

## On Teaching

by Gavin Black

### Intervals, tuning, and temperament, part 1

In this series of columns, I want to share a few ideas about how to introduce aspects of tuning and temperament to students. In so doing I will unavoidably simplify a very complicated subject. My hope is not to oversimplify, but to simplify in a way that completely avoids inaccuracy.

Most organists do not have to do any tuning as such, or at least can do without tuning if they prefer. However, it is very convenient indeed for any organist to be able to touch up a tuning, or to help out with tuning, or to do a bit of tuning of a chamber organ. And of course anyone who plays harpsichord has to expect to do all or most of their own tuning. Beyond that, however, it is very useful and enlightening for any organist to understand the role of tuning, temperament, and the nature of different intervals in the esthetics of organ and harpsichord sound and repertoire, and in the history of that repertoire.

Tuning is one of those areas that many people—including, especially, beginning students—tend to find intimidating. It certainly can be complicated, and can, in particular, involve a lot of math, some of it rather arcane (the 12th root of 2 can be involved, for example, or the ratio between  $2^2$  and  $1.5^{12}$ ). However, the concepts are straightforward, if not exactly simple. I will start from the very basic here—indeed with the question of what a musical sound is, since everything about tuning arises out of that. I myself, who have tuned constantly for over thirty years, still find it useful to revisit the most basic notions about tuning.

#### What is a musical sound?

Sound travels in waves, and those waves have peaks and valleys spaced at regular intervals. When the peaks and valleys of a sound wave traveling through the air arrive at a solid material they will tend to make it vibrate. Some materials vibrate inefficiently (a block of granite, for example, or a piece of fabric); some, like an eardrum or the diaphragm of a microphone, vibrate very efficiently indeed. In any case, a sound wave will tend to make a solid vibrate at a speed that corresponds to how often—how frequently—the peaks and valleys of that wave arrive at the solid. This is what we call the frequency of the sound: a very common-sense term. The wavelength of a sound wave is the distance between two successive peaks. The longer this is, the less frequently those waves will arrive at a given object (say, an eardrum), the more slowly they will make that object vibrate, and the lower the frequency of that sound will be. The shorter the wavelength is, the more frequently the peaks will arrive, the faster the vibrations will be, and the higher the frequency will be. This assumes that these two waves are traveling at the same speed as each other. It is also true that the peaks of any given sound wave will

arrive at a given place more frequently if that wave happens to be traveling more quickly and less frequently if that wave is traveling more slowly. (This is an important point to remember in connection with the practical side of organ tuning, as I will mention later on.)

It is the frequency of a sound that humans interpret as pitch. A sound wave that makes our eardrums vibrate faster we describe as “higher” in pitch than one that makes our eardrums vibrate more slowly. We do not hear wavelength directly: we hear frequency. (This is also an important point for organ tuning.) Frequency, being a measurement of how often a particular thing happens, is described in terms of how often that thing (vibration) happens per second. This is, of course, just a convention: it could have been per minute, or per year, or per millisecond.

Sounds that we tend to experience as “music” have wavelengths and frequencies that are consistent and well organized. Other sounds have frequencies and wavelengths that are in many respects random. This is actually a distinction that—even absent oversimplification—cannot be defined perfectly or in a cut-and-dried manner. It is not just scientific, it is also partly psychological and partly cultural. However, for the (also cultural) purpose of thinking about tuning musical sounds, it is enough to describe those sounds as follows: **a musical sound is one made up of sound waves with a frequency that remains constant long enough for a human ear to hear it, which may be joined by other sound waves with frequencies that are multiples of the frequency of that first wave.** A conglomeration of sound waves in which the peaks are spaced irregularly will not be heard as music. To put arbitrary numbers to it, a musical sound might have a wave with a frequency of 220 vibrations per second, joined by waves that cause vibrations of 440, 660, 880, 1100, and 1320 per second. (Vibrations per second or cycles per second are abbreviated Hz.) In a musical sound, the lowest (slowest, largest wavelength) part of the sound (220 Hz, above) is called the *fundamental*, and the other components of the sound (440 Hz, etc.) are called *overtones* or *upper partial tones*—*upper partials* for short. A sound consisting of only one frequency with no overtones will be heard as a musical sound; however, this is very rare in non-computer-generated music. Essentially every device for producing music produces overtones, some (oboes, for example) more than others (flutes). (By convention we usually label or describe or discuss a musical sound by referring only to its fundamental, but that never implies that there are no overtones.)

There is categorically no such thing as an organ pipe or harpsichord string that produces a fundamental with no upper partials. (Though of course the mix and balance of upper partials can vary infinitely.) This fact is crucial in the science and art of tuning, and for the relationship between tuning and esthetic considerations.<sup>1</sup>

#### What is an interval?

Any two musical notes form some interval with each other. We are accus-

tomized to identifying intervals by the notes’ linear distance from each other in the scale, and the terminology for common intervals (second, fifth, etc.) comes from that practice. However, in fact intervals arise out of the *ratio* between the frequencies of the fundamentals of two notes. The number of possible intervals that exist is infinite, since the number of possible frequencies is infinite. However, the common intervals in music are some of those in which the frequency ratios are simple: 1:1, 2:1, 3:2, 4:3, and a few others. And of course these are the intervals that have common names: 1:1 is the unison, 2:1 is the octave, 3:2 is the perfect fifth, 4:3 is the perfect fourth, and so on. To put it another way, if we say that two notes are a perfect fifth apart—as in, say, E above middle C and A below middle C—that means that the frequency of the higher note is in the ratio of 3:2 to the frequency of the lower note, or  $1\frac{1}{2}$  times that frequency. (A below middle C is often 220 Hz, so E above middle C should be 330 Hz.) If two notes are an octave apart, then the frequency of the higher one is twice the frequency of the lower one, for example middle C at 256 Hz and C above middle C at 512 Hz. The names—both of the notes and of the intervals—are arbitrary conventions, the existence of notes with these ratios a natural fact.

The question of why those particular intervals have been important enough to so many people that they have formed the basis of a whole system of music—indeed many different systems—is a complicated one that probably cannot be answered in full. It seems self-evident to people brought up listening to music based on fifths and thirds, etc., that those intervals “sound good” and that they should form the basis for harmony—itsself in turn the basis for music. Explanations for this have been sought in the structure of the universe, in various mathematical models, and through neurological research. However, for the purpose of thinking about how to tune intervals on keyboard instruments, the interesting and important thing is that the intervals that we use in music and consider consonant are the intervals that are found in the overtone series described above, and in fact found amongst the lower and more easily audible partial tones. The octave (2:1) is the interval between the first upper partial and the fundamental. The perfect fifth (3:2) is the interval between the second and first upper partials. The perfect fourth (4:3) is the interval between the third and second upper partials. The major third (5:4) is the interval between the fourth and third upper partials. This may in fact explain some of the appeal of those harmonies: in a major triad, all of the notes other than the tonic are found in the overtone series of the tonic. (Of course this is only actually true if you accept the notion that notes an octave apart from one another are “the same” note. This appears to be a universal human perception, and has recently been found to be shared by other primates. Possible neurological sources of this perception have also recently been found.) For example, starting with the note C, the first few upper partials give the notes C, G, C again, E, G again. These are the notes of the C major triad.

#### What does it mean for an interval to be in tune?

If intervals are ratios, then there ought to be a simple definition of what it means for an interval to be in tune: the ratio of frequencies should actually be what the theoretical definition of the interval says it should be. Thus, if a given note has a frequency of (for example) 368.5 Hz, then the note a perfect fifth above it should have a frequency of 552.75 Hz. Or if a note has a frequency of 8.02 Hz then the

note a major third above it should have a frequency of 10.025 Hz. Also, since these commonly used intervals are related to the overtone series, it makes sense to believe that their being really in tune this way is important: if they are not exactly in tune, then, presumably, they fail to correspond exactly to the overtones. And it may be this correspondence to overtones that gives those intervals their artistic meaning and power.

The very last statement above, however, is speculative and perhaps subjective—a proposed value judgment about the effect of a kind of sound. It is also quite possible that some interested parties—listeners, composers, performers, instrument builders—might happen to prefer the sound of a given interval in a tuning that is *not* theoretically correct. It is indeed very common for instruments on which intonation can be shaded in performance (that is, most non-keyboard instruments, including the voice) to be played with a kind of flexible intonation. Notes are moved a little bit up or down to express or intensify something about the melodic shape or the harmony. This is something that keyboard instruments, with limited exceptions on the clavichord, simply cannot do. However, it is an idea that can influence choices that are made in setting a keyboard tuning.

So another definition of what it might mean for an interval to be in tune is this: an interval is in tune if it sounds the way that a listener wants it to sound. Obviously, this is almost a parody of a subjective definition, but it also might be the closest to a true one. If the tuning of an interval does indeed fit some theoretical definition but the musician(s) hearing that interval want it to sound a different way then, as a matter of real musical practice, it probably should be that other way (that is, assuming careful and open-minded listening). This notion, and in general the interaction between certain kinds of theory and certain kinds of esthetic preferences, have also been important in the history of keyboard tuning.

#### What is the problem with keyboards?

The very premise of the existence of keyboard “tuning and temperament” as a subject is that there are special issues or problems with keyboard instruments from the point of view of tuning. Understanding clearly what these problems are is the prerequisite to understanding keyboard tuning systems themselves, to understanding the role of tuning in the history of keyboard repertoire and, should the occasion arise, to engaging successfully in the act of tuning itself.

The first issue or problem is simply that **keyboard instruments must be tuned.** That is, prior to playing anything on a keyboard instrument, a set of hard and fast choices must be made about what pitch each note will have. This is perhaps obvious, but still important to notice. Of course the instrument can be tuned differently for another occasion—more readily with a harpsichord or clavichord than with an organ. But at any moment of playing, each note and each interval is going to be whatever it has been set up to be.

The second problem is an extension of the first, and is the crucial issue in keyboard tuning. The number of keys on the keyboard is simply not enough to represent all of the notes that in theory exist. That is, the notion that, for example, c and b# or g# and ab are the same as one another is a fiction or, at the very best, an approximation. This is where the math of the so-called “circle of fifths” comes into play. We are all taught that, if you start at any note—say c—and keep moving up by a fifth, you will come back to the note at which you started: c-g-d-a-e-b-f#-c#-g#-ab-d#/eb-a#/bb-f-c. This circle provides a good working description



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of the way that we use these notes, but it glosses over the fact that if the fifths are pure (theoretically correct) it simply doesn't work: the circle is actually a spiral. Going one way ("up") it looks like this: c-g-d-a-e-b-f#-c#-g#-d#-a#-e#-b#-f-c-g, etc. Going the other way ("down") it looks like this: c-f-bb-eb-ab-db-gb-cb-fb-bbb-ebb-abb-dbb-gbb, etc. If each fifth is really in the ratio of 3:2—the frequency of the higher note is 1½ times the frequency of the lower note—then none of the enharmonic equivalents work. The b# will simply not be at the same frequency as the c, the gb will not be the same as the f, and so on.<sup>2</sup> This in turn means that it is impossible to tune all of the fifths on a keyboard instrument pure: not just difficult but literally impossible.

The third issue or problem of keyboard tuning also arises out of the first and exists in a kind of balance or conflict with the second. On keyboard instruments the tuning of one class of interval determines the tuning both of other intervals and of the scale as a melodic phenomenon. If you tune a keyboard instrument by fifths, then the thirds, sixths, etc. will be generated by those fifths. If you tune the fifths pure, the thirds will come out one way, if you tune the fifths something other than pure (as you must with at least some of them), the thirds will come out some different way. This is an esthetic matter rather than (like the second issue) a practical one.

These three issues have defined and determined the choices made in the realm of keyboard tuning over several centuries. Next month I will discuss what some of those choices have been and how they have arisen. ■

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#### Notes

1. Overtones are also important to the art of registration on the organ, and I discussed them in the April 2008 DIAPASON column dealing with registration.

2. I have posted a worksheet with some of the actual numbers at the Princeton Early Keyboard Center website: <www.pekc.org>.

## Music for Voices and organ

by James McCray

### Easy settings for summer choirs

Why is it that summer belongs to children? Even grown-ups who relish summer find it mixed with more joyous memories than the other three seasons combined.

—Hugh Downs  
*Perspectives*

Summer is that penumbra for the year, its arrival like an oasis in the desert. While hibernation is not recommended, some kind of change of routine clearly is needed during these halcyon days. As the preacher in Ecclesiastes says, "For everything there is a season, and a time for every matter under heaven." The overriding shibboleth, however, is that for most people this is not a time to coast but rather a time to refuel.

In summer, church choirs have either an abbreviated singing schedule, or take all summer off from their weekly responsibilities, and it is a well-deserved change for the singers and their director. The majority of church choir positions are part-time, some even volunteer situations. Only a few of the larger churches have full-time positions for the organist and/or choir director, so many directors need some kind of respite after working two very busy jobs most of the year.

We all have become accustomed to school schedules that reward us with the annual summer break, so convincing choirs to sing through the summer is a daunting task, indeed. In the Middle Ages even the most mistreated peasant never worked more than 150 days a year.

Seasonal slack times in the fields and an abundance of holidays somehow made life more bearable for these oppressed, provincial people. Today's Europeans continue to enjoy far more holidays than American workers. The great nineteenth-century French novelist and essayist, Stendhal, firmly stated the need for "solitude and leisure" as "indispensable for the process of crystallization." There are those who would suggest survival instead of crystallization in our modern society.

So, as we face each day with the threat of terrorism, a recession, and the most horrible economic times in many years, let summer wash you clean; but, be careful that it does not cause you to lose sight of your goals. A reduction, not a stoppage, of intellectual activities is suggested. Seek a reasonable balance and continue your growth efforts through music workshops, learning new music, and reading. Treat these glorious weeks not as a vacation, but more importantly as a refueling station.

For those directors whose positions require choral participation in the summer church services, the reviews below are of easy anthems, most needing less than 20 minutes of rehearsal. Enjoy your summer but remember that Rally Sunday, which for most church choirs is the second Sunday in September, is lurking in the shadows of that big shade tree.

**Two Songs for Gathering and Sending, John L. Bell. SATB and keyboard, GIA Publications, G-6526, \$1.30 (E).**

Each work is one page in length, and both have four repeated verses. The first, "One Is the Body," has a brief keyboard introduction and then doubles the voices throughout. The second, "Jesus Christ, Here Among Us," opens with a refrain, which is then repeated after each verse. Very simple, straightforward music.

**Great the King of Israel, George F. Handel, arr. John Simonds. Two-part mixed chorus and keyboard, Theodore Presser Co., 392-42390, \$1.30 (E).**

Taken from *Judas Maccabaeus*, this spirited anthem is arranged with two texts; the second one is designed for Advent. The choral parts are imitative, with both written in treble clef, and the keyboard part is primarily chordal, on two staves.

**O God Our Help in Ages Past, Mark A. Miller. Unison mixed voices and keyboard, Abingdon Press, 0687028027, \$1.25 (E).**

Although the familiar text of Isaac Watts is used, the music is not the well-known ST. ANNE tune. The rhythmic, syncopated music has a gospel feel to it, and an accompaniment tape is available for sale (0687-3-722, \$15.00). The

melody is retained as the music moves through a series of modulations. This may take a little work, but is certain to enliven summer services.

**Easy Choir, Volume 7, compiled by Jack Schrader. Two- or three-part with keyboard, some with additional handbells, Hope Publishing Co., B427, \$8.95 (M-).**

The ten settings are for various times in the church year, including Christmas, and are hand-picked by the editor from successful SATB anthems; they have been reduced in required voices so that smaller SAB choirs may perform them. Additional rhythm parts and full orchestration plus a performance CD (8328C) are also available from the publisher. This very attractive collection with a wide variety of musical styles is highly recommended for small church choirs, and a bargain at less than a dollar an anthem.

**I Give You a New Commandment, Peter Aston. Two-part and organ, GIA Publications, G-4331, \$1.10 (E).**

British composer Aston originally published this work with the Royal School of Church Music. It may be performed with women alone or in a mixed two-part version. The singers almost always move together without counterpoint, and often in unison. A gentle setting of the text from John 14.

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