# How Sound is Perceived: the Ear

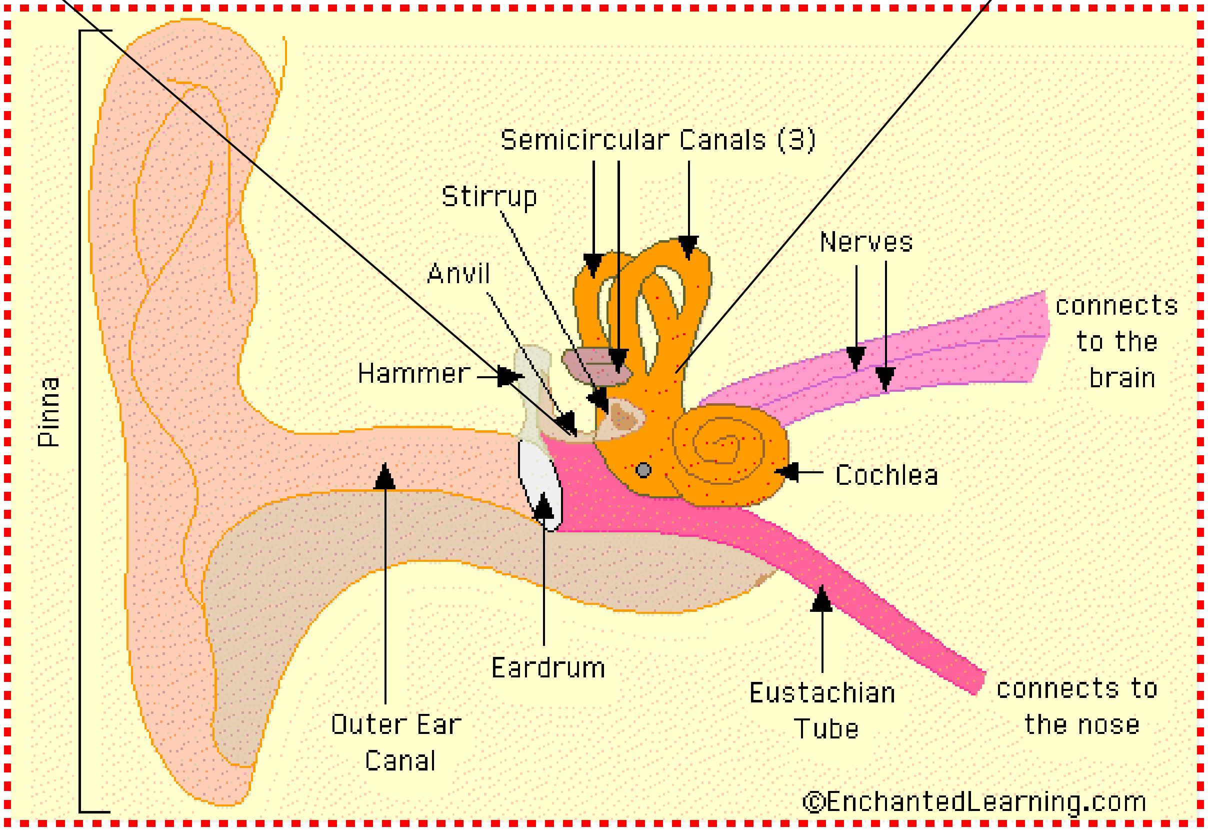
Middle Ear

Inner Ear

Sound ⇨ ⇨

Sound ⇨ ⇨

Sound ⇨ ⇨



# How Sound is Perceived

<u>The Basic Mechanics of Sound:</u>

•A sound is composed of variations in air pressure that disturb the eardrum.

•The eardrum moves with the air that is being pushed into the outer ear and moves back again when the air moves away.

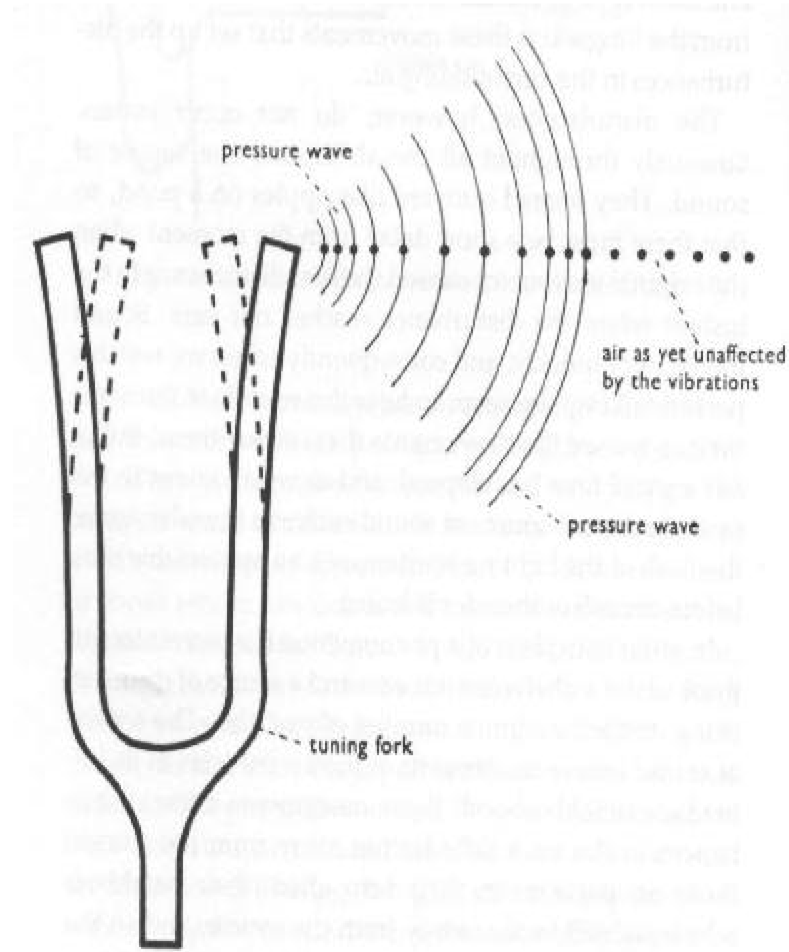
•These vibrating motions are transmitted via the bone chain to the inner ear, disturbing the liquid there, which in turn awakens the auditory nerves.

# Facts about Air

When air particles are close together, the air is compressed.

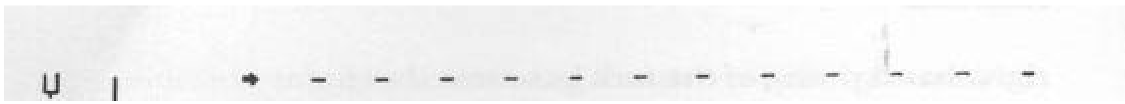
Conversely, a ***region of rarefaction*** occurs when air particles are farther apart than normal.

Alternating moments of compression and rarefaction occur when air is set in motion by some outside force, as with a tuning fork.



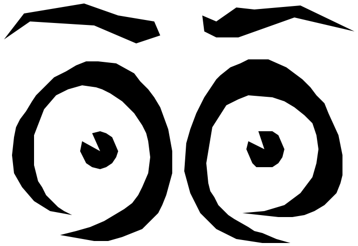

From Ladefoged,, *EAP*, p.4

# A Closer Look



From Ladefoged,, *EAP*, p.6

# But Wait!



Of course not all disturbances of air result in sound - wind, a fan, or breathing out can also move air but in ways that can only be felt, not heard.

Only certain very fast vibrations in the air are perceived as sound; others are too slow or too irregular.

This is similar to the way in which only certain things can be felt - too light a touch may be unnoticeable because the sensation is “out of our range”.

# Sources of Sound

Sound is produced by anything that causes air particles to be disturbed at the appropriate rate of vibration, although you may not always be able to see the source moving.

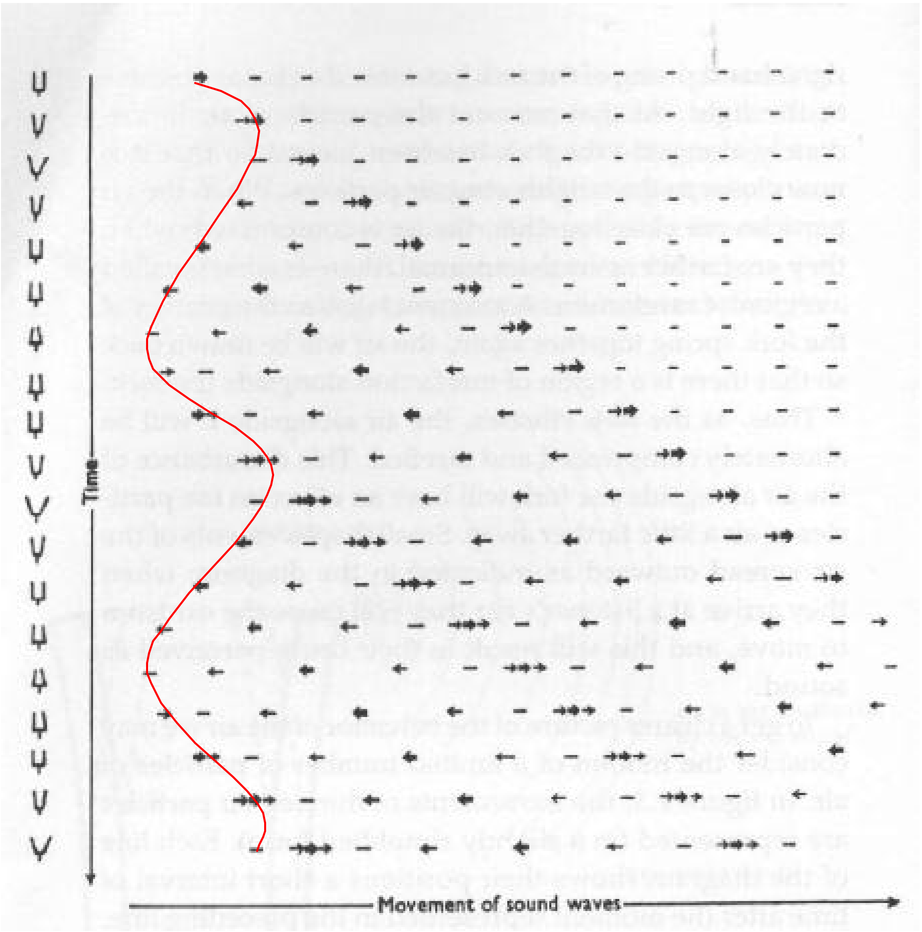
- ⇨For example, tuning forks and wine glasses move back and forth when you tap them - but only the fact that you can still the sound with your hand tells you that there was movement.

**The human voice is also a source of sound, which is caused primarily by the rapid vibration of the vocal folds.**

- ⇨The closing of the vocal folds causes air pressure to build behind them, which is then released when the vocal folds are opened; these variations in air pressure are further affected by the shape of a speaker’s vocal tract.

# Representing Sound

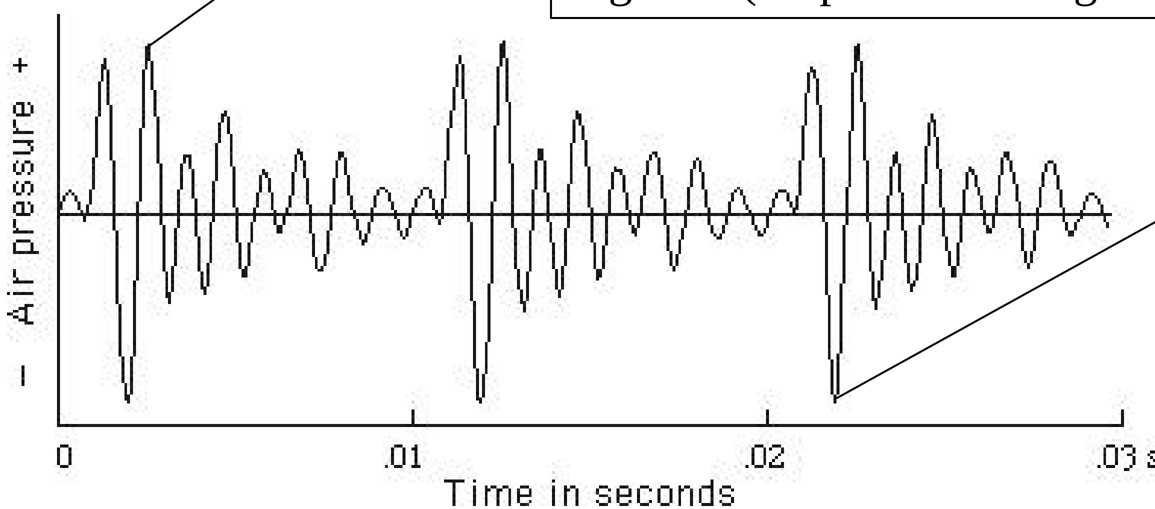
One way of seeing just exactly what the air particles are doing in speech is to examine the path of just one particle.



# Representing Sound

A more efficient way of seeing sound is to first record it and then graph the result in such a way that the fluctuations in air pressure can be seen over time either as high or low points (with respect to the pressure of the surrounding air).

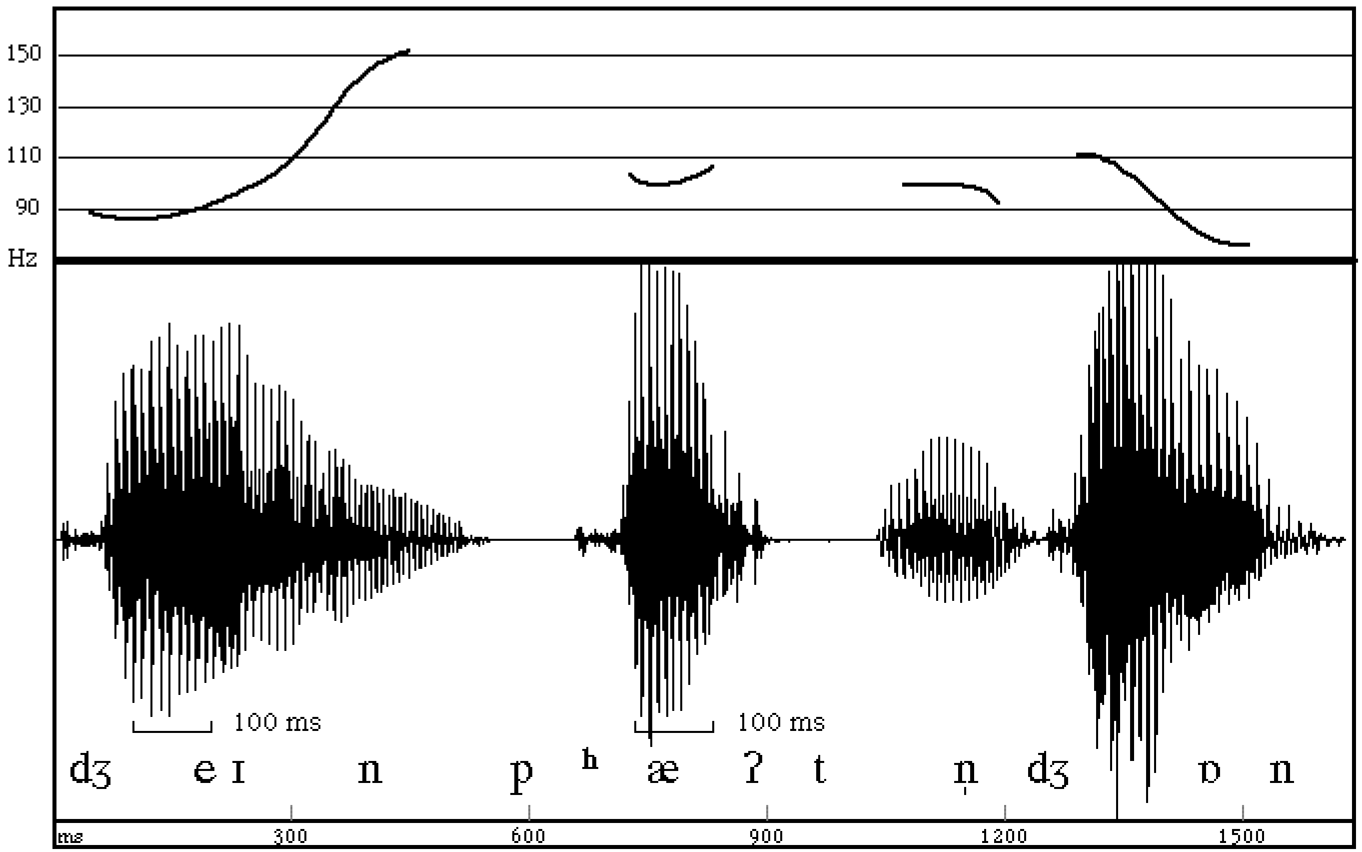
Peaks indicate when air particles are close together (air pressure is higher).




Troughs indicate when air particles are farther apart (air pressure is lower).

From Ladefoged,, *CIP*, p.162

# Representing Sound




From Ladefoged,, *CIP*, p.163

# Ways to Differentiate Sounds

- ☞ Pitch (or frequency)
- ☞ Loudness (or intensity)
- ☞ Quality (or vocal tract shape)

**All of these are independent from each other, such that any two sounds that vary along one of these dimensions will be different sounds. Sounds may also vary in more than one of these ways.**

# Pitch

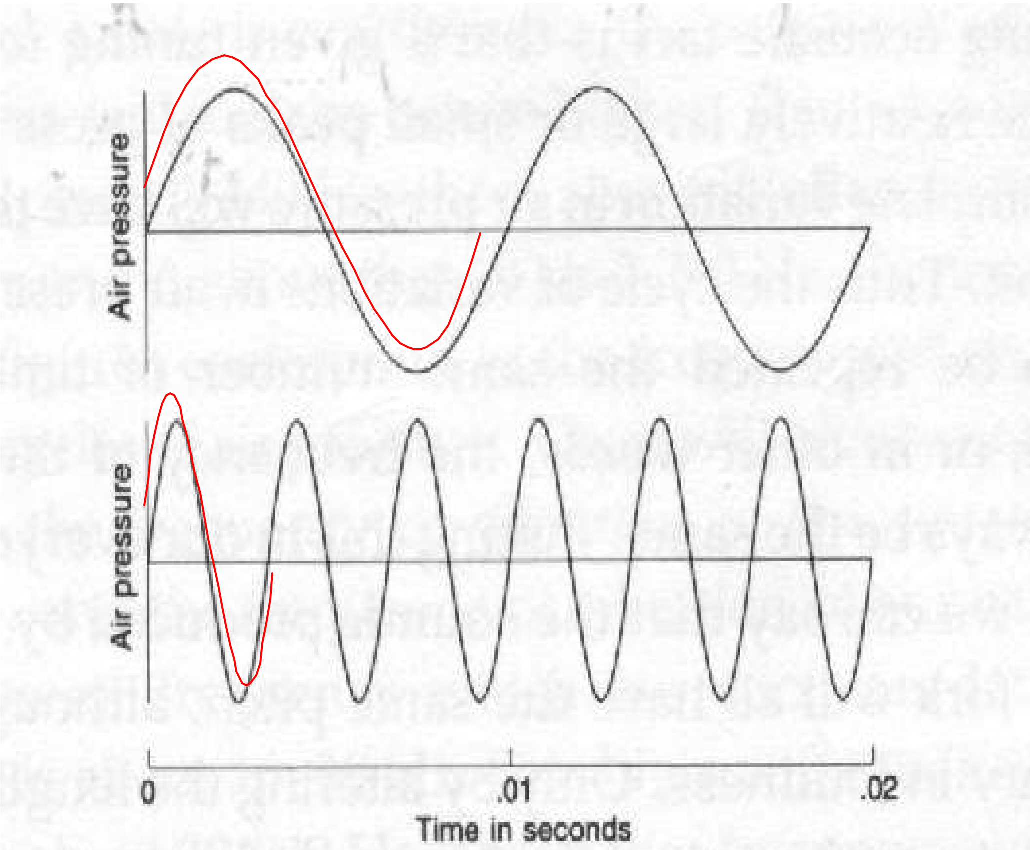
Varying the rate of vibration of a body of air affects the rate at which corresponding pressure peaks are produced - and this affects the pitch of a sound.

- ⇨For example, if one tuning fork is vibrating faster than another in a fixed time period, then it will have a higher pitch.

For a sound to have pitch, the variations in air pressure must be regular - occurring in the same way over and over again over time.

A complete variation of air pressure from from normal to peak to trough to normal is referred to as a ***cycle***.

# Pitch




From Ladefoged, *EAP*, p.19

In the top graph, a cycle occurs every 1/100th of a second. In the bottom graph, a cycle occurs every 1/300th of a second.

The **frequency** of a sound refers to the rate at which cycles occur per second and is usually measured in Hz (hertz).

Thus, the top sound has a frequency of 100 Hz (100 cycles per second) and the bottom sound has a frequency of 300 Hz (300 cycles per second).

# Pitch and Speech

The pitch of a speech sound depends on the rate of vibration of the vocal folds.

- Pitch is an auditory quality – one that allows us to rate a sound as high or low in pitch.

- Frequency is the acoustic correlate of pitch and is how we measure it. As with other sounds, the pitch of the voice is measured in hertz.

  - ⇨ 1 Hz = 1 complete cycle of vocal fold vibration per second.
  - ⇨ 220 Hz = 220 cycles of vocal fold vibration per second.

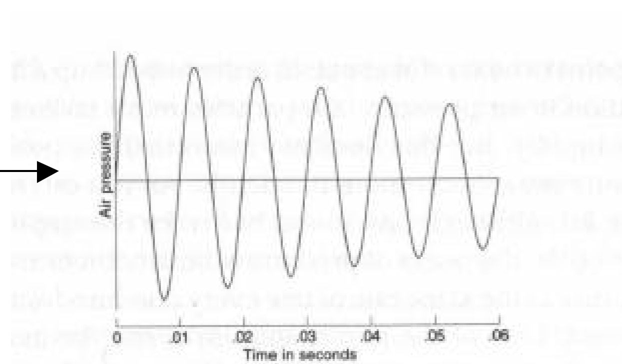
# Loudness

The loudness of a sound depends on the size of the variations in air pressure being produced.

In general, an impetus that forces a large movement of air particles will result in a louder sound.

- ⇨ A large movement of the source causes greater fluctuations in air pressure, which causes greater movement of the eardrum.

Sound waves produced by a tuning fork →



# Loudness

We can measure the loudness of a sound by considering its **amplitude** – or the point of maximum variation in air pressure from normal.

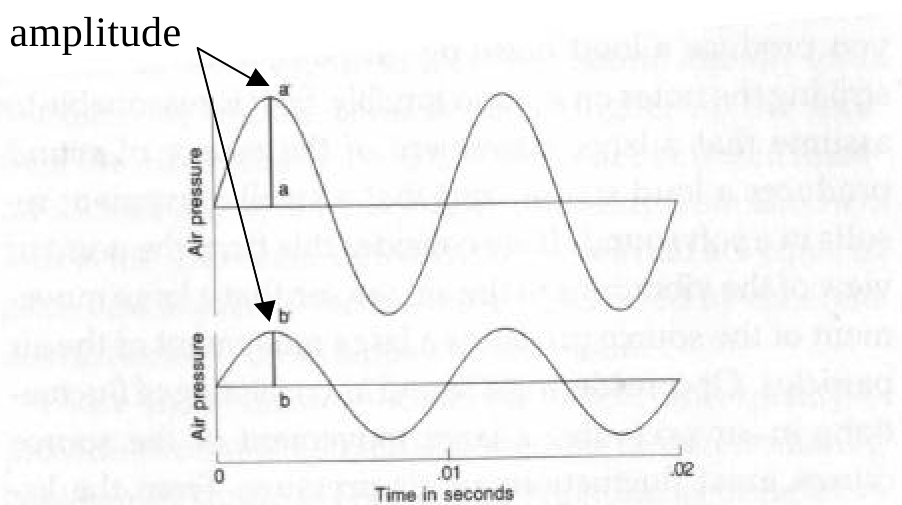



Fig. 2.1. Two sounds, one with twice the amplitude of the other.

# Loudness

Loudness is of course an auditory property – one that allows us to define a sound as loud or soft.

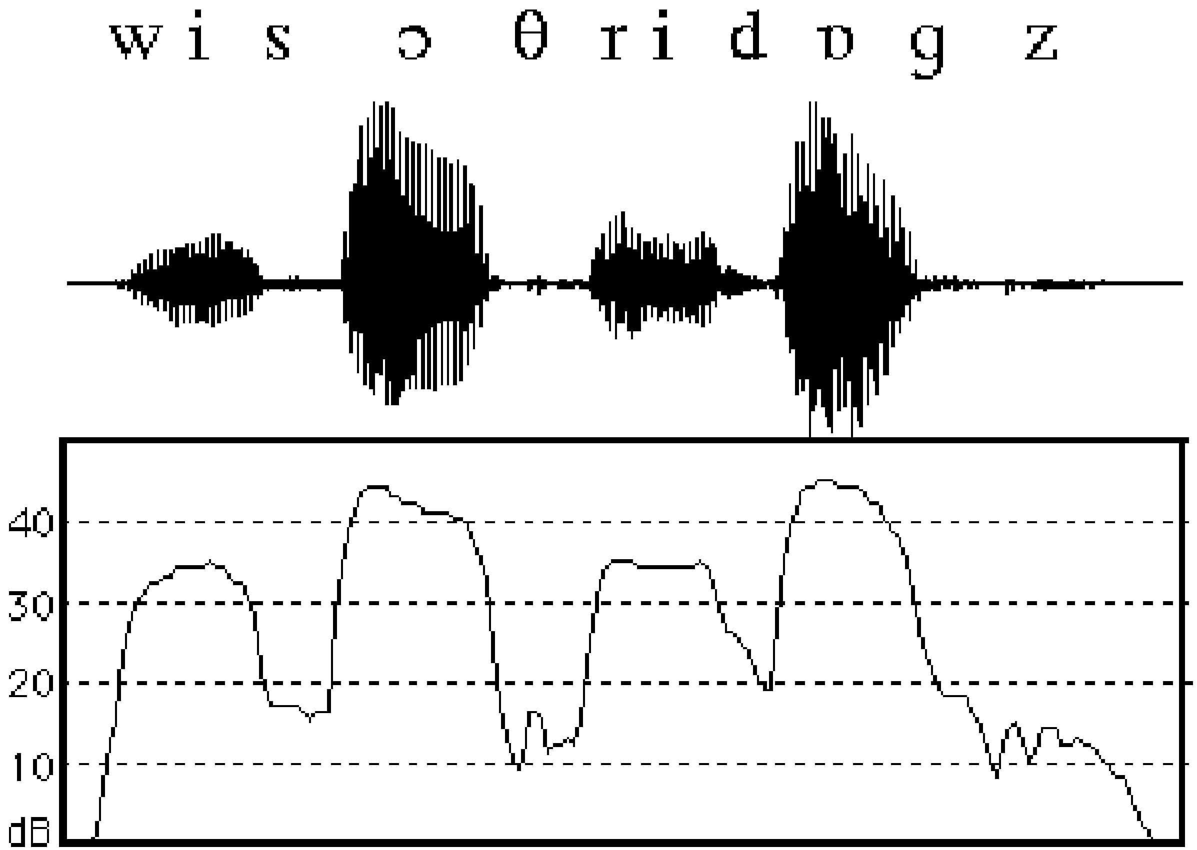
Intensity is the acoustic correlate of sound and is measured in decibels (dB).

- ⇨ Human ear can tolerate a range of 120 dB.
- ⇨ In general if a sound has an intensity of 5dB greater than another it sounds roughly twice as loud.

**A larger variation in air pressure does not mean that the peaks occur more frequently, only that they move faster and further apart.**

- ⇨ In fact, even if one sound is twice as loud as another, the rate at which peaks of air pressure occur in both sounds is exactly the same.

# Representing Loudness



# Ways of Seeing Sound

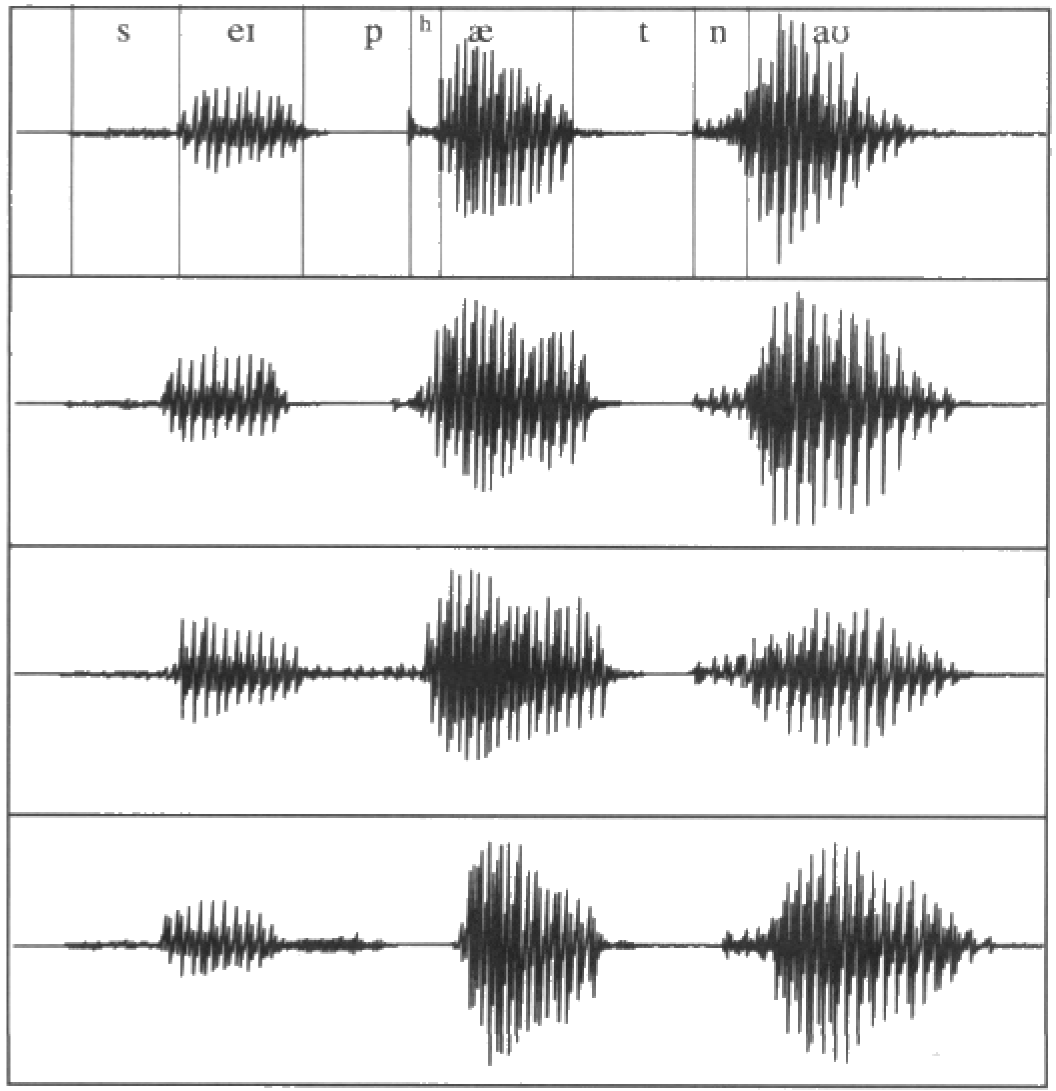
- **Waveform**: ideal for duration and intensity

- **Pitch Track**: ideal for pitch

- **Spectrogram**: ideal for quality

# Demonstration

**FIGURE 8.4** Waveforms of “Say pat now; say pad now; say bad now; say spat now.” Only the first of these phrases has been segmented. You should try to segment the other three phrases yourself.



# Demonstration

FIGURE 8.5 Waveform and pitch records of "Bonny told Peter she'd plans to leave," said in two different ways.