Exhibit message

This exhibit demonstrates an auditory illusion where the scale keeps ascending or descending in pitch (depending on which option the visitor chose to hear).

This auditory illusion is called Shepard's scale, Shepard's effect or Shepard's tone.

Quick Fact

Johann Sebastian Bach was believed to have used a version of Shepard's scale in his *Musical Offering* piece before it had been identified as an auditory illusion.

This possible melody can be heard at: http://cips02.physik.uni-bonn.de/~scheller/acoustic-illusions/main.html

Graphic panel text

Your brain may think that:
• the rising note should keep getting higher until it becomes squeaky and shrill, or
• the falling note should keep getting lower until it becomes deep and booming.

Why does the note seem to keep rising or falling, but also seem to sound the same overall?

This is an auditory illusion called **Shepard's illusion**.

It is similar to the optical illusion of the barber's pole.
You're hearing a series of overlapped soundtracks, where the notes change volume as they change pitch.

These soundtracks are cycled, so that the first soundtrack note becomes softer as it continues to change pitch. It is then replaced by another soundtrack that grows louder as it changes pitch.

Our brain is better at picking how a note **changes** pitch, rather than a note's **actual** pitch.

This ability to detect changing pitch may also be important for learning speech patterns.

Want to know more about the never-ending scale?

Our brains are better at picking **changes** in pitch rather than **absolute** pitch.

This means we can distinguish when a note rises or falls, but only a small minority of the human population can say "that is D" upon hearing a note. People who can name a note are said to have perfect pitch.

In 1964, a psychologist named Shepard undertook an experiment where he played a sound consisting of a layered tones separated by **octaves.**

In music, an **octave** is the interval between one musical note and another whose pitch is twice its frequency.

So, if one musical note is vibrating with a frequency of 400 Hz (hertz or vibrations/second), the note an octave above it is vibrating at 800 Hz, and the note an octave below is vibrating at 200 Hz. The ratio of frequencies of two notes an octave apart is therefore 2:1.

The human ear tends to hear both notes as being essentially "the same". For this reason, Western music notation gives the same name to notes that are one octave apart (the note one octave above A is also A).

The brain's way of interpreting sound (and visual) information is often used to create illusions.

Our tendency to be 'fooled' by auditory illusions also depends a little on our childhood experiences and cultural background.

A researcher named Deutsch tested an auditory illusion called the **tritone paradox** on parents and their children.

This tritone paradox contains notes that lack a clear octave distinction.

To make an ambiguous C note, Deutsch combined the harmonics of all C notes and manipulated their relative amplitudes (in essence, playing all six C notes on a keyboard simultaneously).

A person listening to this might be able to identify the note as C but remain unsure if it is middle C or the C an octave above or below.

Deutsch then paired each ambiguous C note with another note one half of an octave away (a musical distance called a **tritone**).

For instance, volunteers heard a C followed quickly by F sharp or an A sharp, followed by E.

The volunteers were asked to judge whether a pair of notes was rising or descending in pitch.

Because listeners were unsure about which octave the note belonged to, some people found it difficult to judge whether the notes were rising or falling.

The children's perceptions of what notes were being played were the same as the perceptions of their mothers, even when they had been born and raised in different countries.

So a Californian child heard what her British mother perceived, rather than hearing what other Californians heard.

"This very strong correlate must reflect the fact that we are very attuned to the pitch of speech," says Deutsch.

This raises an interesting point for composers, as the music they are composing and hearing may be perceived quite differently by listeners in different countries.

This difference in tone perception may also be useful for the study of neurological disorders. People suffering from certain types of brain damage often have flat speech intonations.

Extra for experts

People listening to an instrument playing in a concerto can often pick a note played incorrectly.

This is because the relationship between note pitches in a piece of music, known as **tonality** and **spatial relationships**, primes the brain to hear certain pitches and patterns of pitch together.

If our brain does not hear an expected pattern of notes, it interprets disharmony in the pattern, or gets confused.

Scientists believe that the area of the brain located just behind a person's forehead is involved in tracking the spatial relationships between tones in a piece of music.

The brain activity of eight volunteers listening to a melody was measured using magnetic resonance imaging (fMRI). The melody moved through all 24 major and minor keys in a pattern representative of Western music.

This pattern of musical notes can also be depicted as a geometric, doughnut-shaped figure called a torus.

The volunteers were asked to identify test tones and the sound of a different instrument buried within the tune.

The volunteers' brain regions known as the rostromedial prefrontal cortex seemed to be responsible for tracing the music as it 'moved' over the surface of the torus.

This brain region is also important for mediating interactions between emotional and non-emotional information, which may help to explain the link between music and emotion.

Further information

- *Demonstration of auditory illusion* http://littleshop.physics.colostate.edu/Auditory_Illusion.html
- Acoustic illusions http://cips02.physik.uni-bonn.de/~scheller/acoustic-illusions/main.html
- *Escher for the Ear*, Philip Yam Scientific American, March 1996.
- *Paradoxes of Musical Pitch*. Diana Deutsch. Scientific American, August 1992.
- *Scientists Refine Musical Map of the Brain*. New Scientist. December 13, 2002.
- *The Octave Illusion Revisted Again*. Diana Deutsch. Journal of Experimental Psychology: Human Perception and Performance. Vol 30 (2), April 2004.
- *Circularity in relative pitch judgments for inharmonic complex tones: The Shepard demonstration revisited, again*. Edward M Burns. Perception and Psychophysics. 1981, Vol 30 (5), 467-472.
- *The Neural Networks of Music*. E Baeck. European Journal of Neurology, 2002. Vol 9.
- *Relationships between Pitch-Matching Accuracy, Speech Fundamental Frequency, Speech Range, Age and Gender in American English-Speaking Preschool Children*. Valerie L Trollinger. Journal of Research in Music Education. Spring 2003, Vol 51 (1).
- *The Octave Illusion Revisted: Suppression or Fusion Between Ears?* Diana Deutsch. Journal of Experimental Psychology: Human Perception and Performance. Volume 28, 6, 2002.
- *Auditory paradox based on fractal waveform*. Manfred R Schroder. Journal of the Acoustical Society of America. January 1986, Vol 79 (1).
- *Continuation of auditory frequency gradients across temporal breaks: The Auditory Poggendorff*. Irwin Pollack. Perception and Psychophysics. 1977. Vol 21 (6).