Exhibit message

The two-dimensional surface of a drum skin produces different patterns depending on the frequency of vibration.

Quick Fact

Drums are classed as **percussion** instruments because they do not usually produce notes of definite pitch and are mainly rhythm keepers. Drums have timbres that do not match other instruments in the orchestra. This makes drums stand out and they are therefore used to highlight particular melodic tones.

Unlike most drums, the kettledrum has an 'almost definite' pitch. This is because the modes, although not harmonic, are nearly so. If the kettledrum is out of tune it is very noticeable.

Because drums produce sounds by vibrating a stretched skin (membrane) over a cavity they are technically known as **membranophones**. Percussion instruments that vibrate the entire body, such as xylophones or triangles, rather than a stretched skin are known as **idiophones**.

Graphic panel text

The patterns you see on the drum are made up of nodes and antinodes.

To know a node
The **nodes** on the drum are the areas that are not moving at all. On either side of a node is an area that is either pushed above or pulled below the normal height of the drum skin. These areas are the **antinodes**.

Patterns on the drum
The patterns of nodes seen on the drum depend on the **frequency of the vibration** and are made up of a mixture of **circular** and **linear** (straight line) nodes.

Circles and lines
Linear nodes usually make the musical sound of the drum, while **circular nodes** make the 'thump' sound.

Want to know more about standing waves on the surface of drums?

When a drum is played, waves spreads out from the point at which the drum is struck. These **waves are reflected** from the edge from the edge of the drum and travel back in the reverse manner. The waves travelling in opposite directions interfere with each other constructively and destructively.

Constructive interference occurs when two waves add together to produce a larger wave. **Destructive interference** occurs when two waves create a smaller wave or cancel each other out completely.

A regular pattern of constructive and destructive interference creates a **standing wave**. The **frequency** of a standing wave determines the numbers of 'nodes' and 'antinodes' present in the wave.

The **nodes** on the drum are areas that are not moving at all. Nodes are also called **nodal lines** because they form a line rather than a point.

On either side of a node is a bump which is above the normal height of the drum skin, or a dent which is below the normal height of the drum skin. These opposing areas are **antinodes**. Antinodes switch between being a bump or a dent. Nodes, on the other hand, remain at the normal height of the surface of the drum skin.

The two-dimensional standing waves in drums are seen as a frozen pattern of bumps and dents, with nodes in between.

The nodes can appear in a circular pattern, or a linear (straight line) pattern depending on the frequency of the vibration of the drum skin.

Patterns of nodes and matching frequencies are called **modes**. The **first mode** is the slowest (fundamental) frequency. In string and wind instruments the fundamental frequency (first mode) determines the pitch of the note. Unlike other instruments, the first mode in the drum is not musically important as it disappears quickly. In the drum, it is the **second mode** that is heard as the **lowest sound** from the drum.

The modes most responsible for the **musical sounds** of the drum are the second, third, fourth and fifth. All of these modes have **linear nodes** (as well as a circular node around the edge of the drum). Linear nodes are responsible for the musical sounds of the drum. Modes that have **only circular** nodes contribute to the 'thump' sound of the drum and not much to the musical sound or pitch.

Both the **tension and size** of a drum skin affects the pitch or sounds that it makes. The frequency of the vibration, and therefore the pitch, depends on the thickness and size (diameter) and stiffness (tension) of the skin. Larger skins vibrate more slowly, have lower frequencies and thereby produce lower pitches. Stiffer, tenser skins vibrate faster, have higher frequencies of vibration and produce higher notes.

The size (surface area) of drum skins is usually fixed for any given drum, but the player can **tune the drum** by adjusting the tension of the skin. This is done by tightening or loosening screws at the edges of the drum. Tightening a drum skin increases the tension while loosening a drum skin reduces the tension. Increasing the tension of the drum skin increasing the fundamental frequency, thereby raising the pitch. This is similar to shortening the length of the string in a string instrument.

The **loudness** of the sound of a drum depends on the size (amplitude) of the vibrations and overall surface area of the drum. A larger amplitude or surface area produces a louder sound.

The sound of a drum is also affected by the nature and shape of the drum **cavity**.

Extra for experts

Percussion instruments, such as drums, have waves travelling in **two dimensions**, that is, they spread out in all directions along the surface of the drum. The waves of string and pipe instruments, on the other hand, travel in only one dimension, forwards or backwards in a linear direction.

The energy of the waves on the two-dimensional drum surface spreads out. As it does so any single particle collects only some of the energy from the one before it and passes on to more than one, so the amount of energy decreases as it spreads out. Drums and other percussion instruments therefore vibrate in a more complicated manner than other instruments.

Unlike other instruments, the frequencies of the **modes** of drums are not whole number multiples of the fundamental frequency, that is, they are **not harmonics**. In this case, higher frequencies than the fundamental frequency are called **overtones**. Overtones do not easily sustain their sound and the sound dies away quickly. Drums, cannot give out a sustained tone without changing their sound.

The frequency of the overtones determines the pattern of linear and cicular nodes on the surface of a drum skin. The patterns of the **modes** can be represented by a **notation** which represents the number of linear and circular nodes present, such as (2,3). Using this notation, the **first number** represents the number of **linear nodes** and the **second number** represents the number of **circular nodes**. There is always a circular node around the fixed edge of the drum as the drum skin cannot move here, so the second number will never be less than '1'.

The **first mod**e if a drum produces only one circular node (around the edge of the drum) and no linear nodes. Its **notation** is therefore **(0,1)**. The second mode has a pattern of one linear node and one circular mode is therefore notated as (1,1).

Frequency and patterns of the first six modes

Mode	Frequency	Pattern
1st (fundamental frequency)	*f*	(0,1)
2nd	1.59*f*	(1,1)
3rd	2.14*f*	(2,1)
4th	2.30*f*	(0,2)
5th	2.65*f*	(3,1)
6th	2.92*f*	(1,2)

** These are values for the membrane only, not the membrane and cavity.*

The first and fourth modes are produced when struck in the middle; while the other modes are produced when hit off-centre.

The drum cavity affects the frequency of the modes. The first mode compresses and expands the enclosed air within the drum cavity. The second mode moves it from side to side which increases the mass of the head without changing the volume of air. This raises the frequency of the first mode slightly but decreases the frequency of the second mode.

The first mode is not considered musically very useful. A small hole in the cavity releases pressure and allows sound created by the first mode to escape and be dulled, further lessening the musical importance of this mode but contributing to the dull, thud sound created by the drum.

The second mode is the lowest note heard. It is the 'apparent fundamental'. The higher modes are overtones of the true fundamental (first mode), not the apparent fundamental (second mode).

Helpful terms

Amplitude: The distance of the wave crest or trough from the equilibrium point.

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

Fundamental frequency: The lowest frequency of a musical sound.

Harmonic: An overtone that is a whole number multiple of the fundamental frequency. All harmonics are overtones, but not all overtones are harmonics. Drums do not produce harmonics.

Overtone: Frequency produced by a note from a musical instrument that is above the fundamental frequency. May be a whole number multiple of the fundamental frequency or not.

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.

Further information

- *Musical Acoustics, 3rd edition*. D E Hall, 2002. Wadsworth Group (Brooks/Cole), California.
- *Measured Tones*. I Johnston, 2002. Institute of Physics Publishing Ltd, Bristol, UK.
- *Tuning Drums*. Clay Vernon. http://scatcat.fhsu.edu/~crvernon/resume/tuningdrums.htm
- *The Physics of Musical Instruments, 2nd edition*. N H Fletcher and T D Rossing, 1998. Springer-Verlag, New York.

To see animations of the different modes of a drum skin:

- *Vibrational Modes of a Circular Membrane* – Dr Dan Russell, www.gmi.edu/~drussell/Demos/MembraneCircle/Circle.html