Music Physics

Some physics

Since sound is the medium of music, most of the physics of music is the physics of sound. Here's a *little* bit of music-related physics.

Vibration

Vibration is the source of all sound. Vibrating objects push against the air (or other medium- you can substitute water, jello, or whatever) around them, creating little zones of compressed air (or water, or jello). The zone of compressed air pushes against the air around it, which pushes against the air around that, and so on. Between compression pulses the air "springs" out past the pressure where it began, creating a zone of less pressure, or *rarefaction*. You end up with zones of compression and rarefaction that travel outward from the sound source, one after another at a rate equal to the rate of that source's vibration. These, friends, are sound waves.

Sound waves

It's important to remember that sound waves are compression waves. You can imitate a compression wave by stretching out a slinky (you do have a slinky, don't you?) and flicking your finger against a coil at the end. Sound waves are not like the waves on the ocean or the waves you get by waving a stretched-out rope.

Frequency and pitch

Sound waves have a **frequency**, which is the number of compression pulses that go past a fixed point in a given amount of time. The frequency of audible sound is measured in hertz, or cycles per second. Sound waves have a **wavelength**, which is the physical distance between compression pulses. The wavelength is inversely proportional to the frequency. Sound waves also have an **amplitude**, which is the amount of air (yes, water or jello) that gets moved with each pulse of pressure. Without going far into the physiology of it, you hear sounds when the pulses of compressed air of sound waves excite your eardrum, which excites your inner ear, which sends signals to your brain, which makes you dance, dance, dance! In general, you perceive the frequency of the wave as a particular **pitch** (see the pitch discussion, above). You perceive the amplitude of the wave as loudness.

Resonance

Take a tuning fork (you do have a tuning fork, don't you?) and whack it on your knee. What do you hear? Unless you hold the tuning fork right next to your ear, you won't hear much of anything. This is because a small tuning fork can't push very much air around. Now take the same tuning fork, whack it on your knee again, and touch the non-forked end to a tabletop or other handy wooden surface. The sound should be a lot louder. This is because the vibrating tuning fork causes the tabletop to vibrate. The tabletop can push much more air around than the fork alone. If you touched the end of the tuning fork to a hollow box or, say, the body of a guitar, the sound would be even louder. This is because the vibrations get transferred to the air inside the box, which vibrates as well. If the dimensions of the inside of the box are a multiple of the wavelength of the sound, some of the sound waves will reinforce each other for even more volume. If a vibration or sound wave can excite another object into vibrating, the second object is said to **resonate**. This phenomenon is called **resonance**.

Overtones

The vibrating and resonating parts of musical instruments (and almost everything else that makes sounds) don't produce sound waves of just one frequency. This is because the vibrating body (e.g. string or air column) does not just vibrate as a whole; smaller sections vibrate as well. In the case of musical instruments, these additional frequencies are usually even multiples of the vibration frequency of the whole string, air column, bar, etc. For example, suppose you squeeze your accordion (the most sublime of all musical instruments) and press the key that lets the air out past a reed which, due to certain physical properties, vibrates 440 times per second. The vibrating reed will generate sound waves with a frequency of 440 Hz. (cycles per second), which happens to correspond to the A above Middle C. Because of other physical properties of the reed and the accordion, the instrument will also generate waves with a frequency of 880 Hz. (2 x 440), 1,320 Hz (3 x 440), 1,760 Hz. (4 x 440), etc. These extra frequencies are called **overtones**. Amazingly enough, when the overtones are close to even multiples of the fundamental frequency, our brains interpret the whole conglomeration of frequencies as a single pitch. Different instruments differ in the relative strengths of the various overtones, and that is what gives the instruments different timbres. This is also what makes your voice sound different from someone else's, even when you sing the exact same pitch. In the case of cymbals, gongs, snare drums, and the other indefinite-pitch percussion instruments, there are so many frequencies and overtones all at the same time that our brains don't pick out a definite pitch. You might notice, though, that the sound of a drum or woodblock can still be "higher" or "lower" than the sound of another.

If you have any questions or comments please contact (exhibits@pacsci.org)