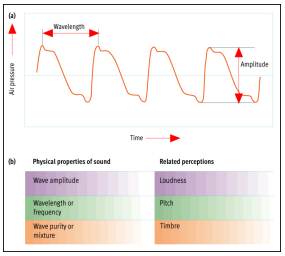
Sound Perception

- Similarities between sound and light perception
- Characteristics of sound waves
  - Wavelength = Pitch
  - Purity = Timbre
  - Amplitude = loudness

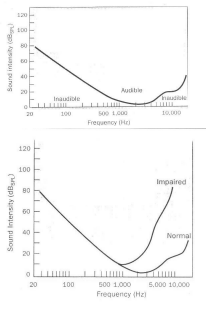


Sensitivity to Sound

- Not physically sensitive to all possible sound frequencies
- Range
  - Low: 20 Hz
  - High: 20,000 Hz

Sensitivity to Sound

- Sounds at boundaries difficult to hear
- Profile used for diagnosis



Subjective Experience of Frequency

- Middle C = 261.62 Hz
- TV whine = 15,750 Hz
- Adult human speech
  - 200 Hz to 8,000 Hz
  - Most sensitive to sounds with this frequency

Resonant Frequency

- Sound can cause solid objects to vibrate
  - Shattering wineglass with high note
  - Windows rattling from thunderclap
- Resonant frequency
  - The frequency at which an object vibrates when set into motion

Resonant Frequency

- Ringing sound when glass struck by spoon
  - Sound corresponds to resonant frequency of glass
  - Occurs because glass molecules are vibrating
- Resonant frequency depends on size and rigidity of object

Amplitude

- As amplitude increases, perceived loudness increases
- Amplitude/loudness measured in decibels
- Perceived loudness
  - Doubles every ten decibels

Psychological Consequences

- Perceived loudness can have psychological consequences
- Tasks requiring alert performance
  - Suffer in noisy surroundings
- Living with continuous noise
  - Suffer elevated stress-related disorders

Glass & Singer (1972)

- Had people perform various tasks
  - Varied loudness
  - Varied predictability
- Adapted to noise
  - Later exposure to unpredictable loud noise affected performance
- Noise is stressful when unanticipated or uncontrolled

Purity

- Purity = timbre
- Purest sounds consist of a single frequency of vibration
- Most sounds are a mixture of wavelengths

Differences in Sound Purity

- Differences are useful for identifying sounds
- Are not enough pure tones we can perceive to uniquely specify important sounds
- Voice recognition dependent on unique wavelength "signature"

Pinna

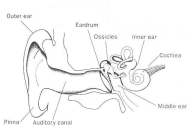
- Sound collecting cone
- Many animals have rotating pinnas
- Curves and folds act like reflecting surfaces
  - Color complexity of sound entering ear
  - Degree of coloration depends on direction of sound
- Aids in ability to localize sound

The Location of Sound

- Ear placement allows us to hear "in depth"
  - Sound localized on left side
    - Left ear receives a more intense sound
    - Left ear receives sound sooner
- Intensity and time differences are VERY small
- Pinna aides in sound localization

Eardrum

- Vibrates in response to sound waves
- Very sensitive
  - Whisper displaces eardrum $.10^{-7}$ cm
- Very sturdy
  - Resembles umbrella with framework of supporting ribs

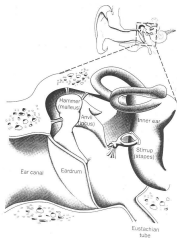


Middle Ear

- Depends on the vibration of moveable bones
- Smallest bones in the body
- Collectively known as the ossicles
  - Hammer
  - Anvil
  - Stirrup

Purpose of Ossicles

- Inner ear filled with fluid
- Sound does not travel well between air and fluid
- Ossicles funnel vibrations
  - From eardrum to oval window
  - Amplify the sound energy

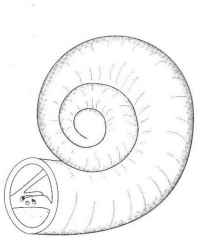


Inner Ear

- Sound perception
  - Depends on waves in a fluid
- Cochlea
  - Contains receptors for hearing
- Oval window
  - Passage from middle ear to inner ear
  - Vibrated by ossicles

Basilar Membrane

- Lies within cochlea
- Divides cochlea into upper and lower chambers
- Holds the auditory receptors
  - Hair cells

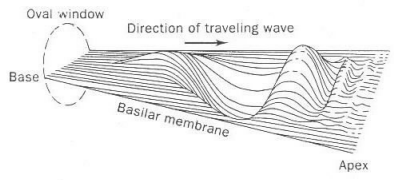


Hair Cells

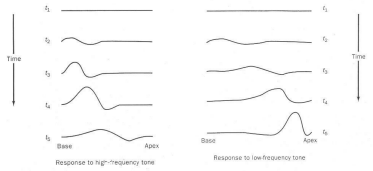
- Transform sensory information into nerve impulses
- Stimulated by waves in inner ear
  - Trigger impulses in adjacent nerve fibers
  - Nerve fibers converge to form auditory nerve
- Neural impulses sent to brain
- Routed through thalamus to auditory cortex

Place Theory

- Theory of pitch perception
- Corresponds to vibrations of basilar membrane



Place Theory



- George Bekesy (1957)
- High pitched sounds
  - Hair cells near beginning of basilar membrane stimulated
- Low pitched sounds
  - Hair cells on other areas of basilar membrane stimulated

Problems with Place Theory

- Not as accurate predicting perception of low pitches
- Neural signals generated by low pitches
  - Not neatly localized on basilar membrane
- Resulted in proposal of frequency theory

Frequency Theory

- Perception of pitch
  - Depends on rate of vibration of entire basilar membrane
- Whole membrane vibrates
  - Brain detects tone frequency by rate at which auditory nerves fire

Problems with Frequency Theory

- Has trouble explaining perception of high pitch tones
- Individual neurons
  - Max firing rate of 1000 times per second
- Can perceive sounds with frequencies above 1000 waves per second

Resolution

- Both theories are partially correct
- Frequency theory
  - Hair cells vibrate in unison
  - Pattern of vibration is a wave
- Place theory
  - Wave peak depends on frequency of wave

Resolution (continued)

- Sounds under 1000 Hz
  - Translated into pitch through frequency coding
- Sounds between 1000 and 5000 Hz
  - Depend on a combination of frequency and place coding
- Sounds over 5000 Hz
  - Translated into pitch through place coding

Deafness

- Conduction deafness
  - Problems with the mechanical system conducting sound to the cochlea
- Nerve Deafness
  - Damage to hair cells
  - Occasionally caused by disease
  - Biological changes associated with aging

Repairing Nerve Damage

- Hearing aid
  - Does not repair nerve damage
  - Amplifies signals to activate other hair cells
- Stimulating hair cell regeneration
  - Guinea pigs & rats
- Cochlear implant
  - Bionic ear

Cochlear Implant

- Translates sounds into electrical signals
- Signals wired into cochlea's nerves
- Convey some information about sound to the brain

Deaf Culture

- 90% of deaf children have hearing parents
  - Parents support cochlear implants
- National Association of the Deaf take pride in culture and language
  - Object to using implants on children deafened before learning to speak
    - Deafness is not a disability
    - Signers are not linguistically disabled

Deaf Experience

- Most people experiencing deafness consider it to be a disability
  - Especially true for those who have experienced hearing
- 9% of people experience hearing loss
  - 1% of these 9% were born deaf
- Hearing loss is the most common of disabilities
  - 17-20 million people

Deaf Experience

- Describe experience as "frightening"
- Isolates the individual
  - From others
  - From the security of life's background hum
- People frequently find hearing loss to be socially disabling

Social Consequences of Hearing Loss

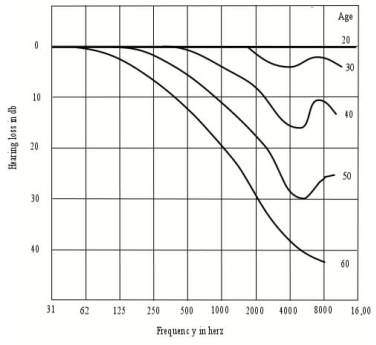
- Struggle to coordinate play
- Adolescents may experience low self-confidence
- Adults experience social shyness
  - Withdraw from stress of trying to communicate

Educational Consequences for Deaf Children

- Schooling
  - 1/4 attend residential schools
  - 2/4 attend special education programs in public schools
  - 1/4 are mainstreamed into regular classrooms
    - Sometimes have the help of interpreters
- All face challenges
  - Academic subjects and instruction are rooted in spoken language

Age and Hearing Loss

- Most common (inevitable?) cause of hearing loss is age
- Gradually lose sensitivity to high frequencies
  - 30 years old
    - Unable to hear frequencies above 15,000 Hz
  - 50 years old
    - Unable to hear frequencies above 12,000 Hz
  - 70 years old
    - Unable to hear frequencies above 6,000 Hz
- Gender
  - Men exhibit larger degree of hearing loss



Hypothesized Causes

- Loss of elasticity in cochlea
- Changes in vasculature
  - Change in blood flow
  - Inner ear does not receive enough blood
- Cumulative exposure to loud noise

Cumulative Exposure to Loud Noise

- Cross cultural studies
  - Normal hearing
    - 70 year olds
    - African tribal population living in natural environments

Noise and Hearing Loss

- Loud noises can damage receptors in inner ear
- Sudden explosive noise
  - Explosions can produce sudden, permanent damage
  - Small explosions can cause a major loss in hearing
    - Gunfire

Sustained Loud Noises

- Loud Music
  - Headphones
- Contribute to high incidence of hearing loss in college students
- Some estimate 60% of students affected

Sustained Loud Noises

- Rock concerts and clubs
  - Loud amplified music
  - Contributes to permanent hearing loss

Hanson & Fearn (1975)

- Group 1
  - Attended at least 1 rock concert a month
- Group 2
  - Never attended rock concerts
- Measured pure tone threshold
- At frequencies tested (500 - 8,000 Hz)
  - Group 1 had higher pure-tone thresholds
    - Differences btwn groups was small but reliable
    - Those in Group 1 were entirely unaware of their deficits

Chronic Noise Exposure

- Occupational hazard for many
  - Assembly plants
  - Airports
  - Construction sites
- Permanent increase in pure-tone thresholds
- Higher rates of accidents
  - Unable to hear warning shouts?

Drugs and Hearing Loss: Nicotine

- Chronic cigarette smokers
  - Higher pure-tone thresholds than non-smokers
- Loss more pronounced at higher frequencies

Drugs and Hearing Loss: Nicotine

- Loss probably due to poor circulation
  - Narrows ear's blood vessels
  - Makes blood pressure irregular
- These effects reduce blood supply to the cochlea

Drugs and Hearing Loss: Aspirin

- Normal dose
  - 1/4 grams in one typical aspirin
- Large doses
  - 4-8 grams daily
    - Typical dose prescribed for patients with rheumatoid arthritis
  - Can produce temporary hearing loss

Drugs and Hearing Loss: Aspirin

- 10-40 dB shift in pure tone thresholds
  - Loss more pronounced at higher frequencies
- Often accompanied by tinnitus
  - High-pitched ringing in the ears
- Effects persist as long as aspirin is ingested
  - Normal hearing returns in a couple of days
  - Tinnitus disappears

Tinnitus

- Not very loud
- Persistence can make it very annoying
- Difficult to estimate incidence of tinnitus in population
  - Habituation
    - Fail to notice ringing

Tinnitus: Causes

- Spontaneously emitted sound from the ear?
  - Not true for majority of cases
  - Characteristic frequency of ringing for each individual
  - Does not correspond to frequency spontaneously emitted from ear
- Neuronal degeneration

Tinnitus: Consequences

- Can cause psychological distress
  - Can't escape,drown out or ignore sound
- Depression can result
- Can be treated with white noise emissions