Online Physiology 2130 – Sensory Systems

Introduction

Dear Student,
Thank you for opening this resource for Physiology 2130, and welcome. This resource has been created by the Education Team at WebStraw. The Education Team consists of students that have previously taken and/or students that are currently taking Physiology 2130.

Purpose

This resource focuses on key concepts that are important for students to understand to succeed within this course. This resource was created by students for other students. Our goal is to help students (1) further develop their understanding of course content and (2) achieve greater academic success. (3) Our resource is also open access meaning there are no financial or legal barriers to students who wish to access and use our resource.

Instructions

These study resources consists of several parts. The first part includes a condensed review of the major takeaways from each physiology module. This is followed by a series of questions and fill in the blank worksheets that should be completed after you have gone through the module and course material, in order to verify your understanding.

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We wish you the best of luck on your exams!
The WebStraw Team

Note to Instructors: If this resource has been created for your course and you would like to collaborate with us, please email us at team@webstraw.ca

Module 7 – Sensory Systems

Stimuli

1. **Mechanical**: stretch sensory receptors which open ion channels to cause depolarization and AP
2. **Chemical**: binds with receptor, causing depolarization and AP
3. **Electromagnetic**: absorbed by photoreceptors of the eye and produce AP

Somatosensory System – detects/processes sensations of touch vibration, temperature and pain

Cutaneous Receptors

- **Hair follicle receptors:** sensitive to fine touch and vibration
- **Free nerve endings:** respond to pain and temperature
- **Meissner's corpuscles**: detect low-freq. vibrations
- **Ruffini's corpuscles:** detect touch
- **Pacinian corpuscles:** detect high-freq. vibrations

Spinothalamic (anterolateral) tract

Transmits <u>very basic</u> sensations – pain/temp/crude touch

- Information from sensory neuron (first order nerve) enters the spinal cord where it synapses with second order neuron
- Second order neuron *crosses to the opposite/contralateral side of the spinal cord*
- Ascends to the thalamus in the brain (**thalamus**: relay station)
- Second synapse with a third order neuron occurs in the thalamus and travels to somatosensory cortex

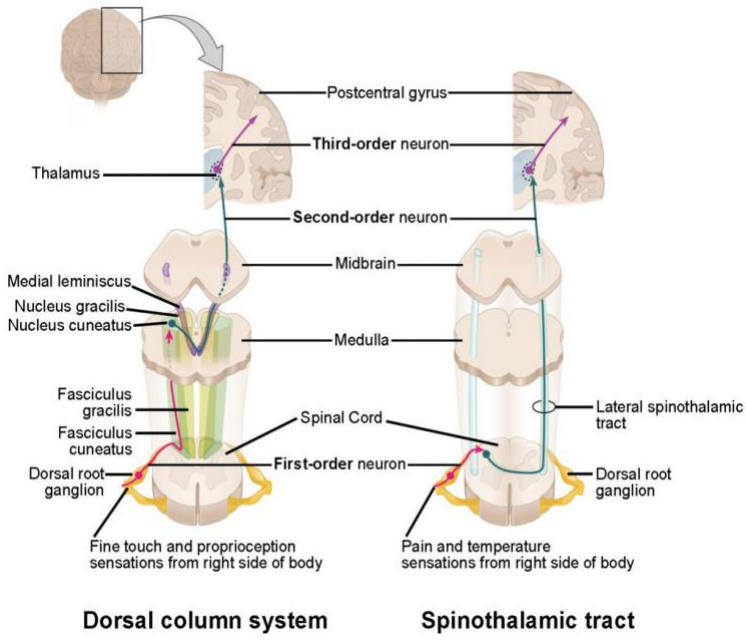
Dorsal column, medial lemniscal system

Transmits <u>more advanced</u> sensations – detailed touch/proprioception/vibration

- Information from sensory neuron (first order nerve) enters the spinal cord
- In the upper spinal cord, the sensory neuron synapses with second order neuron which **then** crosses to opposite side of the spinal cord
- The second order neuron continues to the thalamus where it synapses again onto a third order neuron
    - That neuron then travels to somatosensory cortex

Receptor/Generator Potential

- Local depolarization of the sensory neuron as a result of stimulation by an environmental stimulus
- Depolarization must spread to an area on the neuron that has voltage-gated ion channels needed to fire AP
    - Usually, the first node of Ranvier
    - AP will then be generated and propagated along the axon and into spinal cord
- *Proportional to strength of the stimulus*
- *Local and graded potential*



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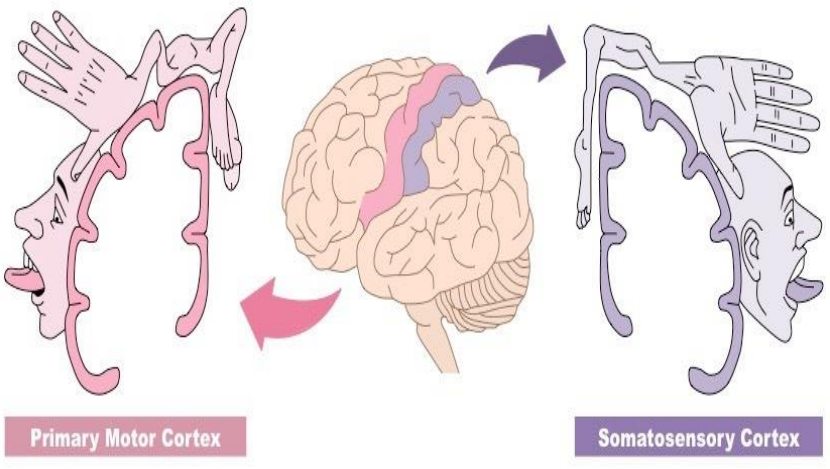
Somatosensory Homunculus: distorted representation of the human body based on map of areas and proportions of the brain dedicated to processing sensory functions



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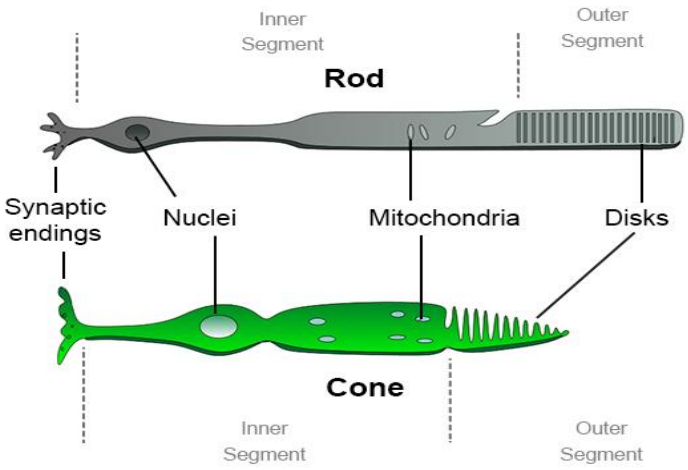
Visual System

Rod Cells

- Extremely sensitive to light → functions best under low light conditions
- Contains only one type of photopigment
- Located mostly in the region of the retina that is outside the fovea (toward the periphery)

Cone Cells

- Functions best under bright light and ideal for detecting detail
- 2 types of cone cells (each with a different photopigment sensitive to a primary colour)
- Found in large concentrations in fovea



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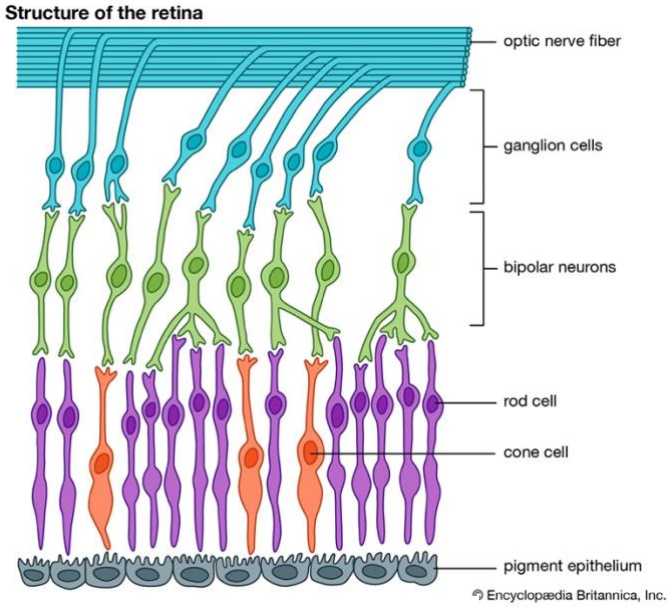
Type of Eye Movements

- **Saccades**: rapid, jerky
  - Rapidly move the eye to object of interest
- **Smooth pursuit**: smooth movement of eyes
  - Keep moving object of interest focuse on fovea
- **Vestibular ocular reflex (VOR)**: eye movement made when you focus on an object while head is moving
- **Vergences**: eye movements that are made when object is approaching or moving away from you
  - Move away: eyes *diverge*
  - Move closer: eyes *converge*

Sound Frequency: number of waves per unit of time
Sound intensity: height or amplitude of the sound wave



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Transduction of Light to AP

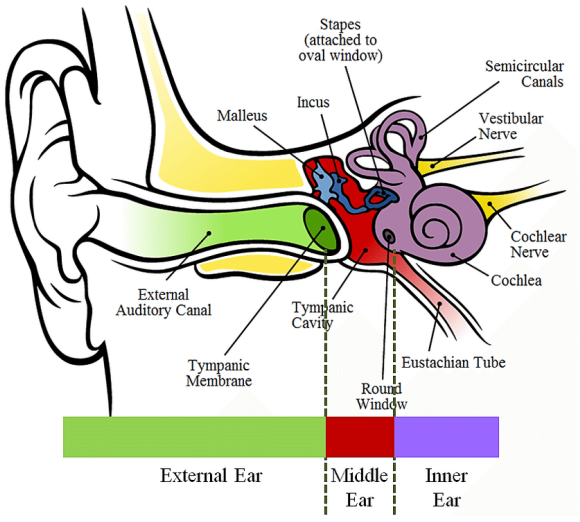
When light is not present:

- Na^+ flows into the photoreceptors, resulting in depolarization of rod and cone cells
- Rod/Cone cells release an inhibitory neurotransmitter to bipolar cells, shutting them off
- Bipolar cells hyperpolarize and no AP is generated in ganglion cells

When light is present:

- Light causes Na^+ channels in the rod and cone cells to close
- Photoreceptors hyperpolarize and shut off
- Release of inhibitory neurotransmitter to bipolar cells stops
- Bipolar cells become activated and depolarize
- AP in ganglion cells in generated

Auditory System



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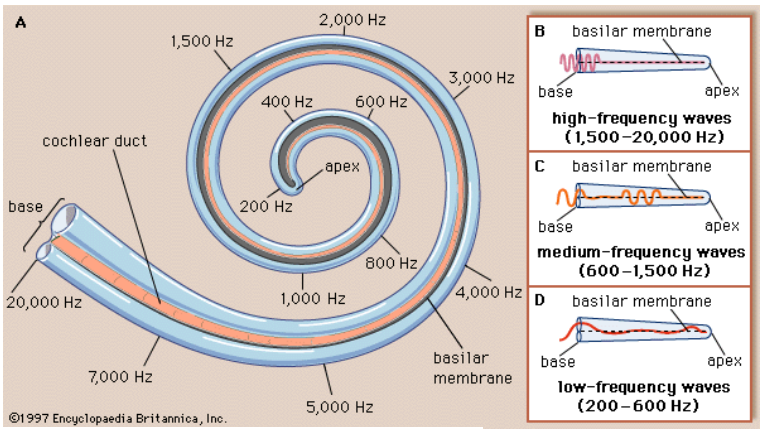
Transfer and Amplification of sound waves

1. Airwaves travel through air and into outer ear
2. Waves funnel into external auditory canal and strike the tympanic membrane
3. Waves cause movement of ear ossicles, which cause the oval window to vibrate
    a. Ossicles amplify vibrations onto oval window by 15-20x their original
4. The oval window causes pressure waves in the fluid inside the cochlea – travels to the hair cells embedded in the basilar membrane
    a. The pressure waves produce a travelling wave that reaches its peak at different regions of the basilar membrane, allowing us to hear different frequencies
5. Hair cells detect the vibrations and turn them into APs in the auditory nerve

Sound

- Basilar membrane vibrates, causing hair cells to bend – ion channels open and hair cells depolarize
- Depolarization causes release of neurotransmitter from the hair cells
    - Excite neurons of auditory nerve to fire APs which travel to auditory cortex in temporal lobe of the brain
- The louder the sound → the stronger the vibration → more bent the hair cells → more neurotransmitter released → higher frequency of APs produced



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Basilar (basement) membrane

- The length and stiffness of the hair cells differ slightly along the length of the basilar membrane, helping to distinguish different frequencies
- **Low frequencies**: stimulate hair cells at the **apex/top** of the cochlea
    - Membrane is widest and thinnest
- **High frequencies**: stimulate hair cells on the membrane near the oval window
    - Membrane is narrowest and thicket

Vestibular System

- Responsible for maintaining balance, equilibrium, and postural reflexes
- Detects linear and rotational motions
- Detects the position of the head relative to the rest of body
- Responsible for vestibular ocular reflex (VOR)

Otolith Organs

- Detect <u>linear</u> accelerations and <u>position</u> of the head when tilted
- **Utricle**: horizontal acceleration
- **Saccule**: vertical acceleration
- Each contains hair cells that are anchored in the vestibular nerve and their cilia are embedded in a gelatinous membrane with ***otolith crystals***

How do these send signals?

- No acceleration = regular series of APs produced in the vestibular nerve
- *Acceleration* = otolith crystals lag behind and move in opposite direction of acceleration
    - Cilia of hair cells bend and increase AP frequency
- *Deceleration* = decreased frequency of AP
    - Hair cells bend in the other direction

Semicircular Canals

- Detect <u>rotational</u> or <u>angular</u> acceleration of the head
- Filled with ***endolymph fluid***
- At the end of each canal is a swelling called the **ampulla**, which has a sensory region inside called **crista ampullaris**
    - This contains *sensory hair cells* which are fixed at their base and their cilia are embedded in the **cupula**

How do these send signals?

- When head rotates, endolymph lags behind and moves in the opposite direction
    - Hits the cupula and bends the hair cells embedded in it
- When hair cells are bent in a particular direction, they will depolarize and fire APs

Questions

1. What helps distinguish different frequencies of sound?
    a. The length of the hair cells along the basilar membrane
    b. The stiffness of the hair cells along the basilar membrane
    c. The thickness of the basilar membrane
    d. A & C only
    e. All of the above

2. Imagine you are standing in a completely dark room, which of the following can you expect to happen in your visual system?
    1) Rod and cone cells will depolarize
    2) Rod cells will release an inhibitory neurotransmitter
    3) Bipolar cells will hyperpolarize and action potentials are not produced
    4) Rod and cone cells will shut down due to the absence of light and no APs will be produced

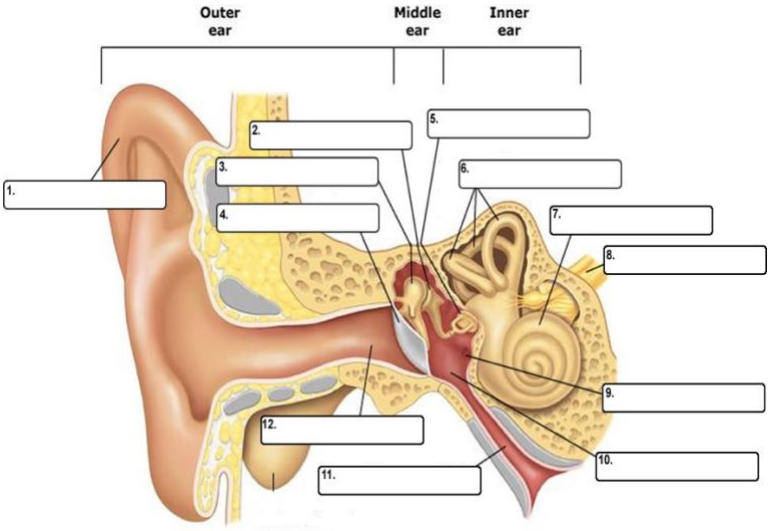
    a. 1, 2, and 3 only
    b. 1 and 3 only
    c. 2 and 4 only
    d. 4 only
    e. All are correct

3. Which of the following does not correspond to its function?
    a. Iris – regulates the amount of light that enters
    b. Retina – contains photoreceptors called rod and cone cells
    c. Fovea – contains the highest concentration of rod cells
    d. Lens – focuses the light onto the retina

4. Which of the following is not true regarding the dorsal column, medial lemniscal system?
    a. It transmits information associated with <u>more advanced sensations</u> like fine detailed touch, proprioception, and vibration
    b. The first order neuron synapses with the second order neuron as soon as it enters the spinal cord
    c. The second order neuron crosses to the opposite side in the upper spinal cord
    d. Second order neuron synapses onto the third order neuron in the thalamus

5. Which of the following is sensitive to head tilt from sideways position and upright position, respectively?
    a. Saccule; utricle
    b. Utricle; saccule
    c. Saccule; semicircular canals
    d. Semicircular canals; ampulla

Answers
1. E 2. A 3. C 4. B 5. A



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Rearrange in order

A. Cilia on the hair cells bend
B. Sound waves strike the oval window
C. Basilar membrane vibrates at specific location depending on the frequency of sound
D. Neurotransmitter is released
E. AP is created in the auditory nerve
F. Ion enters the hair cells causing depolarization
G. Soundwaves travel through the perilymph

Fill in the blanks

1. _____: fluid inside the cochlea
2. _____: fluid inside the semicircular canals
3. The _____ is responsible for detecting horizontal acceleration in the horizontal plane
4. _____ is the smallest cilia on a hair cell, while _____ is the largest
5. When the stereocilia bends towards the kinocilium, the hair cells produce ____ neurotransmitter, causing _____ action potential in the sensory nerve

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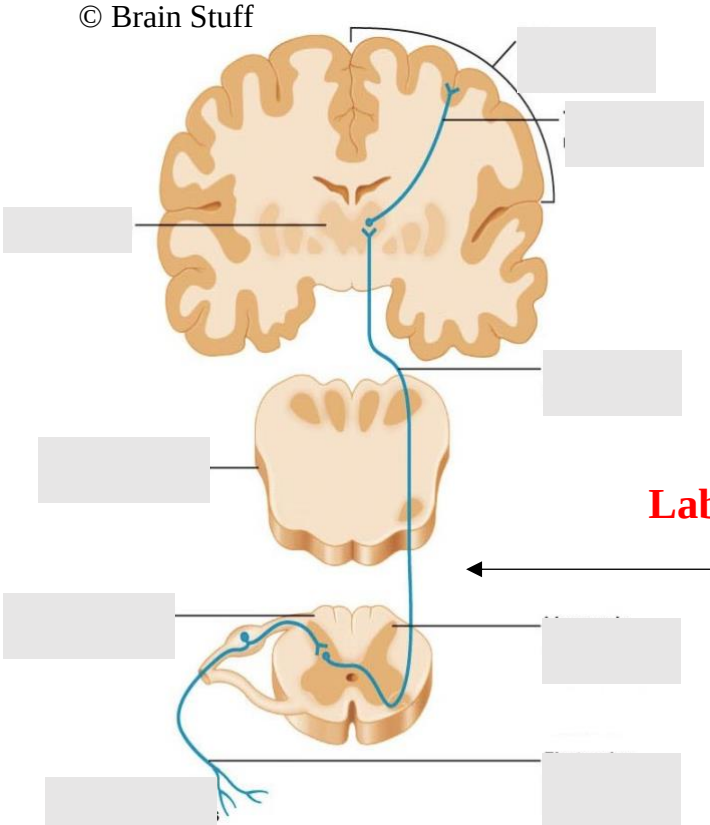
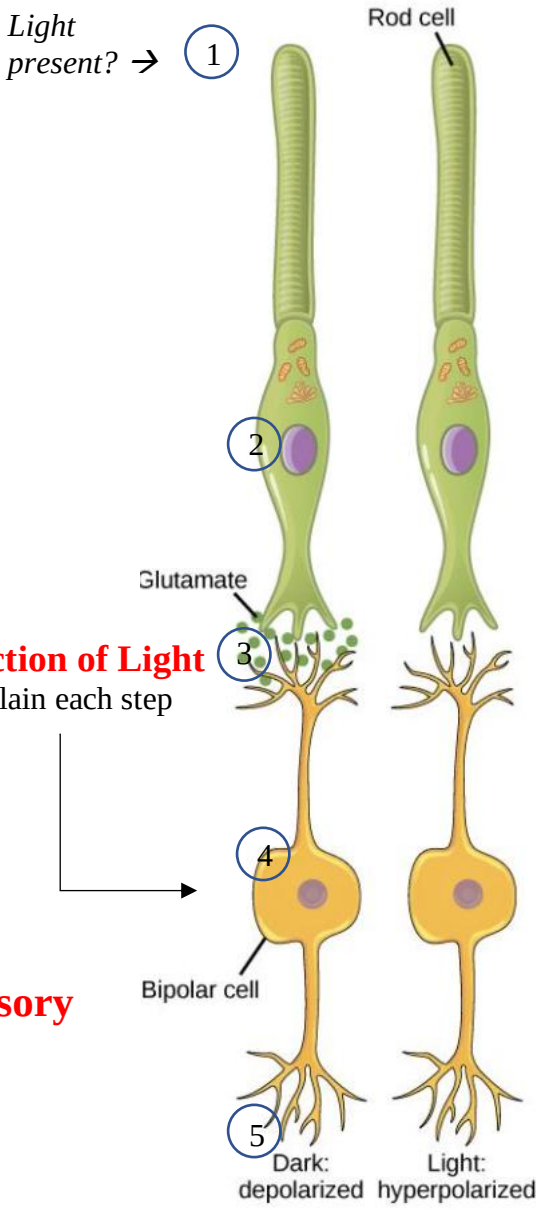


Label the somatosensory tract

Transduction of Light

- Explain each step



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