A&P I
Final Exam Review Slides
Fall 2014

Nervous System
Lectures 18-22

1

Function of the Nervous System

- The nervous system is a coordination and control system that helps the body maintain homeostasis. It
  - Gathers information about the internal and external environment (sense organs, nerves)
  - Relays this information to the spinal cord and the brain
  - Processes and integrates the information
  - Responds, if necessary, with impulses sent via nerves to muscles, glands, and organs

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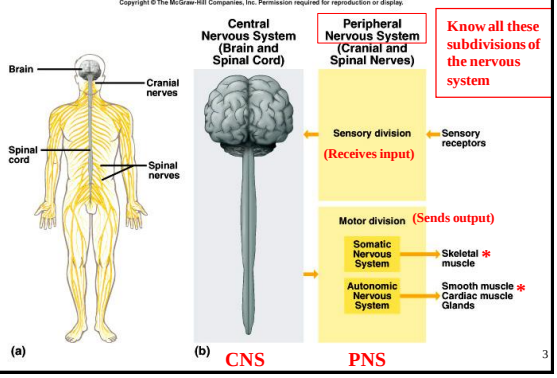
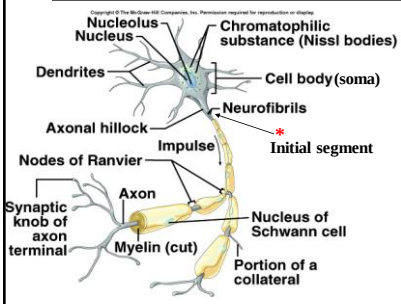
Divisions of the Nervous System



Know all these subdivisions of the nervous system

3

Neuron Structure



Be able to label/define structures on left

- Dendrites bring impules TO the soma
- Soma is the 'processing' part of the neuron
- Axon carries impules AWAY from the soma
- Synaptic knobs contain ntx
-- Myelin is found on axons
-- Neurons conduct nerve impulses

*Initial segment – where action potentials (nerve impulses) begin

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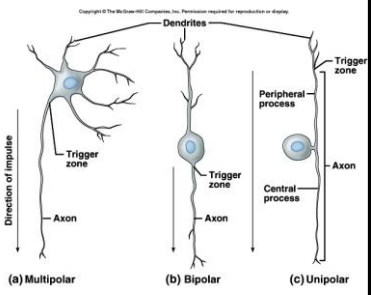
Structural Classification of Neurons

Bipolar
- two processes
- sense organs

Unipolar
- one process
- ganglia

Multipolar
- many processes
- most neurons of CNS



**Classification is based on the number of processes coming directly from the cell body

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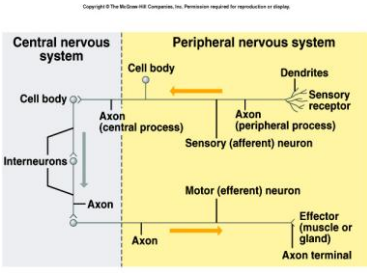
Functional Classification of Neurons

Sensory Neurons
- afferent, ascending
- carry impulse to CNS
- most are unipolar
- some are bipolar

Interneurons
- link neurons
- integrative
- multipolar
- in CNS

Motor Neurons
- efferent, descending
- multipolar
- carry impulses away from CNS
- carry impulses to effectors



Notice the directionality – *one-way*

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Table of Neuroglia

Name of Cell	Location	Function(s)
Satellite Cells	Ganglia of PNS	Regulate microenvironment of neurons
Astrocytes	CNS	Regulate microenvironment of neurons; scar tissue in CNS
Schwann Cells	PNS	Myelination of axons; structural support for non-myelinated axons
Oligodendrocytes	CNS	Myelination of axons; structural framework
Microglia	CNS	Phagocytes of the CNS
Ependymal Cells	CNS	Assist in producing and controlling composition of CSF

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Neurophysiology

If you are still a little 'fuzzy' about this material or want a bit more detail, be sure to look at the Supplemental Study Notes for Neurophysiology (on the Web site under Lecture 18 Supporting Materials)

Neurophysiology is summarized using the most important points in your Nervous System Study Notes for Final Exam (a completed study guide for the nervous system) on the Web site under Exam Study Guides

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Membrane Channel Proteins

1. Passive channels are ALWAYS open
   - Also called 'leak' channels
   - Passive K^+ channels always allow K^+ through
2. Active (gated) channels open or close in response to signals
   - a. Mechanical – respond to distortion of membrane
   - b. Ligand-gated (Chemically-gated)
     - Binding of a chemical molecule, e.g., ACh on MEP
     - Present on dendrites, soma, sometimes on axons
   - c. Voltage-gated
     - Respond to changed in electrical potential
     - Found on excitable membranes, e.g., axons, sarcolemma

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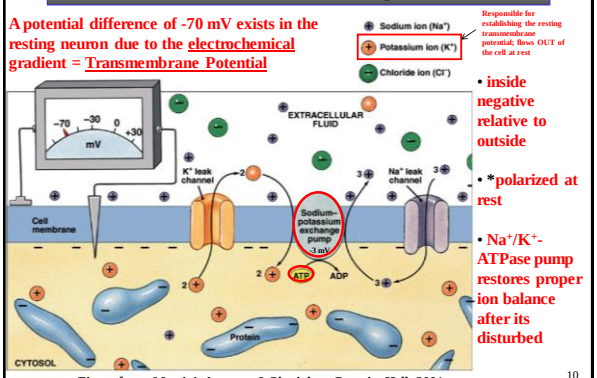
Transmembrane (Resting) Potential

A potential difference of -70 mV exists in the resting neuron due to the electrochemical gradient = Transmembrane Potential



- inside negative relative to outside
- *polarized at rest
- Na^+/K^+-ATPase pump restores proper ion balance after its disturbed

Figure from: Martini, *Anatomy & Physiology*, Prentice Hall, 2001

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Postsynaptic Potentials

Excitation

- depolarizes membrane of postsynaptic neuron
- postsynaptic neuron becomes more likely to become depolarized and generate its own action potential

Inhibition

- hyperpolarizes membrane of postsynaptic neuron
- postsynaptic neuron becomes less likely to become depolarized and generate its own action potential

One neuron acts on the next, postsynaptic, neuron by changing the resting membrane potential of the postsynaptic neuron; either de- or hyperpolarizing it

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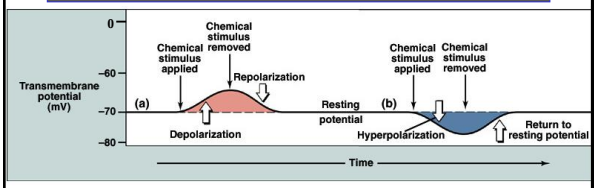
Changes in Membrane Potential



- If membrane potential becomes more positive than its resting potential, it has depolarized (Movement of ? charges causes this?)
- A membrane returning to its resting potential from a depolarized state is being repolarized (Movement of ? charges causes this?)
- If membrane potential becomes more negative than its resting potential, it has hyperpolarized

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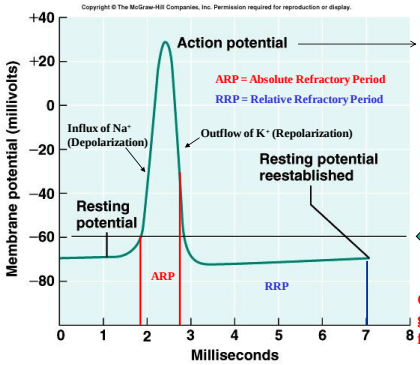
Figure from: Martini, *Anatomy & Physiology*, Prentice Hall, 2001

Action Potential and Refractory Period



Action Potential begins in initial segment of neuron

Threshold; MUST reach this for AP to occur.

Great summary graphic to know for exam!

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Action Potentials

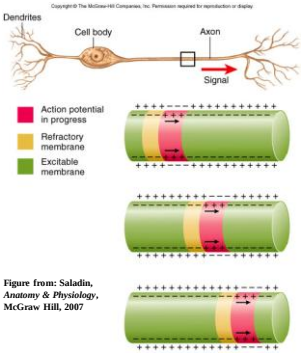

Figure from: Saladin, *Anatomy & Physiology*, McGraw Hill, 2007

Action Potential

Shown at left is an example of continuous propagation (~ 1m/s)

What keeps the action potential going in ONE DIRECTION, and not spreading in all directions like a graded potential?

Absolute refractory period of the previously depolarized segment.

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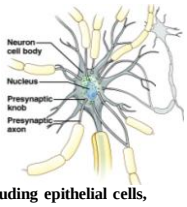
Local (Graded) Potential Changes

- Caused by various stimuli
  - chemicals
  - temperature changes
  - mechanical forces
- Cannot spread very far (~ 1 mm max)
  - weaken rapidly



- Uses ligand-gated Na^+ channels
  - On membranes of many types of cells including epithelial cells, glands, dendrites and neuronal cell bodies
  - General response method for cells
- Can be summed (so that an action potential threshold is reached; change in membrane potential ∝ stimulus strength
- ***Starting point* for an action potential

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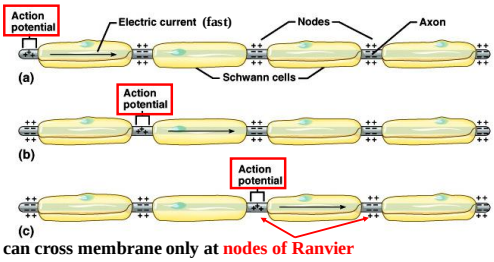
Saltatory (Leaping) Conduction

Myelin acts as an insulator and increases the resistance to flow of ions across neuron cell membrane



Ions can cross membrane only at nodes of Ranvier

Impulse transmission is up to 20x faster than in non-myelinated nerves. Myelinated axons are primarily what makes up white matter.

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Chemical Synaptic Transmission

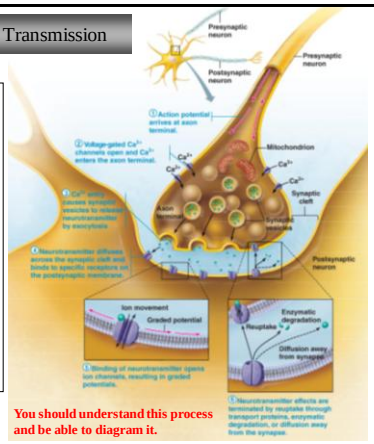
Neurotransmitters (ntx) are released when impulse reaches synaptic knob

This may or may not release enough ntx to bring the postsynaptic neuron to threshold

Chemical neurotransmission may be modified

Ultimate effect of a ntx is dependent upon the properties of the receptor, not the ntx

How is the neurotransmitter neutralized so the signal doesn't continue indefinitely?



You should understand this process and be able to diagram it.

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Postsynaptic Potentials

EPSP

- **excitatory postsynaptic potential**
- **depolarizes membrane of postsynaptic neuron**
- **postsynaptic neuron becomes more likely to become depolarized**

IPSP

- **inhibitory postsynaptic potential**
- **hyperpolarizes membrane of postsynaptic neuron**
- **postsynaptic neuron becomes less likely to become depolarized**

One neuron acts on the next, postsynaptic, neuron by changing the resting membrane potential of the postsynaptic neuron; either de- or hyperpolarizing it

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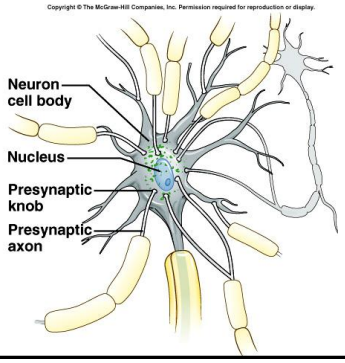
Summation of EPSPs and IPSPs

- **EPSPs and IPSPs are added together in a process called summation**
- **Summation can be temporal (over time) or spatial (within a certain space)**
- **Summation uses graded potentials**



Neurotransmitters

TABLE 10.4 Some Neurotransmitters and Representative Actions

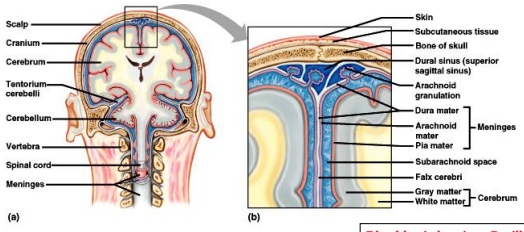
Neurotransmitter	Location	Major Actions
Acetylcholine *	CNS	Involved in control of skeletal muscle actions
	PNS	Stimulates skeletal muscle contraction at neuromuscular junctions. May excite or inhibit at autonomic nervous system synapses
Biogenic amines		
Norepinephrine*	CNS	Creates a sense of feeling good; low levels may lead to depression
	PNS	May excite or inhibit autonomic nervous system actions, depending on receptors
Dopamine	CNS	Creates a sense of feeling good; deficiency in some brain areas associated with Parkinson disease
	PNS	Limited actions in autonomic nervous system; may excite or inhibit, depending on receptors
Serotonin	CNS	Primarily inhibitory; leads to sleepiness; action is blocked by LSD, enhanced by selective serotonin reuptake inhibitor drugs
Histamine	CNS	Release in hypothalamus promotes alertness
Amino acids		
GABA *	CNS	Generally inhibitory
Glutamate	CNS	Generally excitatory
Neuropeptides		
Substance P	PNS	Excitatory; pain perception
Endorphins, enkephalins	CNS	Generally inhibitory; reduce pain by inhibiting substance P release
Gases		
Nitric oxide	CNS	May play a role in memory
	PNS	Vasodilation

Neuromodulators: Influence release of ntx or the postsynaptic response to a ntx, e.g., endorphins, enkephalins

Protection of the Brain

- The brain is protected
  - Mechanically by
    - The skull bones
    - The meninges (singular: meninx)
    - The cerebrospinal (CSF) fluid
  - Biochemically by the blood-brain barrier
    - Capillaries interconnected by tight junctions
    - Astrocytes/ependymal cells control permeability of general capillaries/choroid capillaries
    - May be obstacle to delivery of drugs
    - May become more permeable during stress

Meninges of the Brain

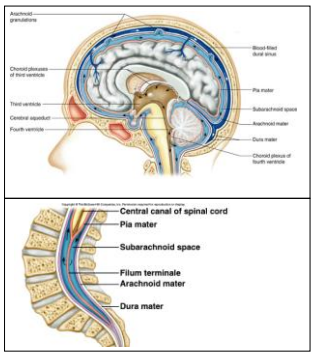


- dura mater – outer, tough (anchoring dural folds)
  - Subdural space – like interstitial fluid
- arachnoid mater – web-like
  - Subarachnoid space – CSF*
- pia mater – inner, delicate

Blood-brain barrier - Capillaries interconnected by tight junctions, astrocytes/ependymal cells control permeability of general capillaries/choroid capillaries

Cerebrospinal Fluid

- secreted by choroid plexus of ventricles (~500 ml/day)
- circulates in ventricles, central canal of spinal cord, and subarachnoid space
- completely surrounds brain and spinal cord
- nutritive and protective
- helps maintain stable ion concentrations in CNS
- ependymal cells are glial cells that play a role in generating CSF



Flow of CSF

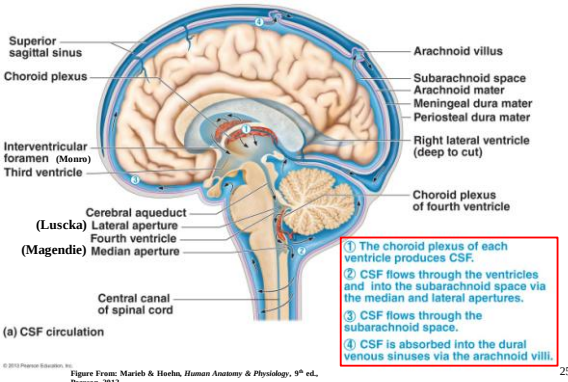


Figure From: Marieb & Hoehn, *Human Anatomy & Physiology*, 9th ed., Pearson, 2013

Overview of Cerebral Cortex

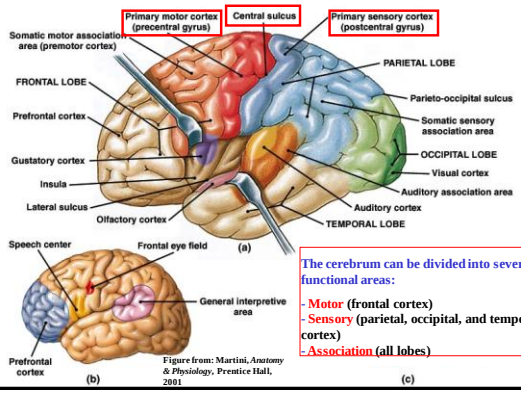


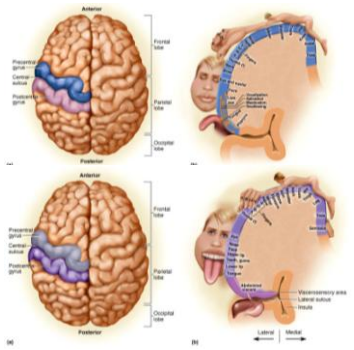
Figure from: Martini, *Anatomy & Physiology*, Prentice Hall, 2001

The cerebrum can be divided into several functional areas:

- **Motor (frontal cortex)**
- **Sensory (parietal, occipital, and temporal cortex)**
- **Association (all lobes)**

Cortex = Conscious Awareness

The Homunculi shown here are associated with the CORTEX of the cerebrum



Functions of Parts of Brain

Part of Brain	Major Function
Motor areas	
Primary motor cortex (Precentral gyrus)	Voluntary control of skeletal muscles
Broca's area (motor speech area)	Controls muscles needed for speech
Frontal eye field	Controls muscles needed for eye movement
Sensory areas	
Cutaneous Sensory Area (postcentral gyrus)	Receives somatic sensations
Visual area (occipital lobe)	Receives visual sensations
Auditory area (temporal lobe)	Receives auditory sensations
Association areas (all lobes)	Analyze and interpret sensory experiences; coordinate motor responses memory, reasoning, verbalization, judgment, emotions
Basal nuclei	Subconscious control certain muscular activities, e.g., learned movement patterns (a nucleus is a collection of neuron cell bodies in the CNS); putamen, globus pallidus, caudate
Limbic system	controls emotions , produces feelings, interprets sensory impulses, facilitates memory storage and retrieval (learning!)
Diencephalon	
Thalamus	gateway for sensory impulses heading to cerebral cortex, receives all sensory impulses (except smell)
Hypothalamus	Vital functions associated with homeostasis
Brainstem	
Midbrain	Major connecting center between spinal cord and brain and parts of brainstem; contains corpora quadrigemina (visual and auditory reflexes)
Pons	Helps regulate rate and depth of breathing, relays nerve impulses to and from medulla oblongata and cerebellum
Medulla Oblongata	Contains cardiac, vasomotor, and respiratory control centers, contains various nonvital reflex control centers (coughing, sneezing, vomiting)
Reticular formation (system)	Filters incoming sensory information; habituation , modulates pain, arouses cerebral cortex into state of wakefulness (reticular activating system)
Cerebellum	Subconscious coordination of skeletal muscle activity, maintains posture

Memory

- A "Memory" is the persistence of knowledge that can be accessed (we hope!) at a later time.
- Memories are <u>not</u> stored in individual "memory cells" or neurons; they are stored as pathways called engrams, or memory traces that use strengthened or altered synapses.

- Immediate memory lasts a few seconds, e.g., remembering the earliest part of a sentence to make sense of it.
- Short-term memory (STM) lasts a few seconds to a few hours
  - Working memory is a form of this (repeating a phone number over to yourself just long enough to dial it – and then forget it!)
  - Limited to a few 'bits' of information (about 7-9). So, 'chunk up'!
- Long-term memory (LTM) can last a lifetime
  - Can hold much more information that STM
  - Declarative (events and facts); Procedural (motor skills)
  - Remembering childhood events as an adult

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Spinal Cord Structure

• Functions of spinal cord:
• is a center for spinal reflexes
• aids in locomotion
• is a conduit for nerve impulses to and from the brain

• cauda equina - Begins around L2 and extends to S5. Good area for lumbar puncture and collection of CSF.

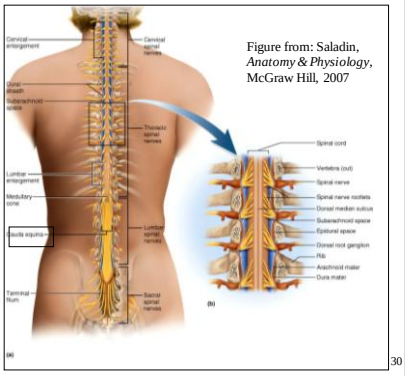

Figure from: Saladin, *Anatomy & Physiology*, McGraw Hill, 2007

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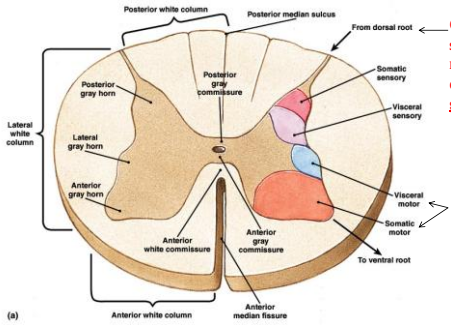
Organization of Spinal Gray Matter



Cell bodies of sensory neurons are in dorsal root <u>ganglion</u>

Cell bodies of motor neurons are found here

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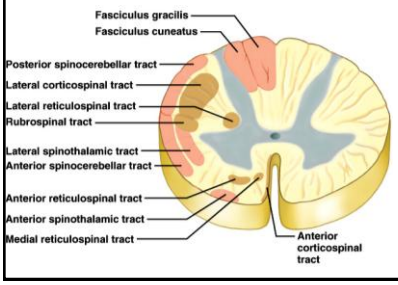
Figure from: Martini, *Anatomy & Physiology*, Prentice Hall, 2001

Tracts of the Spinal Cord

- **Ascending tracts conduct sensory impulses to the brain**
- **Descending tracts conduct motor impulses from the brain to motor neurons reaching muscles and glands**



Tract: Contains axons that share a common origin and destination

Tracts are usually named for their place of origin (1st) and termination (2nd)

1st, 2nd, and 3rd Order Sensory Neurons

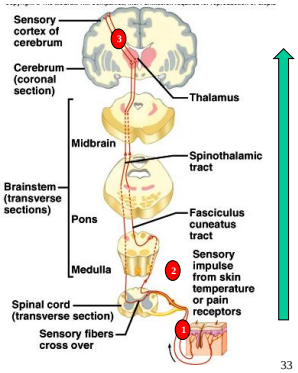
Examples of sensory (ascending) tracts (note how the names tell you where they're coming from and where they are going to…)

- **Spinothalamic**
- **Spinocerebellar**
- **Fasciculus cuneatus/gracilis**

1st order neuron – from receptor to the spinal cord (cell bodies are located in the dorsal root ganglion)

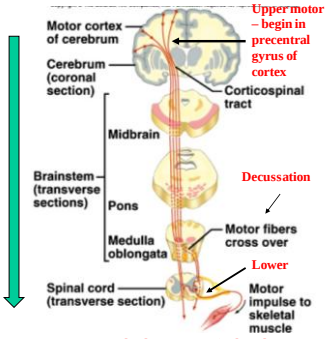
2nd order neuron – from spinal cord to thalamus

3rd order neuron – from thalamus and terminate in the cerebral cortex



Descending Tracts

- **Examples of descending spinal tracts**
- **corticospinal**
- **reticulospinal**
- **rubrospinal**

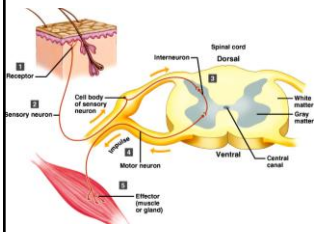


Upper MN – Cerebral cortex to spinal cord

Lower MN – Spinal cord to effector

Reflex Arcs

Reflexes – automatic, subconscious, quick, stereotyped responses to stimuli either within or outside the body, and occur in <u>both</u> the somatic and autonomic division



The 3 different somatic reflexes we discussed in class:

1. Knee-jerk: monosynaptic, ipsilateral

2. Withdrawal: polysynaptic, ipsilateral

3. Crossed extensor: polysynaptic, contralateral

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Peripheral Nervous System

- **Cranial nerves arising from the brain**
  - **Somatic fibers connecting to the skin and skeletal muscles**
  - **Autonomic fibers connecting to viscera**

- **Spinal nerves arising from the spinal cord**
  - **Somatic fibers connecting to the skin and skeletal muscles**
  - **Autonomic fibers connecting to viscera**

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The Cranial Nerves

Numeral	Name	Function	Sensory, Motor, or Both (Mixed Nerve)
I	OLFACTORY (OLD)	OLFACTION/SMELL	SENSORY (SOME) ←
II	OPTIC (OPIE)	VISION	SENSORY (SAY) ←
III	OCULOMOTOR (OCCASIONALLY)	MOVE EYE	MOTOR (MARRY)
IV	TROCHLEAR (TRIES)	MOVE EYE (superior oblique)	MOTOR (MONEY)
V	TRIGEMINAL (TRIGONOMETRY)	CHEWING, MASTICATION AND SENSORY FROM FACE (*MAJOR SENSORY NERVE OF FACE*)	BOTH (BUT)
VI	ABDUCENS (AND)	MOVE EYE	MOTOR (MY)
VII	FACIAL (FEELS)	FACIAL EXPRESSION (*MAJOR MOTOR NERVE OF FACE*)	BOTH (BROTHER)
VIII	VESTIBULOCOCHLEAR (VERY)	HEARING AND EQUILIBRIUM	SENSORY (SAYS) ←
IX	GLOSSOPHARYNGEAL (GLOOMY)	MOVE MUSCLES OF TONGUE AND PHARYNX	BOTH (BIG)
X	VAGUS (VAGUE)	INNERVATE VISCERA/VISCERAL SMOOTH MUSCLE IN THORAX/ABDOMEN; MOTOR FOR SPEECH/SWALLOWING	BOTH (BOOBS)
XI	ACCESSORY (AND)	MOVE NECK MUSCLES	MOTOR (MATTER)
XII	HYPOGLOSSAL (HYPOACTIVE)	MOVE TONGUE	MOTOR (MOST)

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You should know this table

Classification of Nerve Fibers

TABLE 13.2	The Classification of Nerve Fibers
Class	**Description**
Afferent fibers	Carry sensory signals from receptors to the CNS
Efferent fibers	Carry motor signals from the CNS to effectors
Somatic fibers	Innervate skin, skeletal muscles, bones, and joints
Visceral fibers	Innervate blood vessels, glands, and viscera
General fibers	Innervate widespread organs such as muscles, skin, glands, viscera, and blood vessels
Special fibers	Innervate more localized organs in the head, including the eyes, ears, olfactory and taste receptors, and muscles of chewing, swallowing, and facial expression

→ **SOMAtic**

- **Skin**
- **BOnes**
- **Muscles**
- **Articulations**

Table from: Saladin, *Anatomy & Physiology*, McGraw Hill, 2007

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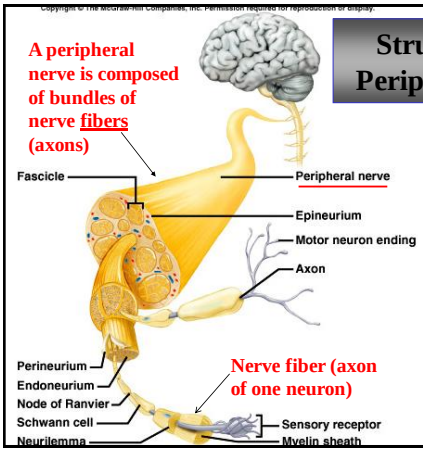
Structure of a Peripheral Nerve

A peripheral nerve is composed of bundles of nerve fibers (axons)



Nerve fiber (axon of one neuron)

Epineurium – surrounds entire nerve

Perineurium – surrounds a bundle of nerve fibers = fascicle

Endoneurium – surrounds each axon (nerve fiber)

Similar to the naming of the CT around muscle!!

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Spinal Nerves

- **spinal nerves contain mixed (motor/sensory) nerves**
- **31 pairs**
  - **8 cervical (C1 to C8)**
  - **12 thoracic (T1 to T12)**
  - **5 lumbar (L1 to L5)**
  - **5 sacral (S1 to S5)**
  - **1 coccygeal (Co)**

THIRTY ONEderful flavors of spinal nerves!

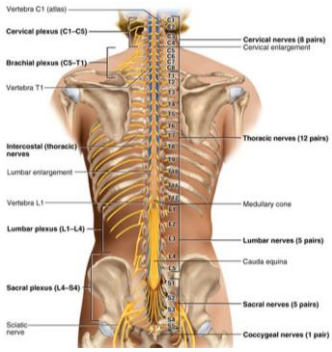

Figure from: Saladin, *Anatomy & Physiology*, McGraw Hill, 2007

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Nerves Plexuses

Nerve plexus – complex network formed by anterior (ventral) branches of spinal nerves; fibers of various spinal nerves are sorted and recombined

Contains both sensory and motor fibers

Name of Plexus	Spinal nerves	Major nerves/innervation	Major actions
Cervical	C1 - C4	To muscle skin of neck	Head movement
		Phrenic nerve	Controls diaphragm
Brachial	C5 - T1	Musculocutaneous Median Ulnar	Flexion forearm/hand
		Radial	Extension forearm/hand
		Axillary	Muscles/skin shoulder
Lumbosacral	L1 - S5	Obturator (Lumbar Plexus) Femoral (Lumbar Plexus) Saphenous (Lumbar Plexus	Muscles/skin of thighs and leg
		Sciatic (Sacral plexus)	Muscles/skin thigh, leg, and foot
		Pudendal (Sacral plexus)	Muscles of perineum

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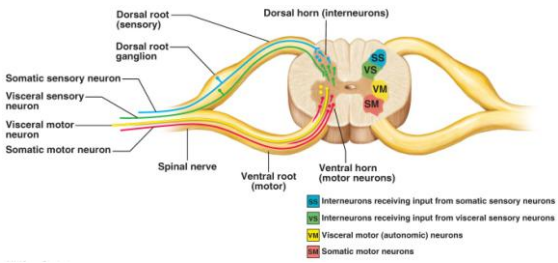
Spinal Cord and Nerve Roots



Ventral root - axons of motor neurons whose cell bodies are in spinal cord

Dorsal root - axons of sensory neurons in the dorsal root ganglion

Dorsal root ganglion - cell bodies of sensory neurons

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Somatic vs. Autonomic Nervous Systems

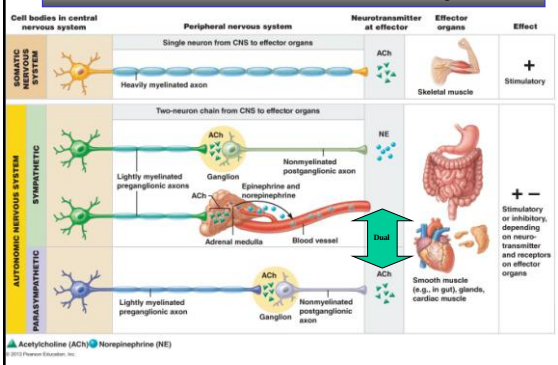

Figure from: Marieb, *Human Anatomy & Physiology*, Pearson, 2013

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Review of Autonomic Nervous System

Branch of ANS	PARASYMPATHETIC	SYMPATHETIC
General Function	* "rest and digest" * (SLUDD); Salivation, lacrimation, urination, digestion, defecation * 3 decreses; ↓ heart rate, ↓ pupil size, ↓ airway diameter	* "fight or flight" * E situations: Emergency, exercise, embarassment, excitement
Origin of Preganglionic fiber	cranial region of brain or sacral region of spinal cord (craniosacral outflow)	thoracic or lumbar region of spinal cord (thoracolumbar outflow) Divergence for widespread activation of body
Location of Ganglia	within or near effector organ	alongside or in front of spinal cord (paravertebral ganglia; collateral ganglia)
NTx secreted by postganglionic fiber	acetylcholine	Norepinephrine (some acetylcholine; sweat glands, smooth muscle on blood vessels, brain)

Good summary chart to know

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Sympathetic Division of ANS

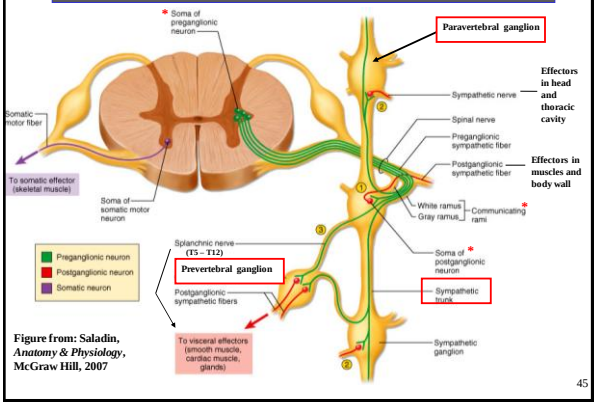

Figure from: Saladin, *Anatomy & Physiology*, McGraw Hill, 2007

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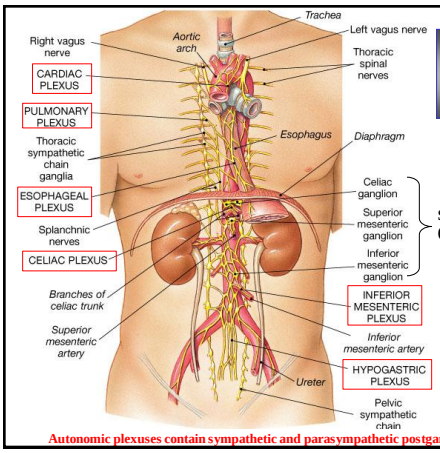

Autonomic Plexuses

Sympathetic collateral (prevertebral) ganglia

Figure from: Martini, *Fundamentals of Anatomy & Physiology*, Pearson Education, 2004

Autonomic plexuses contain sympathetic and parasympathetic postganglionic fibers

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Actions of Autonomic Neurotransmitters

- depend on receptor

Cholinergic receptors
- bind acetylcholine
- nicotinic
  - excitatory
- muscarinic
  - excitatory or inhibitory

Adrenergic receptors
- bind norepinephrine
- alpha (Types 1 and 2)
  - different responses on various effectors
- beta (Types 1 and 2)
  - different responses on various effectors

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Sensory Receptors

Sensory Receptors
- specialized cells or multicellular structures that collect information (transduce information into nerve impulses)
- stimulate neurons to send impulses along sensory fibers to the brain (receptor vs. generator [action] potentials)

Chemoreceptors (general)
- respond to changes in chemical concentrations

Pain receptors or nociceptors (general)
- respond to stimuli likely to cause tissue damage

Thermoreceptors (general)
- respond to changes in temperature

Mechanoreceptors (general, special)
- respond to mechanical forces

Photoreceptors (special)
- respond to light

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Mechanoreceptors

- Sense mechanical forces such as changes in pressure or movement of fluid
  - Two main groups
    - baroreceptors – sense changes in pressure (e.g., carotid artery, aorta, lungs, digestive & urinary systems)
    - proprioceptors – sense changes in muscles and tendons

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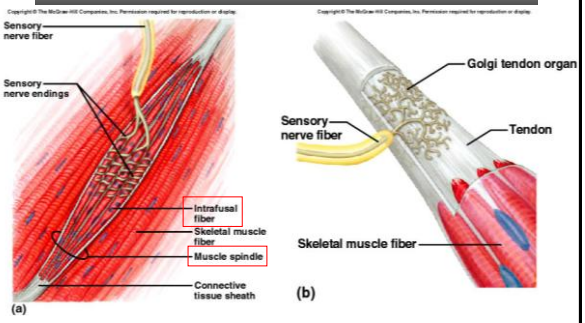
Stretch Receptors - Proprioceptors



Muscle spindle – initiates contraction (stretch reflex)

Golgi tendon organ – inhibit contraction

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Temperature Sensors (Thermoreceptors)

Warm receptors

- **sensitive to temperatures above 25°C (77° F)**
- **unresponsive to temperature above 45°C (113°F)**

Cold receptors (3-4x more numerous than warm)

- **sensitive to temperature between 10°C (50°F) and 20°C (68°F)**
- **unresponsive below 10°C (50°F)**

Pain receptors are activated when a stimulus exceeds the capability (range) of a temperature receptor

- **respond to temperatures below 10°C**
- **respond to temperatures above 45°C**

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Sensory Adaptation

- **reduction in sensitivity of sensory receptors from continuous stimulation (painless, constant)**
- **stronger stimulus required to activate receptors**
- **smell and touch receptors undergo sensory adaptation**
- **pain receptors usually do not undergo sensory adaptation (at level of receptor)**
- **impulses can be re-triggered if the intensity of the stimulus changes**

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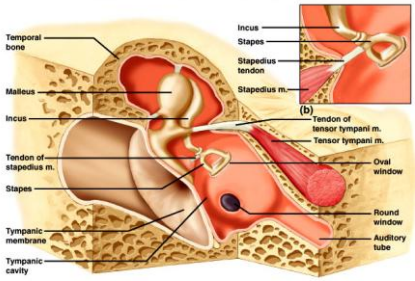
The Middle Ear (Tympanic Cavity)



Typanic reflex: Elicited about 0.1 sec following loud noise; causes contraction of the tensor tympani m. and stapedius m. to dampen transmission of sound waves

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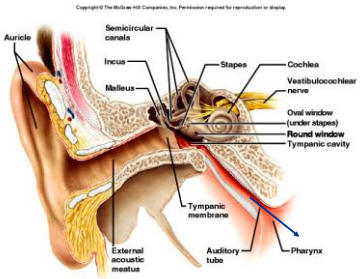
Auditory Tube

- **eustachian, auditory, or pharyngotympanic tube**
- **connects middle ear to throat**
- **helps maintain equal pressure on both sides of tympanic membrane**
- **usually closed by valve-like flaps in throat**



When pressure in tympanic cavity is higher than in nasopharynx, tube opens automatically. But the converse is not true, and the tube must be forced open (swallowing, yawning, chewing).

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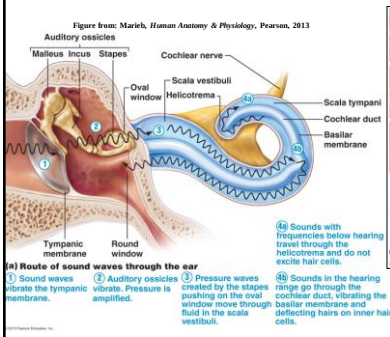
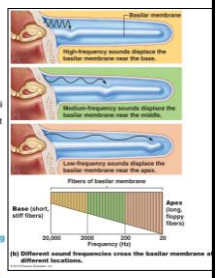
Physiology of Hearing





Tympanic membrane → malleus → incus → stapes → oval window → scala vestibuli → scala tympani → round window ← **Know pathway for exam**

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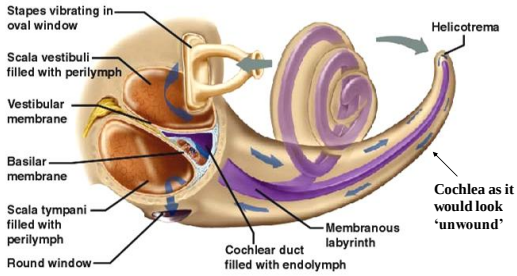
Cochlea



Scala vestibuli
- upper compartment
- leads from oval window to apex of spiral
- part of bony labyrinth

Scala tympani
- lower compartment
- extends from apex of the cochlea to round window
- part of bony labyrinth

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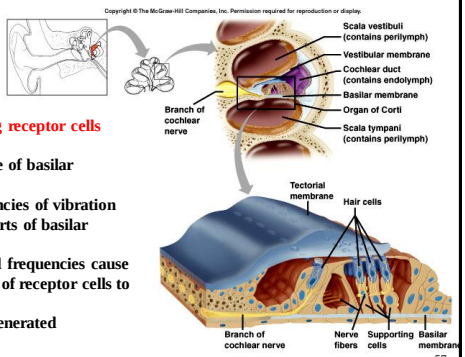
Organ of Corti – in Cochlear Duct



- group of hearing receptor cells (hair cells)
- on upper surface of basilar membrane
- different frequencies of vibration move different parts of basilar membrane
- particular sound frequencies cause hairs (stereocilia) of receptor cells to bend
- nerve impulse generated

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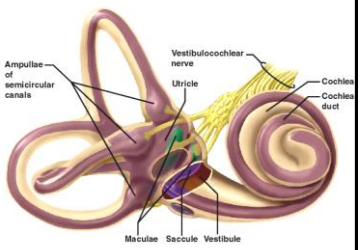
Vestibule



- **Utricle**
  - communicates with saccule and membranous portion of semicircular canals
- **Saccule**
  - communicates with cochlear duct
- **Macula**
  - contains hair cells of utricle (horizontal) and saccule (vertical)

Utricle and saccule provide sensations of: 1) gravity and 2) linear acceleration

These organs function in static equilibrium (head/body are still)

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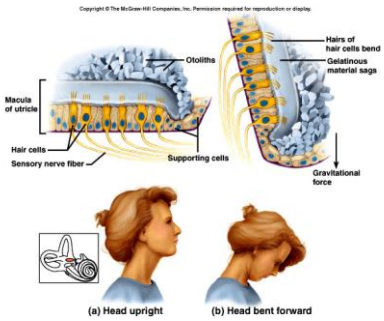
Macula & Static Equilibrium

- responds to changes in head position
- bending of hairs results in generation of nerve impulse



These organs function in static equilibrium (head/body are still)

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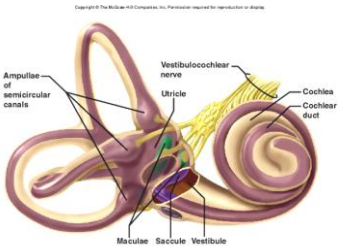
Semicircular Canals

- three canals at right angles
- ampulla (expansion)
  - swelling of membranous labyrinth that communicates with the vestibule
- crista ampullaris
  - sensory organ of ampulla
  - hair cells and supporting cells
  - rapid turns of head or body stimulate hair cells



Acceleration of fluid inside canals causes nerve impulse

These organs function in dynamic equilibrium (head/body are in motion)

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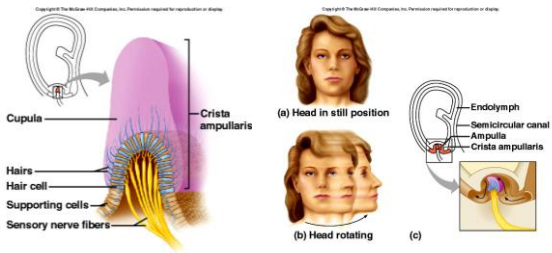
Crista Ampullaris & Dynamic Equilibrium



Semicircular canals respond to rotational, nonlinear movements of the head = Dynamic Equilibrium

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Eyelids

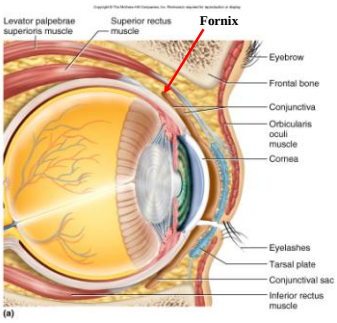
- palpebrae = eyelids
- composed of four layers
  - skin
  - muscle
  - connective tissue
  - conjunctiva

- orbicularis oculi – closes eye (CN VII)

- levator palpebrae superioris – raises eyelid (CN III)

- tarsal (Meibomian) glands – secrete oil onto eyelashes; keep lids from sticking together

- conjunctiva – mucous membrane; lines eyelid and covers portion of eyeball

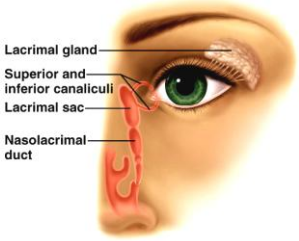


Sagittal section of right eye

Figure from: Saladin, *Anatomy & Physiology*, McGraw Hill, 2007

Lacrimal Apparatus

- lacrimal gland
  - lateral to eye
  - secretes tears
- canaliculi
  - collect tears
- lacrimal sac
  - collects from canaliculi
- nasolacrimal duct
  - collects from lacrimal sac
  - empties tears into nasal cavity



Tears:
- supply oxygen and nutrients to cornea (avascular)
- are antibacterial (contain antibodies and lysozyme)
- lubricate and bathe the conjunctiva

Extraocular Eye Muscles & their CN

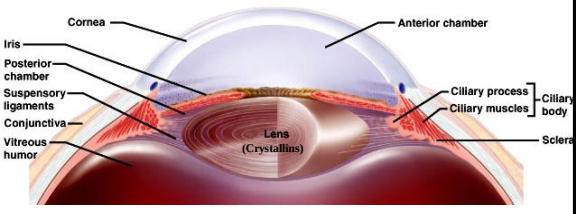
Muscle	Action	Controlling cranial nerve
Lateral rectus	Moves eye laterally	VI (abducens)
Medial rectus	Moves eye medially	III (oculomotor)
Superior rectus	Elevates eye and turns it medially	III (oculomotor)
Inferior rectus	Depresses eye and turns it medially	III (oculomotor)
Inferior oblique	Elevates eye and turns it laterally	III (oculomotor)
Superior oblique	Depresses eye and turns it laterally	IV (trochlear)

(c) Summary of muscle actions and innervating cranial nerves

Which cranial nerves innervate each of the muscles in the diagram above? $LR_6SO_4AO_3$

Lens

- transparent, avascular
- biconvex
- lies behind iris
- largely composed of lens fibers
- enclosed by thin elastic capsule
- held in place by suspensory ligaments of ciliary body
- focuses visual image on retina (accommodation)



Loss of lens transparency = cataracts

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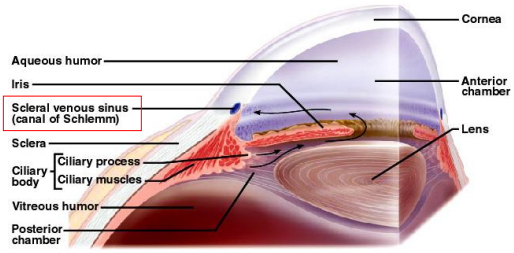
Aqueous Humor

- fluid in anterior cavity of eye
- secreted by epithelium on inner surface of the ciliary processes
- provides nutrients
- maintains shape of anterior portion of eye
- leaves cavity through canal of Schlemm (scleral venous sinus)



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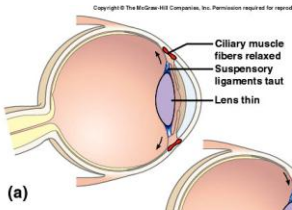
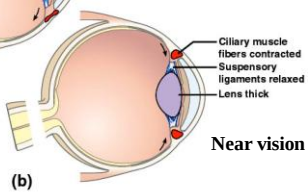
Accommodation

- changing of lens shape to view objects nearby
- ciliary muscles (intrinsic) change shape of lens



Far vision (emmetropia) (20 ft. or greater)



Near vision

Presbyopia is the loss of the ability to accommodate with age

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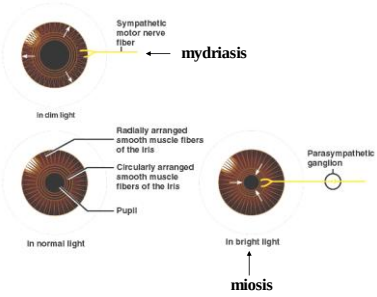
Iris

- composed of connective tissue and smooth muscle (intrinsic muscles)
- pupil is hole in iris
- dim light stimulates (sympathetic) radial muscles and pupil dilates
- bright light stimulates (parasympathetic, CN III) circular muscles and pupil constricts



How would viewing near objects affect pupil size?

Visual Receptors

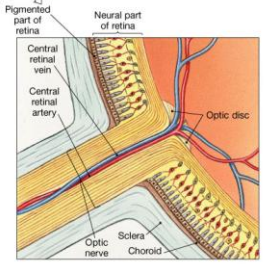
Rods
- long, thin projections
- contain light sensitive pigment called rhodopsin
- hundred times more sensitive to light than cones
- provide vision in low light/darkness
- produce colorless vision
- produce outlines of object
- view off-center at night
- outward from fovea centralis

Cones
- short, blunt projections
- contain light sensitive pigments called erythrolabe, chlorolabe, and cyanolabe (photopsins)
- provide vision in bright light
- produce sharp images
- produce color vision
- in fovea centralis

Dark adaptation by the rods takes approximately 30 minutes. This adaptation can be destroyed by white light in just milliseconds

Optic Disc (Blind Spot)

Optic disc(k) – Exit of optic nerve; no photoreceptors = no vision
Macula lutea – area immediately surrounding fovea centralis
Fovea centralis – contains only cones; area of most accute vision



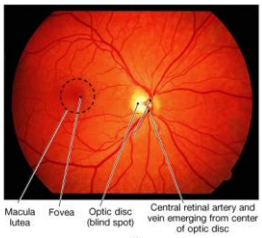


Figure from: Martini, *Fundamentals of Anatomy & Physiology*, Benjamin Cummings, 2004

Visual Pathway

The right side of the brain receives input from the left half of the visual field

The left side of the brain receives input from the right half of the visual field

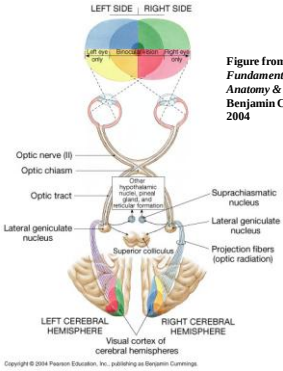


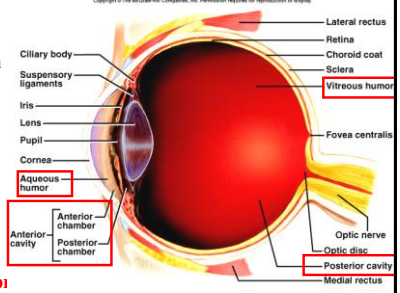
Figure from: Martini, *Fundamentals of Anatomy & Physiology*, Benjamin Cummings, 2004

Outer (Fibrous) Tunic

Cornea
- anterior portion
- transparent
- light transmission
- light refraction
- well innervated
- avascular

Sclera
- posterior portion
- opaque
- protection
- support
- attachment site for extrinsic eye muscles

Figure from: Hole's Human A&P, 12th edition, 2010



Transverse section, superior view

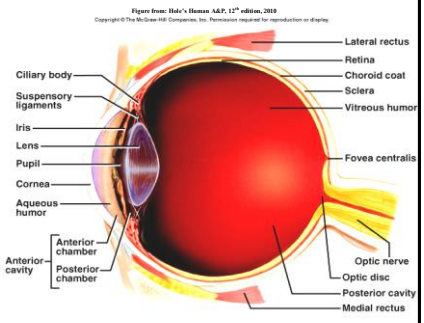
Middle (Vascular) Tunic = Uvea

1. Iris
- anterior portion
- pigmented CT
- controls light intensity

2. Ciliary body
- anterior portion
- pigmented
- holds lens
- muscles reshape lens for focusing
- aqueous humor

3. Choroid coat
- provides blood supply
- pigments absorb extra light

Figure from: Hole's Human A&P, 12th edition, 2010



This layer contains the intrinsic muscles of the eye
- Regulate the amount of light entering the eye
- Regulate the shape of the lens