Exhibit message

The pitch of a pipe instrument can be changed by changing the pipe's length. Generally, longer pipes produce lower pitches.

Quick Fact

Pipe or wind instruments are classified as 'aerophones' because they vibrate a column of air to produce their sound. Aerophones are further grouped according to how the air going into them is vibrated. The three main categories are:

- **mechanical reeds**, such as the thin reed vibrated in the mouthpiece of a saxophone or clarinet
- **lip reeds**, such as a trumpet player's vibrating lips, and
- **air reeds**, such as the bevelled edge of a recorder where the edge causes only the air itself to vibrate.

Graphic panel text

In general, the **longer the length of the pipe, the lower the note**.

- Use **short lengths** to create high notes.
- Use **long lengths** to create low notes.

The pipe length determines the **wavelength** of the standing wave that forms in the pipe. The wavelength matches the **frequency of the wave**, and the frequency matches the **note we hear**. Longer pipes form longer wavelengths, lower frequencies and, therefore, lower notes.

Changing the note without changing length

1. **Closing the end of the pipe** doubles the wavelength of the standing wave, and therefore lowers the note by half.
2. Changing **how hard you blow** changes the note. Using **'lower' air** will give a lower note.

Want to know more about changing the pitch of a pipe instrument?

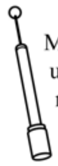
One of the easiest ways to change the pitch of a pipe instrument is to change its **length**. In general, the longer the length the lower the pitch.

Holes along a pipe, like those found in a recorder or flute, change the length of the pipe by letting air escape at different distances.

Covering all the holes creates the longest possible pipe, and the lowest possible note. Uncovering holes from the bottom of the pipe allows air to escape at shorter distances, effectively creating a shorter pipe. The shorter pipe will give a higher note. Opening all of the holes will produce the highest note.

Open or closed **holes** let air escape at different distances along the pipe.

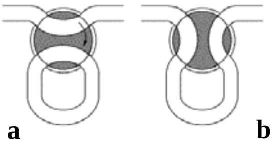
Using a slider, like those found in a pipe whistle or trombone, creates a smooth transition between high and low pitches. The lowest note is made when the slide is fully extended and at its longest length. The highest note comes from the shortest pipe, when the slide is completely contracted within the instrument. Trombone players have to be able to judge pitch and distance very accurately as there are no marks on the trombone to indicate the position of different notes.



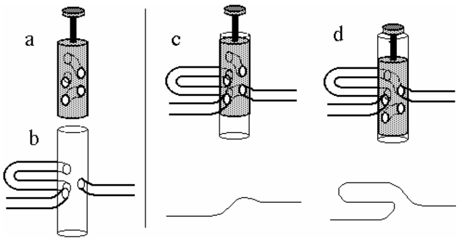
Moving a **slider** up and down makes a smooth transition.

Valves are used in brass instruments to switch between different lengths of pipe thereby changing the overall length of the instrument. Brass instruments use either rotary or piston valves.

Rotary valve



Piston valve



Images courtesy of Professor Joe Wolfe, Acoustics Lab, School of Physics, UNSW.

You can also change the pitch of a pipe without changing its length.

Covering the end of an 'open pipe' creates a **'closed pipe'**. An 'open pipe' is one that is open at both ends, such as a flute or recorder. A 'closed pipe' is one that is closed at one end. A closed pipe will produce a note that is twice as low (an octave lower) than an open pipe of the same length.

Another way of changing the pitch of a pipe instrument without changing its length is to change the **speed of the air** entering the pipe. **'Overblowing'** is a common technique used to achieve different notes when playing wind instruments such as flutes or recorders. Higher notes are produced by blowing harder (increasing the air speed) without changing the pipe's length.

Importantly, curves in a pipe generally don't change the pitch. It is the **overall length** that is important! Flares and bells, common on brass instruments, change the volume of the overtones but don't actually change the pitch of the note. Generally, flares and bells tend to make the overall sound **louder**. Wide bells radiate the higher overtones giving the instruments a 'bright' sound.

Extra for experts

Blowing into a pipe instrument causes the air to vibrate within the pipe, setting up a longitudinal sound wave in the air. This wave travels to the end of the pipe and is reflected back. The reflected wave then interferes with the first travelling wave and a **standing wave** is established.

The **wavelength** of the standing wave corresponds to the frequency of the wave, and is mainly determined by the **length of the pipe**.

The lowest frequency of the standing wave in a pipe is called the **fundamental frequency**. The fundamental frequency corresponds to the note we hear as it tends to be the loudest. Other standing waves are also produced in the pipe. These all have higher frequencies than the fundamental frequency and are known as **overtones**. The overtones are usually not as strong and add to the timbre of the instrument without changing the actual pitch.

The wavelength (λ) of the fundamental frequency of an 'open pipe' is twice the length (L) of the pipe (i.e. $\lambda = 2L$).

Given the wavelength, you can calculate the fundamental frequency (f) and therefore the expected note of a given length of pipe.

f_1= fundamental frequency
v = speed of sound in air of pipe (at 20ºC = 344 m/s)
L = pipe length

$$f_1 = v / 2L$$

Fundamental frequency of an open pipe

For example, a 66 cm long pipe (0.66 m) will produce a fundamental frequency of ~262 Hz, which corresponds to middle 'C'.

A longer pipe produces a longer wavelength which corresponds to a lower frequency and note. The first overtone (second harmonic), with a frequency twice that of the fundamental, has a wavelength that is **half** the length of that of the fundamental and the **same** length as the pipe. The equation for the frequency of the second harmonic of an open pipe is $f_2 = v / L$. Similarly, the frequency of the third harmonic can be found with the equation: $f_3 = 3v / 2L$, with a wavelength that is $\frac{2}{3}L$.

Closed pipes

The wavelength of the fundamental frequency of a 'closed pipe' is four times as long as the pipe and twice as long as that in an 'open pipe' of the same length, producing a note one octave lower.

f_1= fundamental frequency
v = speed of sound in air of pipe (at 20ºC = 344 m/s)
L = pipe length

$f_1 = v / 4L$

Fundamental frequency of a closed pipe

The wavelength of the third harmonic is 4/3 the length of the pipe and the frequency is calculated with the following equation: $f_3 = 3v / 4L$; while the frequency of the fifth harmonic, with a wavelength of 4/5 L is $f_5 = 5v / 4L$. It is important to note that closed pipes produce only **odd-numbered harmonics**.

Overblowing

Pitch gets lower as a pipe gets longer, but at some point, even though the length of the pipe may increase, the pitch rises.

Air from the source sets up an air jet with its own natural frequency.

The frequency of the jet of air is determined by how hard the pipe is blown, or, the speed of the air entering it.

At the point where the pitch rises without a change in pipe length, the standing wave of the pipe's fundamental (lowest) frequency can no longer influence the faster, higher frequency air from entering the mouthpiece. The higher frequency of air from the mouthpiece thus raises the pitch.

Using a slower airflow at this point (that is, blowing softer) will achieve a continuation in the descending pitch.

Helpful terms

Frequency: The number of times a vibration occurs in one second (hertz or Hz). Fast vibrations have high frequencies and produce high notes or pitches.

Octave: The distance between one note and the next higher or lower note with the same name. A note one octave higher than the next has double the frequency.

Overtone: Frequency produced by a note from a musical instrument that is above the fundamental frequency.

Pitch: The perceptual phenomenon of how high or low a tone seems. The pitch of a tone corresponds to its frequency. High frequencies are perceived as high pitches while low frequencies are heard as low pitches.

Timbre: The distinctive mixture of overtones that gives the characteristic quality to instruments; pronounced 'tom-ber'.

Wavelength: The distance between one wave crest, trough or matching phase and the next one. Waves with longer wavelengths have slower frequencies.

Further information

We would like to extend our special thanks to Professor Joe Wolfe from the Acoustics Lab, School of Physics, University of New South Wales (UNSW) for his assistance.

General acoustics of pipe instruments:

- *Measured Tones*. I Johnston, 2002. Institute of Physics Publishing Ltd, Bristol, UK.
- *Musical Acoustics, 3rd edition*. D E Hall, 2002. Wadsworth Group (Brooks/Cole), California
- *How do woodwind instruments work?* Acoustics Lab, School of Physics, UNSW: http://www.phys.unsw.edu.au/~jw/woodwind.html
- *Introduction to flute acoustics*. Acoustics Lab, School of Physics, UNSW: http://www.phys.unsw.edu.au/~jw/fluteacoustics.html

Brass instruments:

- *Introduction to the acoustics of brass instruments*. Acoustics Lab, School of Physics, UNSW: http://www.phys.unsw.edu.au/~jw/brassacoustics.html

General musical acoustics:

- *Conceptual Physics, 9th edition*. P Hewitt, 2002. Addison Wesley, Boston, Illinois.
- *Jacaranda Physics 2*. G Lofts, et al, 2004. John Wiley & Sons, Milton, Qld.
- *Physics, Principles with applications, 6th edition*. D C Giancoli, 2004. Prentice-Hall, New Jersey.
- Acoustics Lab, School of Physics, UNSW www.phys.unsw.edu.au/music