Midterm 2 study guide MCB

PRACTICE FINALS FROM NATALIAS PAST COURSES:

<http://classes.biology.ucsd.edu/bipn142.WI09/documents/Exam1KEY.pdf>

<http://classes.biology.ucsd.edu/bipn142.WI10/documents/Exam2Key.pdf>

<http://classes.biology.ucsd.edu/bipn142.WI10/documents/Exam3Key>

<http://classes.biology.ucsd.edu/bipn142.WI10/documents/Exam4KEY.pdf>

Do your thang on here everybody. The goal is to try and get this done by Sunday and then meet up next week for a Q and A review session. Check the FB messages for the chapter you’re summarizing. If you want a different chapter or can’t help out let us know ASAP. Thanks MCBesties.

CH. 8 -- Vania

Taste

* Organs of Taste
  + tongue has papillae (ridged, pimples, mushrooms)
    - papillae has many taste buds, which has 50-150 taste receptor cells
    - humans have 2,000-5,000 taste buds
    - Taste Receptor Cells - depolarize when activated
* Mechanisms of taste Transduction
  + “transduction” - process by which external stimulus turns into nerve signals
  + saltiness
    - ions directly come in (Na in salt)
  + sourness
    - caused by acids - H+ ions come in and change membrane potential directly
  + bitterness
    - T1R and T2R genes
    - detect poisons
  + sweetness
    - also T1R and T2R proteins, but instead bound in a pair rather than singular.
  + umami
    - “Amino Acids”
    - identical to sweetness, but T1R1+ T1R3
* Central taste pathways
  + taste buds → primary gustatory axons → brain stem → thalamus → cerebral cortex
  + taste axons go to gustatory nucleus in medulla
  + ventral posterior medial nucleus in thalamus deals with taste
* neural coding of taste
  + labeled line hypothesis - separate signal for each taste
  + population coding - spectrums of responses get averaged together

Smell

* pheromones
  + hormones, can be used as signals. unclear in humans.
* organs
  + olfactory epithelium - small sheet in nasal cavity
  + direct neuron contact with air (through the mucus)
  + also called olfactory bulb
* Central Olfactory Pathways
  + Odorants →
  + Binding to membrane odorant receptor proteins →
  + G-protein (Golf) stimulation →
  + Activation of adenylyl cyclase →
  + Formation of cyclic AMP (cAMP) →
  + Binding of cAMP to specific cation channel →
  + Opening of cation channels and influx of Naϩ and Ca2ϩ →
  + Opening of Ca2ϩ-activated chloride channels →
  + Current flow and membrane depolarization (receptor potential).
* Nerve structure
  + glomeruli - 2,000 spheres on input of olfactory bulbs
* Encoding
  + 350 types of receptors
  + population coding
    - combination of receptors to get unique smell
  + maps
    - orderly arrangement, strands that respond to same smell
  + temporal coding
    - timing of action potentials can indicate intensity or clarity

CH. 9 -- Schuyler

Introduction

* Based on the light bounced into our eyes from objects around us, we somehow make sense of a complex world.
* At the back of the eye is the retina, which contains photoreceptors specialized to convert light energy into neural activity
  + The retina is actually part of the brain
  + Each eye has two overlapping retinas: one specialized for low light levels that we encounter from dusk to dawn, and another specialized for higher light levels and for the detection of color, from sunrise to sunset
  + Specialized to detect differences in the intensity of light falling on different parts on it
* Optic Nerves
  + Some targets of the optic nerves are involved in regulating bio rhythms, while others control eye position and optics
  + The first synaptic relay in the pathway that serves visual perception occurs in a cell group of the dorsal thalamus called the lateral geniculate nucleus, or LGN
    - From the LGN, visual information ascends to the cerebral cortex, where it is interpreted and remembered

Properties of Light

* Light
  + Wavelength
    - Distance between successive peaks or troughs
  + Frequency
    - Number of waves per second
  + Amplitude
    - Difference between wave trough and peak
* Optics
  + Waves of electromagnetic radiation travel in a straight line, thus are called a ray
  + Reflection is the bouncing of light rays off surface
  + Absorption is the transfer of light energy to a particle or surface
  + Some compounds absorb light energy only in a limited range of wavelengths, then reflect the remaining wavelengths
    - Light sensitive photoreceptor cells in the retina contain pigments and use the energy absorbed from light to generate changes in membrane potential
  + Images are formed in the eye by refraction, the bending of light rays that can occur when they travel from one transparent medium to another
    - The bending of light happens because the speed of light differs in two media; light passes through air more rapidly than through water

The Structure of the Eye

Gross Anatomy of the Eye

* The pupil is the opening that allows light to enter the eye and reach the retina
  + Dark b/c of light-absorbing pigments in the retina
* The iris contains the color of the eye and two muscles that make the pupil larger and smaller
* The cornea covers the pupil and iris, and is the glassy transparent external surface of the eye
* The cornea is the continuous with the sclera
  + White of the eye
* Socket in which the eye sits is called the eye's orbit
* Inserted into the sclera lie three pairs of extraocular muscles, which move the eyeball in the orbit
  + They are not visible because they are covered by the conjunctiva, a membrane that folds back from the inside of the eyelids and attaches to the sclera
* The optic nerve carries axons from the retina and exits the back of the eye, through the orbit, and reaches the base of the brain near the pituitary gland

Opthalmoscopic Appearance of the Eye

* When observing the eye through an opthalmoscope, the most obvious feature is the blood vessels on the surface
  + They originate from a circular region called the optic disk
    - Also where optic nerve fibers exit the retina
* Light cannot occur at optic disk because there are no photoreceptors
  + Brain fills in our blind spot
* The macula is in the middle of the retina and is a darker colored region with a yellowish hue
  + Central vision
  + Lacks large blood vessels
* The fovea is a dark spot about 2mm in diameter
  + Means pit in Latin
  + Retina is thinner here than elsewhere
  + It marks the center of the retina

Cross-Sectional Anatomy of the Eye

* The aqueous humor is the fluid nourishes the cornea
* Lens is located behind the iris
  + Suspended by ligaments (zonule fibers) attached to the ciliary muscles
    - Attached to the sclera and form a ring inside the eye
* Lens divides the interior of the eye into two compartments containing slightly different fluids
  + The aqeuous humor is the watery fluid that lies between the cornea and the lens
    - The more viscous, jelly-like vitreous humor lies between the lens and the retina; its pressure serves to keep the eyeball spherical

Image Formation By the Eye

Refraction by the Cornea

* The light ray that strikes the curved surface of the cornea bend so that they converge on the back of the eye; those that enter the center of the eye pass straight to the retina
* The distance from the refractive surface to the point where parallel light rays converge is called the focal distance
* The reciprocal of the focal distance in meters is a unit of measurement called the diopter
  + The fact that many prescription eyeglasses have a power of only a few diopters is a testament to the large amount of refraction produced

Accommodation by the Lens

* Although the cornea performs most of the eye's refraction, the lens also contributes another dozen or so diopters to the formation of a sharp image at a distant point
  + More importantly involved in images of objects closer than 9m from the eye
  + When greater refractive power is needed (closer objects)
    - Provided by changing the shape of the lens, or accommodation
    - The ciliary muscle that forms a ring around the lens contracts and swells in size, making the area inside smaller and decreasing the tension in the suspensory ligaments
      * Becomes rounder and thicker
        + Rounding increases the curvature of the lens surfaces, thereby increasing their refractive power

* The ability to accommodate changes with age

The Pupillary Light Reflex

* The pupil adjusts for ambient light levels
* The pupillary light reflex involves connections between the retina and neurons in the brain stem that control the muscles that constrict the pupils
  + Consensual reflex: shining a light into only one eye causes the constriction of pupils of both eyes
    - Lack of symmetry of pupil size usually indicates a serious neurological disorder involving the brain
* Decreasing the aperture--constricting the pupil--reduces the size of this blurred circle so that its image more closely approximates a point

The Visual Field

* The ability of the eye to distinguish two nearby points is called visual acuity
  + Depends strongly on spacing of photoreceptors in the retina and the precision of eye's refraction
* Distance across the retina can be described in terms of degrees of visual angle
* The Snellen eye chart tests our ability to discriminate letters and numbers at a viewing distance of 20 feet
  + Vision is 20/20 when you can recognize a letter that subtends an angle of .083 degrees

Microscopic Anatomy of the Retina

* The most direct pathway for visual information to exit the eye is from:
  1. Photoreceptors
  2. Bipolar Cells
  3. Ganglion Cells
     + Fire action potentials in response to light
       - Impulses propagate down the optic nerve to the rest of the brain
* Horizontal cells receive input from the photoreceptors and project neurites laterally to influence surrounding bipolar cells and photoreceptors
* Amacrine cells receive input from bipolar cells and project laterally to influence surrounding ganglion cells, bipolar cells, and other amacrine cells
* Important points
  1. Photoreceptors are the only light-sensitive cells in the retina
  2. The ganglion cells are the only source of output from the retina

Laminar Organization of the Retina

* Cells are organized in layers
* Light must pass from the vitreous humor through the ganglion cells and bipolar cells before it reaches the photoreceptors
* Pigmented epithelium (lies below the photoreceptors) plays a critical role in the maintenance of the photoreceptors and photopigments
  + Absorbs any light that passes entirely through the retina, thus minimizing the reflection of light within the eye that would blur the image
* Cell layers of the retina are named in reference to the middle of the eyeball
  + Innermost is ganglion cell layer
  + Next is inner nuclear layer
    - Cell bodies of the bipolar cells, horizontal, and amacrine
  + Next is outer nuclear layer, which contains the cells bodies of photoreceptors
  + Layer of photoreceptor outer segments contains light-sensitive elements of the retina
    - Embedded in the pigmented epithelium
  + Between the ganglion cell and the inner nuclear layer is the inner plexiform layer, which contains the synaptic contacts between bipolar cells, amacrine cells, and ganglion cells
  + Between the outer and inner nuclear layers is the outer plexiform layer
    - Where photoreceptors make synaptic contact with the bipolar and horizontal cells

Photoreceptor Structure

* Every photoreceptor has four regions
  + Outer
  + Inner
  + Cell Body
  + Synaptic Terminal
* Photopigments in disk membranes absorb light, which triggers changes in the photoreceptor membrane potential
* Rods have long, cylindrical outer segments with many membranous disks
  + Rods contribute to vision in scotopic (nighttime) conditions
  + Have the same photopigment
* Cones have shorter, tapering outer segments with fewer membranous disks
  + Cones contribute to vision in photopic (daytime) conditions
  + Three types of cone that have different pigments
* The greater number of disks and higher photopigments concentration in rods makes them over 1000 times more sensitive to light than cones

Regional Differences in Retinal Structure

* Peripheral retina is more sensitive to light
  + Rods are specialized for low light
  + There are more photoreceptors feeding information to each ganglion cell
* The region of retina most highly specialized for high-resolution vision is the fovea
  + Structural specialization (pit-nature) maximizes visual acuity at the fovea by pushing aside other cells that might scatter light and blur the image

Phototransduction

* Rods outnumber cones 20 to 1

Phototransduction in Rods

* Light stimulation of the photopigment activates G-proteins, which in turn activate an effector enzyme that changes the cytoplasmic concentration of a second messenger molecule
  + Causes a membrane ion channel to close, and the membrane potential is thereby altered
* Rod membrane potential is -30mV
  + Depolarization is caused by a steady influx of Na+ through special channels in the outer segment membrane
* Dark current is the movement of positive charge across the membrane which occurs in the dark
* Sodium channels are stimulated to open--are gated--by an intracellular second messenger called cGMP
  + Continually produced in the photoreceptor by guanylyl cyclase
  + **Light reduces cGMP, causing the Na+ channels to close, and the membrane potential becomes more negative**
    - Photoreceptors hyperpolarize in response to light
  + Hyperpolarizing response to light is initiated by the absorption of electromagnetic radiation by the photopigment in the membrane of the stacked disks in the rod outer segments
    - Pigment is rhodopsin
      * Receptor protein is called opsin
        + Prebound agonist is called retinal

Derivative of vitamin A

* + - * Process of absorbing light that creates a conformational change is called bleaching
        + Photopigment changes color from purple to yellow
        + Bleaching stimulates transducin (G-protein) in the disk membrane

Activates effector enzyme phosphodiesterase (PDE)

Breaks down the cGMP normally present in the cytoplasm of the rod (in the dark)

Na+ channels close and membrane hyperpolarizes

* Due to the use of G-proteins, the signal is amplified
  + Gives visual system the ability to detect as little as a single photon

Phototransduction in Cones

* Bright sunlight causes cGMP levels in rods to fall to the point where the response to light is saturated
  + Additional light causes no more hyperpolarization
* Vision during the day depends on the cones
  + Require more energy to become bleached
* The cones in our retinas contain one of three opsins that give photopigment different spectral sensitivities
* Become maximally activated at wavelengths:
  + Blue cones- 430 nm
  + Green cones- 530 nm
  + Red- 560 nm

Color Detection

* Color we perceive is determined by relative contributions of blue, green, and red cones to the retinal signal
* Young-Helmholtz trichromacy theory states that the brain assigns color bed on a comparison of the readout of the three cone types
  + When all types of cones are equally active, we perceive white

Dark and Light Adaptation

* During dark adaptation, sensitivity to light increases a millionfold or more
  + One component is pupil dilation
    - Ranges only from 2-8mm
  + Larger component is the regeneration of unbleached rhodopsin and an adjustment of the functional circuitry of the retina
    - Information from more rods is available to each ganglion cell
  + Because of tremendous increase in sensitivity, the eye becomes temporarily saturated when it goes into bright light
  + Over next 5-10 minutes, it undergoes light adaptation, which reverses the changes made

Calcium's Role in Light Adaptation

* cGMP-gated Na+ channels also admit calcium
* In the dark, Ca++ enters the cones and has an inhibitory effect on guanylyl cyclase (synthesizes cGMP)
* When cGMP channels close, the flow of Ca++ into the photoreceptor is curtailed
  + More cGMP is synthesized, allowing cGMP-gated channels to open again
* When the channels close, a process is initiated that gradually reopens them even if the light level does not change
* Ca++ also affects photopigments and phosphodiesterase to decrease their response to light

Retinal Processing

* John Dowling and Frank Werblin were able to show how ganglion cell responses are built from the interactions of horizontal and bipolar cells
* Most direct path
  + Cone photoreceptor
    - Bipolar Cell
      * Ganglion Cell
* At each synaptic relay, the responses are modified by the lateral connections of horizontal cells and amacrine cells

Transformations in the Outer Plexiform Layer

* Photoreceptors release glutamate when depolarized
  + **D**epolarized in **d**ark
  + Hyperpolarized by light
    - Dark rather than light is the preferred stimulus for a photoreceptor
      * When a shadow passes across a photoreceptor, it responds by depolarizing and releasing neurotransmitter
* In the Outer Plexiform layer, each photoreceptor is in contact with
  + Bipolar cells
    - Direct pathway from photoreceptors to ganglion cells
  + Horizontal cells
    - Feed information laterally in the outer plexiform layer to influence the activity of neighboring bipolar cells and photoreceptors

Bipolar Cell Receptive Fields

* Categorized into
  + OFF bipolar cells
    - Glutamate-gated cation channels mediate a depolarizing EPSP from the Na+
  + ON bipolar cells
    - G-protein coupled receptors and respond to glutamate by hyperpolarizing
  + Names refer to whether cells depolarize in response to light off (more glutamate) or on (less glutamate)
  + The receptive field of a bipolar cell is the area of the retina that, when stimulated with light, changes the cell's membrane potential
    - Two parts
      * Circular area of retina providing direct photoreceptor input
        + Receptive field center
      * Surrounding area of retina providing input via horizontal cells
        + Receptive field surround
  + Measured in millimeters across the retina or in degrees of visual angle
    - One mm ~ 3.5 degrees
      * Bipolar cell receptive field diameters range from a fraction of a degree in the central retina to several degrees in the peripheral retina
* Response of bipolar cell's membrane potential in center is opposite to light in the surround
  + Center is depolarization of the bipolar cell (ON response), then illumination of the surround will be a hyperpolarization
    - Cells are said to have antagonistic center-surround receptive fields
      * Comes from a complex interaction of horizontal cells, photoreceptors, and bipolar cells
* The lateral connections of the amacrine cells in the inner plexiform layer also contribute to the elaboration of ganglion cell receptive fields and integration of rod and cone input to ganglion cells

Retinal Output

* Ganglion Cell Receptive Fields
  + In both ON and OFF cells, the response to stimulation of the center is canceled by the response to stimulation of the surround
  + Appears that the ganglion cells are mainly responsive to differences in illumination that occur within their receptive fields
  + Read pg 302-303, difficult to summarize
  + **The center-surround organization of the receptive fields leads to a neural response that emphasizes the contrast at light-dark edges**

Types of Ganglion Cells

* Most ganglion cells in the mammalian retina have a center-surround receptive field with either an ON or an OFF center
  + M-type ganglion cells (large)
    - 5% of ganglion cell population
    - Larger receptive fields
    - Conduct action potentials more rapidly in optic nerve
    - More sensitive to low-contrast stimuli
    - Respond with transient burst of action potentials
  + P-type ganglion cells (small)
    - 90% of ganglion cell population
    - Sustained discharge of action potentials (as long as stimulus is on)
  + nonM-nonP ganglion cells
    - 5% of ganglion cell population

Color-Opponent Ganglion Cells

* Some P and nonM-nonP cells are sensitive to differences in the wavelength of light
* Color-opponent cells reflect the fact that the response to one wavelength in the receptive field center is canceled by showing another wavelength in the receptive field surround.
  + Red vs. Green
  + Blue vs. Yellow

Ch. 9 -- Carol

Sorry guys! I typed it up in Word and then when I pasted it here, the formatting got all messed up and weird so I just uploaded it to another google doc. Sorry for the hassle

<https://drive.google.com/file/d/0B_WYTfBR76alaDhfUzhqN0QtTUE/edit?usp=sharing>

Ch. 10 -- Annie

**The Retinofugal Projection**

* *retinofugal projection*- neuronal pathway that leaves the eye
* ganglion cells pass through 3 structures before they form synapses in the brain stem:

1. *optical nerves*- exit both eyes at the optic disks, travel through fatty tissue behind the eyes, then pass through holes in the floor of the skull
2. *optic chiasm*- where optic nerves from both eyes combine, lying at the base of the brain

* here the axons originating in the nasal retinas cross from one side to the other, creating partial decussation
  + *decussation*- the crossing of a fiber bundle from one side of the brain to the other

1. *optic tracts-* axons of the retinofugal projections run under the pia along the lateral surface of the diencephalon

* most of these axons innervate the *lateral geniculate nucleus (LGN)* of the dorsal thalamus
  + these neurons give rise to axons that project to the primary visual cortex, creating *optic radiation*
    - any lesions in the retinofugal projection from eye to LGN to visual cortex cause blindness in humans
* some of these axons form synaptic connections with cells in the hypothalamus
  + these play an important role in synchronizing a variety of biological rhythms with the daily light-dark cycle
* some of these axons innervate the pretectum (located in the midbrain)
  + these control the size of the pupil and certain eye movements
* about 10% of these axons innervate the superior colliculus (located in the midbrain)
  + these control the head and eye movements that bring the image onto the fovea
* *binocular visual field*- center portion of right and left visual hemifields that is viewed by both retinas
  + objects in the binocular region of the left visual hemifield will be imaged on the nasal retina of the left eye and the temporal retina of the right eye
    - all of the information about the left visual hemifield is directed to the right side of the brain
  + without binocular neurons, humans probably would not be able to use the inputs from both eyes to form a single image
* transection of…
  + left optic nerve= blindness in left eye only
  + left optic tract= blindness in right visual field as viewed through either eye
  + optic chiasm= blindness in peripheries on both sides

**The LGN**

* the LGN has 6 distinct layers
  + in the right LGN, the right eye (ipsilateral) axons synapse on cells in layers 2, 3, and 5 while the left eye (contralateral) axons synapse on cells in layers 1, 4, and 6
  + layers 1 and 2 contain larger neurons
    - therefore called magnocellular LGN layers
  + layers 3 through 6 contain smaller cells
    - therefore called parvocellular LGN layers
  + within all layers the neurons are activated only by one eye and ON-center and OFF-center cells are intermixed
* visual receptive fields of LGN neurons are almost identical to those of the ganglion cells that feed them
  + magnocellular LGN neurons are just like M-type ganglion cells
    - have relatively large center-surround receptive fields
    - respond to stimulation of their receptive field centers with a transient burst of action potential
    - are insensitive to differences in wavelength
  + parvocellular LGN neurons are just like P-type ganglion cells
    - have relatively small center-surround receptive fields
    - respond to stimulation of their receptive field centers with a sustained increase in the frequency of action potentials
    - many exhibit color opponency
* the retina is not the main source of synaptic input to the LGN
  + receives 80% of excitatory synapses come from the primary visual cortex
  + receives inputs from neurons in the brain stem whose activity is related to alertness and attentiveness

**The Striate Cortex**

* striate cortex (AKA primary visual cortex, V1) is located in the occipital lobe
* the striate cortex has 9 layers of neurons
  + layer I, just under the pia mater, is largely devoid of neurons and consists almost entirely of axons and dendrites of cells in other layers
  + layer IV has subsets A, B, C alpha, and C beta in order to account for all 9 layers while still following Brodmann’s convention that neocortex has 6 layers
  + within all of these layers there are pyramidal cells, stellate cells and inhibitory neurons
    - pyramidal cells send axons out of the striate cortex to form connections with other parts of the brain
    - stellate cells and inhibitory neurons make local connections within the striate cortex
* the majority of axons from the LGN terminate in layer IVC of the striate cortex where information from the left and right eye remain segregated
  + magnocellular LGN neurons project to IVC alpha
  + parvocellular LGN neurons project to IVC beta
* most neurons in layers II and III of the striate cortex receive binocular input coming from both eyes but there continues to be considerable segregation of magnocellular and parvocellular LGN neurons

**Retinotopy**

* *retinotopy*- organization whereby neighboring cells in the retina feed information to neighboring places in their target structures
  + in this way the 2-dimensional surface of the retina is mapped onto the 2-dimensional surface of subsequent structures
  + 3 important points to remember about retinotopy:

1. mapping of the visual field onto a retinotopically organized structure is often distorted because visual space is not sampled uniformly by the cells in the retina
   * thus, the representation of the visual field is distorted in the striate cortex with the central few degrees of the visual field magnified in the retinotopic map
2. a discrete point of light can activate many cells in the retina and often many more in the target structure due to the overlap of receptive fields
   * thus, when the retina is stimulated by a point of light, the activity in the striate cortex is a broad distribution with a peak at the corresponding retinotopic location
3. perception is based on the brain’s interpretation of distributed patterns of activity, not liter snapshots of the world

**Cortical Module**

* *cortical module*- 2 x 2 mm chunk of the striate cortex believed to be necessary and sufficient to analyze the image of a point in space
  + CONTAINS:
    - 2 complete sets of ocular dominance columns
      * *ocular dominance columns* were discovered by David Hubel and Torsten Wiesel when they injected a radioactive amino acid into one eye of a monkey
        + only those cells that were postsynaptic to the inputs from the injected eye incorporated the protein

this revealed that the left and right eye inputs into layer IV are laid out as a series of alternating bands

* + - 16 blobs
      * *blobs*- pillars of cytochrome oxidase-rich neurons in layers II, III, V, and VI of the striate cortex that are each centered on an ocular dominance stripe located in layer IV
        + appear to be specialized for the analysis of object color
    - all possible orientations
      * *orientation selectivity*- the tendency of some neurons to respond to a bar with a particular orientation
        + thought to be specialized for the analysis of object shape

*direction selectivity*- subset of cells that are orientation selective

occurs when receptive fields respond to a bar of light at the optimal orientation moving perpendicular to the orientation in one direction but not in the opposite direction

thought to be specialized for the analysis of object motion

* + - * *orientation column*- neurons in layers II through VI that have the same preferred orientation
        + contrastingly, neurons in a single layer have preferred orientations that progressively shift

**Simple and Complex Cells**

* *simple cells*- ON and OFF regions are strictly segregated
* *complex cells*- ON and OFF regions overlap
* simple and complex cells:
  + usually binocular
  + typically sensitive to stimulus orientation
  + many are direction sensitive
  + are relatively insensitive to the wavelength of light, though color sensitivity is sometimes observed

**Pathways**

* Magnocellular Pathway- thought to be involved in the analysis of object motion and the guidance of motor actions
  + PROCESS:

1. M-type ganglion cells
2. axons to magnocellular layers of LGN
3. layer IV C alpha of striate cortex
4. Layer IV B

* Parvo-Interblob Pathway- thought to be involved in the analysis of fine object shape
  + PROCESS:

1. P-type ganglion cells
2. axons to parvocellular layers of LGN
3. layer IV C beta of striate cortex
4. layer II and III interblob regions

* Blob Pathway- thought to be involved in the analysis of object color
  + PROCESS:

1. non M-non P cells
2. koniocellular layers of LGN
3. blobs in layers II and III

* signals from this pathways interact

**Dorsal and Ventral Streams**

* *dorsal stream* appears to serve the analysis of visual motion and the visual control of action
  + *Area MT*- likely where specialized processing of object motion takes place
    - its neurons have large receptive fields that respond to stimulus movement in a narrow range of directions
    - is most notable for the fact that almost all the cells are direction-selective
* *ventral stream* is thought to be involved in the perception of the visual world and the recognition of objects
  + *Area V4*- appears to be important for shape and color perception
    - its neurons have larger receptive fields than those cells in the striate cortex
    - many of the cells are orientation and color selective
  + *Area IT*- appears to be important for visual perception and visual memory
    - only a small percentage of neurons responds strongly to pictures of faces

**Visually Related Syndromes**

* *achromatopsia*- a rare clinical syndrome in humans characterized by partial or complete loss of color vision despite the presence of normal functional cones in the retina
  + a person with this syndrome sees the world in shades of grey
* *prosopagnosia*- syndrome characterized by difficulty recognizing faces even though vision is otherwise normal
  + a person with this syndrome can describe faces but does not understand the importance of facial recognition
    - usually results from stroke and is associated with damage to the extrastriate visual cortex
* *Capgras Delusion*- syndrome characterized by an inability to make an emotional connection with an individual face
  + a person with this syndrome can recognize the loved one but cannot comprehend that it is truly the loved one’s face
    - “my boyfriend has been taken over by aliens”

Ch. 11 -- Pier

1. THE NATURE OF SOUND

- sounds are audible variations in air pressure, creating compressed and rarified patches of air

-**frequency** is the number of rarified or compressed patches that pass by our ears each second (expressed in hertz Hz). High frequency = high pitch. Low frequency = low pitch.

-our auditory system responds to range from 20 Hz to 20,000 Hz

-**intensity**is loudness (difference in pressure between the compressed and rarified patches)

-bonus: the loudest sound that doesn’t damage our ears is 1 trillion times as loud as the faintest sound we can hear.

2. THE STRUCTURE OF THE AUDITORY SYSTEM

a. **Pinna** – the outside, visible part of the ear (cartilage/lobe/skin part)

-helps us collect sounds from ahead

b. **Auditory canal** – entrance into the internal ear.

-about 1 inch long

-ends at the tympanic membrane [parts a,b = OUTER ear]

c. **Tympanic membrane** – our eardrum

d. **Ossicles** – connected to the inner part of the tympanic membrane

-transfer air movement from eardrum to the **oval window** [parts c, d = MIDDLE ear]

e. **Cochlea­** – Fluid filled spiral that transforms motion of oval window into a neuronal auditory response [cochlea = INNER ear]

3.THE MIDDLE EAR

-composed of tympanic membrane, ossicles, and two tiny muscles that attach to the ossicles

-ossicles: from eardrum moving inward = malleus, incus, stapes

-ossicles are a mechanism to amplify soundwaves before hitting the oval window (window on the cochlea) because the cochlea is fluid filled, not air filled, so the waves need more strength to be registered.

-sound is also amplified onto the oval window because it has a smaller surface area than the tympanic

-**Eustachian tube:** air in the middle ear is continuous with the air in the nasal cavities via this tube, but it is usually closed – that’s why we feel pressure in airplanes. To “pop” our ears, we open the Eustachian tube, eg by yawning

-**Attenuation reflex** – two small muscles attached to the ossicles that contract at the onset of a loud sound. This greatly diminishes sound conduction. Works more for low frequencies than high frequencies.

-why attenuation reflex?

-protection from loud sounds (but delay of 50-100 msec, so can’t protect from sudden sounds like explosions)

-to parse out high frequency sounds, like voices, and ignore the constant low background rumble

-attenuation reflex might be activated when we speak, so that we don’t hear our own voices as loudly as we otherwise would.

4. THE COCHLEA

-Latin for “snail”

-the hollow tube is made of bone. It is 32 mm long and 2 mm in diameter. (size of a pea when rolled up)

-at the base of the cochlea are two membrane-covered holes: oval window and round window

-when looked at cut in cross section, divided into three fluid-filled chambers: scala vestibuli, scala media, and scala tympani.

-Reissner’s membrane separates scala vestibuli from scala media. Basilar membrane separates the scala tympani from the scala media. (Clear pictures on page 351-352 of text)

-Organ of corti sits on basilar membrane and contains the hair cell bodies.

-Tectorial membrane hangs over the organ of corti.

-The fluid in the scala vestibuli and tympani is called perilymph – similar to CSF. (low K and high Na)

-The fluid in the scala media is called endolymph, and is unusual because it has high K and low Na.

-why the weird concentration? active transport is taking place at the stria vascularis, the endothelium lining one wall of the scala media. The difference in electrical potentials endo and perilymph, we have *endocochlear* *potential*, which enhances auditory transduction

PHYSIOLOGY OF THE COCHLEA

* Basilar membrane
  + The basilar membrane is flexible and bends in response to sound
    - wider at the apex than at the base by a factor of five
    - stiffness decreases from base to apex (think of it as a swimming flipper - narrow side is stiffer than the wide floppy side)
    - The distance a wave travels up the basilar membrane depends on the frequency of the sound. Low frequency will travel all the way to the floppy apex of the membrane until the energy is dissipated.
* Organ of corti & associated structures
  + contains the hair cells, the rods of corti, and various supporting cells
  + auditory receptors are called **hair cells** because each one has 100 hairlike stereocilia extending from its top.
  + The critical event in the transduction of sound into a neural signal is the bending of these cilia.
  + The hair cells are sandwiched between the basilar membrane and a thin sheet of tissue called the reticular lamina
  + INNER hair cells are between the modiolus and the rods of corti
  + OUTER are farther out than the rods of corti (view picture on page 355)

Neural pathway:

* Hair cells form synapses on neurons whose cell bodies are located in the **spiral ganglion** in the modiolus.
* Axons from the spiral ganglion enter the auditory nerve, a branch of the auditory vestibular nerve, which projects to the cochlear nuclei in the medula.
  + To treat certain kinds of deafness, can use electronic device (cochlear implant) to bypass middle ear and hair cells and activate the auditory nerve axons directly.

Transduction by hair cells:

* basilar membrane moves in response to motion of stapes → rods of corti, reticular lamina, hair cells all move (because all connected). → either move up toward, or away from tectorial membrane→ this bends the stereocilia one way or the other
* bending the stereocilia in one direction causes depolarization, the other direction causes hyperpolarization.
* There are special types of cation channels (TRPA1) on the tips of the stereocilia. Mechanically open and close and release or stop flow of K.
  + Each channel connected by elastic filament (spring) called a tip link
* Entry of K into the hair cell triggers Ca to enter, which triggers release of a neurotransmitter (probably glutamate) and activates postsynaptic spiral ganglion fibers

Inner vs outer hair cells:

* 3x more outer hair cells than inner hair cells, but more than 95% of spiral ganglion neurons communicate with the inner hair cells
* vast majority of information leaving cochlea comes from inner hair cells
* OUTER hair cells amplify the movement of the basilar membrane during low intensity sound stimuli (quiet sounds)
  + outer hair cells referred to as “cochlear amplifier”
  + use motor proteins (called prestin) to change length of hair cell - when prestin is deleted from mice, they are 100x less sensitive to sound (nearly deaf)
  + increases peak movement of basilar membrane by up to 100 times
  + explains how antibiotics that damage outer hair cells leads to deafness
  + Also brain to cochlea pathways
* There are 1000 efferent axons traveling FROM the brainstem TO the cochlea. These can regulate auditory sensitivity by synapsing onto outer hair cells.

CENTRAL AUDITORY PROCESSES

* more complex than visual - more possible pathways and synapses

Anatomy:

* At level of medulla, axons innervate to the dorsal cochlear nucleus and ventral cochlear nucleus on the same side as where they originated
* Each axon branches onto both cochlear nuclei
* One particular pathway is the cochlear nucleus to the auditory cortex.
  + Cells in the ventral cochlear nucleus send out axons to the **superior olive** (or superior olivary nucleus) on both sides of the brainstem.
  + These axons ascend in the lateral lemniscus and innervate in the inferior colliculus of the midbrain.
* ALL ascending auditory pathways converge onto the inferior colliculus. The neurons here send out axons to the medial geniculate nucleus (MGN) of the thalamus, which projects to the auditory cortex.

Response properties of neurons in the auditory pathway:

* most neurons that relay info to the cortex have a characteristic frequency (tuning which is more sensitive to a certain frequency than others). also, some responsive to complex sounds, like voices. some responsive to rapidly changing frequencies, like music- so, on its way to cortex, the info is interpreted by varying cells that recognize different aspects of the input (similar to visual system). This gives us a more solid grasp on the information we are taking in (can describe it in many different ways)

Encoding sound intensity and frequency:

- Stimulus intensity:

- information about sound is coded via: the firing rate of neurons and # of active neurons

- As a stimulus gets more intense, basilar membrane vibrates with greater amplitude, causing hair cells membrane potential to become either hyper or depolarized.

- Nerve fibers fire action potentials at greater rates

- More intense stimuli move basilar membrane over a greater distance, leading to the activation of more hair cells

- Loudness we perceive correlates with # of active neurons in the auditory nerve + their firing rate

- Tonotopy:

o There is a map of the basilar membrane within the cochlear nuclei

o The systematic organization of characteristic frequency within an auditory structure is tonotopy

o location of active neurons in auditory nuclei is one indication of the frequency of the sound

o frequency must be coded in some way other than the site of maximal activation in tonotopic maps, for two reasons:

§ maps do not contain neurons with very low characteristic frequency, must find a way to distinguish them

§ the region of the basilar membrane maximally displaced by a sound depends on its intensity in addition to its frequency

- Phase locking:

o The consistent firing of a cell at the same phase of a sound wave

o Volley principle = intermediate sound frequencies are represented by the pooled activity of a number of neurons, each of which fires in a phaselocked manner

o Phase locking occurs with sound waves up to 4kHz – above this is random sound wave phases

o Low frequency = phase locking, intermediate frequencies = phase locking and tonotopy, high frequencies = tonotopy

Mechanisms of sound localization

- Interaural time delay = if we aren’t facing a source directly, it will take the sound longer to reach one ear than the other (delay is about .6 msec)

- High frequencies take a shorter amount of time to reach other ear == i*nteraural intensity difference* exists between the two ears

- With sounds in the range of 20–2000 Hz, the process involves *interaural time delay*

- From 2000–20,000 Hz - interaural intensity difference

o these two processes constitute the **duplex theory of sound localization**.

- Neurons in the cochlear nuclei are monaural – only respond to sound presented in one ear

- Binaural neurons are found in the later stages of auditory processing

o First one is superior olive

- Neural circuits of superior olive use axons as delay lines to produce neurons sensitive to interaural delay

o Also sensitive to interaural intensity

- Comparing inputs to both ears is not very useful for localizing sounds in the vertical plane because as a sound source moves up and down, neither the interaural delay nor the interaural intensity changes

- Vertical localization of sound is seriously impaired if the convolutions of the pinna are covered

Auditory cortex

- Axons leaving the MGN project to auditory cortex via the *acoustic radiation*

- Primary auditory cortex (A1) has isofrequency bands running mediolaterally across A1

o strips of neurons running across A1 contain neurons that have fairly similar characteristic frequencies

- normal auditory function is retained after unilateral lesions in auditory cortex b/c both ears send output to cortex in both hemispheres

Vestibular system

- vestibular system monitors the position and movement of the head, sense of balance and equilibrium, and helps coordinate movement of the head and eyes and body posture

- vestibular system uses hair cells to transducer movements

- evolved from lateral line organs

- vestibular labyrinth = where hair cells are contained

o contains the:

o otolith organs – detect the force of gravity and tilts of the head

o semicircular canals – sensitive to head rotation

o each structures purpose is to transmit mechanical energy from head to hair cells

- otolith:

o pair of relatively large chambers called sacule and utricle

o detect changes of head angle, as well as linear acceleration of the head(ex. Elevator)

o contains macula = sensory epithelium vertically oriented within the saccule and horizontally between the utricle

o contains hair cells

o contain the unique otoliths – key to the tilt sensitivity of macula

o each hair cell has exceptionally tall kinocilium

§ bending towards this results in depolarization

§ bending away from this results in hyperpolarizaiton

- semicircular canals:

o detect turning movements of head(ex. shaking up and down)

o sense angular acceleration: sudden rotational movements

o hair cells are clustered within the crista – located within the ampulla

o cilia project into the cupula

o three semicircular canals on one side of the head help sense all possible head-rotation angles

- central vestibular pathways coordinate and integrate information about head and body movement and use it to control the output of motor neurons that adjust head, eye, and body positions

- primary vestibular axons make direct connections to the vestibular nucleus

o vestibular nuclei combine incoming vestibular information with data about the motor system and other sensory modalities

- **vestibulo-ocular reflex =** keeps your eyes pointed in a particular direction

- EX) When the head turns to the left and the VOR induces both eyes to turn right : Axons from the left horizontal canal innervate the left vestibular nucleus, which sends excitatory axons to the contralateral (right) cranial nerve VI nucleus (abducens nucleus). Motor axons from the abducens nucleus in turn excite the lateral rectus muscle of the right eye. Another excitatory projection from the abducens crosses the midline, back to the left side, and ascends (via the medial longitudinal fasciculus) to excite the left cranial nerve III nucleus (oculomotor nucleus), which excites the right medial rectus muscle of the left eye

Ch. 12 --Meron

Somatic Sensation- Catch all name for sensations that aren’t seeing, hearing, tasting, smelling and balance. Allows our body to feel, ache, chill.

Touch

-two major types of skin: hairy and glabrous(hairless)

Layers:

Outer-layer= epidermis

Inner-layer= dermis

Function of skin:

Protective

Prevents evaporation of bodily fluids

Contact with world

Mechanoreceptors:

-most abundant sensory receptor

- sensitive to physical distortion ex. Bending and stretching

-vary in persistence and responses to long lasting stimuli

Types of mechanoreceptors

Pacinian corpuscles:

Largest and best studied mechanoreceptor(1 of 4)

Lies in dermis

Sensitive to vibration (200-300 Hz) and pressure

Meisner corpuscles:

Similar to pacinian corpuscles but much smaller receptive field

Located in finger tips

Sensitive to vibration as well(50Hz)

Merkel’s disk:

Located in the epidermis

Small receptive field

Ruffinis endings:

Found in both glabrous and hairy skin

Large receptive field

-Pacinian and Meisners corpuscles are rapidly adapting meaning they respond quickly but stop firing soon after even if stimulus still present

- Merkel’s disk and Ruffinis endings are slowly adapting meaning they have a more sustained response during a long stimulus.

Two-Point Discrimination:

-Our ability to discriminate the detailed features of a stimulus varies greatly across the body.

- Fingertips have the highest resolution, Calf lowest, then back and forearm

-Higher resolution = high density of mechanoreceptors

= small receptive fields

= more brain tissue devoted to specific area

Primary Afferent Axons:

- Primary Afferent Axons- Axons bringing information from the somatic sensory receptors to the CNS.

-skin is innervated(supplied with nerves) by axons that move through peripheral nerves on their way to CNS

-These axons enter spinal cord through dorsal roots

-Widely varying sizes: different size= different sensory receptor

Spinal Cord:

-Most peripheral nerves communicate with the CNS via Spinal Cord encased in Vertebral Column.

-Consists of dorsal and ventral root axons.

-Consists of 30 spinal segments divided into 4 groups

From top to bottom: Cervical (1-8)

Thoracic (1-12)

Lumbar (1-5)

Sacral (1-5)

-Spinal cord composed of an inner-core of gray matter, surrounded by a thick covering of white matter tracts called columns

-Dermatome- An area of skin innervated by the right and left dorsal roots of a single spinal segment. 1:1 ratio between dermatomes and spinal segments.

Somatosensory Cortex:

- most complex levels of somatosensory processing occur in the cerebral cortex.

- most of cortex concerned with somatosensory system= parietal lobe

-Area 3B is the *primary*  somatosensory cortex because:

-neurons are very responsive to somatosensory stimuli

-damage here results in impairment of somatic sensation

- electrically stimulated, it evokes somatic sensory experience(??)

Area 1 and 2 receive inputs from 3b: 3b -> 1 = texture information

3b -> 2 = size and shape

Somatotopy:

-electrical stimulation of a specific primary somatosensory cortex region can cause somatic sensations localized to a specific part of the body. The mapping of the body’s surface sensations onto a structure in the brain using techniques such as this is called somatotopy.

-somatic map not always continuous and not scaled to actual human body (ex homunculus)

-the relative size of cortex devoted to each body part is correlated with the density of sensory input received from that part

- size on map is also related to importance of the sensory input from that part of body. How often used (LOOK AT PICTURES IN BOOK. VERY HELPFUL)

Cortical Map Plasticity:

- cause of map rearrangement after amputation is absence of input from missing limb.

- takes some time and doesn’t always happen ex. Phantom limb.

Posterior Parietal Cortex:

-Posterior Parietal Cortex includes area 5 and 7 in the somatosensory cortex.

- Brings senses together ( ex looking for key inside pocket requires knowledge of size shape, texture and weight)

- Essential for the perception, interpretation of spatial relationships, accurate body image, learning of new tasks involving coordination of the body in space.

-Functions involve integration of somatosensory info with that from other sensory systems, particularly vision system

-Damage to Posterior Parietal Cortex can result in:

Agnosia- inability to recognize objects even though simple sensory skills seem to be normal. Ex. Visual agnosia- person cant name or describe use of object in front of them, but when holding that object, they may be able to use their sense of touch to identify its use.

Neglect Syndrome- Parital cortical lessions in which part of the body or part of the world ( ex the entire visual field left of the center gaze) is ignored or suppressed, and its very existence is denied.

Pain

-Somatic sensation depends on nociceptors as well as mechanoreceptors

Nociceptors:

- nociceptors- the free branching, unmyelinated nerve endings that signal that body tissue is being damaged or is at risk of being damaged.

-information from nociceptors takes a path to the brain that is distinct from that of mechanoreceptors, resulting in differing subjective experience.

-There is a difference between pain and nociception: Pain is the feeling or perception of irritating, stinging etc… sensations. Nociception is the sensory process that provides the signals that trigger pain.

Painful Stimuli:

- Nociceptors activated by stimuli that has potential to cause tissue damage are due to: strong mechanical stimulation,

extremes in temperature

oxygen deprivation

exposure to certain chemicals

-membrane of nociceptors contain ion channels that are activated by theses types of stimuli

Types of Nociceptors:

-Transduction of painful stimuli occurs in the free nerve endings of:

unmyelinated c fibers and,

lightly myelinated A8 fibers

Polymodal Nociceptors:

-majority of nociceptors

-respond to mechanical, thermal and chemical stimuli:

mechanical nociceptor- strong pressure

thermal nociceptor – burning heat or extreme cold

chemical nociceptor- histamine and other chemicals(can cause

perception of itch)

-Nociceptors are present in most body tissues except in the brain besides the meninges.

Hyperalgesia:

- Hyperalgesia- a reduced threshold for pain or increased intensity of painful stimuli even spontaneous pain to an area on the body that has already been damaged.

- Primary hyperalgesia- occurs within area of damaged tissue

- Secondary hyperalgesia- occurs in tissues surrounding a damaged area

First and Second Pain:

- First Pain- fast and short pain mediated by A8 fibers (lightly myelinated axons)

-Second Pain- duller, longer lasting, mediated by C fibers (unmyelinated axons)

-Neurotransmitters of pain afferents believed to be Glutamate

-Substance P- a peptide that is released by high frequency of action potentials and is required to experience moderate-intense levels of pain.

Differences Between Touch and Pain Pathways:

1) Nerve endings: touch pathway = specialized structures in the skin

pain pathway = has free nerve endings

2) Diameter of axons: touch pathway = swift and uses fat myelinated AB fibers

pain pathway = slow and uses lightly myelinated A8 and

unmyelinated C fibers

3) Connections in Spinal Cord: touch pathway= AB axons terminate in deep dorsal horn

pain pathway= A8 and C fibers branch, run within

zone of Lissauer and terminate in substantia

gelatinosa

Spinothalamic Pain Pathway:

- spinothalamic pain pathway- pathway through which information about pain and temperature in the body is conveyed from spinal cord to the brain

-spinothalamic fibers project up the spinal cord and through the medulla pons and midbrain without synapsing until they reach the thalamus

-touch information ascends ipsilaterally while pain information ascends contralaterally. (look at book for illustrations)

Regulation of Pain:

Afferent Regulation:

-pain evoked by activity in nociceptors can be reduced by simultaneous activity

in low-threshold mechanoreceptors (AB fibers)

-explains why it feels good to rub skin that has been bruised

- Gate theory of Pain- the relay of nociceptive signals by the

projection neuron is gated by the activity of an inhibitory

interneuron

-suppresses nociceptive signals

Descending Regulation:

-several brain regions implicated in pain suppression

-periaquaductal gray matter(PAG)- area of brain regions that

are associated with pain suppression. Localized in midbrain

-PAG receives input from several brain structures into

various midline regions of the medulla. Medullary neurons

in turn project axons to spinal cord where they can depress

the activity of nociceptive neurons.

Referred Pain:

-internal organs synapse onto the same spinal cord as specific skin areas. No pain receptors present on internal organs.

- Since internal organs rarely send information, brain interprets the activation of the spinal cord neurons as coming from the skin. (ex. When heart fails to receive adequate amount of oxygen, pain is localized in upper chest wall and left arm)

Temperature

Thermoreceptors:

-solely sensitive to temperature

- temperature sensitivity not spread uniformly

- some spots on skin, about 1mm wide are especially sensitive to either hot or cold, but not both

- sensitivity of a sensory neuron to a change in temperature depends on the type of ion channels the neuron expresses

-6 distinct Trp channels in thermoreceptors that confer different temperature

sensitivities

- different thermoreceptors neurons appear to express only a single type of

ion channel. This may be why different parts of body = different sensitivities

-Temp pathway organization identical to pain pathway

-cold receptors cable to A8 and C fibers

-hot receptors cable to C fibers only

A Few Concluding Notes on the Topic:

-Just before the nerves attach to the spinal cord, the fibers divide into dorsal and ventral roots.

Dorsal Root: enters towards the back of the spinal cord. Contains axons bringing

Information into the spinal cord( ex signal from thumbtack entering

foot). CARRIES SENSORY AXONS

Dorsal Root Ganglion- A collection of cell bodies of the sensory

neurons that are part of the somatic PNS. There is 1 dorsal root

ganglion for each spinal nerve.

Dorsal Horn- The dorsal region of the spinal cord containing neuronal cell bodies. Receives sensory input from the dorsal root fibers.

Ventral Root: enters towards the front of the spinal cord. Contains axons bringing

information out of the spinal cord (ex the muscles that jerk foot away after thumbtack has entered foot) CARRIES MOTOR AXONS

Zone of Lissauer: region where A8 and C pain fibers travel a short distance up and

down spinal cord.

Plasticity of the Brain -- Gillian

**Cortical plasticity:** cortical maps on the brain’s surface will reorganize when inputs are deleted (ie, damaged or surgically removed) or trained (ie piano playing or very delicate work). Inputs are the part of the body which send the sensory information to the brain. (eyes for the visual system, cochlea for the auditory).

* We discussed plasticity in terms of **somatosensory** plasticity (touch/pain/itch and propioception). Somatosensory inputs would be any area on the outside of the body. (fingers and toes are the best example, as they are very sensitive and mapped individually).
* Most experiments on this subject have been done on monkeys (owl monkeys in the textbook).
* Cortical maps can be obtained with electrodes.

**DELETION EXAMPLE:**

Each input has a corresponding area on the cortex responsible for sensation of that body part. For example, we have five separate areas for our five digits on our right hand. Plasticity refers to the brain’s ability to adapt when one digit is removed. Take the example of having five distinct areas, one for each finger.

Our map looks like this: 1 2 3 4 5. We surgically remove the 3rd finger. Our map now looks like this: 1 2 4 5, but 2 and 4 have grown to fill in the area previously responsible for digit 3.

* Plasticity is an important concept because it proves that our brain adapts to new sensory inputs, rather than just atrophying in the area that had been responsible for a digit that is no longer in use.

**TRAINING EXAMPLE:**

When we play an instrument that requires delicate and exact movements, we train certain digits to be more sensitive.

* Experiments to get the same effect have been done on owl monkeys by stimulating two digits (digits 2 and 3) using a rotating disk with teeth on it.
* When scientists map the cortical areas of their hand after training these digits, the cortical map shows that the areas for digits 2 and 3 have filled in some of the space previously given to digits 1 and 4. (The brain decides these digits are more important and should have more cortical area allowed).
* Right handed guitarists use their left hand for much more precise movements on the neck of the guitar compared to the right hand, which strums, so their map for their left hand digits is considerably larger than their right.

**Phantom Limb** sensations are a result of cortical plasticity. After a limb has been removed, other areas of the body take over that cortical area previously belonging to the leg. Stimulating these neighboring areas which have now moved in, (which can be completely different, such as the face or belly) can activate the brain’s previous “leg” area, which can sometimes still give us the feeling of leg stimulation.

**Activity dependent plasticity lecture (10/29):**

* synaptic organization is NOT fixed

SEGREGATION OF RETINAL INPUTS IN LGN

* in development, we have complete overlap of left and right eye input in LGN
* after our visual system has fully developed (6 months in humans), we see segregated columns of cells responsible for left and right eye input. (similar to cats, so they are used for studying visual system)

OCULAR DOMINANCE (OD) - Hubel and Wiesel in 1960’s

* certain neurons more responsive to contralateral (opposite side) eye stimulus, some to ispilateral (same side) eye stimulus
* made 5 categories of ocular dominance (1=completely contra, 3=equally contra and ispi, 5= completely ispi)
* in cats, most visual neurons are group 3
* **monocular deprivation** used to study plasticity of our visual system.
  + if done in early life, the visual cortex reorganizes so all cells are responsive to open eye (or undamaged eye in the case of an accident)
  + if done in adult life, our distribution of 1-5 group neurons doesn’t change.
    - this suggests a critical period

CRITICAL PERIOD

* will vary in onset and duration depending on: Sensory experience, animal species, property one is analyzing
* Changes can still occur in adulthood, but it is much harder and other variables matter
  + attention, high motivation, arousal all required. These are provided by neurotransmitters norepinephrine and ACh
* plasticity of visual system is based on competition (the cells that are used - ie are stimulated - survive, while the others get pushed out/reorganized to make room for helpful ones)
  + further supported by the fact that binocular deprivation does NOT change distribution of type of OD cells

Condensed Study Guide:

* Visual
  + Retina
    - light and dark current - know by heart (slide 4 of Retinal 2)
      * by default cells depolarized
  + Lesions
  + pathways of processing
  + eye anatomy
  + receptive fields
  + cortex layers - columns, stripes, etc. (LGN)
* Auditory
  + anatomy

SAMPLE QUESTIONS

1. 1. How does the visual field change if the left optic nerve is cut? What about the left optic tract? What about the optic chiasm?
2. Why do we feel pain in the upper chest and left arm when the heart is damaged?
3. Name 3 types of sensory receptors, and give an example of each.