# The Ear

## **Audible range** – *20Hz-20kHz*

- children typically hear up to 20kHz
- Adults hear up to 10-14kHz
- >70 years old usually can't hear > 8kHz

## Form and Function

- Air pressure changes are perceived by the brain through nerve cells
  - **i)** **Outer ear** : pinna, and cavity to ear drum
    - a) auricle/pinna:
      - i. collects and filters sound
      - ii. ridges help focus echolocation
        - horses can independently aim to localize sound
        - humans localize with CNS, through loudness and arrival time differences between ears
    - b) Outer canal
      - i. helps to amplify sound and protect eardrum with wax
    - c) Ear drum/tympanic membrane

  - **ii)** **Middle Ear**: air cavity on inside of ear drum ventilated by Eustachian tube through nose
    - a) 3 ossicles: malleus/hammer, incus/anvil, and stapes/stirrup
      - i. uses lever and hydraulic phenomena to efficiently transmit sound
        1. hammer covers large portion of drum to relay air pressure changes that hit the ear drum
        2. anvil levers
        3. small stirrup pushes on oval window which moves fluid in cochlea/inner ear
      - ii. protect the inner ear from loud noises and sudden pressure changes by retracting the stirrups from window (triggered at 80-95db)

  - **iii)** **Inner Ear**: liquid filled cavity surrounded by hard bone with the Cochlea, Vestibular/Semicircular Canals
    - a) Cochlea: hearing organ
    - b) Vestibular/semicircular canals (or labyrinth): balance (gravity and motion) organ
    - c) when ossicles kick the window, fluid in inner ear is pushed against hairs in inner ear, which release neuro transmitters when stimulating/bending

## Hearing Loss

***Causes:***

1) **Birth Defects**:

- fixed or missing ossicles
- holes in the tympanic membrane

**2) Damage**

- impacted ear wax
- inflammation/infection
- abrasions (qtips) → scarring/thickening of eardrum, reducing sensitivity
- calcification over time → wrecks bones
- loud sounds/high pressure differences (explosions/diving) →
    - can burst ear drum
    - break ossicles
    - destroy inner ear hair cells
- overexposure → destruction of the outer hair cells
- antibiotics- ex. tetrcyclines → damage the hair cells

***Timescale of hearing loss:***

**1) Temporary**

- ear can desensitize to large amounts of noise in a short time
- physiological fatigue can set in, requiring 16 hours to disappear
- severe exposure can cause pathological fatigue, requiring up to 3 weeks for complete recovery

**2) Permanent**

- Prolonged exposure to loud noises
- greatest risks at frequencies above 4kHz
- loss of <5kHz sounds affects understandability of speech→ especially plosives (p b ) and fricatives (s, f)

## Protection

- soft deformable plastic can give reduction of 20-30 dB
- musicians have specially made ones that drop all frequencies by 15 dB
- some have a small channel in centre yields 30dB reduction at high frequencies, only passing low frequencies

## EXPERIMENT

speaker with function generator to "test hearing"

- slowly sweep down from 20KHz to see when start hearing
- if below 10kHz, see an audiologist!

# Ear and the Brain's Sifting of Sound

- ear has the amazing capability of discriminating between pitch, loudness, and tone colour

- Nervous system function
    - assesses modes from each ear, and performs averaged measurement
    - can make "running averages", summing info over a short period of time and averaging it (to correct for movement)

- can "make sense" out of complicated signals by comparing info from both ears, and the timing relative arrival times

- "Precedence effect" : Ear combines identical sounds if the arrive within 35ms of each other

- 1st to arrive predominately determines location of the source

- unless the 2nd, 3rd etc… are > 3x amplitude, they will augment

- but initial reflections arriving after 10ms can assist in determining location and intelligibility of sound

- reflection or secondary source come earlier than source?

    - Confusion in brain yields muddles intelligibility
    - electronic delays of amplified sound can balance
    - to avoid, loud speakers tend to be placed behind source
    - high ceilings can delay these confusing reflections.