# CSC 2700
# Intro to Programming for Audio/Music

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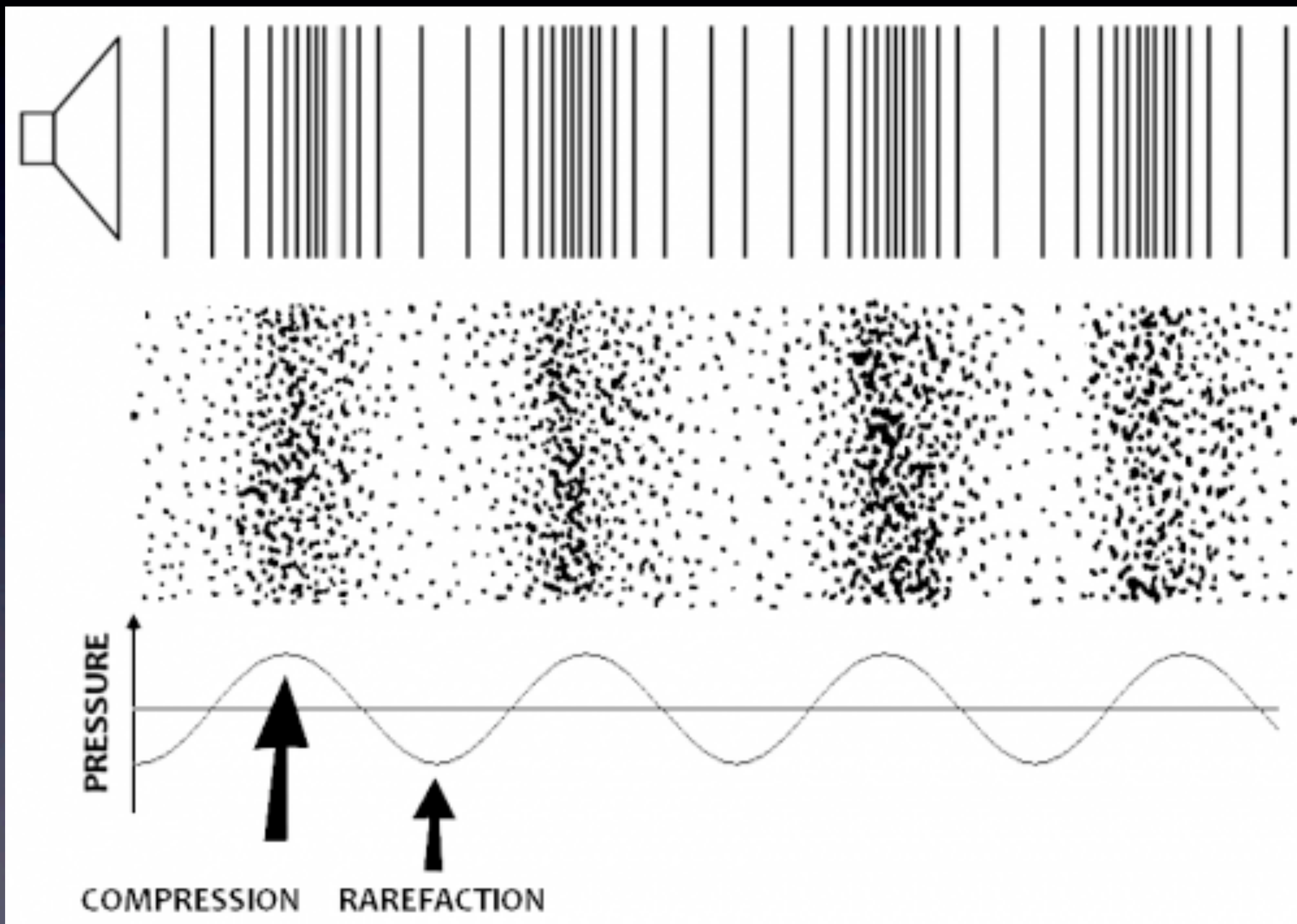
# What is Sound?

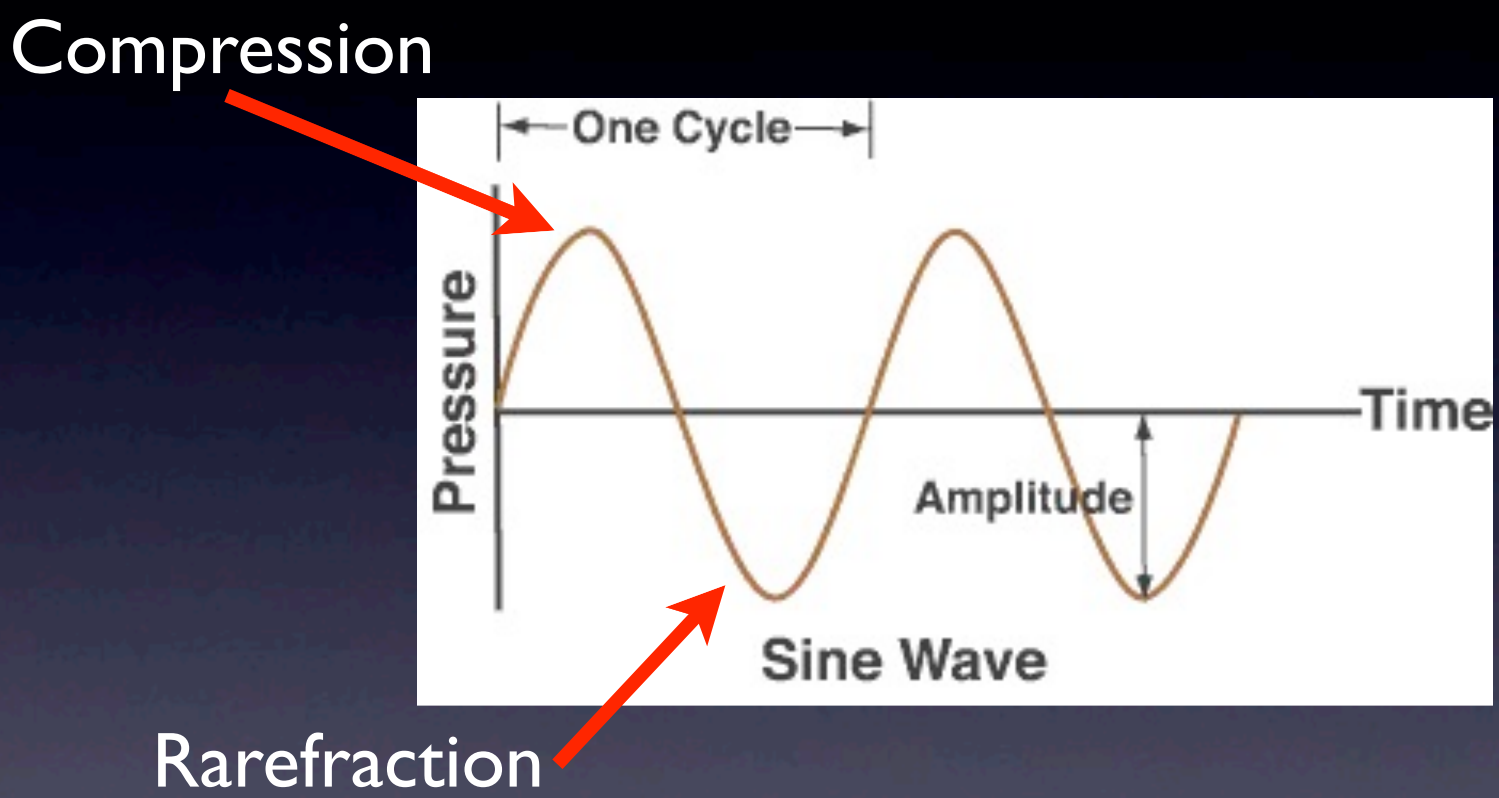
# What is sound?

Sound is when air molecules are disturbed and set in motion

# What is sound?

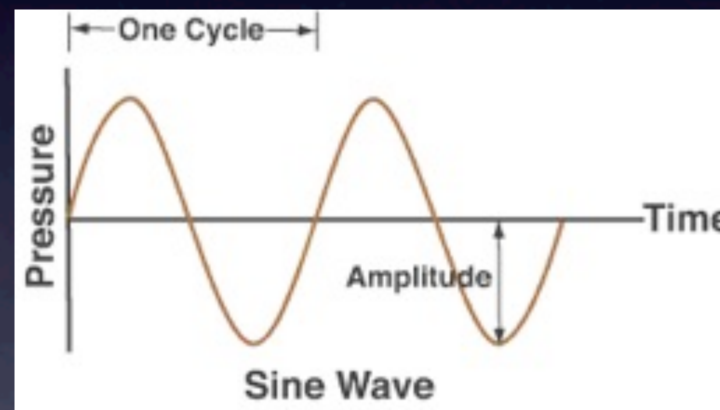


# What is sound?



# Parameters of sound

- Amplitude
  - The amount of energy in the sound
- Waveform
  - The shape of a regular vibration
- Frequency
  - Cycles per second



# Waveform

- Amplitude => height of waveform
- Measured as Intensity $Watts/m^2$
- Threshold of hearing is $10^{-12}W/m^2$
- Threshold of pain is $1W/m^2$

# Decibels

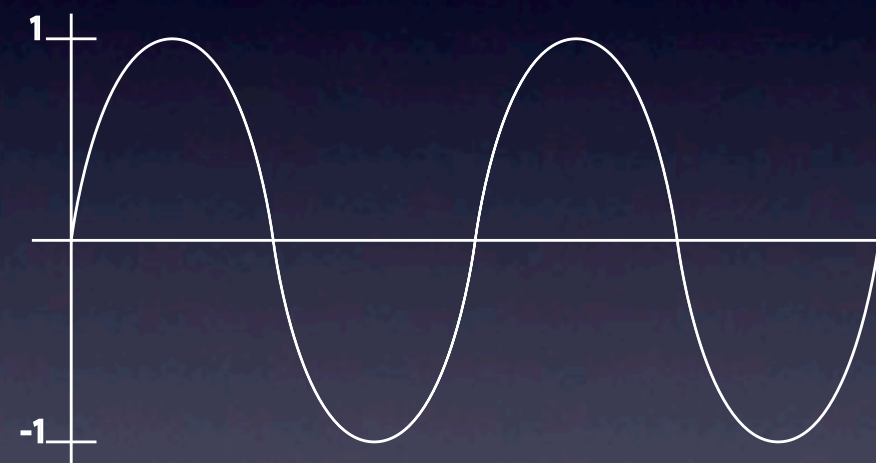
- Perception of Intensity/Amplitude is exponential
  - $I$ is measured intensity
  - $I_o$ is threshold of hearing $10^{-12} W/m^2$

$$Bel = log(\frac{I}{I_0})$$

$$deciBel = 10 * log(\frac{I}{I_0})$$

# Waveform

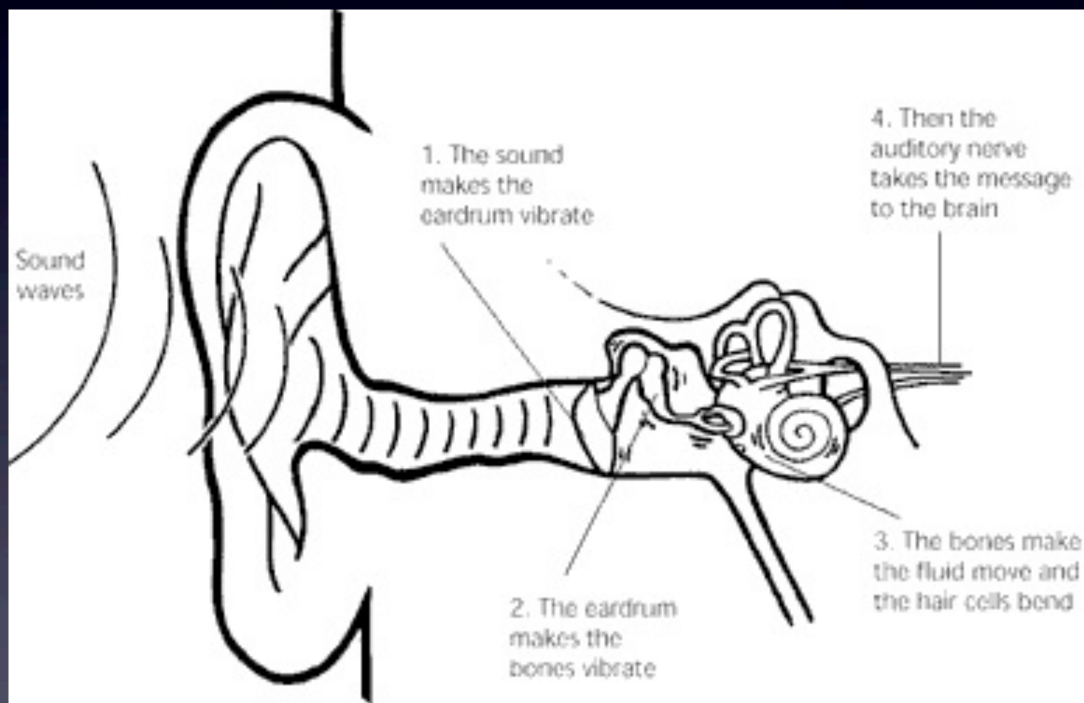
- Frequency => number of waveforms or cycles per second
- Unit of measurement => Hz
- kHz is 1000 Hz



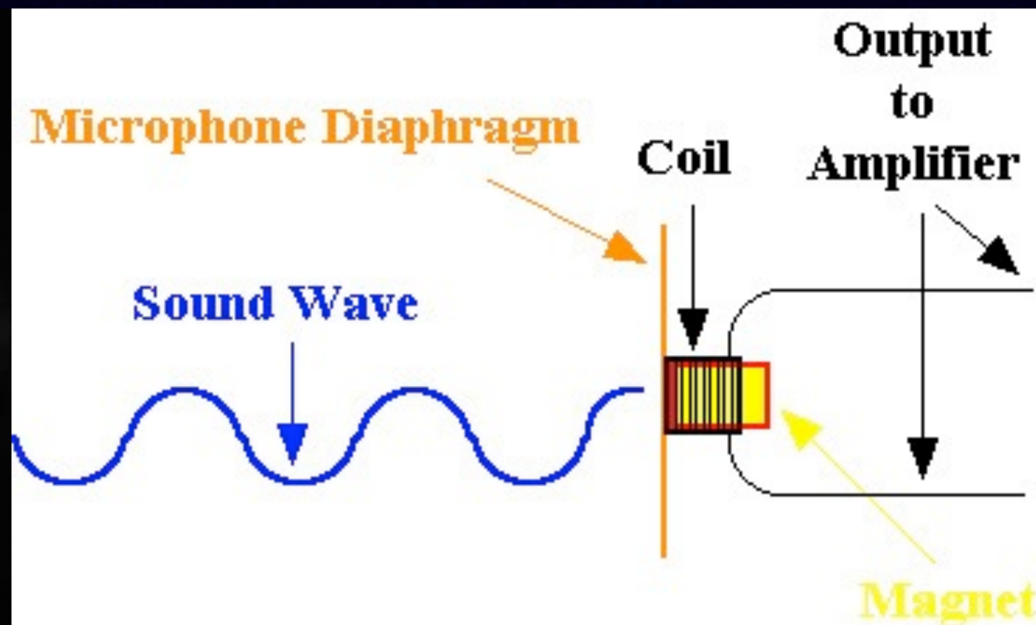
# Frequency

- Perception of Frequency is also exponential
- Pitch is the ratio of two frequencies
  - A440 => 440 Hz
  - 2:1 is Octave
  - 3:2 is Fifth

# The Analog Process



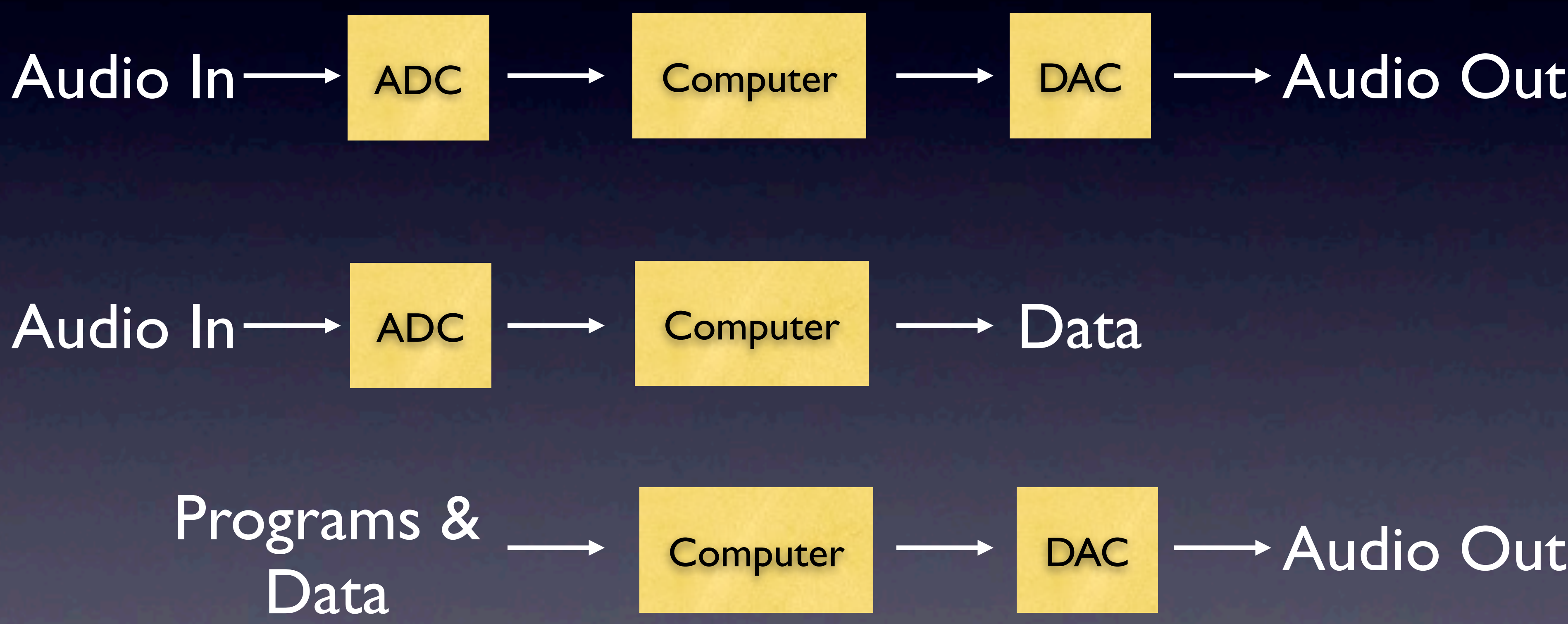
# Analog Recordings



# Digitizing Sound

- When analog signal is recorded digitally:
  - Signal enters an Analog-to-Digital-Converter (ADC)
  - Measures instantaneous amplitude of input signal
  - Outputs stream of numbers

# Digital Audio



# Digital vs Analog

- Analog is continuous
- Digital is discrete
  - Need lots of “samples” of the analog signal
  - Need good representation of amplitude values

# Terminology for Digital Audio

- Sampling Rate
  - The number of samples / sec the ADC or DAC processes
  - Sampling Rates for
    - CD = 44,100 Hz (44.1 kHz)
    - DVD = 48,000 Hz (48 kHz)

# Nyquist Theorem

A discrete time sequence of a continuous signal contains enough information to accurately reproduce the signal when the sampling rate is twice the highest frequency in the original signal

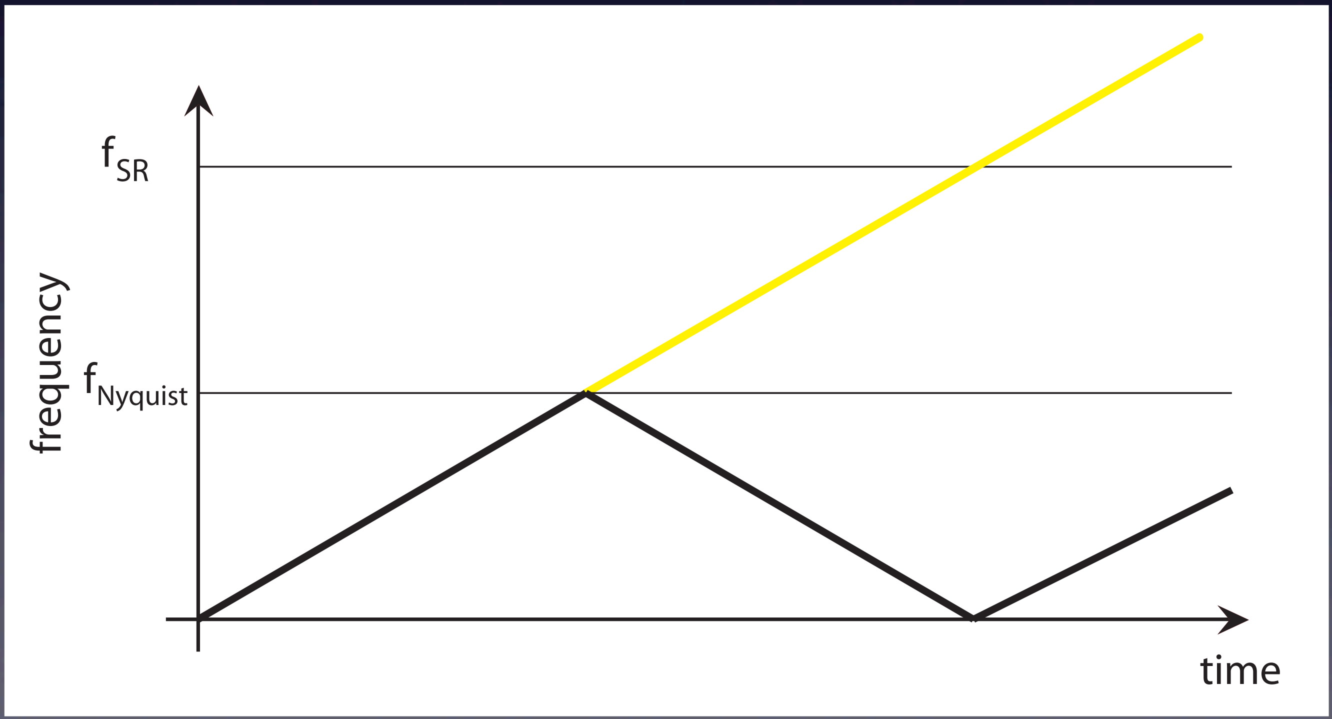
$$f_{Nyquist} = \frac{f_{SR}}{2}$$

# Aliasing

- "Wagon-wheel" effect
  - As wheel moves faster, it appears to move faster
  - As wheel speed approaches Nyquist limit, wheel appears to slow down, stop and then reverse

# Aliasing Effect

- As measured frequency rises past $f_{Nyquist}$ the playback frequency decreases at same rate

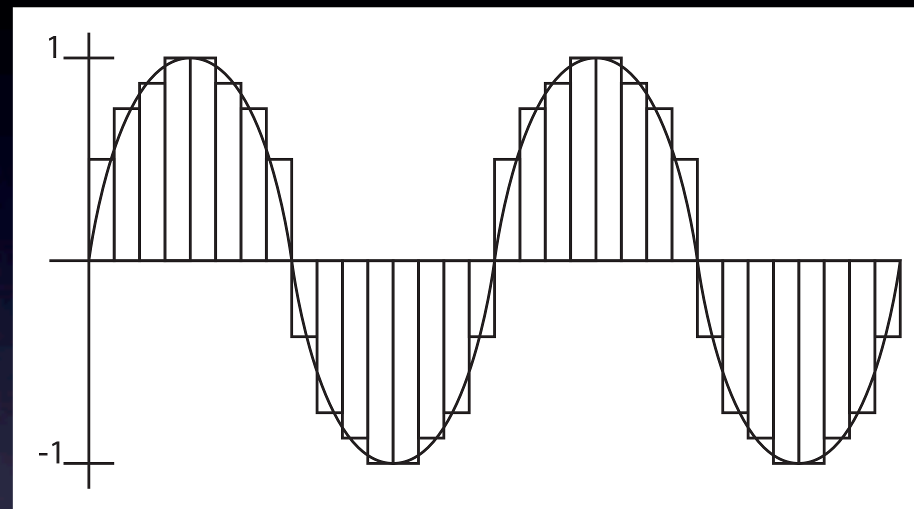


# Terminology for Digital Audio

- Resolution or bit-size
  - The size in bits of each sample
  - Binary storage is in 0s and 1s (bits)
  - 8-bit datum = 0010 0111
  - $2^8 = 256$ possible states / values
    - only 256 values between -1 and 1

# Quantization Error

- Low bit size =>
  high quantization error

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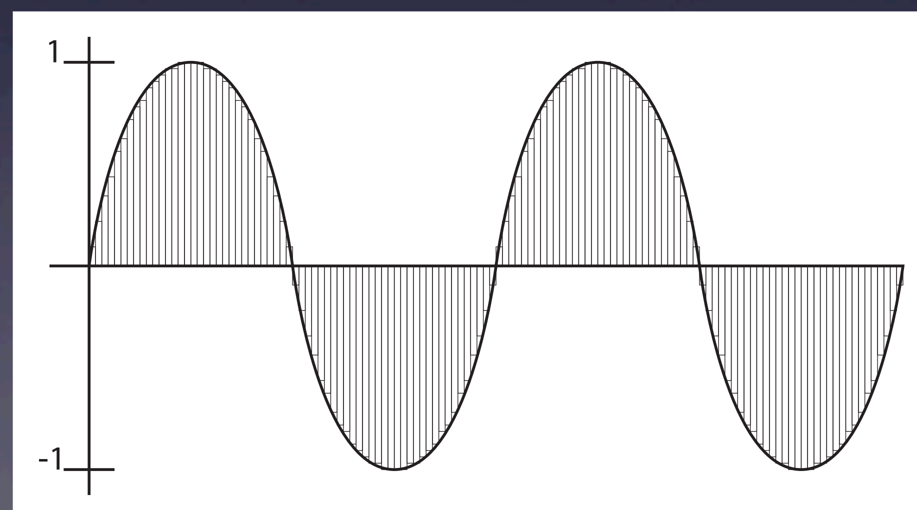


# Terminology for Digital Audio

- Resolution
  - In digital audio, -6 dB of S/N ratio per bit
  - 8 bits ($2^8 = \pm 128$) => -48 dB S/N
  - 16 bits ($2^{16} = \pm 32768$) => -96 dB S/N
  - 24 bits ($2^{24} = \pm 8,388,608$) => -144 dB S/N

# Acoustics Theory

- Sound is generated by vibrating systems
- Regular vibrations are measured by amplitude (dB) and frequency (Hz) of waveform
- Simple sound => sine wave

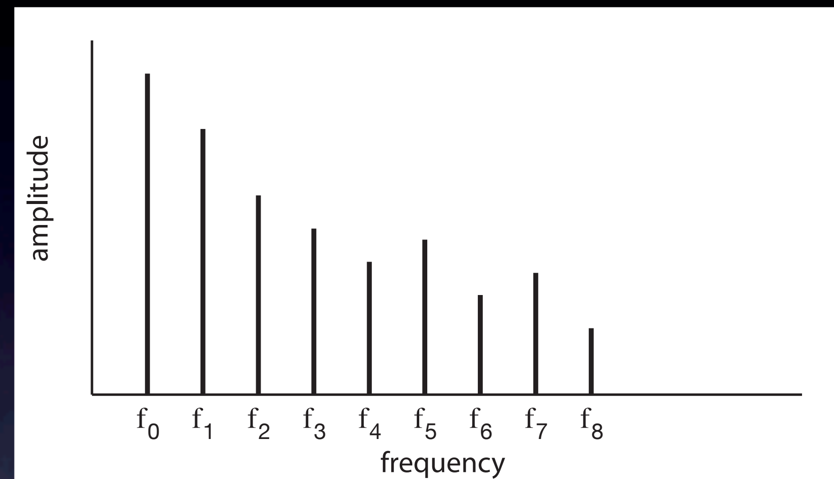
$$A_{(t)} = A * \sin(2\pi f t + \phi)$$

- Complex sound => many sine waves

$$A_{(t)} = \sum_{n=0} A_n * \sin(2\pi f_n t + \phi_n)$$

# Timbre

- Harmonic Spectrum
  - Component frequencies are integer relations of $f_0$

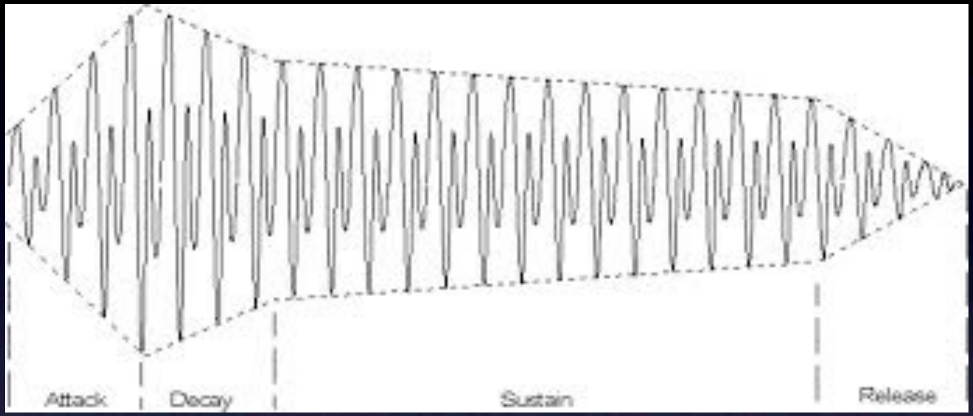



$$A_{(t)} = \sum_{n=0} A_n * \sin(2\pi(n * f_0)t + \phi_n)$$

- Inharmonic Spectrum
  - Not!

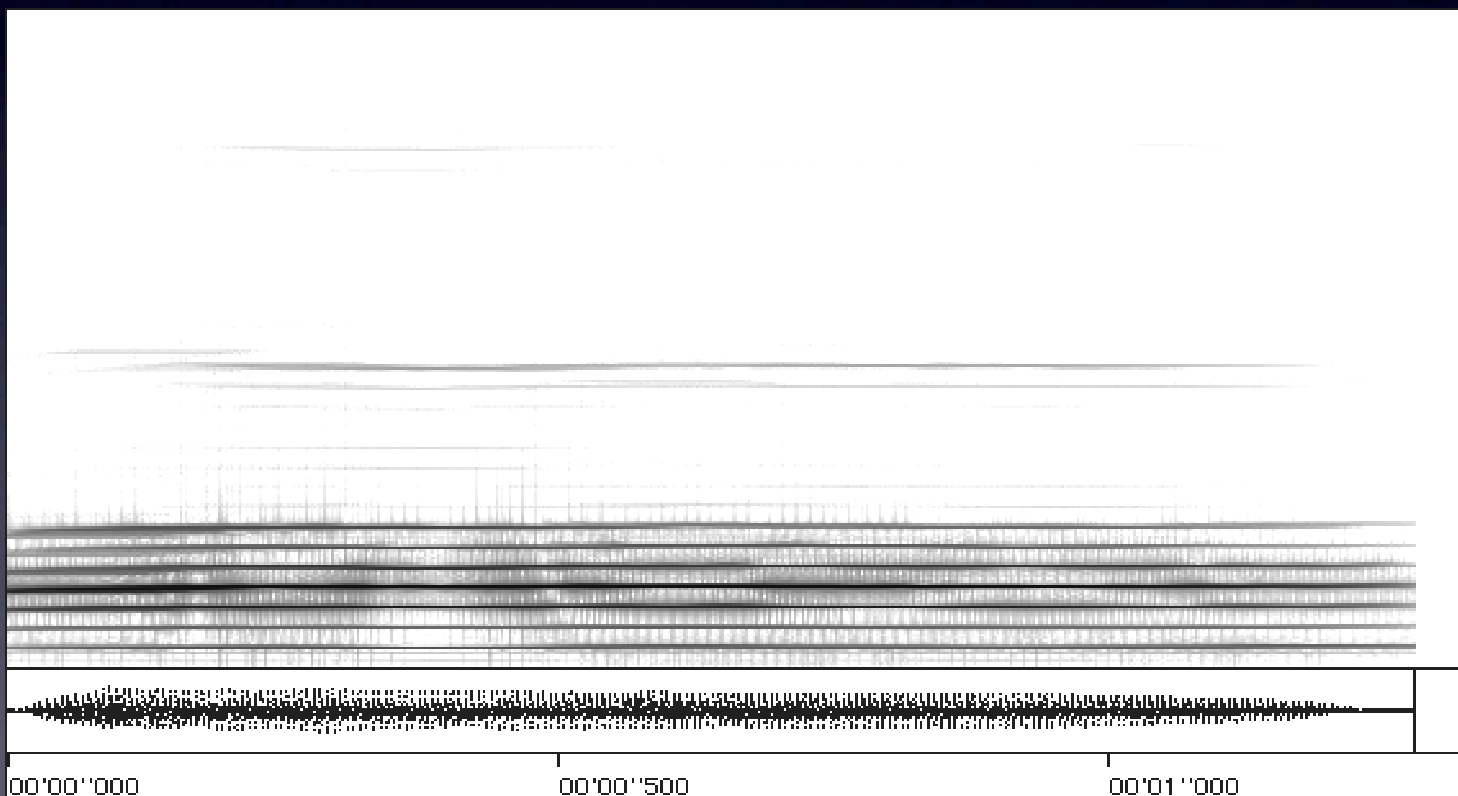
# Classical Theory of Timbre

- Spectrum is "steady-state"
- Sound is articulated by an envelope
- Spectrum remains constant over frequency domain




# Modern Theory of Timbre

Spectra is DYNAMIC



# Modern Theory of Timbre

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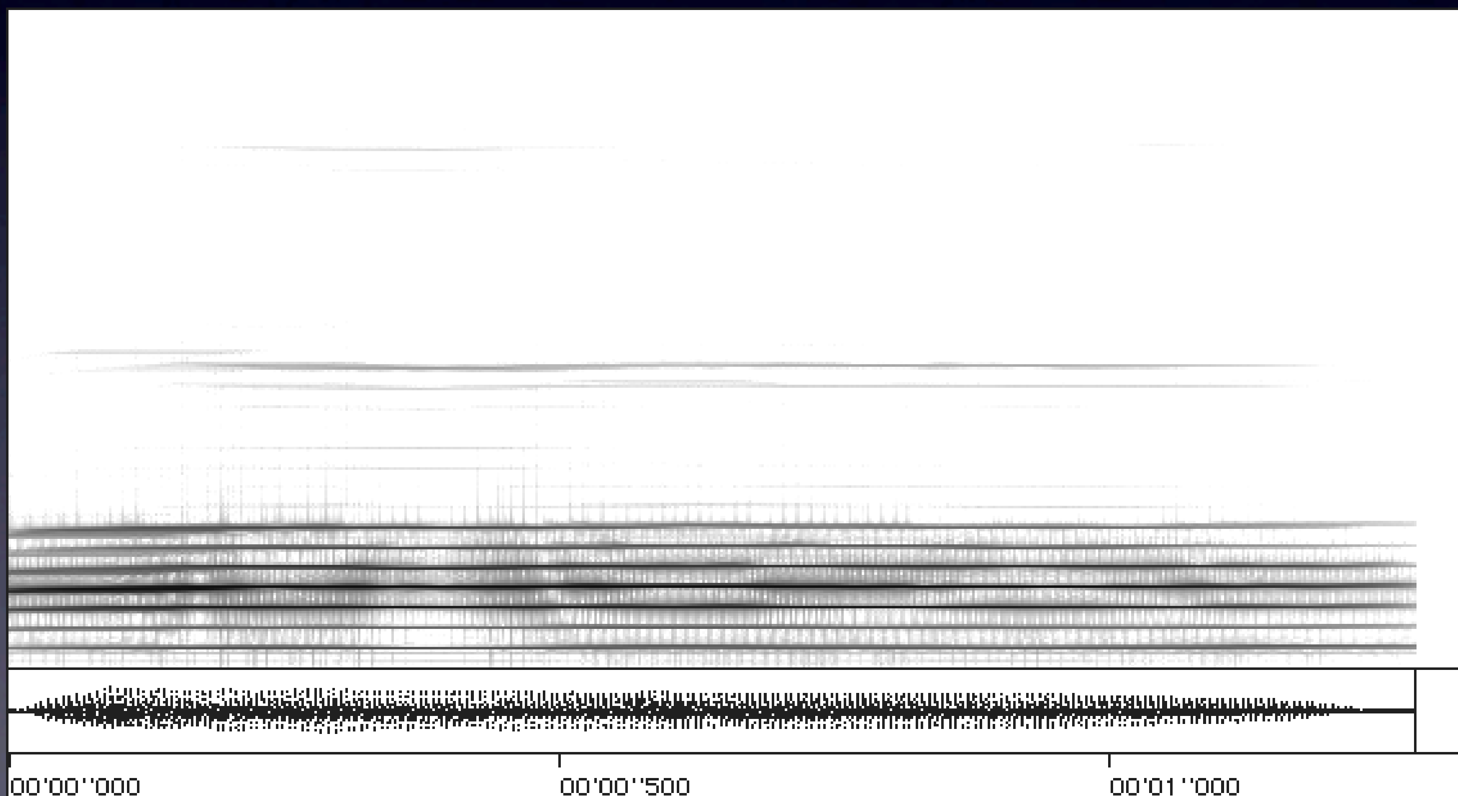
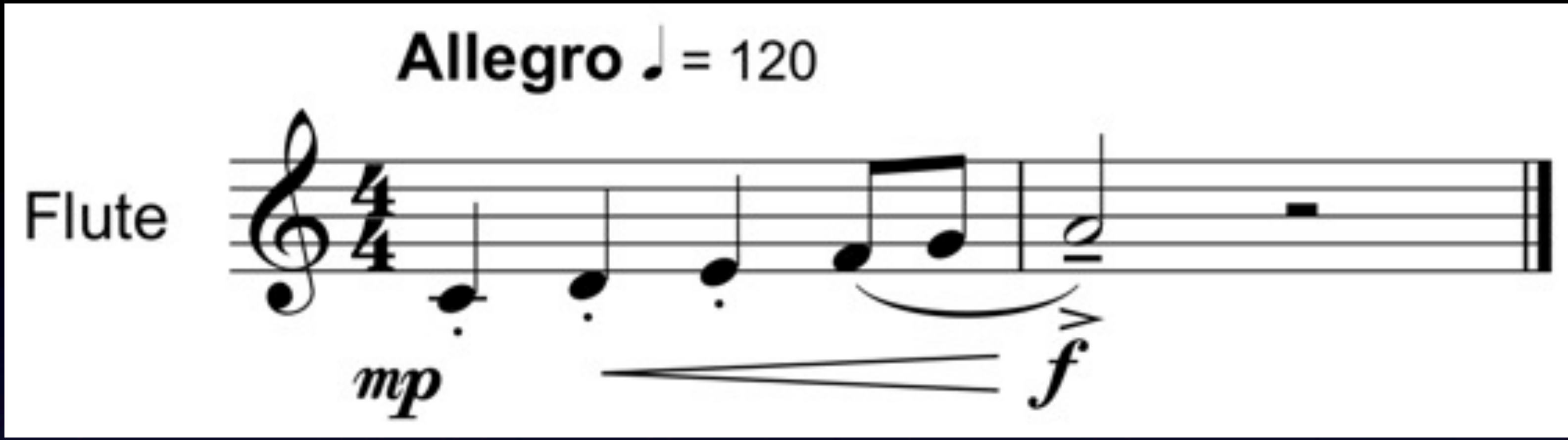


# What is Musical Data?




- Instrument
- Notes
- Dynamics
- Articulations
- Tempo Description
- Metronome
- Meter