CISC 3250
Systems Neuroscience

Perception

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JMH 332

Pathways to perception in 3 (or fewer) synaptic steps

0 Input through sensory organ/tissue

1 Synapse onto neurons in spinal cord/brain stem

2 Synapse onto neurons in thalamus

3 Synapse onto cortical neurons in "primary ____ cortex"

4+ Further cortical processing

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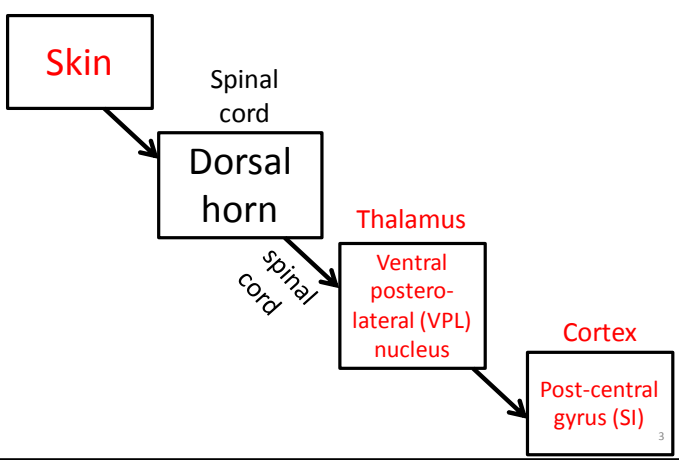
Touch/"Tactile"



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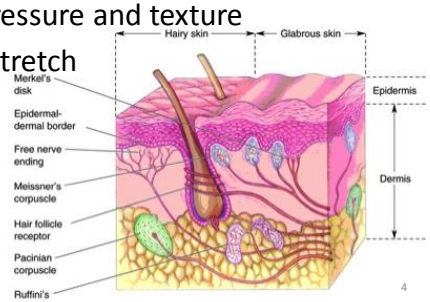
Touch: Inputs

Mechanoreceptors in skin

- Pacinian corpuscles – vibrations
- Meissner's corpuscles – light touch
- Merkel's discs – pressure and texture
- Ruffini endings – stretch



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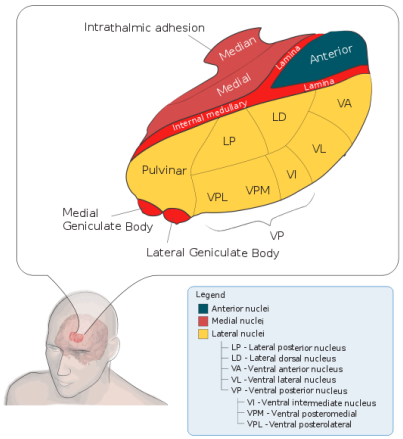
Thalamus – the "relay" station

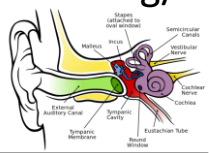


Region names largely based on location

VPL for somatosensation

http://en.wikipedia.org/wiki/File:Thalamus-schematic.svg

Hearing/"Auditory"



Cochlea

Cochlear nerve

Cochlear nucleus (-> Superior olive) -> Inferior colliculus

Brain stem

Thalamus

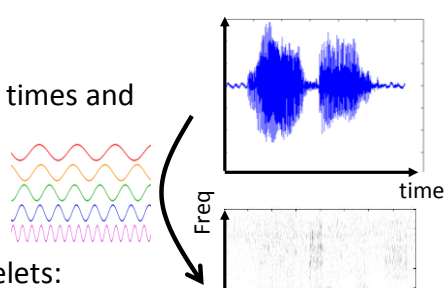
Medial geniculate nucleus (MGN)

Cortex

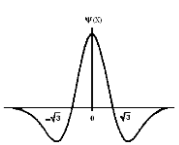
Primary auditory cortex (AI)

Hearing and frequency decomposition

Sound consists of times and frequencies



Time-bound wavelets:



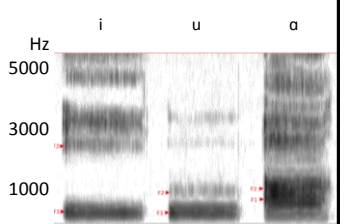
"Mexican hat"

Similar to cochlear neurons

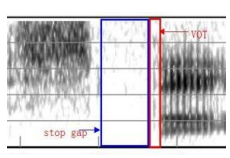
$$\frac{2}{\sqrt{3\sigma}\pi^{1/4}}\left(1-\left(\frac{t}{\sigma}\right)^2\right)e^{-\frac{t^2}{2\sigma^2}}$$

Common patterns in speech

- Vowels (a,e,i,o,u) correspond to steady frequency combinations

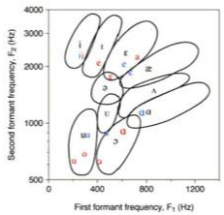


- Consonants may be broad-range frequencies, or sweeps

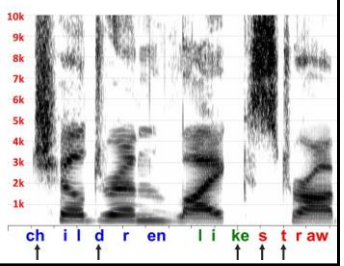


More speech pattern

- Speech formant ranges by frequency



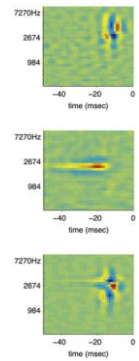
- ch, s – long high freq
- d, k, t – broad freq burst
- l, r, n, m – freq slide



Spectro-temporal receptive fields

Nagel 2008 Neuron
Zebra Finch (field L)

AI (primary auditory cortex) neurons selective for patterns in space and time



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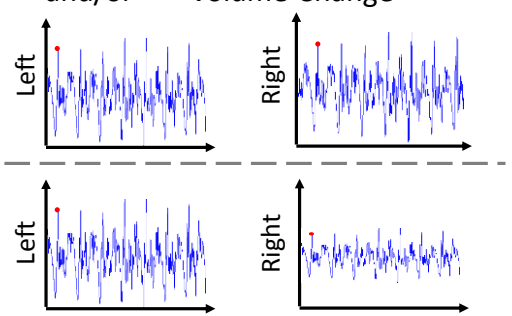
Binaural hearing

Comparing sounds from left and right

- Time shift and/or Volume Change



Applications:

- Localize sound source
- Distinguish sounds from multiple sources

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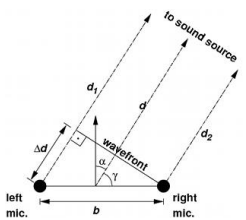
Math of sound localization

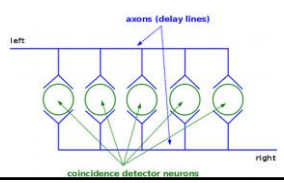


Speed of sound
c=343 m/s

Human head
b=0.2m

$$\alpha = \sin^{-1}\frac{c\Delta t}{b}$$

Jeffres '48
sound delay/
axon delay model



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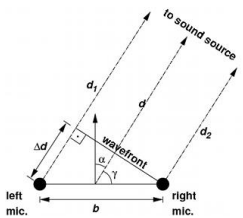
Math of sound localization



Speed of sound

c=343 m/s

Human head

b=0.2m

$$\alpha = \sin^{-1}\frac{c\Delta t}{b}$$

Pick direction for comparison

$$\Delta t = \begin{cases} > 0 & \text{rightSound earlier} \\ < 0 & \text{leftSound earlier} \end{cases}$$

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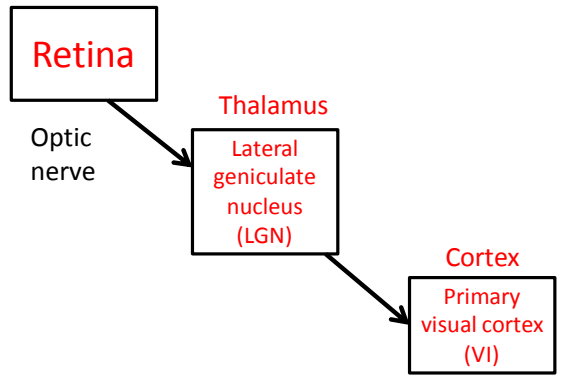
Seeing/"Visual"



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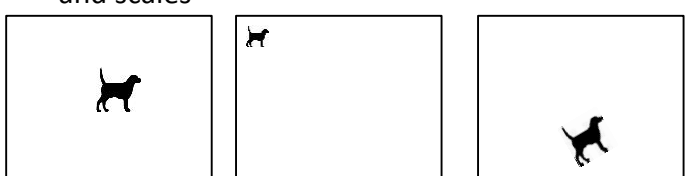
Sensitivity to perceptual variations

- V1: Surround-suppression for shifted edges

- PFC: Same object detected at diverse locations and scales



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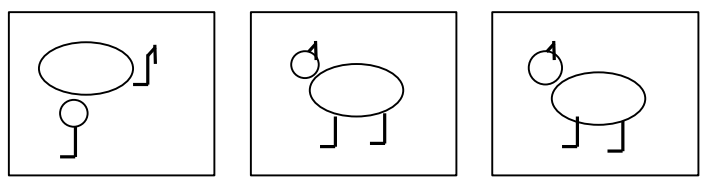
Selectivity to perceptual variations



- More complex percepts invariant to greater spatial transformations

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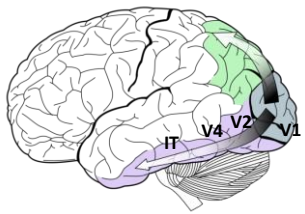
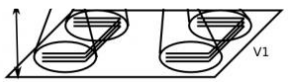
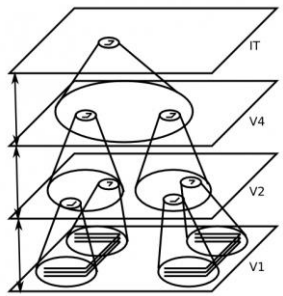
HMAX – model of hierarchical vision





- Higher cortical levels cover larger visual spans
- Object recognition invariant to changes in location and orientation

HMAX – model of hierarchical vision



1. Gabor "filters" (edge detectors)

2. Perform "Max pooling" (semi-invariance over space)
3. Weighted combination of space-invariant edges
4. Further max pooling

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