Pitch Battles

Does the choice of concert pitch really affect our physiology?

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A battle of concert pitches currently exists between two major opposing factions: those who support the traditional 440Hz tuning and those who vehemently support 432Hz tuning. Another group of musicians is sitting not too quietly in the wings who would like the concert pitch to rise to 444Hz.

All proponents of this pitch battle are passionate about their preferred concert pitch and believe that their favoured pitch is the best. Thus, the key question that I seek to answer—Is there one pitch that is natural and offers enhanced healing attributes for our physiology? The answer, as I will reveal, is both fascinating and insightful.

Many musicians and vocalists claim that a particular concert pitch is natural or that they can hear more pleasing tones and feel an emotional difference in relation to other tuning pitches. However, science deals with empirical evidence and, setting aside a musician's emotional response to a particular concert pitch, the question arises whether there is a greater reality, perhaps a scientific foundation that underpins one particular concert pitch as having greater benefits both biologically and physiologically, or in some other, as-yet-unknown way?

To initiate a foundation of understanding, let us first define what is meant by the term *concert pitch* and provide meaning to the term *Hertz* (abbreviated to Hz). Also, to avoid confusion between *pitch* and *frequency*, we will briefly discuss the differences.

Concert Pitch

Concert pitch may be defined as "the standard pitch to which instruments are normally tuned for performance".[1]

Typically, the standard is to tune note "A" above middle C, to 440Hz. Although 440Hz is the international standard, there are actually many different concert pitches in use among the world's orchestras, ensembles and individual musicians. We will focus on three pitches: 432Hz, 440Hz and 444Hz.

Hertz: Cycles in Time

Hertz measures the frequency at which something vibrates during one second of time; the number of complete oscillations or cycles that occur in one second.[2]

It should be remembered that Hertz (frequency) is used to measure both sound and light, yet these two forms of energy are completely different, natural phenomena. Confusion often arises, for example, when a particular sound frequency is multiplied by 40 octaves to reach its equivalent light frequency. Such manipulation of frequency is fun but, unfortunately, it is scientifically invalid simply because sound and light are different forms of energy.

Difference Between Pitch and Frequency

Pitch is a musical term, used when referring to a particular musical note, whereas *frequency* is a scientific term; they are not quite the same thing. To illustrate the difference, let us compare a tuning fork with its equivalent piano note. A tuning fork creates a very pure sound because it vibrates at only one frequency, while a piano note consists of many frequencies, that is, the fundamental frequency plus many harmonics that tell our ears we are listening to a piano and not some other musical instrument. These additional frequencies excite more areas of the frequency-sensing organ in our ear (known as the organ of Corti) and, thus, the cochlea–brain mechanism has a lot more input to work with to identify the nature of the sound.

The tuning fork creates only one, pure frequency

In summary, the term *pitch* is used when specifying a musical note or when describing how high or low a musical note sounds. The term *frequency* is used to describe a single component of a musical sound or to describe any *pure* sound, meaning a sound that has only one frequency, such as a tuning fork.

Concert Pitch Base-10 Number System

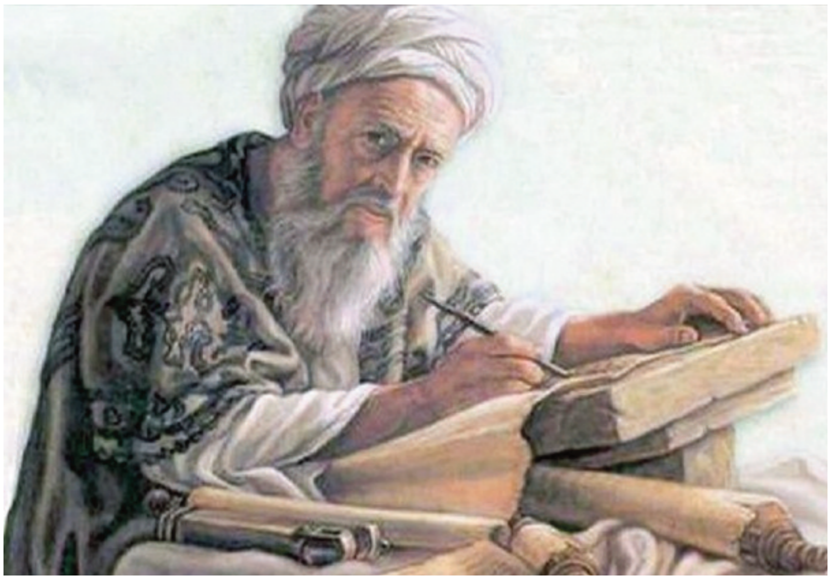
When discussing 432, 440 and 444Hz concert pitches it is easy to forget that they are derived from our base-10 number system. The importance of this in relation to concert pitch can be illustrated by converting these numbers to a different base number. For example, if we convert the base-10 number 432Hz to its equivalent base-8 number, it becomes 660Hz.[3] Or if we convert the base-10 number 432Hz to its equivalent number in base-12 (as used by the ancient Egyptians), it becomes 300Hz.[3] Therefore, the commonly asserted claims that the number 432 has special significance in relation to some aspect of solar mechanics or the speed of light are perhaps based on aspirational thinking, versus natural, mathematical phenomena. It is often suggested that there is a mathematical relationship between 432Hz tuning and the speed of light. Squaring 432 [432 x 432] gives us 186,624—suspiciously close to 186,282, the speed of light in miles per second. However, light speed in Imperial units is measured in miles, which is a human-made unit of length, along with distance travelled in seconds, which is a human-made unit of time, both of which are arbitrary.

This challenge of human-made, base number changes applies equally to Nature-related claims made for 440Hz and 444Hz.

The "Second" Unit of Time and Its Concert Pitch Connection

Apart from the challenge presented by the formulated, mathematical base numbers of a given concert pitch, it is also all too easy to forget that the unit of time known as the *second* was also assigned by humans, not by Nature. The division of the hour into 60 minutes is a legacy of the Babylonian astronomers, who used a sexagesimal system, that is, a base-60 framework, to study the heavens, and decided around 300 CE that all 24-hour periods should be of equal length.[4] The Babylonians, in turn, borrowed their base-60 number system from the Sumerians, who may have used it as early as 5,000 years ago.

But the concept of splitting the hour into 60 minutes and minutes into 60 seconds was likely inspired by Claudius Ptolemy who, around 150 CE, in his treatise



The Persian scholar, Al-Burini, circa 1000 CE

Almagest[5], subdivided a circle into 360 degrees and subdivided each degree into 60 parts *minuta prima*, or "first minute", and the second segmentation, *partes secondae minutae* or "the second minute" that became known as "the second". However, it was not until the Middle Ages that scientific studies reached a level of sophistication requiring a short period of time measurement that the *second* was needed and implemented. In all likelihood it was borrowed from Claudius Ptolemy's geometry by the Persian scholar, al-Biruni who, writing around 1000 CE, first mentions *seconds*, a 60th of a minute, in the context of New Moon observations. Following al-Biruni's work, the concept of splitting the hour into minutes and seconds eventually filtered down to medieval clockmakers.

As mentioned above, Hertz denotes cycles per second, but if the Babylonians had chosen a different number of divisions of an hour to create the minute, or if al-Biruni had chosen a different number of divisions of a minute to create the second, the frequencies 432, 440 and 444, which we might imagine as having some natural or cosmic significance, would be completely different numbers. For example, if by international agreement the world suddenly changed the basic time period of the second, such that one "old second" now has a value of 1.2 "new seconds", with a little simple arithmetic we find that the frequency 432Hz would change to 518.4Hz; 440Hz would become 528Hz; and 444Hz would become 532.8Hz. Therefore, it is clear that any associations suggested between concert pitch and number, in relation to solar or celestial mechanics, are likely based on mathematical coincidences. However, strange as it may seem, these facts do not necessarily rule out the possibility of a particular concert pitch being discovered at some point in time that has a natural resonance with our physiology, as I will demonstrate later.

Why Down-tuning or Up-tuning a Musical Instrument Changes its Timbre

When proponents of 432Hz tuning say that their instruments sound "softer" than when tuned to 440Hz, or when 444Hz adherents say that their instrument feels "brighter" than when tuned to 440Hz, these are not merely subjective statements, but very real. Stringed instruments, such as the piano, cello, violin, guitar and harp, are manufactured to very precise string weights to achieve the optimum timbre of harmonic balance. If we down-tune a piano that uses 440Hz-designed strings, many of the higher harmonics will be reduced in amplitude, resulting in an overall softer timbre. The manufacturing calculations take into consideration the concert pitch, string length, string density, string diameter and tension.[6,7] While some people may prefer the softer tonal quality, the manufacturer's precise specifications would be skewed, having spent countless hours developing the instrument to produce its optimum sound at 440Hz tuning.

The manufacturer's precise tuning specifications would also be greatly altered by up-tuning, resulting in a brighter timbre, due to the higher harmonics becoming more prominent. These principles apply to all stringed instruments. So, if someone says they have down-tuned their guitar to 432Hz concert pitch and it now sounds "wonderfully soft", there is a very good reason for that, but the result does not mean the 432Hz tuning is natural or better; it's just different, just as we would expect. The case is a little more complex for other categories of musical instrument but, in essence, de-tuning or up-tuning alters the inherent, harmonic balance of the instrument.

Tartini Frequency Immersion

The idea that tuning a musical instrument to a particular concert pitch will create frequencies that are unique to that pitch (and perhaps frequencies that have particular healing qualities) is, at first thought, reasonable. After all, when a musical instrument is tuned to a particular concert pitch, every note of the instrument will have a unique, fundamental frequency related to the chosen concert pitch. While that remains true, there exists a more complete truth, due to the laws of acoustic physics, which is that the pitch to which a musical instrument is tuned will immerse us in a range of frequencies that relate to that particular pitch *in addition to a myriad of other frequencies that directly relate to other concert pitches.* This frequency immersion occurs due to the myriad of harmonics (exact multiples of the fundamental), sub-harmonics (exact sub-multiples of the fundamental) and

Giuseppe Tartini, 1692–1770, violinist and composer

mixtures of frequencies that occur naturally within any musical instrument, regardless of our choice of concert pitch. Each type of musical instrument has a unique set of harmonics that have a particular intensity (loudness) and this difference in intensity and harmonics provides the information that allows us to audibly differentiate between instruments.

With stringed instruments, a third frequency is experienced when two frequencies are sounded together, sometimes lower in pitch, which corresponds to the difference in vibration between the two notes, and is called the *differential tone*; and sometimes a note is heard that is higher than the two notes, corresponding to the sum of their vibrations, called the *summational tone*.[8] More popularly, these two acoustic–physics effects are given the general term, *Tartini tones* after the violinist and composer, Giuseppe Tartini, who first noticed them.

The fact that frequencies relating directly to other concert pitches are heard even when a musical instrument is tuned to a specific concert pitch demonstrates that whatever pitch is chosen, clear-cut results cannot be produced; a myriad of harmonics will bathe our cells in a complex sound field.

For those interested in concert pitch cross-correspondences, some examples are presented in the textbox to the right, which gives two examples from each of the three "pitch battle" frequencies, demonstrating this surprising aspect of Nature.

Anyone with an interest in arithmetic and musicology will have fun in finding many cross-correspondences between the various concert pitches. Theodore Zuckerman's online page contains a chart showing the fundamental frequencies of all 88 piano notes. By entering a particular concert pitch and clicking on a single button, his special online calculator will list all 88 fundamental frequencies relating to the pitch entered.[9] My own method of finding Tartini tones involves printing a hard copy of the 88 fundamental frequencies relating to 432, 440 and 444Hz and, with a calculator, choosing pairs of frequencies in one of the lists and deducting the lower frequency from the higher to see if the resulting number is the same or close to one of the frequencies in either of the other two lists.

Music Medicine

The question often arises: does one particular concert pitch offer greater healing benefits than others?

Music therapy is a concept first espoused by Pythagoras of Samos around 2,500 years ago. He believed that music could be used in place of medicine and that it contributed greatly to health.[10] It is now a clinical discipline and focuses on, for example, supporting patients with depression or relieving anxiety during the pre- and post-operative phases of a patient's hospitalisation. It is generally defined as an intervention in which "the therapist helps the client to promote health, using music experiences and the [patient/therapist]

Concert Pitch Cross-correspondences

Piano tuned to A=440 Hertz

When a piano is tuned to A=440Hz and pitch 15 (B1) is played, with a fundamental frequency of 61.73Hz, the seventh harmonic of that note equals 432.11Hz.

When pitch 25 (A20) is played, with a fundamental frequency of 110Hz, and pitch 53 (D5 flat), with a similar frequency of 554.36Hz, are simultaneously played, the difference pitch will sound as 444.36Hz.

Piano tuned to A=432 Hertz

When a piano is tuned to A=432Hz and pitch 8 (E1) is played, with a fundamental frequency of 40.45Hz, the 11th harmonic of that note equals 444.95Hz.

When pitch 29 (D3 flat) is played, with a fundamental frequency of 136.07Hz, and pitch 54 (D5), with a fundamental frequency of 576.65Hz, are simultaneously played, the difference pitch will sound as 440.58Hz.

Piano tuned to A=444 Hertz

When a piano is tuned to A=444Hz and pitch 9 (F1) is played, with a fundamental frequency of 44.05Hz, the 10th harmonic of that note equals 440.5Hz.

When pitch 52 (C5) is played, with a fundamental frequency of 528Hz, the 11th sub-harmonic of that note equals 48Hz, which is almost identical to the fundamental frequency of pitch 11 (G1) when the piano is tuned to A=432Hz, that is: 48.1Hz.

relationships developing through them."[11] Many studies have been conducted that demonstrate the efficacy of music therapy[12], but now interest is growing in the field of music medicine which, as its name implies, focuses on the demonstrable benefits of music as treatment for specific health challenges; in other words, the music alone (without a therapist) produces physiological effects for the patient. Several recent studies have demonstrated beneficial effects by immersing a patient in music, from both live and recorded sources.[13–16]

Musical Effects on Blood

To test whether choice of concert pitch is a significant factor for music as medicine, I designed an experiment involving whole human blood, in collaboration with Professor Ji of Rutgers University, USA, who visited our lab to help design the experimental protocol. In brief, for each experiment, a test tube of blood was warmed to 23°C (from 4° at which it was supplied from a blood bank) and decanted into two smaller vials. One was placed in an incubator (37°C) in the very quiet environment of our laboratory Faraday cage (25dBA sound level, which is quieter than the quietest bedroom) for 20 minutes. The other vial was placed in the laboratory music incubator (37°C), which contained a speaker fed by recorded music for 20 minutes. The music selections had been recorded in three different concert pitches from musical instruments tuned to the three test pitches, 432, 440 and 444Hz (the music was not merely pitch-changed in audio software). For each category of music and each concert pitch the sound level averaged 85 dBA. Following each 20-minute experiment, a red blood cell count was carried out for the blood from both the quiet environment and musical environment.

Any test tube of fresh blood that is a few days old will contain large numbers of red blood cells that are alive and healthy, large numbers of dead cells and large numbers of cells that are in a transitory phase in which they are classed as "old" and beginning to die. What we found was fascinating and may prove to be important in the future of music medicine. The blood that had been immersed in music yielded far greater numbers of living red blood cells than the blood tested from the quiet environment, regardless of the choice of concert pitch.

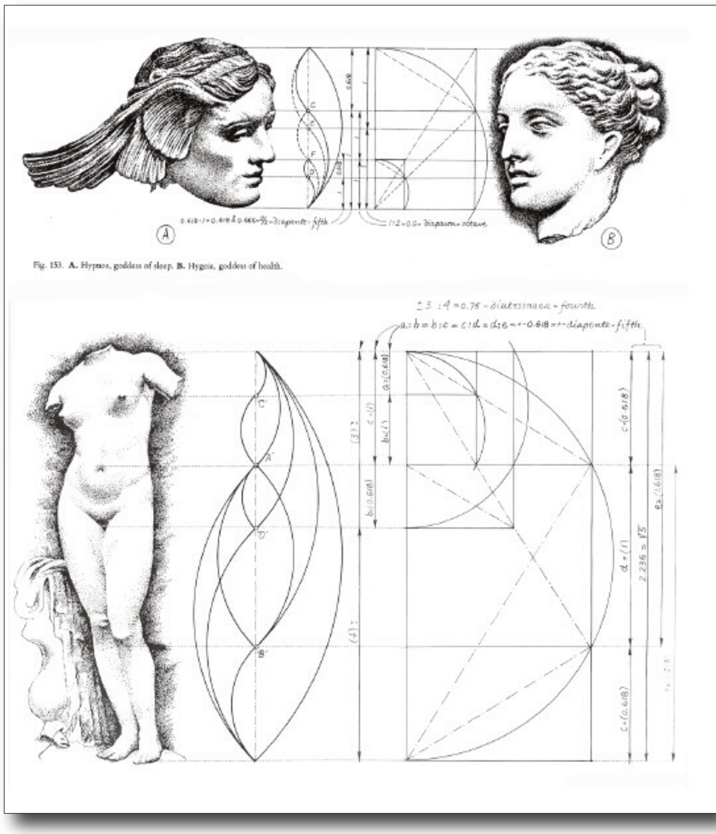
The full report was published on www.experiment.com[17], whose backers kindly supported the experiments with funding, and it includes a working hypothesis that proposes why music offers life-giving properties [see also NEXUS volume 26, number 5, (August–September 2019), "Blood and Music"]. In a nutshell, music cannot bring dead blood cells back to life but it appears that it can repair the membranes of red blood cells that are in the transitory phase, a mechanism involving access to dissolved oxygen, thus resulting in them being counted as "live" by the automatic cell counter. In contrast, the transitory cells in the quiet environment and total absence of music are counted as dead after 20 minutes.

The blood that had been immersed in music yielded far greater numbers of living red blood cells than the blood tested from the quiet environment...

Cells may respond in the same way to music regardless of which concert pitch they are being exposed to due to the innate relationship between musical sounds and the Phi ratio, found throughout Nature (Phi ratio=1:1.618). All sounds created by musical instruments follow the mathematical law of the sine, or put differently, all musical instrument sounds oscillate sinusoidally, regardless of the choice of concert pitch. It is an interesting fact that the sine curve and the Phi ratio are closely related by several formulae; here are three examples of many:

$\text{Phi} = 1/(2 \sin 18°)$; $\text{Phi} = 2 \sin 54°$; $\text{Phi} = 1/(2 \cos 72°)$.

Therefore, all music created on traditional musical



Excerpts from “The Power of Limits” book by György Dóczi

instruments (whether stringed or otherwise) contains the Phi ratio. In his book, *The Power of Limits*,[18] György Doczi provides many illustrated examples of the Phi ratio throughout life.

And since the Phi ratio is found in almost all life forms, including the human body, it should not be surprising to find that cells respond to all musical instrument sounds in a positive way, provided the sounds are maintained at moderate sound levels. And here the "Goldilocks" metaphor is useful, as a guide to sound levels when we immerse ourselves in music (see text box).

A glimpse of hope for 432Hz tuning has emerged from research conducted by the Institute for Frontier Science in Emeryville, California, USA.[19] They tested the crystallisation of a solution of sodium chlorate, which ordinarily makes approximately equal numbers of right-handed and left-handed crystals as it is a random process. But when the solution was immersed in a 432Hz tone for 24 hours during crystallisation, there was a significant change in this random process, resulting in 67 per cent right-handed crystals and 33 per cent left-handed crystals—about twice as many right-handed crystals.

The salt solution immersed in 432Hz also produced significantly larger, more perfect crystals than the control solutions that were not exposed to 432Hz. The researchers, biophysicist Dr Beverly Rubik and physicist Harry Jabs, have not yet tested other concert pitches, but when the results of further crystallisation experiments are known, a full update will be published on the CymaScope website. If it turns out that only 432 Hz creates this effect, it will open new avenues of research, with implications for musicians and possibly even for medical science.

Another piece of interesting research is relevant to this discussion.[20] The authors studied the response of infants to a range of musical frequency ratios to test whether or not they had a natural, biological predisposition to simple musical intervals, such as 2:1, 3:2 and 4:3, as opposed to the complex interval, 45:32. They concluded that infants (therefore people) are indeed preferentially sensitive to simple musical intervals, which they suggest may be due to the spectral structure of speech sounds. However, one must remember that the human preference for simple intervals holds true whether the concert pitch is 432, 440 or 444Hz or any other, because the ratios remain unaltered. Therefore, in this context the term "natural" can be applied to any concert pitch.

In summary, simply immersing ourselves in music of moderate sound level appears to provide health benefits regardless of our choice of concert pitch. No evidence was found that one particular concert pitch is more natural than any other, regardless of its arithmetic elegance. While there will be those who disagree with my conclusions, I remain open to new research, such as that offered by the crystallisation experiments and by the science of Sonocytology[21], first explored by Dr James Gimzewski, revealing that every cell in our body emits sound, poetically termed, "the song of the cell". Perhaps it will eventually be discovered that our cells find greater resonance with one concert pitch than another; for the present though, I recommend enjoying music, both live and recorded, in all concert pitches.

Goldilocks' Music Levels

Music levels below 70 dBA are generally too low energetically to directly stimulate biological change, but low-level music may still offer some physiological effects as a result of uplifting the mood of the listener.

Music levels above 90dBA are generally too high in energy for cell comfort and can cause stress physically and psychologically.

Music levels in the range of 75 to 85 dBA are just right and offer physiological benefits—the musical "Goldilocks" zone.

Endnotes
1. Jacobs A. *Dictionary of Music*, 6th edn, Penguin, London, 1997, p339.
2. Barnes-Svarney P, ed. *New York Public Library Science Desk Reference*, McMillan, New York, USA, 1995, p285.
3. Number Bases Conversion calculator: http://convertxy.com/index.php/numberbases/
4. Barnes-Svarney P, op. cit., p73.
5. Heiberg JL, ed. *The Almagest*, under the Latin title, *Syntaxis Mathematica, Claudii Ptolemaei opera quae exstant omnia*, vols. 1.1 and 1.2 (1898, 1903).
6. http://pianomaker.co.uk/technical/string_formulae/
7. Arto's string calculator www.cs.helsinki.fi/u/wikla/mus/Calcs/wwwscalc.html
8. Jacobs A, op cit, p.364.
9. Piano pitch frequency calculator. http://shakahara.com/pianopitch2.php
10. Taylor T. *Iamblichus' Life of Pythagoras*. Trans. from the Greek, p7. Inner Traditions, VT, USA, 1986.
11. Bruscia KE. *Defining Music Therapy*, 2nd edn. Barcelona Publishers, Gilsum, NH, 1998.
12. Bradt J et al. Music for stress and anxiety reduction in coronary heart disease patients. Cochrane Database Syst Rev. 2013;(12):CD006577.
13. https://tinyurl.com/y4ghxntx
14. https://tinyurl.com/yy3zeoxt
15. https://tinyurl.com/km54kmh
16. https://tinyurl.com/y52pa7v9
17. https://tinyurl.com/y5rtmc3n
18. Doczi G. *The Power of Limits: Proportional Harmonies in Nature, Art and Architecture*, 2nd edn, Shambhala Publications, Boston, MA, 2005.
19. http://frontiersciences.org, also http://brubik.com
20. Schellenberg EG, Trehub SE, Natural musical intervals: evidence from infant listeners. Psych Sci 1996;7(5):272-7.
21. Sonocytology: www.darksideofcell.info/bg.html

About the Author:
Acoustics pioneer, John Stuart Reid, is a man on a mission to educate and inspire the world in the field of visible sound. His articles "Blood and Music: Testing a 2,500-year-old Hypothesis" and "Rediscovering the Art and Science of Sound Therapy" with Annaliese Reid, featured in NEXUS volume 26, number 5 (August–September 2019), and volume 25, number 6 (October–November 2018), respectively. His CymaScope invention has changed our perception of sound forever: seeing sound allows us to understand this omnipresent aspect of our world and universe fuller and deeper. For more information, see www.cymascope.com.