SENSORY PHYSIOLOGY

Topic #1 - Sensory Receptors

Readings:
Silverthorn (3rd ed.): p. 322 - 330 (2nd ed.): p. 282 - 289

Sensation

Stimulus → sensory receptor → primary sensory neuron → secondary sensory neuron → tertiary sensory neuron → brain

Types of sensory receptors

- Chemoreceptors =
- Mechanoreceptors =
- Photoreceptors =
- Thermoreceptors =
- Nocireceptors =

- **Receptors may be:** ***example***
  - single neuron
  - single neuron with specialized ending
  - specialized receptor cell

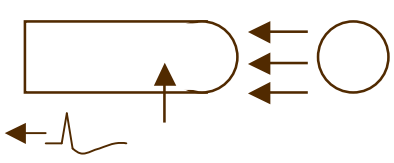
Sensory Transduction

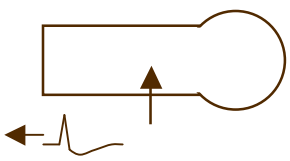
transduction =

- results into depolarization when: →

  hyperpolarization when: →

- creates a **receptor** potential or **generator** potential
  - these are **graded** responses =





Sensory Representations

1. **Stimulus modality** - each receptor type responds to a **specific** type of stimulus

   - may respond to other types of stimuli if intensity is strong enough
     BUT the sensation is that normally detected by the receptor
   - **labeled line coding** =

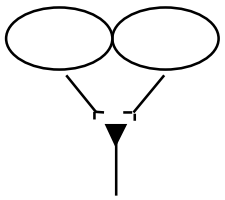
2. **Stimulus Location**

   RECEPTIVE FIELDS =

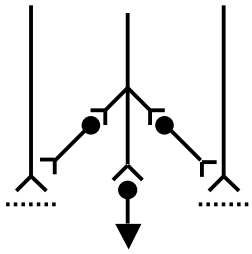
   - **convergence** =

     - effect on acuity: →

     - **2-point discrimination** =

   LATERAL INHIBITION =

   - topographical organization of receptor input to brain
     - phantom limb pain

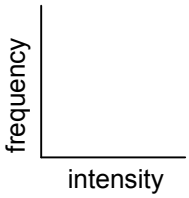
3. **Stimulus Intensity**
   - action potential is all-or-none so intensity coded by :
     1.

     2.

   Frequency of response follows a **POWER LAW**:

   $$R \propto S^p$$

   i.e., permits both sensitivity to weak stimuli AND retains responsiveness to strong stimuli as well

   - **perceptual threshold =**

4. **Stimulus Duration**

- **adaptation =**

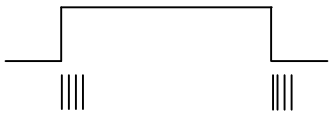
- two types of responses to longer duration stimuli:

1) **TONIC** =

e.g. baroreceptors (sense blood pressure)
proprioceptors (sense limb position)

2) **PHASIC** =

e.g. touch



Topic #2 - Sensory Neural Pathways

Readings:

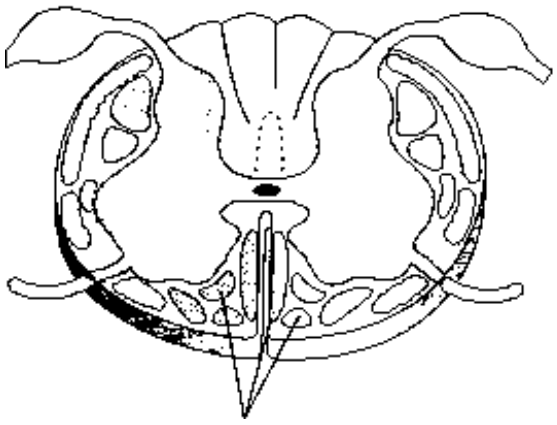
Silverthorn (3rd ed.):	p. 330 - 331	(2nd ed.):	p. 289 - 290
	p. 293 - 294 (spinal cord)		p. 259 - 260
	p. 302 - 304 (cortex)		p. 265 - 266
	p. 312 - 313 (language)		p. 274 - 275

Pathways for Sensory Perception

- inputs to cortex come from: →
  - exception: →

Spinal Cord

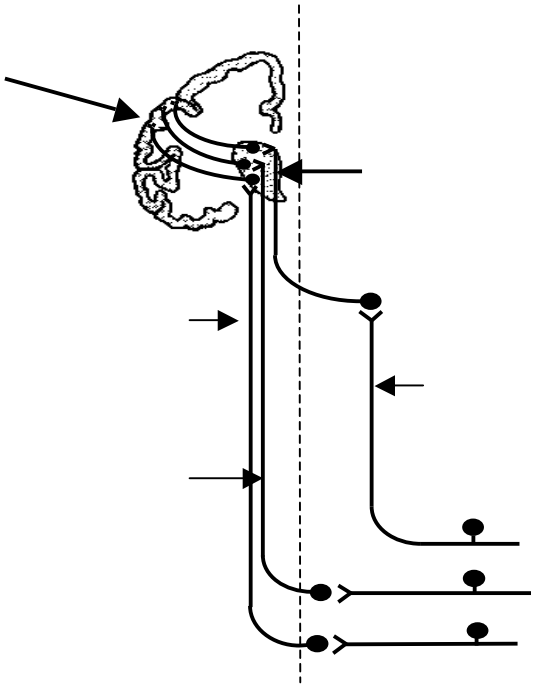
- combination of:
  - **WHITE MATTER:**
    - **consists of** : →
    - ascending tracts (afferent = towards brain) carry sensory **input**
      - e.g. Lateral spinothalamic tract
    - descending tracts (efferent = from brain) carry motor **output**
      - e.g. Ventral corticospinal tract
  - **GRAY MATTER**
    - **consists of** : →
    - cell bodies of afferent neurons entering spine are outside the spine in the **dorsal root ganglia**



Somatic Pathways

(see table 10-3)

- a minimum of 3 neurons from receptor to brain
- sensory pathways cross to other side of body, but cross at different points
- inputs all eventually go to: →



DORSAL COLUMN

- faster, larger, myelinated fibres
- **carries:** →
- **cross over at:** →

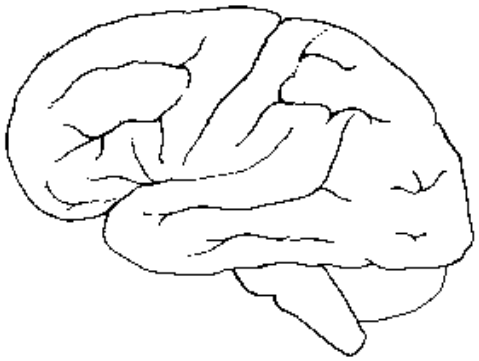
SPINOTHALAMIC TRACT

- SLOWER, smaller neurons
- **carries:** →
- **cross over at:** →

Cerebral Cortex

Lobe: ***Function:***

- **Frontal:**
- **Occipital:**



- **Temporal:**

- **Parietal:**

- **SOMATOSENSORY CORTEX**
  - in Parietal lobe just behind Central Sulcus
  - **somatotopic arrangement** =

  - this map of the body is called a **HOMUNCULUS**

    - some areas of the body are disproportionately represented (e.g. lips, fingers) due to high density of sensory receptors

  - **plasticity =**

Cerebral Function

- ASSOCIATION AREAS

- **hemisphere specialization of higher functions:**
  - LEFT: →
  - RIGHT: →

- LANGUAGE ability is located in several areas:
  - WERNICKE'S area (parietal/ occipital/ temporal junction)
    - **function:** →
  - BROCA'S area (Frontal lobe near motor cortex)
    - **function:** →

  - **APHASIA =**

Topic #3: Hearing and Equilibrium

Readings:

Silverthorn (3rd ed.):	p. 340 - 346	(hearing)	(2nd ed):	p. 298 - 306
	p. 347 - 349	(equilibrium)		p. 306 - 308

Hearing

Sound Principles

- sound is formed by waves of alternating compression and rarefaction of air
- **pitch (tone) =**

- **loudness (intensity) =**

- **decibel scale:** 0 decibels =

- with each 10 decibels, sound gets:→

- prolonged intensities > 100 dB are painful and can be permanently damaging

The Middle Ear

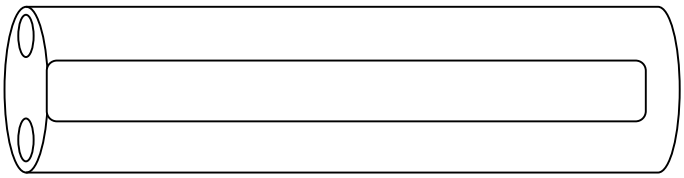
- sound vibrates the **tympanic membrane** (eardrum)
  - function: →

- **Eustachian tube** on inner side helps keep pressure equal on both sides
  - 3 ossicles (bones): (malleus, incus, stapes = hammer, anvil, stirrup)
  - **carry sound to**: →

  - oval window is smaller than eardrum, so sound is amplified about 20 times

The Cochlea

- the **cochlea** consists of 3 fluid filled compartments:



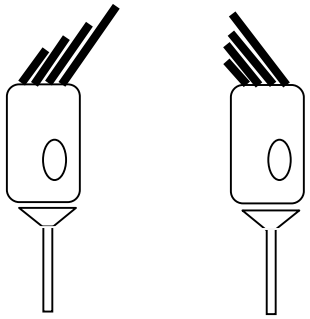
- **perilymph =**
- **endolymph =**

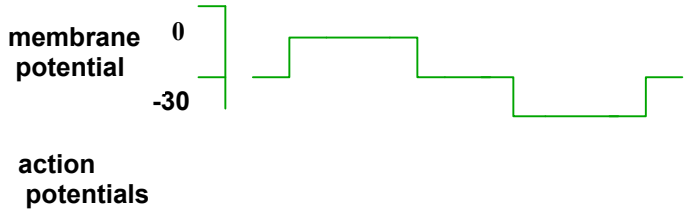
- **Organ of Corti**
  - **stereocilia =**

- hair cells rest on basilar membrane with stereocilia embedded in tectorial membrane

Signal Transduction

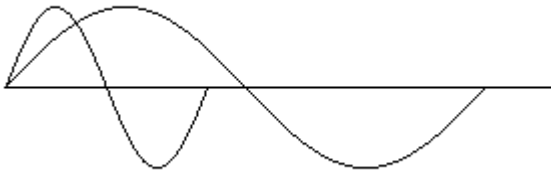
- sound waves cause endolymph and tectorial membrane to move
  - stereocilia bent: →
- K^+ channels react by: →
- neurotransmitter release stimulates action potentials in primary sensory neuron
- sound wave passes & tectorial membrane pulled in opposite direction
- K^+ channels react by: →



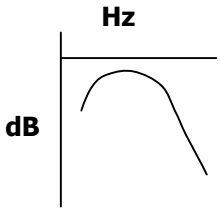


Coding Pitch and Loudness

- each hair cell responds best to a particular sound pitch
- high frequencies detected by:→
- low frequencies detected by:→
- **tonotopical arrangement** =



- sound loudness is coded by: →
- mid-range frequencies are perceived to be louder
- pressure wave exits via round window to prevent an "echo" effect



Auditory Pathway

- auditory nerve take signals to cochlear nucleus before thalamus and auditory cortex in the temporal lobe
- each tone "mapped" to a different area of the cortex
- some fibers cross over in brainstem
  - unlike other senses, each cortical lobe receives input from both ears

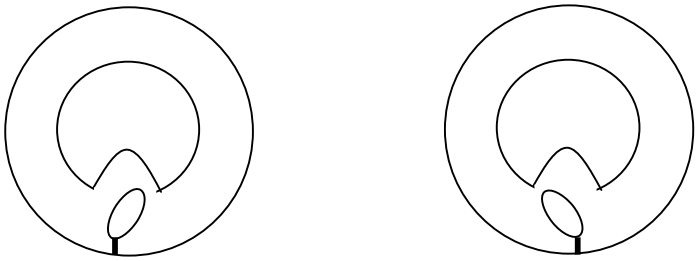
Equilibrium

The Vestibular Apparatus

SEMI-CIRCULAR CANALS: detect rotational movement
- 3 canals oriented in different planes (horizontal about 30° off)
- an **ampulla** is located at the base of each canal - contains hair cells that ***depolarize*** or ***hyperpolarize*** depending on direction of movement of the fluid (endolymph) above it

1. head moves - **delay** before the endolymph starts moving causes: →
2. endolymph catches up - hairs return to original position
3. head stops - endolymph keeps moving, causing: →

- canals do not respond when the head is ***motionless or moves at a constant speed***



OTOLITH ORGANS: detect translational movement
- Utricle and saccule located in sac between semicircular canals and cochlea
- calcium carbonate crystals (otoliths) found in fluid layer above hair cells

- **Utricle** function: →

- **Saccule** function: →

Equilibrium Pathway

- vestibular nerve projects to brainstem and cerebellum
- convergence of vestibular and proprioceptive inputs in vestibular nuclei
- important to stabilize gaze

Topic #4: Vision

Readings:
Silverthorn (3rd ed.) p. 350 - 361 (2nd ed.): p. 309 - 320

Ocular Anatomy

Structure: ***Function:***

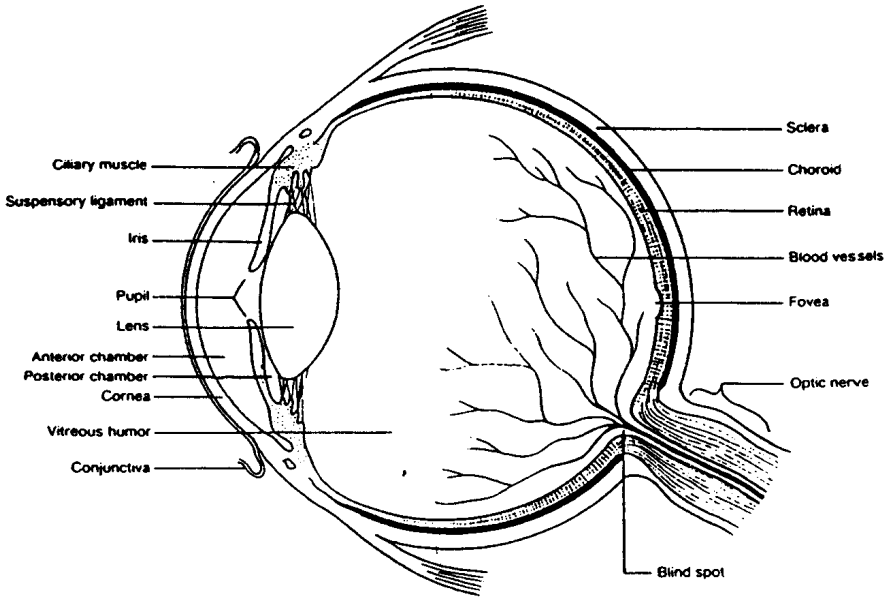
Iris/pupil

Cornea/lens

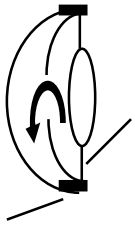
Aqueous humor

Vitreous humor

Retina



Nourishing the Eye

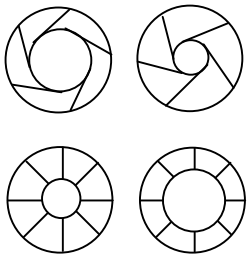


- **cornea and lens** are living tissue whose nutrients are
  - supplied by: →
  - drained by: →

  - **glaucoma** =

- **Retina**
  - receptors nourished by **blood vessels in:** →
  - blood vessels on vitreous humor side nourish ganglion cells
    - used to assess health of small blood vessels

Pupillary Light Reflexes



- Controlled by:
  - **Parasympathetic nerves**
    - type of muscle: →
    - action: →
  - **sympathetic nerves**
    - type of muscle: →
    - action: →
- brainstem injury or drugs will suppress responses

Retinal Image Formation

1. retinal image formation depends on: →
2. angle of light refraction depends on: →
   - most refraction occurs in the: →
   - **emmetropia** =

Lens Mechanism

- as objects move <u>closer</u>, the lens must refract <u>more</u> to focus light on the retina
  - **rounder lens** =

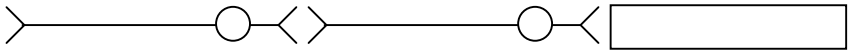
- ciliary muscles change lens shape
  - to focus on near objects: →
  - to focus on far objects: →
  - **accommodation** =
- ciliary muscles change through the action of: →
- closest distance the lens can focus is called: →
  - **presbyopia** =

Retinal Image Problems

- **Hyperopia**
  - defect: →
  - location of focus : →
  - corrected by : →

- **Myopia**
  - defect: →
  - location of focus: →
  - corrected by : →

Retinal Organization



- **Blind Spot =**

Photoreceptors

	RODS	**CONES**
Shape:		
Range of Operation:		
Distribution:		
Connectivity:		
Visual Function:		

Phototransduction

= conversion of light to a neural signal

- **Photopigments:**
  - a combination of: →
  - respond to light by: →

DARK ADAPTATION =

LIGHT ADAPTATION =

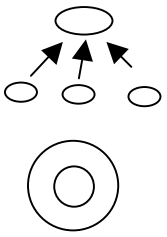
DARK	LIGHT
	• change in photopigment configuration
• high levels of cyclic GMP	• phosphodiesterase activated cGMP breaks down
• Na^+ channels **open**	• Na^+ channels **close**
• receptor cell depolarizes	• receptor cell hyperpolarizes
• inhibitory neurotransmitter **released**	• **less** inhibitory neurotransmitter released

ON and OFF Channels

- BIPOLAR cells can be either EXCITED or INHIBITED by photoreceptors
  - light turns them either OFF or ON (via disfacilitation or disinhibition)
  - ***graded*** potentials only

- GANGLION cells take signal to brain
  - action potentials are produced
  - inputs from bipolar cells produce two types of receptive fields:
    1) **OFF-Center cells:**

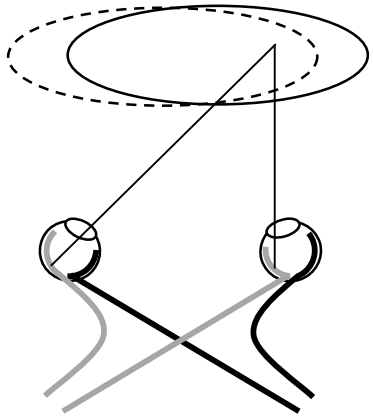
    2) **ON-Center cells:**



- these receptive fields have a <u>center-surround</u> organization thanks to: →
  - this emphasizes **contrast** at the expense of absolute amount of light

Visual Pathways

- signals from RIGHT visual field go to LEFT hemisphere, and vice-versa
  - **binocular visual field** =
  - fibers from inner (nasal) half of each retina **cross over** at the **optic chiasm**



- the optic tracts project primarily to the thalamus, which then projects to the visual cortex in the occipital lobe

Topic #5 - Temperature, Touch & Pain

Readings:
Silverthorn (3rd ed.) p. 332 - 335 (2nd ed.) p. 291 - 294

Primary Sensory Fibers

- Aβ - large, myelinated, fast (30 - 70 m/sec)
- Aδ - small, myelinated, slower (12 - 30 m/sec)
- C - small, unmyelinated (0.5 - 2 m/sec)

Touch-Pressure Receptors

- different types of receptors for different types of touch sensation:
  - free nerve endings -
  - Meissner's corpuscle -
  - Pacinian corpuscle -
  - Ruffini's corpuscle -
  - Merkel receptors –
- some receptor types are superficial; others are deep
- different rates of adaptation

Sensing Temperature

- separate cold (< body temperature) and hot (> body temperature) receptors
- non-adapting if beyond 20° - 40° C
- discharge spontaneously

Sensing Pain

- no special receptor structure: naked nerve endings respond to mechanical, thermal or chemical stimuli
- no receptor adaptation to repetitive stimulus
- **tissue damage releases:** →
- **primary neurotransmitter:** →

PAIN FIBERS:
Aδ - carries →

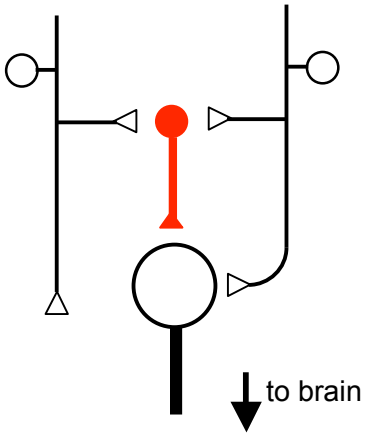
C - carries: →
  - itching produced by →

SPINAL REFLEXES:

- Nociceptive responses such as withdrawal reflexes can be mediated by local circuit within the spinal cord

GATING THEORY OF PAIN MODULATION:

- pain modulation by somatic (non-nociceptive) receptor activation
- tonically active **interneurons** normally inhibit ascending fibers in spinal cord
- painful stimulus C fibers **block** the interneurons
- touch (Type A) fibers also synapse on these interneurons but **increase** the inhibition



REFERRED PAIN:

- pain from internal organs often seems to come from unrelated locations
  e.g., heart to arm; stomach to back
- may be caused by neurons converging on same 2° neuron
  (more nerve fibers in periphery than in lateral spinothalamic tract)
  - **dermatomes** =

ANALGESIA:

- endogenous **analgesic** neurotransmitters**:** →
- released from descending fibers to block release of Substance P by afferent fibers at presynaptic terminals