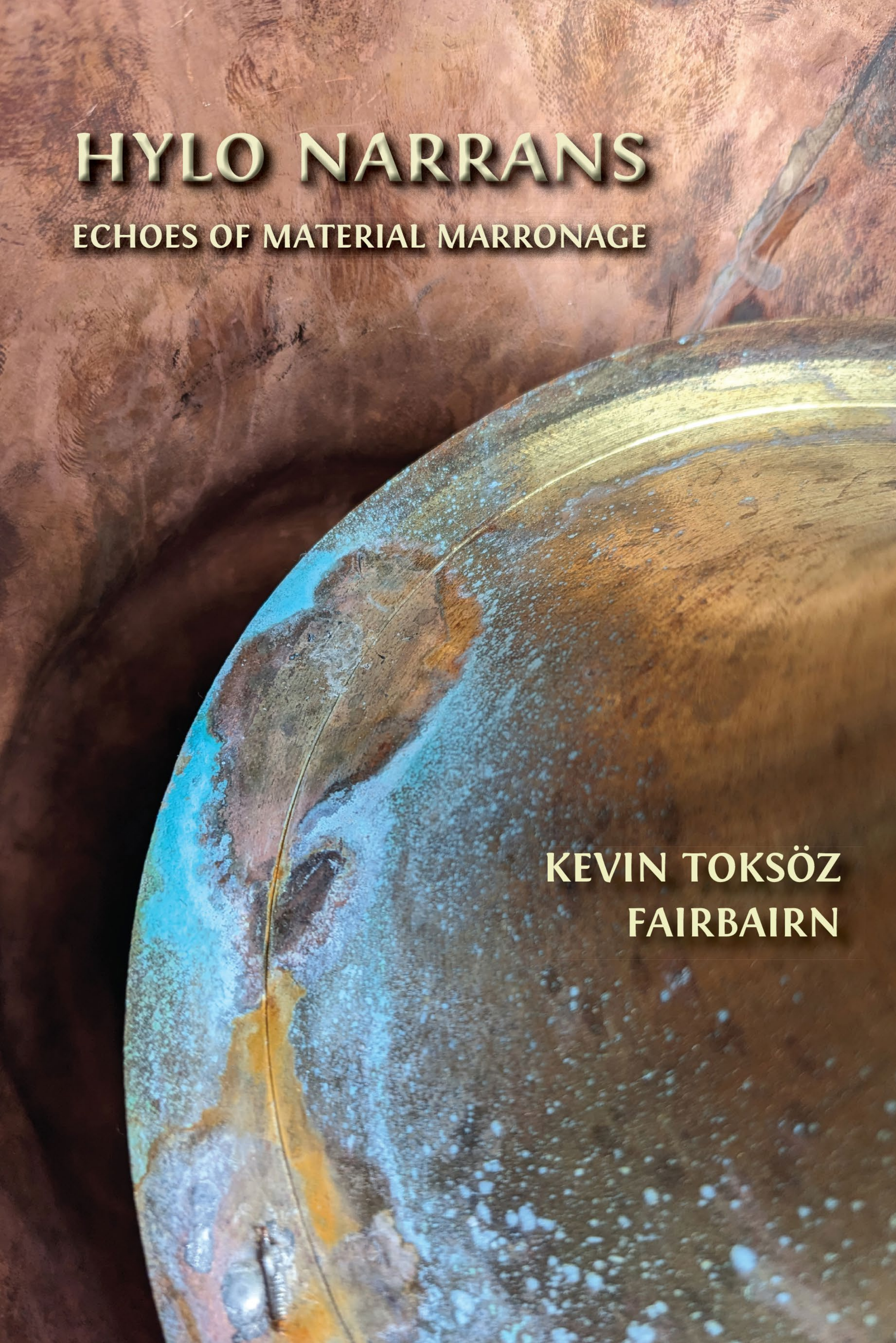

HYLO NARRANS

ECHOES OF MATERIAL MARRONAGE

KEVIN TOKSÖZ FAIRBAIRN

https://www.openbookpublishers.com

Digital material and resources associated with this volume are available at https://doi.org/10.11647/OBP.0476#resources

ISBN Paperback: 978-1-80511-643-1
ISBN Hardback: 978-1-80511-644-8
ISBN Digital (PDF): 978-1-80511-645-5
ISBN HTML: 978-1-80511-647-9
ISBN Digital ebook (epub): 978-1-80511-646-2

DOI: 10.11647/OBP.0476

Cover image: Kevin Toksöz Fairbairn, CC BY-NC
Cover design: Jeevanjot Kaur Nagpal

1. Monochord

Fig. 7 Solo performance with chimeracord: *Verdigris.* Photo by author (2024).

Audio Recording 3 *Verdigris*. Recording by author (2024),
http://hdl.handle.net/20.500.12434/47aac5b5

Video Recording 3 *Verdigris*. Recording by author (2024),
http://hdl.handle.net/20.500.12434/862b78b8

The chimeracord is a monochord of sorts, with a single cord of steel wire strung from end to end of its long hourglass body. This string runs directly through two small holes drilled in the tubular brass body

 https://doi.org/10.11647/OBP.0476.01

itself, with a small bit of copper winding placed at each point to help thread it into the sound chamber and, on one end, back out the other side to a tuning peg. The term monochord refers to this single string, and like all monochords, the chimeracord is in some way defined by this single strand's tension, vibration, and amplification. But monochords have evolved in many different cultures around the world (such as the Vietnamese *đàn bầu*, the Chinese *duxianqin*, or the musical bows popular throughout Africa and the African diaspora, such as the Brazilian *berimbau*), and the history of such single-string instruments presents an abundance of technical, musical, and cultural variation. Some are plucked or struck while others are bowed. Some are melodic while others are rhythmic, though many blur these boundaries altogether. But perhaps the greatest variation is in the mode of amplification. Monochords around the world map an endless capacity for invention, using human bodies, gourds, tubes, boxes, and even the earth itself as resonators and sound boxes for amplifying a single string. Each of these monochords embodies a particular imaginary, an expression of the peoples and places and cultures that produced them, and the chimeracord is no exception. Although developed only recently—and quite literally millennia after many of its monochord cousins—the chimeracord reflects not only the histories of the metals in its body or the workshops in which it is crafted, but also the cultural context in which those metals and workshops are embedded. It emerges in dialogue with traditions of Western music and harmony that interweave with the histories of material extraction and capitalist production that accompany its genesis.

Within this tradition of Western culture and music, the monochord occupies an exaggerated position. As a foundational character in the origin story of Western thought, this instrument has acquired totemic significance, compounding and growing with every passing century. Nonetheless, as in every other culture, before it was a symbol, it was simply an instrument. In fact, according to the standard mythologies passed down in music history textbooks to this day, the history of the monochord in Western music can be traced back to a single, particular instrument crafted two and a half millennia ago, and just as in any other culture where monochords emerged, it reflected the particular materials, sounds, and stories that surrounded it. But in this case, its story accrued a different kind of interest over time, as the unassuming monochord purportedly crafted by Pythagoras in Samos evolved gradually into metonymy, becoming not only *the* monochord in Western imagination, but also the embodiment of an entire system of harmony and, indeed, even of philosophy. Before that, though, like any other instrument, this Pythagorean monochord was just an object with its own unique story: a single string strung taught across a box—a commingling of catgut and wood—whose physical resonance burst and decayed in real time and space before being swallowed up by its unique history and interpretation.

This monochord occupies a special place in the mythology of Pythagoras, emerging as a kind of material muse, both loud enough to grab Pythagoras's attention but also somehow voiceless—more a tool of scientific measurement than a musical instrument. With the benefit of this hindsight, it is perhaps unsurprising that this monochord's story begins from Pythagoras's dissatisfaction—one might even say contempt—for the materials used to build musical instruments in his day. As we are told in numerous accounts, Pythagoras had exhaustively examined materials like gutstrings and wood, ultimately deeming them too erratic to rely on in his search for the immutable laws of harmony. With strings, for example, Pythagoras had found that "more humid air may deaden the pulsation, or drier air may excite it, or the thickness of a string may render a sound lower, or thinness may make it higher, or, by some other means, [alter] a state of previous stability" (Boethius 1989: 18). And he had encountered this problem not only with strings, but with other instrumental consorts as well, "[a]ssessing all these instruments as unreliable and granting them a minimum of trust" (Boethius 1989: 18). But the story continues, for, having seemingly exhausted these resources and therefore abandoning any hope of progress, Pythagoras then stumbled upon a breakthrough far removed from the spaces of musical performance or philosophical speculation. As the legend goes, when walking by a forge where a number of smiths were at work, Pythagoras was struck by the remarkable consonance sounded by the clamor of their hammer blows. With his curiosity sufficiently piqued, he rushed inside to discover the source of this remarkable concord. He first considered the materials being hammered, but they turned out not to be relevant. He then considered the muscles of the men doing the hammering, but again, these variations proved to be a dead end. Eventually, he turned to the hammers themselves, whereupon he discovered that each of the four hammers he examined produced a different tone as they were used, and that, moreover, their different masses mapped a series of proportions whose ratios would famously spark Pythagoras's incalculably influential investigations into harmony, rationality, and purity.

There are a number of notable details about this story—not least among them an illusory additional hammer, immortalized with the single phrase: "The fifth hammer, which was discordant with all, was discarded" (Boethius 1989: 18). We might ask ourselves, what else has been discarded along the way? As this monochord slowly transcended the physical boundaries of its single string's finite resonance, breaching the realms of philosophical speculation, which strands of materiality, culture, and history were uprooted? As the actual sounds and music that Pythagoras heard have receded, how has this story been reshaped and repurposed? Because Pythagoras was, by all accounts, an avid listener. Indeed, as the histories we have inherited acknowledge, he had already inquired exhaustively of other instruments before the hammers and the forge triggered his experiments with the monochord. This is, after all, the same Pythagoras who, according to legend, mollified a belligerent drunk by instructing the nearby aulete to change his harmonic mode, demonstrating his intimate fluency with musical harmony, instruments, and their affective capacities:

> Who does not know that Pythagoras, by performing a spondee, restored a drunk adolescent of Taormina incited by the sound of the Phrygian mode to a calmer and more composed state? One night, when a whore was closeted in the house of a rival, this frenzied youth wanted to set fire to the house. Pythagoras, being a night owl, was contemplating the courses of the heavens (as was his custom) when he learned that this youth, incited by the sound of the Phrygian mode, would not desist from his action in response to the many warnings of his friends; he ordered that the mode be changed, thereby tempering the disposition of the frenzied youth to a state of absolute calm. (Boethius 1989: 5)

While posterity has not recorded more of this encounter, it was an oft-cited proof of music's intimate connection to the soul and, indeed, even to the more fundamental composition of the human body and its humours (cf. Quintilian *Institutio oratoria* 1.10.32, Sextus Empiricus

Adversus musicos 6.8, Elias, *Prolegomena philosophiae* 2, Ammonius *In Porphyrii isagogen sive v voces*, Augustine Contra *Julianum* 5.5.23). This singular soothing intervention managed to provide the anecdotal basis for generations of philosophical speculation about how "the whole structure of our soul and body has been joined by means of musical coalescence" (Boethius 1989: 7). But it also indicates Pythagoras had far more than a passing acquaintanceship with the musical modes and practices of his day, which in turn casts doubt on his supposed dissatisfaction with the strings of the *kithara* and the reeds of the *aulos* before his fortuitous encounter with the forge.

Was Pythagoras truly so exasperated by the fickleness of these instruments? While it is surely true that the response and intonation of strings would vary with fluctuations in humidity, temperature, or tension (as his experiments with the monochord would later confirm), these issues are really only problematic when making comparisons over longer durations or with more dissimilar instruments. The strings available to Pythagoras would certainly have provided enough stability for a comparison between pitches within controlled conditions (as, once again, his own experiments with the monochord would later demonstrate). And as for the reeds and tubes of the *aulos*, how are we to reconcile the conflicting propositions that they were an untrustworthy basis for investigating the mathematical rules of harmony while simultaneously a stable base to understanding the harmonic foundation beneath complex human emotions and dispositions? The *aulos* is, of course, an instrument uniquely capable of foregrounding harmonic relationships; it was precisely this compelling interplay between melodic and drone pipes that allowed Pythagoras to exploit the affective power of musical modes to calm the storms of drunken rage.

It is quite unlikely that the strings, reeds, and pipes of his day were indeed completely unsuitable to the needs of his scientific inquiry—especially considering that it was those same catgut strings that were later stretched across his famous monochord. Despite what were certainly appreciable fluctuations with humidity or construction, it is unreasonable to entertain the idea that the same *kitharas* and *auloi* whose modal legibility could excite and soothe human temperament were incapable of rendering the relationships of harmonic proportion equally legible. On the contrary, it is perhaps safe to suggest that rather than turning to the serendipitous intervention of the forge after exhausting the limits of the musical instruments around him, Pythagoras had in fact *not* been on the search for the truth of harmonic consonance *until* that moment when it was literally hammered into his skull by the smiths he was lucky enough to overhear. It was the materials themselves—and their utility—that impelled this act of discovery. The hammers voiced their consonance, revealing a tactile foundation beneath the harmonic series and its cascade of rational overtones. They generated both the means and the medium for this initial breakthrough, for as Pythagoras asked the smiths to attempt different configurations of hammers, hands, anvils, and other tools, he came to realize that the harmonic phenomena that had drawn him in derived not from the strength or speed of the strike, or from the hands that bore them, but from the very masses of the materials and their proportion to one another. The four hammers were not only different sizes, but their masses were directly proportional to one another, providing Pythagoras a key to unlocking a fundamental relationship between harmony and proportion. These ratios would construct the scaffolding that supported an entire philosophy of universal harmonic laws: Pythagoreanism.

But just as this lucky discovery lay rooted in Pythagoras's purportedly contemptuous disregard of the instrumental materials already available to him, so did these first steps towards his comprehensive elucidation of harmonic ratios also bear a subtle, disdainful betrayal of their debt to the hammers' material stimulus. This tension between the materiality of the forge and its immaterial, philosophical legacy is only one of many tensions dispersed beneath the surface of Pythagoreanism. Pythagoras's story includes an unrecorded but influential adjustment, a minor restructuring of material reality that allowed Pythagoreanism to leverage the resonance of the hammers into an intelligible, reproducible epistemological paradigm, thereby establishing a foundation for its vaunted philosophical vision of the world as an elegant, harmonic symphony. The monochord—in both its material and speculative forms—helps reveal this dissonance between Pythagorean idealism and the material reality that belies it.

By examining the hammers, Pythagoras was able to ascertain a link between their consonances and their materiality. He could move beyond simply identifying harmonic relationships—which had been known and cataloged well before—to ascertaining the underlying physical characteristics that engendered them. What the brute mass of the hammers showed Pythagoras was the "ratio [by which the] concord of sounds was joined together" (Boethius 1989: 18). Pythagoras had found that

> those which sounded together the consonance of the diapason were found to be double in weight. Pythagoras determined further that the same one, the one that was the double of the second, was the sesquitertian of another, with which it sounded a diatessaron. Then he found that this same one, the duple of the above pair, formed the sesquialter ratio of still another, and that it joined with it in the consonance of the diapente. These two, to which the first double proved to be sesquitertian and sesquialter, were discovered in turn to hold the sesquioctave ratio between themselves. (Boethius 1989: 18)

This complex set of four-way relationships could be simplified, though, allowing the relative simplicity of their whole number ratios to become more evident.

> So that what has been said might be clearer, for sake of illustration, let the weights of the four hammers be contained in the numbers written below.
>
> 12: 9: 8: 6.
>
> Thus the hammers which bring together 12 with 6 pounds sounded the consonance of the diapason in duple ratio. The hammer of 12 pounds with that of 9 (and the hammer of 8 with that of 6) joined in the consonance of the diatessaron according to the epitrita ratio. The one of 9 pounds with that of 6 (as well as those of 12 and 8) commingled the consonance of the diapente. The one of 9 with that of 8 sounded the tone according to the sesquioctave ratio. (Boethius 1989: 19)

At this point, deigning to sully his hands with the inconstant and unreliable resources of musical instruments, Pythagoras set out to mirror the ratios of the hammers in other media. The specific ratios that he derived from the hammers—and which he apparently translated successfully to strings, percussion, and reed consorts—became famous in their own right. These four numbers garnered a unique valence, representing not only Pythagoras's initial burst of genius, but also its extrapolation to other applications, as shown in this famous illustration of his varied experiments in Franchinus Gaffurius's *Theorica musicae* from 1492:

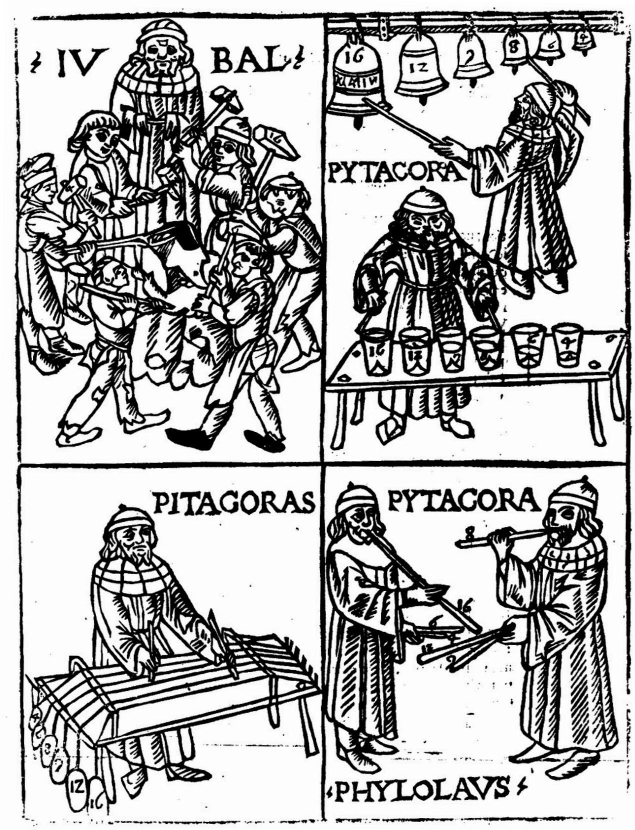

Fig. 8 Illustration of Pythagoras's experiments in Gaffurius's *Theorica musicae* (1492). Wikimedia Commons, public domain, https://commons.wikimedia.org/wiki/File:Gaffurio_Pythagoras.png#/media/File:Gaffurio_Pythagoras.png

Pythagoras's initial attempts to translate the hammers' proportional consonances into other media maintained a fairly analog correspondence. Mimicking the four hammers with masses of 12, 9, 8, and 6, he experimented by testing each of these proportional units in collections of similar objects: a bell, a glass partially filled with liquid, a tube, or a string with a weight attached to one end (to apply proportionally variable tension):

> Upon returning home, Pythagoras weighed carefully by means of different observations whether the complete theory of consonances might consist of these ratios. First, he attached corresponding weights to strings and discerned by ear their consonances; then, he applied the

> double and mean and fitted other ratios to lengths of pipes. He came to enjoy a most complete assurance through the various experiments. By way of measurement, he poured ladles of corresponding weights into glasses, and he struck these glasses—set in order according to various weights—with a rod of copper or iron, and he was glad to have found nothing at variance. (Boethius 1989: 19)

However, at some point he realized that these ratios and their harmonic ratios could be more elegantly demonstrated by a monochord. Consisting of a single catgut string stretched across a sounding board, one could divide that string with a finger (or centuries later, a moveable bridge) in order to generate the ratios previously expressed by these other experimental or musical apparatuses. By using a single string to compare different harmonic proportions, Pythagoras could demonstrate not only simple consonances, as with the hammers, but far higher orders of proportional harmonic phenomena, as well. And because these ratios could be quickly generated and compared on the same string, they were less subject to any vagaries of imprecision introduced by multiple strings, instruments, or other instrumental technologies. Fittingly, as the apotheotic tool for demonstrating these ratios, the monochord would come to be known as the *regula* or *canon*.

Although, as previously noted, monochord instruments are well-known and well-loved melodic instruments in many cultures, it never became a popular instrument in Pythagoras's time, nor in the ensuing centuries of Western fixation with Pythagoreanism. It was primarily seen as a tool, as an authoritative reference rather than as an expressive medium in itself. Only many centuries later did this gradually change, when Guido of Arezzo's introduction of the moveable bridge breathed new momentum into its evolution. "Shortly after the year 1000 A.D., [clavis (keys)] were applied to the monochord, which then was built with more than one string [...] As soon as the clavis was pressed down, [its] tangent would prick the string on the proper division of the scale and thus assure the sounding of the correct tone required for the guidance of the singers. The use of the clavis soon led to an increase in the number of strings [...] These experiments led finally to the invention of the 'clavicytherium'" (Dolge 1911: 28-29), which was, in turn, a forerunner of the clavichord, the harpsichord, and eventually the modern piano. It is curious to compare this history with instruments such as the *đàn bầu* (a single string zither that utilizes natural harmonics and a flexible rod to modulate string tension) or the *berimbau* (a musical bow with a resonator that can be manipulated and struck to produce overlapping layers of tones and rhythms), which are characterized by an array of inventive playing techniques that plumb their single string for hugely varied modes of melodic, harmonic, and expressive potential. In contrast, the evolution of the monochord followed a different path, essentially accumulating banks of strings each tasked with their own fundamental pitch. Rather than plumbing the depths of each string for its harmonic or expressive potential, these new instruments housed dozens of monochords in soundboxes that insulated them from contact, limiting their potential to the single plectra or hammers that would elicit each string's one, predetermined tone. Though these organological evolutions unfolded over centuries, and far removed from Pythagoras's Samos, it is difficult not to trace the threads that connect these developments back to the philosophical principles of Pythagoreanism. Through its adherence to principles of harmony and, by extension, purity, Pythagoreanism became equally inextricably linked to justifications for limitation and control, influencing not only localized, quotidian musical practices but also broader social and cultural evolutions.

At the heart of Pythagoreanism is an idealistic universality: an appeal for a rational, cosmic truth stitched through the heart of matter, from our quotidian world up to and through the celestial bodies themselves. One of the most alluring components of Pythagoras's initial discovery was the simplicity of the ratios that seemed to govern harmonic consonance. The original sets of proportions that the hammers represented generated whole number ratios, such as 2:1 for the octave, 3:2 for the fifth, and 4:3 for the fourth. The difference between the fifth and the fourth—what would come to be known as a single tone—could be demonstrated by a similar ratio further in this series, 9:8. These ratios are all similar in that they are formed by two successive whole numbers in relation to one another, which the Greeks called "superparticular," possessing "the mathematical shape of $n+1:n$. Each of the three intervals that Pythagoras identified in the mythic forge shares this arithmetical nature" (Heller-Roazen 2005: 34) That is to say, this arithmetic rule can define and generate each of the musical elements originally voiced by the hammers: the octave, the fifth, the fourth, and the single tone between the latter two.

But despite their compelling arithmetical elegance, these ratios didn't account for all of the musical intervals that characterized the musical modes of the day—those same musical modes that Pythagoras knew so intimately. In fact, even the most basic consonances produce strange misalignments when these simple ratios are rigorously applied. One of the most well-known is the progression of fifths. If one tunes a fifth in perfect harmony on the monochord, at the ratio of 3:2, and then proceeds to tune the next fifth at 3:2 of the former, after twelve iterations of this tuning exercise, the original fundamental pitch is once more generated. The only problem is that, if one actually does this, the fundamental that is reached by this cycle of fifths is not, in fact, identical to the original fundamental, but is instead a notably higher pitch—a pitch notably discordant with its original counterpart. How could it be that these immutable consonances could result in such literal discord? And there were further problems, as well, some even more troubling for musicians of Pythagoras's day. Despite their pride of place as the most pure consonances, music did not consist of only fourths and fifths, and the definition of smaller intervals triggered heated debates lasting generations. "According to Aristoxenus, the fourth-century thinker whose *Elements of Harmony* contains the most detailed surviving account of the subject, the music of the ancient Greeks was conceived in an intervallic expanse of two octaves. Each octave was composed of two fourths, or tetrachords, joined by the one tone. Within the fourth, two outer positions were fixed, while two inner ones varied" (Heller-Roazen 2005: 31). This tetrachord was clearly too large to contain two single tones, and yet far too small to contain three.

Aristoxenus himself proposed that this intervening harmonic interval could be construed as half a step, meaning that the tetrachord would comprise two whole tones and one half tone.

"Aristoxenus's argument about the fourth implied one major proposition that, to the ancients, was anything but self-evident. His claim clearly suggested that to define the extension proper to the fourth, one must imagine parts of the single tone, admitting, simply, that this basic interval may be halved" (Heller-Roazen 2005: 32). Halving the tone in this manner, though, was a mathematical operation totally incompatible with the Pythagorean logic of ratios and proportion. For the ancient Greeks, there were two, fundamentally discrete modes of mathematical operation: arithmetical operation, such as ratios, in which new terms are generated by multiplication of whole numbers (with, as in the case of ratios, the reduction to simpler whole number terms when possible, such as representing the ratio 8:4 as 2:1); and geometrical operation, such as the mathematics of the circle, in which continual subdivisions of the whole could be represented by precise divisions. For the Pythagoreans, then, having established harmonic consonance as a phenomenon of arithmetic ratios, the geometrical halving of the single tone was a distinctly irrational procedure. Halving a tone implied applying a geometrical operation to an arithmetical ratio—an irresolvable insolubility. "The Pythagoreans pronounced that solution untrue, as well as mathematically incoherent. Yet they thereby obligated themselves to find another answer to offer in its place." (Heller-Roazen 2005: 35). On its surface, this was not the most difficult task, for surely there would be some ratio that could generate this interval. After all, the succession of superparticular ratios that defined the octave, the fifth, and the fourth produced ever-diminishing intervals as the series progressed, such as the single tone itself. But the rational identity of the mysterious musical interval left over by the two whole tones in the tetrachord proved distinctly elusive.

> To find the exact quantities of tones that compose the fourth, it sufficed for them to "withdraw" from the fourth two tones. Originally, that operation may have been difficult to perform, but by the fifth century, if not sooner, it had been done. Then, it could be shown that, after the "subtraction" of two tones from the tetrachord, an interval remained that was less than half a tone. This was an inequality that could be defined by a complex arithmetical ratio: two hundred and fifty-six with respect to two hundred and forty-three (256:243). That seemingly arcane relation was to be found not only in the works on harmonics. Plato's famous investigation into cosmology, the *Timaeus*, contained it too. Explaining the secrets of the world soul, Timaeus recounts that in his act of making, the demiurge chose to "fill up" the interval of the fourth (4:3) with the intervals of the tone (9:8). An "interval," he explains, then "remained," and it was equal to two hundred and fifty-six to two hundred and forty-three (256:243). In deference to that passage, thinkers after Plato called this subtle ratio *leimma*, or "remainder." (Heller-Roazen 2005: 35-36)

Although not superparticular and well beyond the capacity of normal human beings to conceive of on the soundboard of a traditional monochord, this ratio at least provided some rational foundation to the claim that there could be no such thing as half of a single tone. It allowed Pythagoreans to persist in asserting that, by the rational extension of the series of harmonic proportions, the mysteries within the melodic tetrachord could be explained by the arithmetic (not geometric!) laws of the universe. Unfortunately, though, just as with the imperfections generated by the cycle of fifths, this explanation only led to further conundrums. Because of their superparticular construction, according to the rules of arithmetic, "neither one mean number nor several mean numbers will fit in proportionally" (Boethius 1989: 118). In simpler terms, this means that by finding the ratio to explain the "remainder," the interval of 256:243 effectively divided the single tone slightly lopsidedly, just as it had with the tetrachord: this alternative to the half tone was slightly larger than half of a whole tone, raising the question of how to define that altogether new leftover interval. And so, once again, the discrepancy between this new interval and the rational proportion that it related to had to be explained, leading to ever more extravagant ratios.

> The discrete quantity of the *leimma* could be compared with that of the tone; the difference between the two could consequently be measured in a ratio. They called this inequality the *apotomē*, literally, "what is cut off." At the limits of imaginable relations, this interval could be expressed by the ratio of exactly two hundred and seventy three and three eighths to two hundred and fifty-six ($273^{3/8}$:256, or 2187:2048). Venturing still further into the subtleties of logistics, the Pythagoreans also envisaged the difference between the *leimma* and the *apotomē*. They called this last remainder "the comma" [...], "what is struck out," defining its ratio as 531,441:524,288. (Heller-Roazen 2005: 36)

These irreducible remainders gnawed away at the heart of Pythagoreanism, a nagging irrationality in their arithmetical certainty. Maintaining the rational edifice of harmonic order demanded that these subtle incommensurabilities be erased, and yet as their arithmetical calculations to resolve these remainders grew ever more complex and arcane, the remainders themselves not only persisted but were themselves amplified by these operations. And yet rather than placing these mathematical conundrums in dialogue with the acoustic resonances that they sought to describe, Pythagoreans turned away from the sound of harmony altogether. When faced with practical questions about harmonic intervals and the inconceivably complex ratios that defined them, they abandoned the acoustic reality of strings, bells, and hammers, and dove headlong into theoretical abstraction. "Once his disciples committed themselves to the mathematical study of nature [...] they found that, at a certain point, the ways of conscious perception and arithmetical consideration must part. Then, to the perplexity of their contemporaries and later commentators, the disciples of Pythagoras resolved to follow an unexpected path: they renounced the evidence of their senses for the certainty of their arithmetic" (Heller-Roazen 2005: 37).

This resulted in a strange entrenchment, devoted simultaneously to two conflicting endeavors. On the one hand, Pythagoreanism reinforced the bulwarks against irrationality with continually evolving arithmetical proofs, seeking to establish beyond any shadow of a doubt the harmonic laws stitched into the cosmos at every level. On the other, they developed a conspiratorial intensity, insistent that these mathematical laws be shared only with the initiated and limiting awareness of these irreducible irrational remainders to the true believers of their mathematical truth.

> [N]umerous records [...] indicate that the Pythagoreans never intended to divulge their knowledge of such matters to those uninitiated into their teachings. It is said that a Pythagorean revealed to the ancient world the existence of mathematical "irrationalities," but it is also said that he was punished as a result [...] Iamblichus recounts that [...] "[n]ot only did they banish him from their community of study and their way of life. In addition, they built for him a tomb, as if the one who had once been their companion had truly departed from the life of men." Other reports suggest that as a consequence of his impious deeds, the Pythagorean suffered a far more violent fate: the gods drowned him at sea. (Heller-Roazen 2005: 41)

This story served primarily as a caution against the consequences of sharing such potent knowledge with the proverbial masses. Contemporary commentators considered it a "parable [about] the soul which by error or heedlessness discovers or reveals anything of this nature [who then] wanders thereafter hither and thither on the sea of non-identity [...] where there is no standard of measurement" (Pappus, trans. Thomson 1939: 164). As this mindset solidified, Pythagoreans "resolved not to name that immeasurable reality[, ...] develop[ing] means to moderate it as best they could, reducing asymmetries to the ordered inequalities of measured multitudes" (Heller-Roazen 2005:

29). Their commitment was an existential admission: the threat these remainders posed was not to something as simple as a mere mathematical tool for calculating consonance and harmony, but was rather a threat to the foundations of their entire metaphysical paradigm. Pythagoras had extrapolated from the rules of harmony in the hammers a complete system or order that stretched even into the celestial realm, declaring "a doctrine of the intelligibility of the natural world" (Heller-Roazen 2005: 9). His successors were therefore committed to obscuring any small discrepancies in this system that might suggest, however minutely, that there was some limit to its correspondence with reality.

In his far-reaching monograph on Pythagoreanism, linguist and critic Daniel Heller-Roazen identifies this lurking irreducible remainder with the character of the discarded fifth hammer, that long-forgotten character in the Pythagorean origin myth. In identifying this irresolvable incommensurability as a form of corrosion within the millennia-spanning Pythagorean project, he points out that by erasing the fifth hammer—"which was discordant with all" (Boethius 1989: 18)—from history, they revealed a much more subtle but damning limitation to the Pythagorean ideal: "What is this 'all,' if something—if even only one thing—sounds in utter dissonance with it?" (Heller-Roazen 2005: 16). In Heller-Roazen's astute examination of the Western world's long and intimate relationship to Pythagorean harmony and philosophy, this question continues to gnaw away in the background. Because no matter how florid or arcane their formulations, so long as they failed to resolve that irreducible remainder revealing Pythagoreanism's ultimate non-correspondence with the natural world, the universality they claimed to represent was held together by censorship rather than truth. They could only define the natural laws of the universe by carefully curating what counted as part of that universe to begin with.

Throughout the institutional progression of Western harmony, musical theorists devoted text after text to mathematical proofs defining the Pythagorean authenticity of the musical advances they gradually sanctioned. Propelled by a constant friction between practical innovation and the conservative idealism of Pythagoreanism, the harmonic and rhythmic palette of Western music grew increasingly more refined and complex. But even as this seemingly inevitable process ground slowly forward, Pythagoreanism persisted as a metric by which to judge or justify these innovations. Following Boethius's influential *De institutione musica* from the sixth century (largely just an extension of classical texts), centuries of Western music theory was framed by Pythagorean discourse and the language of ratios. Even though the practical application of thirds, sixths, and passing tones often preceded their theoretical explanation—just as the tetrachords and half tones of Aristoxenus reflected practical usage exceeding the Pythagorean imagination—these expansions of the melodic and harmonic palette were all eventually married to a Pythagorean rationalization (Burkholder, Grout, and Palisca 2014: 157). These evolving understandings of harmony were often linked to the similarly evolving discourse of tuning and temperament, which also often justified their specific intonational decisions in the language of Pythagorean ratios. And just as with the Pythagoreans before them, their appeal to the language of ratios proved equally exclusionary as inclusionary, as with the influential theorist Gioseffo Zarlino, whose elegant Pythagorean rationalization of thirds and sixths helped retrench the discordant designations of sevenths, elevenths, and other higher order whole number ratios (Partch 1949/1974: 378).

This appeal to mathematical purity was not limited to harmony, though, and as the rhythmic complexity of Western notation evolved, it fell into this same orbit, sucked in by the gravity of Pythagorean idealism. "Just as Boethius defined five types of ratio corresponding to five kinds of related multitudes, so in the fifteenth century Guilelmus Monachus, Gaffurius, and Johannes Tinctoris would admit in their doctrine five rhythmic 'proportions.' And just as, for the ancient thinker, multitudes were collections of ones, so for the medieval composers, such ratios of rhythm would be commensurable by nature" (Heller-Roazen 2005: 48). With their theoretical imaginations of not just harmony but also temperament, rhythm, notation, and other musical elements rooted firmly in Pythagorean arithmetical language, these Western appropriators of Pythagoreanism displayed the same preoccupations that the ancient Greek adherents had before them. Categorization was paramount: defining the limits of consonance mattered far more than exploring how or why other sounds might also be expressive or pleasing. These foundational and influential theoretical texts continued to value the circumscription of reality by ideal rationalization over the perception of their senses and the gradual but inexorable development of Western harmony. These attitudes can perhaps be summarized most pointedly by Boethius, a man more mathematician than musician, whose work's influence derived less from "what is written in it [than] by whom it is written, when it was written, and for how long its words were read by musicians" (Williams and Balensuela 2008: 24). Boethius was the primary intellectual link between Pythagoras's monochord and its later Western outgrowth, and he made clear that this instrument was more metrical than musical. In a play on words between the double meanings of the Latin word *regula* as both a metrical stick and a system of judgment, Boethius makes clear that, although he refers to the carefully demarcated sounding board of the monochord as a *regula*, the term derives not from its similarity to a ruler, but from its unique role as a vessel of the "rule" passed down from Pythagoras (Boethius 1989: 19). But rules only exist when there are elements that persist outside the boundaries they demarcate. In its stubborn drive to regulate both the awareness and the interpretation of the real-world remainders that bled at the edges of the monochord's rule, Pythagoreanism sought to define an idealized description of the universe that had, in fact, been flawed from the moment Pythagoras first examined the hammers.

While Heller-Roazen astutely asserts that the discarded fifth hammer helps symbolize a Pythagorean predilection for control, the decisive turning point in this choice between regulation and accommodation actually lies back in the story of the other four hammers. The myth surrounding Pythagoras was firmly rooted in his Promethean journey into the forge, where he wrested the laws of harmony directly from these four physical hammers before transcribing their ratios and revealing the immutable universal *regula*. Despite Pythagoreanism's glorification of reason over sensation, its claim to authenticity had always been reliant on an appeal to the material authenticity of Pythagoras's discovery. But that material foundation was flawed from the beginning, for even that initial set of simple ratios—the immortalized '12: 9: 8: 6' that triggered the ensuing tangle of remainders, apotomēs, and commas—were already based on an unrecorded discrepancy. As composer, theorist, and lutenist Vincenzo Galilei noted in 1589 (after approximately two millennia of Pythagorean influence on philosophy, culture, and music), the initial ratios that Pythagoras recorded were inaccurate or, one might even say, dishonest. Whereas Pythagoras claims that the simple ratios such as 2:1, 3:2, and 4:3 translated into consonances in each of the variety of masses, strings, weights, and tubes that he tested (as shown, for example, in Gaffurius's illustration), these different media do not in fact produce these identical harmonic relationships at corresponding proportional relationships.

By reconstructing these experiments, Galilei discovered that the ratios were in fact more varied, and that, for example, in masses such as the original hammers, the ratio required to produce a fifth was not 3:2, but 9:4, and that this adjustment carried over into all of the other consonances, as well. In short, unlike the simple multiplicative proportions that applied to string length, the proportions describing the consonances in mass—which, Galilei found, also applied to tension (such as the experiments with weights on strings)—must be squared rather than simply multiplied. Moreover, when calculating the same consonances with volume (such as in a tube), these proportions must be cubed! Put simply, the historically received record of Pythagoras's initial experiments was a flagrant misrepresentation of material reality. Rather than revealing a simple analog correspondence between these different media, his experiments would have shown a much greater divergence of proportional relationships. What is most striking about this lacuna in Pythagorean lore is that, despite these complexities, each of these proportional relationships are still so clearly related to one another (by square, by cube, etc.), and that when placed alongside each other, they describe a straightforwardly scalar spectrum of proportional harmonic rules; it would not have been difficult, one thinks, to present these exponential divergences as even stronger proof that the foundational ratios of this spectrum described a powerfully intrinsic relationship between proportion and harmony. But even at this very first hurdle, when translating the proportions of the hammers into strings and tubes and other media, Pythagoras and Pythagoreans preferred to obscure divergence and complexity behind a thin facade of elegant simplicity. It was as though the rule was more important than the physical resonances it described, and ultimately the hammers had to be "discarded in order to save the model (tonality) from its materiality (sound)" (Dyson 2014: 21).

Once Galilei had shown that the most basic tenet of Pythagoreanism—that is, that "[w]hatever the work, whatever the instrument, whatever its matter, certain arithmetical regularities were bound by nature to produce certain consonances" (Heller-Roazen 2005: 65)—was based on unstable, shifting ground, other recreations of Pythagoras's physical experiments were also found to generate as much doubt as explanation. In his own reconstruction of the monochord and Pythagoras's experiments, the seventeenth-century polymath Marin Mersenne found further elisions. Mersenne, who was inspired by Galilei's work and maintained regular correspondence with his son, Galileo Galilei (who had assisted his father's acoustic experiments), "discovered the overtone series [and] observed that these produced the 'major' chord but that the series did not stop there, and [...] [s]eeing the series go beyond the 'major' triad, he proposed the inclusion of [seven] as an integral musical resource" (Partch 1949/1974: 382). Somewhat surprisingly, in the centuries since, the idea of Pythagorean intonation has come to be associated with precisely these extensions of the overtone series, far removed from the ascetic limitations of the hammers' initial four intervals. Despite their spurious Pythagorean attribution, these overtone-derived harmonies are largely antithetical to ancient Pythagorean ideals; whereas they derive from a sensorially tactile immersion in sympathetic resonance, the early Pythagoreans valued the arithmetical simplicity of the smaller ratios early in the overtone series and held little real interest for their practical acoustic qualities. But this gradual shift in interpreting the relationship between Pythagoreanism and extended proportional calculations was indicative of a broader trend. In fact, over time, much of the terminology associated with Pythagorean harmony underwent a strange inversion: "We are now confronted with [a] complete change in terminology, from ancient to modern: the Harmonical Proportion is now the overtone series (Mersenne); the Arithmetical Proportion is now a limited 'minor' tonality (Zarlino); Aristoxenean approximations are now any of various temperaments [...], and Pythagoreanism is now more often one of the 'cycles of perfect fifths'" (Partch 1949/1974: 382).

As strange as these inversions may sound when viewed in hindsight, they may also be traced back to that fundamental paradigm of Pythagorean thought: that the rule transcends the resonance, and that the discourse surrounding harmony was more valuable than the sensorial experience of those harmonies. Just as they discarded the hammers from the forge, they ignored the monochord's *regula* just as soon as it actually began to sound. The monochord became an instrument, to be sure, but not an audible, musical one; rather, it became a metonymy, an instrumental assertion of a philosophical law. It was not valued for its musical utility but for its embodiment of an entirely immaterial rational idealism whose true cultural influence lay far outside the concert hall. As Heller-Roazen notes, Pythagoreanism's defining characteristic was this drive to contain all irreducible exceptions at the liminal outskirts of the rule, rendering them unpronounceable. Scholar of cinema and technocultural studies Frances Dyson builds on Heller-Roazen's observations in her own extensive reckoning with the legacy of Pythagoras and his monochord, *The Tone of Our Times*. She notes that this Pythagorean compulsion to silence or obscure its most fundamental irrationalities triggered "a logical glitch at the very beginnings of Western thought" (Dyson 2014: 4), allowing certain paradoxes to not only survive but thrive. As Pythagorean harmony subsumed these glitches and remainders into a comprehensive cosmology, this capacity for paradox seeped into every pillar of society, "enabl[ing] the progression through the centuries of something like a metaphysical wormhole into which the materiality of power, the force of legislation, the division of populations and their enslavement" disappeared (Dyson 2014: 4). Instead of resolving these remainders, Pythagoreanism simply banished them from view, insulating them from resolution in order to protect the fundamental tenets of their harmonic cosmology. This ultimately invested these glitches with a transformative capacity to absorb and neutralize the most irrational paradoxes, sowing a tolerance for imbalance and inequality directly into the fabric of Western thought and society. Dyson argues that this "accommodation of irrationality and incommensurability at the highest level of imagination (God, the infinite, cosmic time, and space) produces a form of 'cognitive dissonance[,' enabling] governance as an institution and governments in democratic nations to sustain massive contradictions without falling, like a house of cards" (Dyson 2014: 4).

Dyson posits the Pythagorean remainder as a seed of what would become a defining trait of Western thought, that the model could be more perfect—and therefore more true—than the world it represents. As a suspended state of the "unresolvable incommensurable," this remainder's erasure from Western cosmology embodied a rot at the core of the model—the secret "that the world can only be mathematical by plugging your ears" (Dyson 2014: 23). This wilful dismissal—rooted in an infatuation with the intellectual purity of the model at the expense of the world it sought to explain—allowed the simple harmonic rules derived from the monochord to undergird a massive intellectual evolution in Western culture:

> The cosmology that Pythagoras developed launched the monochord into the heavens, leading scholars to argue that the planets, given their geometrical rotations and relations, must, as moving magnitudes, also be sonorous since movement produces sound. For whom would they sound though? As the planets required an ear to hear them, a mind to perceive them, and a reason for their co-relation, they affirmed the existence of a divine being, an infinite universe. (Dyson 2014: 27)

Pythagoreanism blossomed from the strings of the monochord into a model of cosmological universalism, but "these neat correlations instituted one of the major flaws of unitary thinking: the impossibility of change" (Dyson 2014: 27), with the "necessary consequence" of also discarding "the excess baggage of social injustice, inequity, and the always questionable rationality of ethics, within what was supposed to be a perfectly harmonized cosmos" (Dyson 2014: 21). The Western world would resolve these problems in the same way that the Pythagoreans before them had dealt with the remainder, the apotomē, and the comma: by constructing a deliberate aporia at the heart of the system, neither resolving nor denying but merely preserving these incompatibilities in a state of eternal disregard.

Dyson's work shifts elegantly from register to register, revealing how the harmonic consonances endorsed by Pythagoreanism scale seamlessly upwards into the right to have a voice in society. She shows how the musical evolution of the monochord's tonal system morphs into the discursive control of contemporary capitalism, dictating what can and cannot be said, and in many ways even what can and cannot be thought. In sketching the trajectory of these transformations over the last two millennia, Dyson identifies the role of the church and the liturgy as an important fulcrum leveraging the philosophical scaffolding of Pythagorean harmony as a platform for the institutional exercise of discursive (and in many cases also material) power. Following Giorgio Agamben, she bases this analysis in the concept of acclamation, like the "amen," an "incantation [...] that is always in response to something said and always in agreement [...] a form of echo" (Dyson 2014: 36). But in the static harmonic perfection of a Pythagorean cosmos, this echo never dies; this acclamation is rooted not in the ebb and flow of quotidian life but in the eternal choir of celestial harmony, an "eternal repetition [that] confirms God but also obliterates the possibility for a silence that might make room for a different voice" (Voegelin 2019: 20). Dyson relates how this deployment of acclamation as a means to curate unitary discourse modulates over time from the church to the state and eventually to the more amorphous power of capital. But Dyson also notes that these operations replicate the stubborn Pythagorean compulsion to organize the world around an ideal model overlaid on the palimpsest of an effaced but persistent material reality. Even today, contemporary intellectuals appropriate "Pythagorean accounts of [...] social and cosmic harmony [to] adopt acoustic resonance as an analogy for the math neoliberalism and biopolitics use to create social inequalities" (James 2019: 22). And just as with the irreducible remainder lurking behind the mathematical logic of consonance, the discursive control that these regimes exert rely on a disavowal of material reality and the bodies and voices that compose it. "[U]niversal concepts and projections into the infinite seem to flow as if part of a logical formula. Yet the actual trajectory of this formula passes everywhere but through the physical reality [... T]hese are all strategies of dematerialization [...] of escape from the sweat of industry and animals" (Dyson 2014: 36).

With this in mind, Dyson sounds a call for resistance that she roots in corporeal potency. This "resistive echo-ing, or echopraxia" (Dyson 2014: 152) counters the ontological flattening of the eternal, ceaseless acclamation by asserting the agencies contained in the "the materiality of bodies—the sounds that they make, the atmosphere they breathe, the ground on which they walk, the space they occupy, and the interactions that occur between them" (Dyson 2014: 146). As she notes, the static continuity of this acclamation leaves no space for breath, eliminating the pause and silence of the "comma" (Dyson 2014: 23), and thereby eliminating any opportunity for meaningful response, misdirection, or dialogue. In opposition to the immaterial permanence of the acclamatory echo, she proposes a more worldly echo—rooted in the "eco" (Dyson 2014: 1-2, 17)—and formed from the rhythms of breath and voice within communal interaction. She proposes the concept of the "people's microphone," popularized by the Occupy Wall Street protests, as an example of how this echopraxia might emerge within the convergence of sounding bodies in social space:

> When related to the so-called Arab Spring, occupations in Spain, Syntagma Square in Greece, and riots in London that occurred in 2011, many commentators have noted the importance of corporeal occupation and a horizontal system of organization—such that there is no identifiable leader and everyone has a chance to speak. "The people's microphone" acts as a poignant enactment of these features: it enables multiple voices to be heard, its echoes incorporate its participants—indeed the participants are the echoes, materially and consensually—and it presupposes the occupation of a common space where the entirety of the sensible and sensory environment is shared. (Dyson 2014: 150)

For Dyson, the people's microphone is an "articulation" of the "physical act of occupying and reclaiming the common," imbuing corporeal rhythm to an "echoing [that] punctures, or inserts a comma, a pause, in the covering up of power" (Dyson 2014: 17). In her thoughtful and incisive reflections on "the political possibility of sound" (Voegelin 2019), philosopher and artist Salome Voegelin embraces Dyson's "echography of material practice[, which] does not produce a visible geography, an organization of the invisible on a map, but explores the unseen reverb of reflection where plural causes become visible and their consequences thinkable, and where other voices can make themselves heard rather than theorized" (Voegelin 2019: 21). Nevertheless, "while agreeing with the affirmative of her echo practice," Voegelin critiques its binary relationship to the power structures it resists, noting that "her resistive echo-ing implies a politics of the antis, the anti-stance of the 'people's microphone' and the centrifugality of its dissonance as a counter-politics remains trapped in the circularity of harmony and discord, violence and anti-violence, as the anti-nomic logic of power" (Voegelin 2019: 21). Voegelin suggests an echopraxia that is perhaps more alternative than resistive, imagining "a more agonistic and playful dispersion,"

> a sonic practice whose voice does not rise against harmonic tonality, the dominant self, but sounds itself, and whose clamour therefore, cannot be silenced in its opposition, but whose possibilities are inexhaustible: generative of an unfamiliar world that sounds actuality's hidden pluralities. (Voegelin 2019: 21)

Whereas Voegelin turns to the eco-corporeality of breath to articulate a less binary practice of resistive echoing, researcher and artist Annie Goh opens the concept up to a wider "echo-logical" perspective in which, as "material-semiotic actors, echoes are to be considered as neither purely acoustic, material and 'real' nor entirely symbolic, metaphorical and figurative[; ...] they are entangled in nature *and* culture as *natureculture*" (Goh 2019: 258). In attending to these material-semiotic valences, Goh situates echo alongside Donna Haraway's cyborg. Goh's echo expands on Haraway's influential figure, though, leveraging the porous boundaries between vibration and signification to embody a "*sounding* feminist figuration" (Goh 2019: 27). She probes the act of acoustic reflection that *produces* echo, problematizing concepts of originality and difference to help undermine a binary understanding of sound and its perception. Instead, she asks how we might embrace the speculative agency of echo, unlocking resonance as a form of "border thinking" (Anzaldua 1987) that unlocks the collective agency of human and more-than-human bodies that meet and merge in its diffractive mediation. In noting that "situatedness does not necessarily arise out of embodiedness" (Goh 2019: 141), Goh reaches beyond the envelope of a single sounding moment. Instead of regarding echo as a purely physical phenomenon, she proposes that echo can also "mediate between sound and the production of knowledges[, ...] a boundary figure, alerting us to the contingencies of subject-object relations and other pervasive dualisms" (Goh 2019: 27). In postulating an epistemological dimension, Goh's echoes reach towards the philosophical-political imaginaries of an 'elsewhere' and 'elsewhen' (Goh 2019: 276-277). Goh further invokes the mythological character of Echo to embody this disruptive, cyborgian intervention in sonic knowledge production; this Echo is not interested in "the 'truth' of the echo, but its truth-effects[, ...] less interested in what an echo *is* and more interested in what an echo *does*" (Goh 2019: 28). In this context, situatedness remains rooted in physical, haptic proximity, but also reaches out to suture disparate modalities of agency across time and space. Goh's Echo is not a tool for scientific positivism but a facilitator for collective imaginaries and world-building, a figure capable of "foreground[ing] human-nonhuman relationality in its multi-faceted richness" (Goh 2019: 276). Goh uses this conception of Echo to ground her theory of "sounding situated knowledges" (Goh

2019: 14), in which sound is more than just a physical phenomenon but also a powerful mediator of potential material and immaterial creativity. Sounding situated knowledges embrace Echo as an agent capable of supplanting the scientific positivity of a dying vibration into a form of "persistent questioning" (Goh 2019: 267) that binds the momentary transparency of sympathetic resonance to the multivalent "opacity" of our environment (Glissant in Goh 2019: 268).

With the assistance of Echo, Goh helps indicate how sounding situated knowledges carry the imprinted traces of the myriad agencies and spaces that converge in their coming-into-being, opening up Dyson's and Voegelin's resistive practices to additional, unexpected orientations towards plurality. Goh's Echo sounds a call for situated awareness that both affirms and extends the ecological embeddedness of Dyson's and Voegelin's political echopraxia, reminding us that resistance is an ongoing form of collective creativity that emerges from the human and more-than-human relationships that are cultivated over time and in space. Together, these three evocations of echo articulate a call to resist linear, teleological temporalities. They point us towards sound's powerful mediating potential, capable of calling our attention and orienting our imaginations, encouraging us to seek landscapes and communities that embody the responsivity that is Echo's indelible imprint. Positioned in opposition to the dematerialized essentialization of Pythagorean echoes (embodied in the ideological reverberation of the monochord), the shifting confluences of Dyson's, Voegelin's, and Goh's echoes celebrate our material entanglement in the world as opportunity for call-and-response, sounding out not-yet-imagined possibilities for collective human and more-than-human futures.

This more-than-human call-and-response disrupts the linear, hierarchical reductionism of Pythagorean space by scaling up its singular teleological gaze to a pluralistic multi-dimensional field of awareness. Echo's capacity to respond introduces a sonic contingency, an embedded awareness of the other as a physical interlocutor; rather than an abstract ethical consideration, the other within the echo demands an immersion in time and space in order to be heard, experienced, and engaged with. Echo-praxia confronts the ideological constraints of Pythagoreanism, reclaiming the commons—as Dyson suggests—and planting the seeds for alternative, multi-dimensional political imaginations—as Voegelin proposes. Goh's echo takes one further step, though, by attuning to echoes bridging more complex spatiotemporal and cultural divides. One encounters this echo in the spaces where she resides, in the edifices of ancient civilizations but also in the landscapes and environments that they found refuge in, inhabited, and became a part of. Again following Haraway, Goh proposes "[c]onceiving of echo as a companion species," enabling "us to purposefully blur the boundaries" and "foreground human-nonhuman relationality in its multi-faceted richness" (Goh 2019: 276). For Haraway, "'[c]ompanion species' thinking inquires into the projects that construct us as a species, philosophical or otherwise. 'Species' is about category work. The term is simultaneously about several strands of meaning—logical type, taxa characterized through evolutionary biology, and the relentless specificity of meanings" (Haraway and Gane 2006: 140). In appropriating the language of biological taxonomy, Haraway moves beyond a posthuman conception of the cyborg to explore similarly hybrid tendencies at larger scales, inviting a sweeping "interrogation of relationalities" (Haraway and Gane 2006: 140) across spectra of community, species, or even animacy.

In this guise as companion species, echoes pool in the collective awareness and agency of the bodies, buildings, and landscapes that imbue its diffractive call-and-response with murmuring vitality. Just as with the people's microphone that Dyson describes, this echo-praxia is not yet truly formed when sound radiates from a central source, but rather when that agency slowly distributes in a wider arena of actors and affordances. Goh's formulation of echo as companion species undermines Pythagoreanism on a far more fundamental level than the pluralistic reclaiming of the commons that Dyson describes. If an echo is simply reflecting and returning, defined by its relation to—or perception by—its acoustic source, then it simply delays and complicates that sound's eventual absorption into the linear course of history. By embracing material and more-than-human capacities in echo as companion species, Goh turns our attention to a much more complex interdependence, in which the situated sounding body is as much an echo chamber itself as it is a sounding source. In examining multiple genres of echo as modes of attentiveness and epistemology (see Chapter 6 for further discussion), Goh reveals the agencies latent in the land that echoes and in the bodies, materials, and accumulated stories that produce their own echoes therein.

From my own positionality as a performer, scholar, and luthier in Western traditions, I have sought to embrace these echo-praxias through engagement with materials, themselves. Mindful of Pythagoreanism's disregard for the physical resonance of hammers and strings, I propose here a response to Pythagoras that is articulated not by words but by physical (re)constructions, material interventions in the story of the monochord. Well before beginning this text, I turned my attention to the forge and the metals that are shaped there, embracing my expertise as a luthier and metalworker to revisit both the echoes of the workshop as well as the human and more-than-human bodies that produce them. The instruments that emerged from this endeavour, *chimeracords*, help turn our attention towards these material echoes and the agencies that pool in their acoustic activation. Through their collection, construction, performance, and reception, these chimeracords formulate questions about how collective human and material imaginaries might help generate forms of "resistive echoing" and thereby contribute to voicing the world's "inexhaustible [...] hidden pluralities." I envisioned a monochord free from the straitjacket of the *regula* and the *canon*, a monochord whose umbilical cord to the material phenomena that birthed it had not yet been severed. Rather than simply building an alternative monochord (there are plenty of such instruments that already exist), the chimeracord returned to the forge that Pythagoras stumbled upon, diffracting the sound of the hammer into alternative monochordal imaginations, thereby inviting material complicity into collective echo-praxias.

Fig. 9 Chimeracord in performance, bowing the string. Photo by Davids Danoss (2025).

Although the chimeracord has only a single string (like any proper monochord), that string passes across the entire body on one side, through the inside of the sound chamber, and then halfway back down the body. Through these three interlinked transversals, the unity of the "mono"-chord already starts to dissolve. As each of these three stretches of cord are played, they pull and stretch each other, their tensions intrinsically interlocked, perfectly mirroring each other's wavering vibrato, pitch, or timbre. Pulling or plucking any one leg of this string will also alter the others, enacting a sympathetic entanglement in which their harmonies and resonances merge, meld, and shimmer in tandem.

Monochords around the world utilize a huge variety of materials for their resonating chambers, from wooden boxes to gourds, from the human mouth to the earth itself. Because the chimeracord emerged as a response to the Pythagorean monochord—attempting to reimagine a relationship to the forge upstream from Pythagoras's mythical diversions—it has a sound chamber formed of metal that might have been found in that forge. In this case, it is brass that has been cast, drawn, tapered, and spun into a long chamber comprising two conical sections joined in the middle. This resonator creates several strange effects as its volume and distribution (long and thin rather than round or boxy) modulate the resonance and harmonic overtones of the vibrating string that stretches across and through it. However, this brass sound box also affords several other acoustic possibilities, and it is through this metallic resonating chamber that the chimeracord's hybridity is further refracted into a broader spectrum of organological superposition. This brass resonator invites a confluence of instrumental consorts, weaving together not only the string of the monochord but also the unique affordances of reed, percussion, and brass families, as well.

Fig. 10 Chimeracord in performance, bowing the bell. Photo by Davids Danoss (2025).

Like any soundbox, the chimeracord's resonator can be struck or scraped like a percussion instrument. From berimbaus to zithers, resonators have always afforded at least the capacity for percussive interpolations. But as the brass in the chimeracord resonator flares outwards at either end in its distinctive hourglass shape, it produces more varied and malleable acoustic vocabularies. Borrowing from the craft tradition of brass instruments like trumpets and horns, these brass flares are drawn and spun, stretched thin onto a steel mandrel, like a ball of dough kneaded into a thin sheet. But while a traditional brass bell would be reinforced around these sometimes paper-thin edges, the chimeracord's flares remain thin and fragile. In addition to the metallic frequencies of the soundbox's main body, these thin flares can be bowed or struck like a cymbal. These flares are much thinner than a traditional cymbal, though, voicing unique and highly reactive harmonic overtones and clusters when activated. Echoing then through the body of the resonator and back into the surrounding space, these flared apertures of the chimeracord's brass resonator produce unique and vibrant vocabularies that weave into the upper partials of the monochordal string resonance vibrating in the brass body.

The tubular construction of the resonator also opens up the possibility to be activated not only as a resonating chamber, but as a column of air, which in turn invites traditional wind instrumental practices—ranging from flute techniques to single or double reeds or even to lip buzzing, as with traditional brass instruments. The chimeracord has a small aperture at one end of the resonator that allows these different embouchures to activate its internal air column, projecting out the other end. This aperture can also be extended back up the instrument, effectively doubling the length of the activated column of air, thereby increasing the amplitude as well as lowering the frequency of the pitches it produces. These lower frequencies inhabit deep pitched registers that weave together with the low tones of the long monochord, while simultaneously the reeds and toneholes also access higher overtones and harmonic spectra within the resonating fabric of the composite instrument.

Given its inclination towards multiplicity and hybridity, the chimeracord has continued to grow and evolve beyond these basic sound-producing syntheses. Using repurposed steel string wire attached to the brass body and the monochord string, the chimeracord stretches outwards in space, building small networks of collective amplification and variation through a series of vibrating membranes mounted on smaller flared brass hourglasses. These additional resonators function as primitive analog amplifiers, absorbing and transmitting the sounds produced by the chimeracord, even as these additional cords, membranes, and flares introduce their own flickering variations of harmonic spectra and sympathetic frequencies to the composite voice of this ever-expanding instrumental collectivity.

As an experiment postulating how a monochord might develop if left to germinate in the forge rather than extracted and dissected in a Pythagorean laboratory, the chimeracord embodies a diffractive hybridity synthesizing discrete organological paradigms that congeal within the vibrating air column inside its strange brass body. It invites seemingly incompatible instrumental families into an entangled embrace, dissolving polyphony into a corporeal union—a chimerical fusion of reeds, strings, and metals. As they activate each other, vibrating in mutual tension and release, they declaim a provocatively polyvocal story of hybrid ontogenies and entangled collective futures.

Pythagoras's monochord epitomized a teleological mentality, its single string mirroring its single-minded purposefulness. It was first and foremost a tool and a metric, a means to measure the universe and tabulate its dimensions. And as attested to by the inaccurate or misattributed proportions in his early experiments, it was a masterpiece of preconception, an instrument designed to amplify its master's voice. Pythagoras's monochord was not an experimental device built to explore the harmonic phenomena of the world, but rather a valedictory monument, crafted to enshrine the foretold truth of a static, immutable law of consonance. Its single string, stretched taut across its wooden sound box, was never truly meant to sound, but to silence. It was not the opening of a mouth, but the foreclosure of a sentence already pronounced and complete.

The chimeracord attempts to articulate stories and histories that have been muffled by their absorption into the univocal acclamation of the monochord, to return to the constituent materials constrained and contained therein. These stories stretch into the soil beneath the forge itself, radiating out from the workshop into ecology and society alike. just as the gut strings and the wood that Pythagoras deployed, the materials in the hammers themselves were also extracted, refined, and repurposed. The metals from the forge have their own ontogenies, encompassing both the lands from which they were torn and the bodies that extracted them, arcing in long trajectories across space and time. Within the workshop, these metals still carry the accumulated scars of these journeys, and the metallic voices pealing under hammer blows in the forge are the ongoing echoes of those material memories.

In their material, and in the tools that work them, we are able to place an ear against the machinery by which ecology is subsumed into economy. As both raw materials of modern industrial production and cultural megaphones for creative expression, these pieces of brass help to problematize some of the ways in which "the connection between space, sense, and eco (meaning the management of a home and 'ecology') has been smothered under centuries of de-coupling, abstracting, separating what are essential relations between the extensiveness of space, the perceiving, understanding and experiencing of sense, the resonance of echo, and the flows, currents, and currencies of cents" (Dyson 2014: 1). Like Pythagoras's monochord, whose *regula* sucks the air out of its voice, deadening its corporeal vibration within a vacuum of philosophical idealism, this brass is beaten into predetermined forms and smothered in a blanket of enamel to ensure its sheen never dulls, an interchangeable mouthpiece voicing a cultural ideal in which plurality is silenced by "the absence of the environment in which echo can occur" (Dyson 2014: 151). But as they are nurtured into the evolving bodies of chimeracords, they are able to shed these forms of acclamation. In its place, these materials reach back through the violent echoes of their own extractive manufacture, recuperating what traces of their ecological ontogeny still persist as their organological hybridity helps give voice to the ores and flames, the chemicals and hammers, that are smelted together in the molecular lattice of their alloy.

In these new guises, they embrace an inquisitive pluralism, generating new forms of autopoietic material agency through the sounding materialism that reverberates within their chimeric brass bodies, spilling out into their environment as inquiry, as invention, and as invitation.