Tuning, Frequency, and Tempo in Relation to Bio-Energy, Cognition, and Natural Order

Greg Delapaix

Art 5300~ Art and Technology, Fall 2013

Summarizing the second chapter of his book *Tuning, Timbre, Spectrum, Scale,* William Sethares writes "When a tree falls in the forest and no one is near, it has no pitch, loudness, timbre, or dissonance, since these are perceptions that occur inside a mind. The tree does, however, emit sound waves with measurable amplitude, frequency, and spectral content. The perception of tone quality, or timbre, is correlated with the spectrum of the physical signal as well as with temporal properties of the signal such as envelope and attack. Pitch is primarily determined by frequency, and loudness by amplitude(46)." This is an interesting statement, since on the one hand Sethares states that pitch exists in the mind, while on the other hand he says that pitch is a function of frequency.

What is the relationship between pitch as frequency and pitch as a function of mental cognition? It is not clear how the dissonance of a falling tree can emit sound waves of measurable frequency, but in music the relationships between frequencies are clearly chosen by the minds of those who create or modify the system out of which the music emanates. These systems include the way that relationships between various pitch frequencies are established, and the standardization of specific frequency tunings for the successful musical integration of various types of instruments. Doing his part to make the communication of musical ideas more feasible, Pythaghoras noted that a pair of vibrating strings with lengths according to simple ratios will produce various intervals of pitch. A ratio of 2/1 produces an octave. A ratio of 3/2 produces a fifth, a ratio of 4/3 produces a fourth. Pythagoras built complete musical scales by moving up and down the ratio of two strings by intervals of a fifth (Sethares, 51). Moving down by fifths is the same as moving up in fourths, which can easily be seen by looking at a piano keyboard.

Going down from 'G' to 'D' moves across four white notes, while going up from 'G' to 'D' moves across five white keys. Building a scale the way Pythagoras did creates a large number of perfect fifths and fourths. The thing that is so special about octaves, and especially fourths, and fifths in this context is this: a string vibrates at a fundamental frequency *f,* along with a set of partial frequencies located at integer multiples of *f* (Sethares, 50). All of the partials of an octave, and most of the partials in fourth and fifth intervals "line up" or resonate with the fundamental frequency. Remember that partials are parts of the vibrating string which vibrate at various discreet frequencies. Other intervals have partial frequencies (partials) which do not resonate as well with the fundamental- they are not as well "fused" into a "more perfect" sound. Though Pythagoras was certainly delighted with his discovery and construction of a scale, he soon ran into a bit of a problem. Here, we can first follow Pythagoras in the construction of his scale. Suppose for simplicity that Pythagoras starts with a note called C, at frequency "1." He adds G at the interval of a fifth, followed by D a fifth above that. This would be the equivalent of (3/2)(3/2), or 9/4. 9/4 is greater than an octave, so the easy thing to do is to transpose down an octave by dividing by 2. At this point, we have C, D, and G. Continuing the process, we go from D to A, A to E, E to B, and B to F, and F back to C, to finish constructing the scale, dividing by 2 as necessary to stay within the octave. The problem appears when continuing with successive steps. For example, after 12 steps (a complete circle of the circle of fifths, where we return to the starting note an octave higher), the ratio is $(3/2)^{12}$, which is $^{531441}/_{4096}$. Dividing this by two produces 2.0273, which is one fourth of a semitone sharp of an octave, in this case the next octave up. Thus, an instrument tuned to an exact Pythagorean scale would require an infinite number of notes. The correction for this is simply to pick one of the perfect fifth intervals and lower it a small amount. This however produces an unpleasant sound, as the frequency partials of that particular fifth are then no longer "justified," or resonating with each other. In Pythagoras' time this was called the "wolf" interval, presumably because it made people howl (Sethares, 52).

By dividing the octave into 12 notes instead of eight, smaller intervals could be added, and with the invention of the equal temperament, composers could then easily modulate to other keys without hitting these wolf tones. The twelve tone chromatic scale required the use of additional keys, and the black and white arrangement seen on most keyboards was an efficient means for the use of space.

Equal temperament divides the space between adjacent notes on a piano into equal amounts, which dissolves the clarity of the fourths, fifths, thirds, and sixths- i.e., it creates more non-aligned partials. It also creates oddities of tonality and resultant musical practices such as the prohibition of parallel fourths or fifths in Western classical music before the twentieth century. As other Western instruments were designed to be used in conjunction with pianos, the twelve tone equal tempered scale achieved complete dominance. I would argue at this point that the convenience factor of the twelve tone equal temperament, though it does have its charms as exemplified by J.S. Bach in his *Well Tempered Clavier,* should not be an overriding factor as it is today, but relegated to one of many options for composers of music, based simply on the way that all intervals in the equal temperament system are muddied. A tuning system based on frequencies which divide naturally into one another, rather than the imposition of a stiff mathematical grid over all frequencies would be a positive step forward in the evolution of our music. Our tuning system in place today has an economy based stranglehold on our music, working hand in hand with established methodologies of musical theory. The tendency of parallel movements of perfect fourths and fifths to destroy the effect of independent voice movement in music is just one example of many deficiencies inherent in the twelve tone equal temperament (Tymoczko, 210). Certainly for the instruments in use today it is an inconvenience for musicians to re-tune, or maintain and practice multiple instruments and/or multiple tunings, but in the end it is the music which suffers in no small way for the sake of convenience.

Yet there is more to this story. In his book *Tuning, Timbre, Spectrum, and Scale* William Sethares explains and demonstrates how any interval which may sound dissonant based on a certain timbre can be made consonant simply through the changing of the timbre, i.e. a restructuring of musical partials associated with the primary sound. For example, this can be done using digital audio software by adjusting the amounts of energy in various regions of the sound spectrum, without changing the primary frequency or pitch (Hosken, 101). Quoting Norman Cazden from the *Journal Aesthetics*, volume four in 1945, Sethares adds that "it is not possible that laws which are themselves immutable can account for the profound transformations which have taken place in musical practice." In other words, cognitively speaking, musical consonance and dissonance are completely cultural and based arbitrarily on the timbre of instruments in use (78). This becomes obvious when considering the widespread acceptance of detuned intervals today, for the sake of equally tempered keyboard instruments. Technology and skill now allow for much wider realms of artistic expression.

On a deeper level, it is becoming apparent to me that many avenues exist for the creation of music which can affect people on deeper energetic levels beyond simple cognition. I want to focus on another musical standard unfortunately in place today, one that is certainly outdated and which has outlived its usefulness by many decades, namely the A440 Hz standard for the A note (the first A above middle C on a piano) around which to base the tuning of other notes on musical instruments, both singularly and when used in conjunction with other instruments. Currently, much of the music produced in the Western world relies on the A at 440 Hz standard pitch, established in the early twentieth century by the American Standards Association and subsequently adopted by the International Organization for Standardization (Collins, 1). My argument here is that this frequency, along with the equal tempered scale, are antagonistic to human beings on subtle energy levels. This can be demonstrated mathematically. While popular for reasons of convenience and money, these systems are not universally in use, and while most

listeners of music on a pedestrian level, including many musicians, may not qualitatively question the value of this standardization, I would like to argue that our music and our physiology both are being negatively impacted by this seemingly arbitrary pair of standards. This is not the first time that this assertion has been made, but it may well be that clear enough explanations for this needed change have not been forthcoming up until recently. With the help of newly expanded scientific knowledge centered on the way that sound affects materials, especially organic material found in the bodies of various life forms including humans, and with a better scientific appreciation of relationships between energy, sound, and matter, it may be that a tipping point can be reached, one which can provide more freedoms of musical expression along with a higher level of social reward from the music we create. An added bonus may be a dearth of derogatory remarks from those with misplaced faiths in status quo belief systems. The great thing about music is that it can be used in an experimental way– new tuning modalities can be tested over time and repeated listenings and comparisons with other music can be made. Our technology and our freedom allow for this.

I have begun composing music based both on alternate tuning systems, and according to established standards. As an example, the only difference between two compositions might be that one will be based on the equal temperament tuning system with the note A at standard 440 Hz, while another will be tuned to A at 432 Hz, and based on the Pythagorean scale, a scale which in this case has each note simply doubled at higher octaves. This example is just a starting point, it is somewhat unfortunately challenging today to find ways to implement tuning systems beyond minor modifications to existing keyboard technologies and variations of equal temperament, especially when working with digital instruments, despite what many might say. Nonetheless, it is possible, and I anticipate a wider breadth of experimentation among contemporary musicians (including myself) as they learn more about these ideas, and as more ways to implement them are brought to light. In doing experiments with different tuning

systems, I want to see if listeners are able through repeated listenings, to identify music which is structured according to a more bio-compatible frequency and tuning system.

In her massive work titled *The Subtle Body*, Cyndi Dale highlights some of the newest research on unseen yet measurable energy fields and frequencies which determine human physical conditions. Dale points out that a frequency derived from the Solfeggio scale, a variant of the Pythagorean scale kept secret for hundreds of years, has actually been used by molecular biologists to cure genetic defects (142). Researchers Dr. Michael Isaacson and Scott Klimek, who teach sound healing at Normandale College in Minneapolis Minnesota, assert along with Dr. Alfred Tomatis, that the first *in utero* function of the ear is to establish growth for the rest of the body, because sound feeds the electrical impulses which charge the neo-cortex (Dale, 142). Research by Russian scientists Peter Gariaev and Vladimir Poponin, along with Harvard trained Dr. Leonard Horowitz and three other Nobel Laureates has led to the assertion by all that the primary function of DNA is not to synthesize proteins but to carry out bioacoustic and bioelectrical signaling.

The science of cymatics, which is geometry through vibration, was researched by Dr. Hans Jenny, who published a book titled *The Study of Wave Phenomena* in 1967 (Collins). Modern cymatic imaging techniques are producing high resolution 3D images of sounds within liquids and solids which clearly show geometric structures within sound (Dale, 142-144). Certainly these types of studies will ultimately connect directly with the possibility of practical therapeutic applications of sound to the human body/energy system in quantitative ways, just as they have been shown to be therapeutic in the more subjective sense throughout history across cultures.

The challenge here is to draw clear connections between frequencies, geometries, and human beings. Certainly there are real phenomenon associated with frequencies and their interactions with humans and others on the planet in which we live, as Doug Kahn points out in his book *Earth Sound Earth Signal* (177). There are so many variations on the theoretical

relationships between frequencies, forms, and human beings in circulation today that it may best be left to the intent of artists or holistic practitioners and their respective audiences to choose how to employ them. Yet there are fairly universal common denominators among the ways in which we have utilized sound and the ways that it affects us. Though it would be simplistic to assume that there are one or even several "magic" frequencies that we should be using, certainly it seems worthwhile to consider ways to use music which may enhance our lives on a deeper level. Brian Collins, writing on his blog "Omega 432," makes an interesting case for the use of the 432 Hz as a standard frequency, and this case is more compelling than any that seem to have been made for the 440 Hz standard. Based on his (and others) writing, I have adopted the 432 Hz frequency along with the Pythagorean scale doubled at each octave, which allows for more perfect intervals. Collins mentions an author named Maria Renold who developed a way to tune pianos based on 432 Hz and harmonic alignments with C at 256 Hz, and that in Renold's book, conclusive evidence is claimed that the 440 Hz standard tuning, along with raising C to above frequencies such as 128 Hz and 256 Hz disassociates the connection of consciousness to the body and promotes anti-social conditions in humanity. According to Collins, various audiophiles today also claim that the A 432 tuning can seem to fill a room with sound while A 440 is more directional and linear sounding. While this may seem subjective, it can easily be shown that tunings such as the A 432 and Pythagorean scale produce more resonance because of a greater incidence of aligned partials within the scale than can be found in equal temperament with A at 440 Hz. Invoking cymatics, Collins also mentions the new CymaScope device, co-developed by acoustic engineer John Stuart Reid. Collins provides a transcript of John Reid's correspondence regarding A 432:

> "We captured it on video also and it looks like it's alive, it writhes and pulsates and refuses to take up any other form. We researched the reason why it takes up this

geometry and it turns out to be an interesting case: When A is tuned to 432Hz the frequencies of the other A's shift (within a decimal point) to 27 Hz, 54, 108, 216, 864, 1728 in other octaves. D becomes 576 Hz which becomes 9 Hz, 18, 36, 72, 144, 288, 1152 in other octaves. E becomes 324 Hz which becomes 81 Hz, 162, 648, 1296 in other octaves. All of these frequencies are divisible by 3… Regards, John Stuart Reid."

Many ancient sites on Earth, in their relationships with objects in space, also reflect the number 432. Dividing the second ring of stones at Stonehenge in England into the number of years in the galactic precession, the number is 432 (Collins). The galactic precession is the number of years it takes for a point on earth to return to the same point in relation to a point on the zodiac, moving one degree every 72 years. This is usually measured on the equinox. This is one example of countless ways that numbers in stone monuments all over the world reflect the same numbers which 432 Hz produces in sympathetic vibrations in other strings, divisible by 3, as pointed out by John Reid.

Another example is that the planet Saturn is also known to trace the precession of the equinox in 864 years (2 X 432). Collins quotes the famous French alchemist Fulcanelli regarding Saturn:

"…Saturn, because it is at the greatest distance from the sun of all the visible planets, has the longest "year," taking a little less than 30 years to complete one circuit of the zodiac. This makes it the best precessional timekeeper of all the planets.

Saturn completes one precessional Great Year of 25,920 years every 864 of its "years," a half cycle every 432 of its "years," a quarter cycle every 216 of its "years," and an eighth of a cycle every 108 of its "years." This equals (108 x 30) 3240 years,

> or 45 degrees of precessional arc. We can continue counting in Saturn years down to 9, one 96th of the precessional year, or 3.75 degrees of arc and 270 earth years, which brings us to the alignment period of the galactic meridian and the zenith/nadir axis.
>
> If we note when Saturn fell on a significant marker, such as the galactic center or antipode, then we can simply count Saturn cycles to mark the span of the Great Precessional Year. In this way, we could determine that if Saturn fell on the galactic antipode and made a station (since the earth is moving faster than Saturn, it appears as if it is overtaken, making it appear to stand still in the sky to mark the moment), then 432 Saturn cycles ago it was making a station at the same location, and would be doing so again at the completion of 864 Saturn cycles."

The numbers seen in stone monuments around the world are significant in that they reflect sequences of musical frequencies which produce high numbers of resonant tones, along with numbers divisible by three, six, nine, and twelve. It is apparent that resonance is one way that music can be given extra power of influence. The purpose here is not to begin to catalog all the ways in which these numbers appear in ancient sacred geometries or astronomical configurations and motions, but to highlight their significance, in relation to numbers and time as a whole, as important components to the structure of music. In fact it is the relationship between numbers and time which takes us to another aspect of standardization, or lack thereof.

Placing music into alignment with aspects not only of frequencies within pitches of notes, but with aspects of tempo leads further into a higher quality of music. How is this so? While frequency is measured in vibrations per second, tempo is measured in beats per minute. If someone playing a percussion instrument at 60 beats per minute (bpm) were somehow able to accelerate their playing to 20 beats per second, the sound would begin to sound like a continuous fluid tone, because of the proximity of beats to one another within the second. This is the lowest

frequency at which humans begin to hear sounds as continuous tone. In this case the sound would be a kind of square wave rather than something smoother like a sine wave (Bombaci, 3). Square waves are often used in sound synthesis for variations of sound outside of purer frequency waves such as sine waves. Before going further in an analysis of frequency in relation to tempo, it may be worthwhile to consider why we even measure time in minutes and seconds. Our measurements of many things seem to have their origins in ancient Sumeria, where the use of the sexagesimal system originated for the measurement of time and angles (Nagai). Why this is so probably is related to the fact that 60 is the least common multiple of 10 and 12. The number sixty is also divisible by 12 divisors. No positive integers less than 120 have more divisors than does the number sixty (Nagai). Other important considerations include measurements of the motion of the moon and planets, all of which are done using the sexagesimal system, where important numbers appear. These include 12 for the months of the year and signs of the Zodiac along with the respective numbers of daytime and nighttime hours, 30 for the number of days in phases of the moon, and the high probability that the 360 degrees chosen for units of a circle is directly related to the motions of Jupiter and Saturn through 30 and 12 degrees of the Zodiac each year, respectively. It is the Egyptians who are credited with dividing day and night each into 12 hours, likely based on the number of lunar cycles in a year (Lombardi, 1). Jupiter and Saturn are very important in ancient Babylonia (Nagai). It is obvious also that humans have 12 finger joints on each hand, not counting those of the thumbs. Using the thumbs optionally as addends or multipliers allows counting in multiples of 12, 30, 60, etc. Further analysis of our use of seconds and minutes for measuring time notwithstanding, we measure frequencies for both pitch and tempo with the same system. With this in mind, it is also worth noting that human heartbeats are measured in bpm, so for instance a heart beating at 120 bpm is beating at 2 Hz. Additionally, studies show correlations between brain processing and physical movement, and that under optimal conditions, the brain processes visual information at 60 Hz (Yirka, Leake).

With these in mind, the idea of designing visual movies around sound, rather than the other way around would be interesting, such as what Randy Thom outlines in *Audio Anecdotes* (Greenbaum, 403). After all, filmmaker David Lynch has argued that sound is at least 50% of a film, and in some scenes almost 100 percent (Sider, 52). With all of this in mind, a final argument integrates things very well. Brenndan Bombaci, writing in a small eight page document produced in 2012 titled *A=432hz: On the Proper Concert Pitch and a New Standardization of Tempo,* explains that a building constructed with flawed ratios between floors and ceilings needed for integrity will ultimately crumble (8). The fact that our musical culture today does not align tempo as expressed in beats per minute, with tuning frequencies expressed in smaller denominations of the same scale, produces mathematical chaos. For example, Bombaci explains that using a sexagesimal based tuning system, where B is tuned to 60 Hz rather than to 61.74 Hz according to the A 440 standard, middle C would become 256 Hz, a number easily reducible to 1 by octaves. In this scenario, other intervals, with minor adjustments to the augmented fourth, would be easily divisible by smaller frequencies. Instead, what we have with the A 440 standard is middle C at 261.3 Hz. This doesn't seem like a big number, but it creates tension in the music through discrepancies of frequency, as there are no resonances among frequencies when they cannot divide naturally into one another. Technically speaking, the widely used standard tuning system we are currently saddled with is continuously turning out music which is mathematically chaotic. Furthermore, and this is a very important distinction to be made– if the tempo of the music is not in alignment with the timing of tonal frequency, further discrepancies are brought about! The math is undeniable and available for anyone to look at. Thus, in an ideal sense, music could be further improved through the use of better and less standardized tuning systems along with the application of musical tempos which do not clash with the more finely grained frequency tempos using the same system of measurement.

There are many factors which can affect biology. Bio-artists have brought to light various ways that we as humans are stakeholders in the results of our manipulations of genetics, living materials and other substances, along with our environment. The same can be true of the way we manipulate energy, sound, light, and frequency, all of which are interrelated. As embodied subjects within listening spaces, or within environmental creative installations, we have the opportunity to identify and expand on tunings, timbres, spectrums, and scales which can passively, dynamically, directly or indirectly enhance our bio and mental energies in deeper and subtler and objective ways.

Works Cited

Bombaci, Brendan. *A = 432Hz: On the Proper Concert Pitch.* San Francisco: Creative Commons, 2012. Digital File (Kindle Book).

Collins, Brian T. "The Importance of 432 Hz Music." *Omega 432.* Omega 432, 2013. Web. 30 Nov. 2013. ‹http://omega432.com/432-music/the-importance-of-432hz-music#mc4wp-form-1›.

Dale, Cyndi. *The Subtle Body.* Boulder, CO: Sounds True, 2006.

Greenebaum, Ken, and Ronen Barzel, eds. *Audio Anecdotes.* Natick, MA: A K Peters, 2004

Hosken, Dan. *An Introduction to Music Technology.* New York: Routledge, 2011.

Kahn, Douglas. *Earth Sound Earth Signal*. Los Angeles: University of California Press, 2013.

Leake, Elizabeth. "How To Measure Human Body Frequency?" *Blurtit.* Blurtit Ltd. 15 July, 2011. Web. 30 Nov. 2013. ‹http://science.blurtit.com/2207685/how-to-measure-human-body-frequency›.

Lombardi, Michael. "Why is a minute divided into 60 seconds, an hour into 60 minutes, yet there are only 24 hours in a day?" *Scientific American*. Scientific American, 05 March 2007. Web. 30 Nov. 2013. ‹http://www.scientificamerican.com/article.cfm?id=experts-time-division-days-hours-minutes›.

Nagai, Toshiya. "Why Did Sumerians Use the Sexagesimal System?" *Systemics Blog.* Systemics Blog/Wordpress, 04 February 2013. Web. 30 Nov. 2013. ‹http://www.systemicsblog.com/en/2013/sexagesimal/›.

Sethares, William A. *Tuning, Timbre, Spectrum, Scale.* London: Springer-Verlag, 1997.

Sider, Larry, w/ Diane Freeman and Jerry Sider, eds. *Soundscape: The School of Sound Lectures, 1998-2001.* London: Wallflower Press, 2003.

Tymoczko, Dmitri. *A Geometry of Music.* New York: Oxford UP, 2011.

Yirka, Bob. "Study shows brain processing similarities between music and movement." *Medical Xpress.* Medical Xpress, 18 Dec. 2012. Web. 30 Nov. 2013. ‹http://medicalxpress.com/news/2012-12-brain-similarities-music-movement.html›.