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

Divisions of the Nervous System

- Know all these subdivisions of the nervous system
Neuron Structure

- Initial segment – where action potentials (nerve impulses) begin
- Dendrites bring impulses TO the soma
- Soma is the ‘processing’ part of the neuron
- Axon carries impulses AWAY from the soma
- Synaptic knobs contain axons
- Myelin is found on axons
- Neurons conduct nerve impulses

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

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
Neuroglia (glia = glue)

Table of Neuroglia

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

Neurophysiology

Be sure to look at the Supplemental Study Notes for Neurophysiology (on the Web site under Lecture 18 Supporting Materials)

This should help if you are still a little ‘fuzzy’ about this material.

You should also use these notes to address the points in your study guide.
Membrane Channel Proteins

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

Transmembrane Potential

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

- Inside is negative relative to the outside
- Polarized membrane due to distribution of ions
- Na⁺/K⁺-ATPase pump

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

Both of these act by changing the resting membrane potential of the postsynaptic neuron; either de- or hyperpolarizing it.
• 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**

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

---

**Action Potential and Refractory Period**

- **Absolute Refractory Period (ARP)**
- **Relative Refractory Period (RRP)**

Influx of Na+ (Depolarization)

Outflow of K+ (Repolarization)

Action Potential begins in initial segment of neuron

Great summary graphic to know for exam!

---

**Action Potentials**

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.
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

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.

Chemical Synaptic Transmission

Neurotransmitters (ntx) are released when impulse reaches synaptic knob
This may or 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
How is the neurotransmitter neutralized so the signal doesn’t continue indefinitely?
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

Both of these act by changing the resting membrane potential of the postsynaptic neuron; either de- or hyperpolarizing it

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>
<thead>
<tr>
<th>Neurotransmitter</th>
<th>Location</th>
<th>Major Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetylcholine</td>
<td>CNS</td>
<td>Involved in control of skeletal muscle actions</td>
</tr>
<tr>
<td>Noradrenaline</td>
<td>CNS, PNS</td>
<td>Stimulates heart rate; causes contraction of smooth muscle; provides sense of alertness</td>
</tr>
<tr>
<td>Dopamine</td>
<td>CNS, PNS</td>
<td>Involved in movement; involved in reward pathways; involved in pleasure and pain perception</td>
</tr>
<tr>
<td>Serotonin</td>
<td>CNS, PNS</td>
<td>Involved in mood regulation; involved in appetite control; involved in sleep cycle</td>
</tr>
<tr>
<td>GABA</td>
<td>CNS</td>
<td>Inhibitory neurotransmitter; involved in calming and relaxation</td>
</tr>
<tr>
<td>Glutamate</td>
<td>CNS</td>
<td>Excitatory neurotransmitter; involved in memory and learning</td>
</tr>
</tbody>
</table>

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

Organization of Spinal Gray Matter

You should know what types of cells are found in the different areas of gray matter of within the spinal cord.

Organization of Spinal White Matter

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)

Most axons cross over during their travel.

What will this mean clinically?

---

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

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 to sensory cerebral cortex - terminate in the cerebral cortex

---

Descending Tracts

- **corticospinal** (direct, pyramidal)
  - voluntary movement of skeletal muscles
  - lateral cross in medulla
  - contralateral

- **reticulospinal** (indirect, extrapyramidal)
  - subconscious muscle tone
  - sweat glands
  - some lateral cross, anterior do not cross

- **rubrospinal** (indirect, extrapyramidal)
  - subconscious regulation of upper limb tone/movement
  - cross in brain (less important in humans)
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

### Classification of Nerve Fibers

**TABLE 13.2 The Classification of Nerve Fibers**

<table>
<thead>
<tr>
<th>Class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Afferent fibers</td>
<td>Carry sensory signals from receptors to the CNS</td>
</tr>
<tr>
<td>Efferent fibers</td>
<td>Carry motor signals from the CNS to effector organs</td>
</tr>
<tr>
<td><strong>Somatic fibers</strong></td>
<td>Innervate skin, skeletal muscles, bones, and joints</td>
</tr>
<tr>
<td><strong>Visceral fibers</strong></td>
<td>Innervate blood vessels, glands, and viscera</td>
</tr>
<tr>
<td><strong>General fibers</strong></td>
<td>Innervate widespread organs such as muscles, skin, glands, viscera, and blood vessels</td>
</tr>
<tr>
<td><strong>Special fibers</strong></td>
<td>Innervate more localized organs in the head, including the eyes, ears, olfactory and taste receptors, and muscles of chewing, swallowing, and facial expression</td>
</tr>
</tbody>
</table>

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

- **Somatic**
  - Skin
  - Bones
  - Muscles
  - Joints

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

- **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!!
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!

Below cervical spine, each spinal nerve leaves inferior to the same numbered vertebra.

Nerve 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

**Cervical Plexus - C1-C4**
- Supplies muscles and skin of the neck
- Contributes to phrenic nerve (diaphragm)

**Brachial Plexus - C5-T1**
- Supplies shoulder and upper limbs

**Lumbosacral Plexus - T12 – S5**
- Supplies pelvis and lower limbs

Spinal Nerves – Somatic Motor Fibers

- **Ventral root**: axons of motor neurons whose cell bodies are in spinal cord
- **Ventral ramus**: supply ventrolateral body surface, body wall, and limbs
- **Dorsal ramus**: skin and skeletal muscles of the back
Spinal Nerves – Somatic Sensory Fibers

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

Dorsal root ganglion
- cell bodies of sensory neurons

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

Somatic Reflex Arcs

Reflexes – automatic, subconscious, quick, stereotyped responses to stimuli either within or outside the body

They occur in both the somatic and autonomic divisions

Protection of the Brain

- The brain is protected
  - Mechanically by
    - The skull bones
    - The meninges
    - 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

What are the 3 different reflexes we discussed in class? How many synapses does each have? Are they ipsi- or contralateral?
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

Overview of Cerebral Cortex

The cerebral cortex is divided into several functional areas:
- Motor (frontal cortex)
- Sensory (parietal, occipital, and temporal cortex)
- Association (all lobes)
Cortex = Conscious Awareness

Functions of Parts of Brain

<table>
<thead>
<tr>
<th>Part of Brain</th>
<th>Major Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor areas</td>
<td>Primary motor cortex: Voluntary control of skeletal muscles</td>
</tr>
<tr>
<td></td>
<td>Broca's area (motor speech area): Controls muscles needed for speech</td>
</tr>
<tr>
<td>Frontal eye field</td>
<td>Controls muscles needed for eye movement</td>
</tr>
<tr>
<td>Sensory areas</td>
<td>Cutaneous Sensory Area: Receives somatic sensations</td>
</tr>
<tr>
<td></td>
<td>Visual area: Receives visual sensations</td>
</tr>
<tr>
<td></td>
<td>Auditory area: Receives auditory sensations</td>
</tr>
<tr>
<td>Association areas</td>
<td>Analyze and interpret sensory experiences; coordinate motor responses</td>
</tr>
<tr>
<td>Basal nuclei</td>
<td>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</td>
</tr>
<tr>
<td>Li b i l i f i i il f ili</td>
<td>Li m b i c system controls emotions, produces feelings, interprets sensory impulses, facilitates memory storage and retrieval (learning!)</td>
</tr>
<tr>
<td>Diencephalon</td>
<td>Thalamus: gateway for sensory impulses heading to cerebral cortex, receives all sensory impulses (except smell)</td>
</tr>
<tr>
<td></td>
<td>Hypothalamus: Vital functions associated with homeostasis</td>
</tr>
<tr>
<td>Brainstem</td>
<td>Midbrain: Major connecting center between spinal cord and brain and parts of brainstem; contains corpora quadrigemina (visual and auditory reflexes)</td>
</tr>
<tr>
<td>Pons</td>
<td>Helps regulate rate and depth of breathing, relays nerve impulses to and from medulla oblongata and cerebellum</td>
</tr>
<tr>
<td>Medulla Oblongata</td>
<td>Contains cardiac, vasomotor, and respiratory control centers, contains various nonvital reflex control centers (coughing, sneezing, vomiting)</td>
</tr>
<tr>
<td>Reticular formation (system)</td>
<td>Filters incoming sensory information; habituation, modulates pain, arouses cerebral cortex into state of wakefulness (reticular activating system)</td>
</tr>
<tr>
<td>Cerebellum</td>
<td>Subconscious coordination of skeletal muscle activity, maintains posture</td>
</tr>
</tbody>
</table>

Memory

- A “Memory” is the persistence of knowledge that can be accessed (we hope!) at a later time.
- Memories are not 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 than STM
  - Declarative (events and facts), Procedural (motor skills)
  - Remembering childhood events as an adult
### The Twelve Pairs of Cranial Nerves

<table>
<thead>
<tr>
<th>Numeral</th>
<th>Name</th>
<th>Functions</th>
<th>Sensory, Motor, or Both (Mixed Nerve)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>OPTICOCYCLIC (OLD)</td>
<td>Olfaction</td>
<td>Sensory (SOMA)</td>
</tr>
<tr>
<td>II</td>
<td>OCULOMOTOR</td>
<td>Vision</td>
<td>Sensory (SAY)</td>
</tr>
<tr>
<td>III</td>
<td>TRIGEMINAL</td>
<td>Move Eye</td>
<td>Motor (MARRY)</td>
</tr>
<tr>
<td>IV</td>
<td>TROCHLEAR</td>
<td>Move Eye (superior oblique)</td>
<td>Motor (MONEY)</td>
</tr>
<tr>
<td>V</td>
<td>FACIAL</td>
<td>Major Sensory Nerve From Face</td>
<td>Both (BUT)</td>
</tr>
<tr>
<td>VI</td>
<td>ABDUCENS</td>
<td>Move Eye (lateral rectus)</td>
<td>Motor (MY)</td>
</tr>
<tr>
<td>VII</td>
<td>FACIAL</td>
<td>Major Motor Nerve of Face</td>
<td>Both (BROTHER)</td>
</tr>
<tr>
<td>VIII</td>
<td>VESTIBULOCOCHLEAR</td>
<td>Hearing and Equilibrium</td>
<td>Sensory (SAYS)</td>
</tr>
<tr>
<td>IX</td>
<td>GLOSSOPHARYNGEAL</td>
<td>Move Muscles of Tongue and Pharynx</td>
<td>Both (BIG)</td>
</tr>
<tr>
<td>X</td>
<td>VAGUS</td>
<td>Innerve Visceral Smooth Muscle; Muscles of Speech</td>
<td>Both (BOOBS)</td>
</tr>
<tr>
<td>XI</td>
<td>ACCESSORY</td>
<td>Move Neck Muscles</td>
<td>Motor (MATTER)</td>
</tr>
<tr>
<td>XII</td>
<td>HYPOGLOSSAL</td>
<td>Move Tongue</td>
<td>Motor (MOST)</td>
</tr>
</tbody>
</table>

You should know this table

### Somatic vs. Autonomic Nervous Systems

![Diagram](Figure from: Marieb, Human Anatomy & Physiology, Pearson Education, 2004)

### Sympathetic Division of ANS

![Diagram](Figure from: Saladin, Anatomy & Physiology, Mcgraw Hill, 2007)
Sympathetic Division of the ANS

SYMPATHETIC (Thoracolumbar outflow)

Fight or Flight

- "E" situations
- Emergency
- Embarrassment
- Excitement
- Exercise

"REST AND DIGEST"

- Embarrassment
- Excitement
- Exercise

3 decreases
- Heart rate
- Airway diameter
- Pupil size (constrict)

Parasympathetic

(Craniosacral outflow)

Salivation
Lacrimation
Urination
Digestion
Defecation

NTs secreted by postganglionic fiber
- Nicotinic choline
- Acetylcholine
- Norepinephrine

Know this chart

Review of Autonomic Nervous System

<table>
<thead>
<tr>
<th>Branch of ANS</th>
<th>PARASYMPATHETIC</th>
<th>SYMPATHETIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Function</td>
<td>&quot;rest and digest&quot; (SLUDD; 3 decreases)</td>
<td>&quot;fight or flight&quot; (&quot;E&quot; situations)</td>
</tr>
<tr>
<td>Origin of Preganglionic fiber</td>
<td>from cranial region of brain or sacral region of spinal cord</td>
<td>from thoracic or lumbar region of spinal cord (thoracolumbar outflow)</td>
</tr>
<tr>
<td></td>
<td>(craniosacral outflow)</td>
<td>Exhibits divergence for widespread activation of body</td>
</tr>
<tr>
<td>Length of Preganglionic fiber</td>
<td>long</td>
<td>short</td>
</tr>
<tr>
<td>Location of Ganglia</td>
<td>within or near effector organ</td>
<td>alongside or in front of spinal cord (paravertebral ganglia; collateral ganglia)</td>
</tr>
<tr>
<td>NTs secreted by postganglionic fiber</td>
<td>acetylcholine</td>
<td>Nicotinic choline (some acetylcholine; sweat glands, smooth muscle on blood vessels, brain)</td>
</tr>
</tbody>
</table>
You should know which neurotransmitters are released, and the locations where they are released.

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

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
**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

**Stretch Receptors - Proprioceptors**

- Muscle spindle – initiates contraction (stretch reflex)
- Golgi tendon organ – inhibit contraction

**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
**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

**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

**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).
**Physiology of Hearing**

Tympanic membrane → malleus → incus → stapes → oval window → scala vestibuli → scala tympani → round window

**Know pathway for exam**

---

**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 cochlea to round window
- part of bony labyrinth

---

**Organ of Corti**

- 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
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).

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).

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).
Crista Ampullaris & Dynamic Equilibrium

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

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

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

Which cranial nerves innervate each of the muscles in the diagram above? LR, SO, AO.

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

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

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

**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)

**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
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 accurate vision

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