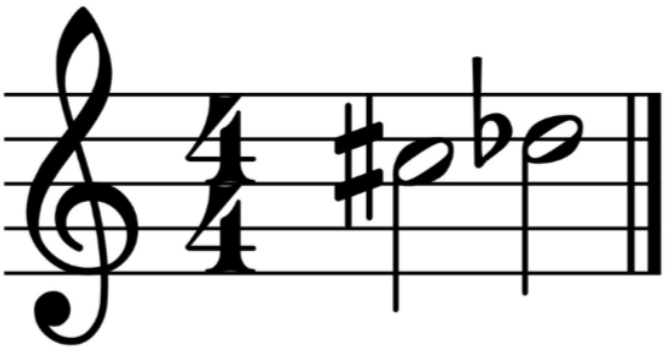
WHY GUITAR PLAYERS SPEND HALF THEIR TIME TUNING… AND THE OTHER HALF PLAYING OUT OF TUNE:

A rough overview of the physics of guitar tuning by Steve Mason

C# AND Db ARE NOT THE SAME NOTE:

In fact C# is slightly higher than Db, but they are played by the same key on the piano, and there is only one fret for them on each string on a guitar. What gives?



There is a mathematical relationship between every note in a scale. I won't bore you with all the math but the simplest relationships are: the octave is twice as many vibrations per second as the prime and the fifth is the prime plus one third of the difference between the prime and the octave. If you start on C and do all the math to calculate the vibrations per second for all the notes in a C scale and then calculate the vibrations per second for a D scale you will see that an E in a C scale is a slightly different note than an E in a D scale. This means that if your guitar is perfectly in tune to play a C chord and you want to play a perfect D chord you must raise your E and B strings a little. People apply "logic" to this situation and conclude that the E and B pegs are loose and need to be tightened or replaced or even soldered.

J.S. Bach, with his "well tempered" system, had started down the road toward solving the problem. A system called "equal temperament" evolved. This is a system in which all the notes are slightly out of tune so that nothing is shockingly out of tune and you can play in any key with equal success. Pianos are tuned in equal temperament, and guitar fingerboards are fretted in equal temperament. Fiddlers (the good ones anyway) play in perfect pitches because they can micro adjust their finger positioning to play exactly the vibration per second required. The fixed frets of a guitar preclude this option.

A piano is a big clunky thing more closely related to a Chevy than to a violin. The tuning is expensive and takes a long time, so you tend to tune it and then play it as it sits. The guitar is more complicated: even though the frets are placed in equal temperament, guitar tuning pegs are easily accessible, and the strings can be "bent" with your fingers as you play.

Hence, the guitar player with a good ear is at constant war adjusting the string tension to approximate "just intonation" against the intentional misplacement of the frets. Very roughly, the first fret is 1/18 the distance from the nut to the saddle, the second fret is 1/18 the distance from the first fret to the saddle etc. In other words there is an equal distance between the notes (expressed logarithmically as the twelfth root of two). There is such a thing as a "just intonation fingerboard", the frets don't go straight across and are not evenly spaced. They play perfectly in tune, but they are only good for one key and are way out of tune in other keys.

STRINGS ARE HUMAN TOO: THEY ARE IMPERFECT AND THEY DIE

The picture is further complicated by the physical makeup of your strings. As a string gets old it develops metal fatigue at some spots and not others, it gets a little dent everywhere it goes over a fret, the windings fill up with crud, the steel part of the string can rust and you can even wear it thin in spots. This uneven stress makes the string vibrate unevenly, so that the center point of the string is no longer the octave harmonic. You may have noticed that the first symptom that you need to change strings, just before they get "thumpy", is that you just can't get in tune.

And even fresh strings are imperfect. A string must be stretched to 80% of breaking tension so that the pull on it's molecular bonds will make it act more like a fluid than like a rod. People using lots of different tunings will have noticed that a string tuned too low for it's gauge won't "sing". A nice new string does great at producing primary vibrations but as the harmonics get higher and higher they are produced by smaller and smaller fractions of the string, and at some point the string section is so short that it acts more like a rod than like a fluid, and that pushes these high harmonics sharp.

PHYSICAL ATTRIBUTES OF YOUR GUITAR

The "action" of a guitar is the playability as governed by the straightness of the neck, the evenness of the fret tops, the roundness of the fret tops, the height of the nut and the height of the saddle, and the angle from the bridge to the pin holes and the nut to the peg barrels. This is all adjustable by adding material or taking material away. Guitars do not come adjusted from the factory. All new guitars must be adjusted (Martin makes no pretense of adjustment, they don't even fit their bridge and butt pins). It takes this amalgamation of fine woods a while to get used to being a guitar, so you will probably have to readjust your action at six months and then yearly for the first five years. Every time the weather changes your guitar wood changes shape. If it bows backward it can come forward again, but if it bows forward it has 180 pounds of string tension holding it there. The normal motion is for the neck to bow up over time. It is then either a simple or difficult process to

straighten it, depending on the brand of your guitar. After five years or so your guitar should stabilize to the point where you may go for two or three years between adjustments.

As you play, the high carbon steel strings wear down the nickel silver frets. This makes low spots on your favorite frets and turns the frets you rarely use into high frets. When you push a string down to a low fret it will buzz against the high fret in front of it. You can always miss that high fret by jacking your action up higher and higher. Every music store in the world knows how to shim your saddle to stop a buzz. This solves the problem, but makes your strings hard to push down. The proper solution is to let an experienced luthier "dress" your frets: file the fret tops so that all the fret tops are at the level of your lowest wear. This puts little flat spots on the tops of the frets that were too high. They are then rounded and polished. A good guitar in normal use can probably be adjusted 7 to 10 times before the frets are too low (worn about half way through) and must be replaced. However some very hard players wear through their frets in a few years.

So…., here's how this relates to the topic at hand: if your strings are too high you must "bend" them down to the frets. The extra stretch that it takes to get the string down to the fret tightens it in the same way as turning the tuning peg does. The string length from nut to saddle is designed (with more or less accuracy, depending on the guitar maker) to play in tune (equal temperament) at a certain string height. If you exceed that height the pitch will be sharp by the time the string contacts the fret.

Fret misplacement (actual misplacement, not to be confused with intentional misplacement) is very rare on modern guitars but saddle misplacement is common. In fact, saddle placement on vintage guitars seems quite random. If new strings do not yield a good match between your octave harmonic and your 12th fret go see your luthier. If you are using vastly different strings than the guitar manufacturer intended, their bridge placement, though perfectly within their specs, will have to be changed for you.

Many people notice the tuning dilemma for the first time after they have shelled out the big bucks for a high quality guitar. A fine guitar has the ability to project, clearly and resonantly, the nuances of the string vibrations. Hence, you are more likely to hear the difference between C# and Db on your new Taylor / Collings / Santa Cruz / Martin / Larrivee / Thompson / etc. than you were on your old junker. Also, on a fine guitar you don't notice that your strings are dead as quickly and you tend to not change them as often.

PSYCHO ACOUSTICS

This is the study of how the human hearing system works. One major discovery of this field is that our hearing is often effected by things that we can't hear and we hear things that aren't really there. Another good reason to take up the violin is to hear a great demonstration of psycho acoustics: Play "Boil em Cabbage Down". As you play C# and E you will clearly hear an "undertone" of A, 2 octaves below. As you play the tune it sounds as if someone is playing bass with you. If you give the human ear the 1 and 3 it will interpolate the 5 of the chord when it is not being played.

And, perfect intonation does not necessarily please us. According to psycho acoustic research, we tend to like the high notes a little sharp and if any note is out of tune our first inclination is to "tune up". When players do the move from a D chord to a C chord, instead of lowering the E and B they tend to raise the bottom four strings. When they go back to D they raise the E and B and then when they switch to C they raise the bottom four again. Some of you old timers may remember jam sessions before the days of electronic tuners when the fixed pitch instruments would have to drop out by 9:00 and by 11:00 the guitars were tuned up to F and were popping strings left and right.

Our ears are much more accurate in the high range than in the low. For example, a violin player must put his fingers in exactly the right place or we all notice, but if the bass player's fingers are within a half inch of where they're supposed to be it's close enough. Bear this in mind, and always tune your highest string first.

Besides the few specifics already given, human hearing is too vastly complex for us to deal with in any completeness here. Suffice it to say: hearing varies from person to person, with temperature and humidity, and as we get older we tend to loose it (especially in the upper registers).

SO WHAT DO I DO OBI WAN?

First, make sure that your guitar is adjusted properly and has good strings. Then there are two true paths:

1) Equal temperament. Buy an electronic tuner, use it and trust it. The guitar won't sound perfect to a very good ear but it will sound fine to most of us, and you can switch keys with impunity. If you don't have an electronic tuner, tune your high E to whatever is available and then find an E on every string and match it to the high E. Don't mess with harmonics. Harmonics are perfect pitches above an equal temperament fingerboard.

2) Approximating Perfect. Start with the electronic tuner and then adjust your tuning using your tuning pegs or by bending individual notes in a chord as you play until the sound pleases your ear. Try tuning to perfect pitches where you are going to spend most of your time in a song. For example: in the key of C tune the C chord in first position to a perfect C chord. The F and G chords will be fine and when you go up the neck to play lead, bend into tune . If a perfectly in tune note at the bottom of the neck yields a sharp note up the neck tune it low and bend it. Or, play fast and no one will notice.

About the author:

For a day job Steve is a luthier: one who repairs, improves and creates stringed instruments. To make a guitar he starts with a tree and carves away everything that doesn't look like a guitar. He plays fiddle, guitar, bass, mandolin and sings in the Alferd Packer Memorial String Band: www.alferdpackerband.com. Steve also maintains a wealth of information of interest to luthiers on his website: www.ask-a-luthier.com