Basic Acoustics

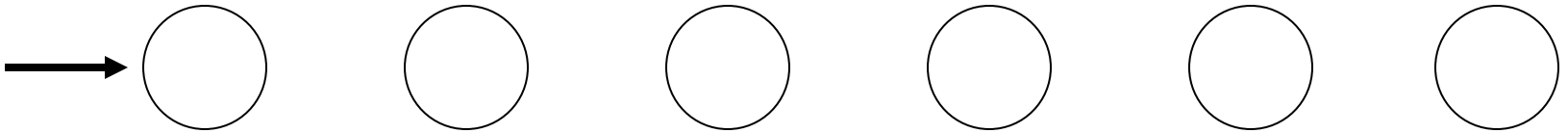
What is a sound?

- A pattern of pressure variation that moves out in waves from a source
- Must be within the ranges to which our ear is sensitive
- Normally talk about the sound waves travelling through the air

What does sound look like?

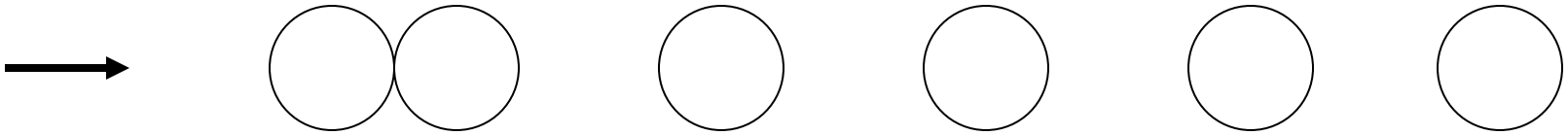
- Air consists of floating air molecules
- Normally, the molecules are suspended and evenly spaced apart from each other

- What happens when we push on one molecule?

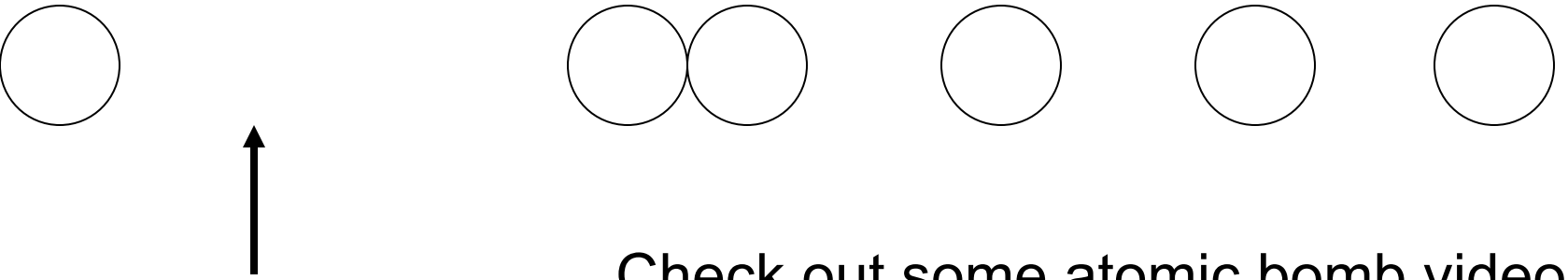


What does sound look like?

- The force knocks that molecule against its neighbor



- The neighbor, in turn, gets knocked against its neighbor
- The first molecule bounces back *past its initial rest position*

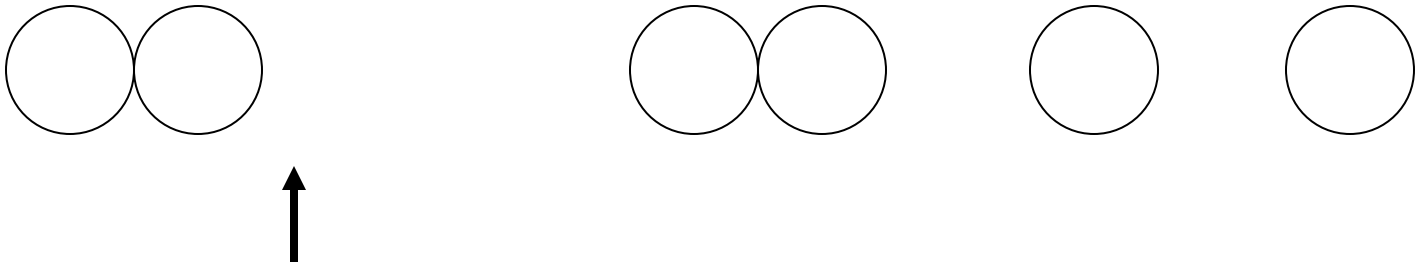


initial rest position

Check out some atomic bomb videos…

What does sound look like?

- The initial force gets transferred on down the line



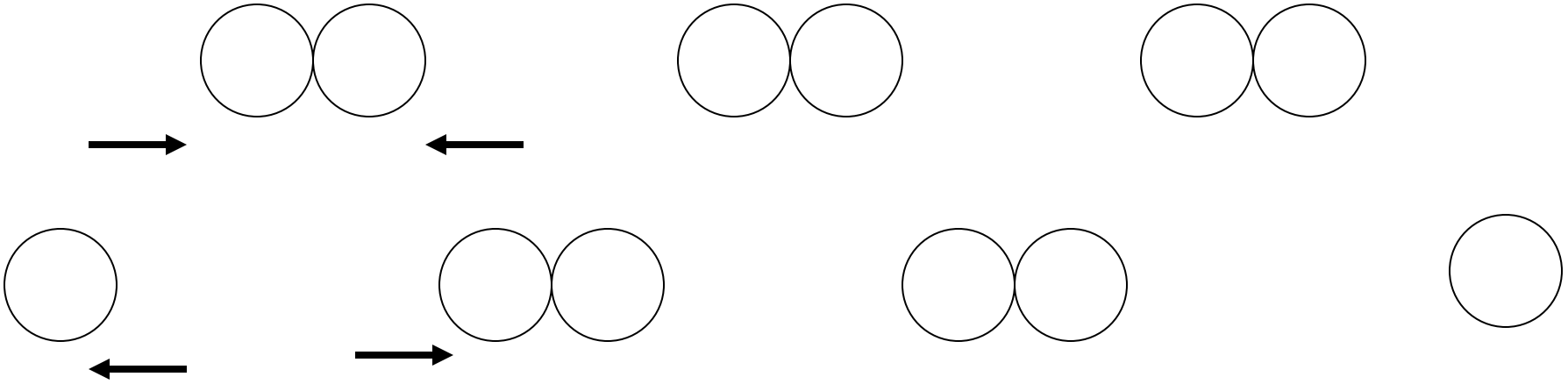
rest position #1

rest position #2

- The first two molecules swing back to meet up with each other again, in between their initial rest positions
- Think: bucket brigade

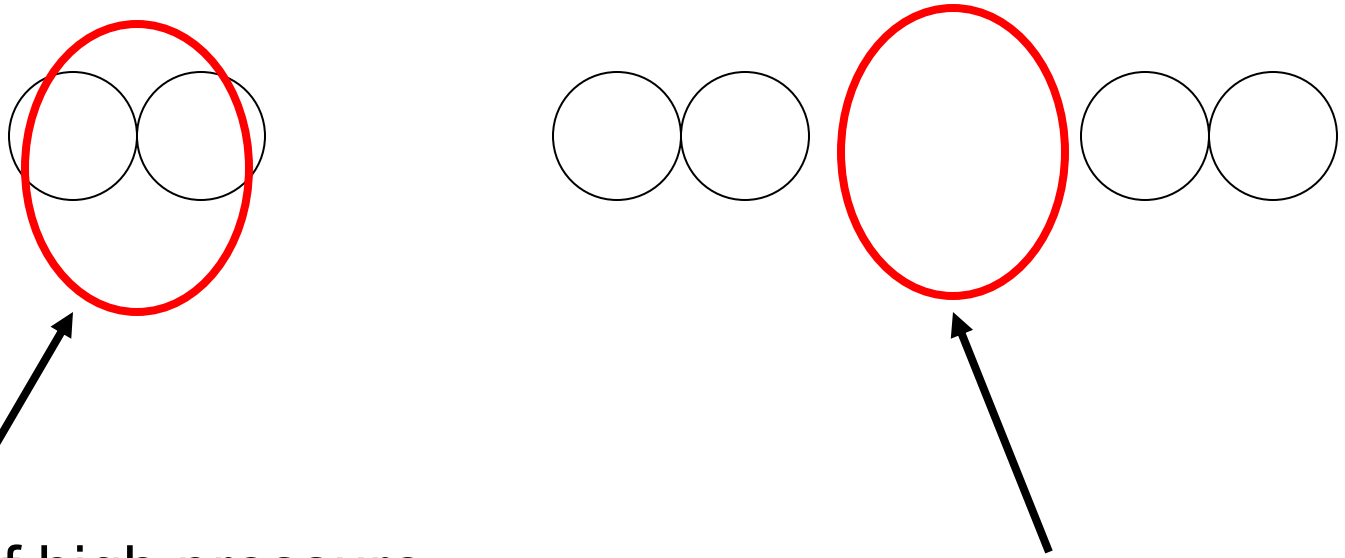
Compression Wave

- A wave of force travels down the line of molecules
- Ultimately: individual molecules vibrate back and forth, around an equilibrium point



- The transfer of force sets up what is called a **compression wave**.
- What gets “compressed” is the space between molecules

Compression Wave



area of high pressure

(**compression**)

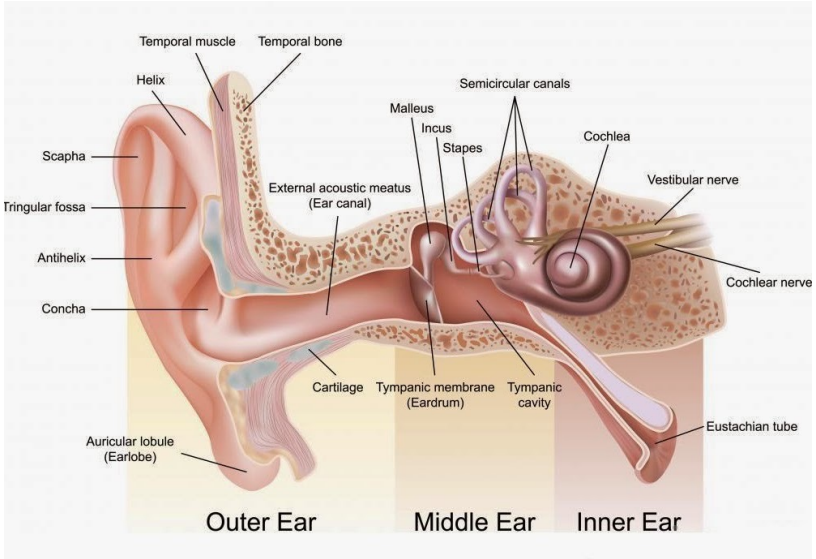
area of low pressure

(**rarefaction**)

- Compression waves consist of alternating areas of high and low pressure

Pressure Level Meters

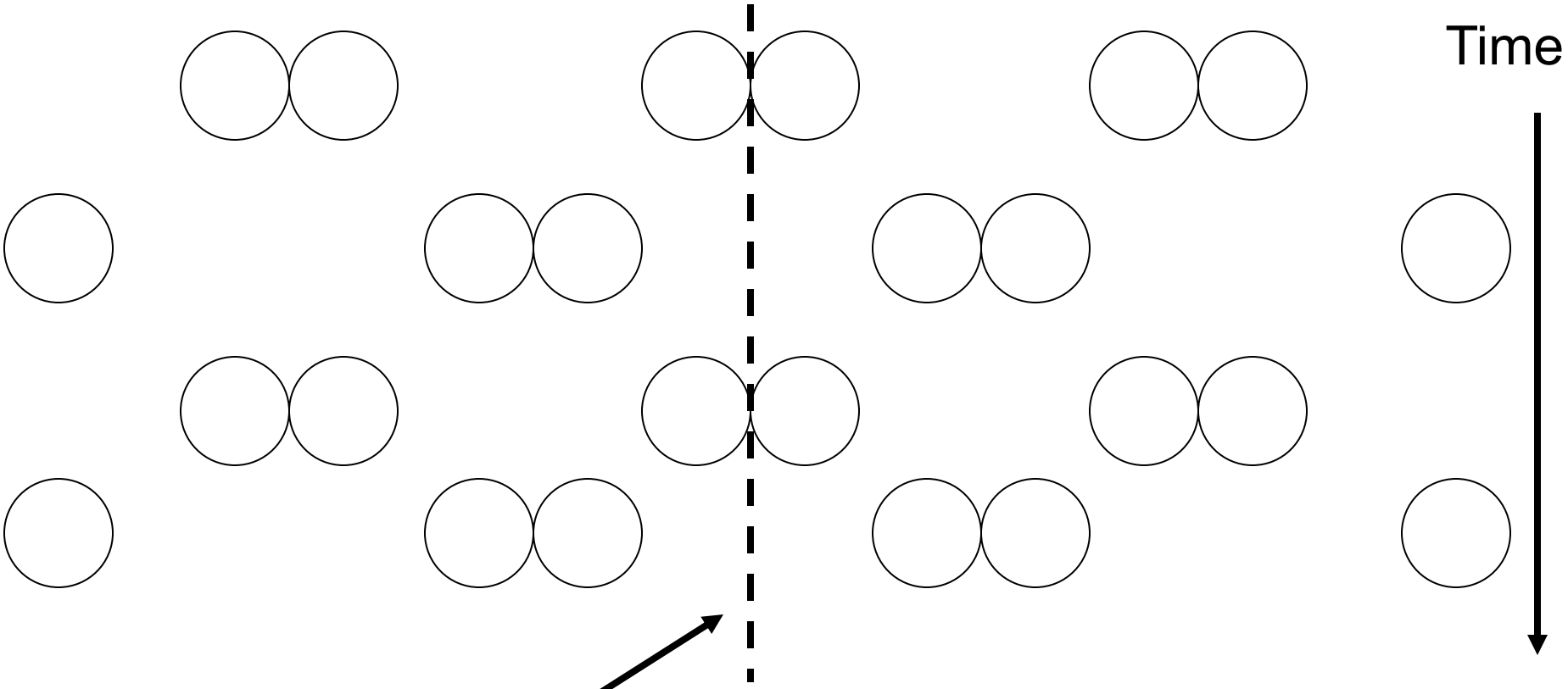
- Microphones
  - Have diaphragms, which move back and forth with air pressure variations
  - Pressure variations are converted into electrical voltage
- Ears



- We experience fluctuations in air pressure as **sound**

Measuring Sound

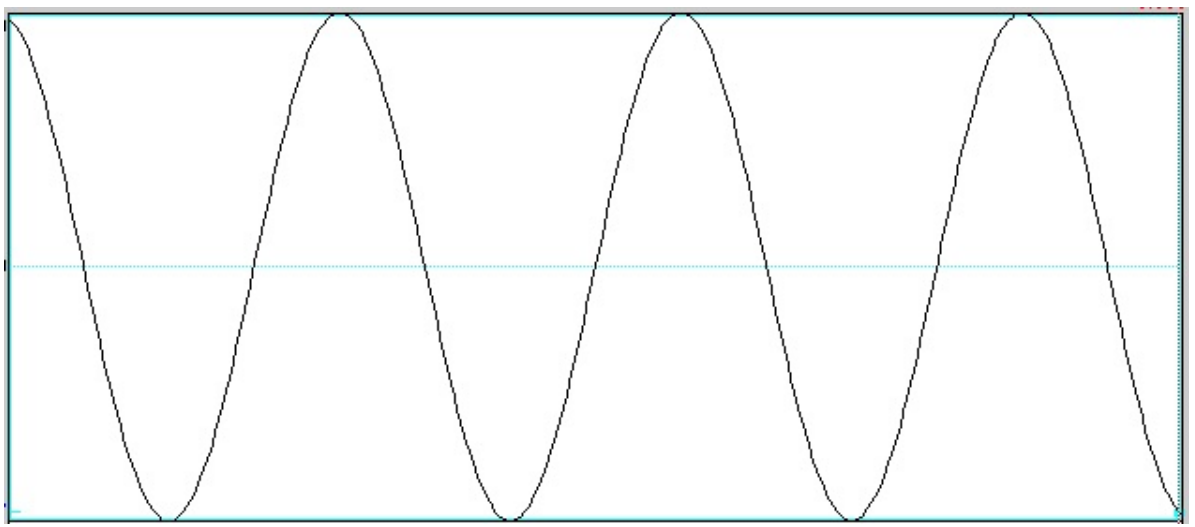
- What if we set up a pressure level meter at one point in the wave?



- How would pressure change over time?

Sine Waves

- The reading on the pressure level meter will fluctuate between high and low pressure values
- In the simplest case, the variations in pressure level will look like a **sine wave**.



pressure

time

Other Basic Sinewave concepts

- Sinewaves are **periodic**; i.e., they recur over time.
- The **period** is the amount of time it takes for the pattern to repeat itself;
    - P = 1/ Frequency
- The **frequency** is the number of times, within a given timeframe, that the pattern repeats itself.
    - Frequency = 1 / period
    - usually measured in cycles per second, or **Hertz**
- The **peak amplitude** is the maximum amount of vertical displacement in the wave
    - = maximum/minimum amount of pressure

Waveforms

• A **waveform** plots amplitude on the y axis against time on the x axis.

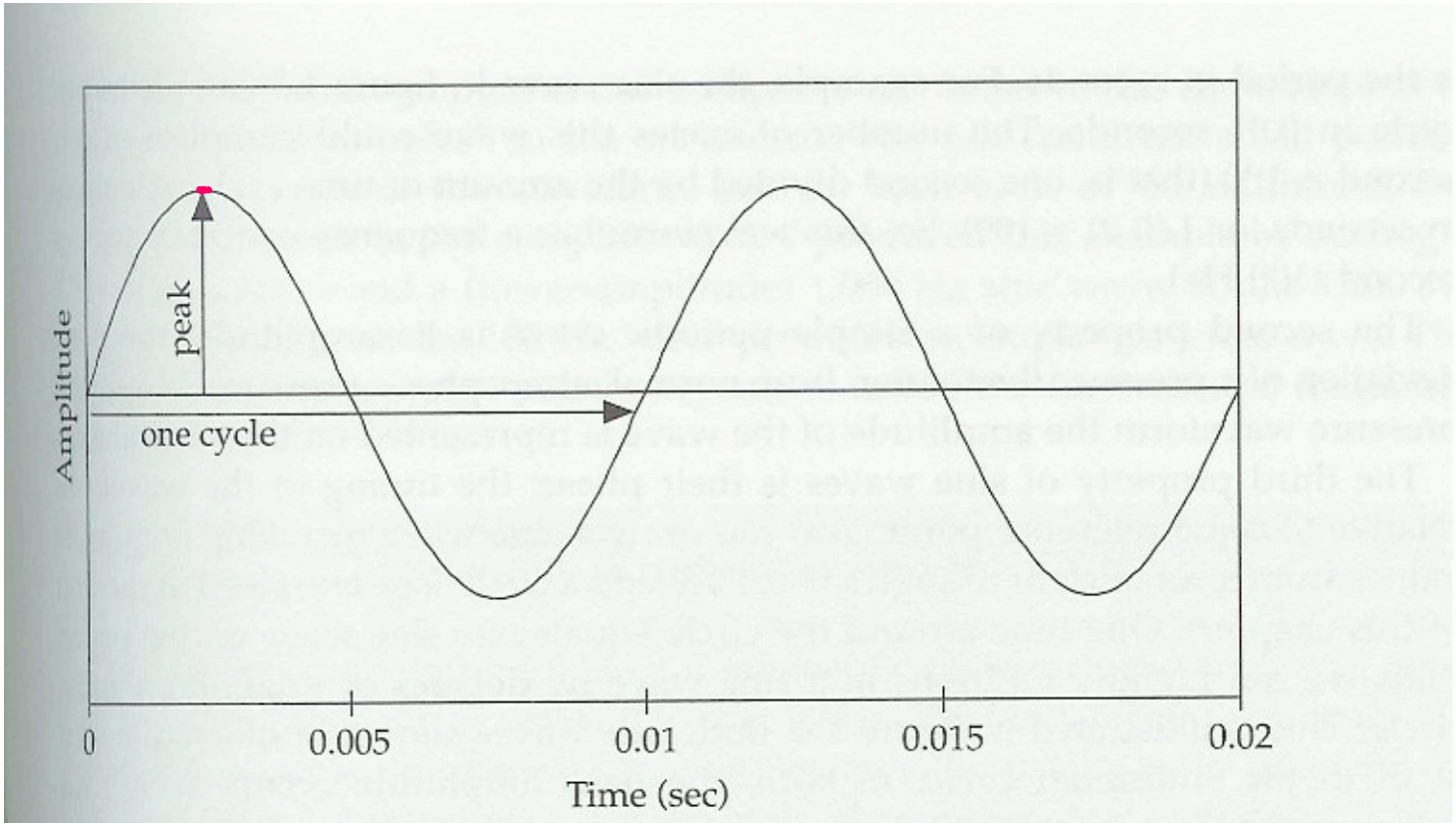


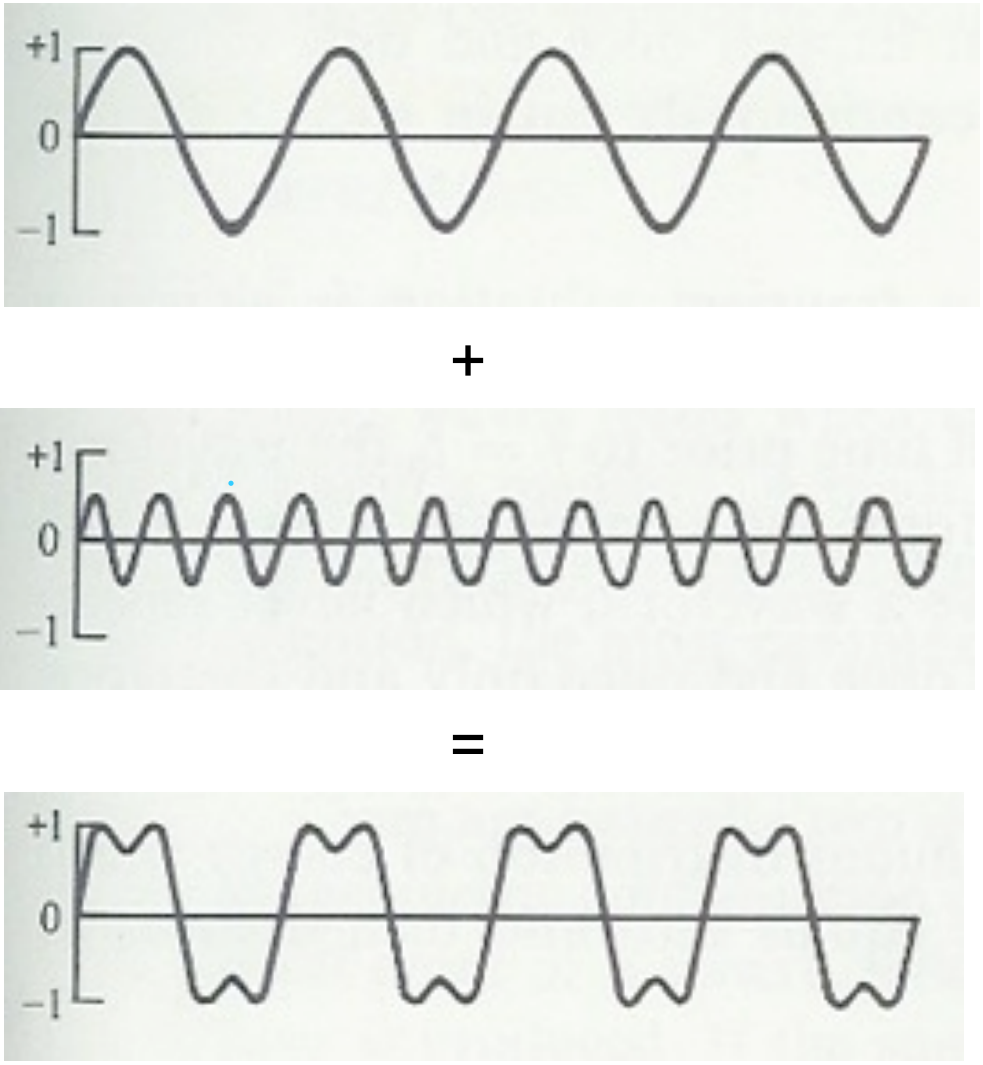
Figure 1.3 A 100 Hz sine wave with the duration of one cycle (the period) and the peak amplitude labeled.

Complex Waves

- When more than one sinewave gets combined, they form a **complex wave**.
- At any given time, each wave will have some amplitude value.
  - $A_1(t_1)$:= Amplitude value of sinewave 1 at time 1
  - $A_2(t_1)$:= Amplitude value of sinewave 2 at time 1
- The amplitude value of the complex wave is the sum of these values.
  - $A_c(t_1) = A_1(t_1) + A_2(t_1)$

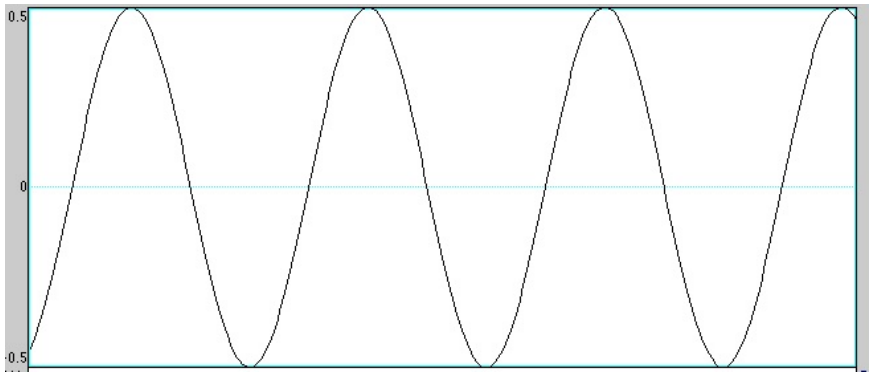
Complex Wave Example

- Take waveform 1:
  - high amplitude
  - low frequency
- Add waveform 2:
  - low amplitude
  - high frequency
- The sum is this complex waveform:

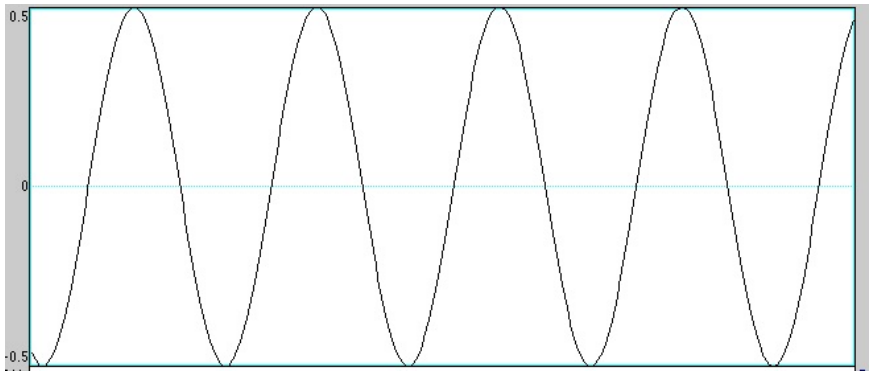


Other Examples

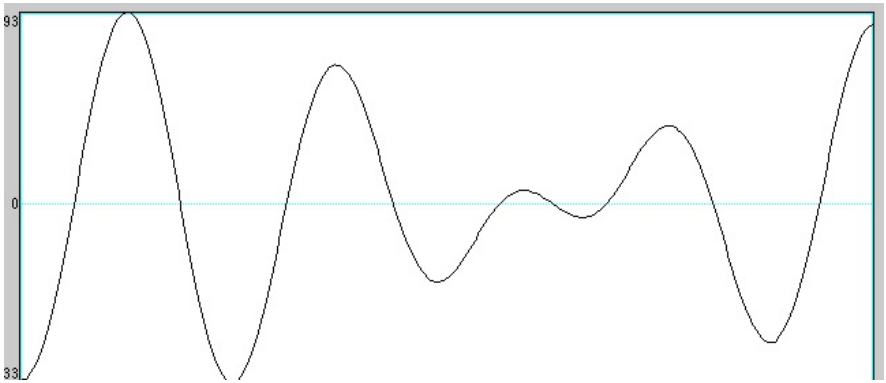
- 480 Hz tone



- 620 Hz tone



- the combo = ?



Fundamental Frequency

- The fundamental frequency of a complex wave is the frequency at which the complex wave repeats itself.
- = greatest common denominator of frequencies of component waves.
- Greatest common denominator =
    - largest number that two (or more) numbers can be divided by to yield an integer (whole number) value.
- Q: What's the fundamental frequency of a complex wave consisting of 600 Hz and 800 Hz tones?
- How about one with 120 Hz and 150 Hz tones?

Linguistically Speaking

- In speech, the fundamental frequency of voiced sounds is based on the rate at which the vocal folds open and close.
- The wave set up by the vocal folds is a **complex wave**.

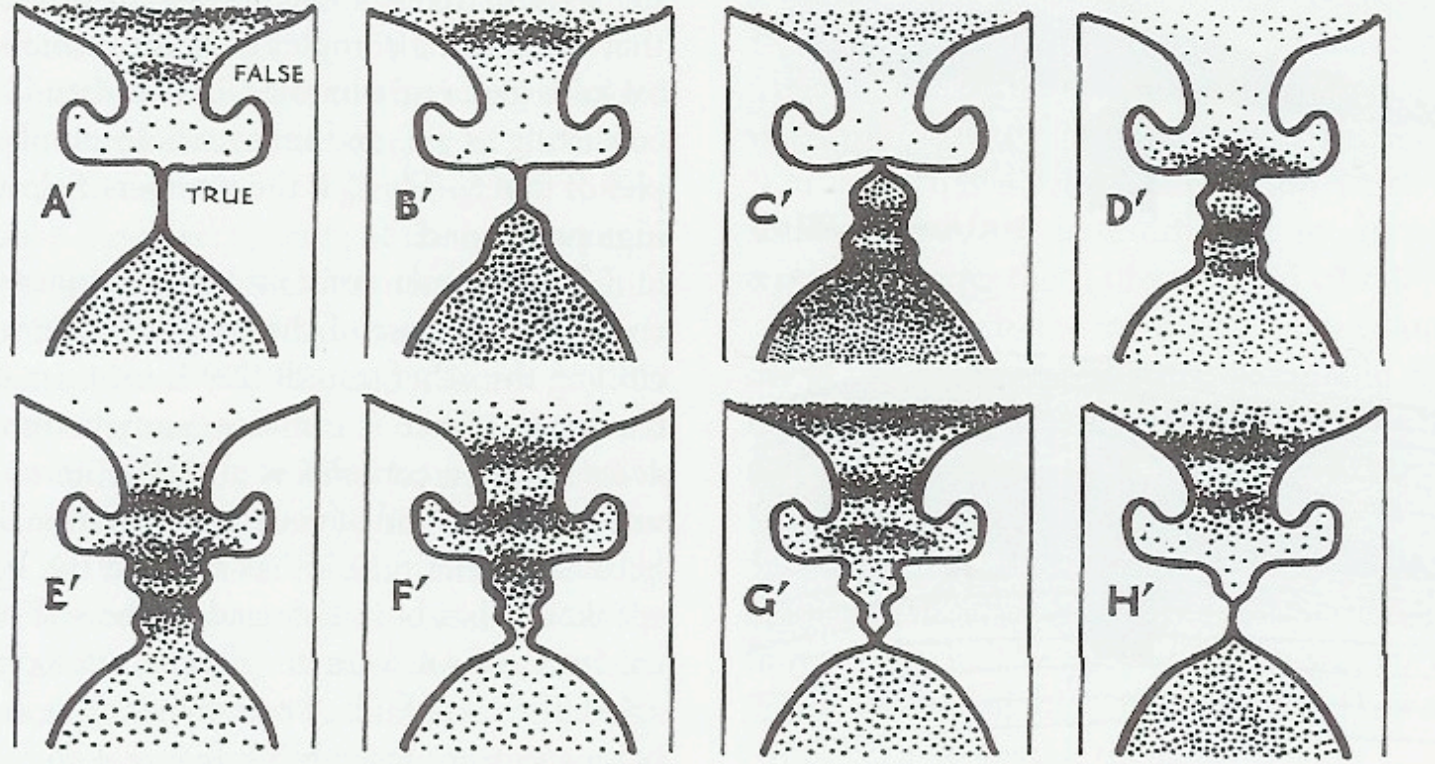
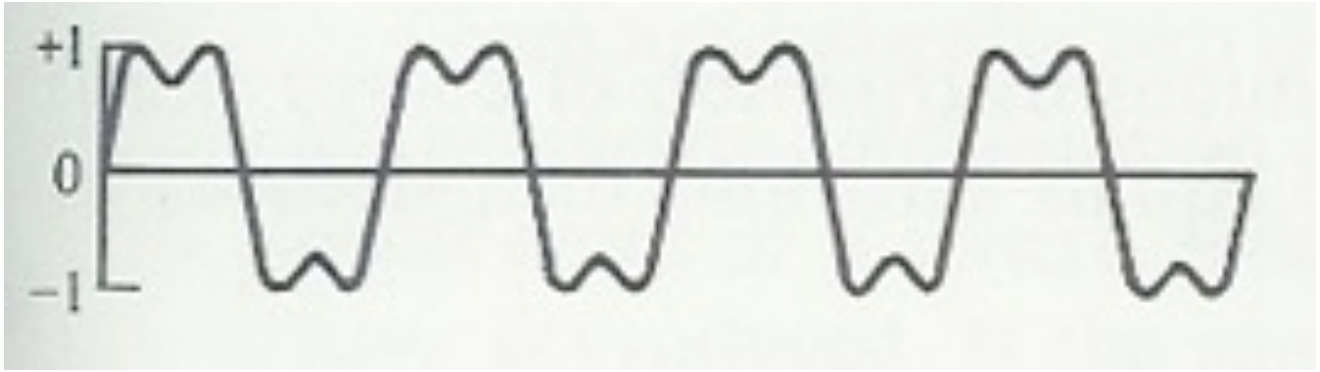


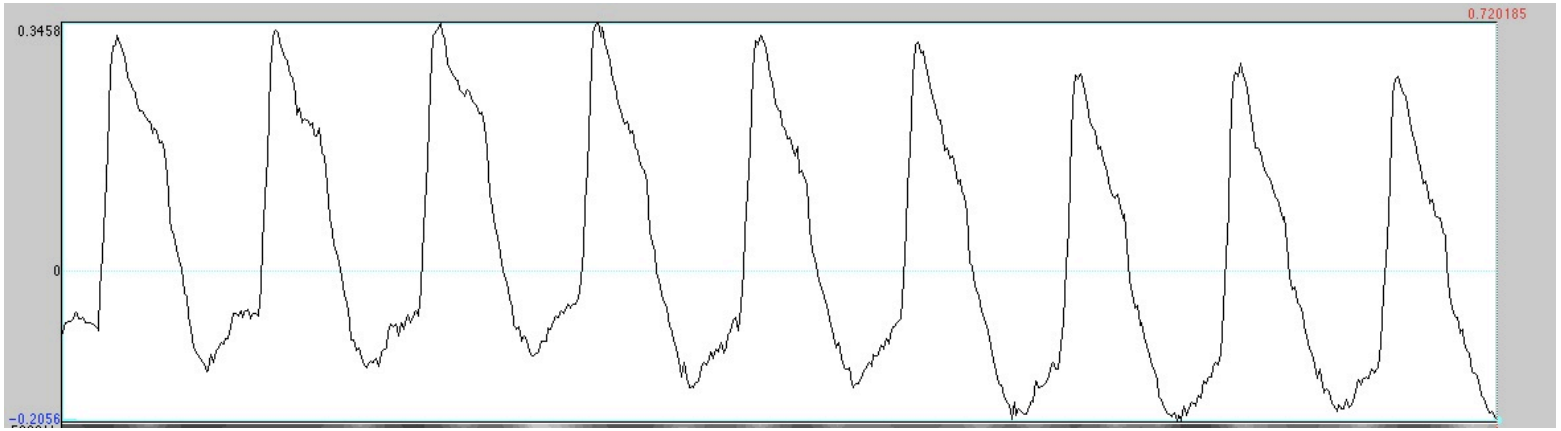
Figure 4.41. Cross sections of the vocal folds during vibration. The folds open and close from bottom to top. (Reprinted with permiss
from Vennard, W., *Singing: the Mechanism and the Technic*, New York: Carl Fischer, 1967.)

Complex Wave Visual

- Combination of 100 Hz and 300 Hz wave.



- Voicing sort of looks like this, but it's even more complex:



Why Should You Care?

- The modulation of fundamental frequency in speech can have linguistic meaning.
  - Tone
  - Pitch Accent
  - Stress
  - Intonation
- Since this modulation can occur (relatively) independently of the stream of vowel and consonant segments in speech…
  - these linguistic properties are often referred to as **suprasegmentals**.