VET-114
Animal Anatomy and Physiology 2

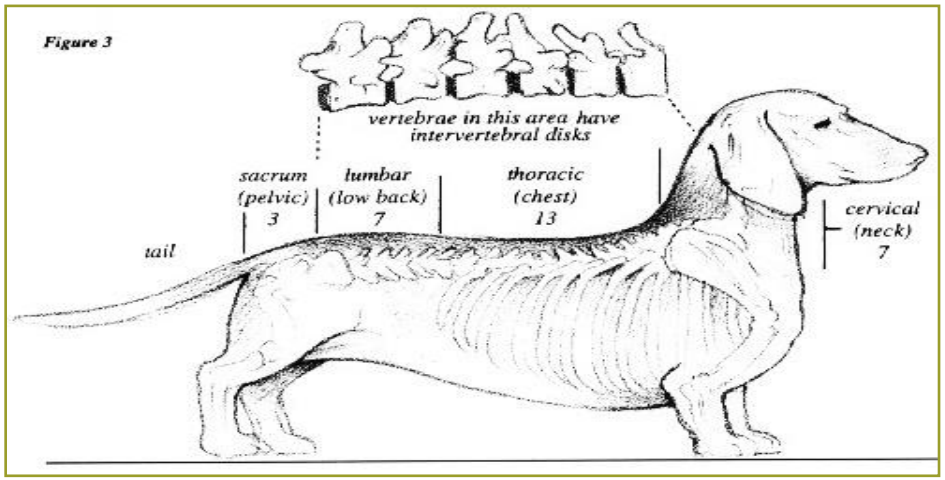
Lesson 2

Nervous System and Sense Organs

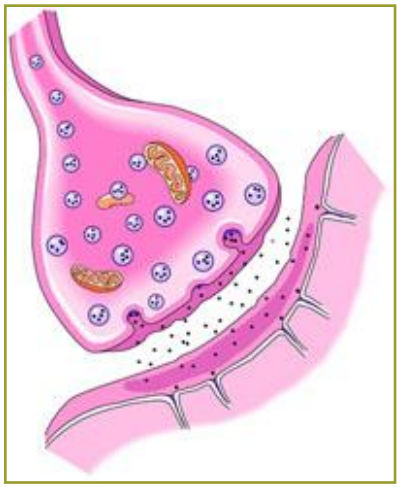
Chapters 13, 14

Are We Covering Animal Behavior in This Lesson? ☺


NO! ☺



The Nervous System
Chapter 13



Pages 314-336

Textbook Learning Objectives

Chapter 13 – Page 314

- Describe the structures and functions of the neurons and neuroglia of the cerebrum, the cerebellum, the diencephalon, and the brain stem.
- Differentiate between white matter and gray matter.
- Describe the functions of afferent and efferent nerves.
- List the components of the central nervous system and the peripheral nervous system.
- Differentiate between the autonomic and somatic nervous systems.
- Describe the process of depolarization and repolarization of neurons.
- List the excitatory and inhibitory neurotransmitters and describe their role in conduction of nerve impulses.
- Describe the connective tissue layers surrounding the brain and spinal cord.
- Explain the function of the cerebrospinal fluid.
- List the cranial nerves and describe their functions.
- Differentiate between the sympathetic and parasympathetic nervous systems and between autonomic and somatic reflexes.
- Describe the components of a reflex arc and explain the role of each.
- Describe the stretch reflex, withdrawal reflex, crossed extensor reflex, palpebral reflex, and pupillary light reflex.

Nervous System Overview

- Electronic communication system within body
- Controls and integrates all body activities within limits that maintain life
- Neurology

3 Basic Functions

- Stimulus – sensing changes with sensory receptors
  - Fullness of stomach or sun on your face
- Processing – interpreting and remembering those changes
- Response – reacting to those changes with effectors (target organs)
  - Muscular contractions
  - Glandular secretions

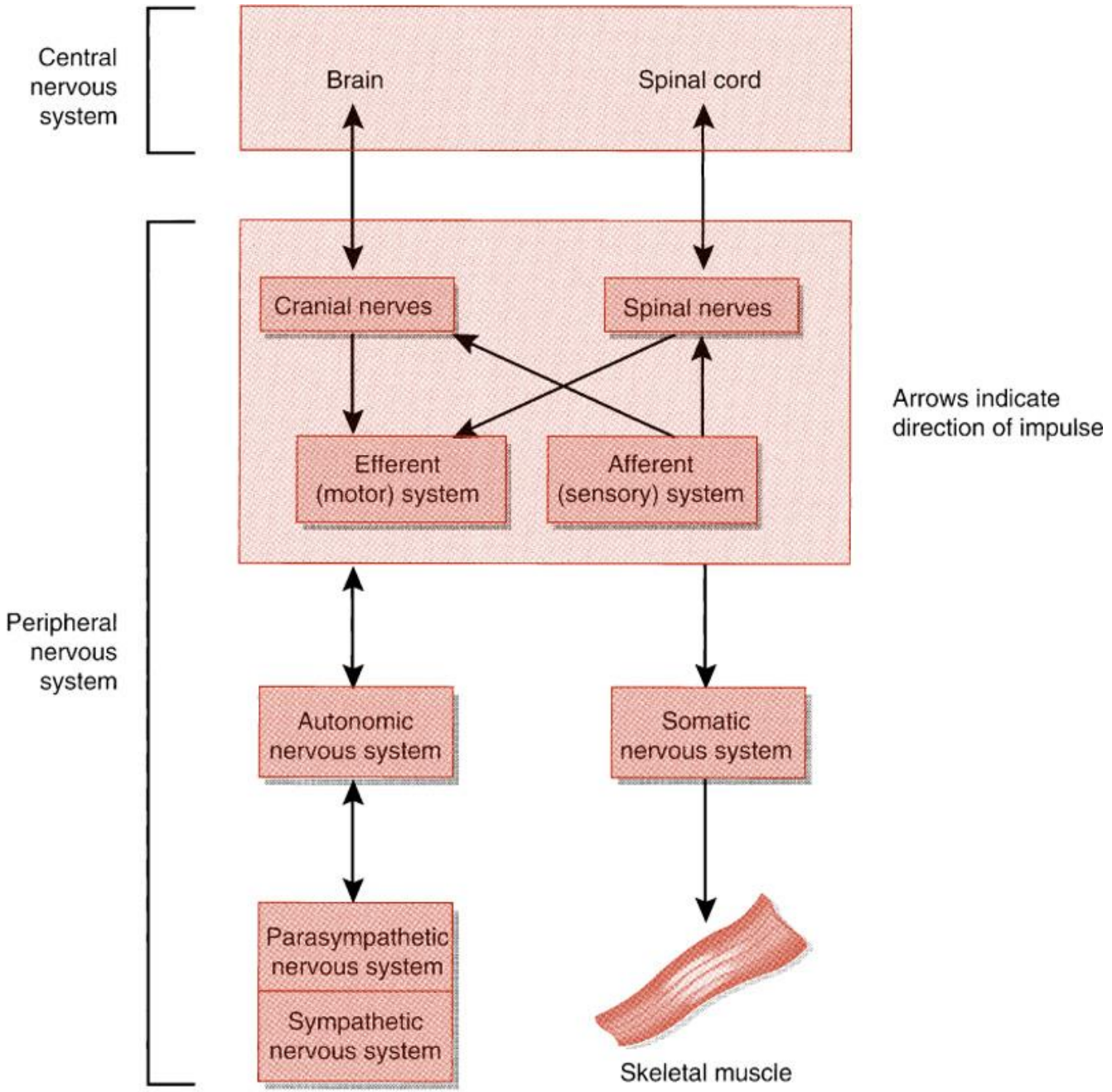
2 Divisions of Nervous system

Central Nervous System (CNS)

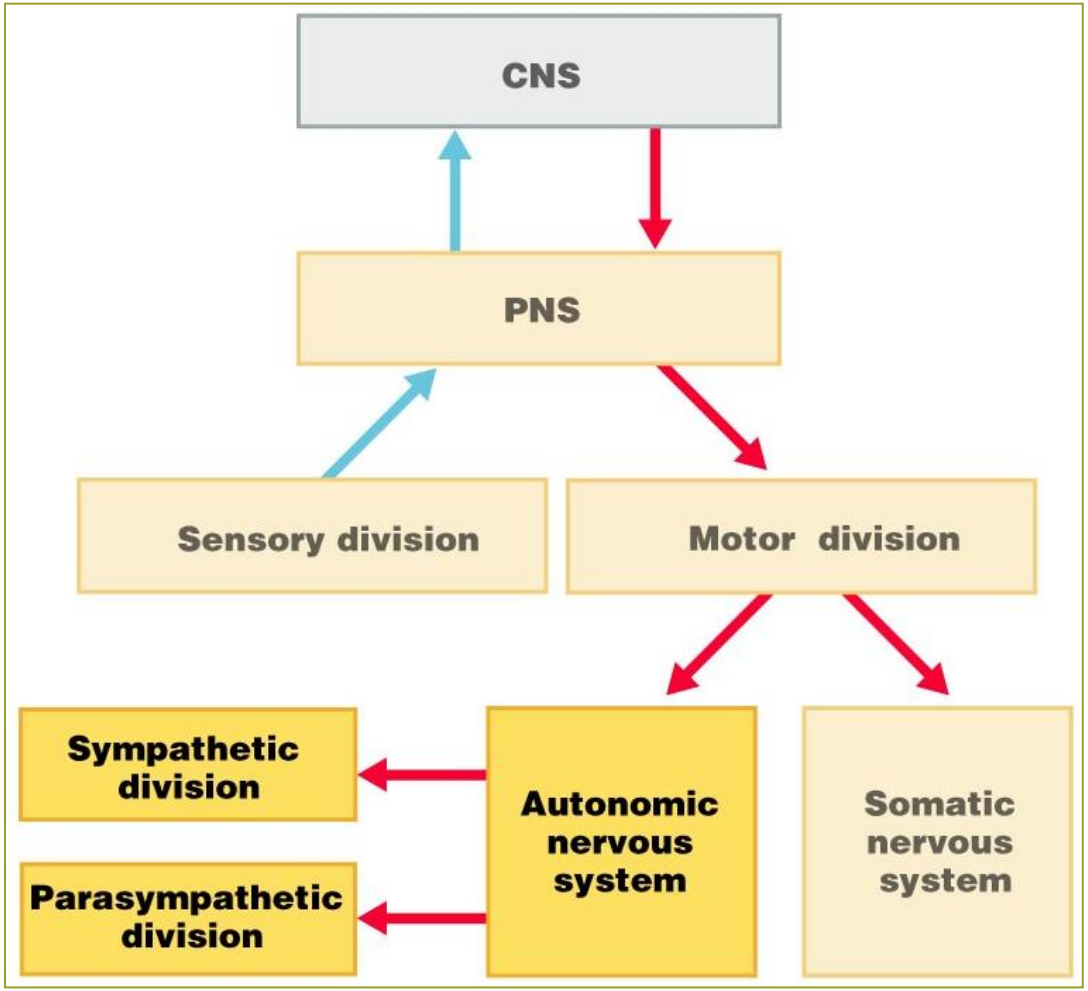
Peripheral Nervous System (PNS)

Anatomy Overview

- Central Nervous System (CNS)
  - Brain
  - Spinal cord
- Peripheral Nervous System
  - Cranial nerves
  - Spinal nerves
  - Autonomic Nervous System (ANS)
    - Sympathetic division
    - Parasympathetic division


Central nervous system
Brain
Spinal cord
Cranial nerves
Spinal nerves
Efferent (motor) system
Afferent (sensory) system
Arrows indicate direction of impulse
Peripheral nervous system
Autonomic nervous system
Somatic nervous system
Parasympathetic nervous system
Sympathetic nervous system
Skeletal muscle

Nervous System Overview



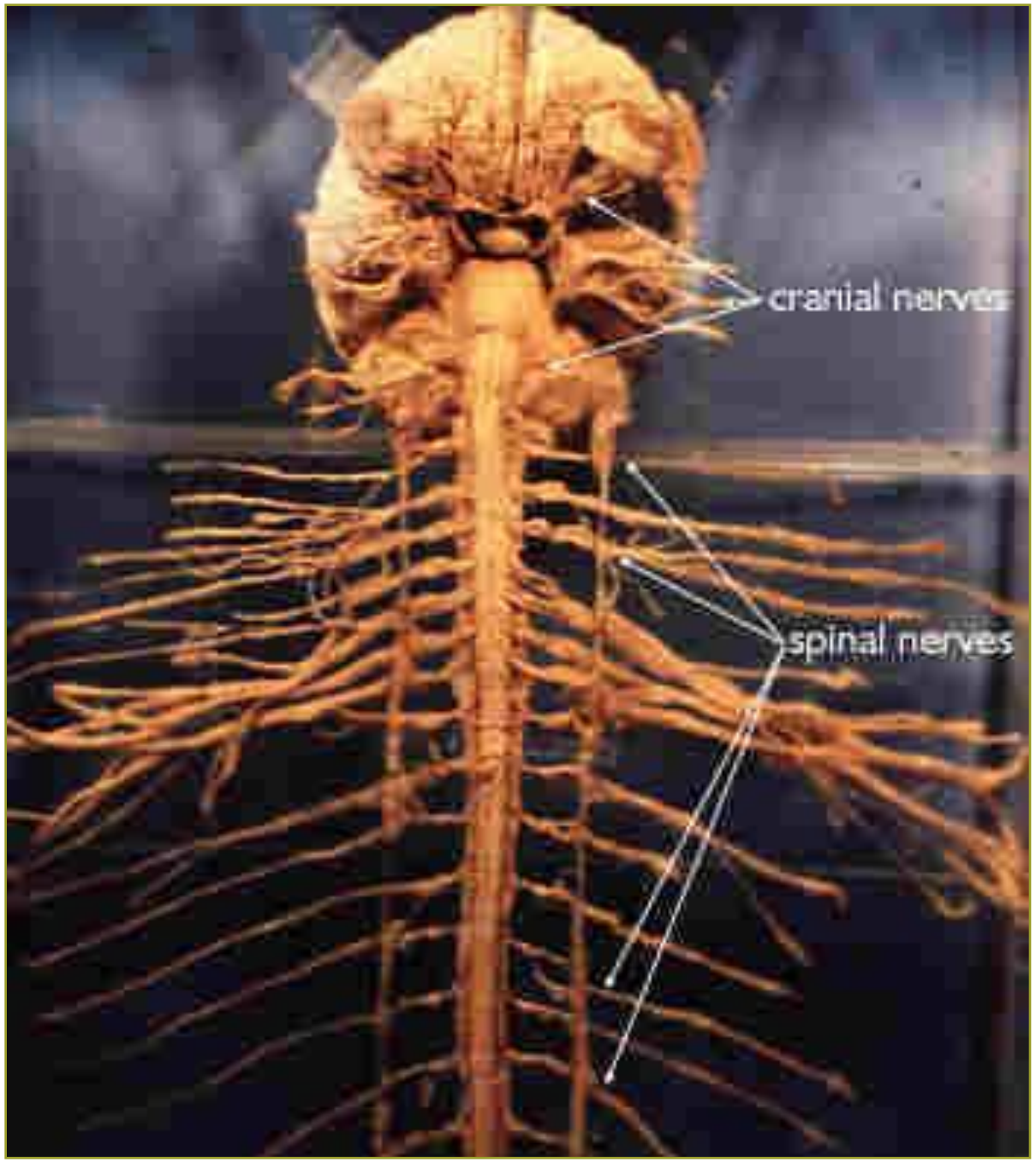
Central Nervous System (CNS)

- Brain
  - The “mainframe computer”
- Spinal cord
  - “Big fat wires”!!!

Peripheral Nervous System (PNS)

- Somatic Nervous System
  - Cranial nerves
    - Directly from brain
  - Spinal nerves
    - Directly from spinal cord
- Autonomic nervous system (ANS)

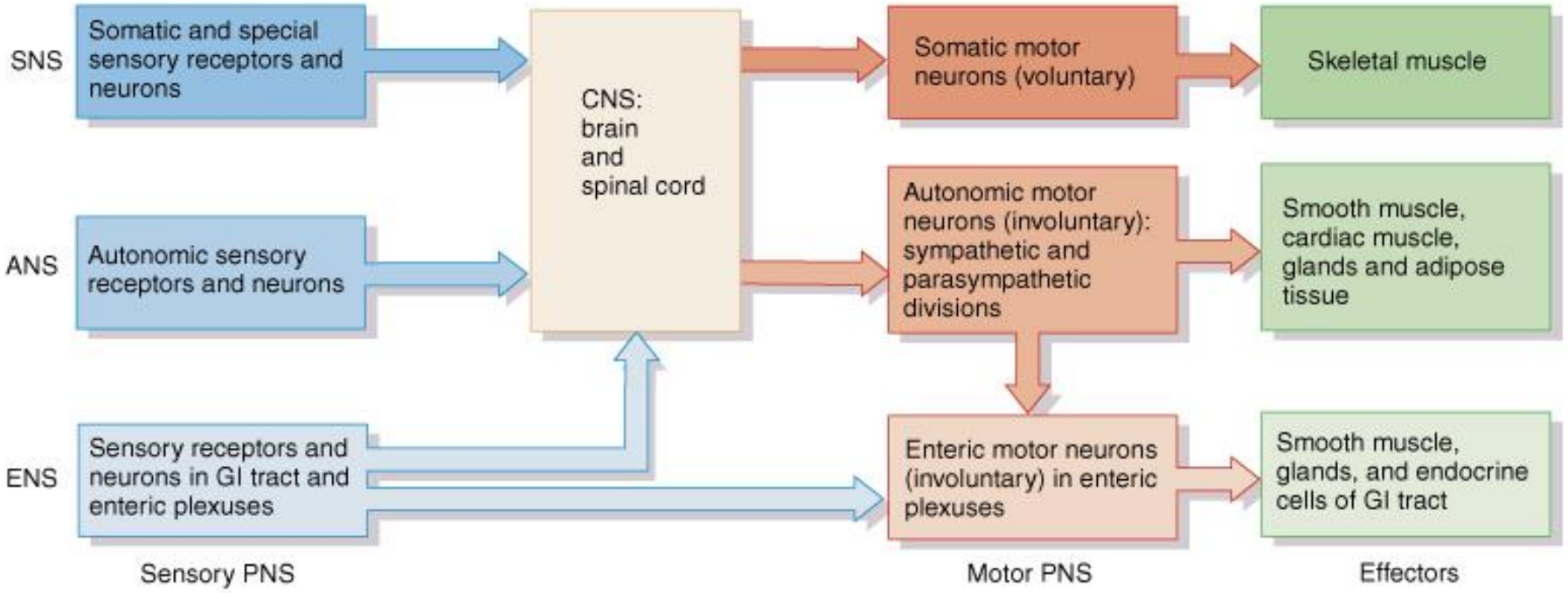
Cranial & Spinal Nerves



Somatic vs. Autonomic Physiology

- Somatic nervous system
  - Actions under conscious or voluntary control
- Autonomic nervous system
  - Controls and coordinates automatic functions
  - Example: slowing of the heart rate in response to an increased blood pressure

Overview

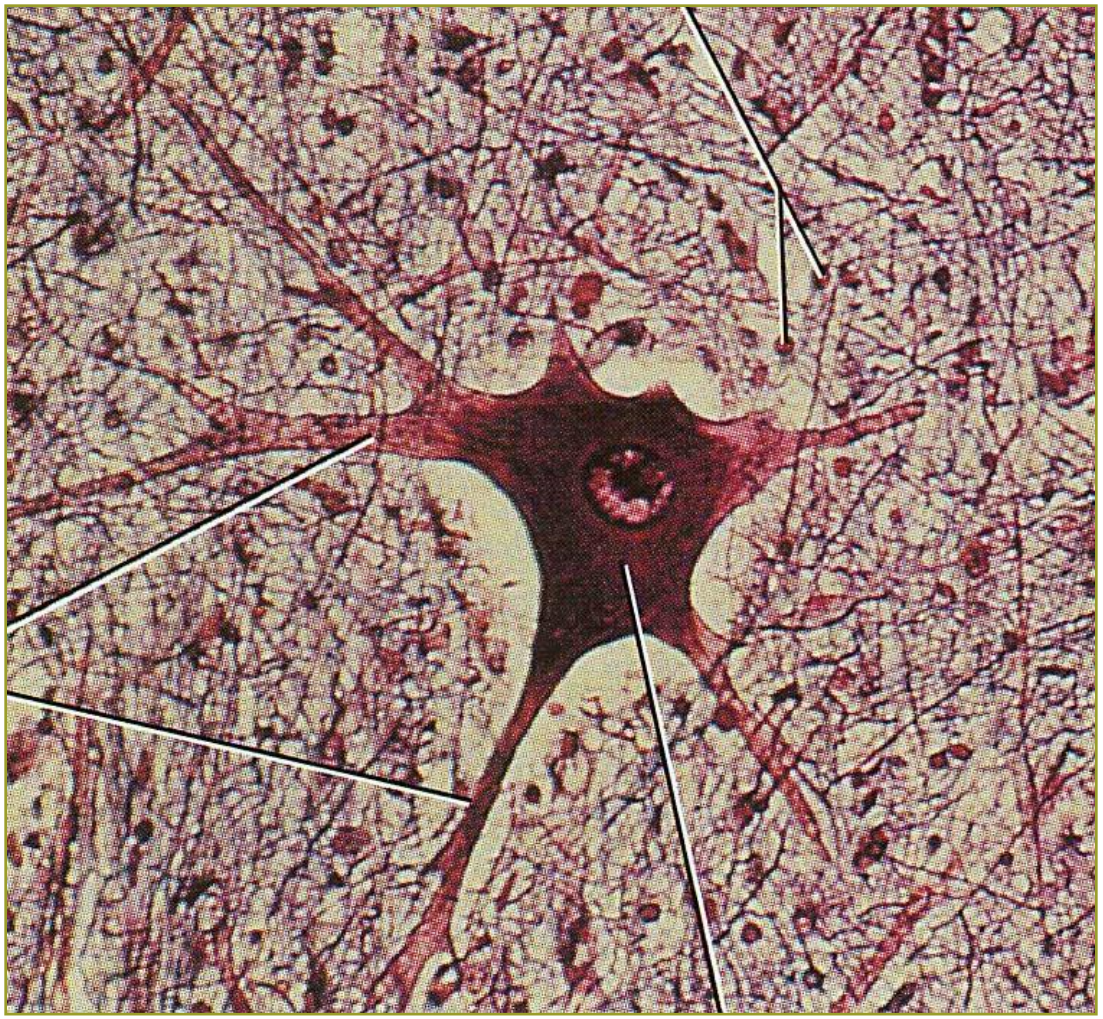


CNS is brain and spinal cord

PNS is everything else

Types of Cells

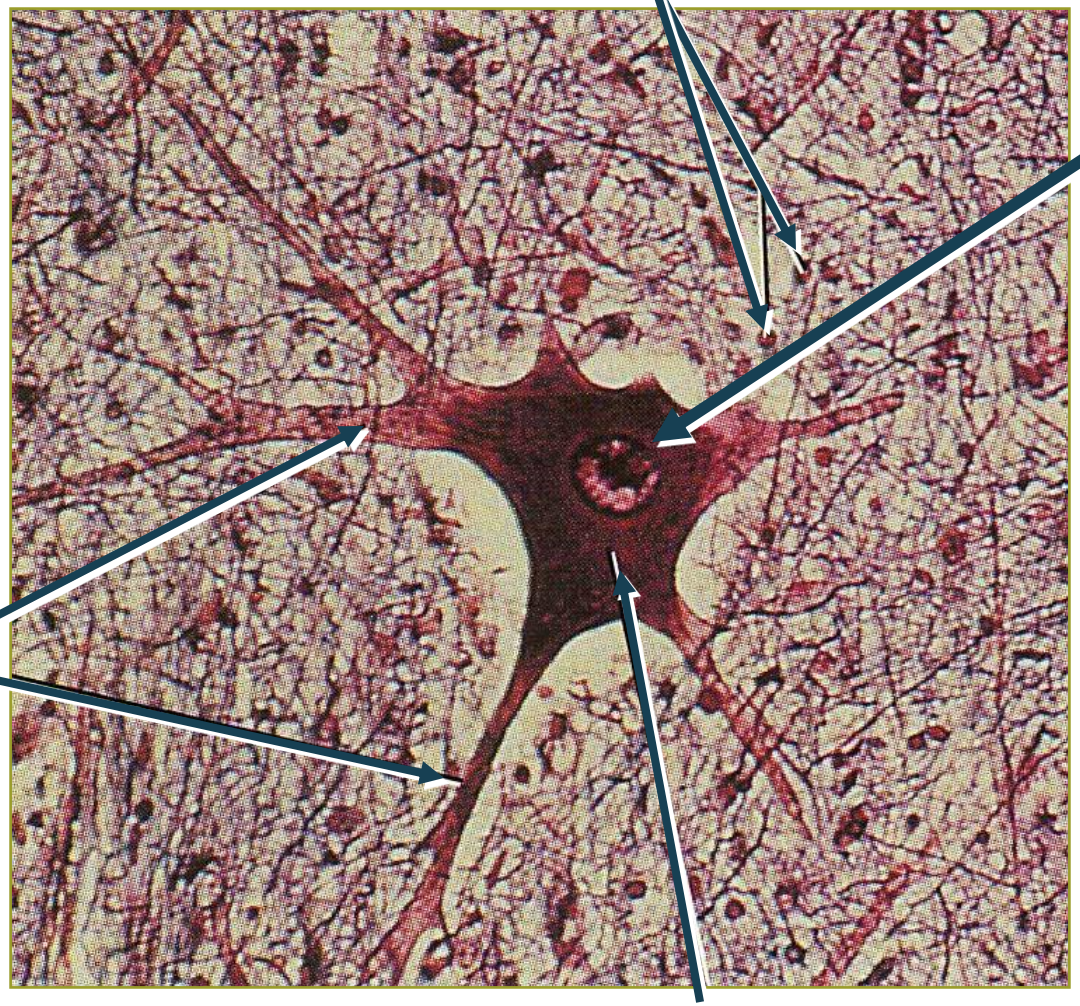
- Neurons
  - Structural and functional unit of nervous system
- Neuroglial cells
  - “Helper” cells

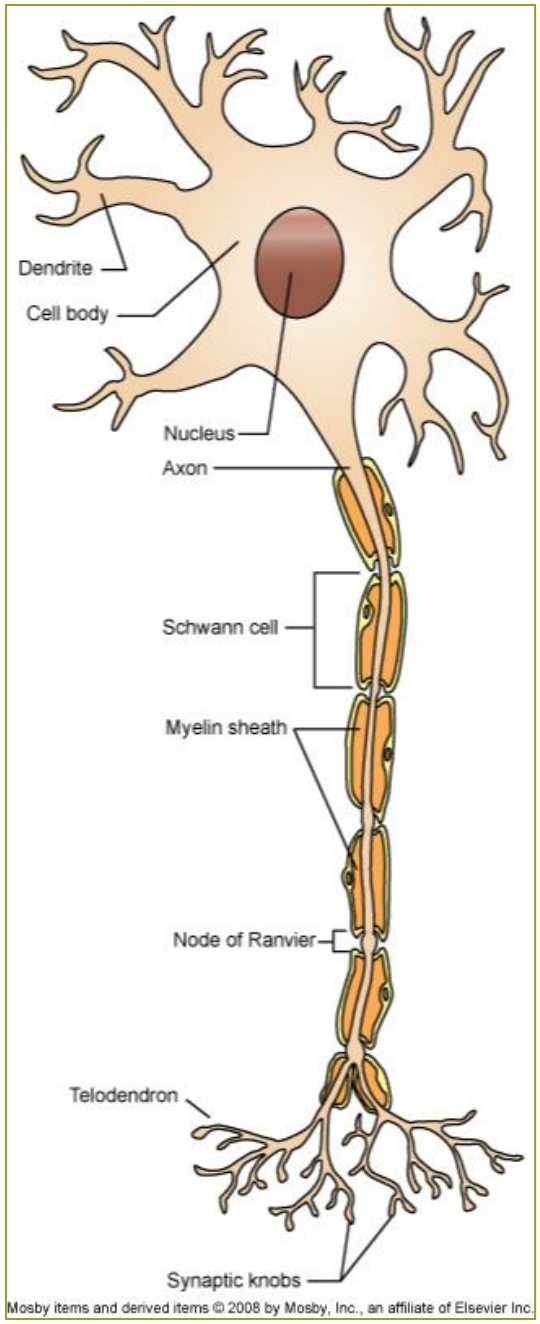


Functions

- Neurons
  - High requirement for oxygen
  - Cannot reproduce but can regenerate cell processes if the cell body remains intact
- Neuroglial cells
  - Structural & functional support to neurons
  - Protection to neurons

Parts of a Neuron





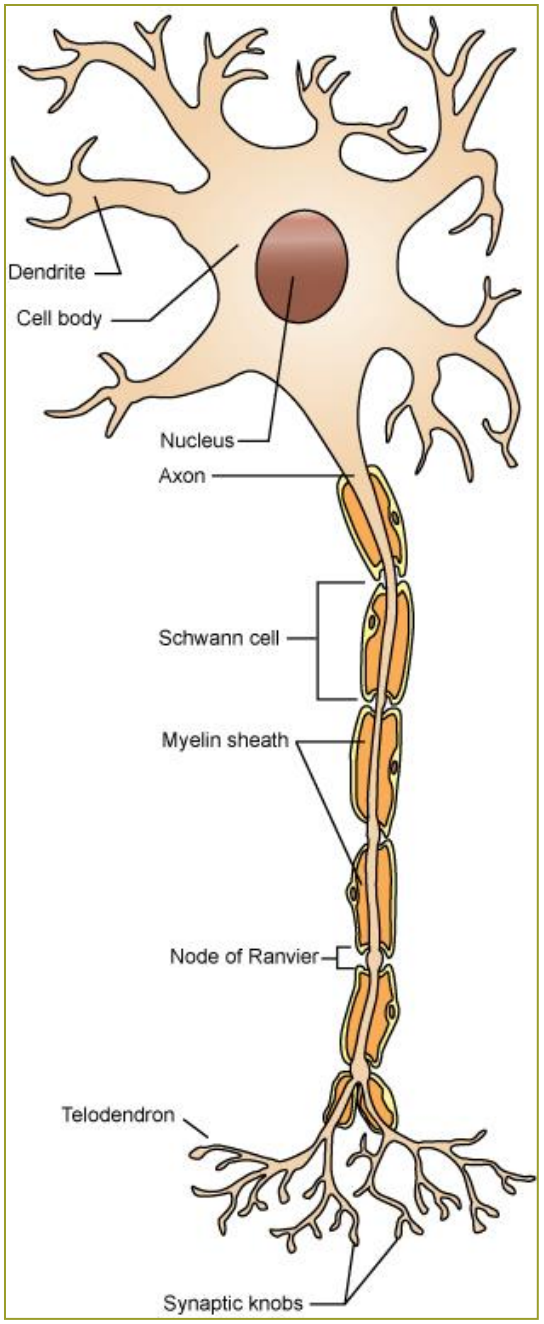
Structure of Neuron

Figure 13-1, Page 315

- Dendrite
- Cell body
- Axon
- Myelin sheath
- Mode of Ranvier
- Synaptic knobs

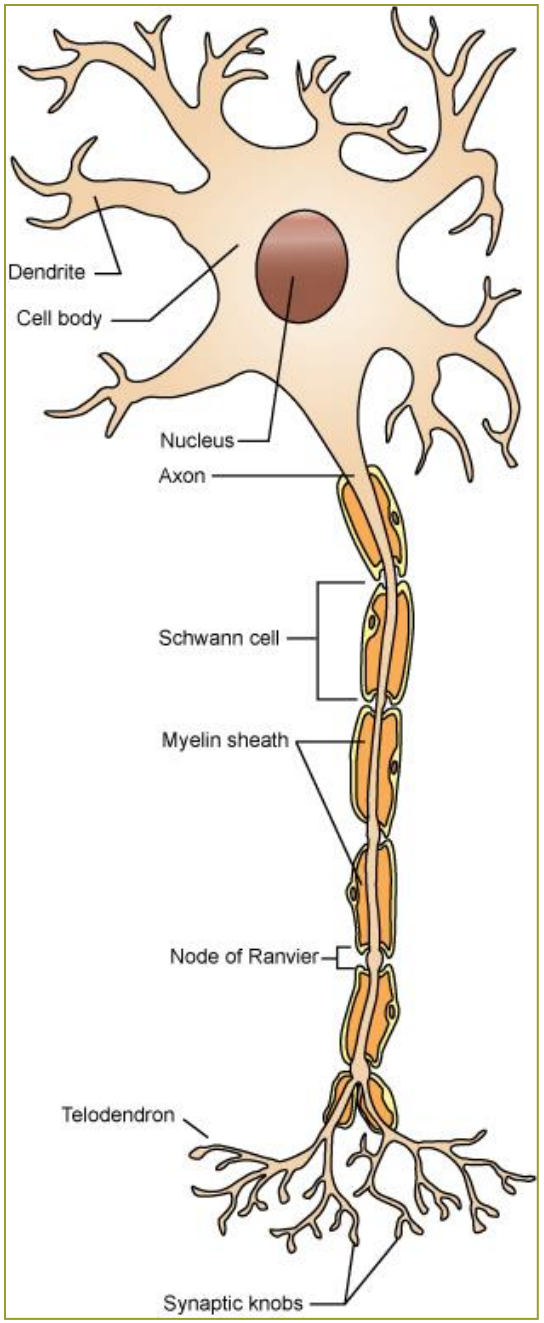
Dendrites

- Short, numerous, multibranched
- Receive nerve impulse from other neurons
- Conduct nerve impulse to cell body
- May serve as sensory receptors
  - Heat, cold, touch, pressure, stretch, pain



Axons

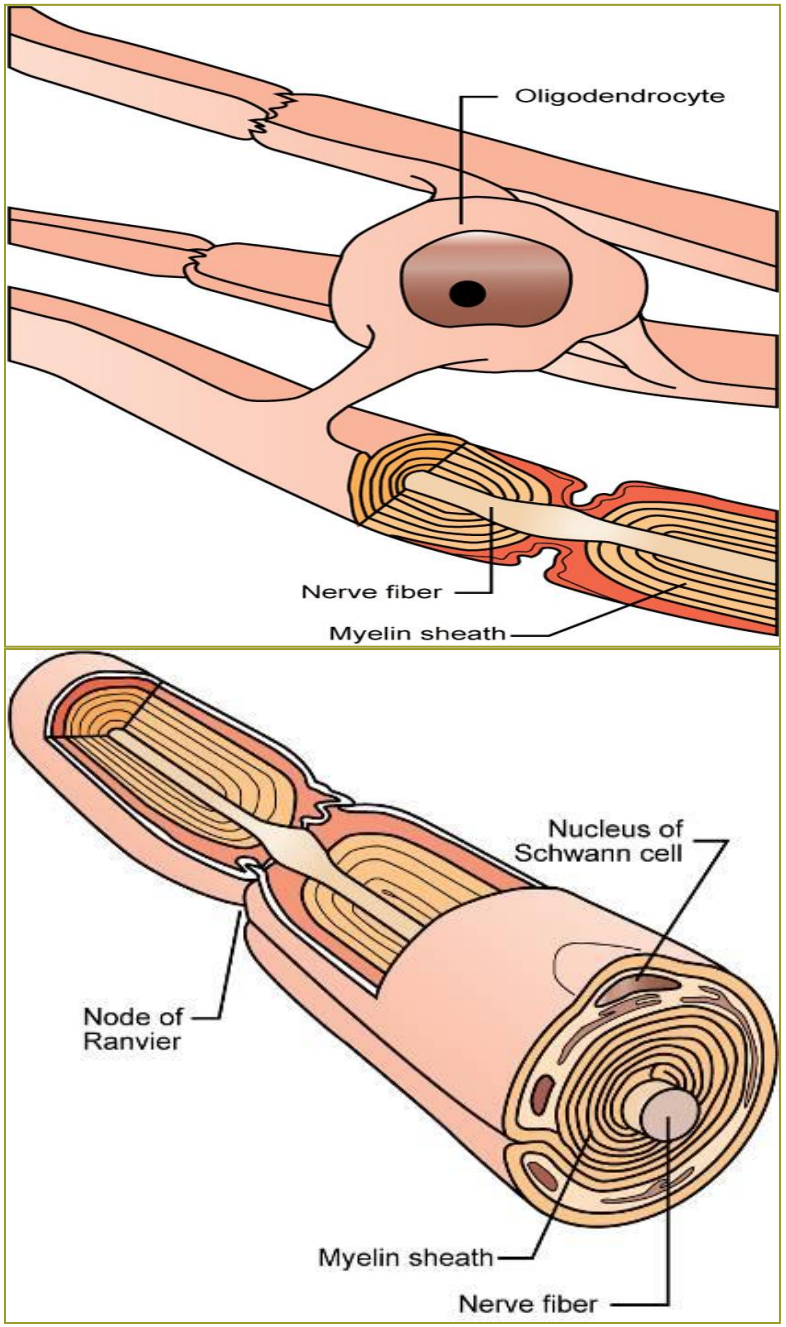
- Single, long process
- Conduct nerve impulse away
  from cell body
  - Myelinated
  - Unmyelinated
- Myelinated axons conduct impulses faster than unmyelinated



Myelin Sheath

Figures 13-2 & 13-3, Page 316

- Cell membrane of glial cells tightly wrapped around axon
  - Oligodendrocytes in brain and spinal cord
  - Schwann cells in nerves outside brain and spinal cord

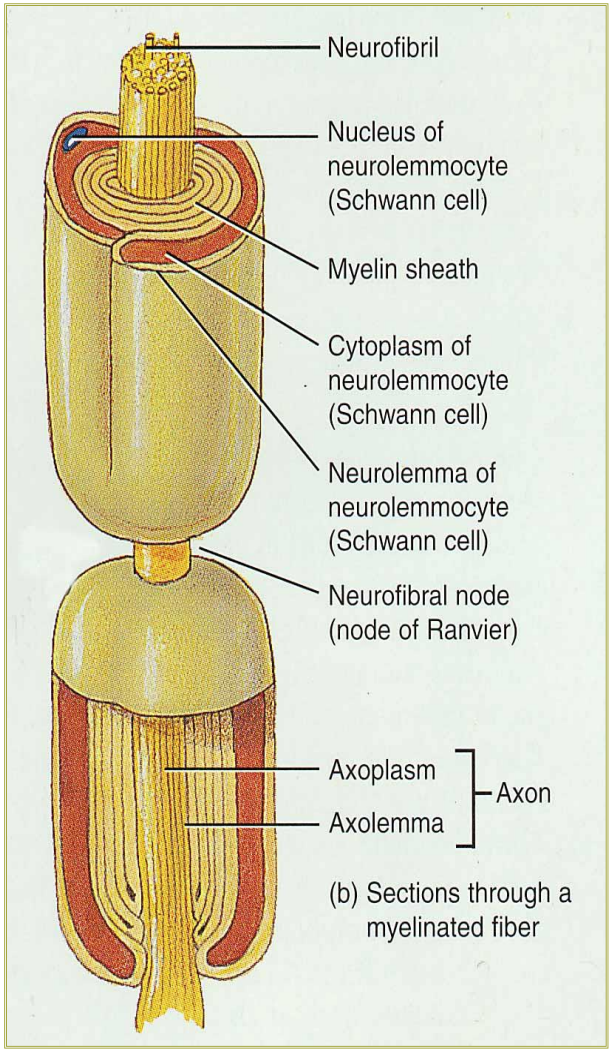


Myelinated Axons

- Multiple Schwann cells or oligodendrocytes cover the entire length of the axon (nerve fiber)
- Nodes of Ranvier
  - Gaps between adjacent glial cells
  - Reason for increased transmission speed in these axons

Neuron Physiology

- Electrical conduction of information
- Action Potential (Nerve Impulse)
- Myelinated axons **(Figures 13-2 & 13-3, Page 316)**



Nerve Impulse Conduction – Steps

- AKA "Action Potential"
  - "The WAVE"!!! ☺
- Resting membrane potential
- Depolarization – Na^+
  - All-or-none principle (threshold)
- Repolarization – K^+
- Refractory period – Na^+/K^+ pump

Resting Membrane Potential

- Resting state
  - When a neuron is not being stimulated
- Difference in electrical charge across neuronal membrane

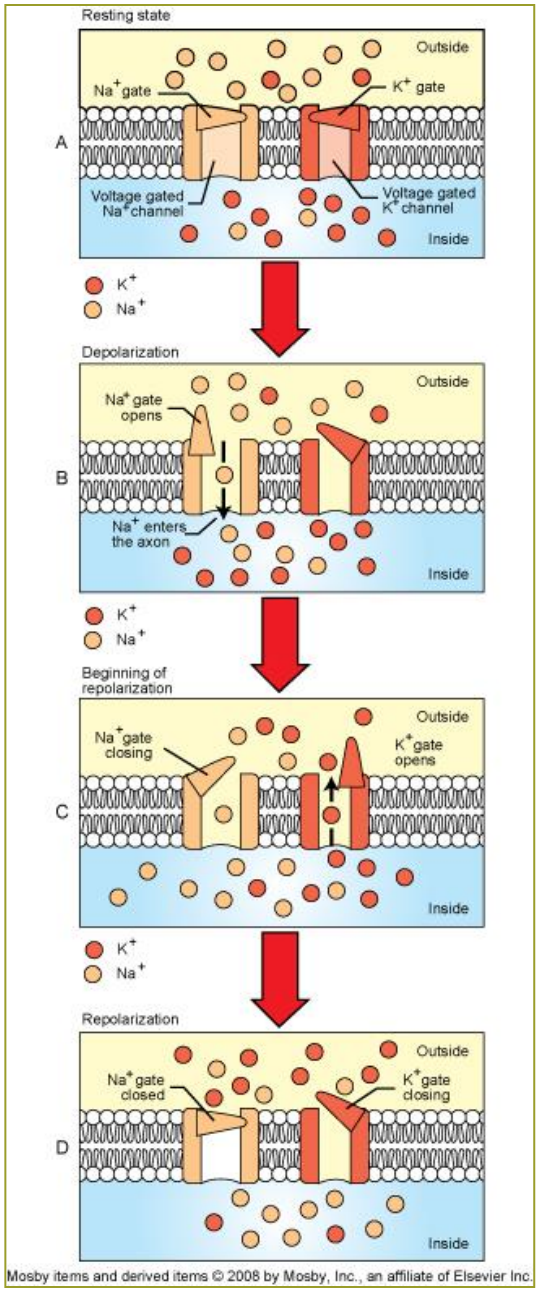
Threshold Stimulus

- Sufficient stimulus to make neuron respond & cause wave of depolarization (nerve impulse)
  - "All-or-nothing principle" – neuron depolarizes to its maximum strength or not at all
- Conduction of action potential –
  - Spreading wave (nerve impulse)
  - Opening sodium channels in sufficient numbers to allow depolarization

Depolarization & Repolarization

Figure 13-5, Page 319

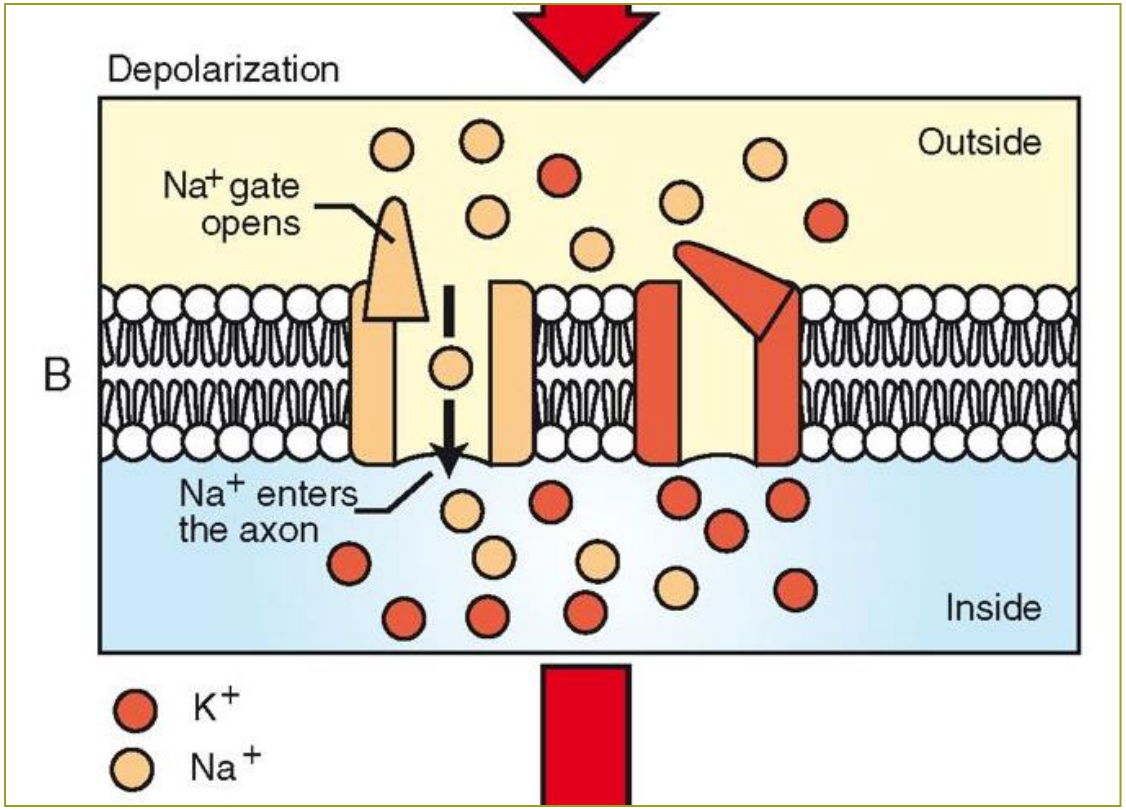
- Threshold stimulus
  - "The WAVE"!
- Depolarization – Na^+ into neuron
- Repolarization – K^+ out of neuron



Depolarization

Figure 13-5B, Page 319

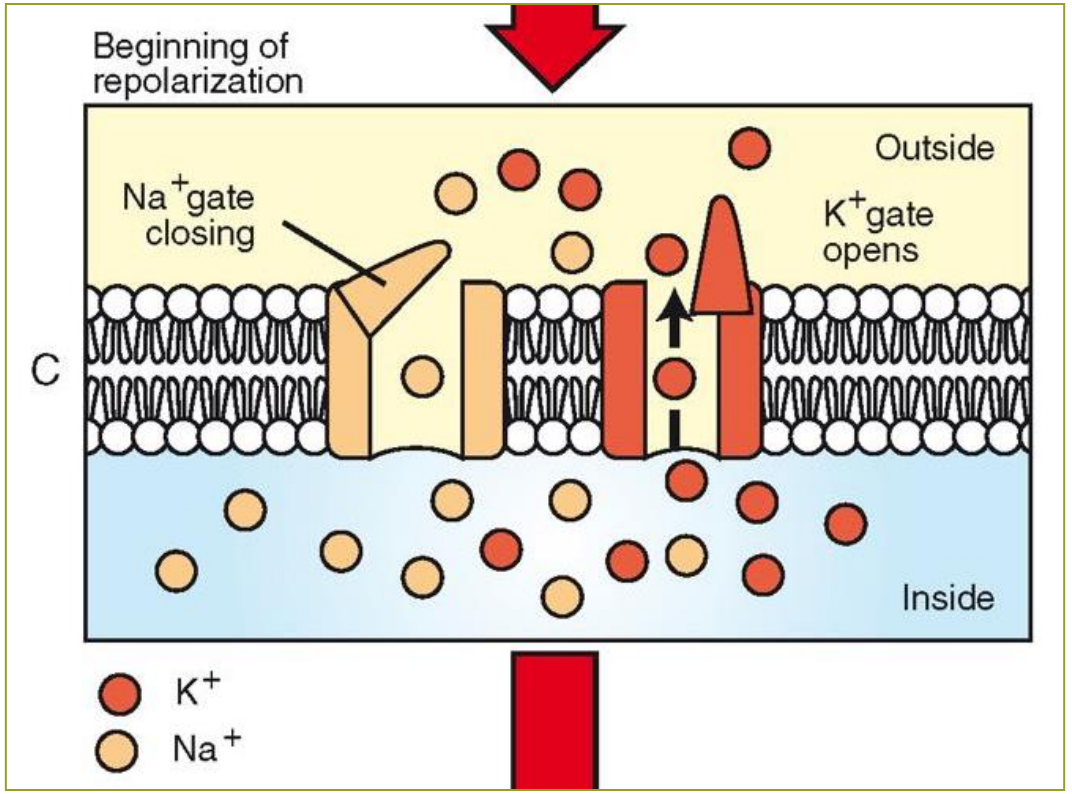
- Neuron receives external stimulus
- Sodium channels open on neuron cell membrane
- Sodium ions flow into cell by **passive** diffusion



Repolarization

Figure 13-5C, Page 319

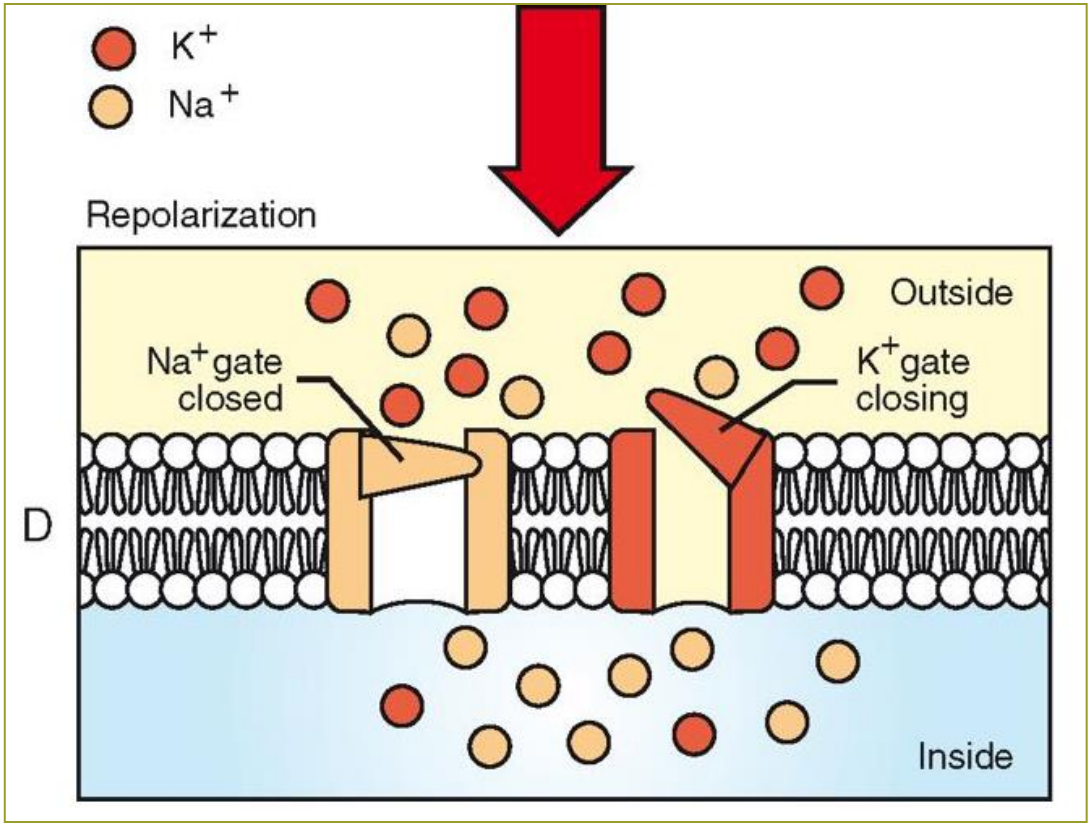
- Sodium channels close
- K^+ channels open
- K^+ diffuses out of the cell
- Resting state restored



Refractory Period

Figure 13-5D, Page 319

- Repolarization ends
- Sodium-potassium pump moves sodium & potassium ions back to original sides
- Resting state restored



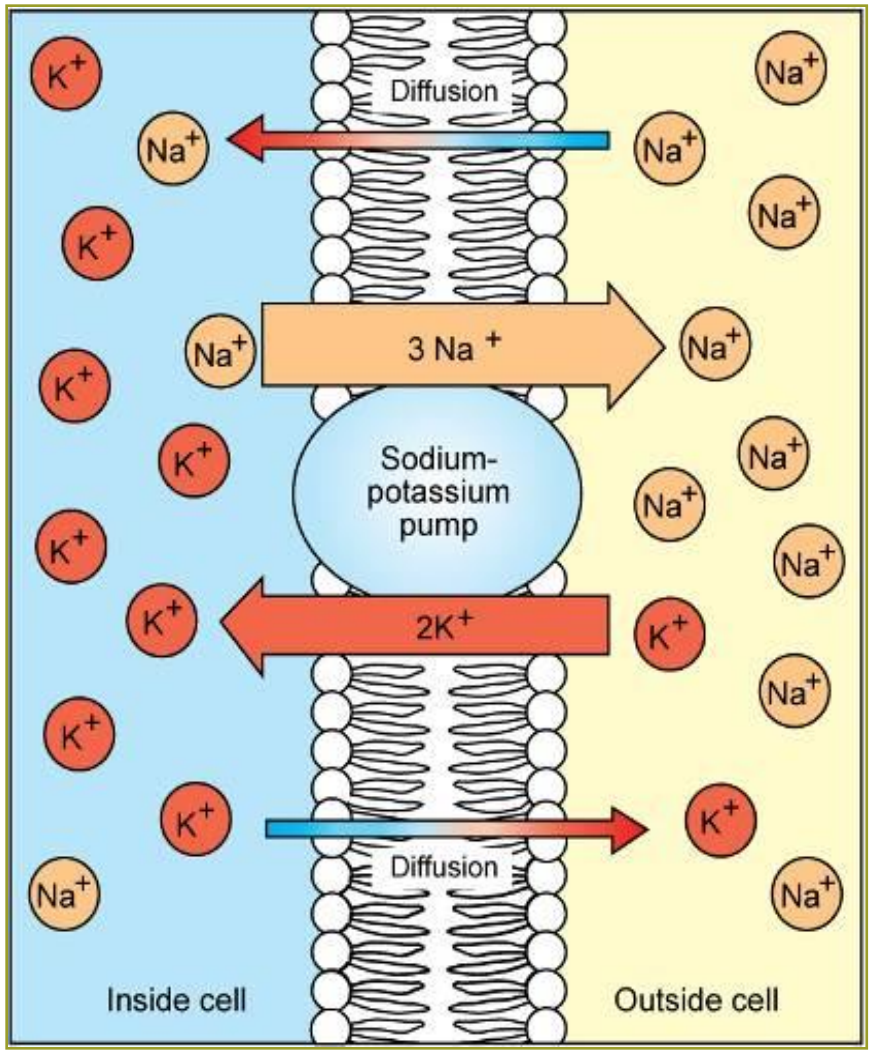
Refractory Period

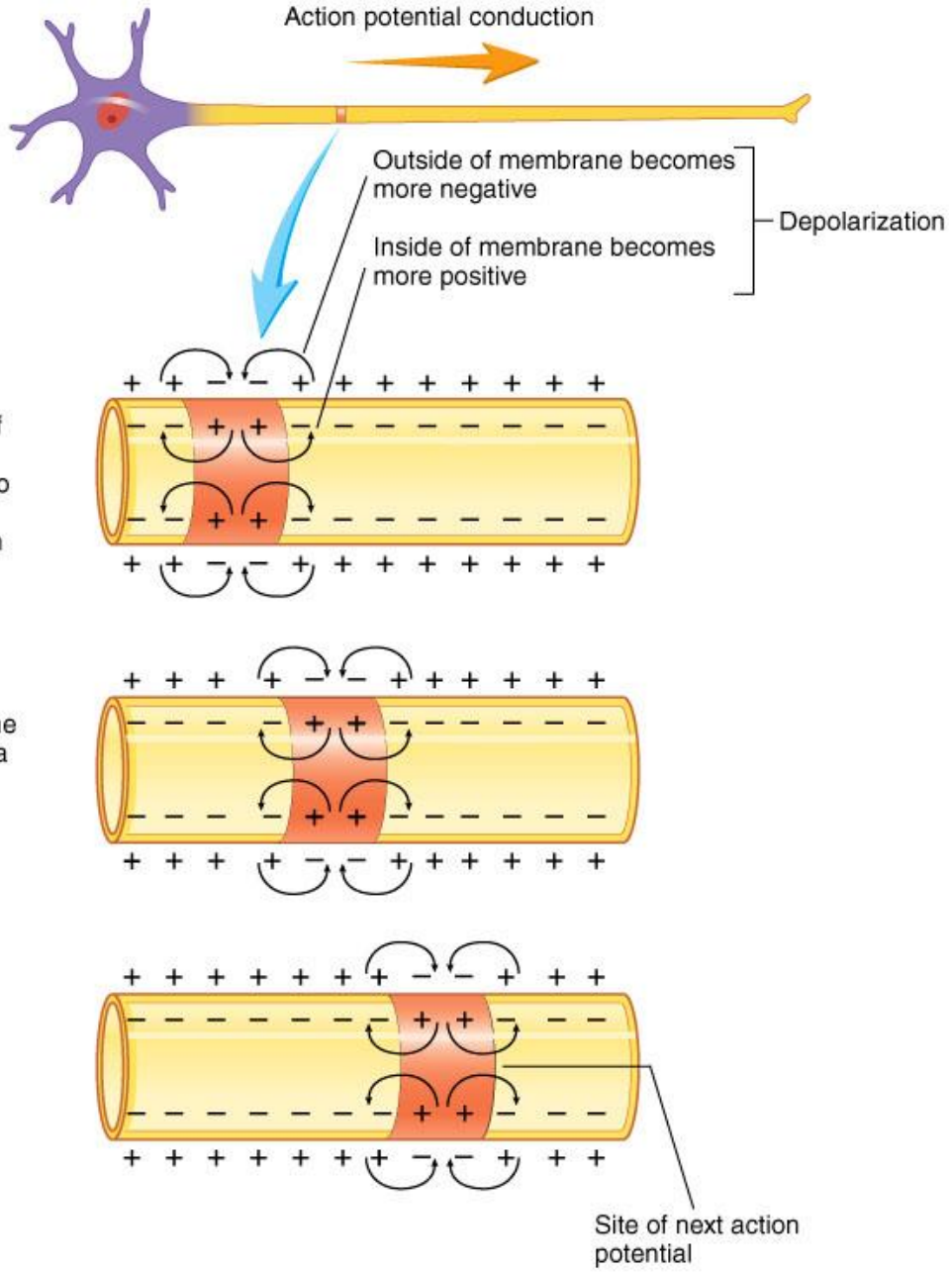
- Time period during which neuron is insensitive to additional stimuli
- Absolute refractory period – during sodium influx & early potassium outflow
- Relative refractory period – during end of repolarization period
  - May be possible to stimulate another depolarization if stimulus is very large

Sodium-Potassium Pump

Figure 13-4, Page 318

- Refractory Period (Returns neuron to resting state)
  - Pumps Na^+ from inside of neuron to the outside
  - Pump K^+ from outside of neuron to inside
  - LOTS of ATP needed



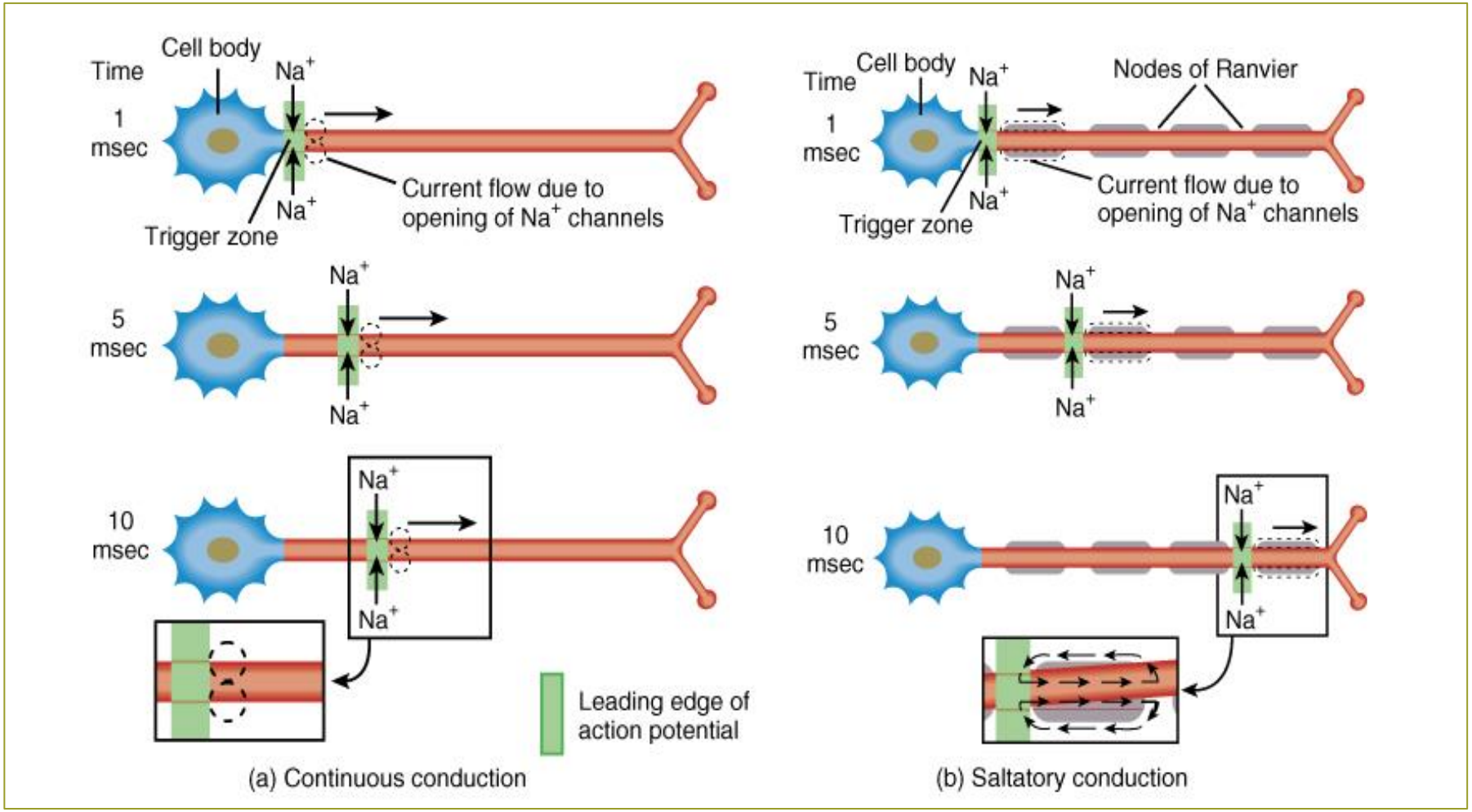


1. An action potential (orange part of the membrane) generates local currents (*black arrows*) that tend to depolarize the membrane immediately adjacent to the action potential.

2. When depolarization caused by the local currents reaches threshold, a new action potential is produced adjacent to where the original action potential occurred.

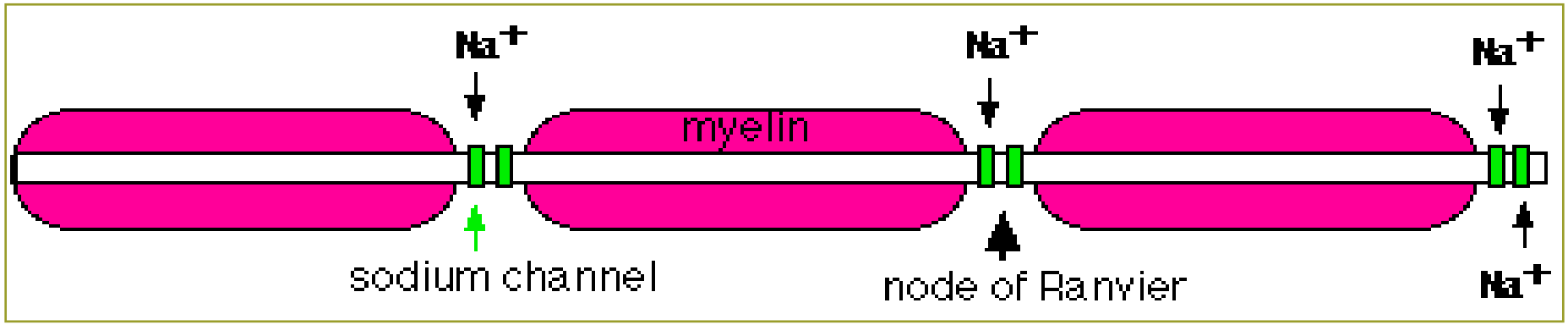
3. The action potential is conducted along the axon cell membrane.

Continuous vs. Saltatory Conduction



Myelinated Nerve Fibers (Axons)

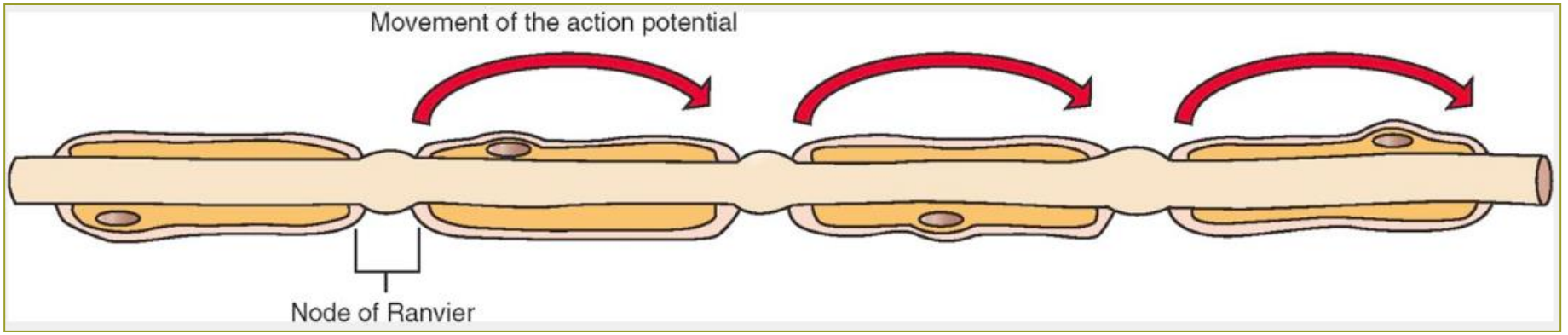
- Myelin sheath made by Schwann cells (neuroglia)



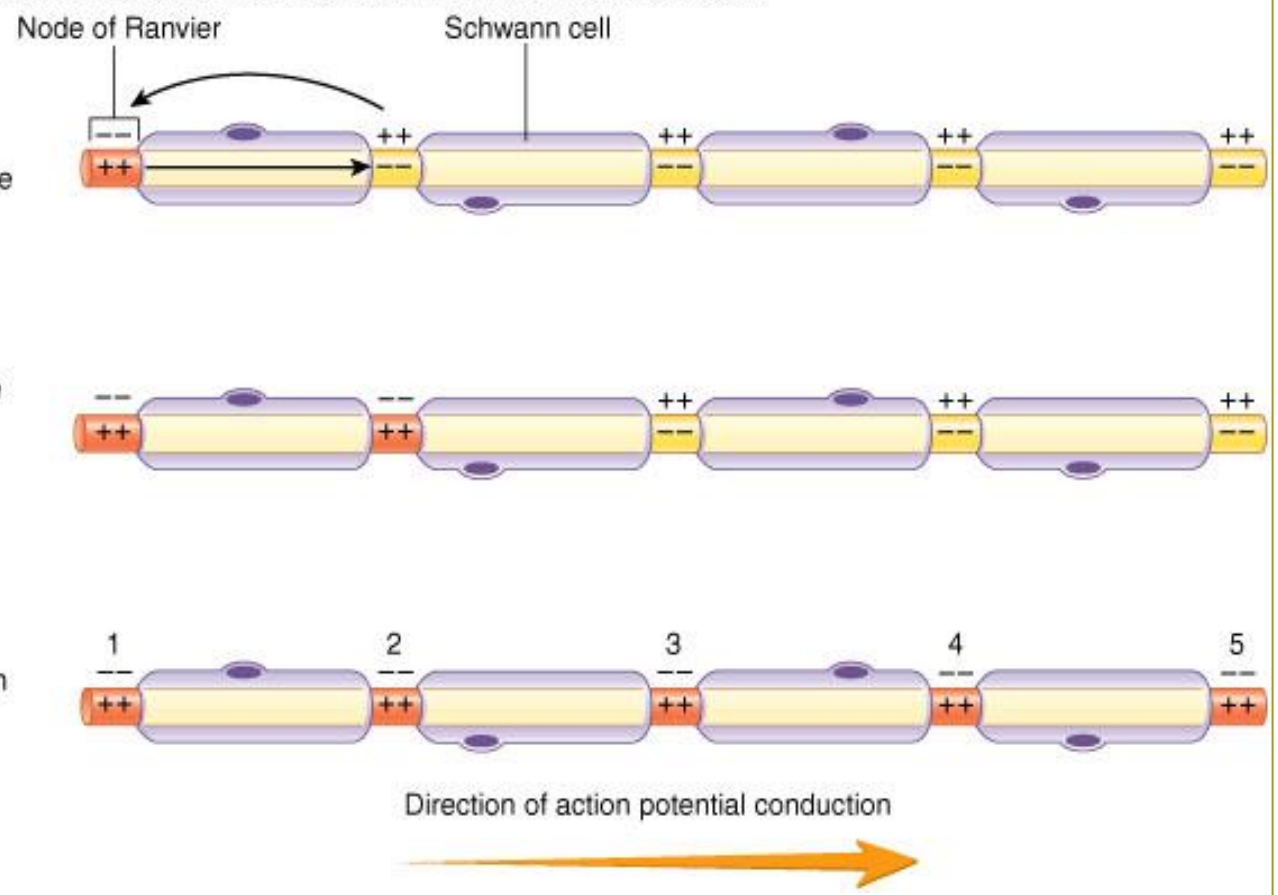
Saltatory Conduction

Figure 13-6, Page 321

- Rapid way of conducting an action potential
- Depolarization in myelinated axons can only take place at the nodes of Ranvier



Saltatory Conduction



1. An action potential (*orange*) at a node of Ranvier generates local currents (*black arrows*). The local currents flow to the next node of Ranvier because the myelin sheath of the Schwann cell insulates the axon between nodes.

2. When the depolarization caused by the local currents reaches threshold at the next node of Ranvier, a new action potential is produced (*orange*).

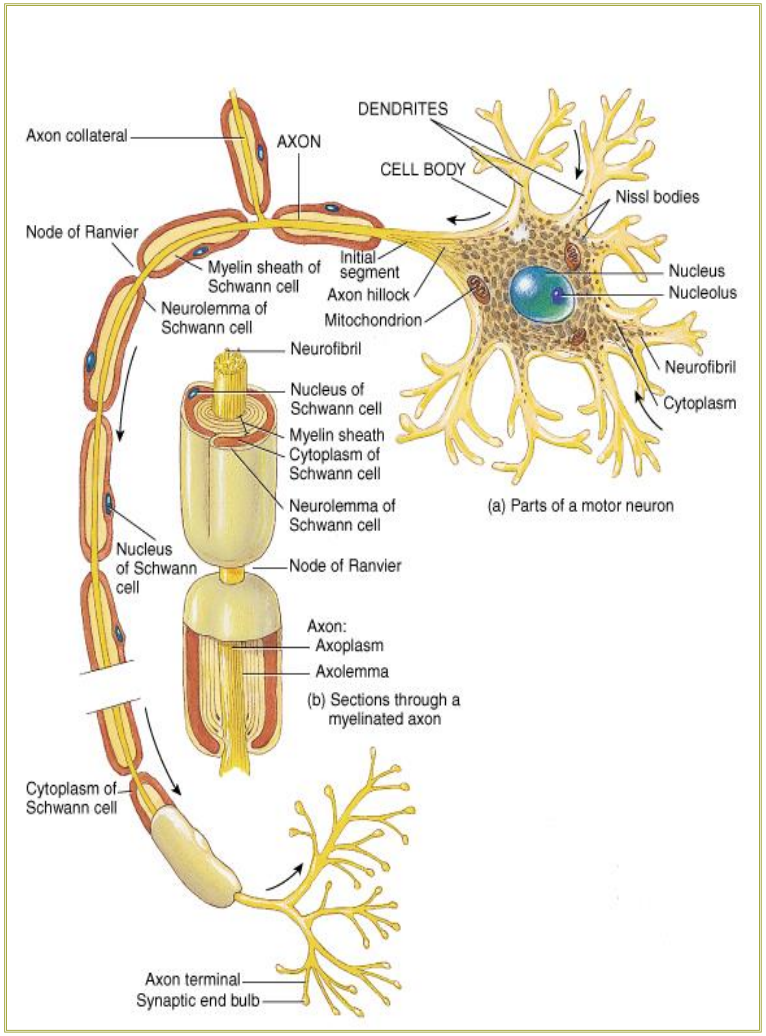
3. Action potential conduction is rapid in myelinated axons because the action potentials are produced at successive nodes of Ranvier (*1–5*) instead of at every part of the membrane along the axon.

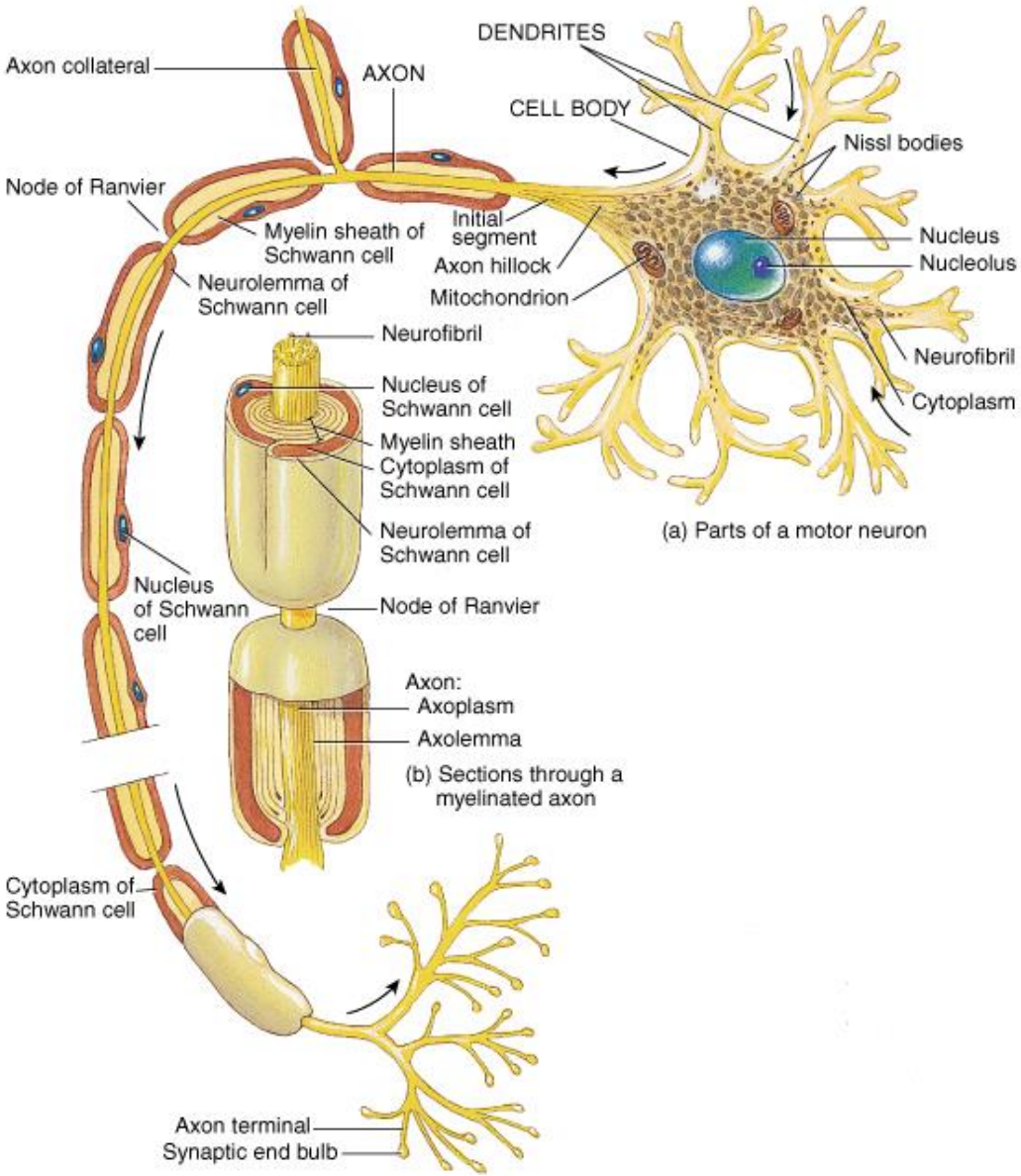
Anesthesia Application – Local Anesthetics

- Prevent opening of voltage-gated Na^+ channels
- Nerve impulses cannot pass the anesthetized region
- Novocaine, lidocaine, marcaine, bupivacaine, procaine

Neuron Morphology Review

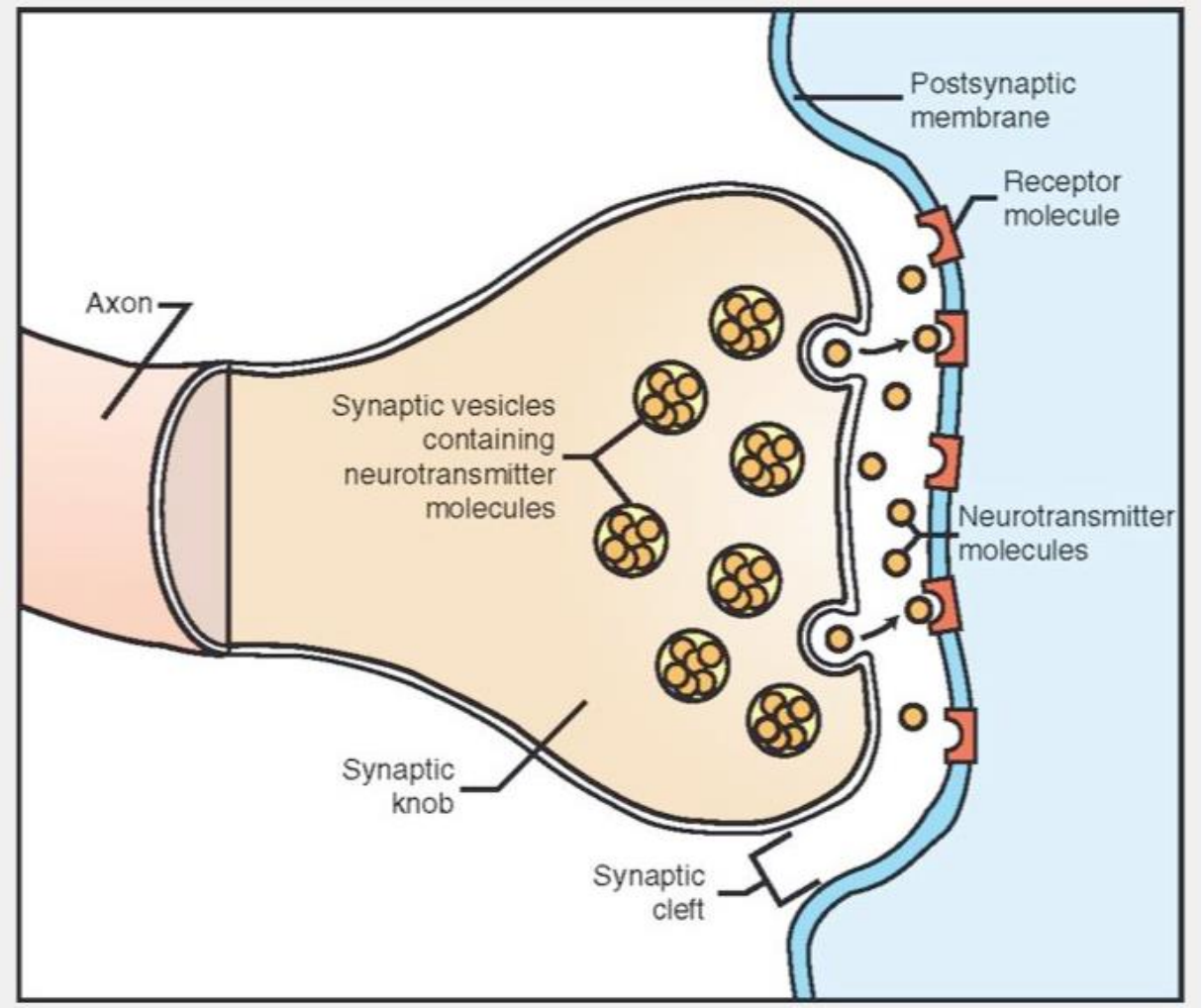
- Dendrites
- Cell bodies
- Axons
  - Nerve fibers
- Synapse
  - (Figure 13-7, Page 322)
- Neurotransmitter

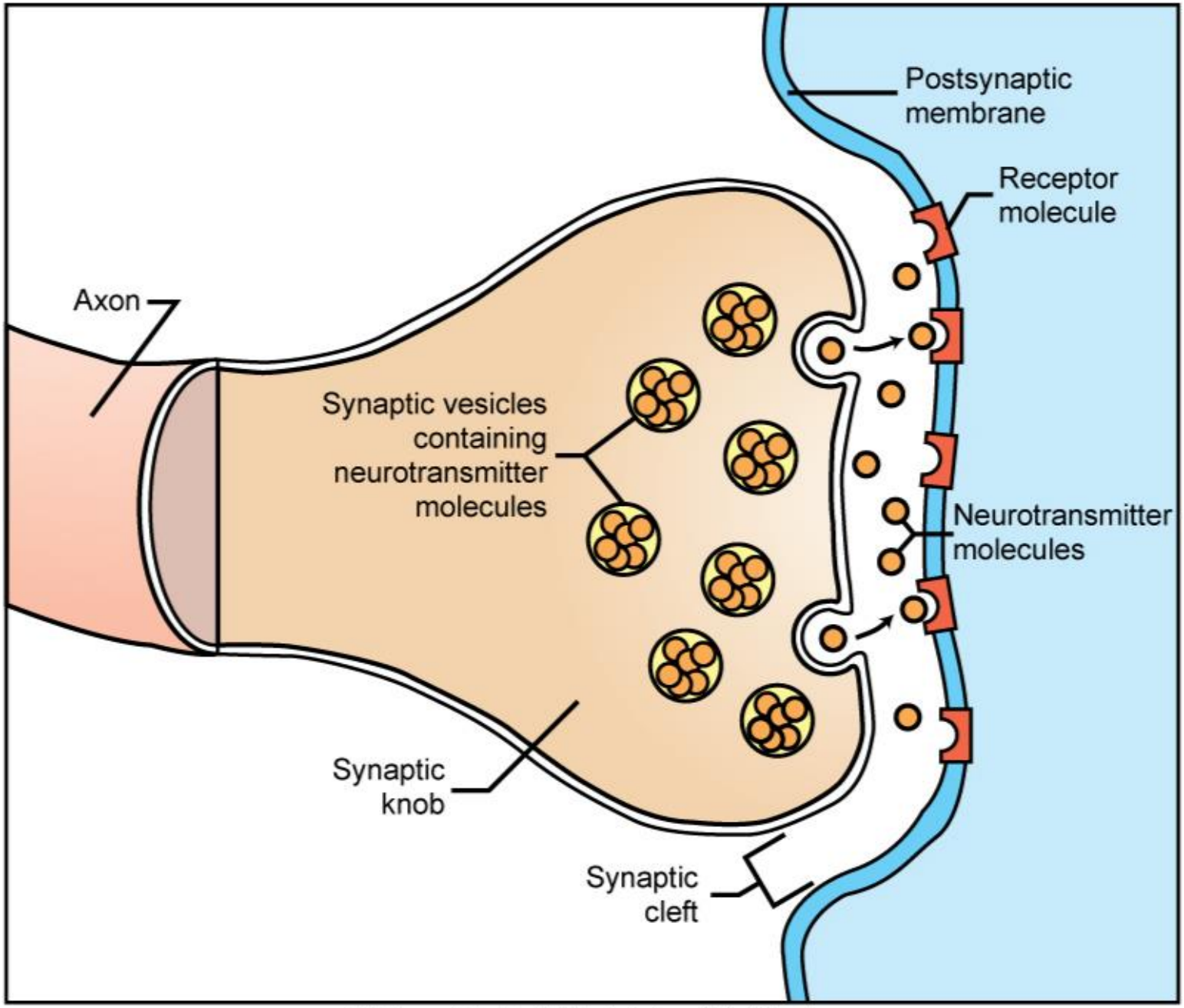




The Synapse

Figure 13-7
Page 322





Synapse Morphology

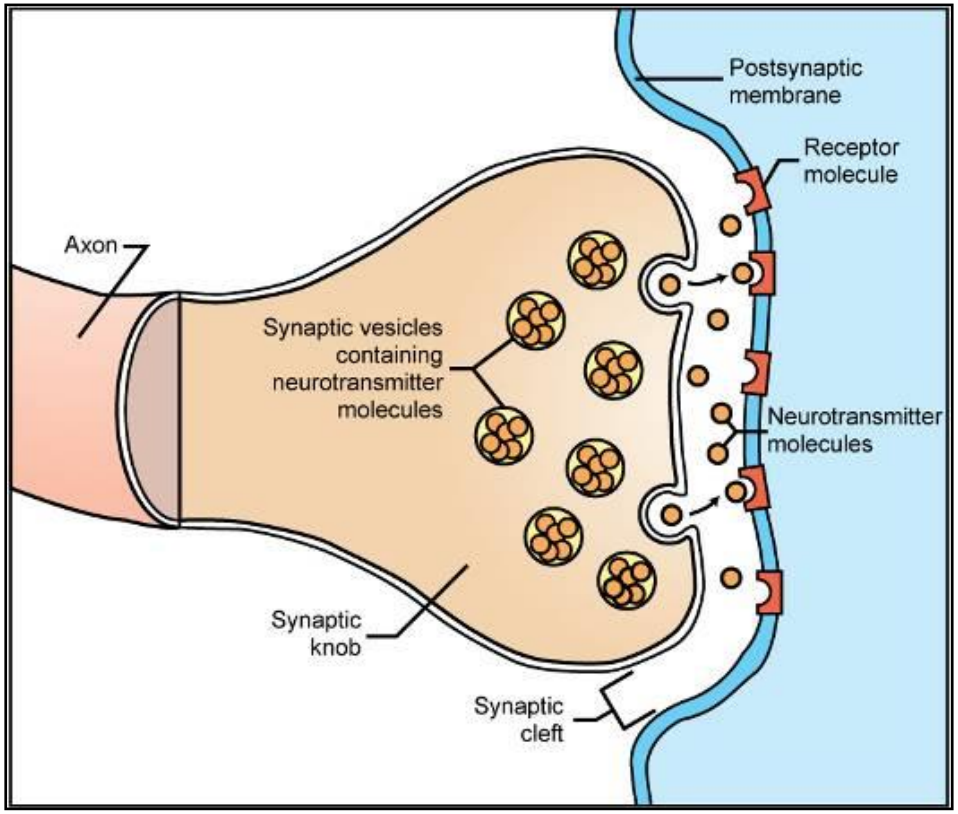
- Definitions
  - Space between two neurons
  - Space between neuron & target cell
- Synaptic cleft – gap between adjacent neurons
- Presynaptic neuron – neuron bringing nerve impulse (action potential) to synapse
  - Releases neurotransmitter
- Postsynaptic neuron – contains receptors for the neurotransmitter

Synapse Morphology

- Synaptic end bulb (synaptic knob) slightly enlarged bulb on each end of axon (nerve fiber)
- Vesicles in knob contain neurotransmitter
- When nerve impulse reaches synaptic knob
  - Vesicles fuse with knob's cell membrane
  - Dump neurotransmitter into synaptic cleft

Synaptic Transmission

- Neurotransmitters diffuse across synaptic cleft toward postsynaptic membrane
- Receptors on postsynaptic membrane bind neurotransmitter



Types of Neurotransmitters

- Excitatory neurotransmitters
  - Usually cause an influx of sodium so that postsynaptic membrane moves toward threshold
- Inhibitory neurotransmitters
  - Move charge within postsynaptic cell farther away from threshold

Specific Neurotransmitters

- Acetylcholine
  - Either excitatory or inhibitory depending on location in body
- Catecholamines
  - Norepinephrine & epinephrine – associated with "fight or flight" reactions of sympathetic nervous system
  - Dopamine – involved with autonomic functions and muscle control
- Gamma-aminobutyric acid (GABA), serotonin, glycine & endorphins – generally all inhibitory

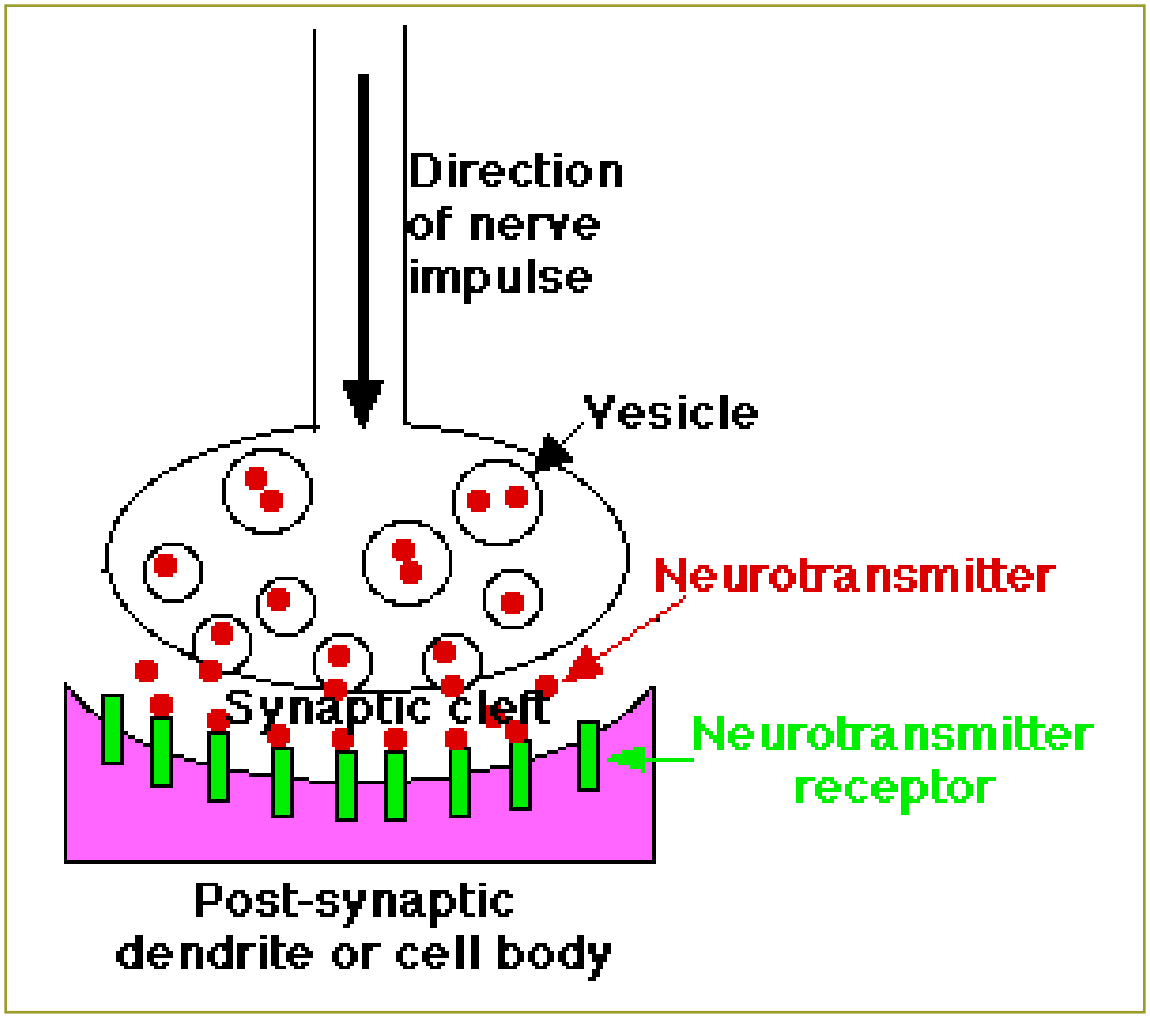
Table 8.2 Neurotransmitters

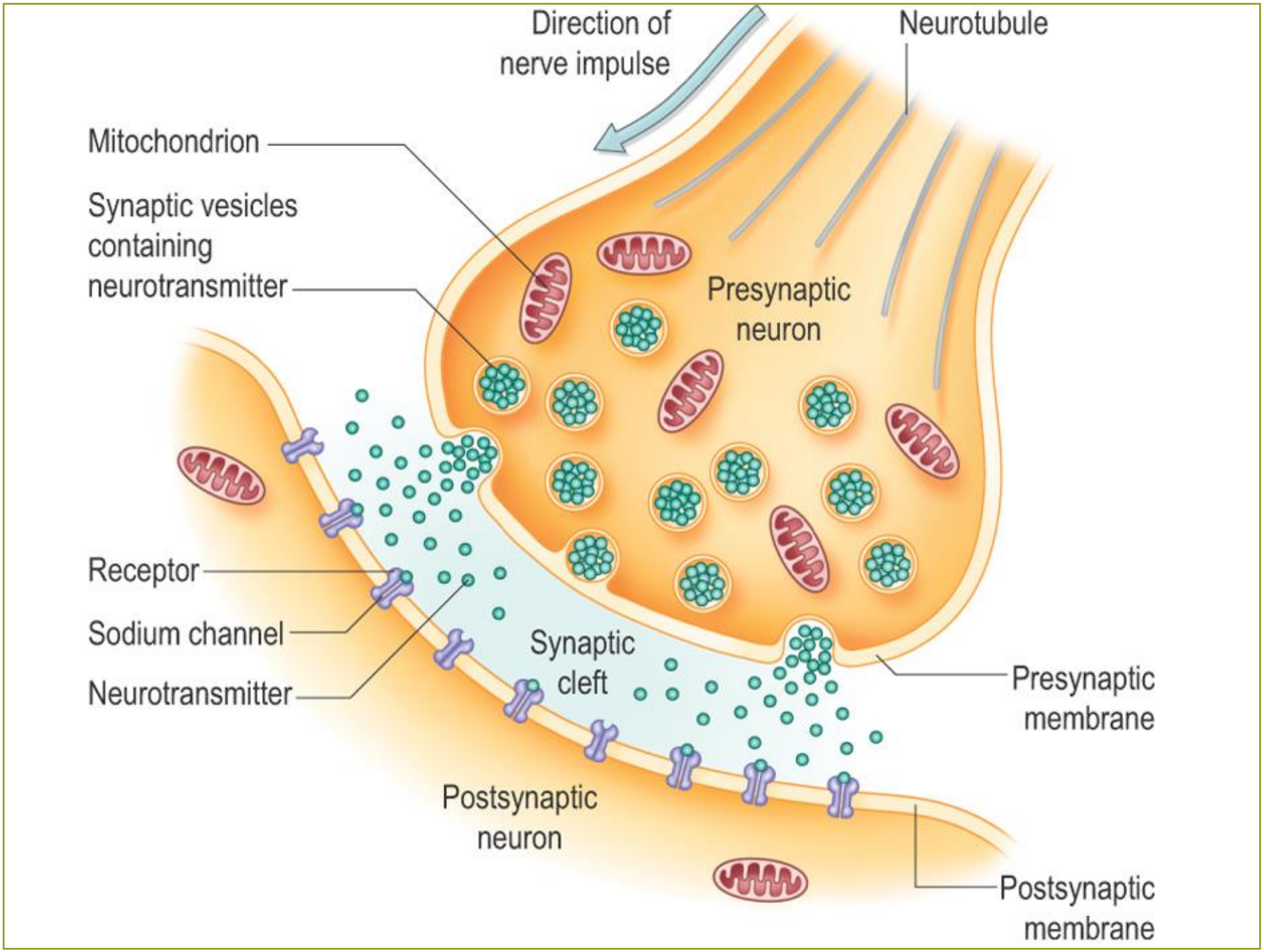
Substance	Location	Effect	Clinical Example
Acetylcholine	Many nuclei scattered throughout the brain and spinal cord. Nerve tracts from the nuclei extend to many areas of the brain and spinal cord. Also found in the neuromuscular junction of skeletal muscle and many ANS synapses.	Excitatory or inhibitory	Alzheimer's disease (a type of senile dementia) is associated with a decrease in acetylcholine-secreting neurons. Myasthenia gravis (weakness of skeletal muscles) results from a reduction in acetylcholine receptors.
Norepinephrine	A small number of small-sized nuclei in the brainstem. Nerve tracts extend from the nuclei to many areas of the brain and spinal cord. Also in some ANS synapses.	Excitatory or inhibitory	Cocaine and amphetamines increase the release and block the reuptake of norepinephrine, resulting in overstimulation of postsynaptic neurons.
Serotonin	A small number of small-sized nuclei in the brainstem. Nerve tracts extend from the nuclei to many areas of the brain and spinal cord.	Generally inhibitory	Involved with mood, anxiety, and sleep induction. Levels of serotonin are elevated in schizophrenia (delusions, hallucinations, and withdrawal).
Dopamine	Confined to a small number of nuclei and nerve tracts. Distribution is more restricted than that of norepinephrine or serotonin. Also found in some ANS synapses.	Generally excitatory	Parkinson's disease (depression of voluntary motor control) results from destruction of dopamine-secreting neurons. Drugs used to increase dopamine production induce vomiting and schizophrenia.
Gamma-aminobutyric acid (GABA)	GABA-secreting neurons mostly control activities in their own area and are not usually involved with transmission from one part of the CNS to another. Most neurons of the CNS have GABA receptors.	Generally inhibitory	Drugs that increase GABA function have been used to treat epilepsy (excessive discharge of neurons).
Glycine	Spinal cord and brain. Like GABA, glycine predominantly produces local effects.	Generally inhibitory	Glycine receptors are inhibited by the poison strychnine. Strychnine increases the excitability of certain neurons by blocking their inhibition. Strychnine poisoning results in powerful muscle contractions and convulsions. Tetanus of respiratory muscles can cause death.
Endorphins	Widely distributed in the CNS and PNS.	Generally inhibitory	The opiates morphine and heroin bind to endorphin receptors on presynaptic neurons and reduce pain by blocking the release of a neurotransmitter.

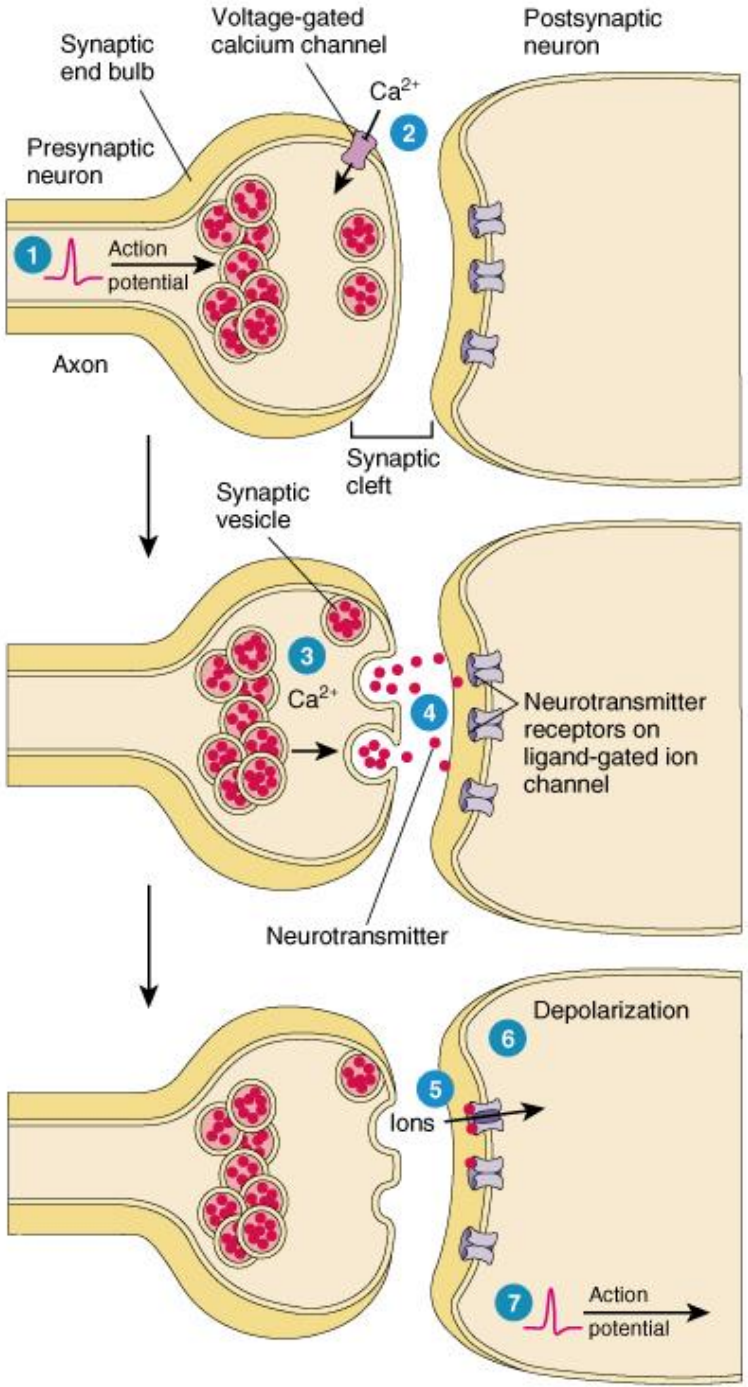
Recycling Neurotransmitter

- Acetylcholinesterase
  - Found on postsynaptic membrane
  - Breaks down acetylcholine
- Monoamine oxidase (MAO)
  - Breaks down norepinephrine

Synapse Review

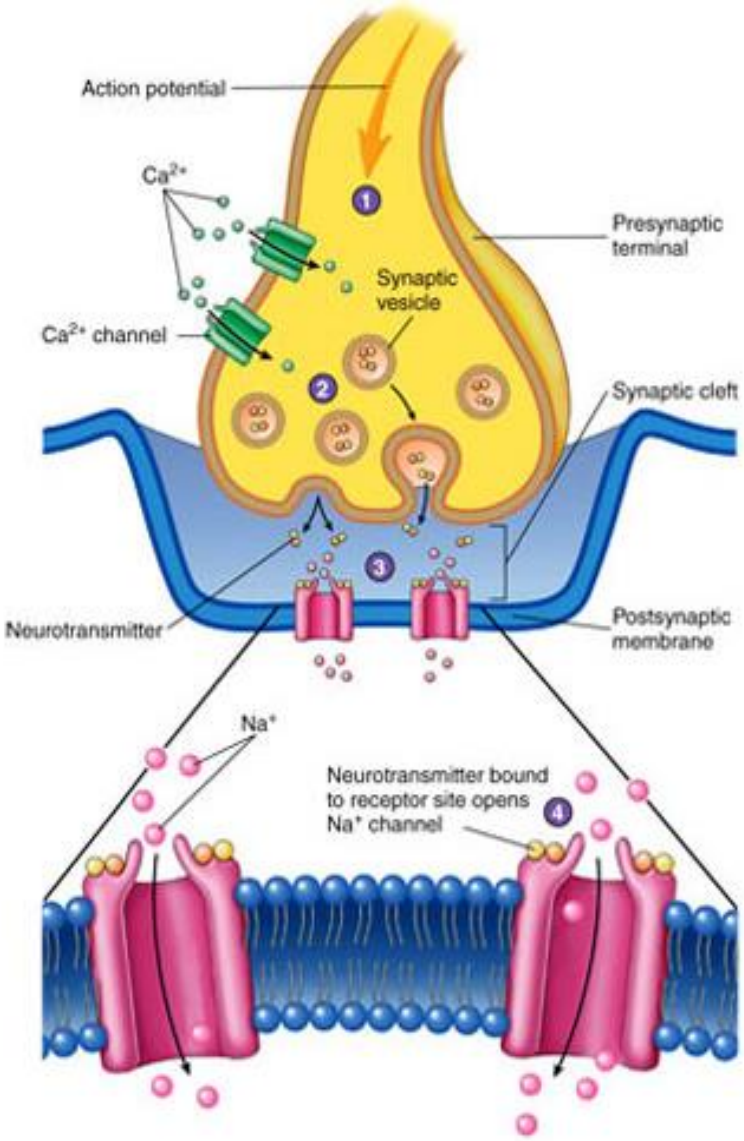



Direction of nerve impulse
Neurotubule
Mitochondrion
Synaptic vesicles containing neurotransmitter
Presynaptic neuron
Receptor
Sodium channel
Neurotransmitter
Synaptic cleft
Presynaptic membrane
Postsynaptic neuron
Postsynaptic membrane

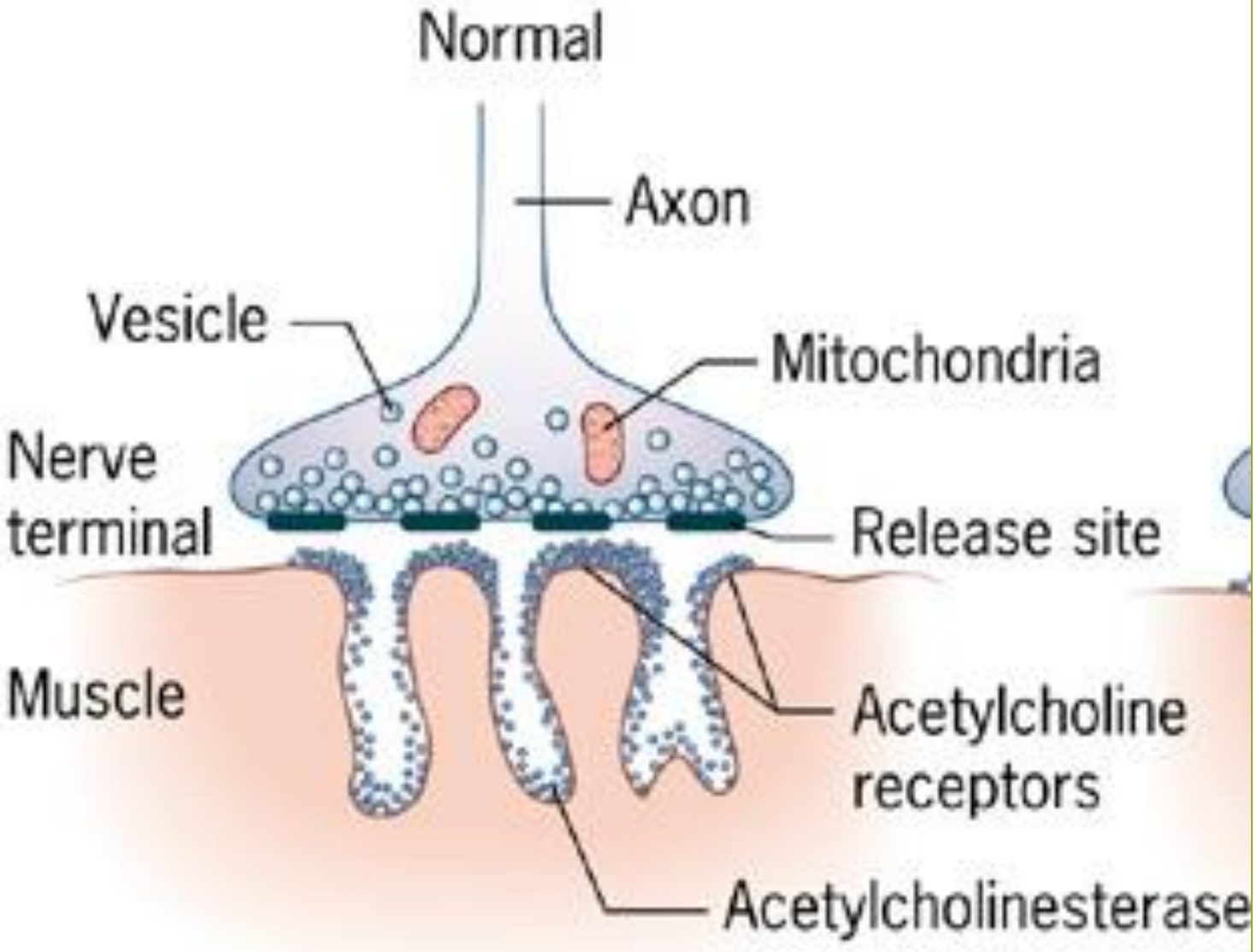


Pharmacology

- How many of the drugs work in the animal's body



1. Action potentials arriving at the presynaptic terminal cause Ca^{2+} channels to open.
2. Ca^{2+} diffuse into the cell and cause synaptic vesicles to release neurotransmitter molecules.
3. Neurotransmitter molecules diffuse from the presynaptic terminal across the synaptic cleft.
4. Neurotransmitter molecules combine with their receptor sites and cause Na^+ channels to open. Na^+ diffuse into the cell (*shown in illustration*) or out of the cell (*not shown*) and cause a change in membrane potential.


Normal
Axon
Vesicle
Mitochondria
Nerve terminal
Release site
Muscle
Acetylcholine receptors
Acetylcholinesterase

Neurons & Nerves

- Types of neurons
  - Sensory neurons
  - Motor neurons
  - Interneurons
- Types of nerves
  - Sensory (afferent)
  - Motor (efferent)
  - Mixed

Direction of Impulses

- Afferent (Sensory) Nerves
  - 100% sensory neurons
  - Conduct impulses toward CNS
- Efferent (Motor) Nerves
  - 100% motor neurons
  - Conduct impulses away from CNS
- Mixed Nerves
  - Both sensory & motor neurons
- Nerve Tracts
  - Bundles of axons in CNS
  - Sensory, motor, or both

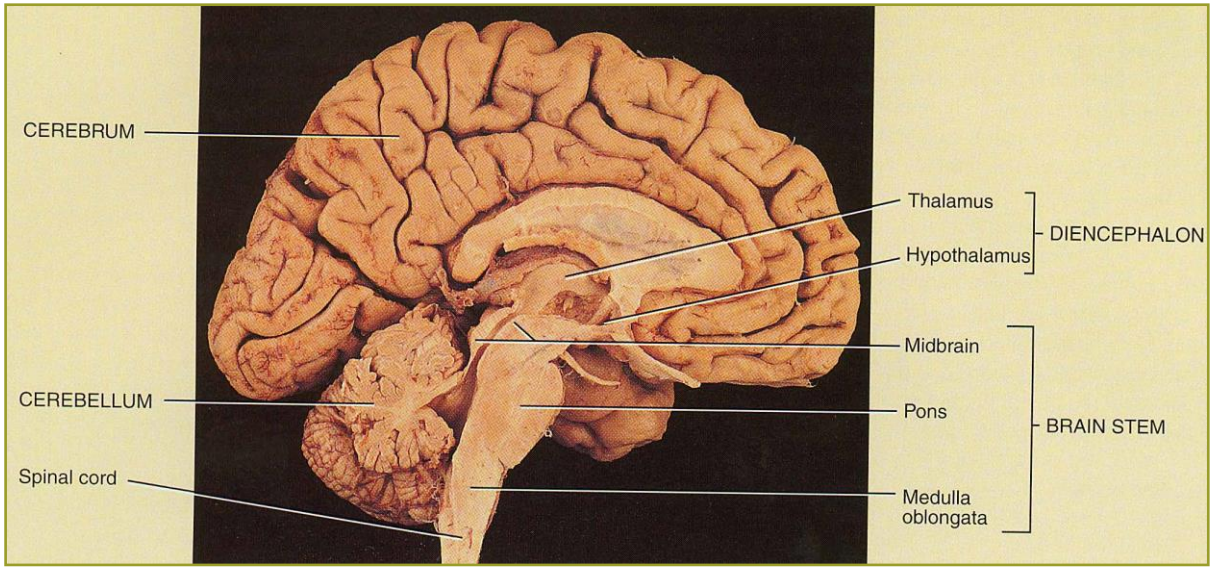
Central Nervous System (CNS)

Brain

Spinal Cord

The Brain

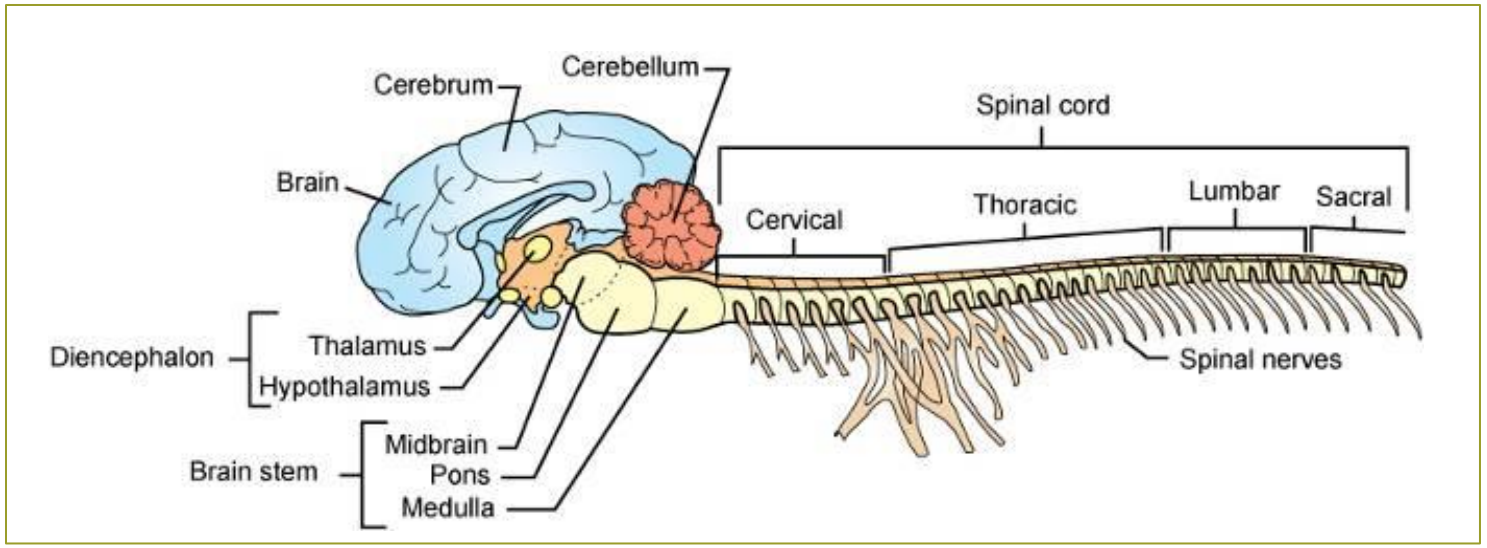
- Cerebrum
- Cerebellum
- Diencephalon
- Brain stem



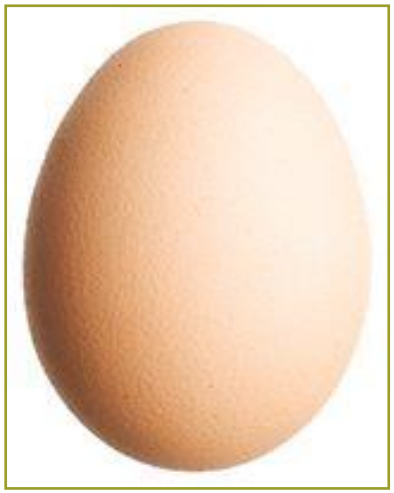
Mammal Brain

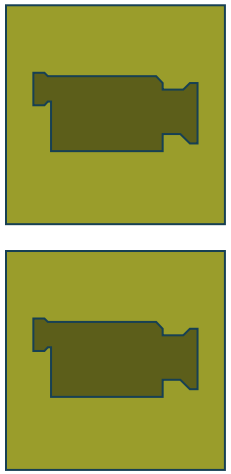
Figure 13-8, Page 324

- Cerebrum
- Cerebellum
- Diencephalon
- Brain stem

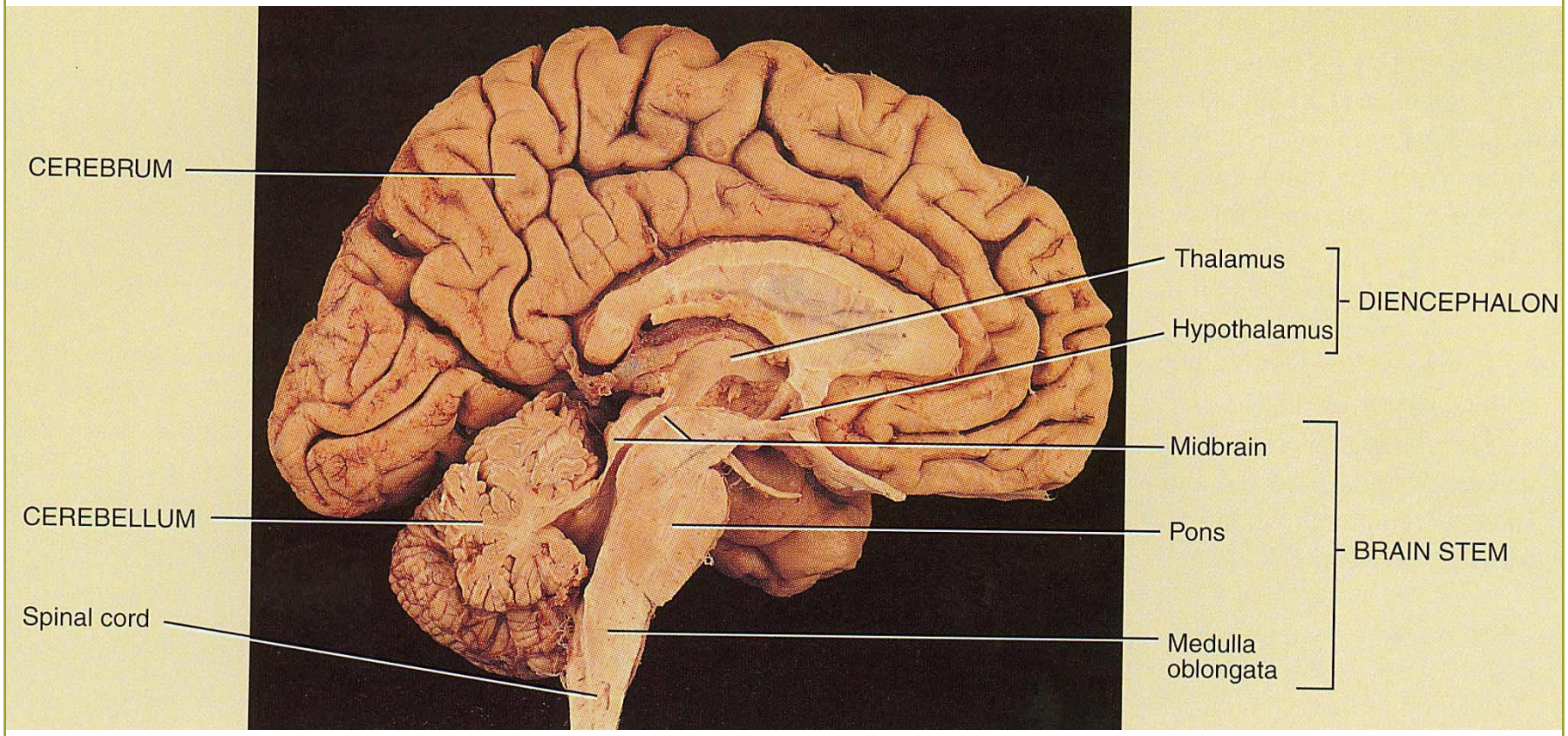


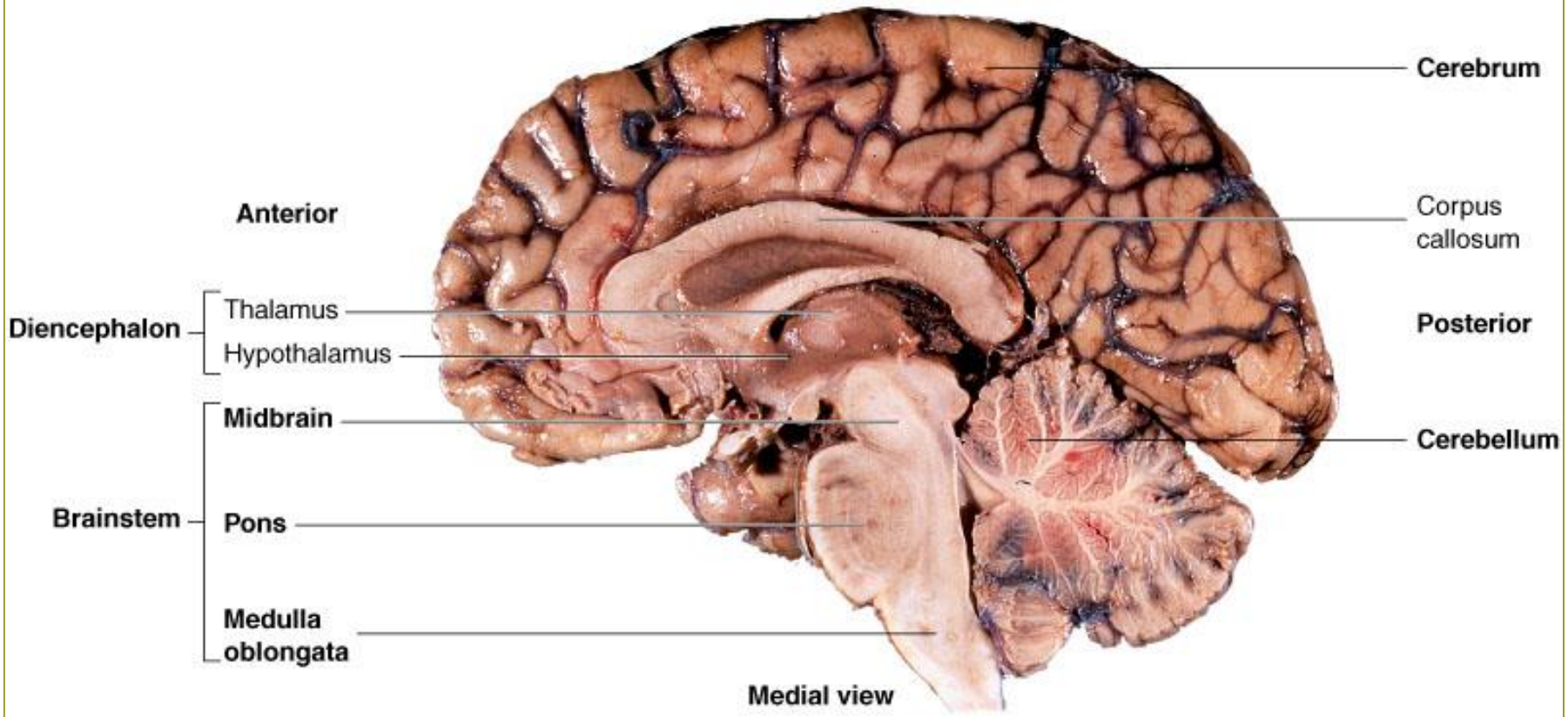
This Is Your Brain……..





Are Dogs Smart?


CEREBRUM
CEREBELLUM
Spinal cord
Thalamus
Hypothalamus
Midbrain
Pons
Medulla oblongata
DIENCEPHALON
BRAIN STEM



Sheep Brain

Bassert Lab Manual, Page 305

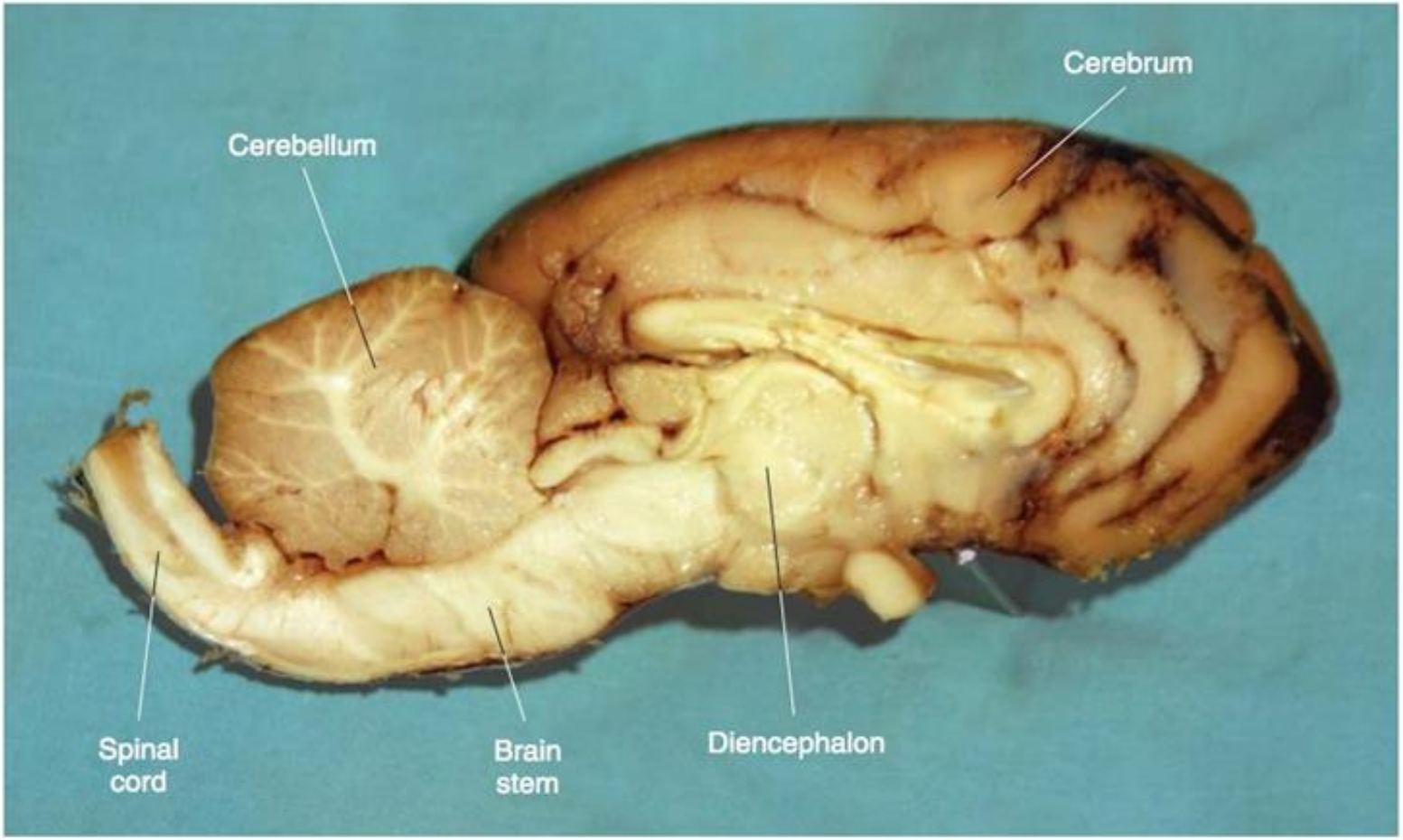


Figure 11-6 Sagittal View of a Sheep Brain.

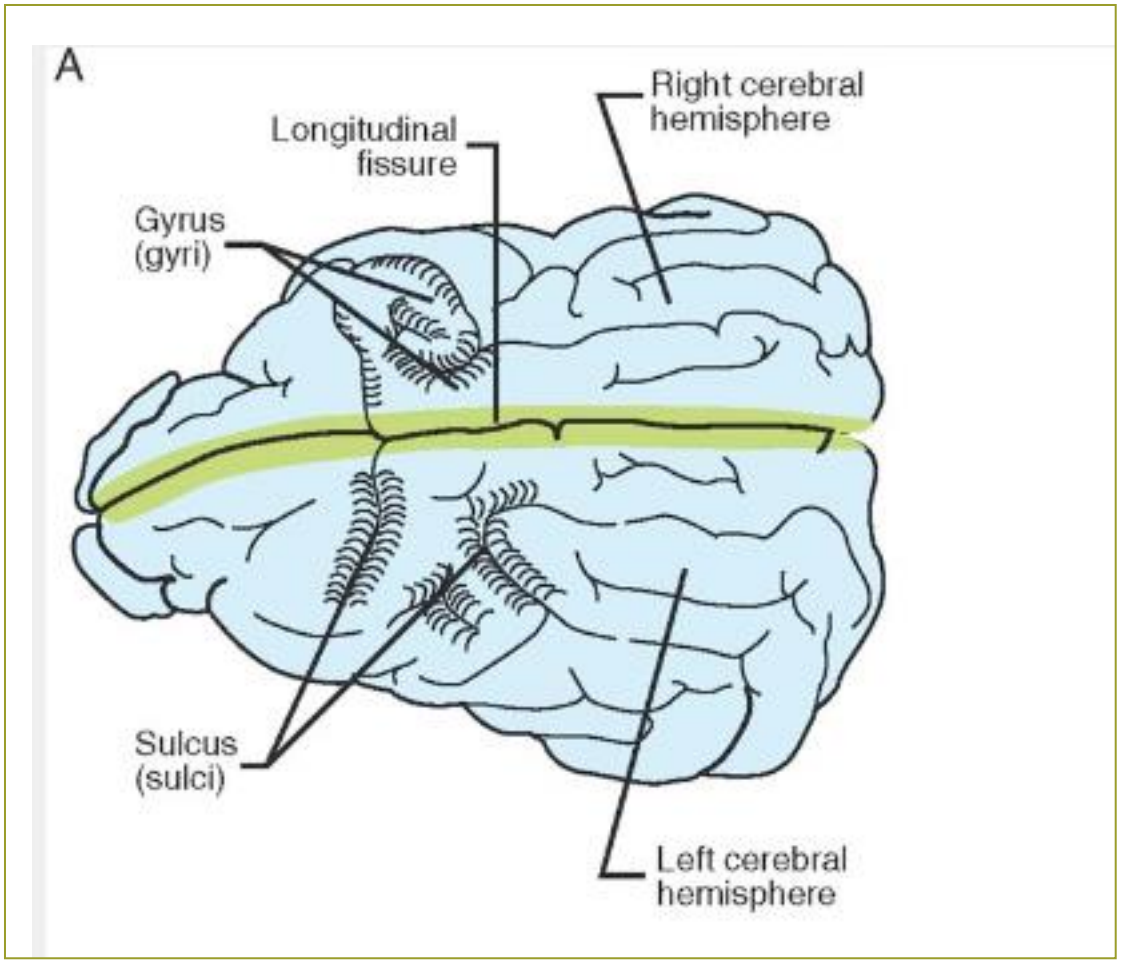
Cerebrum, Cerebellum

- Cerebrum
  - Hemispheres
  - Site for major thought processes, emotions
- Cerebellum
  - Muscle coordination
  - Balance

Cerebrum

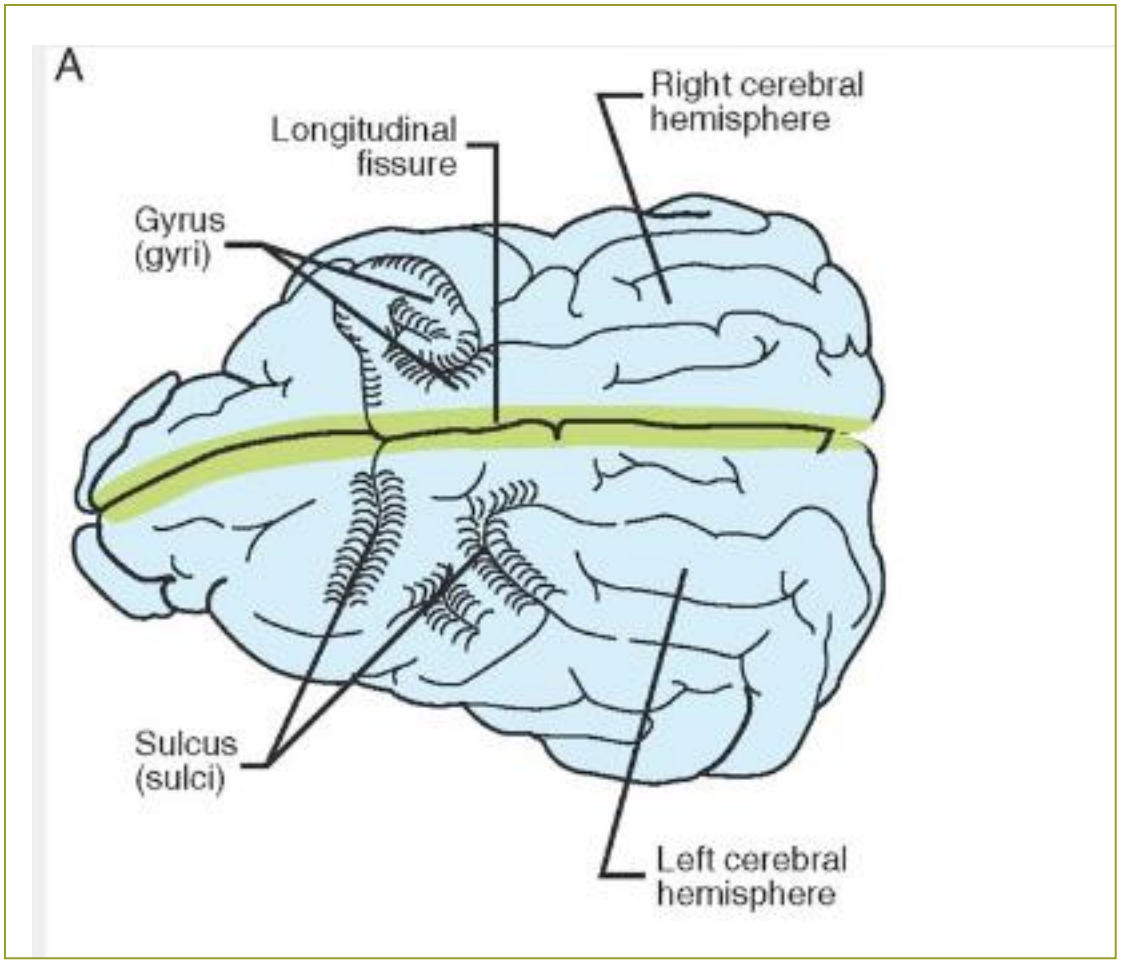
Figure 13-9A, Page 325

- Sulci (sulcus)
  - Shallow grooves separating gyri
- Gyri (gyrus)
  - Folds (bumps) in cerebral hemispheres



Cerebrum

- Fissures
  - Deep grooves separating gyri
- Longitudinal fissure
  - Prominent groove
  - Divides cerebrum into right and left cerebral hemispheres

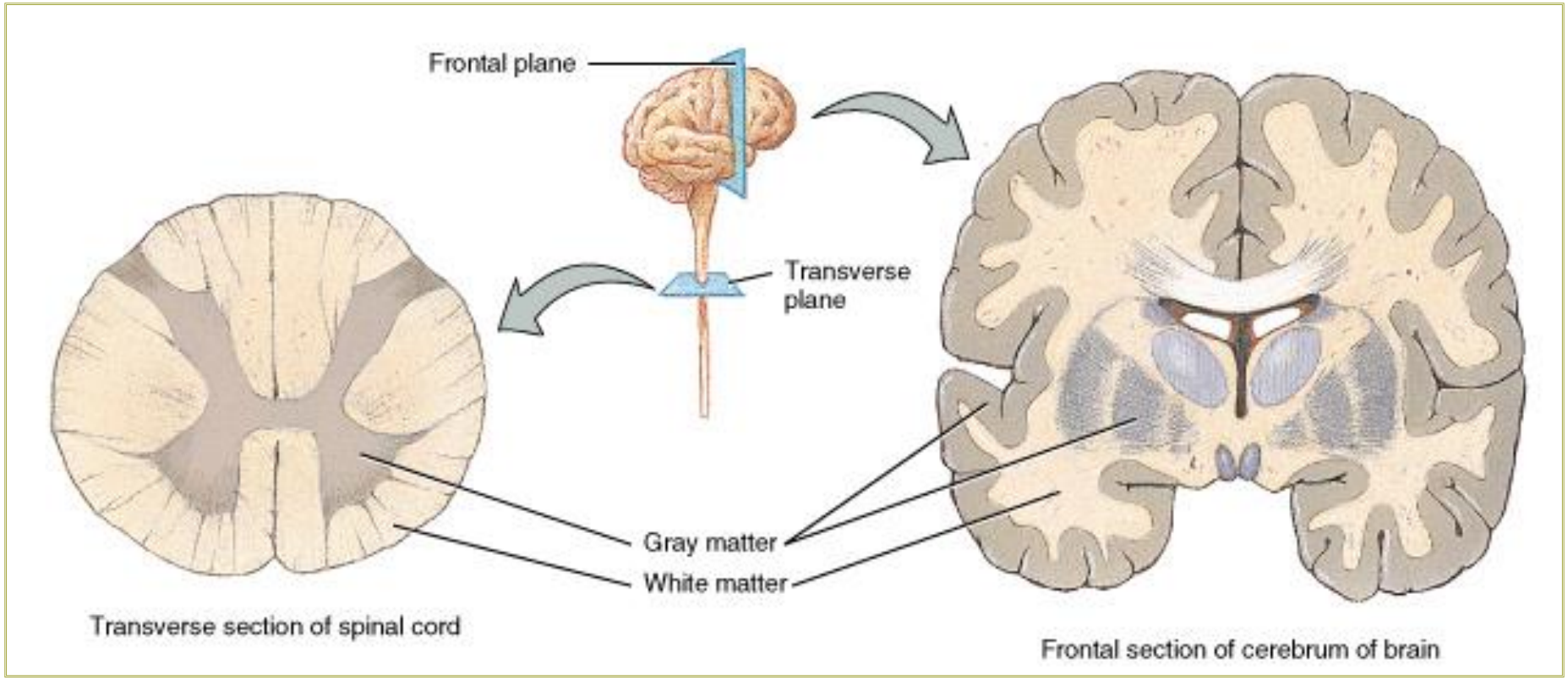


Cerebrum

- Gray matter
  - Cerebral cortex
  - Outer layer of brain
- White matter
  - Fibers beneath cortex and corpus callosum
  - Fibers that connect two hemispheres of cerebral cortex
- Area of brain responsible for higher-order behaviors (learning, intelligence, awareness, etc.)

Gray & White Matter

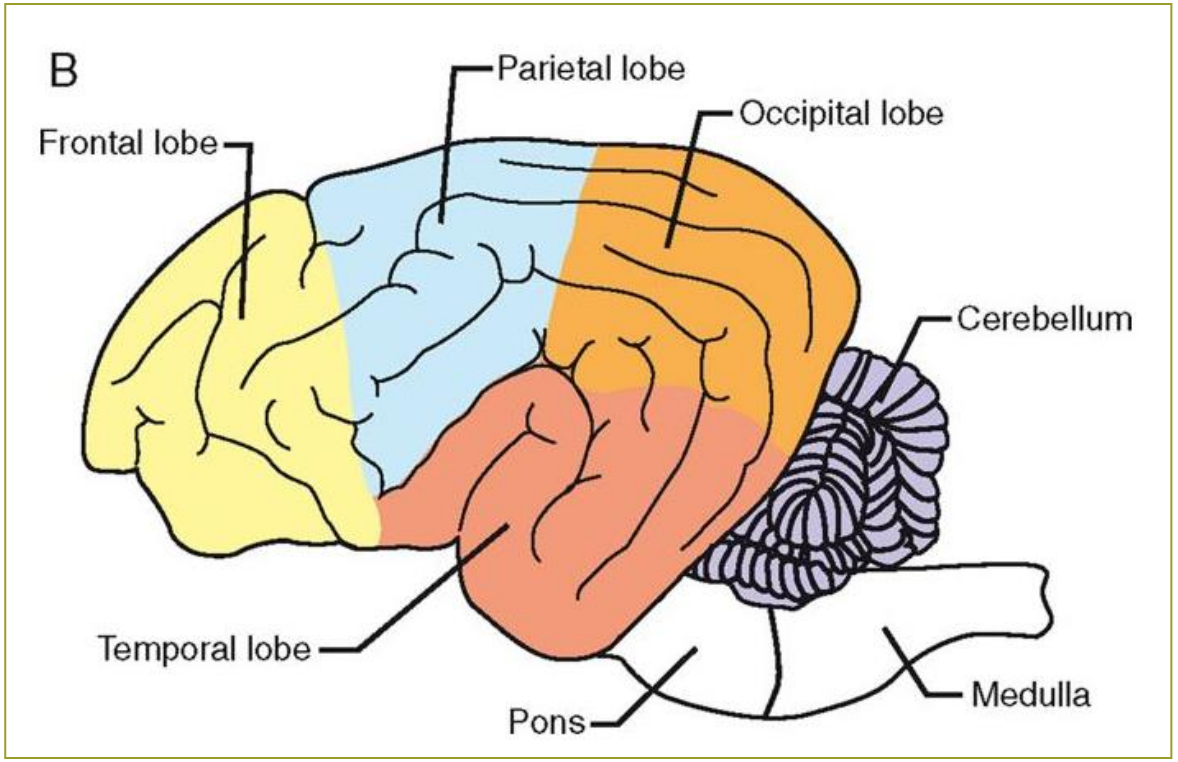
- Found in brain & spinal cord



Cerebellum

Figure 13-9B, Page 325

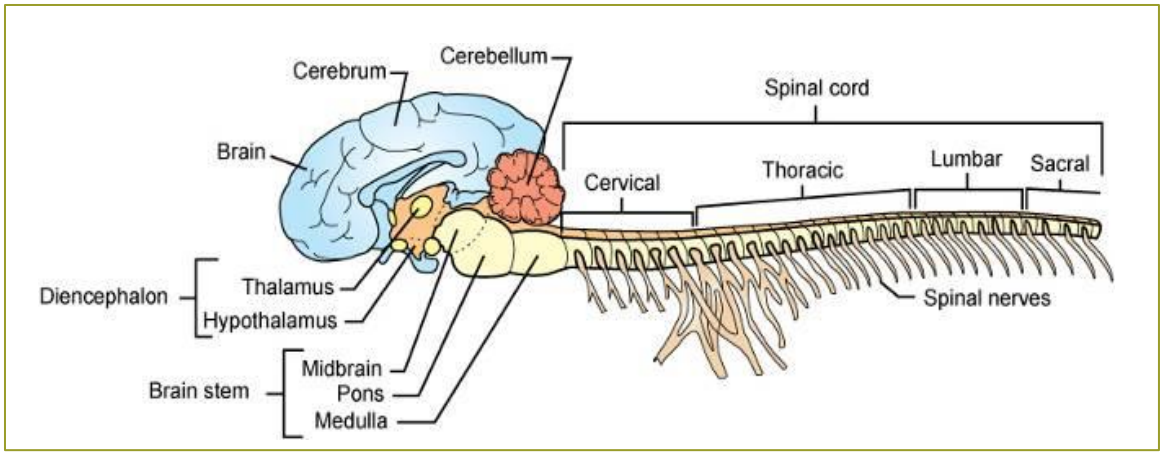
- Caudal to cerebrum
- Area of brain responsible for coordinated movement, balance, posture



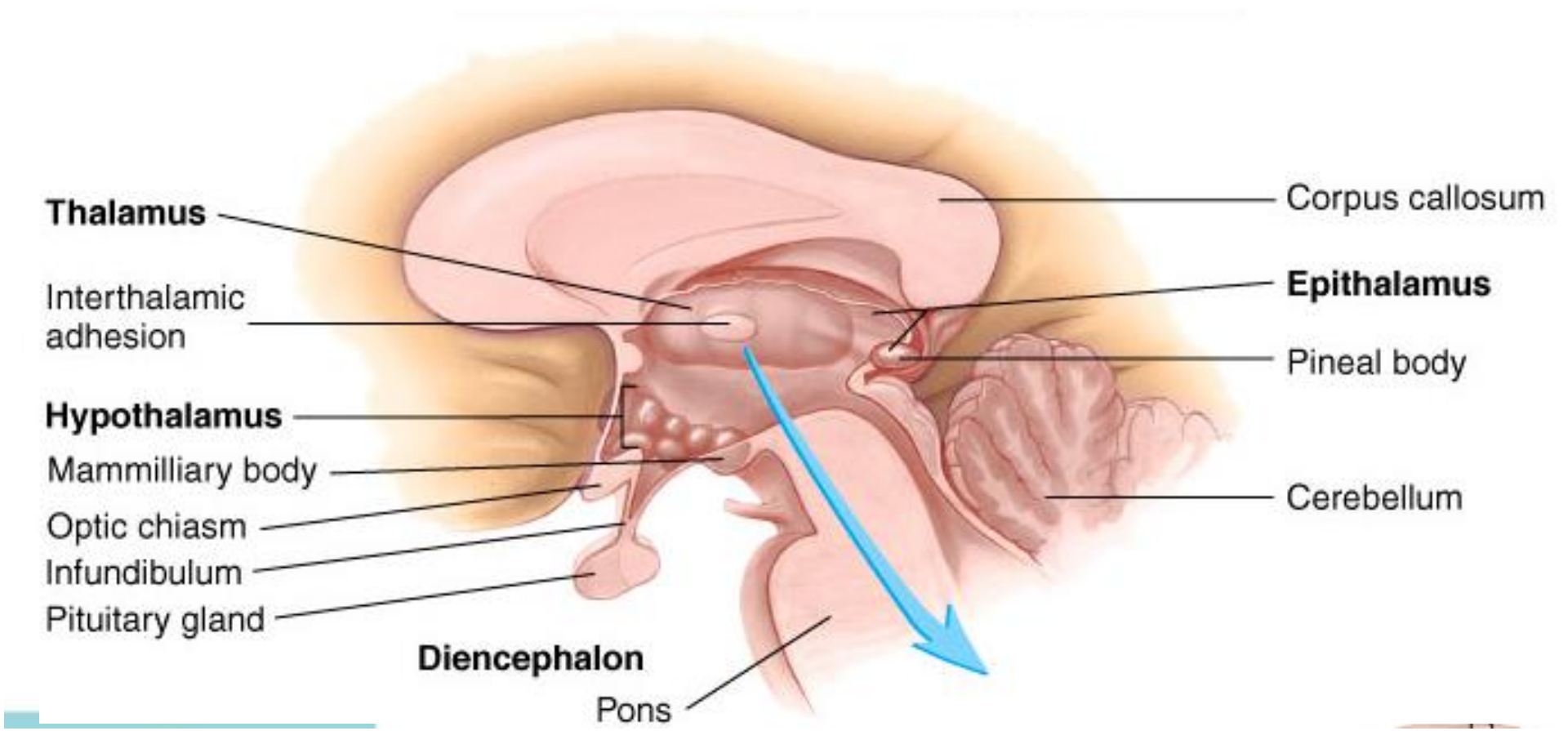
Diencephalon, Brain Stem

Figure 13-8, Page 324

- Diencephalon
  - Thalamus
  - Hypothalamus
  - Pituitary gland
- Brain stem
  - Medulla oblongata
  - Pons



Secret of Life!!!



Brain Stem

- Connection between rest of brain and spinal cord
- Composed of medulla oblongata, pons, and midbrain
- Area of brain responsible for basic support functions of body
- Many of cranial nerves originate from this area of brain

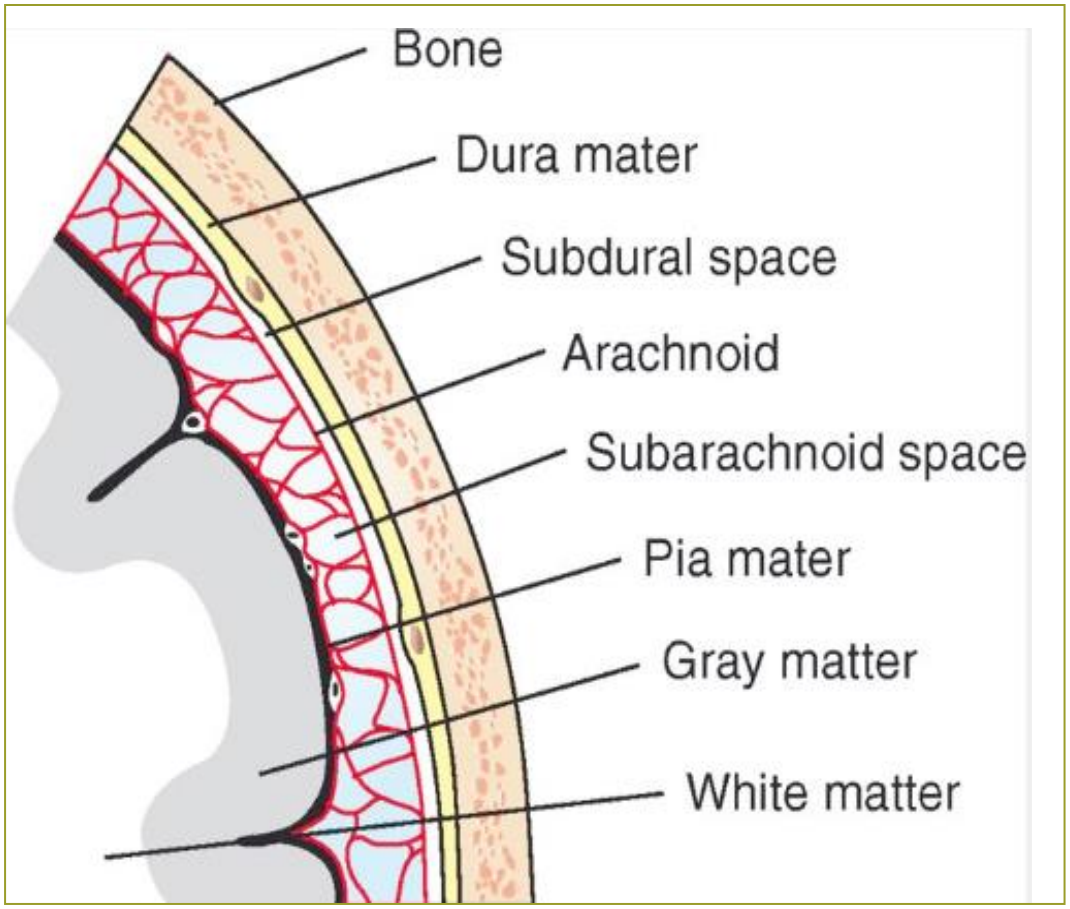
Meninges

- Connective tissue layers that surround brain and spinal cord
- Contain blood vessels, fluid, and fat
  - Supply nutrients and oxygen to superficial tissues of brain and spinal cord
  - Provide some cushioning and distribution of nutrients for the CNS

Meninges – Three Layers

Figure 13-10, Page 326

- Dura mater
  - Tough, fibrous
- Arachnoid
  - Delicate
  - Spiderweb-like
- Pia mater
  - Very thin
  - Lies directly on surface of brain and spinal cord



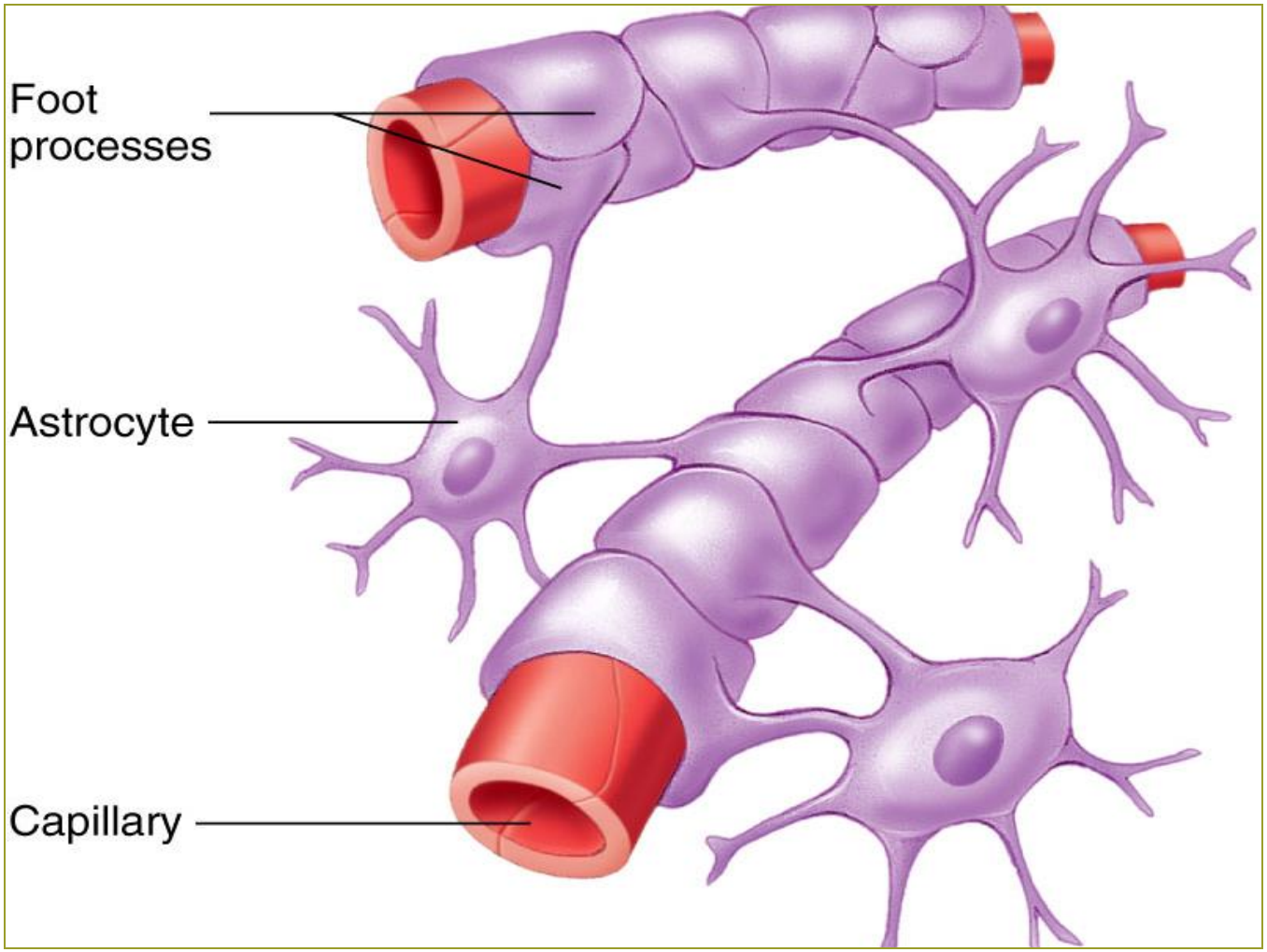
Cerebrospinal Fluid

- Where?
  - Between layers of the meninges
  - In canals and ventricles inside the brain
  - Central canal of spinal cord
- Provides cushioning function
- May play role in regulation of autonomic functions such as respiration and vomiting

Blood-Brain Barrier

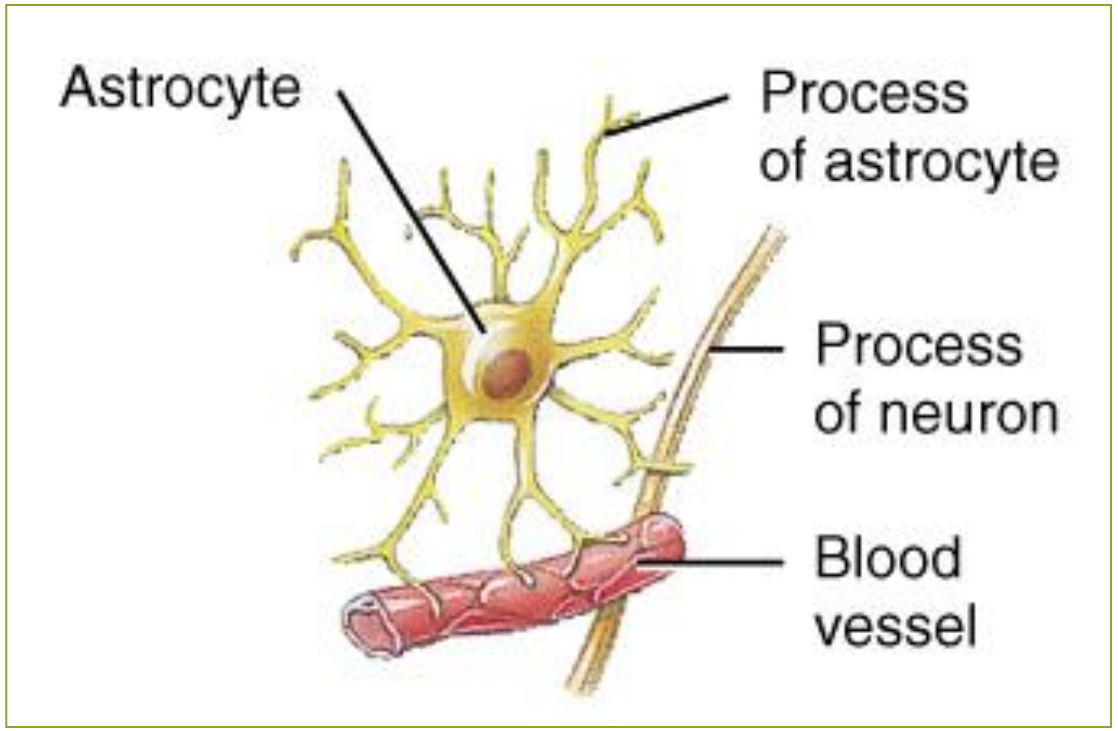
- Separates the capillaries in brain from nervous tissue
- Capillary walls in brain have no fenestrations
  - Covered by cell membranes of glial cells
- Prevents many drugs, proteins, ions, and other molecules from readily passing from blood into brain

Blood-Brain Barrier



Astrocytes

- Star-shaped cells (neuroglia)
- Form blood-brain barrier by covering blood capillaries



Clinical Applications

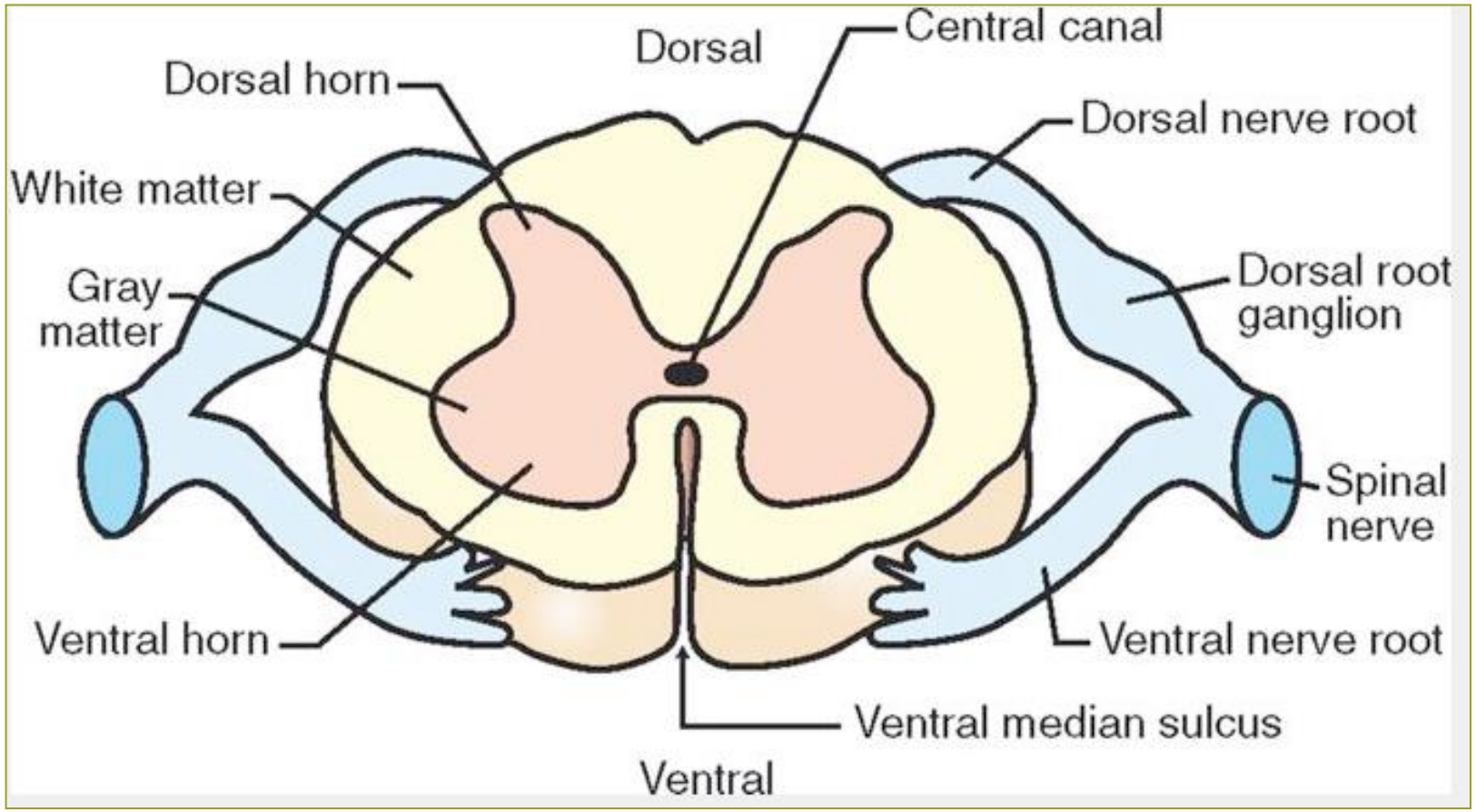
- Local Anesthetics (Page 320)
  - Lidocaine
- Poisons That Affect the Nervous System (Page 323)
  - Insecticides
  - Rodenticides
  - Poisonous Plants
- Epidural Anesthesia and Myelograms (Page 326)

Spinal Cord

- Gray, white matter
- Spinal tracts
  - Ascending
  - Descending
- Spinal nerves – all mixed

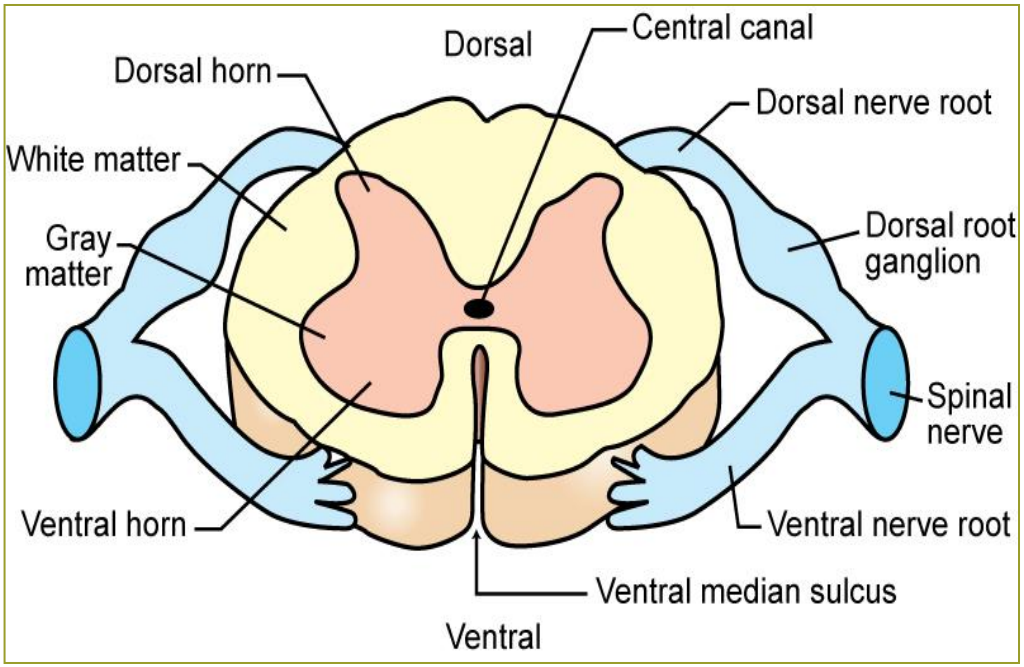
Spinal Cord Anatomy

Figure 13-11, Page 328



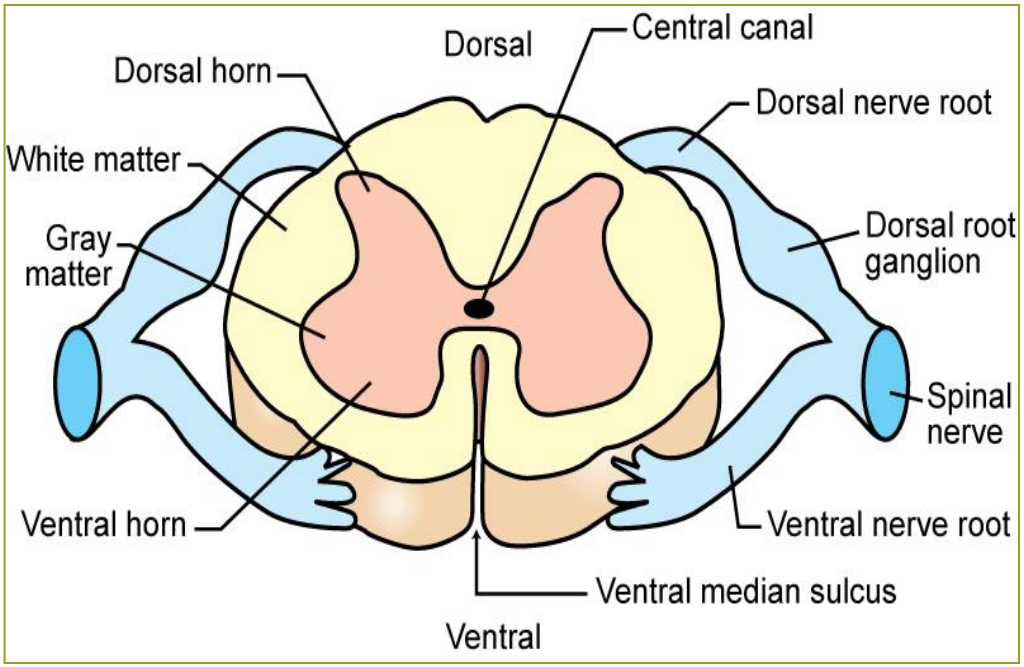
Spinal Cord Anatomy

- Cortex – white matter surrounds gray matter
- Dorsal and ventral nerve roots of spinal nerves
  - Emerge from between each pair of adjacent vertebrae



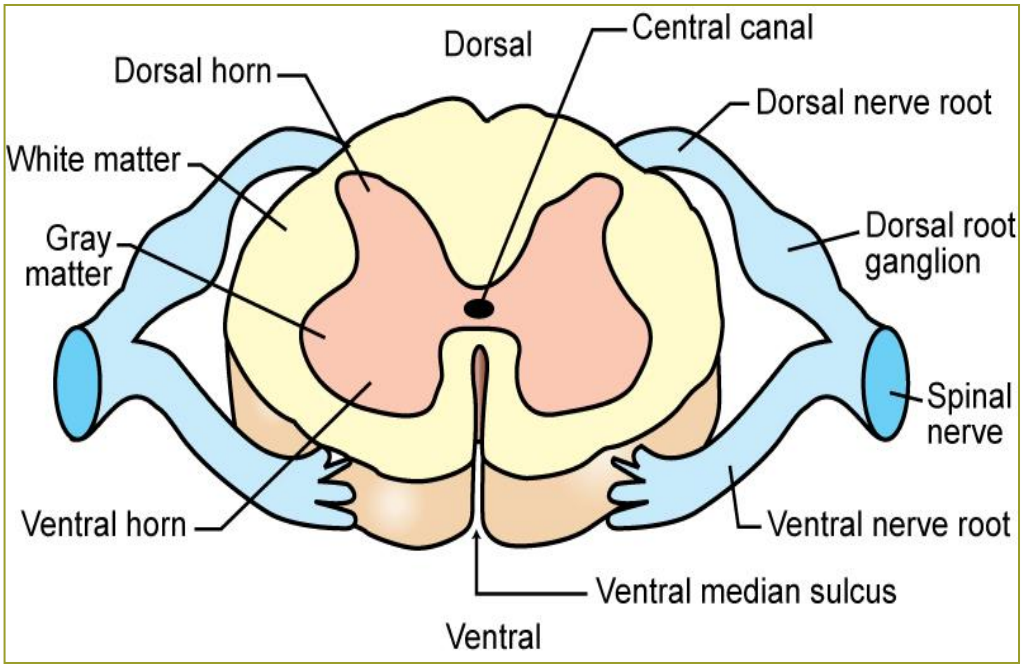
Spinal Nerve Anatomy

- Dorsal nerve roots contain sensory fibers
  - Dorsal root ganglion
- Ventral nerve roots contain motor fibers



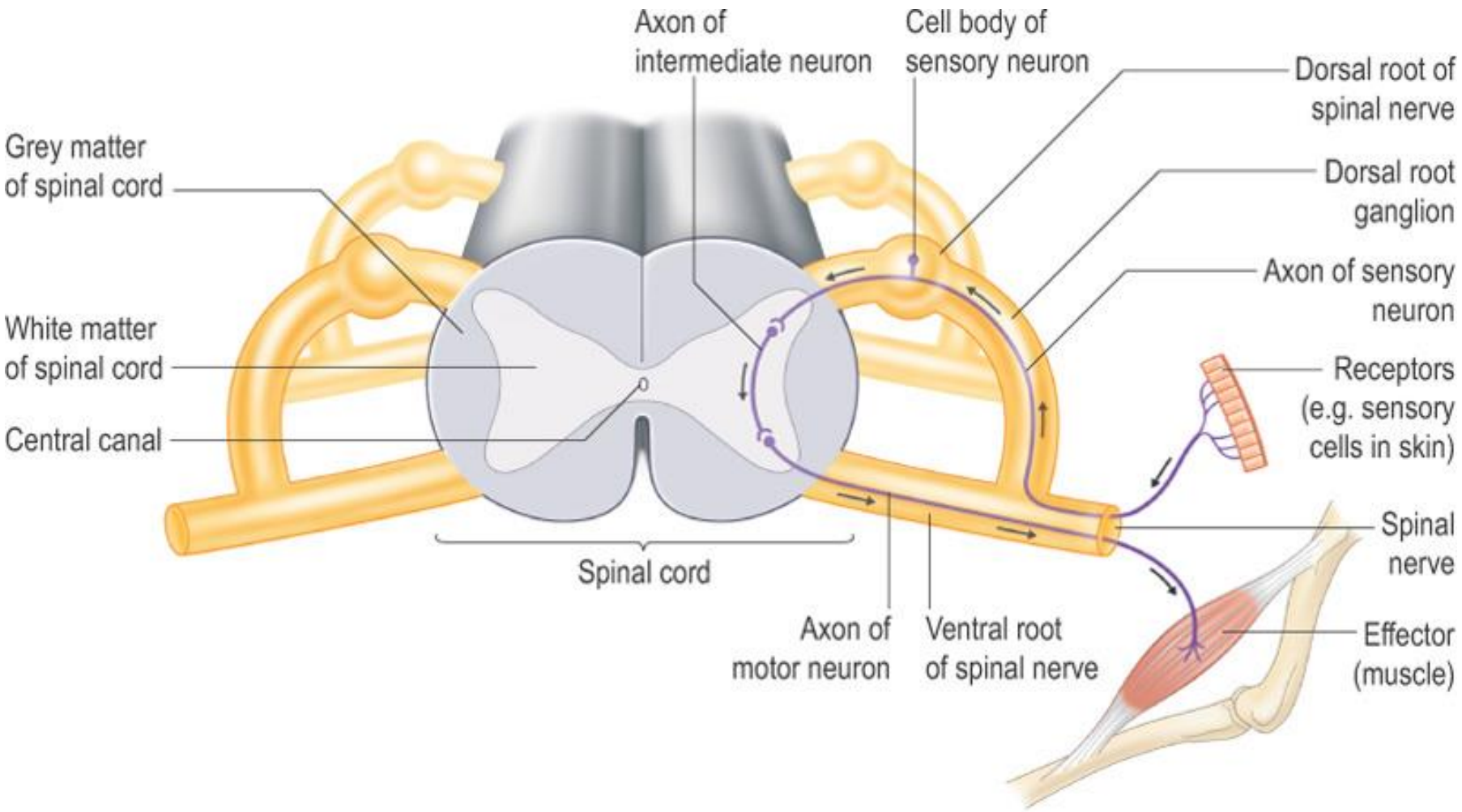
Spinal Cord Anatomy

- Medulla – central part of spinal cord (butterfly)
  - Composed of gray matter
  - Central canal – center of medulla



Spinal Cord Gray Matter

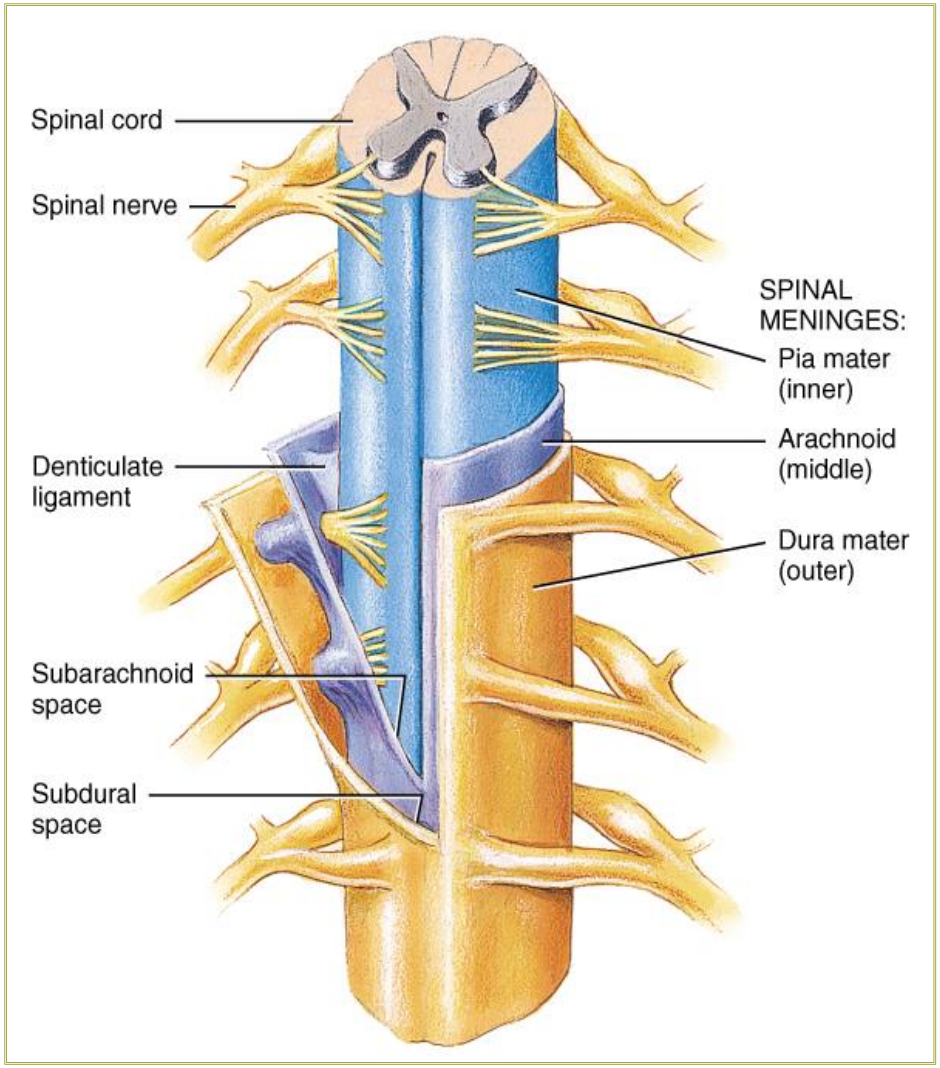
- Dorsal horns
  - Neurons in gray matter that forward sensory (afferent) nerve impulses to brain or other parts of spinal cord
- Ventral horns
  - Neurons in gray matter that forward motor (efferent) nerve impulses to spinal nerves

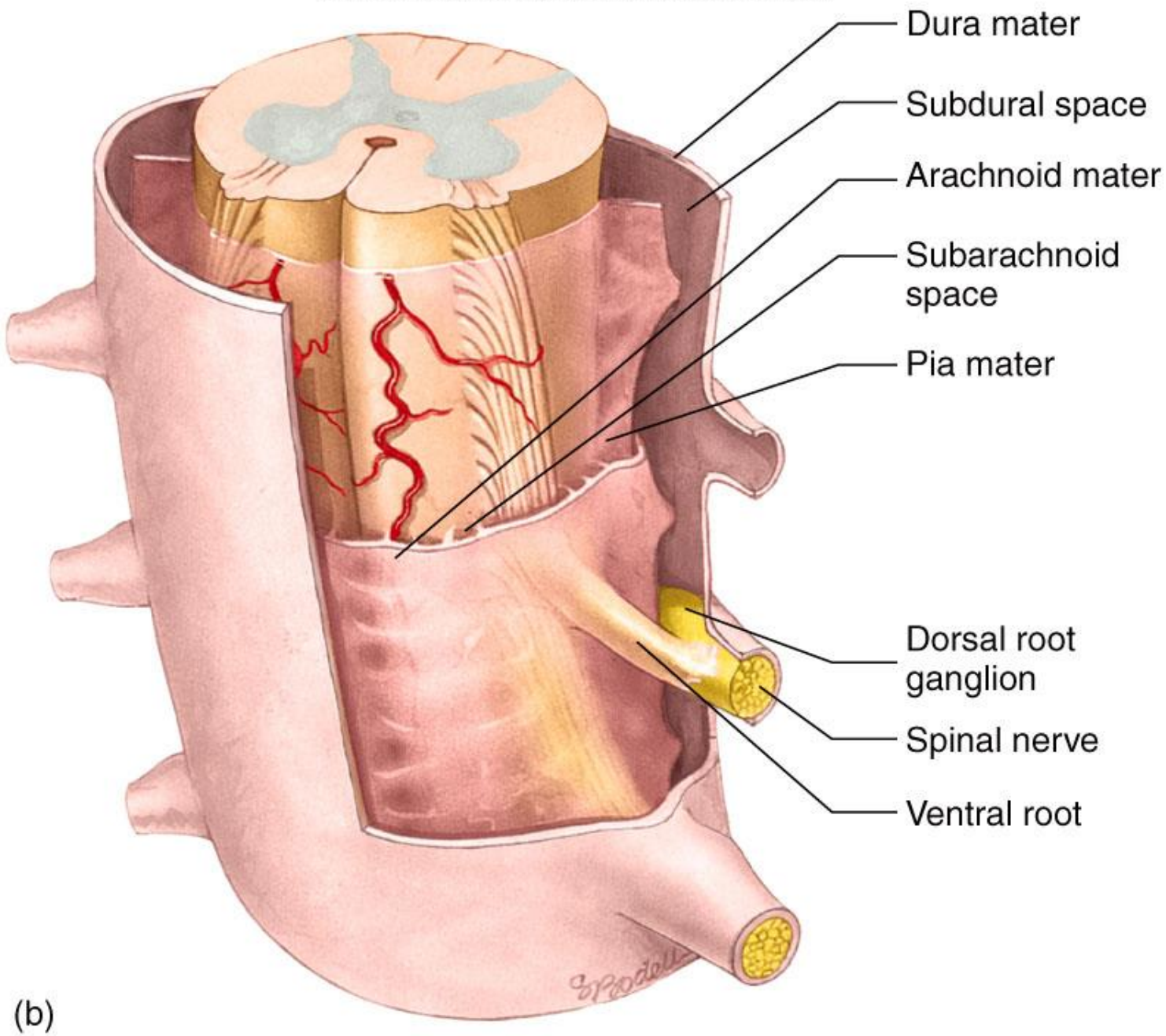


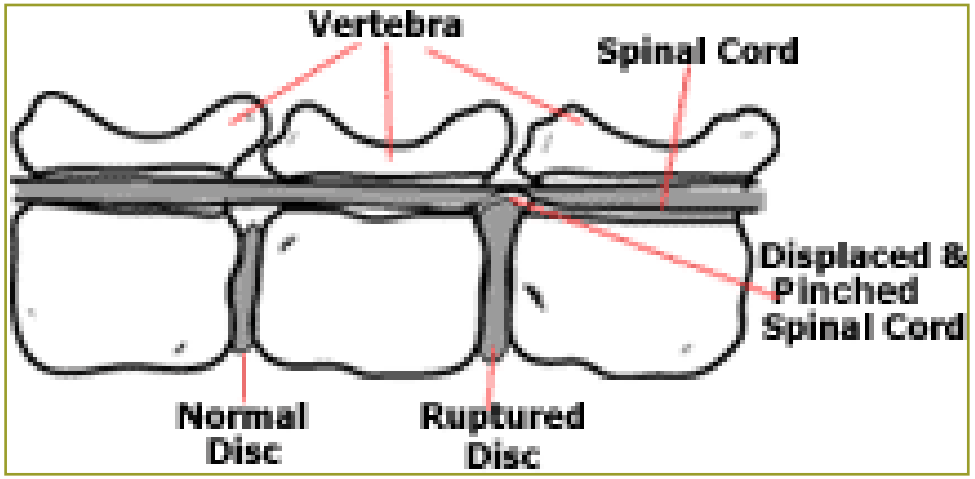
Spinal Cord Meninges

- Epidural space
- Dura mater
- Subdural space
- Arachnoid mater
- Subarachnoid space
- Pia mater

- Cerebrospinal fluid
  - CSF






Vertebra
Spinal Cord
Displaced &
Pinched
Spinal Cord
Normal
Disc
Ruptured
Disc

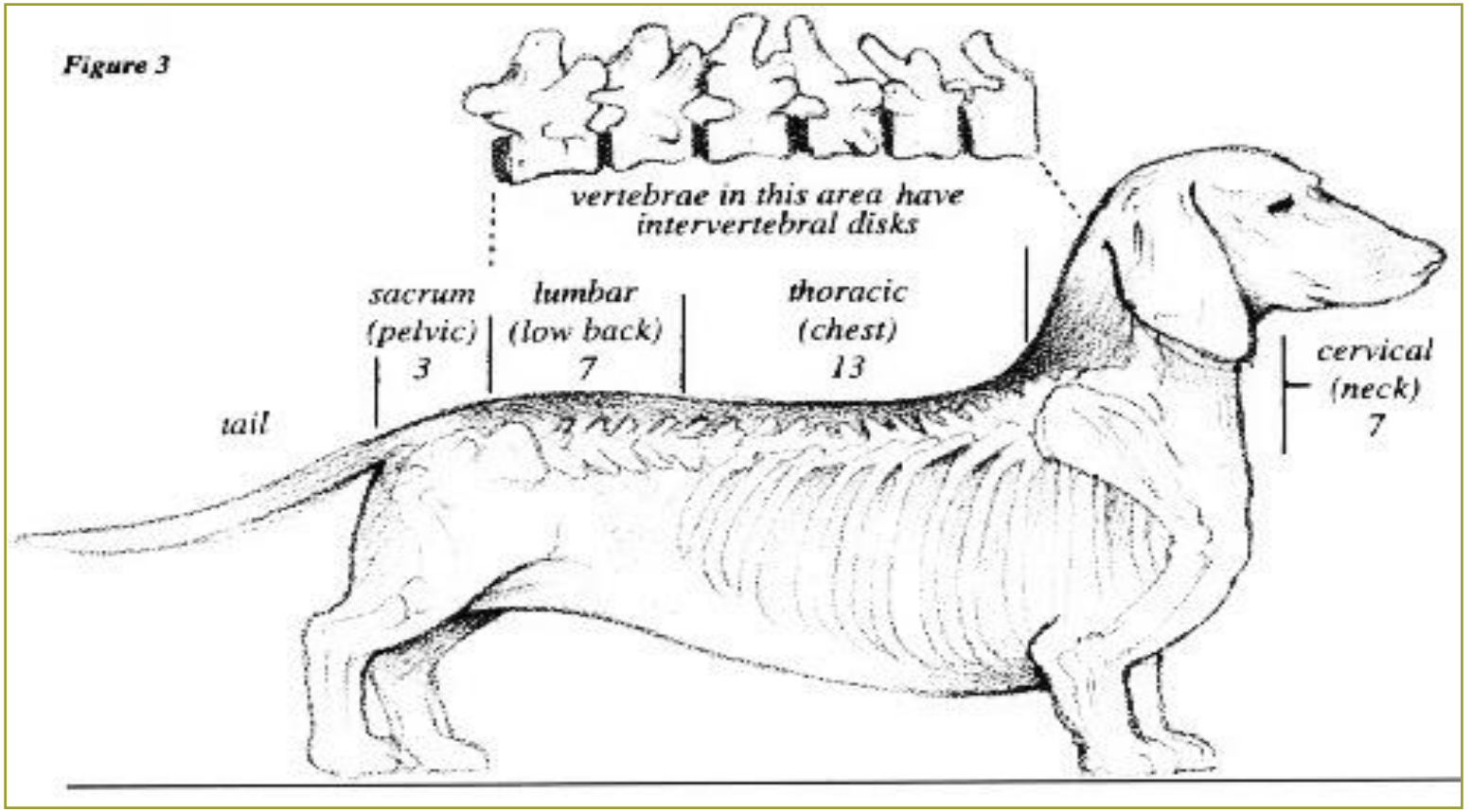


Figure 3
vertebrae in this area have
intervertebral disks
sacrum
(pelvic)
3
lumbar
(low back)
7
thoracic
(chest)
13
cervical
(neck)
7
tail

Peripheral Nervous System (PNS)

Cranial Nerves

Spinal Nerves

Autonomic Nervous System (ANS)

Peripheral Nervous System

- Cranial nerves – from brain
- Spinal nerves – from spinal cord
- Autonomic nervous system (ANS)
  - From spinal cord
  - Sympathetic division
  - Parasympathetic division

Cranial Nerves

Tables 13-1 & 13-2, Page 327 & 328

- 12 nerve pairs in PNS that originate directly from the brain
  - Roman numerals, from anterior to posterior
- Each nerve may contain axons of motor neurons, axons of sensory neurons, or combinations of both
- Know nerve & number (mnemonics)

Mnemonics, What's THAT? ☺

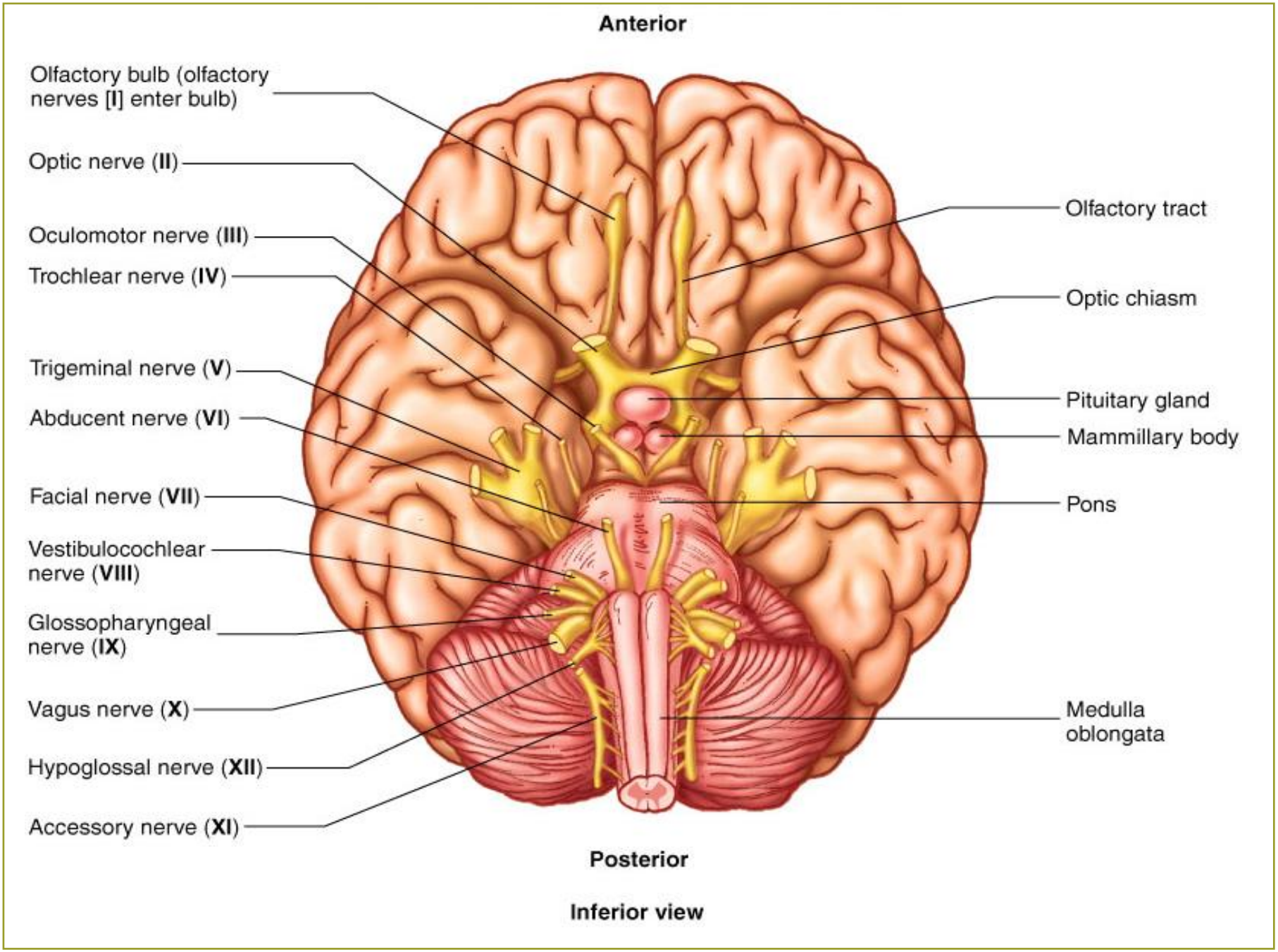
Knuckle mnemonic for the number of days in each month of the Gregorian Calendar. Each projecting knuckle represents a 31-day month.

Mnemonics for Cranial Nerve Names

Table 13-2, Page 328

- On Old Olympus' Towering Top, A Fine Vocal German Viewed Some Hops
- Oh Once Our Tests Terminate, A Festive Very Good Vacation Seems Heavenly! ☺

Cranial Nerve	Nerve Name	Word of the Saying	Type of Nerve	Word of the Saying
I	Olfactory	On	Sensory	Six
II	Optic	old	Sensory	sailors
III	Oculomotor	Olympus'	Motor	made
IV	Trochlear	towering	Motor	merry,
V	Trigeminal	top,	Both sensory and motor	but
VI	Abducent	a	Motor	my
VII	Facial	fine,	Both sensory and motor	brother
VIII	Vestibulocochlear	vocal	Sensory	said,
IX	Glossopharyngeal	German	Both sensory and motor	"Bad
X	Vagus	viewed	Both sensory and motor	business,
XI	Spinal accessory	some	Motor	my
XII	Hypoglossal	hops.	Motor	man."


Anterior
Olfactory bulb (olfactory nerves [I] enter bulb)
Optic nerve (II)
Oculomotor nerve (III)
Trochlear nerve (IV)
Trigeminal nerve (V)
Abducent nerve (VI)
Facial nerve (VII)
Vestibulocochlear nerve (VIII)
Glossopharyngeal nerve (IX)
Vagus nerve (X)
Hypoglossal nerve (XII)
Accessory nerve (XI)
Olfactory tract
Optic chiasm
Pituitary gland
Mammillary body
Pons
Medulla oblongata
Posterior
Inferior view

Functions of the 12 Cranial Nerves

Table 13-1, Page 327

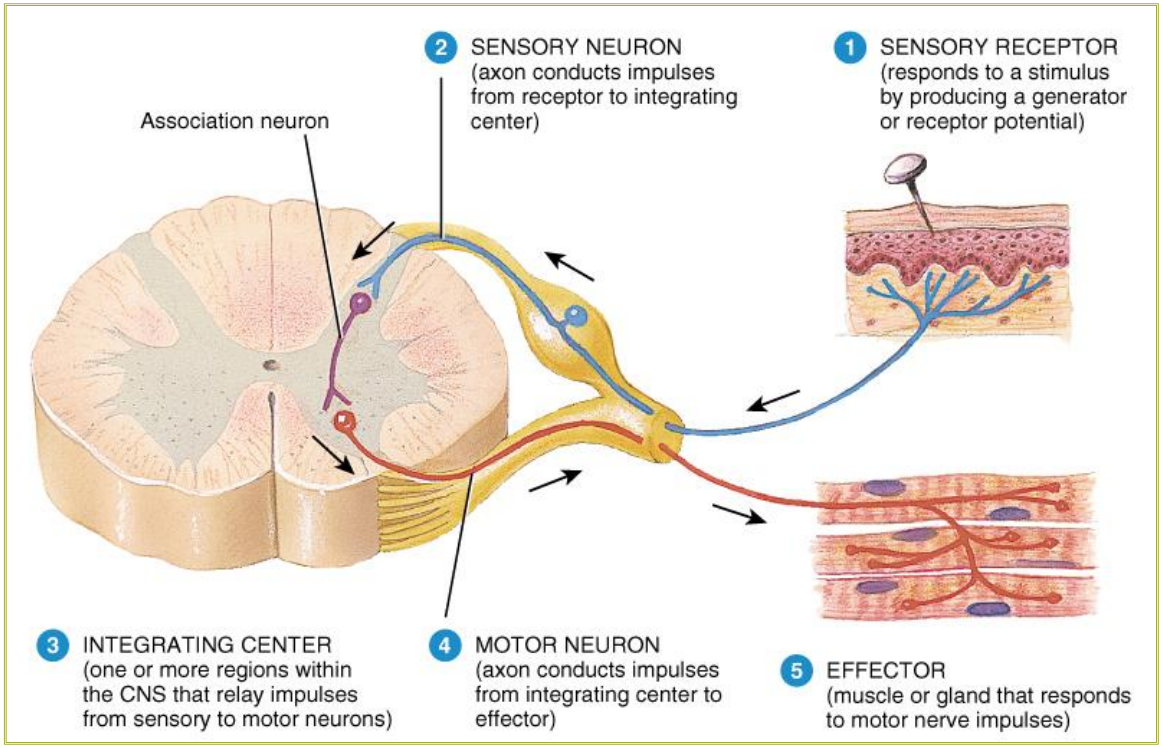
TABLE 13-1 Functions of the 12 Cranial Nerves

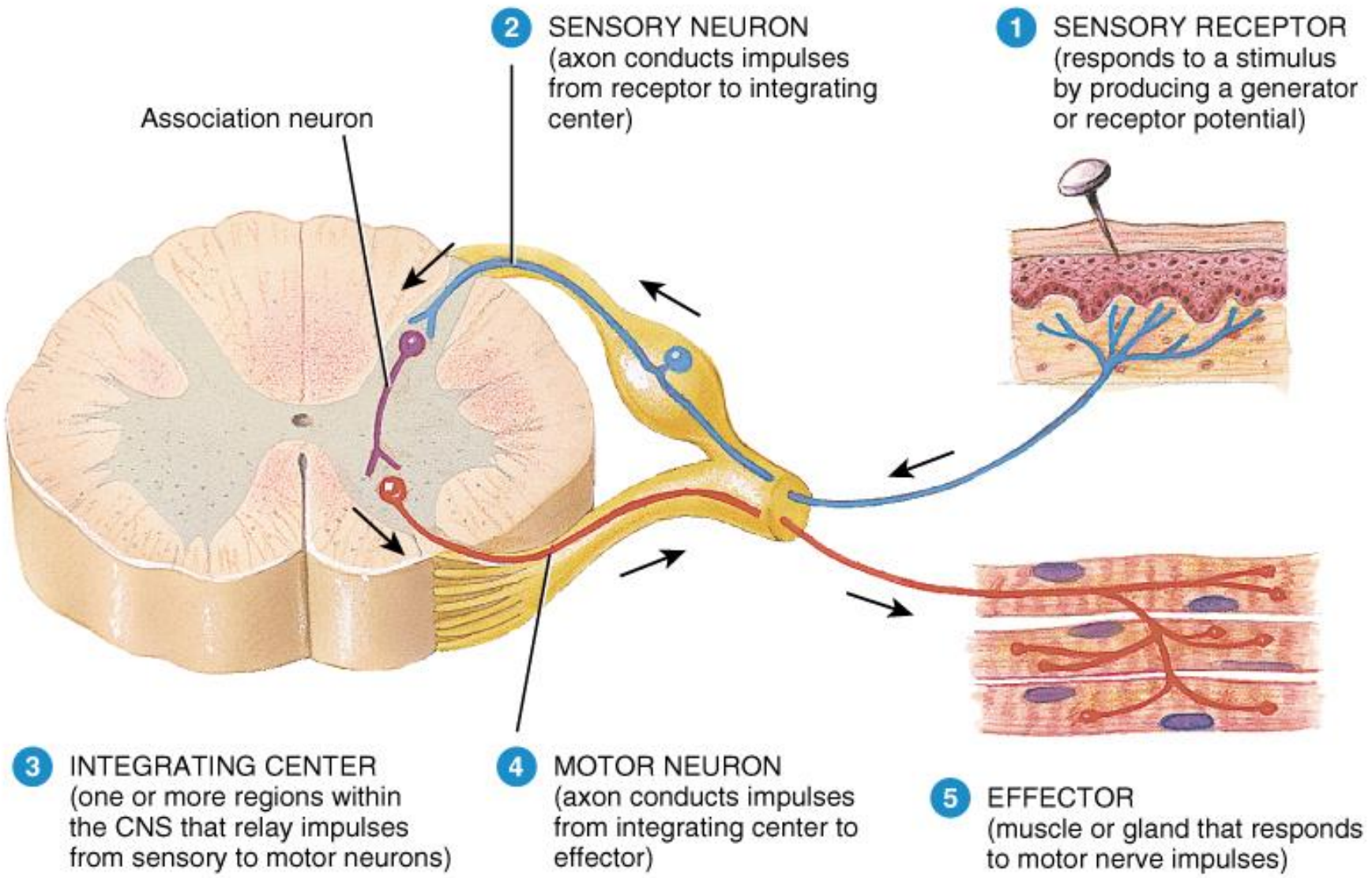
Number	Name	Type	Key Functions
I	Olfactory	Sensory	Smell
II	Optic	Sensory	Vision
III	Oculomotor	Motor	Eye movement, pupil size, focusing lens
IV	Trochlear	Motor	Eye movement
V	Trigeminal	Both sensory and motor	Sensations from the head and teeth, chewing
VI	Abducent	Motor	Eye movement
VII	Facial	Both sensory and motor	Face and scalp movement, salivation, tears, taste
VIII	Vestibulocochlear	Sensory	Balance, hearing
IX	Glossopharyngeal	Both sensory and motor	Tongue movement, swallowing, salivation, taste
X	Vagus (*wanderer*)	Both sensory and motor	Sensory from gastrointestinal tract and respiratory tree; motor to the larynx, pharynx, parasympathetic; motor to the abdominal and thoracic organs
XI	Accessory	Motor	Head movement, accessory motor with vagus
XII	Hypoglossal	Motor	Tongue movement

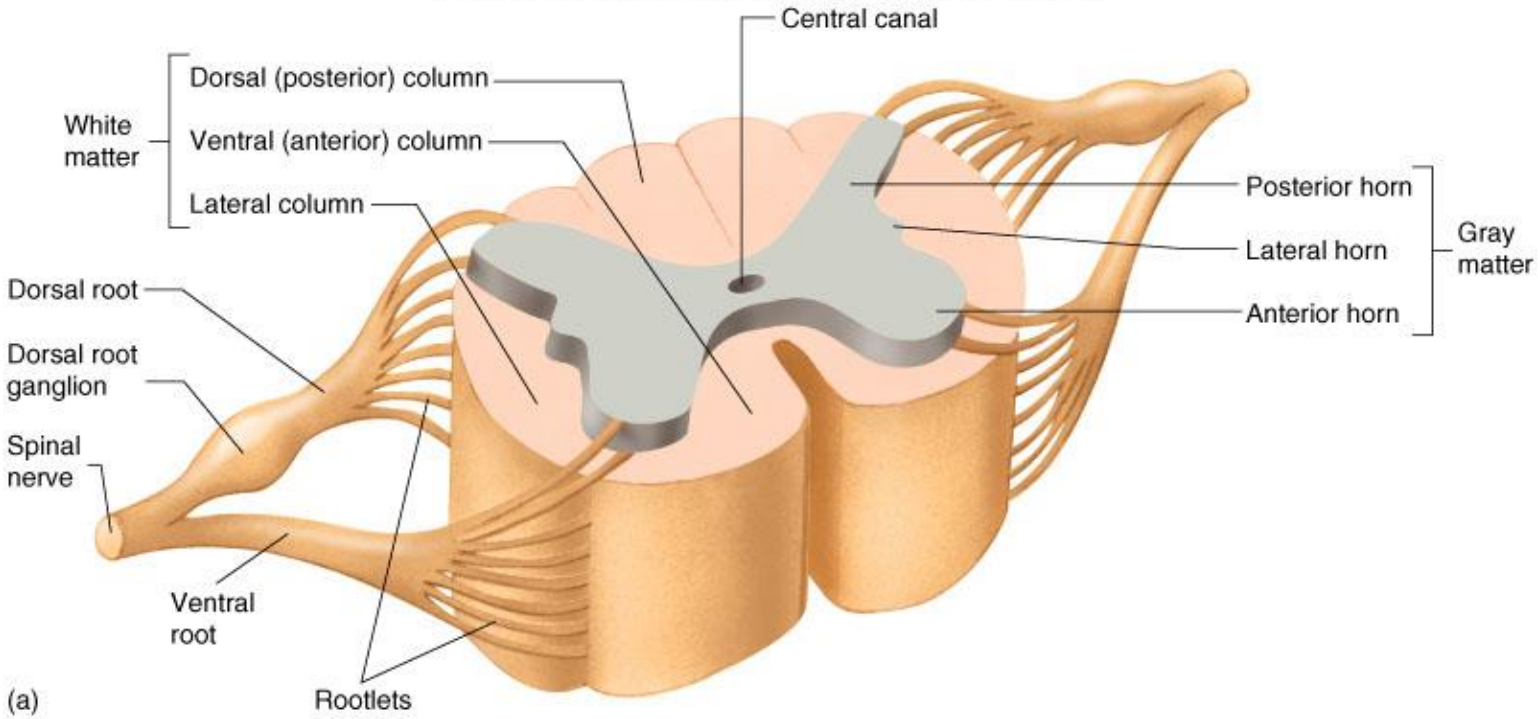
Spinal Nerves

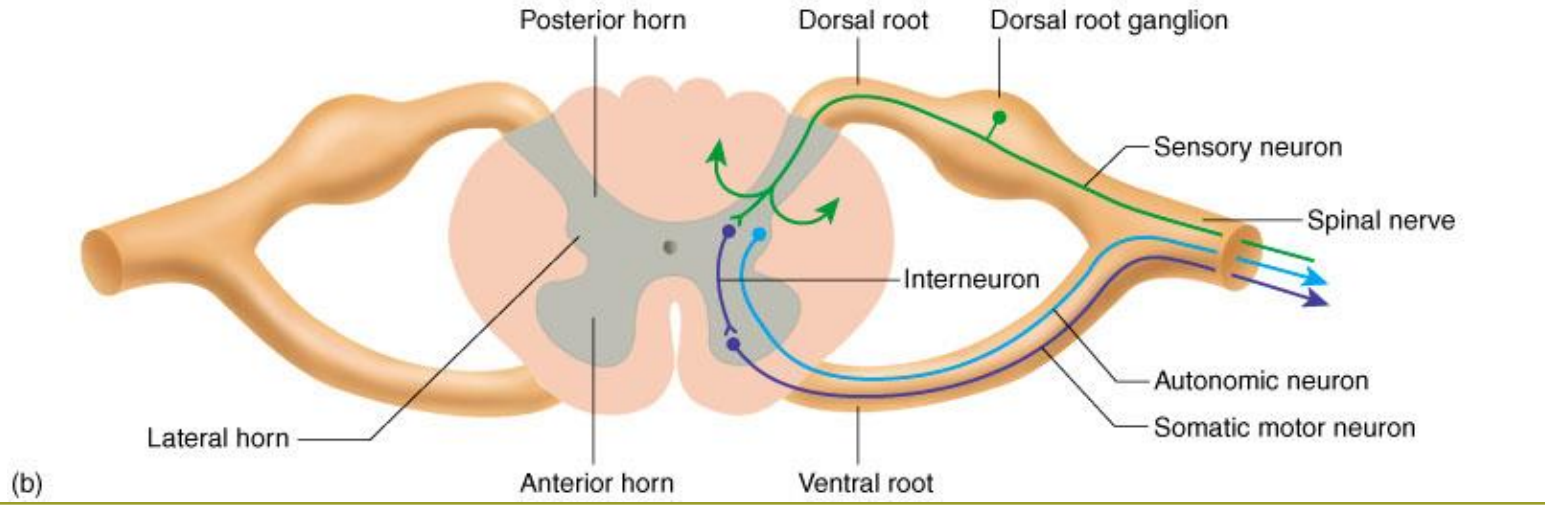
Figure 13-15, Page 333

- 36 pair in the dog, mixed nerves
- Exit spinal cord through intervertebral foramen
- Structure
  - Dorsal root
  - Dorsal root ganglion
  - Ventral root







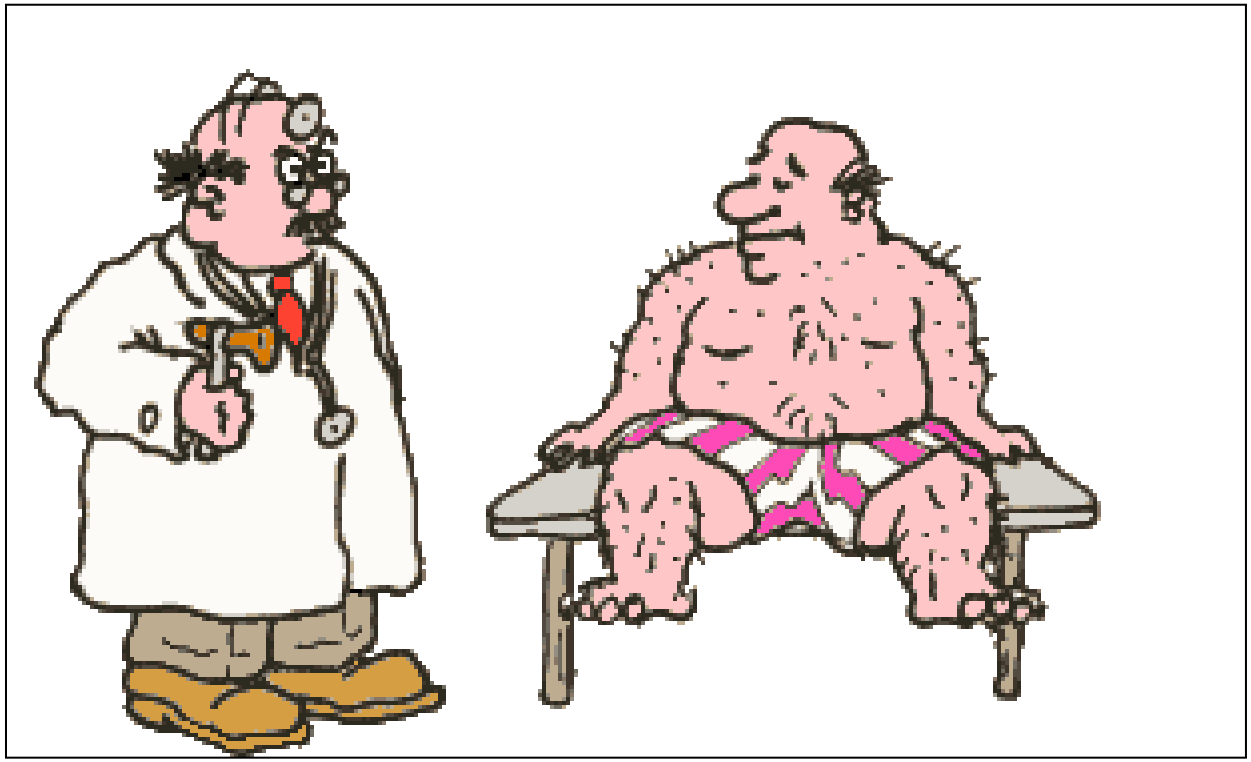


Other Spinal Nerve Terms

- Reflexes
- Reflex arc **(Figure 13-15, Page 333)**
- Plexus
  - Brachial plexus
  - Lumbosacral plexus

Reflexes

- Definition – stimulus-response bypasses the brain
  - A “no-brainer” ☺
  - FAST reaction time without thinking
- Types
  - Somatic vs. autonomic
  - Contralateral vs. ipsilateral

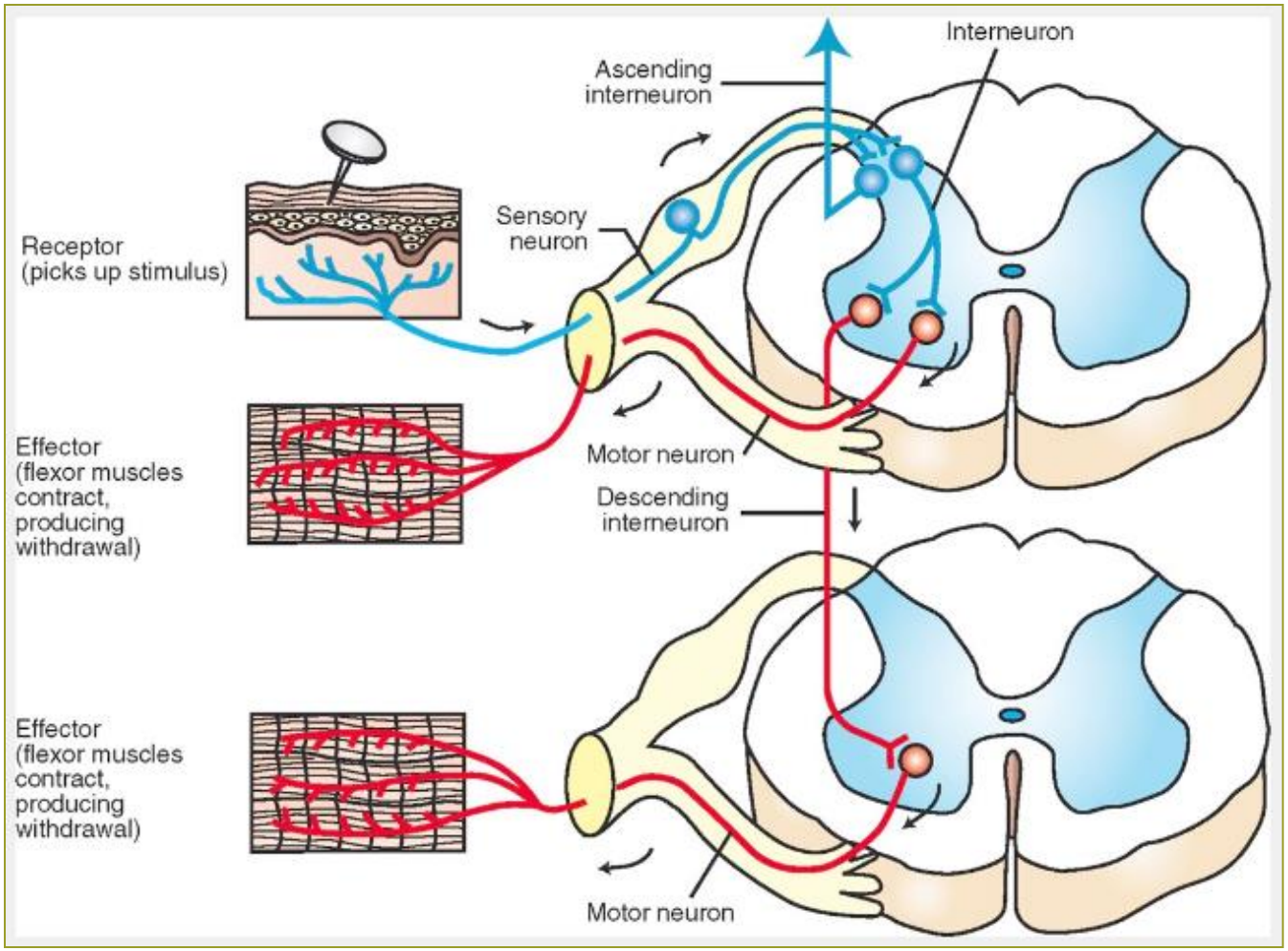


Reflex Arc

- Sensory receptor sends action potential along sensory neuron to gray matter of spinal cord
- Sensory neuron synapses with interneuron in spinal cord
- Integrated response of the reflex is sent out by motor neuron, which ends at target organ (effector)

Flexor Reflex

Figure 13-15, Page 333

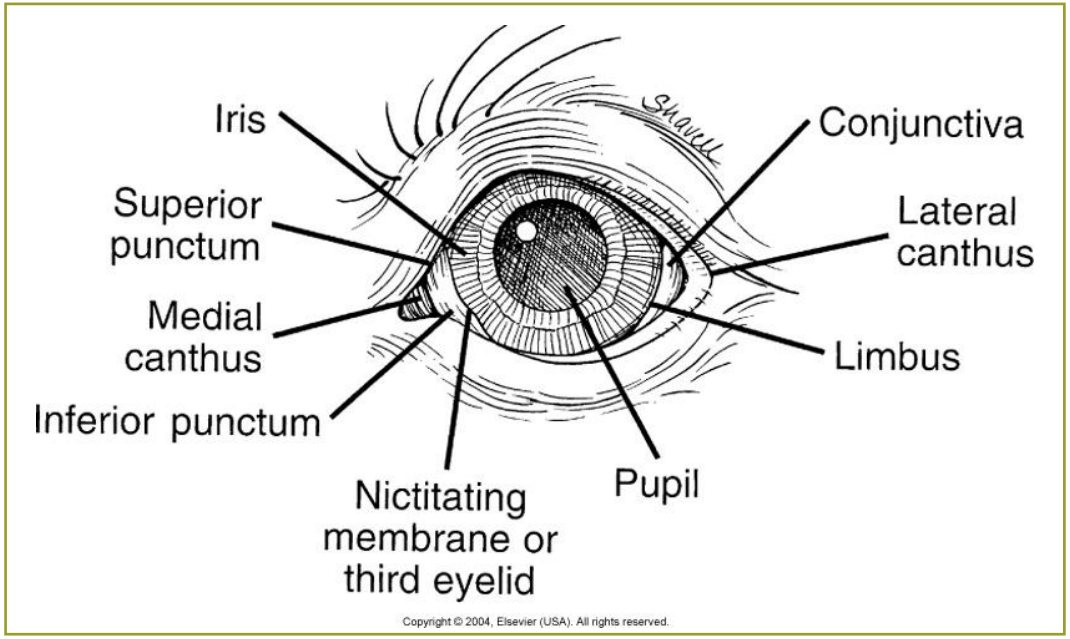


Somatic vs. Autonomic

- Somatic reflexes
  - Involve contraction of skeletal muscles
- Autonomic reflexes
  - Regulate smooth muscle, cardiac muscle, and endocrine glands

Clinically Significant Reflexes

- Palpebral (eyeblink) reflex arc
  - Light tap on medial canthus of eye produces a blink of the eyelids
- Pupillary light reflex (PLR)
  - Normal response to shining light in eye of animal is for iris in both eyes to constrict
  - Shining the light in one eye causes constriction in both eyes



Autonomic Nervous System

Sympathetic Division

Parasympathetic Division

ANS Overview

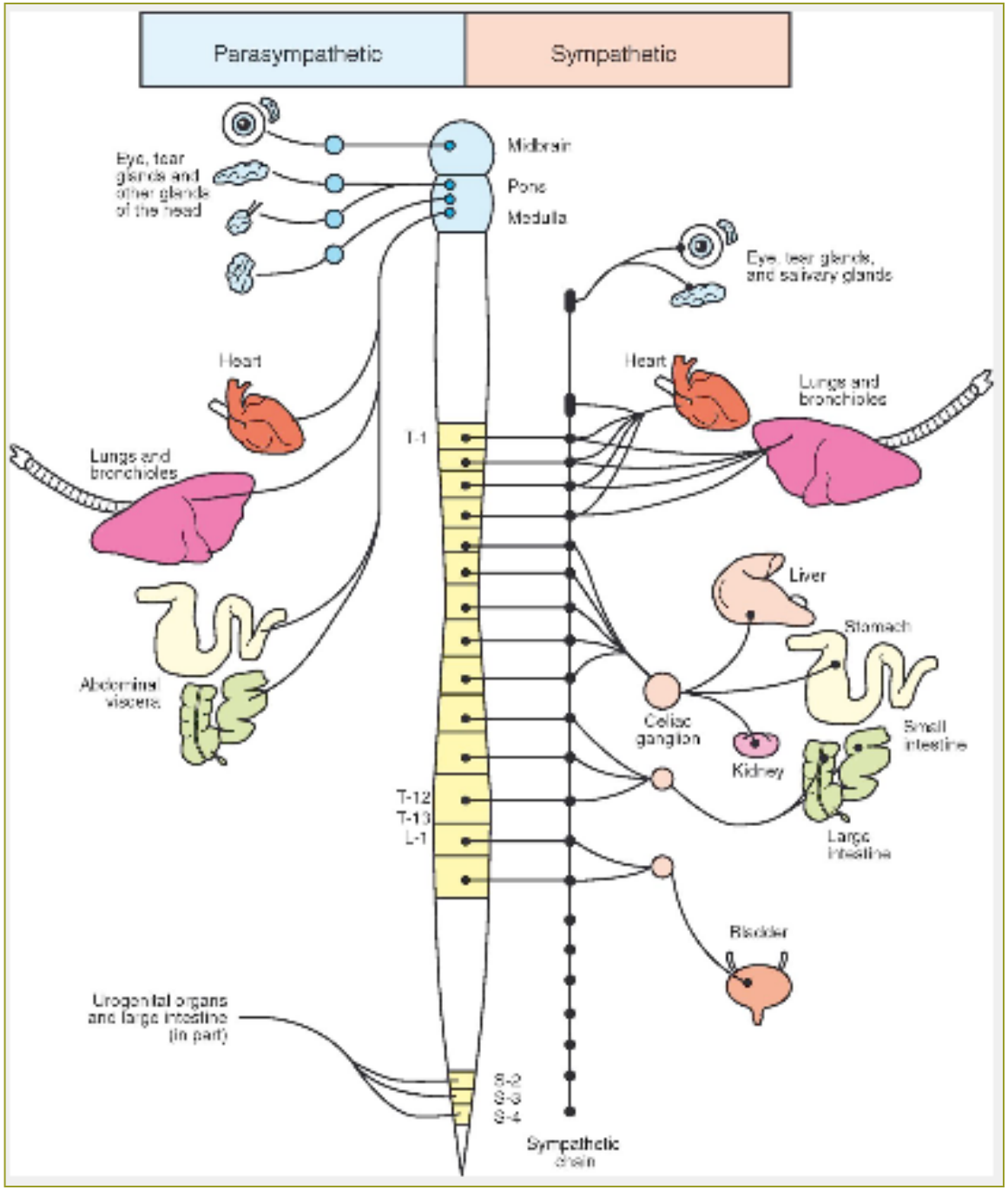
- 2 motor neuron system from spinal cord
- Controls all involuntary internal structures
- Regulated by hypothalamus
- Both divisions have SAME target organs

Autonomic Nervous System

- Controls automatic functions at subconscious level
- Sympathetic division
  - Nerves emerge from thoracic and lumbar vertebral regions (thoracolumbar system)
- Parasympathetic division
  - Nerves emerge from the brain and sacral vertebral regions (cranial-sacral)

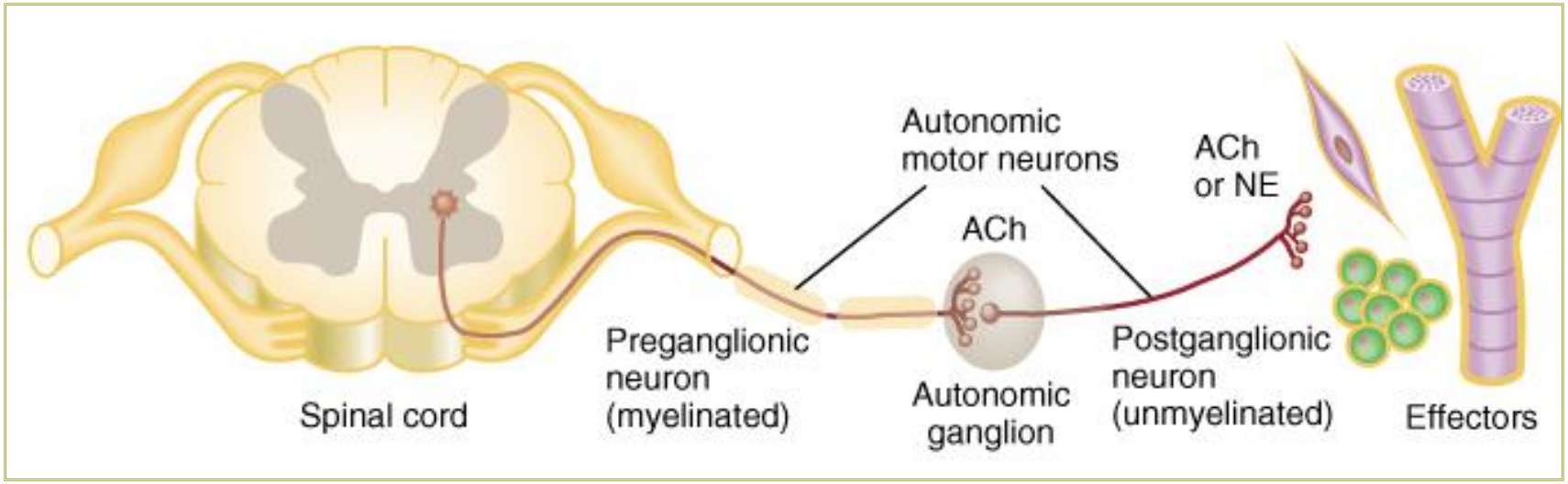
Autonomic Nervous System Anatomy

Figure 13-12, Page 330



ANS Anatomy

- Preganglionic neuron
- Ganglion (and synapse)
- Postganglionic neuron
- Synapse on target organ (effector)



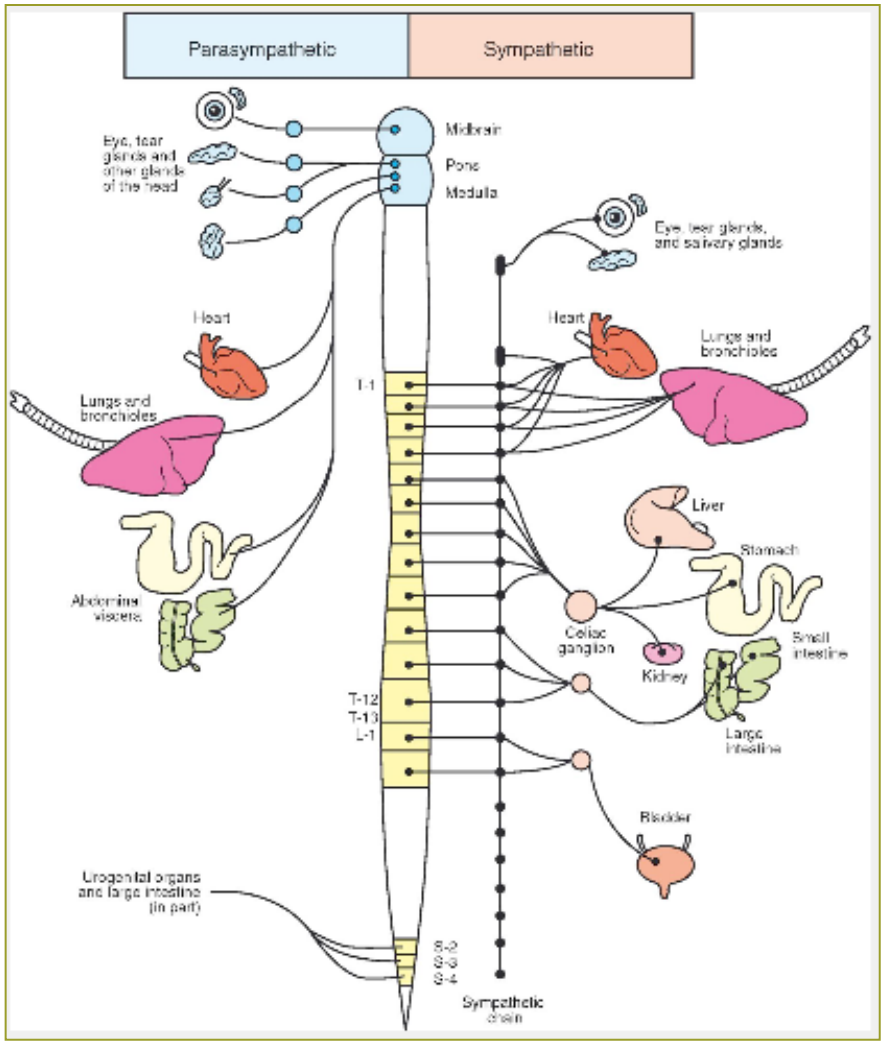
Sympathetic Division

- Prepares the body for "fight or flight"
- Thoracolumbar region of SC
- Short preganglionic neurons
  - Chain ganglia
- Preganglionic synapse
  - Nicotinic receptors – Ach
- Postganglionic synapse – norepinephrine (NE)
  - Adrenergic receptors

Sympathetic Effects – Fight or Flight

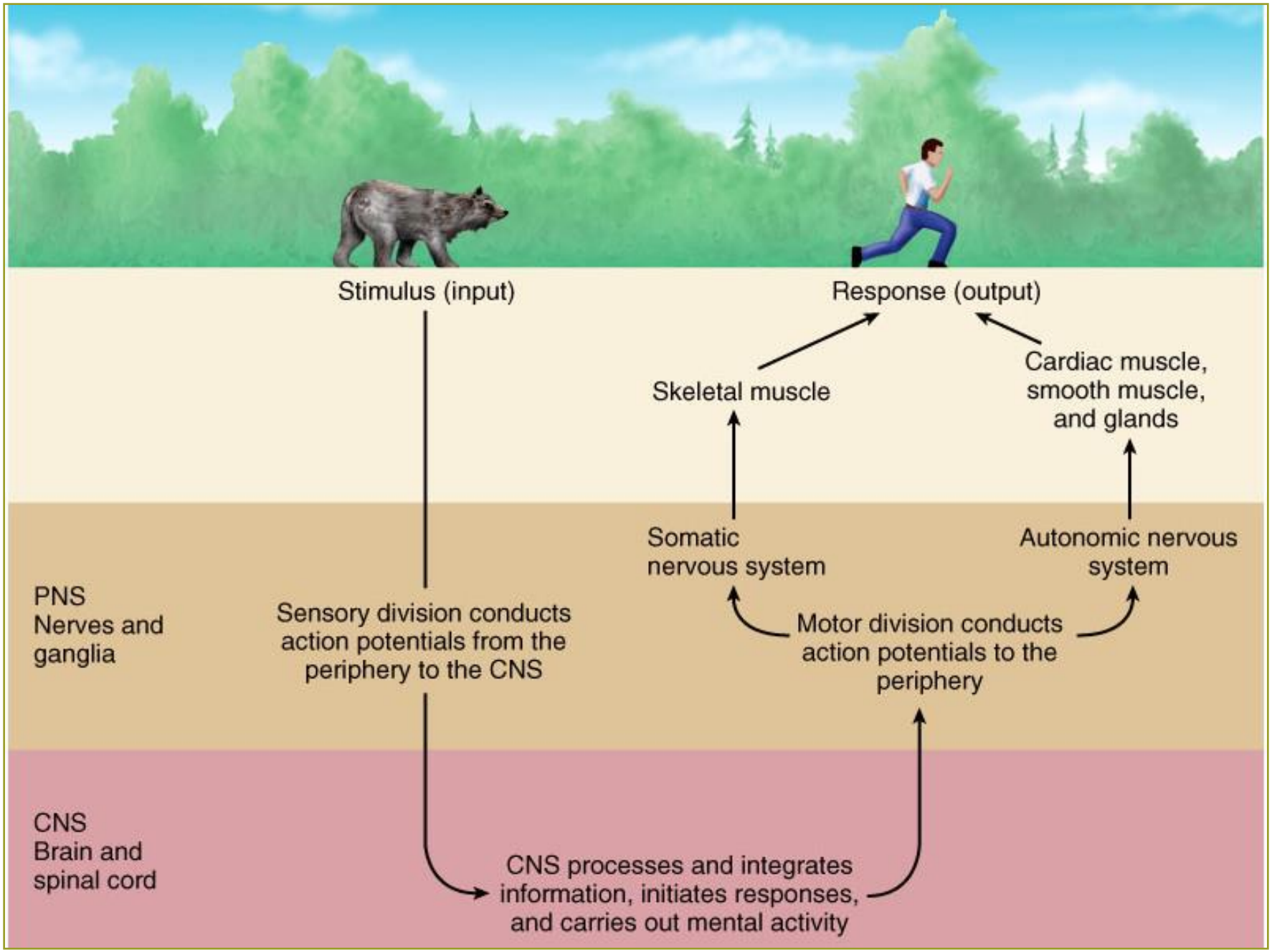
Table 13-3, Page 329

- Heart rate – increased
- Bronchioles – dilated
- Salivary glands – secretion reduced
- Pupils – dilated
- Sweat glands – secretion increased
- GI motility – decreased



Roger and the Bear! ☺

Fight or Flight! ☺


Stimulus (input)
Response (output)
Skeletal muscle
Cardiac muscle, smooth muscle, and glands
Somatic nervous system
Autonomic nervous system
PNS
Nerves and ganglia
Sensory division conducts action potentials from the periphery to the CNS
Motor division conducts action potentials to the periphery
CNS
Brain and spinal cord
CNS processes and integrates information, initiates responses, and carries out mental activity

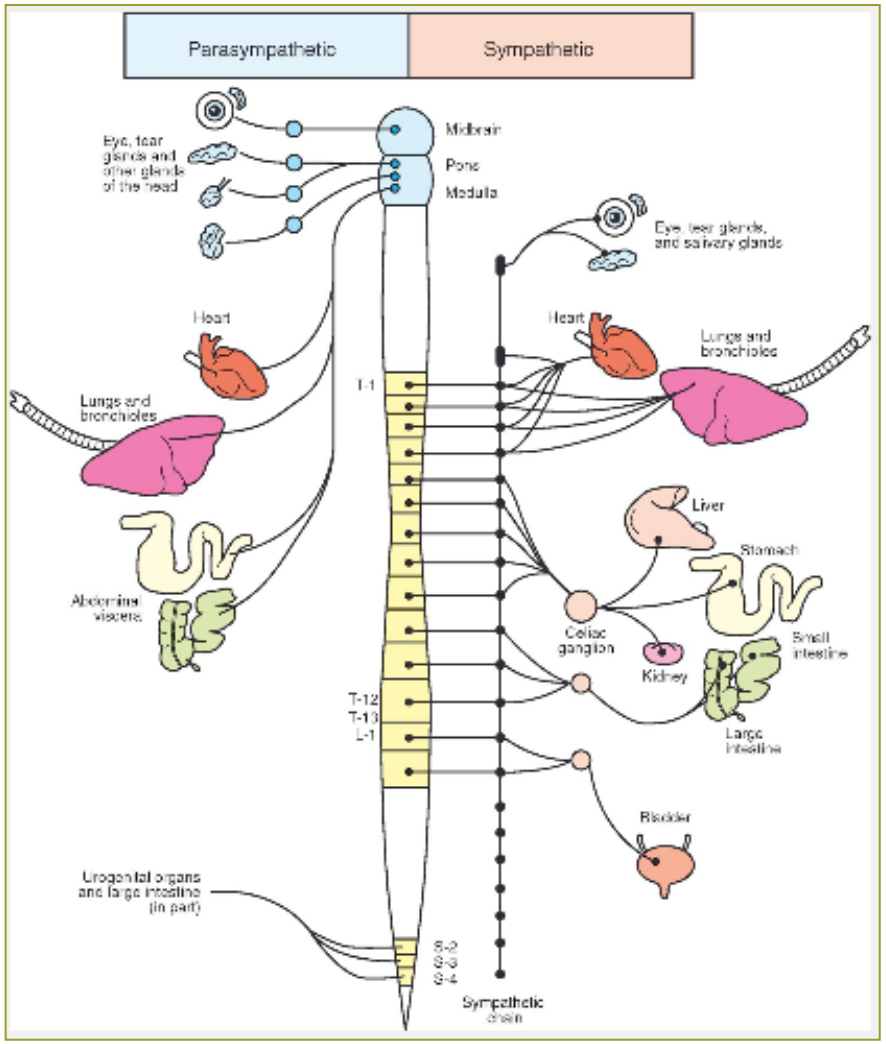
Parasympathetic Division

- Homeostasis of internal organs
- Cranial/sacral region of SC
- Long preganglionic neuron, synapse on target organ
- Both synapses contain Ach
  - Nicotinic receptors
  - Muscarinic receptors

Parasympathetic Effects – Rest and Digest

Table 13-3, Page 329

- Heart rate – decreased
- Bronchioles – constricted
- Salivary glands – secretion restored
- Pupils – constricted
- Sweat glands – secretion normal
- GI motility – increased

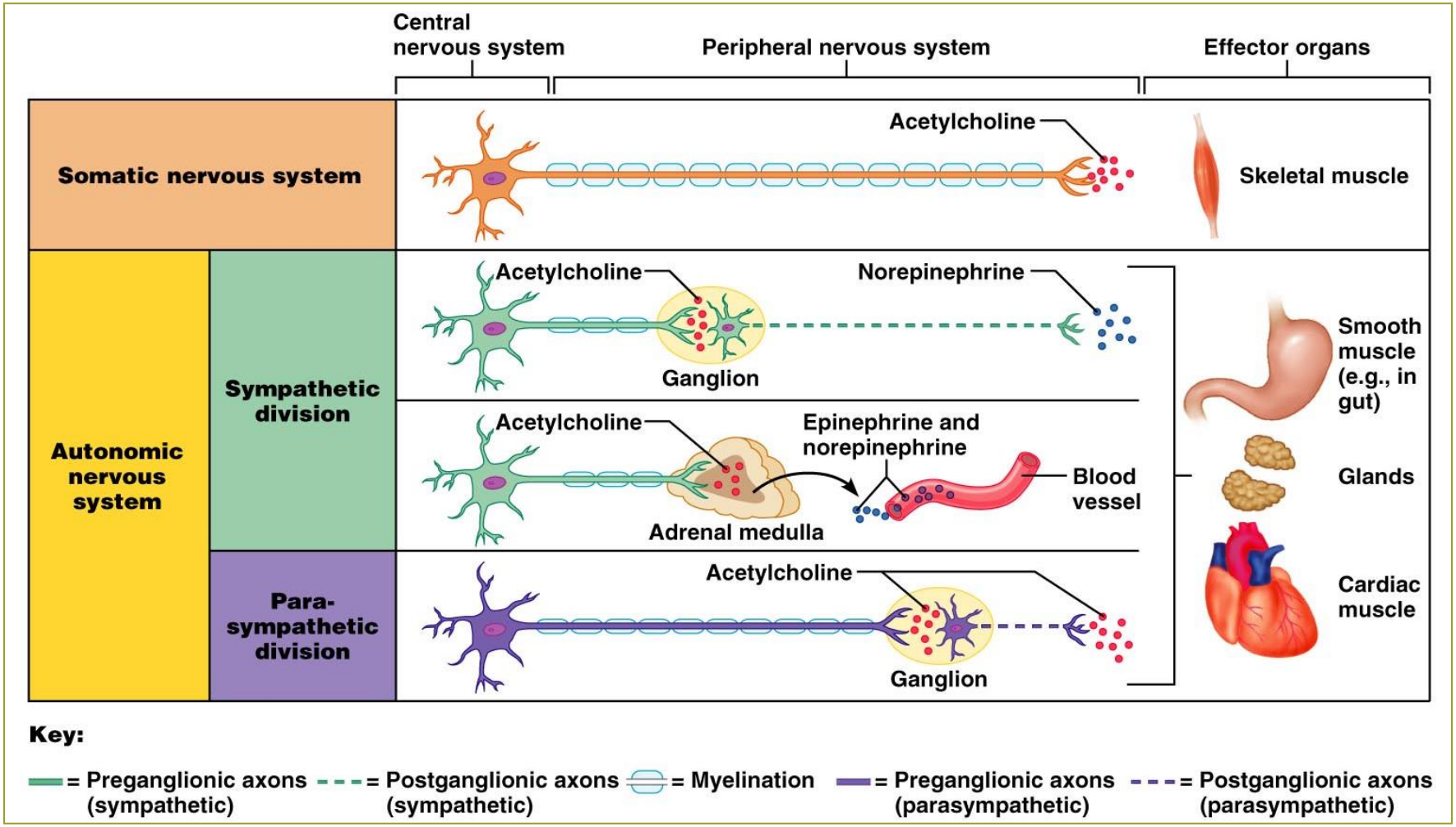


ANS Comparison of Effects

Table 13-3, Page 329

	Sympathetic System	Parasympathetic System
	Effect	*Effect*
Heart rate	Increases	Decreases
Force of heart contraction	Increases	No significant effect
Diameter of bronchioles	Increases (dilates)	Decreases (constricts)
Diameter of pupil	Increases (dilates)	Decreases (constricts)
Gastrointestinal motility, secretions, and blood flow	Decreases	Increases
Diameter of skin blood vessels	Decreases	No significant effect
Diameter of muscle blood vessels	Increases	No significant effect
Diameter of blood vessels to kidney	Decreases	No significant effect

Comparison of Somatic and Autonomic Systems



Neurotransmitters and Receptors

Sympathetic Division

Parasympathetic Division

Sympathetic Division

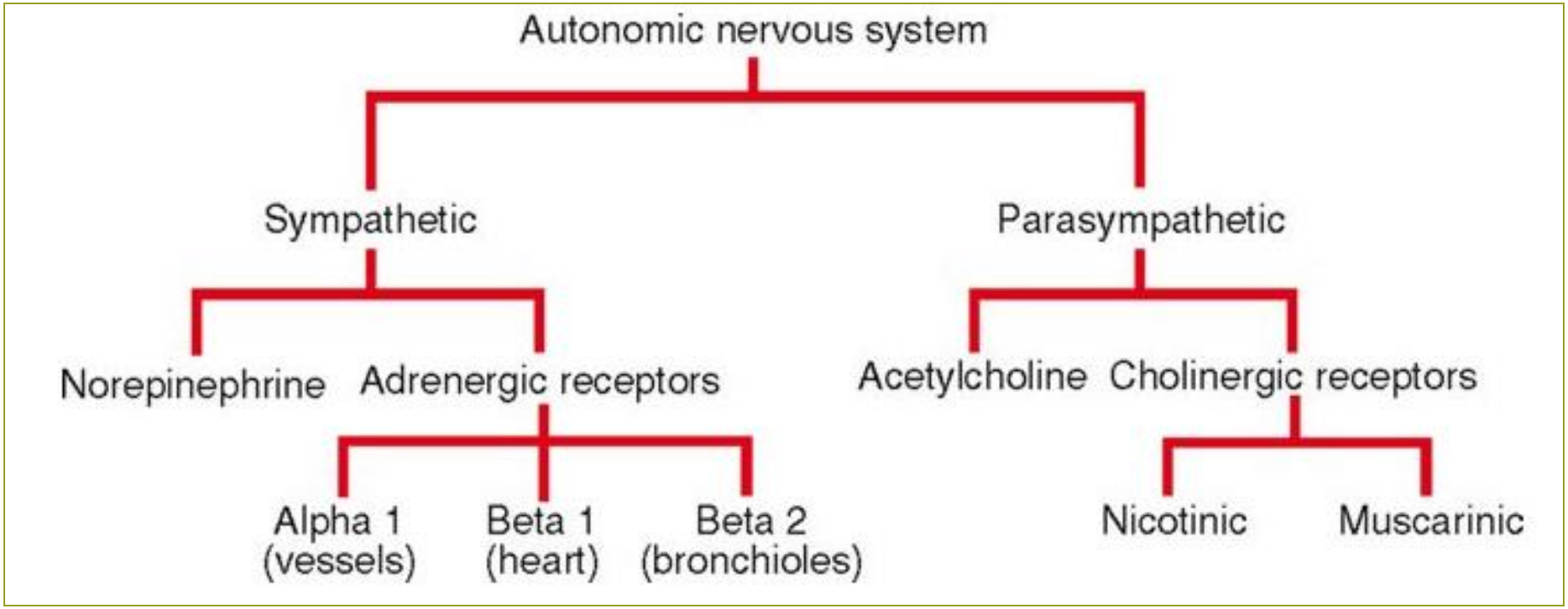
- Neurotransmitter – norepinephrine
  - Adrenergic neurons – neurons that release norepinephrine
  - Epinephrine and norepinephrine also released from adrenal medulla
- Receptors
  - Blood vessels in skin, GI tract, and skeletal muscle have adrenergic (catecholamine) receptors

Parasympathetic Division

- Neurotransmitter – acetylcholine
  - Cholinergic neurons – neurons that release acetylcholine
- Receptors
  - Nicotinic acetylcholine receptors
    - On postganglionic neurons of sympathetic and parasympathetic systems
    - Between motor neurons and muscle
  - Muscarinic acetylcholine receptors
    - On target organs and tissues supplied by the postganglionic neuron of the parasympathetic nervous system

ANS Receptors Summary

Figure 13-13, Page 331



Nervous System Pathology

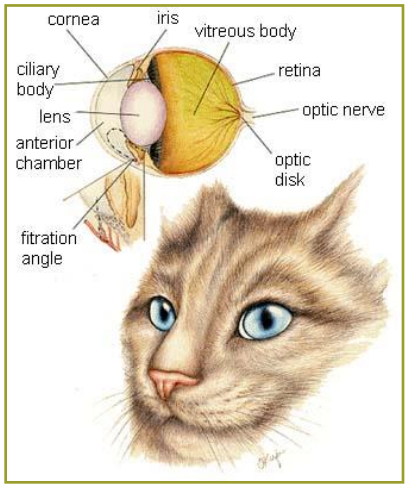
- Seizures
  - Seizure threshold
- Epilepsy
- Brain tumors
- Cerebellar hypoplasia

Test Yourself

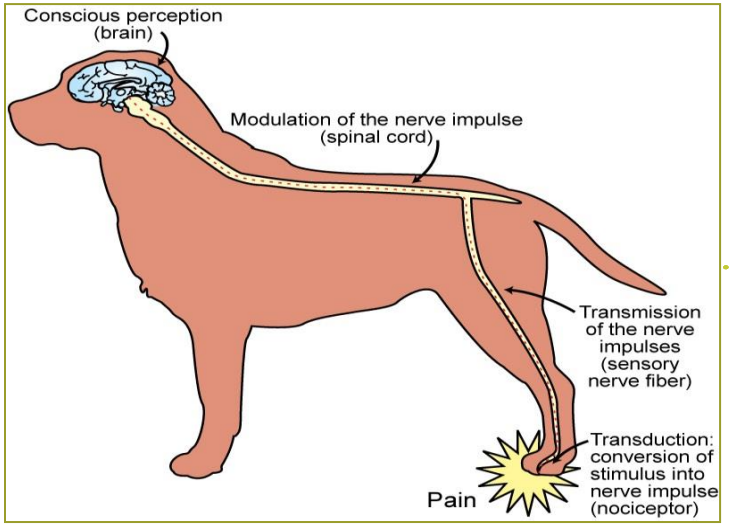
Pages 316, 317, 321, 324, 325, 327, 332, 336

Clinical Applications

Pages 320, 323, 326, 331, 335



Sense Organs
Chapter 14



Pages 337-357

Nervous System – Sense Organs

Textbook Learning Objectives

Chapter 14 – Page 337

- List the four general types of stimuli that can trigger a response from sensory receptors.
- List and describe the visceral senses.
- Differentiate between superficial and central temperature sensors.
- List and describe the processes that contribute to nociception.
- Describe the structure of the taste buds.
- List and describe the special senses.
- Describe the structures and functions of the components that make up the ear and the eyeball.
- Describe the processes that contribute to the sense of equilibrium.
- Describe the structures of the conjunctiva and eyelids.
- Describe the origin of tears and explain how tears flow onto and drain from the eye.

General Senses

Table 14-1, Page 338

- Distributed generally through body
- Simple structure
- Rarely involved in diseases

Definitions

- Sensation – any stimulus the animal body is aware of
- Perception – conscious awareness & interpretation of a sensation

Types of Stimuli

1. Mechanical stimuli (e.g., touch, hearing, balance)
2. Thermal stimuli (e.g., hot and cold)
3. Electromagnetic stimuli (e.g., vision)
4. Chemical stimuli (e.g., taste and smell)

Stimuli Need Sensory Receptors

General Senses

Special Senses

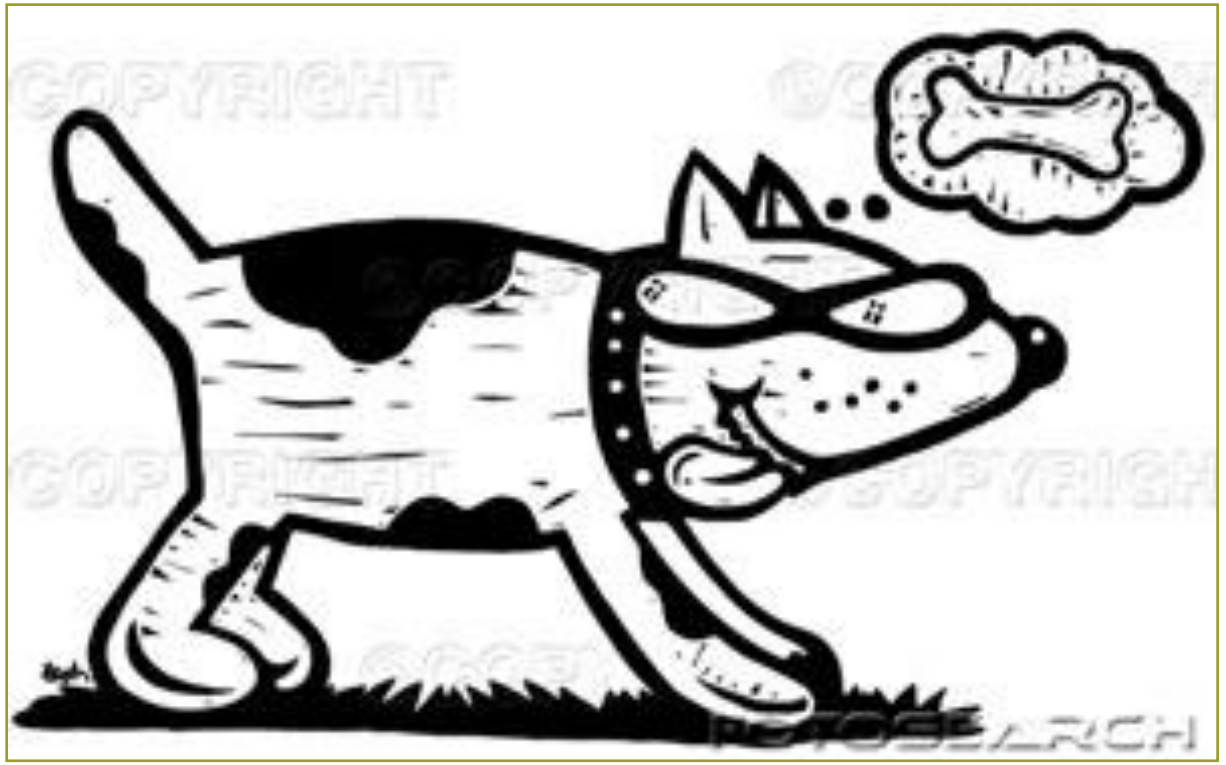
5 General Senses

Table 14-1, Page 338

Sense	What Is Sensed	Type of Stimulus
Visceral sensations	Hunger, thirst, hollow-organ fullness	Chemical, mechanical
Touch	Touch and pressure	Mechanical
Temperature	Heat and cold	Thermal
Pain	Intense stimuli of any type	Mechanical, chemical, or thermal
Proprioception	Body position and movement	Mechanical

Visceral Sensations

- Vague, poorly localized
- Hunger, thirst
- Hollow organs
  - Stretch receptors



Touch and Pressure

- Tactile sense: sensation of something being in contact with the surface of the body
  - Something being in contact with the surface of the body
  - Example – whiskers
- Pressure: sensation of something pressing on the body surface
- Operate at unconscious levels unless contact is abrupt

He’s Touching Me!!! ☺

Temperature

- Receptors detect changes in body temperature
  - Hypothermia
  - Hyperthermia

Temperature Receptors

- Superficial temperature receptors
  - In skin
  - Detect upward or downward changes in skin temperature
- Central temperature receptors
  - In hypothalamus
  - Monitor temperature of blood
- CNS can activate mechanisms (e.g., sweating, piloerection) to correct hypothermia or hyperthermia

Warm!

Pain

- Nociceptors – pain receptors
- Pain receptors are widely distributed inside and on the surface of the body
  - **Not present in the brain**
- May be simple free nerve endings (dendrites) or more specialized structures that detect mechanical forces, temperature, etc.

What Is Pain?

- Definition – "an unpleasant sensory and/or emotional experience associated with actual or potential tissue damage"
- Pain perception – conscious awareness & interpretation of a sensation
- Pain pathways

Pain Pathways

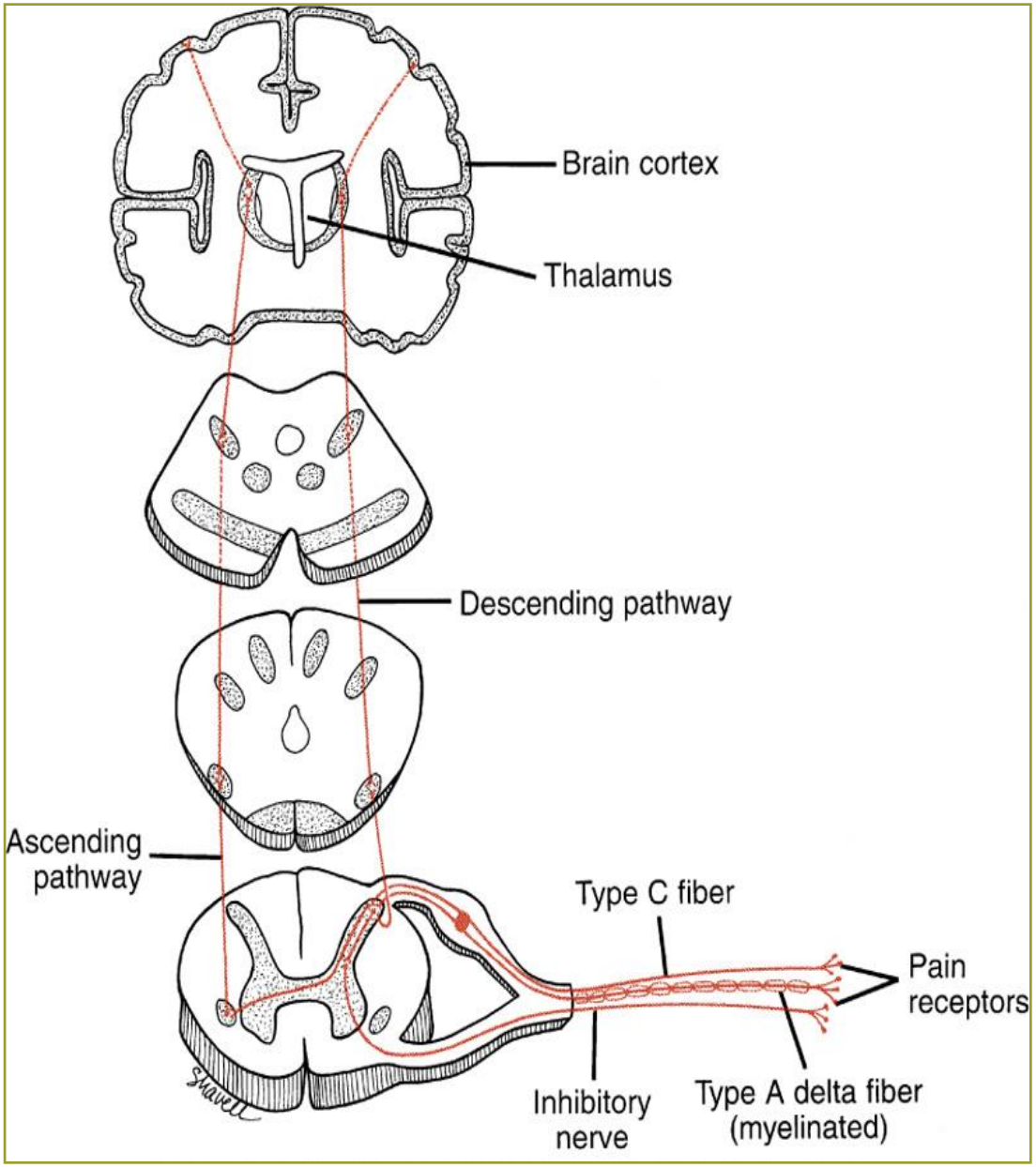
Transduction

Transmission

Modulation

Perception

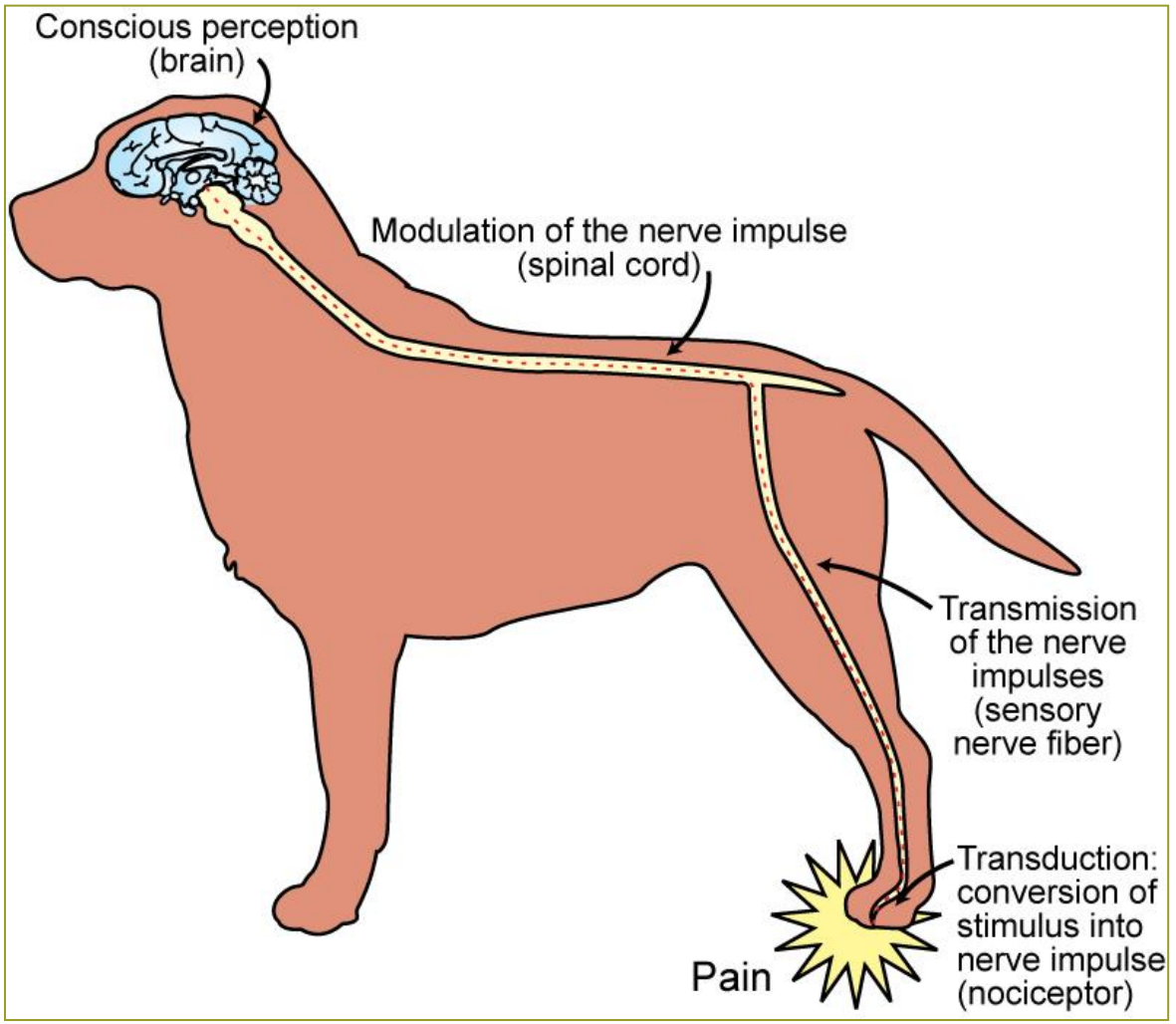
Pain Pathways – 3 Sensory Neurons



Pain Processes

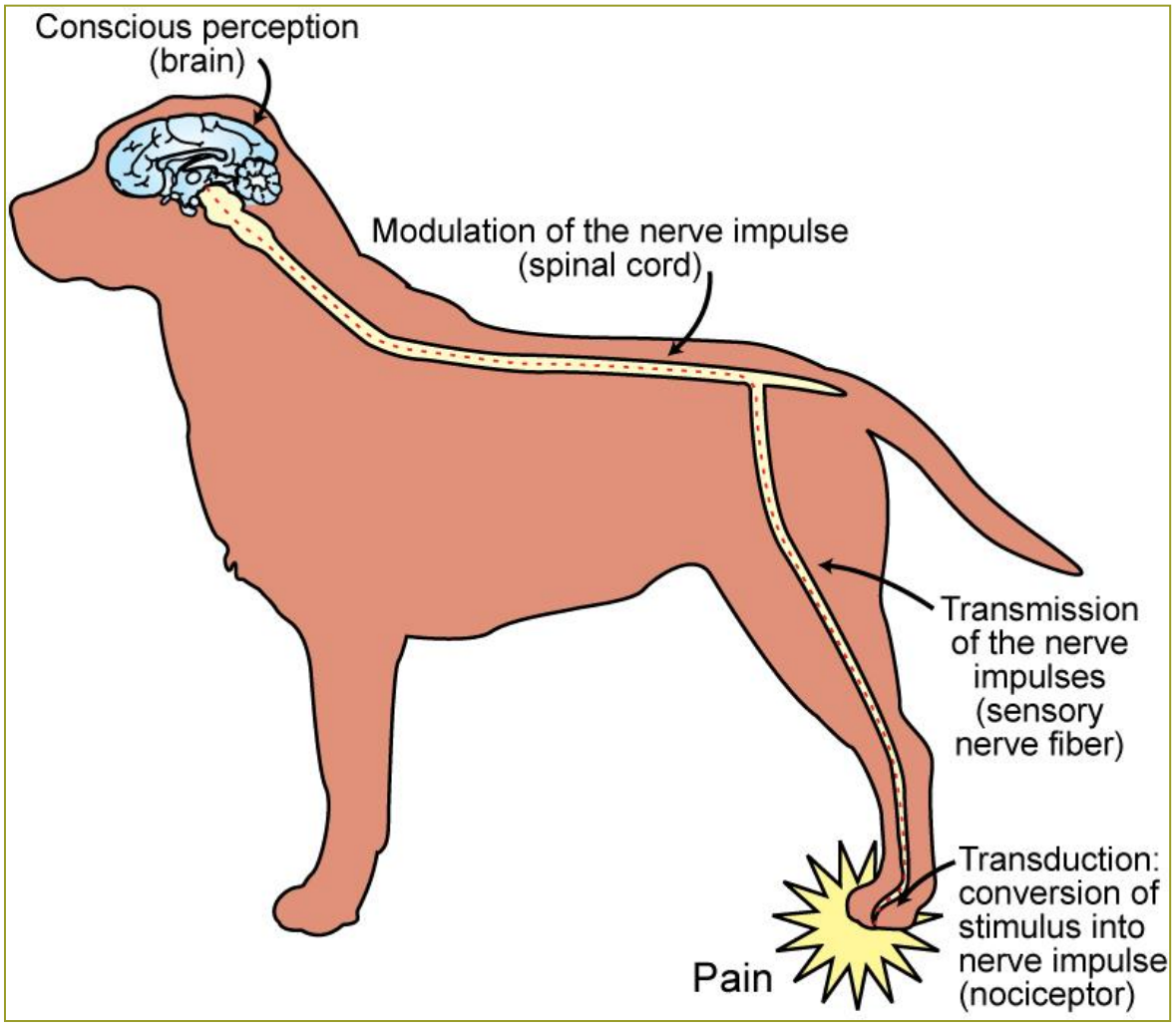
Figure 14-1, Page 340

- Sensation: OUCH!!!



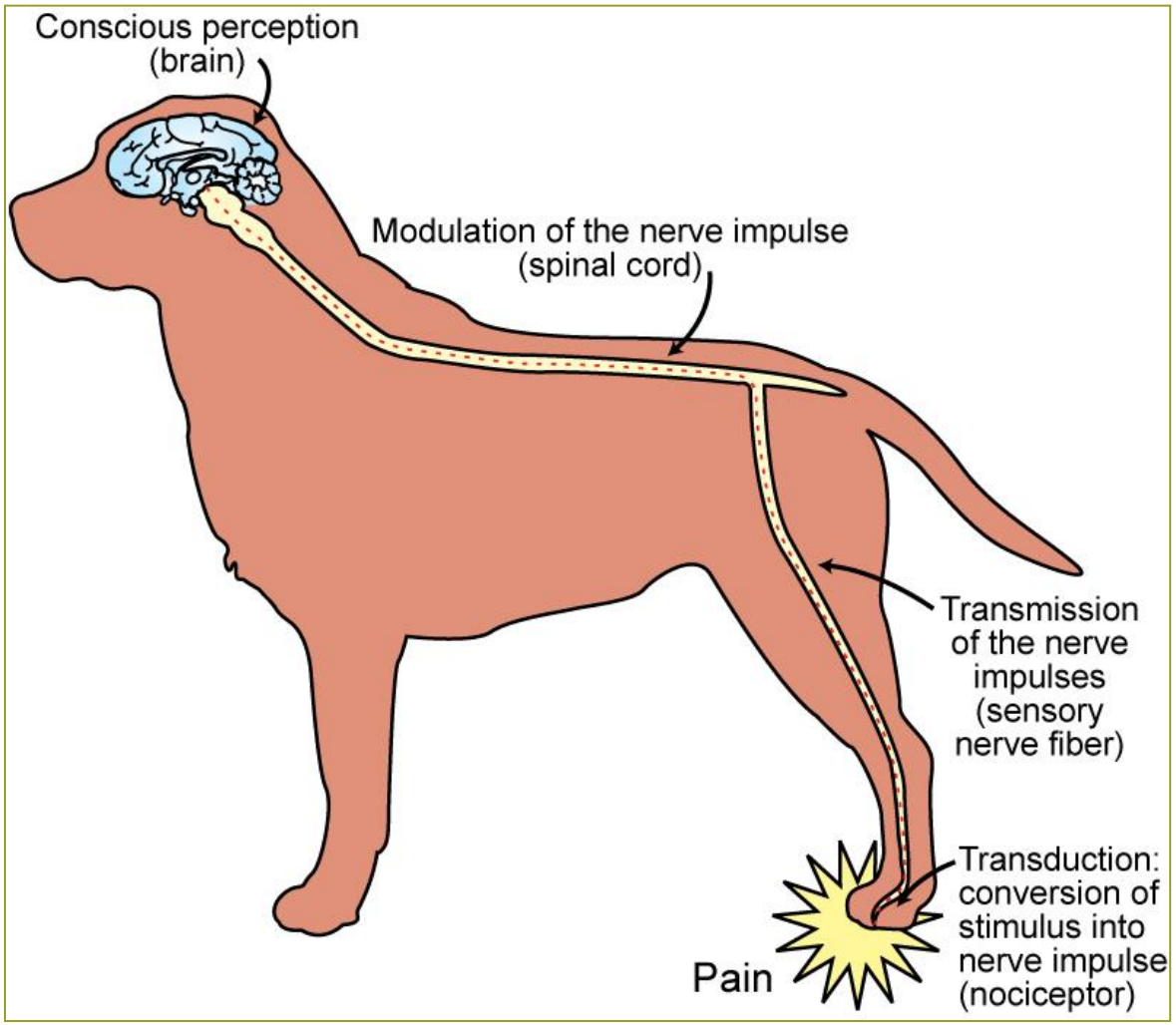
Pain Pathways

- Transduction: conversion of painful stimulus into nerve impulse (action potential)
- Transmission: conduction of nerve impulse to the spinal cord

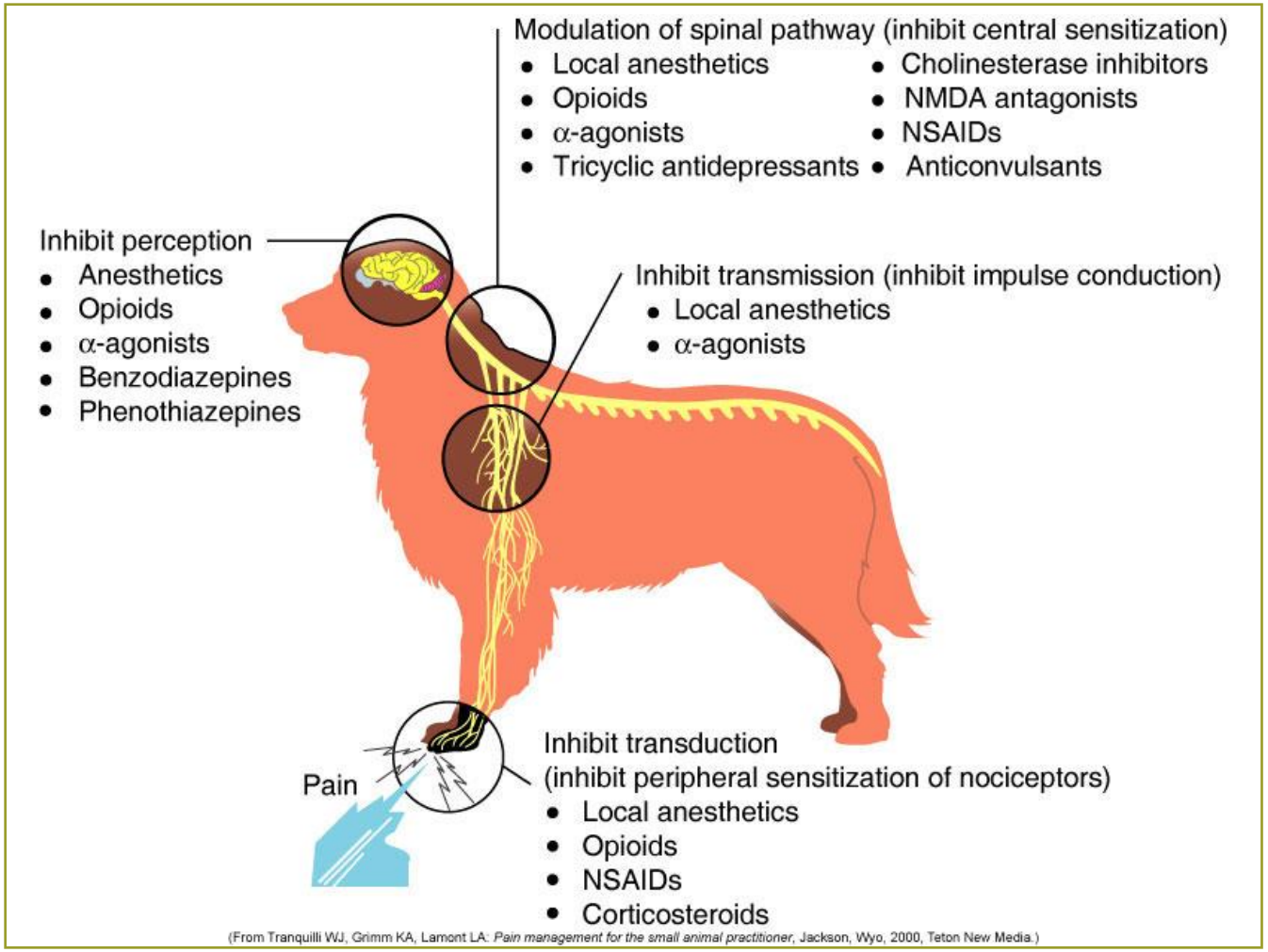


Pain Pathways

- Modulation: changes the sensory nerve impulse
  - Can amplify or suppress sensory impulses
- Perception: conscious awareness of painful stimuli



Pain Medications – Pharmacology



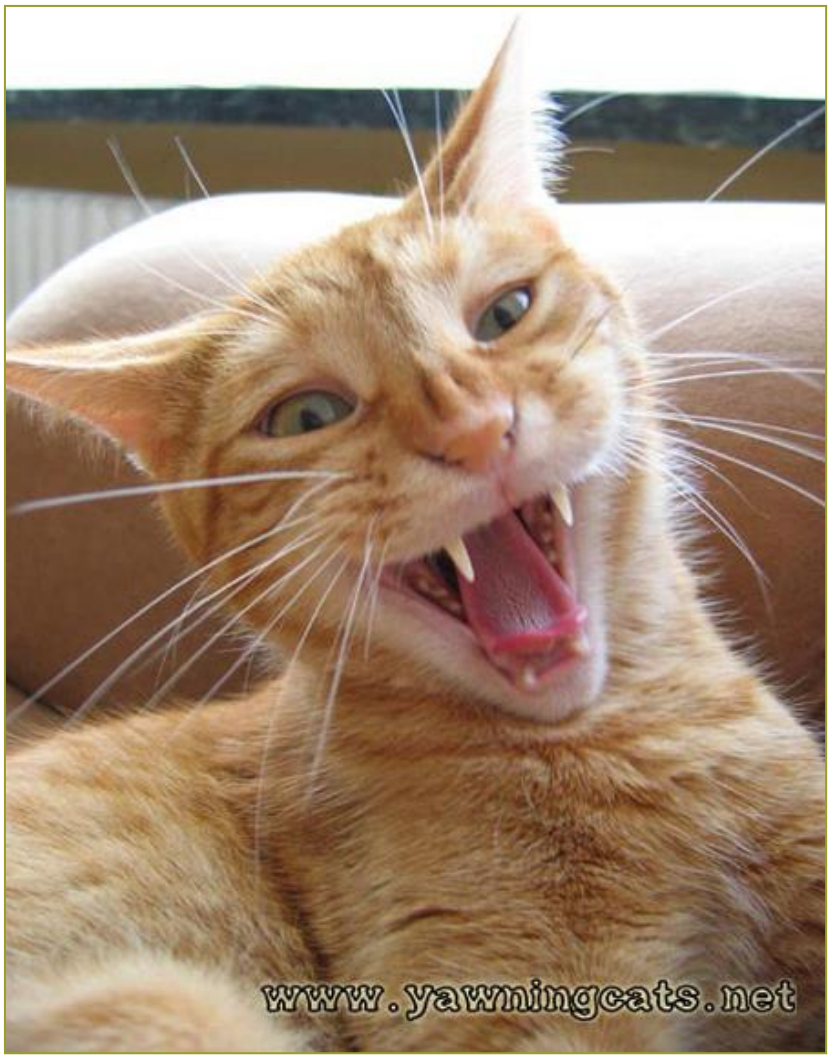
(From Tranquilli WJ, Grimm KA, Lamont LA: *Pain management for the small animal practitioner*, Jackson, Wyo, 2000, Teton New Media.)

Types of Pain

Acute (sharp)

Chronic (dull)

Ouch!



Acute Pain

- Unmyelinated "C" nerve fibers (axons) → DULL pain
  - Inside body
- Myelinated "A" nerve fibers (axons) → SHARP pain
  - Usually superficial

Proprioception

- Sense of body position and movement
- Stretch receptors in skeletal muscles, tendons, ligaments, and joint capsules sense movements of limbs, positions of joints, the state of contraction of muscles, and the amount of tension being exerted on tendons and ligaments

5 Special Senses

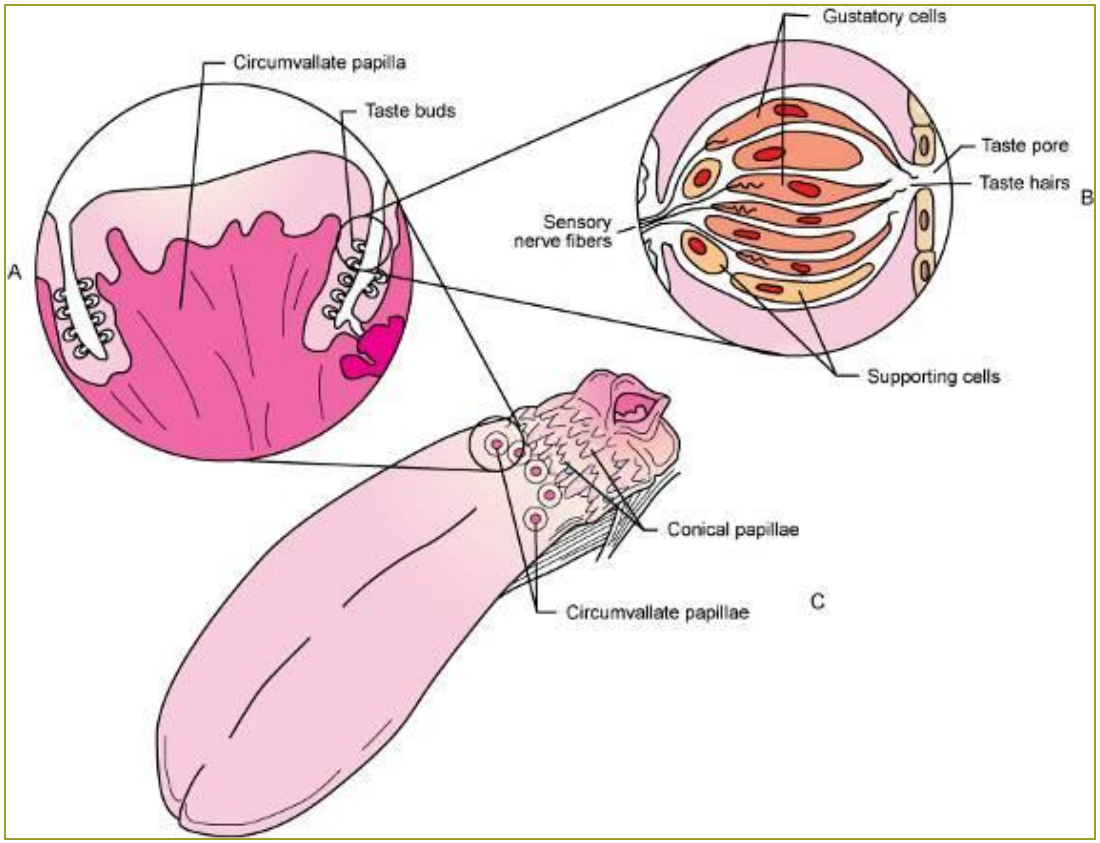
Table 14-1, Page 338

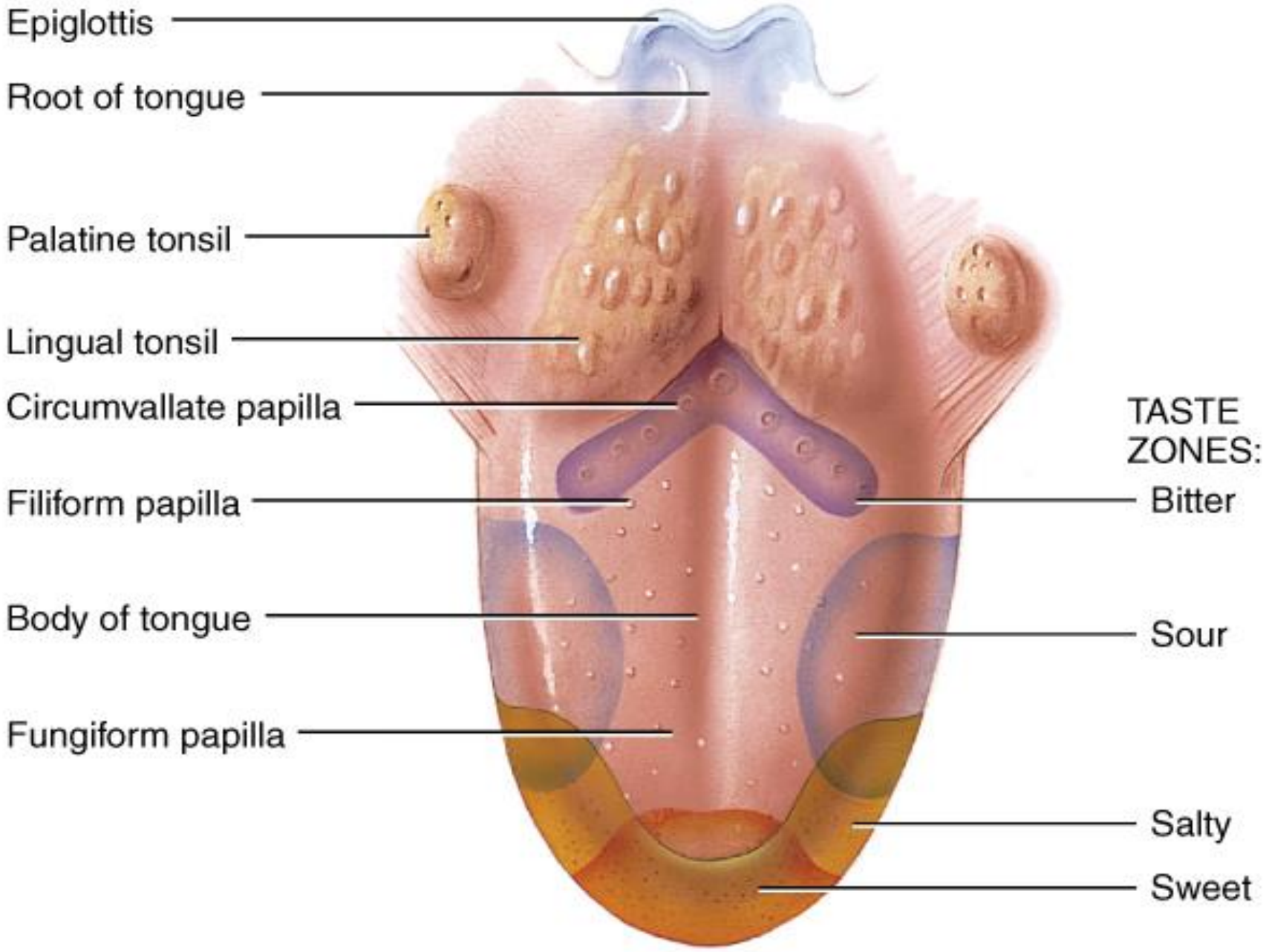
Sense	What Is Sensed	Type of Stimulus
Taste	Tastes	Chemical
Smell	Odors	Chemical
Hearing	Sounds	Mechanical
Equilibrium	Balance and head position	Mechanical
Vision	Light	Electromagnetic

Taste

Figure 14-2, Page 343

- Gustatory sense
- Chemical receptors: taste buds in oral cavity
  - Papillae – small elevated structures on the tongue
  - Also found in the lining of the mouth and pharynx

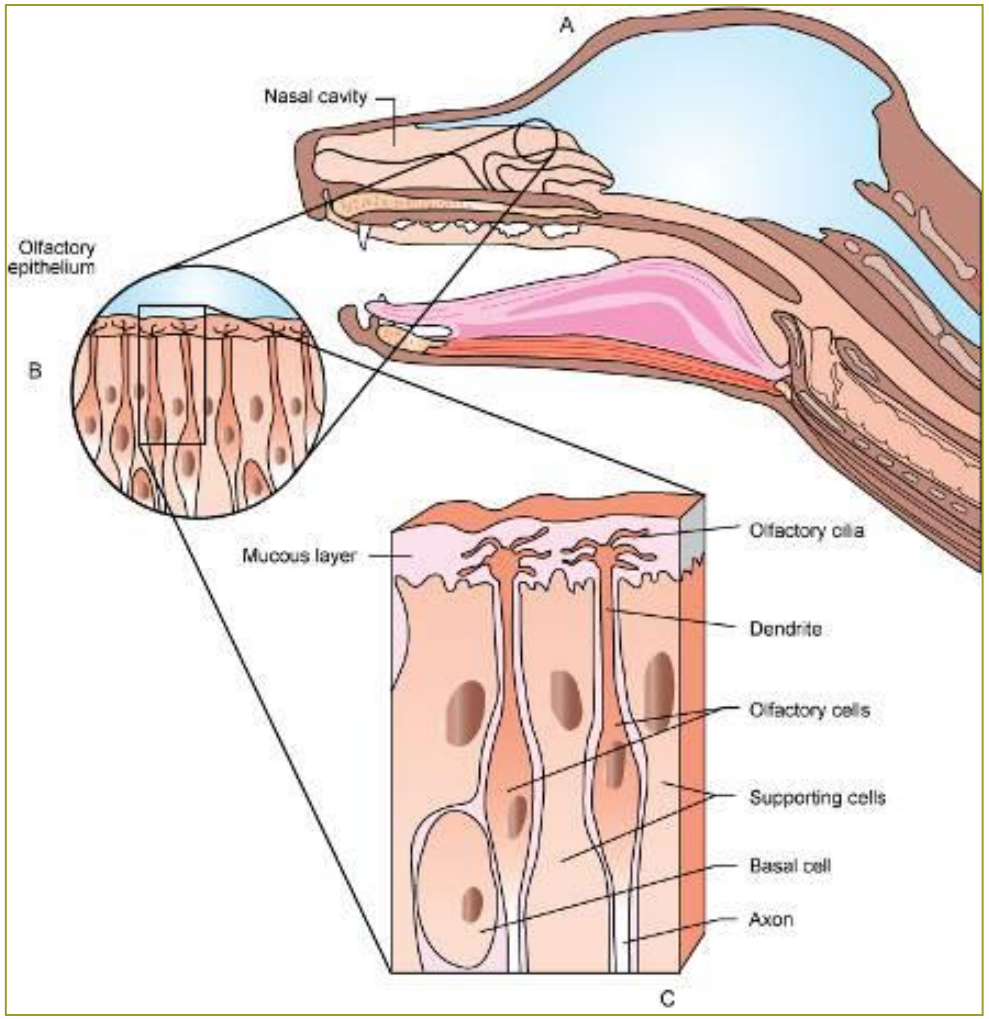



Epiglottis
Root of tongue
Palatine tonsil
Lingual tonsil
Circumvallate papilla
Filiform papilla
Body of tongue
Fungiform papilla
TASTE ZONES:
Bitter
Sour
Salty
Sweet

Smell

Figure 14-3, Page 344

- Olfactory sense
- Very important in most nonhuman animals
- Olfactory cells and supporting cells in epithelial patches in nasal passages



The reason you're receiving this is.....

...dogs can smell a good person a mile away!

Smell

- Hair-like processes project up from olfactory cells into the mucous layer that covers the nasal epithelium
- Odor molecules dissolve in the mucus and contact the sensory processes
  - Nerve impulses are generated, travel to the brain, and are interpreted as particular smells

Hearing – 3 Layers of Ear

External Ear

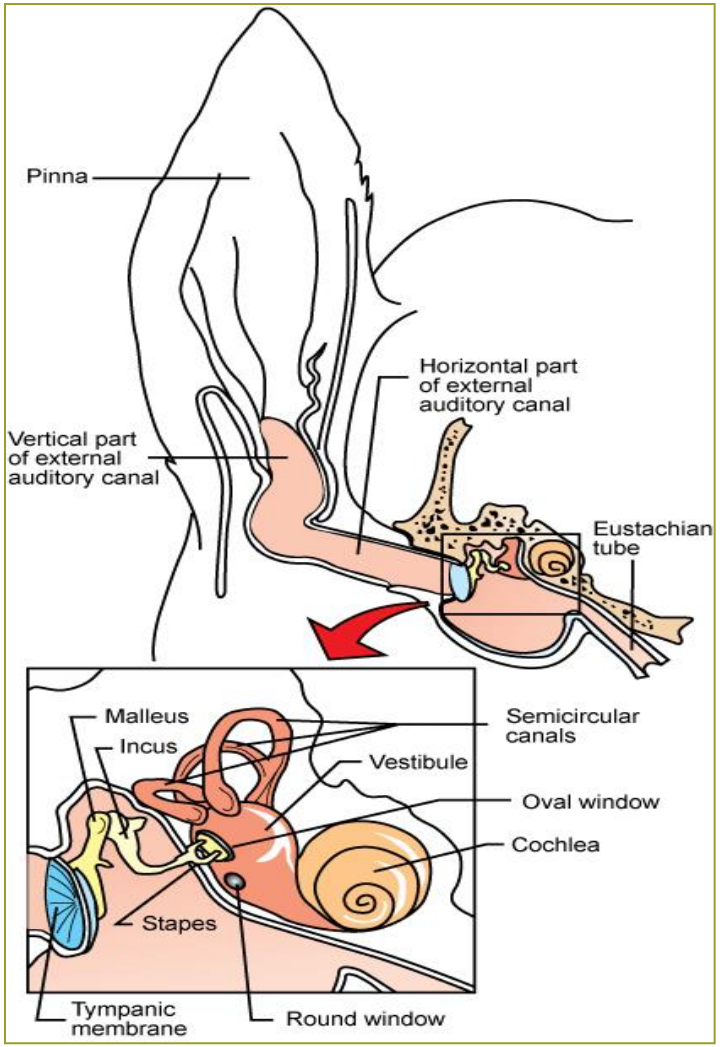
Middle Ear

Inner Ear

Hearing

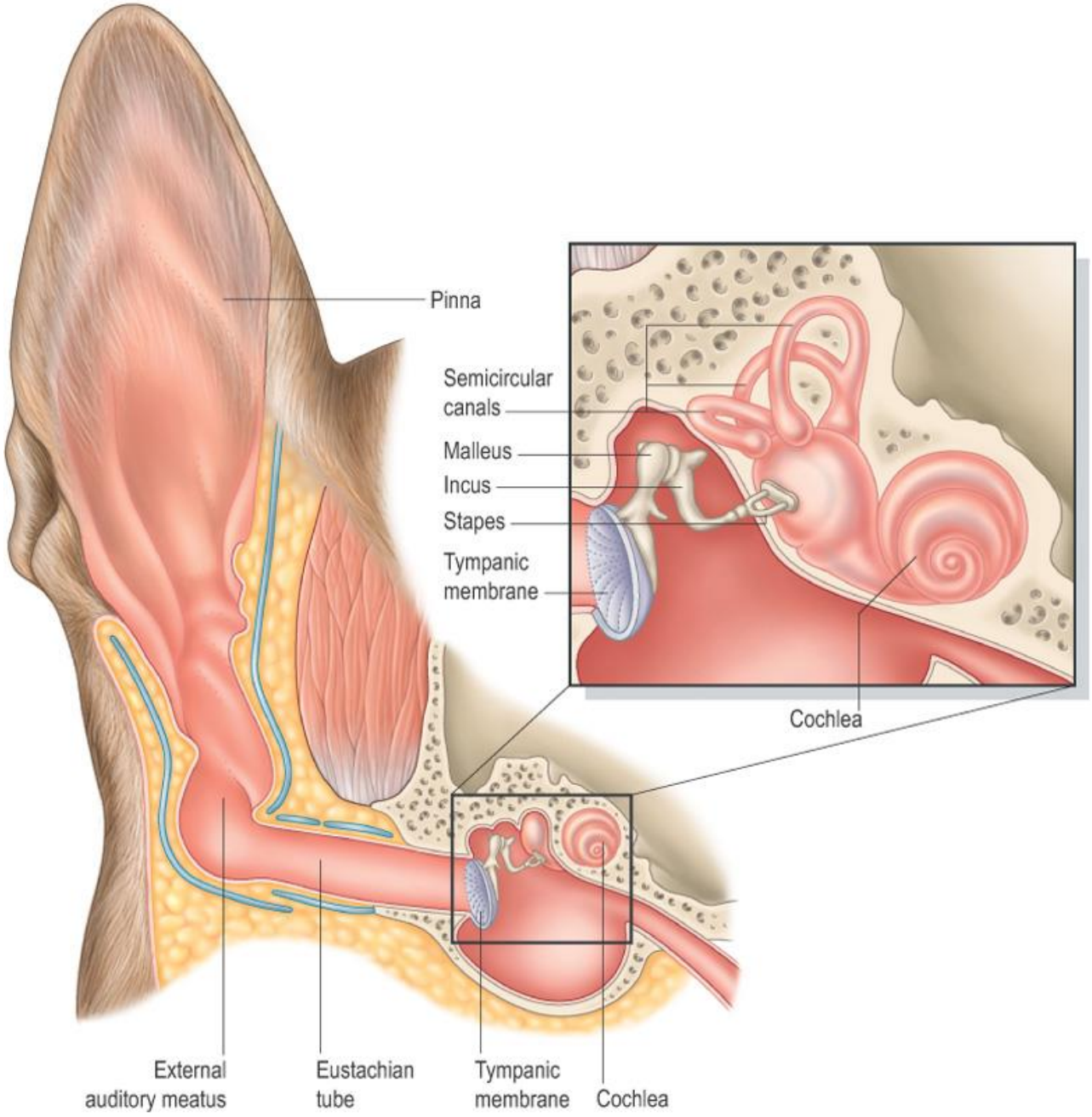
Figure 14-4, Page 345

- Auditory sense
- Converts vibrations of air molecules into nerve impulses
- Most structures of the ear are located in the temporal bones of the skull



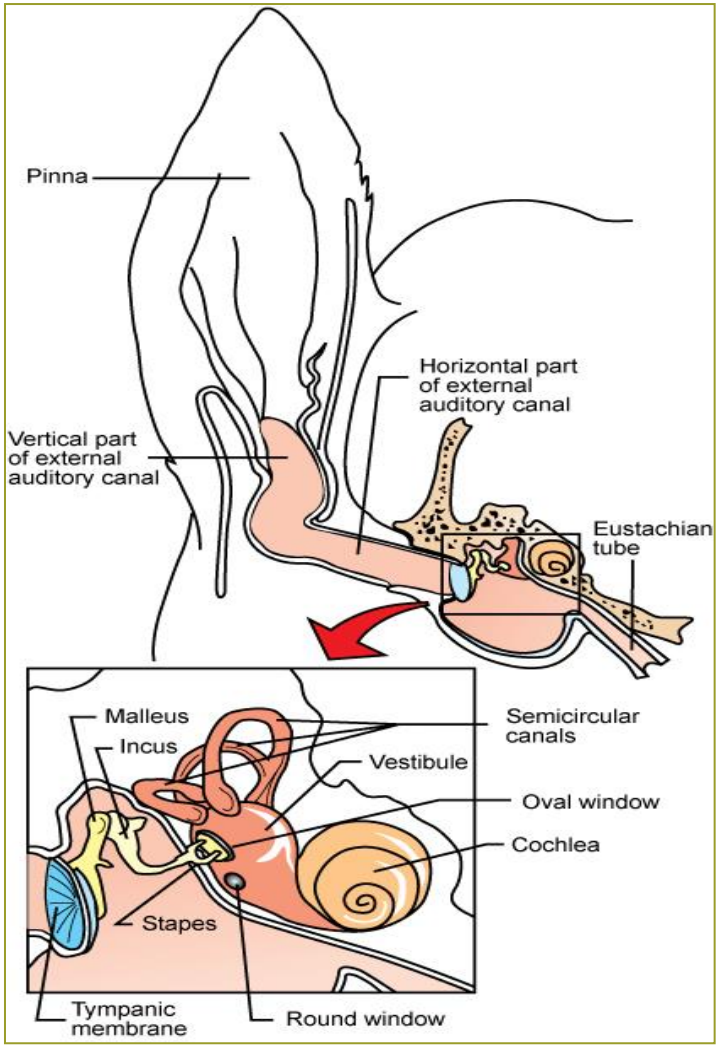
Hearing

- External ear – acts as a funnel to collect sound wave vibrations and direct them to the eardrum
- Middle ear – amplifies and transmits the vibrations from the eardrum to the inner ear
- Inner ear – contains the sensory receptors that convert the mechanical vibrations to nerve impulses, along with receptors for the equilibrium sense



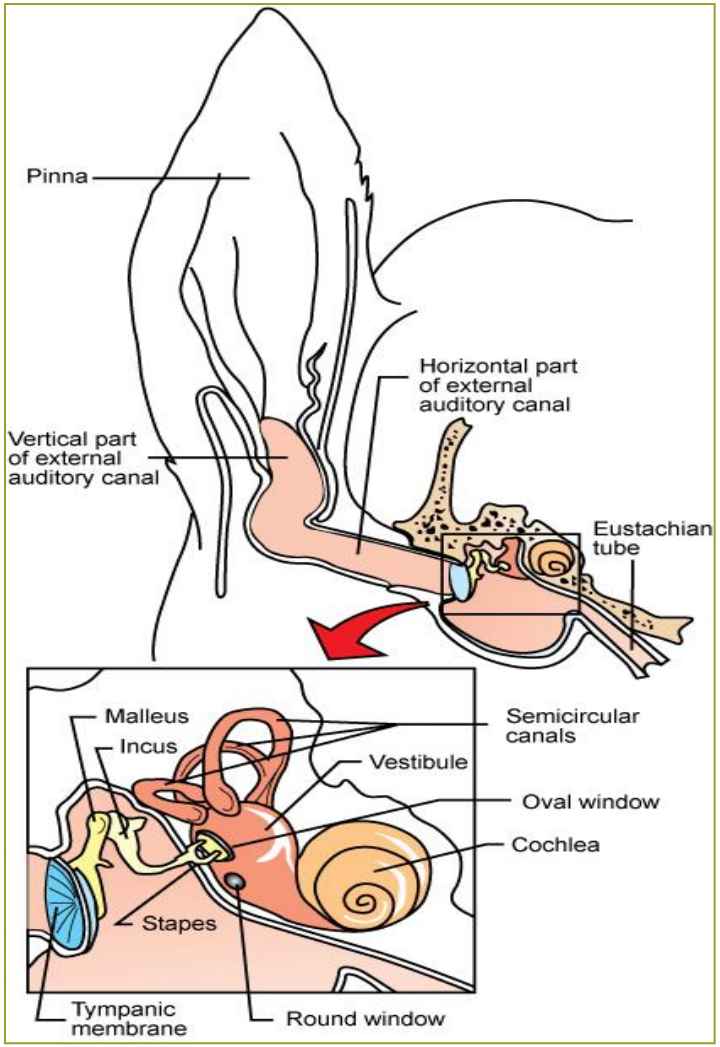
External Ear

- Pinna: elastic cartilage and skin
- External auditory canal: membrane-lined tube



External Ear

- Tympanic membrane (eardrum): thin connective tissue membrane
  - Tightly stretched across the opening between the external auditory canal and the middle ear cavity
  - Sound wave vibrations strike the tympanic membrane and cause it to vibrate

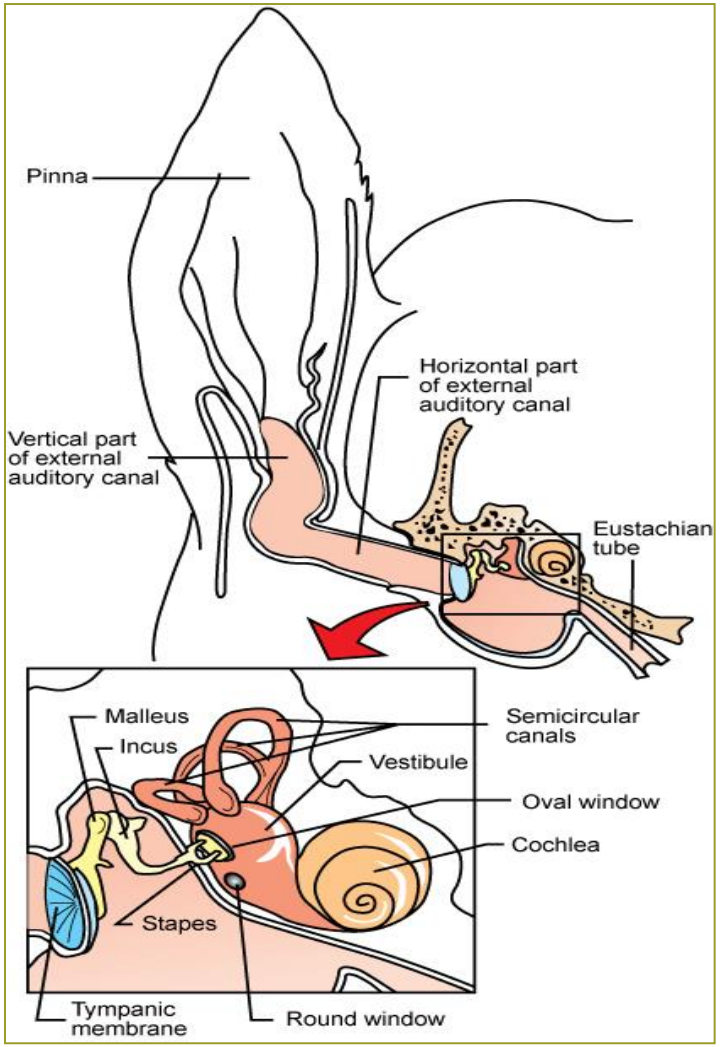


Middle Ear

- Three ossicles (small bones) link the tympanic membrane with the cochlea of the inner ear
  - Act as a system of levers that transmit sound wave vibrations from the tympanic membrane to the cochlea
- Eustachian tube connects the middle ear cavity with the pharynx
  - Equalizes air pressure on the two sides of the tympanic membrane

Middle Ear Ossicles

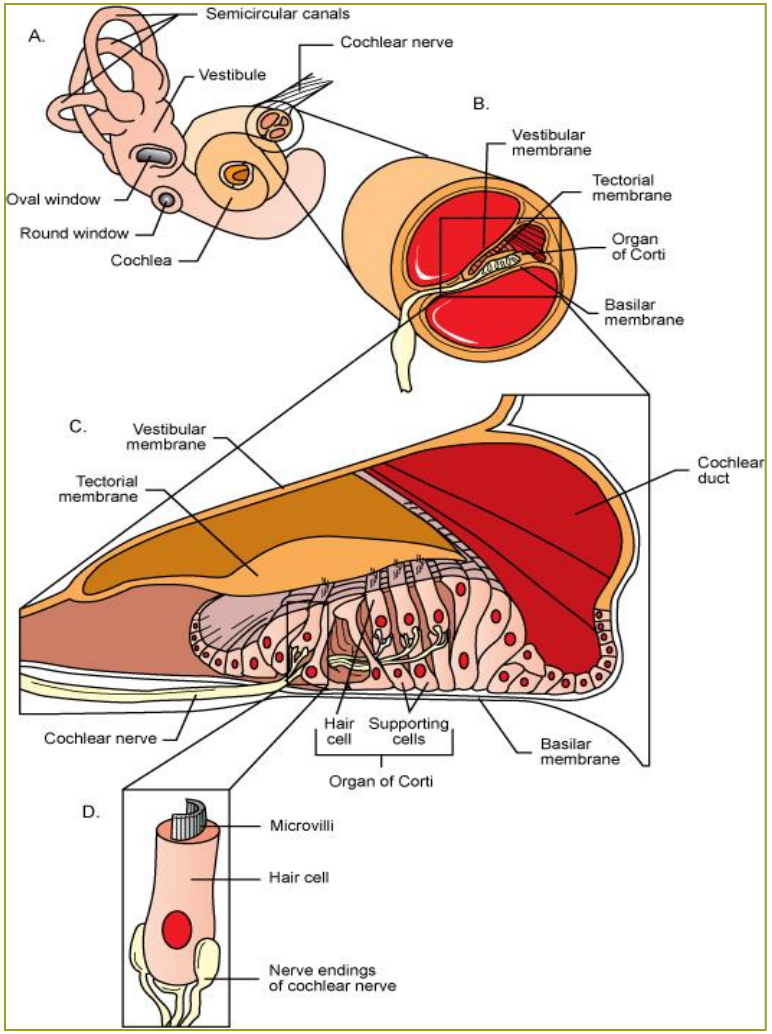
- Malleus: outermost bone; attached to tympanic membrane
- Incus: middle bone
- Stapes: medial-most bone; attached to membrane that covers the oval window of the cochlea



Inner Ear

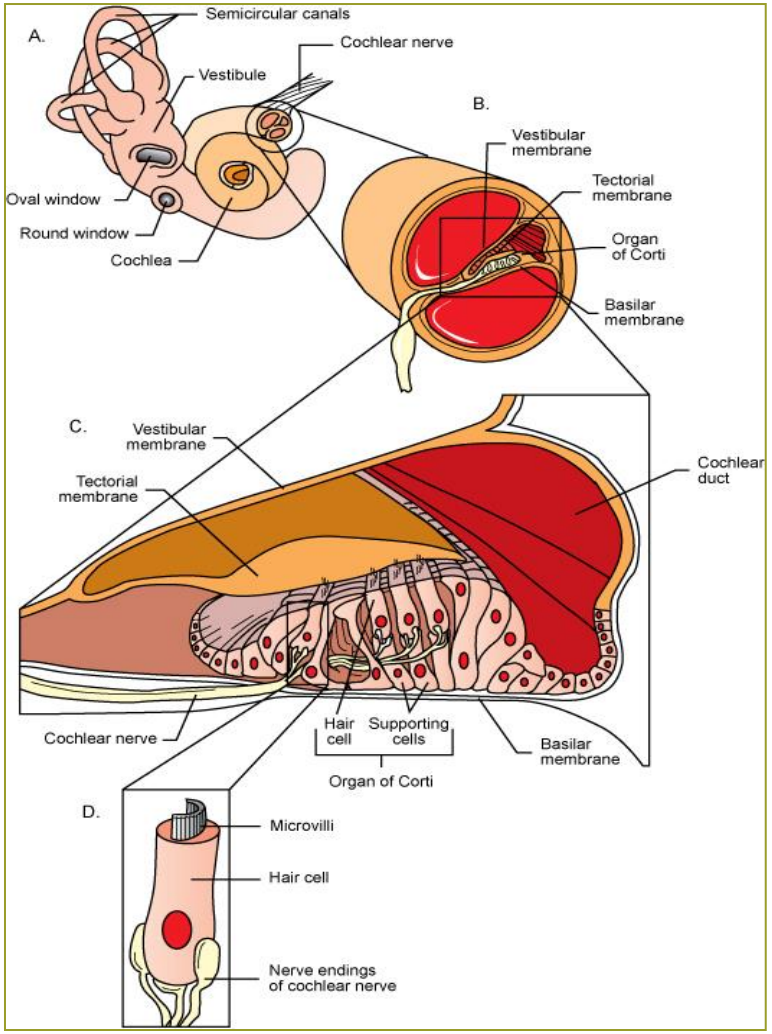
Figure 14-5, Page 347

- Cochlea: shell-shaped spiral cavity in the temporal bone
- Organ of Corti: fluid-filled portion that makes up the receptor organ of hearing



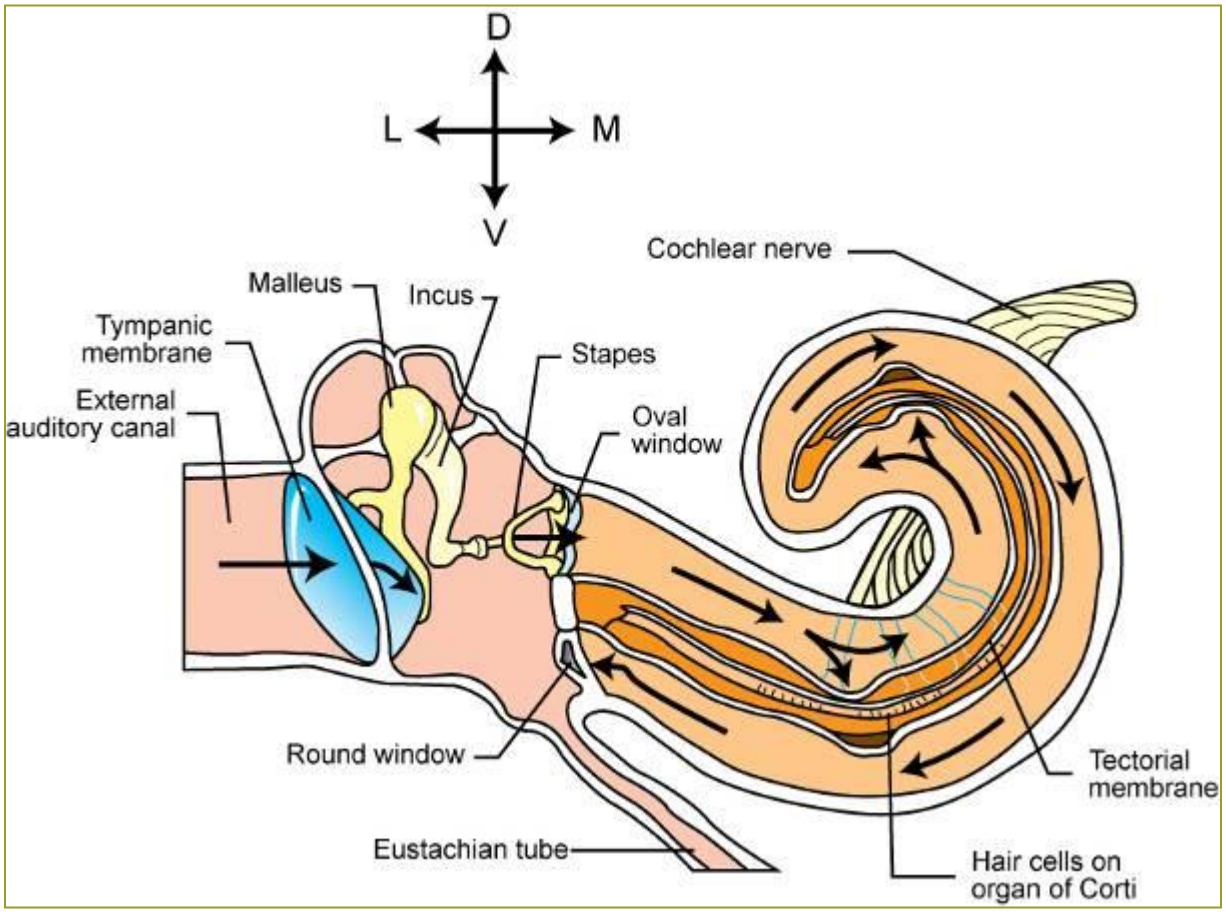
Inner Ear

- Organ of Corti
  - Runs along the cochlear duct on the basilar membrane
  - Consists of hair cells (hearing receptors), supporting cells, and the tectorial membrane



Hearing

Figure 14-6, Page 348



The Ear – Review

Bassert Lab Manual – Page 334

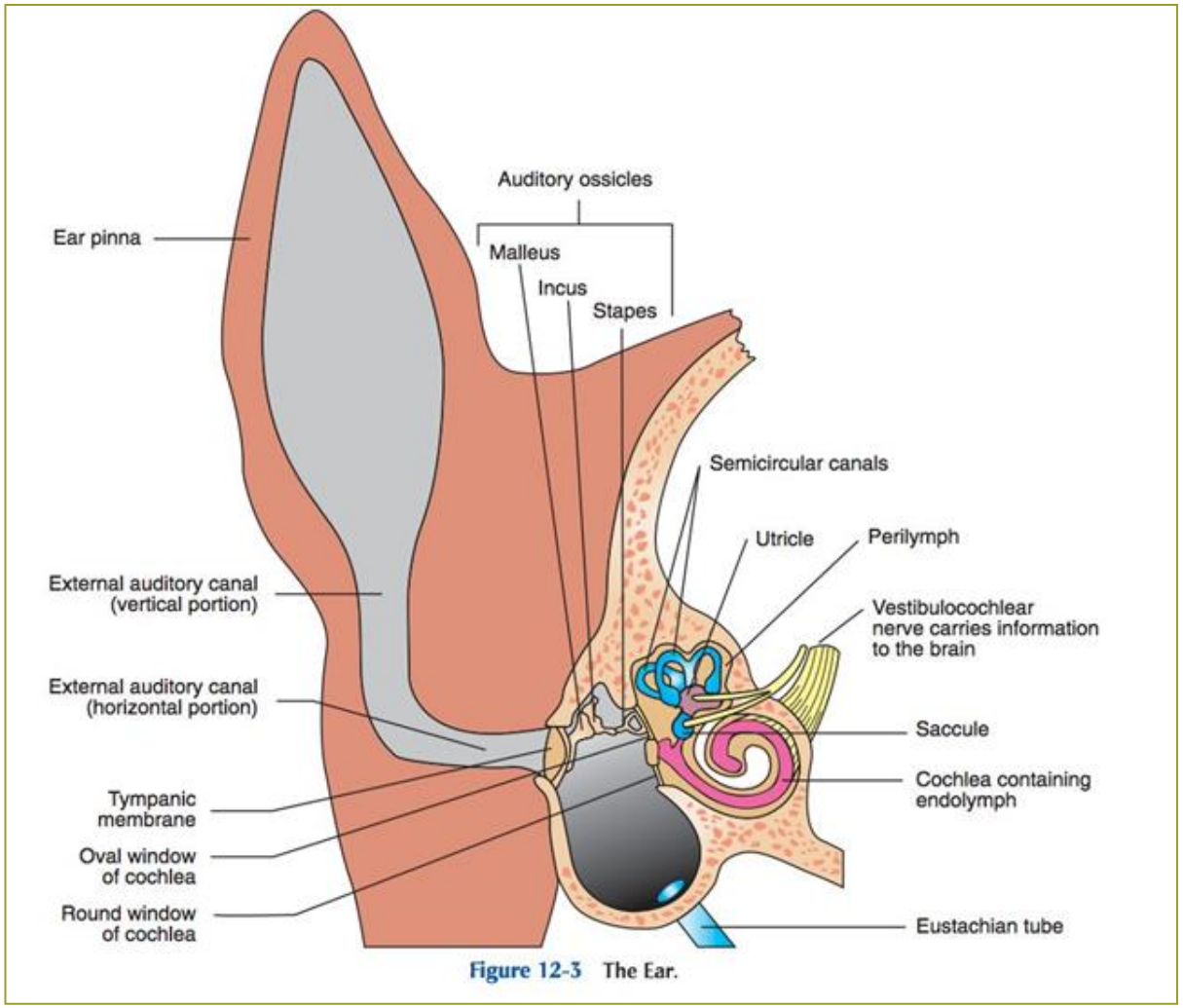
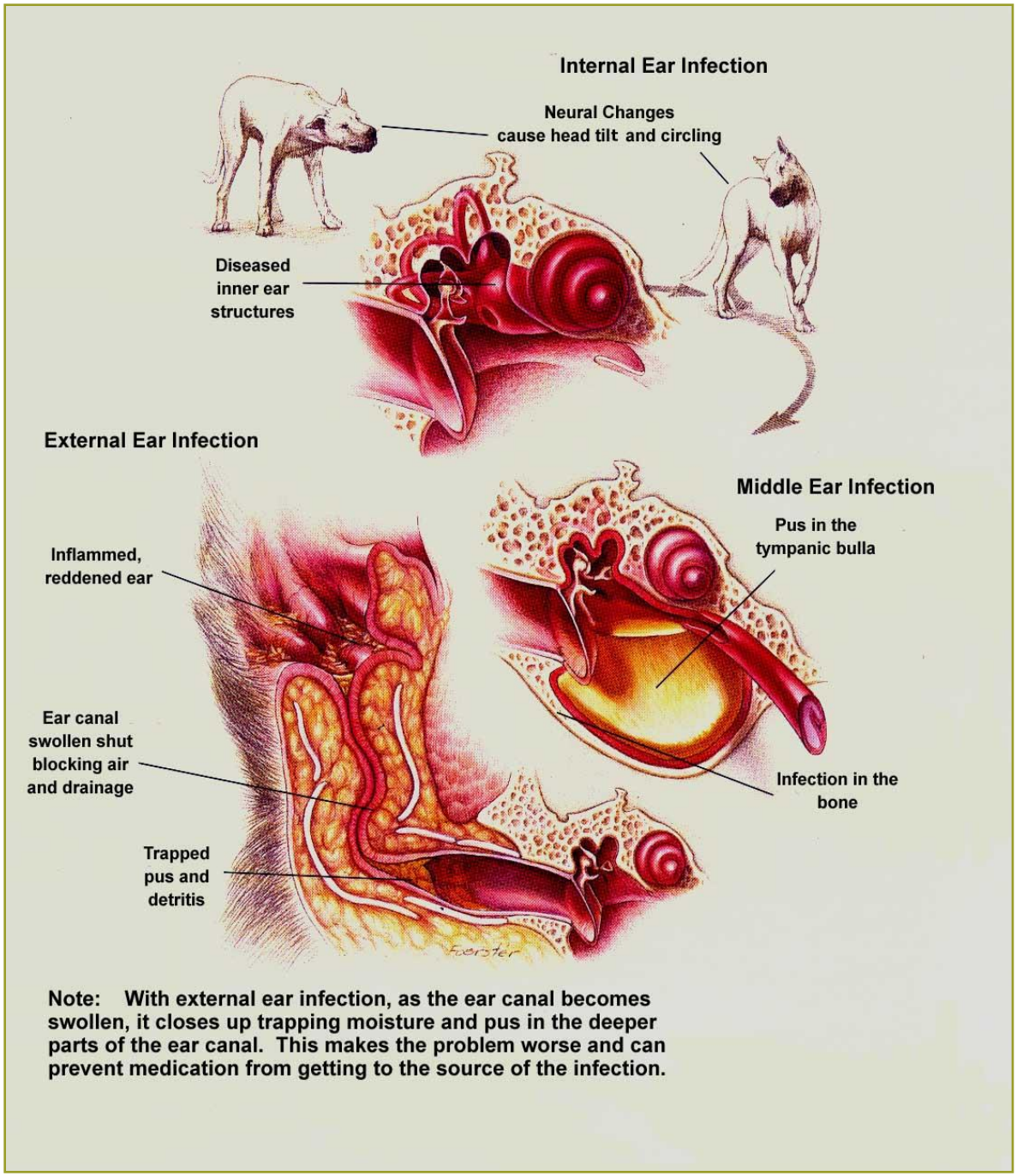


Figure 12-3 The Ear.

Ear Disease – Otitis



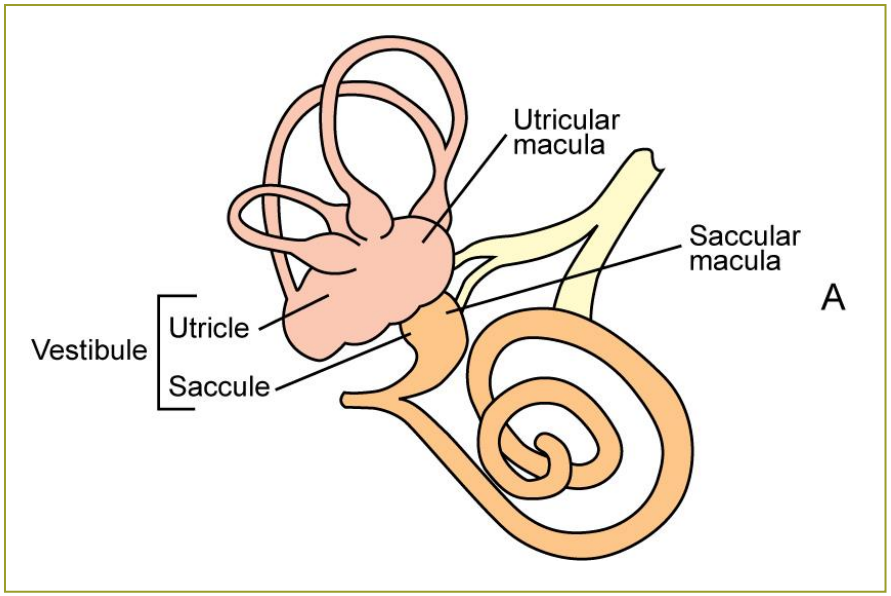
Equilibrium

- Mechanical sense – helps maintain balance by keeping track of the position and movements of the head
- Involves equilibrium receptors and information from the eyes and proprioceptors
- Receptors are located the vestibule and semicircular canals in inner ear

Vestibule

Figure 14-7A, Page 349

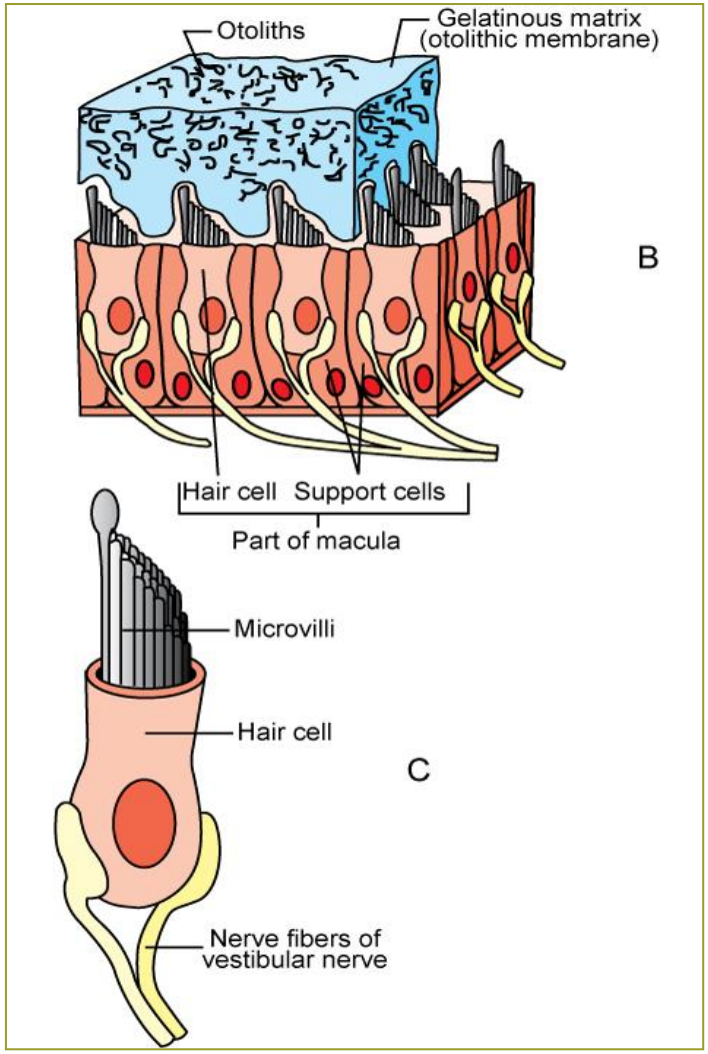
- Between the cochlea and semicircular canals
- Composed of utricle and saccule
- Hair cells covered by a gelatinous matrix that contains crystals of calcium carbonate (otoliths)



Vestibule

Figure 14-7B&C, Page 349

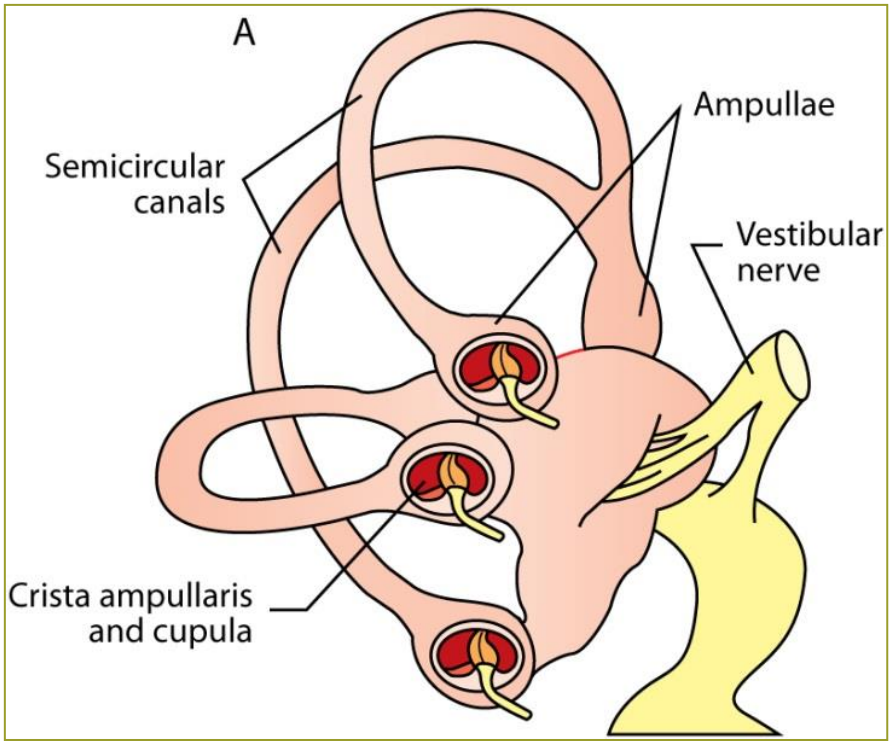
- Gravity causes otoliths and the gelatinous matrix to put pressure on the hairs
- Movement of the head bends sensory hairs
- Generates nerve impulses that give the brain information about position of the head



Semicircular Canals

Figure 14-8A, Page 350

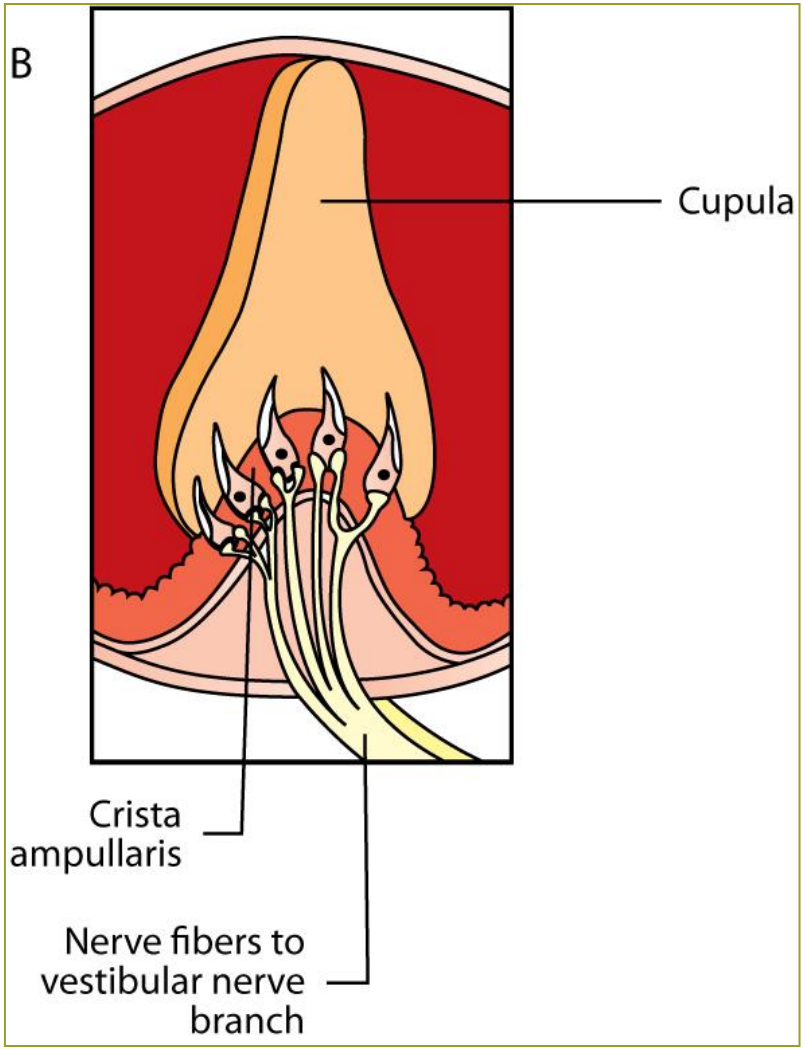
- Located opposite the vestibule from the cochlea
- Contain fluid-filled membranous tubes
- Ampulla: enlarged area near the utricle end of each semicircular canal



Semicircular Canals

Figure 14-8A, Page 350

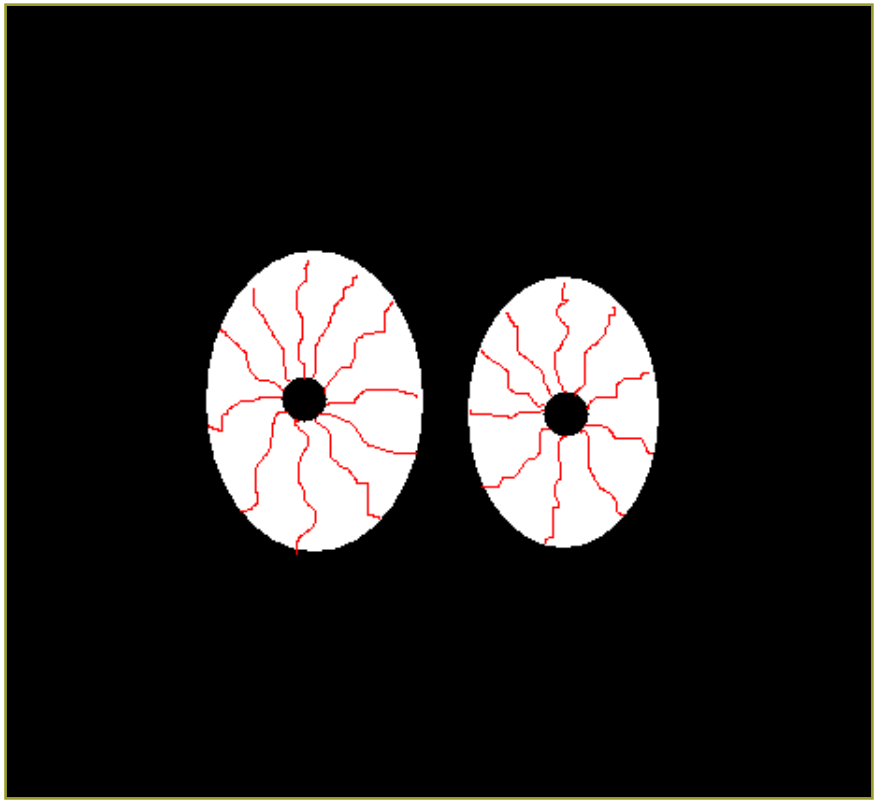
- Crista ampullaris: receptor within ampulla
  - Supporting cells and hair cells with **modified dendrites** sticking up into gelatinous structure (cupula)



Semicircular Canals

- When the head moves, fluid movement lags behind the movement of the canal itself.
- Movement of the fluid pulls on the cupula and bends the hairs.
- Generates nerve impulses that give the brain information about motion of the head

Vision



Vision – 3 Layers of Eye

Outer Fibrous Layer

Middle Vascular Layer

Inner Nervous Layer

All Sorts of Eyes! ☺

3 Layers of Eye

Bassert Lab Manual – Page 336

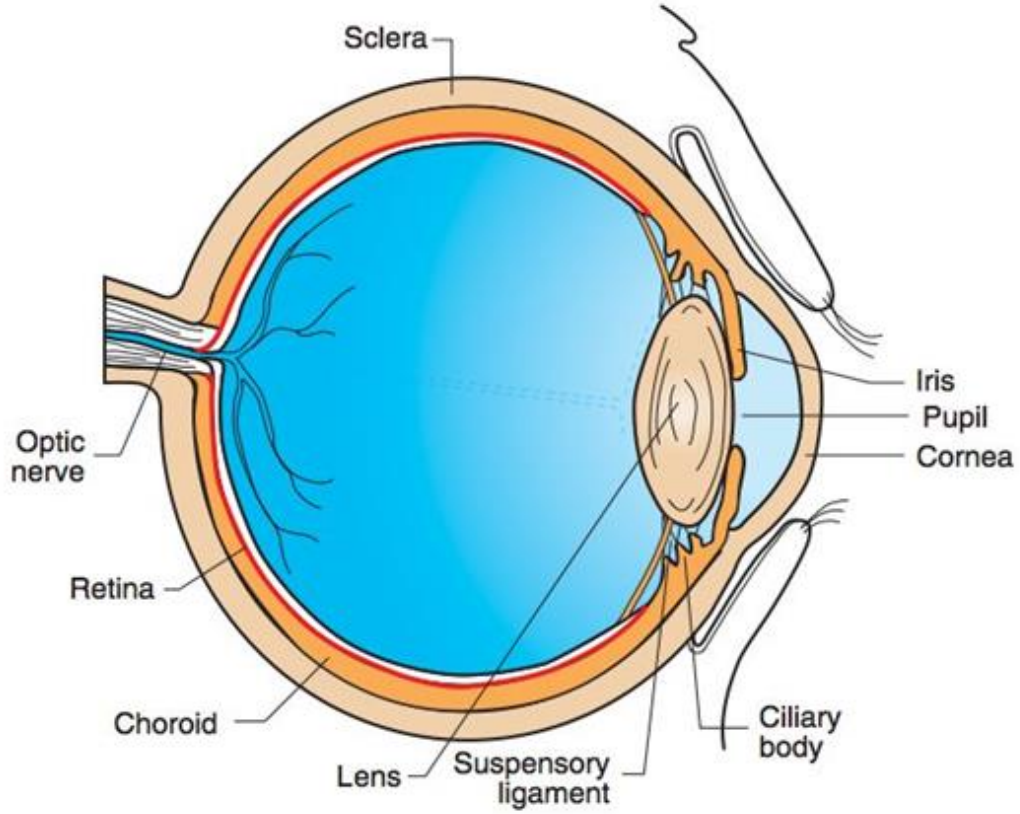
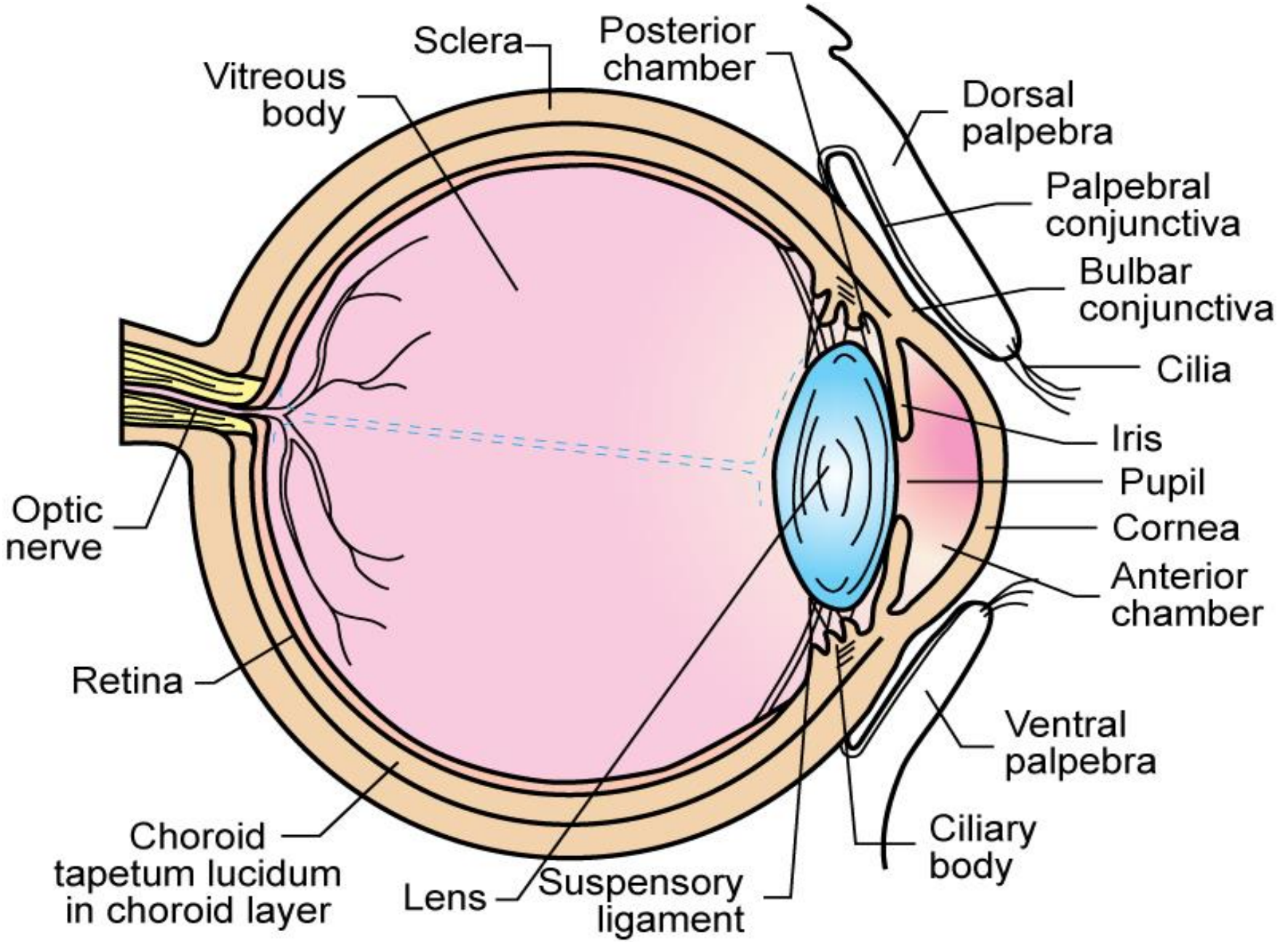


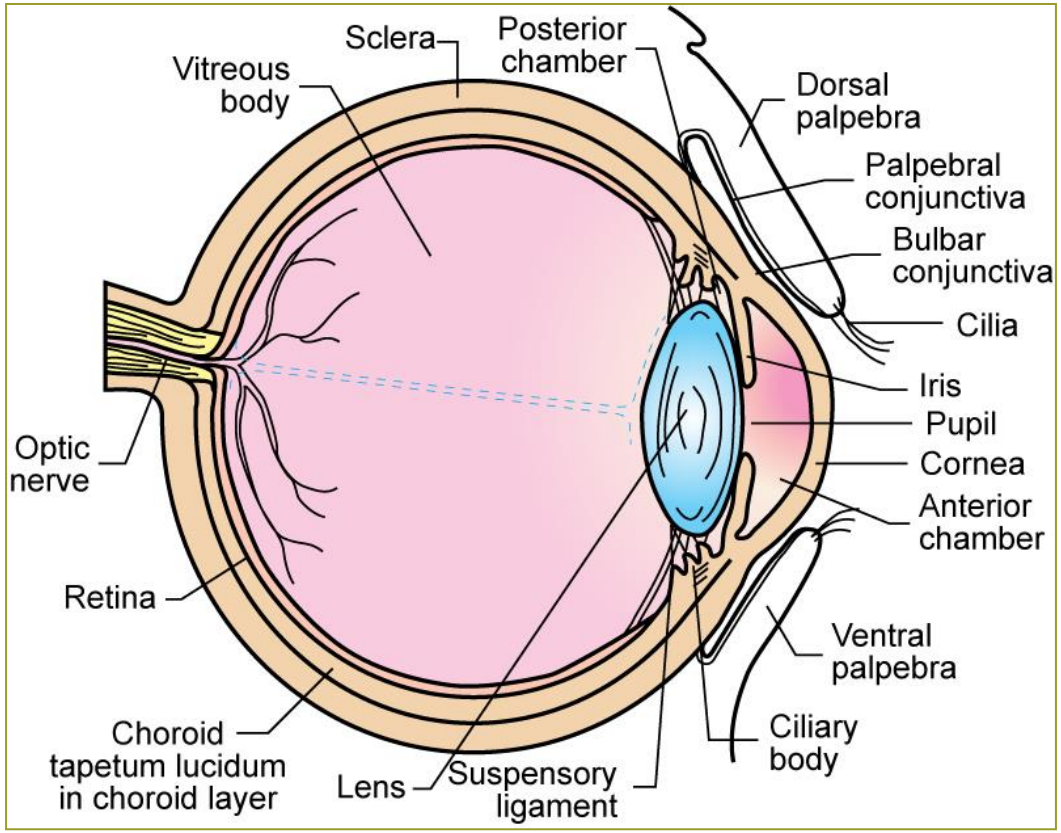
Figure 12-7 Cross Section Diagram of the Eye.


Sclera
Posterior chamber
Vitreous body
Dorsal palpebra
Palpebral conjunctiva
Bulbar conjunctiva
Cilia
Iris
Pupil
Cornea
Anterior chamber
Optic nerve
Retina
Ventral palpebra
Choroid tapetum lucidum in choroid layer
Lens
Suspensory ligament
Ciliary body

Vision

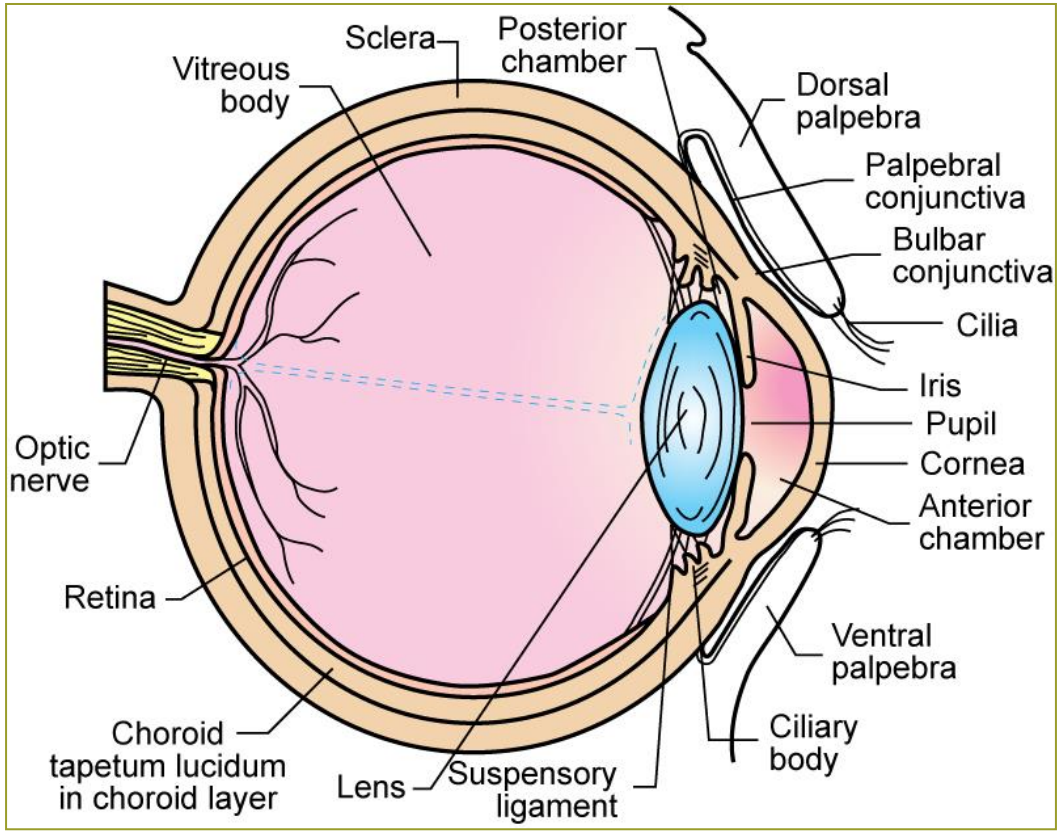
Figure 14-9, Page 350

- Most components of the eye function to help form an accurate visual image, not detect it
- Photoreceptors that detect the image and generate visual nerve impulses are in a single layer of cells in the retina



Eyeball Outer Fibrous Layer

- Cornea: transparent; admits light to interior of the eye
  - Arrangement of collagen fibers; no blood vessels
- Sclera: "white" of the eye
  - Dense fibrous connective tissue
- Limbus: junction of the cornea and the sclera



Cornea & Sclera

Bassert Lab Manual – Page 337

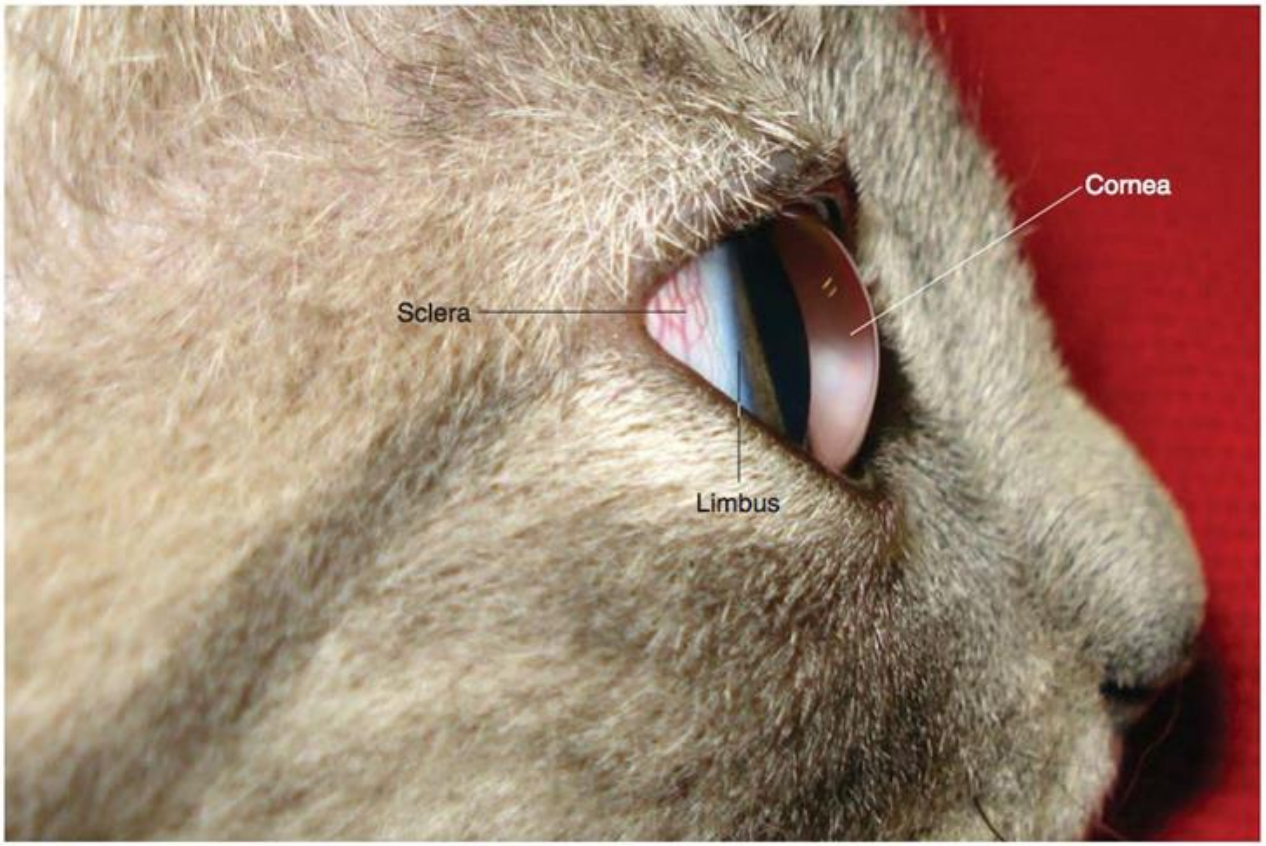
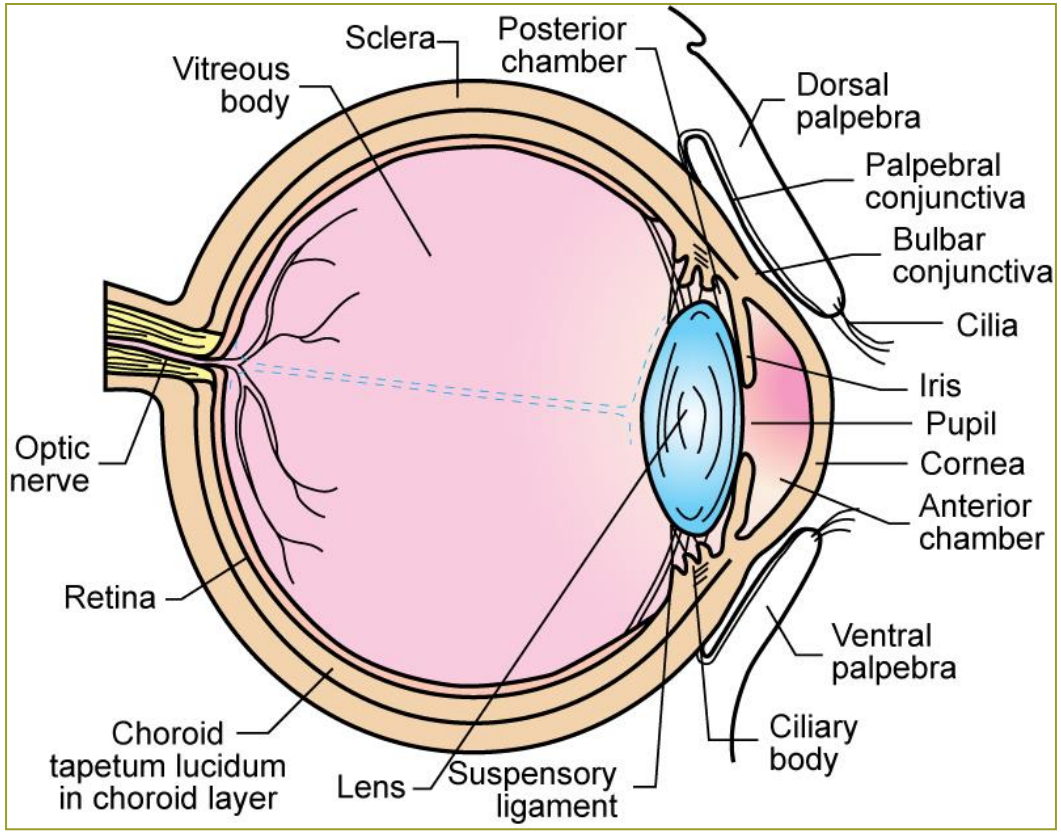


Figure 12-9 **Outer Fibrous Layer of a Cat's Eye.** Note the rounded shape of the cornea.

Eyeball Middle Vascular Layer

- Choroid: between the sclera and the retina
  - Pigment and blood vessels
  - In most animals, choroid forms the tapetum – highly reflective area in the rear of the eye



Tapetum

Bassert Lab Manual – Page 340

Figure 12-14 **Tapetum and Irises.** This cat has one pigmented and one non-pigmented iris.

Right eye:

- Gold colored iris
- Green colored tapetum reflecting light

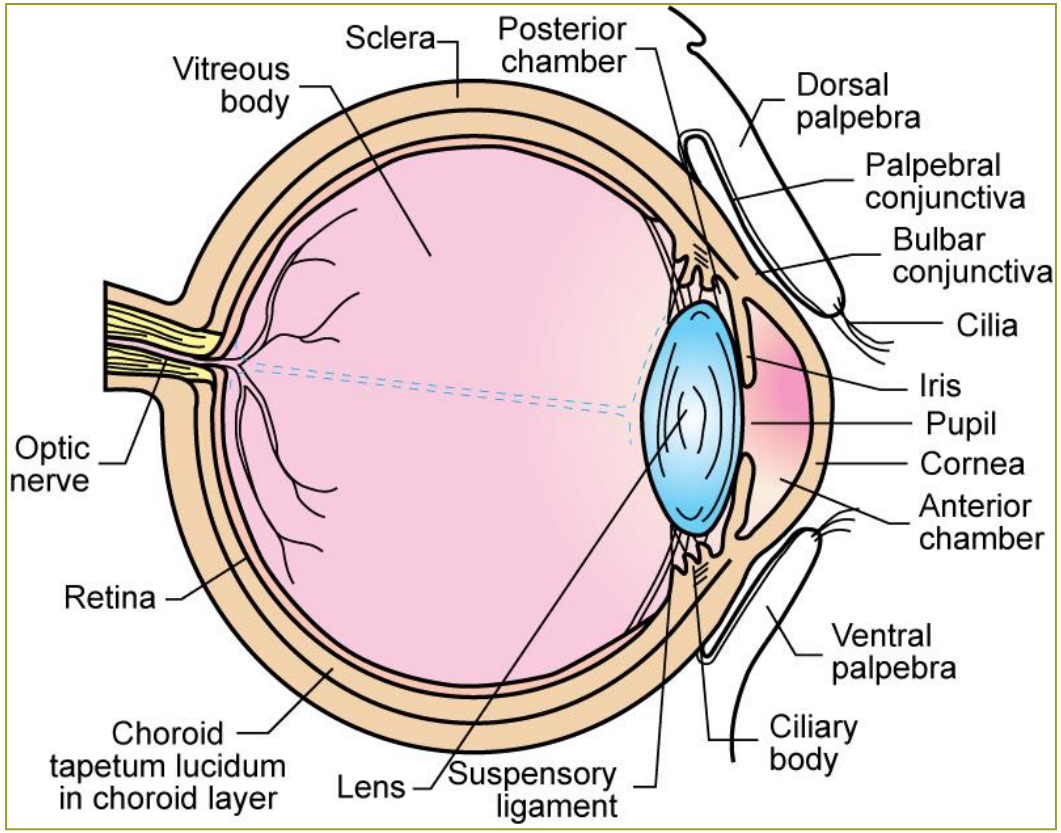
Left eye:

- Pale blue colored iris
- Red color caused by light reflecting off blood vessels in the choroid layer in the back of the eye because there is no tapetum. Because humans don't have tapeta, we are frequently cursed with red eyes on flash photographs, particularly in dim light when the pupils are large

Tapetum Lucidum

Eyeball Middle Vascular Layer

- Iris: pigmented muscular diaphragm
  - Controls amount of light that enters the posterior part of the eyeball
  - Pupil: opening at center of iris



Cat Irises

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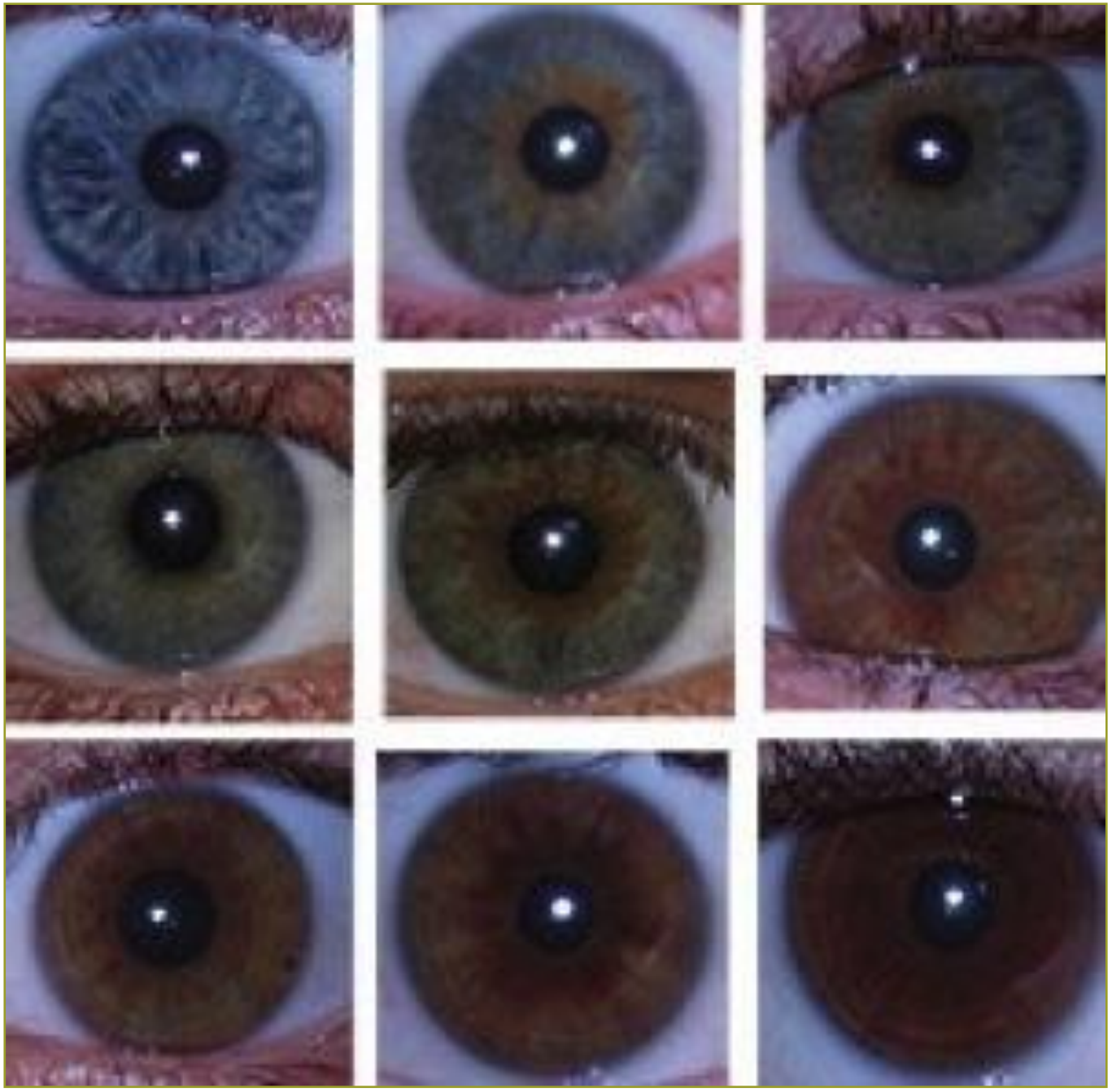
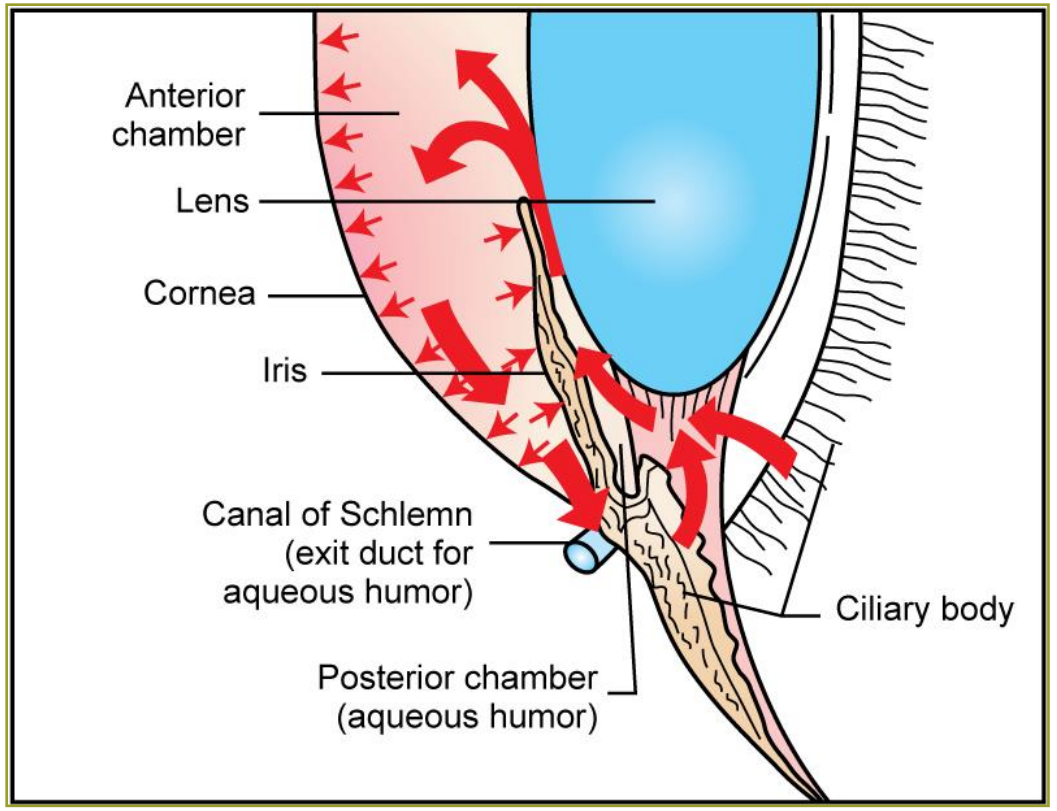
Figure 12-10 Variations in the Colors of Cat Irises.



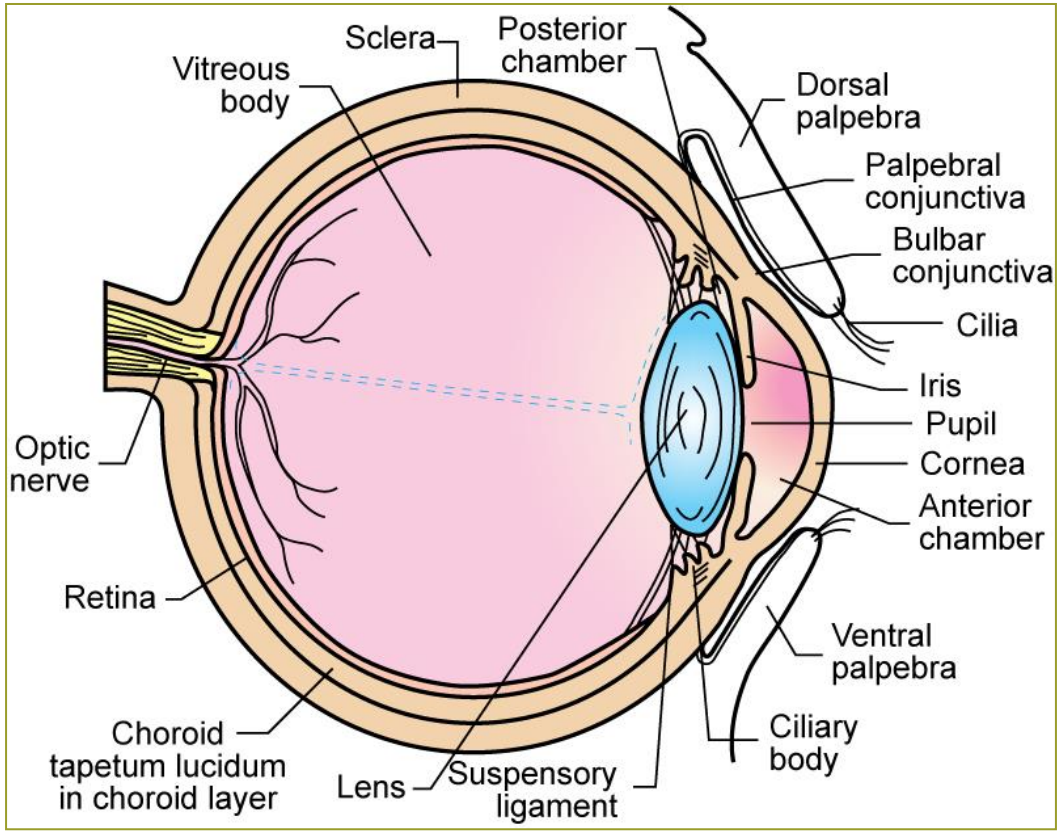
Eyeball Middle Vascular Layer

- Ciliary body: ring-shaped structure behind the iris
  - Muscles that adjust shape of the lens to allow near and far vision



Eyeball Inner Nervous Layer

- Retina
  - Lines the back of the eye
  - Contains the sensory receptors for vision, the rods and cones



Compartments of the Eyeball

Aqueous Compartment

Vitreous Compartment

Aqueous Compartment

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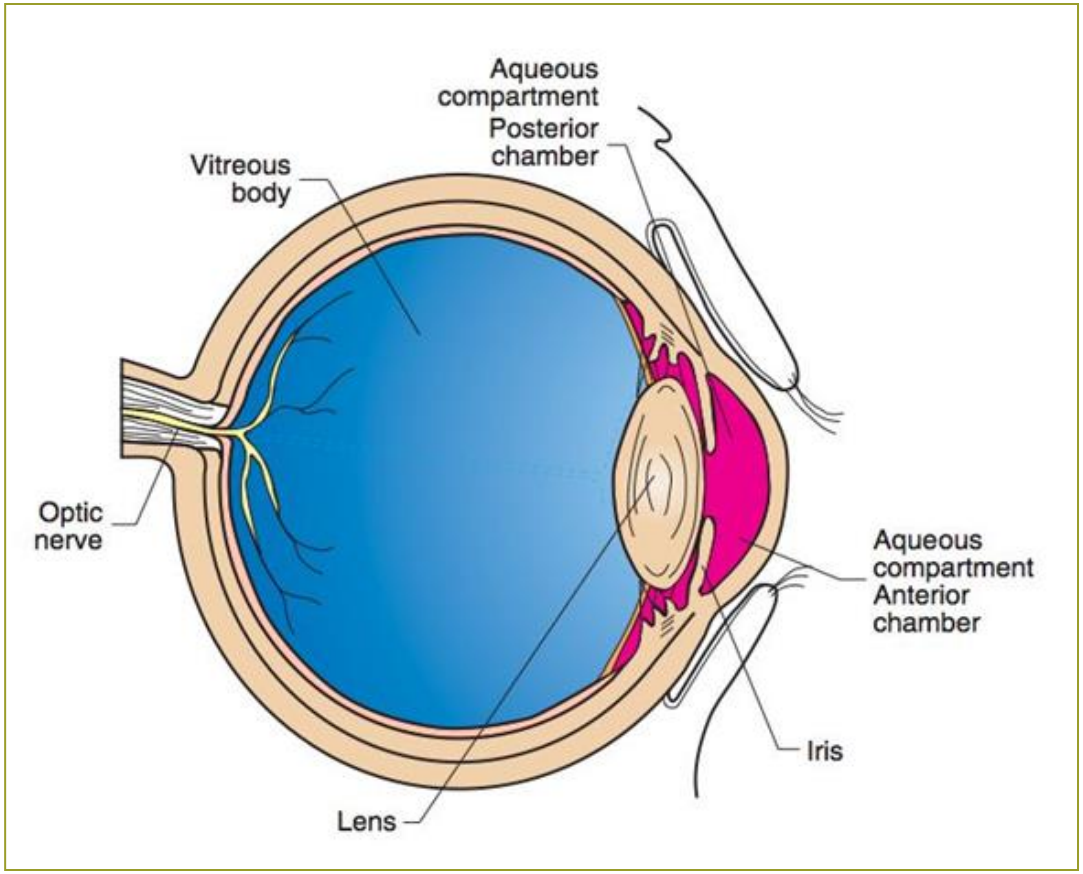
- Subdivided by the iris into anterior and posterior chambers
- Contains a clear watery fluid: aqueous humor
- Produced in the posterior chamber by cells of the ciliary body



Vitreous Compartment

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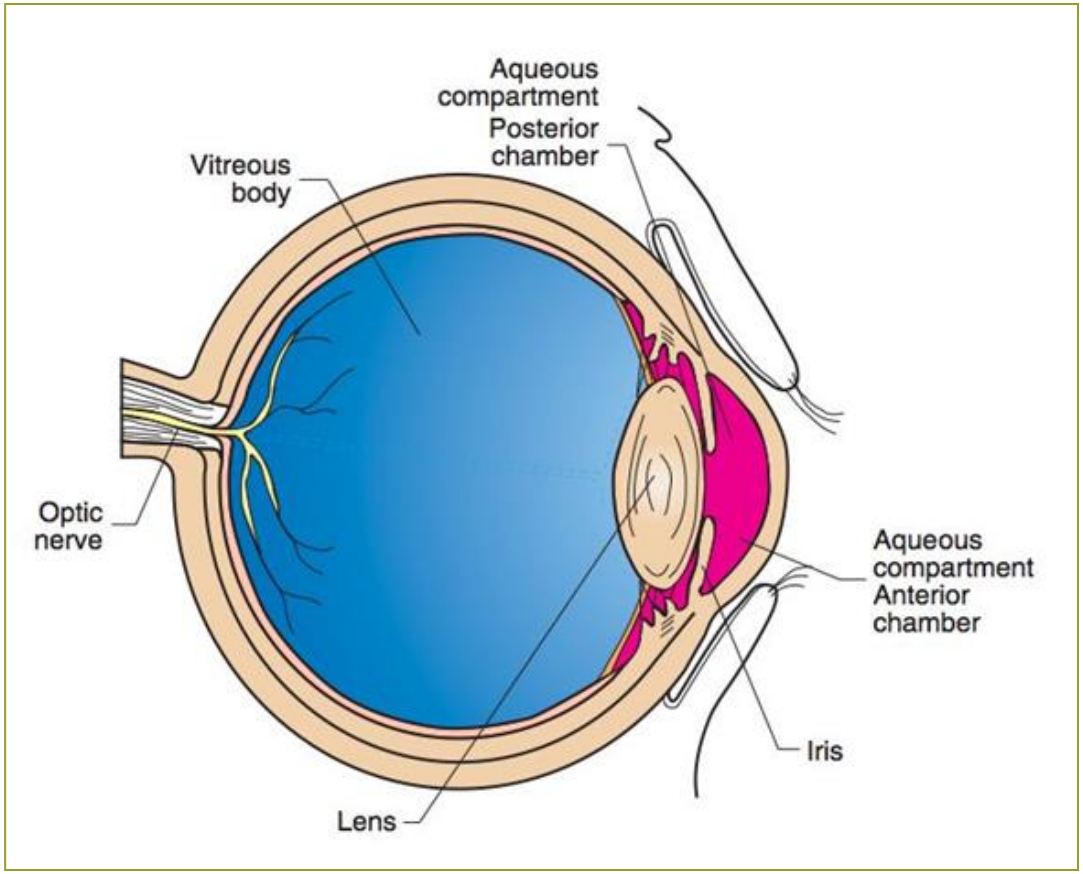
- Contains a clear gelatinous fluid called vitreous humor
- Vitreous humor fills the whole back of the eyeball behind the lens and ciliary body



Lens

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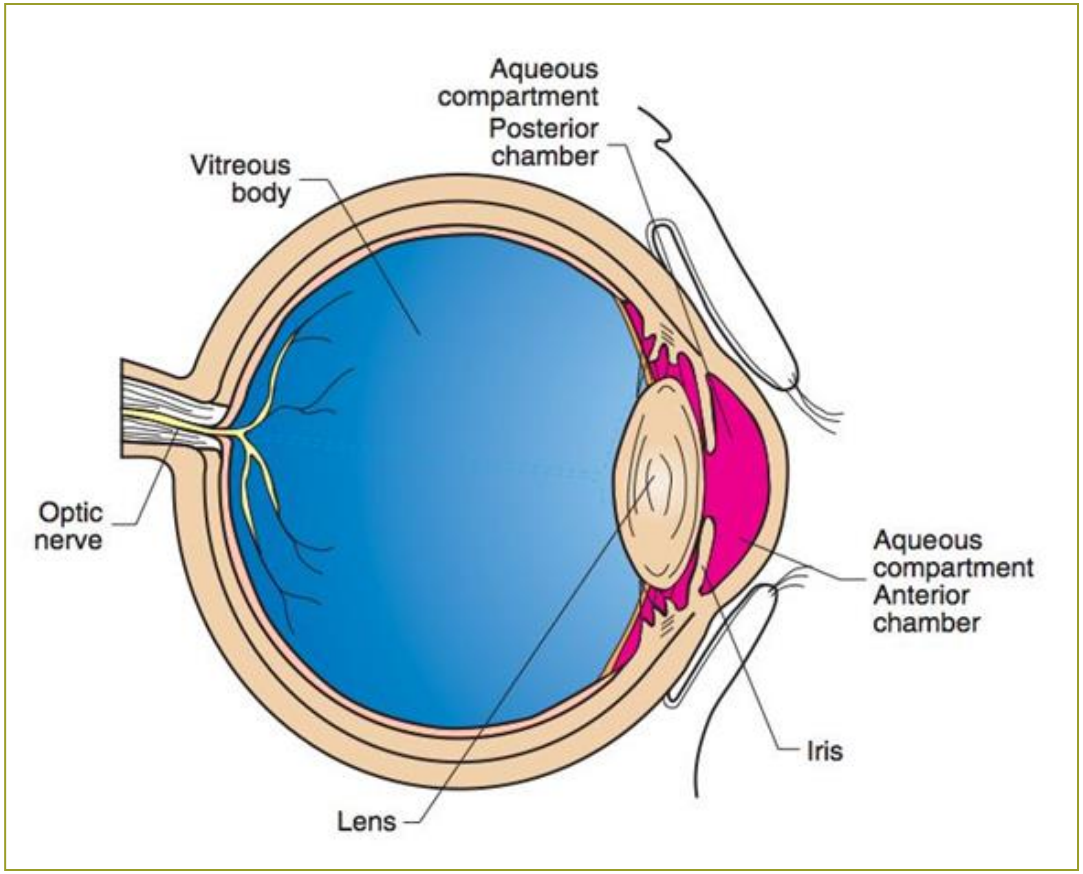
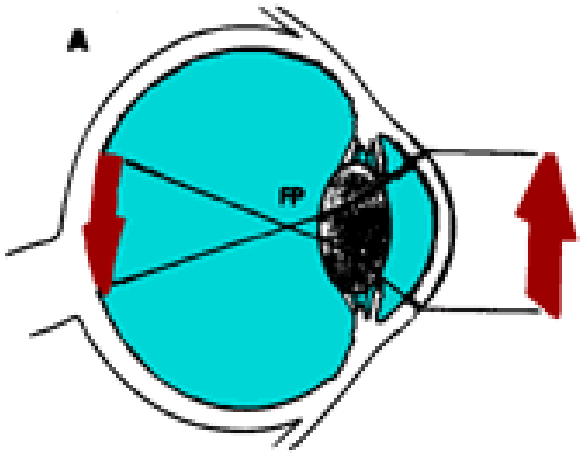
- Layers of fibers
- Elastic and biconvex
- Front surface is in contact with aqueous humor; back surface is in contact with vitreous humor
- Helps focus a clear image on the retina



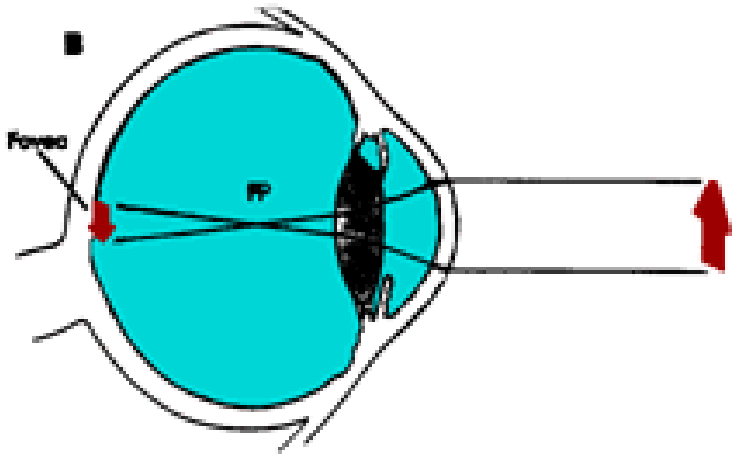
Lens Accommodation

- Accommodation: process by which the shape of the lens is changed to allow close-up and distant vision
  - Relaxation of ciliary muscles causes tension on suspensory ligaments; flattens the lens
  - Contraction of ciliary muscles releases tension on the suspensory ligaments

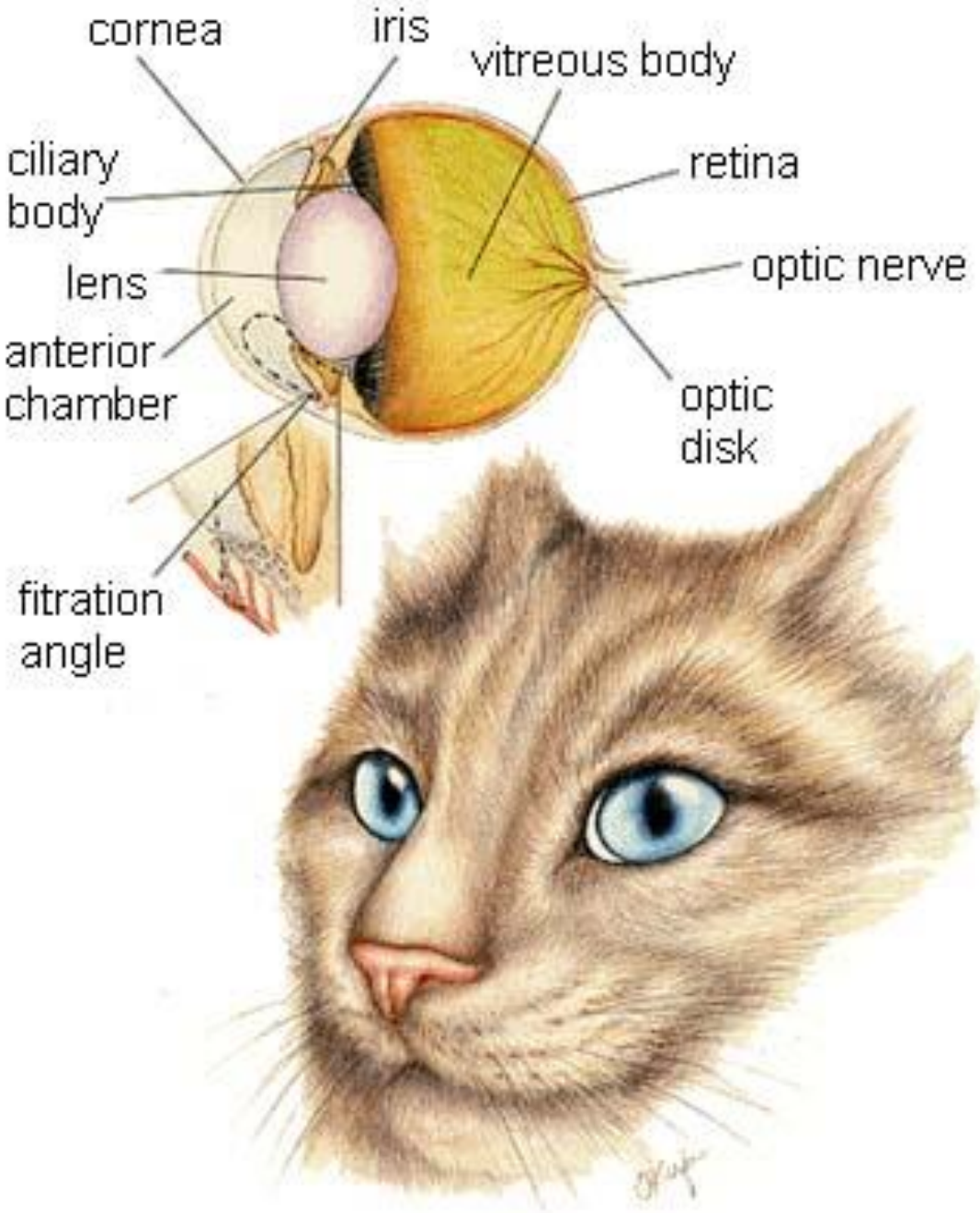
Near & Far Objects – Accommodation



Near Object



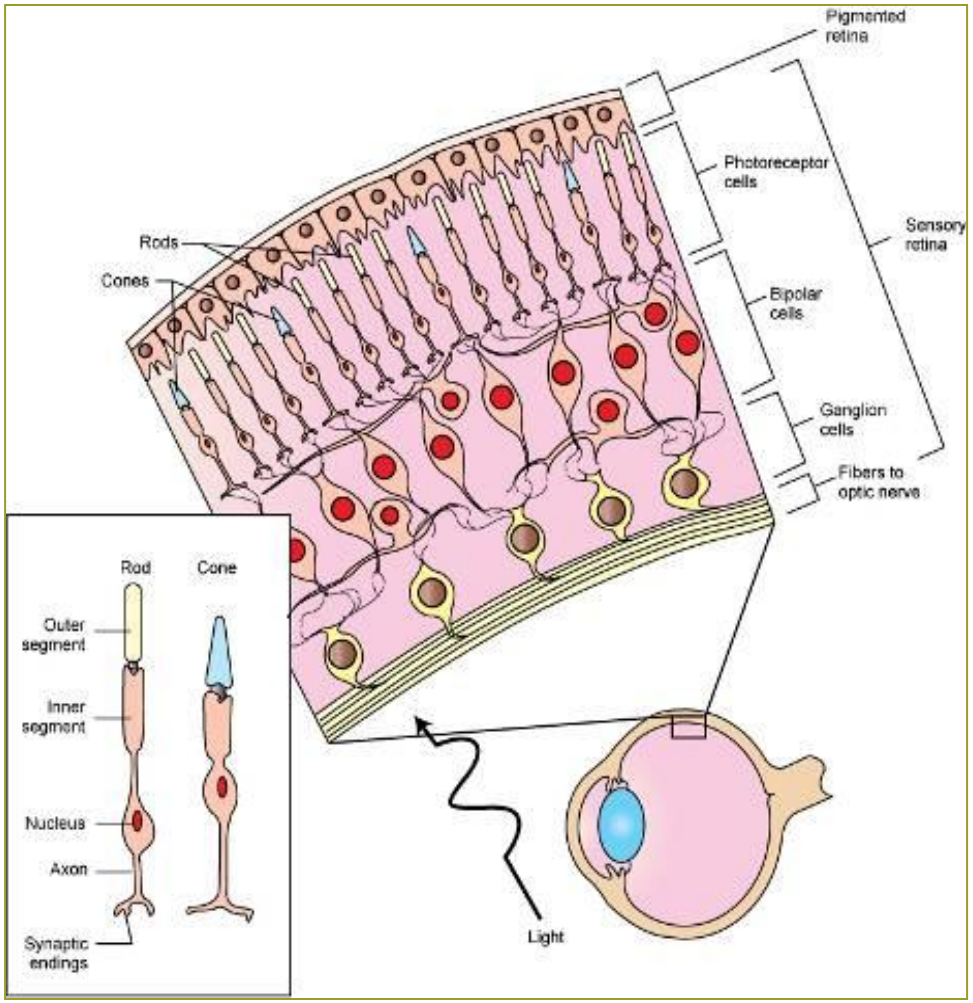
Far Object

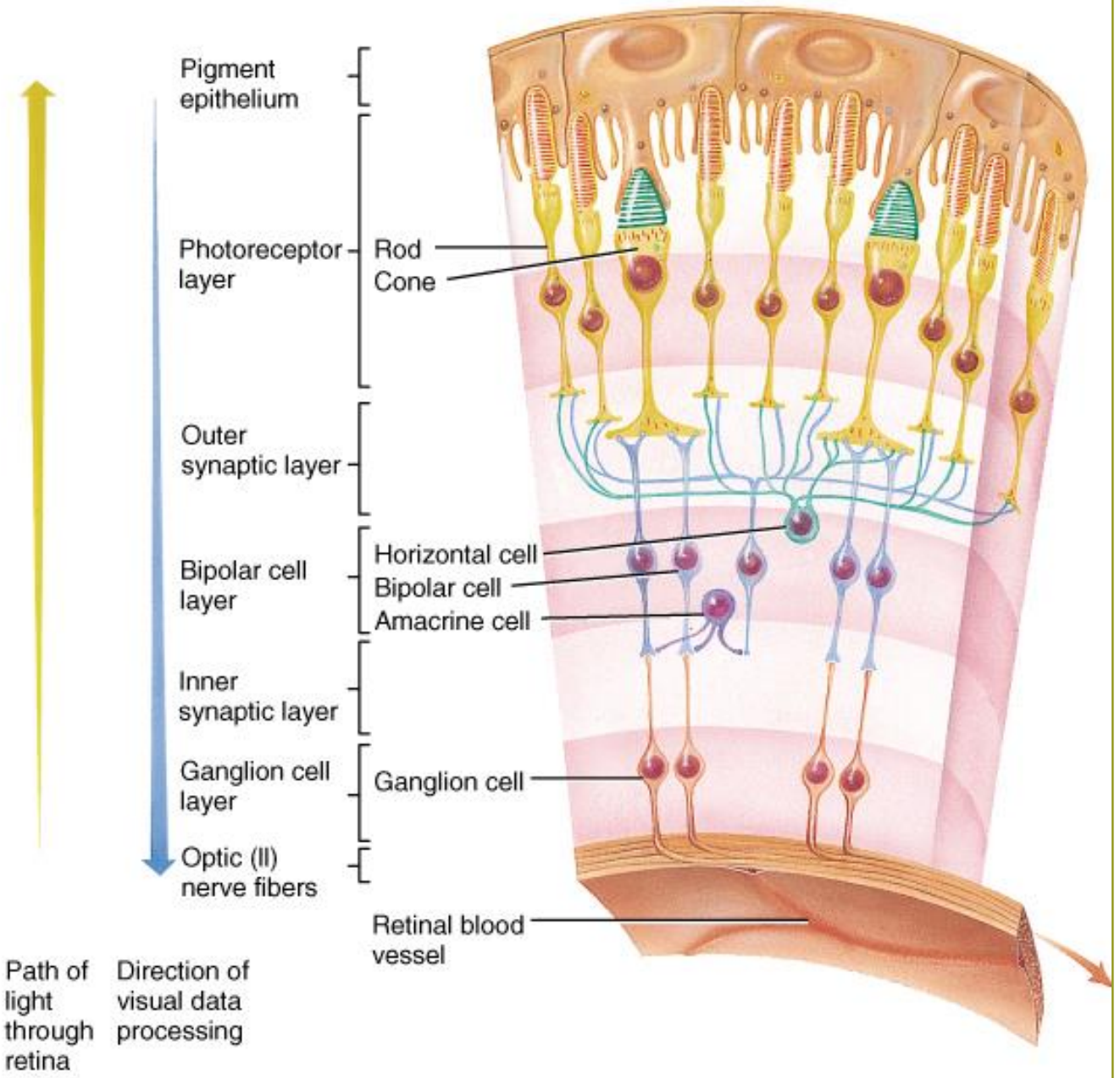

cornea
iris
vitreous body
ciliary body
retina
lens
optic nerve
anterior chamber
optic disk
fitration angle

Retina

Figure 14-11, Page 354

- Lines the back of eye
- "Movie Screen" or "Film in Camera"
  - Where visual image is formed
- Contains sensory receptors for vision
  - **Rods**
  - **Cones**
- Optic disc
  - Forms optic nerve




Pigment epithelium
Photoreceptor layer
Rod
Cone
Outer synaptic layer
Bipolar cell layer
Horizontal cell
Bipolar cell
Amacrine cell
Inner synaptic layer
Ganglion cell layer
Ganglion cell
Optic (II) nerve fibers
Retinal blood vessel
Path of light through retina
Direction of visual data processing

Retina

- Optic Disc: site where nerve fibers on the inside surface of the retina converge and leave the eye to form the optic nerve
- Photoreceptor cells: neurons with modified dendrites
  - **Rods** – more sensitive to light
  - **Cones** – more sensitive to color and detail

Ophthalmoscope

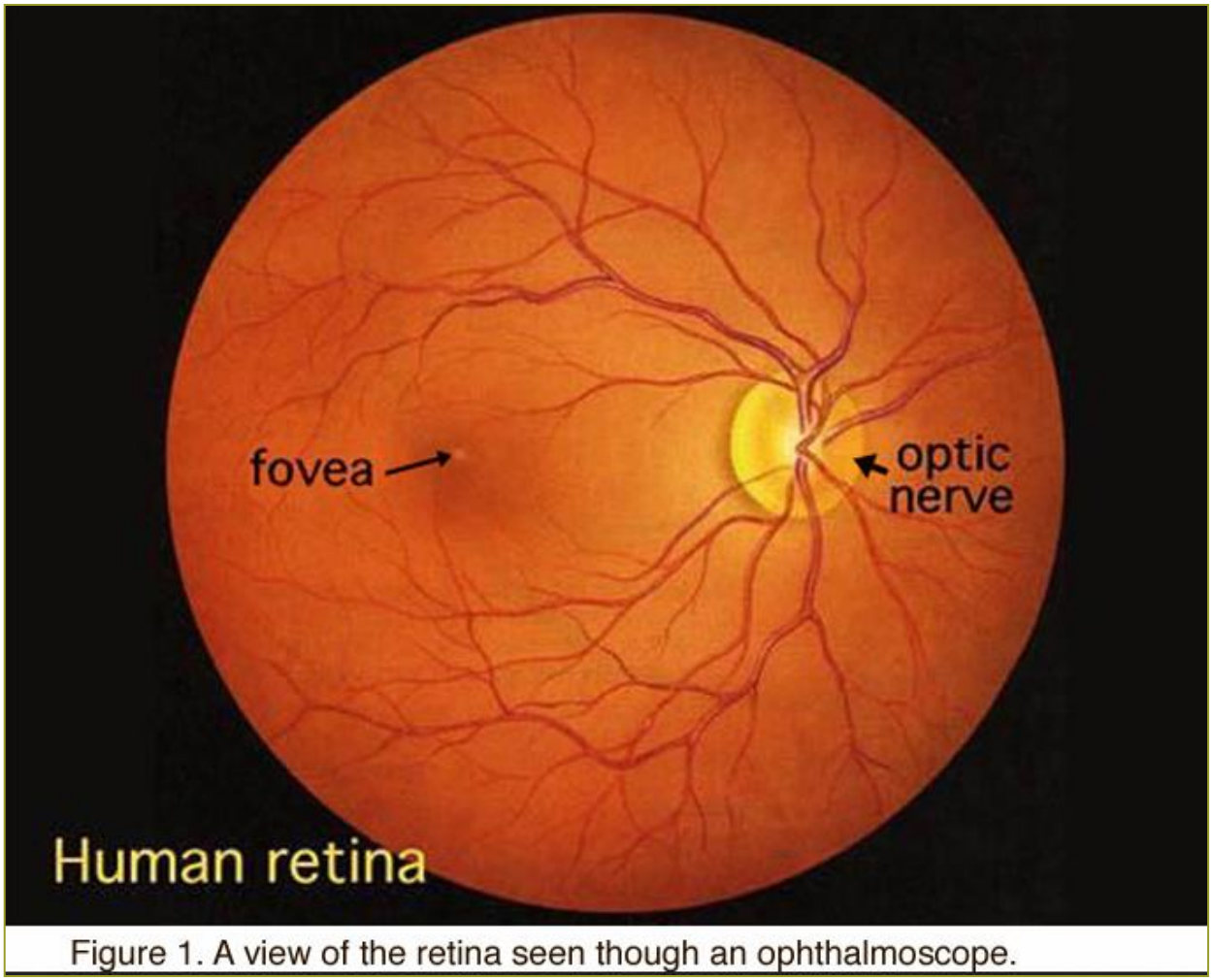
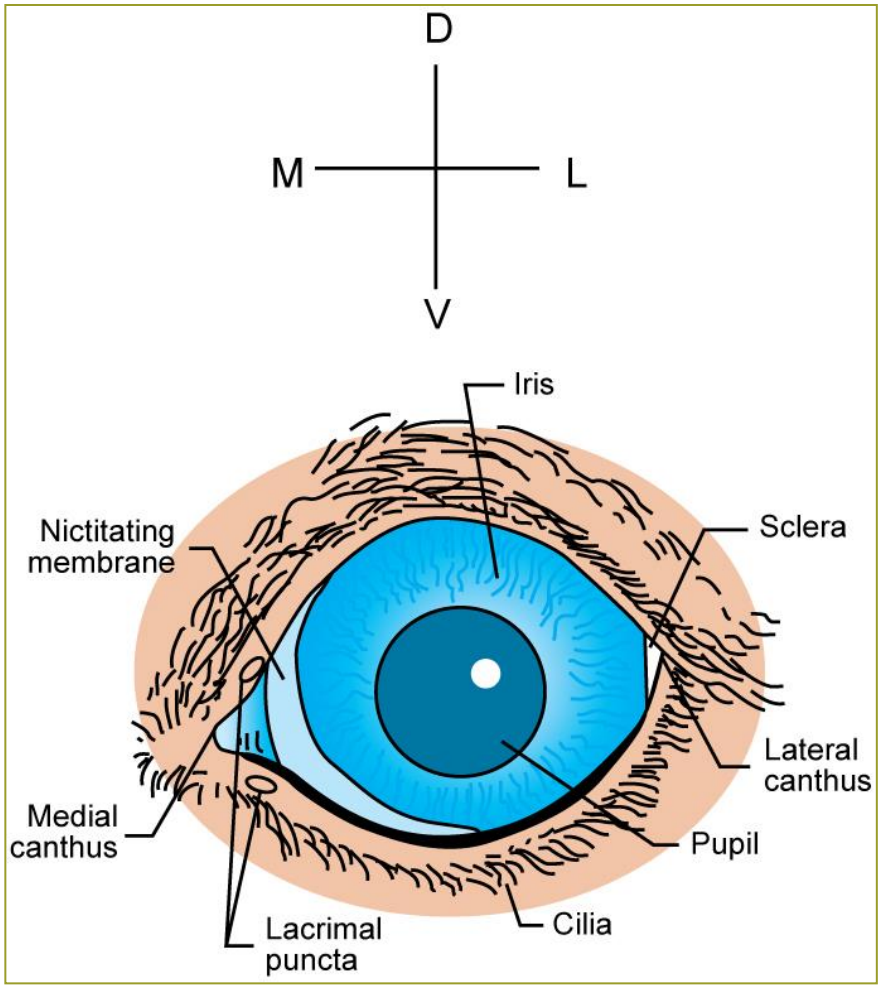


Figure 1. A view of the retina seen though an ophthalmoscope.

Extraocular Structures

Figure 14-12, Page 355

- Conjunctiva: thin transparent membrane
  - Covers the front portion of the eyeball and lines the interior surfaces of the eyelids
- Conjunctival sac: space between the bulbar and palpebral portions of the conjunctiva



Extraocular Structures

- Eyelids: upper and lower folds of skin lined by the thin, moist conjunctiva
- Lateral and medial canthus: corners where the eyelids come together
- Tarsal glands: produce waxy substance that helps prevent tears from overflowing onto the face

Lateral and Medial Canthus

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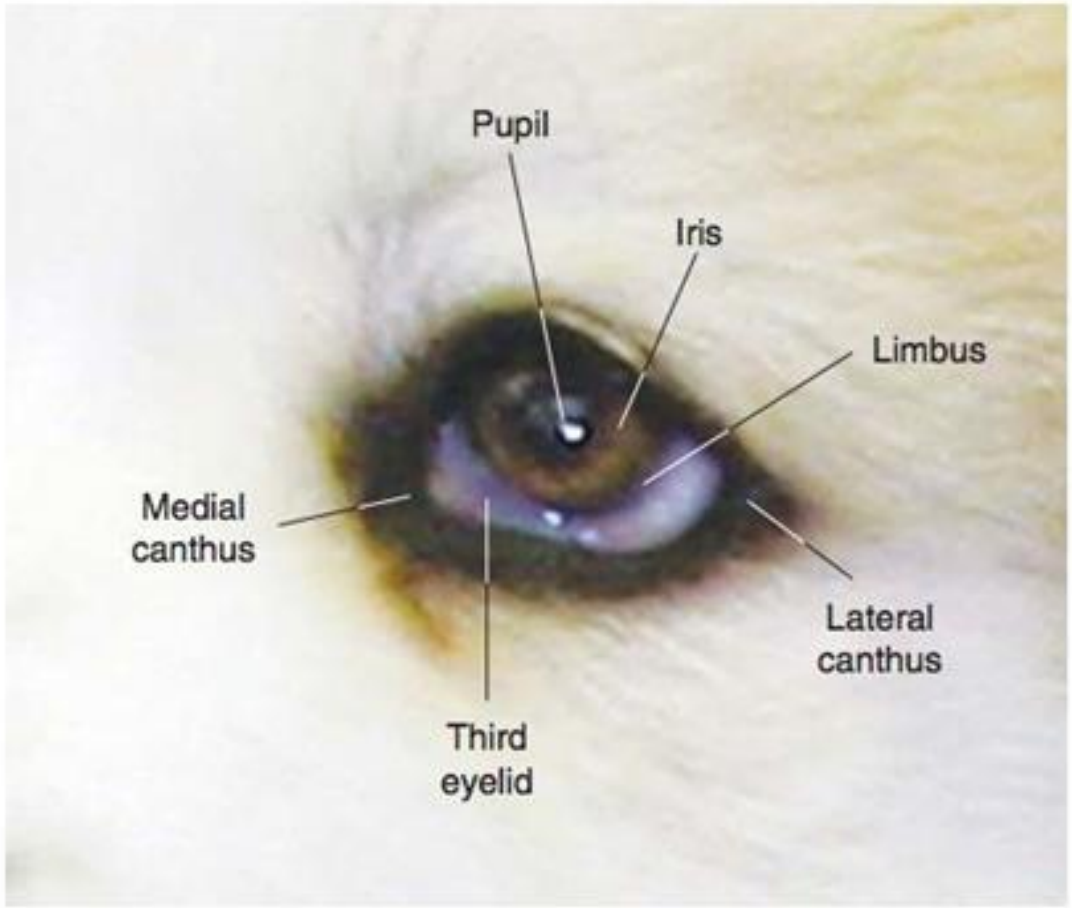
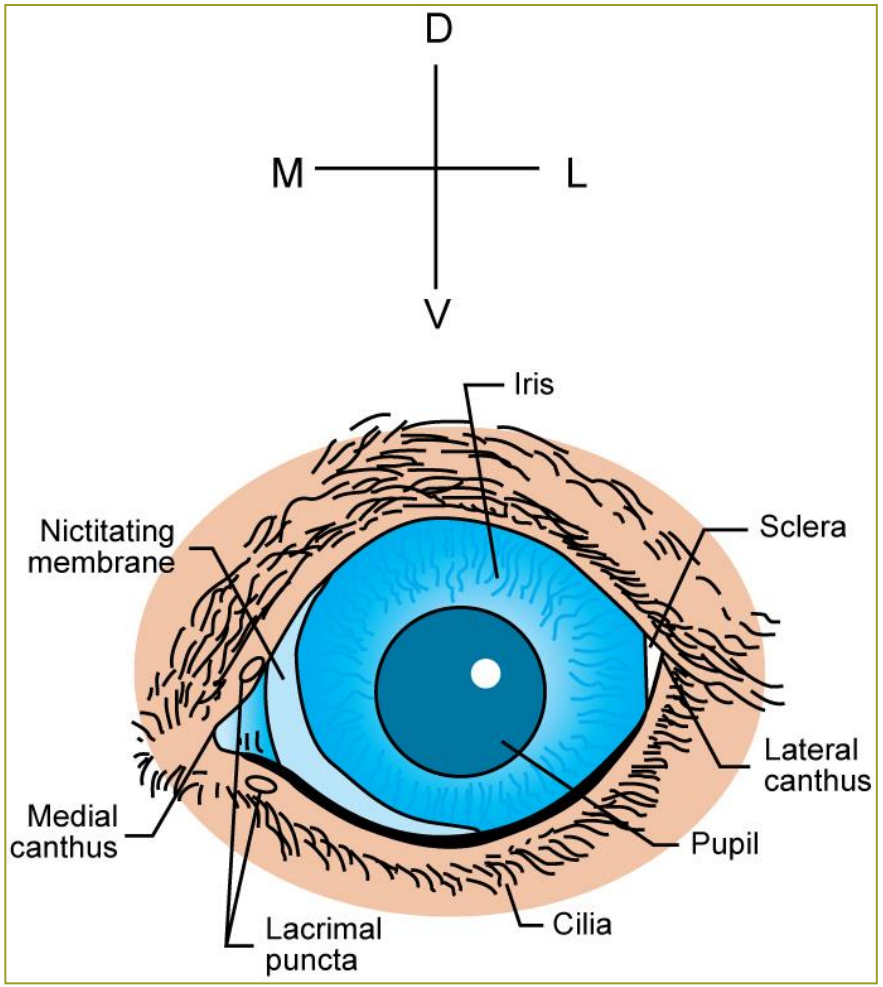


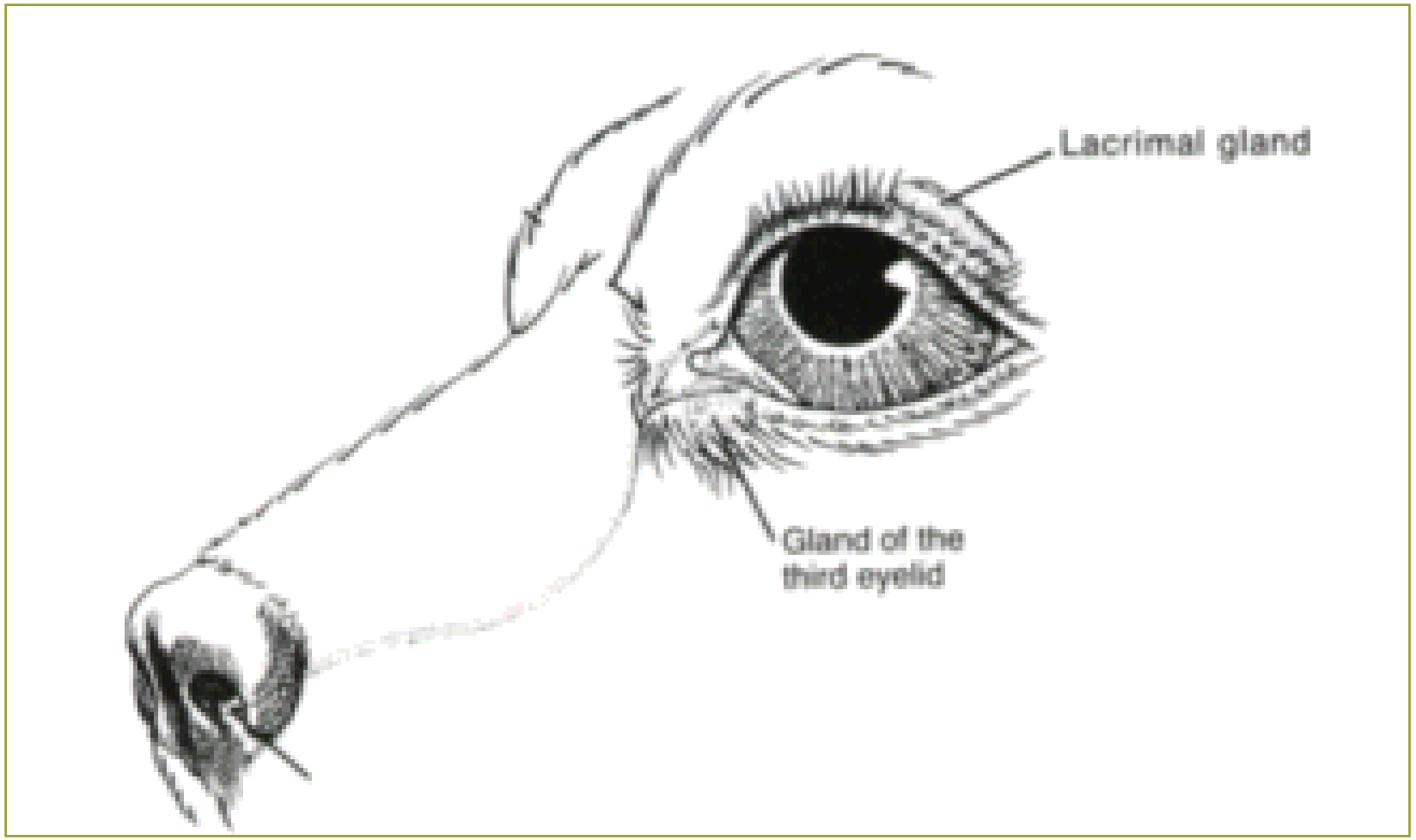
Figure 12-27 External View of Dog's Left Eye.

Extraocular Structures

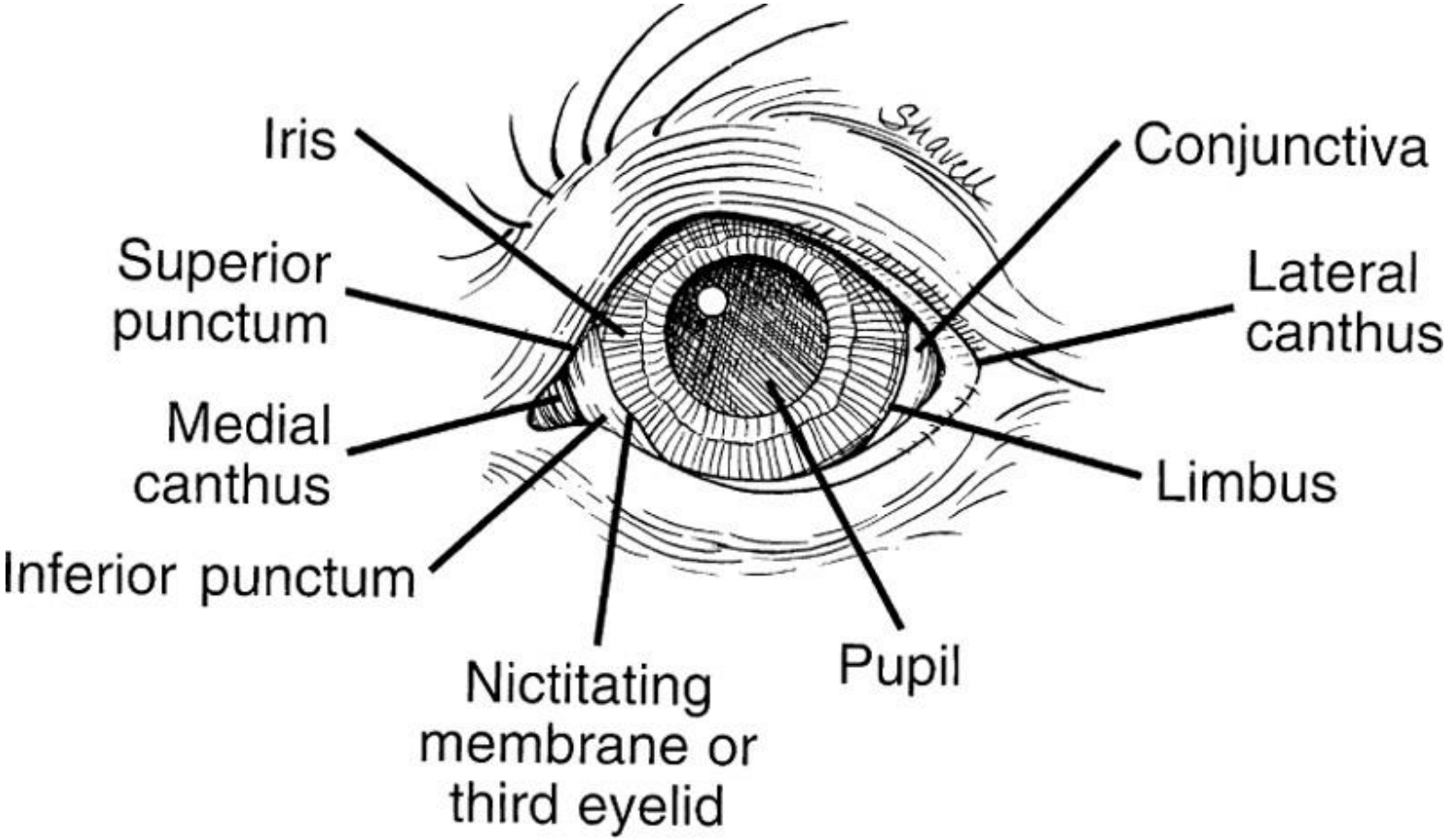
- Nictitating membrane: third eyelid of domestic animals located medially between eyelids and eyeball
  - T-shaped plate of cartilage covered by conjunctiva



Gland of 3rd Eyelid



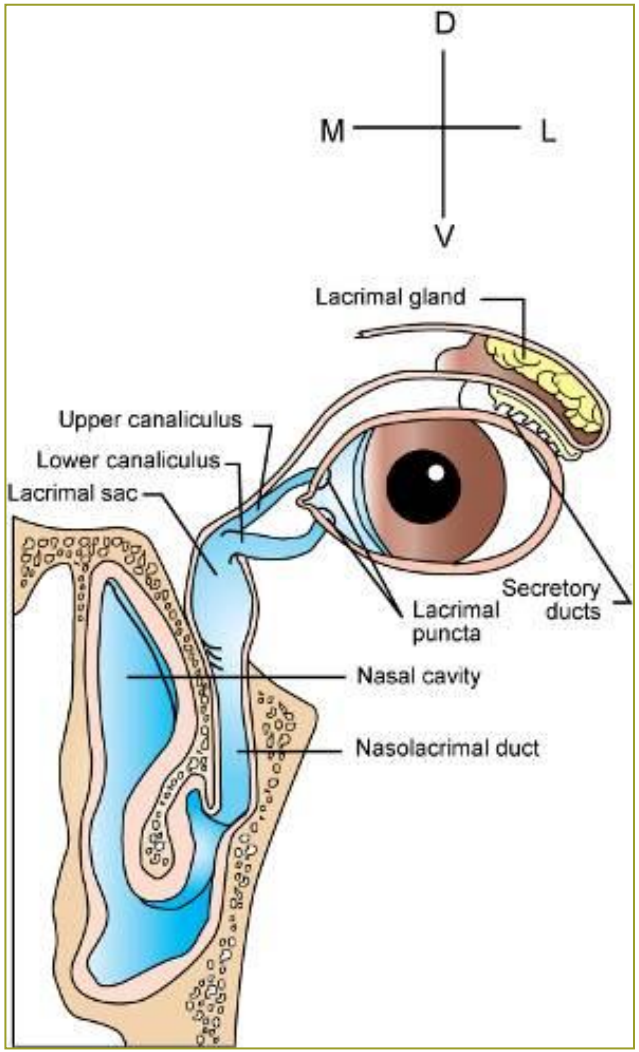
Canine Eye – Front View



Lacrimal Apparatus

Figure 14-13, Page 356

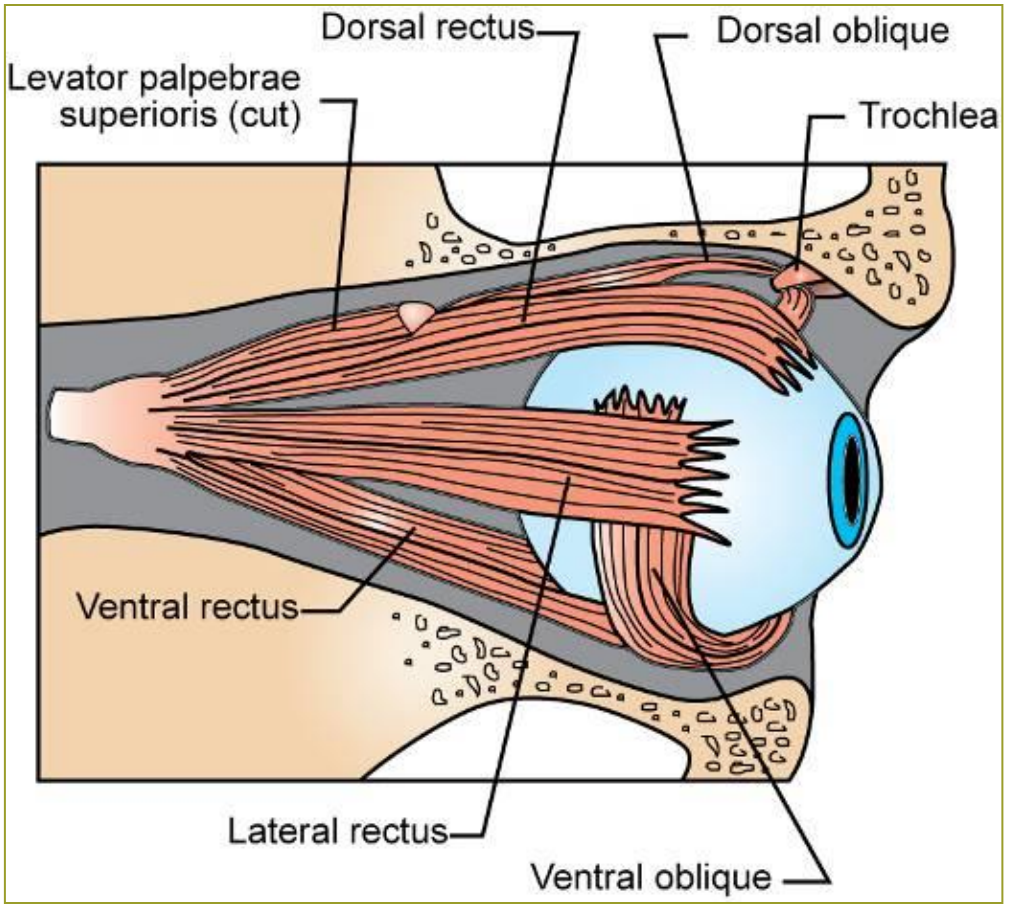
- Structures that produce and secrete tears and drain them away from the surface of the eye
- Lacrimal puncta
- Lacrimal sac
- Nasolacrimal duct



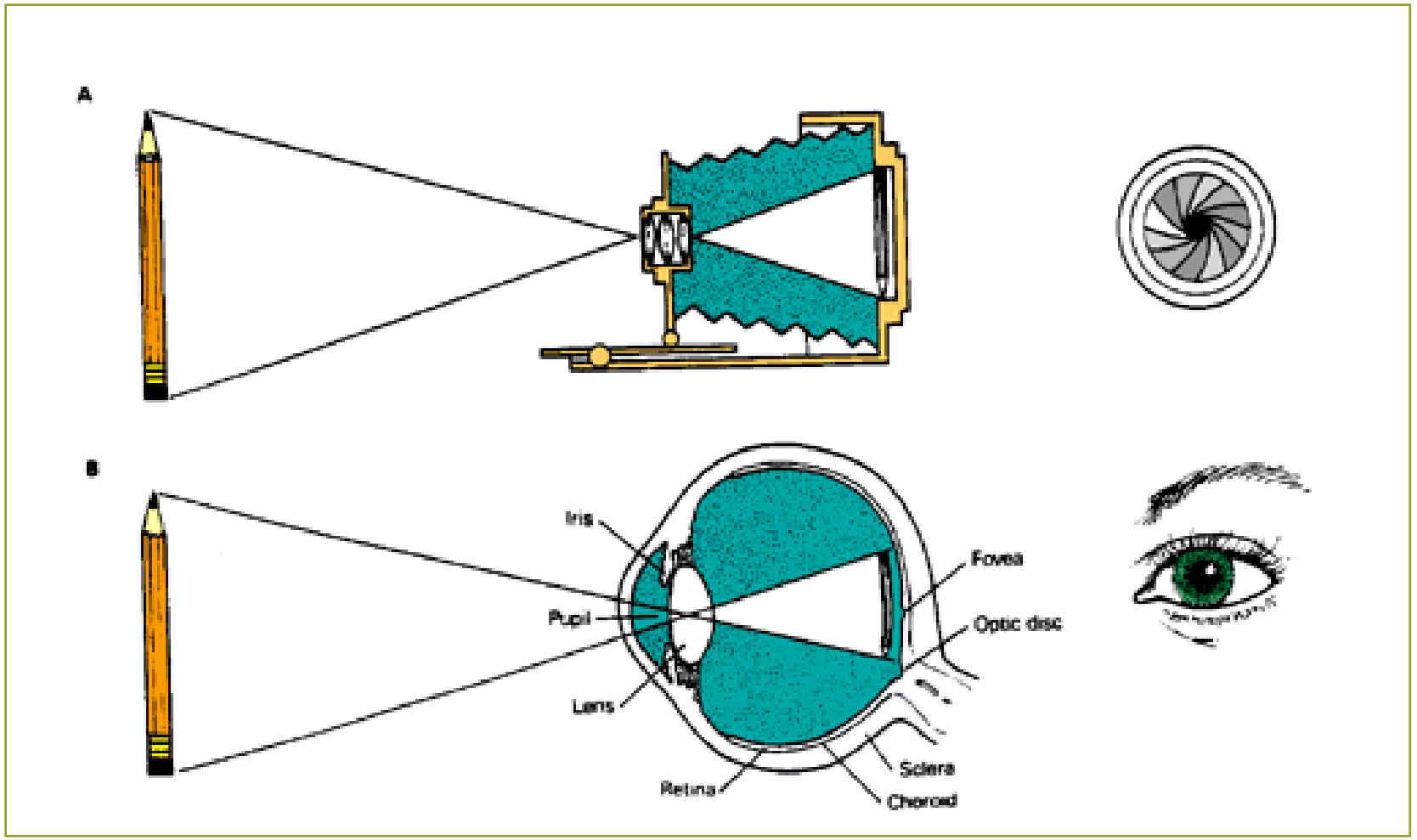
Extraocular Structures

Figure 14-14, Page 357

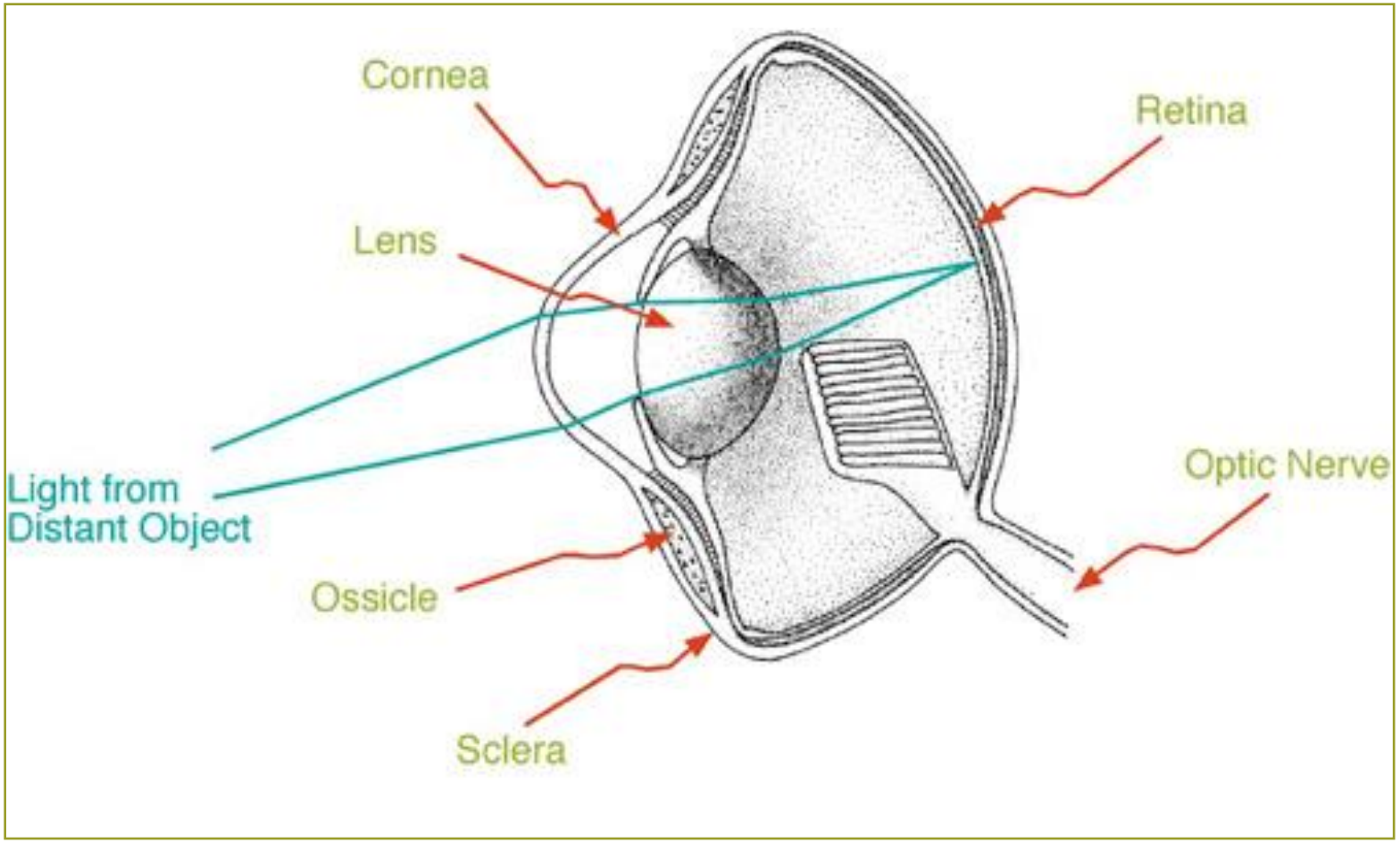
- Eye muscles attach to the sclera of the eye
- Capable of a wide range of movements
- Dorsal, ventral, medial, and lateral rectus muscles
- Dorsal and ventral oblique muscles

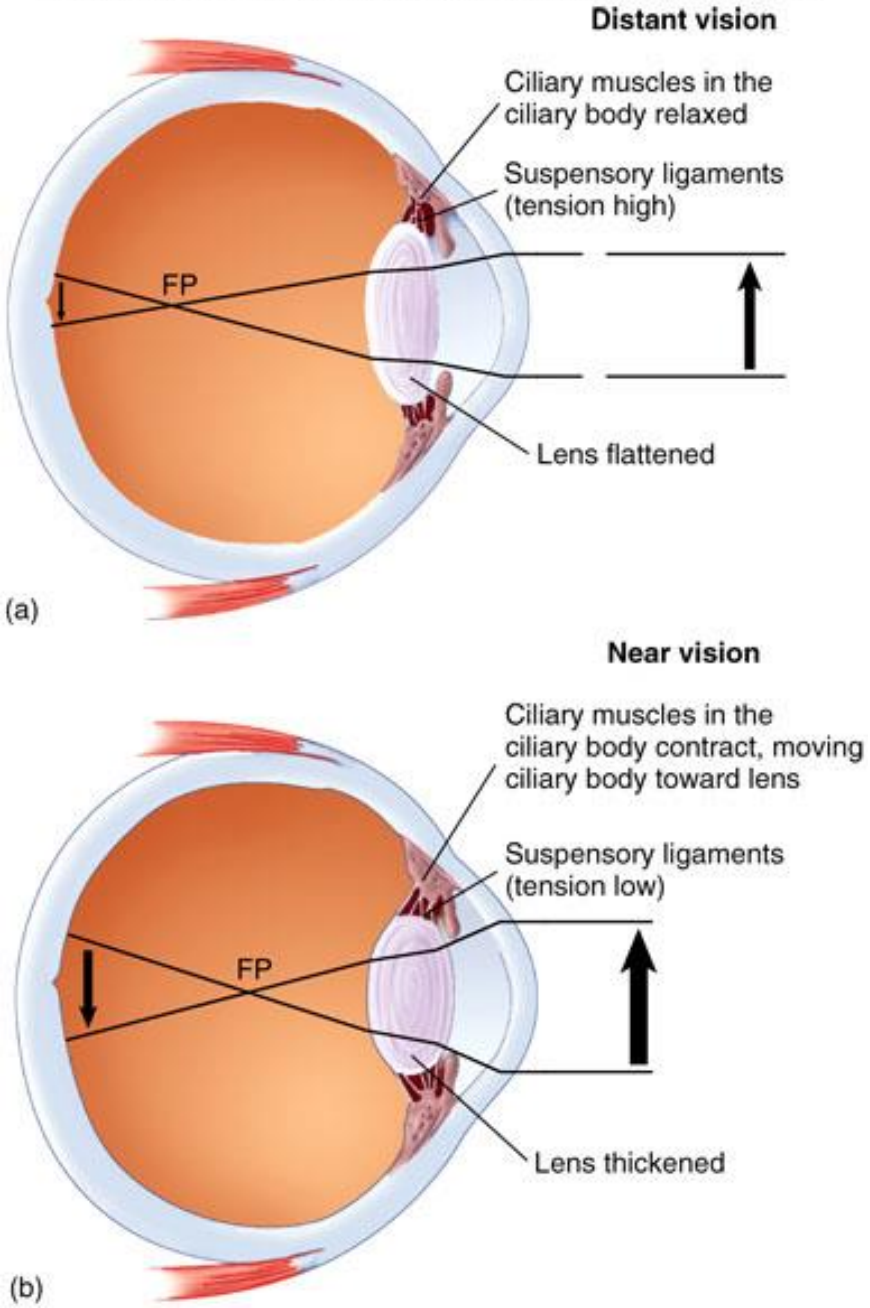


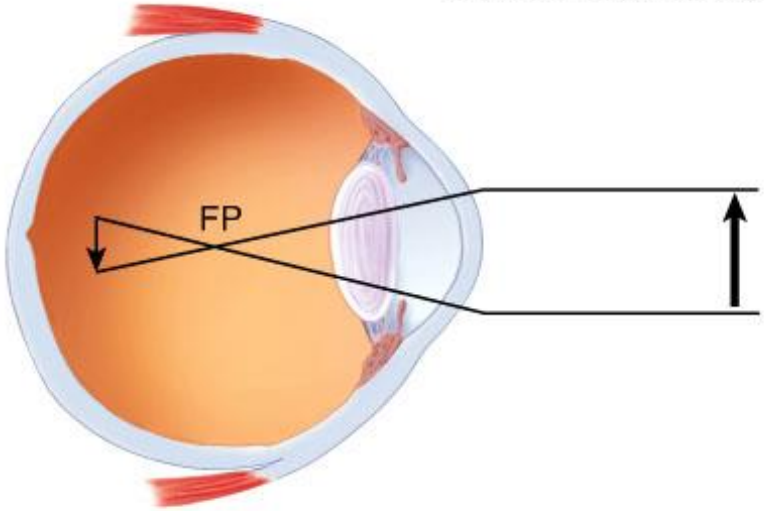
Eye Physiology – A Camera?



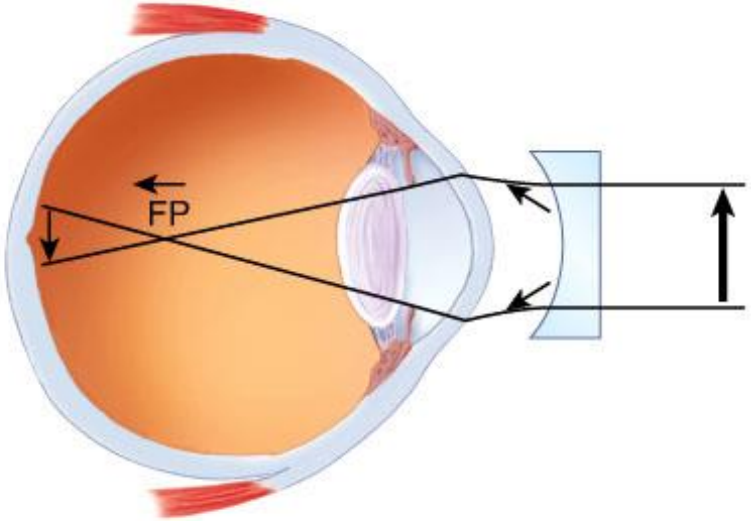
Refraction of Light



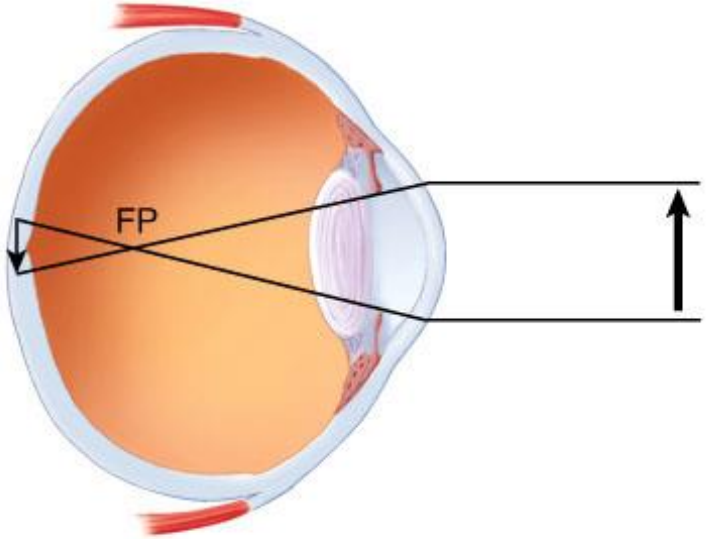




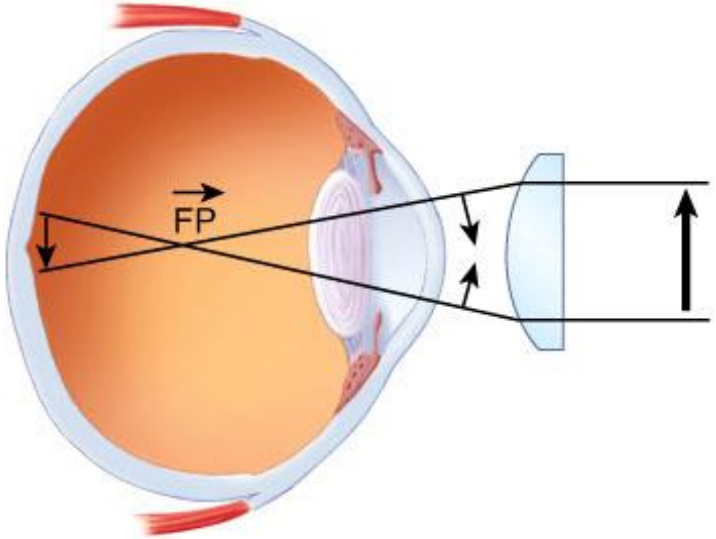
(a) Myopia (nearsightedness)



(b) Concave lens corrects myopia

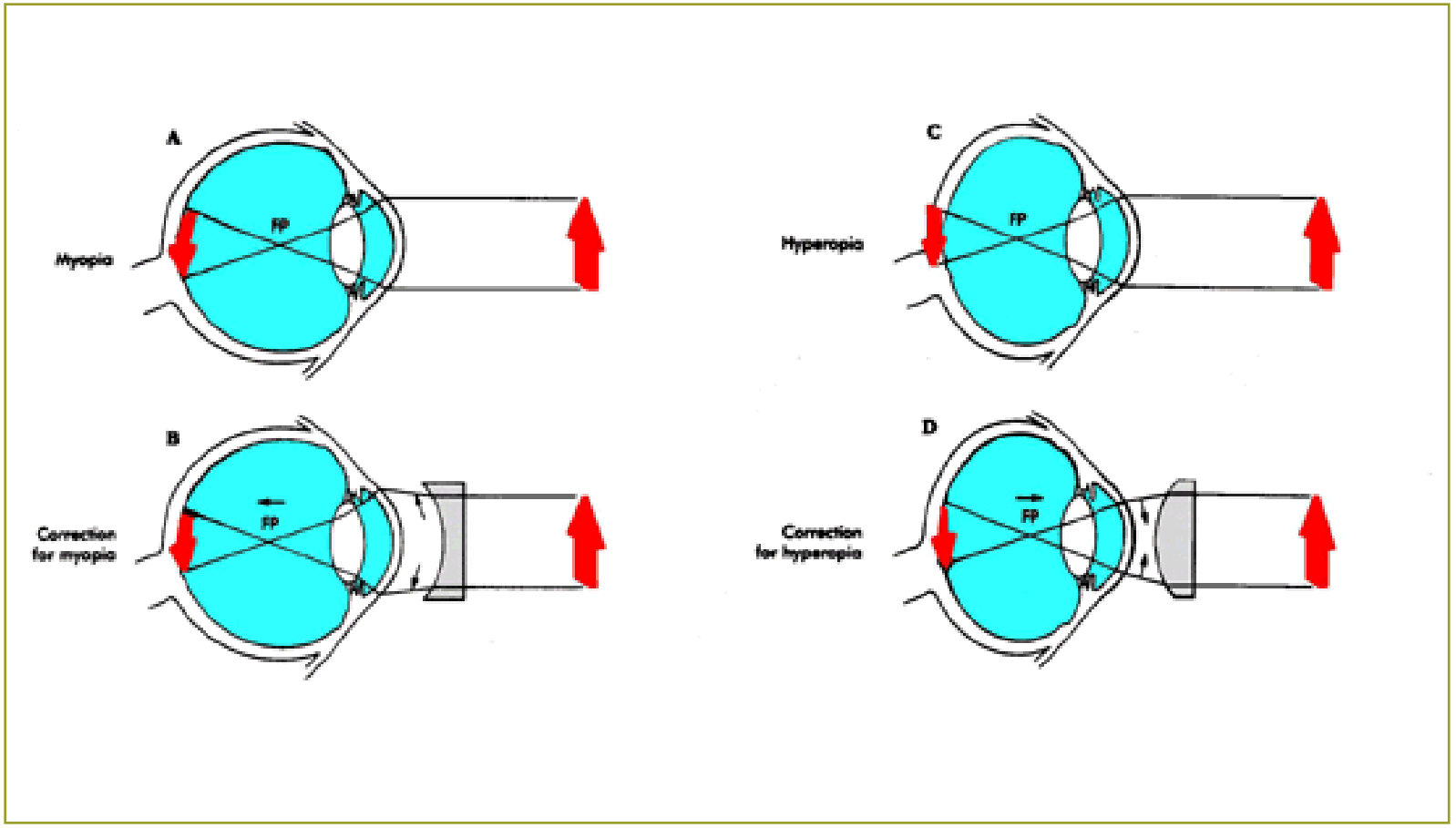


(c) Hyperopia (farsightedness)



(d) Convex lens corrects hyperopia

Near-Sighted? Far-Sighted?



Can Dogs See Color?

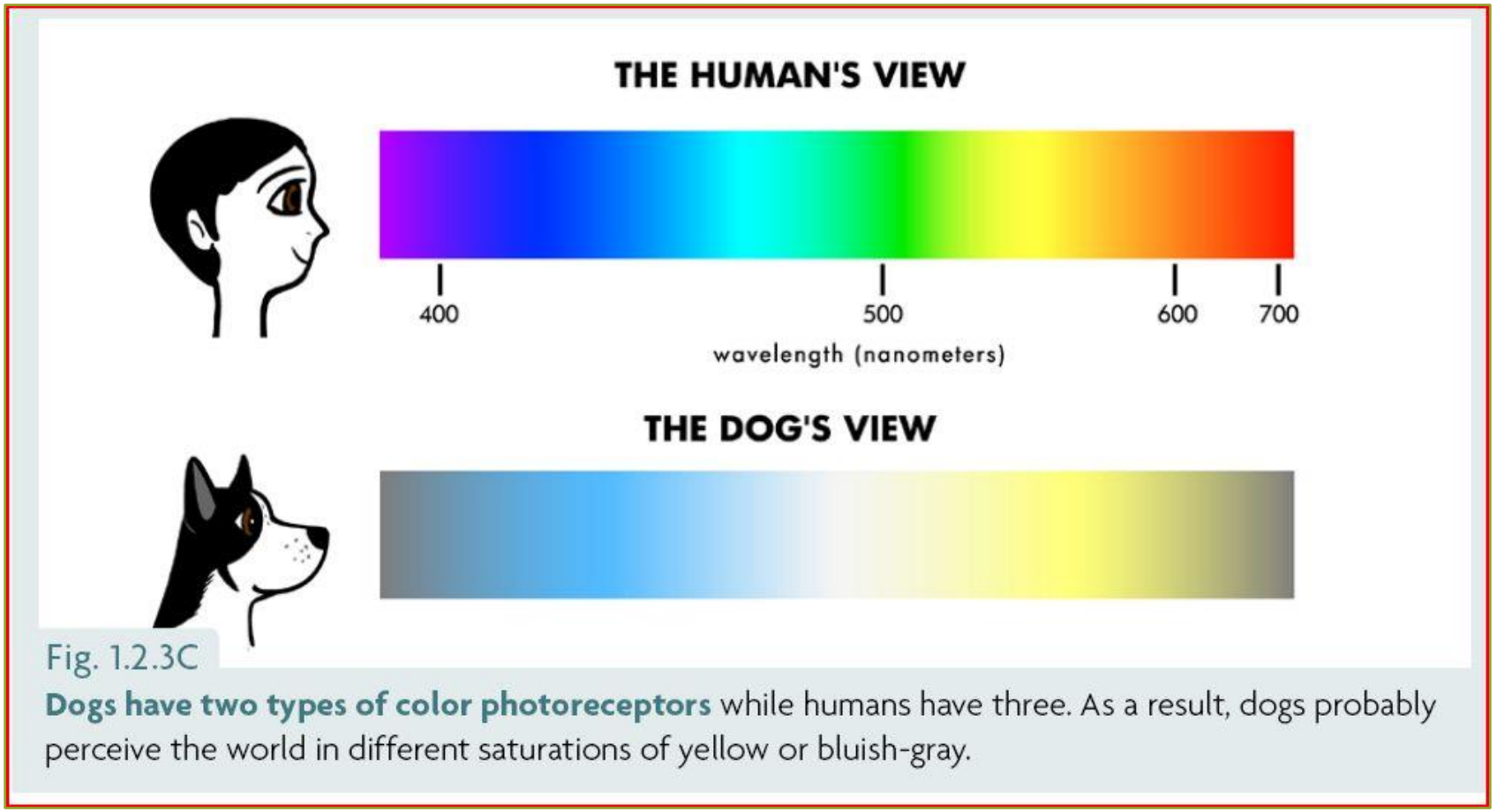


Fig. 1.2.3C

Dogs have two types of color photoreceptors while humans have three. As a result, dogs probably perceive the world in different saturations of yellow or bluish-gray.

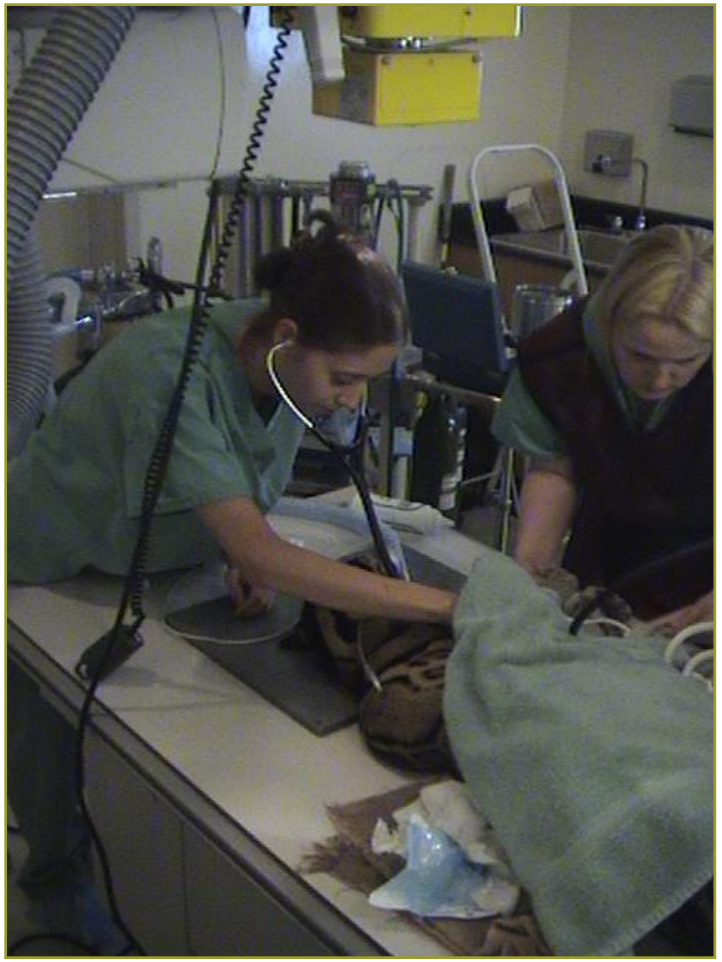
Canine Glasses? ☺


http://go.to/funpic
Larson

Clinical Applications of Sense Organs

- Heatstroke & Hypothermia (Page 359)
- Anesthesia & Analgesia (Page 341)
  - General anesthesia
  - Local anesthesia
  - Analgesia
  - Recovery (Page 348)
- Upper Respiratory Tract Infections (Page 344)
- Otitis Externa (Page 346)
- Ear Hematomas (Page 346)
- Motion sickness (Page 351)

Anesthesia & Analgesia
Important Clinical Applications!



Lion Anesthesia Anyone? ☺

Jennie with Casey (Audubon Zoo)

Clinical Applications – Eye Diseases

- Glaucoma (Page 352)
- Cataracts (Page 353)
- Conjunctivitis (Page 355)

Test Yourself

Pages 342, 342, 348, 350, 352, 355, 357

Clinical Applications

Pages 339, 341, 341, 344, 346, 346, 348, 351, 352, 353, 354, 355,