Introduction

At the start of the journey, **just intonation** can seem impenetrable. A 43 note-per-octave scale?[1] How could one hear and execute this?

Part of the impenetrability of just intonation (or JI) is that most of us must teach ourselves how to hear it, execute it, and make music with it. This has pros and cons— it makes the barrier to entry significantly higher because any curious person must spend a considerable amount of time drawing on different resources and figuring out the best method for hearing these ratios. But it has also led to a proliferation of different ways of engaging with just intonation, making it an increasingly rich corner of the musical world.

This book answers a question: how do musicians new to just intonation learn to hear it and apply it to their music? *Tuning the Ear* offers a series of progressive exercises alongside a systematic introduction of new ratios,

[1] À la American Composer, Theorist, and instrument builder Harry Partch's famous 43 tone gamut. Partch was a foundational just intonation thinker who outlined his ideas in his pivotal book *Genesis of a Music*.

beginning with the simplest JI concepts and advancing through more difficult ones through 7-limit just intonation. It applies these intervals to a range of contexts, explores their compositional applications, and engages with the acoustics and philosophy of just intonation along the way.

To begin— **why learn just intonation**?

There is an audible quality when we listen to a musician with mastery over the fundamentals of their music. A good sense of pulse, good feel, good ears for harmony and melody. I believe **tunefulness** is one of these fundamentals.

When you hear a sindhen (Javanese female singer) locked into a gamelan, or a dhrupad singer disappearing into the tanpura, or a violinist seamlessly navigating changing harmonies in a solo sonata, tunefulness is a fundamental aspect of the experience — both playing and listening. Tunefulness does not consist solely in striking a pitch at an exact cent value or frequency. It is a quality of sound: the sound of a performer's ears and pitch/timbral delivery in alignment. **Tunefulness is the sound of listening.** Just intonation is a powerful way to practice and explore this, but it is far from the only way.

Through the practice of just intonation, we learn how to access a new layer of the experience of sound: a richness of intervals, shadings, tonal interaction, timbre, and tunefulness that cannot help but color the way we approach other music. We also develop a new sensitivity to the production of sound and the way our environment interacts with it. The harmonic series and the ratios within it begin to reveal not only acoustic truths but philosophical ones: how diversity arises from unity, how fixed tones generate dynamic fields, how there is always another layer of experience. These insights align not only with a deeper musical understanding but with systems of thought across cultures that explore interdependence, emergence, and perception itself.

There is also reason to believe that the perceptual capacities we draw on in this practice are among the oldest things about us as a species. The neuroscientist and musicologist Gary Tomlinson has argued that long before music existed in any cultural sense, early hominin brains developed the capacity for neural oscillations to synchronize with external rhythmic stimuli— a process called **entrainment**[2]. This basic neural attunement to periodicity in the environment, which Tomlinson traces back millions of years, is the deep substrate out of which later capacities for coordinated rhythm, synchronized vocalization, and musical listening emerged. When we sit with a just interval and make micro-adjustments in response to beating, our auditory neurons are entraining to the periodicity of the fused waveform. The dynamic feedback loop of perception and action that defines JI practice — listening, adjusting, listening again — is a highly refined, culturally specific activation of one of our oldest cognitive capacities, directed with unusual precision at the structure of sound itself.

It is for these reasons I believe the concepts in this book could be of use to many different types of musicians, regardless of their proximity to the world of microtonality or tuning. As Marina Kifferstein, violinist and composer, notes in *Chamber Music for Strings in Rational Intonation: Performance Practice and Analysis*:

> For composers: I believe that a robust tuning practice has the capacity to revolutionize one's harmonic language, or at the very least to lend a deeper understanding of the ways in which pitch is a facet of timbre. For performers: the performance practice of this music requires a great deal of ear training, which has the effect of refining a performer's intonation and heightening their sensitivity to pitch and timbre. This skill is transferable to standard classical repertoire and other styles of performance, including explicitly equal-tempered music[3].

---

[2] Tomlinson, Gary. *A Million Years of Music: The Emergence of Human Modernity*. Zone Books, 2015.

[3] Kifferstein, Marina. *Chamber Music for Strings in Rational Intonation: Performance Practice and Analysis.* CUNY Graduate Center, 2026. *CUNY Academic Works*, City University of New York.

New Standards

In this book, I aim to establish conventions surrounding the **language**, **notation**, and **practice** of just intonation. While diverse methods and modes of thinking enrich JI, a "language barrier" often hinders the goal of music-making. To address this, I have chosen the tools I believe best fit the job: the notation system HEJI[4], the direction of ratios, the language of up/down commas when discussing JI in the rehearsal room, the names of intervals, and more. There is no definitive "best tool," but this is an opportunity to formalize conventions that will enhance our collective practice of tuning and facilitate quicker rehearsals and learning.

[4] Helmholtz-Ellis Just Intonation, the system of notation we will introduce as we go.

Throughout this book, we will both expand and complicate the age-old idea of just intonation as "universal"—not as a fixed destination all tuning aspires to, but as a rich framework that invites variation, context, and reinterpretation. The octave is a prime example: While often considered "pure" or "fixed" in many theoretical systems, in practice, it's a flexible interval shaped by aesthetics, tuning systems, and instrumental constraints.

#5 — Harmonic Fusion + Resultant Tones: The Psychoacoustics of JI

just intonation has a certain sonic quality that separates it from Equal Temperament—of course it does, or else why all this fuss? There's something special about fitting notes together the same way that sounds relate to one another acoustically—a tactility of the sound, the way it shimmers and buzzes, the way two notes fuse to become one entity (and somehow produce a host of other notes out of thin air). This is called *Harmonic Fusion*.

From a technical standpoint, two notes have achieved Harmonic Fusion when certain phenomena occur:

1) **The wavelengths of the two frequencies begin to "line up," or the composite waveform becomes periodic.** What does this mean?

Sound travels as pressure waves in the air. Each wave vibrates at a certain frequency, which means there are a certain number of peaks and valleys in the sound happening every second. If we have two notes sounding, their waveforms will interact via constructive interference (they reinforce each other) or deconstructive interference (they negate each other in some way).

modulation effects— an idea explored in the work of Maryanne Amacher and others. Listen not only for a single low pitch, but for pulsing, swirling, and phasing textures in the lower register of your hearing field.

It may feel like the difference tones are moving, merging, or beating against each other, forming an almost architectural sense of space. What you are hearing is not a trick—it's the auditory system itself engaging in nonlinear synthesis.

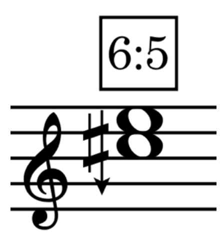
Let this final demonstration open the door toward ecological listening— tuning in to the emergent sonic environments that JI intervals can generate in the real world. So far, we've treated difference tones as discrete perceptual markers. But they also point to something larger: whole listening environments that emerge when tones interact.

Now that we've engaged our ears to the world of difference tones, let's explore an important component of difference tones: **register dependence**.

Difference Tones and Register Dependence

Let's consider an example ratio in the A harmonic series:

6:5 or E^{+2c} down to $C\sharp^{-14c}$



This interval is a species of minor third[46] with the

[46] This **6:5 interval** is more specifically named the **syntonic minor third**. We will cover this interval in depth in the syntonic chapter.

Despite being the 81st partial in the harmonic series, this new major 3rd is *not* as sweet and harmonious as its lower ratio cousin, 5:4, and it is also difficult to tune!

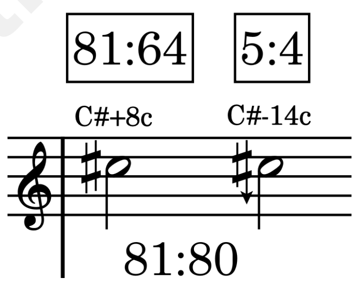
By comparison, the ratio of 5:4 ($C\sharp^{-14c}$) is easy to tune and exceedingly consonant. Let's summarize this before we get to the punchline:

- 81:64 is the major 3rd in the Pythagorean layer, or 3 limit. It is the 81° in the harmonic series and can also be found by stacking 4 perfect fifths up from the fundamental.

- 5:4 is the major 3rd in the Syntonic layer, or 5 limit. It is the 5° in the harmonic series.

The Punchline

The melodic or cent distance between these two different major 3rds—81:64 and 5:4—is ~22c apart and is called the **Syntonic Comma**.



The **Syntonic Comma** even has its own ratio, **81:80**. How did we arrive at that?

Remember this comma measures the tiny difference between the Pythagorean major third (81:64, the 81st partial) and the syntonic major third (5:4).

To compare these two intervals more directly, let's rewrite

However, the degree to which these effects are *noticed*, valued, or intentionally shaped depends on attention, training, and cultural framing[113]. Resultant tones can be brought to the foreground by attending to them[114], and that attention is easier to sustain when a culture has a language—verbal or conceptual—for describing them. In some traditions, these sensations are central to musical aesthetics: Balinese gamelan musicians speak of *ombak* (the "wave" created by deliberate tuning offsets), and barbershop singers cultivate "lock and ring" as a sign of perfect chord alignment. In others, they may be ignored, minimized, or even regarded as undesirable "roughness," as in much of the Western classical pursuit of "pure" tone.

What a given musical culture chooses to notice, name, and valorize is shaped by both history and aesthetics. The same beating between two pitches can be heard as a warm shimmer, an expressive intensity, a spiritual sign, or an intonational flaw—depending entirely on the cultural ear. The raw perceptual capacity is universal; the meanings we attach to it are not.

Is all music actually based or rooted in just intonation?

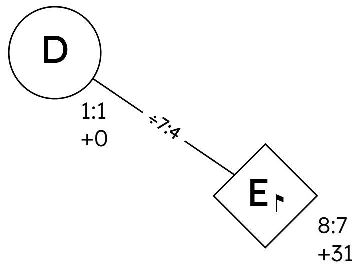
No, not all music is based or rooted in just intonation. Like many so-called "rational" explanations or aspects of

[113] A useful parallel comes from studies of language and color perception. Different languages divide the color spectrum in different ways, which can shape how their speakers categorize and recall colors. The famous phrase "wine-dark sea" from Homer has long puzzled translators; it likely reflects the ancient Greek color vocabulary, which grouped certain hues by brightness or saturation rather than by hue alone. Similarly, in music, the "palette" of perceptual distinctions is culturally mediated—without a term or conceptual frame for a psychoacoustic effect like slow beating or a prominent resultant tone, listeners may register it only vaguely or treat it as incidental.

[114] We have already gotten a taste of this from Edward Tichtener's writings on difference tones and introspection.

8:7

Septimal Major Second



Cent Deviation: +31c sharp of equal temperament major second
Cents from Fundamental: 231
Character:

- A kind of bright urgency
- Taut, pulled, stretched— an equilibrium that could snap at any moment
- Expectant, with a lot of forward energy

8:7 is the reciprocal of **7:4**. We can see this reflected in 8:7's cent deviation, which is a perfect mirror of 7:4.

8:7 – +31c from an ET major second
7:4 – -31c from an ET minor seventh

We have encountered two flavors of major second thus far: the pythagorean major second 9:8, and the syntonic major second 10:9. The septimal major second, 8:7, is our third addition to this category. It is a wide major 2nd, at +31c.