

# Audition:

Kaylah Jacques and Doris Serrano

# Sound propagation

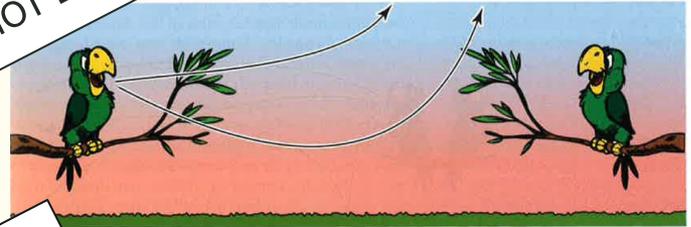
- Signals are invariably altered during propagation between sender and receiver.
  - Sender minimizes potential propagation effects → increases the **active space** of its signal.
- Acoustic degradation has multiple roles in animal interactions.
  - **Ranging** allows a receiver or eavesdropper to estimate the distance to the sender.
- There are 4 main types of degradation:
  - Overall attenuation
  - Distortion of its frequency composition.
  - Distortion of its temporal pattern
  - Masking by noise.



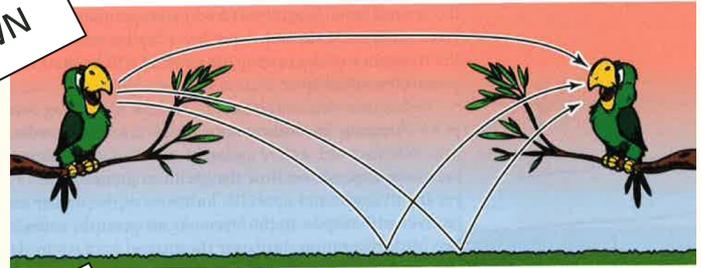
# Overall Attenuation

- Spreading losses and refraction result in decreasing overall signal amplitudes with distance from the sender
- Spreading losses cause pressure of a sound signal to decrease as distance increases
- Refraction causes changes in speed of sound due to changes in pressure, temperatures or current velocities.

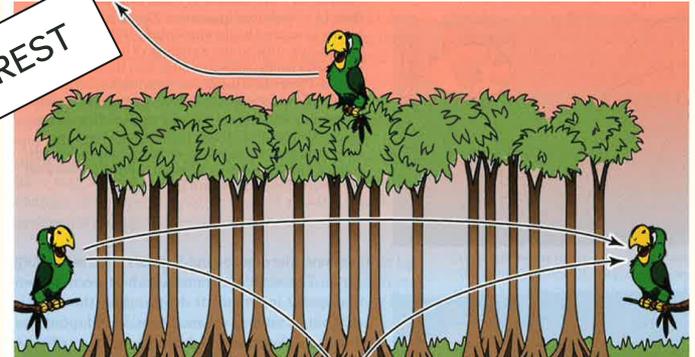
HOT DAY



DAWN



FOREST



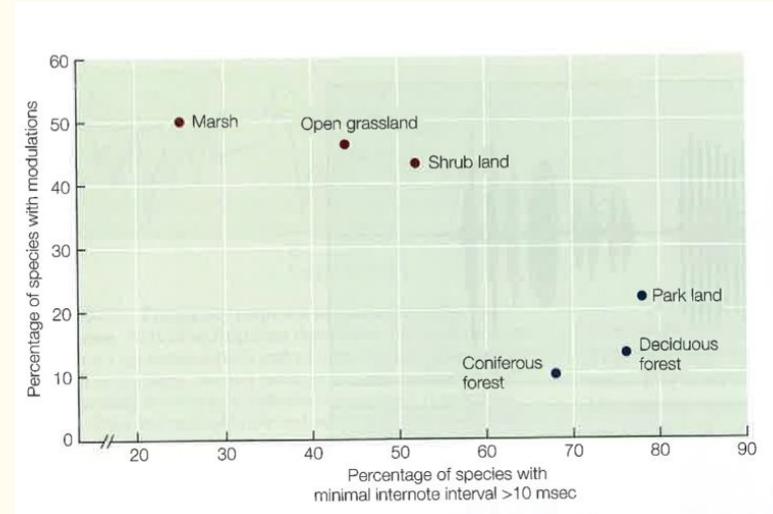
# Frequency Composition

- Changes in frequency composition of a sound -> changes in its waveform.
- High frequency sounds attenuate quicker than low-frequency sounds.
  - During propagation, sound signals lose energy due to **heat loss**
  - **Scattering** filters out high frequency components.
  - A **boundary** reflects waves towards the receiver that affect the waves directly travelling between both.
    - Ground wave restores lower frequencies
    - If both are between two reflective boundaries-> waveguide -> frequency preference
    - Sounds propagates in one medium but receiver is in another.



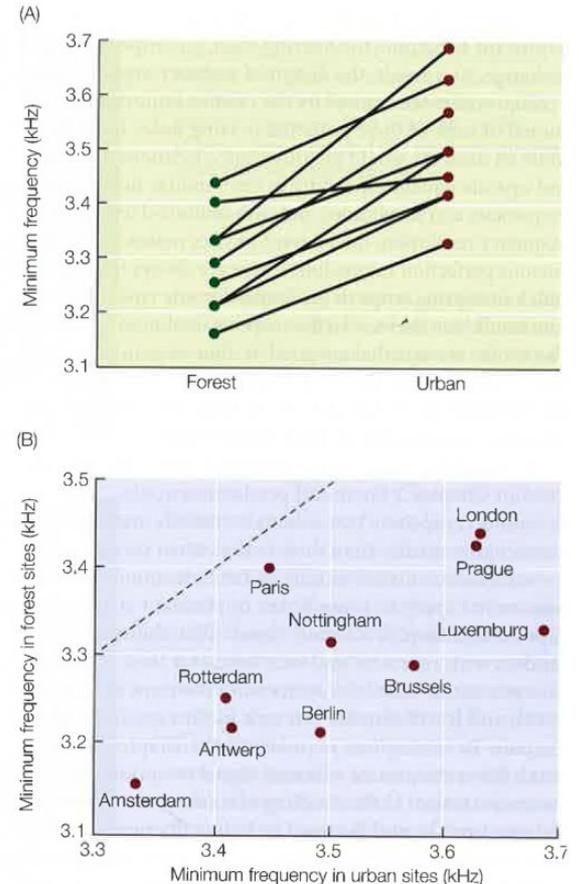
# Temporal Pattern

- Any change in the frequency composition of a signal -> a change in the signal's waveform->changes in the temporal pattern of a signal
- Reverberation and dispersion are processes that modify temporal pattern directly
- Sounds propagating on water or solid boundary -> different frequencies propagating at different speeds
- Open areas have more modulations and shorter note succession compared to forests.

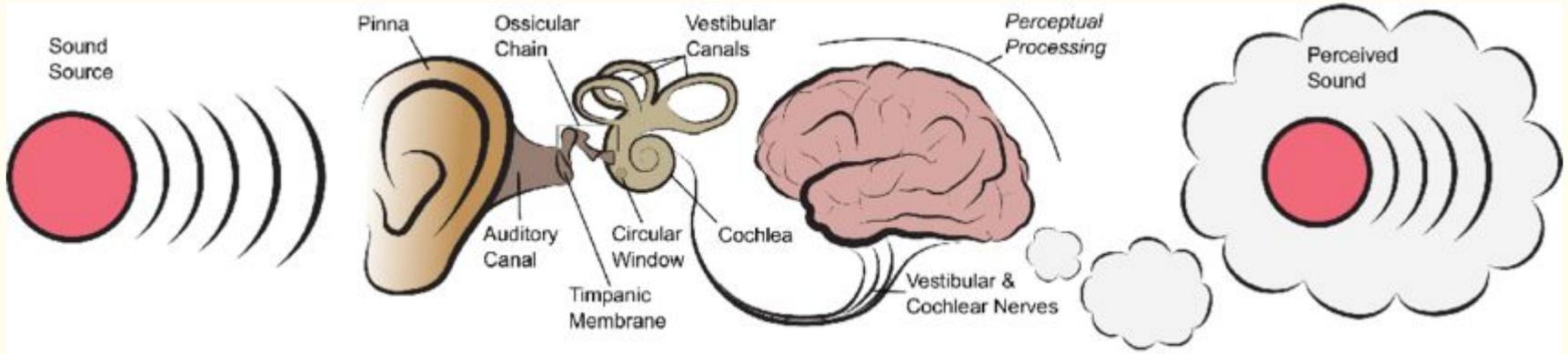


# Noise masking

- At high intensities, noise hinders the receiver detection of a signal
- At low intensities, noise hinders signal recognition
- To combat this, animals can increase signal amplitude, shift signal frequency to reduce overlap with ambient noise or focus on intermediate frequency.
- The frequency zone between upper margins of wind noise and lower limits of frog/insect noise -> favored by birds and mammals for vocalizing.



# Sound Reception

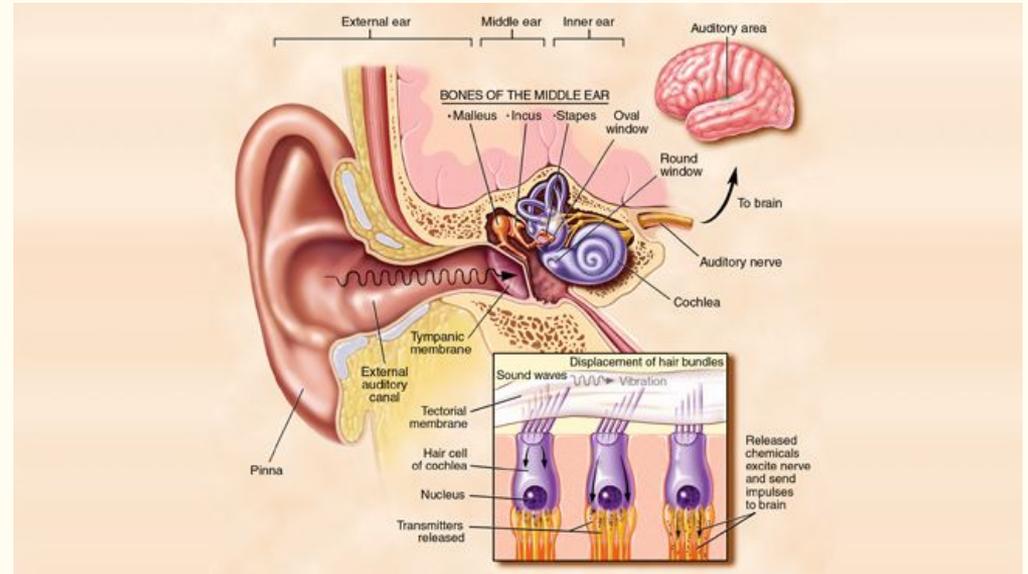


# What Ears have to do:



# The Ear's 3 Main Jobs

1. Couples sound from the medium (air or water) to the body
2. Modify it
3. Analyze it



However, there are tradeoffs!!!



# Coupling Sound into the Receptor

Main Goal: Pass sound from air or water into tissues despite impedance difference

Near-Field

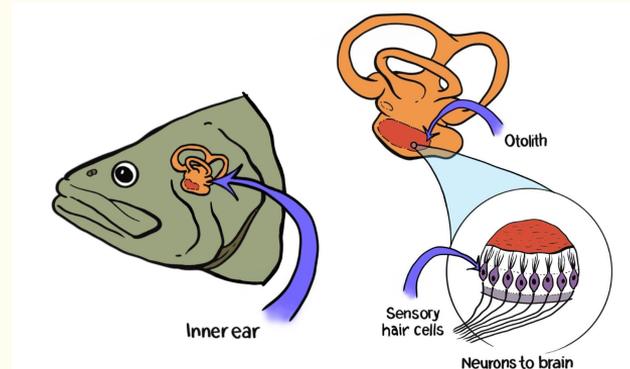
Particle Motion

Far-Field

Pressure Changes

Tissue = Water

Ex. fish (statocyst-style ears) and bony fish (swim bladder-ear)



# Modify the Signal

- Middle ear + ear canal/pinna act as impedance-matching amplifier
- External structures (pinna, ear canal, feather rims in birds) act like small horns: boost some bands and filters others
  - help amplify and directionally filter sound before it hits the tympanum

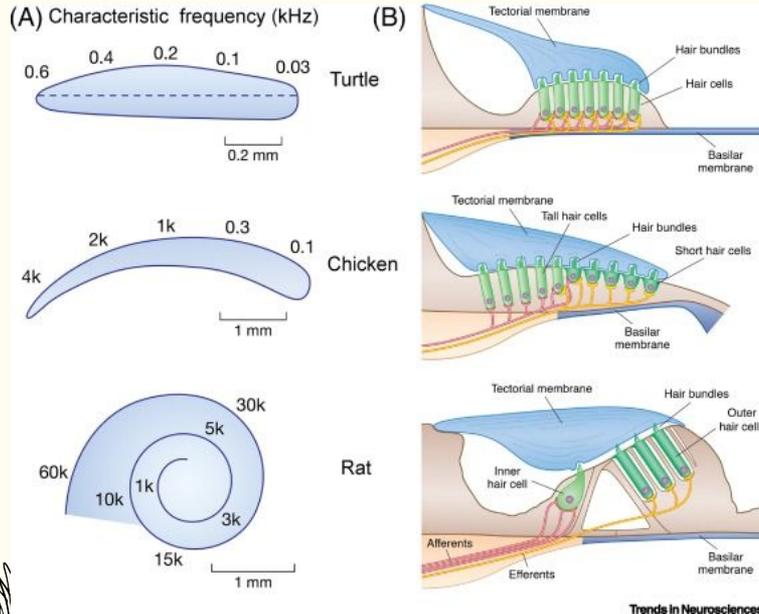
Ex. Marine animals

- Odontocetes and mysticetes



# Analyzing Frequencies

All vertebrates use directional hair cells as mechanoreceptors

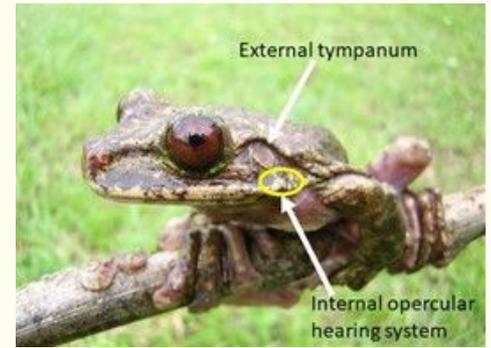


- Tonotopic basilar papilla/cochlea: stiff base = high  $f$ , floppy apex = low  $f$
- Traveling wave peaks where stiffness matches frequency (“place coding”)



# Tuning and Bandwidth

- Many cells are tuned to a characteristic frequency
- Narrow tuning (high Q) = great frequency resolution, worse temporal resolution



## Amphibians

Problem: Air-fluid impedance mismatch



Answer: Tympanum + ossicles + oval window converts air pressure into fluid motion

Amphibian's inner ear have:

- Sacculle (low-frequency/ seismic via operculum)
- Amphibian papilla (mid frequencies)
- Basilar papilla (higher, often matching call frequencies)



# Localization and Body Size

- ITDs: interaural time differences scale with head width.
- ILDs: interaural level differences need wavelengths  $\lesssim$  head/pinna size.
- Larger heads = good localization at lower frequencies; smaller heads rely more on higher frequencies.
- Overall: physics of production, propagation, and reception explains why small vertebrates skew high-frequency and large ones low-frequency.

