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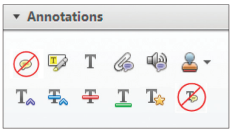

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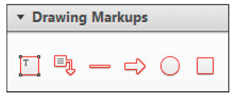

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On equal temperament: Tuning, modernity and compromise

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Abstract
In this article, I use Stengers' (2010) concepts of 'factish', 'requirements' and 'obligations', as well as Latour's (1993) critique of modernity, to interrogate the rise of Equal Temperament as the dominant system of tuning for western music. I argue that Equal Temperament is founded on an unacknowledged compromise which undermines its claims to rationality and universality. This compromise rests on the standardization which is the hallmark of the tuning system of Equal Temperament, and, in this way, it is emblematic of Latour's definition of modernity. I further argue that the problem of the tuning of musical instruments is one which epitomizes the modern distinction between the natural and the social. In turn, this bears witness to what Whitehead calls the 'Bifurcation of Nature'. Throughout this article, using the work of Stengers and Latour, I seek to use tuning as a case study which allows social research to talk both of the natural and of the social aspects of music and tuning, without recourse to essentialism or simple social construction. In this way, my argument seeks to avoid bifurcating nature.

Keywords
Bruno Latour, natural-social, Isabelle Stengers, tuning, A. N. Whitehead

Introduction

In this article, I aim to utilize some of the arguments set out in Stengers' (2010) text *Cosmopolitics*, vol. I, in order to investigate the problem of the tuning of musical instruments in the West and one, dominant, solution to this question, namely 'Equal Temperament', which developed from the late 17th century. Put simply, Equal Temperament refers to the

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system of tuning where the ‘distance’ between each note is equal. This is, perhaps, best envisaged in terms of the modern piano keyboard where each note is one equal step up from the previous one. Today, this model has become so ubiquitous that it is sometimes difficult to see it in its specificity, and as only one possible solution. Indeed, many people are surprised to learn that there could be other ways of tuning, rather than assigning a specific frequency to each note, with an equal gap between all notes. Other paths, other courses could have been taken. There is a historical specificity to Equal Temperament but this does not reduce it to a mere social phenomenon, or so I will argue. Rather, the notion of history invoked here is more redolent of, though not synonymous with, the approach of the early Foucault (for example, 1967, 1974) in that the historical refers to the contingency of the manner in which thoughts, words, actions, different knowledges and, importantly, things, all coalesced to produce a state of affairs which is nowadays taken for granted but which could have been otherwise.

Before turning to my argument, I should point out that the history and theory of tuning is a vast and complex area with an abounding literature. The problem of tuning is one which has been discussed for over 2,000 years and it is not possible to do justice to the diversity and depth of this field within this article.[1] However, what is noticeable, as Duffin (2007) stresses, is that the question of tuning (and of Equal Temperament especially) has not often broached the realms of musicology. Indeed, even within musicology the problem of tuning is often seen as an interesting but difficult subset, a specialist area which is not essential to an understanding of modern western music. For example, in Westrup’s (1955) *An Introduction to Musical History*, tuning is not mentioned at all. Nor does Blanning in his more recent (2008) *The Triumph of Music* deem it necessary to discuss the role of tuning. Having said this, the fact that Equal Temperament is premised on a compromise is well known to theorists of tuning. Indeed, as will be seen, all tuning systems involve some kind of a compromise. It is the manner of the compromise and the basis of its justification that are at stake. The aim of this article is not to say something new about Equal Temperament in musicological terms. Rather, I want to draw out some of the implications of this topic for the history of knowledge and cultural theory.

To jump ahead to the main point that I want to draw out, I will suggest that so used are we to the ‘Equal Temperament’ as a theoretical and practical device that we forget what it was originally designed to do, namely, to overcome a specific musicological problem. Worse, we are now unable to think or hear much of the music that surrounds us except in these limited and limiting terms. A further strand of my argument is that there is no need to make a strict division between what is natural with regard to tuning and what is social. That is to say, this article also constitutes an attempt to think the natural and the social together, using tuning as a case study (see Halewood, 2012 for another attempt to think the natural and social together, in terms of Marx’s conception of the commodity). My aim is not simply to decry ‘Equal Temperament’; it is to draw out and consider some of the ramifications of this compromise and to describe how far removed it is from the original conceptions of resonances in nature.[2]

Forgetting that western tuning is founded on a compromise is an indicator of the inconsistency which lies at the heart of modernity. The tuning of western modern music is another example of western modernity’s attempt to render its own abstractions as universal, as based on an unquestionable rationality and direct access to the truth of the world. This supposed universality, which gains its power from the standardization of tuning, is then used to deem other approaches to tuning as exotic, simple, quaint, folkish, backward, closer to nature. However, Equal Temperament is *more* than that. It is one of the concrete modes of thought and action which has the *appearance* of universality. It is not what it thinks or says it is. For, as will be seen, this seeming universality is also based on a compromise. In this sense, Equal Temperament could be seen as an example of what Whitehead (1932[1925]: 94) calls a 'radical inconsistency at the basis of thought [which] accounts for much that is half-hearted and wavering in our civilization. It would be going too far to say that it distracts thought. It enfeebles it, by reason of the inconsistency lurking in the background.' Whitehead is talking about what he calls the 'Bifurcation of Nature' (Whitehead, 1964: 26–48; see also, Halewood, 2011: 1–22). Within this model, hard science, especially physics, deals with the inert, external, natural world while social and cultural analyses deal only with the values and meanings in which humans find themselves immersed; or so it is supposed. This reinforces a division of academic labour, thought and activity which is inherent in western modernity and universities in particular; it creates and sustains the supposed division between the natural and the social.

With regard to music, such an approach draws a strict line between the physics of music and human perceptions thereof. It maintains a sharp dividing line between the mathematical-physical elements of music, such as resonance and frequency, and social analyses of music, which deal with cultural and historical factors that alter over time and from place to place. Such an approach is evident in the work of psychologists such as Levitin (2006) who separate the brain's (or mind's) reaction to music from the sound phenomena themselves. For example: 'Music, then, can be thought of as a type of perceptual illusion in which our brain imposes structure and order on a sequence of sounds' (Levitin, 2006: 109). This reduces the human (and hence, social) aspects of music, literature, or art to some kind of illusion, an interesting but culturally arbitrary epiphenomenon. This is akin to one strand within the sociology of music that has emphasized the extent to which music must be analysed within the framework of the social construction of reality, as it is the meanings and definitions that humans apply to music which are of interest. For example, Martin (1995) insists that music is solely a social activity which is to be distinguished from the music itself which lies behind such activity:

> It should be clear that the process by which collective definitions are established – the social construction of reality – is in principle independent of the intrinsic properties of the activities and objects being defined. Mahler's scores have presumably remained basically unchanged since his death, for example, but public perception of them has been transformed. (Martin, 1995: 31)

Whitehead comments witheringly on such conceptual positions:

> The poets are entirely mistaken. They should address their lyrics to themselves, and should turn them into odes of self-congratulation on the excellency of the human mind. Nature is a dull affair, soundless, scentless, colourless; merely the hurrying of material, endlessly, meaninglessly. (Whitehead, 1932[1925]: 68–9)

The task that Whitehead sets himself throughout his work is to avoid this Bifurcation of Nature. In the case of music, the bifurcation is between the musical scores, notes, sound waves, resonances, performances, and the human perceptions, reactions and feelings of and towards these. Throughout this article, I will also attempt to avoid such a division, not by reconciling the social and natural aspects of music but by taking both together, thereby refusing any conceptual split. As Prior puts it, 'we need to move away from a sociology *of* music ... toward a sociology *with* music' (Prior, 2011: 132). In some respects, my starting point is close to Latour's (1993) position as outlined in the title of his book *We Have Never Been Modern*. Where I differ from Latour is that I am prepared to allow for, indeed to insist upon, some of the wider political implications of such statements, especially with regard to questions of post-colonialism.

While I stated previously that models of tuning are not central to social analyses of music, this does not mean that they have not been addressed at all. For example, Blackstone (2011) attempts to distinguish the original Pythagorean model of tuning from the manner in which music has been commodified under capitalism. More importantly, the development of western music, and the role of tuning within this, is comprehensively discussed by Max Weber in his text *The Rational and Social Foundations of Music* (Weber, 1958[1921]). Here, and in a similar vein to the argumentation of *The Protestant Ethic and the Spirit of Capitalism* (Weber, 2003[1904–5]), Weber attempts to set out the specific development of western music along with how and why such a development took a different path from the forms of music of other cultures, such as those to be found in China or Java. It is rationalization that is the key factor. Weber's argument displays his usual erudition and a detailed knowledge of harmonic theory. Yet, although he does spend some time discussing the role of Equal Temperament (Weber, 1958[1921]: 89–103), recognizing that it involves an 'arbitrary equalization of tones' (ibid.: 93), he views such a 'rational' tuning system as secondary to the development of a rationalized harmonic system. Moreover, Weber makes no mention of the natural in his text; the closest that he comes being on the first page where he refers to the problem posed by such resonances for tuning musical instruments[3] as, simply, an 'unalterable state of affairs' (ibid.: 3). In this way, Weber replicates the approaches of much of the sociology of music, as discussed above, in that it takes the social (human) element as primary and avoids the status of the actual, natural, frequencies of musical notes. So, while Weber's exposition does point to the relevance of tuning for social analysis, he also points to an ongoing problem in certain approaches to this field, namely the avoidance of the role of the natural. This is a situation which I hope to partially redress throughout this article. The first step that I will take is a brief exposition of Latour's conception of modernity and compromise. This is followed by an outline of three of Stengers' (2010) key ideas as set out in *Cosmopolitics*, vol. I, namely, 'factish' and the two associated terms of 'requirements' and 'obligations'.

A compromise at the heart of modernity

In *We Have Never Been Modern*, Latour (1993) carefully and subtly sets out his position that what he terms the 'Modern Constitution' is premised on a supposed division between Nature and Society (with a bracketing of God). This constitution employs the practice of purification (and critique) both to establish and guarantee its premises. Scientific practice represents objects and its procedures entail a purification to ensure that it is nature alone which is its source and goal. Political and social analyses ignore nature and premise a realm of subjects; they purify their analyses to develop accounts which deal only with the machinations of humans, considered as societal or cultural entities (ibid.: 29–32). That which is ruled out is the 'old-fashioned', mystical, messy, impure mixing of nature and culture which Latour describes as 'hybrids' (ibid.: 10 and *passim*). 'If we consider hybrids, we are dealing only with mixtures of nature and culture; if we consider the work of purification, we confront a total separation between nature and culture' (ibid.: 30).

With regard to musical tuning, all this leads to a series of questions. Is Equal Temperament natural? Is Equal Temperament social? Or is Equal Temperament a hybrid?

We moderns are not naïve enough to believe that our music with its tuning system is natural in that it represents some kind of pure manifestation of nature. So, we might ask – Is Equal Temperament 'social'? – Is it a social construction, a mere cultural fiction, simply 'made up' by a small ethnic group at a specific point in history, and therefore no better or worse than any other musical system ('world music')? This approach would also seem somewhat naïve, not only in the light of Latour's work but in respect to other theorists of music who insist that the materiality of music, its objects, things, sounds, also need to be addressed (see, for example: Born, 2005, 2012; Hennion, 2012). So, is Equal Temperament a hybrid? While I would not want to provide a resounding 'no' to this question, I do believe that we should treat it with caution. For Stengers, the insistence on asking whether Equal Temperament is *either* natural *or* social, is part of the problem (see, for example: Stengers, 2011: 172, 324–5, 331–2; Stengers, 2008; Stengers, 2009; Pignarre and Stengers, 2011; 23–30). It is what we must resist. And, by simply stating that Equal Temperament is a hybrid, we may have answered the question too easily, not resisted enough, and not really gone beyond the bifurcation of the natural and the social aspects of this problem.

The argument that I want to make is that Equal Temperament is neither simply social or natural, but nor is it a hybrid. It came to be at a certain point in time. In this sense it has a history. But its coming-to-be proceeded from, and continues to rely upon, the natural resonance of things, as well as the technical development of devices able to measure frequencies and resonance accurately, and the humanly social endeavours which run throughout these; to systematize music (perhaps for the glory of God), to produce beauty, to solve a problem, to make money. What is produced in and through these is a powerful construction which, once it appears, seems to have always been possible, if not always to have been there. It then becomes a powerful, standardized abstraction with which to celebrate and denigrate whole swaths of other music and musical 'others'. To make this argument, I believe that Stengers' work provides the best path forward.

Factishes, requirements and obligations

One reason that Stengers (2010: 18–27) introduces the notion of 'factishes' is to get over the widespread but somewhat simple-minded notion that science deals with facts and that any form of construction or fabrication in terms of experimental, social, or aesthetic practice somehow undermines or misrepresents the facticity of fact.[4] Human involvement always tends towards artifice, or so it is maintained. And, it is supposed, artifice is artificial and not a true expression of nature, which is neither artificial nor fabricated, by definition. In this respect, Stengers agrees with Latour; indeed Stengers is clear that the term 'factish' is one that she shares with Latour (ibid.: 19).

One difference in emphasis between these two thinkers is that, for Stengers (2010), it is important to reclaim construction and fabrication as inherent both to nature and to experimental, scientific, endeavour. Stengers is much more of a philosopher of science than Latour is (or would probably want to be). Stengers' aim is to enable us to view the operations of physics, for example, as able to generate new 'factishes' which are really real but were not simply there in reality, waiting, patiently, to be discovered by brilliant individual humans who then simply report on their new discoveries to an accepting, passive, quiescent audience. As Stengers puts it: 'the beings fabricated by physics may nonetheless be referred to as "real", endowed, no matter that they are "fabricated", with an autonomous existence' (ibid.: 19). The role of physics in the standardization of Equal Temperament and the link between this and an apparent universality will be taken up at a later stage.

For Stengers, that which prevents any charge that this emphasis on fabrication necessarily entails a form of relativism, and also enables her to differentiate successful scientific experiments from mere dabbling or the delusional claim that an unlimited number of factishes can be created at will, by anybody, are the twin notions of 'requirements' and 'obligations'. This again signals a different approach to that of Latour and will ultimately provide a way of thinking about Equal Temperament which does not view it as some kind of hybrid.

Although Stengers does not offer a definition of 'requirements', as such, she does state that 'requirements are entirely directed at phenomena, whereas obligations are entirely relative to colleagues and controversy' (Stengers, 2010: 51). Requirements are to do with that aspect of the world with which the investigator is concerned. But this is not a passive world, and it is not Nature, considered as a whole, unique realm. Requirements are addressed to that aspect or those elements of the world which are of interest, and which, following Deleuze, Stengers describes as constituting a 'problem' (ibid.: 58–61). This notion of problem signals the specificity of requirements. There are not (scientific or experimental) requirements in general: rather, there is that which is required of this specific phenomenon.

Obligations, on the other hand, refer to the more 'human' side of a practice. But to refer to the human is not to invoke some blessed or gifted individual, nor is it to suggest that *any* interpretation of the phenomenon or problem can be generated. As Stengers puts it:

> . . . facts have value only if they can be recognized as being able to obligate practitioners to agree about their interpretation. And the practitioner who represents this fact, and claims to speak in its name, can do so only if she has first satisfied the strict obligations that will determine the value of what she proposes. (Stengers, 2010: 50)

That which obliges the practitioner is not an abstract set of rational or moral rules. The practitioner, precisely insofar as she or he wishes to report upon the 'findings', is obliged by the very requirements that have been established and isolated. What is involved is the process of 'transforming a phenomenon into an "experimental fact", a *reliable witness*, capable of making a difference among those who interpret it' (Stengers, 2010: 50). Successful scientific practice does not involve either human discovery of an inert world or human interpretation of an inherently unknowable world. There is a 'reciprocal capture' (ibid.: 35–41) where a '*dual* process of identity construction is produced ... identities that coinvent one another' (ibid.: 36). The researcher is invented and obliged by the problem while the researcher requires the problem to express itself as a factish. I will return to the relation of requirements and obligations to the problem of tuning after making a short detour through a brief conceptual history.

A very brief history of tuning

All things resonate. Chairs, tables, windows, flowers, amoebae, bones, trains, computers all resonate at a certain frequency. Such resonance may suffuse nature but this does not make it musical (Johnston, 1989: 30). Music, though I am shy of giving a definition, would seem to involve the ordering of resonances; as opposed to random or disordered resonances which only make noise. The question then becomes, which resonances should we choose to order? This is an element of the *requirement* that we make of the world – that it exhibit resonances which are constant and replicable. But how many such resonances are we to allow? If one imagines a single violin string, it would seem that there is a vast range of possible notes that can be played on this; that is why learners of the violin often sound 'out of tune'. They are not consistently playing the same note or, more importantly, notes which are clearly related to each other.

This importance of the relation of notes was one which was addressed in detail by Pythagoras. It was he, it is claimed, who first noticed that there is a relationship between the length of a piece of metal (or animal gut) and the frequency at which it resonates – what we might call its 'pitch' (Duffin, 2007: 24; Johnston, 1989: 5–7). Put simply, if you take a piece of metal (or gut) of a certain length and hit it, it resonates at a specific frequency. If you halve the length (apply a ratio of 1:2) then you get a strongly related frequency which replicates the original frequency at a higher level (or pitch). In modern parlance we would say that you get the same note, only an octave above. But what is more interesting, and upon which Pythagoras bases his theory, is that if you shorten your original piece of material by a third, then you create a different but strongly related frequency. This is what we would now call a fifth above the original note. The relation of two-thirds to the original length is important. The ratio which it expresses of 2:3, is even more so (Duffin, 2007: 21–30; Johnston, 1989: 7–10).

This raises the question as to whether such a ratio or relation is arbitrary, one which human ears are 'tuned' to hear, one which is culturally specific and alterable, as some, such as Levitin (2006), suggest: 'Sound waves – molecules of air vibrating at various frequencies – do not themselves have pitch ... it takes a human (or animal) brain to map them ... We perceive color [*sic*] in a similar way ... Newton was the first to point out that light is colourless' (Levitin, 2006: 22). As stated earlier, this strict division between a featureless, natural, world and the cultural realm of human perception of this external world, in which humans grant the colour, sounds and music to the meaningless, external world, is what Whitehead refers to as the ‘Bifurcation of Nature’ It is exactly the kind of division which I am attempting to avoid here.

To return to the initial problem of how to generate a set of ordered pitches, Pythagoras initially felt that the best way to do this was by deploying the ratio of 2:3. This ratio of 2:3 replicates and enhances specific frequencies which were already there in the first note; frequencies which complement and enhance each other, reinforce each other, bring out the qualities that are present in the original. This is why this ratio is often called, in musical terms, the ‘dominant’ (Duffin, 2007: 20–3). Practically speaking, this is accomplished by repeatedly reducing a piece of metal by a third. This may seem peculiar nowadays when the piano keyboard is regarded as the starting point (and end point) of deciding what notes there are in a scale. We tend to imagine that you start with one note and then move up a little bit to get the next, then up a bit more, then up a bit more, moving by semitones (or halftones). But this does not actually *generate* notes – it is simply a way of ordering notes which have been generated by other means.

As Duffin (2007: 23–7) and Johnston (1989: 7–10) state, the accurate generation of notes in the West has historically followed Pythagoras’ procedure and used the ratios of resonances produced by a piece of metal as its foundation. One frequency is taken as a starting point and given a name – ‘C’, for example. The 2:3 ratio is then applied and another note, a fifth above C, is generated (which is then called G). This procedure is then repeated and, using the commonly agreed notation of western music, the following notes are generated:

1. C-G-D-A-E-B-F#-C#-G#-D#-A#-E#(F)-C.

This all seems straightforward, and 12 notes have apparently been generated which correspond to the 12 notes which make up the modern octave[5] on a keyboard. But there is a major problem, one that Pythagoras noticed and which is, indeed, named after him; this is the problem of the Pythagorean Comma (Duffin, 2007: 25–7). For the second C generated out of this cycle of fifths, through this repeated application of the ratio of 2:3, does not generate a frequency which has sympathetic overtones with that of the original C. In fact, if these two ‘Cs’ are played together, they are extraordinarily dissonant, they are genuinely out of tune. But this is not simply because humans hear it so. It is the extrapolation via the process of applying the ratio of 2:3 which means that nature is, at this point, ‘out of tune’ in comparison with a C which is generated through the repeated division of a length of metal using the ratio of 1:2.

This problem can be expressed in mathematical terms (the following analysis is adapted from Duffin, 2007; Jorgensen, 1991). Halving the length of a piece of metal, applying a ratio of 1:2, produces a sympathetic frequency, indeed the same note, one octave above. But it does not produce a new ‘note’. To adopt the modern formulation, such frequencies are measured in Hertz (Hz) which increase when the length of metal is shortened. Eight different ‘Cs’ can be generated simply by doubling the frequency. Hence:

1. C = 100 Hz
2. C^1 = 200 Hz

3. $C^2 = 400$ Hz
4. $C^3 = 800$ Hz
5. $C^4 = 1600$ Hz
6. $C^5 = 3200$ Hz
7. $C^6 = 6400$ Hz
8. $C^7 = 12800$ Hz

But if the aim is to create ‘new’ notes which can be ordered and put in a scale (this is the initial problem), then we need to use the cycle of fifths, which draws out the dominant overtones and thus generates new notes. As Pythagoras noted, this involves a ratio of 2:3. So, each frequency is multiplied by 1.5. So from the original C at 100 Hz, a G of 150 Hz is generated. Hence:

1. C = 100 Hz
2. G = 150 Hz
3. D = 225 Hz
4. A = 337.5 Hz
5. E = 506.25 Hz
6. B = 759.375 Hz
7. F# = 1139.0625 Hz
8. C# = 1708.5937 Hz
9. G# = 2662.8905 Hz
10. D# = 3844.3357 Hz
11. A# = 5766.5035 Hz
12. E#(F) = 8649.7552 Hz
13. $C^7 = 12974.632$ Hz

As becomes clear, the stark out-of-tuneness comes from the difference between:

1. C^7 calculated at 12800 Hz (through the application of the 1:2 ratio) and C^7 calculated at 12974.632 Hz (calculated through the application of the 2:3 ratio, in order to generate new notes). This produces a difference of 174.632 Hz between the two different Cs and it is this which means that the second C is out of tune (Duffin, 2007: 25).

Pythagoras was aware of this problem, and that is why it is named the Pythagorean Comma. However, it did not trouble him too much. For Pythagoras and his followers, the generation of such a wide range of notes (from C to C^7) was not practical, and this was simply a theoretical problem. The world, for Pythagoras, had done what was required (in Stengers’, 2010, sense of the term); it had demonstrated itself in terms of the ratios of resonances. We might say that a factish had been created – a scale of different tones. Pythagoras was obliged to speak of this scale but also to speak of the problem, of the comma, generated by the circle of fifths. His ‘solution’ to this problem was simply to state that there was only a limited number of notes which could be safely generated (Johnston, 1989: 14). Hence he went on to expound the ratios which make up only the notes A, B, C, D, E, F and G. The point to be stressed is that Pythagoras was clear and open about the compromise, why it was required and how it was constituted. Nevertheless, we might still be tempted to ask – is this scale natural or social? In one sense it appears natural, in that the resonances occur in nature. In another sense, it seems social as the out-of-tuneness, and the avoidance of this, seem to involve human perception and action. However, dividing the natural from the social in this instance is not helpful. For the out-of-tuneness is also real (natural) in that there is a clash between the initial resonance (C^1) and the final one (C^7), as generated through the cycle of fifths.

To put it another way, the great advance that Pythagoras made was to recognize that resonance, pitch and tuning were not a simple matter of identifying a given frequency but of establishing relationships within which these frequencies were concordant or sympathetic. As Whitehead puts it (though not discussing tuning, as such): 'The practical counsel to be derived from Pythagoras, is to measure, and thus to express quality in terms of numerically determined quantity' (Whitehead, 1932[1925]: 37). This linking of quantity and quality is crucial as it suggests that there is no split between the natural and the social, as nature always manifests itself in a certain kind of way. Quality is inherent to all existence and not simply designated or produced by (social) humans. Describing the different modes in which quality and quantity intertwine is indicative of a way of thinking the natural and social together. Tuning and especially Equal Temperament are important for this, for within it, quantity and quality, number and tone are irreducibly interlinked.

As stated previously, this history and theory of tuning is a vast and complex area and it is not possible to do justice to it here. I will give only one example of a different solution of how to distribute Pythagoras' comma, namely that of 'Meantone Intonation' which was developed in the early 1500s (Barbour, 1951: 26). This was a system which did not generate notes from a cycle of fifths but prioritized the intervals based on thirds (C-E, for example) with the ratio of 4:5, rather than 2:3 (Duffin, 2007: 34). However, this system still faced the problem of the Pythagorean Comma, namely that notes generated from such ratio or intervals (be they a cycle of fifths or a cycle of thirds) do not fit into a 12-note scheme.[6] The Meantone system emphasizes the importance of getting the intervals of thirds and sixths in tune and is less worried about fifths. Yet it still comes up against a similar problem to that of Pythagorean tuning, in that three such thirds do not add up to an octave. Again, what was required was to distribute the Pythagorean Comma between these ratios so that it did not disrupt the whole system. There were various ways of doing this.

One solution which may seem remarkable nowadays was to have semitones (or halftones) of different ratios. The difference (interval) between a B flat and a B would therefore be of a different magnitude to that between an F and an F#. Thus there is a *real* difference (not just a notational one) between a B flat and an A#. Therefore it is possible to have a keyboard with many more keys (and notes) within the octave, such as that designed by the Dutch physicist Fokker (1887–1972) which has 31 'notes' in an octave (Goodall, 2001: 106) or the keyboard suggested by the German physicist Helmholtz (1821–94) with 24 keys to the octave (Weber, 1958[1921]: 123). Consequently, the modern 12-note keyboard, which was in development since at least the 13th century, might have appeared to have all of its notes available all the time but it did not do so in practice (Duffin, 2007: 48–51). The problem is that whatever key one starts in defines the ratios of other notes in that scale; this means that certain notes become unplayable (Goodall, 2001: 118–20). Furthermore, this system generates what is known as a 'wolf tone' (Weber, 1958[1921]: 99; Goodall, 2001: 117; Duffin, 2007: 35), which is an extremely out-of-tune interval between A# and E flat, with which, it is reported, Bach used to taunt his organ tuner. This problem was well-known. Not playing such an interval became part of the compromise necessary for the Meantone System to operate. As with Pythagorean tuning, this compromise and the reason for it were clear and recognized. Yet, the outcome of this compromise was not acceptable to all and the search was still on for a more adequate system of tuning. Today, the most important of these is that of Equal Temperament.

Equal temperament

As the name suggests, the key aspect of Equal Temperament is equality. The problem of the different (or unequal) ratios between notes which dogged earlier tuning systems is 'solved' by asserting that the intervals between each note in a scale should be equal. This may seem like common sense nowadays but it represented a musical revolution. Interestingly, it was a contemporary of Galileo who first came up with the mathematical formulation of Equal Temperament. In the late 1500s, Simon Stevin worked out that for the 12 notes on a modern chromatic keyboard to all be usable all of the time, each semitone should be 1.059463094 times the frequency of the previous one (Goodall, 2001: 122). However, this seemingly innocent mathematical formula had to wait a couple of centuries until it was put into practice.

The eventual development of piano keyboards in which each note bears the same mathematical ratio to all the others meant that the difficulties associated with earlier systems were overcome. This is reflected in the development of new composing techniques, with great washes of colour and peculiar key changes as evidenced in the work of Wagner, Mahler, Ravel and Debussy. No longer were melodies or keys fixed by their starting point. They could go anywhere, end anywhere, and mix themselves freely, knowing that they were always in tune and did not risk discord. (Paradoxically the seeming discord that many find in 20$^{\text{th}}$-century western music – Schoenberg, Messiaen, Berio, Stockhausen – is only made possible by the assumption of the initial lack of discord in tuning provided by Equal Temperament.)

When Equal Temperament did come into effect, it had one remarkable consequence: to make the point starkly, within Equal Temperament, *everything is out of tune*. At least, this is the case if the initial discovery of Pythagoras is taken into account, namely that there is a precise relation between notes generated via sympathetic resonances and frequencies. Equal Temperament is a severe compromise which moves tuning away from the principles which had held sway for well over a millennium. Nevertheless, it is a very efficient compromise, and in many ways it is a very successful one. But, to return to the concepts of Stengers, as discussed earlier, it involves a move away from (a betrayal of) the status of the initial problem (the ordering of the relations of frequencies) and does not conform to the initial obligations which these impose on those involved in this problem. Instead, it shifts the problem, the requirements and the associated obligations without acknowledging that it does so. Unlike Pythagorean tuning, this is a *dishonest* compromise.

To reiterate: the Pythagorean system utilized the natural ratios inherent in the resonances produced by striking metal. However, when extrapolated through the application of the 2:3 ratio, these resonances did not return to their original point but produced new, unsympathetic, frequencies. In attempting to solve this problem and to fix a set of notes which produced a scale of notes that enabled musicians to play any note within that scale without accentuating such a lack of sympathy, the system of Equal Temperament renounces the initial stance that tuning is produced naturally. Instead, a new, rationalized system is imposed which severs any such link. Now there is simply an equal gap between each note. But the renunciation of the natural resonance between notes does not make Equal Temperament inherently social. It cannot be said to be a mere construction of human thoughts or actions. Instead, it is a curious kind of entity; mathematical yet historical; absolute yet contingent; a rational yet imperfect compromise. It is not a hybrid; it is not a combining of the natural and the social (or cultural). It is both at once, more of an accretion than an addition.

This is analogous to a similar manoeuvre which Stengers (2010: 112–28) identifies in chapter 9 of *Cosmopolitics*, vol. I, 'The Lagrangian Event', in which she outlines how the 18th-century mathematician Joseph Louis Lagrange developed a mathematical formalization of the experiments and conclusions of Galileo on the character of falling bodies. Galileo had produced an account which enabled an equilibrium to be posited, so that falling bodies could be measured 'at an instant', but he did so by always relating this equilibrium to its relation to (accelerating) bodies, thereby staying faithful to the experimental requirements and obligations which had originally been outlined. Lagrange, on the other hand, generalizes Galileo's account so that, as Stengers puts it, 'the effect of forces can be defined independently of whether the bodies on which they act are in a state of rest or in motion' (Stengers, 2010: 117). But such a generalization is achieved by a 'mathematical sleight of hand' (ibid.: 119) which entails that Lagrange's theory is premised on a 'fiction' (ibid.: 118 ff.). This is not to say that Stengers condemns Lagrange's work. She celebrates the ingenuity and power of this abstraction but insists that it is necessary to recognize it as an abstraction and not a description of reality as it really is (ibid.: 126–8). It is, as with all abstractions, both creative and dangerous.

Lagrange abstracts from the specificity of the problem identified by Galileo and attempts to describe the relation of any force to any body. But Lagrange's abstraction involves an assumption:

> What this means – and it is here that the power of the Lagrangian fiction comes into its own – is that the description of the instantaneous state can be construed as if it referred to a state of static equilibrium like that of the Galilean weight-counterweight situation. 'As if' is the keyword of the Langrangian event. (Stengers, 2010: 119)

This 'as if' is hidden behind the supposed all-conquering authority of the mathematical sign for equality ("="), which appears to outline an equality in reality. 'This power comes from the mathematical sleight of hand the = sign authorizes' (Stengers, 2010: 119). Yet this equality is only an abstract equality which proceeds from and relies upon no fixed thing in actuality; it is not an equality 'in reality'.

This ‘as if’, this ‘sleight of hand’, this attempt to insert equality into reality, when it is not really there, through the recourse to the unwarranted authority of abstract and universal mathematicization, is, I would suggest, exactly what happened and still happens, in the case of Equal Temperament. The correct interval is (=) 1.059463094. To put it another way, the equals signs helps mask the specific compromise which is at the heart of Equal Temperament. As has been seen, all tuning systems involve some compromise but that of Equal Temperament is based on a rejection of the ratios of natural resonance as its starting point. Instead, it forces an equality into nature which is not there but still claims another kind of naturalness, that which is premised in, and justified by, the rational, mathematical precision of equal steps between notes. As will be seen in the following and final section, the role of this equality in Equal Temperament is a dangerous one.

Compromise, standardization and the appearance of universality

There was no one event in which Equal Temperament came to be generally accepted in western music; it was a long and tortuous process. Importantly, this is a process which did not involve only those involved in music. While there might have been some agreement among musicians and musicologists on the need for a standard method of tuning, there was a lack of a system for providing this. It is here that physics made its contribution, perhaps most clearly in the work of Hermann van Helmholtz (1954[1885]). Through his development of a device (now known as the Helmholtz resonator), Helmholtz was able to establish, experimentally, the fundamental resonating frequency of various membranes. He claimed to be able to identify and replicate exact frequencies. These could then be standardized and put into an accurate scale. By providing a fixed scheme of natural resonances which could then be ordered into a scale, physics helped justify and promulgate Equal Temperament as a supposedly universal, rational yet natural system. The question of resonance and the definition of Equal Temperament were taken out of the hands of musicians; the scope was widened and an inextricable link was made between music, tuning, resonance and physics.

One important aspect of this was the fixing of a standard pitch from which all other notes would be tuned. This is what is now termed ‘concert pitch’. Previously, it was possible, and likely, for individual tuners to decide what resonance would be the starting point from which all other notes would be derived. For example, the organ in one town or city could be tuned to one starting frequency, while that in another town or city could have a different one. The point being that any frequency could be used. This is similar to the question of ‘local time’. Up until the 19th century, clocks in different towns and cities were set according to local observations of the sun’s path and zenith. This meant that the time in Bristol was 10 minutes ‘behind’ London. With the introduction of the telegraph, and national railways (and timetables), it became necessary to standardize time in the UK, basing it on Greenwich Mean Time. This was effected in the 1840s (Karsten, 2013: 152–4). The UK thereby established a theoretical and practical universal time for itself and the world as all time zones were, and still are, defined in relation to their longitudinal relation to the observatory in Greenwich Park in London. Again, this involves a forcing of equality onto reality in the name of mathematics, so that the same time always holds throughout the UK.

In a similar way, and following the link between electrical resonance and frequency established in the 19th century by scientists such as Hertz and Helmholtz, the French government decreed, in 1859, the A above middle C to be 435 Hz (Haynes, 2002: 346–8). In 1896 the British adopted 439 Hz (ibid.: 355–8). In the 20th century A was deemed to be 440 Hz and this was adopted by the International Organization for Standardization in 1939 (ibid.: 361; Johnston, 1989: 38). The linking of questions of resonance and tuning to those of physics marks an important stage. No longer is it a 'local', though important, problem which is played out in the realm of music and musicians. It is now tied to questions of standardization and physics. In terms of concert pitch A *is* 440 Hz: A = 440 Hz and we should remind ourselves of the subtle role that this sign of equality plays, after Lagrange. And, as Stengers argues throughout the first volume of *Cosmopolitics* (2010), in the 20th century it was physics, most especially theoretical physics, which claimed that it alone had the authority to make accurate and adequate statements about reality, about nature, as only physics was 'capable of unravelling the enigma of reality' (Stengers, 2010: 234). Stengers' aim is to retrace and reinvigorate the path and the questions which led to this state of affairs. In doing so, she makes the crucial point that any claim to being able to explain *all*, involves a very specific understanding of universality (ibid.: 180–2). The 'all' which physics claims for itself needed to be constructed. The same applies to the 'equals' which is the template of Equal Temperament.

The power of Equal Temperament comes precisely from its misrecognition of its constructedness. Unlike earlier tuning systems which recognized themselves as compromises, as approximations designed to work with and against nature (to avoid the Pythagorean Comma or the wolf tone, for example), Equal Temperament denies its own constructedness and claims itself to be universal. It can be used by anyone, anywhere, as long as he or she has access to a device that will give him or her an A at 440 Hz (a simple tuning-fork will do). The simplicity and crucially the portability of Equal Temperament appear to make it available to all. Through its standardization it claims universality. But in doing so, it masks its particularity and the very specific compromise upon which it is premised. It hides behind the equals sign inherent in Equal Temperament. Like the whole of modernity (if such a thing can be said to exist), there is a compromise at its very heart which it papers over and claims does not exist.

Universality, it turns out, is not universal. This is a point which needs to be emphasized. The so-called and self-claimed universalism which appears to be an inherent trait of the Enlightenment conception of the (male) human subject, as pointed out by many feminists, post-colonial theorists and post-structuralists, does not simply take one form. It is not in itself universal. This is why it needs to be countered in its individual manifestations. I would suggest that one neglected aspect of such universalism is precisely that of Equal Temperament which has become the ubiquitous background to the music of the West. The compromise and banality that are at its heart are supported by its standardization. To paraphrase Adorno and Horkheimer: 'The whole world is made to pass through the filter of Equal Temperament ["the culture industry" in the original]' (Adorno and Horkheimer, 1997: 126). Or, as Weber puts it: 'The whole of modern chordal harmonic music is unthinkable without temperament and its consequences' (Weber, 1958[1921]: 101). The problem is that the compromise which is at its heart is more severe than the compromises which were involved in other systems of tuning. It is not that Equal Temperament is either more, or less, natural or social than other forms of tuning. It is that the character of its compromise is masked by the apparent objectivity granted to it through its alliance with physics. It presents itself as a seemingly logical solution which is apparently applicable anywhere and anywhen. It is both standard and universal.

Because of its portability, standardized form and claims to universality, Equal Temperament has driven out more local or different forms of tuning. This was initially a problem for the non-standard tunings of folk music: throughout the 19^{th} century, continuing to today, Celtic music, Balkan music, Jewish music, ‘Gypsy’ music have been confronted with the juggernaut of the abstract-concrete system of Equal Temperament which has no truck with narrow thirds, quarter tones, etc. Indeed the accordion, an instrument which was itself developed in the 19^{th} century, was one of the main harbingers of Equal Temperament into folk music. The accordion has a fixed tuning of its reeds, completed at source, to which all other instruments must tune. It is also very loud. It would seem that the implacable and unalterable fact of the Equal Temperament tuning of the accordion has driven out the various, non-standard tunings of much western folk music. This colonization of the compromise of Equal Temperament goes beyond this. In its rigid designation of equal distances between each semitone, it completely disallows the possibility of any smaller gaps, such as that of the quarter tone, which is to be found, for example, in the music of the ‘Middle East’, in Turkey, Iran, Iraq, Syria, and so forth. This is not to say that the quarter tone ever played a major part in western music, as it has, perhaps, always been deemed to be different, exotic, even out of tune. But the adoption of Equal Temperament as the only system of tuning founded on universal mathematical principles has led those of us brought up in this culture to judge other tuning systems even more harshly, in that they are not ‘rational’ or ‘universal’ in the same way that Equal Temperament is supposed to be. Other forms of tuning, therefore, are relegated to being merely cultural, evocative, or quaint. The spread of Equal Temperament keyboards (such as the accordion or, more recently, the synthesizer or electronic keyboard) has also had a huge influence around the world, for example, in the music for Bollywood films which now use such devices extensively, thereby distorting the original tuning which would have pervaded such music of the ‘Indian subcontinent’. This abstract-concrete system of Equal Temperament certainly appears to be another element of Said’s (2003) notion of orientalism.

This mention of Said is important and should help temper any suspicions that my argument is, itself, universalist. For, despite the tenor of what has gone before, it is important to state that Equal Temperament has not been successful in eradicating all other forms of tuning. In terms of the standardization of concert pitch, UK orchestras do tend to adhere to 440 Hz as is the case with most North American ones. However, some prefer 442 Hz or 443 Hz, as do many European orchestras. The Berlin Philharmonic tunes to 443 Hz, for example (see Haynes, 2002: 360, 369–80; Berliner-Philharmoniker, 2012). String quartets will tune each instrument in relation to itself and the other three instruments, and not by simply matching each individual string to the notes on a piano tuned to Equal Temperament. Choirs, especially unaccompanied ones, are unlikely to sing notes which completely correspond to the notes of Equal Temperament, as this is surprisingly difficult. Furthermore, Equal Temperament has not driven out or eradicated other forms of tuning. Despite being confronted by the accordion or the synthesizer, Bollywood music, and with it that of the Balkans, Jewish and 'Gypsy' music, have not simply bowed down. They have had to confront but not acquiesce to Equal Temperament. There has been resistance, perhaps through accommodations. I do not have knowledge or ability to detail these. However, I would suggest that the specific ways in which different systems of tuning meet and mingle could provide an interesting insight into the incomplete but ongoing interrelations of a self-styled modernity with other ways of living and doing.

In conclusion, the development of Equal Temperament, based as it is on a logical, abstract compromise, is not, as Miller (1993) suggests, a mere metaphor or trope of the development of modernity. Equal Temperament is one aspect of the development of what we term modernity, though its character and import have not been recognized to the extent that they should have been. Returning to the question of whether Equal Temperament is natural or social, following Stengers, I would suggest that making such a strict division is part of the problem and is what we must resist. If we do not then we are in danger of seeing the mathematical formulation of Equal Temperament (each interval = 1.059463094) as no simple social construction. It appears to be a purified, objective (natural) description, produced through the authority of the certainty of mathematics, to produce an elegant and universal system of tuning. Furthermore, this is backed up by the later work of physics on resonance and frequency. We have the assurance of Helmholtz and Hertz with the measurement system named after the latter to be able to pronounce upon the accuracy of Equal Temperament. This is a more complex notion of the natural than that which is associated with Pythagoras (or so it would seem). Yet, at the same time, Equal Temperament is often viewed as the tuning system which supports and expresses the uniqueness of western music, of a specific social-cultural system. It is a crucial element of what founds western music and differentiates it from other musical forms around the world. In this respect, it retains an important degree of sociality.

Such approaches return us to Latour (1993) and his claim that 'we have never been modern', for this jumping back and forth is indicative of the procedure of modernity:

> The critical power of the moderns lies in this double language: they can mobilize Nature at the heart of social relationships, even as they leave Nature infinitely remote from human beings; they are free to make and unmake their society, even as they render its laws ineluctable, necessary and absolute. (Latour, 1993: 37)

I agree with Latour on this point but I do not think that stating that Equal Temperament is a hybrid does justice to the complexity and specificity of this peculiar, abstract but concrete entity. Instead, as I have tried to argue throughout this article, there is a need to refuse to immediately differentiate between what is natural and what is social. What is required is a tracing of the path by which Equal Temperament came to be. Once this is accomplished, we can begin to assess the wider impacts that it has had, for example, in its contemporary relation to other tuning systems and how this reflects and reinforces a whole host of enduring power relations. I do not want to state that Equal Temperament is just another example of the Enlightenment project gone wrong; an example of the inherent imperialist character of the modern West. It is both more and less than that.

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1. A detailed and comprehensive account can be found in Jorgensen's (1991) *Tuning: Containing the Perfection of Eighteenth-century Temperament, the Lost Art of Nineteenth-century Temperament, and the Science of Equal Temperament, Complete with Instructions for Aural and Electronic Tuning*. A more user-friendly text is Goodall's (2001) *Big Bangs: The Story of Five Discoveries That Changed Musical History*. For readers of German, a recent text which makes some of the points I want to draw out in this article is Harrasser's (2013) 'Musicalische Paradoxal-Discourse. Oder: Gute Temperaturen für glückliche Ohren'.
2. Throughout this article, I will resist the temptation to put the terms 'nature' or 'natural' in inverted commas. For, as will be seen as the argument develops, I do not want to assert or dismiss either of these terms or their apparent counterparts, 'social' and 'cultural'. Instead, one main strand of my argument is to interrogate and reorient the manner and status of these terms as they are used within modernity. This may make for uncomfortable reading at points. However, I feel this to be more satisfactory than the alternative which would pepper the text with inverted commas and lessen the force of my argument.
3. This problem is known as the 'Pythagorean Comma' which I will discuss in more detail in the body of this article.
4. It should be noted that the term 'factish' was developed by Isabelle Stengers in conjunction with Tobie Nathan (and also Bruno Latour). One of their aims in developing this concept was to counter the idea that fetishism was somehow restricted to 'other', non-western, cultures. This critique of a 'colonialist' approach which denigrates unfamiliar practices can be linked to the idea that Equal Temperament is a tuning system which is more rational and universal than those found in other cultures or subcultures (see Nathan and Stengers [2012(1995)]) and Latour (2010 – especially ch. one). I am grateful to the anonymous reviewer of this text who pointed this out to me.

5. It is, perhaps, unfortunate that ‘octave’ is the accepted term for this as it suggests that only 8 notes are involved. The reason for this is that those originally involved in generating notes were only confident of being able to establish clean ratios for the notes C, D, E, F, G, A, B, C^1 (C^1 refers to the note with twice the frequency of the original C). It will be noted that these are represented by the ‘white’ keys on a piano. Only later were the more complex, chromatic notes able to be accurately generated, hence producing C#, D#, F#, G#, A# – the ‘black’ notes on a keyboard.
6. The move from C to E and from E to G#, which is based on an interval of a third (and a ratio) of 4:5, might suggest that the next note generated would be C^1. However, this does not occur. As with the cycle of fifths, there is a discrepancy between C and C^1 generated by applying the ratio of 1:2 once and applying that of 4:5 three times.

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