Chapter 10 The Nervous System: Sensory Systems (I)

General Principles of Sensory Physiology
- The Somatosensory System
- Vision

10.1 General Principles of Sensory Physiology
- Afferent nervous system signals are from
  - External environment: Sensory
  - Internal environment: Visceral afferent
- Perception
  - Is conscious interpretation of external world based on the sensory system, memory and other neural processes
    - Duck or rabbit?
- Somatosensory System
  - Perception of
    - Somatic (body, skin)
    - Proprioception (body position)
- Special Sensory System
  - The perception of
    - Vision
    - Hearing and equilibrium
    - Taste
    - Smell
- Receptor Physiology
  - Sensory receptors are specialized neural structures that detect a stimulus.
  - Receptor properties
    - Specificity: The law of specific nerve energy (Table 10.1)
    - Adaptation
- The sensory stimulus contains an energy form called modality
  - Law of specific nerve energies: Receptors show specificity to one modality
  - Adequate stimulus: Modality for which a receptor is specific and is the most sensitive
- Two Sensory Receptor Structure and Function Forms Figure 10.2.
  - Receptor is a specialized afferent neuron ending.
  - Receptor is a separate cell that communicates with an afferent neuron via chemical synapses.
- Sensory Receptor Function: Sensory transduction
  - Sensory receptors detect stimuli and convert the energy of the stimulus into receptor potential or generator potential in a process called _______ ________
- Receptor Potentials
  - Receptor potentials are graded potentials generated in response to a stimulus acting on a sensory receptor
• A stimulus alters the receptor’s membrane permeability by opening and closing ion channels

• **Sensory Adaptation**
  - Sensory adaptation is the decrease in amplitude of receptor potential over time in presence of a constant stimulus
  - Corresponding decrease in frequency of action potentials
  - Types:
    - Slow adapting or tonic receptors
    - Rapidly adapting or phasic receptors

• **Slow Versus Fast Adaptation (Figure 10.3)**
  - The receptor potential reduces its strength to base line during the duration of the stimulus in _________ (fast/slow) adaption.
  - Slow adapting examples:__________________________, _____________________ and ________
  - Fast adapting example:____________________________

• **Sensory Pathways**
  - The particular neural pathway that transmits sensory information from receptors to the central nervous system pertaining to a particular modality also called **labeled lines**
  - Each sensory modality has a specific neural pathway which leads to a particular region of cerebral cortex for interpretation.

• **Generalized Sensory Pathway**
  - **First-order** neuron (afferent neuron) transmits information from PNS to CNS.
  - **Second-order** neuron is an interneuron that relays information to the thalamus
  - **Third-order** neuron passes information to cerebral cortex for sensory perception

• **Neural Interpretation: Cortical Sensory Areas (Figure 10.4)**

• **Sensory Unit (Figure 10.5)**
  - A sensory unit is a single afferent neuron, plus all receptors associated with it.

• **Receptive Field (Figure 10.5)**
  - A receptive field is the area in which an adequate stimulus can generate a response (either excitatory or inhibitory).
  - It is inversely with density of receptors

• **Sensory Coding**
  - Stimulus type
  - Stimulus intensity
  - Stimulus location

• **Stimulus Type Coding**
  - ____________: law of specific nerve energies
  - ____________: Brain integrates information from different sensory system for perception such as wet skin (thermoreceptors and touch receptor)

• **Stimulus Intensity Coding**
  - ____________ coding of action potentials
• **Stimulus Intensity Frequency Coding**
  o After reaching the threshold, the stronger stimuli will produce a higher __________ of action potentials
  o Which has stronger intensity (Figure 10.7)? A or B

• **Stimulus Intensity Population Coding (Recruitment) (Figure 10.8)**
  o Stronger stimulus activates more receptors (recruitment) in a ________ ___________ unit
  o Receptors in _____________ sensory units recruitment

• **Stimulus Location Coding**
  o Location coding is based on receptive fields in somatic senses and vision
    ▪ Size of __________ __________
    ▪ Degree of __________
    ▪ Lateral ____________
  o Sensory ___________ is the precision with which the location of a stimulus is perceived

• **Localization Acuity**
  o Any stimulus in the overlapped area will activate both neurons.

• **Lateral Inhibition**
  o A stimulus that activates the receptors in the area inhibits activity the nearby area.

• **Two Point Discrimination**
  o Ability to perceive two distinct points on skin
  o Two point discrimination threshold
    ▪ Is the minimum distance that must exist between two points for them to be perceived as separate points
    ▪ Measures tactile acuity
    ▪ Table 10.2 the body region has the greatest acuity: ____________

### 10.2 The Somatosensory System

• Involves body sensations such as pressure, temperature, pain, and body position

• **Somatosensory Receptors (Table 10.3)**
  o Somesthetic sensations are associated with skin
  o Proprioception is the awareness of body’s position in space
    ▪ Receptors in the muscles, tendons, ligaments, joints and skin

• **Somatosensory Pathways:**
  o The dorsal column-medical lemniscal pathway (Figure 10.15 a) informs the information from __________ and ________ to the CNS.
  o Spinothalamic tract (Figure 10.15 b) transmits information from __________ and ________ to the CNS.

• **Summary of General Sensation**
  o A sensory stimulus alters the membrane permeability to ions in a specific sensory receptor
  o This specific receptor converts the adequate stimulus into receptor potentials
through sensory transduction.
- Receptor potentials may trigger action potentials which are transmitted via a specific sensory pathway to particular region of CNS for interpretation

10.3 Vision
- Vision Overview
  - Light enters the cornea of the eye → pupil → lens → vitreous → retina.
  - Focus is formed on the retina.
  - Light energy is converted into electric signals.
  - The nerve impulse enters the optical nerve and reaches the visual cortex for interpretation.
- The Nature and Behavior of Light Waves
  - Light energy
  - Reflection
  - Refraction
  - Refraction of light in the eye
- Electromagnetic Spectrum (Figure 10.21)
- Reflection
  - Light waves reflect off objects
  - We perceive reflected (some emitted) light
- Refraction (Figure 10.22)
  - Light waves bend as they pass from one medium density to another at an angle other than perpendicular
  - Degree of refraction depends on
    - Differences in densities
    - Angle
- Light Refraction (Figure 10.23)
  - Cornea and lens are curved
  - Refract light as it enters eye
- Light Refraction by Eye (Figure 10.24)
  - Image projected onto retina is ______ ______and ______
- Visual Acuity
  - Visual acuity is sharpness of vision
  - Depends upon resolving power: ability to resolve two closely spaced dots
- Eye Accommodation (Figure 10.26)
  - Increasing lens curvature in order to focus on near objects
  - Greater refractive power of a lens is needed to focus on retina
- Vision of Distant Object
  - No ____________________________ stimulation, little refractive power is needed for distant vision
- Accommodation for Near Vision
  - Under parasympathetic control, ciliary muscle contracts
  - Decreased tension on zonular fibers; lens becomes rounder (refractive index increases)
• Clinical Abnormalities
  o Normal Eye (emmetropia) (Figure 10.27)
    | Condition   | Description                                                      |
    |-------------|------------------------------------------------------------------|
    | 1) Presbyopia | a) Lens or cornea is too round (strong refractive power) for the length of the eyeball, use concave lens to correct |
    | 2) Cataract  | b) Hardening of lens with ageing, use correction lens             |
    | 3) Astigmatism | c) Far slightness, focus behind retina while review near object   |
    | 4) Myopia    | d) Decreased transparency of lens due to opacification, use artificial lens |
    | 5) Hyperopia | e) Irregularities of the surface of lens or cornea; use correction lens |

• Regulating the Amount of Light Entering the Eye
  o Size of pupil regulates the amount of light entering eye
  o Iris consists of two layers of smooth muscle
    ▪ Inner circular muscle—constrictor
    ▪ Outer radial muscle—dilator

• Pupillary Constriction and Dilation (Figure 10.28)
  o Pupillary constriction is caused by the _______________ stimulation of ____________ muscle.
  o Pupillary dilation is caused by the ____________ stimulation of ____________ muscle.

• Anatomy of the Retina (Figure 10.29)

• Cells of the Retina
  o Rods and cones are photoreceptor cells that communicate with bipolar cells
  o Bipolar cells communicate with ganglion cells
  o Axons of ganglion cells form optic nerve
  o Horizontal and amacrine cells provide lateral modulation

• Anatomy and Function of Photoreceptors (Figure 10.31)
  o The conversion of light energy into electrical energy is called ___________________. This is the function of photoreceptors.

• Distribution of Photoreceptors
  o Fovea has the greatest number of cones and no rods.
  o Blind spot: There are no photoreceptors in optic disk

• Photoreceptor Absorbance Spectra
  o Four photopigments
  o Each has retinal and opsin
  o Four different opsins
    ▪ One for the rods (black and white vision, rhodopsin)
    ▪ Three for the cones (color vision): L, S and M

• Components of Rods (Figure 10.32)
• Characteristics of Rods and Cones (Table 10.5)
• **Photo transduction in the Dark (Figure 10.33)**
  - cGMP levels are _____ (high/low)
  - cGMP keeps sodium channels _____ (open/close).
  - Photoreceptor cells are____________________(hyperpolarized/depolarized)

• **Photo transduction in the Light (Figure 10.33)**
  - cGMP levels are _____ (high/low)
  - Sodium channels are _____ (open/close).
  - _____ ions keep moving out
  - Photoreceptors are____________________ (hyperpolarized/depolarized).

• **Light Input to Circadian Rhythms**
  - Many daily rhythms
  - Without light, circadian rhythms would run longer than 24 hours
  - Special photoreceptors contain melanopsin
  - Link to rhythm-generating center of the brain

• **Bleaching of Photoreceptors in Light**
  - Adaptation to light and dark
  - Small changes in light intensity
  - Pupillary dilation and constriction
  - Larger changes in light intensity such as bright light
  - Sensitive rods are overwhelmed
  - Rods begin to be "bleached"

• **Color Adaptation**
  - Stare at next slide
  - Continue staring at same place on screen with the following slide

• **Neural Processing in the Retina**
  - Photoreceptors communicate to bipolar cells, and bipolar cells communicate to ganglion cells
  - Convergence
    - More than one photoreceptor to bipolar neuron
    - More than one bipolar cell to ganglion cell
  - Rods converge more
    - Lower visual acuity
    - Greater sensitivity
  - In fovea
    - One cone communicates with one bipolar cell
    - Greater acuity and sensitivity

• **Bipolar Cell Receptive Fields**
  - Glutamate
    - Stimulatory at ionotropic receptors
    - Inhibitory at metabotropic receptors
  - Direct photoreceptor → bipolar causes response in center receptive field
    - Glutamate released in dark (decreased in light)
    - OFF-bipolar cells excited by glutamate are inhibited by light
• ON bipolar cells inhibited by glutamate are excited by light
  o OFF bipolar cell
    ▪ Excited by light in surround receptive field
    ▪ Due to interaction between photoreceptors, bipolar cells and horizontal cells
  o ON bipolar cell
    ▪ Inhibited by light in surround receptive field
    ▪ More correct terminology: ON-center, OFF-surround and Off-center, ON-surround

• Photoreceptor cells receive light or dark signals and release neurotransmitters (more in the dark) to synapse with bipolar cells
  o Bipolar cells
    ▪ Transmit graded potentials (excitatory or inhibitory)
    ▪ Synapse with ganglion cells
    ▪ Some excitatory or others inhibitory
  o Ganglion cells are first cells in pathway to generate action potentials
    ▪ Axons of ganglion cells = cranial nerve II
    ▪ Convergence of excitation and inhibition gives complex receptive fields

• Receptive Fields of Ganglion Cells
  o Either increase or decrease the frequency of action potentials
  o Bipolar cells transmit graded potentials, not action potentials
  o Receptive field properties of bipolar cells are continuous to ganglion cells
    ▪ ON-center, OFF-surround
    ▪ Off-center, ON-surround
  o Lateral inhibition by amacrine cells
  o Transmit action potentials
  o Disinhibition causes excitation

• Neural Pathways for Vision
  o Right visual field to left cortex; vice versa

• Parallel Processing in the Visual System
  o Parallel pathways transfer different types of visual information by different neurons
    ▪ Color
    ▪ Shape
    ▪ Movement

• How to maintain good eye health
  http://www.webmd.com/eye-health/good-eyesight

• Additional Eye Information:
  o http://www.eyecareamerica.org/