520.445 – Audio Signal Processing
☞ Topic 5 ☜

Sound Perception

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The auditory system

- Two major components in the auditory system
  - The peripheral auditory organs (the ear)
    - Converts sounds pressure into mechanical vibration patterns, which are then transformed into neural firings
  - The auditory nervous system (the brain)
    - Extracts perceptual information in various stages

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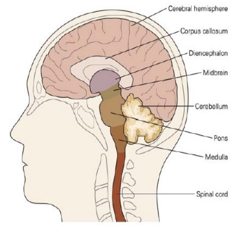
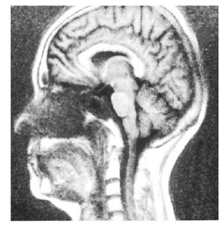
The brain





- Weighs ~ 3 pounds [mostly water ~80%, fat 10%]
- Consistency is soft (~jello)
- made up of about 100 billion neurons
- Surface of the brain is wrinkled with deep olds
  - Increases the surface area
  - Allows for more connections
- Consists of two main structures
  - Cortical structures on the surface
  - Subcortical structures deeper in the brain

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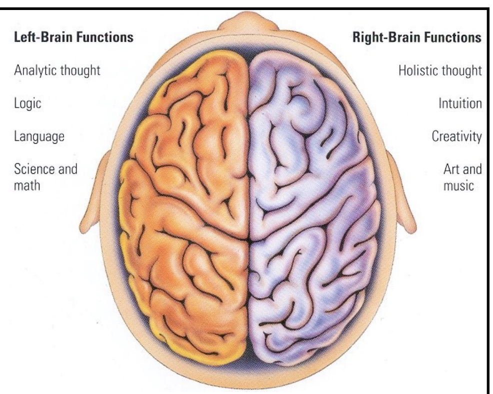
Brain anatomy



- Two relatively symmetric halves (hemispheres)
- Contralateral control
  - Left side of the brain controls right side of body
  - Left side of the brain processes sounds from the right ear
- Some specialized functions for both sides

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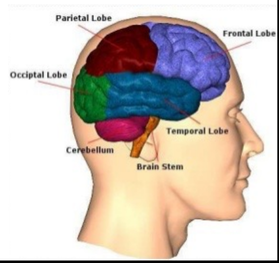
Brain anatomy

- Subcortical (brainstem) structures (deeper)
  - Most basic/primitive regions in the brain
  - Life sustaining / survival functions
  - Control of heart rate, breathing, etc
- Cortical structures (surface)
  - Newer parts of the brain, developed as species evolved
  - “thinking” parts of the brain



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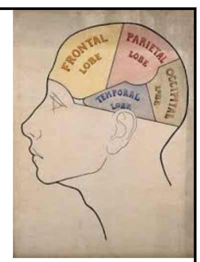
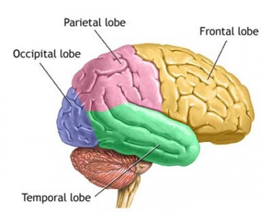
Cortical structures



- Cortex is divided into 4 functional units
  - Temporal Lobe
    - Left and right side above and around the ears
    - Primarily responsible for **hearing**, memory, meaning, and language.
  - Occipital Lobe
    - Back of the brain
    - Primarily responsible for vision
  - Frontal Lobe
    - Area around forehead
    - Involved in purposeful acts like judgment, creativity, problem solving, and planning.
  - Parietal Lobe
    - Top back area of the brain
    - Processes higher sensory and language functions



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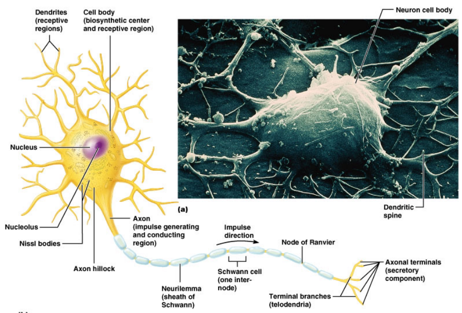
The Brain



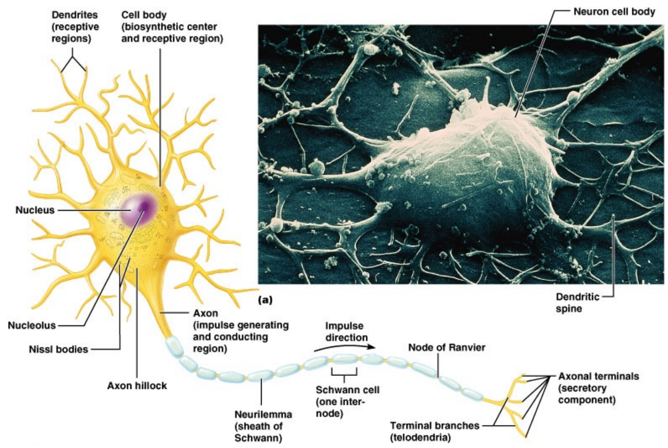
- The basic unit of the nervous system is a *neuron*
- The brain contains over 100 billion individual neurons
- Neurons have both chemical and electrical processes

Neurons

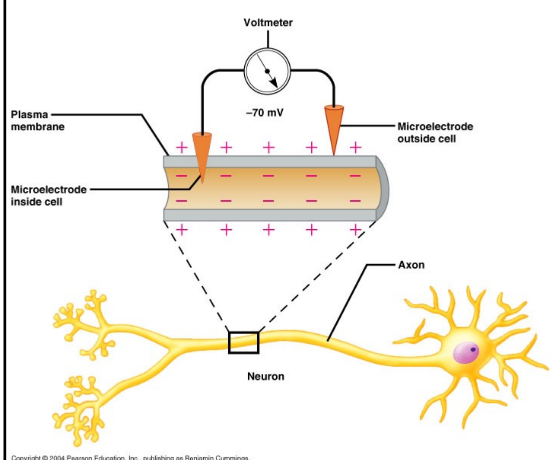
- Neurons are complex cells that communicate by means of an electrochemical “language”
  – Each neuron is connected to ~1000 other neurons
  – Each has many inputs, usually only one output
- Chemicals stimulate the cell to transmit an electrical impulse. When the impulse reaches the end of the cell, chemicals are released, which are picked up by neighboring cells which stimulate those cells…

Neuron's anatomy

- Dendrites:
  - Receive chemicals called neurotransmitters from neighboring cells and start an electrical signal
- Axon:
  - Transmits the electrical impulse down the length of the cell
- Terminal buttons:
  - Release chemical neurotransmitters to neighboring cells



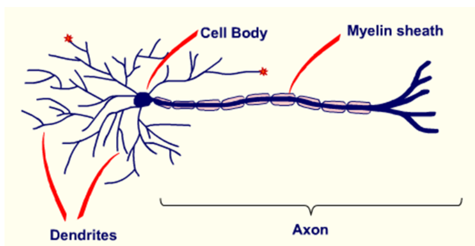
Measuring membrane potential



- Neurons maintain different concentrations of charged ions inside and outside the cell membrane.
- At rest, , there are relatively more sodium ions outside the neuron and more potassium ions inside that neuron.
- This differential gives a resting potential (voltage difference) of -70mV

How do neurons communicate?

- Impulses arriving simultaneously are added together and, if sufficiently strong, lead to the generation of an electrical discharge, known as an **action potential** (or nerve impulse, or spike).
- Action potentials are fixed in amplitude and shape but only vary in frequency (depending on input).



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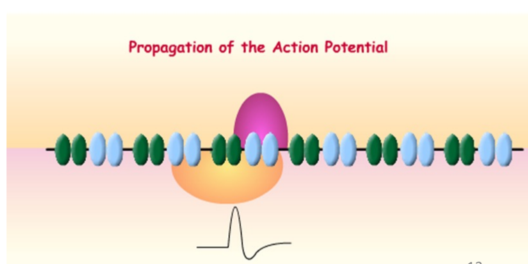
Propagation of action potentials

- When an action potential depolarizes the membrane, the leading edge activates other adjacent sodium channels

⇨ Wave of depolarization spreads

⇨ Action potentials propagate

-Propagation along the axon occurs in one direction (refractory period of sodium channels)



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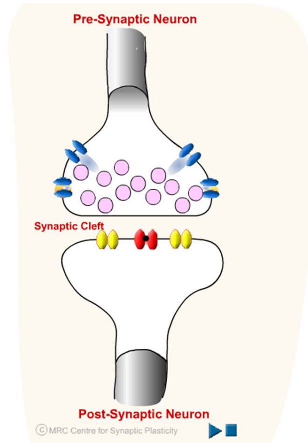
Synaptic transmission

- Neurons communicate at synapses
- Synapse consists of 2 neurons
  - Pre-synaptic (transmitter)
  - Post-synaptic (receiver)
- Synaptic transmission is a chemical process
  - Pores in pre-synaptic terminal open and release neurotransmitters
  - Receptors in the postsynaptic neuron allow influx of ions
  - Different neurotransmitter chemicals will have different effects on post-synaptic neuron (make it more likely 'excite' or less likely 'inhibit' a new action potential)



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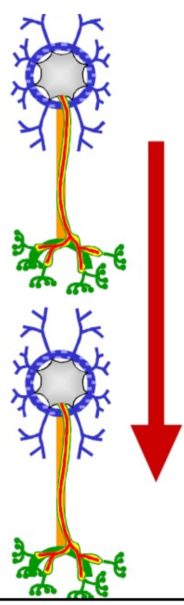
Network of neurons

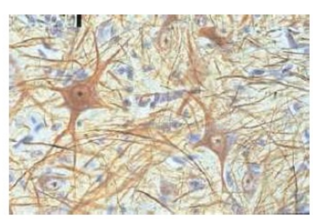


Action potentials only travel in one direction.

Each neuron is like an on and off switch. It either fires or it doesn't.

Each neuron connection carries information about experience or behavior (pleasure, pain, hunger, thirst, movements of your body, etc.)

…but what is most important is a **pattern of activity** across groups of neurons



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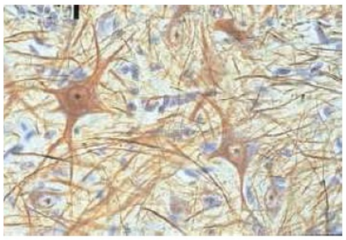
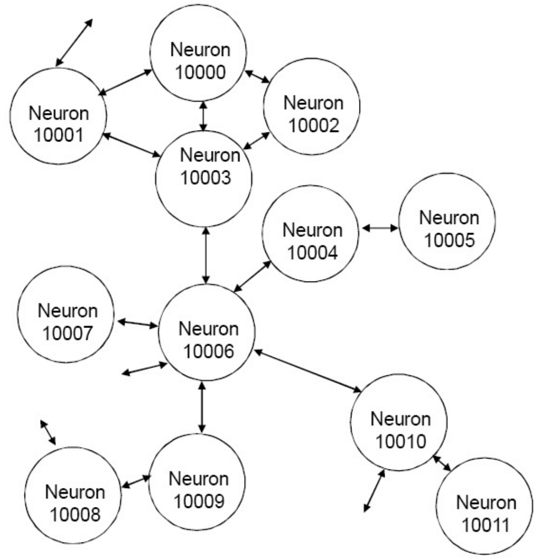
Network of neurons

The 100 billion neurons in the brain can be thought of as 100 billion “on-off” switches



Each on-off pattern means something different to the brain



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How the brain works

- https://www.youtube.com/watch?v=JQEiux-AOzs

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Neurobiology of hearing

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Auditory system

- The auditory pathway starts from the ear
- It consists of multiple stages of neuronal circuits, each performing a specific set of functions
- The system analyzes incoming sounds along multiple feature dimensions

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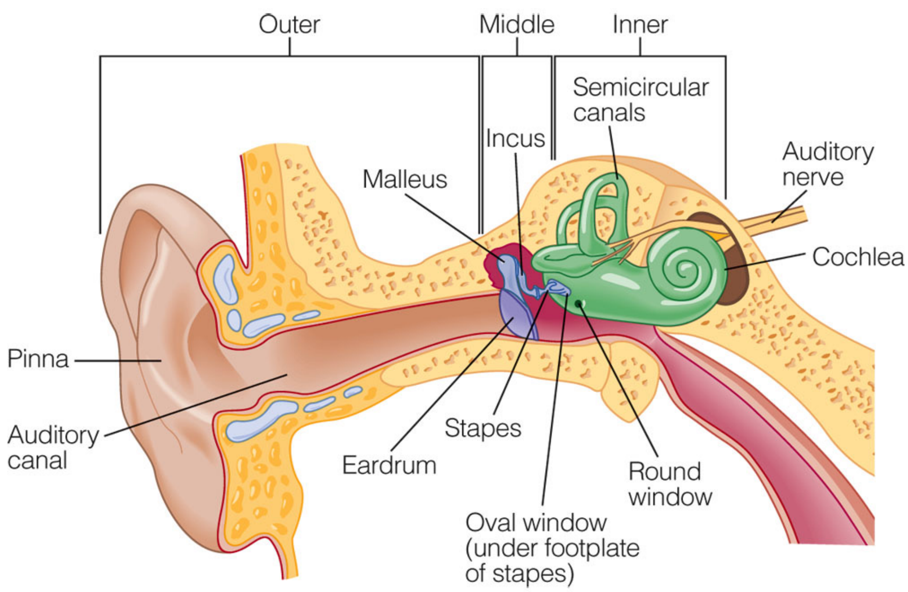

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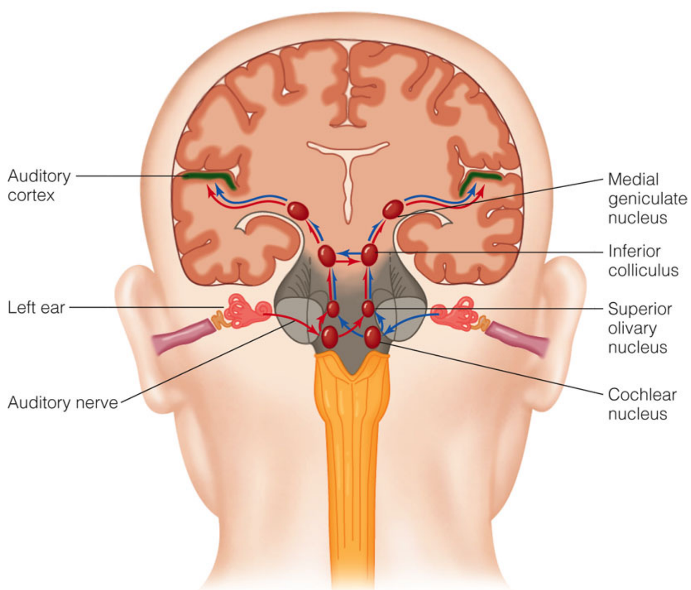
Auditory Pathway



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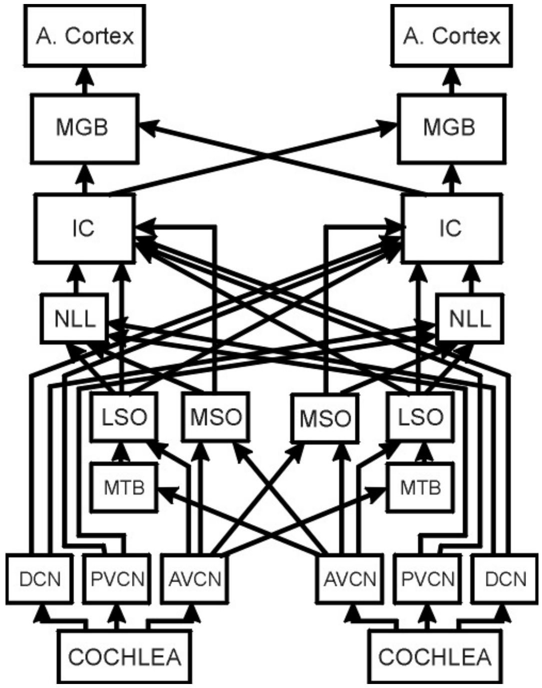

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MOVIE…

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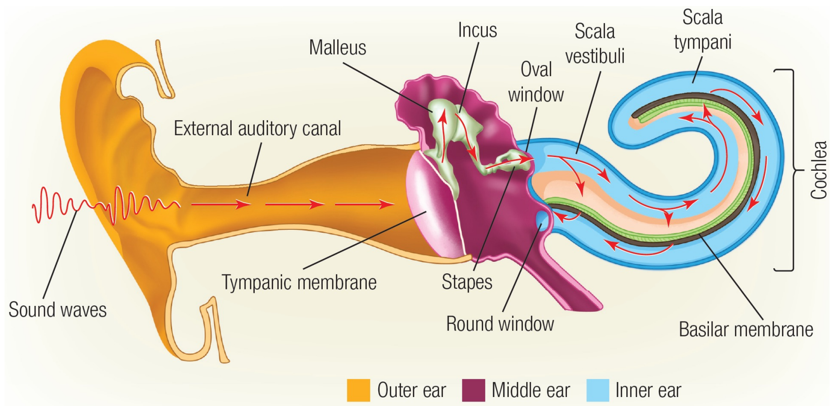
Flow of acoustic energy



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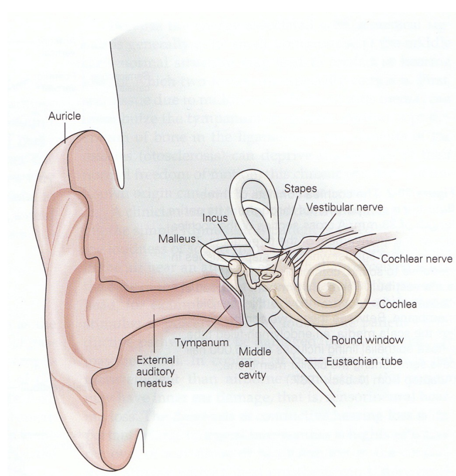
The ear

- The ear is the organ of hearing
- It changes sound pressure waves from the outside world into a signal of nerve impulses sent to the brain.
- It consists of 3 components:
  - Outer ear
  - Middle ear
  - Inner ear



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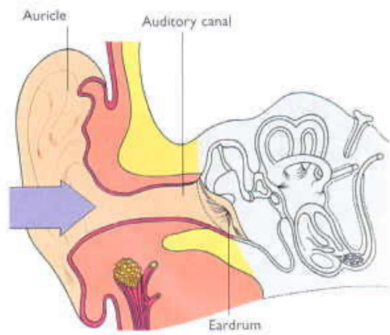
Organ of hearing
outer ear

- The external ear plays the role of an acoustic antenna,
- It diffracts and focuses sound waves (pinna), while the ear canal acts as a resonator => amplifies sounds in 2-5 kHz range
- The end of the canal has an eardrum which vibrates with sound



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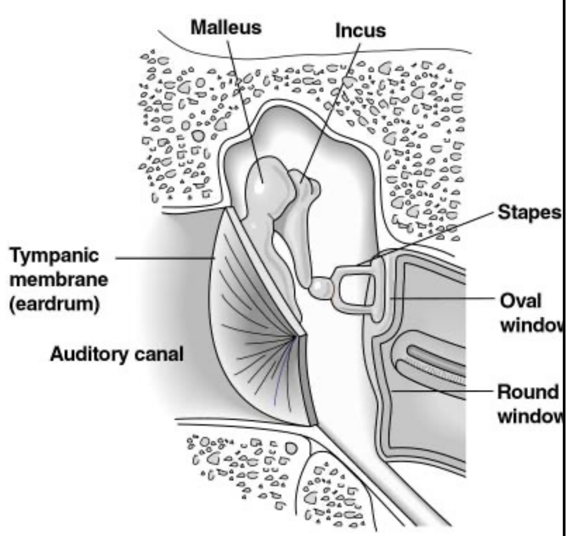
Organ of hearing
middle ear

- Eardrum (or tympanic membrane) vibrations cause mechanical motion of the small bones of the middle ear (malleus, incus & stapes) [3 smallest bones in the human body]
- The middle ear acts as an impedance adapter to adjust energy difference between air environment and fluid environment



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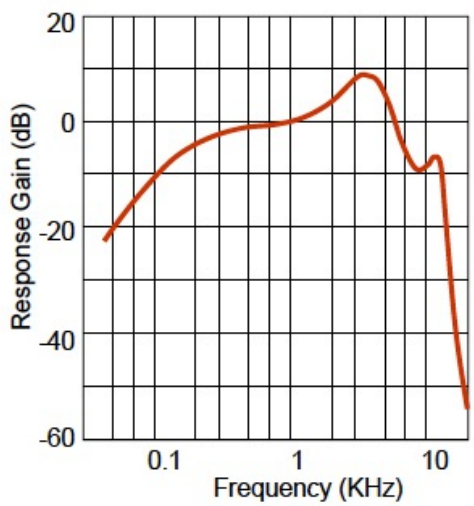
Transfer function @ periphery (outer + middle ear)



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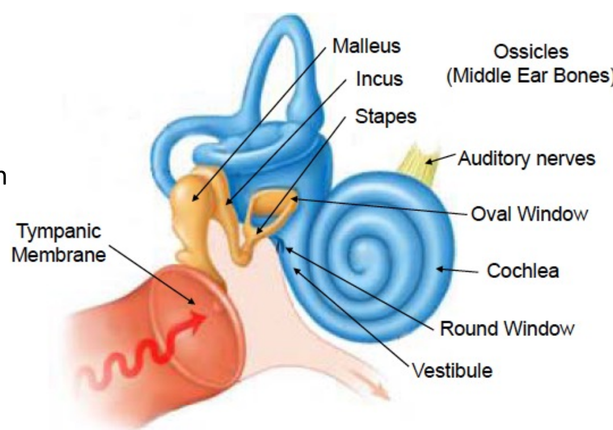
Organ of hearing inner ear

- Cochlea translates physical vibrations into electrical signals for the brain to process
- Cochlea acts a frequency analyzer of sound signals



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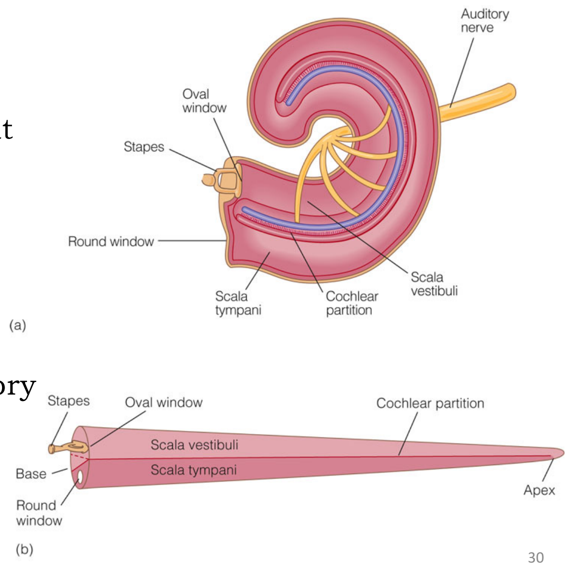
The Cochlea

- The cochlea is the inner ear organ that converts sound waves into neural signals.

- The neural signals are passed to the brain via the auditory nerve.



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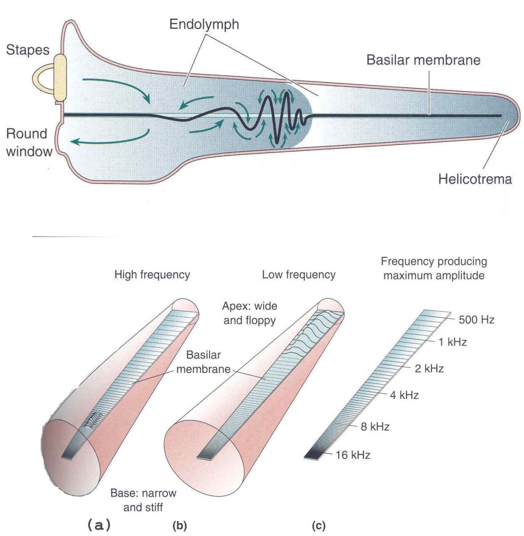
The Cochlea



- Sound waves cause the basilar membrane to vibrate.
- The basilar membrane is stiff at its base and loose at its apex. Just like a guitar string, this causes it to resonate to high frequencies at its base and low frequencies at its apex.

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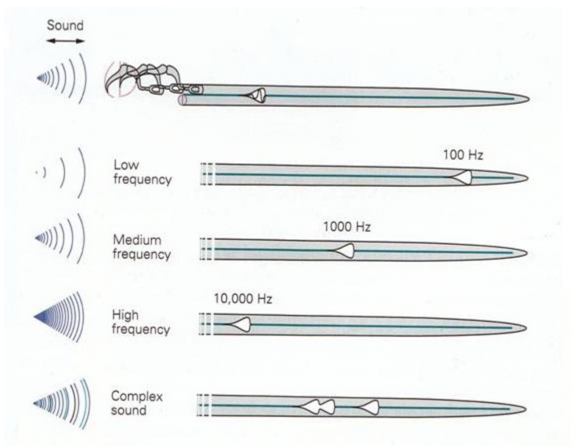
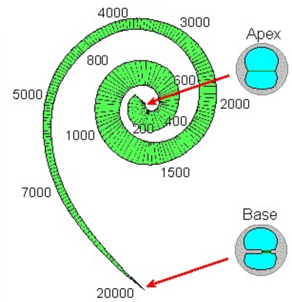
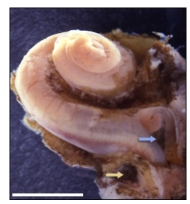
Cochlea as frequency analyzer







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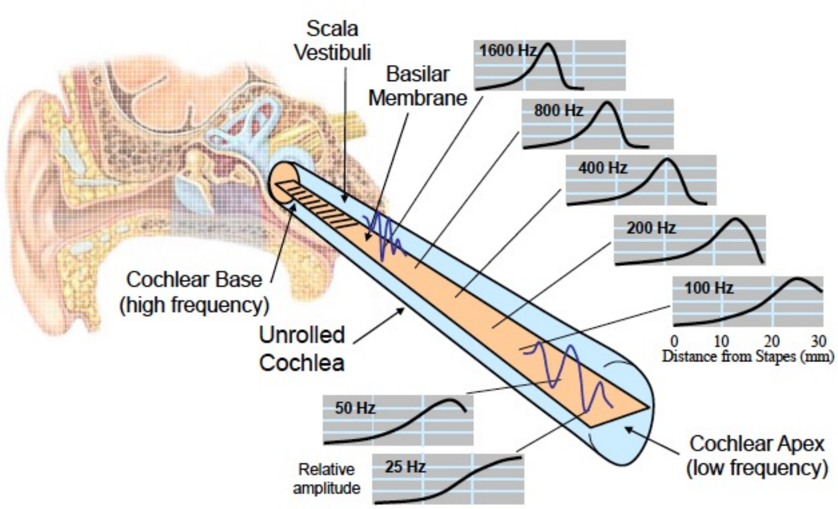
The cochlea



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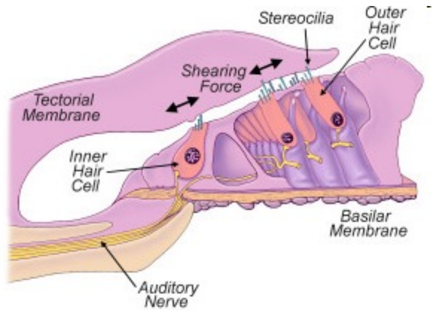
Cochlear Anatomy

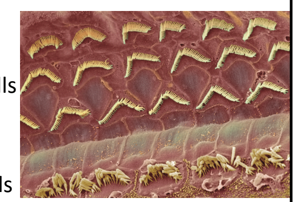
— The basilar membrane contains ~15,000-20,000 hair cells (sensory cells)

— *Inner hair* cells transduce vibration into electrical signal and send them to the brain

— *Outer hair* cells receive signals from the brain and transduce it to mechanical vibrations



Outer hair cells



Inner hair cells

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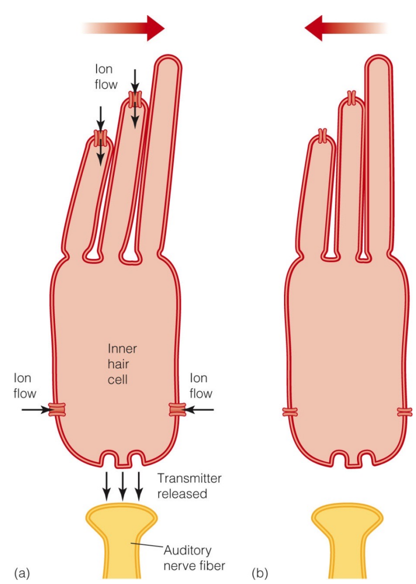
Inner haircells

- Hair cells transduce vibrations into depolarization.
- This leads to vesicular release that excites auditory nerve fibers.



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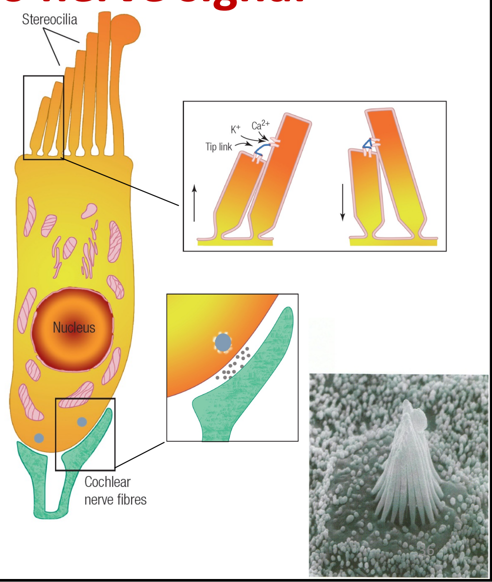
Inner haircells:
from sound to nerve signal

- The deflection of cilia opens gated ion channels in the cell
- Inner hair cells do not fire action potentials even though the cell is depolarized
- Neurotransmitters are released in a nerve terminal and trigger action potentials in the auditory nerve.



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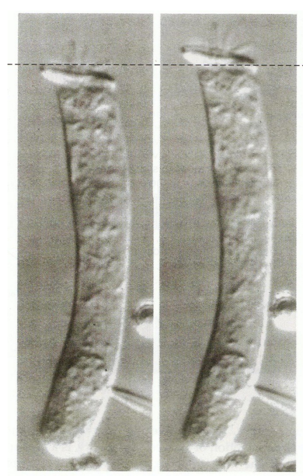
Outer hair cells:
Acoustic pre-amplifiers

- When the outer hair cilia are bent in response to a sound wave, an electromotile response occurs (cells change in length)
- Motility causes a selective amplification of the vibration in the basilar membrane
  - Enhances hearing sensitivity (amplifies quiet signals)
  - Sharpens frequency resolution
- Outer hair cells are also part of an active feedback loop projecting from the central auditory system, which completes the gain control mechanism



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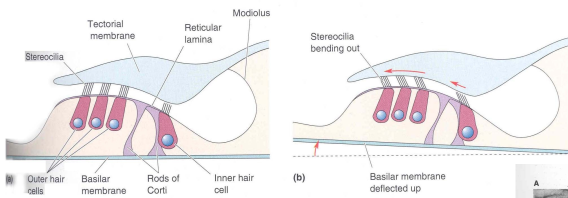
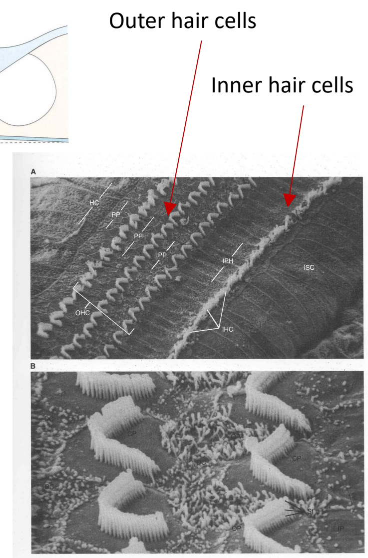
Hair cell movement





- Hair cells are firmly attached to the basilar membrane and therefore move up and down with it as it vibrates.
- The "hairs" or cilia of these cells are attached to a tectorial membrane which is fixed - it does not vibrate in response to sound.
- Transduction process: as the basilar membrane vibrates, the cilia will bend.

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Exposure to loud noise

-2-hours exposure to loud noise can seriously damage cilia bundles on the hair cells (cat inner ear).

-Normal mammalian hair cell bundles have two or three parallel rows of cilia, one taller than the next. The tall cilia are most vulnerable to noise.

Michael J. Mulroy and M. Charles Leberman, Massachusetts Eye and Ear Infirmary

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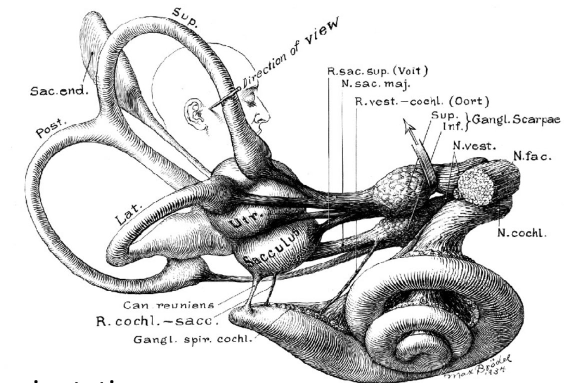
Organ of hearing …
inner ear

* Inner ear is also an organ of the vestibular system

- detects motion of the head-in-space (rotational & linear movements)
- generates reflexes



Sense of balance + spatial orientation
= *Equilibrioreception*

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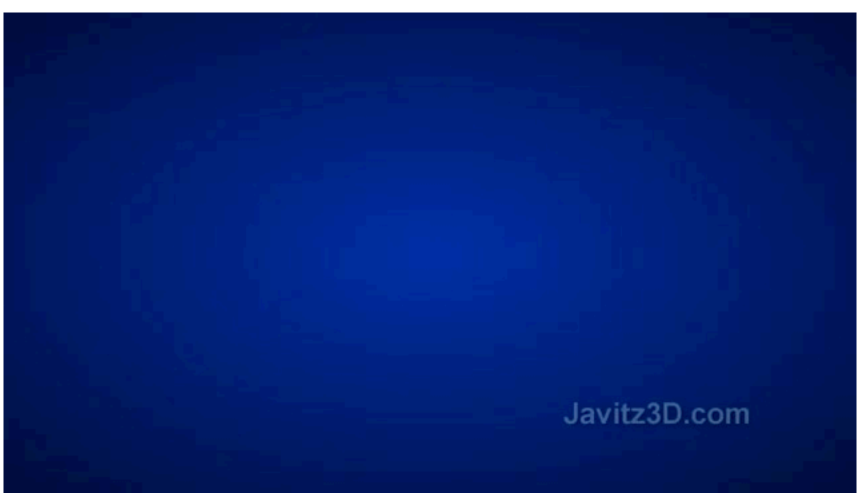
How the ear works (review)



https://www.youtube.com/watch?v=qgdqp-oPb1Q

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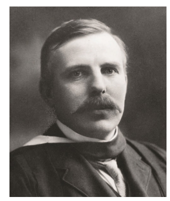
How do we code frequency?

- Two predominant (yet unsettled) theories:
  - The place theory
    - based on the fact that different frequency components of the input sound stimulate different places along the basilar membrane
  - The temporal theory
    - Based on the fact that the timing of action potentials in the auditory nerve reflect the frequency of the stimulus

Place Theory

Georg von Békésy (1899-1972)

Frequency Theory



Ernest Rutherford (1871-1937)

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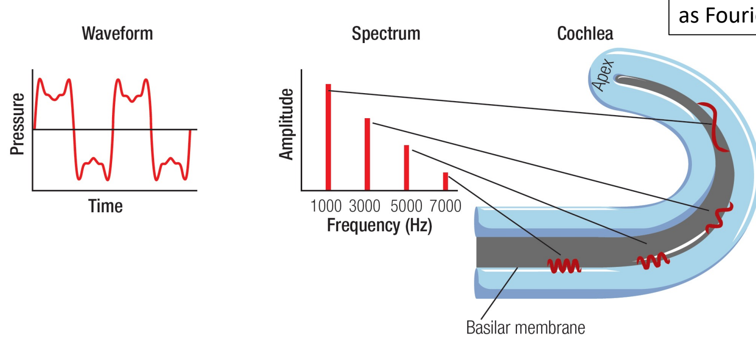
Place Theory

- which fibers are active?
  - labeled lines
- Von Békésy (Nobel prize 1961)

Basilar membrane as Fourier analyzer



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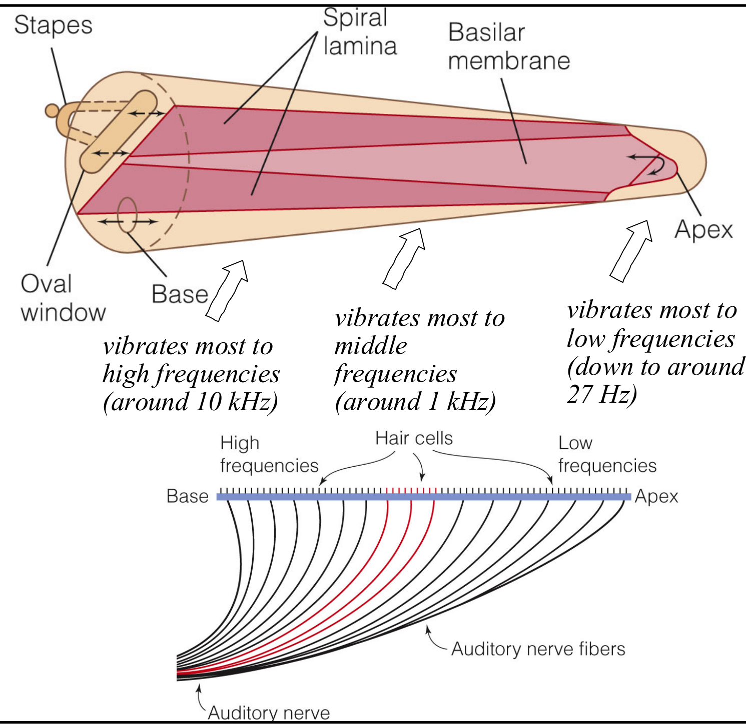

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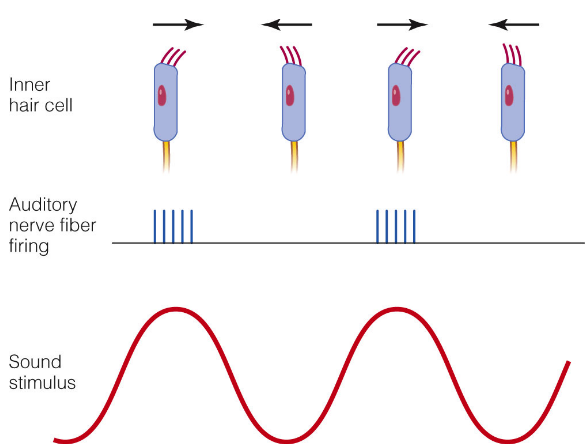
Temporal theory

- Based on the phenomenon of phase-locking
  - the frequency of the sound is reflected in the firing of neuron(s)



Concept of phase-locking

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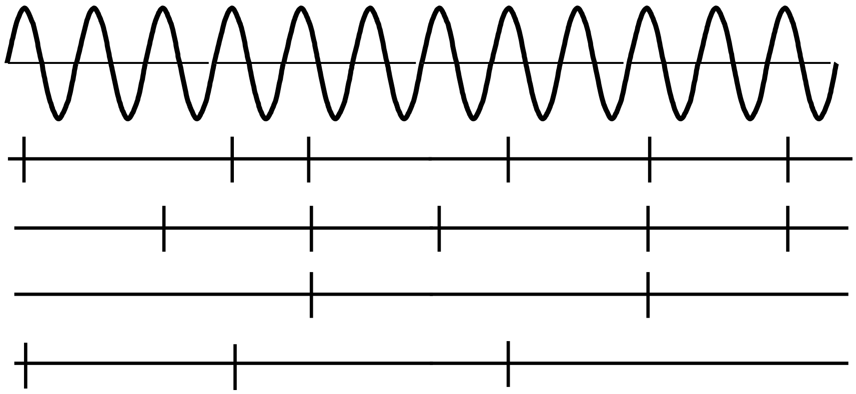

<u>phase locking</u> - the firing of neurons in synchrony with the phase of the stimulus

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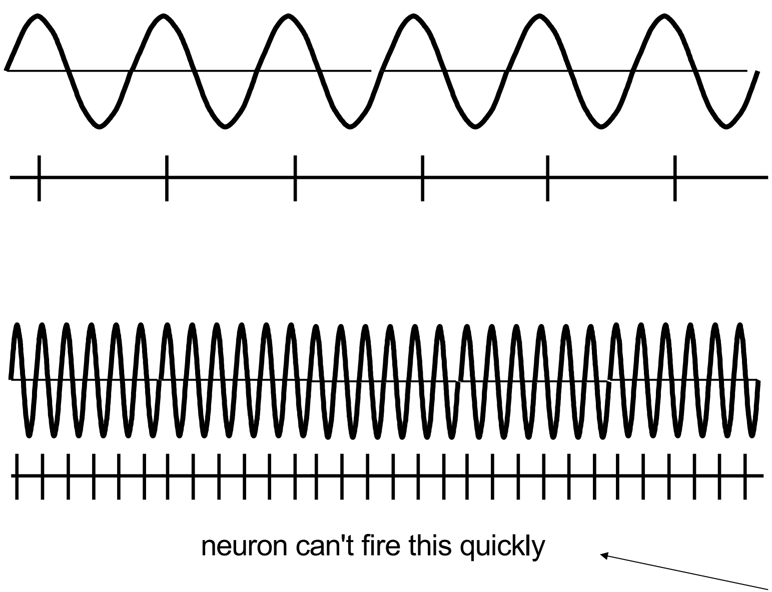

100 Hz

700 Hz

neuron can't fire this quickly

Recall, each spike takes about 2ms
So, ~500Hz

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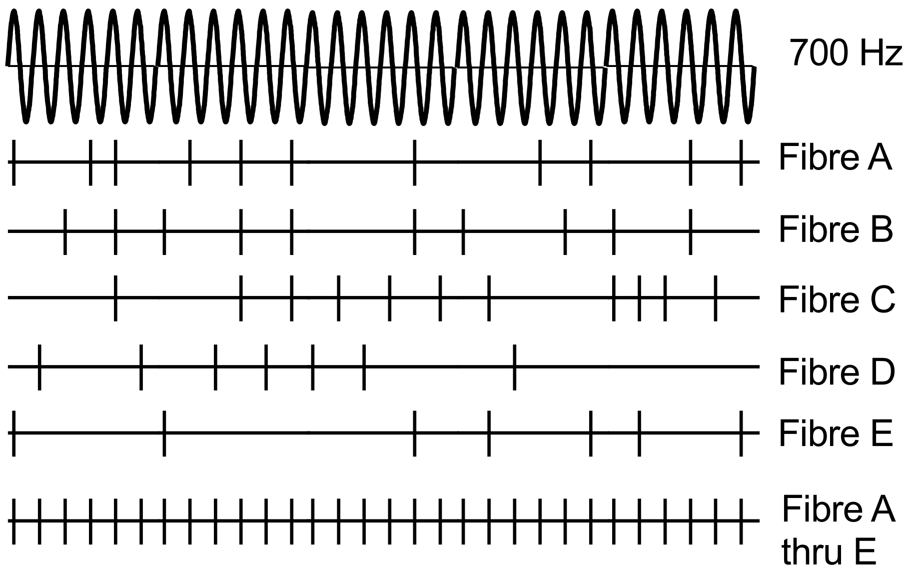

volley principle - high firing rates accomplished by ensembles of nerve fibers

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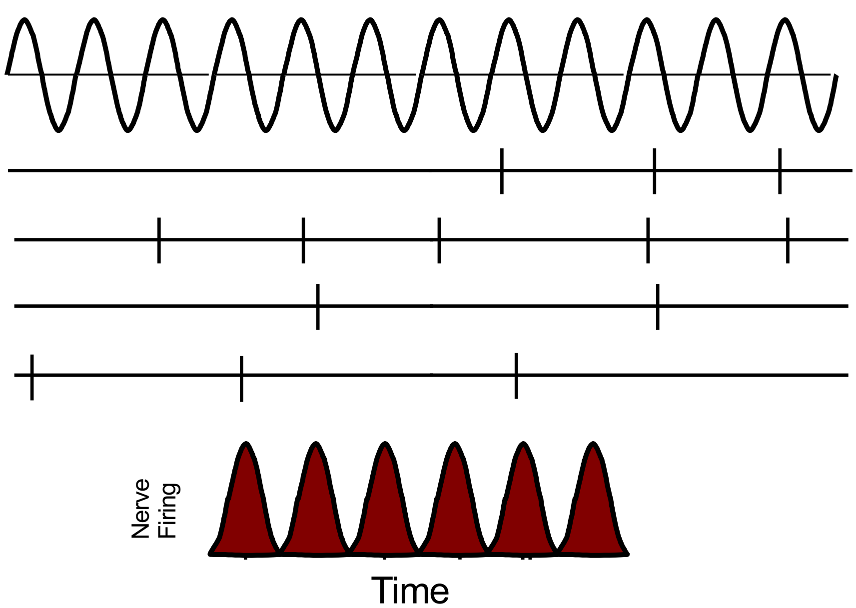

works up to about 4000 Hz

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Two Theories

- <u>Evidence for place theory</u>
  - Physiology

    (cells tuned for frequencies)
- <u>Evidence for temporal theory</u>
  - Multiple cells could do it
  - Phase locking of cells
- <u>Evidence against place theory</u>
  - Missing fundamental (which can be masked)
  - some animals have no basilar membrane
- <u>Evidence against temporal theory</u>
  - cells can't fire fast enough

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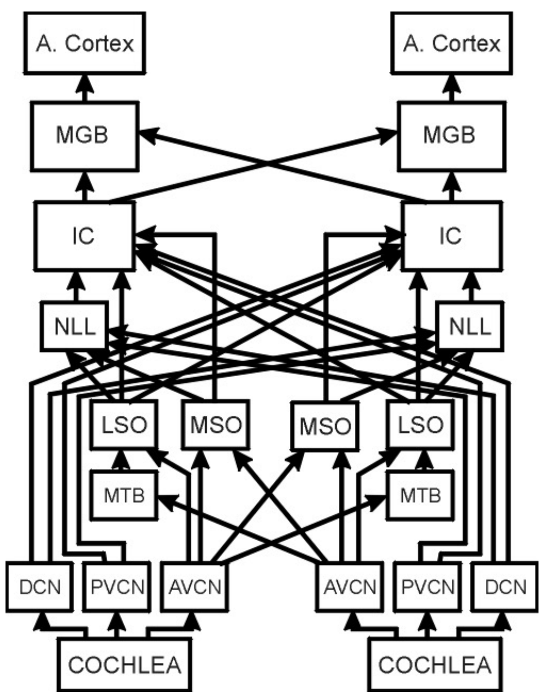

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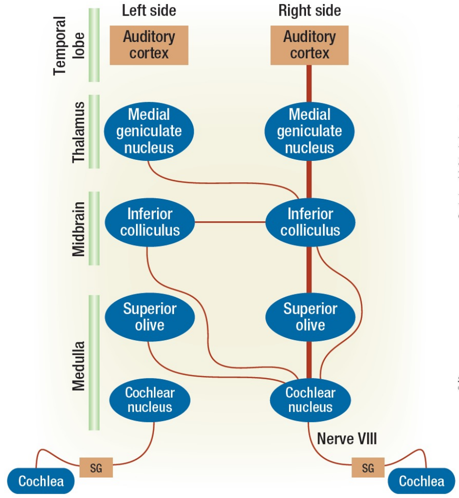
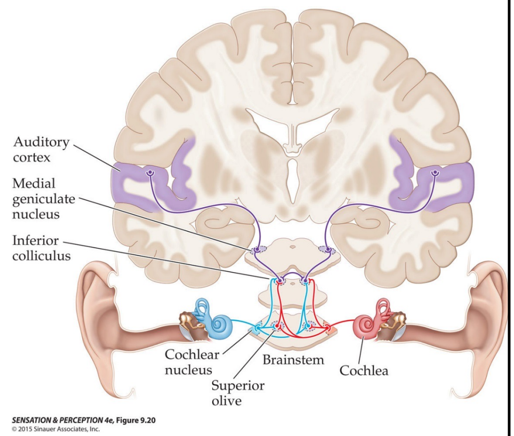
Ascending pathway





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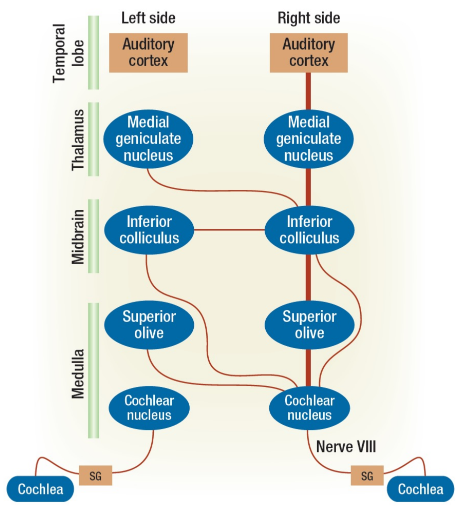
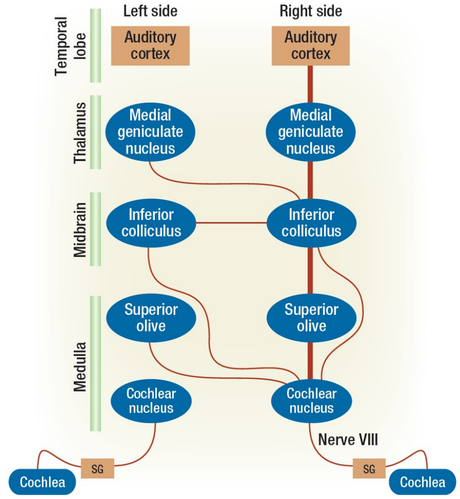
Ascending pathway



- Very complex. Just some major pathways shown.
- Extensive binaural interactions
- General principle:
  - ✓ Increasing complexity of responses (like vision, touch)

53

Ascending pathway



FUNCTION

Identify and process complex sounds

Principle relay to cortex

Form full spatial map

Locate sound sources in space

Start sound feature processing

Sound sensor / periphery

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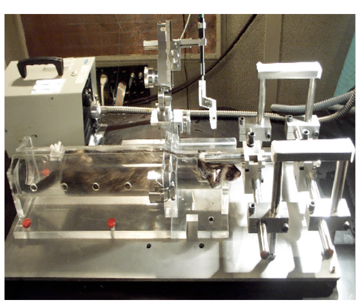
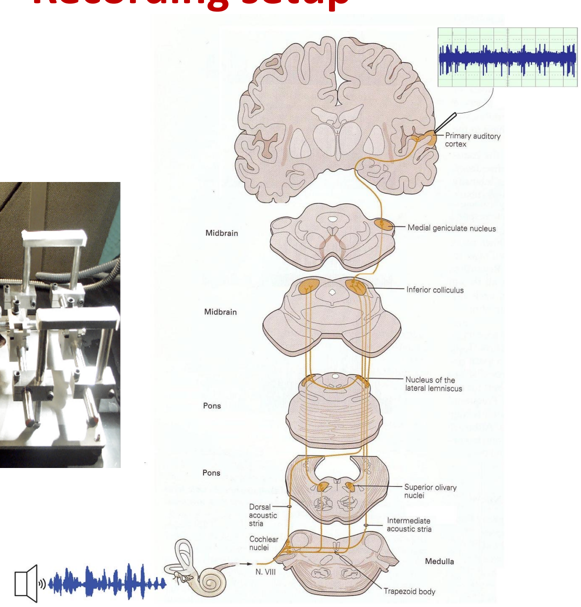
Recording setup





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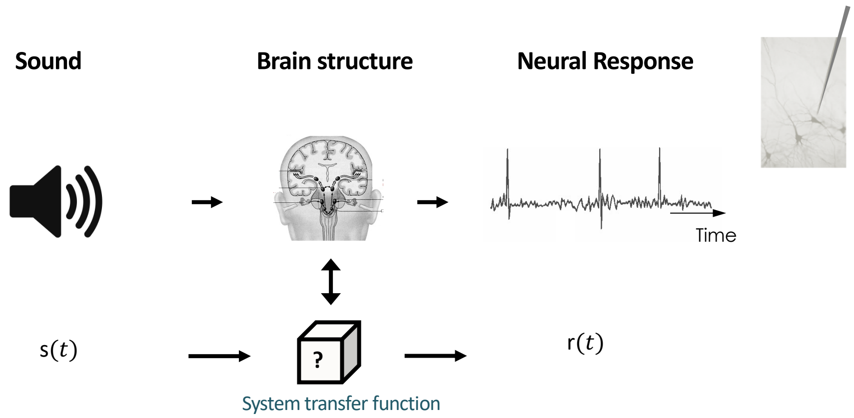
Measuring neural transfer function



$$\mathrm{r}(t) = \int s(t-\tau)h(\tau)d\tau$$

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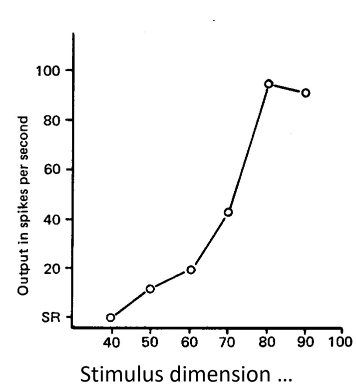
Measuring neural transfer function

- Using appropriately chosen stimuli, we can induce the transfer function of neurons in the auditory system
  - Measure Input-output Function



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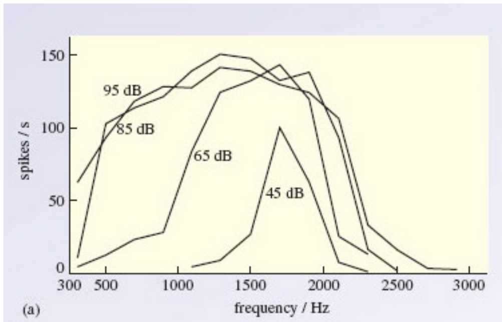
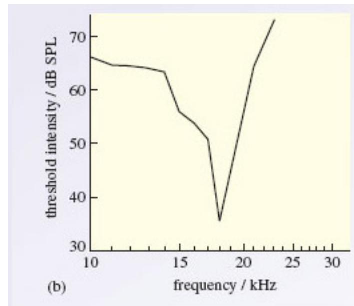
Neural transfer function in 1D

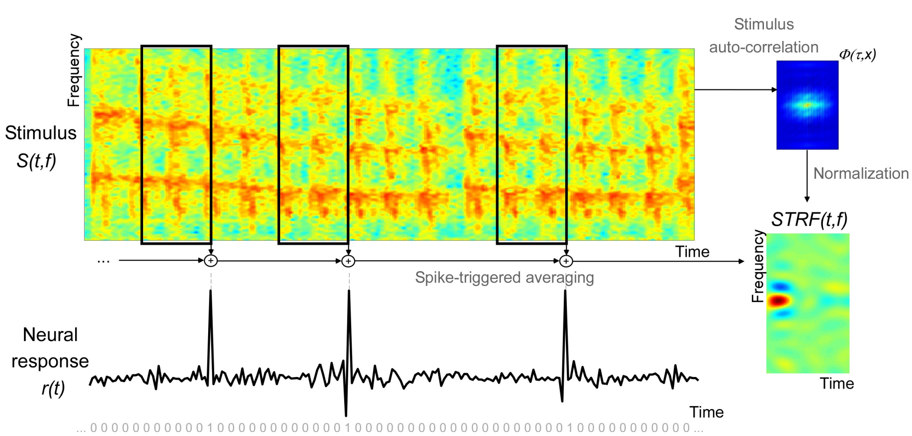


Iso-intensity tuning curves
Neuron fires vigorously to a wider range of frequencies when sound intensity increases



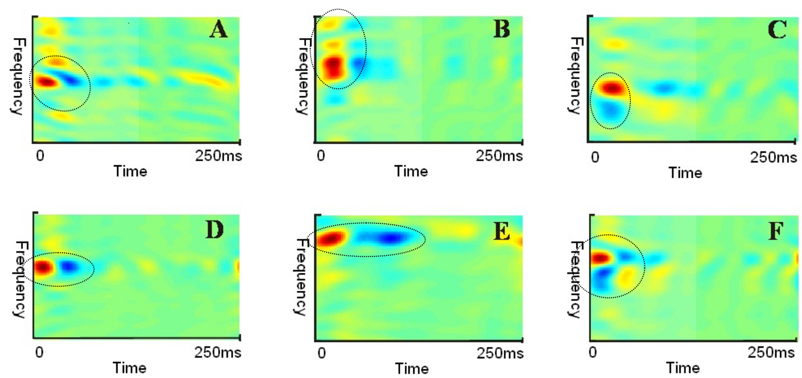
Threshold tuning curve
of an auditory nerve fiber [guinea pig]
(lowest intensity necessary for neuron to fire above its spontaneous rate at each frequency)

Measuring neural transfer function in 2D



2-dimensional response functions in central auditory system (STRFs)

- Different neurons have different transfer functions (Spectro-Temporal Receptive Fields – STRFs).



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Tonotopy

- Tonotopic map:
  - topographic organization (spatial arrangement) of where sound is processed
  - Derived from Greek tono/topos = place of tones

- Most nuclei along auditory pathway from cochlea to A1 are tonotopically organized (inherit *cochleotopy* from periphery)

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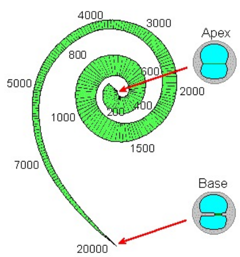
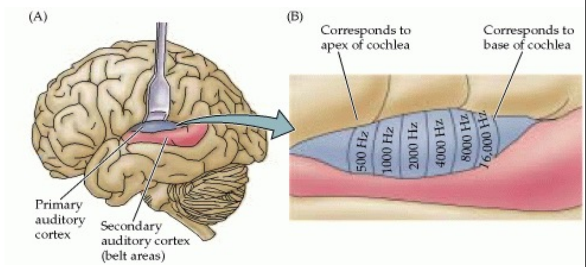
Auditory tonotopy

- Adjacent cells in A1 form a frequency-map, similar to the one observed in the cochlea.



Cochlea



A1

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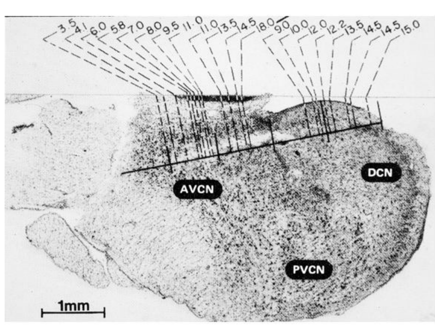
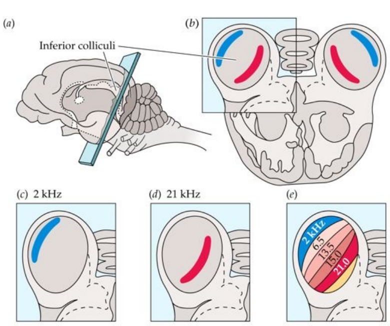
Auditory tonotopy

- Adjacent cells in other auditory nuclei are also organized tonotopically



Cochlear Nucleus



Inferior colliculus

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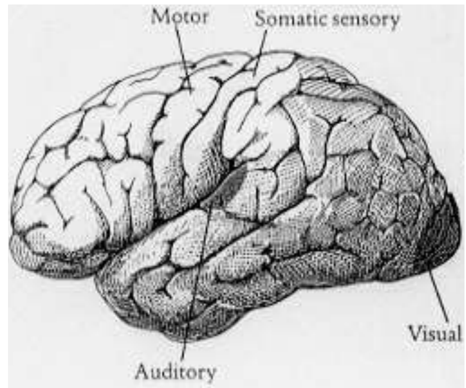
Topography in the brain

- Primary visual cortex (V1) and primary somatosensory cortex (S1) also have topographical maps.
- There are also hints of topographic organization in motor cortex (M1).



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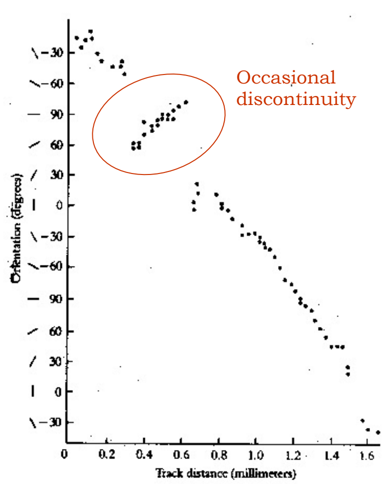
Visual topography

- In V1, cells tuned to similar orientations are physically located in proximity with one another (sometimes called *retinotopy*).
- They are placed vertically below each other in columns perpendicular to the surface of the cortex.



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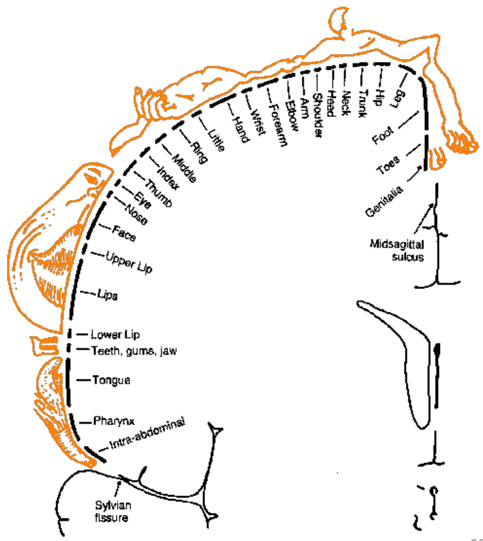
Somatosensory topography

- The cutaneous receptors of the skin project in an orderly fashion through many structures all the way to the primary somatosensory cortex.
- Adjacent areas on the skin are represented by adjacent neurons (map often called *somatotopy*).



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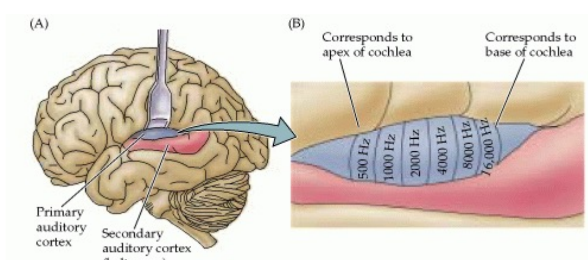
Primary Auditory Cortex (A1)

- Has a precise has a precise topographical map (cochlear map)



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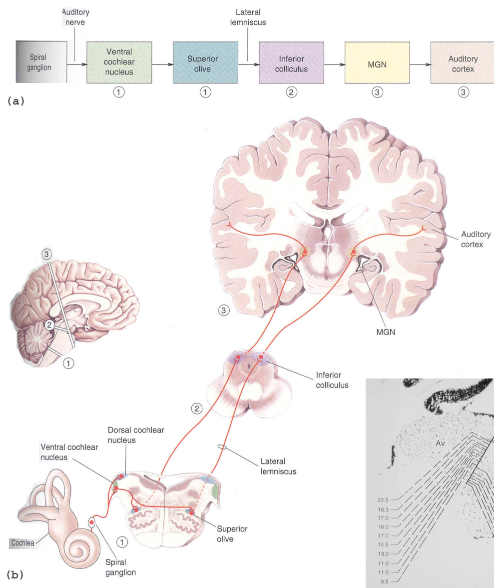
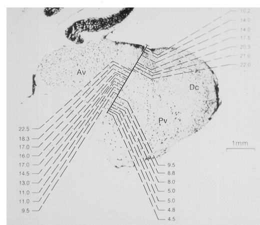
The auditory pathway





- The auditory nerve fibers first reach the cochlear nucleus.
- From there, there is a direct path to the inferior colliculus (IC), then the thalamus (medial geniculate body - MGB), then primary auditory cortex (A1).
- All these stages maintain a tonotopic organization

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The auditory pathway

- Each stage along the auditory pathway extracts complex information from the incoming stimulus
- Very broadly, as you go up the auditory pathway (from periphery – auditory nerve- to midbrain –colliculus- to cortex)
  - Loss of temporal phase-locking
  - Auditory cortex appears to be more sensitive to spectral and temporal modulations of the signal

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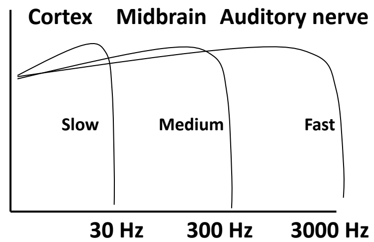
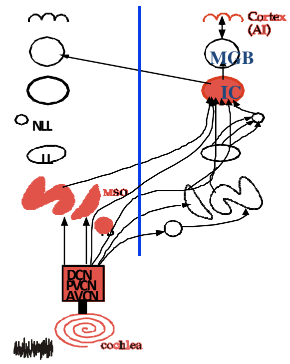
Encoding modulation beyond the cochlea

Range of Temporal modulations





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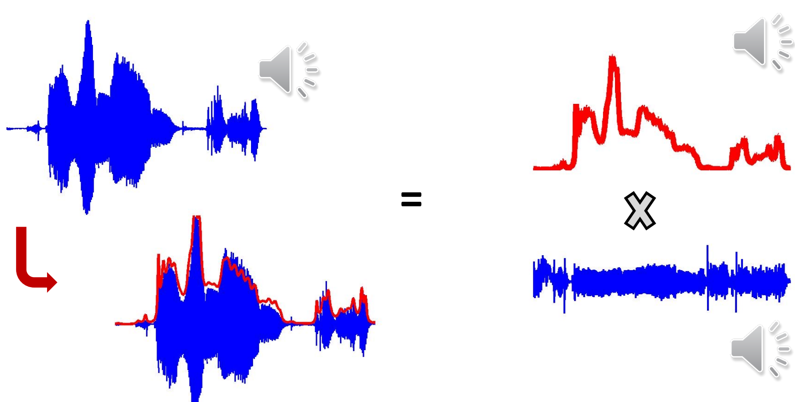
Speech carries information at multiple levels

- Any speech signal can be separated into two signals.



Example of good decomposition…
A non-trivial task

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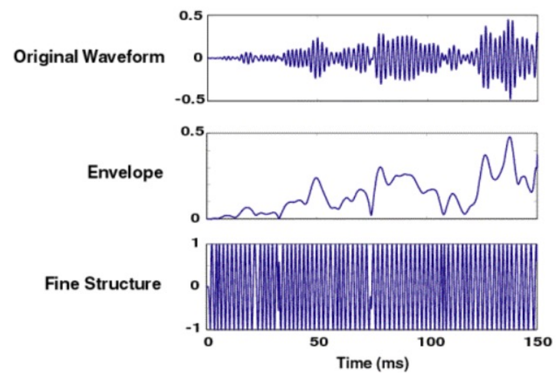
Speech carries information at multiple levels

- Any speech signal can be separated into two signals.
  - The envelope is the amplitude of the sound
  - The fine structure is the detailed waveform, without its envelope



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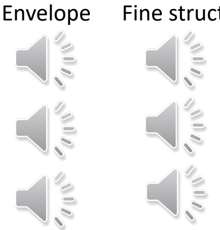
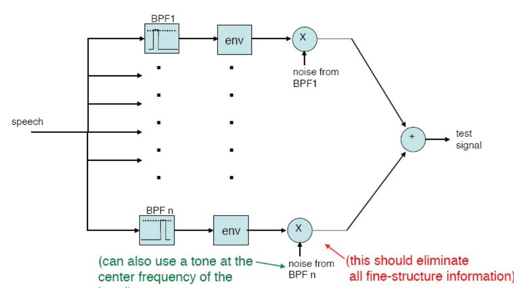
Envelope and Fine structure

- Envelope cues are believed to carry most the information about speech intelligibility (the message in the speech signal)
- Examples of sentences with only envelope or fine structure cues [from: http://research.meei.harvard.edu/chimera/]

	Envelope	Fine structure
2 bands		
4 bands		
16 bands		





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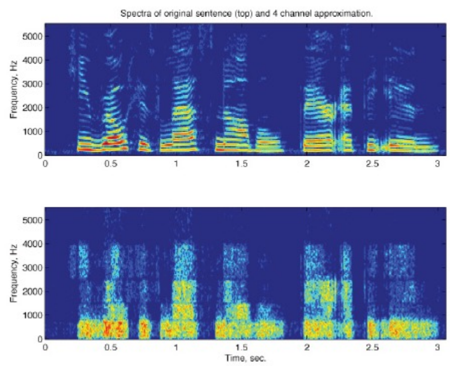
Basis for cochlear implants



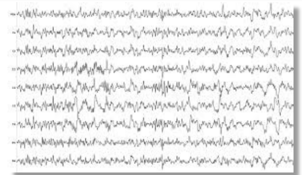
4 channel vocoder

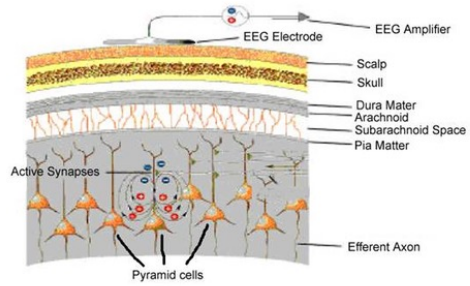
Techniques for probing auditory system

- Brain **imaging** techniques
  - Electroencephalography (EEG) / Magnetoencephalography (MEG)
    - Measures changes in neural activity
    - Good temporal resolutions, bad spatial resolution
  - Magnetic resonance Imaging (MRI) / Functional MRI (fMRI)
    - Good spatial resolution / bad temporal resolution
  - Others
    - Nuclear Magnetic Resonance (NMR)
    - Near-infrared spectroscopy (NIRS) -> good for surface areas
    - Positron omission topography (PET)
    - Multi-modal imaging (MMI) -> mixture of scanning techniques

EEG

- EEG is a scalp recording technique
  - Pain-free
  - Non-invasive
  - electrodes are placed on a person's skull.
- EEG measures differences in electrical potential between electrodes.
- As neurons communicate with each other (using electrical signals), they cause voltage differentials.
- EEG cannot pick contribution of individual neurons; but picks up firing of few thousand neurons firing simultaneously.
- This signal is the amplified to give the final readout.





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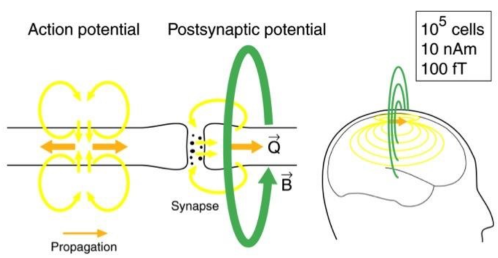
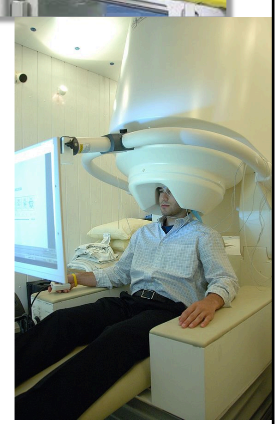
MEG

- MEG works on similar principles as EEG, but records the magnetic field created by electrical activity due to neural communication
- Arrays of SQUIDs (superconducting quantum interference devices) are used as magnetometers





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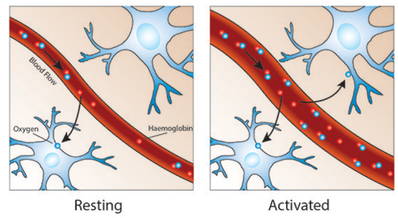
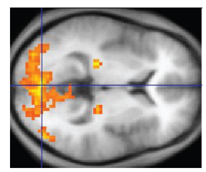
fMRI

- Functional magnetic resonance imaging (fMRI) measures brain activity by detecting changes associated with blood flow.
  - Since blood oxygenation varies according to the levels of neural activity these differences can be used to detect brain activity.
  - This form of MRI is known as blood oxygenation level dependent (BOLD) imaging.
- fMRI results in activation maps





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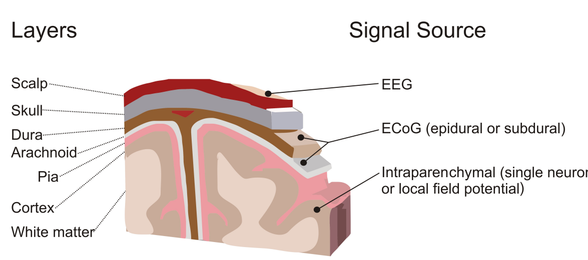
Techniques for probing auditory system

- Finer recording techniques (invasive)
  - Electro-corticography (eCoG)
  - Single-unit Electrophysiology
    - Extracellular
    - Intracellular
  - Local field potentials (LPFs): activity across ensemble of neurons



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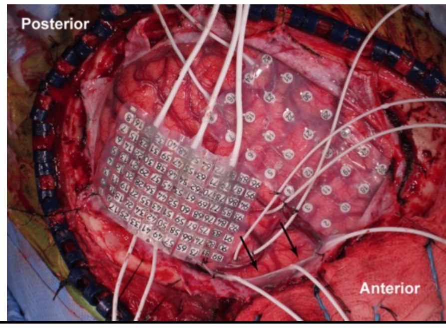
ECoG

- ECoG is also called intracranial electroencephalography (iEEG)
- It uses electrodes placed directly on the exposed surface of the brain
- Typically done for clinical reasons with patients with epilepsy or prior to brain surgeries



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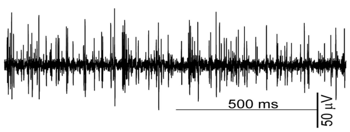
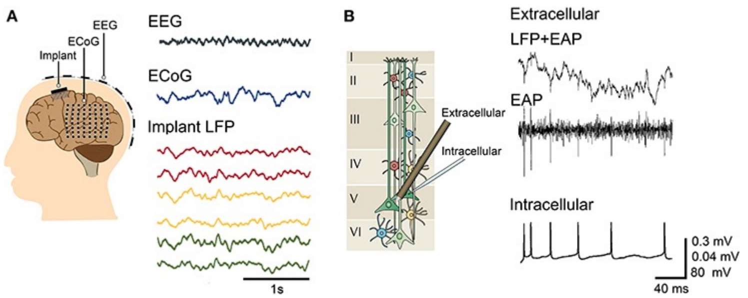
Single-unit physiology

- Can be extra-cellular or intra-cellular recording of activity of single neuron.





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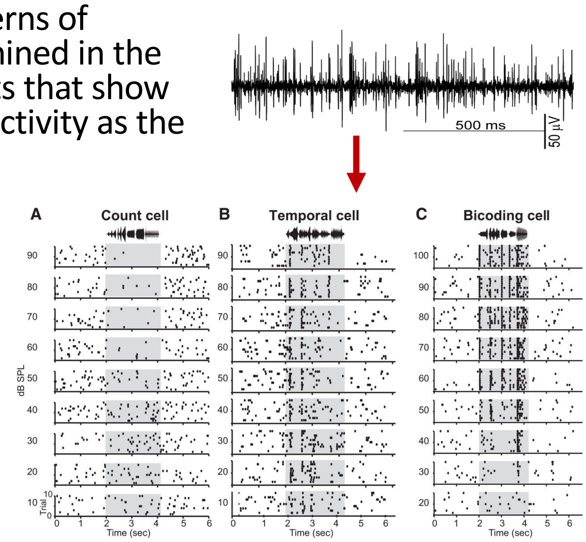
Single-unit physiology

- Spikes (firing patterns of neurons) are examined in the form of raster plots that show change in neural activity as the stimulus changes



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Mathematical auditory models

- Two main groups:
  - Peripheral models
    - mimic cochlear early processing
  - Central models
    - Mimics higher processing stages

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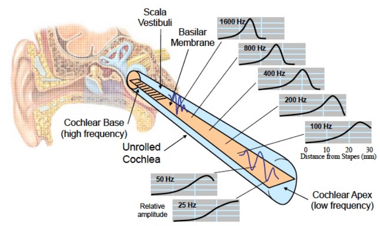
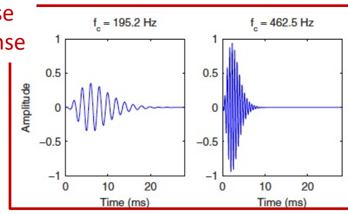
Peripheral model

- Recall frequency tuning of basilar membrane



  - Popular implementations:
    - Gammatone filterbank

Impulse response



A **gammatone filter** is a linear filter.
The impulse response is the product of
a gamma distribution and sinusoidal tone.

$$g(t) = at^{n-1}e^{-2\pi bt}\cos(2\pi ft + \phi)$$

Center frequency

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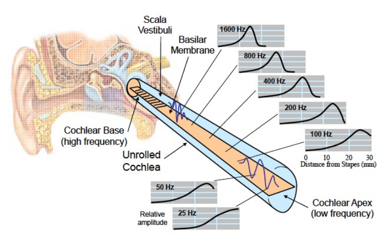
Peripheral model

- Recall frequency tuning of basilar membrane



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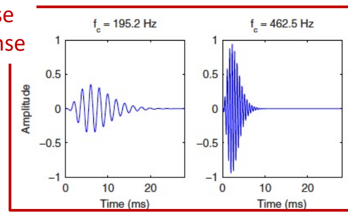
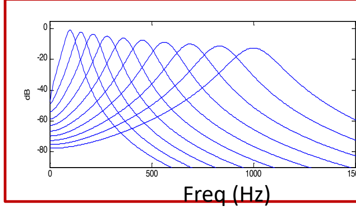
    - Gammatone filterbank

Impulse response





frequency response

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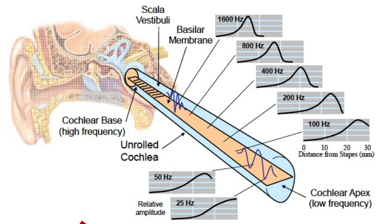
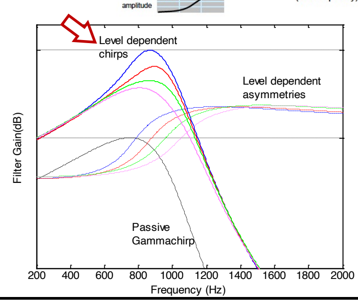
Peripheral model

- Recall frequency tuning of basilar membrane



  - ➢ Popular implementations:
    - Gammatone filterbank
    - Gammachirp filterbank
      - adds a level-dependent correction to Gammatone response



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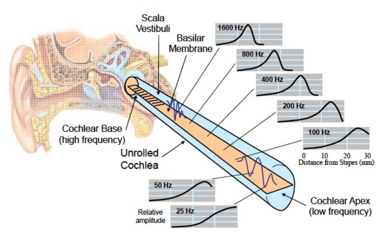
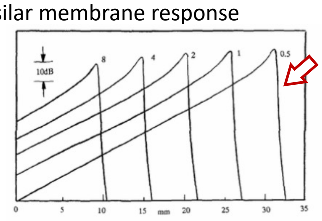
Peripheral model

- Recall frequency tuning of basilar membrane



  - ➢ Popular implementations:
    - Gammatone filterbank
    - Gammachirp filterbank
    - Nonparametric fits to basilar membrane response



Emphasize asymmetric roll-off

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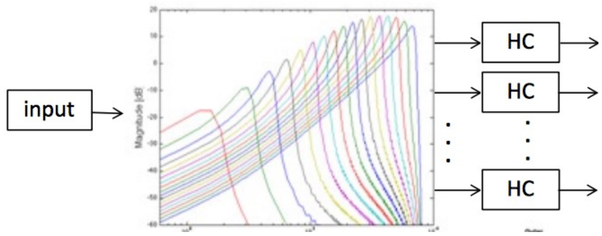
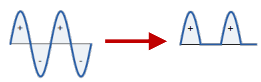
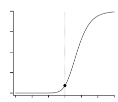
Peripheral model



- The basilar membrane filtering is often followed by nonlinear operations mimicking Hair Cell (HC) mechanisms; e.g.
  - Half-wave rectification 
  - Nonlinear compression 
  - Or, even feedback from outer hair cells

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Many models available

- Basic Gammatone implementation
  - Auditory toolbox: https://engineering.purdue.edu/~malcolm/interval/1998-010/
  - Python/Matlab versions:

  https://www.audiocontentanalysis.org/code/helper-functions/gammatone-filterbank-2/
- Peripheral model
  - https://www.urmc.rochester.edu/labs/carney/publications-code/auditory-models.aspx

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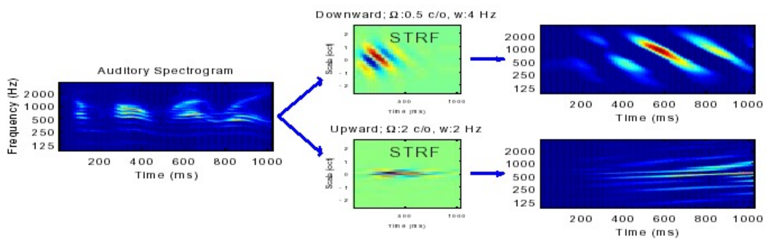
Central models

- Few models explore cortical processes.
- One model uses a filterbank (wavelet) idea to mimic spectrotemporal receptive fields (STRFs)



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Central models

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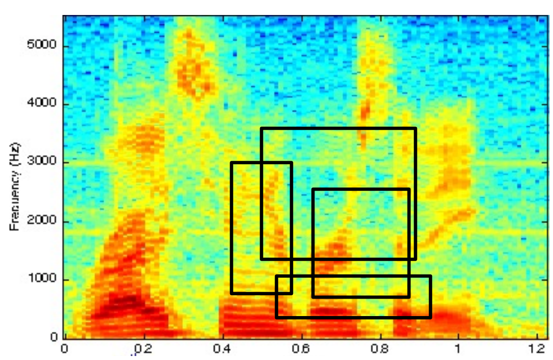

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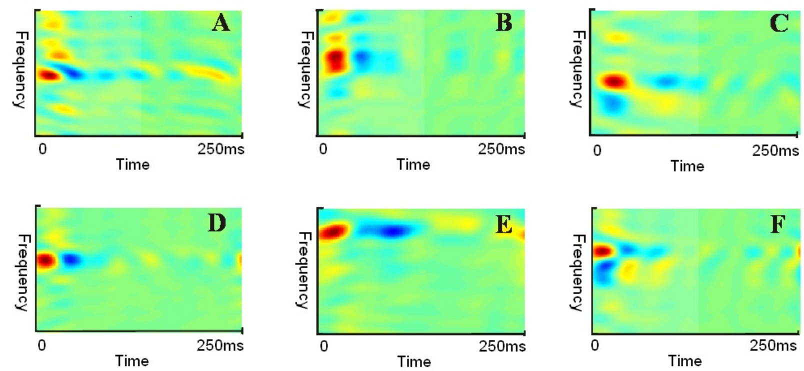
Cortical STRFs

- Different neurons have different transfer functions (Spectro-Temporal Receptive Fields – STRFs).



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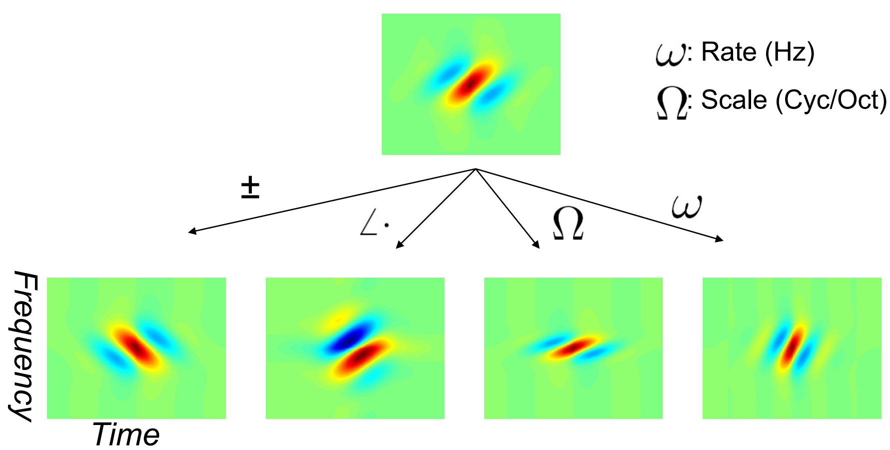
Model STRFs vary along several dimensions

$$STRF_{\pm}(t, f; \omega, \Omega)$$



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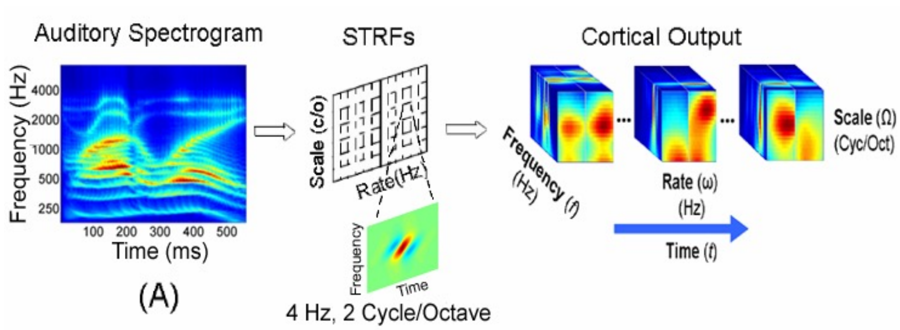
Cortical processes



$$y(t,f) \quad \underset{\text{2D convolution}}{*} \quad STRF_{\pm}(t,f;\omega,\Omega) \quad = \quad cr(t,f;\omega,\Omega)$$

Cortical output: 4D representation $\in \mathbb{C}$

MATLAB code at http://www.isr.umd.edu/Labs/NSL/Software.htm

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Hearing prosthetics

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When hearing fails …

- Lose some sounds (usually consonants)
- Tinnitus (ringing in the ears)
- Can't Hear in Noise
- Loss of Localization
  - Don't Know Where Sound is Coming From
  - Can't Suppress Unwanted Sounds

➡ **When untreated**

- Sadness and depression
- Worry and anxiety
- Paranoia
- Less social activity
- Emotional turmoil and insecurity

(National Council on Aging)

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When hearing fails …

- U.S. population 270+ million
  - 2 million Deaf
  - 26 million Hard of Hearing
- 1 in every 10 people has a hearing loss
- Over age 65, 1 in every 3 persons has some degree of hearing loss
- Hearing aids can help about 95% (26 million) of them, only 6 million use hearing aids.
  - Stigma with wearing a Hearing Aid
  - Denial
  - Cost (order of $10K)
  - Meeting expectations

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Common Causes of Hearing Loss

- Acoustic Trauma (Noise)
- Age related
- Genetic
- Ototoxic Drugs
- Illness; e.g.
  - Autoimmune Disease
  - Meniere's Syndrome
  - Acoustic Neuromas

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Type of Hearing Loss

- 4 Types of Hearing Loss.
  1. Conductive: Sound is not transmitted efficiently from the outer ear to the cochlea.
  2. Sensorineural: Hearing loss due to damage to the cochlea or nerve endings in the inner ear.
  3. Mixed: Combination of Conductive and Sensorineural hearing loss.
  4. Unilateral hearing: Hearing in one ear, Hearing loss in the other.

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Hearing prosthetics

1. **Hearing aids:**
   – Are communication aids; intended for subjects with mild to severe hearing loss. They help a person hear better, but won't return hearing to normal levels.
   – Technically, not a prosthetic device; but a sensory aid.

2. **Cochlear implants:**
   – Are prosthetic replacements for the inner ear (cochlea)… only appropriate for people who receive minimal or no benefit from a conventional hearing aid.

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Hearing Aids

- Hearing aids help a person hear better, but it won't return hearing to normal levels.
- Generally boost all sounds, not just those the person wishes to hear.
- While the aid amplifies sound, it doesn't necessarily improve the clarity of the sound.
  – Monaural = a hearing aid for one ear.
  – Binaural = for two ears.

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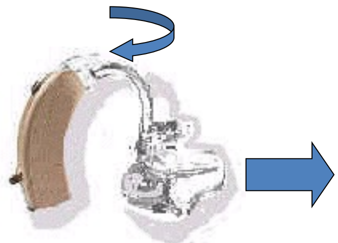
Common Design Principles for Hearing Aids

1. Sound goes in the Microphone.
2. Sound gets amplified.
3. Sound comes out the Speaker into your Ear



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Common Design Principles for Hearing Aids

- A **microphone** to convert sound into electricity.
- An **amplifier** to increase the strength of the electrical signals and alter the balance of the sound.
- A **receiver** to turn electricity back into sound: converts the processed signals back into sound waves and directs them into the ear

A **battery** to provide the power needed for the amplifier.

Additional features can be added to certain aids.

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Hearing Aid specifics

- Style (Small vs. Big, location)
- Technology (programmable, Digital)
- Features (More is better?)
- Settings ('prescription')

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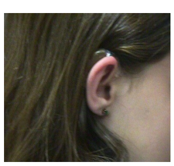
Types of Hearing aids

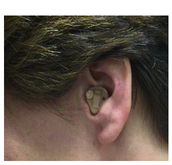


Behind The ear

BTE

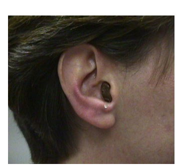
In the Ear

ITE



In the Canal

ITC



Completely in the canal

CIC

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Hearing Aid Technologies

Analog HA

- Pick up sound and convert it into electrical signals.
- Non-programmable.
- Less-expensive.

Digital Programmable HA

- Settings are processed digitally, Sound is processed via analog technology.

Digital HA

- Newest technology- a computer chip processes the sound, separating unwanted sound from the desired speech information.
- Adapts to changes in the listening environment automatically.

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Features

- Volume Control
- Telecoil
- Multiple Microphone Directionality
- Compression
- Clipping
- Direct Audio Input
- FM
- Programmability
- Speech Enhancement/Noise Reduction
- Frequency Shifting
- Earmold/Vent
- Remote Control

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COCHLEAR IMPLANTS

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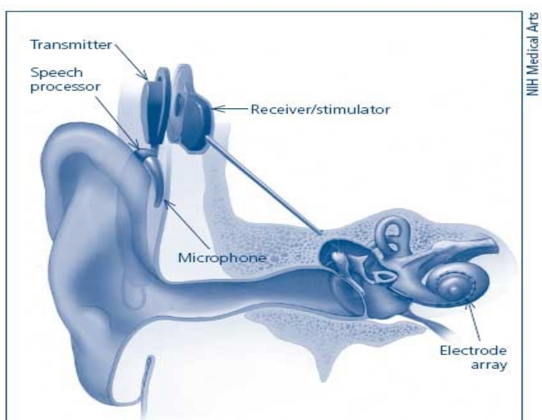
Cochlear Implants

- Cochlear implants bypass damaged parts of the inner ear and electronically stimulates the nerve of hearing.
- Part of the device is surgically implanted in the skull behind the ear and tiny wires are inserted into the cochlea.



Ear with cochlear implant

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Design principles for Cochlear Implant

- A **microphone**, which picks up sound from the environment;
- A **speech processor**, which selects and arranges sounds picked up by the microphone;
- A **transmitter** and **receiver/ stimulator**, which receive signals from the speech processor and convert them into electric impulses;
- **Electrodes**, which collect the impulses from the stimulator and send them to the brain.

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Function of Cochlear Implants

1. Sound is received by a microphone that rests over the ear like a behind-the-ear hearing aid (surgery).
2. Sound is sent from the microphone to the signal processor by a thin cable.
3. Signal processor translates the sound into electrical codes.
4. Codes are sent by a thin cable to the transmitter held to the scalp by its attraction to a magnet implanted beneath the skin.

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Function of Cochlear Implants (cont'd)

5. Transmitter sends codes across the skin to a receiver/stimulator implanted in the mastoid bone.
6. Receiver/stimulator converts the codes to electrical signals.
7. Electrical signals are sent to the specified electrodes in the array within the cochlea to stimulate neurons.
8. Neurons send messages along the auditory nerve to the central auditory system in the brain where they are interpreted as sound.

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