David B. Doty
Technical Writer/Technical Editor/Copyeditor
2751 Via Caballero Del Sur
Santa Fe, NM 87505
505 • 473 • 1924
dbd@dbdoty.com

Writing, Editing, and/or Design/Production Sample

What: *1/1*, The Journal of the Just Intonation Network, Spring 2004

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Just Intonation and Music for Theatre

by Alison Monteith

One Friday in October, 2002, I received a phone call from the secretary of the Scottish Borders Youth Theatre (BYT) asking me to provide music for a production of *Three Tales by Oscar Wilde*. Their musical director had pulled out at the eleventh hour and rehearsals started the next day, with performances the following Friday and Saturday.

Of the several options I had to offer, I proposed using my orchestra of tuned and untuned hand-built instruments. We agreed on a fee and I suggested that the producer, John Haswell, take a look at my website to get a better idea of what he was taking on.

My instruments were built in a period of enthusiasm for the "DIY" ethos that characterizes the work of many of the pioneers of Just Intonation, such as Harry Partch and Lou Harrison. I had to work within the limitations of my wood- and metal-working abilities and so I ended up with a range of slit drums, bamboo marimbas, zithers, long gongs, steel-tube metallophones, glass bowls, aluminum gongs, bowed psalteries, a huge thumb piano, and a random assortment of wood and metal percussion.

At our first meeting John Haswell proved to be an enlightened soul in matters musical. He was enthusiastic about my proposal and was open to all suggestions. We talked round the possibilities and decided to have the instruments visible on stage with different groups of actors playing throughout the performance under my guidance. At a stroke the music had become an integral part of the action.

Of the several tunings at my disposal I chose to work with three of Lou Harrison's just gamelan tunings, a slendro and two pelogs:

Unnamed (I'll call it a septimal minor pentatonic): $^{1}/_{1}$, $^{7}/_{6}$, $^{4}/_{3}$, $^{3}/_{2}$, $^{7}/_{4}$, $^{2}/_{1}$

Kyai Udan Arum: $^{1}/_{1}$, $^{16}/_{15}$, $^{7}/_{6}$, $^{4}/_{3}$, $^{22}/_{15}$, $^{47}/_{30}$, $^{9}/_{5}$, $^{2}/_{1}$ (harmonics 30, 32, 35, 40, 44, 47, 54)

Lou Harrison's: $^{1}/_{1}$, $^{13}/_{12}$, $^{7}/_{6}$, $^{17}/_{12}$, $^{3}/_{2}$, $^{19}/_{12}$, $^{7}/_{4}$, $^{2}/_{1}$. (harmonics 12, 13, 14, 17, 18, 19, 21)

I liked the idea of using Harrison's gamelan tunings for several reasons. First, it felt right to be tapping into that part of gamelan where the music accompanies some sort of dramatic action. Secondly, I had no time to compose large pieces of music (and few of the players could read) so everything would be improvised. One way to get inside a mode or scale is to improvise for up to six hours a day for five or six days.

I placed several limitations on my choice of tunings. The septimal minor pentatonic was used as a general background commentary, avoiding direct reference to the action. It was played on a combination of steel-tube metallophone and hammered zithers (high and low octave), with ostinatos on the large thumb piano. Occasionally, I would point up some of the tension with a more lyrical line on the bowed psaltery, which allows subtle microtonal inflections by string bending. Most of the five tones could also be doubled on aluminum gongs and metal bars. The long gongs ($^{4}/_{3}$, $^{3}/_{2}$, $^{1}/_{1}$ [110 Hz], $^{7}/_{6}$) provided drones and punctuation in much the same way as orchestral timpani. A battery of slit drums and bamboo and metal percussion provided a comfortable rhythmic cushion on which to improvise melodically. Glass bowls and random metal were held for special effects and atmo-

(text continued on page 4)

Bay Area Performance Series to Mark Network's Twentieth Anniversary

2005 marks the twentieth anniversary of the founding of the Just Intonation Network — to be more precise, the network was conceived at a meeting on October 8, 1984 (see **1**/**1** 1:1, p. 16) and made its public debut with the publication of the first issue of **1**/**1** in February 1985. We have decided to celebrate this event with a series of concerts in the San Francisco Bay Area between mid-April and mid-June of 2005. The proposed performance series (we don't have a clever name for it yet — your suggestions are welcome) has several goals:

- ❑ to present good music in Just Intonation for its own sake
- ❑ to get recognition for the network in conjunction with its twentieth anniversary
- ❑ to increase public awareness of Just Intonation
- ❑ to start building a pool of performers and ensembles that we can call on for future events
- ❑ to begin an on-going (maybe biannual?) series

No events have been scheduled as yet, but among the composers and performers who have expressed an interest in participating are Alexis Alrich, David Canright, Ellen Fullman, Kraig Grady, Janis Mattox and Loren Rush (the Good Sound Foundation), Other Music (thirty-year reunion), John Schneider/Just Strings, Robert Rich, Terry Riley, Erling Wold, and your editor. Other network members who are interested in performing in the series are encouraged to submit proposals, with the following caveats: 1. We are working with a limited budget, so we will not be able to pay for your transportation from outside Northern California or your housing while you are here (though local network members may be willing to host some visiting artists). 2. We do not expect to have a house ensemble for this event (though this is a resource that we hope to develop in the future), so submission of scores will not be useful — you must be able to perform your work or make your own arrangements for its performance. Note also that this series is exclusively for music in Just Intonation, rather than for microtonality/alternate tunings in general. However, if you are already in Northern California, expect to be here in April, May, or June of 2005, or are willing to come here at your own expense, and you have justly tuned music to be performed, we would be interested in receiving your proposal. And, of course, we encourage all network members, wherever you may be, to come and attend one or more of the performances.

Please send your proposals before August 31, 2004 (sooner is better), to the Just Intonation Network, attention: Carola Anderson, 535 Stevenson Street, San Francisco CA 94103. Please include the following information: name, address, phone number, and email address; a brief biography; a description of the piece(s) you would perform, including length, instrumentation, number of performers and any other details you consider relevant; preferred performance dates, technical requirements (e.g., any special equipment required, any special features needed in the performance venue, etc.), and financial requirements. Please include a CD or tape of the piece in question, or, if that is not possible, of a similar recent work in Just Intonation.

Check the JIN website (`www.justintonation.net`) and subsequent issues of **1**/**1** for more information about the series as it develops. We look forward to seeing many of you next spring. **1/1**

Kitharist — the Berlin Painter, circa 2500 B.P. (before Partch)

Subscriptions and Back Issues

A four-issue subscription to **1**/**1** is included with membership in the Just Intonation Network. A new membership also includes a copy of *The Just Intonation Primer.* The cost of a new membership, which includes shipping for the *Primer*, is $19.00 for the U.S.A, its territories and possessions; $23.00 for Canada or Mexico, or $30.00 elsewhere. Renewals are $17.50 for the U.S.A., $20.00 for Canada and Mexico; and $25.00 for the rest of the World. Institutional/Library rate is $30.00. Please note that this is not an annual subscription—**1**/**1**'s publication schedule is irregular: at present the rate is approximately two issues per year. Please inform us promptly of any address changes, as we cannot be responsible for remailing returned issues. All back issues are available postage paid—see the Just Intonation Store flyer for details.

Submissions

1/**1** welcomes and encourages the submission of articles on any and all subjects pertaining to Just Intonation. We do not publish articles that focus primarily on temperament, or on other aspects of music theory. We prefer submissions via email attachment — preferred formats are MS Word, RTF, or plain text (ASCII). (For those without computers, a good-quality, double-spaced typed manuscript is also acceptable.) Illustrations, charts, and scores are best submitted as black and white EPS or TIFF files, but camera-ready hardcopy figures are also acceptable. We reserve the right to edit all material accepted for publication, in the interests of brevity, clarity, and factual accuracy. However, we will not make changes affecting the factual content of an article without the author's permission. If you wish your MS. to be returned, please enclose a stamped, self-addressed envelope. The authors retain the copyright to their material, and are responsible for its registration. Authors are welcome to submit material originally published in **1**/**1** to other publications, but are requested to state that the material first appeared in **1**/**1**. We cannot pay for articles, but will provide the authors of published articles with five copies of the issue in which their work appears. If you have any questions about submitting an article, do not hesitate to contact us.

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Phone: (415) 864-8123
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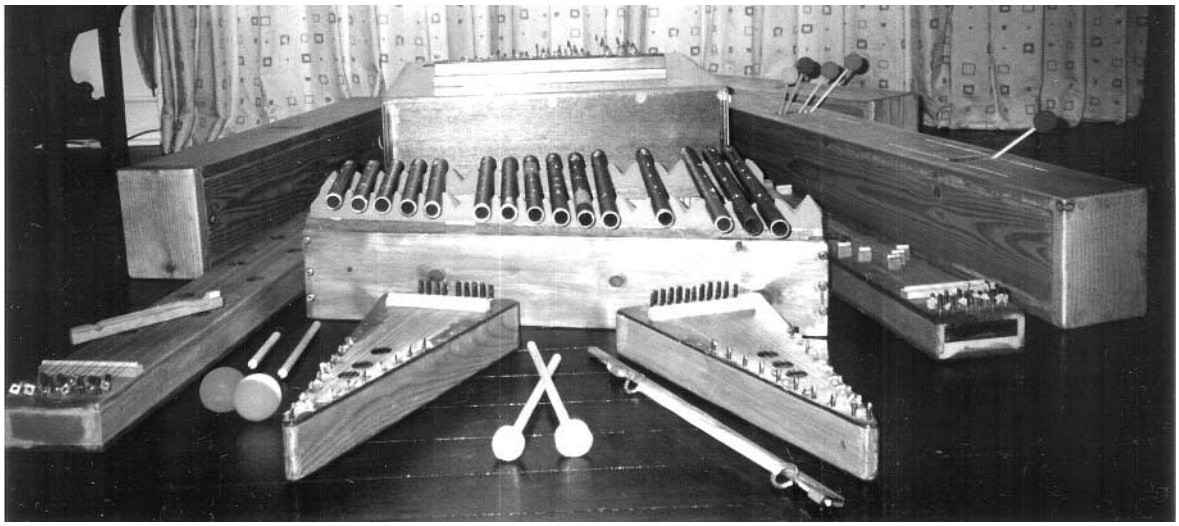


Instruments — back to front: Rumba Box (giant thumb piano), steel-tube metallophone, bowed psalteries, beaters and bows; left and right: six-course zithers and slit drums

*(**Theater**, continued from page 1)*
spheric timbral montages.

I used *Kyai Udan Arum* to contrast with the septimal minor pentatonic. This Phrygian-sounding scale is one that never tires my ears. The very flat fifth adds spice to the overall smoothness of the scale. Throughout the long rehearsals and during the performance I was mesmerized by the subtle undercurrent of difference and combination tones that rose from the strings and by the bubbling tremolo jangle of the metallophones' inharmonic timbre.

If you tune up an instrument to Lou Harrison's pelog you will notice the very prominent "blue" $^{17}/_{12}$. I also sense an off-kilter feel to the whole scale. I used this scale to point up the appearance of a drunken student in the play and once or twice when sharp contrast was required.

I won't go into details about the songs and dances I wrote other than to say that I am now certain that many of the septimal tones can be sung quite effectively against a drone with a little familiarization. One of the songs I wrote was in the shape of a recurring folk ballad refrain starting on my $^{4}/_{3}$ (D) and largely in the Aeolian mode. As the week went by I fed in the $^{7}/_{6}$ and noticed the singer (an untrained but gifted seventeen year – old girl) drift effortlessly towards the tone. I then left the $^{7}/_{6}$ out at times and checked at others. She had locked in nicely and I stored this information for future choral efforts.

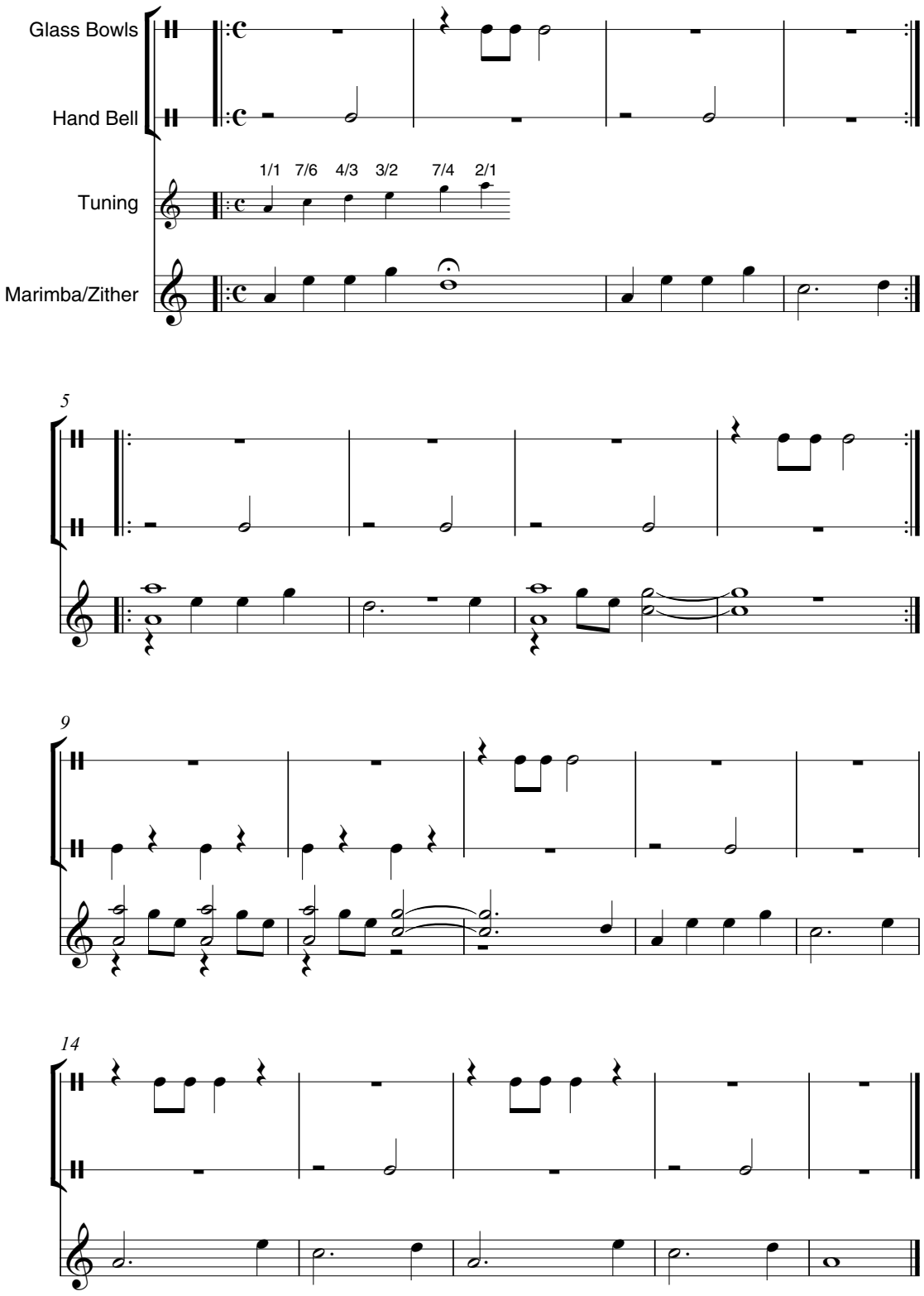
The performances were sold out, hugely successful and I had the great pleasure of being able to deflect praise upon the actors who were also the musicians. Visually, the hand-made instruments make a tremendous set. I can see now what Harry Partch achieved with his incredible orchestra. This was probably the first and last time that any of the audience had ever experienced the voluptuousness of over an hour of live, continuous, justly tuned soundscape.

The Tempest

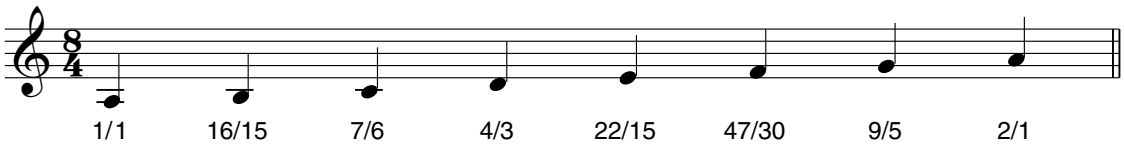
My next call was to provide music for a production *The Tempest*. This time there would be two indoor performances after a week of rehearsal, a midsummer outdoor performance in the historic Scottish border town of Melrose, and a performance in the southern French town of Tournon at a youth Shakespeare festival. The producer was Neil Packham of the renowned Citizens Theatre in Glasgow. We struck up a good working relationship immediately. For this production I had less of a free hand. Neil was enthusiastic and curious in equal measure about my instruments and music but instead of a constant backdrop of sound he asked initially for specific motifs for Miranda and Ferdinand, Ariel and Caliban; songs, percussion for dance pieces and, of course, music for the opening storm scene.

Space was at a premium for the indoor Scottish performances and I was aware that there would be restrictions on what could be transported to France. I cut down on the number of instruments and settled on two tunings, the septimal minor pentatonic ($^{1}/_{1}$, $^{7}/_{6}$, $^{4}/_{3}$, $^{3}/_{2}$, $^{7}/_{4}$, $^{2}/_{1}$) and *Kyai Udan Arum* ($^{1}/_{1}$, $^{16}/_{15}$, $^{7}/_{6}$, $^{4}/_{3}$, $^{22}/_{15}$, $^{47}/_{30}$, $^{9}/_{5}$, $^{2}/_{1}$), both of which had proved successful in

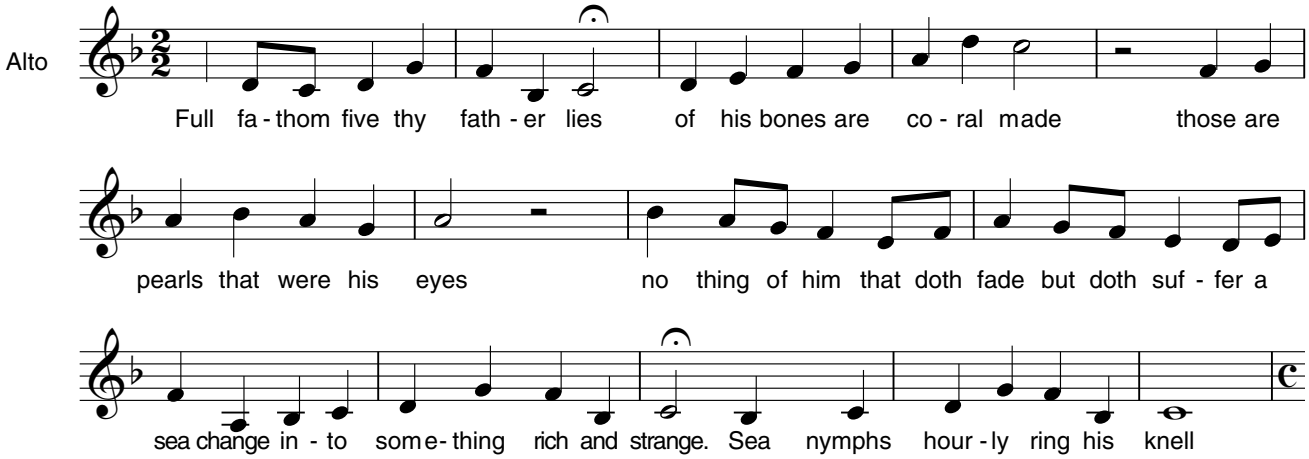
Example 1. Miranda and Ferdinand's Theme



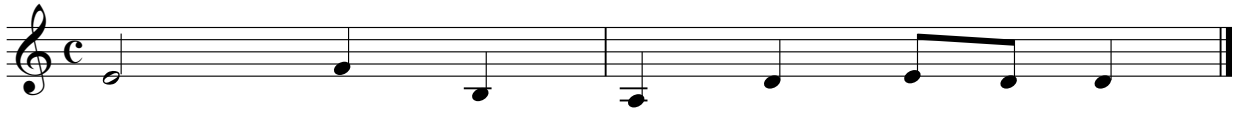
Example 2A. *Kyai Udan Arum* (pelog)



Example 2B. Ariel's first song (melody)



Example 2C. Caliban's theme



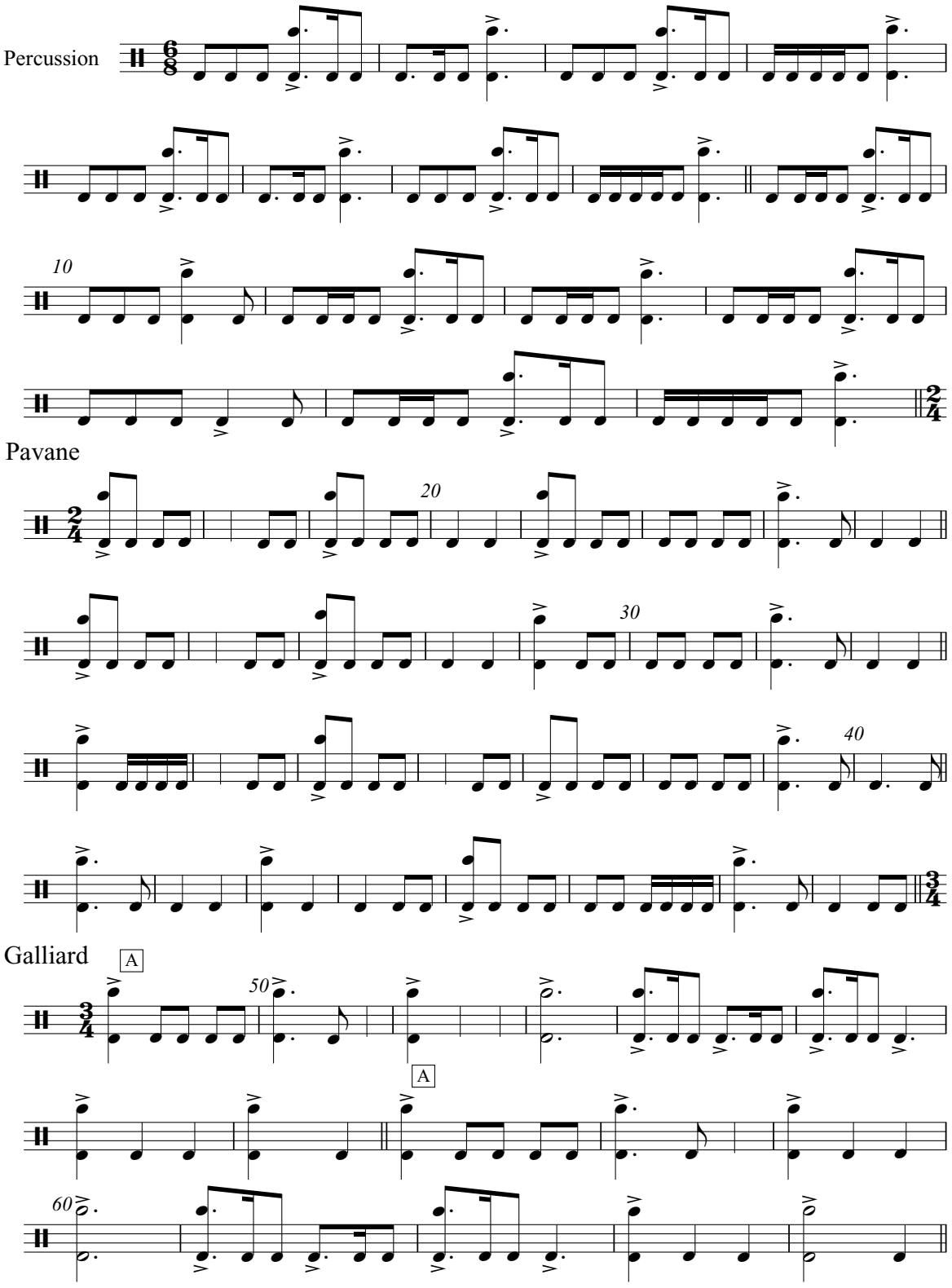
the Oscar Wilde production.

The Tempest is full of magic and magical sound. I had more freedom to orchestrate the music to this effect and I had the luxury of three dedicated players most of the time, all of whom were good young amateurs.

I used the septimal minor pentatonic for Miranda and Ferdinand's theme (Example 1), Miranda represented by the steel-tube metallophone and Ferdinand by the zither. The full arrangement can be seen from the score though this arrangement served more as a sketch pad for improvised ideas. Essentially there are several short phrases. These were eventually played in canon at various time intervals, juxtaposed, layered together or played in augmentation or diminution. These passages were lightly accompanied by handbells (high-quality brass coat-rail brackets) and glass bowls. I used the pentatonic also for a choreographed dance piece during the banquet scene, this time played on steel-tube metallophone, zither, slit drums, long gongs, and bamboo guiro.

For most of the rest of the music I used the *Kyai Udan Arum* pelog (Example 2A). I had arranged Ariel's songs for contralto soloist and chorus (obviously in twelve-tone equal temperament). The basic melody of Ariel's first song is in the conventional mode of D Aeolian (Example 2B). Following the time-honored tradition of reworking existing material, I decided to use fragments from the song, rendered this time instrumentally using *Kyai Udan Arum*. I was able to play the full melody

Example 3. Suite of Three Dances



Outdoor performance of *The Tempest*, Melrose, Scotland. Neil Packham, producer, and young actors. Instruments: slit drum, random steel tubes, bowed psaltery, Zen bowl, six-course zither, bamboo tubes, found handbells. used with permission of Scottish Borders Youth Theatre

on bowed psaltery with ostinatos on zither and random percussion and I could hint at the melody or fragments every time Ariel appeared.

For Caliban's theme (ExampIe 2C) I put the melody through a retrograde inversion, which ties in rather nicely with Shakespeare's juxtaposition of the two elemental characters. This was played on large thumb piano struck with felt-covered zither beaters, with percussive accompaniment.

All the performances were successful, particularly the outdoor events. The music enhanced the magic of the play. As the great Prospero speeches were delivered I remember feeling hugely privileged to be playing my own music on my own justly tuned instruments in the courtyard beneath the ancient towering walls of the medieval Chateau de Tournon.

Hamlet

During the summer of 2003, I was commissioned to write and deliver the music for a large-scale, community-based project that incorporated an adaptation of *Hamlet*. This was to tie in historically with the four hundredth anniversary of the Union of the Crowns of Scotland and England in 1603. The final productions took place in two locations: first at Traquair house, the oldest inhabited house in Scotland, then in the barracks of Berwick upon Tweed, a town which had seen centuries of strife in the cross-border wars (and which is currently in the hands of the English).

Most of my input was for solo and choral singing, though during the final performance I had a free hand to embellish and improvise with my instruments in much the same way that I had with the Oscar Wilde tales.

Of interest here is one of the dance pieces I was asked to provide for the main performance (Example 3). Basically there was to be an outdoor performance of a short suite of Renaissance dance pieces consisting of a 6/8 piece, a pavane in 2/4 and a galliard in 3/4. I arranged the pieces in a five-part arch form, ABCBA, then took rhythms and formal structure for each piece from my lute repertoire and simply laid out the music

(text continued on page 24)

Just Intonation and the Frequencies of DNA: the Music of Susan Alexjander

by Marc Jensen

Different composers approach the idea of working with Just Intonation for different reasons, but beyond pure aesthetic preference, one reason that many composers share is the idea of working with a system that is organized as much as possible around the natural properties of sound, rather than the conventional twelve-tone equal temperament system, which compromises aesthetics for convenience. This idea of working with a system that is rooted in a natural order underlies the music of Susan Alexjander, but brings her to Just Intonation from a much different direction than most composers. Alexjander composes using a tuning system which is derived from the resonant frequencies of DNA, from which she has produced an extremely dense microtonal pitch space, containing many simple, harmonic ratios.

DNA Music

The idea of creating music based on the patterns found in DNA has a relatively short history, because the massive amount of data contained in DNA sequences and the technology needed to process them only began to be popularly available in the mid-1980s. Sonic representation of DNA, which relies on the ear's superb pattern-recognition ability, is a very effective tool for the analysis of genetic structure.[1]

Representing DNA as music acts as an iconic fusion of the best scientific understanding of human physiology, an exploration of human mystery through art, and an attempt to objectively correlate an aesthetic practice with scientific knowledge. "As the science of genetics has moved from the laboratory to mass culture, from professional journals to the television screen, the gene has been transformed. …Instead of an important molecule, it has become the secular equivalent of the human soul."[2] With the human genome project approaching completion and with issues related to genetics affecting growing numbers of people, art making that incorporates DNA speaks to a need to humanize this body of research and articulate it in a more approachable way.

Among the foremost conceptions of the gene in popular culture is the belief that understanding DNA will lead to a fundamentally deeper self-knowledge of some kind, and that ultimately, understanding the genome can quantifiably answer the question of what it means to be human. All sonifications of DNA function within this popular mythos at some level and capitalize on its mystique.

As coded information, DNA is based on a relatively simple system. All DNA sequences are composed of strings of only four nucleotides: adenine, cytosine, guanine, and thymine (represented by the letters A, C, G, and T). These are transcribed into RNA sequences, which provide instructions to cells for the synthesis of amino acids (the building blocks of proteins); the RNA sequences are read by a cell's ribosomes in groups of three, called codons, producing a code with sixty-four possible characters ($4 \times 4 \times 4$ permutations of the order of nucleotides). There is significant redundancy built into this system, often with three or four codons coding for the same protein. Altogether, the sixty-four codons code for only twenty proteins, with three codons that act only as punctuation by telling the ribosomes that a sequence is either beginning or ending.

By chance, three of the four letters used as nucleotide abbreviations also stand for pitches in traditional musical notation, and so the idea of approaching sequences of genetic information as though they were musical notation (replacing "T" with some other pitch), has occurred to a number of composers and scientists independently.[3]

As gene sequences become more widely disseminated, this idea will undoubtedly occur to many more people. Representing strings of nucleotides as sound with a system of only four pitches is ultimately a simplistic technique though, and for practically every composer who has had more than a passing interest in working with genetic source material, this approach has matured into a system with more depth, rigor, and variety.[4]

Among composers working with DNA though—most of whom use gene sequences as a linear code that gets translated directly into a sequence of sounds at some level—Alexjander's system is anomalous, in that it is possibly the only system in which the physical proper-

ties of the nucleotides themselves are used to create the musical palette, defining a musical space within which the composer is then able to compose freely.

Alexjander's Tuning System

In Alexjander's DNA-based tuning system, the infrared resonance frequencies of the four nucleotides have been measured and converted into a set of sixty tones, which are spread over two and one-half octaves. To develop this system, Alexjander worked with University of California at Santa Cruz cellular biologist David Deamer, who was among the very first to note the similarity between gene sequences and musical notation.[5] To determine these frequencies, Deamer used an infrared spectro-photometer to measure the resonant frequencies of each of the chemical bonds in each nucleotide:

> The four DNA bases, adenine, cytosine, guanine and thymine, each consist of carbon, hydrogen, oxygen and nitrogen. There exist a variety of chemical structures, including C=O, N-H, C-H, O-H, and C-O, whose bonds bend, stretch, and rock upon absorbing infrared light with a specific frequency, related to the energy and strength of the bond and the mass of the nucleus of the atom. A tighter, smaller bond from, say, hydrogen, will absorb light with a higher wavenumber (number of waves per centimeter), and a higher "note" in the infrared spectrum…. As the light is passed through the sample, it is absorbed by the sample at specific frequencies and the instrument plots the absorption bands as a spectrum…. For example, the C-H (carbon-hydrogen) bond absorbs infrared light with a wavenumber of approximately 2900 cm-1.6

Alexjander then transposed the resulting wavelength ratios into frequencies within the range of human hearing, rendering the frequencies as sound rather than light.

The unison tones in this pitch set are combined to form one sounding pitch, and so although they form the simplest of ratios, they effectively do not function as such. Aside from the numerous unison pitches, there are only three ratios in this system which are precisely accurate to the limits of the data; however by broadening the search to look for matches within 0.01% accuracy of a just ratio, a large number of effectively just relationships emerge within the first sixteen harmonics. Alexjander believes that this entire system of pitches is harmonically ordered at a level of incredibly high complexity, so that theoretically one fundamental frequency generates all sixty sounding pitches as overtones.

Musical Applications

Alexjander's musical applications of this tuning system, as featured on her album *Sequencia*[7] could be described as generally making use of tonal principles of dissonance resolution with reference to a central pitch in this space. Her descriptions of working with this system include references to a "tonal center" that emerged spontaneously and unmistakably during her experimentation based on frequencies centered around 544 Hz. One pitch within 10 Hz of 544 occurs in the sequence for each nucleotide, and Alexjander feels that these act as a natural balancing point for the entire system.[8]

Alexjander's application of this tuning system can be better understood by a look at one of her pieces: *Pataphysical Thymine*. She describes process of creating the

Table 1. The frequencies of Alexjander's tuning system (in Hz). Although grouped by nucleotide here for comparison, she applies all of these frequencies as a continuous sequence.

Adenine	Guanine	Thymine	Cytosine
3l5.6	300.3	322.l	305.6
347.9	305.6	330.4	345.7
368.0	339.2	354.4	357.9
379.8	370.2	363.2	420.3
398.l	383.2	406.4	429.l
408.l	4l3.4	427.8	440.9
447.4	487.6	447.4	504.2
490.2	5l2.9	523.8	537.8
504.2	529.5	543.4	558.7
545.6	550.0	600.2	594.9
582.7	600.2	733.3	639.5
598.0	6l5.5	768.2	654.8
6l9.8	64l.7	l248.3	7l3.7
632.9	663.5	l274.6	l276.8
654.8	728.9	l385.8	l375.0
698.4	ll69.8		l475.4
726.7	l278.9		
ll39.2	l366.2		
ll78.5	l462.3		
l248.3			
l278.9			
l366.2			
l440.5			

Table 2. Harmonic relationships that occur among the first sixteen harmonics of Alexjander's system

Just Ratio	Frequencies	Accuracy of Match
1:1	305.6/305.6	1.00000
1:1	504.2/504.2	1.00000
1:1	600.2/600.2	1.00000
1:1	654.8/654.8	1.00000
1:1	1248.3/1248.3	1.00000
1:1	1278.9/1278.9	1.00000
1:1	1366.2/1366.2	1.00000
1:2	1278.9/639.5	0.99992
3:2	641.7/427.8	1.00000
5:2	1375.0/550.0	1.00000
4:3	733.3/550.0	0.99996
5:4	1462.3/1169.8	1.00003
5:4	654.8/523.8	1.00007
5:4	447.4/357.9	1.00005
9:4	1178.5/523.8	0.99996
11:4	1440.5/523.8	1.00003
6:5	615.5/512.9	1.00003
6:5	654.8/545.6	1.00012
7:5	427.8/305.6	0.99990
7:5	733.3/523.8	0.99997
12:5	1440.5/600.2	1.00001
7:6	641.7/550.0	1.00005
11:8	768.2/558.7	0.99998
13:8	1248.3/768.2	0.99998
13:8	598.0/368.0	1.00000
10:3	357.9/322.1	1.00003
13:9	619.8/429.1	0.99998
14:11	641.7/504.2	0.99999
14:13	1375.0/1276.8	0.99999

piece in this way: "I specified the synth voice (patch) and a few notes on the keyboard, a rhythm, and a scale for the violin…. Much of the piece was improvised on a theme given the acoustic instruments, but within very tight pitch and rhythmic structures."[9]

This piece is constructed primarily of fluid, ornamented, scalar runs moving over a soft drone in the background, which the melodic line comes to rest on periodically. The combined effect of the tuning system, the playing style in the recording, and the choice of instrumentation is unmistakably evocative of microtonal usage in Indian classical music, and this is even more striking in some of Alexjander's other pieces that include tabla.

The importance of conveying genetic structure is central to Alexjander's music. Referring in her writing to the idea that the mind perceives similar fundamental structures occurring throughout the universe in phenomena of different scales and forms, she believes that listeners identify and are drawn to the genetic frequency ratios that make up her tuning system, citing the visceral responses that a number of listeners have had to it, in a way that she feels would be unexplainable if the system were not composed of a meaningfully related set of frequencies. She says, "There is every reason to believe that our psyches and physiologies can recognize the light, infrared patterns of life through the resonance of sound."

Whether or not this relationship between the structure and perception is actually present in Alexjander's music is questionable, and she offers no hard evidence that composing using this method produces therapeutic results significantly different from other comparable music therapy techniques. However, the music itself is graceful and appealing, and the intimately close microtones provide a refreshingly beautiful pitch space. **1/1**

Notes:

1. The website of the composer John Dunn contains sonification software designed to convert genetic code into sound, as well as links which detail his collaborations with various scientists to produce DNA sonifications that act both as art and music (`http://algoarts.com`).

2. Nelkin, Dorothy and M. Susan Lindee. *The DNA Mystique: the Gene as a Cultural Icon*. New York: W.H. Freeman and Co., 1995. p. 198.

3. The biologist Mary Anne Clark's website (`http://whozoo.org/mac/Music/`) contains a fine bibliography that includes links to a number of composers and composer/scientist collaborations working with DNA.

4. For a much more detailed examination of the variety of techniques of DNA sonification and their history, see Jensen, Marc. "Sonification and Systematic Composition: Evaluating Genetic Music." Oakland CA: Mills College MA thesis, 2004, on which this article draws heavily.

(text continued on page 24)

The Persistence of Just Intonation in Western Musical Practice

Part I: Just Intonation in Western Music History, Music Theory, and Acoustics

by Douglas Leedy

As an artifact of the recent techno-industrial era in the West, twelve-tone equal temperament (12-equal) is a telling example of the modern application of universal, "rational" standards of measurement such as the meter, or the musical pitch norm of a' = 440 Hz. Among ancient civilizations, the Greeks and Chinese knew of 12-equal; it was argued over in the Renaissance; and yet it was not generally accepted — against much protest — until the middle of the nineteenth century. By 1950 the triumph of 12-equal seemed nearly complete. A few malcontents, to be sure, were still complaining of its unsatisfactory attributes, and there was the nearly total isolation of Harry Partch, who had altogether rejected 12-equal for his own just tuning system and instrumentarium, and the almost equally isolated Just Intonation music, later, of Lou Harrison — iconoclastic and futile gestures, or so it seemed at the time.

In 1951, J. Murray Barbour's remarkable *Tuning and Temperament: A Historical Survey*, based on his 1932 Cornell University dissertation, *Equal Temperament: Its History from Ramis (1482) to Rameau (1737)*, was published (East Lansing: Michigan State College Press; reprint, New York: Da Capo, 1972). This still valuable work is a masterly compendium of the most important treatises and other historical writings on temperament: that is, on how to adapt optimal interval tunings to the limited number of pitches available on keyboard instruments. Barbour, significantly, evaluated every tuning and temperament he presented by the standard of 12-equal, which he described as "the ideal system of twelve notes if modulations are to be made freely to every key" (p. vii).

Barbour's study was probably the high-water mark of 12-equal, as I believe the evolution of musical practice since then has demonstrated. Though it seemed to imply that the 12-equal ideal might well be applied retroactively as well as prospectively, a different picture can be seen to emerge as we now look at the history of intonation in the West: not one of "progress" toward the triumph of the utilitarian ideal of 12-equal that is itself a highly flawed compromise, but rather of the constant and ever-present influence of Just Intonation in Western music, today and as far into the past as we can reach.

We can look for evidence of the persistence of Just Intonation in a number of places: first, in works on music theory, from the earliest monochord divisions to the latest harmony textbooks; second, in the treatment of intonation by acousticians of music, especially with respect to the acoustical effects of interval mistuning. These sources, following a brief history of intonation in Western music, will constitute Part I of this essay.

The most revealing evidence, which will take up most of Part II, will be drawn from actual practice: how intonation has been treated in vocal and instrumental method books, tutors and guides, from their eighteenth-century beginnings to the present day, as well as what some selected recorded examples can tell us about intonation in a number of different musical genres. The reader should bear in mind that this study is limited for the most part in its more recent source materials and its survey of intonational practice to the English-speaking musical world.

A Brief History of Intonation in Western Music

The ancient Greeks (who undoubtedly got much of their music theory from older cultures) used, in their mainly monophonic musical expression, a very sophisticated, subtle palette of interval shadings based on, but not limited to, just intervals; these shadings are given most completely in Ptolemy's *Harmonics*.[1]

Western liturgical plainchant (Gregorian chant) and the earliest notated polyphony (parallel and melismatic organum) have only the most tenuous connection to the ancient Greeks, and only by way of music theory. The music of this era was theoretically restricted to three-limit intervals, that is, intervals built from fifths (3:2) and octaves (2:1) only, though we know too little about actual intonational practice of the time in music outside the medieval church, for which a system based on the number three had obvious doctrinal significance.

Five-limit intervals, above all the pure major third (5:4), cannot have been absent from music: the Greeks used them, for example. They show up first in a treatise on music of about 1100, in the British Isles. As represented on the monochord, the instrument used from ancient times until the nineteenth century to demonstrate intervallic proportions, three-limit systems persisted until after 1600. The true major third is a sensuous sonority that seduces with its sweetness, in contrast to the relatively austere sounds of three-limit harmony, and its formal acknowledgement in the West exactly parallels the rise of secular humanism. It is present in English music by the beginning of the twelfth century, and on the continent about a century later.

Five-limit intervals made possible the vertical sonority of the triad, with all its implications. Though fixed-pitch instruments were of ancient origin, triadic harmony gave the keyboard instruments an important foothold in practical music, as they were able to partake of five-limit just intervals through the (coincidentally) very close intonational surrogate of quarter-comma meantone temperament.[2]

Up to about 1700, the intonational standard was provided by the monochord and the voice. The keyboard instruments, however, the first music for which was arrangements of vocal music, began as early as the fifteenth century to develop an independent repertoire, and by the late eighteenth century, in large part due to the rise of amateur music making at that time among the increasingly influential bourgeois class, came to dominate musical thinking in every aspect, including that of its perforce restricted range of intonational expression.

The first intonational revolution in the West was therefore from a three-limit to a five-limit system, clearly evident in the music still extant from the thirteenth to the fifteenth centuries. Now came the second, from just (and meantone) intonation to twelve-tone equal temperament, the ultimate success of which depended on the simplification of the modal/tonal system of the sixteenth and seventeenth centuries into the twenty-four major and minor keys, again, under the influence of musical amateurism, and the advent, in the early 1800s, of the metal-frame piano, the tuning of which was quite stable over time, and the timbre of which was mostly devoid of strong, clashing upper partials that make 12-equal nearly unbearable on many other instruments — in particular, the harpsichord, which the piano eclipsed. There were also economic and technological influences: the industrial revolution called for universal standards of measurement, such as one standard unit for measuring musical intervals, for example — the 12-equal semitone; and the factory-made piano required a specialist for the tuning and service that players and owners of harpsichords were able to do themselves.

Despite the many complaints at this time of prominent musicians about the limitations of 12-equal, it was generally accepted most everywhere by the mid-nineteenth century, largely due to the piano's influence. It was at first regarded as an imperfect but practical approximation of adequate intonation that the finest players and singers, who employed a true and flexible intonation, could largely ignore. Over time, however, it became an absolute: Schoenberg wrote in a 1934 letter to the theorist of nineteen-tone equal temperament, Joseph Yasser,

> Certainly one of the difficulties of my music is that an ear trained on classical music will ask, when it hears a tone C sharp, whether it should not be a D flat, whereas in reality it is nothing else than the exactly measured half step between D and C, without any relationship to harmonic questions. … For to be musical means to have an ear in the *musical* sense, not in the *natural* sense. A musical ear must have assimilated the tempered scale. And a singer who produces natural pitches is unmusical, just as someone who acts "natural" on the street may be immoral.

Yet apart from keyboard instruments 12-equal does not reign supreme today, for a number of reasons: first is the chronic discomfort with its limitations, particularly the poor quality of its thirds and sixths, which in the simpler styles of tonal harmony, at least, have proved quite resistant to assimilation; second is the increasing presence in the West, over the last half century, of non-Western music, with its often quite different tunings and scales and subtly modulated intonation; and third is the influence of the early-music movement, now into its third generation of performers who have decisively returned to intonation and tunings appropriate to its varied musical repertoires. At the core of most of these developments in musical intonation are the physical and acoustical facts of the just intervals of the harmonic series.

Just Intonation in Music Theory

One can follow the history of intonation in Western music by comparing writings in music theory from their earliest appearance, although as history they have almost always tended to lag behind the practice of the day. They

are somewhat divorced from practice in another way as well, seldom accounting for the intonational subtleties that are always a part of the expert musician's art.[4]

The earliest documentation of the use of the pure (five-limit) major third is in the *De legitimis ordinibus pentachordorum et tetrachordorum* of Theinred of Dover, about 1100. The first monochord division that includes this 5:4 major third apparently occurs in Bartolomeo Ramos de Pareia's *Musica practica* of 1482. The pure major third is called for in Pietro Aaron's keyboard tuning instructions in his *Toscanello in musica* (1523), which are evidently instructions for quarter-comma meantone temperament. Monochord divisions for meantone (unless Ramos's somewhat ambiguous division is meant to be such) do not appear until Zarlino's temperaments of two-sevenths-comma (*Istitutioni harmoniche*, 1558) and quarter-comma (*Dimostrationi harmoniche*, 1571), which he found superior to the two-sevenths-comma division. One can argue quite confidently that the theorists' published tuning instructions and monochord divisions were an acknowledgement of long-standing intonational facts.[5]

This same Gioseffo Zarlino (1517–90) is quite specific, in his 1558 *Istitutioni*, about the use of just intervals, writing of the major third, for example, that

> It is formed by the terms 5 and 4, which [belong to] the super-particular class of proportions [i.e., that class where the numerator of the proportion exceeds the denominator by one], [being] the sesquiquarta. It is indeed wonderful how nature has ordered the consonances. The parts of the diapente [fifth] are found by dividing [it] arithmetically into two parts through the terms 6:5:4 [the major triad]. The diapente divided harmonically through the terms 15:12:10 yields these same parts in contrary order [giving the minor triad].[6]

Students of music history will surely recall the strident argument in print between the just tuning advocates, represented by Zarlino, and their opponents who favored — even for unaccompanied vocal music — the theoretical equal temperament of fretted instruments, the most outspoken of whom was Zarlino's erstwhile pupil Vincenzo Galilei (152?–91). In the end the impetuous Galilei had to concede that "we sing today [in] agree[ment] more with the very syntonic of Ptolemy" — i.e., in just tuning, as Zarlino contended — "than with any other distribution."[7]

We can now jump to the latter part of the eighteenth century, where the preserved lesson-books of a pupil of Mozart in Vienna, 1785–87, the English composer Thomas Attwood (1765–1838), show that Mozart taught in the intonational system of just/meantone: he presents to his pupil the two sizes of semitone characteristic of meantone, the large (*grande*) or diatonic semitone (e.g., D–E♭) , and the small (*piccolo*) or chromatic semitone (e.g., D–D♯). (In three-limit — Pythagorean — tuning the relative semitone sizes are the reverse of those of just/meantone, while in 12-equal the semitones are, of course, equal in size.)

Not long after Attwood's tutorials, another English composer, William Crotch (1775–1847), relegates the chromatic semitone to a rather charming footnote in his *Elements of Musical Composition* of 1812:

> The major or diatonic semitone having been mentioned it seems necessary to inform the student that a minor or chromatic semitone … is the difference between a major semitone and a minor tone [of just, rather than meantone, tuning]. … There are also several other intervals resulting from the combination of many keys on the same monochord, the knowledge of which is not necessary to the student (p. 131).

Crotch, it should be noted, is still making didactic use of the monochord, on which he derives the five-limit just intervals, though his treatise is otherwise based on 12-equal. A similarly dismissive footnote can be found nearly a century later in the influential *Harmony, Its Theory and Practice* (1903) by Ebenezer Prout (1835–1909):

> The two semitones composing a tone are not of exactly the same size. A diatonic semitone is larger than a chromatic; neither semitone is therefore exactly *half* the tone; but as the difference is of *no practical importance* [emphasis added] in harmony, the student need not regard it. It is included here for the sake of accuracy (p. 3).

Prout's practical intonational structure is thus that of 12-equal, though he still makes the vestigial gesture to just/meantone. A number of prominent musicians and music theorists of the time, however, continued to hold up Just Intonation as an important ideal, among them another English composer, Charles V. Stanford (1852–1924), who offered the advice that "[f]or the composer … it is an absolute necessity that he should *study the pure scale and write in it*" — meaning the writing of exercises in just tuning.[9]

The theoretical and practical advocacy of Just Intonation of Hermann von Helmholtz (1821–94) is well known. Less so, and perhaps surprising, is a lengthy

article by James Lecky on temperament in the first two editions (1878–1910) of *Grove's Dictionary,* which compares the various historical intonation systems (including 12-equal) and makes a strong recommendation of seven-limit just tuning. The fifth edition of *Grove's* (1954) contains a collection of entries by Llewelyn S. Lloyd (1876–1956) on the theory and practice of intonation, including keyboard temperaments, that are in a direct line from Helmholtz, and are precise, clear, and elegantly written. Lloyd, who will be mentioned again later, is one of the most eloquent proponents of Just Intonation, in his *Grove's* entry of that title and elsewhere.[10]

At the midpoint of the twentieth century one finds the expected impoverishment of information about intonation and tuning systems, as if 12-equal had wiped out any memory of earlier theories and practices, and indeed the very name "music theory" as it was understood in all its richness and mysterious complexity from the time of the ancient Greeks through Zarlino and Helmholtz was reduced to the mere description of what one can find in a textbook of common-practice-period (i.e., eighteenth- and nineteenth-century) harmony.

The third edition of Walter Piston's *Harmony* (New York: Norton, 1962), known to so many American music students, mentions the harmonic series only as a vague guide to four-voice chordal spacing. Allen Forte's *Tonal Harmony in Concept and Process* (1962; 3rd ed. , New York: Holt, Reinhart and Winston, 1979) makes no mention of it at all, building harmonic structures on iterations of a defined unit interval, the 12-equal semitone. Some harmony textbooks briefly cite the harmonic series to help rationalize the basic harmonic intervals and the major triad. More recently a degree of retrenchment is evident, as in the fourth edition of Piston's *Harmony* (New York: Norton, 1977), where in a new section on "Harmonics, Interval Ratios, and Equal Temperament" (p. 537 ff.) the editor, Mark DeVoto, writes,

> However systematic and simplifying the tempered system may be, … it is only a practical, and therefore a partial, solution to the question of musical tuning (p. 543).

Among mainstream music theorists of the twentieth century with a wider view, we must mention Paul Hindemith, who in Book 1 of his *Craft of Musical Composition* (translated by A. Mendel; New York: Associated Music Publishers, 1937) decried the "clouded qualities" of 12-equal (p. 28), but—as a practical musician and composer—resigned himself to acceptance of it. A more recent, excellent study of the broader theory of music, including acoustics and principles of common-practice harmony, that brings back the monochord as a learning tool is Siegmund Levarie and Ernst Levy's *Tone: A Study in Musical Acoustics* (2nd ed., Kent, Ohio: Kent State University Press, 1980); the authors' intonational "norms" are those of just tuning. Intonational structures are the subject of Easley Blackwood's systematic study, *The Structure of Recognizable Diatonic Tunings* (Princeton: Princeton University Press, 1985). Blackwood gives 4:5:6:7 as "the smoothest possible tuning" for the dominant-seventh chord (pp. 81–2), but denies—calling on dubious intonational analyses of various musical examples—that Just Intonation has ever had any practical utility.[11]

At the turn of the century there is heartening evidence of a more inclusivist intonational spirit at or near the center of music theory itself. One recent work in this spirit is Michael Hewitt's *The Tonal Phoenix: A Study of Tonal Progression through the Prime Numbers Three, Five and Seven* (Bonn: Verlag für systematische Musikwissenschaft, 2000), which finds the harmonic seventh (7:4) implicit in the interval of the augmented sixth within the increasingly complex harmonies of late nineteenth- and early twentieth-century music. Another is *Tuning, Timbre, Spectrum, Scale* by William A. Sethares (Berlin: Springer, 1998), a thorough and elegant presentation of the interaction of intonation and timbre in both melody and harmony, contrasting Western and Indonesian tonal systems.

A third example, a study of perhaps signal importance, is W.A. Mathieu's *Harmonic Experience* (Rochester, Vermont: Inner Traditions, 1997), which traces on a Just Intonation lattice the deep-structure intonation of a selection of music that ranges from the early Renaissance through Mozart and Beethoven to Bartók and popular and jazz harmony. The first part of Mathieu's book is a practical tutor in Just Intonation, where, singing with a drone, the student can gradually learn the affective qualities of just intervals through the seven limit, and— with rather intense application—learn to become aware of commas and other small pitch discrepancies in just tuning that are hidden, though implied, in 12-equal.

Just Intonation in Musical Acoustics

A brief survey of the treatment of intonation in books on musical acoustics is also revealing. Helmholtz's advocacy of just tuning has already been mentioned,

and was based on considerations both of aesthetics and of the physics of sound. Up to the time of the Second World War, studies of musical acoustics gave in general an even-handed treatment of the attributes of the just and 12-equal systems, certainly not minimizing the latter's intonational inflexibility and poor quality of most of its supposedly consonant intervals. One well known work is James Jeans's *Science and Music* (Cambridge, 1937; reprint, New York: Dover, 1968), which rather exceptionally places just tuning *after* 12-equal, as a "further system" included in a chapter on "The Music of the Future" (but restricted to five-limit intervals). In his brief section on "The Equal-Temperament Scale" he writes that

> it was not until about the middle of the nineteenth century that English pianos began to be tuned to equal temperament, and not a single one of the organs shewn in the Great Exhibition of 1851 was so tuned.
>
> The equal-temperament system is now in universal use for keyed instruments, and has the great advantage that music can be played equally well in all keys. On the other hand, its defects are many. … Observations shew that the intervals … which the violinist and singer … produce when they are left to themselves differ greatly from those they produce when accompanied by an instrument tuned to equal temperament (pp. 175–6).

One can find a similar treatment of these matters in Ll. S. Lloyd's *Music and Sound*, and in the valuable but neglected *Music: A Science and an Art* (New York: Knopf, 1928) by John Redfield, at one time Lecturer in the Physics of Music at Columbia University, and a strong advocate of Just Intonation.

Altogether different in attitude is John Backus, in his much used and cited *The Acoustical Foundations of Music* (New York: Norton, 1969): 12-equal is to be the virtually unquestioned standard, with the implication that it is the result of progressivist evolution; the deficiencies of meantone and just tunings are emphasized, while those of 12-equal are minimized. Rather than explaining Just Intonation, Backus refers to the "just scale," of which, for example, the "two sizes of whole tone [are] an annoying complication" (p. 126), and which "has never been of any practical use. It appears in every book dealing with the acoustics of music, where it is given an emphasis it does not deserve" (p. 127). As for 12-equal, "musicians have found [its] scale quite practical. The ability to modulate into any key makes up for its … shortcomings, and it has been quite serviceable for some two hundred years" (p. 129).[12]

More recent books on this subject present a less tendentious account of intonational history and practice, among them Donald E. Hall's *Musical Acoustics* (2nd ed., Belmont, California: Wadsworth, 1991). Hall's broader intonational view is influenced by his involvement as a performer in early Western music:

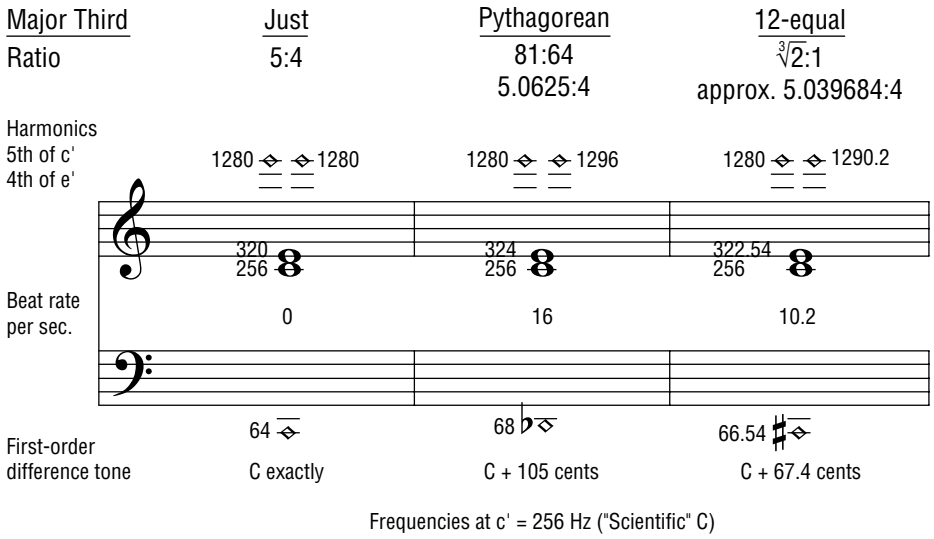
> I testify as a harpsichord and organ player that 386¢ [the size in cents of the pure major third, ratio 5:4] is really a legitimate standard for the major third. The moral is that tuning theory is firmly rooted in the unique problems of keyboard music, and its application to choral or orchestral music must be viewed with great caution. … Equal temperament is only one of many possibilities and for many types of music is not the best choice (pp. 410, 419–20).

A particularly important advocate of an open approach to intonation, but with just tuning in the central position demanded by the laws of physics, is Arthur Benade's *Fundamentals of Musical Acoustics* (New York: Oxford University Press, 1976; reprint, New York: Dover, 1990). Reporting on one of his experiments in the evaluation of the quality of musical intervals as sounded abstractly by tone generators, Benade writes,

> if one sets up two oscillators to give … an equal-temperament interval of exactly 400 cents …, everyone [in the group of subjects] notices the resulting beats, and the musicians in the group will say that an out-of-tune (sharp) major third is being sounded. When I tell [them] that the 400-cent interval is the equal-temperament version of the major third, they typically react with skepticism or dismay. They respond in even more intense fashion to the extremely rough-sounding [Pythagorean major third] of 408 cents.
>
> When I sound [these two] major thirds by means of electronic tone-generators, the usual question is "What makes anyone think that those are acceptable tunings?" My response at this stage is to point out that a laboratory experiment is not quite the same thing as a musical performance (p. 275).[13]

But in fact the deficiencies noted in the mistuning of this and other intervals heard in isolation do disturb musical performances, whether we notice it consciously or not. The physical disturbance to chordal structures caused by deviations from just tuning are of two kinds: first, beats, higher in pitch than the mistuned intervals, that are created by the more-or-less small disagreement in pitch of their adjacent overtones. (Such beating is often quite easy to hear, and is one of the main ways in which one can check and adjust the tuning of a given

Figure 1.



Frequencies at c' = 256 Hz ("Scientific" C)

interval.) The second kind of disturbance is of difference tones, lower in pitch than (or sometimes in the middle of) the mistuned intervals, that disagree with actual chordal pitches and thus muddy, confuse and otherwise interfere with the intended chordal sonority. (Difference tones are especially audible when an interval is sounded by two high-pitched voices or instruments, but in the lower frequencies their presence is usually subliminal.)[14]

A simple illustration of the major third in three different sizes (Figure 1) will serve here as an illustration of these phenomena of harmonic intonation; as the number of intentionally sounded pitches increases, so, too, do the number and complex interactions of the resultant beats and tones.

The strangeness of the minor triad is related to these physical realities: no matter now it is tuned, one or more difference tones will be produced either altogether foreign to the triad, or contradictory to elements of it.

Something must also be said here in general about the laboratory experiments (such as Benade's informal ones mentioned above) that have been conducted to try to establish intonational preferences among musicians and nonmusicians for harmonic and melodic intervals. There have been many such formal experiments over the last century and a half, some of which purport to show the favoring of 12-equal intonation, some of just or Pythagorean interval sizes; all seem to suffer (in my view) from the apparent impossibility of excluding from the experiment the preconditioning of the subject. What result could have been expected if a similar experiment had been carried out in the fifteenth century, when none of its subjects could ever have heard music in twelve-tone equal temperament? **1/1**

Notes:

1. Thorough treatment can be found in John Chalmers's *Divisions of the Tetrachord* (Hanover, N.H.: Frog Peak Music, 1993); Andrew Barker's recent, excellent annotated translation of the *Harmonics* is in his anthology *Greek Musical Writings II: Harmonic and Acoustic Theory* (Cambridge: Cambridge University Press, 1989).

2. Cf. "Intonation (ii)," "Mean-tone," "Pythagorean Intonation" and "Temperaments,' Sec.2, in *The New Grove Dictionary of Music*, 2nd ed., edited by S. Sadie and J. Tyrrell (London: Macmillan, 2001), abbreviated *NG2* below.

3. *The Works of Arnold Schoenberg* by Josef Rufer, trans. by D. Newlin (London: Faber and Faber, 1962), p. 143.

4. For several remarkable early-Renaissance exceptions to this claim, see "Ugolino's 'Intelligent Organist' and the Seventeen-Note Octave" by Margot Schulter, parts 1 and 2, **1/1** 10:3 (2000), pp.l, 4–15, 24 and 11:1 (2002), pp. 8–26. The best evidence of the intended intonation is often the music itself, as can be seen dramatically in the transition from three-limit to five-limit intonation in polyphonic music from roughly 1200 to 1400, mainly in the drastic change in treatment — from dissonance to consonance — of thirds and sixths. Examples can be found in *The Oxford Anthology of Medieval Music*, ed. by W.T. Marrocco and N. Sandon (Oxford, 1977), including the three-limit French and Franconian motets nos. 44 and 47, the "triadic," five-limit English examples nos. 48–50 and 55, and transitional music, including nos. 54, 60, and 77, which clearly have both Pythagorean ditones (81:64) and harmonic major thirds (5:4).

5. Cf. articles on Theinred and Ramos in *NG2* , as well as "Temperaments," Sec. 2. Ramos (or Ramis) receives a substantial if somewhat problematic treatment in Barbour (*Tuning and Temperament,* pp .25–6, 89–92). A full presentation of the medieval and Renaissance monochord can be found in *The Theory and Practice of the Monochord* by Cecil D. Adkins (Ph.D. dissertation, State University of Iowa, 1963). The quarter-comma meantone temperament, usually considered the "standard" meantone, is characterized by pure major thirds, with minor thirds and perfect fifths that are one-fourth syntonic comma (just over 5 cents) narrow; it is a remarkably good approximation to true Just Intonation.

6. *The Art of Counterpoint*, trans. by G. Marco and C. Palisca (New York: Norton, 1968), p. 31.

7. The controversy is recounted in Claude Palisca's *Italian Renaissance Musical Thought* (New Haven: Yale University Press, 1985), pp. 257–79; the quote, from Galilei's *Discorso intorno all' opere di Gioseffo Zarlino da Chioggia* (1589), is on p. 275. Part of Murray Barbour's argument for 12-equal assumes equal-temperament fretting of the fretted instruments of the fifteenth and sixteenth centuries — lute, vihuela, guitar, cittern and a few others — citing *inter alia* the long-known practical ratio of 18:17 (98.9 cents) for the semitone. But the frets of the first three of these instruments (including the guitar of the time) were of tied-on gut, and thus adjustable. As for those with fixed, inlaid frets, pictures show that on at least some of them from that period frets were set at nothing like equal-semitone distances. (See, for example, photographs and drawings in *NG2* illustrating the entries "Cithrinchen," "Cittern" and "Orpharion.") Nor do fixed, 12-equal frets mean a lack of intonational flexibility, as any good guitarist will confirm.

8. "Mozart's Teaching of Intonation" by John Hind Chesnut, *Journal of the American Musicological Society* 30:2 (1977), pp. 258–71.

9. *Musical Composition* (London, 1911), p. 13; the last eight words here are in boldface type in the original. Among the prominent works of music theory of this era that should be mentioned as advocating Just Intonation are *The Philosophy of Music* by William Pole (1814–1900) (London, 1879; 6th ed., 1924) and *The Nature of Harmony and Metre* by Moritz Hauptmann (1792–1868) (1853; edited and trans. by W.E. Heathcote, 2nd ed., London, 1893; reprint, with a new foreword by Siegmund Levarie [New York: Da Capo, 1991]). John Curwen (1816–80), who will be mentioned again in Part II, developed a theoretical rationale for the Just Intonation basis of his Tonic Sol-fa method, used throughout the British Empire for over a half century to teach choral singing. Not without significance for the time, too, is the title of an evidently much used textbook, *A Theory of Harmony, founded on the Tempered Scale* (London, 1881; six subsequent editions) by John Stainer (1840–1901).

10. *On the Sensations of Tone as a Physiological Basis for the Theory of Music* by Hermann von Helmholtz. 2nd English ed., trans. with notes and an appendix by Alexander Ellis (London, 1885; reprint, New York: Dover, 1954).

Grove's Dictionary of Music and Musicians, 1st ed., edited by George Grove; 2nd ed., edited by J.A. Fuller Maitland (London, 1878–90; 1904–10). The first quarter or so of Lecky's article is retained in the 1927 third edition of *Grove's* edited by H.C. Colles. (The fifth edition was edited by Eric Blom.)

Lloyd's writings on this subject are many, and a representative selection of them has been reprinted in *Intervals, Scales and Temperaments* by Ll. S. Lloyd and Hugh Boyle (2nd ed., New York: St. Martin's Press, 1979). Lloyd, a physicist as well as musician, himself wrote two books, *Music and Sound* (Oxford, 1937) and *The Musical Ear* (Oxford, 1940). For "seven-limit just tuning," see the following note .

11. Zarlino limited his consonant intervals to those of what he called the *senario* (literally the numbers 1–6), or the intervals created by the first six harmonics. Seven-limit just tuning admits the next higher prime number, 7, and the intervals created by the addition of the seventh harmonic. Of these, theorists have paid most attention to the so-called "harmonic seventh," 7:4, particularly when combined with the just major triad in the dominant-seventh type chord, 4:5:6:7; other septimal intervals, however, the subminor third, 7:6, and the diminished fifth, 7:5, are also part of this chord; adding the major ninth, 9:4, to it gives directly or by inversion all the basic seven-limit intervals.

In addition to Zarlino, theorists opposed to 7-based intervals include Rameau, Hugo Riemann, Hindemith, who wrote that they "cannot be used" in harmonic practice (*Craft*, p. 37), and Levarie and Levy, who prohibit them as "stand[ing] outside the common language" (*Tone*, p. 32).

Older theorists who approved of 7 include Mersenne, Euler and Tartini. J.S. Bach's pupil Johann Philipp Kirnberger created a special notation for the harmonic seventh. Further information on this controversy can be found in M. Joel Mandelbaum's *Multiple Division of the Octave* (Ph.D. dissertation, Indiana University, 1961), pp. 53–68; Harry Partch's *Genesis of a Music*, 2nd ed. (New York: Da Capo, 1974), pp. 381–95; and in Martin Vogel's *Die Natureseptime: ihre Geschichte und ihre Anwendung* (Bonn: Verlag für systematische Musikwissenschaft, 1991).

12. The "just scale," an artificial construction whose seven diatonic pitches are those of the purely tuned tonic, dominant and subdominant triads of the major modes has, in fact, as Backus states, never been of any practical use, but has been recruited at times to "prove" the "impossibility" of Just Intonation. A practical just scale will have to have, minimally, two intonational values each for the second, fourth and sixth degrees. Lloyd debunks the so-called "just scale" in the oddly titled chapter "Just Temperaments" in *Intervals, Scales and Temperament*, as well as in the "Just Intonation" article in the fifth edition of *Grove's*.

(text continued on page 24)

Performance: Concert in Celebration of the Chrysalis New Music Studio — Instruments and Music by Cris Forster

On October 4 and 5, 2003, the Chrysalis New Music Studio opened its doors to introduce itself and present some new music to an intrigued public. This studio, located in San Francisco's South-of-Market neighborhood, is the new performance and rehearsal space of the Chrysalis Foundation (see `http://www.chrysalis-foundation.org`), "a nonprofit organization that supports the creation of new acoustic musical instruments, encourages the composition of music in alternative tuning systems, and promotes live performance of this music." It appears that the Chrysalis Foundation is currently devoted to supporting the pioneering work of a single individual who does all of these things extraordinarily well: Cris Forster.

I have known Cris for decades, but he was doing music long before. Working with the Harry Partch Foundation (as curator and performer, 1976–1980), Cris became passionately inspired by certain of Partch's ideals, and has been building instruments, composing and performing acoustic music in Just Intonation ever since. His array of instruments outgrew his space at home, and this new studio at last provides an environment where all his instruments can be together, set up, ready to play.

This studio started as one of those South-of-Market industrial spaces — basically a long boxy space. But Cris and the foundation put a lot of work into transforming it into a very nice studio, with a whole new floor and a small anteroom that acoustically insulates the performing area from street noise. Skylights give a nice ambiance, and overall it has a pleasant, airy feel, with good acoustics for performing before a small audience.

The instruments reflect Cris's consummate craftsmanship and attention to detail; each is a work of art in its own right. Some of his instruments are similar to those of Partch, but with significant improvements, sturdier construction, and finer finish. (While Partch described himself as "a philosophic music man seduced into carpentry," Cris worked for many years as a piano technician, a valuable background for his instrument building.) His Harmonic/Melodic Canon follows Partch's basic layout of a box with strings, but Cris put small holes in his soundboard for placing individual, adjustable bridges for each string, and his choice of a 1-meter string length, with centimeter markings on the soundboard, allow these bridges to be positioned precisely. (Cris also has a Bass Canon, of similar design but larger, which was not played in this performance.) And Cris's Diamond Marimba is comparable to Partch's, but Cris extends the tonality diamond to the thirteen-limit, and adds a few more bars for convenient tones. Also Cris has a Bass Marimba, as did Partch, but Cris developed his own technique of tuning the lowest overtones of each bar to octaves above the fundamental, giving his instrument a unique and powerful sound.

Photo by Will Gullette

Harmonic/Melodic Canon

Other instruments are completely new in concept. The "Chrysalis" has metal strings on both sides of a large rotating wheel. The bridge is an off-center hub, giving a range of string lengths; the hub on the other side is offset in the opposite direction. In performance, this instrument has great visual impact, as Cris spins the wheel to different positions to access different strings. The "Glassdance" is based on the glass harmonica, but instead of having fixed wine glasses that the player strokes, here the stems of the glasses and goblets are mounted through a vertical panel with a mechanism behind that keeps the glasses continuously rotating; the player just touches them (using chamois finger covers dipped in alcohol) to get a sound. Cris went to great

lengths to ensure that the machinery cannot be heard; you hear only the ethereal tones of the glasses.

A relatively recent instrument is "Just Keys," a piano that Cris has restrung and retuned, so that two midrange octaves each cover seventeen keys, higher octaves the usual twelve keys, and the lowest octave only ten keys. (Cris explained that the constraints of the iron harp of the piano limited the possibilities.)

The concert began after an informal reception featuring an impressive array of delicious appetizers. With all the chairs full and a few more people standing, Cris came out and bowed respectfully to the audience (a gesture repeated by each performer later).

The first two selections were from an early work that I had enjoyed in its entirety many years before: *Song of Myself: Eleven Intoned Poems of Walt Whitman.* These poems are delivered by Cris using "intoned speech," a style of speaking on specific pitches (while avoiding any semblance of singing) that Harry Partch incorporated into many of his early works. Some listeners find this approach a bit uncomfortable because it's not speaking and it's not singing. However, being familiar with the style, I feel that Cris uses it effectively to communicate the drama and emotion of the poems.

Cris started with "A child said 'What is the grass?'" accompanying himself on the Chrysalis, which had been tuned so that he could play melodic passages by stroking particular sections of the wheel. With the other poem, "The spotted hawk swoops by and accuses me," Cris plays the Harmonic/Melodic Canon, featuring a descending motif. One particularly memorable effect is where he plucks a string and presses on the other side of the bridge, emulating a haunting hawk cry.

Photo by Will Gullette

Chrysalis

The rest of the concert comprised selections from a large work in progress, *Ellis Island/Angel Island: A Vision of the American Immigrants*. Cris was born in Brazil, then moved to Germany, before coming to the United States, and this work draws not only on his own immigration experience but also on his strong feelings about how immigration has always contributed an essential ingredient to the mix that is America. Expecting more intoned text with accompaniment, I was surprised to find that these selections (maybe the whole piece?) are entirely instrumental.

Cris plays Just Keys, his modified piano, in the first selection, "The Letter," and also in the third selection, "In the Park." (Cris earned a degree in piano performance.) These two pieces seemed similar in texture, with lovely melodies and the clear harmonies of his justly tuned piano; the overall effect was reminiscent of French Impressionist pianism.

In "Lullaby," the second selection, Heidi Forster (Cris's wife) plays Glassdance. The ethereal sounds of the glasses gave this melodic piece a plaintive quality. (I think I was not alone in finding that sound entrancing.)

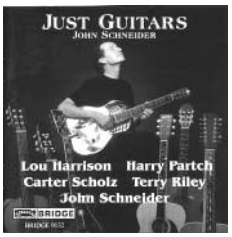
"Time Dance" features Cris on the Diamond Marimba. This piece was very rhythmic and percussive, and explored some of the small intervals that result across the tonality diamond. I was reminded of Partch; perhaps this is unavoidable on an instrument with such a characteristic sound.

The final piece, "The Harbor," at last combined instruments: Cris played Diamond Marimba, Heidi played Glassdance, and Robert Danielson played the Bass Marimba. The rich interplay among these three very different sounds was exciting and effective. This was a rousing finish to the concert, and left me wanting to hear more multi-instrument compositions. Perhaps this new studio will encourage creating more such ensemble pieces.

At the conclusion of the concert the enthusiastic audience expressed their appreciation with a standing ovation. (By request of the performers, there was no applause between pieces.) And with the successful opening of the Chrysalis New Music Studio, we can look forward to many more performances to come. Meanwhile, Cris keeps composing, following his own vision of new music. As Cris said, "The blank page awaits..." **1/1**

—David Canright

John Schneider: *Just Guitars*. Bridge 9132. Bridge Records, Inc. 200 Clinton Avenue, New Rochelle NY 10801 (available from the Just Intonation Store).



To begin with, don't believe the title of this CD – it is not just guitars. True, several different guitars are used on the many varied tracks, and yes, each guitar is tuned in Just Intonation. But besides just guitars you also get some vocals and Harry Partch instruments — the Kithara (on loan) and the Diamond Marimba (a replica) — on the Partch pieces. And some of the pieces were originally for piano, then adapted by Schneider for guitar.

Indeed, one of the delights of this disc is the wide variety of styles and textures it comprises. The bulk of it is nine tracks (totaling 26:46) of Lou Harrison compositions from 1952 to 2002, and seven tracks (15:16) of early (1942 – 1949) Partch pieces for intoned voice with accompaniment. But there are also adaptations of portions of Terry Riley's *Harp of New Albion*, and pieces by Carter Scholz and by John Schneider himself. Altogether this adds up to over an hour of good listening. The program notes are extensive and interesting, and include tuning diagrams and photos.

The disc opens with "Rhythmicon" by Carter Scholz, based on the simple idea of playing each of the seventeen lowest tones of the harmonic series, each at a rate inversely proportional to the pitch. For example, the fifth harmonic is played once every five beats, and so on. Described this way, it might seem boring, but what keeps it interesting is the constantly changing texture as voices enter and depart and the cross rhythms bounce off each other. (As it happens, many years ago I had recorded a very brief guitar piece based on the same idea, but using only the prime harmonics up to 13; Scholz's piece is much richer and more fun in its thorough development.)

Next comes *Scenes from Nek Chand* by Lou Harrison, a series of three melodic pieces, which, with the date 2002, must be among the last of his compositions. Schneider plays a specially fretted National Resophonic guitar (like a dobro) using a six-tone harmonic scale (6 – 11), and the less familiar sounds of 7 and 11 are prominent in the (mostly scalewise) melodies. Nominally inspired by a sculpture garden and Hawaiian music, these three selections are very much "of a piece" due to using the same six-tone scale in similar textures.

Three individual Harrison works for instruments other than guitar are next. "Tandy's Tango" — for Tandy Beal — is a lot of fun (who can resist a tango?), with a strong chromatic theme in an overall minor tonality. Although it was originally for equally tempered piano, here Schneider uses his Vogt guitar with the movable frets tuned to a five-limit C major scale. *Incidental Music for Corneille's Cinna*[1] was also originally for piano, in this case tack piano in the seven-limit tuning $^{1}/_{1}$, $^{16}/_{15}$, $^{10}/_{9}$, $^{7}/_{6}$, $^{5}/_{4}$, $^{4}/_{3}$, $^{25}/_{18}$, $^{3}/_{2}$, $^{8}/_{5}$, $^{5}/_{3}$, $^{7}/_{4}$, $^{15}/_{8}$. The fourth movement, designated "medium slow," is played on the same guitar with the frets appropriately moved. This piece employs some very interesting harmonic movement. Originally for harp, "Palace Music" is a short melodic exploration in the scale $^{1}/_{1}$, $^{25}/_{24}$, $^{5}/_{4}$, $^{4}/_{3}$, $^{3}/_{2}$, $^{5}/_{3}$, $^{9}/_{5}$.

I was surprised that the next pieces were already familiar from Schneider's CD Lou Harrison: *Music for Guitar and Percussion*,[2] recorded in 1985 and 1989, but these, of course, are new recordings. I'm not complaining; these are very enjoyable pieces. In "Plaint & Variations on 'Song of Palestine,'" the performance of the Plaint seems very similar to the earlier recording but sounds a bit warmer here, and the Variations is faster, which works better. The "Serenado por Gitaro" is noticeably more expressive than the earlier version.

Next come the Partch pieces, featuring Schneider's warm baritone voice intoning very much in the style of Harry Partch. (Note that Partch detested the "bel canto" ideal of singing as an unnatural distortion of the language; instead, he insisted that the words be presented as in a regular speaking voice, but spoken on the particular tones of the score: intoned speech. For a listener expecting singing, this can be a bit disconcerting at first.)

"Letter from Hobo Pablo" sets a humorous letter from one of Partch's hobo pals to accompaniment by Adapted Guitar I (a reconstruction that Schneider has used previously for certain Partch pieces) and Kithara. "December 1942" comprises three poems, "Come Away, Death," "The Heron," and "The Rose," for voice and Adapted Guitar I, all sensitively performed. Also consisting of three poems, "Three Intrusions" actually has two of the very same poems ("The Rose" and "The Crane" [aka "The Heron"], along with "The Waterfall"), but this arrangement is from 1949 instead of 1942, and features accompaniment on Adapted Guitar II (a slide guitar) and Diamond Marimba. With the juxtaposition of "The Rose" (1942) followed immediately by "The Rose" (1949), the listener can appreciate how Partch's expanded instrumental resources allowed a complete reconception with a richer texture and more varied harmonic motion.

I never would have imagined that Terry Riley's virtuosic piano work *Harp of New Albion* could be adapted to guitar, but Schneider has done so very successfully, for two out of the original eleven movements: "New Albion Chorale" and "Cadence of the Wind." Admittedly, the guitar version of the Chorale does not remind me of the original. But the notes explain that the score gives only "a series of chords" so that different performers may come up with very different sounding realizations. (Since the original "Cadence" consists largely of playing the chord progressions, the guitar version was very recognizable.) The freedom inherent in the score comes through in Schneider's very expressive renderings.

The disc closes with "Lament" by John Schneider himself, in Pythagorean tuning. This piece, like the Riley ones, has a very free feel, particularly rhythmically, and allows Schneider's sensitivity to shine. I had not realized that Schneider, in addition to his many other talents, was also a composer; in fact, this is one of my favorite tracks on the CD.

This CD extends the territory explored by John Schneider and his "Just Strings" ensemble in new and exciting directions, and is a very welcome addition to my collection. **1/1**

—David Canright

Notes:

1 The complete piece, played on the tack piano, is available on *Lou Harrison: Complete Harpsichord Works, Music for Tack Piano and Fortepiano…*; reviewed in **1/1** 11:3.

2 Reviewed in **1/1** 7:3.

Lou Harrison—The Louisville Orchestra. First Edition Music FECD-0014. *Suite for Symphonic Strings, Strict Songs I–V for Eight Baritones and Orchestra.* The Louisville Orchestra, Robert Whitney Conductor, with members of the Southern Baptist Theological Seminary Choir (available from the Just Intonation Store).

This is not so much a review in the usual sense as an appreciation of the rerelease of a seminal work of twentieth century music in Just Intonation: Lou Harrison's *Four Strict Songs for Eight Baritones and Orchestra.* The *Strict Songs*, begun in 1951 and completed in 1955, under a Louisville Orchestra commission, were Harrison's first significant completed work in Just Intonation and, as far as I am aware, the first major just composition in the twentieth century by a composer other than Harry Partch. They were originally recorded in 1956 and released on the orchestra's First Edition Records LP series, and have long been out of print.[1] The CD reissues this historic recording, along with a 1961 recording of Harrison's *Suite for Symphonic Strings*.

The songs are scored for a chorus of eight baritones, accompanied by what Harrison would later call a "selected orchestra": strings, trombones, piano, harp, and percussion (timpani played with the fingers, tuned water bowls, and maracas). In other words, he chose from the standard Western orchestra only those instruments that could be retuned (piano, harp, timpani, plus the water bowls) or those whose intonation was entirely at the command of the performers (the strings and trombones).

Each of the four songs celebrates a different quality: 1. "Holiness"; 2. "Nourishment"; 3. "Tenderness"; and 4. "Splendor," using an analogous verse form. The lyrics are the composer's own poems:

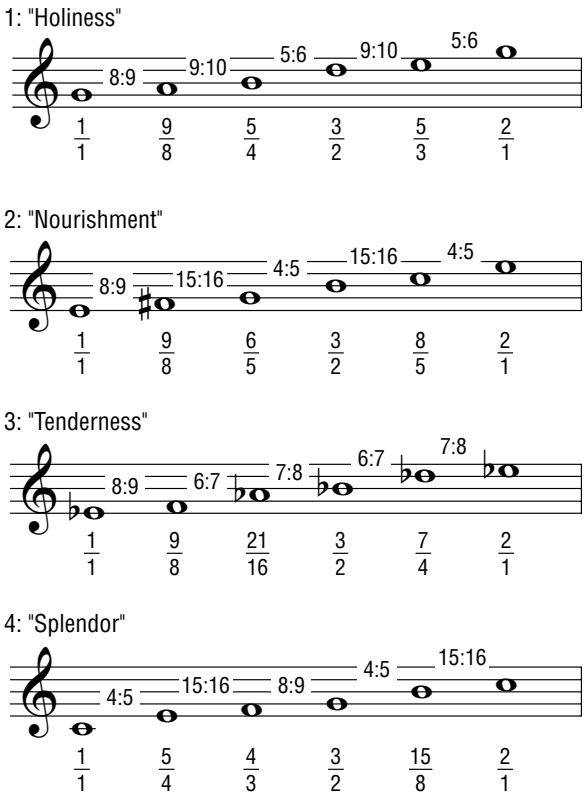
> These are making-things-right-&-good-again songs, after examples of *Hozhonji*—Songs from Navajo. Their tone relationships are simple and exact, their forms exact on a continuous pulse, and their words celebrate our receptions of, offerings of, and relationships to the four divisions of things of which we have awareness; 1. plants (on which we are dependent, our consorts) 2. animals (our symbiotes) 3. heavens (we live in air—which goes on out forever and includes the sun) 4. minerals (with which we have no organic relationships, in metals) which constitute our earth. They are my findings, from grand example, of the-way-things-are-ness.

Harrison's use of the term "strict" here probably simply refers to the songs being in fixed scales:

> After only a brief study of intervals it becomes clear that there are two ways of composing with them: 1: arranging them into a fixed mode or gamut and then composing within that structure. This is Strict Style and is the vastly predominate world method. However, another way is possible—2: to freely assemble or compose with whatever intervals one feels that he needs as he goes along. This is Free Style…[2]

The tunings of the songs comprise four fixed pentatonic scales (see Figure 1); numbers one, two, and four are five-limit—some of the most basic scales from the world's musical palette; number

Example 1. Tunings of the *Four Strict Songs*



three is a typical seven-limit *slendro* scale such as Harrison would later use for a number of Javanese gamelan built for him by William Colvig. The four scales each use a different $^1/_1$, placing each song in a different key as well as a different scale type, and enabling the four scales to coexist on the piano keyboard. Reduced to a common $^1/_1$, the scales comprise the twelve-tone gamut shown in Figure 2. The songs demonstrate what a melodically gifted composer — and the twentieth century produced none more gifted than Harrison — can achieve with such deceptively simple materials. Each song has a distinct mood, determined, at least in part, by its particular scale: the two songs based on anhemitone (*slendro*-type) scales, one and three, are energetic and celebratory; two and four, which use hemitone (*pelog*-type) scales, are languidly ecstatic.

As is well known, Harrison first learned about Just Intonation from Partch's *Genesis of a Music*, published in 1949. It is remarkable, then, how rapidly he assimilated its lessons and created a style of music in Just Intonation that was wholly his own. The songs show no sign of the "high modernist" styles that characterize his work from the 1930s and '40s. The dissonant counterpoint of Cowell and Ruggles and the twelve-tone serialism of Schoenberg have been replaced by flowing lyrical melody and simple, consonant harmony. The one element of continuity with Harrison's earlier work is vigorous rhythm and colorful percussion, characteristic of the "abstract" (unpitched) percussion ensembles he created, along with John Cage, in the 1940s. This is particularly the case in songs one ("Holiness") and three ("Tenderness"). If the songs show no influence of Harrison's modernist past, they show no influence of Partch, either, aside from their using just tunings. The words are sung, rather than intoned, and there is no attempt to preserve either the rhythm or intonation of speech. The most obvious influences are Native American (song one and especially song three) and East Asian (songs two and four).

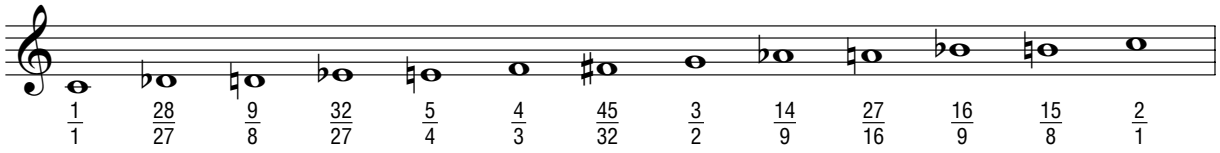
The quality of both the original recording and the remastering are excellent, and there has fortunately been no attempt to convert the original mono recording into "fake stereo." My only complaint about the rerelease is that the booklet omits information about the tunings that was included in the liner notes of the LP, while wasting several pages reproducing the composer's calligraphic correspondence. **1/1**

Notes:

1. A 1992 revision of the *Strict Songs,* for mixed chorus, was released on the Musical Heritage Society CD: *Lou Harrison: a Birthday Celebration,* 513616L, but this CD, like most MHS releases, is virtually unobtainable.

2. Harrison, Lou. *Lou Harrison's Music Primer.* New York: C.F. Peters Corp. 1971. p. 6.

Example 2. Shared gamut of the *Strict Songs*



*(**Theater**, continued from page 8)*

as a rhythmic score with accents. I played a steel-tube metallophone tuned to Barbour's (rearranged) Chromatic ($^{1}/_{1}$, $^{9}/_{8}$, $^{8}/_{7}$, $^{4}/_{3}$, $^{3}/_{2}$, $^{27}/_{16}$, $^{12}/_{7}$, $^{2}/_{1}$), which has a very narrow $^{64}/_{63}$ interval of 27 cents between tones two and three (and six and seven). After several rehearsals of improvisation on the rhythmic patterns I came up with a best version, which, accompanied by slit drums, bamboo, and long gongs and danced beautifully by four athletic teenage girls, was one of the high points of the day — a blend of Renaissance gamelan with a very crunchy tetrachordal scale.

Reflections

All the music created for these theatre productions was accessible, relatively easy to play and enjoyable to listen to. This is as it should be in youth theatre with amateur players. Melody, rhythm, texture and timbre made up the essential elements. Now that I've put the busy summer season behind me I can return to my building schedule. My current projects include an Eikosany marimba, a bass marimba, a quartet of bowed zithers and more found metal and wood percussion. I have recently immersed myself in Erv Wilson's Eikosany tunings, which offer much in the way of harmony and progression and I have rendered several pieces electronically with a view to scoring for my own and for conventional instruments. I'm also busy sampling my hand-built instruments and processing the sounds electronically using digital signal processing software. My intention is to produce a suite of three electroacoustic pieces: "Wood," "Metal," and "Glass." All of which should keep me busy until next summer's theatre and festival season. **1/1**

*(**DNA**, continued from page 11)*

5. Deamer published his first speculations and attempts to represent genetic code as music in 1983, and later created two albums of his own DNA-based music: Deamer, David. "Music: the Arts," *Omni Magazine*. April 1983. p. 28.)

6. Alexjander, Susan. "The Infrared Frequencies of DNA Bases, as Science and Art." *Engineering in Medicine and Biology Magazine*, Institute of Electrical and Electronic Engineers, Inc. March/April 1999. pp. 74 – 75.

7. This CD and mp3 samples are available at the composer's personal website: `http://www.healingmusic.org/SusanA/`

8. Alexjander, S. "The Infrared Frequencies of DNA Bases…" p. 78.

9. Personal email correspondence, March 16, 2004.

10. Alexjander, S. "The Infrared Frequencies of DNA Bases…" p. 78.

*(**Persistence**, continued from page 18)*

13. Benade seems to have used some 7-based intervals in his listening experiments (*Fundamentals*, pp. 274, 295). Helmholtz (p. 195) and Hall (p. 401) say that 7-based intervals are not accepted or used as consonant, but Ellis, Helmholtz's translator and annotator, evidently favored the harmonic seventh in the dominant seventh chord (cf. Partch, *Genesis*, p. 395); for Redfield, too, it was a valid harmonic resource.

14. These unavoidable problems of tuning are best clarified by Helmholtz (*Sensations*, pp. 313 – 14 and chapters 7 – 8); Lloyd (*Music and Sound*, chapters 4 – 5); Benade, in his earlier *Horns, Strings and Harmony* (Garden City, N.Y.: Anchor/Doubleday, 1960), pp. 80 – 83 and chapter 5; and in *Music, Sound and Sensation: A Modern Exposition* by Fritz Winckel, trans. by T. Binkley (New York: Dover, 1967), pp. 134 – 41.

Address Changes: a Reminder

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