Appendix Two

FREQUENCY AND TUNINGS CHARTS

This appendix contains two charts designed to map out the territory of the audible sound spectrum. It supplements information in Chapter 3, "Tuning Systems and Pitch Layouts."

FREQUENCY CHART

The chart on the following two pages shows the pitch name, frequency, wavelength, and musical staff notation for frequencies within the hearing range. It uses several standards and conventions addressed in the following paragraphs.

Pitch Names

There is substantial agreement in western musical practice as to how to name the pitches within the octave, using the familiar note names C, C#, D and so forth. But distinguishing between like-named pitches in different octaves remains confusing. Quite a few systems have been used to give each pitch a unique label. The one given in the left hand column of this chart, using capital letters with subscripted numerals to denote octaves, has become the most commonly used among acousticians; it has been accepted by the American Standards Association; and it is the one we have used throughout this book. In the adjacent column the chart gives note names according to the Helmholtz system, since this system appears in widely used musical sources such as *Grove's Dictionary of Music and Musicians*.

Pitch Standards

The frequency of A above middle C is normally used as a benchmark for fixing musical pitches to a standard. Over the centuries the frequency of that A has ranged from below 400Hz to 455Hz and higher. The International Organization for Standardization has set the modern pitch standard at A=440Hz (1955; reaffirmed in 1975), and this chart is predicated upon that standard.

Just vs. Tempered Tunings

The chart presents frequencies for pitches in 12-tone equal temperament, despite calls from many thoughtful musicians to lessen the dominance of 12-equal. The reason for using 12-equal here is that it presents a familiar frame of reference, while the just systems in use are too diverse to allow for standardized presentation. (The scales chart following this one presents a better picture of just relationships.)

Sharps and Flats

To keep the chart to a manageable size, only the "natural" notes are given. Instructions for finding frequencies and wavelengths for the sharps and flats appear at the end of the chart.

Air Temperature

The wavelengths are accurate for typical room temperature conditions. Instructions for estimating wavelengths at other temperatures, including the slightly elevated temperatures typical in breath-blown wind instrument tubes, appear at the end of the chart.

COMPARATIVE TUNINGS CHART

Following the frequency chart is a comparative chart of tuning systems, showing how various musical scales compare to the most basic just intervals, to the familiar intervals of 12-tone equal temperament, and to one another. It contains the historical European quarter-comma meantone scale system; three raga tunings and blues intonations as representatives of tunings outside the European tradition; Harry Partch's "monophonic fabric" as a model of the work of a 20th-century theorist; plus a couple of higher-order equal temperaments.

The chart presents pitch *relationships* only. Intervals between pitches are shown, but actual frequencies are not specified. For comparative purposes, all the tuning systems are built over a common, unspecified root tone.

Each tuning appears on the chart as a ladder, with the pitches laid out in ascending order, spaced vertically according to interval size. Each tuning is given over a range of one octave. (The one-octave range is adequate if you assume that the same set of intervals are to be duplicated in other octaves. That is true of most tuning systems, though not all.) To help demarcate the tonal territory, horizontal reference lines cross the entire chart at heights corresponding to certain basic just intervals: the major second 9:8, the major third 5:4, the perfect fourth 4:3, the perfect fifth 3:2, and the major sixth 5:3. The pitch locations are marked by a short, bold horizontal line across the ladder. In cases where the scale degrees are flexible or ambiguous, the stippling within the ladder indicates the relevant pitch regions. The notations surrounding each scale degree are as follows:

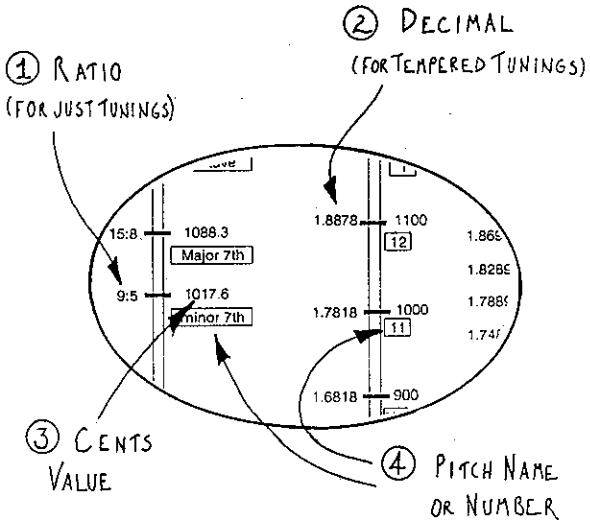
1) For tunings based in just intonation, ratios appear to the left of each scale degree mark. The ratio represents the frequency of the given scale degree over the frequency of the scale's first degree. It is the number by which the frequency

of the first scale degree must be multiplied to obtain the frequency of the higher degree in question.

2) For tempered tunings such as the equal temperaments, the ratio to the left of each scale degree mark is replaced by a decimal number between 1 and 2. Like the ratios, the decimal is the number by which the frequency of the first degree must be multiplied to obtain the frequency of the degree in question.

3) To the right of each scale degree mark is a number representing a cents value. The cents system is a widely used method for precise indication of musical intervals. It uses a basic unit called the cent, defined as 1/100th of a semitone in 12-tone equal temperament. The octave thus comprises 1200 cents. Aside from being useful in its own right as a calibrator, the cents value provides easy comparison to familiar intervals in 12-tone equal temperament. For example, you can recognize that a tone in some exotic tuning standing at 270 cents above the tonic is 30 cents (3/10 of a semitone) below the minor third in 12-equal, since by definition the 12-equal minor third is 300 cents.

4) For some of the tunings a scale degree name or number appears in a box to the right and below the scale degree mark.



The Tunings

Five-limit Just

Five-limit just intonation is usually considered to be the theoretically ideal intonational basis for music in the European tradition, and some other musical traditions as well. The designation "5-limit" refers to the fact that 5 is the largest prime number required in either the numerators or denominators to build the ratios of the tuning. (Roughly speaking, the larger the limit number, the more harmonically complex and potentially dissonant will the intervals of the tuning be perceived.) The sound or mood of an accurately tuned 5-limit is usually described as sweet and restful. A common form of 5-limit is presented here; other variations are possible.

Twelve-Tone Equal Temperament

Twelve-equal, dividing the octave into twelve equal steps, is the standard tuning in current Western music. It has found favor over other equal temperaments because it is the smallest number of equal divisions per octave that does a fairly good job of approximating the important intervals of 5-limit just.

Quarter-Comma Meantone / 31-Tone Equal Temperament

Quarter-comma meantone, an unequal temperament of twelve tones per octave, was one of the widely used temperaments prior to the ascendance of 12-equal in the 18th century. The early unequal temperaments sought to achieve excellent approximations of just intervals in some keys, at the cost of poor approximations in some other keys (which were then avoided).

It happens that the mathematical operation used to generate quarter-comma meantone, if carried a bit further, can generate something indistinguishably close to 31-tone equal temperament. Thus, quarter-comma meantone can be considered to be a subset of 31-tone equal temperament. For that reason, 31-equal and quarter- comma meantone are presented on a single axis on the chart here. The cents values and scale degree multipliers given are correct for 31-equal except on the twelve meantone degrees, where the correct meantone values are given. The two differ by no more than a little over a cent.

Nineteen-Tone Equal Temperament

Nineteen-tone equal temperament has been cited as a practical option for moving to higher-order equal temperaments, since it approximates just intervals nicely, and can be accommodated using keyboard layouts and notational systems close to the familiar forms used for twelve-equal.

Monophonic Fabric (Partch's 43)

Harry Partch set forth this 11-limit scale as his most comprehensive tonal resource. For the reasoning behind his choice of intervals, read his *Genesis of a Music*.

Blues

Blues is an exotic and very subtle approach to intonation as long as it is played on an instrument that allows full intonational expression. It has provided a major counterbalance to the predominance of 12-equal in European and American music of this century. Blue tonalities often use sliding pitches; minute tonal inflections have musical meaning; and pitches can be hinted at (through bending) without actually being sounded.

North Indian Ragas

Dr. David Courtney of Sur Sangeet Services in Houston, Texas, provided the pitch data given here for three selected North Indian ragas. He obtained the data through a set of computer-based samples used in conjunction with intonational evaluations by trained Indian musicians.

Ragas are more than scale systems. Each raga has diverse musical and extra-musical associations, which of course are not reflected on the chart.

The pitch set associated with a particular raga may have five, six or seven tones. Frequently, however, the tones are not discreet, but represent only something like a resting point in a broader pitch region through which the tone can slide. In some cases, as with the *Suddha Kalyan* on the chart, an entire region may be one of sliding pitch, with no recognizable resting point at all. As with the blues, the flexible tones within the ragas are indicated on the chart as gradations rather than fixed points.