THE SCIENCE OF SOUND & MUSICAL INSTRUMENTS

Sound is vibration. It occurs when the rapid movements of an object produce invisible **sound waves** that move through the atmosphere. Sound is heard when sound waves reach the ear and are channeled to an eardrum, which causes the eardrum to vibrate. The brain perceives these vibrations as sound.

Pure sound wave created electronically

For example, plucking or bowing the strings of a violin causes molecules in the air to start moving back and forth. This motion – the sound waves – are the vibrations that move away from the instrument in all directions. The body of the violin **amplifies** the sound vibrations. In a woodwind instrument such as a clarinet, air flows over the reed and down a tube. The reed vibrates and the tube **amplifies** the vibrations into sounds you can hear.

The overtones of a violin note produces a jagged sound wave

The soundwaves of various instruments travel at different rates of speed and with varying intensities and frequencies. The variety of instruments in a band produce different sounds because of the variables. For example, the materials used to make the instrument, its shape, what part or parts vibrate, and overall size are all variables that impact the sound produced. Here are some examples of variables to think about:

- Would a drum sound different if it were struck with a piece of rope rather than a drumstick made of wood?
- Do bamboo flutes sound different than metal flutes?
- How does the sound of an 18th century violin with strings made of animal gut differ from a 21st century violin with metal strings?

Another variable to consider is the combination of instruments that play together. Different combinations will change the sound of a piece of music. For example, imagine your favorite John Phillip Sousa march played on a harp! Or how the rhythmic passages for pencil and music stand in *Rhythm Stand* would sound if they were played by metal spoons on rubber tires.

Describing Musical Sound

What words and phrases do you use to describe the sounds you hear, especially musical sounds? High or low? Loud or soft? How about characteristics of the sound? Is it detached or smooth, bright or dark, thick or thin? These are words musicians use to describe sound organized by its **pitch**, **dynamics**, and **timbre**. We think about and listen for these characteristics all the time. Scientists think about these same characteristics in other terms: **frequency**, **amplitude**, and **waveforms**. The more you know about how sound occurs, the more you will understand how your instrument works.

SOUND WAVES & THE TRANSMISSION OF SOUND

Music is made from organized sound waves where the vibrations are periodic and follow each other regularly and rapidly. These even, regular sound waves produce sounds we recognize as pitches. This is pleasing to our ears. Most instruments are crafted to produce such sound waves, but there are exceptions (think of some of the percussion instruments). Noise, on the other hand, is made from irregular random mixtures of sound waves.

music

noise

Imagine the sound of a timpani head being struck. Sound is transmitted through movement of the air molecules between the timpani head and your ear. The timpani head vibrates by moving up and down, creating an alternating chain called a sound wave. A complete sound wave consists of one up-and-down movement or cycle. The compression and expansion of molecules travel from the source of the vibration (the drum head), through air and eventually reach the ear. This causes the eardrum in the outer ear to also vibrate.

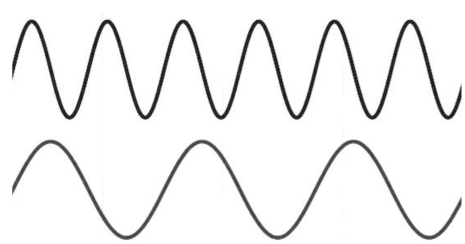
FREQUENCY

Sound waves travel at different rates of speed and with varied intensity and **frequency**. Sound wave frequency is controlled by the number of times an object (and therefore, the sound waves) vibrate in one second. Frequency is measured in units that scientists call **hertz**. Hertz are the number of times (the frequency) that a sound wave passes a specific point each second. The frequency of the vibrations determines the pitch of a sound. The faster the vibrations, the higher the pitch. And at the opposite end, slow vibrating sound waves produce lower pitches.

A good example of this is an experiment with two soda bottles filled with water – one with just a small amount, and the second more fully. When you blow across the top of the bottle, air vibrates within the bottle producing sound. If there is more water in the bottle, the column of air has a short distance to travel, so it vibrates more quickly, producing a higher tone. But the flow of air in the bottle with the less water travels a greater distance, producing a larger column of air, which then causes the air to vibrate at a slower rate. This creates lower pitches. High pitches have high frequencies and short wavelengths. Low pitches have low frequencies and longer wavelengths.

high frequency

low frequency



Sound can travel at a speed of 1100 feet per second (roughly 750 miles per hour) in dry air at a normal air temperature of 20 degrees Celsius or 68 degrees Fahrenheit. Since air temperature affects the speed of sound waves, is also affects the intonation of instruments. That is why instrument goes flat or sharp as the temperature changes.

All instruments produce sound by setting air molecules into vibration. For a flute, air is blown over the top of a hole in the side of the instrument. For other woodwind instruments, a reed vibrates as air passes over it. “Buzzing” lips touching a metal mouthpiece causes air vibration in brass instruments. In all cases, sound waves are produced through the compression and expansion of air molecules.

Sound waves can be measured using a device called an **oscilloscope**. An oscilloscope displays both the shape of a sound wave and the rate of the vibration that produces it – the vibrations per second. The rate of vibrations, the frequency, is expressed as the number of Hertz, the cycles that occur per second. The higher the frequency or number of Hertz, the higher the pitch. Have you ever heard a musician say they are tuning to an A 440? The musician is tuning to the pitch, A, which has a frequency of 440 Hertz or 440 cycles per second.

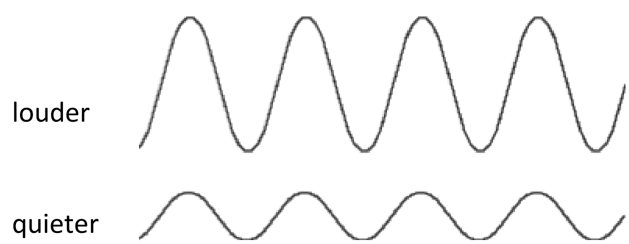
KNOWING ABOUT FREQUINCY HELPS WHEN TUNING

When comparing a flute and a piccolo, which has a higher range? The piccolo, with its shorter tube, can play higher notes. The shorter the vibrating tube or string or the smaller the surface of a drum head, the higher the pitch. Musicians need to keep this important scientific fact in mind when tuning their instruments. In order to adjust the overall intonation of an instrument that is playing flat, one must make the tubing shorter by pushing in the tuning slide. To correct an instrument that is playing too sharp, the performer pulls out the tuning slide to lengthen the tubing, thereby lowering the pitch.

Pushing in or pulling out in the head joint may adjust the intonation of a flute. A clarinet player raises or lowers pitch by pushing in or pulling out on the barrel. It is very important that all instrumentalists know how to adjust the pitch of their instruments to better play in tune with other musicians. Remember, the longer the tubing, the lower the pitch. The shorter the tubing, the higher the pitch.

AMPLITUDE

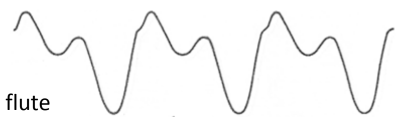
The oscilloscope also measures the amplitude of a sound wave. The amplitude is the intensity or loudness of a sound. Amplitude is represented visually by an oscilloscope as the width of how the waves rise and fall from the center line on its screen.



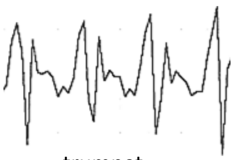
HARMONICS

The sound wave that produces a single frequency is called a **sine wave**. A sine wave represents a pure tone with the shape of a smooth curved line moving up and down. When instruments make sounds, the shape of the sound waves are not so simple and smooth. Typical sound waves of instruments are more complex and reflect additional notes that sound simultaneously with the main that is heard, called **harmonics**.

There are many notes that "ring" along with the main note-some strongly, some weakly. You are able to identify the instrument you are hearing by its tone. The stronger and weaker harmonics that "ring" along with the main note give an instrument its color and characteristics. The shape of the waveform that produces an instrument's tone deviates from the shape of these basic examples depending on how many additional harmonics are sounding strongly. While the shape of the wave produced by a flute is similar to a sine wave's even curves, the sound wave produced by a brass instrument, such as a trumpet, is similar to a **saw tooth wave**. A clarinet and other reed woodwind instruments produce a wave similar to a **square wave**.



flute



trumpet

Learn More

- The Method Behind the Music, http://method-behind-the-music.com/mechanics/physics/, is a website created and updated by high school students who entered a ThinkQuest competition. Retrieved on 3/18/16.
- http://www.earmaster.com/ a company that creates software for ear training and sight singing skill development. The site includes a Music Theory section. Chapter 3 is about the Science of Music and Acoustics. Retrieved on 4/19/16.
- How Music Works, an online tutorial at http://www.howmusicworks.org/100/Sound-and-Music. Retrieved on 4/19/16.