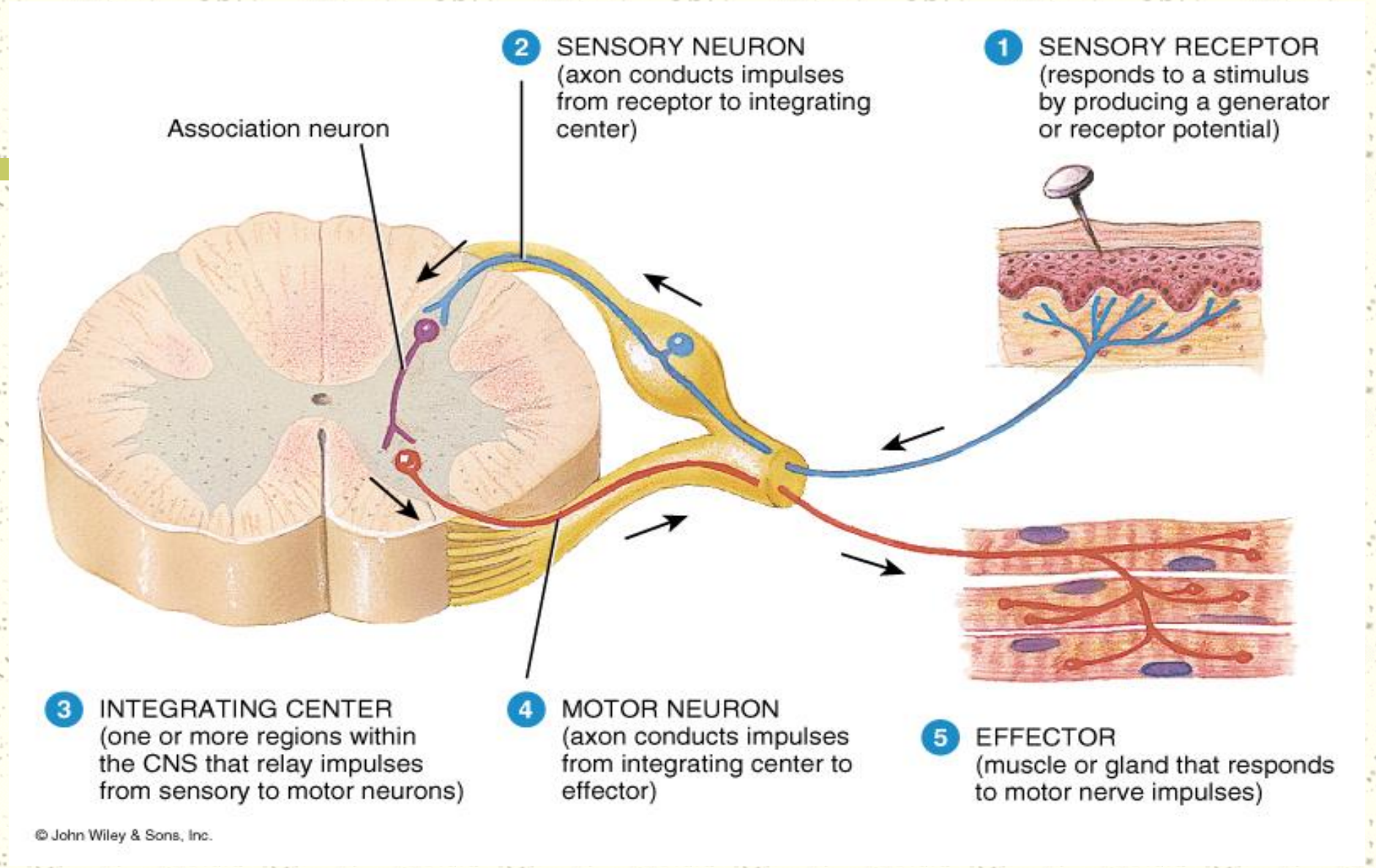
- communication system of the body.
- Controls body functions and actions.
- Maintains physiological homeostasis.

Functions of the Nervous System

1. **Sensory Functions:** Sensory receptors detect both internal and external stimuli.
   - Functional unit: Sensory or Afferent Neurons

2. **Integrative Functions:** CNS integrates sensory input and makes decisions regarding appropriate responses
   - Functional Unit: Interneurons or Association Neurons of the Brain and Spinal cord

3. **Motor Functions:** Response to integration decisions.
   - Functional Unit: Motor or Efferent Neurons


2 SENSORY NEURON
(axon conducts impulses from receptor to integrating center)
1 SENSORY RECEPTOR
(responds to a stimulus by producing a generator or receptor potential)
Association neuron
3 INTEGRATING CENTER
(one or more regions within the CNS that relay impulses from sensory to motor neurons)
4 MOTOR NEURON
(axon conducts impulses from integrating center to effector)
5 EFFECTOR
(muscle or gland that responds to motor nerve impulses)
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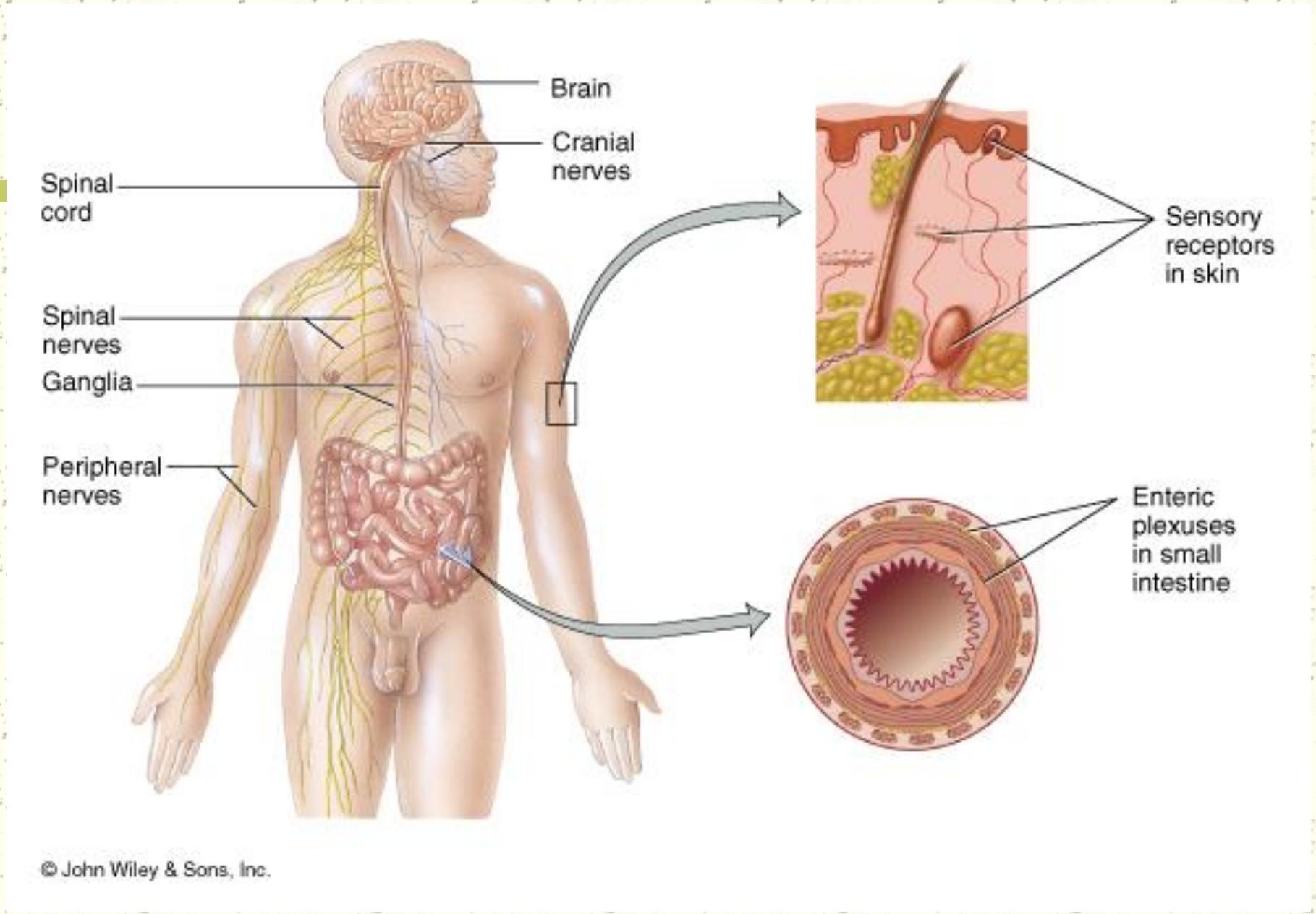
Brain
Cranial nerves
Spinal cord
Spinal nerves
Ganglia
Peripheral nerves
Sensory receptors in skin
Enteric plexuses in small intestine
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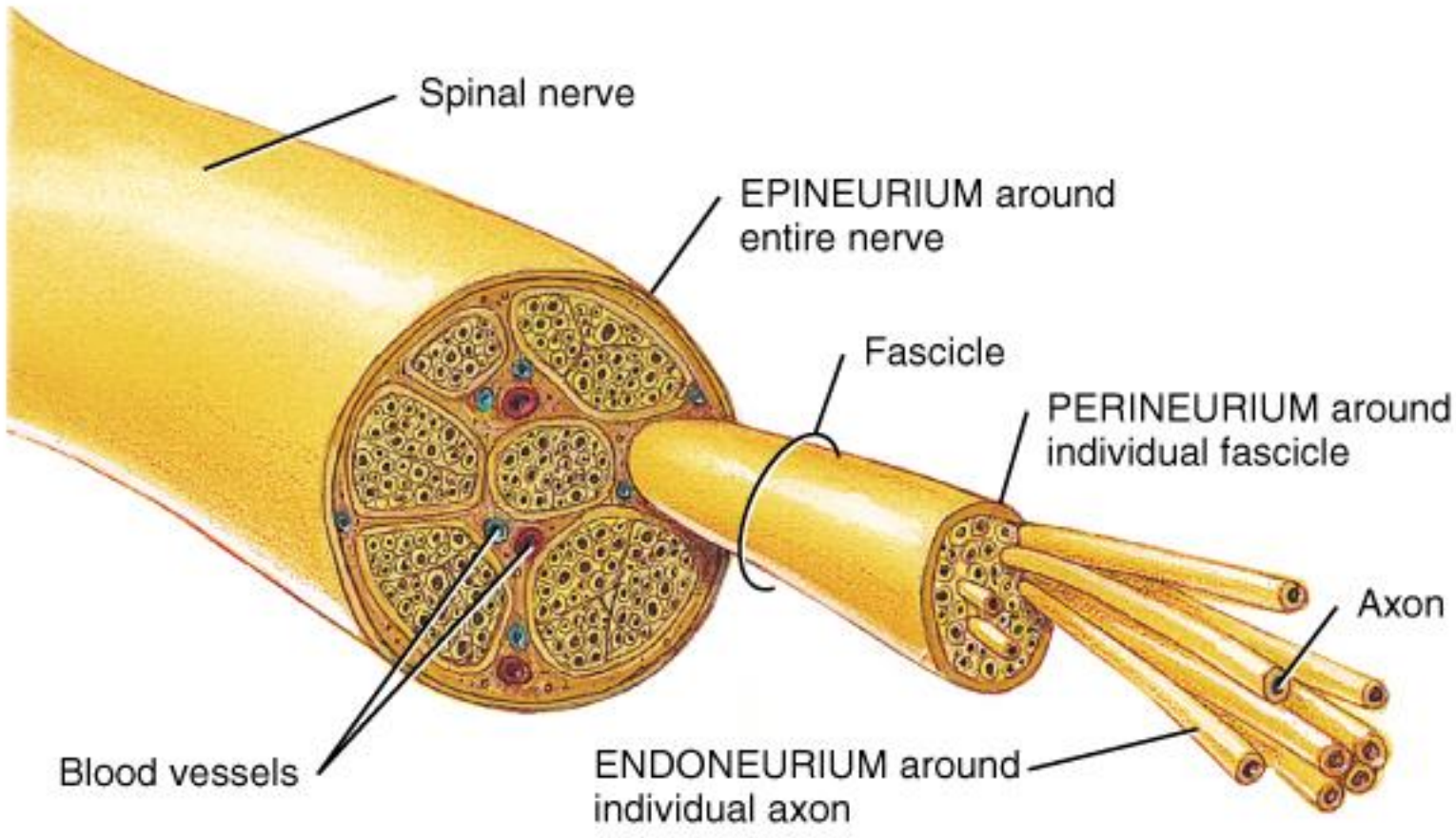
Organization of a Nerve of the PNS



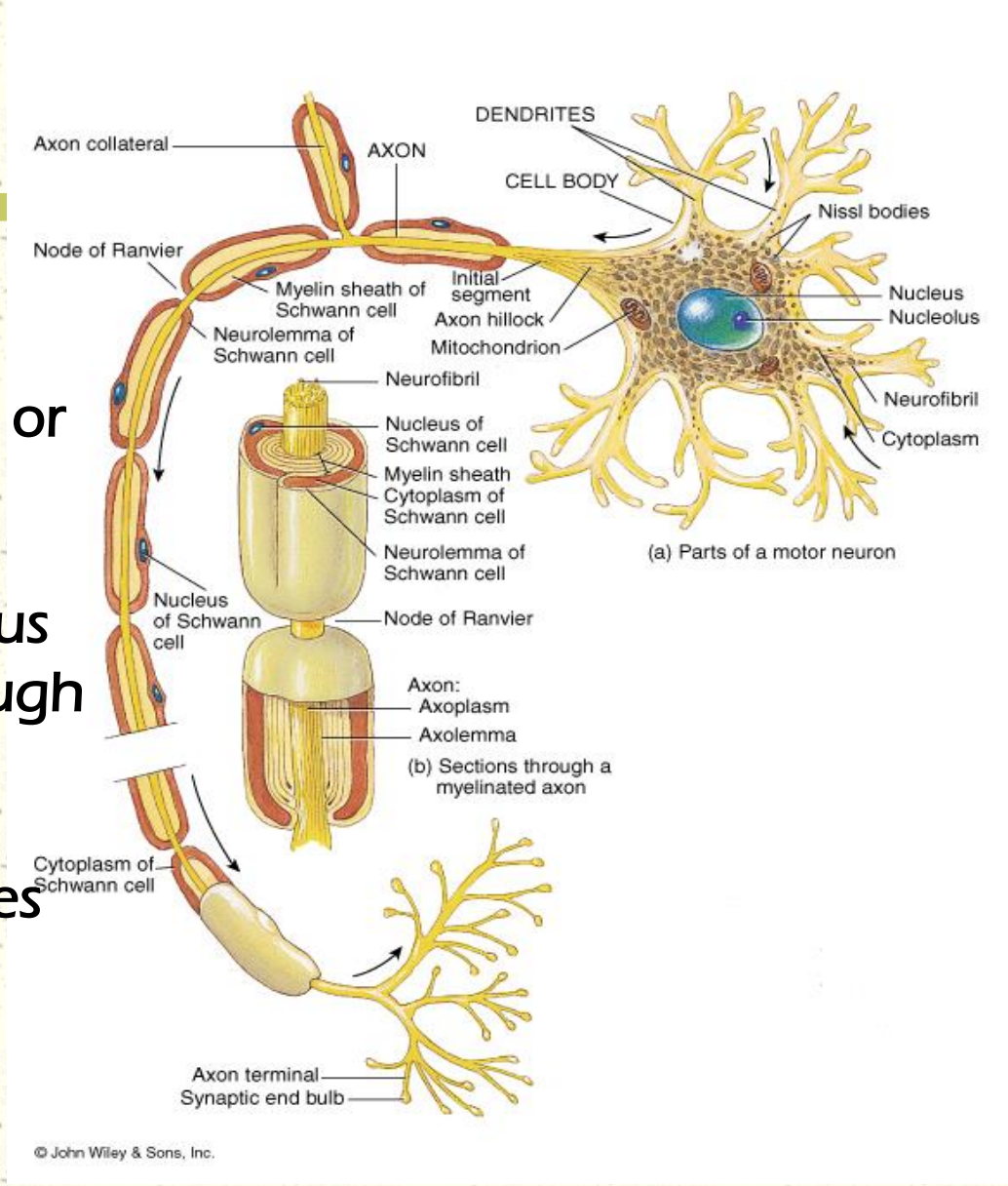
(a) Transverse sections showing the coverings of a spinal nerve

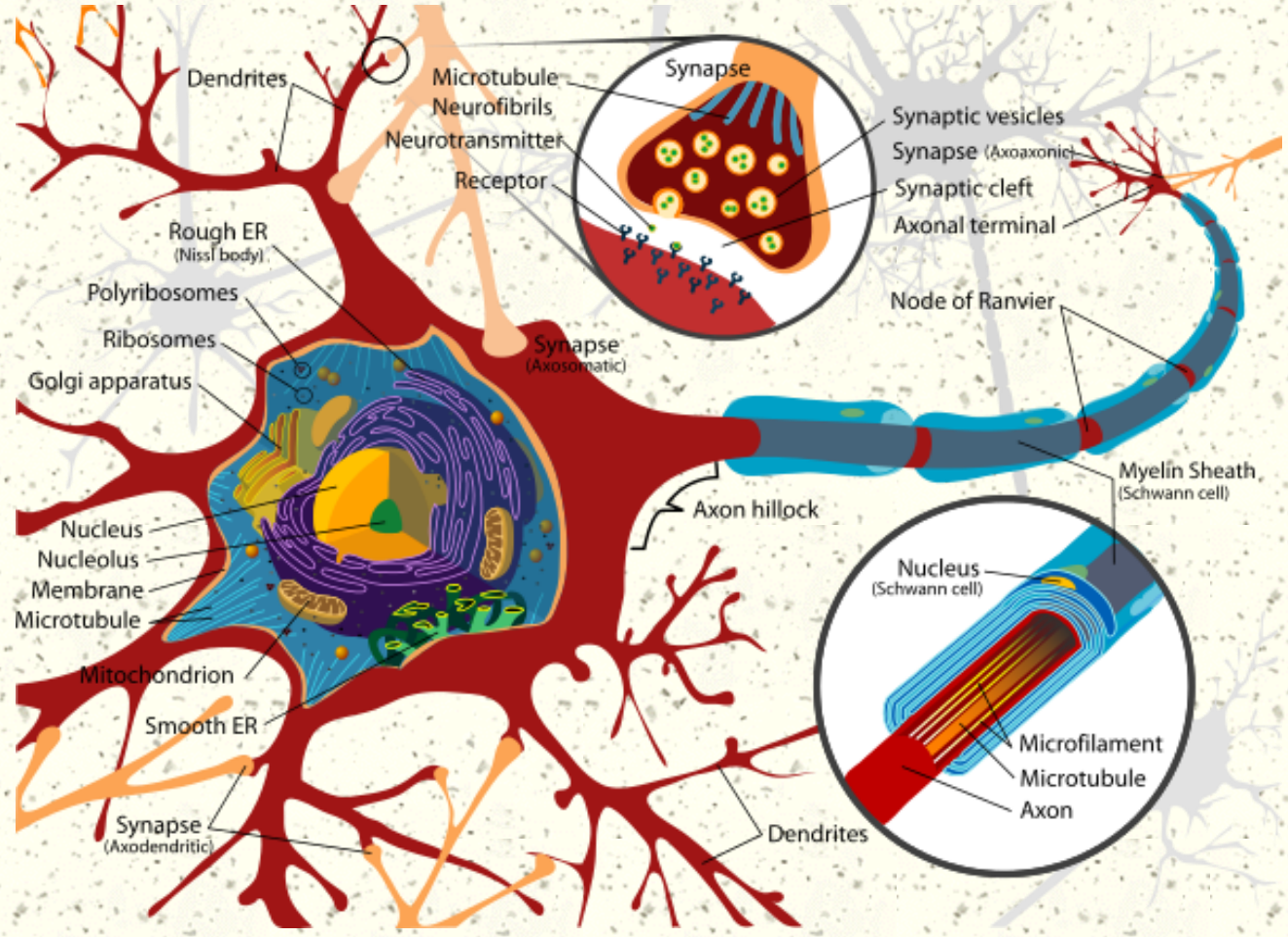
Neuron

- **Dendrites:** Carry nerve impulses toward cell body. Receive stimuli from synapses or sensory receptors.

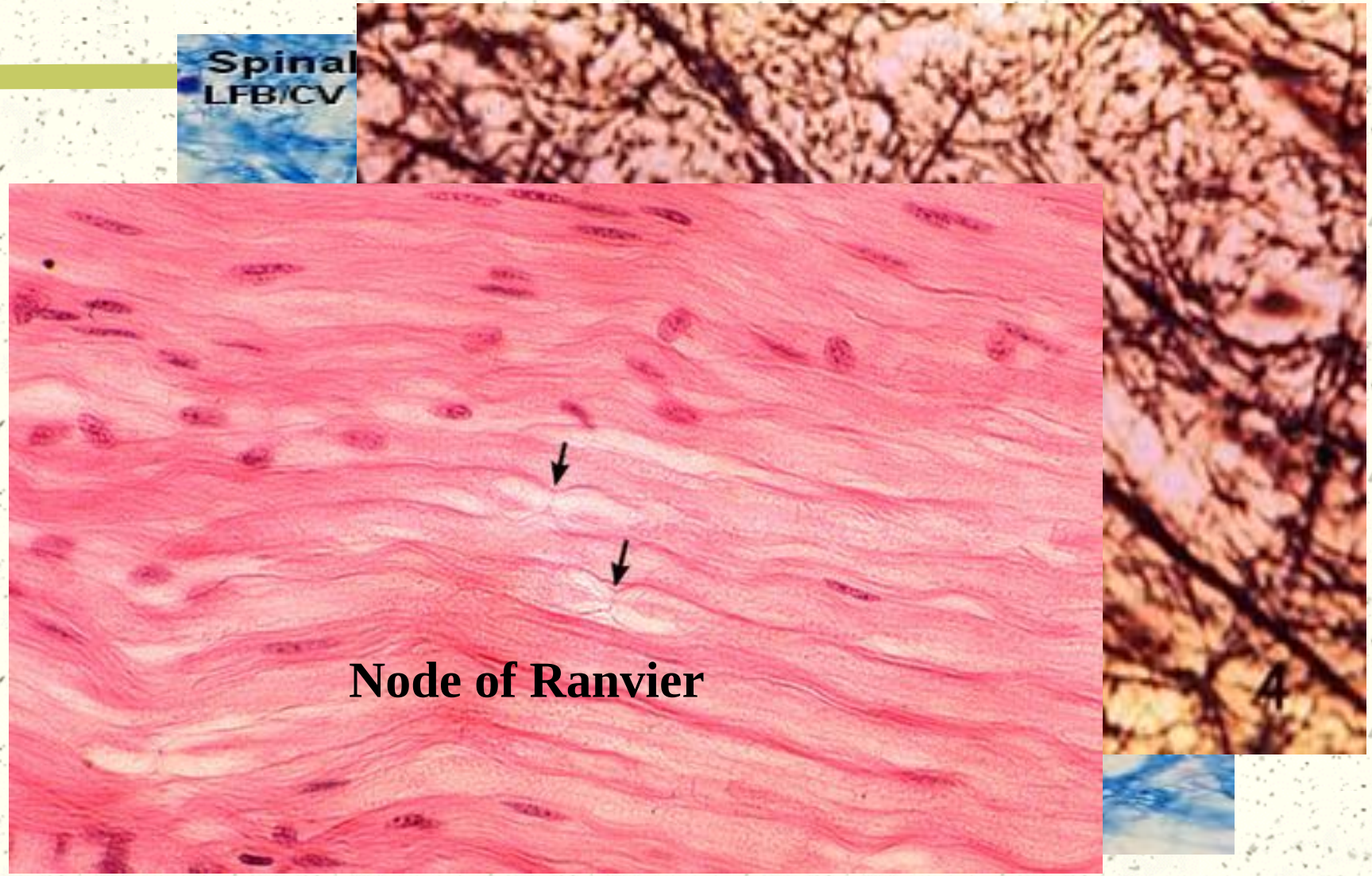
- **Cell Body:** Contains nucleus and nissl bodies, a form of rough endoplasmic reticulum.

- **Axon:** Carry nerve Impulses away from the cell bodies. Axons interact with muscle, glands, or other neurons.

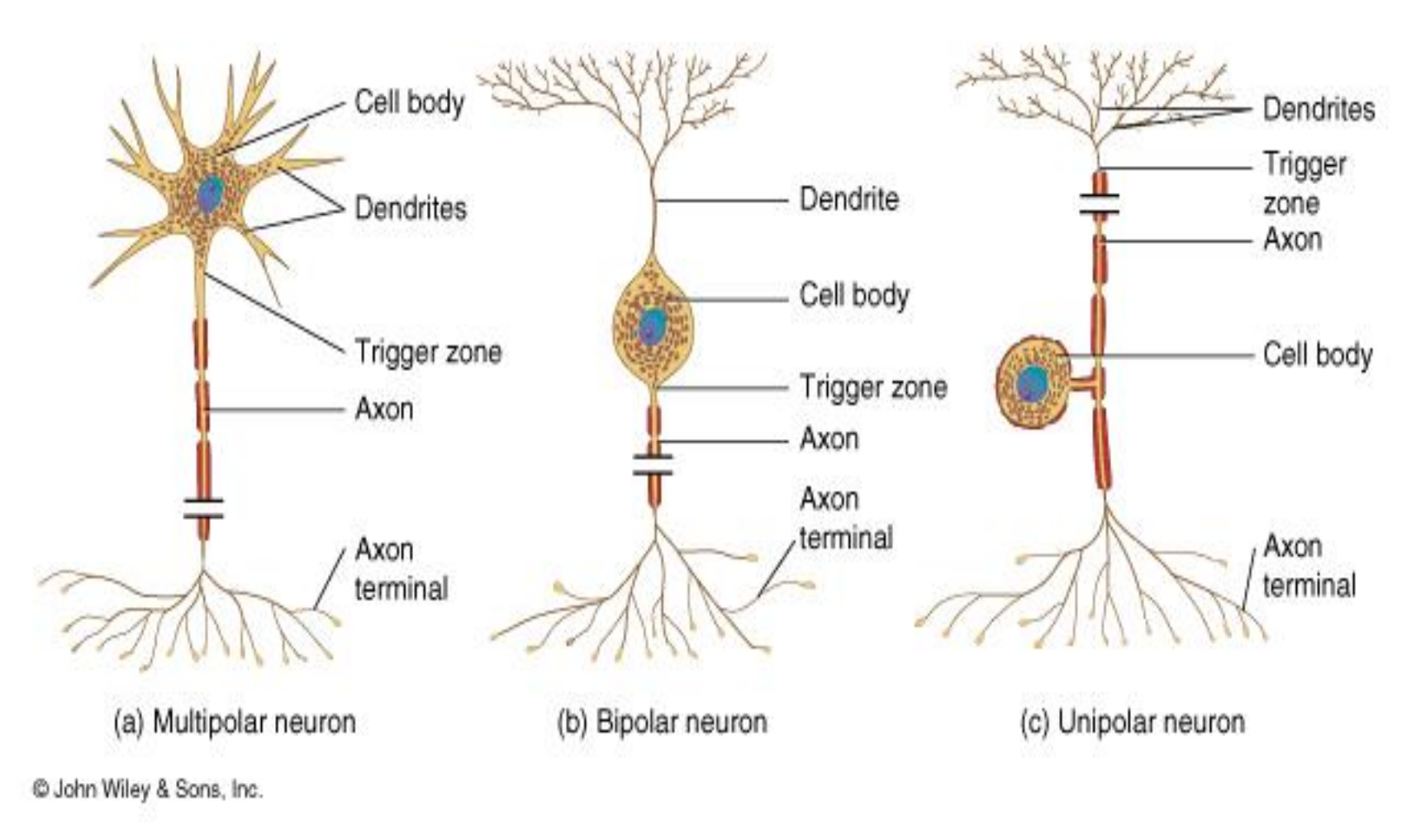



Dendrites
Microtubule
Neurofibrils
Neurotransmitter
Receptor
Synapse
Synaptic vesicles
Synapse (Axoaxonic)
Synaptic cleft
Axonal terminal
Rough ER
(Nissl body)
Polyribosomes
Ribosomes
Golgi apparatus
Synapse
(Axosomatic)
Node of Ranvier
Myelin Sheath
(Schwann cell)
Axon hillock
Nucleus
Nucleolus
Membrane
Microtubule
Mitochondrion
Smooth ER
Synapse
(Axodendritic)
Nucleus
(Schwann cell)
Microfilament
Microtubule
Axon
Dendrites

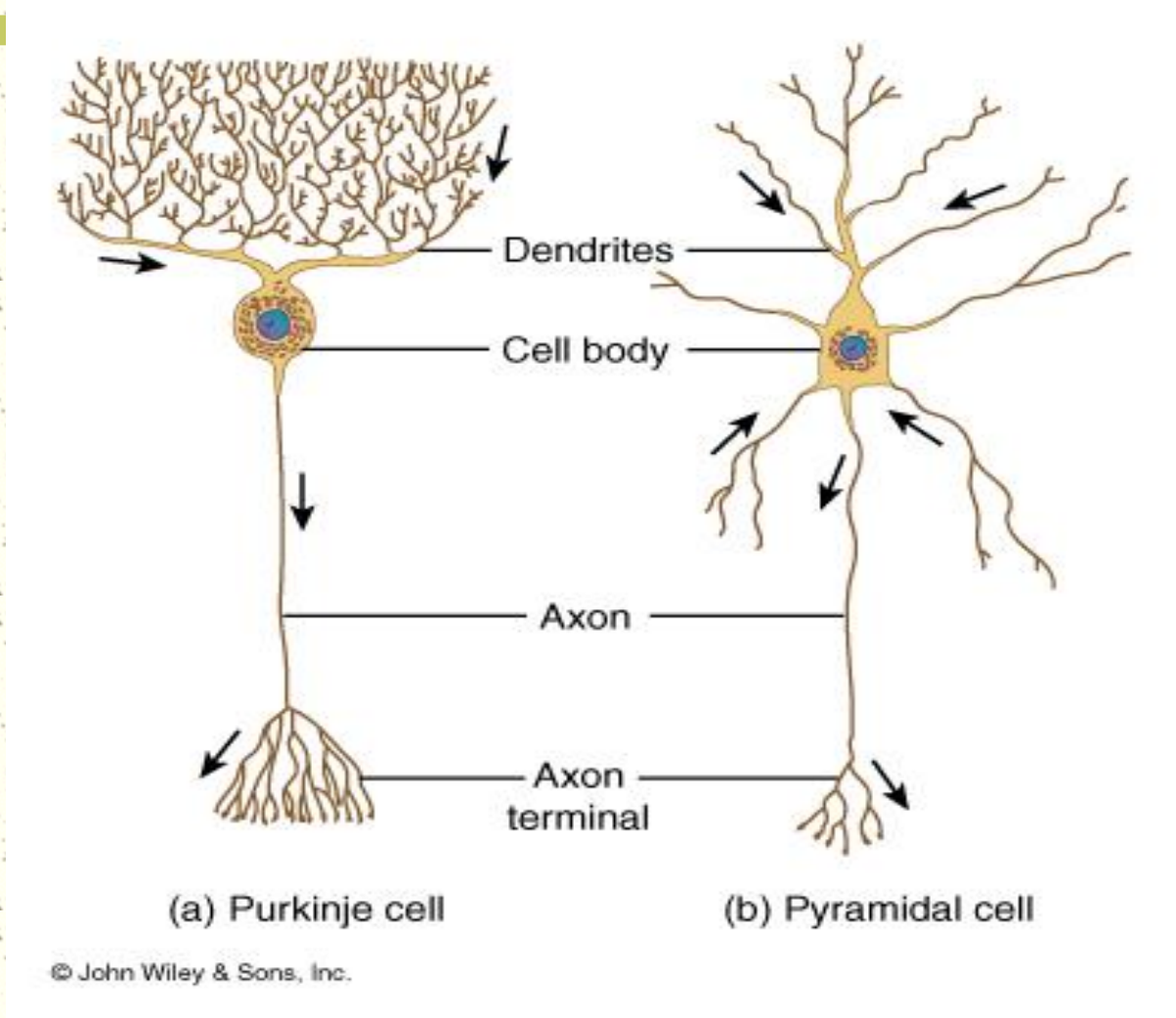
Neuron



Types of neurons



Types of interneurons



Types of neurons

Structural classification

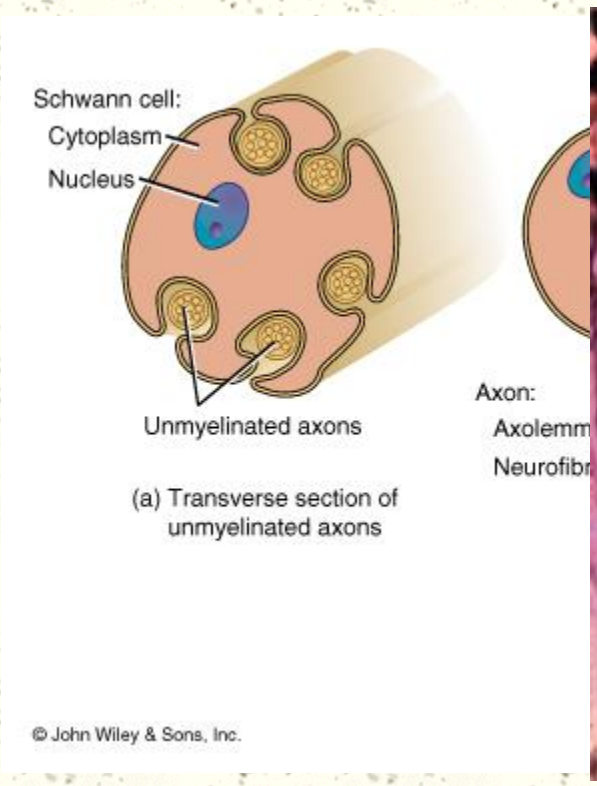
Polarity

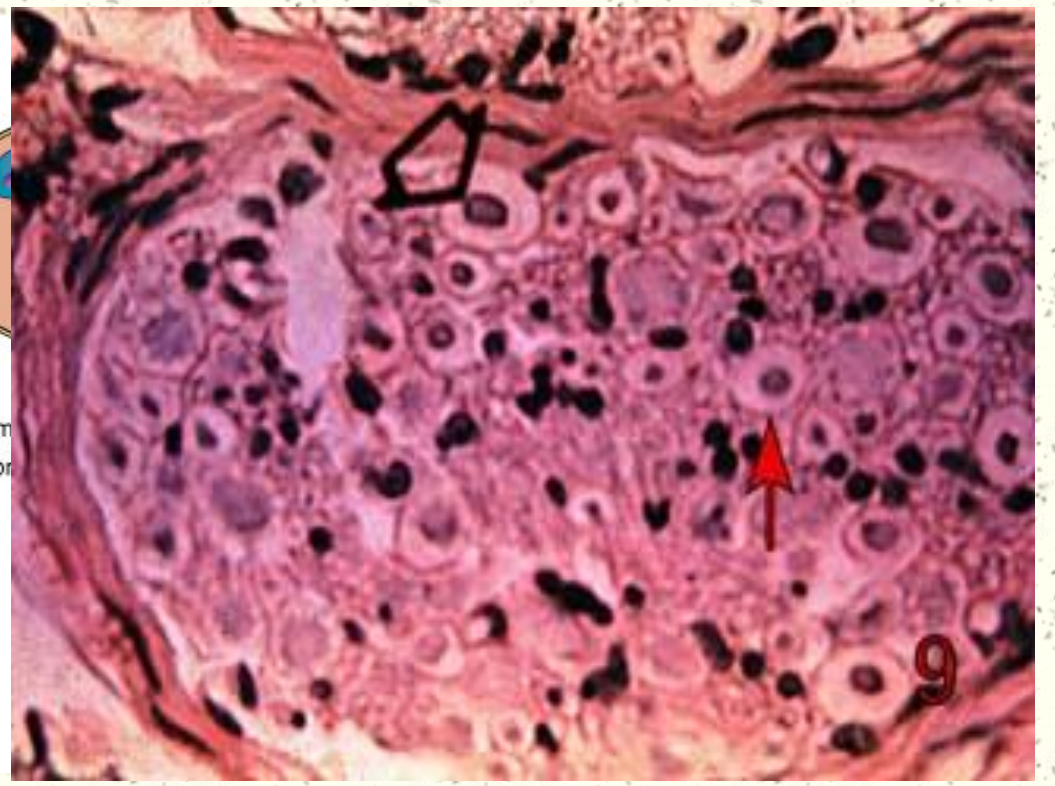
Different kinds of neurons:

1 Unipolar neuron
2 Bipolar neuron
3 Multipolar neuron
4 Pseudounipolar neuron

Types of Supportive Cells of the PNS

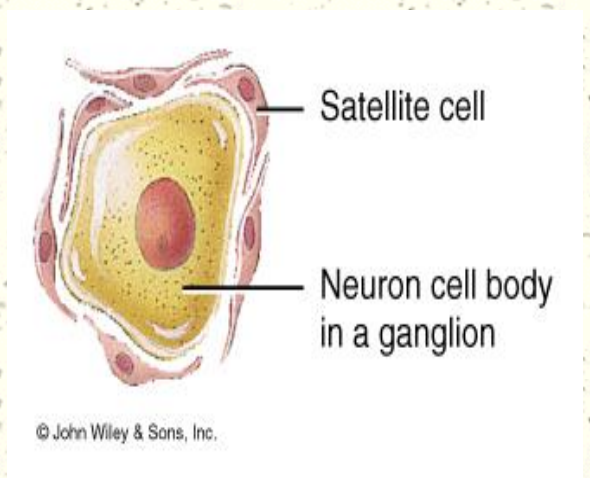
1. Schwann cells that form the myelin sheath

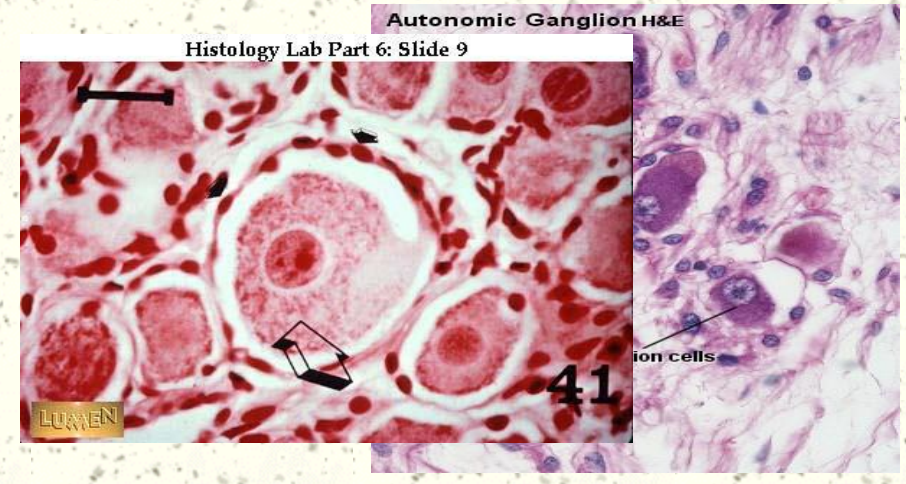




Types of Supportive Cells of the PNS

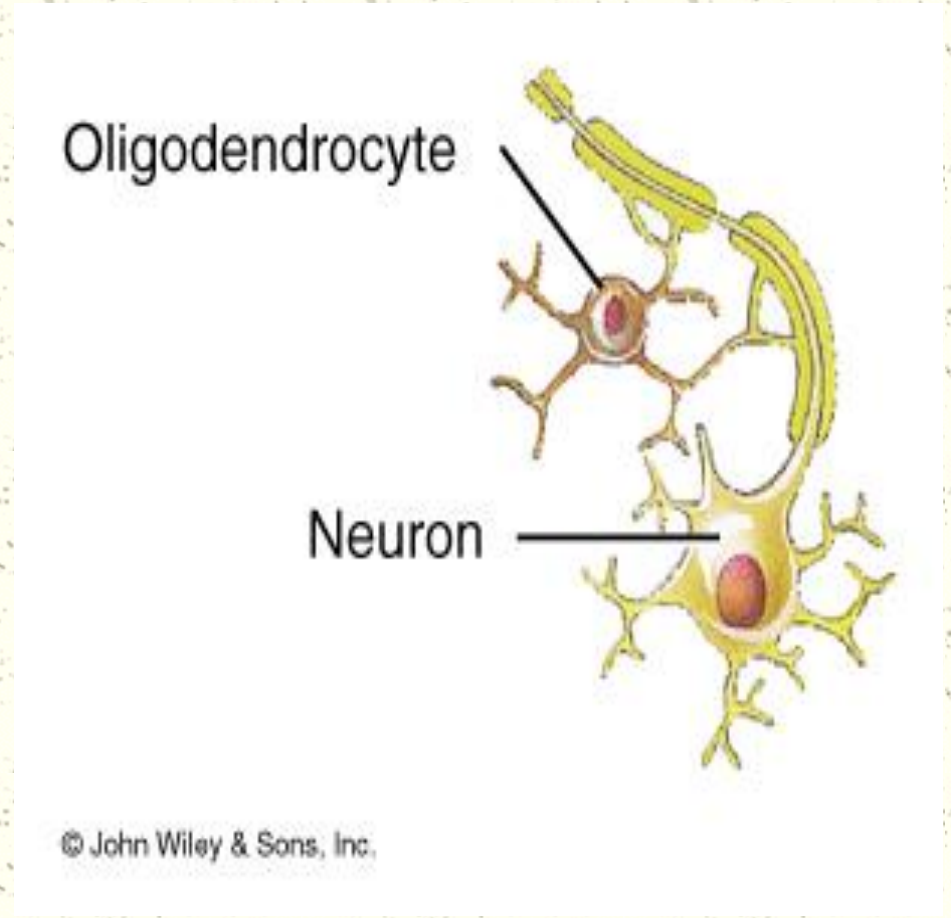
2. Satellite cells associated with sensory neuron cell bodies
- Precursors to skeletal muscle cells, able to give rise to satellite cells or differentiated skeletal muscle cells. They have the potential to provide additional myonuclei to their parent muscle fiber, or return to a quiescent state.

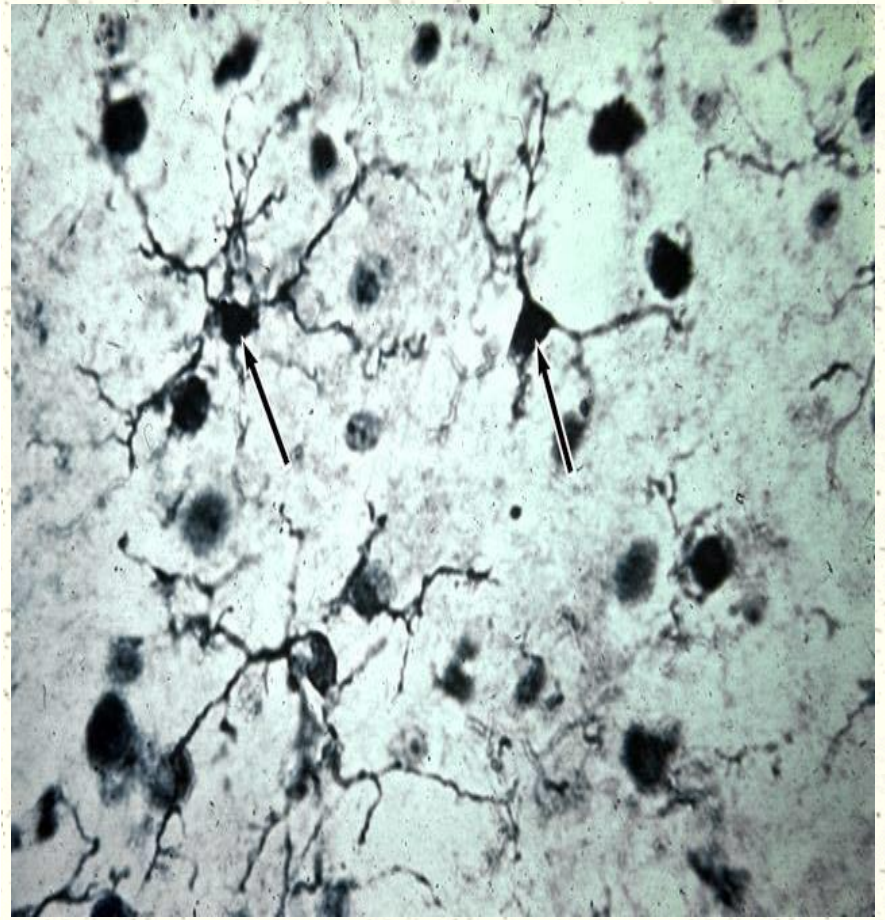




Types of Supportive Cells of the CNS (Neuroglia)

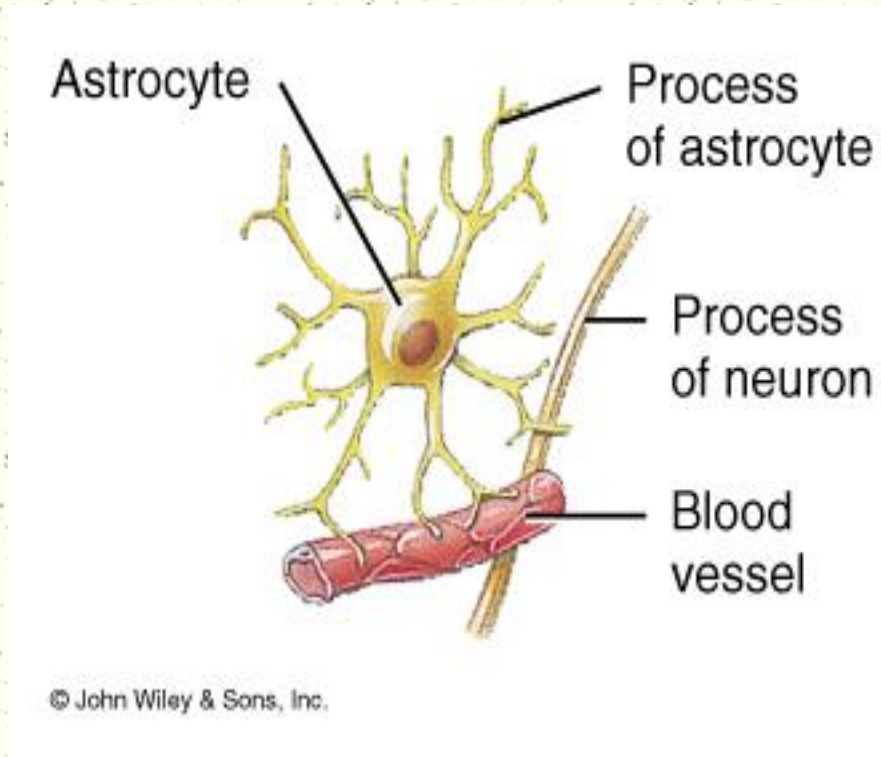
1. Oligodendrocytes: form the myelin sheath of the CNS

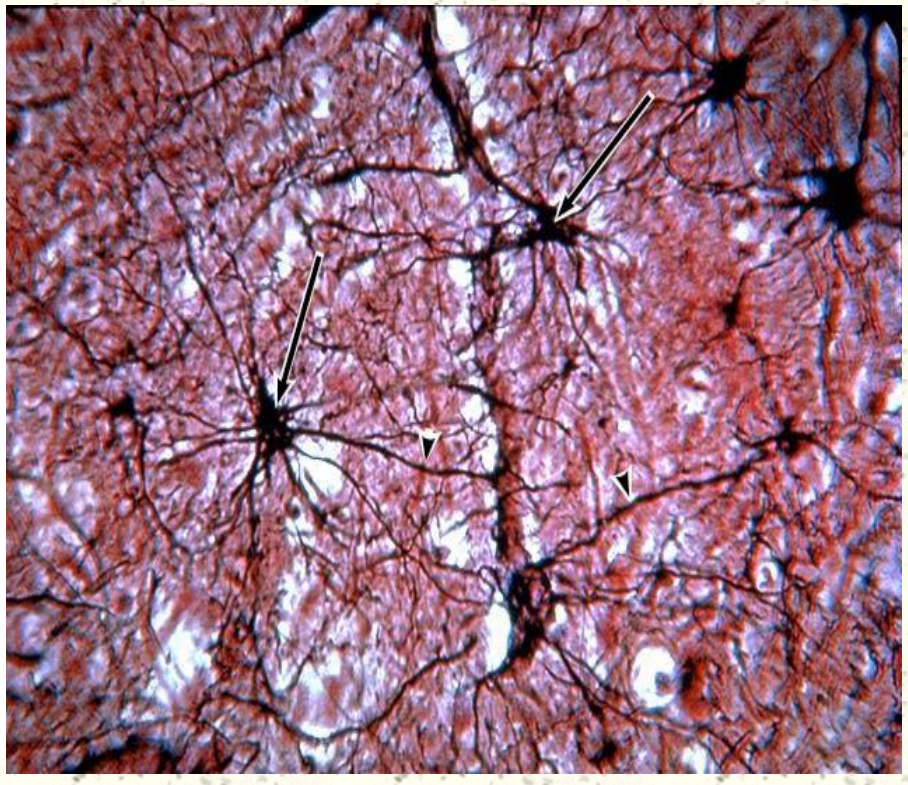




Types of Supportive Cells of the CNS (Neuroglia)

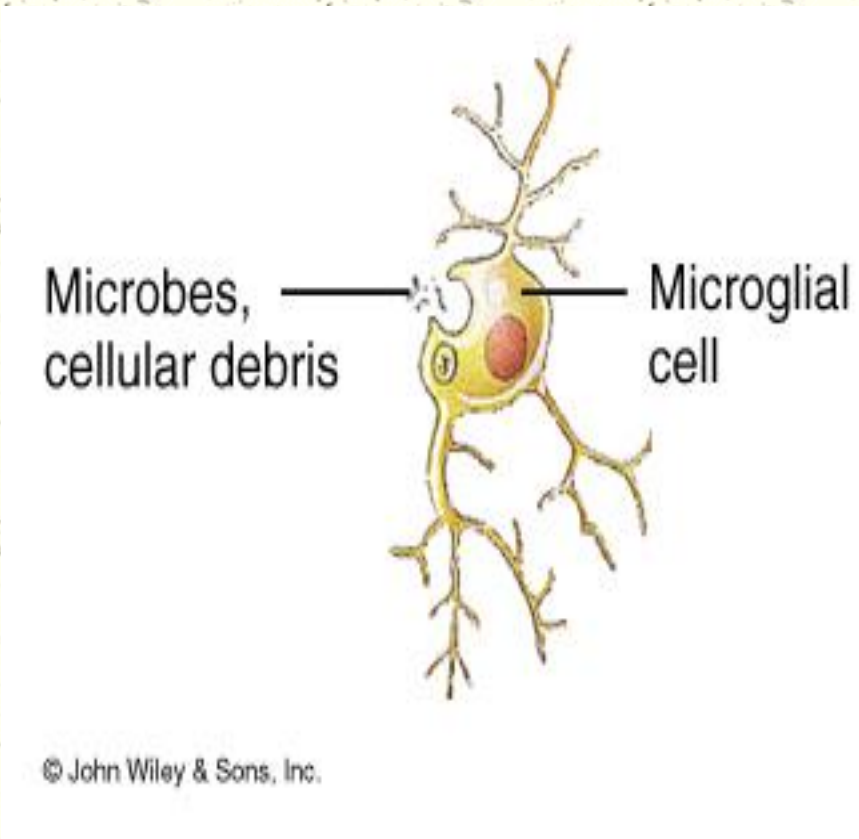
2. Astrocytes: Help form the blood-brain barrier, support the appropriate chemical environment for neurons.

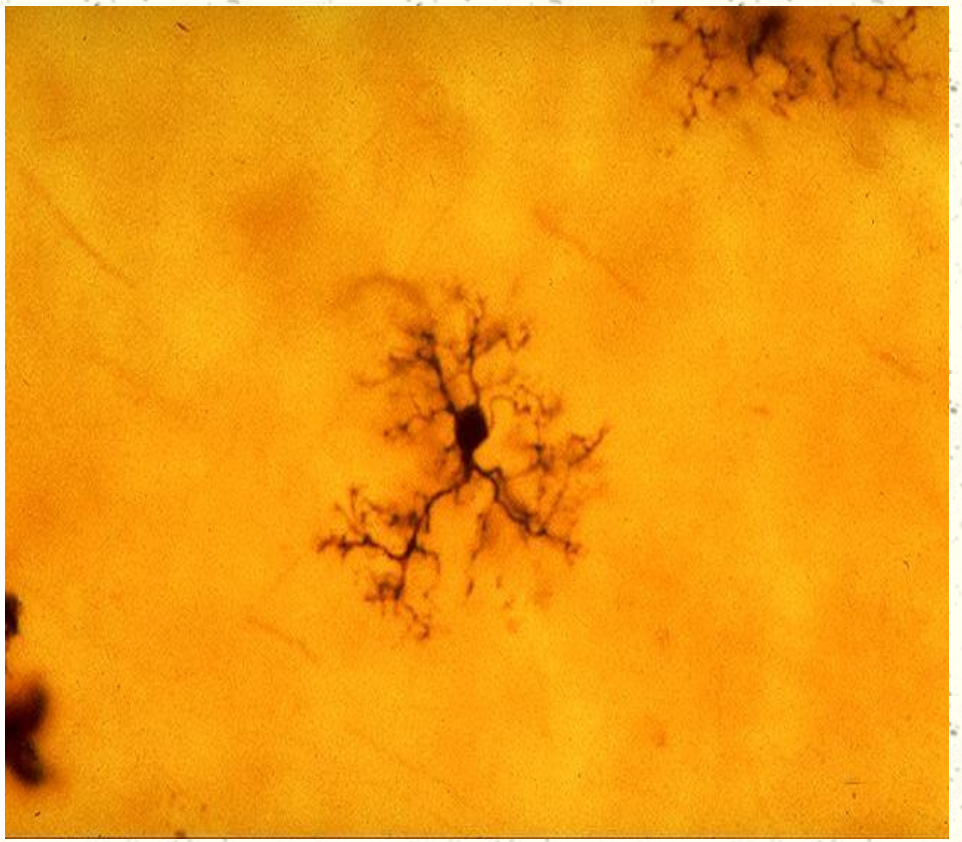




Types of Supportive Cells of the CNS (Neuroglia)

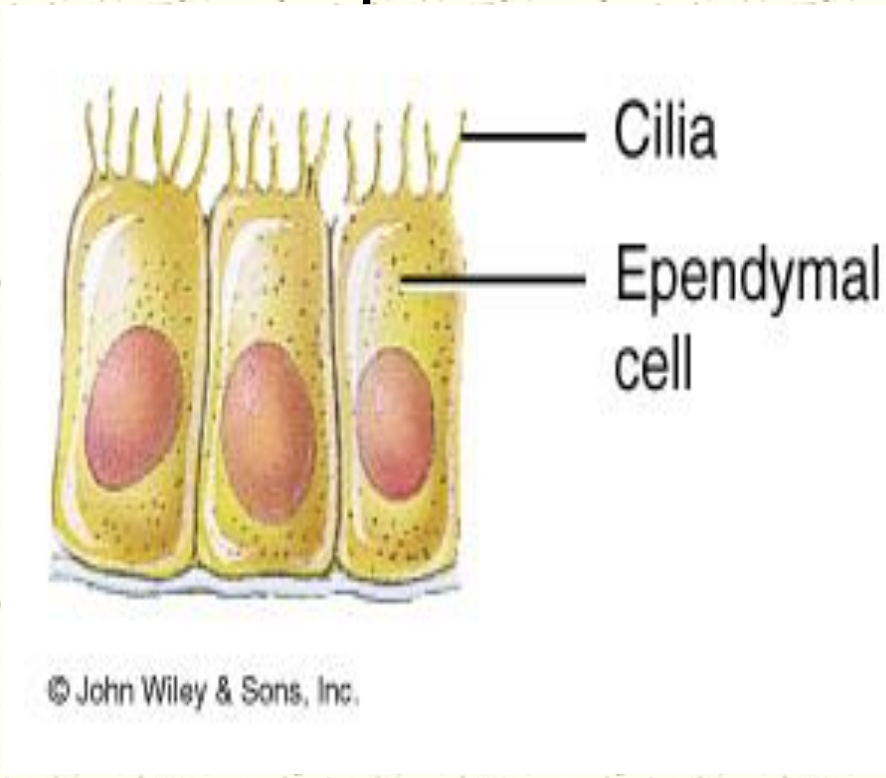
3. Microglia: Phagocytes in the CNS that engulf microbes and cellular debris.





Types of Supportive Cells of the CNS (Neuroglia)

4. Ependymal Cells: Form blood-brain barrier in the brain ventricles and central canal of spinal cord. Produce cerebrospinal fluid and assist in its circulation.

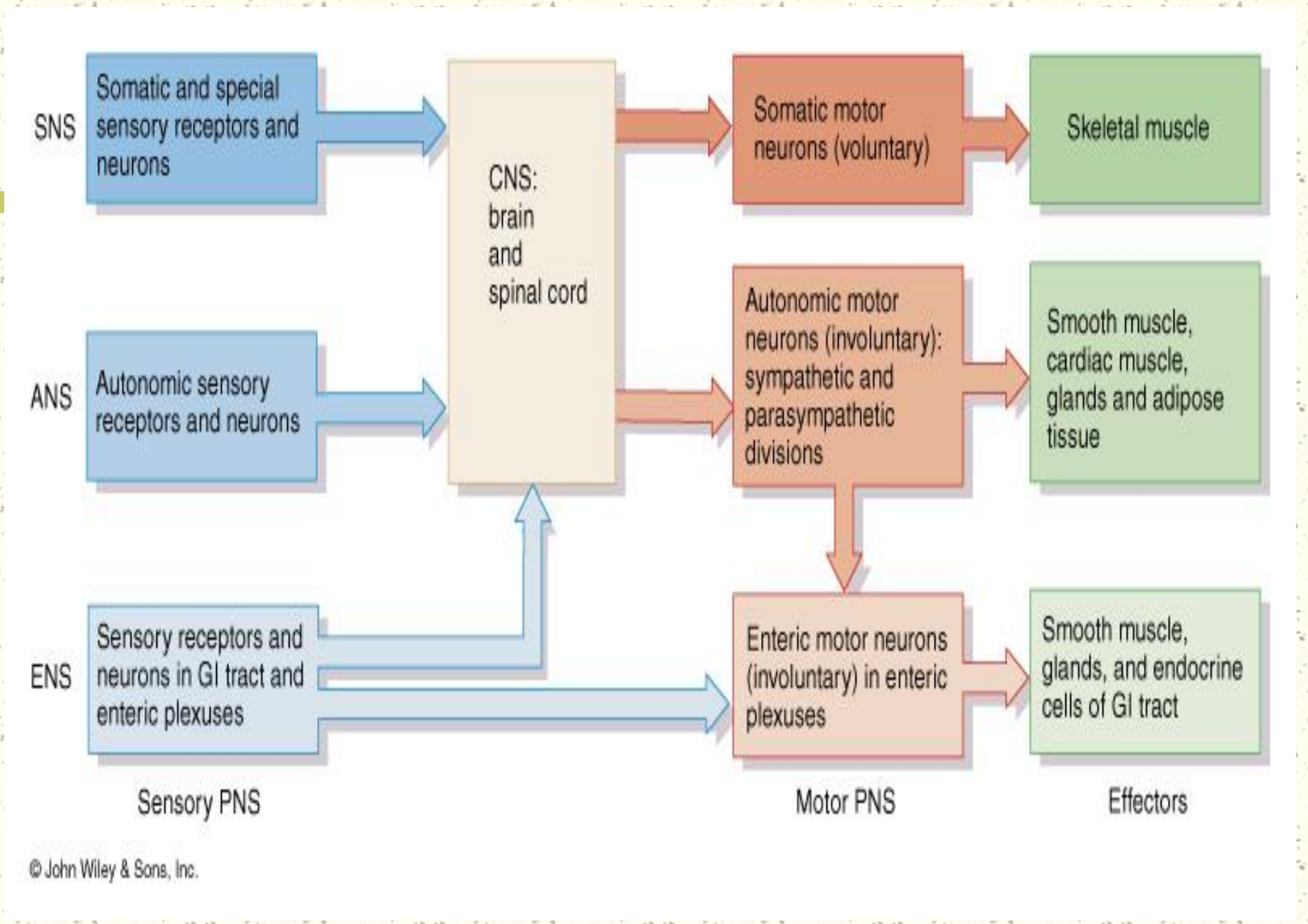


Components of the Nervous System

- Central Nervous System
  - Brain
  - Spinal Cord
- Peripheral Nervous System
  - Sensory and Motor Nerves
  - Cranial Nerves
  - Spinal Nerves
- Autonomic
  - Sympathetic
  - Parasympathetic

The Nervous System

- Central Nervous System (CNS)
  - Brain
  - Spinal Cord
- Peripheral Nervous System (PNS)
  - Motor Neurons
    - Somatic Nervous System
      - voluntary movements via skeletal muscles
    - Autonomic Nervous System
      - organs, smooth muscles
      - Sympathetic
        - "Fight-or-Flight" responses
      - Parasympathetic
        - maintenance
  - Sensory Neurons


SNS
Somatic and special sensory receptors and neurons
ANS
Autonomic sensory receptors and neurons
ENS
Sensory receptors and neurons in GI tract and enteric plexuses
CNS: brain and spinal cord
Somatic motor neurons (voluntary)
Autonomic motor neurons (involuntary): sympathetic and parasympathetic divisions
Enteric motor neurons (involuntary) in enteric plexuses
Skeletal muscle
Smooth muscle, cardiac muscle, glands and adipose tissue
Smooth muscle, glands, and endocrine cells of GI tract
Sensory PNS
Motor PNS
Effectors
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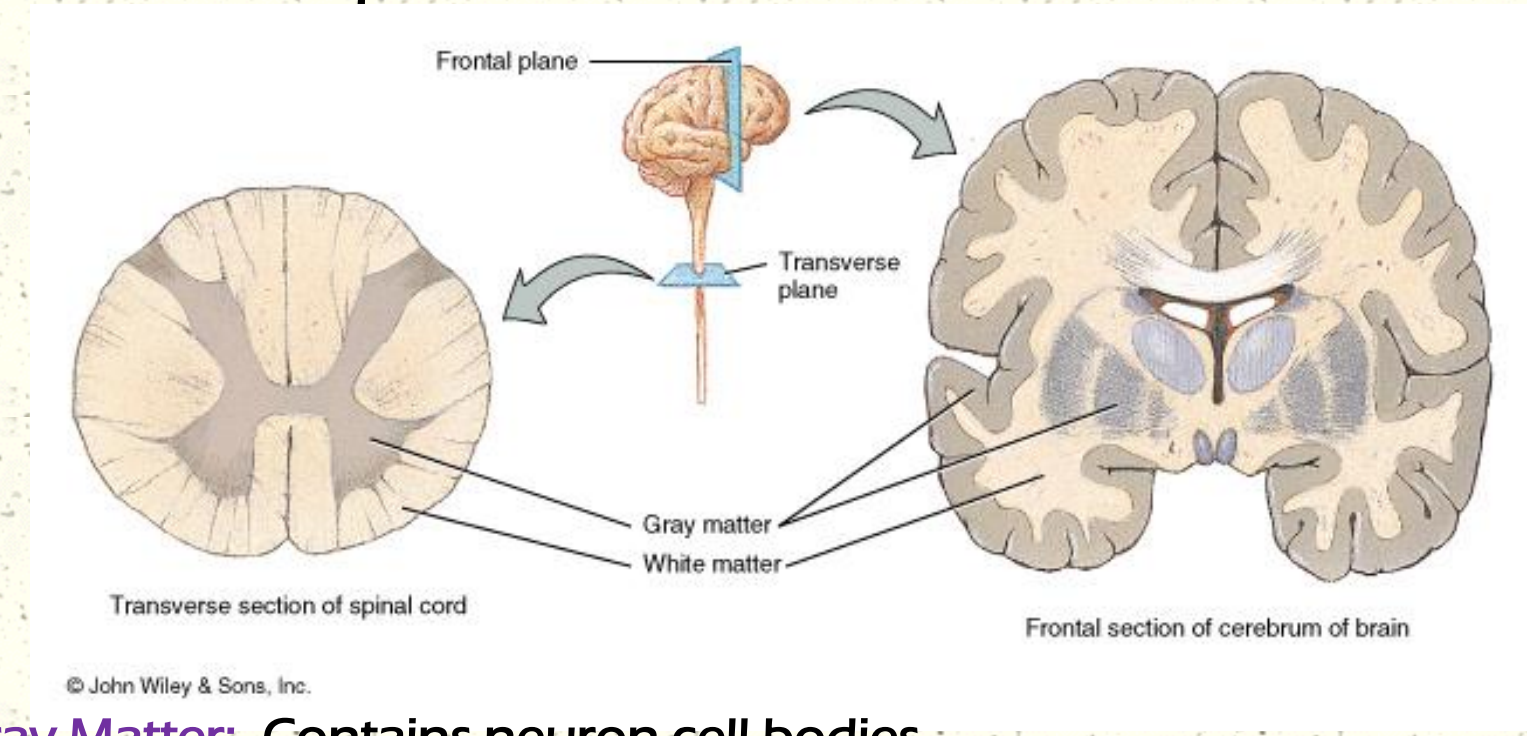
Central Nervous System (CNS)

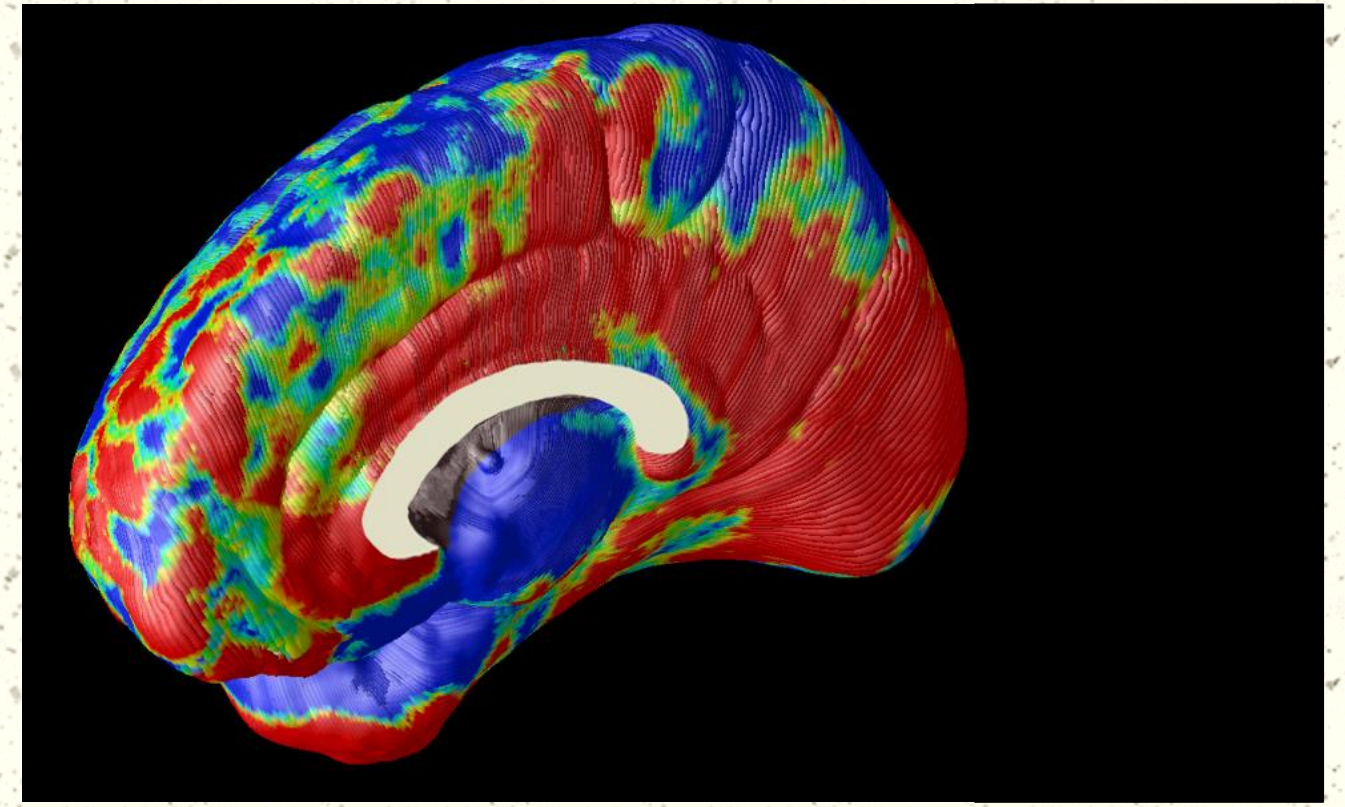
- Brain- lies inside the hard outer shell of the skull, inside a protected cushion of cerebrospinal fluid.



Gray Matter: Contains neuron cell bodies

White Matter: Contains cell extensions organized into tracts

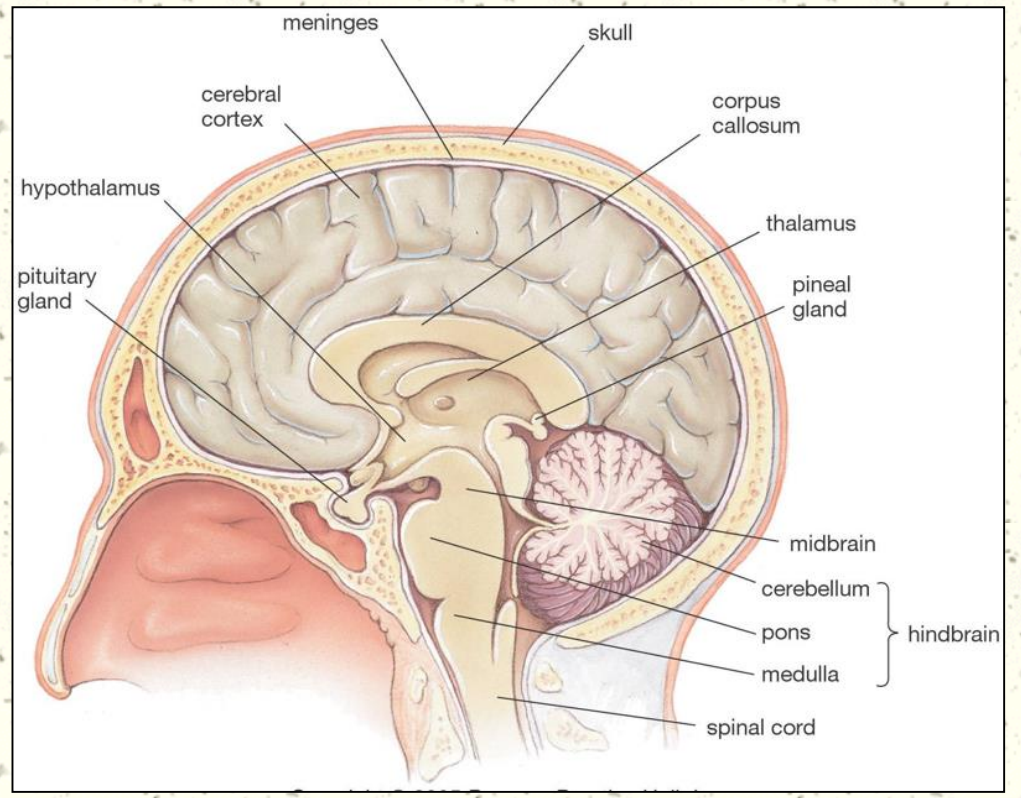
Brain



Brain

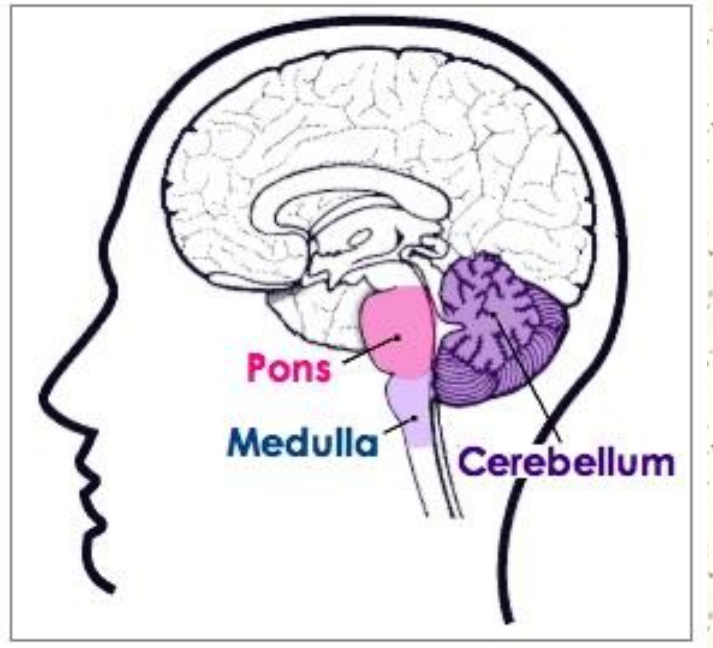
Brain: Structure

- Hindbrain carries out the most basic functions.
- Midbrain coordinates signals.
- Forebrain processes signals, stores memories, creates thought.



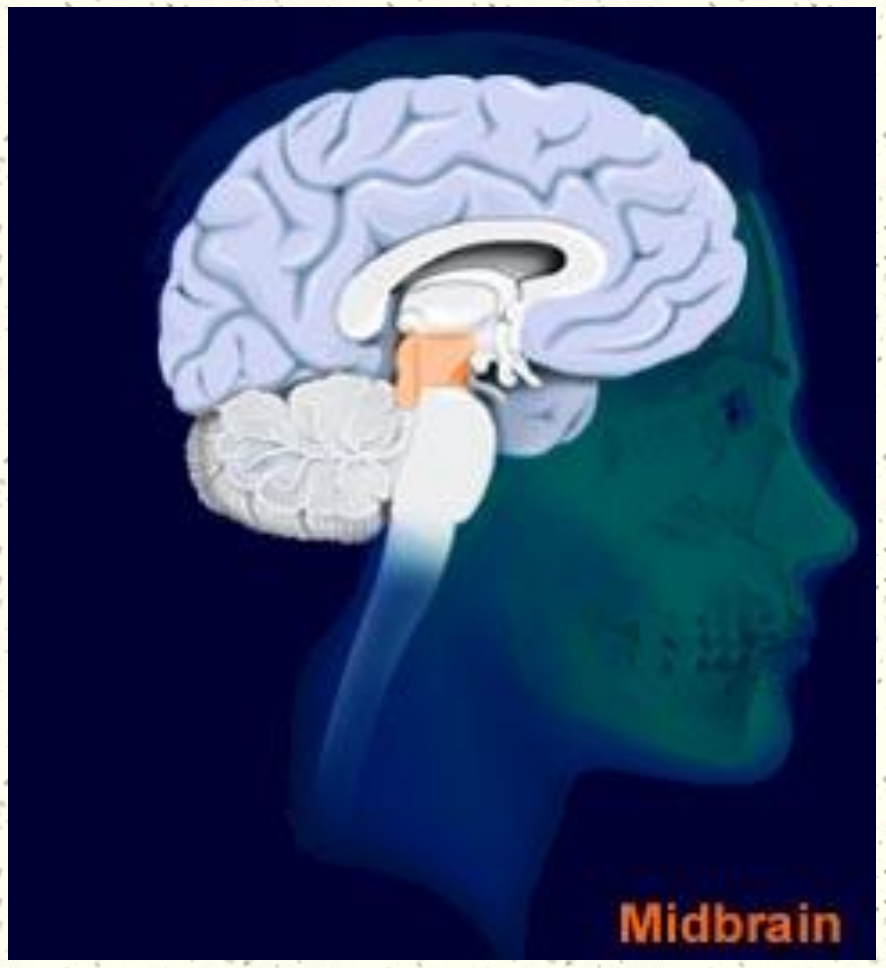
Hindbrain

- Medulla: controls autonomic fuctions.
- Pons: controls sleep stages.
- Cerebellum: coordinates movement, stores some motor memory.



Midbrain

- Reticular formation: the “traffic cops” of the brain.
- Filters sensory input, which allows us to concentrate.
- Filtering can be affected by higher thoughts.

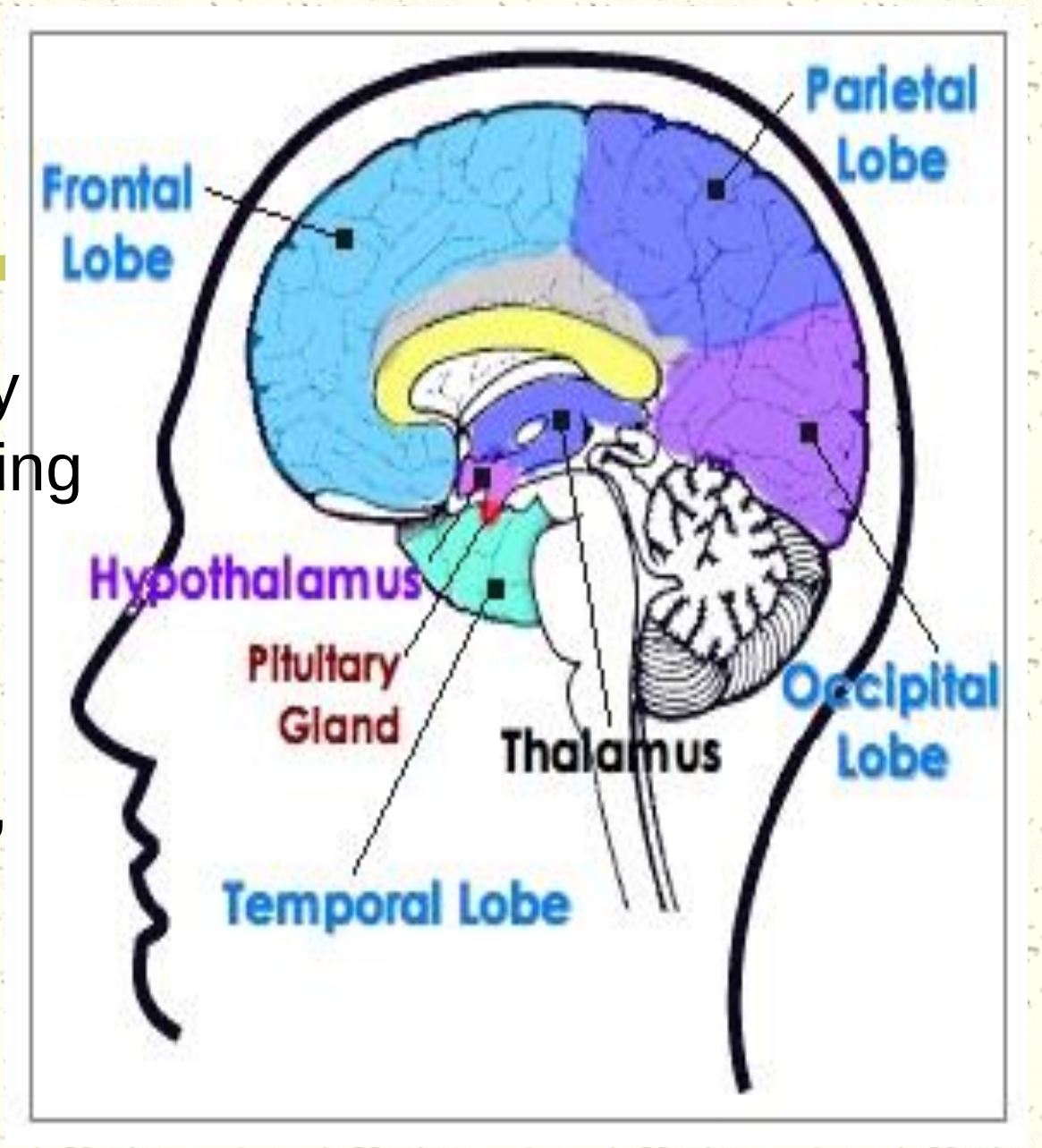


Try this:

- Stop and think: What have you been paying attention to for the last ten minutes?
- Pay attention to the feel of your shirt on your arms. Had you been noticing it during the last ten minutes? That's the reticular formation in action.
- What else have you *not* been paying attention to?

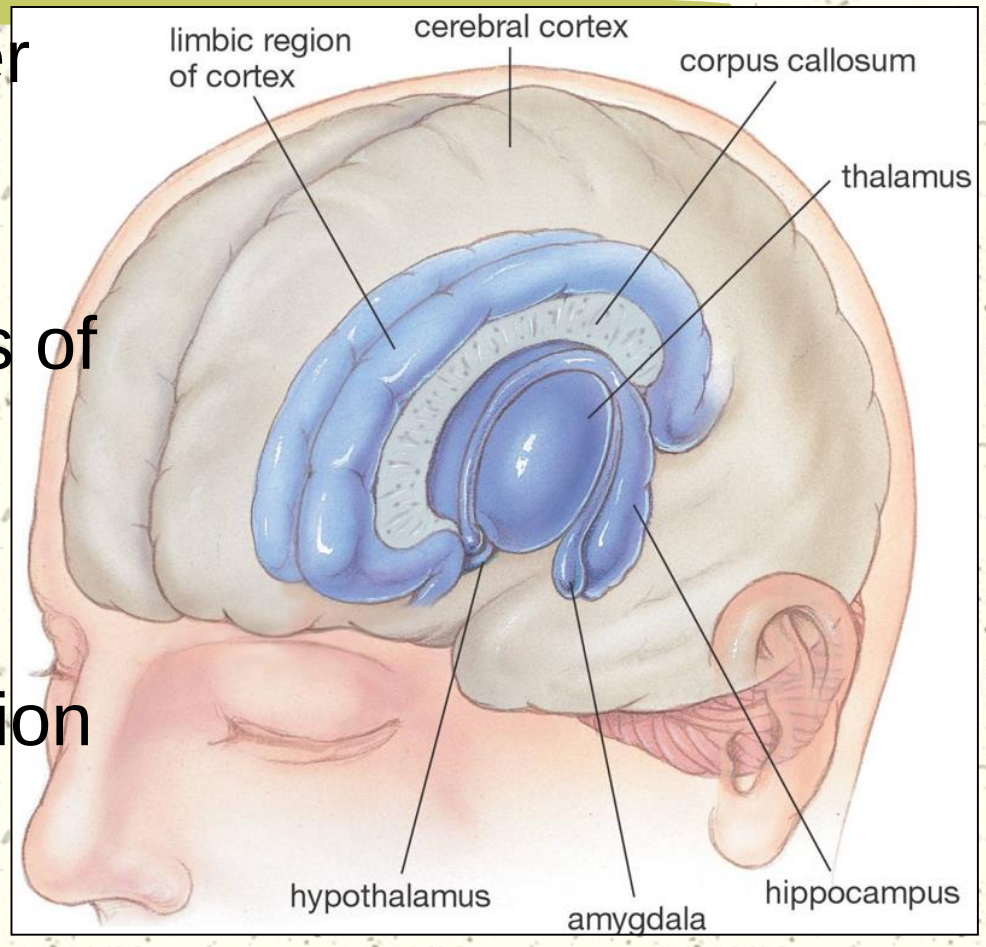
Forebrain

- Thalamus: relay station channeling sensory information.
- Limbic system: basic emotions, drives, and behaviors.
- Cortex: higher thought



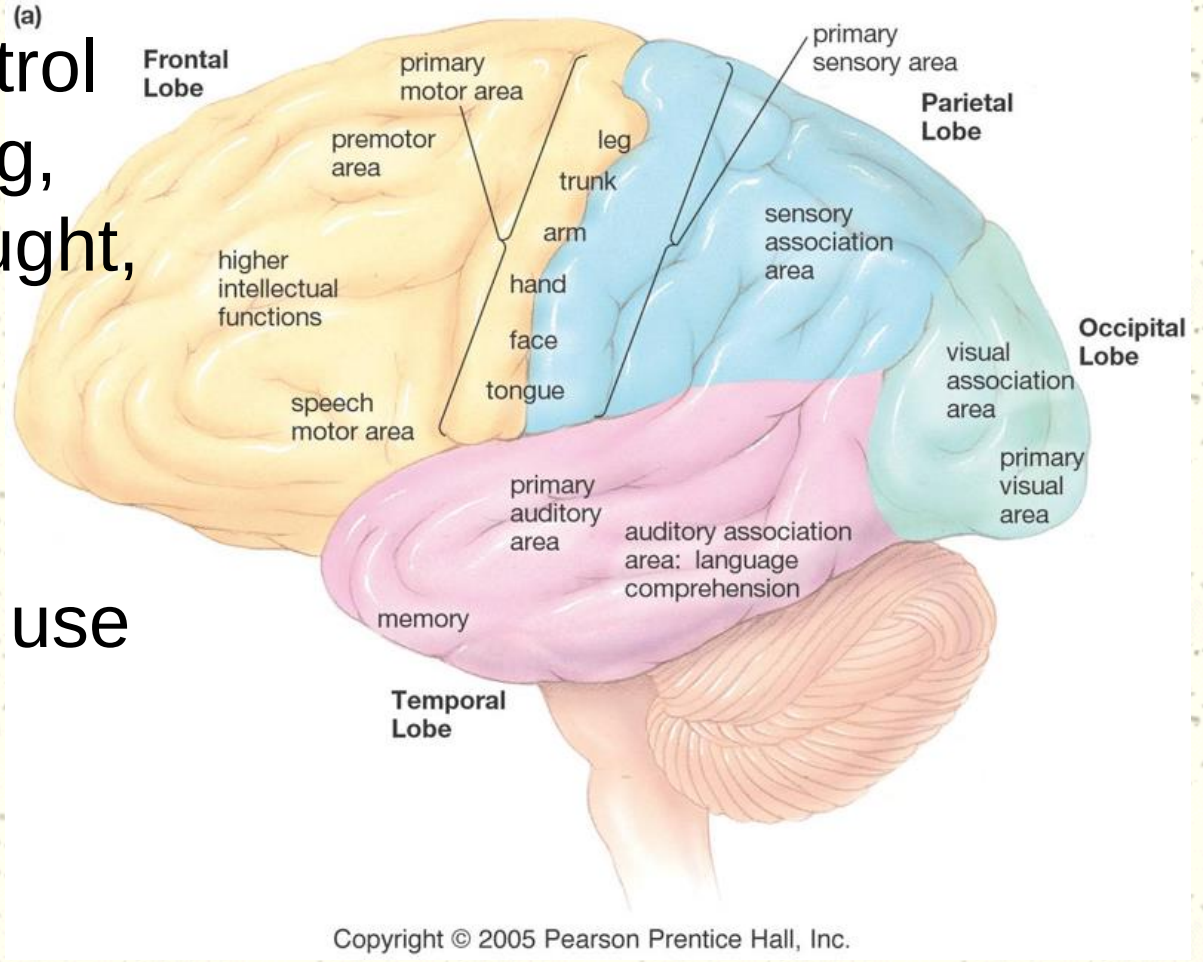
Limbic system

- Hypothalamus: master controller of the endocrine system.
- Amygdala: sensations of pleasure or fear, recognition of fear in others.
- Hippocampus: formation of memories.



Cortex

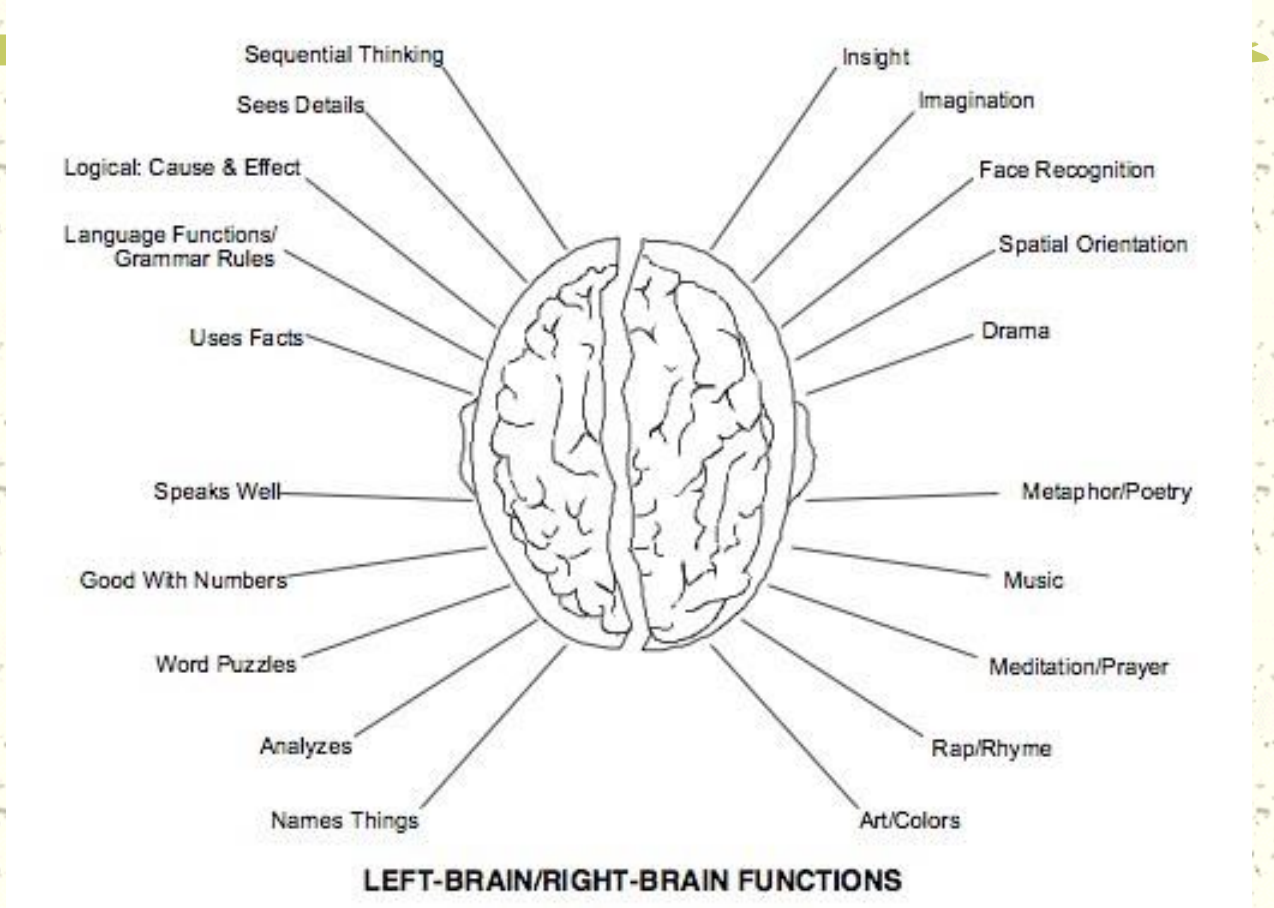
- Various areas control sensory processing, motor control, thought, memory.
- Wiring is plastic: people blind from birth, for example, use parts of the visual cortex to process auditory signals.



Left brain, right brain?

- While there is some specialization to each hemisphere, the idea has been oversimplified.
- The left brain controls the right half of the body; the right brain controls the left half of the body.
- However, “right brain” or “left brain” functions such as math, language, etc. produce activity on both sides of the brain, and processing of these may be different in different people (males vs. females, novices vs. experts, etc.).

Brain "maps"?



While hemispheric research shows some specialization between hemispheres, most "brain maps" like this are nonsense.

Memory

- How humans form memories is poorly understood.
- “Working memory” appears to be distinct from long-term memory. There may be short-term memory as well, things remembered for a few days. Is this because the memory disappears, or because it cannot be retrieved?

Models of Memory

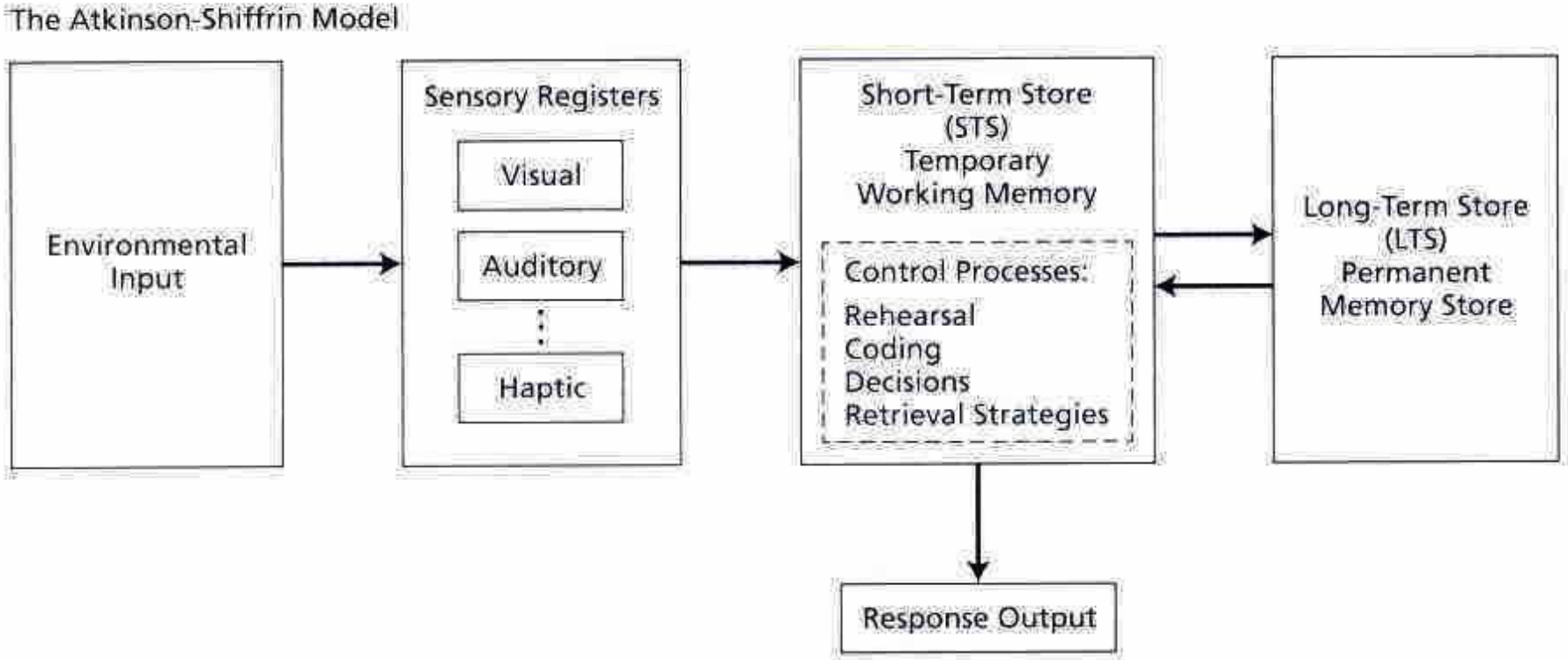
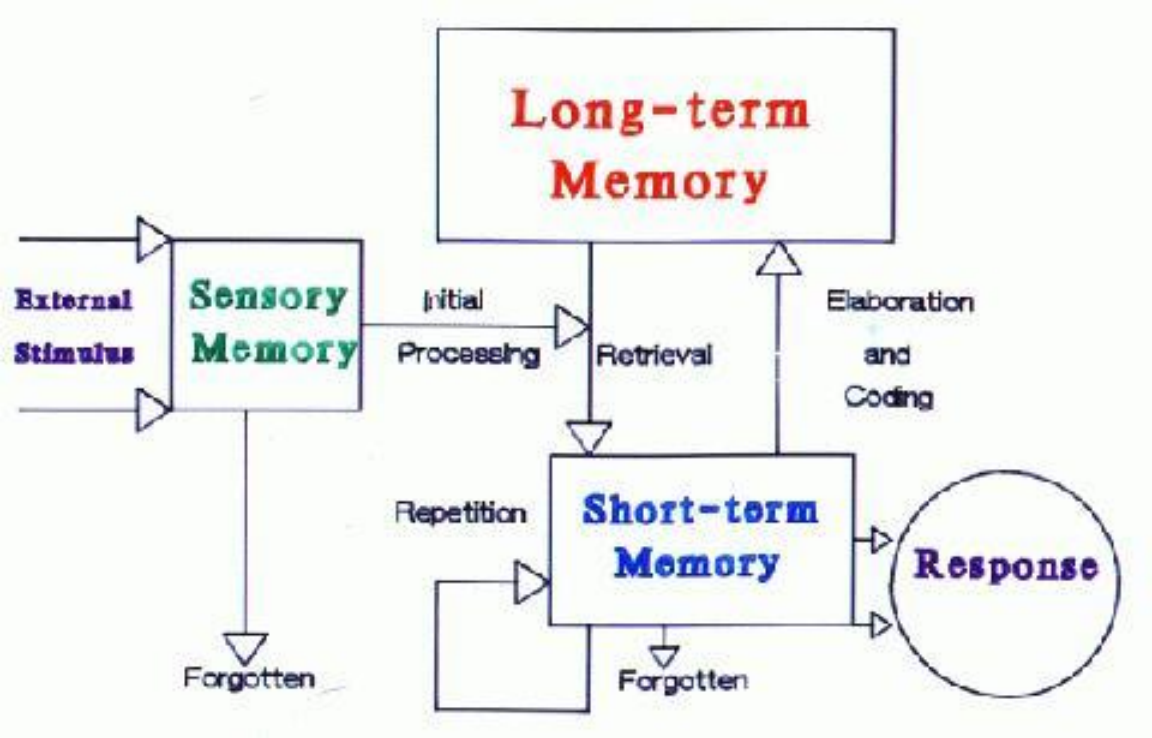


FIGURE 8.2 The Atkinson-Shiffrin Information Processing Model. (From Atkinson and Shiffrin, 1971.) © 1971 Scientific American.

Models of Memory



Craik & Lockhart, 1972

What is mind?

- Many traditions, including psychology, separate “brain” from “mind.”
- What we perceive as “mind” (thought, will, self-perception) does produce evidence of brain activity in brain scans.
- That “brain” influences “mind” is well-established; but some evidence shows “mind” can influence “brain”; as cognitive therapy for depression can physically change the brain.
- Neurology is a very young science, and there is still much to learn about the brain-mind connection.

Central Nervous System (CNS)

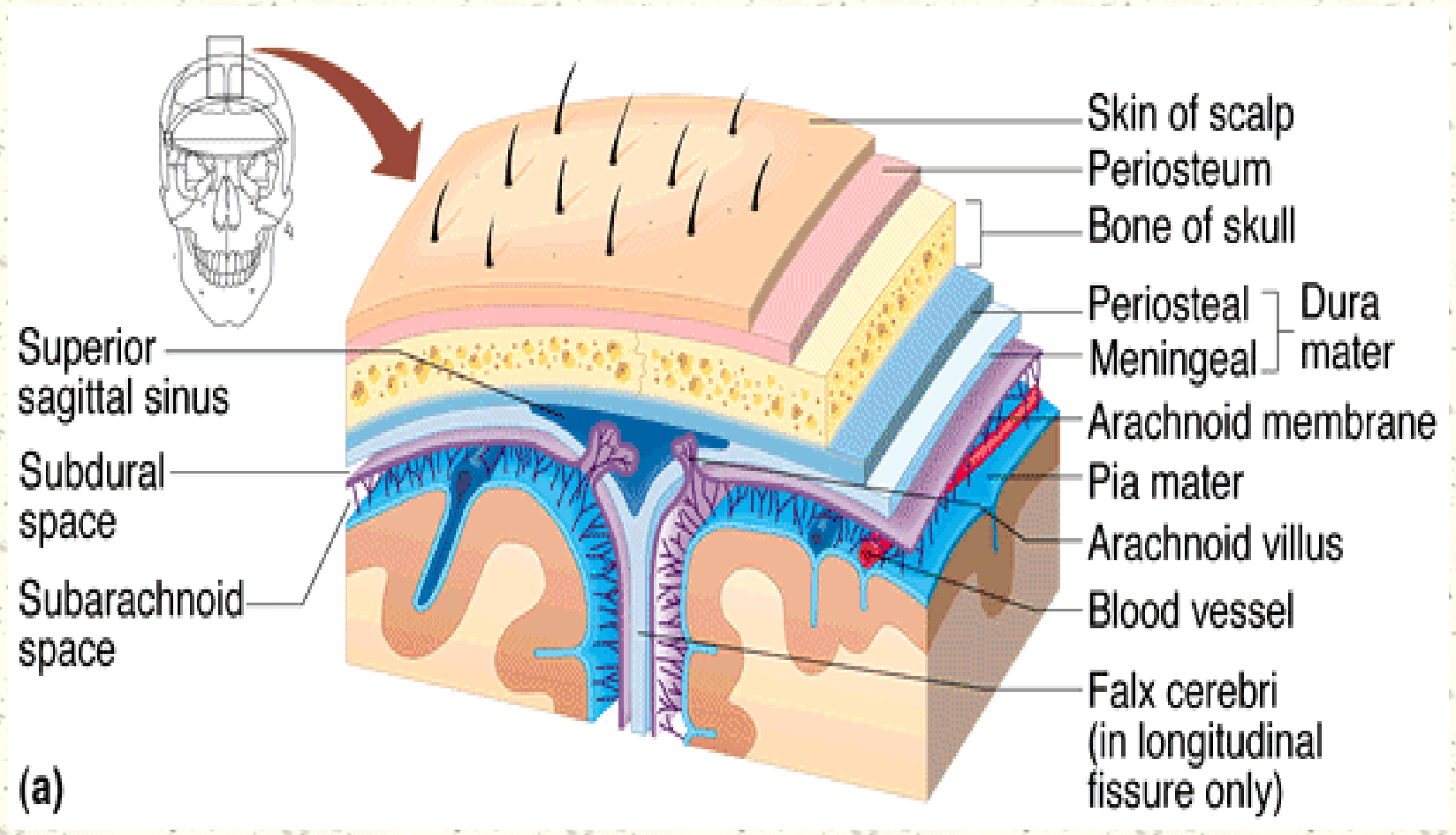
- Meninges are layers of non-nervous tissue that surround and protect the brain and spinal cord .
  - Dura Mater – a tough, fibrous membrane that lies immediately internal to the skull and encloses the brain and spinal cord.
  - Arachnoid- resembling a spider web, this is a delicate layer and a thin, cellular membrane with many silk-like tissue strands.

Central Nervous System (CNS)

- Pia Mater – loose tissue that covers the brain and encases the blood vessels that supply the brain. This is a thin, delicate and highly vascularized membrane.

- The cerebrospinal fluid lies in the space between the arachnoid and pia mater layers. Its main function is to act as a cushion, helping to diminish the transmission of shocking forces.

Central Nervous System (CNS)



Central Nervous System (CNS)

- Cerebrum – the largest part of the brain distinguished by the folds or convolutions of much of its surface.
  - The cerebrum has four paired lobes – frontal, parietal, occipital, and temporal.
  - Memory and conscious thought, speech, motor and sensory functions are controlled by the cerebrum.

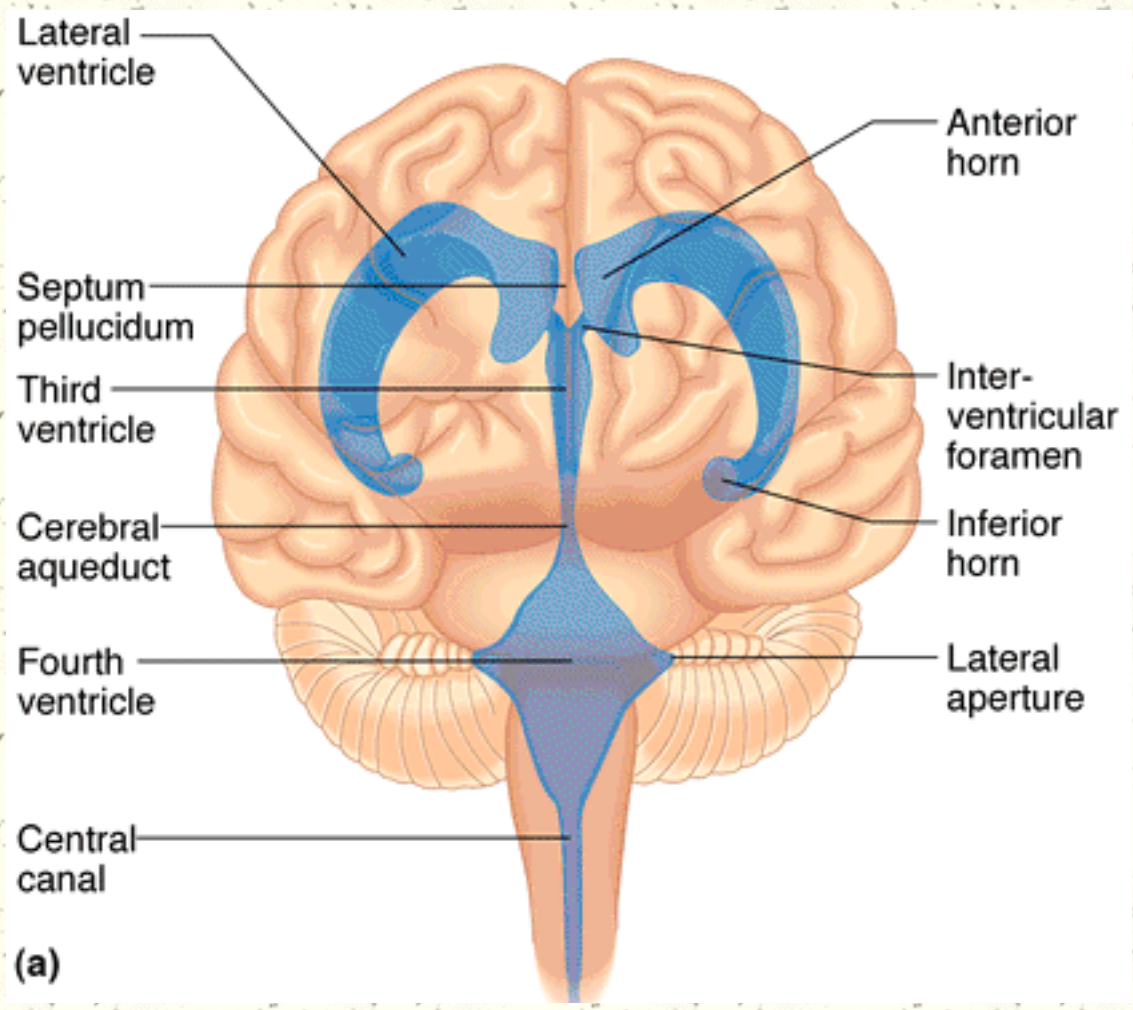
Central Nervous System (CNS)

- Cerebellum – a mass that occupies the posterior part of the cranium.
  - The cerebellum controls the automatic regulation of movement, balance, and posture, as well as skilled movements.
- Medulla Oblongata (Brain Stem) – connects the cerebrum and cerebellum with the spinal cord.
  - The brain stem controls the heart rate, respiration, and body temperature.

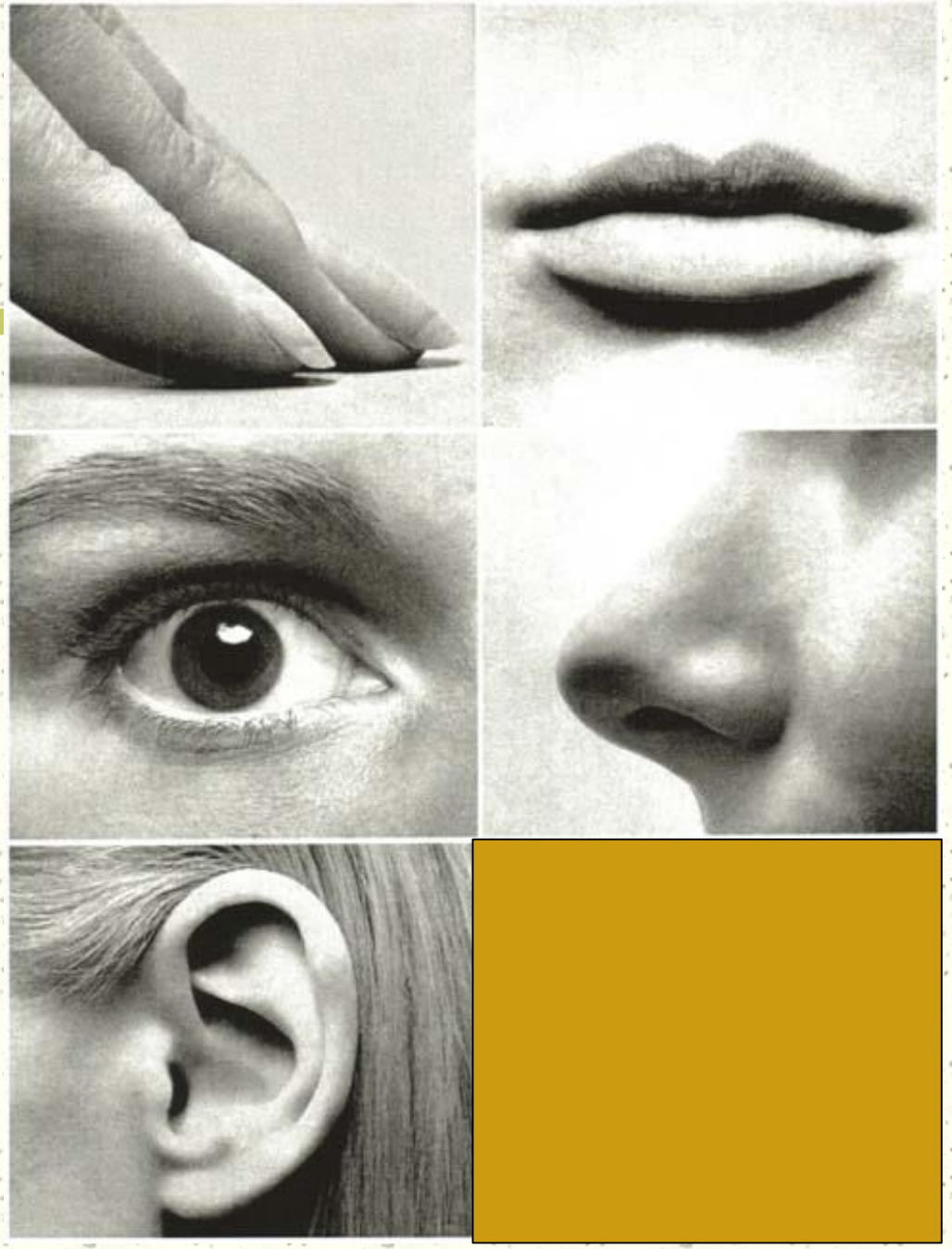
Central Nervous System (CNS)

- Spinal Cord – A continuation of the brain which provides pathways to and from the brain, to and from the body.
  - The spinal cord is also surrounded, protected, and nourished by cerebrospinal fluid.
  - The vertebrae also serve as a bony protection to the spinal cord.
  - The spinal cord terminates with the cauda equina.

Central Nervous System (CNS)



Senses



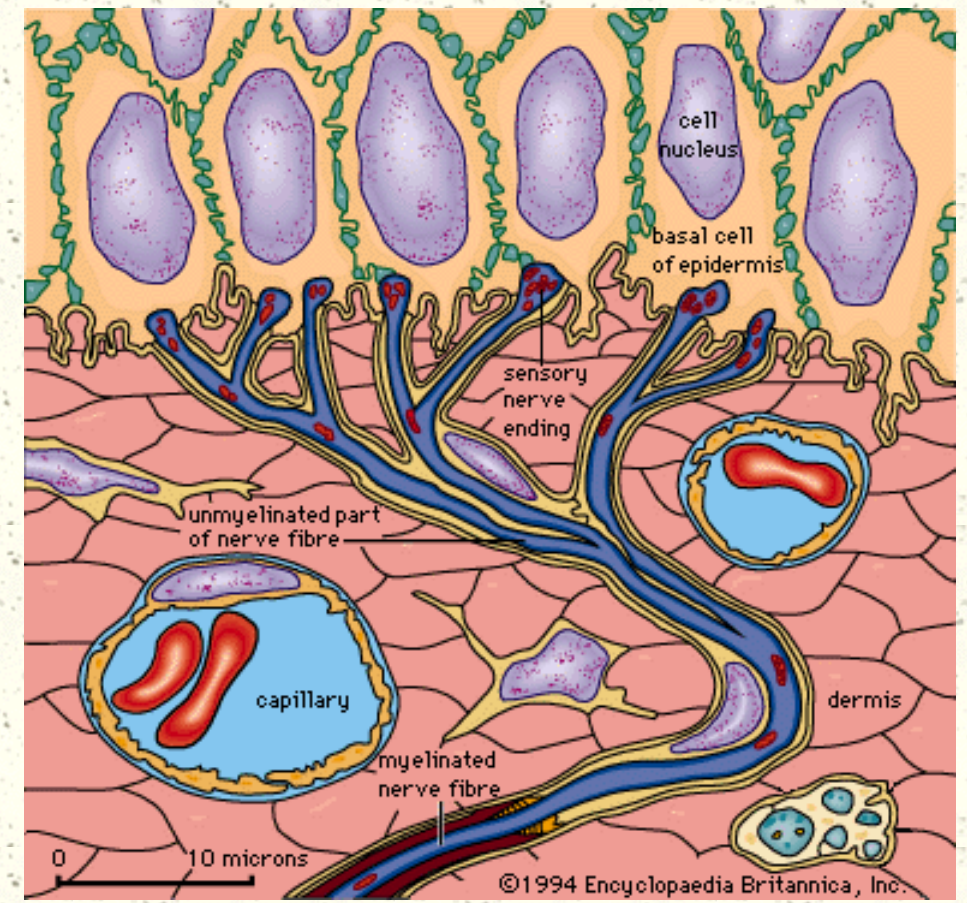
Sensory receptors

- Receptors are found in the sense organs. They receive stimuli from the environment and transmit stimuli to neurons.

- Primary humans senses: photoreception, chemoreception, mechanoreception, thermoreception.

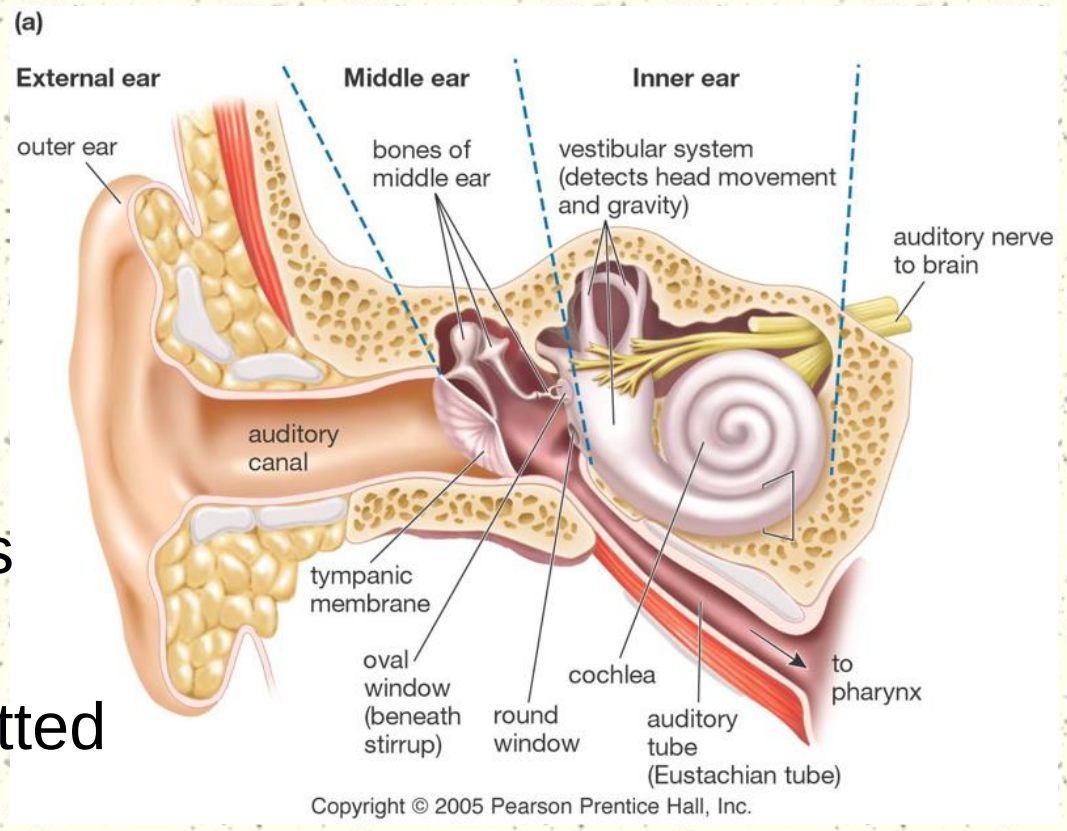
Thermoreception

- Free nerve endings in the skin sense changes in temperature (differences rather than absolutes).
- These are directly transmitted through the PNS.



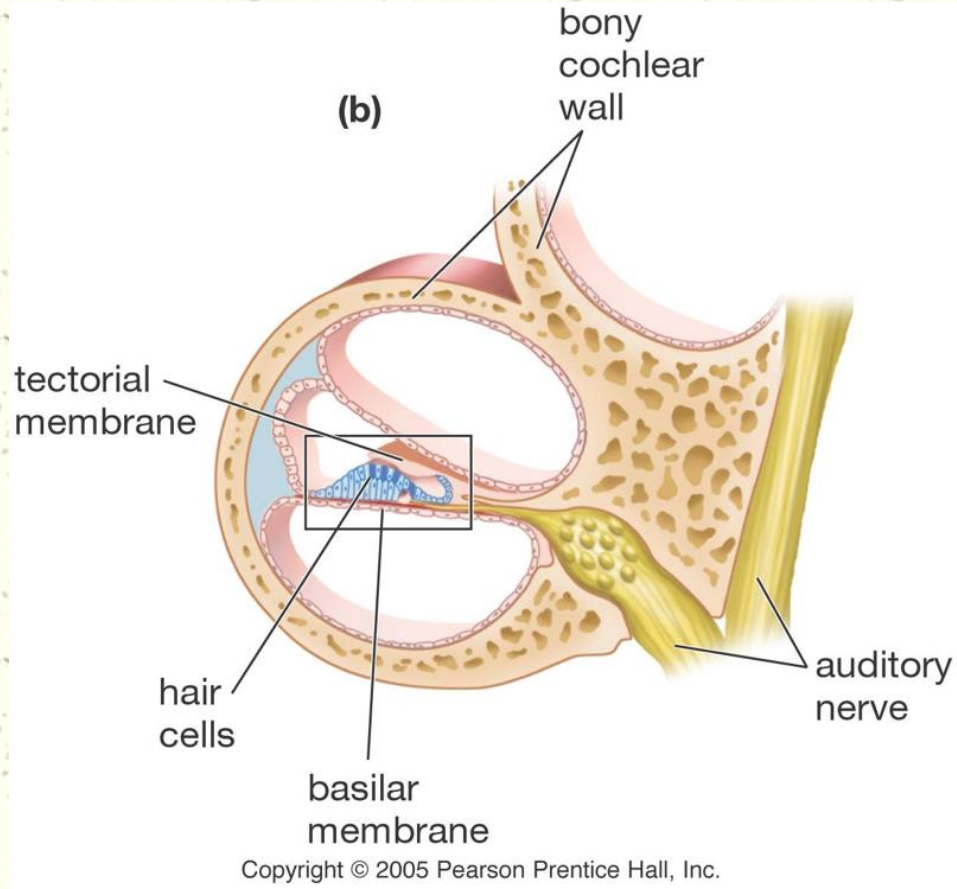
Mechanoreception

- Hearing is a form of mechanoreception.
- Ears gather sound waves from the environment.
- The inner ear bones amplify sounds.
- Sounds are transmitted to the cochlea.



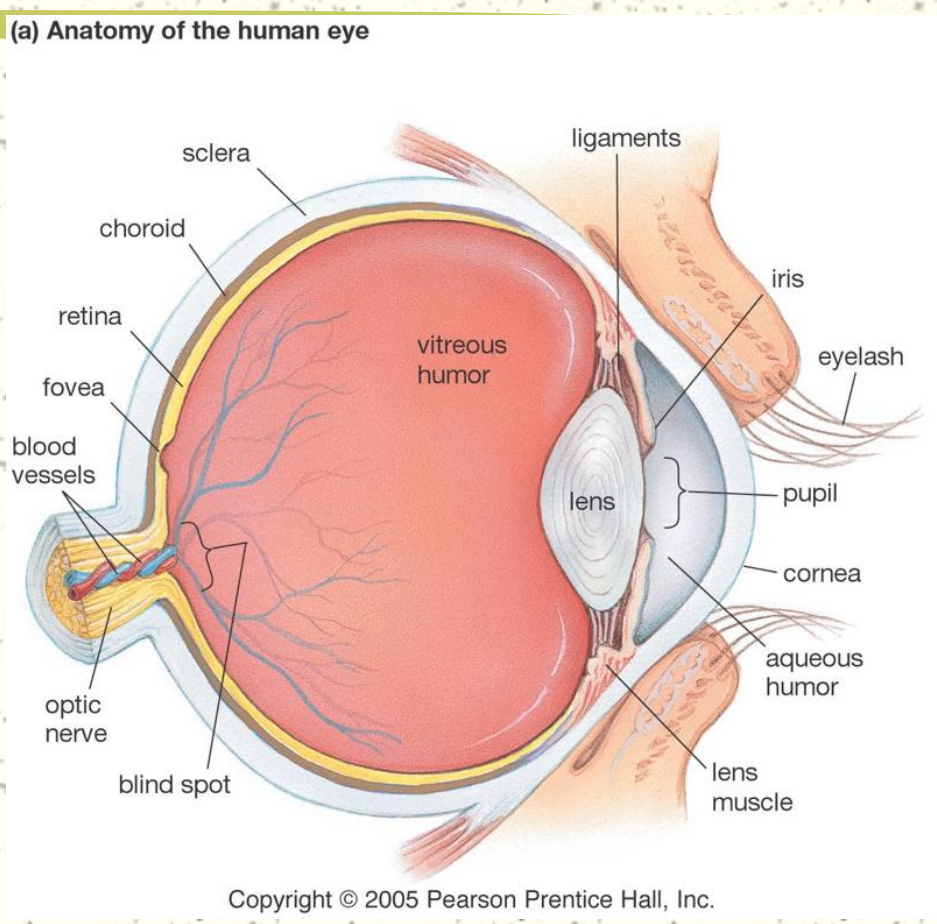
Sound transmission

- Within the cochlea, hair cells on the basilar membrane vibrate to certain frequencies, and send signals down the auditory nerve.
- Loud sounds can damage these sensitive hairs permanently.



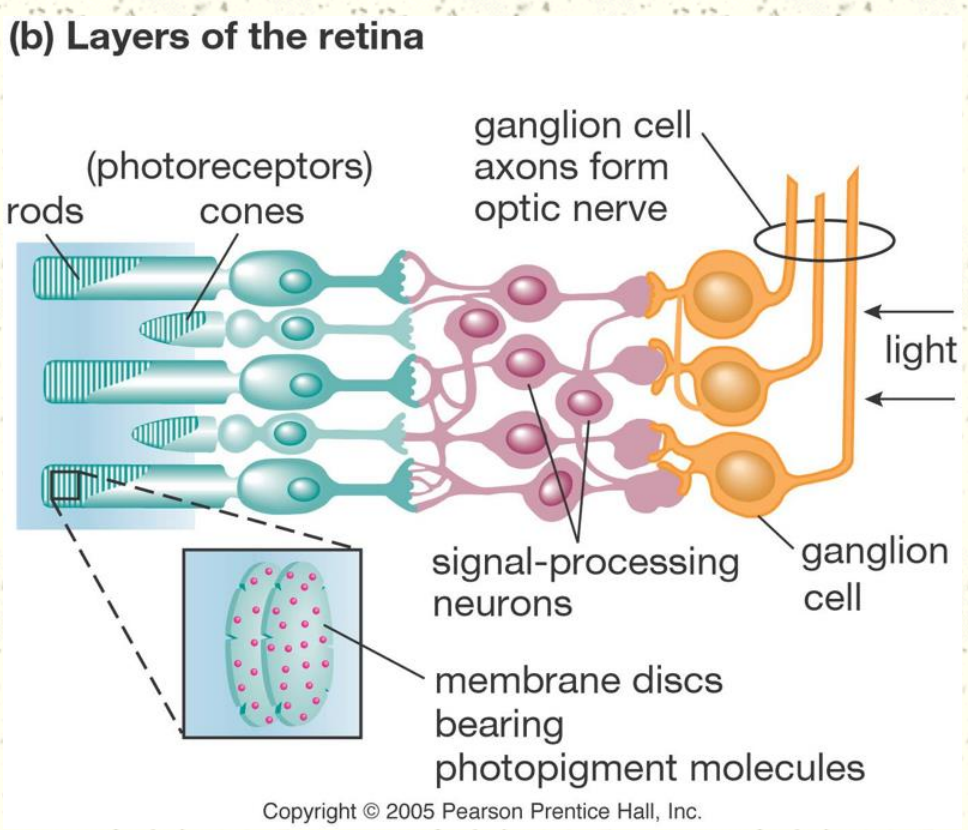
Photoreception

- Sight is photoreception.
- Light enters the eye through the cornea and pupil.
- Light is focused by the lens.
- Light strikes the retina, and stimulates receptors.



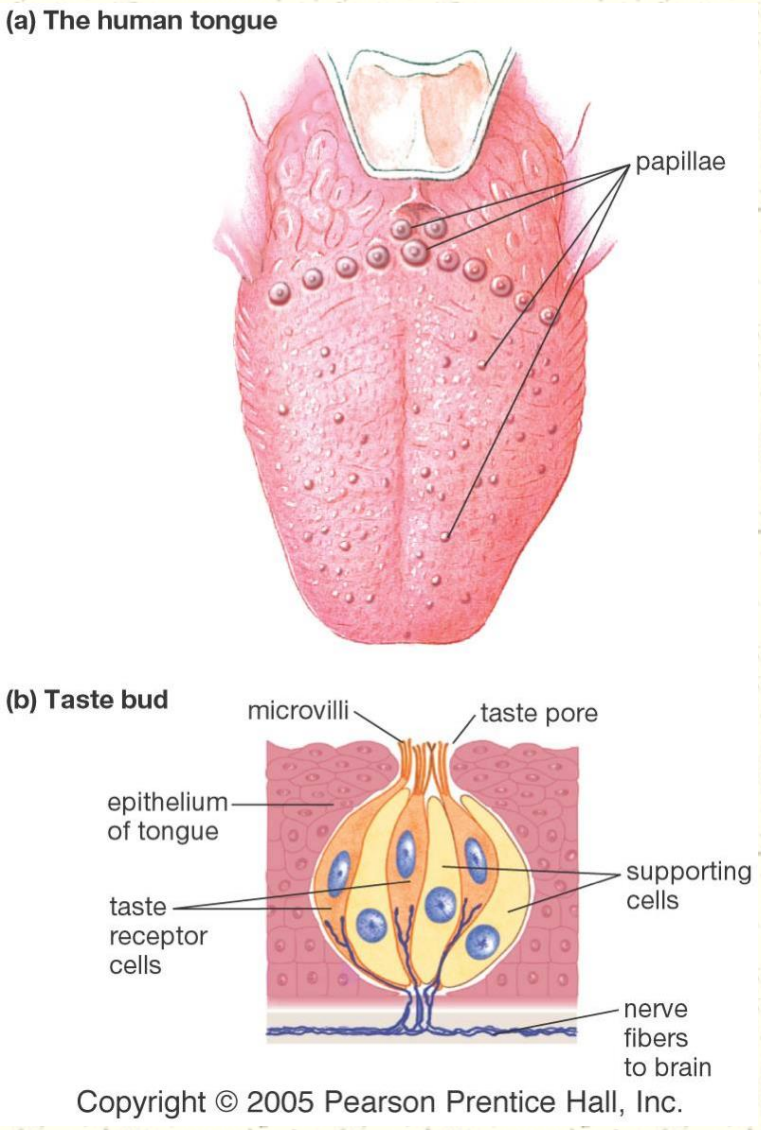
Photoreceptors

- Light breaks pigments in the receptor cells, releasing energy that stimulates neurons connecting to the optic nerve.
- Rod cells detect amount of light, cone cells distinguish colors.



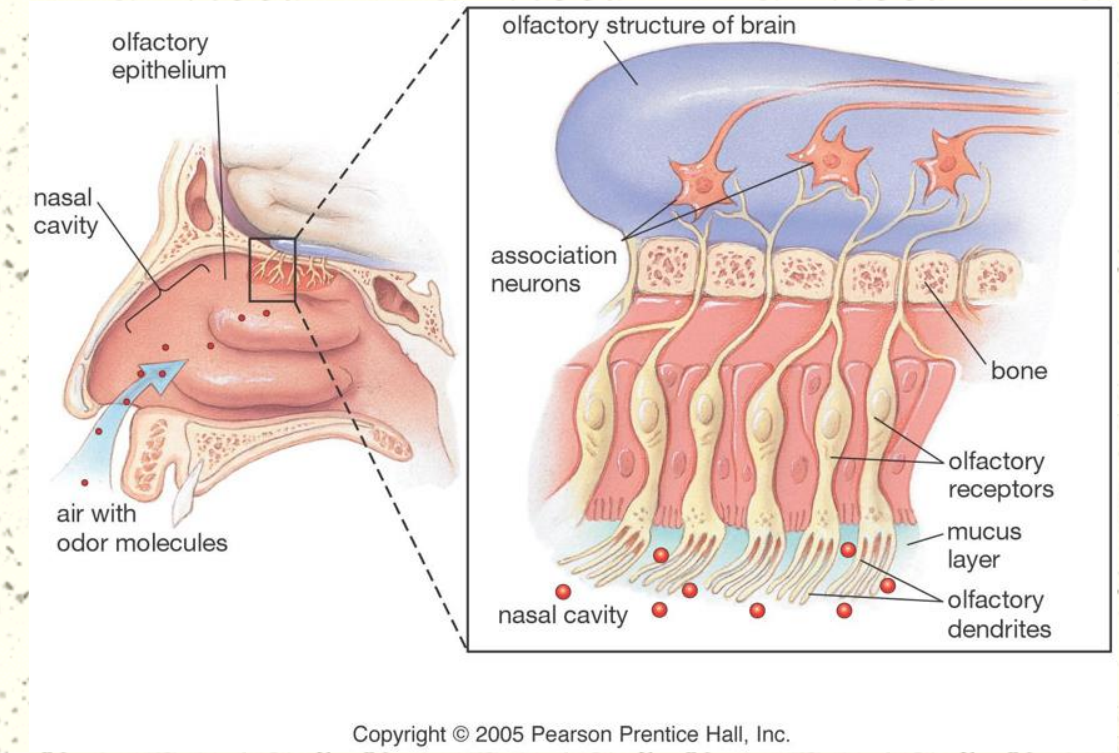
Chemoreceptioin

- Taste is one form of chemoreception.
- Taste buds detect certain ions dissolved in saliva.
- Tastes: salty, sweet, sour, bitter, “umami.”



Chemoreception

- Smell is another form of chemoreception.
- Receptors in the olfactory patch in the human nose can distinguish between about 1000 different chemicals in the air.



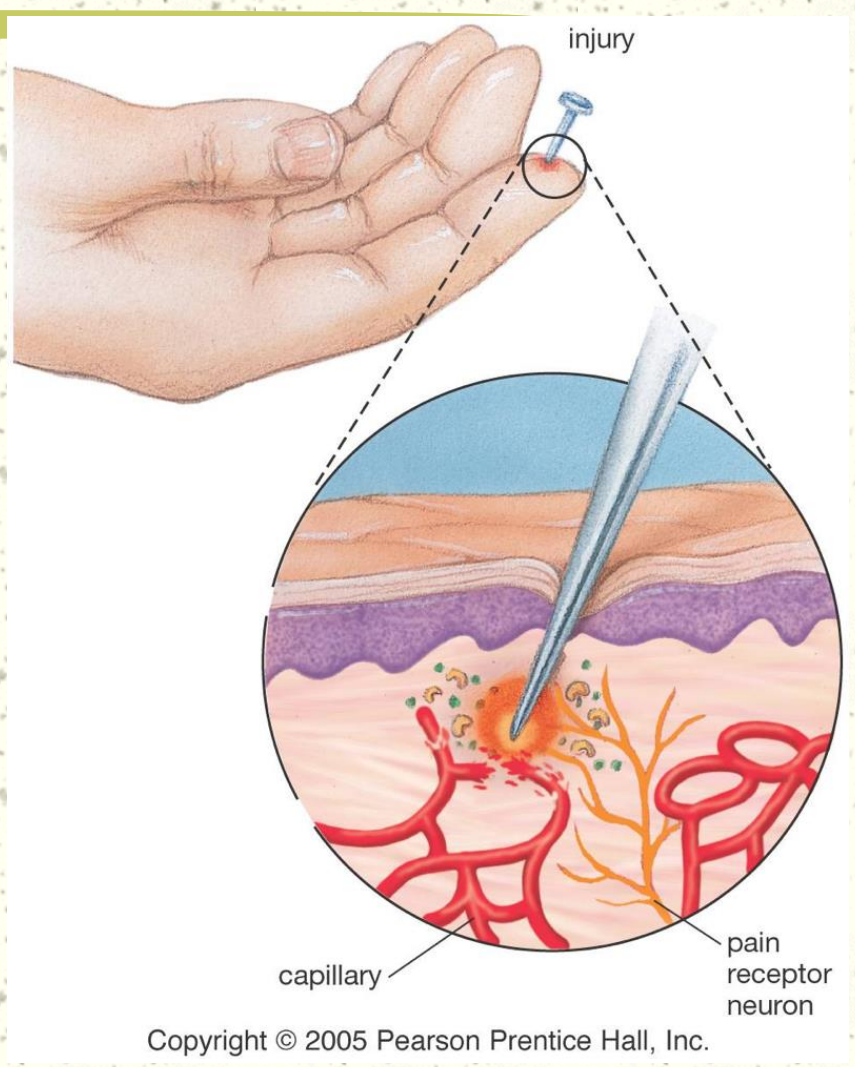
"Flavor"

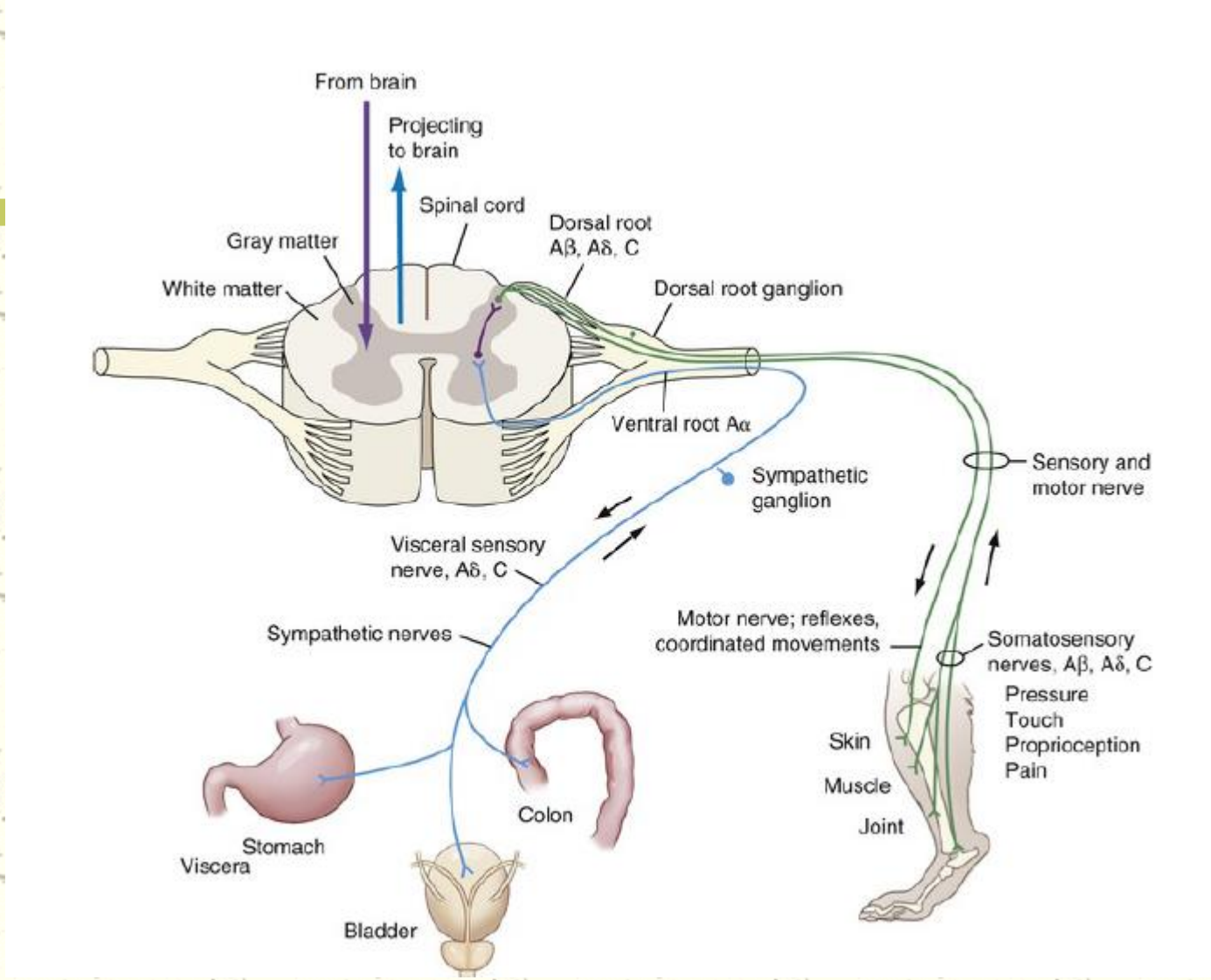
- What we sense as the "flavor" of food is not taste alone. Smell and taste together create the sensation of "flavor."

- This is why things don't "taste" good when we have a cold; we lose the sense of "flavor."

Chemoreception

- The sense of pain is another form of chemoreception.
- Injured tissues release chemicals as a response. These chemicals stimulate free nerve endings in the skin and the stimulation is perceived as pain.




From brain
Projecting to brain
Spinal cord
Dorsal root Aβ, Aδ, C
Gray matter
White matter
Dorsal root ganglion
Ventral root Aα
Sympathetic ganglion
Sensory and motor nerve
Visceral sensory nerve, Aδ, C
Sympathetic nerves
Motor nerve; reflexes, coordinated movements
Somatosensory nerves, Aβ, Aδ, C
Pressure
Touch
Proprioception
Pain
Skin
Muscle
Joint
Colon
Stomach
Viscera
Bladder

Peripheral Nervous System (PNS)

- Nerves are either motor nerves or sensory nerves.
  - Efferent or motor nerves innervate muscles and glands. In order to accomplish this, they conduct nerve impulses from the CNS to the muscles and glands.
  - Afferent or sensory nerves send sensory information and nerve impulses from sensory receptors in the skin, muscles, and joints to the brain.

Peripheral Nervous System (PNS)

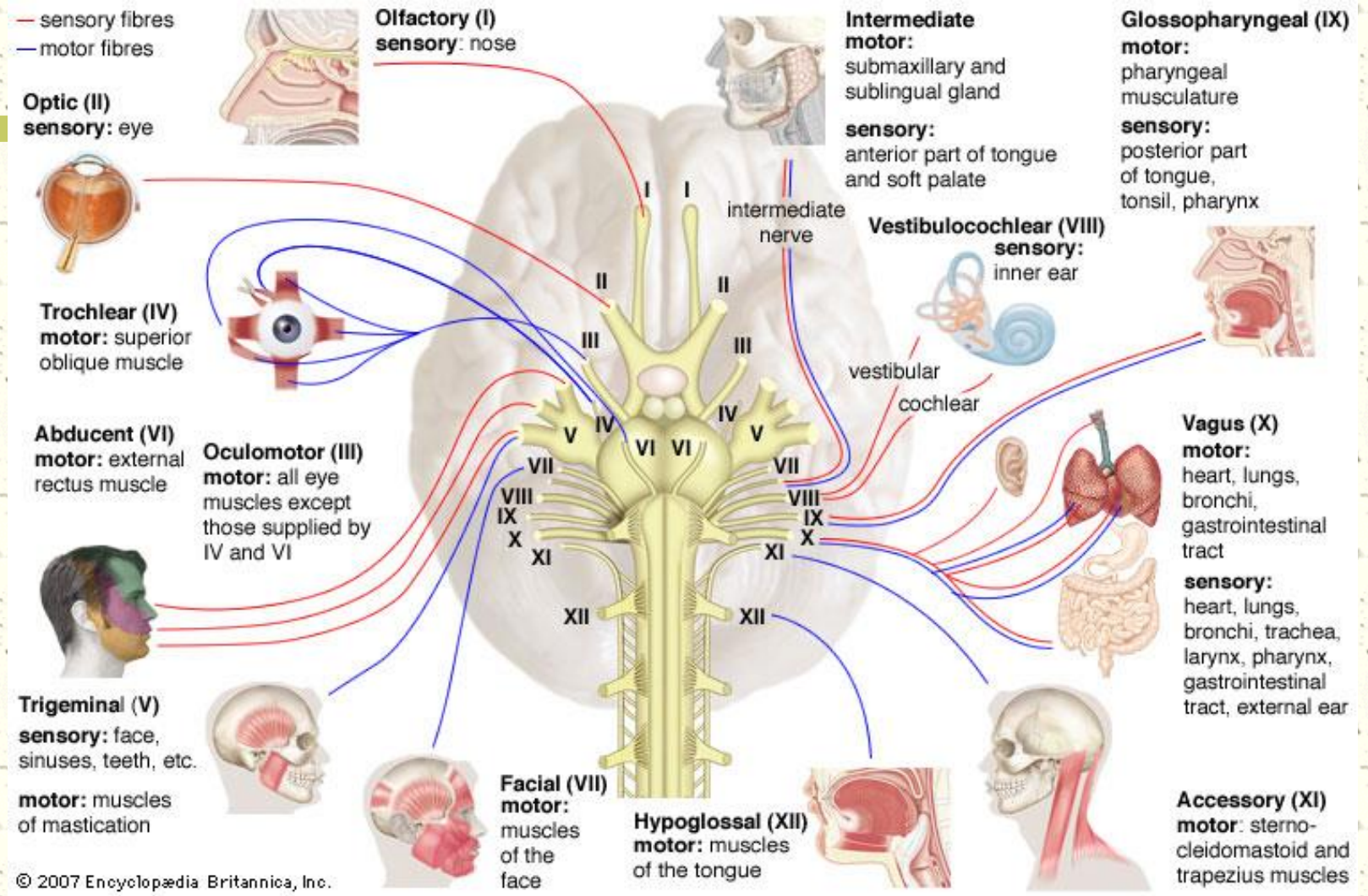
- Cranial Nerves – 12 pairs of cranial nerves which are either sensory or motor nerves. 10 of these nerves originate at the brain stem.
  - Cranial Nerve 1: Olfactory – smell
  - Cranial Nerve 2: Optic – vision
  - Cranial Nerve 3,4&6: Occulomotor, trochlear, and abducens – motor nerves controlling movement of the eyes.

Peripheral Nervous System (PNS)

- Cranial Nerve 5: Trigeminal – sensation of the head, face, and movements of the jaw
- Cranial Nerve 7: Facial – taste, facial movements, and secretions of tears and saliva
- Cranial Nerve 8: Acoustic (vestibulocochlear) – hearing and equilibrium
- Cranial Nerve 9: Glossopharyngeal – taste, sensation and movement in the pharynx, and secretion of saliva

Peripheral Nervous System (PNS)

- Cranial Nerve 10: Vagus – controls taste, and movements in the pharynx and larynx
- Cranial Nerve 11: Spinal accessory – movements of the pharynx, larynx, head, and shoulders
- Cranial Nerve 12: Hypoglossal – movement of the tongue


sensory fibres
motor fibres
Olfactory (I)
sensory: nose
Optic (II)
sensory: eye
Trochlear (IV)
motor: superior oblique muscle
Abducent (VI)
motor: external rectus muscle
Oculomotor (III)
motor: all eye muscles except those supplied by IV and VI
Trigeminal (V)
sensory: face, sinuses, teeth, etc.
motor: muscles of mastication
Facial (VII)
motor: muscles of the face
Hypoglossal (XII)
motor: muscles of the tongue
Intermediate
motor: submaxillary and sublingual gland
sensory: anterior part of tongue and soft palate
intermediate nerve
Vestibulocochlear (VIII)
sensory: inner ear
vestibular
cochlear
Glossopharyngeal (IX)
motor: pharyngeal musculature
sensory: posterior part of tongue, tonsil, pharynx
Vagus (X)
motor: heart, lungs, bronchi, gastrointestinal tract
sensory: heart, lungs, bronchi, trachea, larynx, pharynx, gastrointestinal tract, external ear
Accessory (XI)
motor: sterno-cleidomastoid and trapezius muscles
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
XII
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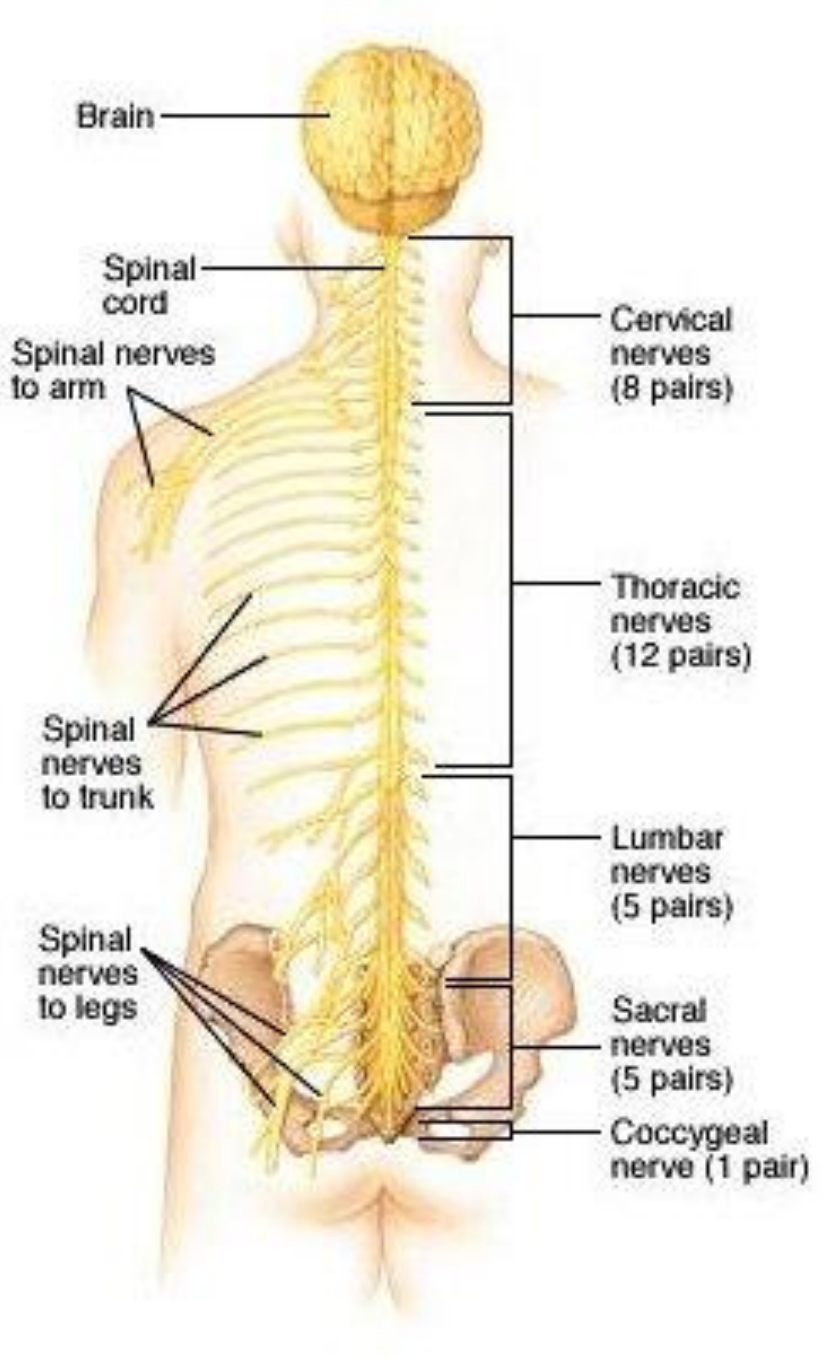
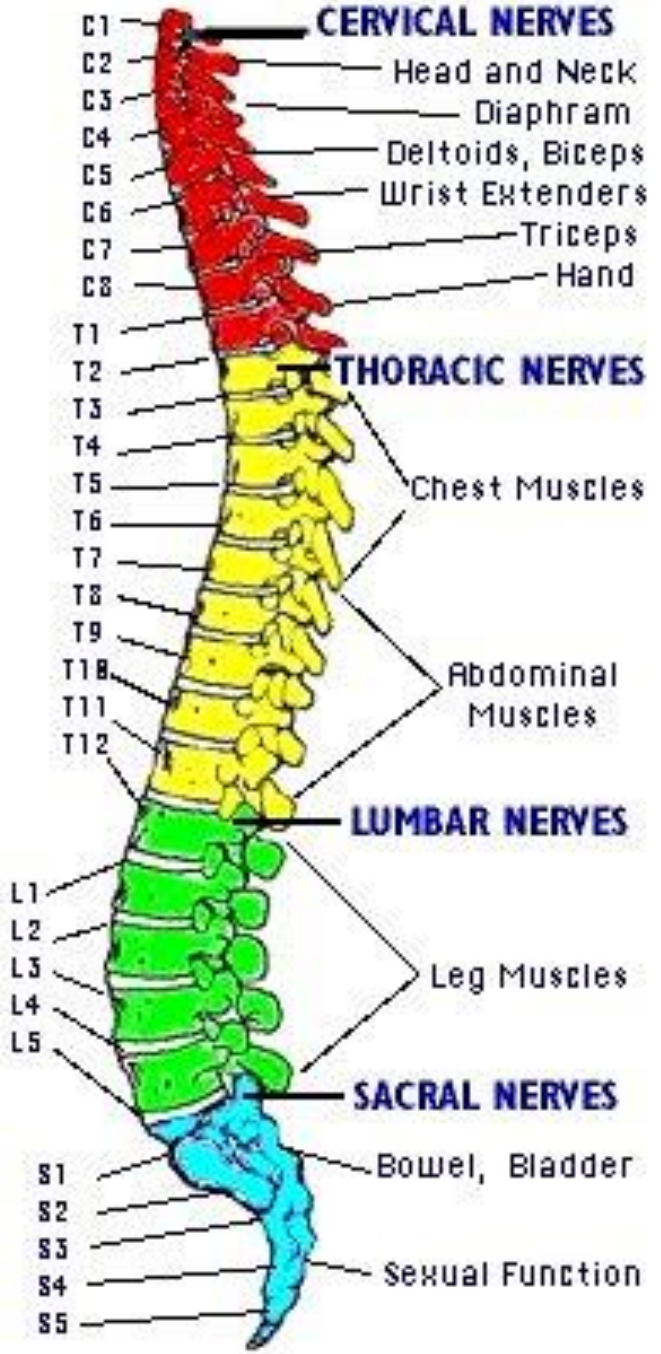
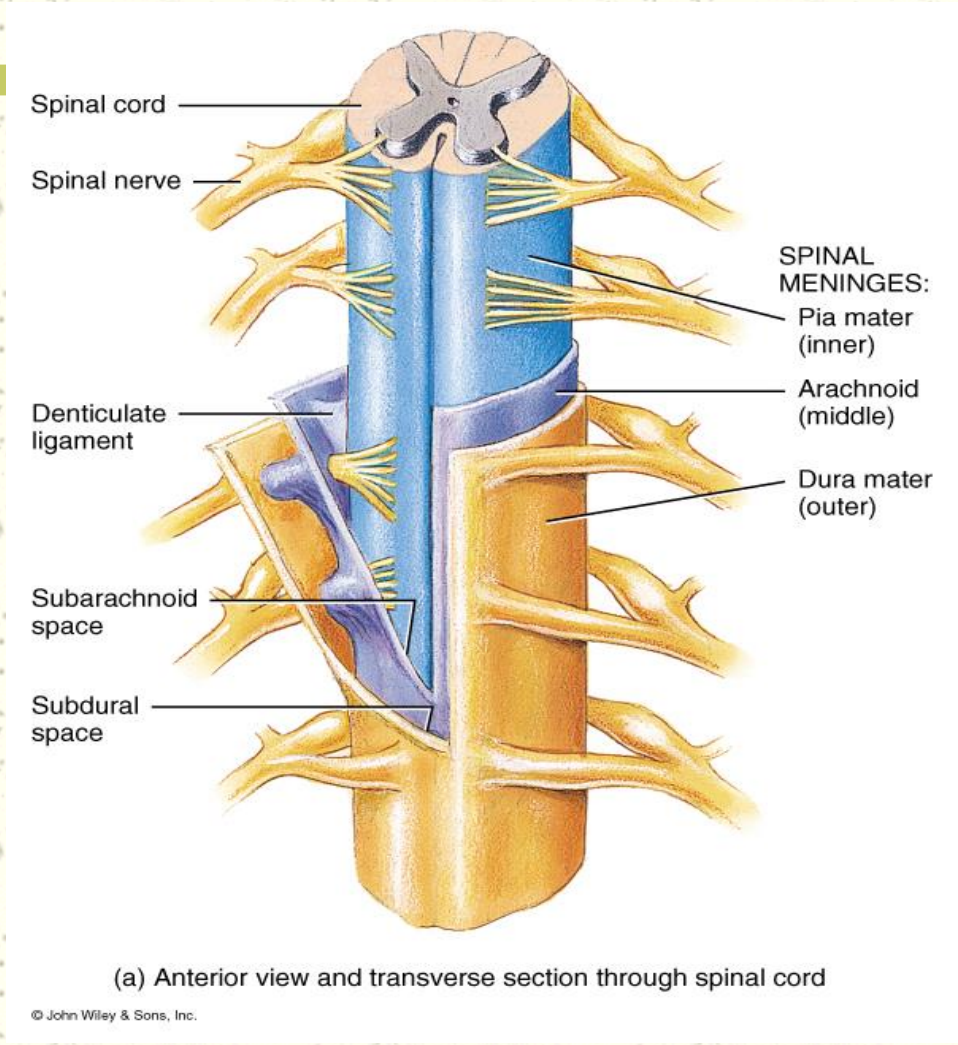
Peripheral Nervous System

- Spinal Nerves – there are 31 pairs of spinal nerves branching off the spinal cord.
  - 8 cervical
  - 12 thoracic
  - 5 lumbar
  - 5 sacral
  - 1 coccygeal

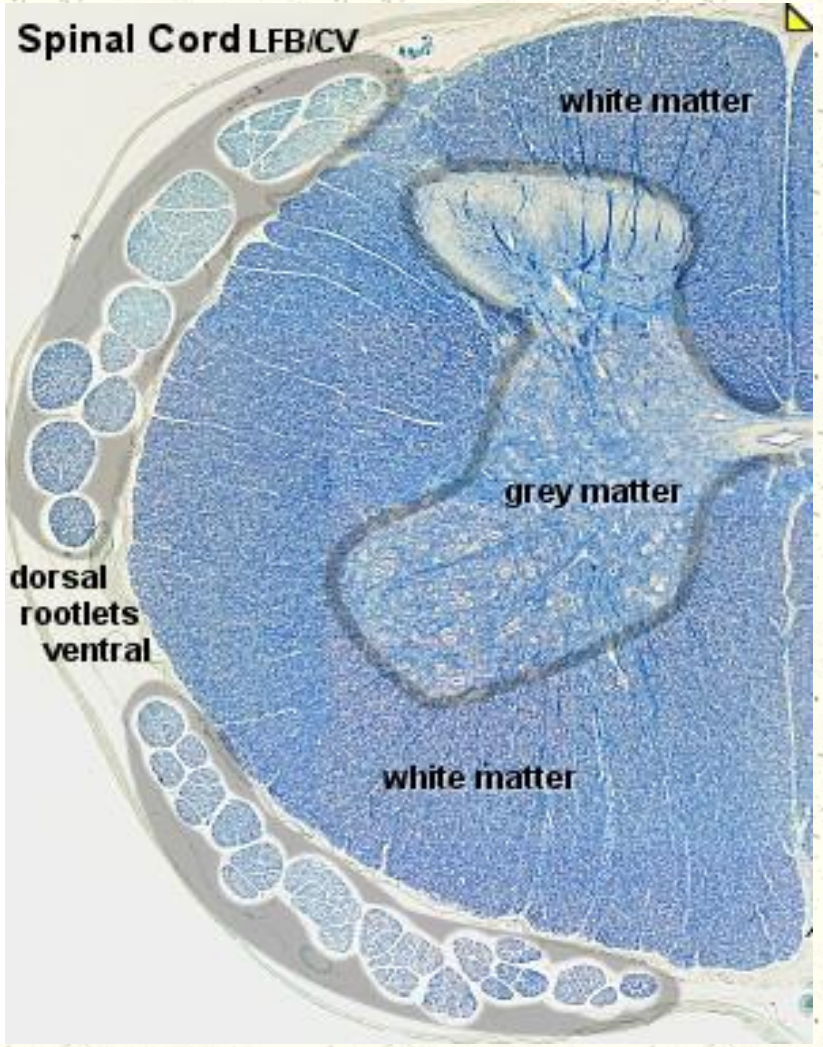

Brain
Spinal cord
Spinal nerves to arm
Spinal nerves to trunk
Spinal nerves to legs
Cervical nerves (8 pairs)
Thoracic nerves (12 pairs)
Lumbar nerves (5 pairs)
Sacral nerves (5 pairs)
Coccygeal nerve (1 pair)


C1
C2
C3
C4
C5
C6
C7
C8
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
T11
T12
L1
L2
L3
L4
L5
S1
S2
S3
S4
S5
CERVICAL NERVES
Head and Neck
Diaphram
Deltoids, Biceps
Wrist Extenders
Triceps
Hand
THORACIC NERVES
Chest Muscles
Abdominal Muscles
LUMBAR NERVES
Leg Muscles
SACRAL NERVES
Bowel, Bladder
Sexual Function

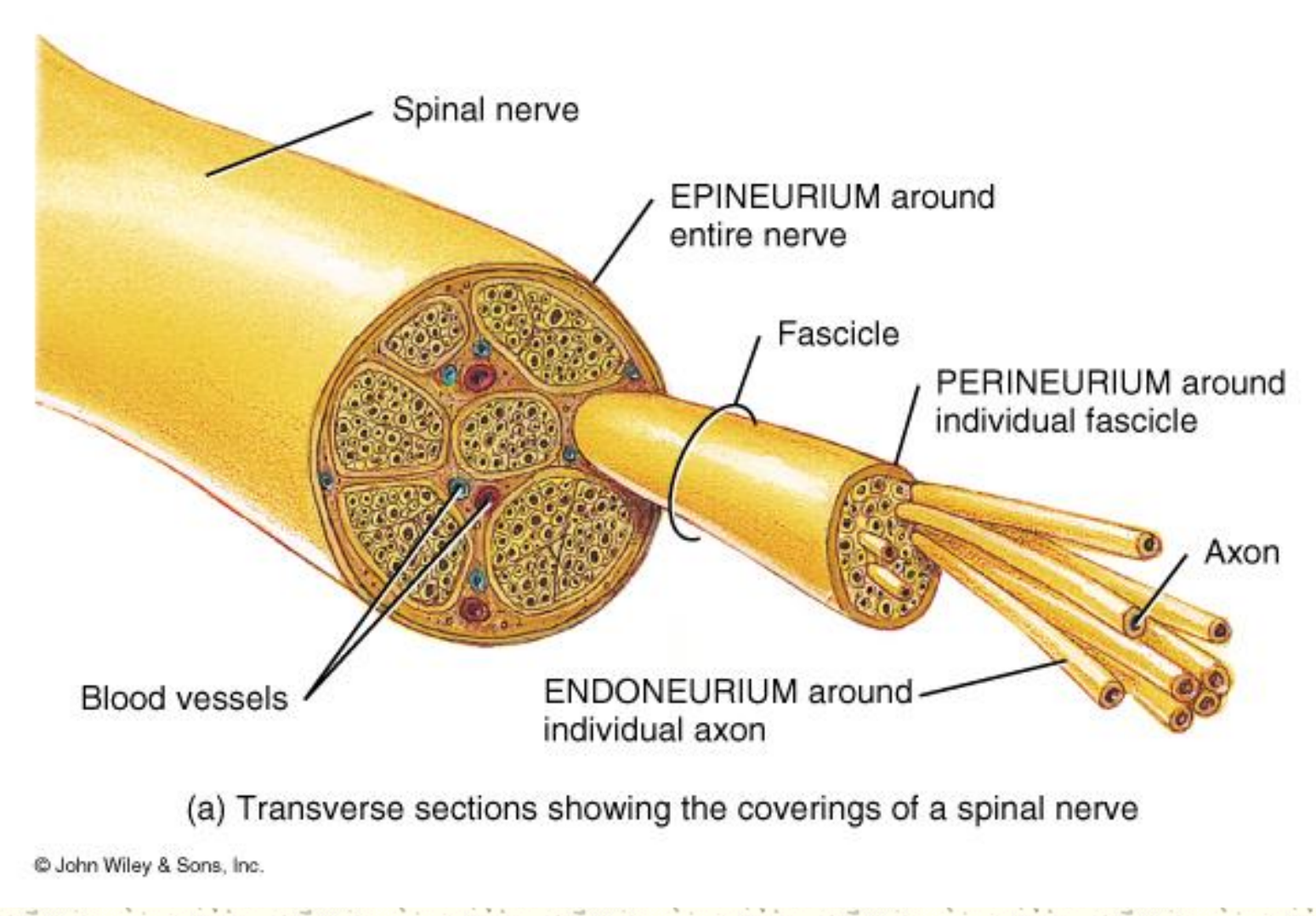
Peripheral Nervous System



(a) Anterior view and transverse section through spinal cord



Peripheral Nervous System



(a) Transverse sections showing the coverings of a spinal nerve

Autonomic Nervous System (ANS)

- The autonomic or involuntary nervous system is that portion of the nervous system which regulates the activity of cardiac muscle, smooth muscle, and the glands.
- The ANS has two parts:
  - Sympathetic
  - Parasympathetic

Autonomic Nervous System

- Sympathetic – stimulates viscera
  - Prepares the body for emergency situations ("fight or flight" response to stress)
  - Fear, emergency, physical exertion, and embarrassment are responded to by this system
  - This system shifts energy and blood toward the skeletal muscles, cardiac muscles, and respiration

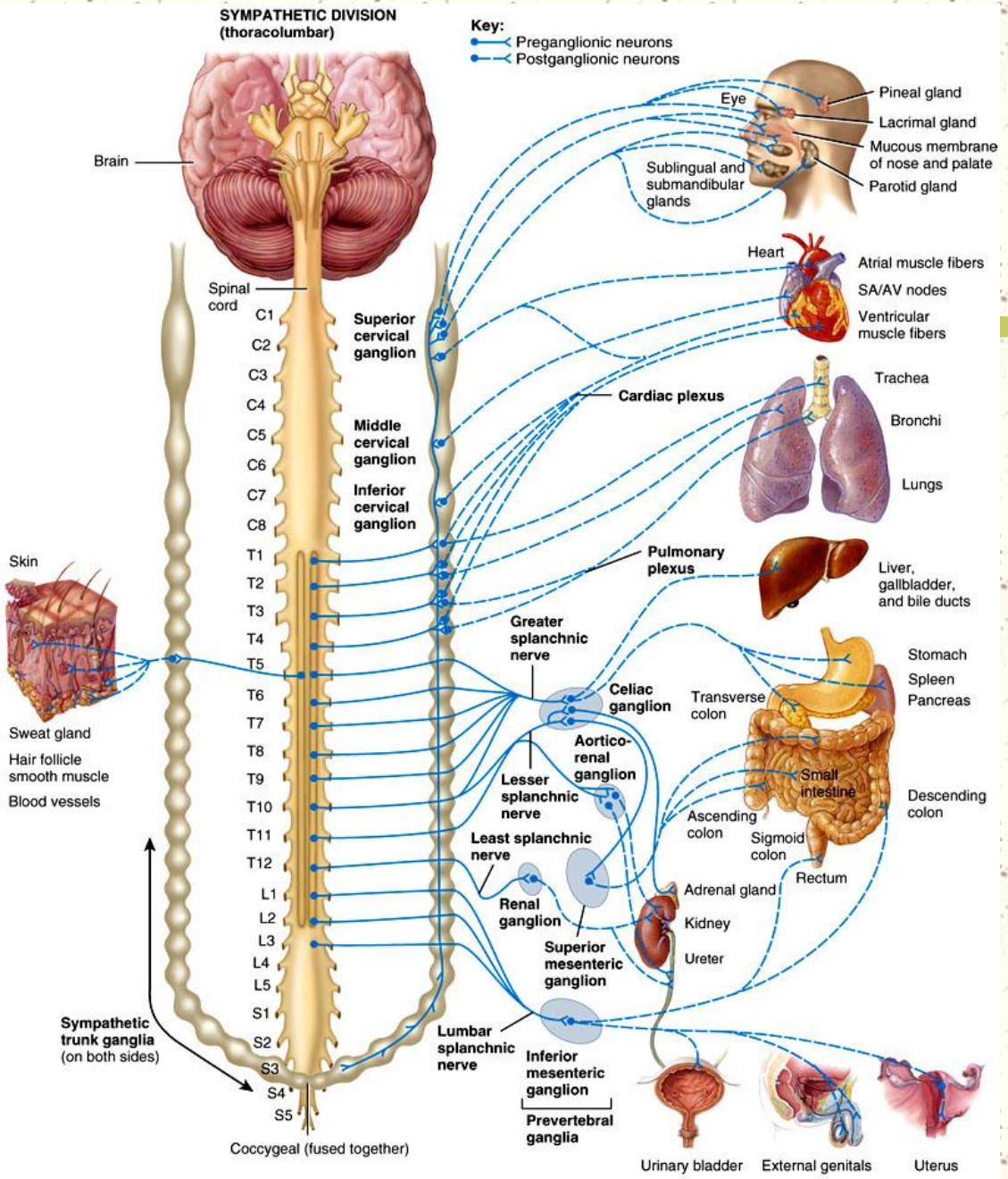


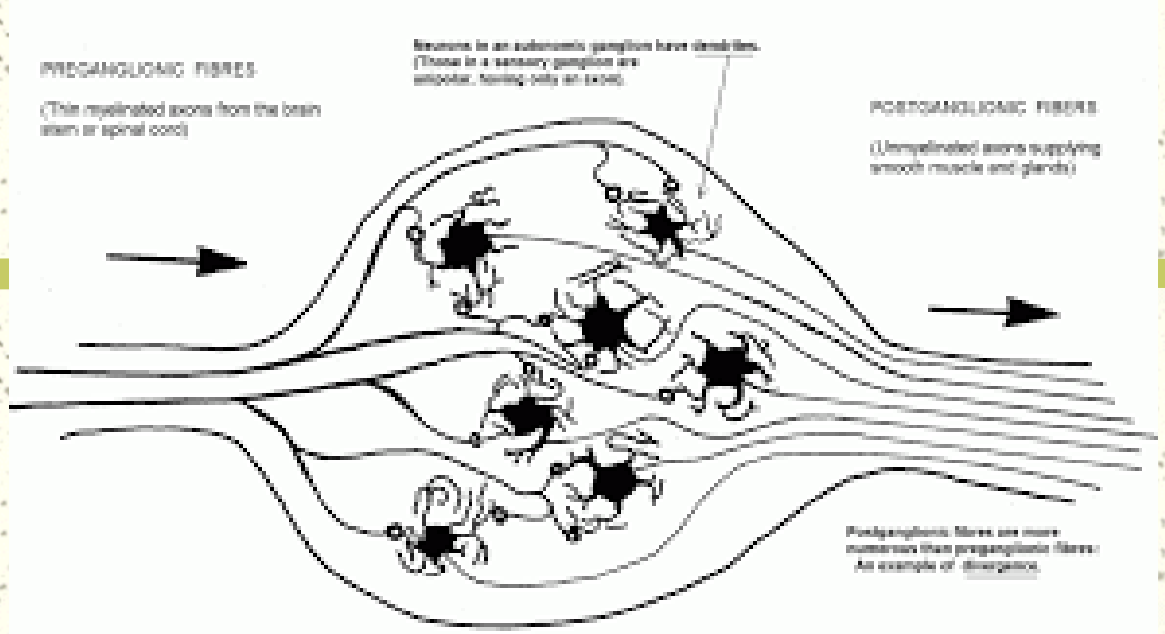
Figure 15.02 Tortora - PAP 12/e

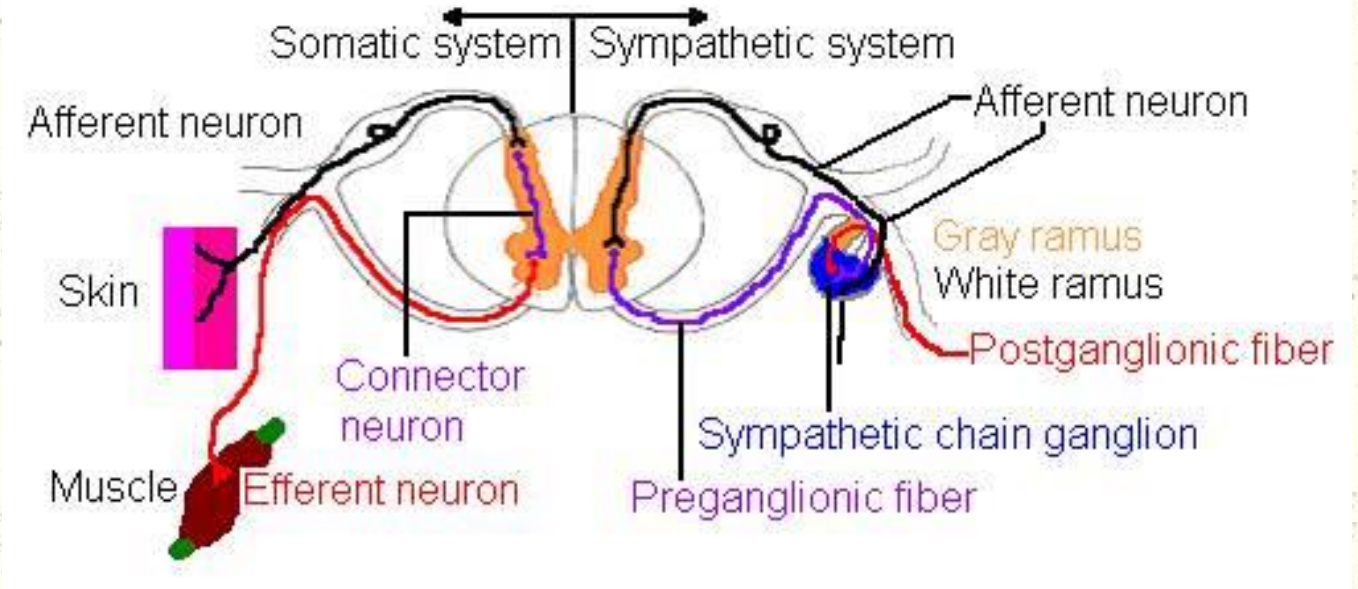
Ganglion

In anatomy, a ganglion is a nerve cell cluster or a group of nerve cell bodies located in the autonomic nervous system and sensory system.

Ganglia house the cells bodies of afferent nerves and efferent nerves.

A pseudoganglion looks like a ganglion but only has nerve fibers and has no nerve cell bodies


PREGANGLIONIC FIBRES
(Thin myelinated axons from the brain stem or spinal cord)
POSTGANGLIONIC FIBRES
(Unmyelinated axons supplying smooth muscle and glands)


Somatic system
Sympathetic system
Afferent neuron
Afferent neuron
Skin
Gray ramus
White ramus
Postganglionic fiber
Connector neuron
Sympathetic chain ganglion
Muscle
Efferent neuron
Preganglionic fiber

Autonomic Nervous System

- Parasympathetic – inhibits viscera
  - Energy conservation system
  - Restores body energy during rest
  - Responses toward digestion, elimination of waste, and decreases heart rate

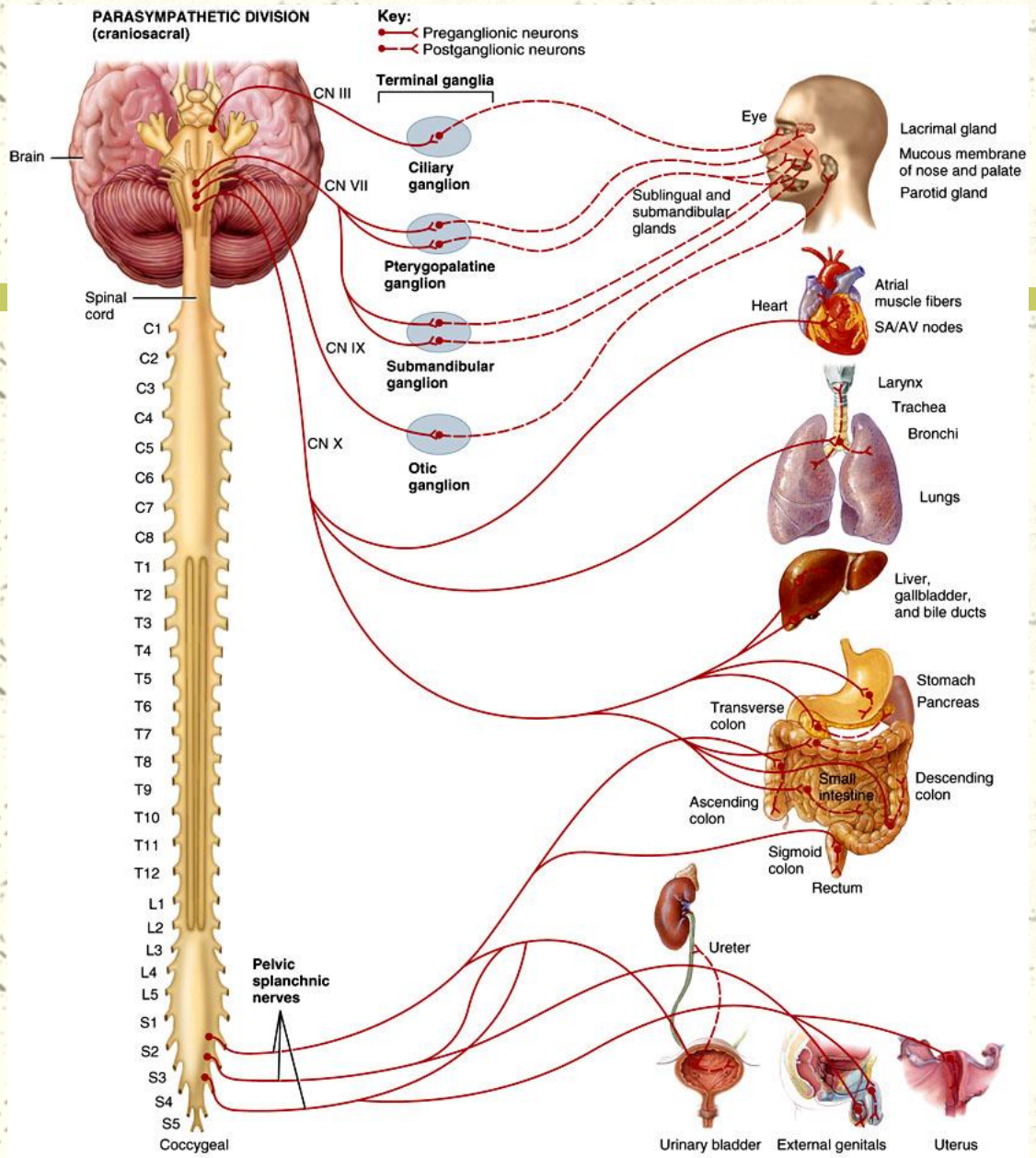


Figure 15.03 Tortora - PAP 12/e

ANS Versus Somatic Nervous System (SNS)

- The ANS differs from the SNS in the following three areas
  - Effectors
  - Efferent pathways
  - Target organ responses
- The effectors of the SNS are skeletal muscles
- The effectors of the ANS are cardiac muscle, smooth muscle, and glands

Efferent Pathways

- Heavily myelinated axons of the somatic motor neurons extend from the CNS to the effector (skeletal muscles)
- Axons of the ANS are a two-neuron chain
  - The preganglionic (first) neuron has a lightly myelinated axon
  - The ganglionic (second) neuron extends to an effector organ

Neurotransmitter Effects

- All somatic motor neurons release Acetylcholine (ACh), which has an excitatory effect
- In the ANS:
  - Preganglionic fibers release ACh
  - Postganglionic fibers release norepinephrine or ACh and the effect is either stimulatory or inhibitory
  - ANS effect on the target organ is dependent upon the neurotransmitter released and the receptor type of the effector

Comparison of Somatic and Autonomic Systems

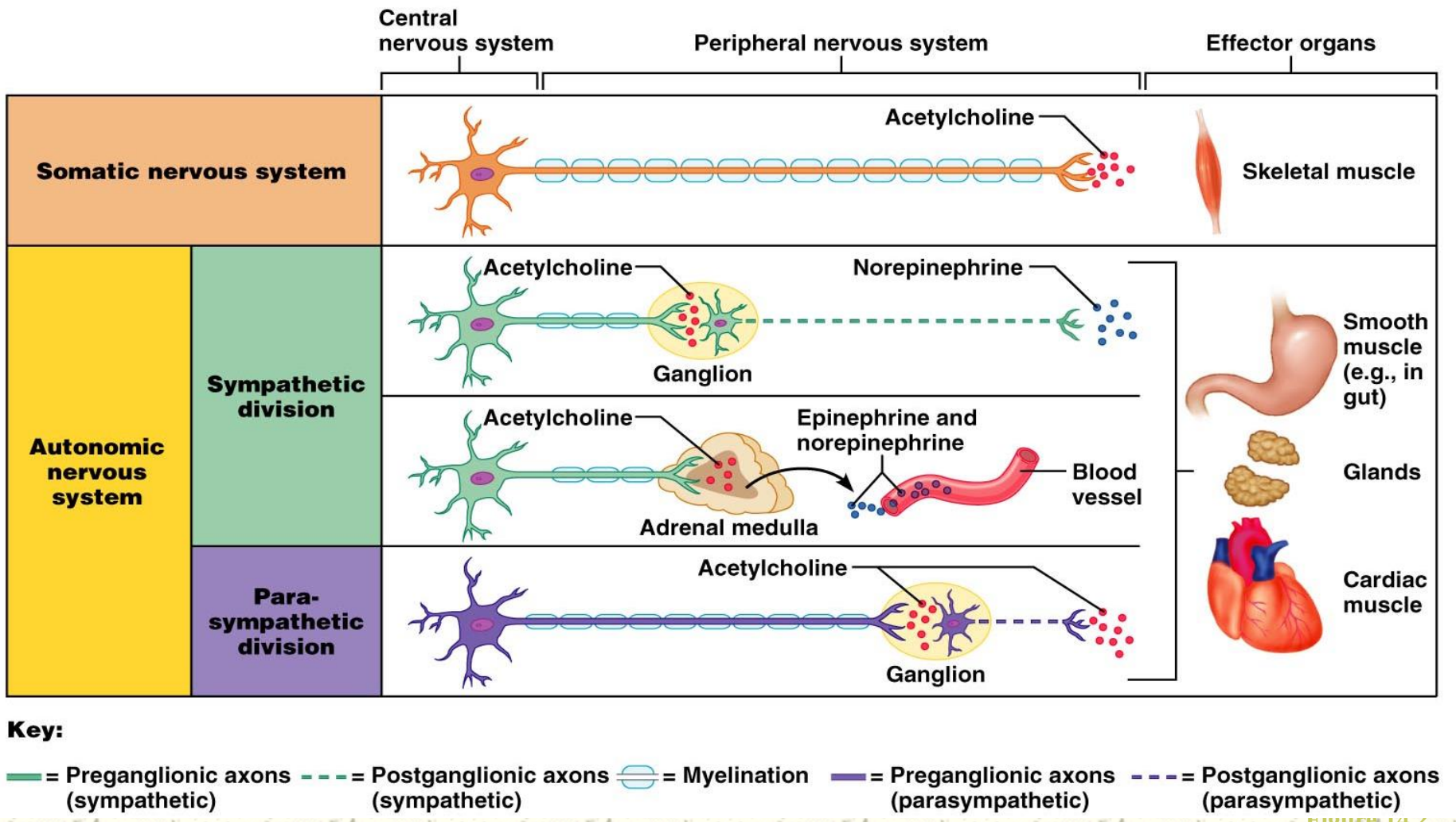
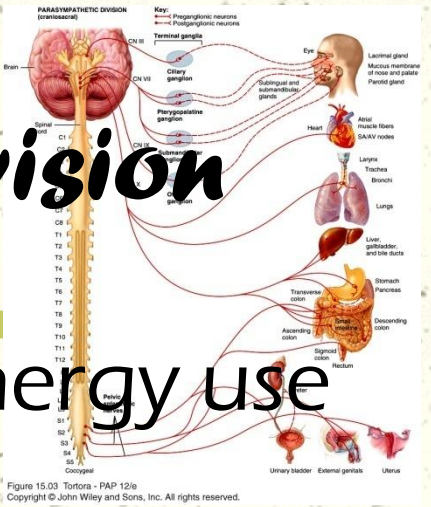


Figure 14.2

Role of the Parasympathetic Division



- Concerned with keeping body energy use low
- Involves the **D** activities – digestion, defecation, and diuresis
- Its activity is illustrated in a person who relaxes after a meal
  - Blood pressure, heart rate, and respiratory rates are low
  - Gastrointestinal tract activity is high
  - The skin is warm and the pupils are constricted

Parasympathetic Responses

- Rest-and-digest response.
- Conserve and restore body energy.
- ↑ digestive and urinary function.
- ↓ body functions that support physical activity.

Role of the Sympathetic Division

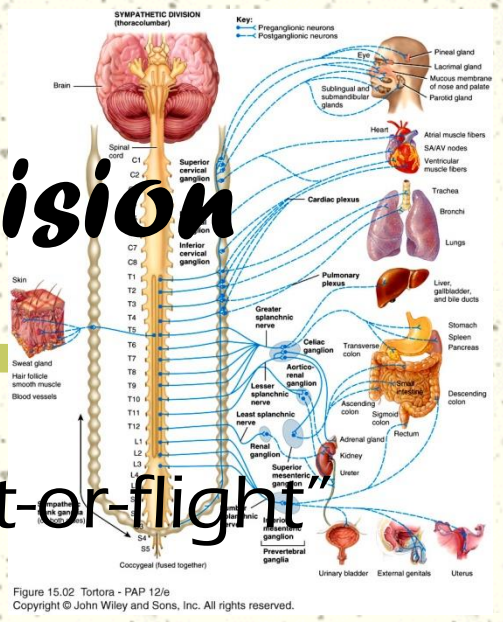


Figure 15.02 Tortora - PAP 12/e

- The sympathetic division is the "fight-or-flight" system
- Involves **E** activities – exercise, excitement, emergency, and embarrassment
- Promotes adjustments during exercise – blood flow to organs is reduced, flow to muscles is increased
- Its activity is illustrated by a person who is threatened

Sympathetic Responses

- Stress ↑ sympathetic system ↑ fight-or-flight response.
- ↑ production of ATP.
- Dilation of the pupils.
- ↑ heart rate and blood pressure.
- Dilation of the airways.
- Constriction of blood vessels that supply the kidneys and gastrointestinal tract.

Sympathetic Responses

- ↑ blood supply to the skeletal muscles, cardiac muscle, liver and adipose tissue
- ↑ glycogenolysis ↑ blood glucose.
- ↑ lipolysis.

Anatomy of ANS

Division	Origin of Fibers	Length of Fibers	Location of Ganglia
Sympathetic	Thoracolumbar region of the spinal cord	Short preganglionic and long postganglionic	Close to the spinal cord
Parasympathetic	Brain and sacral spinal cord	Long preganglionic and short postganglionic	In the visceral effector organs

Cholinergic and Adrenergic Neurons in the Autonomic Nervous System

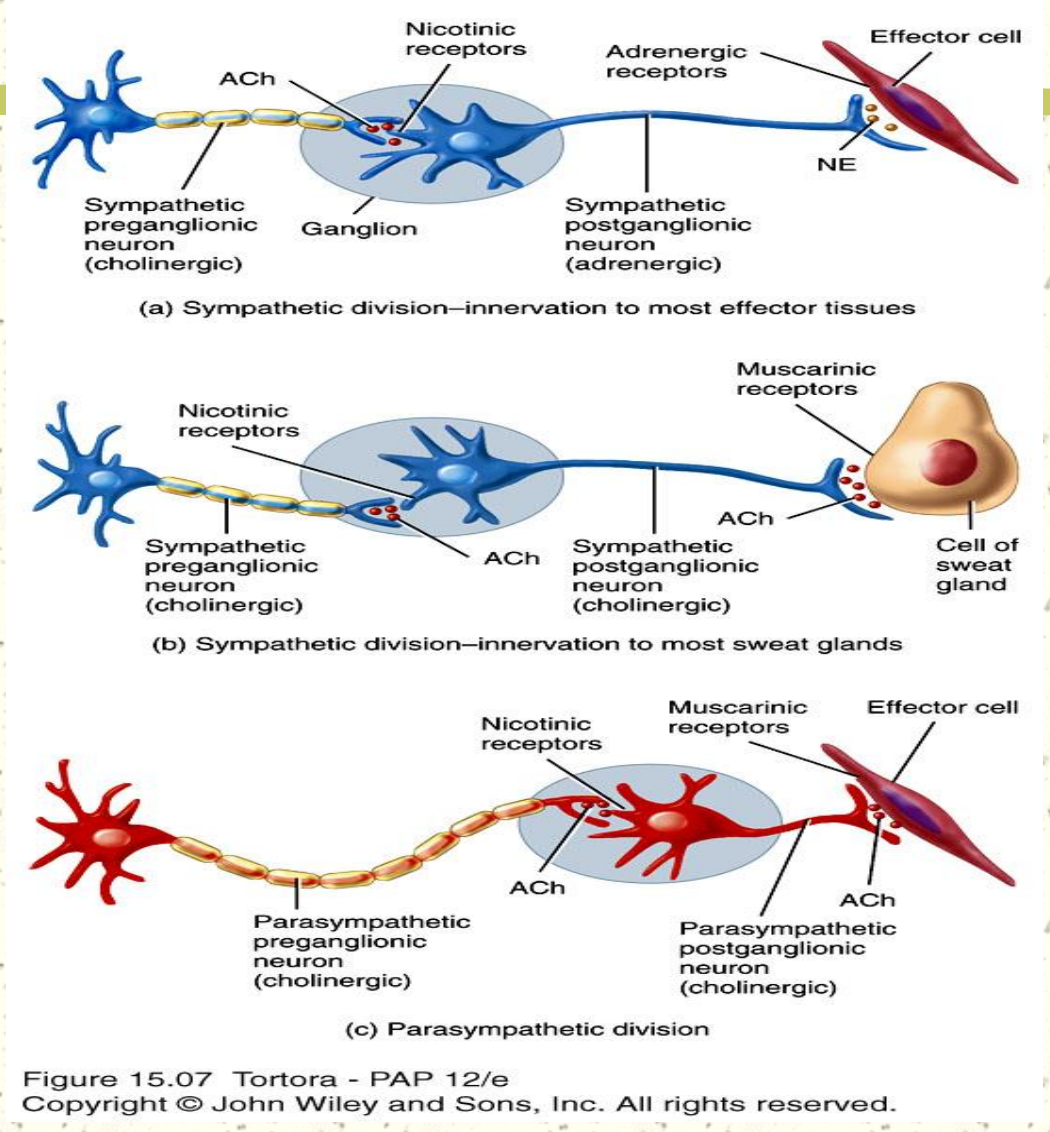


Figure 15.07 Tortora - PAP 12/e

Types of Neurotransmitters

Neurotransmitters and Receptors

Neurotransmitters overview

Neurotransmitters and Receptors

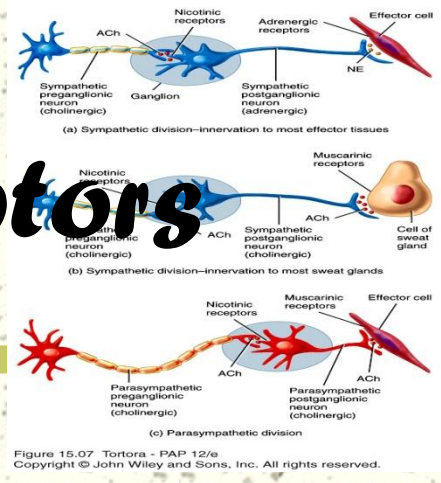


Figure 15.07 Tortora - PAP 12/e

- Acetylcholine (ACh) and norepinephrine (NE) are the two major neurotransmitters of the ANS
- ACh is released by all preganglionic axons and all parasympathetic postganglionic axons
- Cholinergic fibers – ACh-releasing fibers
- Adrenergic fibers – sympathetic postganglionic axons that release NE
- Neurotransmitter effects can be excitatory or inhibitory depending upon the receptor type

Cholinergic Receptors

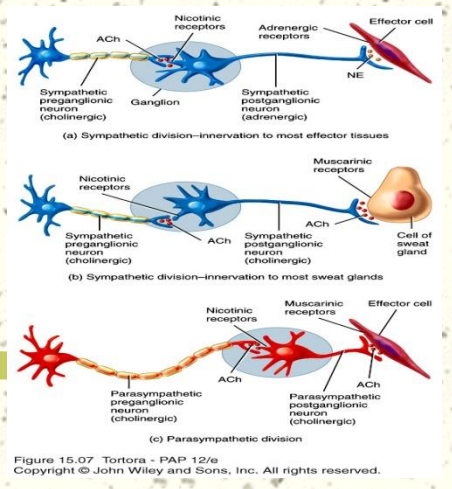


Figure 15.07 Tortora - PAP 12/e

- The two types of receptors that bind ACh are nicotinic and muscarinic
- These are named after drugs that bind to them and mimic ACh effects

Nicotinic Receptors

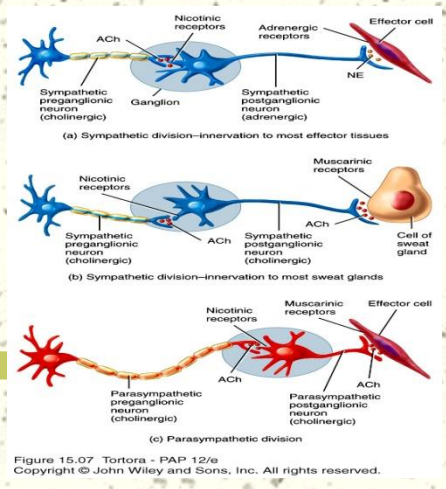


Figure 15.07 Tortora - PAP 12/e

- Nicotinic receptors are found on:
  - Motor end plates (somatic targets)
  - All ganglionic neurons of both sympathetic and parasympathetic divisions
  - The hormone-producing cells of the adrenal medulla
- The effect of ACh binding to nicotinic receptors is always stimulatory

Muscarinic Receptors

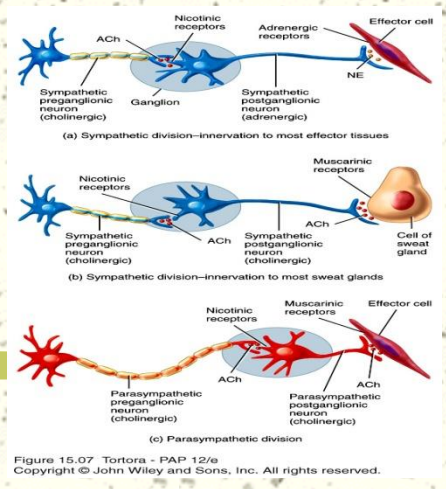


Figure 15.07 Tortora - PAP 12/e

- Muscarinic receptors occur on all effector cells stimulated by postganglionic cholinergic fibers
- The effect of ACh binding:
  - Can be either inhibitory or excitatory
  - Depends on the receptor type of the target organ

Adrenergic Receptors

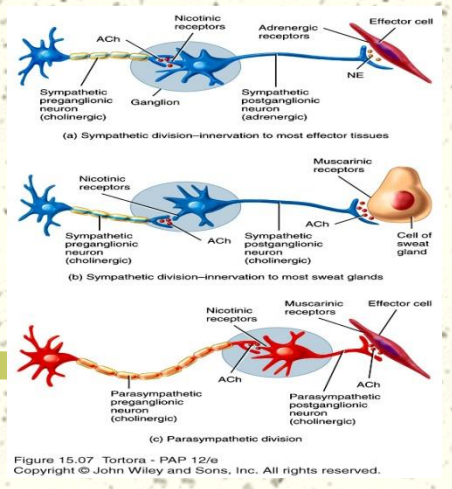
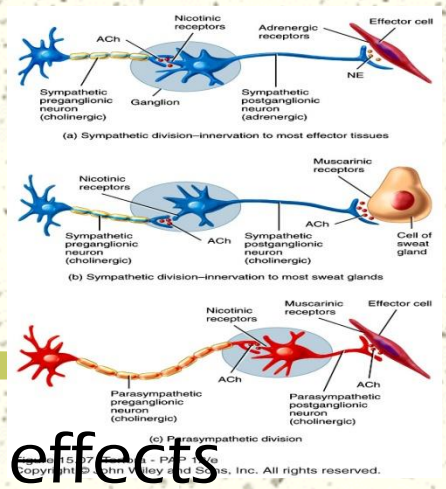


Figure 15.07 Tortora - PAP 12/e

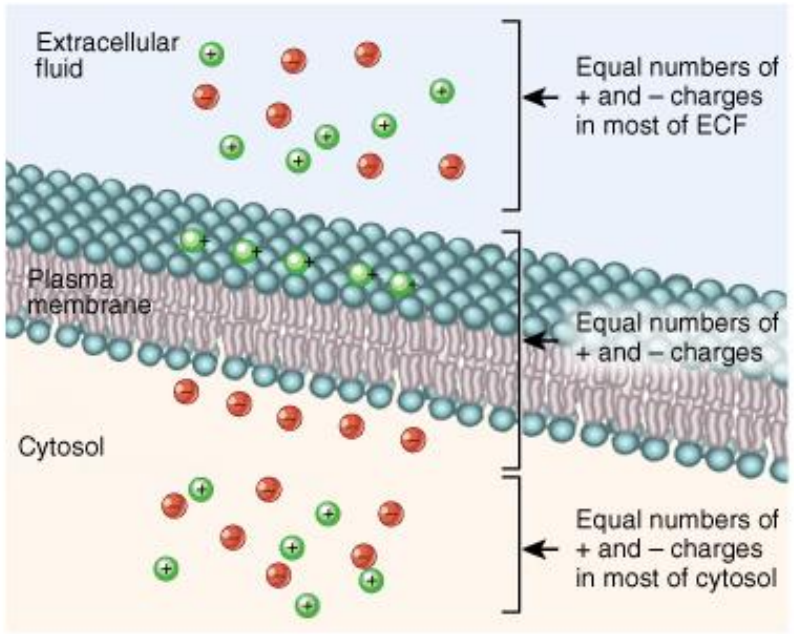
- The two types of adrenergic receptors are alpha and beta
- Each type has two or three subclasses ($\alpha1$, $\alpha2$, $\beta1$, $\beta2$, $\beta3$)
- Effects of NE binding to:
  - α receptors is generally stimulatory
  - β receptors is generally inhibitory
- A notable exception – NE binding to β receptors of the heart is stimulatory

Effects of Drugs

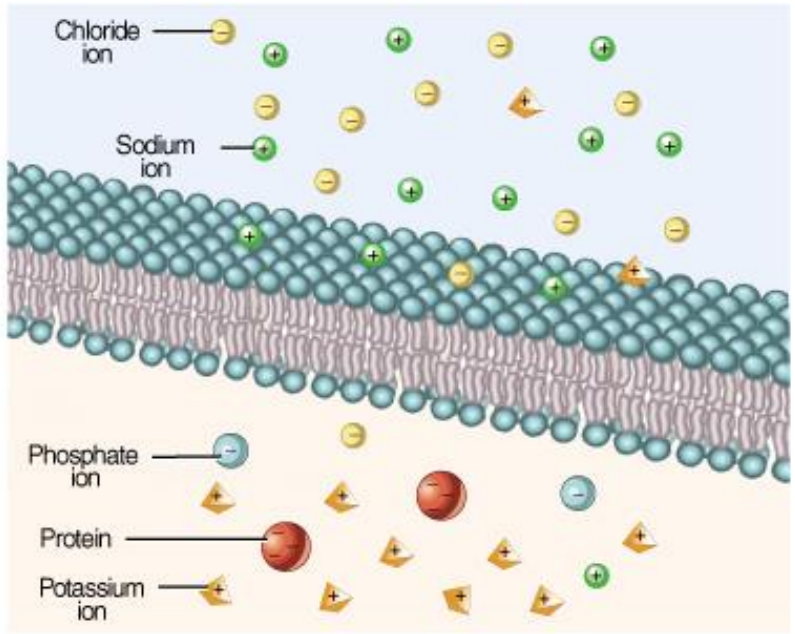


- Atropine – blocks parasympathetic effects
- Neostigmine – inhibits acetylcholinesterase and is used to treat myasthenia gravis
- Tricyclic antidepressants – prolong the activity of NE on postsynaptic membranes
- Over-the-counter drugs for colds, allergies, and nasal congestion – stimulate α-adrenergic receptors
- Beta-blockers – attach mainly to β_1 receptors and reduce heart rate and prevent arrhythmias

Distribution of Ions between ECF and ICF



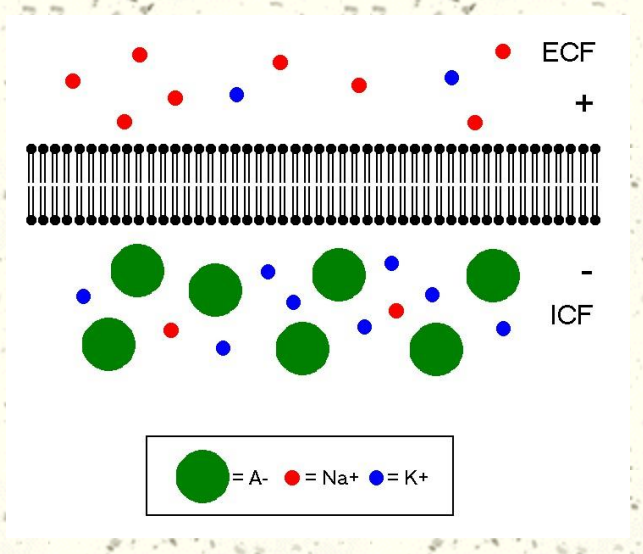
(a) Distribution of charges



(b) Distribution of ions

Membrane Potentials

- All cell membranes are electrically polarized
  - Unequal distribution of charges
  - *Membrane potential* (mV) = difference in charge across the membrane
  - Due to unequal ion concentrations across cell membrane (fixed anions)

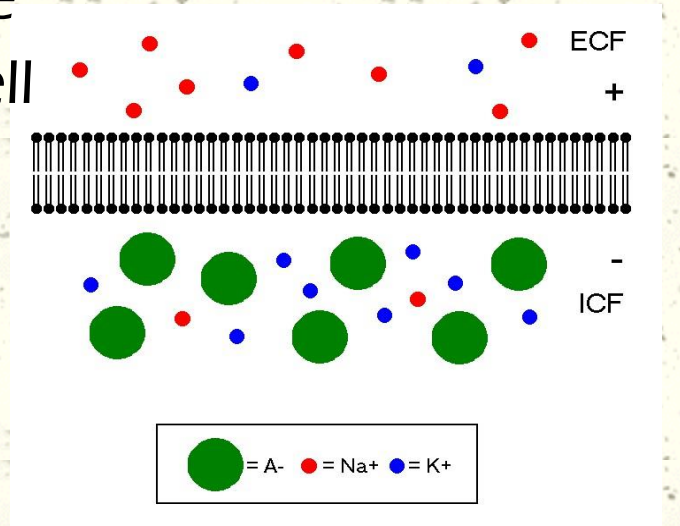


Membrane Potentials

Membrane Potential

Membrane Potentials

- K^+
  - $[K^+]$ higher inside cell than outside
  - Attracted to fixed anions inside cell
  - High membrane permeability
  - Flows slowly out of cell
- Na^+
  - $[Na^+]$ higher outside cell than inside
  - Attracted to fixed anions inside cell
  - Low membrane permeability
  - Flows slowly into cell

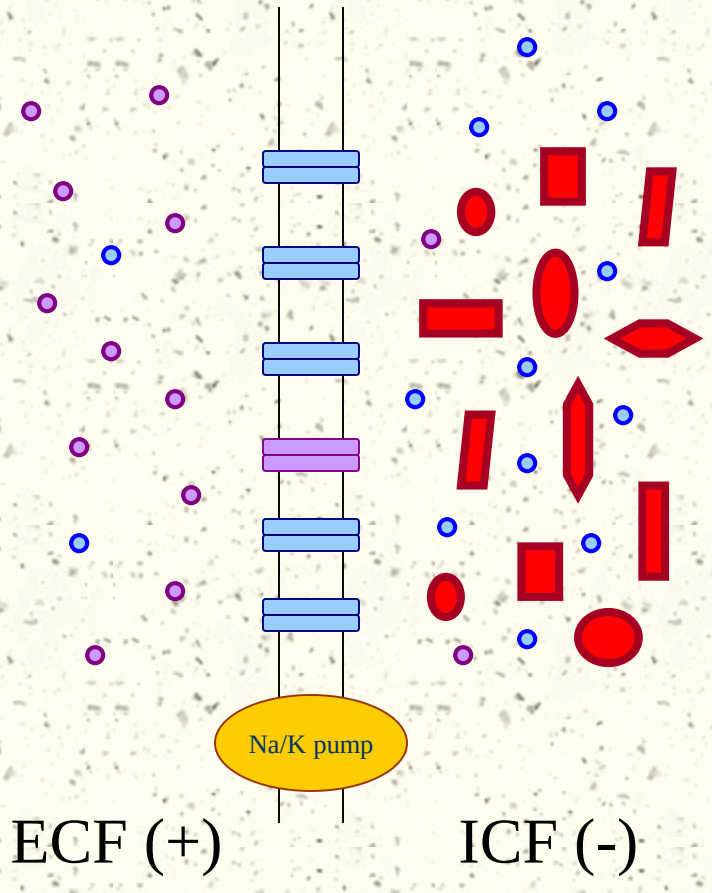


Resting Potentials

- *Resting potential*
  - Typical membrane potential for cells
  - Depends on concentration gradients and membrane permeabilities for different ions involved
    - *Goldman Equation*

$$V_m = \frac{RT}{F} \ln \frac{P_K[K^+]_o + P_{Na}[Na^+]_o + P_{Cl}[Cl^-]_i}{P_K[K^+]_i + P_{Na}[Na^+]_i + P_{Cl}[Cl^-]_o}$$

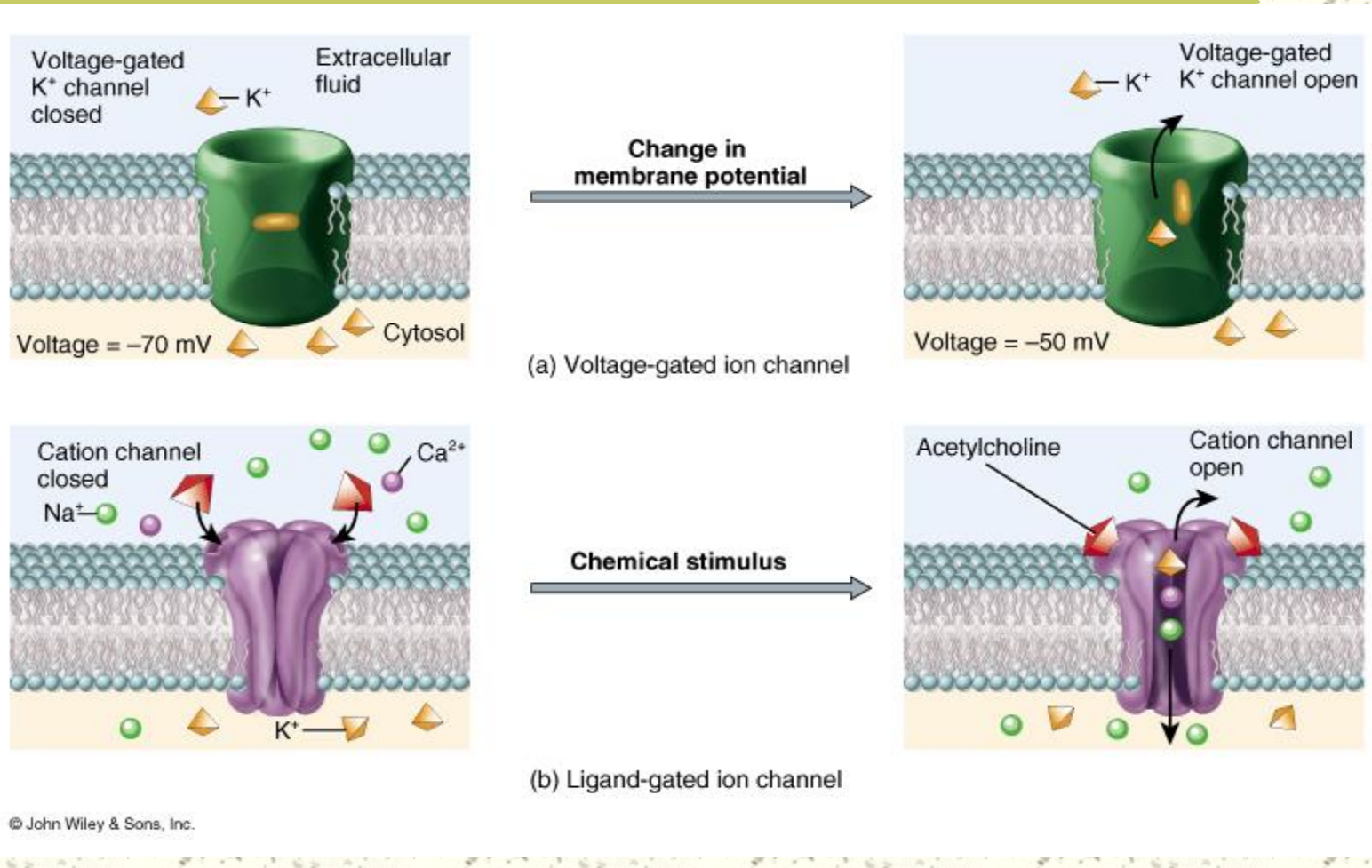
  - -65 to -85 mV (unequal to E_K or E_{Na})
  - $[Na^+]$ and $[K^+]$ inside the cell are maintained using Na^+/K^+ pumps



Membrane Proteins Involved in Electrical Signals

- *Non-gated ion channels* (leak channels)
  - always open
  - specific for a particular ion
- *Gated Ion channels*
  - open only under particular conditions (stimulus)
  - voltage-gated, ligand-gated,
- *Ion pumps*
  - active (require ATP)
  - maintain ion gradients

Types of Channel Proteins



Clinical correlations

History:

You examine an 8-year-old male boxer dog whose owner complains that the dog experiences seizures, weakness, and confusion around the time he is fed.

Clinical correlations

Clinical Examination:

The findings of the dog's physical examination, including his neurological examination, were within normal limits. His fasting serum glucose level, however, was 29 mg/dL (normal, 70-110 mg/dL), and the ratio between serum insulin and serum glucose levels was significantly elevated.

Clinical correlations

Comment.

Neurons depend primarily on oxygen and glucose as metabolites for ATP energy production, and neurons cannot store appreciable quantities of glucose. ATP is needed for maintenance of the normal electrical membrane potential. When deprived of glucose and subsequently ATP, the brain does not function properly; associated clinical signs include seizures, weakness, and confusion. In this animal, these signs were more common at the time of feeding because as the dog anticipated eating or actually did begin to eat, insulin was released, causing hypoglycemia.

Clinical correlations

Diagnosis:

In this case the ratio of insulin to glucose is elevated, probably because of an insulin-secreting tumor of the pancreas. Because insulin facilitates glucose transport through cell membranes, too much insulin results in the transfer of too much serum glucose to the cytoplasm of other cells of the body, thus depriving the brain's neurons of this essential metabolite.

Clinical correlations

Treatment:

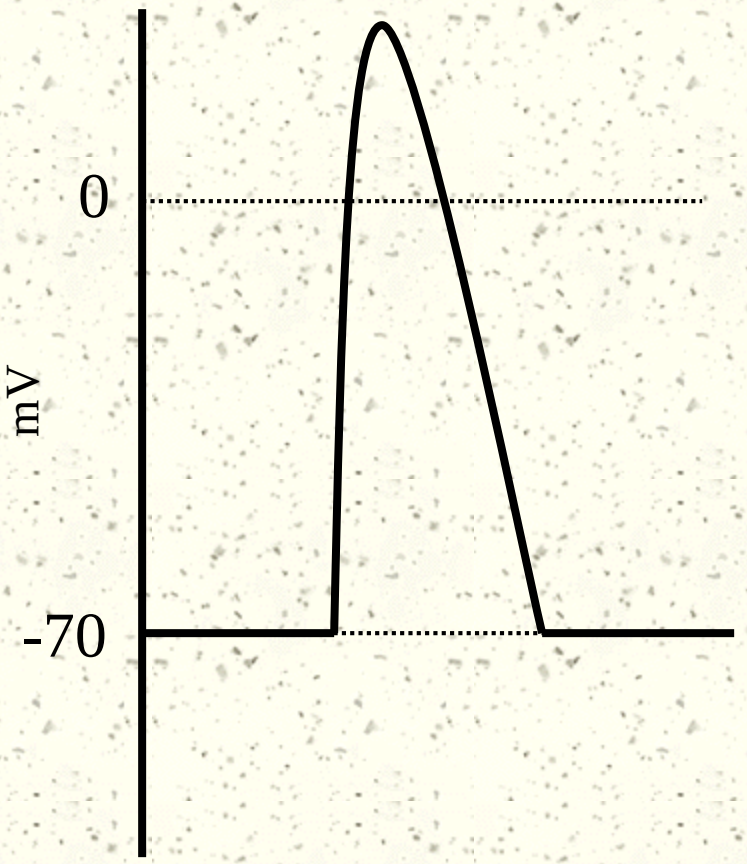
Insulinomas can usually be found and removed from the pancreas surgically. After surgical removal of the tumor, additional medical treatment is warranted to maintain normoglycemia. Medications include glucocorticoids, to stinmiate gluconeogenesis; diazoxide, to inhibit insulin secretion; streptozocin, which is toxic to the beta cells; and somatostatin, which increases gluconeogenesis.

Action Potentials

Action Potentials

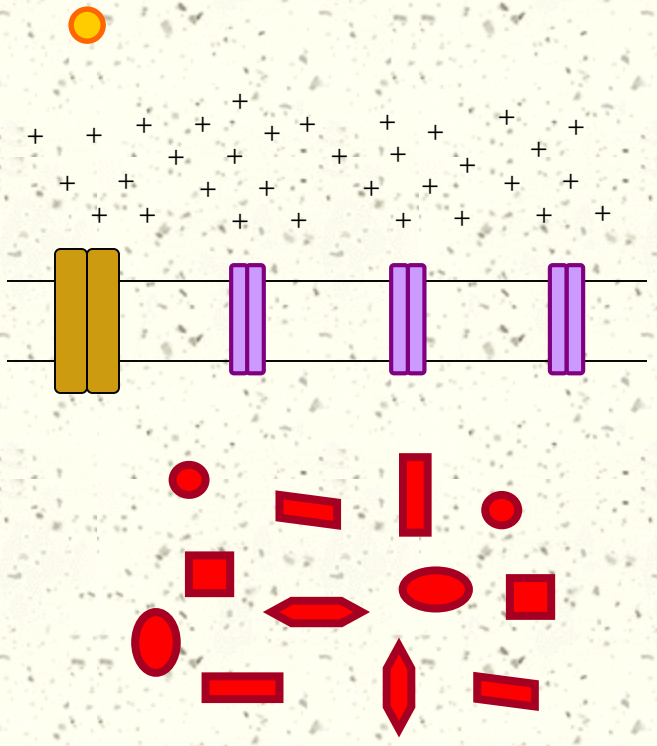
Action Potentials

- begins at the axon hillock, travels down axon
- brief, rapid reversal of membrane potential
  - Large change (~70-100 mV)
  - Opening of *voltage-gated* Na^+ and K^+ channels
  - *self-propagating* - strength of signal maintained
    - long distance transmission



Action Potentials

- triggered
  - membrane depolarization (depolarizing graded potential)
- "All or none"
  - axon hillock must be depolarized a minimum amount (threshold potential)
  - if depolarized to threshold, AP will occur at maximum strength
  - if threshold not reached, no AP will occur

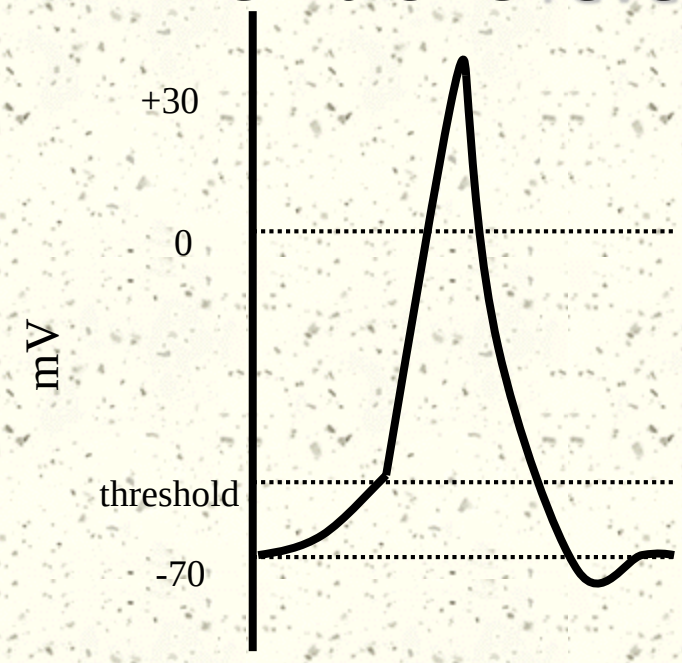


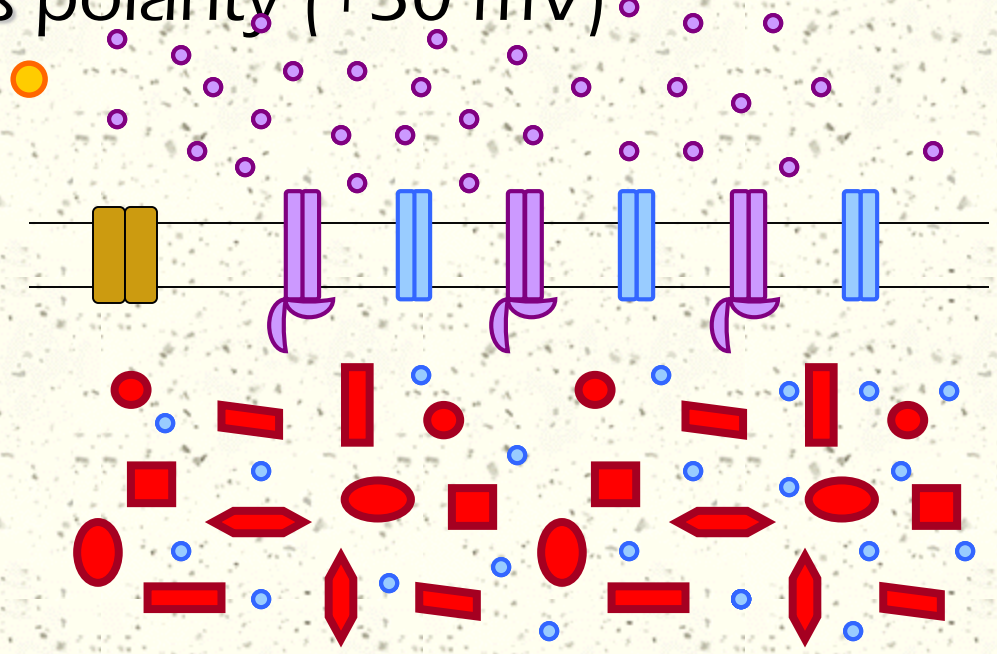
Action Potential: Depolarization

- Na^+ channels close
- K^+ channels close
- Delayed opening of voltage-gated K^+ channels
- K^+ channels open
- K^+ exits cell → repolarization

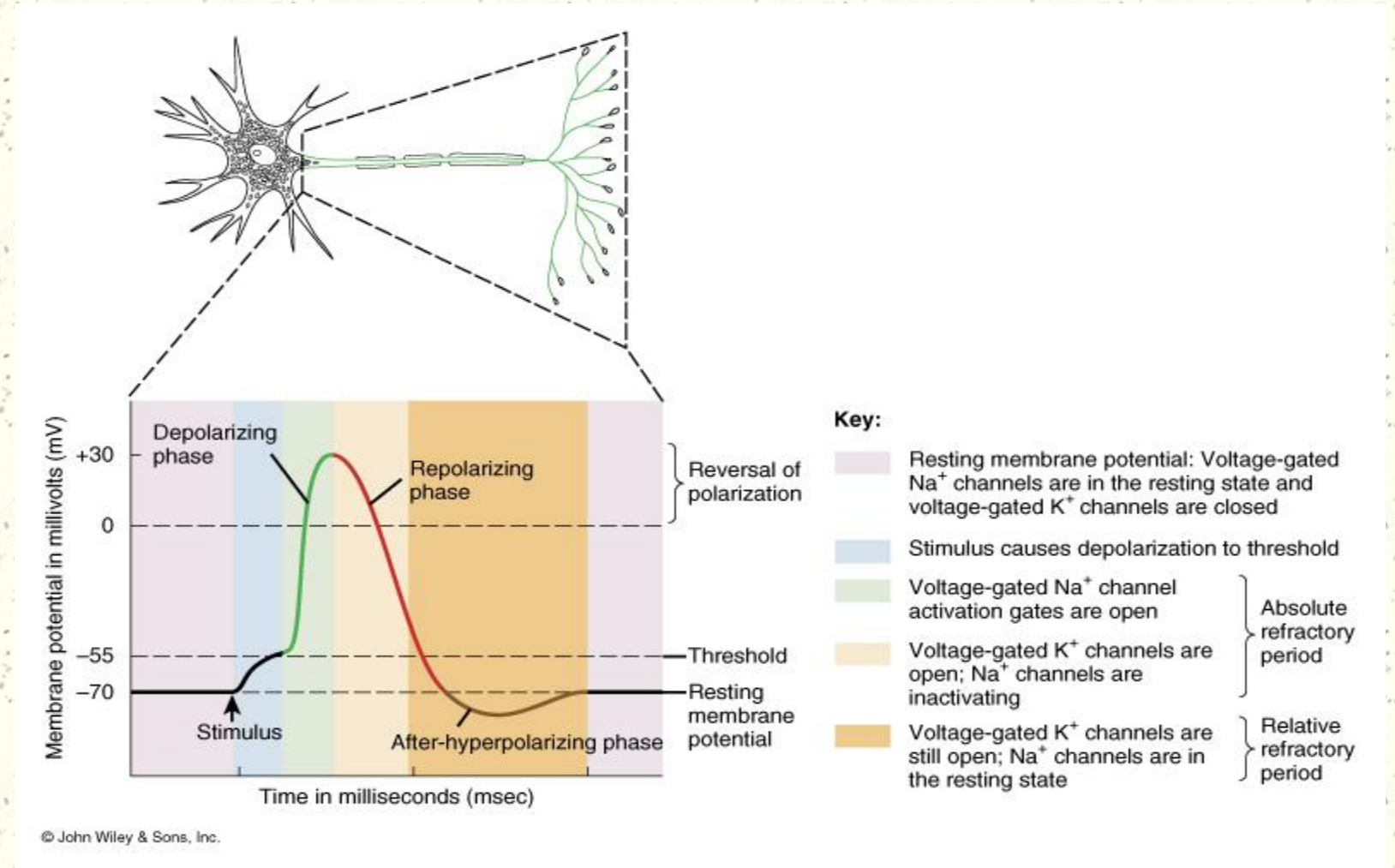
Action Potential: Repolarization

- voltage-gated Na^+ channels open
- Depolarization of adjacent membrane causes
- Na^+ enters cell → further depolarization → more
- Na^+ channels open
- K^+ channels close
- K^+ channels open → further depolarization
- slow membrane potential is restored by the Na^+-K^+ pump
- threshold is reached
- membrane reverses polarity (+30 mV)

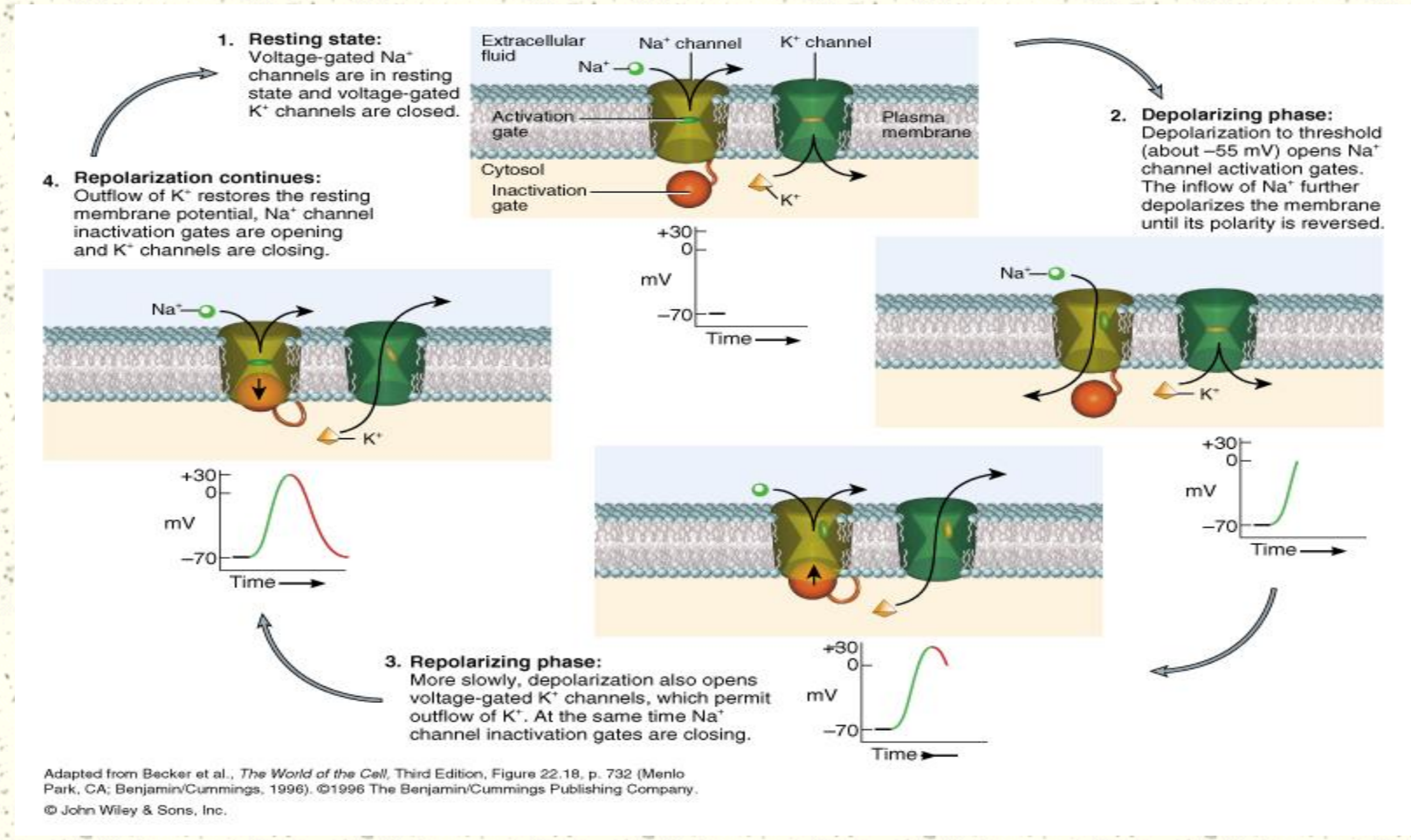




The action potential

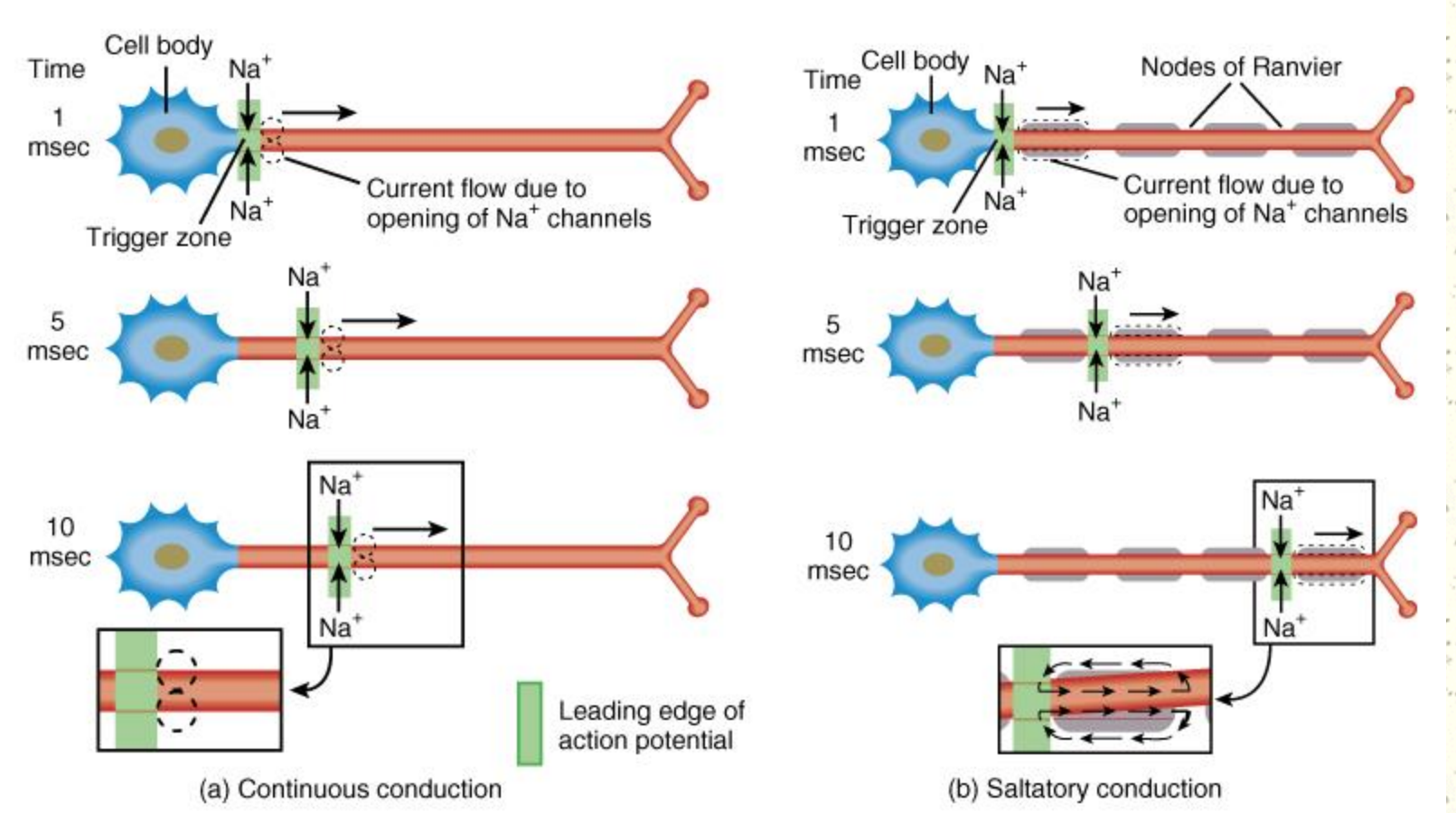


Mechanisms that creates an action potential



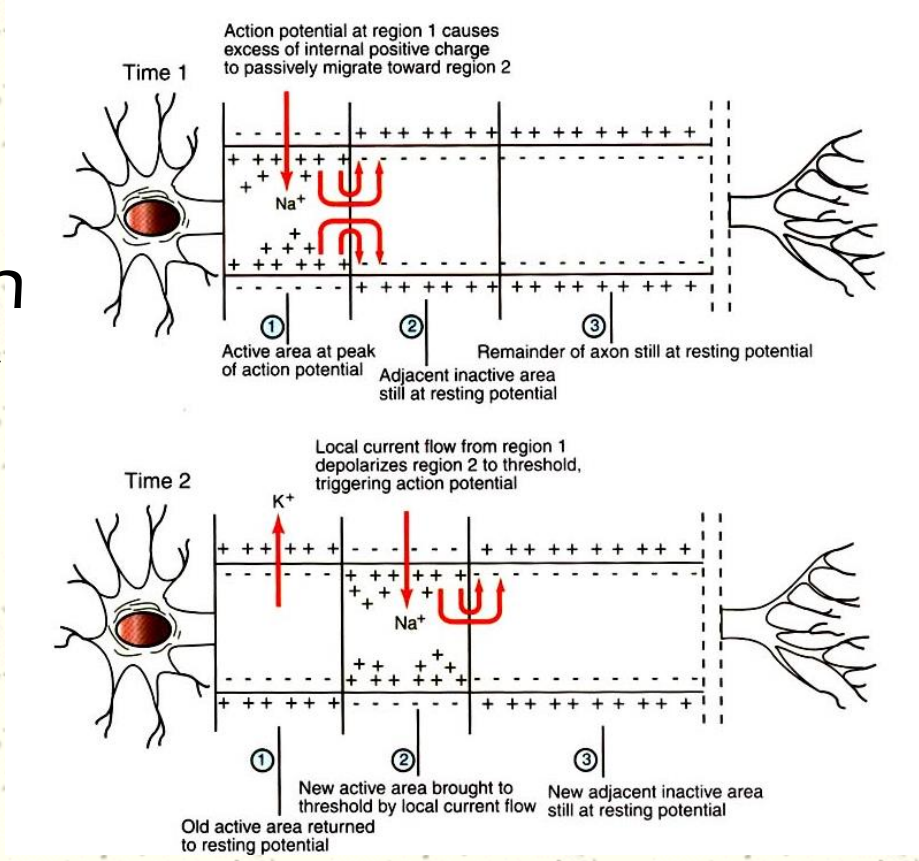
Adapted from Becker et al., *The World of the Cell*, Third Edition, Figure 22.18, p. 732 (Menlo Park, CA; Benjamin/Cummings, 1996). ©1996 The Benjamin/Cummings Publishing Company.

Mechanisms that creates an action potential



Action Potential Propagation

- Na^+ moving into one segment of the neuron quickly moves laterally inside the cell
- Depolarizes adjacent segment to threshold

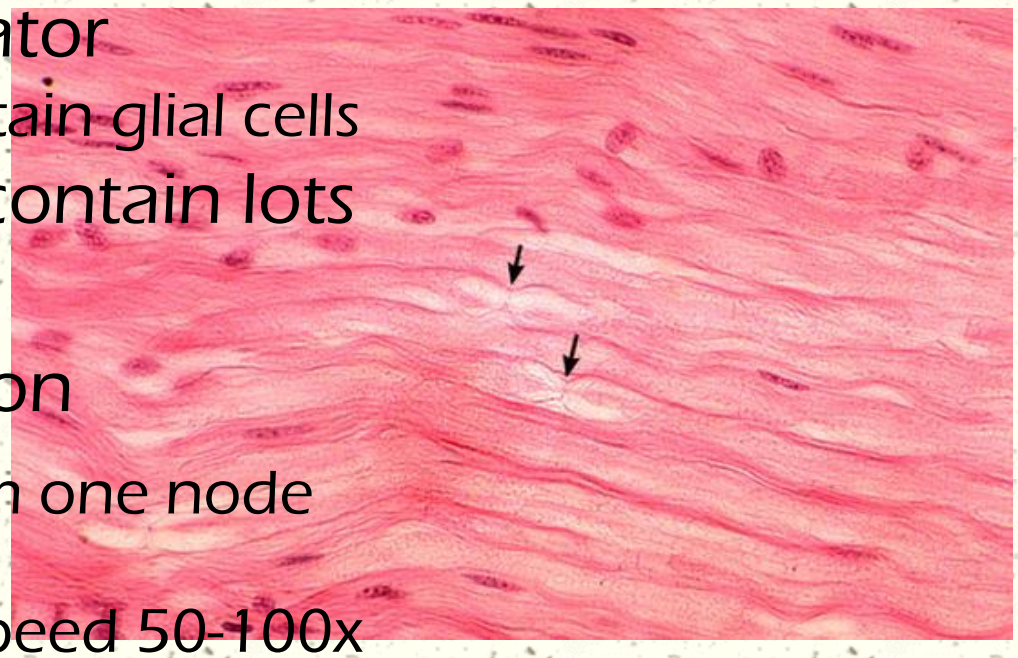


Conduction Velocity

- Conduction velocity
  - speed at which the action potential travels down the length of an axon
  - dictates speed of response
- Velocity directly related to axon diameter
  - Increased diameter lowers internal resistance to ion flow
  - $V \alpha \sqrt{D}$ in unmyelinated axons
  - $V \alpha D$ in myelinated axons

Action Potential Propagation: Myelinated Axons

- myelin - lipid insulator
  - membranes of certain glial cells
- Nodes of Ranvier contain lots of Na+ channels
- Saltatory conduction
  - signals "jump" from one node to the next
  - ↑AP conduction speed 50-100x
- Vertebrates tend to have more myelinated axons than invertebrates



Types of Nerve Fibers

(ERLANGER & GASSER system)

- "A" fibers:

Largest diameter myelinated fibers with the fastest saltatory conduction (12-130 m/sec) and a brief absolute refractory period. Axons of motor neurons and axons of sensory neurons that conduct touch, pressure, and thermal sensations.

- "B" fibers:

Intermediate diameter myelinated fibers With slower saltatory conduction than "A" fibers and longer absolute refractory periods. Dendrites of visceral sensory neurons and axons of presynaptic neurons of the ANS.

Types of Nerve Fibers

- "C" fibers:

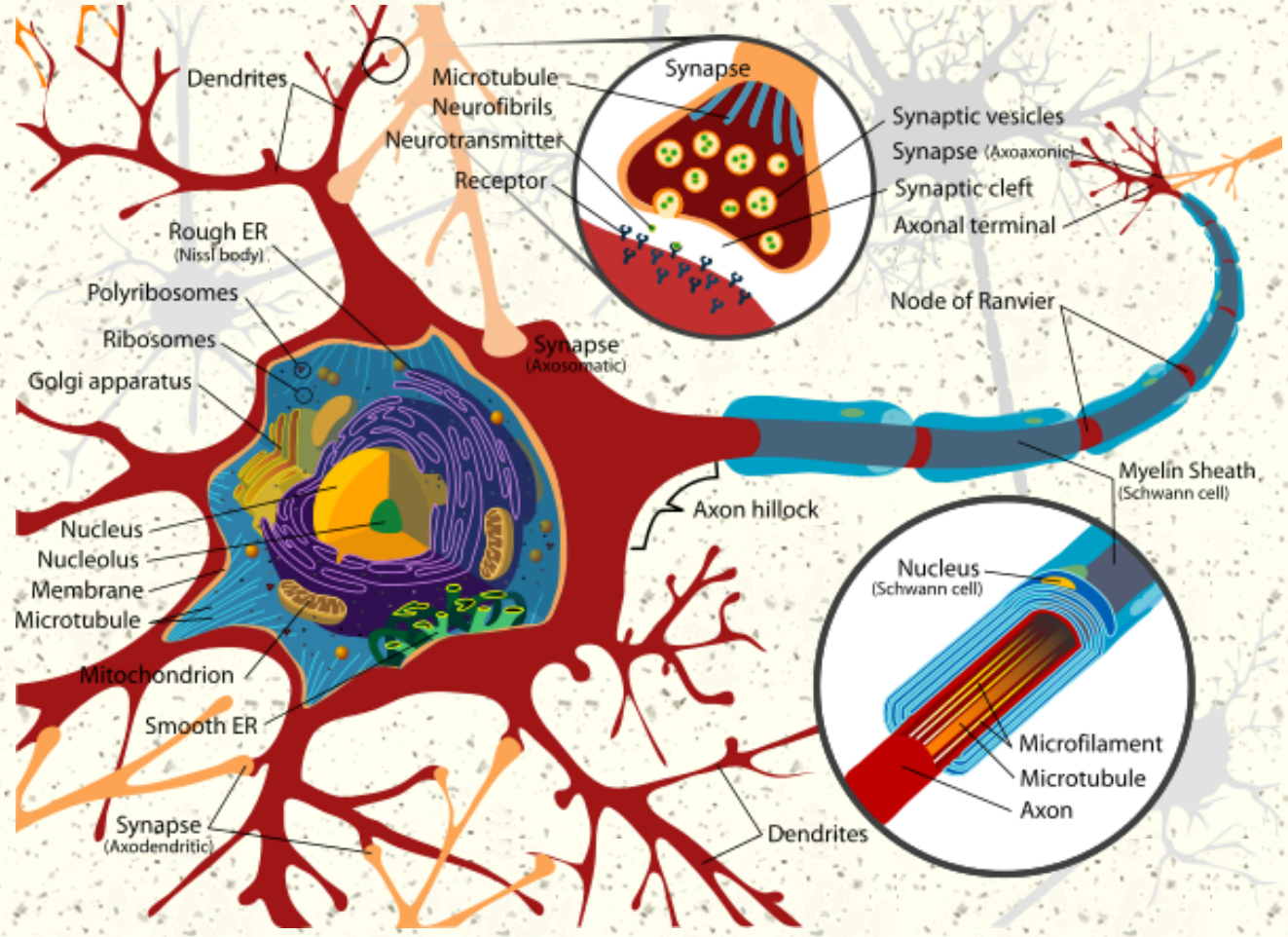
Smallest diameter unmyelinated fibers with slow continuous conduction (.5 – 2 m/sec.) and the longest absolute refractory periods. Axons of some somatic sensory neuron that carry pain, touch, pressure and thermal sensation, neuron that carry visceral pain sensations, and postsynaptic neurons of the ANS

Types of Nerve Fibers

Chemical Synapses

- *presynaptic neuron*
  - synaptic terminal button
  - contains synaptic vesicles filled with neurotransmitter
- *synaptic cleft*
  - space in-between cells
- *postsynaptic neuron*
  - subsynaptic membrane
  - contains receptors that bind neurotransmitter

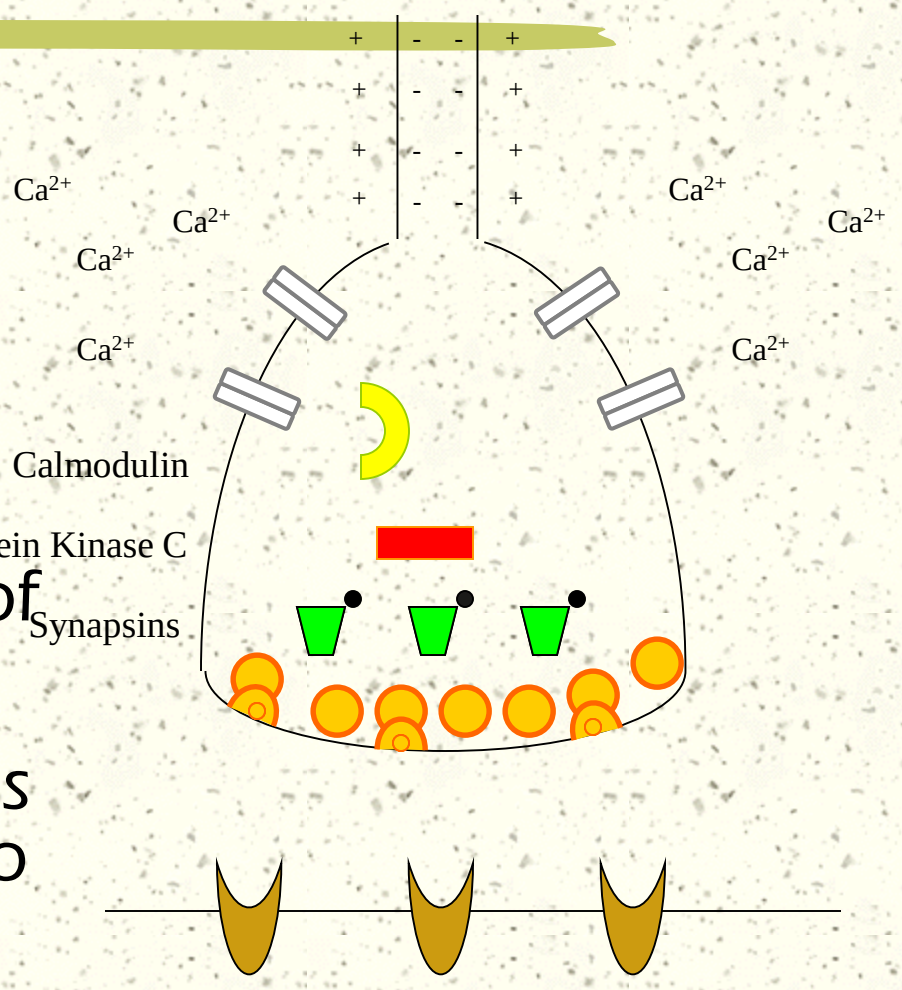
Chemical Synapses



The Synapse

Chemical Synapses

- Many voltage-gated Ca^{2+} channels in the terminal button
  - AP in knob opens Ca^{2+} channels
  - Ca^{2+} rushes in.
- Ca^{2+} induced exocytosis of synaptic vesicles
- Transmitter diffuses across synaptic cleft and binds to receptors on subsynaptic membrane



Chemical Synapses

- Generate Postsynaptic Potentials
  - Specific ion channels in subsynaptic membrane open, altering membrane permeability
  - If depolarizing graded potential is strong enough to reach threshold - generates action potential in postsynaptic cell
- Metabotropic actions
  - Long lasting effects (e.g., synaptic changes in learning and memory)

Clinical correlations

History:

You examine a 5-year-old female German shepherd whose owner states that the dog becomes progressively weaker with exercise. The owner also states that recently, just after eating, the dog has begun to vomit food in formed, cylinder-shaped boluses.

Clinical correlations

Clinical Examination:

All abnormalities found on physical examination were referable to the neuromuscular system. After resting, the dog's neurological examination findings were within normal limits. With even moderate exercise, however, the dog became progressively weaker, particularly in the front legs. Intravenous injection of an acetylcholinesterase inhibitor, edrophonium (Tensilon), eliminated all clinical signs of weakness. Radiographs of the chest revealed an enlarged esophagus and thymus.

Clinical correlations

Comment:

The history of an enlarged esophagus (megaesophagus) and the response to an acetylcholinesterase inhibitor confirm the diagnosis of myasthenia gravis ("grave muscle weakness"). This is caused by a failure of transmission of acetyicholine at the neuromuscular synapse. This transmission failure is caused by antibodies produced by the body against its own acetylcholine receptors.

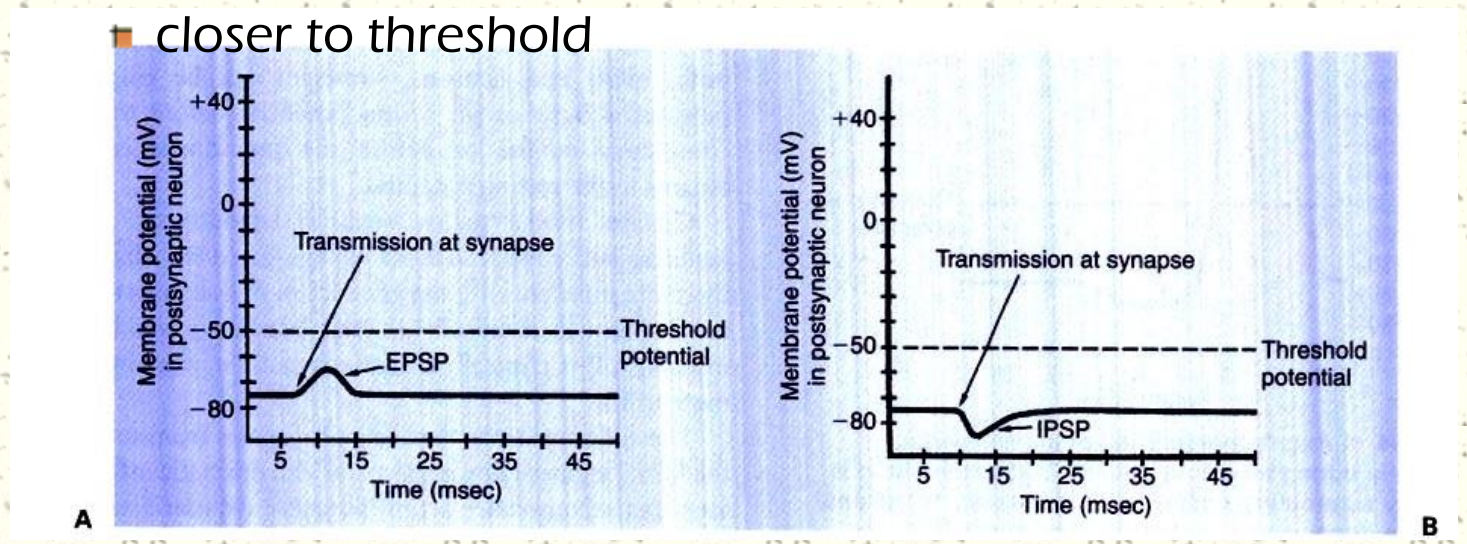
Clinical correlations

Treatment :

Spontaneous remissions are common, depending on the cause. Until then, oral daily acetylcholinesterase inhibitors are given. Surgical removal of mediastinal masses may also be necessary.

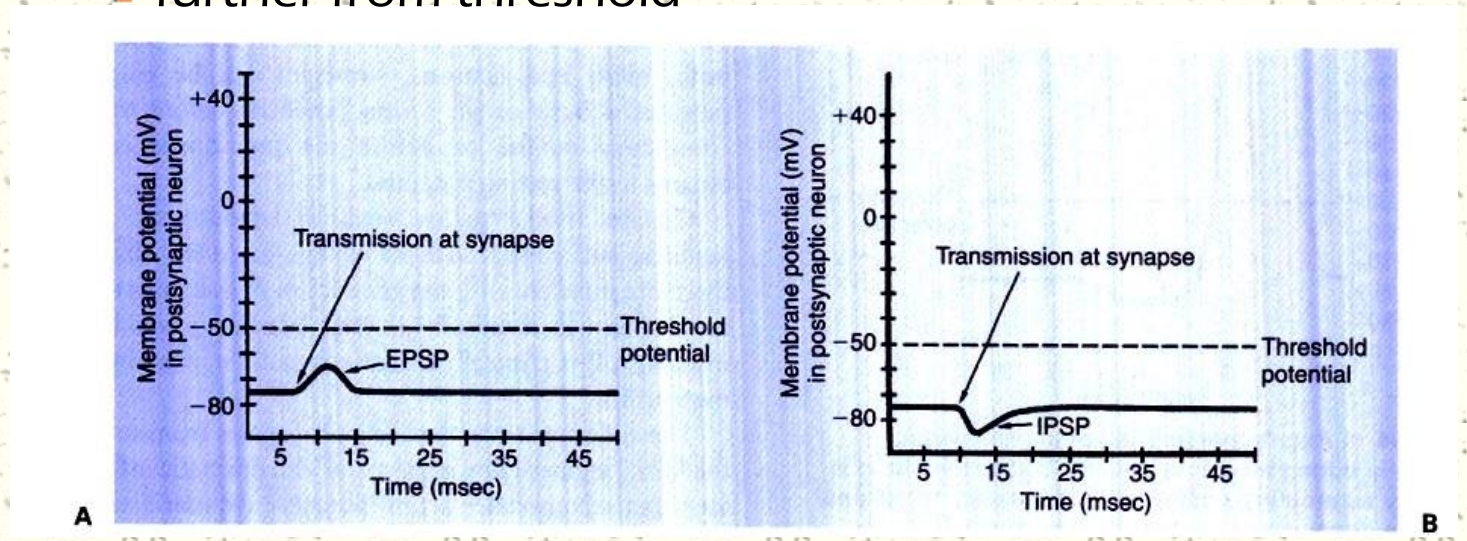
Types of Postsynaptic Potentials

- *excitatory postsynaptic potentials (EPSPs)*
  - Transmitter binding opens Na^+ channels in the postsynaptic membrane
  - Small depolarization of postsynaptic neuron
    - More positive inside the cell
    - closer to threshold



Types of Postsynaptic Potentials

- *inhibitory postsynaptic potentials (IPSPs)*
  - Transmitter binding opens K^+ or Cl^- ion channels
  - K^+ flows out or Cl^- flows in down gradients
  - Small hyperpolarization of postsynaptic neuron
    - More negative inside cell
    - further from threshold



Summation

- *spatial summation*
  - numerous presynaptic fibers may converge on a single postsynaptic neuron
  - additive effects of numerous neurons inducing EPSPs and IPSPs on the postsyn. neuron
- *temporal summation*
  - additive effects of EPSPs and IPSPs occurring in rapid succession
  - next synaptic event occurs before membrane recovers from previous event

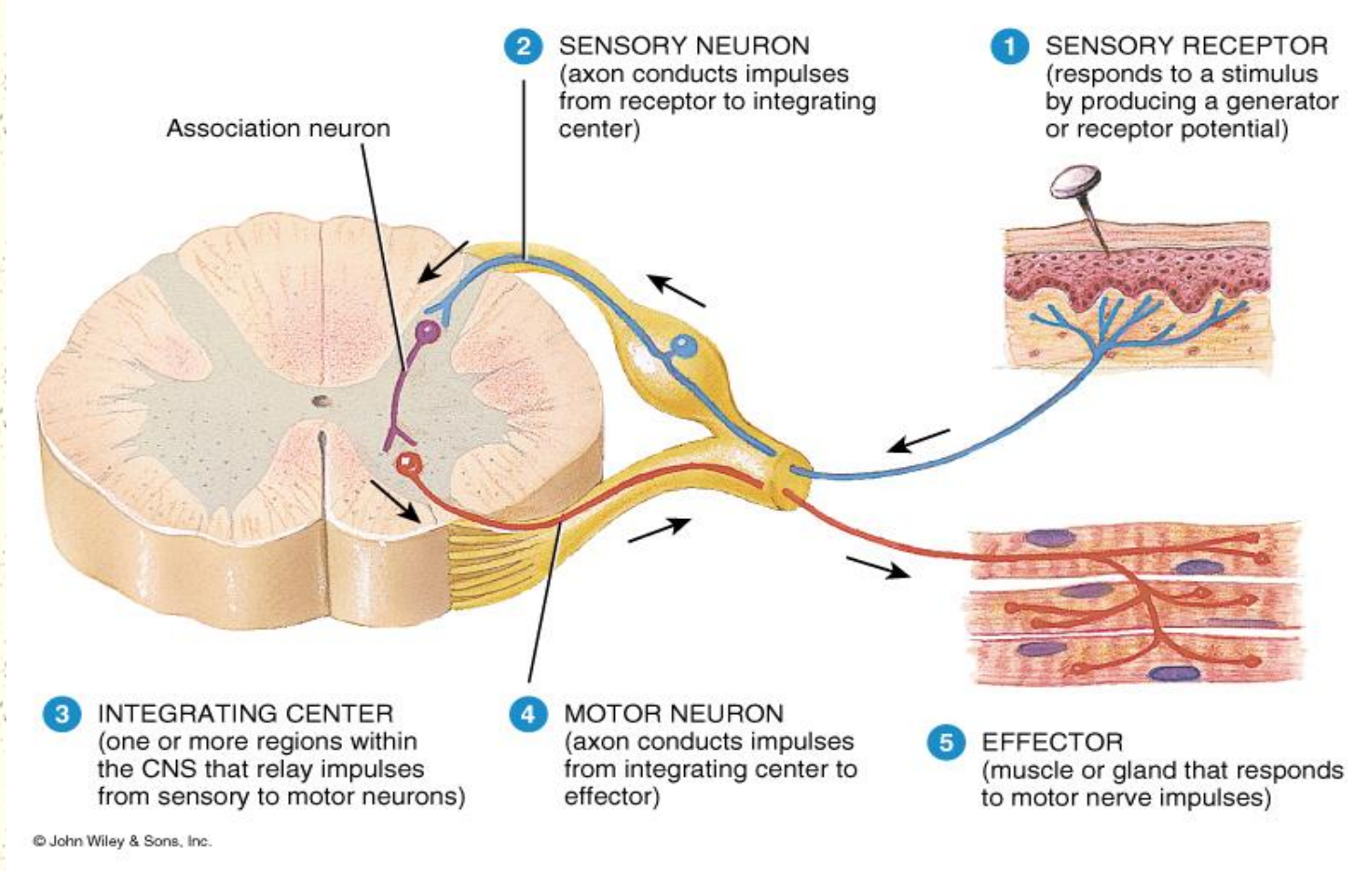
Reflexes

- Fairly fixed patterns of response or behavior similar for any given stimulus. Fast, predictable, automatic responses to changes in the environment that help to protect the body.
- Reflexes may be used as diagnostic tools to determine nervous system disorders.
- Reflex pathways consist of sensory fibers bringing impulses into the spinal cord and motor fibers capable of effecting a response, as well as all the interconnections between the two.

Reflexes

- Stretch reflex
  - Results in the contraction of a muscle when it is stretched suddenly.
  - Example: patellar tendon reflex
- Withdrawal reflex
  - Sudden contraction and removal of a body segment as the result of a painful stimulus.
  - Example: hot stove reflex

Content of a reflex



Clinical correlations

History :

Worried owners call you about their 4-month- old Tennessee Walking Horse colt. He appeared normal this morning when they let him out to pasture with his mother, but later this afternoon, the mare and the foal did not come in to be fed. The owners went out to the pasture and found the mare with the foal, who would not get up. He was lying on his side and seemed unable to position himself sternal. When the owners tried to reposition him, the foal thrashed, trying to get away. You tell the owners not to move the foal and that you will be there soon.

Clinical correlations

Clinical ExamInation :

The foal appears to be responsive but in great pain and unable to rise. 'temperature, pulse, and respirations are all mildly increased. There appears to be a swelling along the cervical (neck) area in the region of CI-C3.
The swelling is hard (bone) and has some fluid (inflammation) as well. There is some crepitus in the area of the swelling (possible fracture site).

Clinical correlations

The foal displays no other areas of swelling or trauma. Neurological examination reveals normal cranial nerves. In the front limbs the biceps and triceps reflexes seem increased on both sides. Deep pain is present, and cutaneous sensation is increased bilaterally. In the hind limbs the femoral, sciatic, and tibial responses are increased.

Clinical correlations

Comment :

Although it is difficult to localize a fracture definitively, based on history and physical examination a fracture seems likely. The fracture appears to be in the region of Cl-C3. Radiographs would be ideal to make a definitive diagnosis. On neurological testing of the biceps, triceps, sciatic, femoral, and cranial tibial responses, all assess segmental reflex arcs. Because of a high cervical fracture, the descending motor tracts that supply both the thoracic and the pelvic limbs are affected.

Clinical correlations

Treatment.

The prognosis for this foal is poor Based on the physical examination and clinical signs, a fracture is likely, and there is little hope for recovery. The complications associated with trying to manage a foal as the fracture heals are enormous. The fracture may not heal, and the foal could have severe residual neurological deficits. In most cases, these foals are euthanized fairly quickly because of the poor prognosis.

Any Questions ?

PATHWAYS AND HIGHER-ORDER FUNCTIONS

Introduction

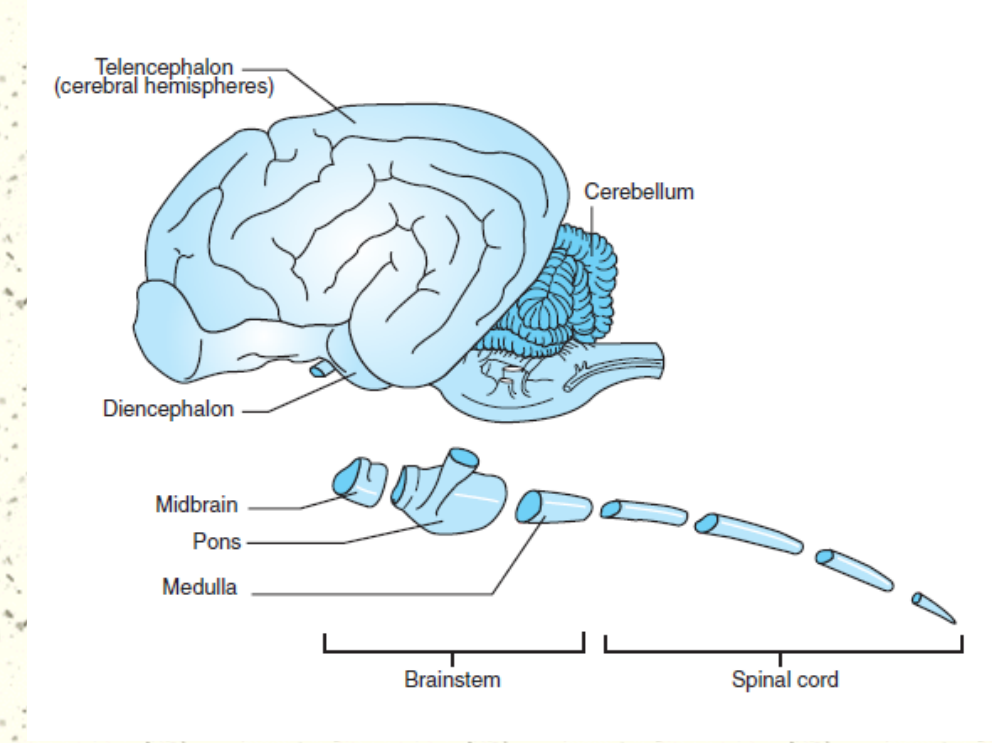
- There is a continuous flow of information between the brain, spinal cord, and peripheral nerves

  - millions of sensory neurons deliver information to processing centers in the CNS, and millions of motor neurons are controlling or adjusting activities of peripheral effectors

  - this process continues around the clock, with many brain stem centers active throughout our lives performing autonomic functions at the subconscious level

- Many forms of interaction, feedback, and regulation link higher centers with the various components of the brain stem

Anatomical regions of CNS



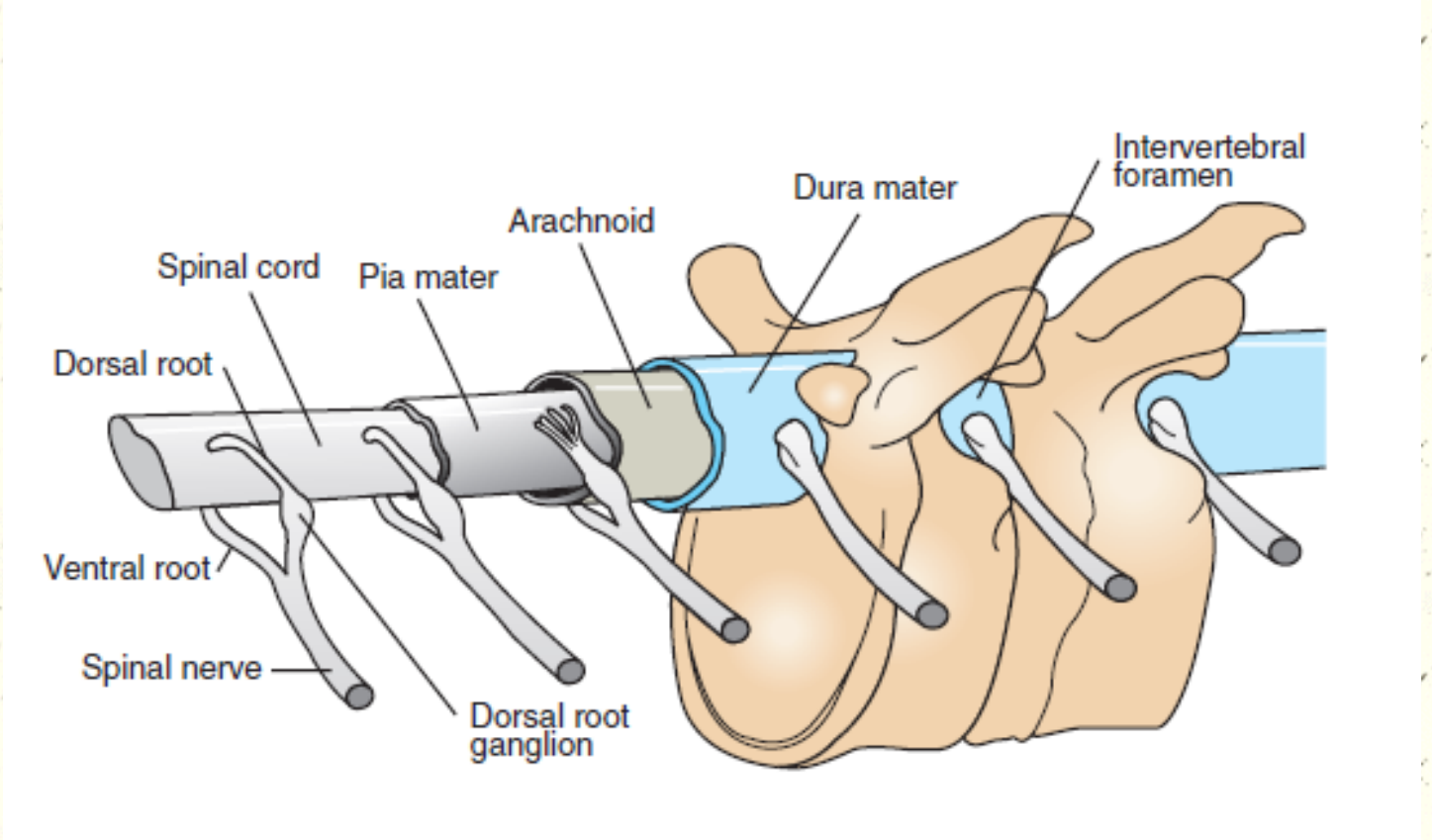
- Spinal cord
- Brain stem
  - Medulla
  - Pons
  - Mid brain
- Diencephalon
- Telencephalon

The spinal cord

- The most caudal region
- Sensory nerves enter from dorsal roots
- Motor nerves exit from ventral roots
- Contains
  - cell bodies and dendrites of motor neurons
  - Vertical tracts of sensory n. to the brain and motor n. from the brain
- The isolated spinal cord can control simple reflexes,

such as muscle stretch reflexes and limb withdrawal from painful stimuli.

The spinal cord



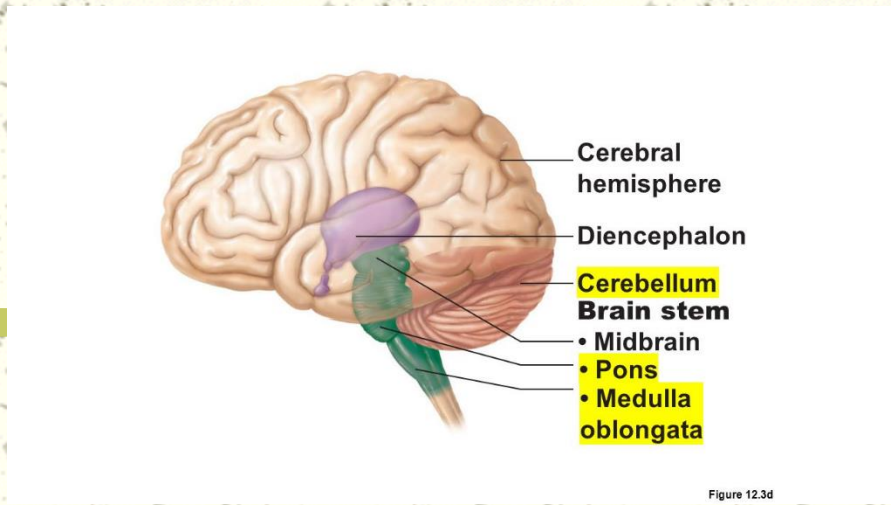
Brain Stem

- Medulla
  - Lies rostral to the spinal cord
  - The cell bodies of medullary neurons aggregates in sensory or motor nuclei, called: *cranial nerve nuclei.*
  - play a critical role in life support functions:
    - Respiratory
    - Cardiovascular
    - Feeding (taste, tongue movement, swallowing, digestion)

Brain Stem

- The pons
  - Rostral to the medulla
  - contains the cell bodies of large numbers of neurons in a two-neuron chain that relays information from the cerebral cortex to the cerebellum.
  - Receives sensory inf. from face, motor control of chewing.
  - The cerebellum is not a part of the brainstem
  - The cerebellum is important for smooth, accurate, coordinated movement and for motor learning.

Brain stem



- Mid brain (Mesencephalon)
  - Rostral to the pons
  - processing and relaying visual and auditory information
  - Directly controls eye movement
  - Reticula formation:

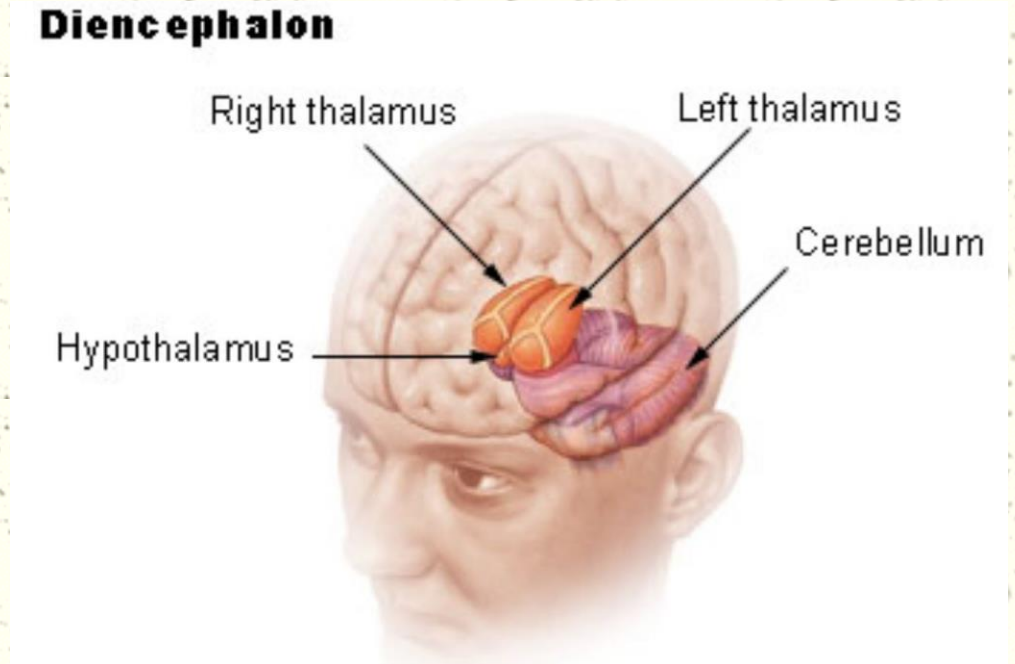
A netlike complex of many small clusters of cell bodies (nuclei), modulating consciousness and arousal, pain perception, and spinal reflexes, as well as in movement

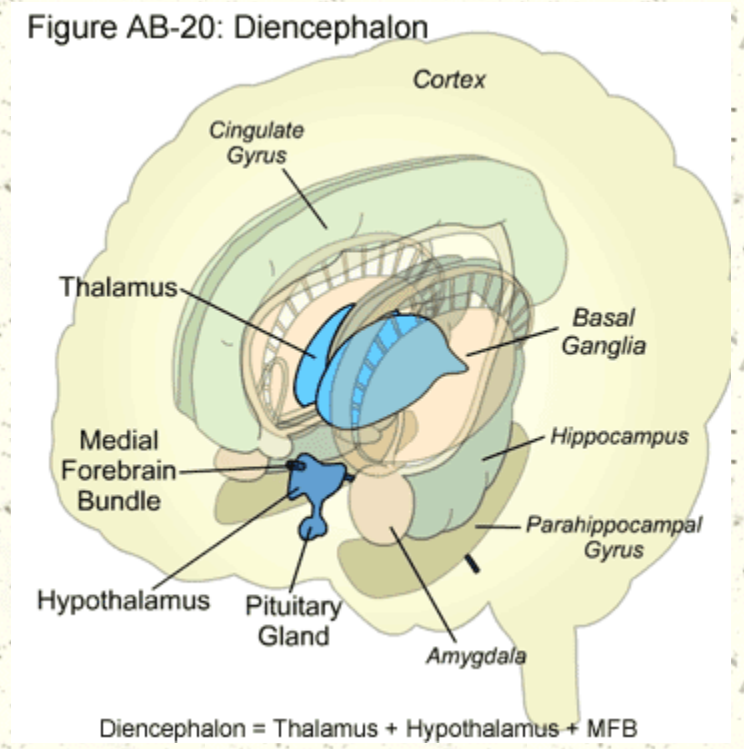
Diencephalon

- contains the thalamus and the hypothalamus
- The *thalamus* is a relay station of information being passed to the cerebral cortex from sensory systems and other brain regions

- The *hypothalamus* regulates the autonomic nervous system, controls hormone secretion of the pituitary gland, and plays a major role in physiological and behavioral aspects of homeostasis (e.g., maintenance of temperature and blood pressure; feeding).

Diencephalon





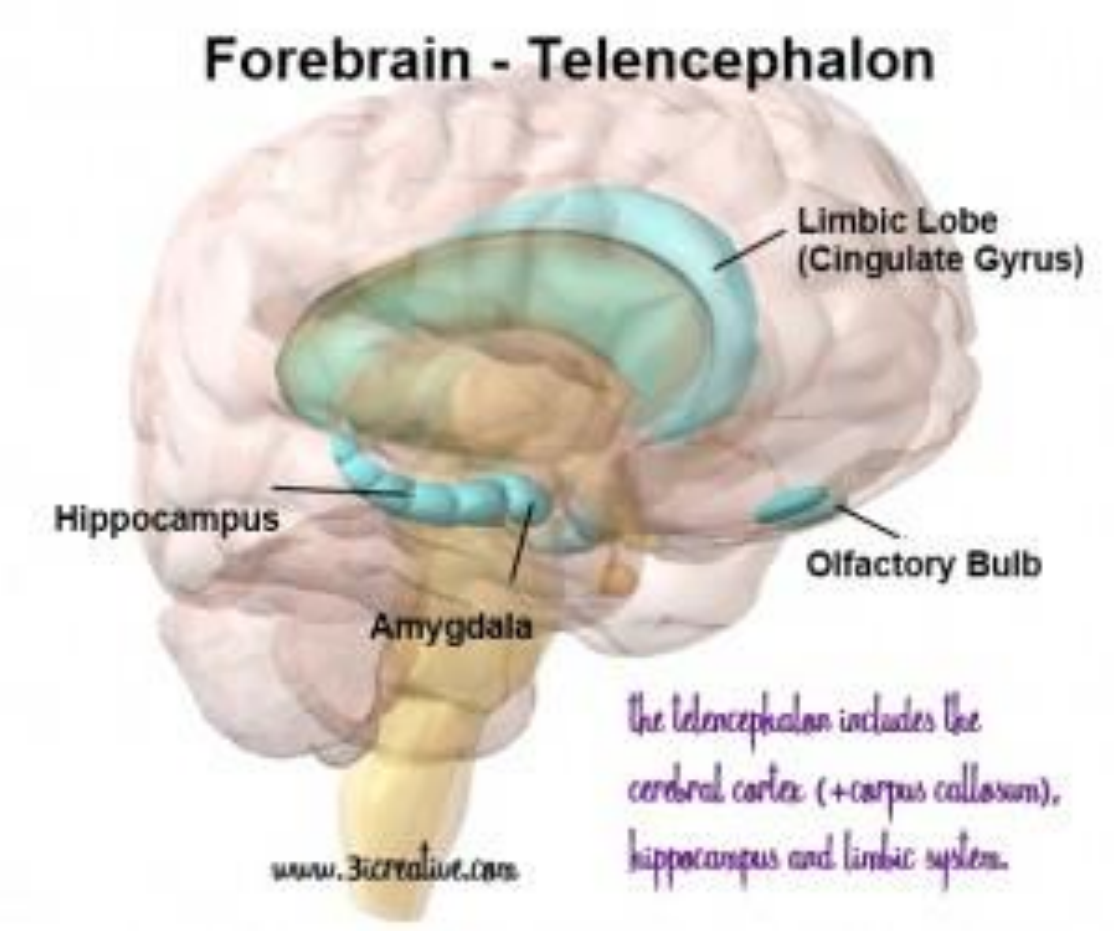
Telencephalon

- made up of the cerebral cortex and a small

number of prominent subcortical structures, such as the basal ganglia and hippocampus

- The *cerebral cortex* mediates the most complex forms of sensory *integration* and conscious sensory perception.
- The *basal ganglia* are a collection of nuclei that modulate the motor functions of cerebral cortex
- the *hippocampus* plays an important role in memory and spatial learning.

Telencephalon



Sensory and Motor Pathways

- Nerve pathways, called **tracts**, relay sensory and motor information between the CNS and PNS
  - consists of a chain of tracts and associated nuclei
  - number of synapses varies from 1 pathway to another
  - all involve both the brain and spinal cord
  - tract name often indicates its origin and destination

Sensory and Motor Pathways

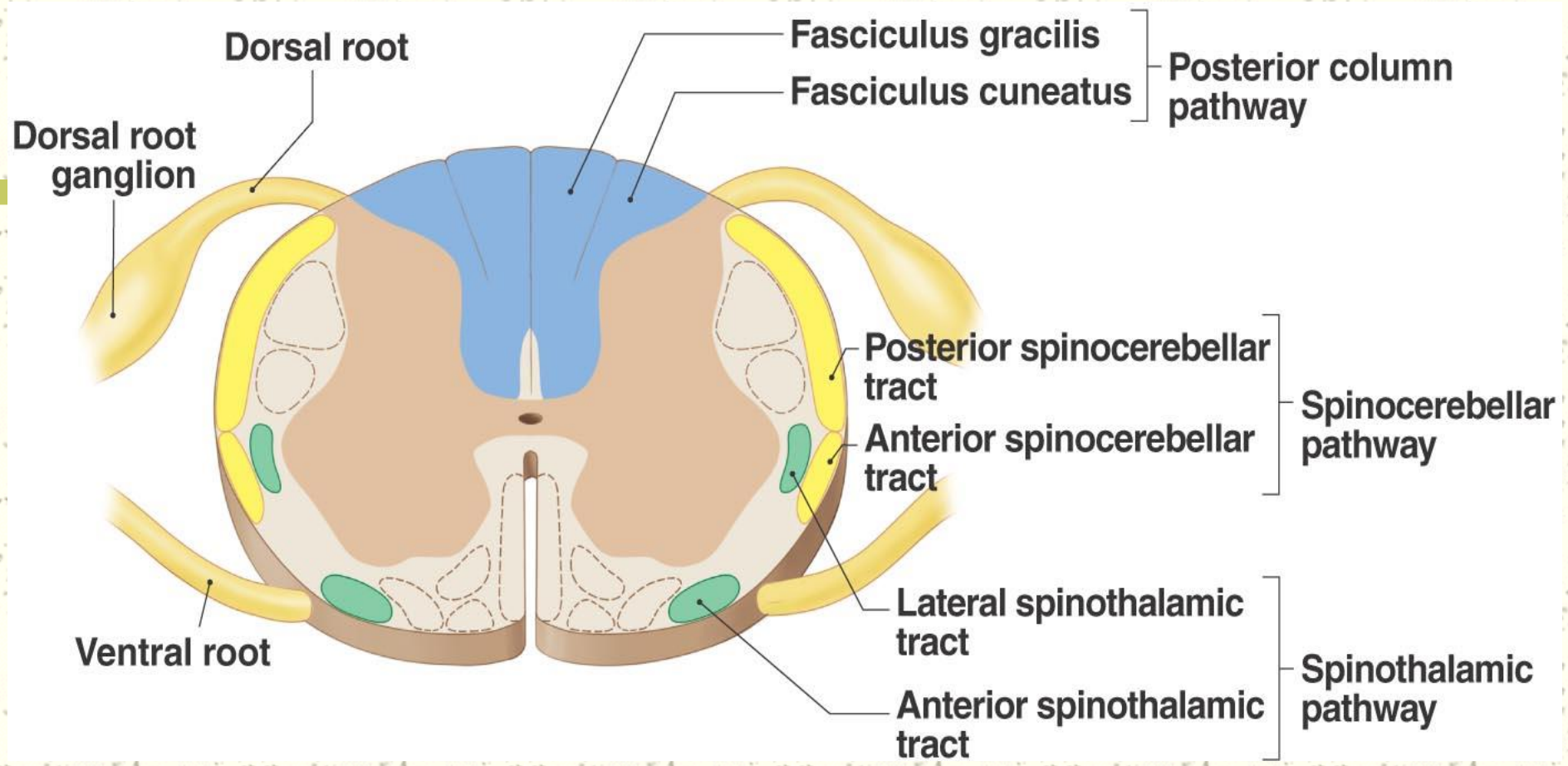
- **Ascending** (sensory) pathways and **descending** (motor) pathways:

  1) these tracts are paired (bilaterally and symmetrically along the spinal cord)

  2) axons within each tract are grouped according to the body region innervated

Spinal Pathways - 1

Spinal Pathways - 2



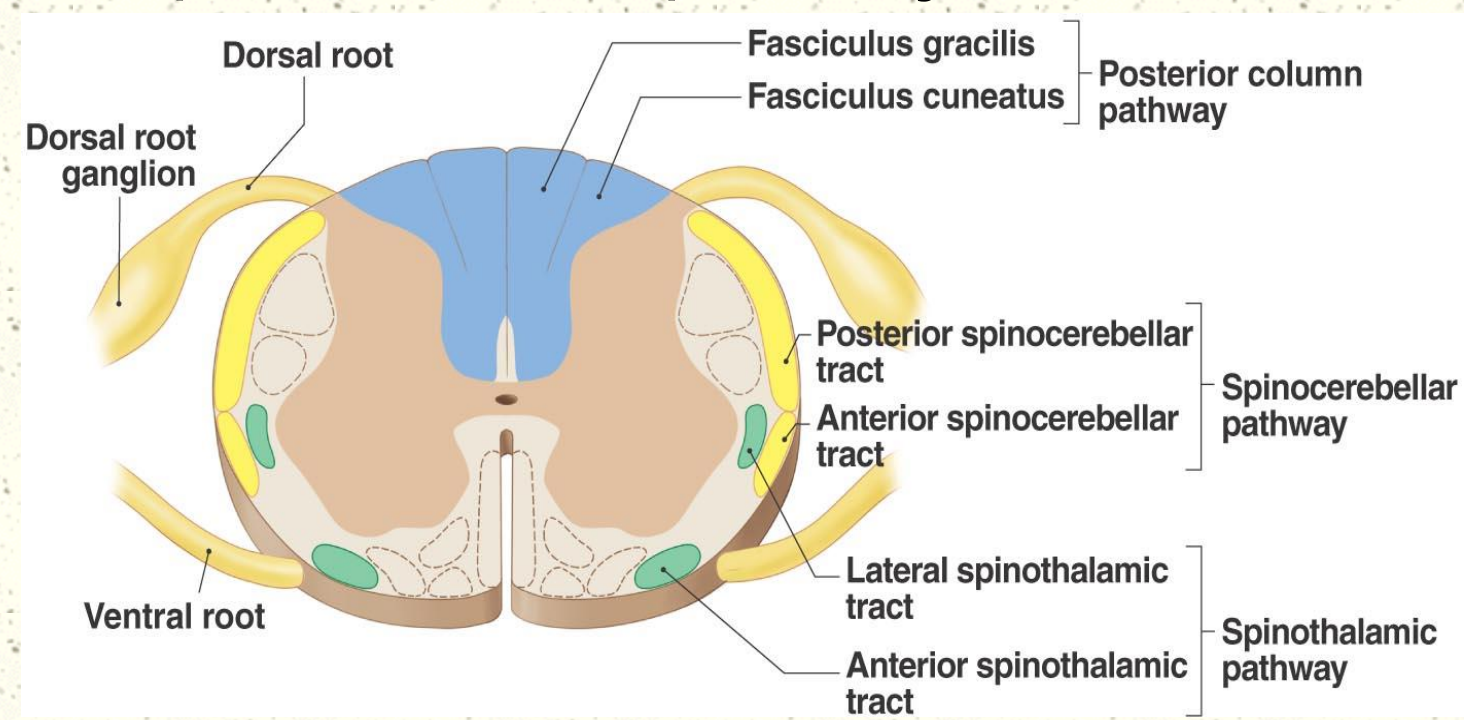
Ascending (Sensory) Pathways and Tracts in the Spinal Cord

Sensory Pathways

- Monitor conditions both inside the body and in the external environment
- Sensation - stimulated receptor passes information to the CNS
  - form of action potentials in an afferent (sensory) fibers
  - processing in the SC can produce a rapid motor response (stretch reflex)
  - processing within the brain stem may result in complex motor activites (positional changes in the eye, head, trunk)
- Most sensory information is processed in the SC, thalamus, or brain stem
  - only ~1% reaches the cerebral cortex and our conscious awareness

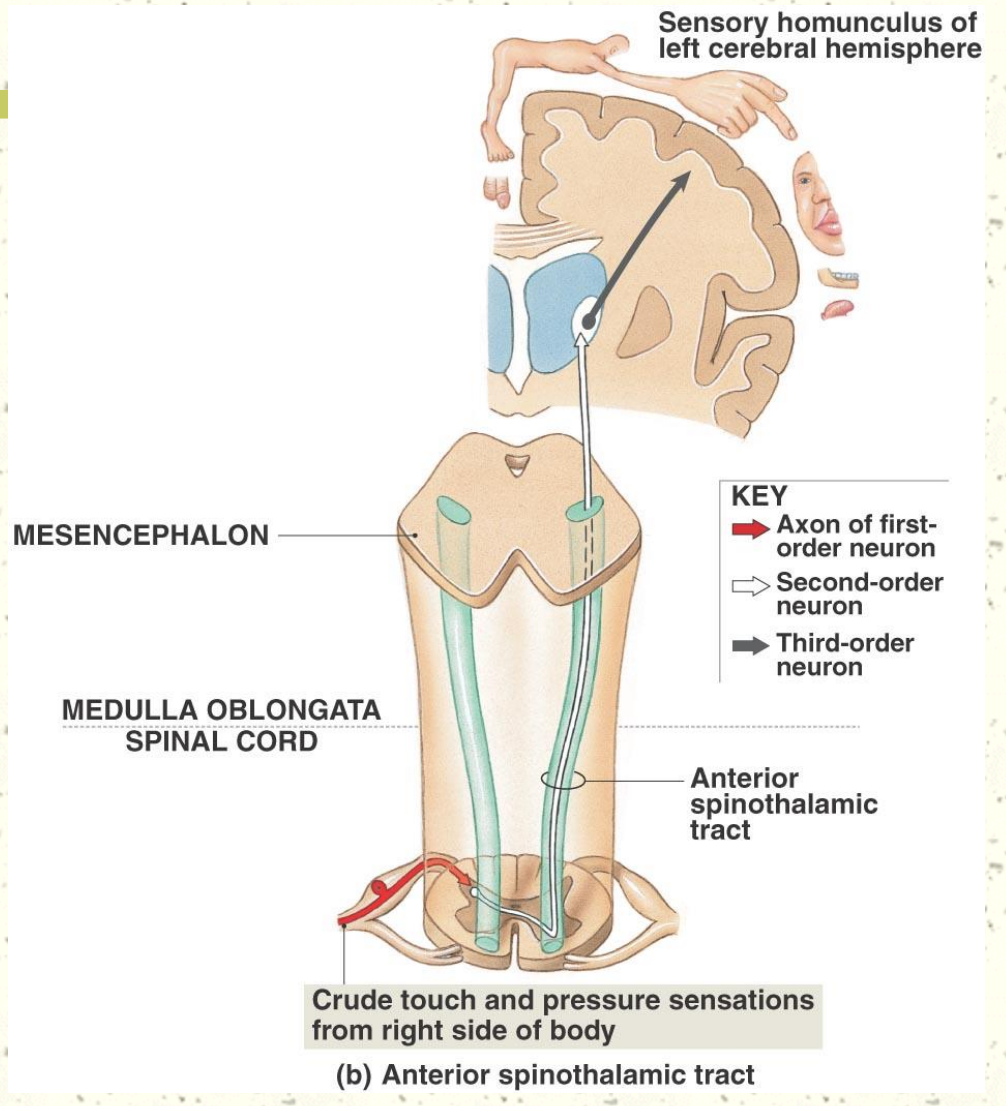
Sensory Pathways

- 3 major somatic sensory pathways:
  1. The posterior column pathway
  2. The spinothalamic pathway
  3. The spinocerebellar pathway



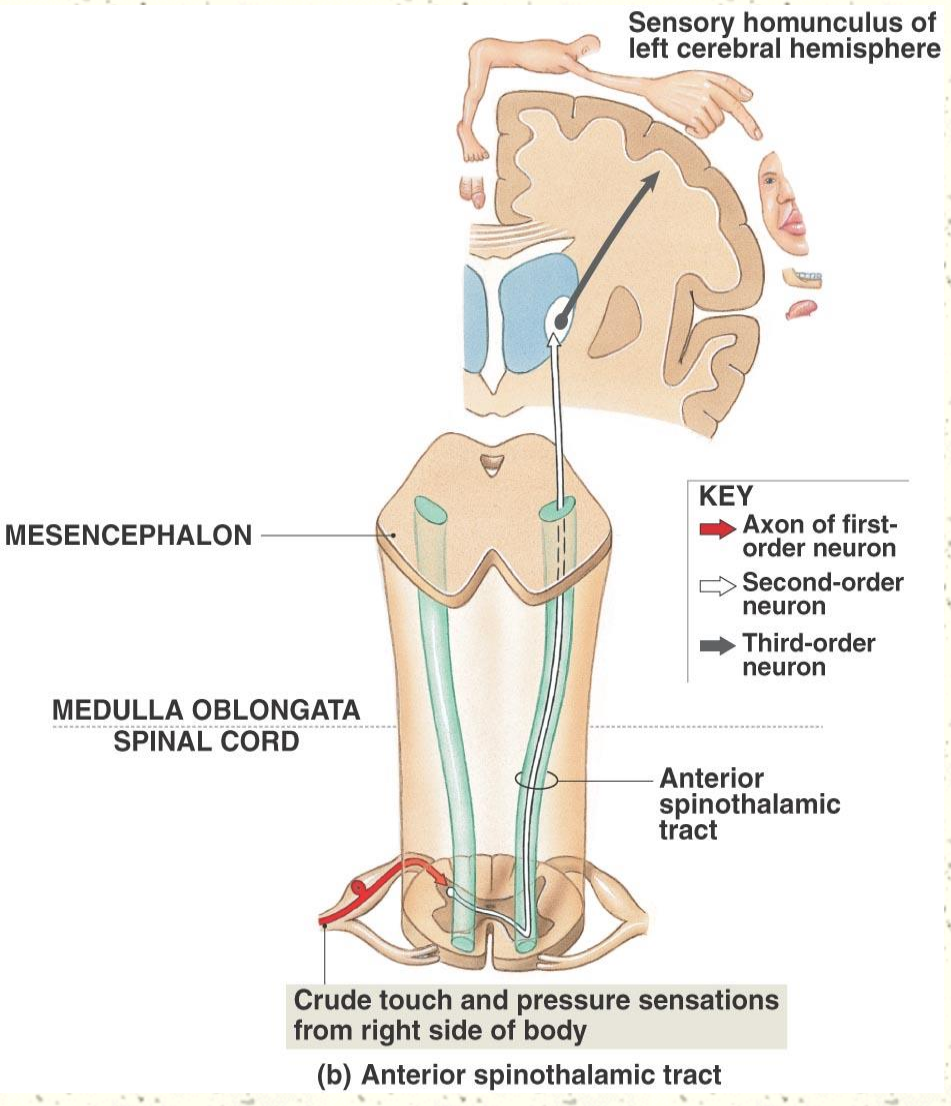
Sensory Pathways

- These pathways involve a chain of neurons:
  - First-order neuron – to the CNS
  - Second-order neuron – an interneuron located in either the spinal cord or the brain stem
  - Third-order neuron – carries information from the thalamus to the cerebral cortex



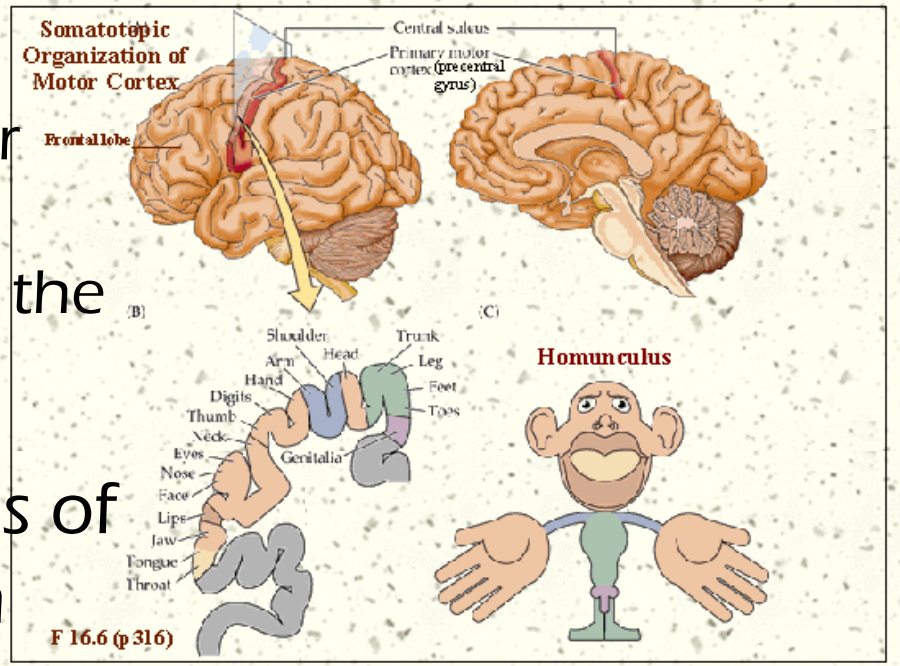
Sensory Pathways

- The axon of the first-order or second-order neuron crosses over (decussation)
- In the posterior column and spinothalamic pathways axons of the third-order ascend within the internal capsule to synapse on neurons of the primary sensory cortex of the cerebrum

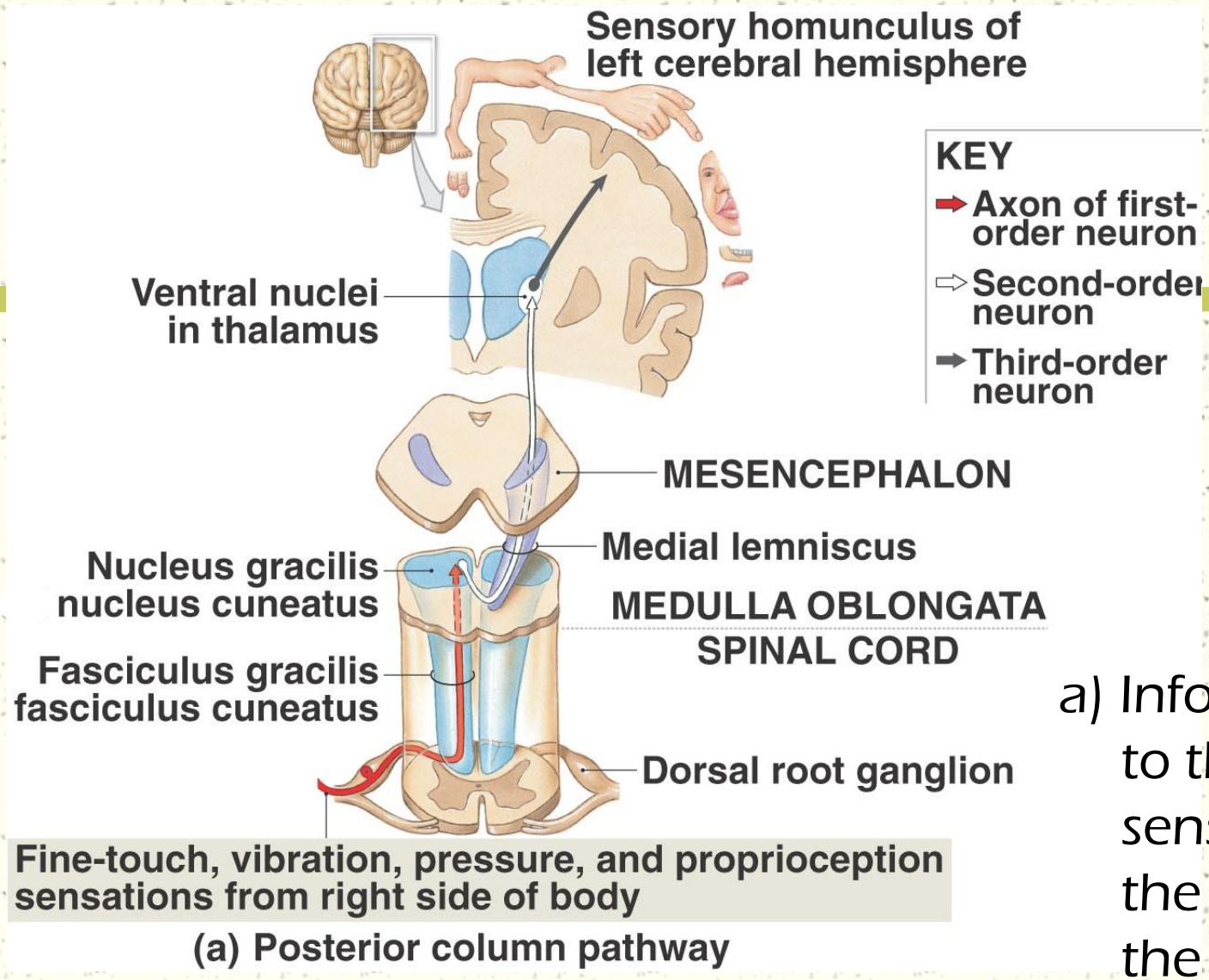


Sensory Homunculus ('little man')

- Functional map of the primary sensory cortex
  - proportions are distorted because the area of sensory cortex devoted to a particular region is proportional to the number of sensory receptors the region contains

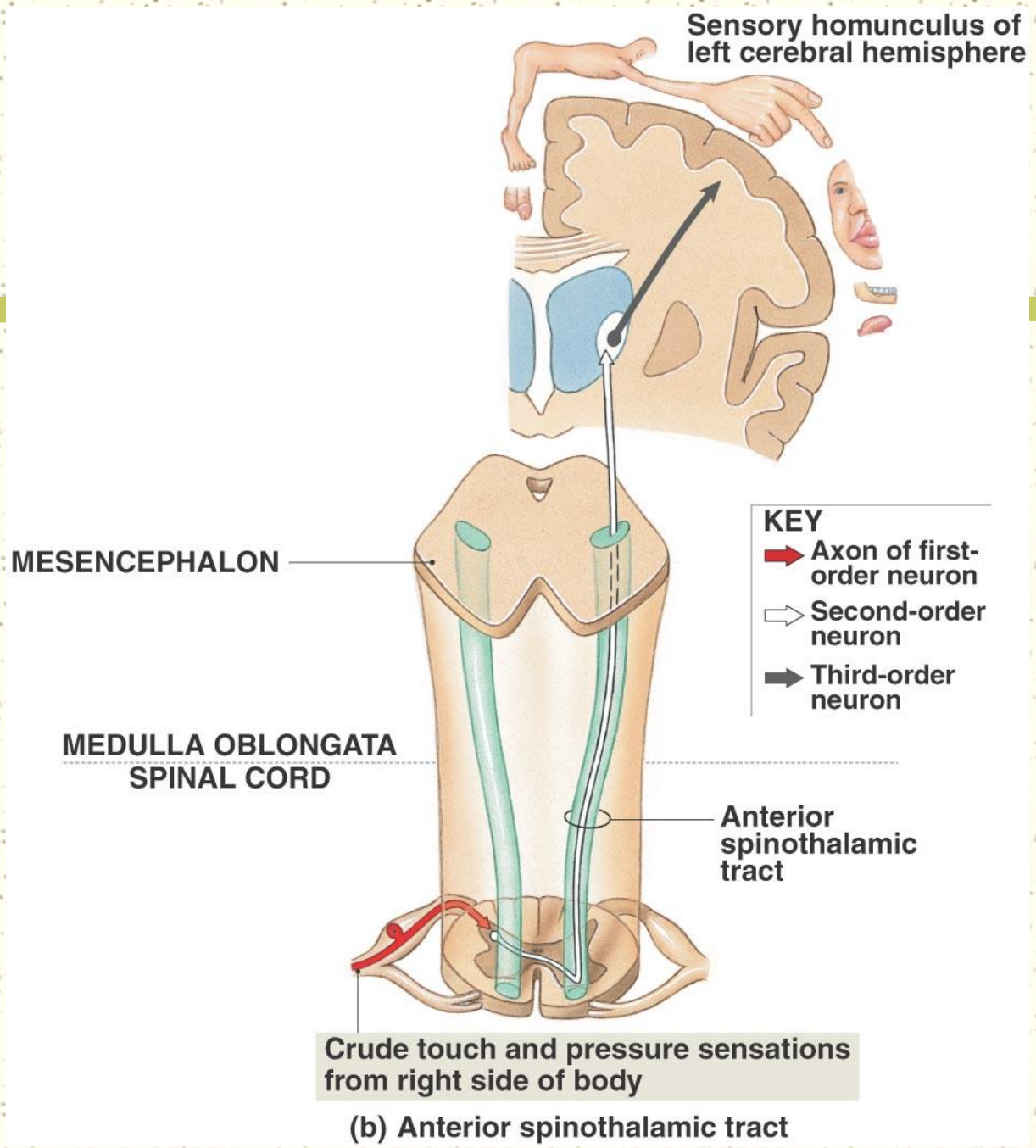


- Example: tongue has 10s of 1000s of taste and touch receptors while the back touch receptors are few and far between



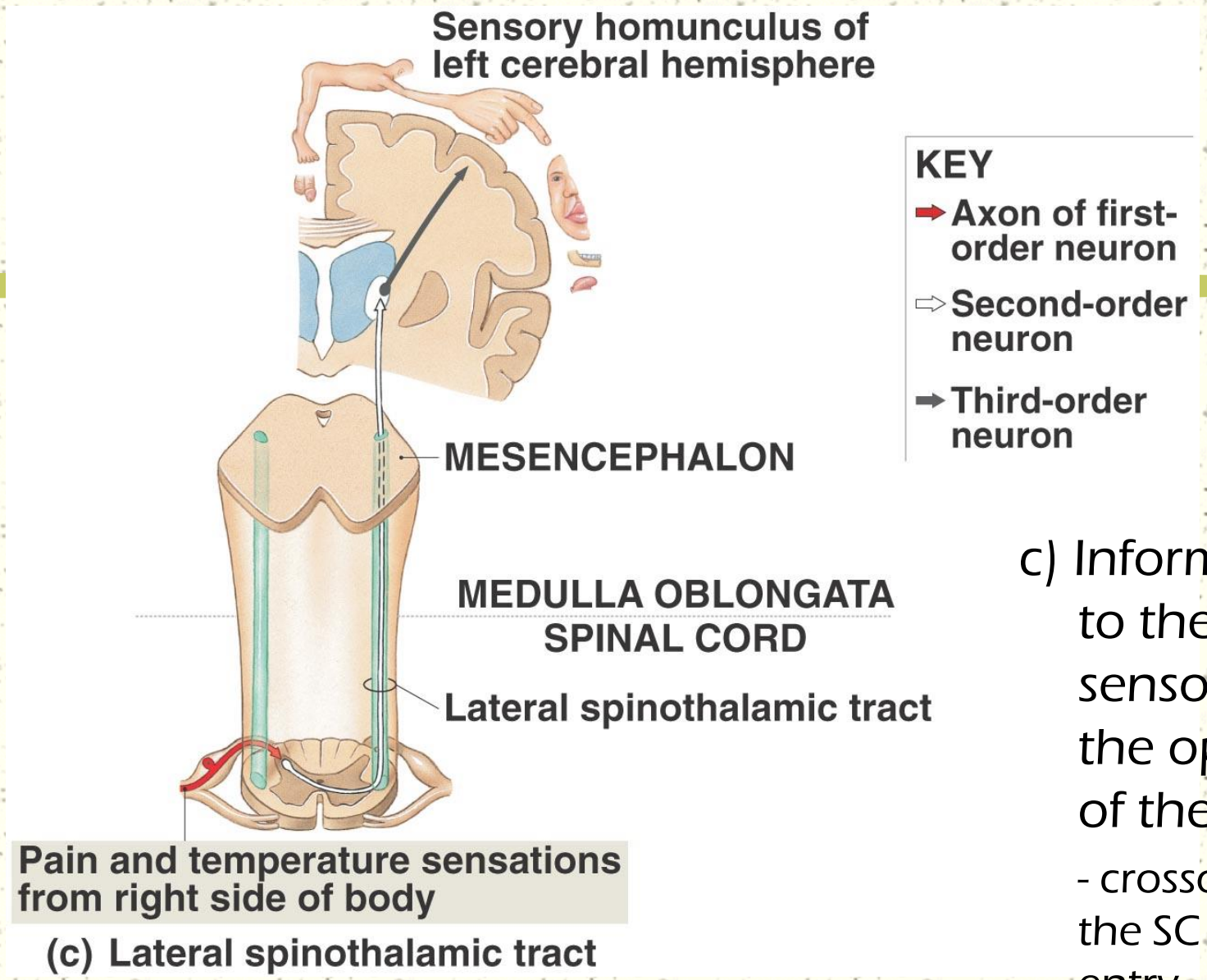
a) Information is sent to the primary sensory cortex on the opposite side of the body

- crossover occurs in the medulla



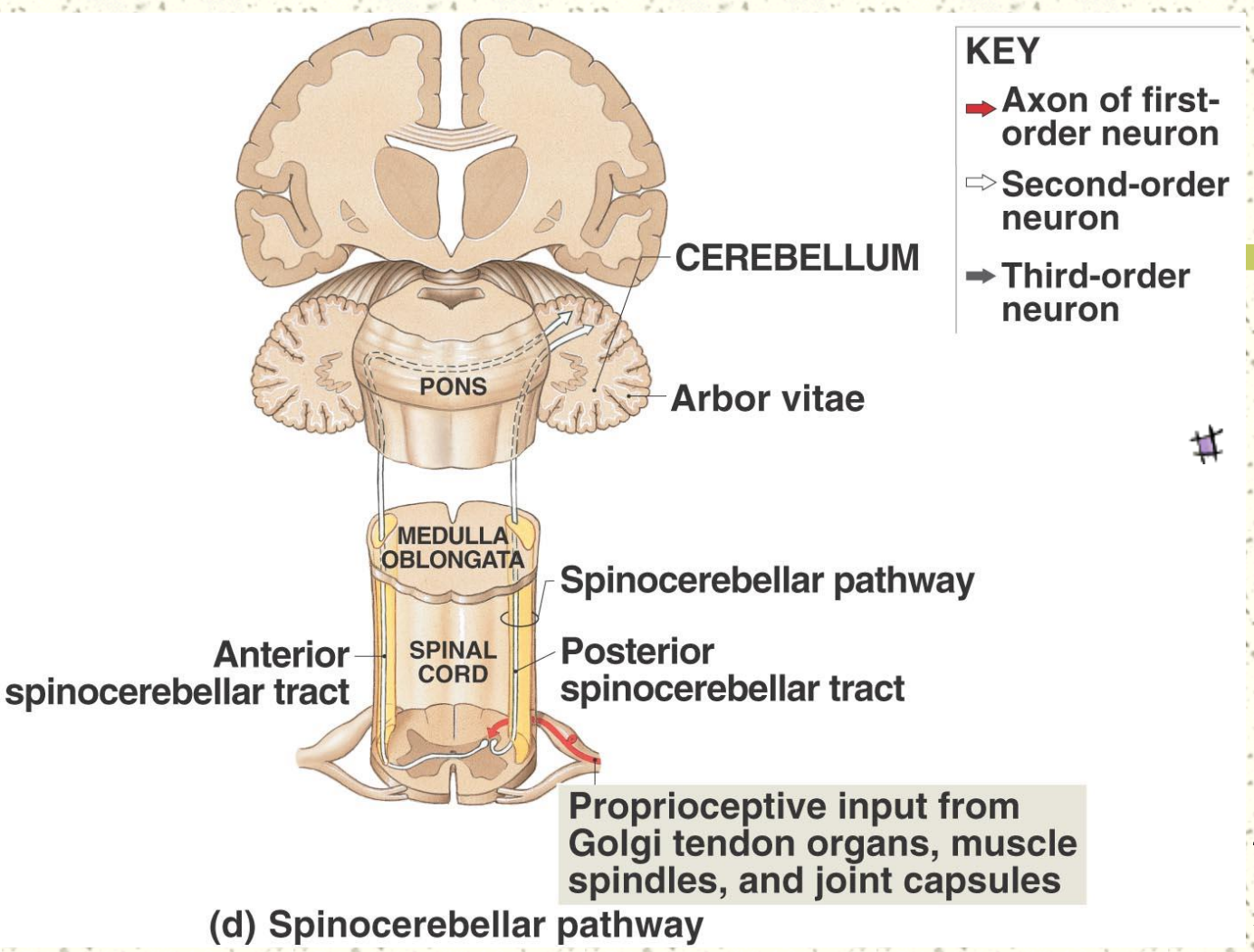
b) Information is sent to the primary sensory cortex on the opposite side of the body

- crossover occurs in the SC at the level of entry



c) Information is sent to the primary sensory cortex on the opposite side of the body

- crossover occurs in the SC at the level of entry



- *d) Information sent to the cerebellum but only the anterior sends it to the opposite side of the body*
  - *cross before entering the tract and after within the cerebellum*

TABLE 16.1 Principal Ascending (Sensory) Pathways and the Sensory Information They Provide

Pathway/Tract	Sensations	Location of Neuron Cell Bodies: First-Order	Second-Order	Third-Order	Final Destination	Site of Crossover
POSTERIOR COLUMN PATHWAY						
Fasciculus gracilis	Proprioception, fine touch, pressure, and vibration from the inferior half of the body	Dorsal root ganglia of lower body; axons enter CNS in dorsal roots and ascend within fasciculus gracilis	Nucleus gracilis of medulla oblongata; axons cross over before entering medial lemniscus	Ventral posterolateral nucleus of thalamus	Primary sensory cortex on side opposite stimulus	Axons of second-order neurons, before joining medial lemniscus
Fasciculus cuneatus	Proprioception, fine touch, pressure, and vibration from the superior half of the body	Dorsal root ganglia of upper body; axons enter CNS in dorsal roots and ascend within fasciculus cuneatus	Nucleus cuneatus of medulla oblongata; axons cross over before entering medial lemniscus	Ventral posterolateral nucleus of thalamus	As above	As above
SPINOTHALAMIC PATHWAY						
Lateral spinothalamic tracts	Pain and temperature sensations	Dorsal root ganglia; axons enter CNS in dorsal roots and enter posterior gray horn	In posterior gray horn; axons enter lateral spinothalamic tract	Ventral posterolateral nucleus of thalamus	Primary sensory cortex on side opposite stimulus	Axons of second-order neurons, at level of entry
Anterior spinothalamic tracts	Crude touch and pressure sensations	As above	In posterior gray horn; axons enter anterior spinothalamic tract on opposite side	As above	As above	As above
SPINOCEREBELLAR PATHWAY						
Posterior spinocerebellar tracts	Proprioception	Dorsal root ganglia; axons enter CNS in dorsal roots	In posterior gray horn; axons enter posterior spinocerebellar tract on same side	Not present	Cerebellar cortex on side of stimulus	None
Anterior spinocerebellar tracts	Proprioception	As above	In same spinal segment; axons enter anterior spinocerebellar tract on same or opposite side	Not present	Cerebellar cortex, primarily on side of stimulus	Axons of most second-order neurons cross before entering tract and then cross again within cerebellum

Motor Pathways

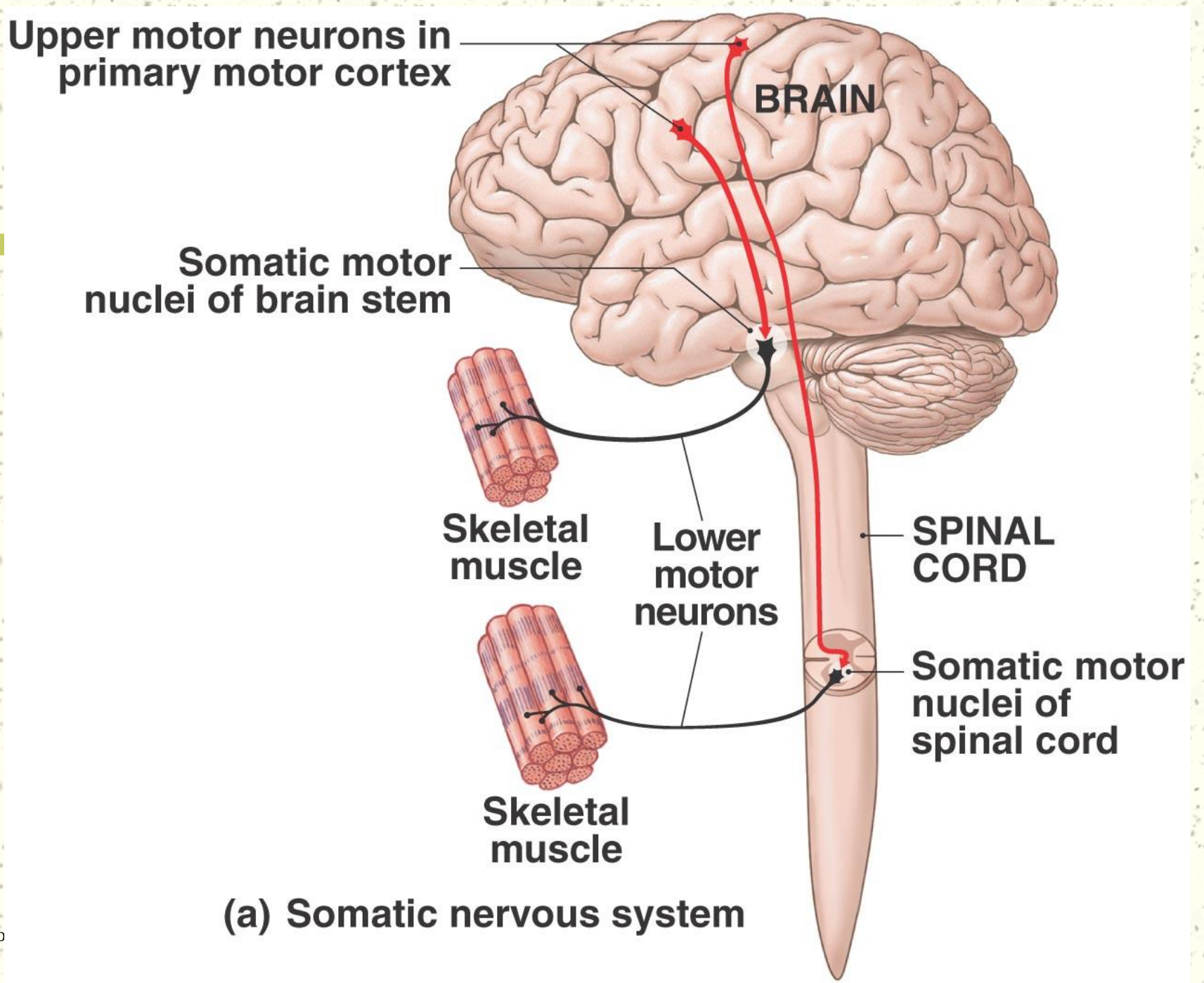
- CNS issues motor commands in response to information provided by sensory systems
  - sent by the somatic nervous system (SNS) and the autonomic nervous system (ANS)
- SNS – skeletal muscle contraction
- ANS – innervates visceral effectors (smooth muscle, cardiac muscle, and glands)
- Conscious and subconscious motor commands control skeletal muscles by traveling over 3 integrated motor pathways

Motor Pathways

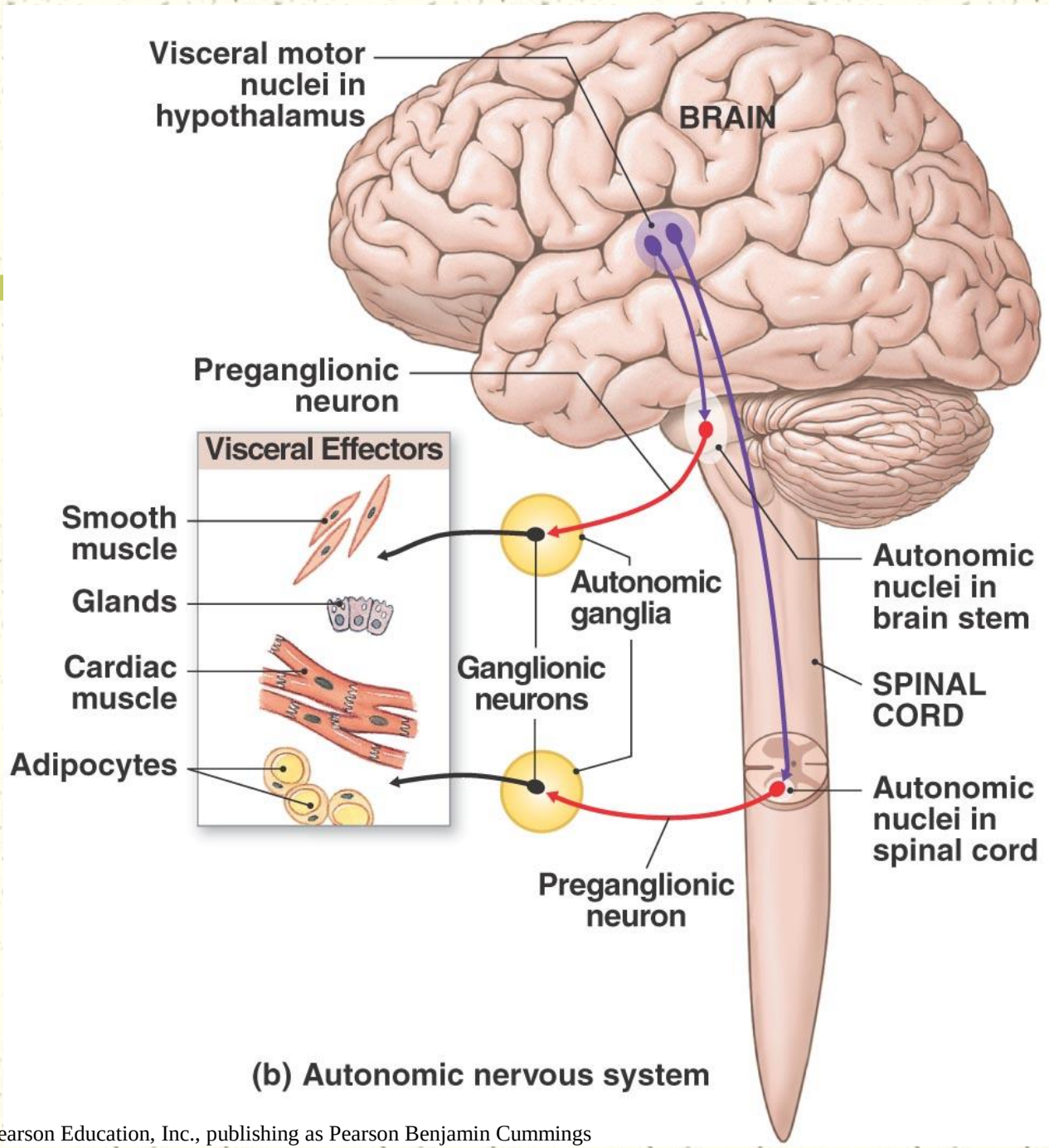
- The corticospinal pathway – voluntary control
  - the corticobulbar tracts
  - the corticospinal tracts
- The medial and lateral pathways – modify or direct skeletal muscle contractions by stimulating, facilitating, or inhibiting lower motor neurons
- Motor pathways usually contain 2 neurons

Motor Pathways

- Somatic nervous system (SNS)
  - upper motor neuron – cell body lies within the CNS
  - lower motor neuron – located in a motor nucleus of the brain stem or SC only axon extends to the effector
- Autonomic nervous system (ANS)
  - preganglionic neuron
  - ganglionic neuron


Upper motor neurons in primary motor cortex
BRAIN
Somatic motor nuclei of brain stem
Skeletal muscle
Lower motor neurons
SPINAL CORD
Somatic motor nuclei of spinal cord
Skeletal muscle
(a) Somatic nervous system

Atrophy of the right side of the tongue in a golden retriever
due to a meningioma that affected the right hypoglossal nerve roots.
(From De Lahunta A, Glass E: *Veterinary neuroanatomy and clinical neurology*, ed 3, Philadelphia, 2009, Saunders.)



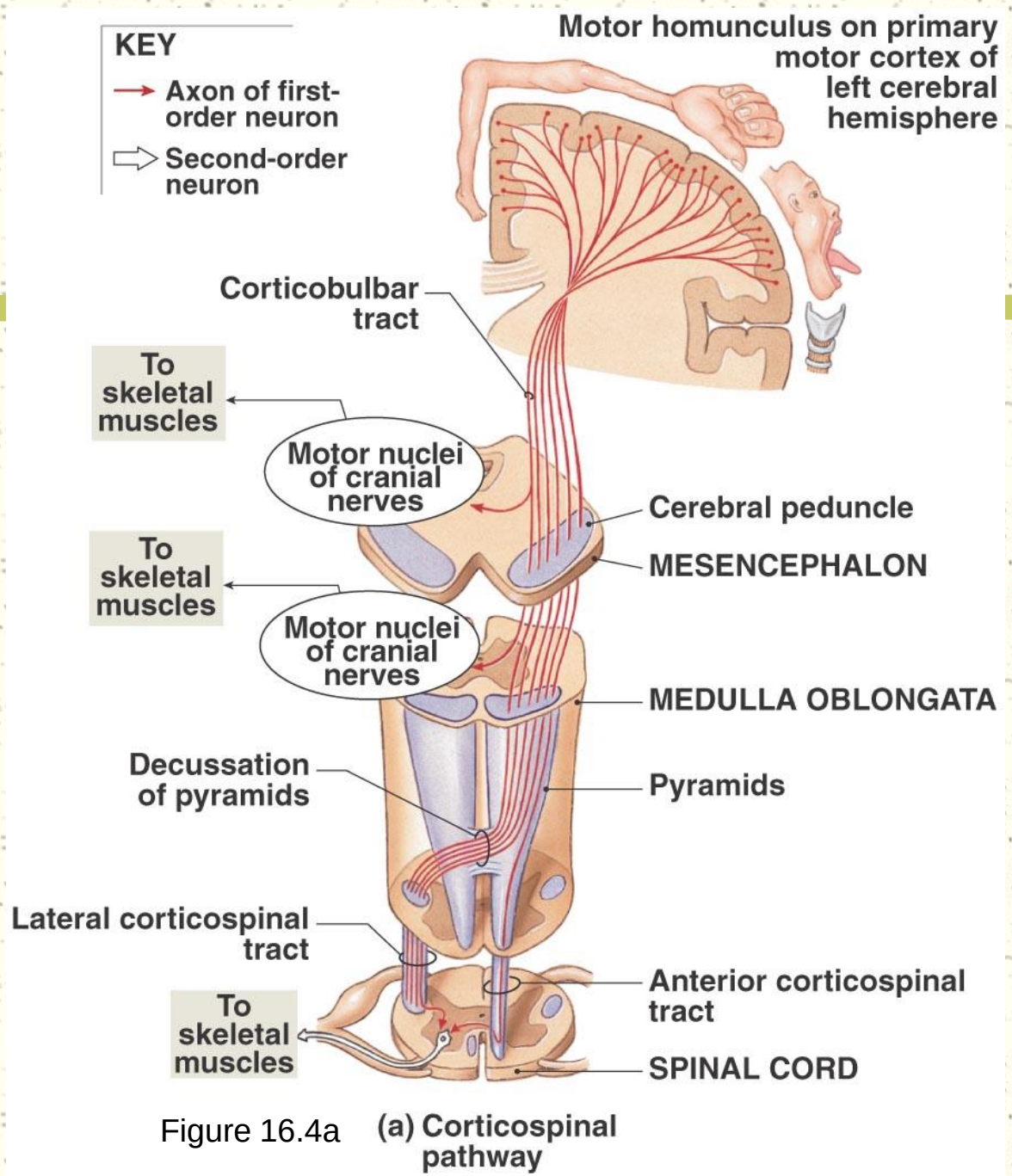


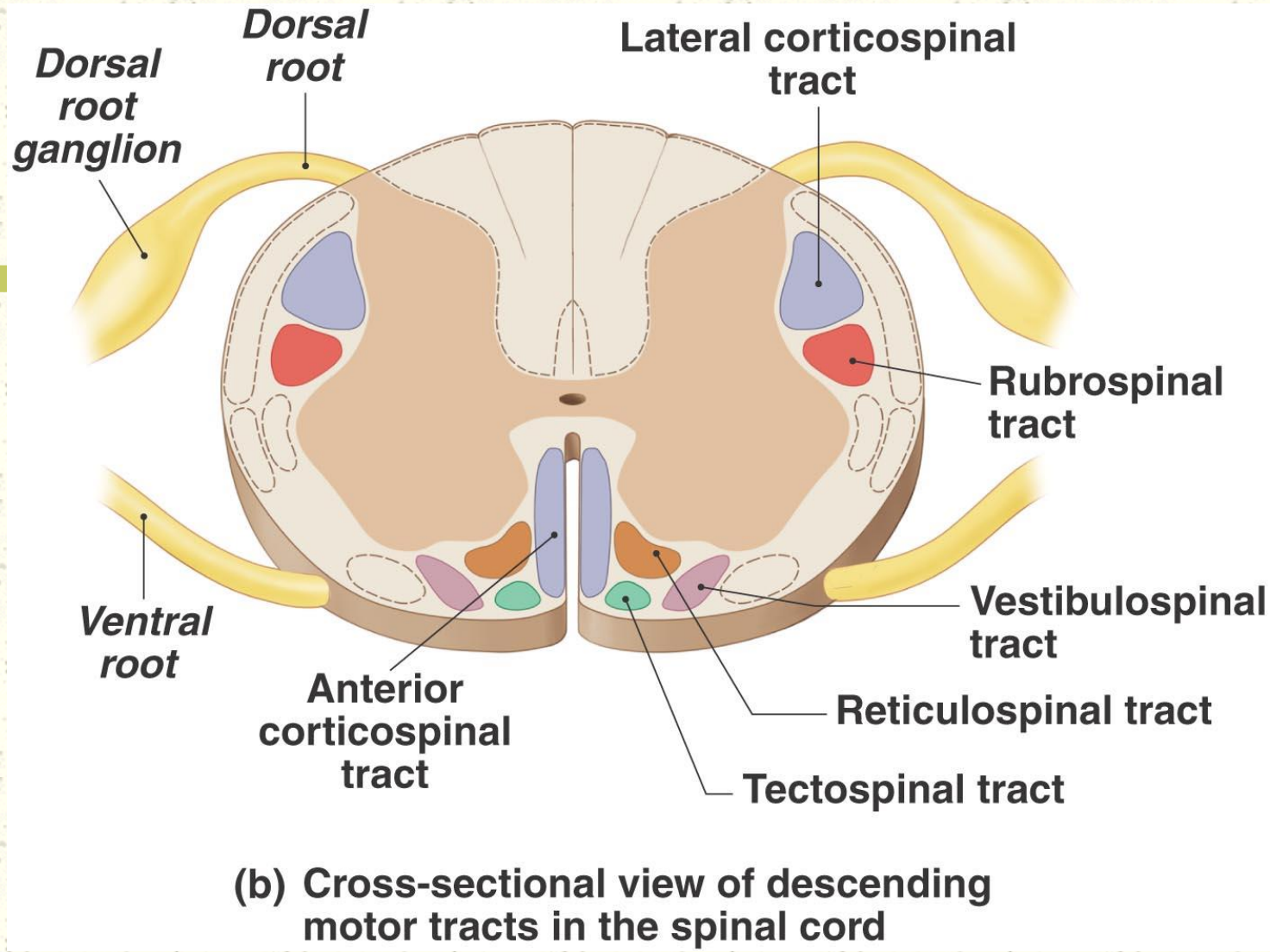
Figure 16.4a (a) Corticospinal pathway

a) Originates at the primary motor cortex

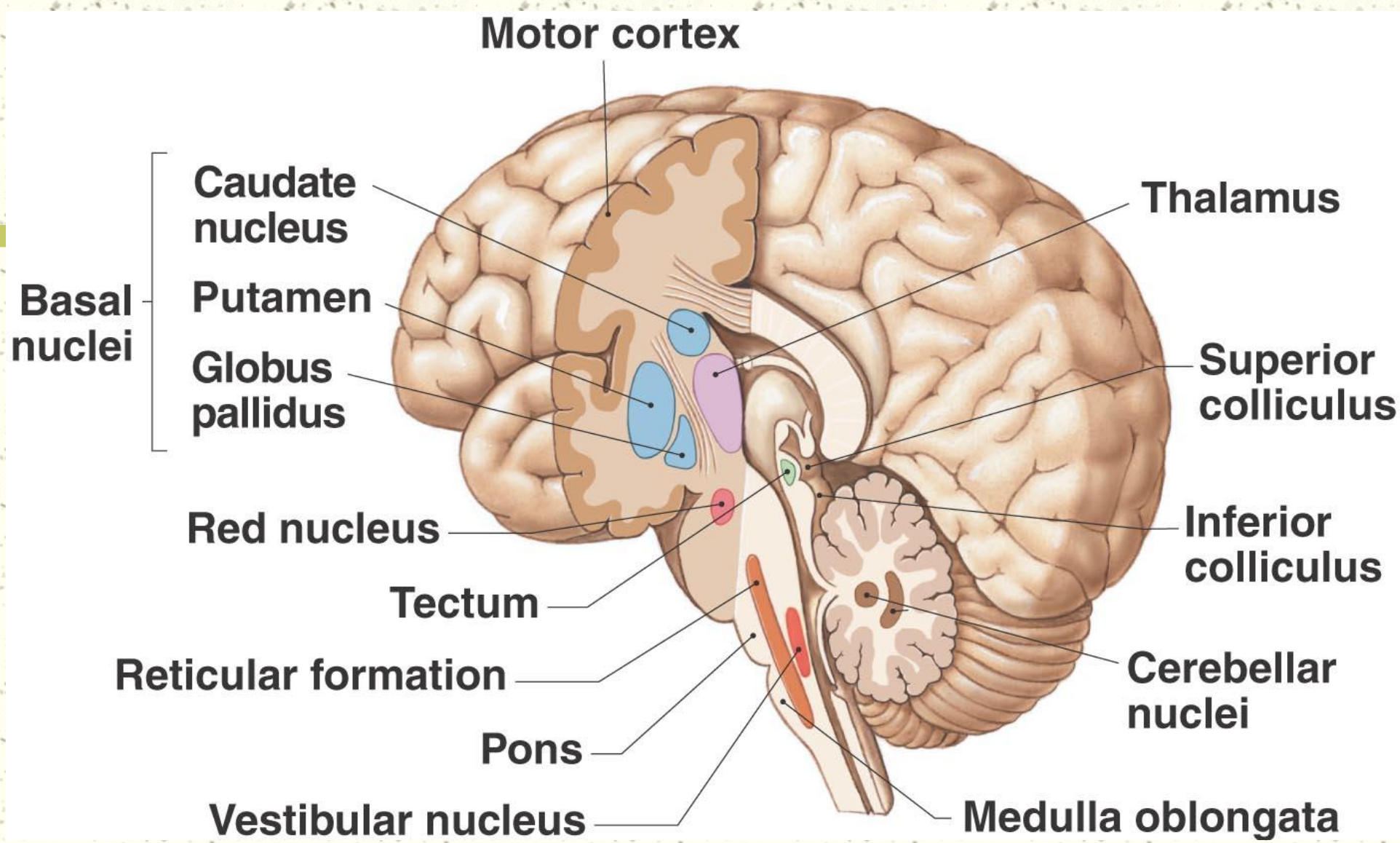
– corticobulbar tracts end at the motor nuclei of CNs on the opposite side of the brain

- most fibers crossover in the medulla and enter the lateral corticospinal tracts

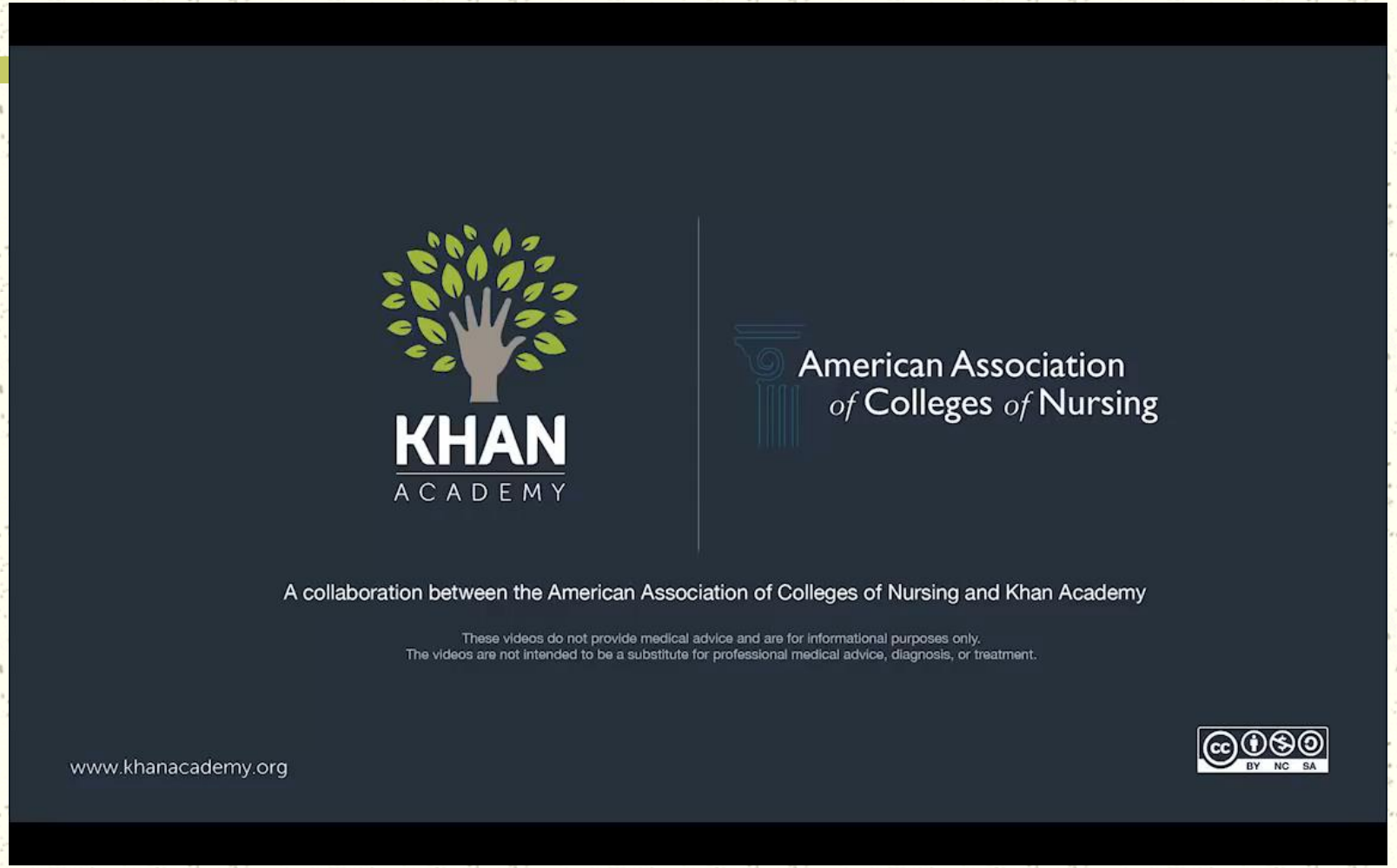
- rest descend in the anterior corticospinal tracts and crossover after reaching target segment in the SC



Locations of major descending motor tracts that contain axons of upper motor neurons



Basal Ganglia – The Direct pathway



Basal Ganglia – The Indirect pathway

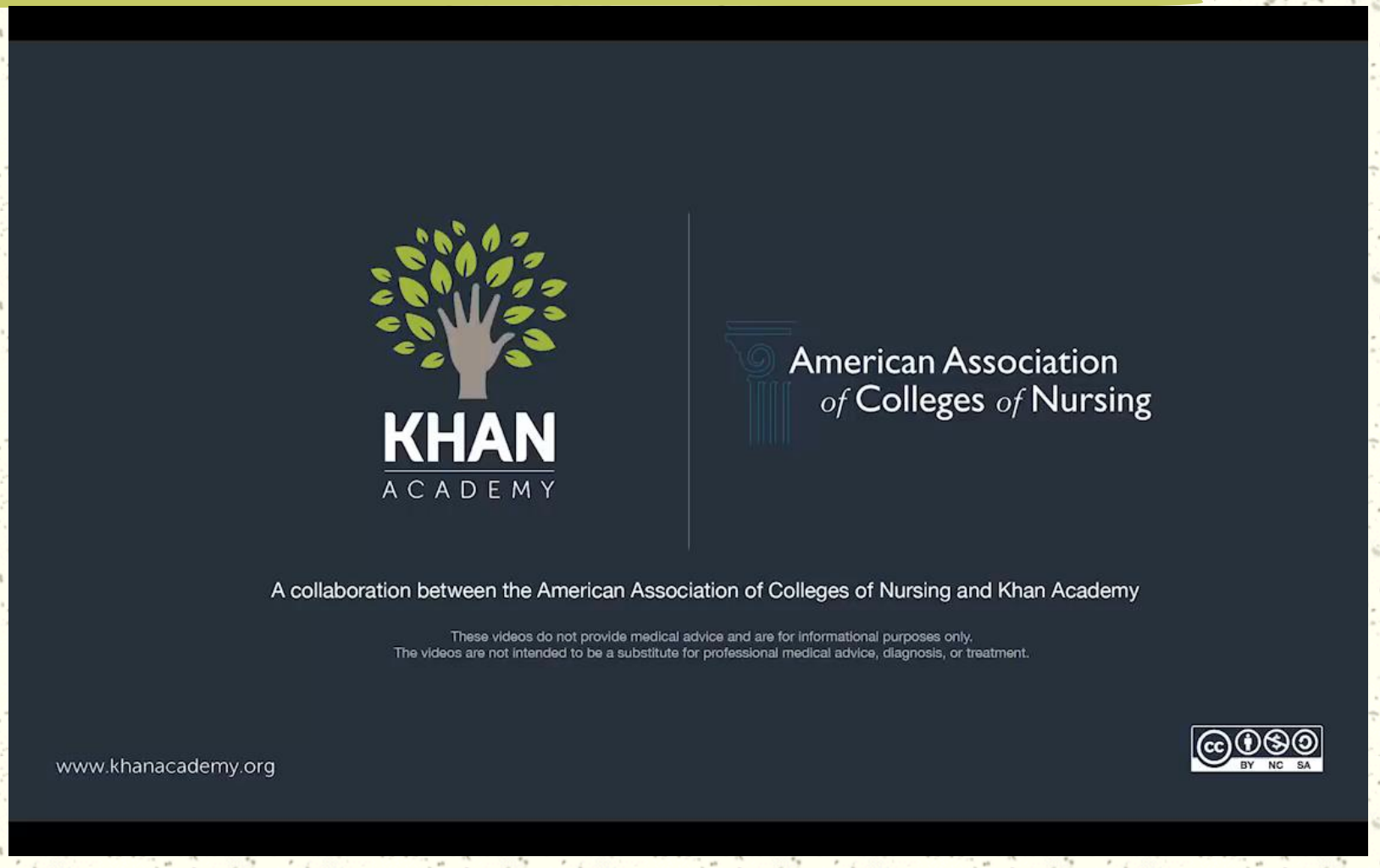
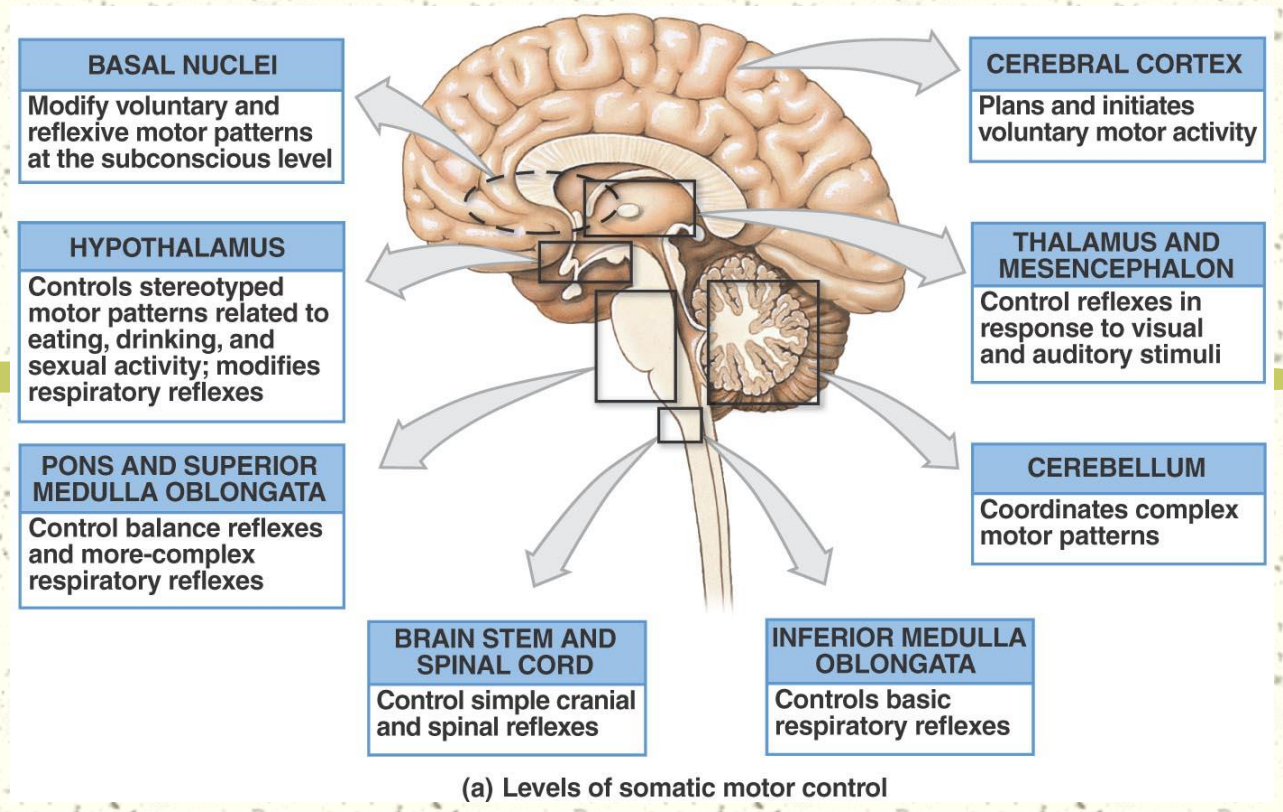
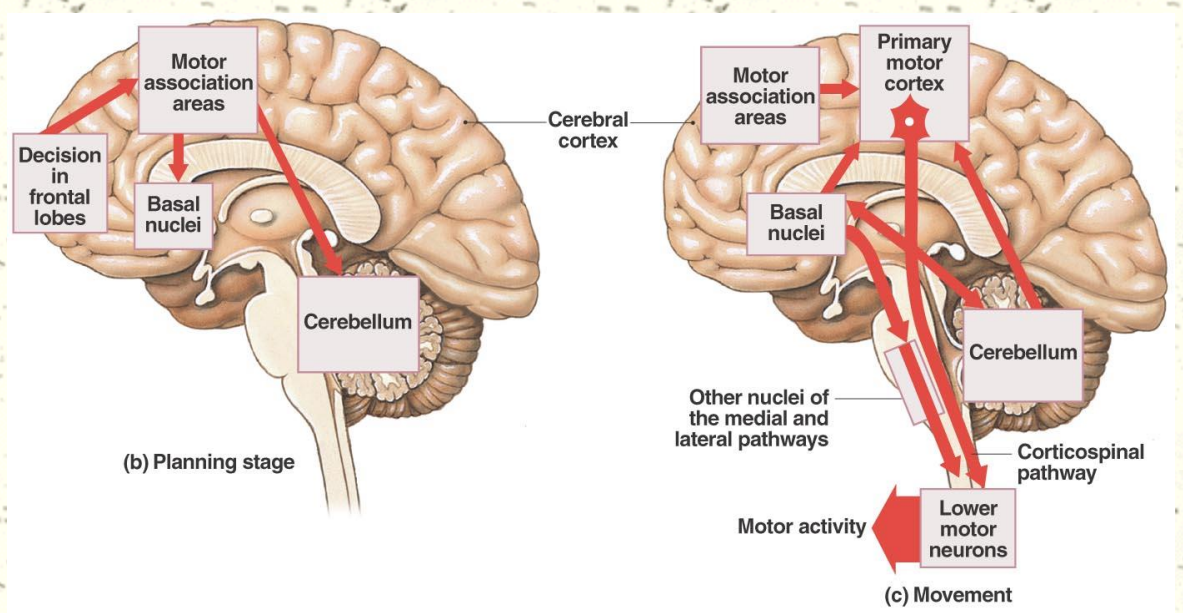


TABLE 16.2 Principal Descending (Motor) Pathways and the General Functions of the Associated Nuclei in the Brain

Pathway/Tract	Location of Upper Motor Neuron	Destination	Site of Crossover	Action
CORTICOSPINAL PATHWAY				
Corticobulbar tracts	Primary motor cortex (cerebral hemisphere)	Lower motor neurons of cranial nerve nuclei in brain stem	Brain stem	Conscious motor control of skeletal muscles
Lateral corticospinal tracts	As above	Lower motor neurons of anterior gray horns of spinal cord	Pyramids of medulla oblongata	As above
Anterior corticospinal tracts	As above	As above	Level of lower motor neuron	As above
MEDIAL PATHWAY				
Vestibulospinal tracts	Vestibular nucleus (at border of pons and medulla oblongata)	As above	None (uncrossed)	Subconscious regulation of balance and muscle tone
Tectospinal tracts	Tectum (mesencephalon: superior and inferior colliculi)	Lower motor neurons of anterior gray horns (cervical spinal cord only)	Brain stem (mesencephalon)	Subconscious regulation of eye, head, neck, and upper limb position in response to visual and auditory stimuli
Reticulospinal tracts	Reticular formation (network of nuclei in brain stem)	Lower motor neurons of anterior gray horns of spinal cord	None (uncrossed)	Subconscious regulation of reflex activity
LATERAL PATHWAY				
Rubrospinal tracts	Red nuclei of mesencephalon	As above	Brain stem (mesencephalon)	Subconscious regulation of upper limb muscle tone and movement



(a) Levels of somatic motor control



Higher-Order Functions

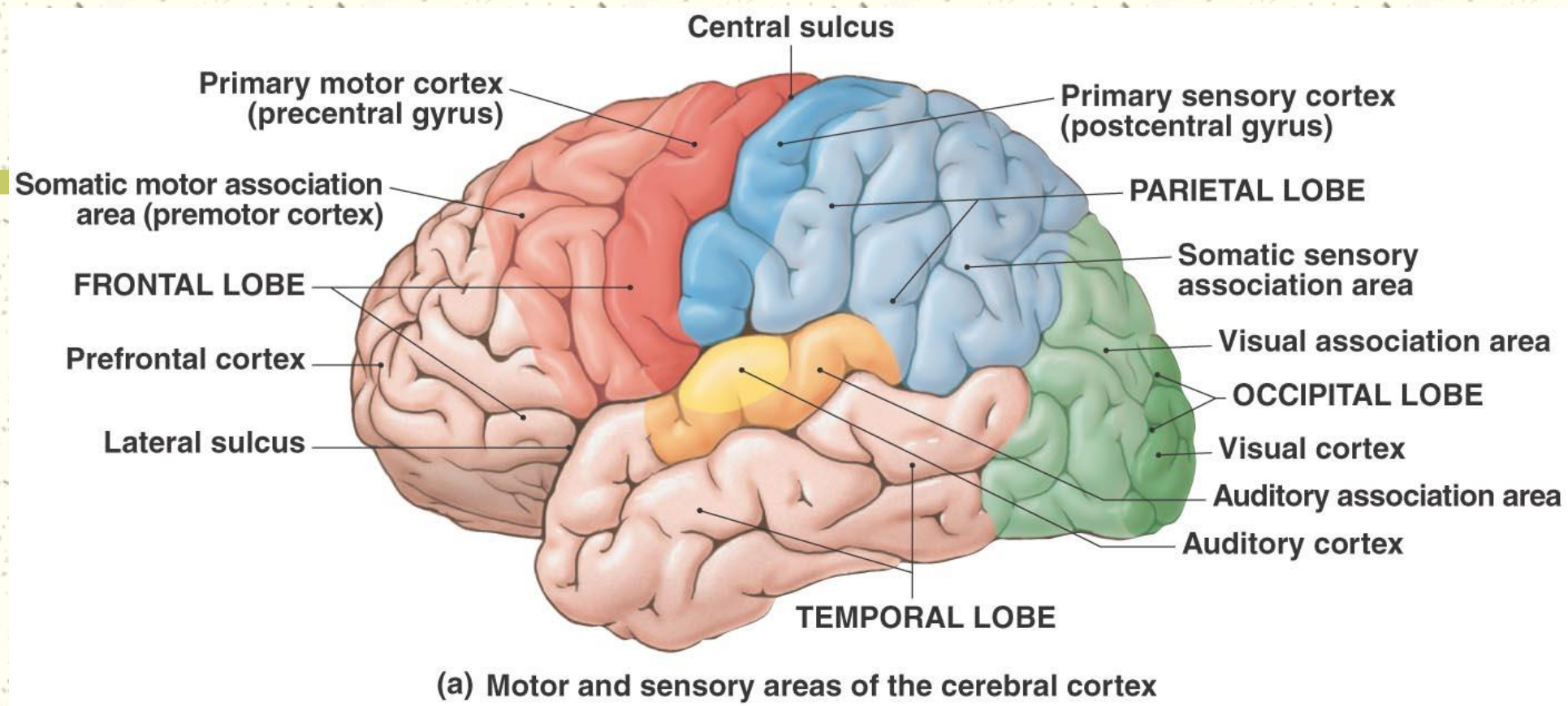
- Characteristics:

  - They are performed by the cerebral cortex

  - They involve complex interconnections and communication between areas within the cerebral cortex and between the cerebral cortex and other areas of the brain

  - They involve both conscious and unconscious information processing

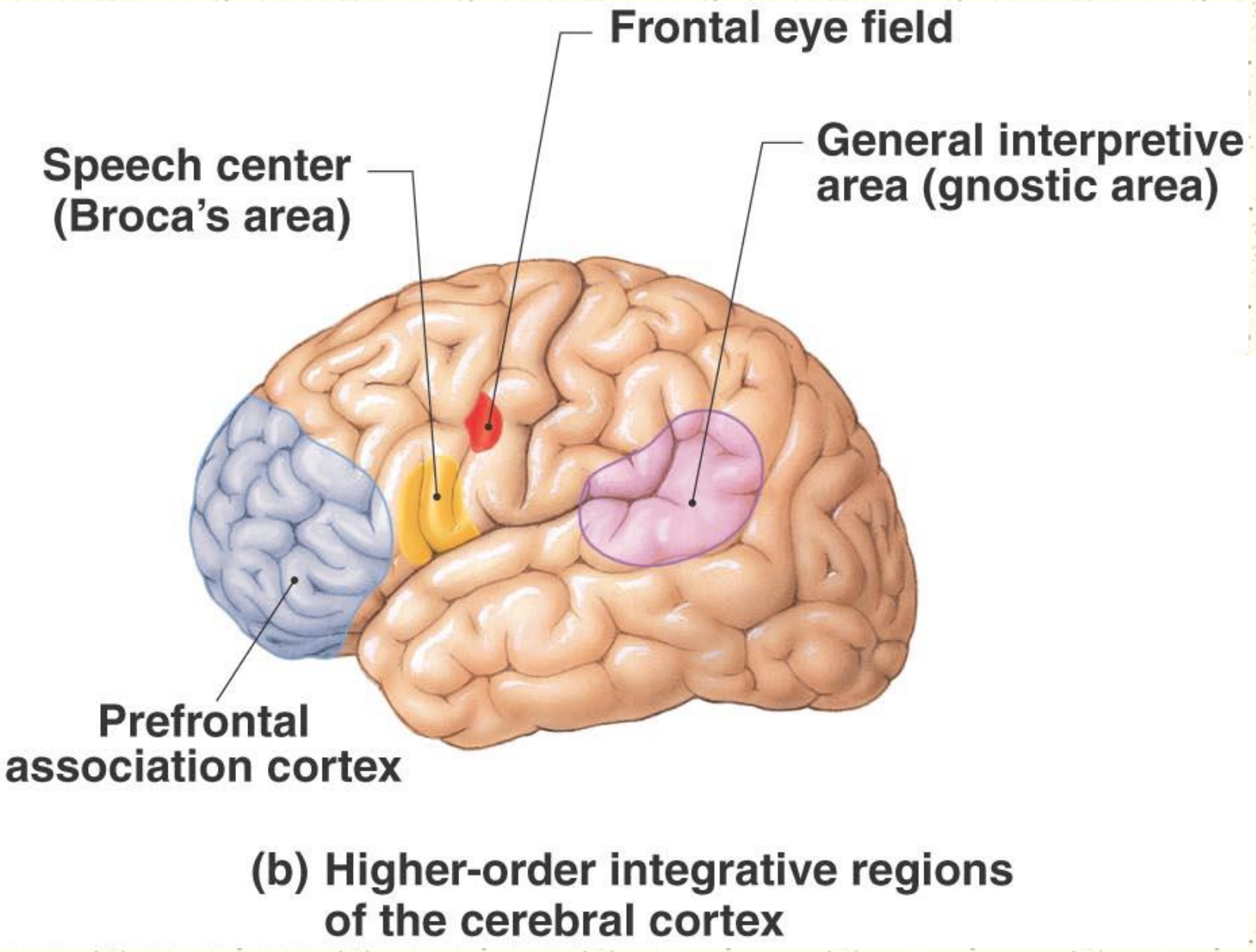
  - They are not part of the programmed 'wiring' of the brains; therefore, the functions are subject to modification and adjustment over time (learning)



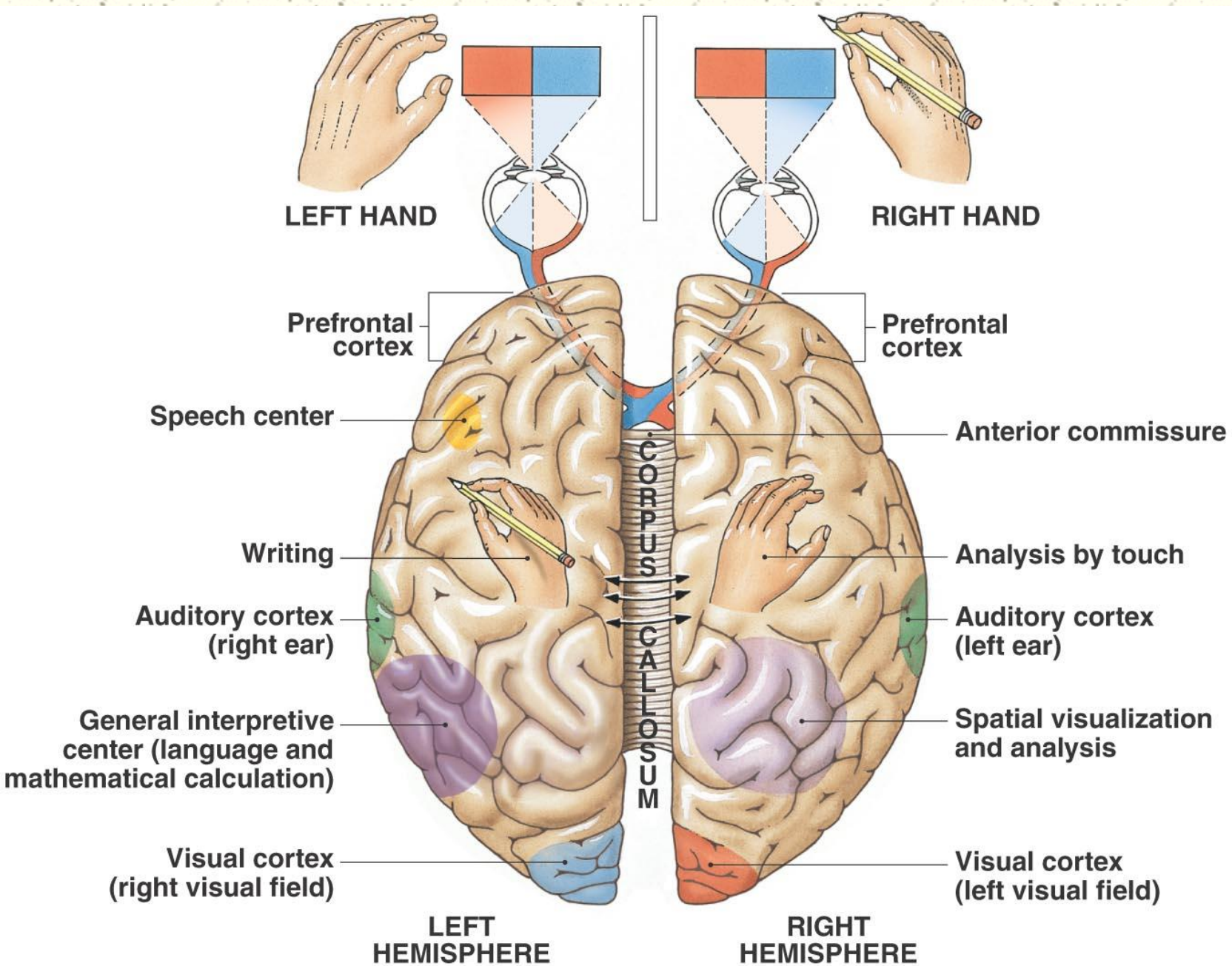
Functional Areas of the Cerebral Cortex

Integrative Regions of the Cerebral Cortex

- Cortical areas that act as centers for complex sensory stimuli and motor responses
  - general interpretive area receives information from all sensory association areas
  - only present in one hemisphere, usually the left
- Speech center – regulates patterns of breathing and vocalization
- Prefrontal cortex – coordinates information from the secondary and special association areas of the cortex
  - performs abstract intellectual functions

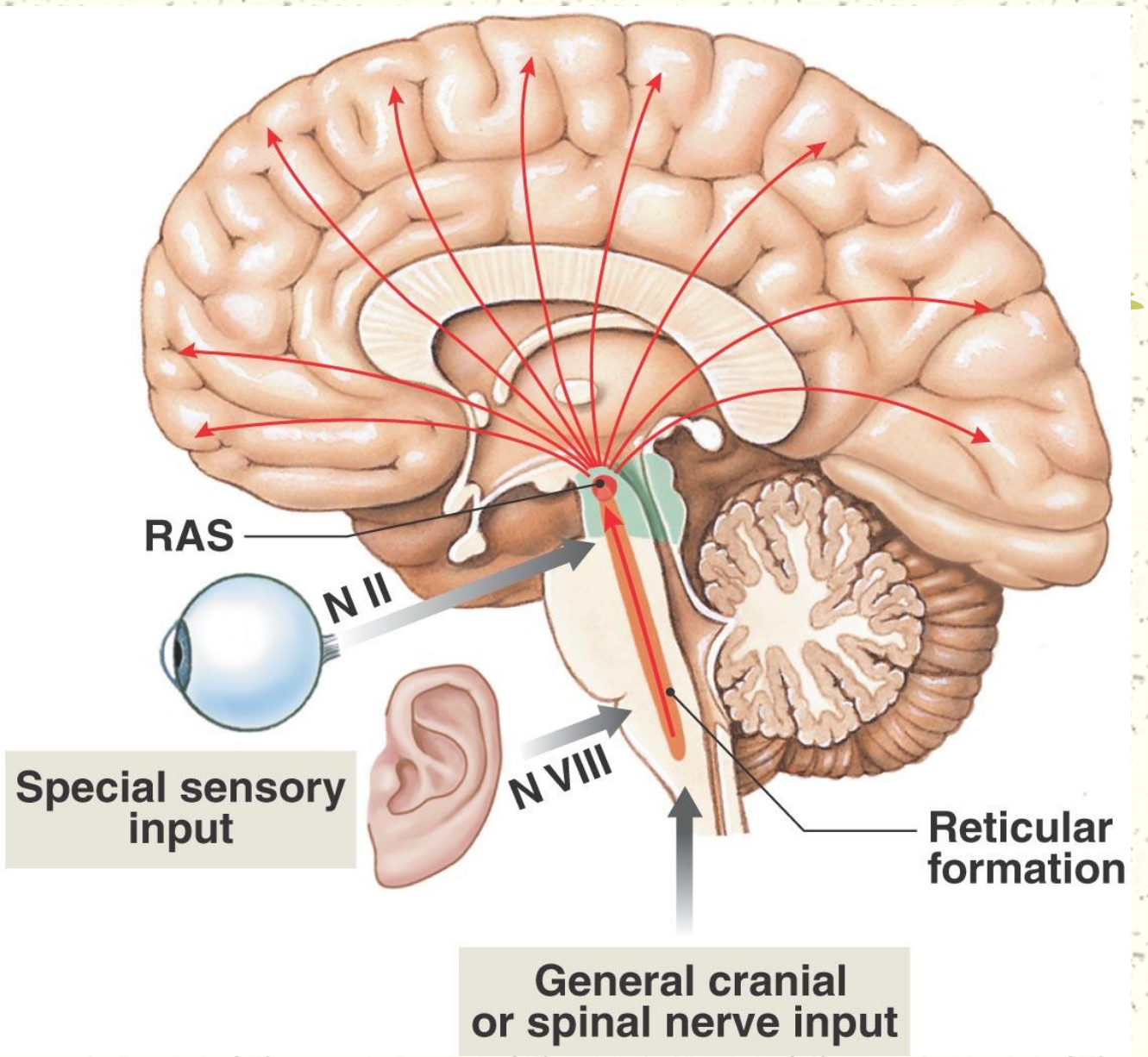


(b) Higher-order integrative regions of the cerebral cortex



Memory

- Process of accessing stored bits of information acquired through experience
- Short-term memories last seconds to hours
- Long-term memories can last for years and are stored in the cerebral cortex
- Memory consolidation – conversion from a short-term memory to a long-term memory
- The amygdaloid body and the hippocampus (limbic system) are essential to memory consolidation



The Reticular Activating System

TABLE 16.3 States of Awareness

Level or State	Description
CONSCIOUS STATES	
Delirium	Disorientation, restlessness, confusion, hallucinations, agitation, alternating with other conscious states; develops quickly
Dementia	Progressive decline in spatial orientation, memory, behavior, and language
Confusion	Reduced awareness, easily distracted, easily startled by sensory stimuli, alternates between drowsiness and excitability; resembles minor form of delirium state
Normal consciousness	Aware of self and external environment, well-oriented, responsive
Somnolence	Extreme drowsiness, but will respond normally to stimuli
Chronic vegetative state	Conscious but unresponsive, no evidence of cortical function
UNCONSCIOUS STATES	
Asleep	Can be aroused by normal stimuli (light touch, sound, etc.)
Stupor	Can be aroused by extreme and/or repeated stimuli
Coma	Cannot be aroused and does not respond to stimuli (coma states can be further subdivided according to the effect on reflex responses to stimuli)

Aging and the Nervous System

- Common, age-related anatomical changes in the NS include the following:
  - a reduction in brain size and weight
  - a reduction in the number of neurons
  - a decrease in blood flow to the brain
  - changes in synaptic organization of the brain
  - intracellular and extracellular changes in CNS neurons

Any Questions ?

Injuries and Diseases of the Nervous System

- Cerebral Concussion
- Paralysis
- Cerebral Palsy
- Cerebrovascular Accident (stroke)
- Aneurysm
- Parkinson's Disease
- Multiple Sclerosis (MS)

Cerebral Concussion

- Despite its considerable protection, the brain is subject to traumatic injury, often with serious consequences.
  - A concussion literally means an agitation or shaking of the brain by either a direct or indirect blow.
  - A concussion is characterized by immediate and transient impairment of neural functions such as alteration of consciousness, disturbance of vision, and equilibrium.

Cerebral Concussion

- Concussions are classified by degree of severity – 1st,2nd,3rd. These distinctions are important for treatment and prognosis.
- Variation in the classification of concussion is common.
  - 1st degree concussion experience no loss of consciousness, possible memory loss, possible dizziness and tinnitus (ringing in the ears), no loss of coordination, and relatively rapid recovery.

Cerebral Concussion

- 2nd degree concussions have momentary loss (10 sec. to 5 min.) of consciousness, transient confusion and mild retrograde amnesia (amnesia for the events prior to the injury), moderate dizziness and tinnitus, slight loss of coordination and varied recovery time.
- 3rd degree concussion experiences a prolonged loss consciousness, severe memory loss , severe dizziness and tinnitus, marked loss of coordination and a prolonged recovery time.

Cerebral Concussion

- Coma and death can also result from a serious concussion.
- After a concussion, the athlete should not be allowed to return to competition that day. In fact, before resuming training, a head-injured athlete must be free of headaches for 24 hours. Athletes who experience a loss of consciousness for any period of time require evaluation and monitoring by a physician.

Cerebral Concussion

- The athlete who sustains repeated concussions requires special evaluation before returning to a sport with the potential for further brain injury. Most team physicians follow the "1-2-3" rule: one concussion= the athlete is out of the game, two concussion= out for the season, three concussions= the athlete should no longer play.

Paralysis

- The inability to voluntarily move a muscle or limb.
- Paralysis can be caused by damage to a sensory nerve that results in a lack of sensation in the area which that nerve innervates.
- Paralysis can also result from damage to the spinal cord or motor nerve.

Paralysis

- The higher the spinal cord is damaged, the greater the extent of paralysis.
  - Paraplegia – paralysis of both lower extremities.
  - Quadriplegia – paralysis of both upper and lower extremities.

Cerebral Palsy

- A disorder of movement and posture caused by an irreparable lesion of the CNS.
- Developmental defects of motor areas of the brain because of trauma at birth.
- Individuals with cerebral palsy may have musculoskeletal problems, mental retardation, speech and hearing difficulties, eye problems, and seizures.
- There is a great deal of variation among individuals with cerebral palsy – some are particularly bright; others have less musculoskeletal abnormalities.

Cerebrovascular Accident (Stoke)

- This is the most common brain disorder.
- Arteries that supply blood to the brain cause blood clots to develop, obstructing blood flow to the brain, precipitating a stroke.
- Symptoms of a stroke include slurred speech, loss/blurred vision, and paralysis of a limb or half the body.

Aneurysm

- Weak, swollen areas of a blood vessel supplying the brain which alters the brain's blood flow, resulting in a partial or complete loss of consciousness.
  - Aneurysms develop slowly and are rarely associated with symptoms.
  - If the weak area ruptures, massive hemorrhage occurs. This can be fatal.

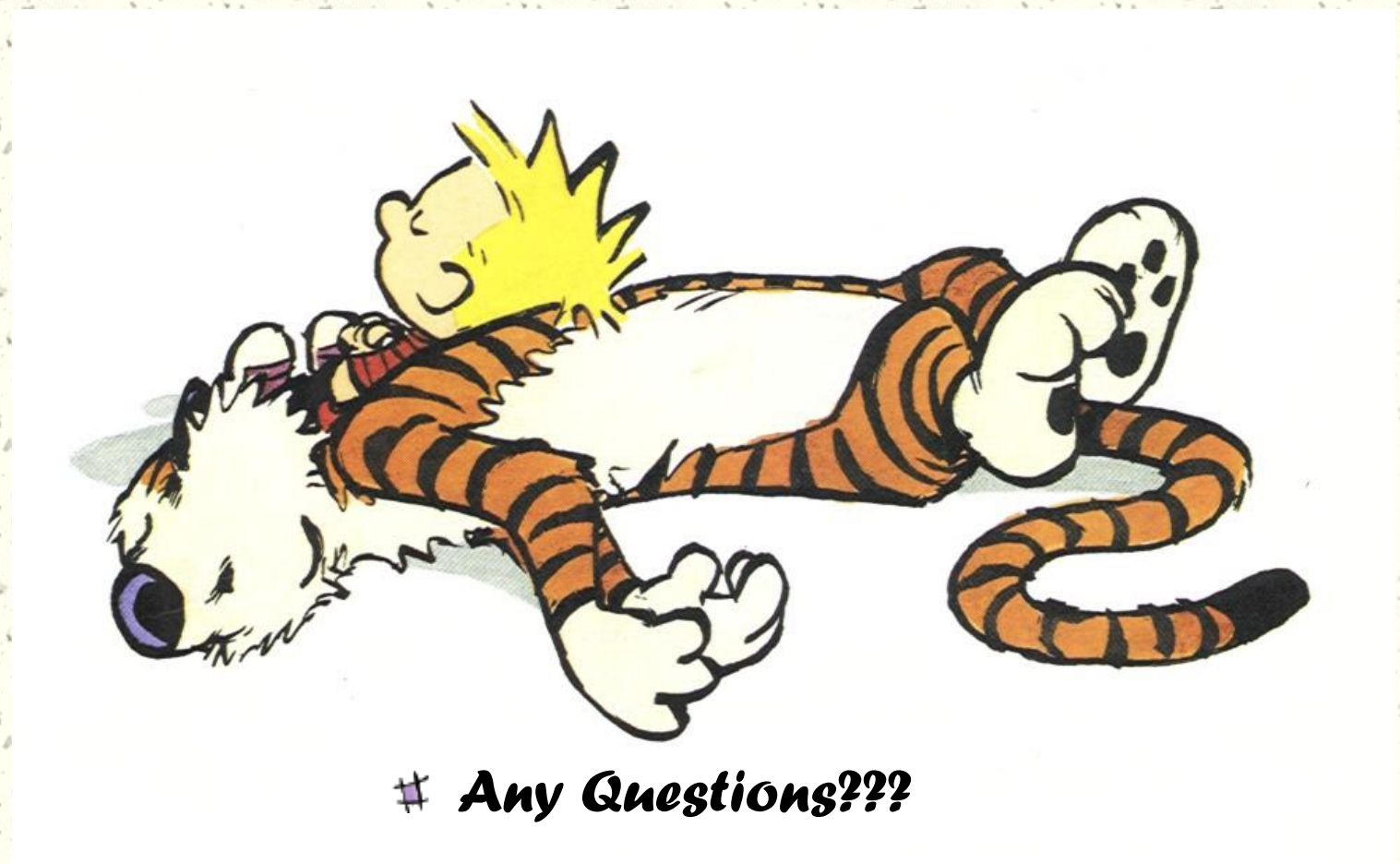
Parkinson's Disease

- A progressive disorder of the CNS (usually in individuals over 60 years of age, but can occur in younger patients).
  - Parkinson's is thought to result from too little dopamine being produced.
  - Symptoms include muscle tremors, muscle rigidity, and slow, difficult movements. Walking and speech are often affected.

Multiple Sclerosis (MS)

- A progressive destruction of the myelin sheaths of the nerves of the CNS. This causes "short circuits" in nerve transmissions.
- There is no known cause or treatment.
- MS most commonly strikes young women in their 20's, but can affect men as well.
- Progressive loss of muscle function is the main symptom.

The End



- Any Questions???