TUNING AND OVERTONES

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Tuning is at the heart and soul of everything we do musically. It is in our Barbershop DNA.

Overtones are the reward for tuning well!

(Or are they? Are overtones just something we imagine hearing? Let's dig a little deeper…)

SOUND

Sound is the result of an object vibrating. If it vibrates in an audible frequency range (around 20 – 20,000 Hz), and if there is a medium through which it may travel (air, water, most solid objects), we will hear sound.

In music, almost anything can be vibrated to produce sound: A string (piano or violin), vibrating lips (trumpet), a reed (clarinet), a column of air (organ or flute), or vocal folds. If the frequency can be controlled, it can be used to produce music.

TUNING

First, let's understand what we mean when we talk about **Pitch**.

Pitch…what note we are singing is determined by its **frequency**.

Frequency is defined by the equation

$$f = 1/T$$

Where f is the frequency, measured in hertz (Hz) whose units are sec^{-1}; and T is the period measured in seconds (for sound; it can be any measure of time).

THE STRING EXAMPLE

What affects the frequency of a vibrating string?

1) Length of the string (think of the shape of a grand piano)
2) Tension on the string (how you tune a piano)
3) Size (cross-section) of the string (take a look at those piano strings)

Change any of those, and you change the frequency, or pitch.

Now let's play with our homemade stringed instrument….

LENGTH OF STRING VS. PITCH

If I only play half the string, will the pitch be higher or lower?

Once again, there is an equation for that:

$$\lambda = v/f$$

….where λ is wavelength, v is phase velocity, and f is frequency. Don't sweat the details; all we're looking for is the relationship. If the string is half as long, the frequency should be twice as high. Here is what that sounds like….

What if we divide the string into thirds? What about the other side of the string?

And so on….here is what you get:

STRING LENGTH	FREQUENCY	OVERTONE	PITCH
Whole	1x	Fundamental	Root
Half	2x	First	Octave
Third	3x	Second	Fifth
Fourth	4x	Third	Octave
Fifth	5x	Fourth	Third
Sixth	6x	Fifth	Fifth

TWO CORE CONCEPTS:

1. Anything (string, vocal folds, air column) that vibrates to make sound produces not only a Fundamental vibration, but also a raft of "harmonics"…..those multiples of the fundamental frequency. (Watch that string closely.) We call them **overtones**. **They are already there**. What we do in our hobby is to stack them up and reinforce them. Hang on; we'll get to that.
2. Those ratios of frequencies--and the pitches they produce—provide a basis for how we tune scales. Problem is, it's not as straightforward as it sounds…

Let's deal with these two concepts separately, one at a time.

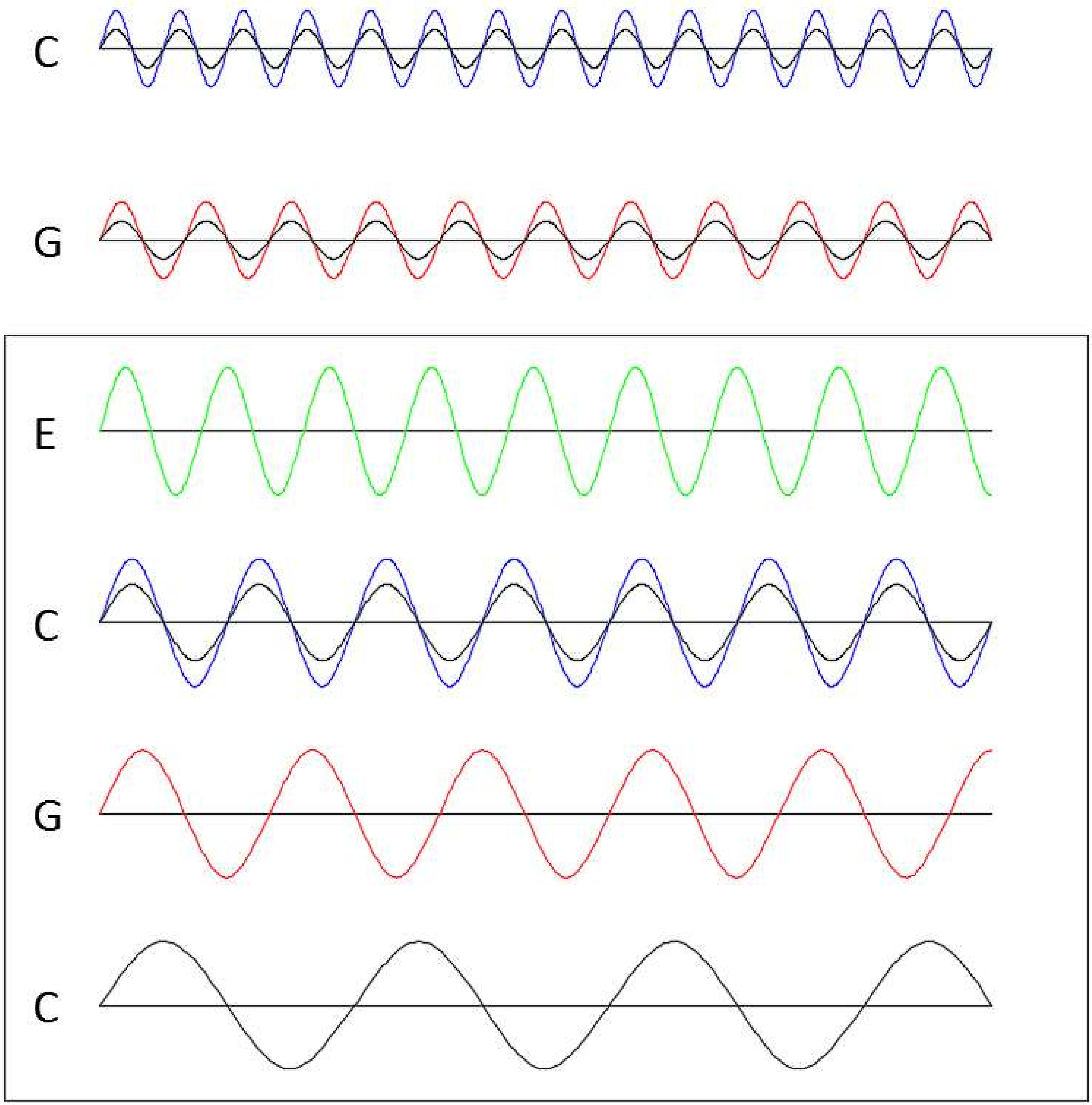
CORE CONCEPT NO. 1: HARMONICS AND OVERTONES

Let's use a pan to water to illustrate **constructive** and **destructive interference**.

Note that where two high points converge, the high points are additive. That's **constructive** interference.

Note also that where a high point meets a low point, they cancel each other out. That's **destructive** interference.

Let's sketch this out:



Those four bottom notes (in the big box) are actually being sung. These are the **fundamental** tones, shown with full amplitude.

All of the smaller amplitude waves represent the **overtones** off the fundamentals below. And those overtones are indeed smaller in amplitude (less volume).

So what happens when the overtones align? You guessed it: **Constructive interference**. The overtones (which were already there!) march in formation to reinforce one another. The result: **Audible** overtones.

OKAY, SHOW ME….

Enough talk for a moment. Let's go find some interesting examples of this, from good old YouTube.

CORE CONCEPT NO. 2: HOW SCALES ARE BUILT, AND HOW THEY ARE TUNED

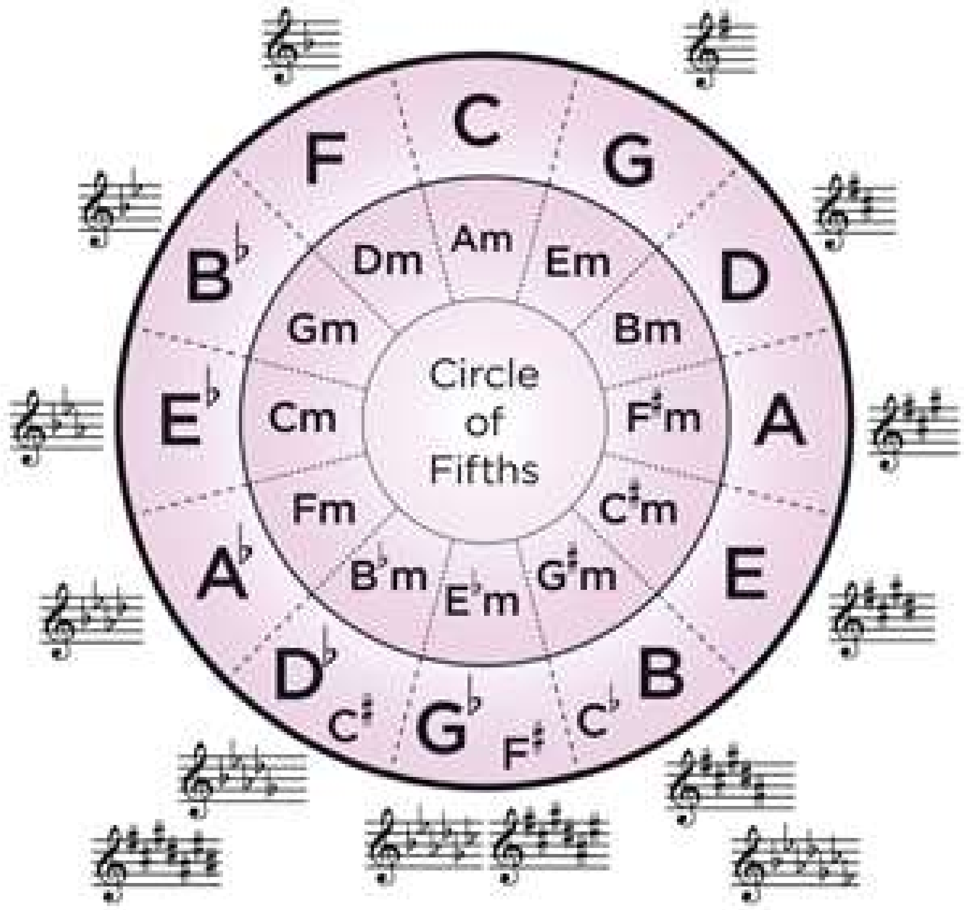
Let's go back to that simple stringed instrument. What did we learn about frequencies and intervals? Here are two pretty basic concepts:

1) Doubling the frequency (half the string length) raises the pitch an octave. And vice versa.
2) Dividing the string into thirds produces intervals of fifths.

Pythagoras (well, maybe Pythagoras; definitely the **Pythagoreans** who followed him) pieced it together: 2/3 of a frequency was the fifth below; 3/2 of that frequency was the fifth above.

How simple. Sort of.

We do know you can build a "circle of fifths," and it looks something like this:



Now…start at A = 440, and use that 3/2 or 2/3 ratio to fill in the circle.

Hint: You can always double or halve the frequency (octave jumps), and that's not cheating!

So what happens when you get to F# = Gb? I got a discrepancy!

F# = 742.5 Hz; Gb = 732.51 Hz

10 Hertz! That's enough to hear!

It's called the **Pythagorean Comma**…and it forces an odd interval, with an odd name: The **wolf interval**.

In the Adeline and Barbershop world, we hear a lot about Pythagorean tuning, but let's be clear: It's not the answer to all tuning.

Here's a snip from Wikipedia:

"Because of the wolf interval, Pythagorean tuning is rarely used today, although it is thought to have been widespread. In music which does not change key very often, or which is not very harmonically adventurous, the wolf interval is unlikely to be a problem, as not all the possible fifths will be heard in such pieces.

Because most fifths in Pythagorean tuning are in the simple ratio of 3:2, they sound very "smooth" and consonant. The thirds, by contrast, most of which are in the relatively complex ratios of 81:64 (for major thirds) and 32:27 (for minor thirds), sound less smooth.[8] For this reason, Pythagorean tuning is particularly well suited to music which treats fifths as consonances, and thirds as dissonances. In western classical music, this usually means music written prior to the 15th century.

From about 1510 onward, as thirds came to be treated as consonances, meantone temperament, and particularly quarter-comma meantone, which tunes thirds to the relatively simple ratio of 5:4, became the most popular system for tuning keyboards. At the same time, syntonic-diatonic just intonation was posited by Zarlino as the normal tuning for singers."

Whew.

JUST INTONATION

Any system of tuning that uses ratios of small whole numbers is called **just intonation**. Pythagorean tuning falls under the umbrella of just intonation, because of that 3:2 ratio.

Here's a form of just intonation that I find interesting: The ratio of 4:5:6 as Do-Me-Sol. We won't go into this in detail, but here is a table showing how you can build a diatonic C-scale (just the white keys) based on that 4:5:6 ratio:

NOTE	Ratio	x2	x2	**NOTE**	Ratio	x3	x2	**NOTE**	Ratio	x9
C	6	12	24	**G**	6	18	36	**D**	6	54
A	5	10	20	**E**	5	15	30	**B**	5	45
F	4	8	16	**C**	4	12	24	**G**	4	36

Let's keep going…

EQUAL TEMPERAMENT

Also called **even tempered** tuning. Because of the quirky nature of just intonation, a perfectly tuned scale is good for that key. Only that one key. Try playing in another key, and it's just not quite right.

Pianos are meant to be played in all keys, so you might say they are tuned to be "equally out of tune" for all keys. Equal temperament. Even tempered.

On the surface, that may not sound very appealing, but in the case of the keyboard, it works.

Once again, we use ratios, but instead of simple ratios between larger intervals like fifths, we boil it down to two precepts:

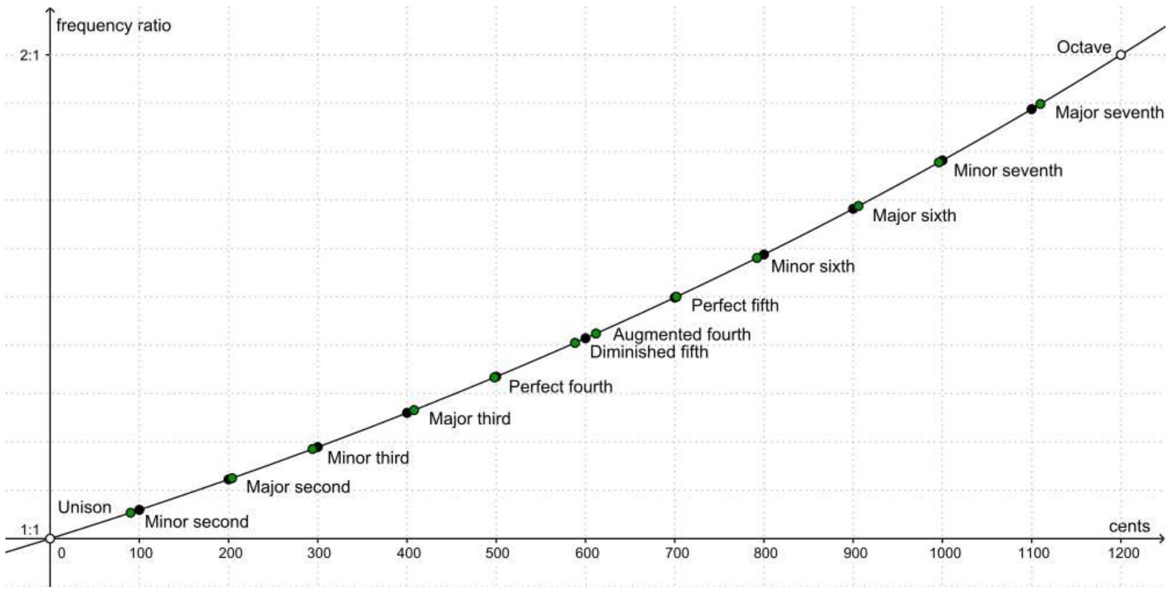
1) All octaves are based on a factor of two. Everyone seems to agree on that.

2) Figure out a set ratio between any note and the half step (semitone) above or below. Mathematically, that means you are looking at the 12th root of 2.

That 12th root of 2 works out to 1.05946309436, give or take, and if you run the numbers, it really does work. Not only do the numbers work out, it actually sounds….."tuned."

SO HOW DO THEY REALLY COMPARE?

This graph (courtesy of Wikipedia) shows the equal-tempered (black dot) versus Pythagorean (green dot) tuning.



Some difference, yes, but still pretty close.

If you've listened carefully to many teachers in the past, you've heard them talk about the tones of the scale most affected by the difference between equal tempered and Pythagorean tuning: **2, 3, 6, 7**. The graph above agrees with this.

Here's a visual/tactile demonstration….

AND WE COULD GO ON AND ON

We could talk about formants, and much more, but that gets pretty complicated pretty fast.

SO HOW DO WE TUNE BETTER?

The problem is that we, as harmony singers, rarely take too kindly to any suggestion that we sing out of tune.

Another dimension: We talk about the various ways to tune (Pythagorean, Just, Tempered, etc.), but more often than not, we are not as close as we should be to **any** of them.

Enter the unbiased listener: A tuning application….as close as your pocket. There are many; the Tonal Energy (T.E.) Tuner is a good example. Try it…

To quote Rob Mance: "What we discovered was no less than scandalous. We were that far out of tune."

WORTH IT

To wrap up, let's listen to a few good examples of well-tuned singing…and the overtones produced!

HAPPY TUNING, AND MAY THE OVERTONES BE WITH YOU!