Central Auditory System Basics and the Effects of Abnormal Auditory Input to the Brain

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Overview

Auditory system tasks
Peripheral auditory system
Central pathways
  - Ascending (afferent)
  - Descending (efferent)
  - Neuron basics
  - Synapse basics
Areas affected by damage
Examples of specific effects
Effects of descending inputs
Recap
Future directions
Auditory System Tasks

• Analyze and encode physical aspects of sound: timing, frequency, intensity
• Transform acoustic cues into percepts:
  – Where is the sound coming from?
  – What is the sound?
  – What does the sound mean?
Peripheral auditory system

The most important structures of the ear:
- sensory cells (hair cells)
- neurons (auditory nerve)

These cells change mechanical vibrations from the eardrum and ossicles (ear bones) into information that the brain can understand.
Damage to the peripheral auditory system

We typically think about hearing loss in terms of damage to the hair cells.
Damage to the peripheral auditory system

New studies have shown that the neurons contacting the hair cells can suffer damage even when hair cells remain intact.
Central auditory system: Ascending pathways

- Auditory Cortex
- Medial Geniculate Nuc.
- Inferior Colliculus
- Lateral Lemniscal Nuclei
- Superior Olivary Complex
- Cochlear Nucleus
- Ear

Cortex
Midbrain
Cochlea & brainstem
Central auditory system: Descending pathways

- Auditory Cortex
- Medial Geniculate Nuc.
- Inferior Colliculus
- Lateral Lemniscal Nuclei
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Cortex
Midbrain
Cochlea & brainstem
The patterns of damage in the cochlea affect auditory neurons of the brain.

These effects may occur at many levels of the auditory system.

The changes that occur depend on the area, the type of brain cell affected, and the part of the cell affected.
Neurons are the building blocks of all of these brain structures.

Neurons communicate via electrical and chemical signals.
Synapse basics

Neurons transmit information from one cell to another via chemical messages sent at junctions called synapses.
Examples of the effects of hearing loss on neurons in the brain
Cochlear nucleus

CN is the first stop for auditory information entering the brain.

Diverse types of neurons in different regions process acoustic cues.
Large auditory nerve synapses in cochlear nucleus: Endbulbs

Endbulbs form synapses with bushy cells.

Fast, hi-fidelity transmission of information.

Adapted from Osen, 1969

Endbulbs of Held
Endbulbs are abnormal in deaf animals

Normal Hearing Cats
Branched, very complex

Deaf White Cats
Less branched, less complex

Ryugo & colleagues (1996-present)
Balance of excitatory and inhibitory input to auditory neurons is disrupted

Inputs to auditory neurons in the brain receive excitatory and inhibitory input from multiple sources.

Normally, these inputs are carefully balanced to promote normal processing.

Ryugo & colleagues; Morest & colleagues (1996-present)
Balance of excitatory and inhibitory input to auditory cells is disrupted

Ryugo & colleagues; Morest & colleagues (1996-present)

Hearing loss causes these inputs to become unbalanced, leading to abnormal processing.
Effects of descending inputs: The olivocochlear system

Descending input from brainstem to cochlea:
- Reduces cochlear output when activated
- May help us adjust to noisy backgrounds
- Helps to protect the ear from noise damage
Effects of descending inputs: The olivocochlear system

Damaged or weak olivocochlear systems can result in:
- Increased susceptibility to hearing loss from noise
- Difficulty discriminating some sounds
- Abnormal synapses in the cochlear nucleus and possibly elsewhere

Work by May, Lauer, and many others
Abnormal organization of olivocochlear synapses on hair cells

MOC efferent terminals disappear from outer hair cells.

Fu et al. (2010). *Molecular Neurodegeneration*
Many efferent terminals move to contact inner hair cells directly.

Lauer, Fuchs, Ryugo, Francis (2012). *Neurobiol. of Aging*
Recap

- Hearing loss is caused by damage to sensory receptors and neurons
Recap

- Hearing loss is caused by damage to sensory receptors and neurons
- Hearing loss affects many brain regions
Recap

• Hearing loss is caused by damage to sensory receptors and neurons
• Hearing loss affects many brain regions
• Hearing loss causes reorganization of the connections between neurons
Recap

- Hearing loss is caused by damage to sensory receptors and neurons
- Hearing loss affects many brain regions
- Hearing loss causes reorganization of the connections between neurons
- Descending inputs from brain to ear affect hearing loss
Future Directions

There is still so much to investigate!

- More details about structural changes
- How do structural changes relate to perceptual changes associated with hearing loss such as abnormal loudness perception, difficulty hearing in noise, tinnitus?
- How can we prevent changes to the brain or promote recovery?
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