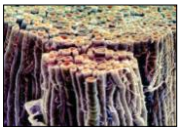
Organization of Human Nervous System:

- Nervous System
  - Integration
  - Central Nervous System (CNS)
    - Brain
    - Spinal Cord
  - Peripheral Nervous System (PNS)
    - Motor output
      - Motor Division (Efferent)
        - Autonomic Nervous System (Involuntary; smooth & cardiac muscle)
          - Sympathetic Division
          - Parasympathetic Division
        - Somatic Nervous System (Voluntary; skeletal muscle)
    - Sensory input
      - Sensory Division (Afferent)

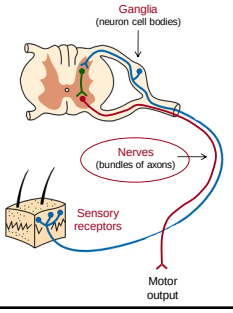
The peripheral nervous system links the brain to the "real" world



Nerve Types:

1) Sensory nerves (contains only afferent fibers)
2) Motor nerves (contains only efferent fibers)
3) Mixed nerves (contains afferent / efferent fibers)

Most nerves in the human body are mixed nerves

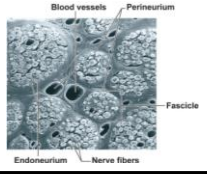


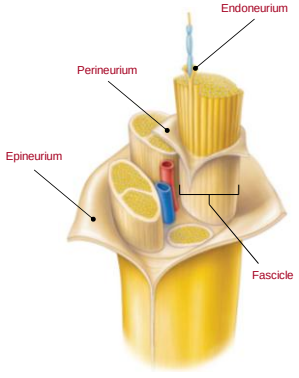
Nerve Structure:

A. Epineurium:
- Outside nerve covering
- Dense network of collagen fibers

B. Perineurium: (Compartments ↓)
- Divides nerve into fascicles
- Contains blood vessels

C. Endoneurium:
- Surrounds individual axons and ties them together

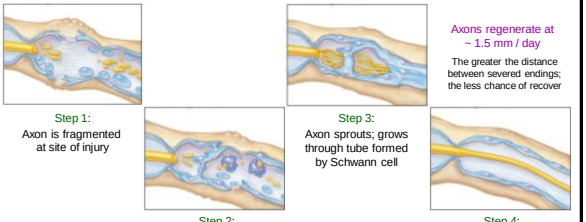




Marieb & Hoehn – Figure 13.26

Nerve Regeneration:

- Requires neuron cell body stays intact
- Regeneration common in PNS; rare in CNS



Axons regenerate at ~ 1.5 mm / day

The greater the distance between severed endings; the less chance of recover

Step 1: Axon is fragmented at site of injury

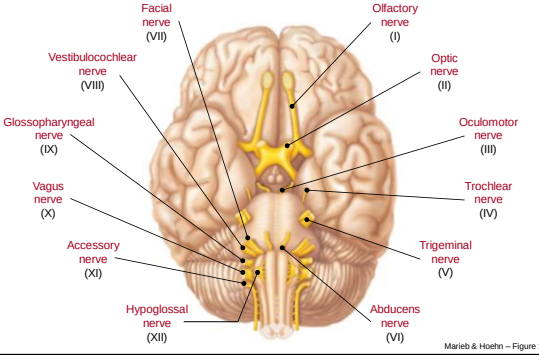
Step 2: Macrophages clean out dead axon distal to injury

Step 3: Axon sprouts; grows through tube formed by Schwann cell

Step 4: Axon regenerates and new myelin sheath forms

Nerve Classification:

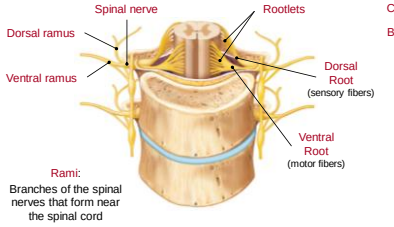
A. Cranial nerves:
- 12 pairs
- Composed of sensory, motor, and mixed nerves



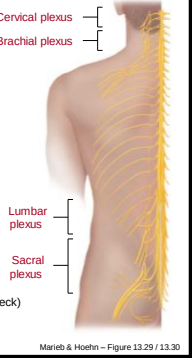
Marieb & Hoehn – Figure 13.28

Nerve Classification:

B. Spinal nerves:
- 31 pairs
- All are mixed nerves



Rami: Branches of the spinal nerves that form near the spinal cord



Nerve Plexus:

Complex, interwoven network of ventral rami in areas of compound muscle development (e.g., limbs / neck)

Offer protection – multiple spinal nerves innervate individual muscles

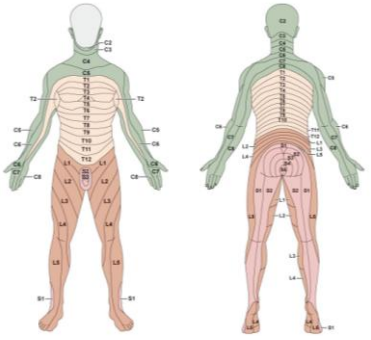
Marieb & Hoehn – Figure 13.29 / 13.30

Marieb & Hoehn – Figure 13.35

Nerve Classification:

B. Spinal nerves:

Dermatome:
Specific bilateral region of the skin monitored by a single pair of spinal nerves



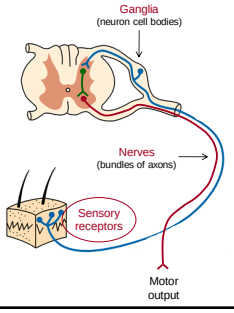
The peripheral nervous system links the brain to the "real" world

Sensory Receptor:
Specialized structure that responds to change in the surrounding environment

NOTE:
Ability to distinguish stimuli depends on the brain

Sensations:
Electrical impulses that reach the brain via sensory neurons

Perceptions:
Interpretations of electrical impulses by the brain

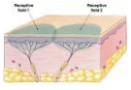


General Characteristics of Sensory Receptors:

Receptor structure dictates specificity
(e.g., free nerve endings = low specificity)

1) Display specificity:
   - Receptor specificity: Specific stimuli necessary to stimulate receptor

2) Display spatial sensitivity:
   - Receptor field: Area monitored by a single receptor cell



The larger a receptor field, the poorer the ability to localize a stimulus

3) Code information electronically (e.g., tranduce signal):
   - Sensory coding: Translation of stimuli into patterns of action potentials

4) Have 'hard-wired' link to CNS:
   - Labeled line: Links between peripheral receptors and CNS

CNS interprets receptor signal based solely on where it arrives from
(e.g., see spots when eye pushed)

5) Are adaptable:
   - Adaptation: Reduction in sensitivity in presence of constant stimulus
     - Phasic receptors: Rapidly decline in sensitivity (e.g., touch receptors)
     - Tonic receptors: Show little / no decline in sensitivity (e.g., pain receptors)

Sensory Receptor Classifications:

A) Stimulus Type:
   - Mechanoreceptors: Respond to mechanical force (e.g., touch)
   - Thermoreceptors: Respond to temperature change
   - Photoreceptors: Respond to light energy
   - Chemoreceptors: Respond to chemicals in solution
   - Nociceptors: Respond to stimuli that damages tissue; perceived as pain

B) Location:
   - Exteroceptors: Respond to stimuli arising from outside the body
   - Interoceptors: Respond to stimuli within the body
   - Proprioceptors: Respond to stretch in muscles / tendons / ligaments

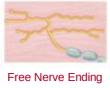
C) Structural Complexity:
   - Simple Receptors: Structurally simple; associated with general senses
   - Complex Receptors: Structurally complex; associated with special senses

(vision, hearing, equilibrium, smell, taste)

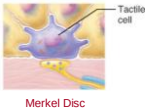
Simple Receptors (General senses):

Small, unmyelinated sensory neurons; knob-like swellings on distal end

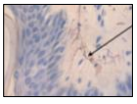
A) Unencapsulated Dendritic Endings



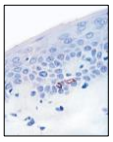
Free Nerve Ending
Location = Epithelia
Detection = Temperature / damage



Merkel Disc
Location = Epidermis
Detection = Light touch



Hair Plexus
Location = Hair follicle
Detection = Light touch



Marieb & Hoehn – Figure 13.29 / 13.30

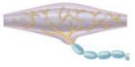
Simple Receptors (General senses):

Sensory neurons with terminals enclosed in connective tissue capsule

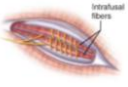
B) Encapsulated Dendritic Endings

Meissner's Corpuscle
Location = Dermis
Detection = Light touch

Pacinian Corpuscle
Location = Dermis / Hypodermis
Detection = Deep pressure



Ruffini Endings
Location = Dermis / Joints
Detection = Deep pressure



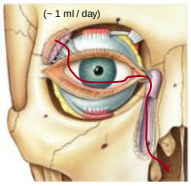
Muscle Spindle
Location = Skeletal muscle
Detection = Stretch

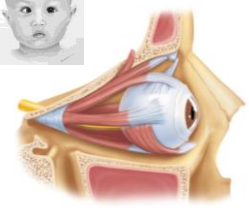
Golgi Tendon Organ
Location = Tendons
Detection = Stretch

Complex Receptors (Special senses):

A) Eye (vision)

70% of sensory receptors
50% of cerebral cortex





Contained in orbit of skull:

1) Orbital fat (cushions / insulates eye)
2) Extrinsic eye muscles (6)
3) Lacrimal gland: Produces tears
   - Lubricates eye
   - Supplies nutrients / oxygen
   - Provides antibacterial enzymes

Strabismus:
A condition in which an eye rotates medially / laterally

Marieb & Hoehn – Figure 13.4

Cornea is the only tissue that can be transplanted with limited rejection issues

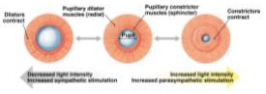
Complex Receptors (Special senses):

A) Eye (vision)

1) Fibrous Layer: (Outermost)
   - Offers structurally support / protection
   - Acts as anchoring point for muscles
   - Assists in light focusing

2) Vascular Layer: (Middle)
   - Contains blood vessels / lymph vessels
   - Regulates light entering eye
   - Controls shape of lens

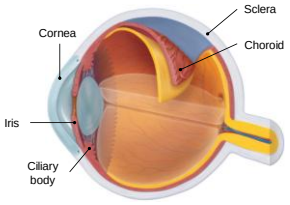
Iris:
Regulates size of pupil (opening)



- Only contain brown pigment

Cornea:
Transparent window

Sclera:
"White of the eye"



Choroid:
Pigmented layer; delivers nutrients to retina

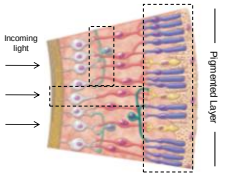
Ciliary Body:
Smooth, muscular ring; controls lens shape

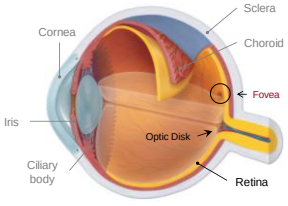
Complex Receptors (Special senses):

A) Eye (vision)

3) Retina: (Innermost)
   - Pigmented layer (light absorption)
   - Neural layer (light detection)

Optic Disk (blind spot)
Origin of optic nerve; no photoreceptors present





1) Photoreceptors (light detectors)
   - Rods (light sensitive - ~ 125 million / eye)
   - Cones (color sensitive - ~ 6 million / eye)

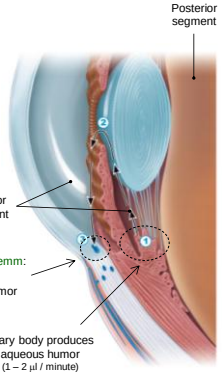
Cones clustered in fovea of macula lutea (sharp focus)

2) Bipolar cells / Ganglion cells (serial links)
3) Horizontal cells / Amacrine cells
(facilitate / inhibit serial link)

Complex Receptors (Special senses):

A) Eye (vision)

Segments of the Eye:



Aqueous Humor:
Circulating fluid in anterior segment
- Nutrient / waste transport
- Cushioning of eye
- Retention of eye shape

Vitreous Humor:
Gelatinous mass in posterior segment
- Transmits light
- Stabilize eye shape
- Holds retina firmly in place

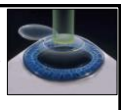
Intraocular Pressure = 12 – 21 mm Hg

Glaucoma:
↑ intraocular pressure

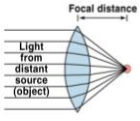
Complex Receptors (Special senses):

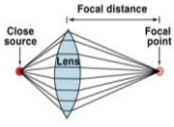
A) Eye (vision)

Lasik eye surgery

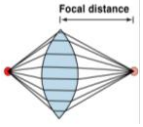


For clear vision, light must be focused on the retina





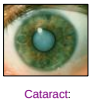
Close objects = ↑ focal distance



Rounder lens = ↓ focal distance

Refraction:
The bending of light when it passes between mediums of different density

1) Cornea: 85% of refraction (fixed)
2) Lens: 15% of refraction (variable)
   - Composed of lens fibers (cells)
   - Crystallins (transparent proteins)



Cataract:
(cloudy lens)

Accommodation:
Changing the shape of a lens to keep an image in focus
(constant focal length)

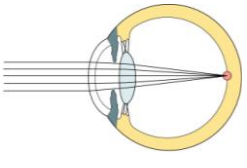
Complex Receptors (Special senses):

A) Eye (vision)

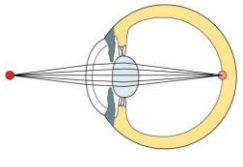
Accommodation:

Near Point of Vision:
Inner limit of clear vision

Loss of lens elasticity
- Children = 7 – 9 cm
- Young Adults = 15 – 20 cm
- Elderly Adults = 70 – 85 cm



Lens flattens for distant object focus;
Ciliary body RELAXES



Lens bulges for near object focus;
Ciliary body CONTRACTS

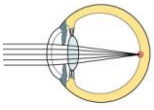
In Addition:
- Pupils constrict
- Eyeballs converge

Complex Receptors (Special senses):

A) Eye (vision)

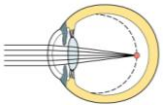
20 / 20 = Standard visual acuity
20 / 200 = Legally blind

When Things Go Wrong:



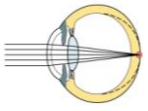
Emmetropia

Near-sighted



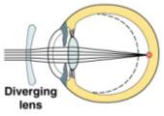
Myopia

Far-sighted

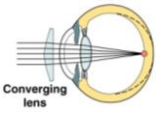


Hyperopia

Astigmatism:
Warping of the lens or cornea leading to image distortion



Correct with diverging lens

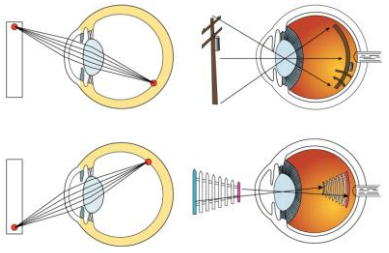


Correct with converging lens

Complex Receptors (Special senses):

A) Eye (vision)

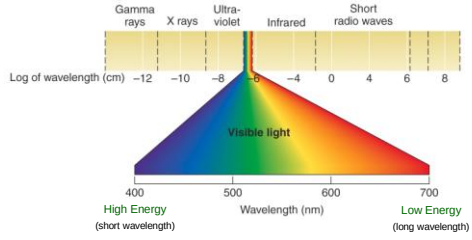
Brain compensates for image reversal



- Images arrive on the retina upside down and backward

Complex Receptors (Special senses):

A) Eye (vision)



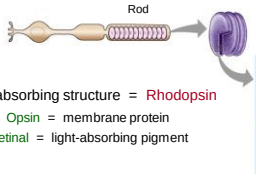
Photon:
Basic unit of visible light

- Rods detect presence / absence of light
- Cones detect wavelength of light (color perception)

Complex Receptors (Special senses):

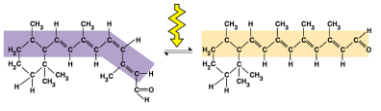
A) Eye (vision)

Phototransduction:
Process by which light energy is converted into electrical energy



Light-absorbing structure = Rhodopsin
Opsin = membrane protein
Retinal = light-absorbing pigment

- When rhodopsin absorbs light, the retinal changes shape and separates from opsin



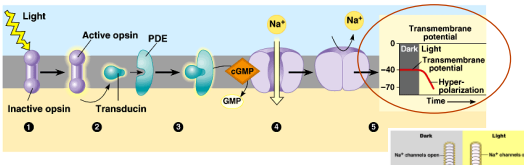
Why does it take several minutes for eyes to adjust to dark?

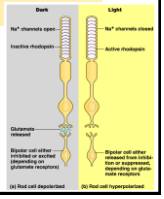
"Bleaching"
Separation of retinal

Complex Receptors (Special senses):

A) Eye (vision)

- Altered opsin (minus retinal) triggers enzymatic pathway:

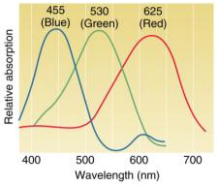




IMPORTANT FACT:
Light does not depolarize rod cell, but hyperpolarizes it

Complex Receptors (Special senses):

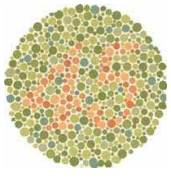
A) Eye (vision)



- Three classes of cones recognized
  - Trichromacy Theory
    - Humans: Blue, Green, Orange
    - Sensation of color = CNS processing
- Color sensitivity depends on opsin structure, not light-absorbing molecule

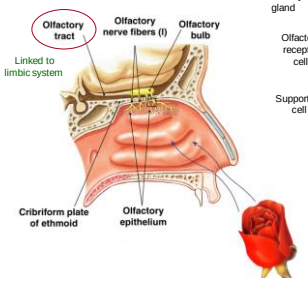
Colorblindness:
Defect in cone opsin gene

- Blue = autosomal chromosome
- Red / Green = X chromosome ← More common in males

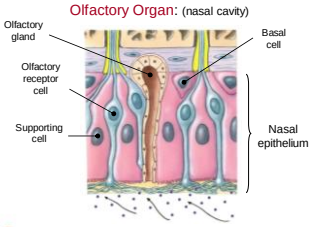


Complex Receptors (Special senses):

B) Olfactory Epithelium (smell)



Olfactory Organ: (nasal cavity)

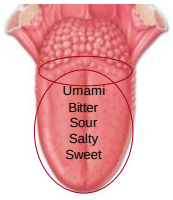


- Olfactory receptor cells (~ 1 million / cm^2)
  - Ciliated (~ 20 cilia / cell)
  - Odorant-binding proteins
- Supporting cells
- Basal cells (stem cells → new receptors)
- Olfactory Glands
  - Thick, pigmented mucus

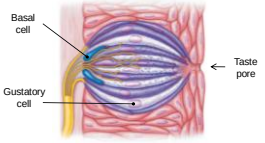
- Odorants must by water / lipid soluble
  - ≥ 4 molecules = receptor activation
  - ~ 1000 receptor types (discriminate ~ 10,000)

Complex Receptors (Special senses):

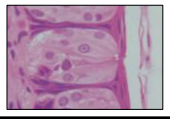
C) Taste Buds (taste)



Taste bud: (~ 10,000 / tongue)



- Gustatory cells (taste receptors)
  - Slender microvilli (taste hairs)
  - 10 day lifespan
- Basal cells (stem cells → new receptors)

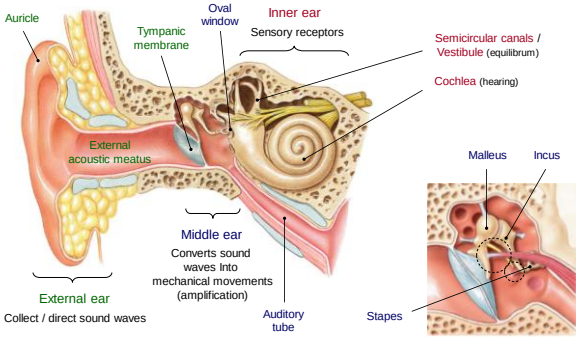


- Taste buds on lingual papillae:

Circumvallate (~ 100 taste buds) | Fungiform (~ 5 taste buds) | Filiform (no taste buds - friction)

Complex Receptors (Special senses):

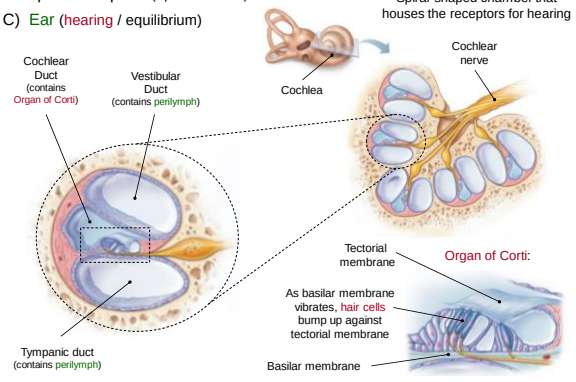
C) Ear (hearing / equilibrium)



Complex Receptors (Special senses):

C) Ear (hearing / equilibrium)

Cochlea ("snail"):
Spiral-shaped chamber that houses the receptors for hearing

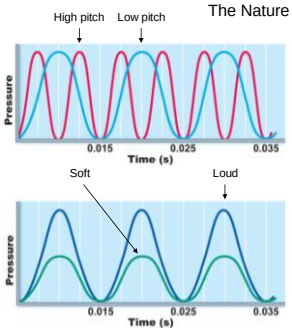


Complex Receptors (Special senses):

C) Ear (hearing / equilibrium)

Sound:
A pressure disturbance produced by a vibrating object

The Nature of Sound:



Frequency:
Number of waves passing a given point in a given time

Pitch = Sensory perception of frequency

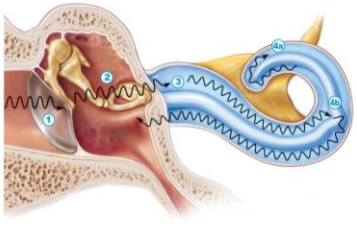
Amplitude:
Intensity of sound

Loudness = Sensory perception of amplitude

Complex Receptors (Special senses):

C) Ear (hearing / equilibrium)

Step 4:
Sound waves enter cochlear duct; vibrate basilar membrane



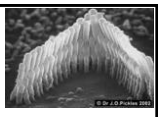
Step 1:
Sound waves vibrate tympanic membrane

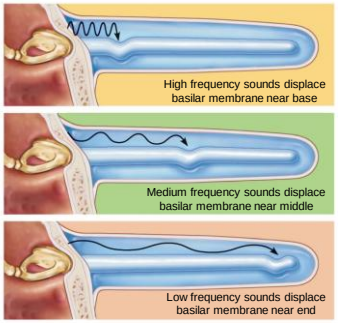
Step 2:
Middle ear bones vibrate; Vibrate oval window

Step 3:
Pressure waves develop In vestibular duct

Complex Receptors (Special senses):

C) Ear (hearing / equilibrium)





Basilar membrane differs in stiffness along length

Hearing Range:
20 Hz to 20,000 Hz

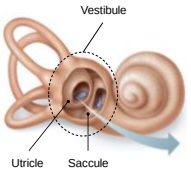
Conduction Deafness:
Sound is not able to be transferred to internal ear

Sensorineural Deafness:
Damage occurs in neural pathway (e.g., hair cells)

Complex Receptors (Special senses):

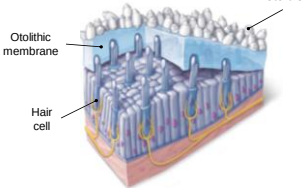
C) Ear (hearing / equilibrium)

Vestibule:
Region of inner ear housing receptors that respond to gravity sensation / linear acceleration
(static equilibrium)



Maculae:
Sensory receptors for static equilibrium

Maculae anatomy:

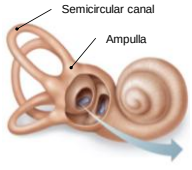


Head acceleration (e.g, forward) causes otolithic membrane to slide; subsequent bending of hair cells modifies AP firing rate

Complex Receptors (Special senses):

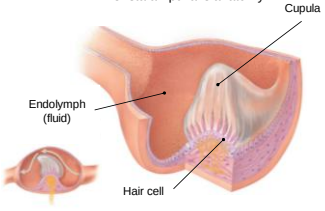
C) Ear (hearing / equilibrium)

Analyze three (3) rotational planes
("yes" / "no" / head tilt)



Semicircular canals:
Region of inner ear housing receptors that respond to rotational movements of head
(dynamic equilibrium)

Crista ampullaris anatomy:



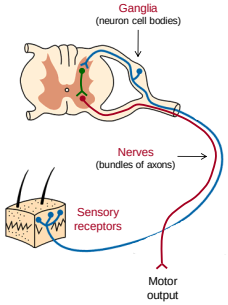
Crista ampullaris:
Sensory receptors for dynamic equilibrium

Head rotation (e.g., spinning) causes endolymph to push against cupula; subsequent bending of hair cells modifies AP firing rate

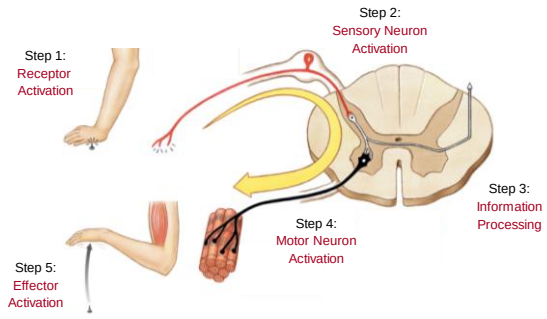
The peripheral nervous system links the brain to the "real" world

Reflex:
Rapid, automatic response to specific stimuli

"Wired" in a reflex arc
(serial processing)



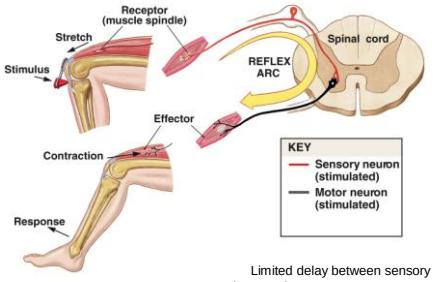
Reflex Arc:



Reflex Arc:

Example: Stretch Reflex

A) Monosynaptic: Sensory neuron synapses directly with motor neuron



Limited delay between sensory input and motor output (20 – 40 msec)

Reflex Arc:

Example: Crossed Extensor Reflex

A) Polysynaptic: Interneuron(s) located between sensory and motor neurons

Reciprocal Inhibition:
Agonist excited;
antagonist inhibited