Music 170: Lecture 0
What is Sound?

Tamara Smyth, trsmyth@ucsd.edu
Department of Music,
University of California, San Diego (UCSD)

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What is Sound?

If a tree falls in a forest and no one is there to hear it, does it make sound?

Figure 1: A mime in the forest.
Sound and Vibration

• The word *sound* is used to describe both:

1. an auditory sensation in the ear

2. the disturbance in a medium that causes an auditory sensation

• Nearly all objects will vibrate when disturbed.

• Sound is the result of a *wave* created by vibrating objects, propagated through a medium from one location to another.
The Science of Sound

- **Acoustics** is the science that deals with the quantifiable measure of the *production, control, transmission* and *reception* of sound:
  - encompasses disciplines such as physics, engineering, psychology, audiology, speech, architecture, neuroscience, *music* and more!

- **Psychoacoustics** is the study of the way humans perceive sound:
  - things are sometimes different than they appear *or sound*
  - interpretation can be quite different from the physical stimulus at the ear.
  - the *McGurk Effect*

![Figure 2: The McGurk Effect](image)
What is a wave?

- A wave is a disturbance or variation that travels from one location to another over a period of time.
- Examples of waves:
  - light
  - sound
  - water
  - radio
  - x-rays
  - shock
- Waves carry information/energy from one point to another—the medium in which they propagate is not transported!
Types of waves

• There are two main types of waves:
  1. **Mechanical**: waves propagate through a *medium*.
  2. **Electromagnetic**: wave propagation does not require a medium (they can travel in a vacuum).

• Which kind of wave is sound?

• Since sound is a mechanical wave, it needs a medium through which to propagate.
  – **Bell in a Bell Jar (Vacuum)**

Figure 3: A bell jar is connected to a vacuum pump illustrating sound’s need of a medium.
Direction of particle displacement

- Depending on the direction of particle displacement, a mechanical wave can be:

  1. **Longitudinal**: Particle displacement is parallel to the direction of wave propagation.

     ![Longitudinal Wave Example](image)
     
     Click image for animation: (Courtesy of Dr. Dan Russell, Kettering University)

  2. **Transverse**: Particle displacement is perpendicular to the direction of wave propagation.

     ![Transverse Wave Example](image)
     
     Click image for animation: (Courtesy of Dr. Dan Russell, Kettering University)
Sound Wave and Waveform

• In fluids, sound is a **longitudinal** compression wave.
• The **waveform** illustrates the *variation* (either temporal or spatial), of the wave.
• Waveforms representing sound waves show the change/variations in pressure.

![Waveform Diagram]

• Depending on the properties of the sound wave, it can be heard. See what else it can do!
Waveform and Wavelength

- Waves are often characterized by their **length**:
  - radio waves are longer than microwaves,
  - infrared longer than ultra violet,
  - gamma longer than x-rays, etc.,

- This waveform shows **spatial** variation:

![Waveform Diagram]

- The **wavelength** is the distance between crests (or troughs), the length of one **cycle** of the waveform.

- **Longest human wave!**
Waveform Period

- Waves may also be characterized by their **period**.
- This waveform shows *temporal* variation:

![Waveform Diagram](attachment:waveform.png)

- The **period** is the *time* to complete one cycle.
- We need the **wave propagation speed** (velocity) to determine the period from the wavelength:

\[
\text{period} = \frac{\text{wavelength}}{\text{velocity}}
\]
Waveform Frequency

• It is also useful to talk the wave’s **frequency**:
  – the number of cycles per second (Hz),
  – the inverse of the **period**.
  
  \[
  \text{frequency} = \frac{1}{\text{period}}
  \]

• Again, if the wavelength is known, the frequency can be determined by:
  
  \[
  \text{frequency} = \frac{1}{\text{period}} = \frac{\text{velocity}}{\text{wavelength}}
  \]

• Of course not all waves are as perfect as this, but properties also apply to more complicated waveforms.
Sound Waves

• Sound waves are **mechanical waves**:  
  – A disturbance travelling through a *medium*  
  – Transports energy from one location to another

• Sound waves travel in a solid, liquid, or gas.

• In fluids (liquid or gas), sound waves are longitudinal (compression) waves.

• **No material is transported as a result of mechanical waves.**
Speed of Sound

• What is the approximate speed of sound in
  1. air? approx. 340 m/s.
  2. water? approx. 1,484 m/s.
  3. iron? approx 5,120 m/s.
  4. vacuum?

• Speed of sound is dependent on medium’s
  1. density / compressibility (inversely related)
     – the more difficult the medium is to compress, the faster sound will travel;
     – sound travels faster in solids than in liquids and faster in liquids than in gases.
  2. stiffness (solids)
  3. temperature (fluids)
Hot chocolate effect (Frank Crawford 1982)

- **Allassonic Effect**

  - The frequency heard from tapping the bottom of a cut of hot cocoa is a function of both the speed of sound and the wavelength.
  - Upon initial stirring of a cup of cocoa, gas bubbles transported by the liquid reduce the speed of sound through the liquid, lowering the frequency.
  - As the bubbles clear, sound travels faster in the liquid and the frequency increases.
  - Try also by adding salt to cold beer.
Audible Ranges

- **Amplitude** range of hearing (humans)
  - Threshold of audibility: 0.00002 Pa (N/m²)
  - Threshold of feeling (or pain!): 200 Pa (N/m²).

- **Frequency** range of hearing
  - humans: 20 - 20 000 Hz
  - dogs: 20 - 45 000 Hz
  - beluga whale: 1000 - 123 000 Hz
Example Sound Sources

- **Vibrating bodies**: drumhead, piano soundboard, ...
- **Changing airflow**:
  - vibrating vocal folds open and close changing rate of airflow from lungs to vocal tract;
  - holes in a rotating siren alternately periodically stop the flow of air;
- **Time-dependent heat sources**:
  - electrical spark producing a crackle;
  - explosion producing a bang due to rapid heating causing air to expand;
  - thunder results from rapid heating of air by a bolt of lighting.
- **Supersonic flow**: shock waves result when air flows faster than the speed of sound:
  - supersonic airplane,
  - speeding rifle bullet,
  - shock waves have been also known to occur in brass instruments (trumpet).
Sound Summary

- Sound waves are mechanical longitudinal (compression) waves.
- A disturbance of a source (such as vibrating objects) creates an initial region of compression or high pressure.
- When the source vibrates, alternating regions of low and high pressure are produced in the surrounding air, called *rarefactions* and *compressions* respectively.
- The alternating pressure propagates through a medium, away from the source, before reaching our ears.