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Addendum to "The Devolution of the Shepherd Trumpet and Its Seminal Importance in Music History"

By Aindrias Hirt

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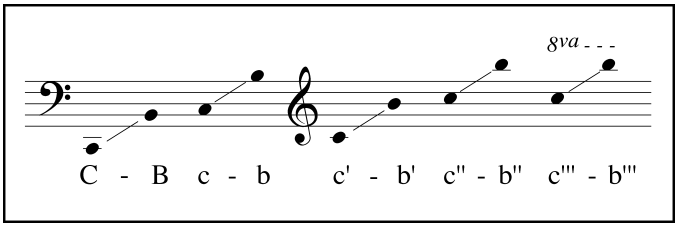
With the recently proposed hypothesis that wooden shepherd trumpets were the dominant force of musical intonation in pre-Christian Europe, several esoteric points concerning medieval musical practices present themselves. First, the hostility of the early Christian Church to the *modus lascivius/lascivus* (lustful mode) seems reasonable if shepherd trumpets can be found to produce pitches of this mode. Second, early folk music can be seen to use the harmonic series as its backbone, a point that can be demonstrated through simple staff placement conventions and a focus on linguistic and musical stress patterning. Third, a possible tuning convergence at courts in Northern Europe may be extrapolated by analyzing the instruments found at a medieval Gaelic chieftain's court. This may be done by comparing the harmonic series of natural trumpets, the rural tuning of Scottish Highland Bagpipes (and bagpipes in general), the High Bass tuning of low-headed medieval Gaelic harps, and the traditional tuning practices of fiddle players in Nova Scotia, Canada. In essence, (in this present article, Gaelic) courts can be seen to be a melting pot of urban (art) and rural (folk) musical forces.



The Shepherd Trumpet: A Brief Review

As mentioned in "The Devolution of the Shepherd Trumpet and Its Seminal Importance in Music History" in the January 2015 issue of the *International Trumpet Guild Journal,* there has been little research done on the shepherd trumpet and its value and influence on art music. Before delving into the subject more intently, it might be wise to have a brief review of the musical scale produced by the valveless shepherd trumpet and its variance from the diatonic scale. Recent investigation suggests the prevalence of wooden shepherd trumpets used to manage livestock[1] and to communicate information to people separated by a great distance. While trumpets certainly existed in Europe prior to the Neolithic Age, the introduction of farming (including animal husbandry) dramatically increased the presence of trumpets in Europe starting about 3,500 BC. These instruments produced a uniform series of notes where no other system of pitch organization existed. The series of notes is variously called the natural scale, harmonic series, or overtone series. If trumpets were so necessary and prevalent, then the harmonies and melodies they produced must have been the dominant system of pitch organization prior to the introduction of the diatonic scale by the early Christian Church. The two systems (diatonic and harmonic series) would be combined over time, arguably with more fervent intensity at a Dark Ages/medieval court. Not only are natural trumpets well known to have been played at court, but the presence of common people and their influence at court is often understated by historians. Common people would have brought their music with them. Particularly in the era of Beowulf, everyone at court—commoners and nobility alike—slept in the same room. It should also be stressed that there was a parallel social and musical conflict that is often obscured today—urban versus rural. The use of shepherd trumpets and their melodic harmonic series declined not just with the solidification of power of the Christian Church in Europe, but with the rise of the cities and industrialism that rendered the use of the shepherd trumpet obsolete.

Figure 1 is an example of a few trumpets made of wood. These trumpets were all shaped from tree branches or the trunks of saplings. Trunks of trees do not produce as marked a flare near the bell area as branches do. Branches are often curved in a twisting shape (often in an "S" curve). This makes the instrument difficult to split during construction and to

Figure 1. Four trumpeters in a trumpet maker's workshop in Romania (Photo: Martin Kleibl)

hold while playing. Using a tree's root or using a tree that has grown up sharply from a steep hillside can help overcome this problem. The flare of a trumpet in the ending (bell) area strongly influences intonation of the resulting pitches and the volume of the instrument. Figure 1 shows shepherd trumpets made from long, curved tree roots, so as to be able to rest them on the ground when playing. Note that these instruments are wrapped in bark to hold the two split halves together; osier rings are often used, spaced about a foot apart.

The harmonic series "scale" produced by natural instruments (a wooden shepherd trumpet, an animal horn, a juice harp/Jews' harp, an un-stopped willow flute, or the more modern brass natural trumpet) is very different from the diatonic scale. When lips are vibrated on the mouthpiece of a trumpet, a compressional standing wave is created. At first, one whole wave can fit within the length of the tube (this is almost physically impossible to do for this low-pitched note). Then, if the player's lips vibrate at a higher frequency, two waves can now fit in the length of the tube. If this process is repeated, then three, four, five, etc. waves can occupy the length of the tube (the number of waves within a tube are called "partials"). As mentioned above, this sequence is called the "harmonic series," "natural scale," or "overtone series." With this series, there are a different number of pitches per octave. Unlike the diatonic scale (the white keys on a piano keyboard, for example), the harmonic series possesses more notes per octave in the upper register than in the lower. This irregularity is only from the perspective of the diatonic scale, however. Actually, the relationship between adjacent notes in the harmonic series is uniform; that is, the distance from one note to the next is the frequency of the principal frequency. For example, if the principal note, the first partial, or "fundamental," has a frequency (cycles per second, called "Hertz" and abbreviated as Hz) of 50 Hz, then the frequencies of the following pitches in the series/scale would be 100 Hz, then 150 Hz, 200 Hz, 250 Hz, 300 Hz, 350 Hz, 400 Hz, etc.[2]

So, if the available notes are plotted against their frequencies, the graph in Figure 2 results.

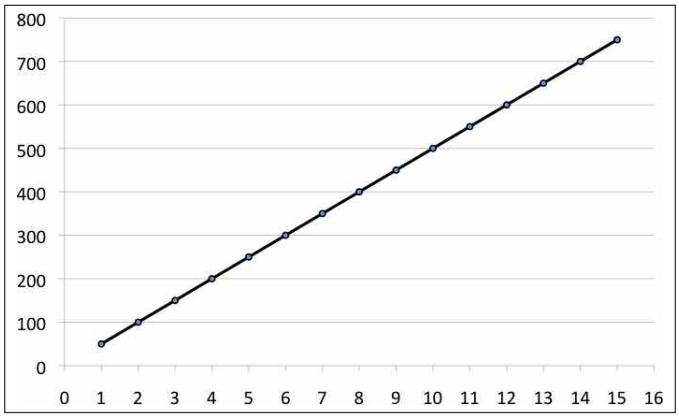


Figure 2. Natural-scale notes vs. Frequency, first to thirteenth partials

In Figure 2, the x-axis represents the note value (here the partial number, but it is simply the integer value of the notes available, in order), and the y-axis represents the corresponding frequency value in Hertz. This series of musical notes can be seen to be scalar and not exponential. Therefore, the exponential diatonic scale and the natural scale are vastly different.

In order to understand the interplay between natural instruments and those tuned to the diatonic scale, it is worthwhile to review the construction of the diatonic scale. It is not known if the diatonic scale came about from the Pythagorean tuning method or if Pythagorean tuning was at one time simply considered the best of many diatonic tuning methods. However, this is how the method is roughly applied. Imagine plucking a string on a harp (naming it, say, c′). Tune a second string (to remove all beating between notes) a perfect fifth higher than the first string (creating g′). Now tune a third string an octave higher than the first (making c″) and a fourth string a perfect fifth above the second string (making d″). Tune the fifth string down an octave (d′) from the fourth and a sixth string a fifth higher than that (a′). Continue this cyclical process on those new notes (with some variation, described below on the section on the harp), and the sequence (c′, d′, e′, f′, g′, a′, b′, c″, etc.) will be created. This scale might be familiar to most people today, but it is actually extremely odd. This is not normally taught in schools, but some reflection might help to see how unusual the scale is. A perfect fifth is actually a ratio of 3:2 (two strings of the same material/diameter under the same tension with one string one-third shorter than the other). A major third is the ratio of two strings of 5:4 (two strings under the same tension with one string one-fifth shorter than the other). This explanation can seem a bit convoluted, but the result is that one cannot have both perfect fifths and major thirds all fitting within one octave, because the ratios of 5:4 and 3:2 cannot fit within the same span. It is akin to finding the last decimal place of π (pi); it is simply not possible. So with the Pythagorean tuning system of combining perfect fifths and octaves, the strings closest to being in the ratio of 5:4 (thirds) are quite out of tune (22 cents sharp—about a quarter of an equally tempered half-step) when played in harmony with the root. Tempering this tuning, that is, making some major thirds flat and some fifths a little out of tune (sharper), then has the effect of making triads (root, third, fifth) bearable. Most people are not aware that in the equal temperament system that we use today, all of the major triads are out of tune. It is, however, quite noticeable if the listener hears a chord played exactly in tune and then the same chord played in equal temperament immediately afterward.

Tuning to fifths and octaves produces the diatonic scale, which has particular features, the most important of which is that there are an equal number of notes per octave. This might seem obvious, normal, and correct to a modern-day musician, but it is not obvious to a shepherd or person from a culture where this diatonic scale is not used. As can be seen in the figure below, the diatonic scale is exponential with respect to frequency. So if a string vibrates at 100 Hz, the next octave will vibrate at 200 Hz (a span of 100 Hz). There will then be six notes added between the octave notes. Now, here is where it becomes apparent that the scale is exponential: the next octave note is double the frequency of the last and is 400 Hz, not 300 Hz. One must now fit six notes between 200 Hz and 400 Hz (a span of 200 Hz, not 100 Hz as it was in the lower octave). To make matters more complicated, in Pythagorean tuning, the six whole and half steps between the octaves are not equally spaced as they are in equal temperament. So there are combinations of two steps that are almost equal (the half steps) and the remainders are approximately equal (the whole steps), but they are not exactly equal. So the distance between c′ – d′ and

the distances between d′ – e′, e′ – f′, g′ – a′, and a′ – b′ are not the same. Each interval is slightly different. This difference was what originally gave each key a different "color."

If notes are placed with regard to equal temperament's half steps and whole steps (c′ = 1, d′ = 3, e′ = 5, f′ = 6, g′ = 8, a′ = 10, etc.), the frequencies will trace a smooth parabolic path, as shown in Figure 3.

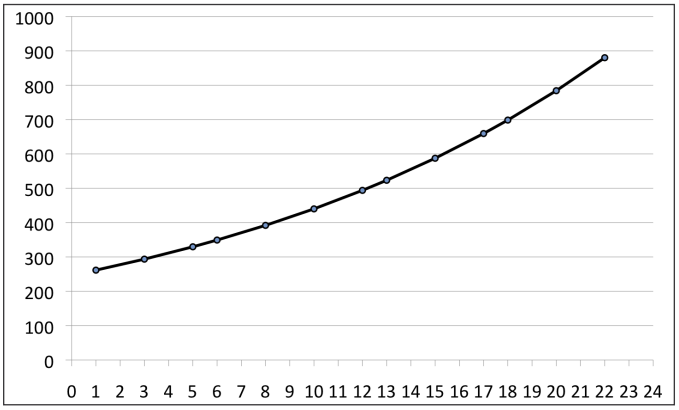


Figure 3. The diatonic equally tempered scale, Half-Step Number vs. Frequency (c′ – a′′)

With respect to frequency, the harmonic series system is linear, while the diatonic scale system is exponential. Those accustomed to the sound of the diatonic scale tend to think of it as equal and linear. It is not, however; it ascends very rapidly as one's eyes scan to the right in the figure above. This is an increase in exponentiation of the frequency. So, if one observes a note with a frequency of, say, 100 Hz, and assigns it a name of, say, "C," then c = 200 Hz, c′ = 400 Hz, c′′ = 800 Hz, c′′′ = 1600 Hz, etc. If one is accustomed to a system where an exponential system is thought to be linear (diatonic scale), then a linear one *appears* to be logarithmic (harmonic series). Hence, the harmonic series appears to have more notes in the upper end and also appears to be gapped in the lower end when compared to the diatonic scale. This can be seen in the way that the harmonic series is represented on a notational system designed for an exponential system. Figure 4 is the harmonic series written in diatonic music notation for a natural instrument approximately 8 feet (2.4 meters) long. This is familiar to diatonically trained musicians as a D natural trumpet as used by Bach, Telemann, Torelli, Fasch, Zelenka, etc. in the "Choral Key" of D major, but with a C crook added.[3]

Some of the notes in Figure 4 have been made solid. This is to indicate that their pitches are significantly different from the intonation of the nearest notes in the diatonic (equal temperament) scale. Some of these notes are the seventh, eleventh, thirteenth, and fourteenth partials. The seventh partial of the harmonic series is between a′ and b-flat′;[4] the eleventh partial is halfway between f-natural′′ and f-sharp′′;[5] the thirteenth partial is between a-flat′′ and a-natural′′;[6] and the fourteenth partial is between a-natural′′ and b-flat′′.[7] Arrows point in the direction that the natural-scale note sounds in comparison to the closest pitch in equal temperament.

Due to this difference between the two scales, there has been a great deal of confusion when attempting to represent the harmonic series using staff notation designed for the diatonic scale. The most obvious is that terms such as "tetratonic" (four notes per octave), "pentatonic" (five notes per octave) and "hexatonic" (six notes per octave) cannot be used to describe music played on shepherd trumpets, because the same number of notes is not available in each octave on the instrument.[8] Additionally, if a transcriber educated in the diatonic system listens to a folk tune played on a natural instrument playing the seventh partial and also hears the tune end on c′ or c′′, he or she would not consider notating that seventh-partial note as b-flat′, since b-flat′ is not in the key of C major. The choice would be between a′ and b-natural′. Since the seventh partial is significantly closer to a′ than b-natural′, the transcriber would probably write a′ (and not b-flat′) if the tune ends on C. Also, the eleventh partial is written in Figure 4 as f-sharp′′. It could be written as f-natural′′, since it sits almost exactly halfway between the two notes; notating f-natural′′ instead of f-sharp′′ would normally occur if the tune ended on c′ or c′′, since f-sharp is not in the key of C major.

If the representation of the harmonic series on the diatonic staff is adjusted with these concerns in mind, the playable notes might be represented as seen in Figure 5.

Although notes appear to be oddly gapped in the lower range and there is a b′ that is absent, the notes are actually the same distance apart (see Figure 2). As mentioned above, this is because the staff notation as it is used in European art music was created to delineate pitches of the diatonic scale, and the diatonic scale is not linear with respect to frequency. This basic difference has obscured the strong presence of shepherd trumpets (and metal natural trumpets used in cities for that matter) in folk music tunes and the resulting conflict with the early Christian Church.

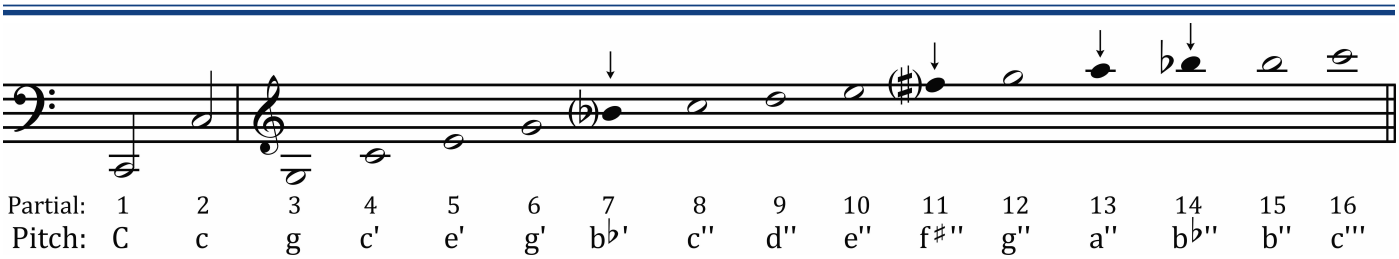


Figure 4. The natural scale as it is often represented

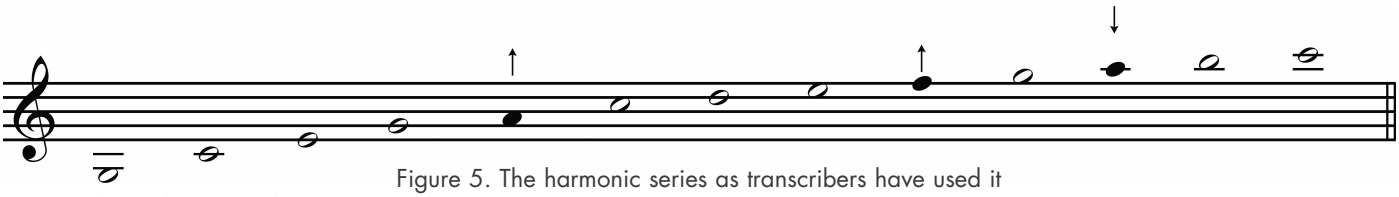


Figure 5. The harmonic series as transcribers have used it

Ecclesiastical Modes and the Harmonic Series

There is very little evidence of scales and tuning used in the Middle Ages. What scant evidence that does exist was written by supporters of the early Christian Church; the written record is, therefore, incomplete and prejudicial. Written records discussed how the Church hierarchy should behave relative to music that surrounded it, but they never discussed that music in detail. With the introduction of the diatonic scale by the early Christian Church, there could have been quite a conflict with pastoral music since the diatonic scale produced through Pythagorean tuning is vastly different from the harmonic series produced on natural instruments. Moreover, since early medieval musical science was rather undeveloped, tools to identify what was "folk" music and what was "art" music were absent. The early European writers who described music, such as Boethius (475 – 524 AD) and Cassiodorus (485 – 580 AD), wrote about Greek music, not what actually existed in Europe at the time. So, vague emotional phrases such as *modus lascivus* (also *modus lascivious*—lascivious mode) were used to describe and purge unwanted folk elements. These practices of the Christian Church in Europe were surprisingly successful. When music theoreticians created tools to do this dispassionately by the tenth century (Hucbald, among others, codified the chants, showing a difference between the Greek emphasis of Boethius and the way that chants were actually sung in Europe), existing chants were analyzed. They were shuffled into this new theoretical system and with a few exceptions, fit in easily.[9]

The musical system as described by Hucbald and others might be rather disconcerting to the trained musician of today. This is due to the *final* (last note) of each chant ending on one of only four notes of the diatonic scale, and those notes do not include C (the major mode) or A (the minor mode). It is common today to think of melodies in relation to harmonic progressions; this was not the way it once was, as the modes existed to set the boundaries of the singer's pitch gamut, not to set harmonic boundaries. Moreover, the pitch movements matched the way that people speak. When a person begins to speak, the pitch is low because the airflow begins at a low level; as the airflow increases toward the middle of the exhalation, the pitch rises (the Bernoulli Effect). As the speaker nears the end of the utterance, the pitch descends. This is a deeply rooted behavior and is displayed in the way that instrumentalists play scales when rehearsing (low to high to low, not high to low to high). The pitch gamut looks something like a bell-shaped curve if frequency is plotted against time. So if a singer begins on a pitch roughly equal to the ending pitch (*final*), the pitch will rise about a fifth (as when speaking); this is called the dominant or reciting tone. The singer's pitch may then ascend higher, but invariably descends to the ending *final*. This sequence creates an "authentic" mode. If the singer starts below the final (about a fourth), rises to the final, ascends beyond the final and then drops to the final, it is called a "plagal" mode and is identified by the "hypo" prefix. Whether authentic or plagal, the ending note is the same for each authentic/plagal set. There were only four finals allowed in the early ecclesiastical system: D (dorian), E (phrygian), F (lydian), and G (mixolydian). However, "the modes on A [the natural minor, or aeolian mode] and C [the major, or ionian mode] were excluded from the ecclesiastical list, their effect judged as being 'lascivious' and 'worldly' and unsuitable for religious use since their influence would be pernicious."[10]

At first blush, this proscription against the major and minor modes makes absolutely no sense. Why would the early Church deliberately forbid these modes? This can be explained by the hypothesis presented in this article. If a culture that threatened the early Christian Church had music that might be described in this manner, the Church might want to fight such an influence. Therefore, it might be wise to examine tunes that can be played on natural instruments to see whether the forbidden modes might be reflected in the harmonic series. If so, the present hypothesis could provide a solution as to why the early Church behaved as it did.

Consider Figure 5 again. Since it is easier to play the lower pitches of a shepherd trumpet (which also reflects how one normally ends a sentence when speaking), there is generally a higher probability of ending a tune on a lower pitch than on a higher one. The first pitch in Figure 5 that most trumpeters can play would be g. Although this pitch often appears in the middle of tunes, the author is not aware of an example where it is used to end a tune, perhaps because it is more difficult to play than c′, e′, or g′ (fourth, fifth, or sixth partial). Ascending the harmonic series by steps, if the tune ended on the fourth partial (c′), it would be considered ionian. If the tune ended on the fifth partial (e′), it would be considered either phrygian or aeolian (relative natural minor of G major, with the eleventh partial acting as the leading tone F-sharp in the key of G major). If ending on the sixth partial (g′), it would be considered mixolydian (the eleventh partial appearing to be f-natural″) or ionian (the eleventh partial appearing to be f-sharp″); the section below on the harp will show that this is actually an extremely important distinction, as the harp defined two different tuning systems based upon how a harp's F strings were tuned (either to F-natural or to F-sharp; also, bagpipes are said to be G mixolydian—a bagpipe in G plays with G drones and has a chanter scale between f′ and g″, which almost matches the notes a C natural trumpet can play—see below for this analysis). If ending on the seventh partial (a′), it would be considered aeolian (relative natural minor of C major); if ending on the eighth partial (c″), it would be considered ionian; if ending on the ninth partial (d″), it would be considered dorian, etc. If all this data is tallied, the probability of European indigenous music played on shepherd trumpets or other natural instruments ending on various finals would be (from highest to lowest probability according to ease of playing and matching how people speak): ionian (major, ending on c′, c″, or perhaps g′), aeolian (natural minor, ending on e′ or a′), mixolydian (ending on g′), perhaps phrygian (ending on e′ or e″), dorian (ending on d″), etc. Indeed, that is roughly the ecclesiastical modal attribution given to folk music by ethnomusicologists in the last century (generally in the order ionian, mixolydian, aeolian, and dorian[11]). So, if the early Christian Church was opposed to aboriginal music, and that music was being played on shepherd trumpets, it would make sense to ban music played on those instruments and all music that might be categorized as being in the ionian and aeolian modes.

Over time, the ecclesiastical system using Pythagorean tuning (which produces major thirds that are 22 cents sharp) and the harmonic series system (where thirds are perfectly in-tune and where triads are possible) fought and melded with each other. The result was that each side borrowed from the other and, in turn, was changed. By the middle of the sixteenth century, both Glareanus and Zarlino began to note that there

were two new modes with finals on C and A that had infiltrated church music and were quite agreeable: "Nevertheless, the seeds were planted that, in the middle of the sixteenth century, would produce four new modes: ionian and hypoionian ending on **C**, aeolian and hypoaeolian ending on **A**."[12] In other words, the ionian and aeolian modes began to dominate the ecclesiastical modal system, even though they had been banned. There were probably a number of reasons for this shift that allowed the ionian and aeolian modes to become acceptable. For one, with Christianity firmly established in Europe, the threat from pagan culture was probably less significant. Although the major and minor modes became popular, the cultures that practiced transhumance continued to be looked upon askance for quite some time.

For example, Handel wrote the piece "Rejoice Greatly" for the *Messiah* in 12/8 meter, but he was persuaded to change it to 4/4 time because pastoral music was not considered appropriate in a religious setting. Compound time is based on triplets. Pastoral music is often in triplets since both the Irish and Scottish Gaelic languages have a pronounced triplet rhythm. Therefore, Gaelic vocal music is normally notated in compound meters. Although many believe that the conflict between Gael and Saxon is one of cultural prejudice, it is more related to an urban vs. rural conflict.

Additionally, consider another example. J.S. Bach composed the cantata "O Jesu Christ, mein's Lebens Licht" (BWV 118) and wrote two parts for two *litui* in B-flat. The pitches matched the natural scale, but the length of the instrument needed to be about nine feet (approximately 2.7 meters) long to produce the pitches as written. A *lituus* is an instrument with a confused past. Most scholarship indicates that it was originally a religious instrument that evolved into a signaling instrument used by the Roman cavalry. There are two related shapes. One is a hollow tube of about the same diameter as the length of the instrument (mainly cylindrical). Three feet long, it curls back on itself and is in the shape of the letter "J." The other shape appears to be a development of a hornpipe (a pipe with an animal horn inserted at one end and a cup-shaped mouthpiece in the other end). In this case, the bell expands rather quickly and points upward, and the instrument is conical. Neither one of these two instruments is the required nine feet needed to produce the overtone series that Bach required.

It is well known that Bach knew how to utilize instruments in order to elicit a desired emotional response in a congregation. For example, when he orchestrated his cantatas for St. Michael's Day (a feast day commemorating war between St. Michael and the serpent/devil), he used trumpets, knowing that the men in the congregation who had fought in combat would remember the sound of the trumpet from the battlefield and empathize with St. Michael and his predicament. In the case of BWV 118, Bach had read some poetry and decided to set it to music. There were fourteen verses in the original poem, but he could only include a few of them in the cantata he was composing. The poetry seems to engender a pastoral feeling, much like the 23rd Psalm. The fourteenth verse of the poem is, "How joyful then I shall be/I shall sing with the angels/and with your chosen flock/forever behold your face clearly." Unfortunately, Bach did not have room for this verse in the cantata, but perhaps wanted somehow to conjure pastoral images in the minds of the congregation. He chose an instrument of the shepherd and orchestrated BWV 118 for two German *alphorns*. This would create a sympathetic response in the congregation, as people there had probably heard *alphorns* being played before (reinforcing the point that pastoral society was becoming more marginalized, yet still present in Germany at the time).

Pastoral instruments were forbidden in the church, so Bach likely gave the instrument a new name in order to have his way. This was not the first time he may have done this. There were no trumpeters where Bach was located in Leipzig. Only members of the *Kammerdshaft* (Brotherhood/Trumpeters' Guild) were allowed to play the trumpet, and they could only ply their trade at court. So Bach employed (among others) Gottfried Reiche who was a *Stadtpfeifer* (city piper) and not a member of the *Kammeradshaft*. Reiche played on a coiled trumpet that did not look like a trumpet, but nonetheless sounded similar. It was called a *Jägertrompete* (hunting trumpet). So Bach could compose for natural D trumpets, because the instrument for which he was composing was not a trumpet, but a hunting trumpet. By giving the trumpet a different name, he could avoid the prohibition. Therefore, it seems likely that Bach wrote BWV 118 for an *alphorn*, but if challenged as to why he brought a shepherd trumpet into the church, he could explain that it was not a shepherd trumpet at all, but the revered, sophisticated, honored instrument of the Roman Empire; it was a *lituus*.

The shift from the ecclesiastical modes to the major and minor modes was also thought to have been the work of singers, who, given time and the increased use of accidentals, altered the modes by making mistakes. With the current hypothesis in mind, this makes sense. If a singer spent the night listening to music being played on natural instruments and then went to church the next day,[13] the ionian mode would likely be rooted in the singer's head.[14] Perfectly in-tune triads would be firmly established and the singer would naturally seek to have major thirds in tune. This would push the Church to have a tempered scale where thirds would be in tune.

Over the next few centuries, the major and minor modes became extremely well established. Pastoral music played on shepherd trumpets faded, as did transhumance (with new farming methods being much more efficient). Ecclesiastical modes also faded from secular musical memory. When folk music was investigated by musicians educated in the major-minor system in the late nineteenth century, the music seemed completely alien; it was an anathema. In order to try to explain it, scholars researched extant written material, but since the Church had not recorded how pastoral/lascivious music was performed—just proscribed it—there were no written records of how it was created or performed, "Although secular music of various sorts must have existed during this long period of time [first 1000 years of the Christian era], almost none has been preserved. Only the chants of the Church remain."[15] So when musicologists (often dilettantes) tried to explain the odd structure of folk music, they went to the "old" ecclesiastical modes; these were not the modes of Hucbald (c. 900 AD), but of Glareanus and Zarlino (c. 1550 AD). Of course, this makes no sense. As Cazden states of the policy of using the ecclesiastical modes to describe folk music:

> [It] shamefacedly called for the invention of two hitherto unused or obscure Greek mode names, ionian and aeolian, in order to account for the obvious prominence of major and minor in music now gov-

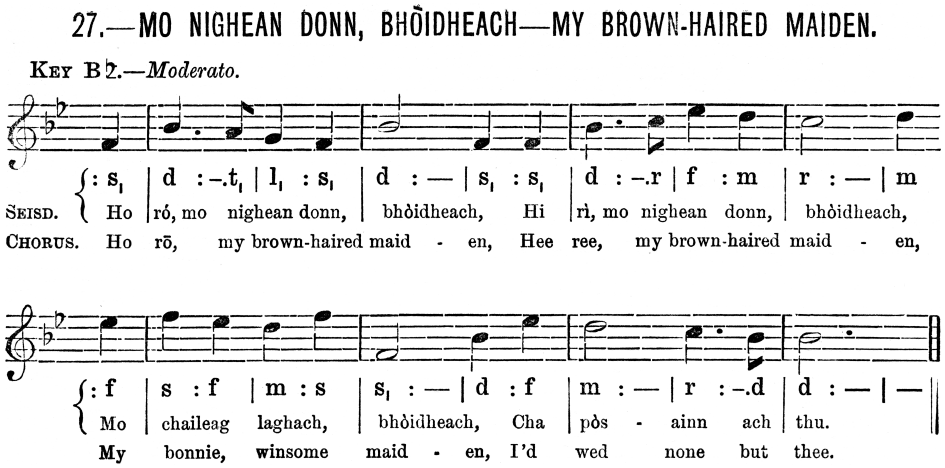


Figure 6. "Mo nighean donn bhòidheach" from *The Celtic Lyre,* c. 1885

erned by harmonic tonality, so as to bring these scale forms also under the protective color of seemingly ancient authority. The earlier church rules had rigorously excluded both the use of such constructions, save surreptitiously under the illuminating excuse "musica ficta", or their recognition as theoretical possibilities, for all their seeming logical inevitability in a complete scheme. Let the lesson not be lost on theorists tempted to devise Bronson-type, Hauer-type, Hindemith-type, Kayser-type or Schenker-type diagrams [to explain the structure of folk music using the ecclesiastical modes].[16]

With this in mind, it might be wiser to use the harmonic series to describe folk music and its intonation, rather than the diatonic scale of the ecclesiastical modes.

Folk Music and the Harmonic Series

It is a simple process to see the harmonic series in old folk tunes; the trick is to halt the transcription process once the harmonic series appears in the notation. At that point, the analyst should check to see if the notation can be reasonably lowered, as most trumpeters (and shepherds) would prefer to play the music with as little effort as possible. The first step is to select a tune thought to be an old folk tune and annotate it using a computer application program such as Sibelius or Finale. This is not necessary, but convenient. One begins by transposing the tune to the key of C major and checking for notes of the harmonic series. If it is not apparent, one can simply transpose up a perfect fourth or fifth; in tunes previously thought to have been pentatonic, this does not have any effect upon the key signature. If this is done with tunes previously thought to have been hexatonic, the note needing the accidental will often correlate to the eleventh partial. Also, for hexatonic tunes, once the tune is transposed to C major, the harmonic series is often revealed when the "missing" note is placed on b′. Once the tune is transposed up a perfect fourth or fifth from C major, generally the harmonic series becomes evident.

As mentioned in the January 2015 *ITG Journal* article "The Devolution of the Shepherd Trumpet and Its Seminal Importance in Music History," the following is an example of this conversion process. Although a folk tune from any culture would suffice, Figure 6 is a well-known example from the Scottish Gaelic community.

Once the tune is transposed to the key of C major, the tune in Figure 7 results.

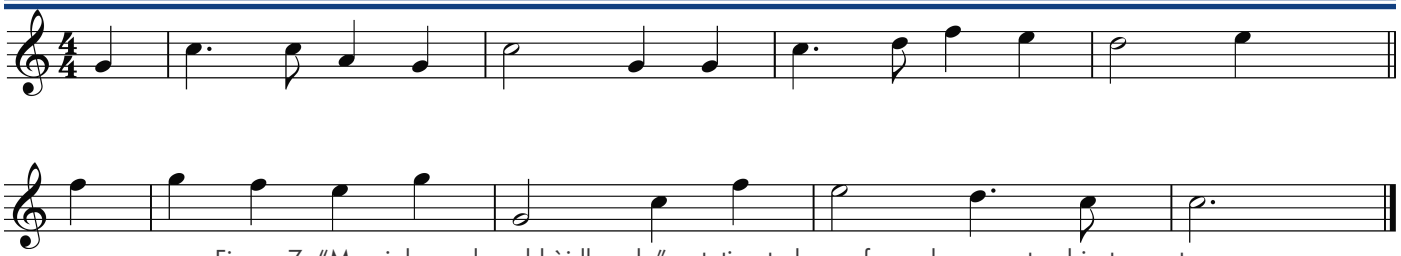


Figure 7. "Mo nighean donn bhòidheach," notation to be performed on a natural instrument

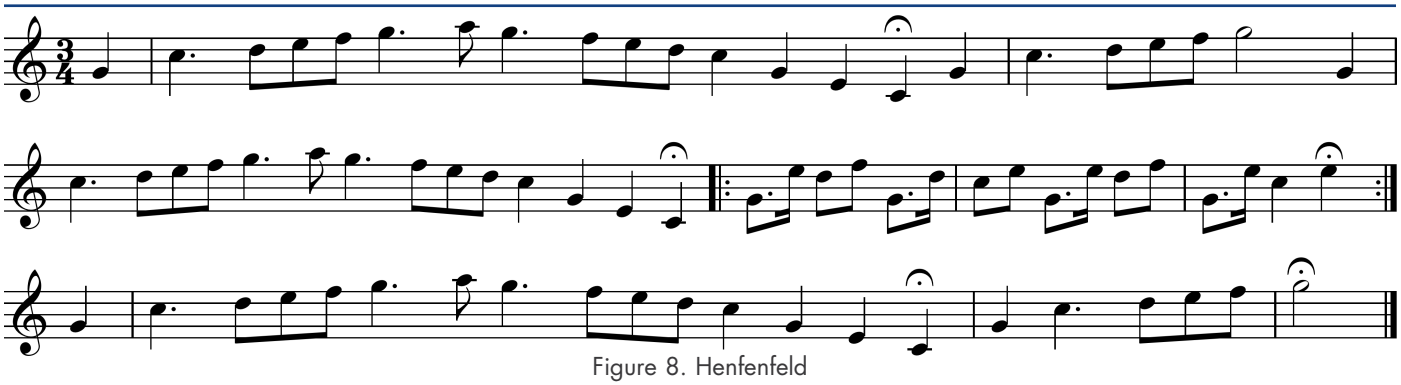


Figure 8. Henfenfeld

The harmonic series is clearly evident. The third note was adjusted to match the harmonic series, as this is how it is often performed.

Figure 8 is another example from Germany. It was transcribed by Konrad Pemset Henstrück from a recording of a wooden trumpet (*Hölzern Trompete),* played by cowherd Jon Kuhn.[17]

This example is representative of many folk tunes from Germany and Switzerland, and although not appearing in this example, it should be noted that German transcribers have often notated the seventh partial in different ways: as a′, b-flat′, or b-natural′. This variation is not significant, since the transcribers were transcribing the sounds of actual shepherd trumpets and not another instrument playing the tune, so there is variation in how the instruments' pitches were perceived. However, there is no doubt as to whether the tune came from a natural instrument or not. This fluidity in notation can be unnerving at first, but it becomes clear over time, since this ambiguity primarily occurs on the seventh and eleventh partials and on unstressed beats.

An example that is very similar in range to the above figures, but which is much better known, is "Amazing Grace," a song that was set to the tune "New Britain," which supposedly was an amalgam of both "Gallaher" and "St. Mary." Figure 9 is "Gallaher," first published in Shaw and Spilman's "Columbian Harmony" in 1829.[18]

This also matches the harmonic series (see Figure 5).

During the transposition process, the tendency is for the tune to be transposed upward in order to remove d′ and f′ if they appear. This can artificially raise the range of the tune. For example, Figure 10 is a published transcription of a performance by the cowherd Heinz Zink, from Oberhof, Thüringen, playing a signalhorn (a bugle pitched in B, transposed up by a half step to C) in the *hirtenfest* in Zella-Mehlis, Germany in 1954.[19]

Figure 10 compares well with the harmonic series displayed in Figure 5; however, notice that there are many gapped intervals. In order to see the harmonic series in a folk tune, it is generally wisest to transpose the piece as low as can possibly be played. In this case, the music in Figure 10 is notated an octave higher than is normally done (as in Figures 4 and 5). If the music is transposed down an octave, the music in Figure 11 results.

If this transposition is performed repeatedly on many tunes, a new pattern emerges. This pattern is logical once one analyzes the progression of urban music over the last few centuries and analyzes the causes that produce a pattern of variation in folk songs. Although obscured in the modern technological age, music is, in essence, a structuring of human speech. Music based on language, not instruments, was the dominant form of musical expression within European folk culture. Analyzing language patterns will invariably reveal the fulcrum that created musical shifts, at least in a folk or early music setting. In order to acquaint the reader with this pattern, it might be informative to follow this author's experience in noticing it.

Trueman Matheson of Sìol Cultural Enterprises asked this author in 2010 to re-set a series of Gaelic musical notation books from the 1890s, named *The Celtic Lyre*.[20] One problem that was observed was that the musical rhythms as written in the original version were a compromise between the rhythms of Scottish Gaelic and English words that were both written under the musical staff. Since there would be no English words in the new edition, the rhythmic compromise was found to be dissatisfying; the rhythms needed to be written as the Gaelic

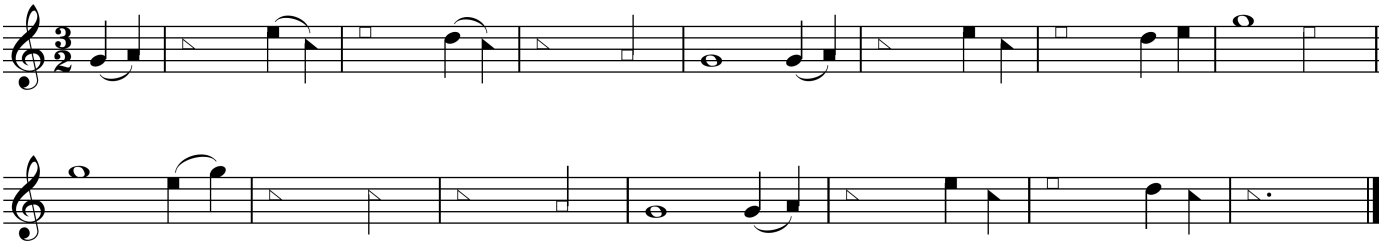


Figure 9. "Gallaher," 1829

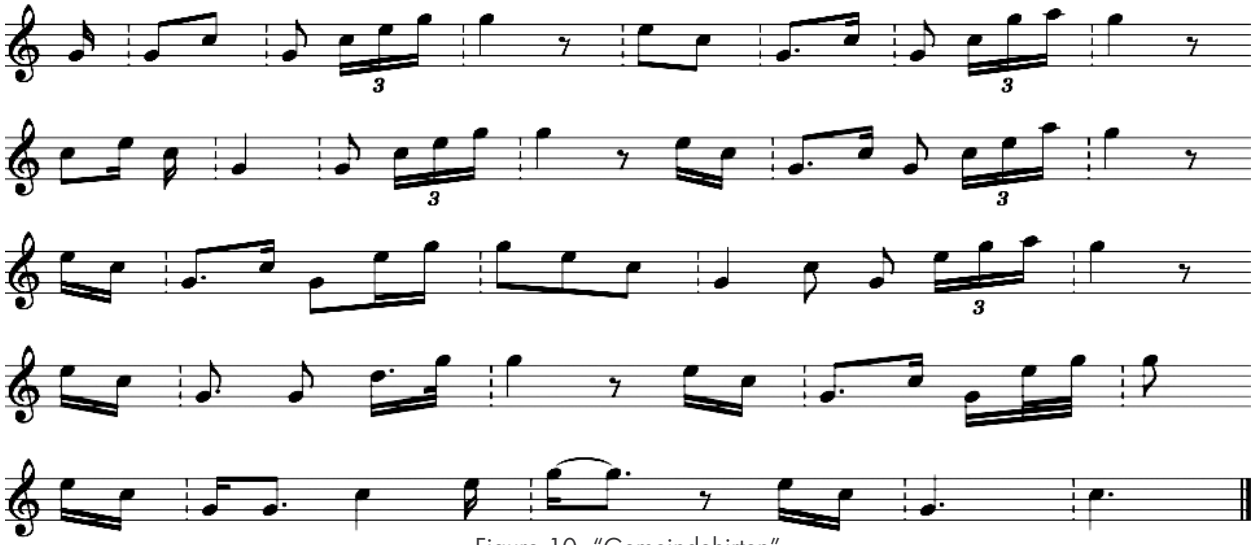


Figure 10. "Gemeindehirten"

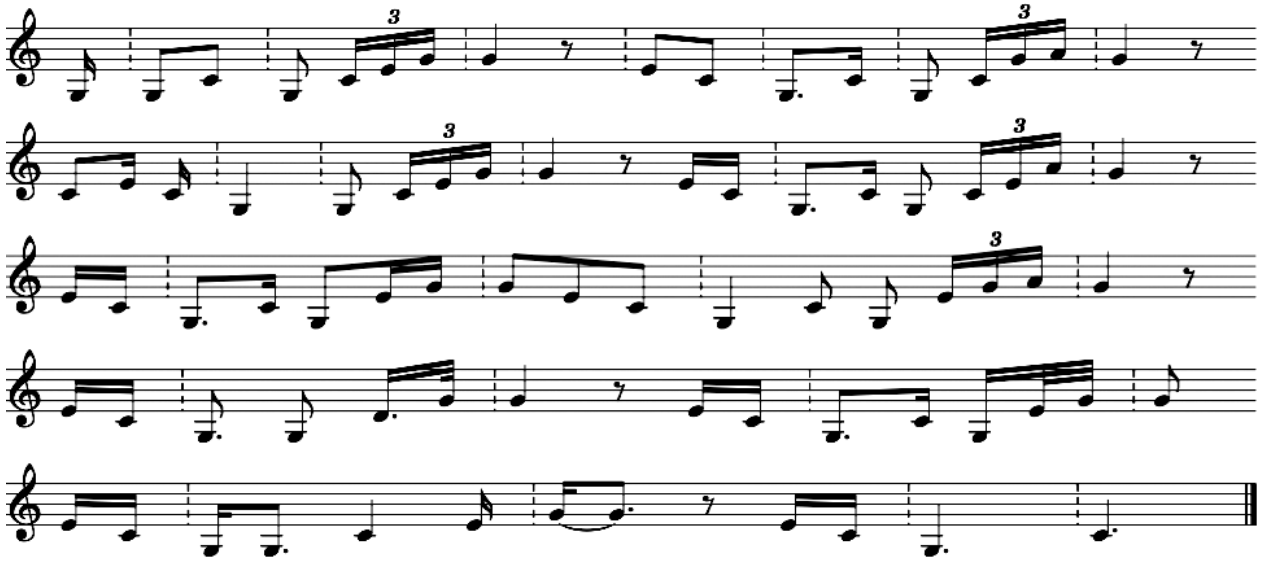


Figure 11. "Gemeindehirten," written down an octave

language required and how the songs were still sung in Gaelic society. Once the correct rhythms were written, the Gaelic words (separated into syllables) were then placed beneath the musical notation. With the removal of the English words, there was now a great deal of space under the musical staff; many verses of Gaelic could be written under the musical notation, where the original publications' cramped conditions and bilingual requirements had made that impossible. Therefore, syllables had to be set to notes for the first time without written examples. This was very difficult. Gaelic song has stress on the downbeat and is almost always in compound meter (6/8, 9/8, or 12/8). Often, matching the syllabic stress with the musical stress was so confused that once the beginning words of a verse were set, the ending syllables had to be set next; and the middle syllables were then sorted. It was only when a great deal of effort was placed on matching stressed syllables to stressed beats that the harmonic series revealed itself. Non-harmonic-series pitches (from the diatonic scale) always fell on unstressed musical beats. Previously, transcribers would simply scan folk music for missing notes. Once an apparent gap was found, the tune would be quickly searched to see if the gap appeared throughout the tune. This was done without concern as to whether the pitch fell on a stressed or an unstressed beat. If an apparent gap was filled anywhere in the music, the missing-note criterion would be increased by one (a tetratonic tune would be reclassified as pentatonic, a pentatonic tune would become hexatonic, and a hexatonic tune would become heptatonic). Furthermore, since the transcribers were trained in the diatonic scale, they would think in terms of octave equivalence; if they saw gaps at f′ and b′, they would tentatively classify the music as pentatonic, but once f′′ (natural or sharp, representing the eleventh partial) occurred, they would simply conclude that the tune was missing only one note (b′) and would reclassify the tune as hexatonic. In short, the natural scale has rarely been seen in folk music because no one has thought to look for it until now.

Folk songs generally begin as syllabic (one note per syllable) and monophonic. In time, singers begin to slur pitches between syllables, and small notes may be seen to intrude between two syllables. Also, singers have a tendency to slide in pitch between two stressed syllables that have an intervening non-stressed syllable, with the result being that the unstressed syllable's pitch ends up between the two stressed syllables' pitches. If a transcriber trained in the diatonic scale hears these

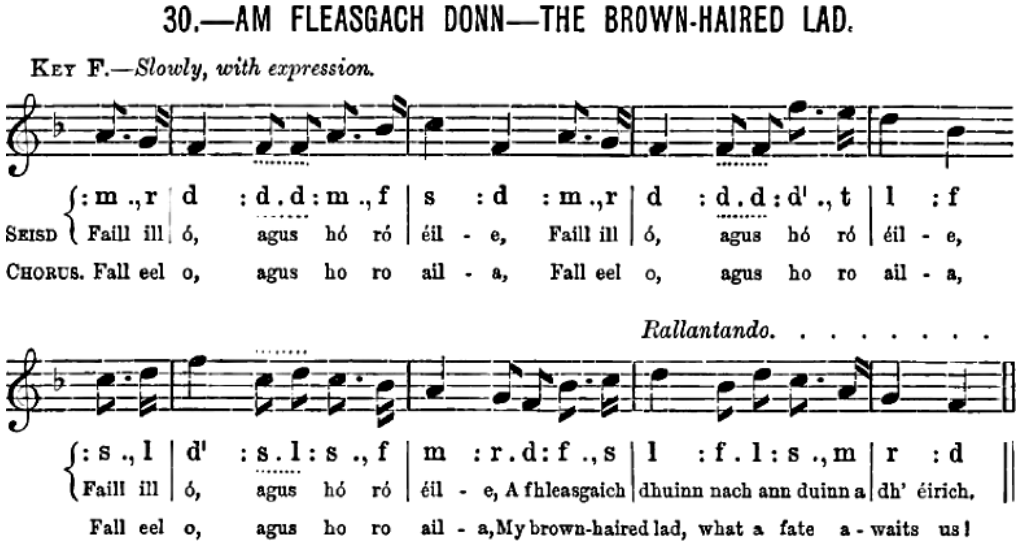


Figure 12. Original "Am fleasgach donn" tune

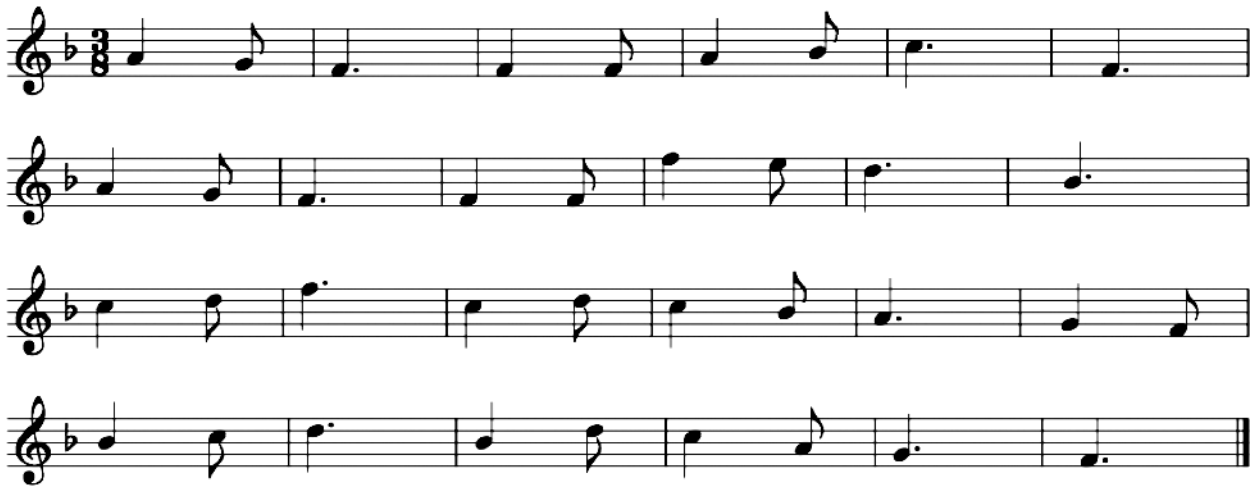


Figure 13. "Am fleasgach donn" in modern notation

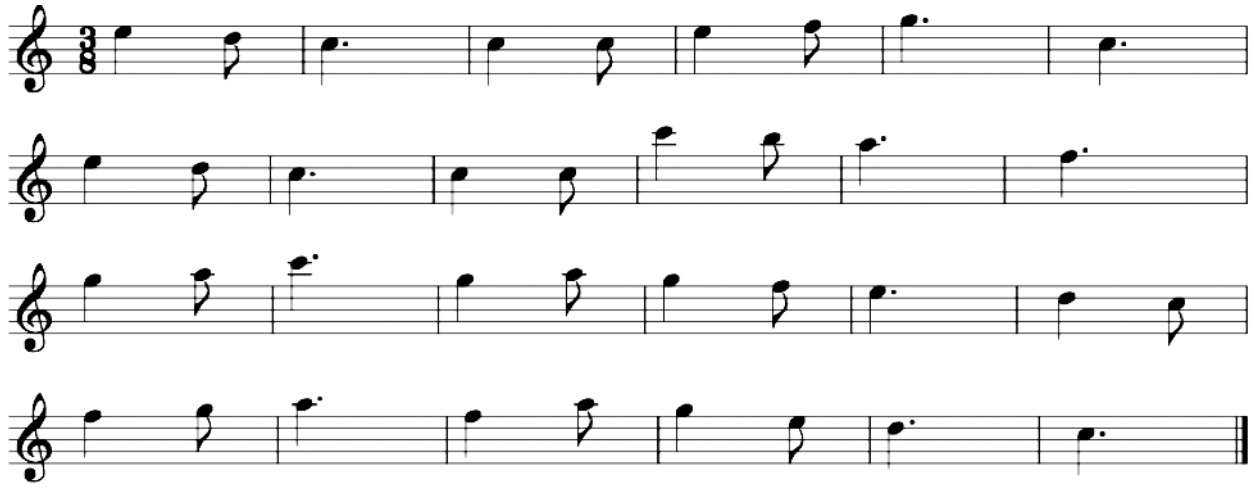


Figure 14. "Am fleasgach donn," transposed to C major

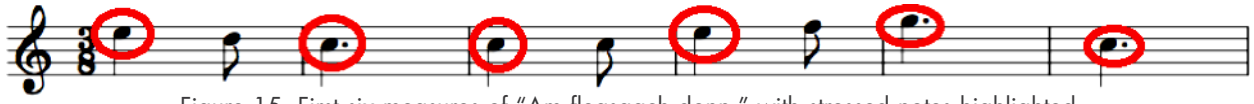


Figure 15. First six measures of "Am fleasgach donn," with stressed notes highlighted

two conditions, the unconscious tendency is to place the middle note on a pitch that exists in the diatonic scale but not in the harmonic series. So, if a musicologist analyses a tune that appears to be heptatonic (having seven notes per octave, or using all the notes of the diatonic scale) and focuses on the stressed syllables (as this author did when re-setting *The Celtic Lyre*), the above progression from Figure 10 to Figure 11 can be accomplished with songs that heretofore have been considered to be heptatonic.

For example, consider "Am fleasgach donn" (better known as "Faill ill ó, agus hó ró éile") which was #30 in the second book of the original *The Celtic Lyre* (Figure 12).

As before, the first step is to place the tune into a computer application program (Figure 13).

Note that the rhythm was changed to match the language and how it is normally performed. In Figure 14, the tune is transposed up by a perfect fifth, to the key of C major.

Although this can be played on a natural instrument, its tessitura is rather high, which makes it difficult to play for the average trumpeter. If attention is placed on the stressed beats, one can see that the stressed beats consist of the pitches e″, c″, c″, e″, g″, c″ respectively, which is actually indicative of the lower-octave pattern of the natural scale e′, c′, c′, e′, g′, c′ (Figure 15).

If that music is then transposed down an octave, Figure 16 results.

Here, one can easily see the harmonic series. However, there are a number of problems, the most important of which is that the notes not included in the harmonic series fall on stressed beats in measures 12, 18, 19, 21, and 23. It is important to realize that the publishers would often confuse the tune as they wrote it or would deliberately change it so as to match the norms of art music. This was a common behavior as publishers of the music of marginalized cultures often camouflaged the music in order to make it seem more complicated (and, thus, more respectable) than it was. Once this realization is made, one needs simply to compare other published versions of the song or listen to old archived recordings. With the proliferation of information on the Internet, many examples of folk songs as sung by older persons may be found online. With regard to Gaelic music, a quick review of music found on internet-based sources such as http://www.gaelstream.stfx.ca

or http://www.tobarandualchais.co.uk will reveal many examples of songs sung by older informants and recorded quite a long time ago. A search done on "Am fleasgach donn," reveals that these contested notes are not correct. Only the non-harmonic series note of the 23rd measure can be routinely heard. If the music is adjusted to account for this, Figure 17 results.

It may appear that the tune was radically changed to force it to match the natural scale, this is actually not true at all. If this tune is performed as described in Figure 17, a native Gael would immediately recognize it, because that is how they sing it.

As another example of this process, consider a more detailed look at an example used in "The Devolution of the Shepherd Trumpet and Its Seminal Importance in Music History" in the January 2015 *ITG Journal*. In Figure 18 is the French tune "Frère Jacques," first published in 1811.[21]

Transposing up to C major results in the music in Figure 19.

The low G adjacent to the C at the end of the tune is indicative of the harmonic series with a trumpet's g and c′. If this example is transposed down an octave with unstressed notes adjusted to match the harmonic series, Figure 20 results.

This same process can be applied to English, Irish, Scottish, Italian, Appalachian, and other kinds of folk music, even if the instruments of transhumance no longer exist in those cultures. Elements of the harmonic series may seem to persist where geographic isolation insulates a culture against the forces of the media. This can be seen to be particularly true of songs con-

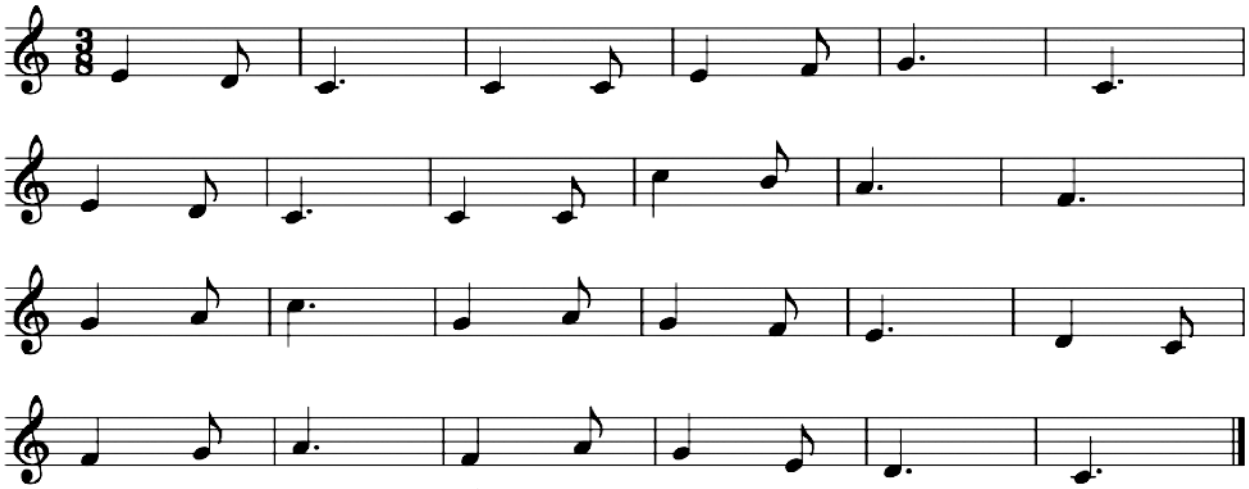


Figure 16. "Am fleasgach donn," transposed down an octave

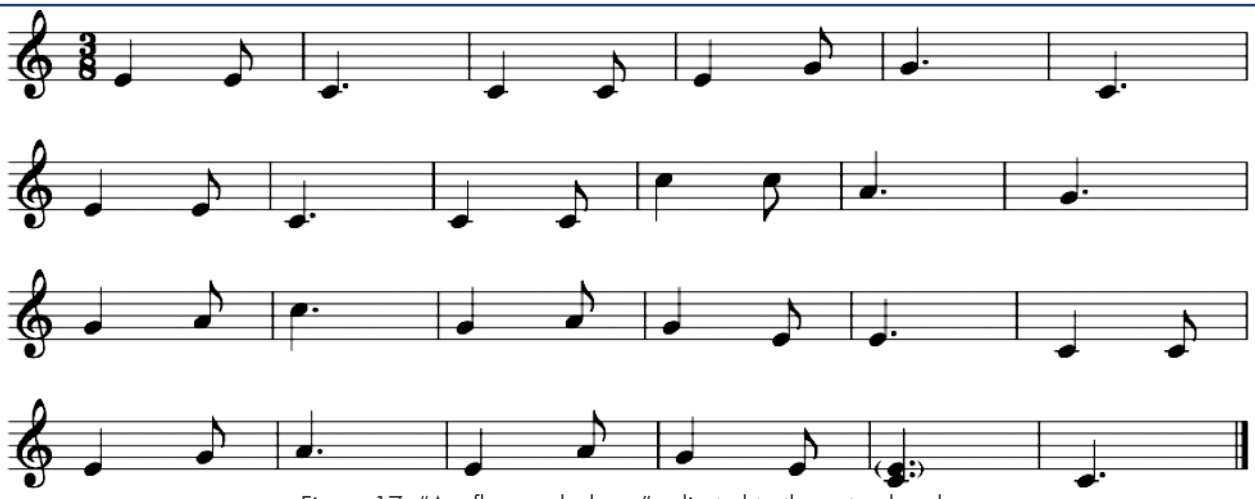


Figure 17. "Am fleasgach donn," adjusted to the natural scale

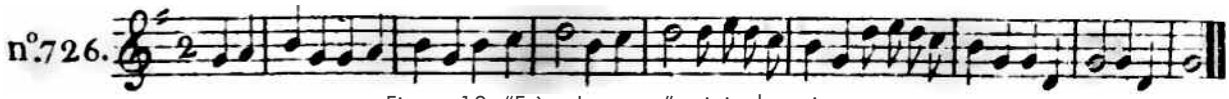


Figure 18. "Frère Jacques," original version

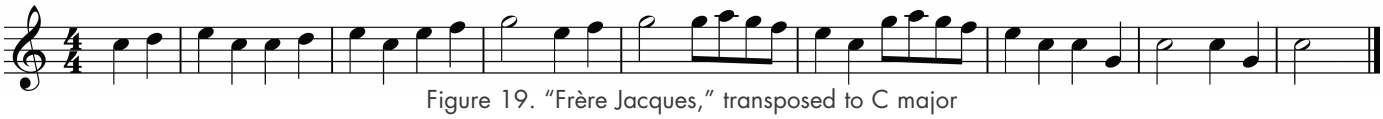


Figure 19. "Frère Jacques," transposed to C major

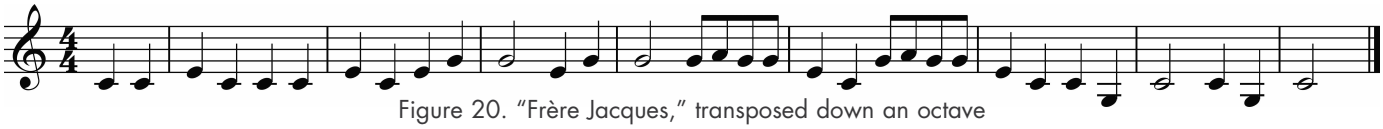


Figure 20. "Frère Jacques," transposed down an octave

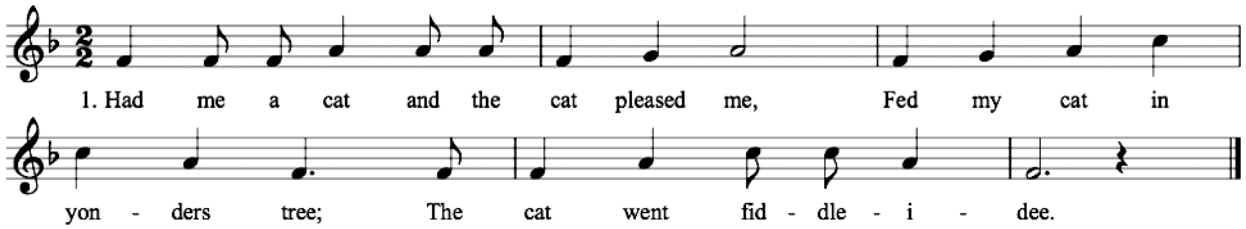


Figure 21. "Had Me a Cat," transcribed by Cecil Sharp

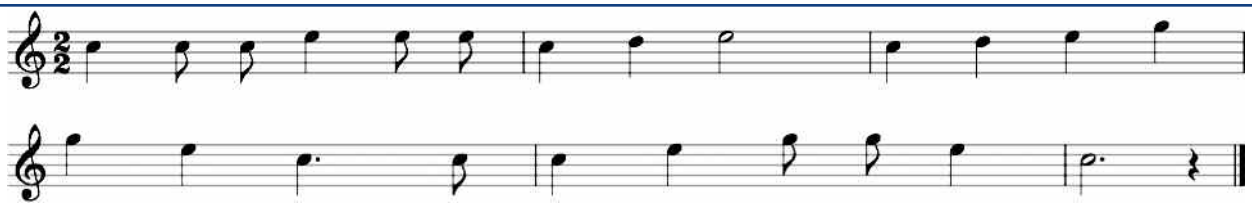


Figure 22. "Had Me a Cat" in C major

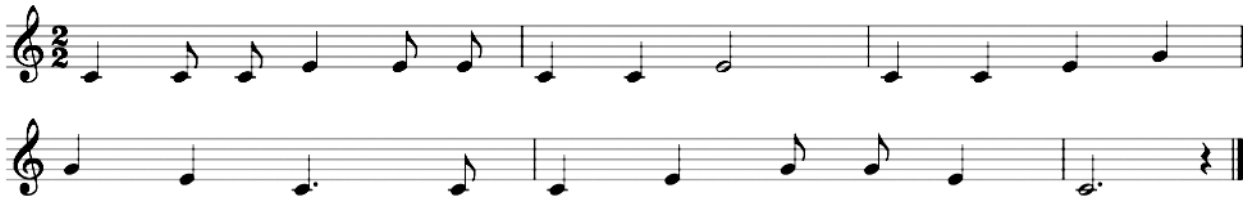


Figure 23. "Had Me a Cat," transposed down an octave

cerning livestock or wild animals. For example, consider songs transcribed by Cecil Sharp in the Appalachian Mountains. Figure 21 is one song from Campbell and Sharp's *English Folk Songs from the Southern Appalachians.*[22]

If this is transposed into the key of C major, Figure 22 results.

While this tune is not difficult to play on a natural trumpet and might have been created to be played with bagpipes (the "rural mode"), the emphasis on C, E, and G indicates that it was perhaps originally intended to be played in the lower octave of a shepherd trumpet. If the notes that fall on unstressed beats are adjusted and the tune transposed down an octave, Figure 23 results.

In reviewing the folk songs of many different cultures in Europe (and brought to foreign shores by emigrants), there appear to be at least three major divisions of tunes that seem to have been created using shepherd trumpets or other natural instruments such as the juice/Jew's harp or willow flute. The first group has tunes that are placed very low in the register of the trumpet and are quite easy to play by even a novice. Some examples of these were just discussed in the preceding section.

The second group contains pitches that range from the third/fourth/fifth partial up to and including the thirteenth partial. Examples from *The Celtic Lyre* include "Mo bheannachd ort, a Màiri" (originally "A nighean donn an t-sùgraidh") and "O, 's toigh leam mo nìonag." Figure 24 is an example of the former.

Figure 25 is another example from Sharp's collection in this range. It is fairly easy to play and again concerns an animal. It is entitled "The Bird Song B" and has a possibly mis-heard F-sharp.

With the exception of the f-sharp′ in the second measure, the pitches of this song clearly match the harmonic series. While Sharp was well known to be rather precise in his transcriptions, it is doubtful if the singer who sang this song for Sharp shared his exactitude.

The third group is restricted to notes above the sixth partial, but avoids the thirteenth partial or higher (the "rural mode"). This will be discussed in the "Bagpipes and Trumpets" section below. Examples from *The Celtic Lyre* include, "Mo nighean

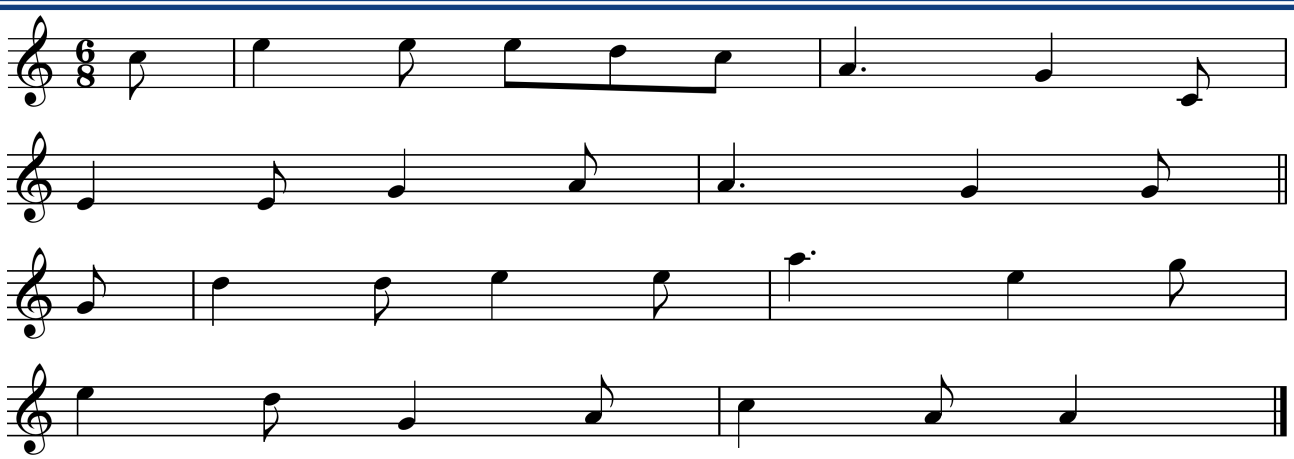


Figure 24. "Mo bheannachd ort, a Màiri," from *The Celtic Lyre*

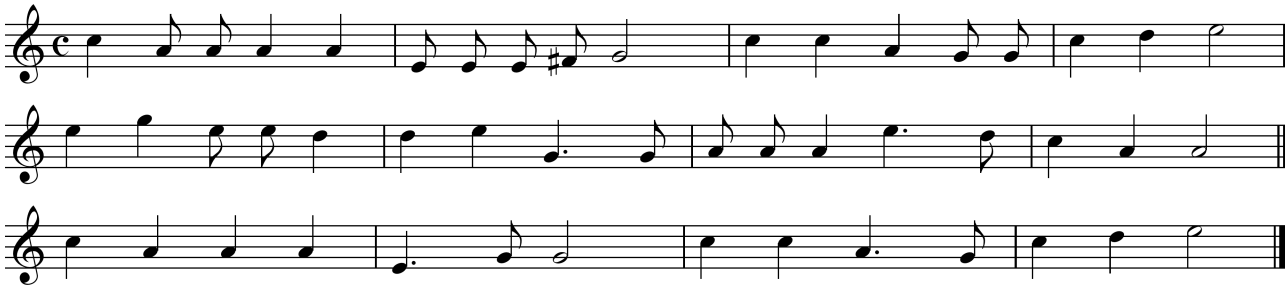


Figure 25. "The Bird Song B," transposed to C major

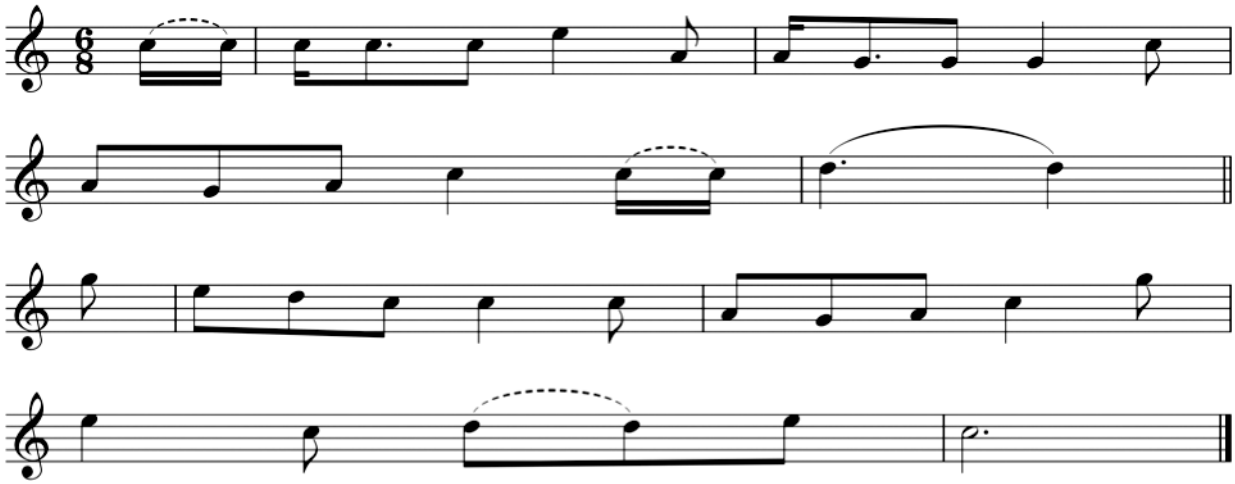


Figure 26. "Gille mo luaidh," from *The Celtic Lyre*

donn, bhòidheach," "Dh'fhalbh mo leannan fhéin," "Na làithean a dh'aom," "Gille mo luaidh," etc. Figure 26 is an example of the latter.

The plethora of examples used here from *The Celtic Lyre* is simply for convenience. The musical examples had already been created; they were simply copied and pasted into this document. While this author is aware of various techniques used to distort music notation due to pejorative pressure felt by the Gaels, this pressure was perhaps not due to one ethnic group judging them (vis-à-vis, the English), but rather an urban vs. rural mentality and positioning. A review of any other indigenous European culture (Irish Gaelic, English, French, German, Lithuanian, Swedish, Polish, Welsh, Spanish, etc.) produces the same results; folk music seems to be based on the harmonic series and not the diatonic scale. Although it may be speculative to suggest that *most* old folk tunes of European origin could be played on shepherd trumpets, the feature of the harmonic series appearing on stressed beats (with associated stressed syllables in songs) is too significant to neglect.[23] This, coupled with the behavior of the early Christian Church and the desire to create in-tune triads through tempering, strongly suggests that shepherd trumpets and other natural instruments dominated early medieval musical intonation systems. If this is true, then it would seem logical that the confluence of the two systems would occur where urban music met rural music and where rural music was not banned—at court.

Introduction to Music at a Gaelic Chieftain's Court

A number of literary and iconographic sources testify to the instruments found at a Gaelic chieftain's (petty king's) court.[24] Predominantly, the main instruments consisted of trumpets, horns, pipes (bagpipes and some [hole-less or otherwise] duct flutes as well), bowed lyres/fiddles[25], and harps (which were considered the highest in social order). There were also various other instruments, including bells (tree of life), bullroarers, drums, etc. While musical anthropologists are happy to recite the names of all these instruments and speculate on their linguistic origins, a performing musician would immediately pause with trepidation at this list. The reason is that the pitch-producing instruments above include at least three different intonational systems: the harmonic series (trumpets, horns, and possibly willow flutes), the Pythagorean-tuned diatonic scale (harps and perhaps bowed fiddles/lyres), and a hybrid system (a type of natural tuning questionably termed "just intonation"), employed by bagpipes. How could these instruments work in any sort of cohesive manner? The answer is rather clear if the sound system of each group of instruments is investigated and correlated with written records, particularly with the tuning system of harps (the oldest were low-headed and wire strung) as described by Bunting from the 1792 Belfast Harp Festival.[26]

For the most part, the intonational system of natural trumpets has been ignored. However, each system has historical features that make practical sense when it is juxtaposed against the others. Therefore, the explanation below is divided into sections (harps, trumpets, fiddles, and bagpipes), each of which defines the sound systems of the four instruments and their relationships to one another.

The Harp

Harpers in a Gaelic chieftain's court stood at a cultural crossroad. In one direction lay the overwhelming presence of folk instruments and the intonation of the harmonic series in songs and tunes (both melodically and harmonically), employed everywhere outside of court and urban areas. This

influence of the harmonic series has been minimized by modern musical academics since their training, and subsequent intellectual authority rests entirely in the diatonic scale. In the other direction, the organization of harp strings numbering more than ten or eleven strings (from the frame harp of the eighth to tenth centuries) required a tuning technology that would be more complex than the melodic harmonic series could provide. Therefore, the basis of tuning a harp of approximately thirty strings (which was used in medieval Gaeldom, perhaps after about the twelfth century) must be diatonic, yet the harper would be required to play for folk singers and natural instruments as well. The tuning systems as recorded by Bunting at the Belfast Harp Festival in 1792 strongly suggest that the harpers employed two different tuning systems that allowed for this dichotomy. The harper could shift from one system to another quickly.[27]

In the harmonic series that was in widespread use prior to the arrival of the diatonic scale, there was no octave equivalence; that is, there were different numbers of notes available per octave. The strings that a harper could employ would be only those notes that existed in the sound-world at that time, and those pitches seem to have been those of the natural scale (as suggested above by the behavior of the early Christian Church and extant old folk tunes). This limits the possible notes to the third through the sixteenth (perhaps—for a good player) partials. It is more probable that an average shepherd trumpeter would only attain the skill to play to the thirteenth partial, though it is known that they can ascend higher. That seems to be reflected in all of the folk tunes that this author has seen. This implies that if a harper were to tune a harp to a shepherd trumpet, then the number of notes/strings allowed would be approximately eleven. Indeed, iconography (which should always be taken "with a grain of salt") suggests that early harps had ten to eleven strings.[28] With the introduction of the new technology of the Pythagorean tuning system and the associated diatonic scale with its feature of octave equivalence, a harper now had an opportunity to increase the number of strings of the harp. Most small, low-headed harps from the Middle Ages had about thirty strings.[29]

The Pythagorean tuning system and its associated diatonic scale[30] were technological improvements for harpers. It gave them increased range and also independence from surrounding instruments. Harp strings could be tuned to fifths and octaves on the same instrument without having to rely on surrounding natural-scale instruments to create a sequence of pitches to which to tune.[31] This system was witnessed by Edward Bunting during the 1792 Belfast Harp Festival, at which he made copious notes concerning traditional harping practices. Bunting ignored most of what he had gathered in order to sell music books to the public trained in art music. However, he did publish some authentic observations, and his unpublished notes still exist.[32] Some of his published information concerns three "keys" (actually tuning systems) used for tuning the high-headed Gaelic harp, but this practice undoubtedly stems from the technique of tuning both small and large low-headed Gaelic harps. The oldest extant harps are low-headed and date from the fifteenth century (the Brian Boru, Queen Mary, etc.). The three tuning systems had either no accidentals, one sharp, or two sharps. The two most important systems had zero or one sharp.

The first tuning method that Bunting listed was the "Natural Key," termed "*Leath Gleas*" (literally "half-note"—it is also referred to as the "Sharp Key"). This system was a type of Pythagorean tuning that is centered on G. The term "natural" is thought to refer to an older manner of saying "major." It required tuning the strings to perfect fifths (and one perfect fourth) and octaves. This created the G major scale (10th, 18th, and 25th strings tuned to F-sharp from F-natural), which may be seen from Bunting's work in Figure 27. The last measure should be ignored at present, as that specifies how to change from the "Natural Key" (one sharp) to the "High Bass" (no accidentals) key. "High Bass" is also referred to as the "Flat Key," or "Flatt Key."

If placed in modern notation with more delineation to attempt to show the string tuning order, the Natural Key might appear as in Figure 28.

Although it is difficult to see from the above figure, the two tuning systems were roughly centered from g to b′ (with a vari-

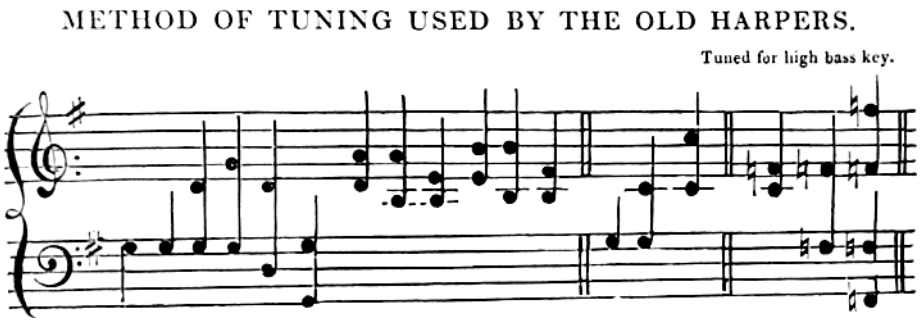


Figure 27. Two tuning systems for the harp

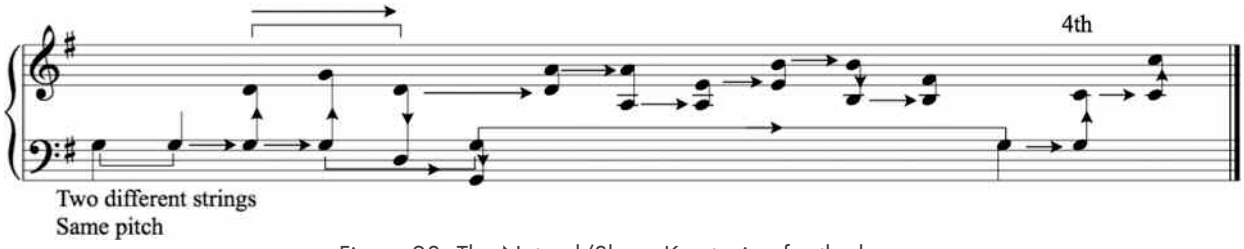


Figure 28. The Natural/Sharp Key tuning for the harp

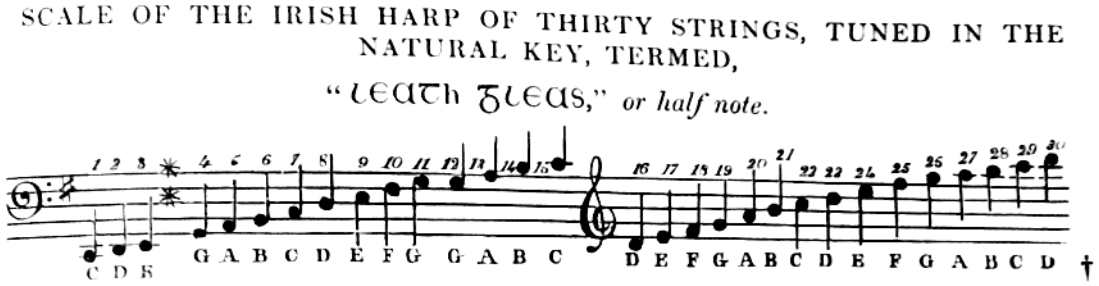


Figure 29. The scale resulting from Natural (G major)/Sharp Key tuning

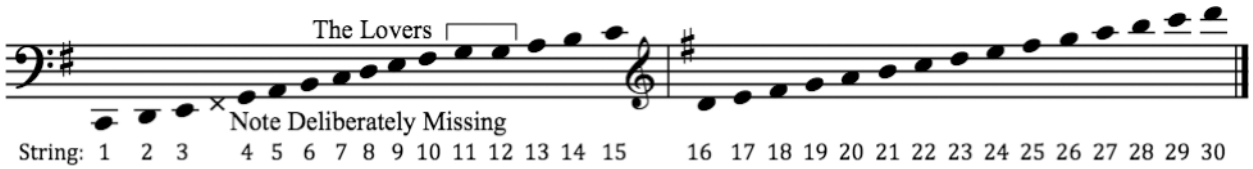


Figure 30. The scale resulting from Natural (G major)/Sharp Key tuning, in modern notation

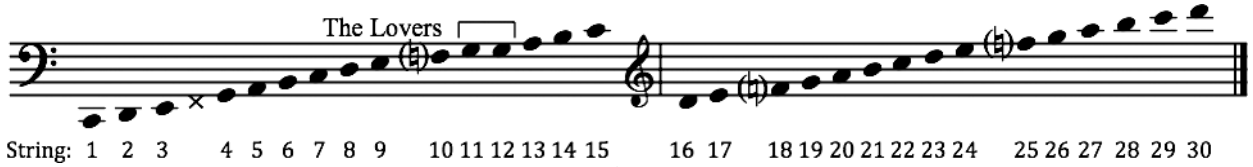


Figure 31. The scale resulting from High Bass/Flat(t) Key tuning

able f-natural′ and f-sharp′; the third system had an f-sharp′ and a variable c-natural″ and c-sharp″); the remaining notes were obtained by tuning to the newly tuned notes (above) by octaves. This resulted in the creation of the following diatonic G major scale (as shown above with f-sharp′ and c-natural″) on a harp of thirty strings (Figure 29).

In modern notation, it would appear as in Figure 30.

Incidentally, there has been much speculation on the string tuning of medieval and pre-medieval plucked lyres, which normally possessed six, and occasionally seven or eight, strings. Since these lyres were plucked and not bowed, it is thought that a lyre's strings were tuned in some melodic manner. Placing one's fingers at nodal points and plucking results in a very dull/quiet sound; therefore, the strings were probably not tuned in some gapped manner as is a bowed chordophone. The process of creating the diatonic scale as indicated above would suggest that many strings would need to be present in order for this process to occur (one would run out of strings on a six-stringed lyre before B, C, or F-sharp could be created). It is unreasonable to expect people to know the diatonic scale intuitively. Today, people have TV, radios, and pianos as references; similarly, in the past there must have been a reference to tune the strings of a lyre. Harps of thirty strings (which, unlike the organ, were portable) did not exist until about 1000 AD; therefore, there was not a ready diatonic reference available. Since shepherd trumpets were widespread, by default, they must have been the lyre string tuning reference. This suggestion is strengthened by the fact that the natural scale appears to be the foundation of folk songs, as demonstrated above, at least in a rural/pastoral setting.

The second tuning convention that Bunting recorded also began and ended on G, as illustrated in Figure 27. However, the last measure shows the difference. The fifteenth string (c′) is used to tune the eighteenth string (which had been f-sharp′) to f-natural′ by a perfect fourth (whose overtone is very faint). The remaining F-sharp strings were tuned to the eighteenth string in octaves. This tuning method was called "High Bass" (also called the "Flat Key") where the harp was still centered from g to b′ (with a variable c-natural″ or c-sharp″ to tune to the third key, discussed below), but the leading tone of F-sharp was lowered to F-natural. This resulted in the scale in Figure 31.

The first tuning (the Natural Key) created a scale that today would be called G major (Figure 30). The second tuning (High Bass) created a scale that perhaps would be called C major (Figure 31). This latter nomenclature is not exactly true; the second tuning would be more accurately referred to as G mixolydian, since it starts and ends on G. This actually makes a difference, as these tunings are not equally tempered; that is, the G major of the Natural Key and the C major of the High Bass key have a different "color" and impart a different feeling to the listener; this does not occur today with exact equal temperament.

This emphasis on G is strengthened by having two notes of the same pitch side-by-side, termed *caomhluighe*, which means "lying together" (or the lovers/couplers); these notes were both tuned to the same pitch. The harper's right (strong/masculine) hand played the bass notes until ascending to those two notes, and the left (weaker/feminine) hand then played the twelfth string and treble notes above; the right hand played notes that men would sing, and the left hand played notes that women would sing. The harp rested on the player's left shoulder.

The difference between the two main scales/tunings/keys is the *tead a' leith ghleas* (literally, "string of the half note:" F-sharp/F-natural). The harp strings were made of metal and plucked by the fingernails, which were shaped by two straight cuts resulting in a shallow point. Recent research has suggested that the lower-pitched strings may have been made of a metal that was rather dense (gold), since brass strings would have to be prohibitively thick to achieve the proper mass for the pitch; a thick string would behave like a rod, resulting in poor sound quality. Middle strings may have been made of silver and the higher-pitched strings of brass. Since strings sound best when

stretched near to (but not over) the breaking point of the metal, modern metal cannot be used, as it is too strong. String makers now must make wires deliberately weak to achieve the best sound.

The focus placed on G by the harpers and other players of early traditional Gaelic instrumental music[33] is important, because it demonstrates that the first accidental in Gaeldom was F-sharp and not B-flat as it was on the European mainland. Both accidentals served the same purpose, and that is to allow the facility of shifting the modes offered by Pythagorean tuning and the resulting diatonic scale by half an octave. Concerning the work of Vincenzo Galilei, Nicholas S. Lander wrote:

> To bring the pitch of the modes into a different relationship with the "tessitura" (or middle compass) of the voice, modes can be raised or lowered in pitch, most usefully by means of a key signature of one flat. The modes are then described as "transposed dorian," "transposed phrygian," etc.[34]

Before the advent of B-flat on the continent, there were a limited number of pitches, referred to as a "gamut." So if a choir had to shift up from the dorian to the mixolydian mode, the members of the choir had their singing range raised by a perfect fourth. This may have made singing a song/chant beyond the ability of the choir. It should be remembered that in early music there was once a gamut, a rigid set of pitches in place, and the current method of musical transposition through the use of keys did not exist. Adding one accidental gave singers much-needed flexibility. With B-flat as an accidental, C ionian (major) becomes F ionian (major), and all of the other modes shift as well (D dorian becomes G dorian, E phrygian becomes A phrygian, etc.). Moreover, not only were singers in the early Christian Church constrained by range as imposed by the modes before the introduction of B-flat, this gamut of pitches further limited the musicians. This is an additional reason to suggest that before the advent of Pythagorean tuning in the early Christian Church, the available notes may have been that of the harmonic series and not that of the diatonic scale. Diatonic scale tuning incorporated the concept of octave equivalency and hence limitless pitches; this did not exist in the very early Christian Church in Europe. Although speculative, it could well be that the harmonic series was incorporated into early European Church music; this may have brought an unwanted pagan element that the diatonic scale (and dorian through mixolydian modes) resolved. However, in the diatonic scale that existed, the special notes of B-flat (and F-natural/F-sharp in Gaeldom) allowed singers to sing all of the ecclesiastical modes comfortably. On the mainland, B-flat was such an important note that it was considered to be *musica vera* and not *musica ficta*.

In insular Britain, the functionality of shifting a tune by a half-octave was supplied by the F-natural/F-sharp dichotomy. So with a variable F, G ionian (major) shifts to C ionian (major) or vice versa, and all of the other ecclesiastical modes shift as well. There were three substantial benefits to using F-natural and F-sharp as an accidental. Firstly, the F-sharp/F-natural shift allowed singers to transpose melodies by half an octave (this could also be done using B-flat). For example, a baritone could easily sing a song performed by a soprano. Secondly, it allowed for the F-sharp/F-natural string to be positioned where the eleventh partial falls on the harmonic series; that is, the three altered strings (10, 18, 25) used to change from G major to G mixolydian (C major) are placed exactly where there is conflict with a natural C trumpet (those are the strings that would be tuned half-way between F-natural and F-sharp to match a natural trumpet). Thirdly, it more closely matched the tuning of bagpipes; this will be described below. Ó Boyle commented on the harp tuning systems of the Natural Key and High Bass; he also included a third and final system that will be described later under the section "Harp and Bagpipes" that included both F-sharp and C-sharp:

> Though their preference in pitch was in G, they nevertheless did not think in keys. Their thinking was modal and the pitch of their modes altered from G Doh to C Doh and D Doh [this tuning method is discussed below]. Bunting, being a man of his time, must be forgiven for not understanding it.[35]

It is interesting that Ó Boyle noticed the emphasis on G but chose to write "C Doh" and not "G Soh." Perhaps he was attempting to explain the one-sharp, no-sharp, two-sharp system to readers who were completely immersed in the modern major-minor modal system. To be more precise, the harpers were shifting between G Doh (ionian–major), G Soh (mixolydian—or a harmonic series hybrid), and A Soh (mixolydian—or a harmonic series hybrid matching a D natural trumpet ending on the sixth partial—discussed below). The difference between the G Doh (G major) and G Soh (G mixolydian—or a harmonic series hybrid) being the variation between F-natural and F-sharp (right at the eleventh partial). So, in essence, the tuning systems as described above allowed the harpers to shift between G major in the diatonic scale, and then lower the F-sharp to match the eleventh partial and play with instruments using the harmonic series.[36] They then could continue the downward tuning of F (making it High Bass tuning) so as then to be a half octave away from G major (the Natural Key) and play in C major; this then allowed singers to sing in a comfortable range and also allowed them to shift between the intonational systems of Pythagorean tuning (art music) and the harmonic series (rural music). Moreover, tuning down to F-natural also put harps in the same key as G mixolydian bagpipes; with bagpipes having pipe drones in G and harps having drone strings in G. With such an apparently important role being played by bagpipes, it might be worthwhile to investigate the instrument and understand its tuning method.

The Bagpipes

The origin of the Scottish Great Highland Bagpipes has been contested over the years. Most early theories suggest that the instrument was imported from India. This seems doubtful, however. Most instruments develop over time due to technological advancements, as instrumentalists are always searching for easier or better ways of playing or tuning. For example, as mentioned above, the early medieval harp in insular Britain is documented as having eleven strings or so before at least the tenth century. When Pythagorean tuning was introduced, this new technology allowed for a way of arranging/tuning strings in a methodical manner. More strings could be added; the number of strings on the harp then increased to about thirty.

As another example, consider the technology of bowing that was introduced in Moorish Spain around 950 AD with the rebec. This was a new technology that allowed a chordophone to sound more like the human voice—that is, have a longer sustain than the normally plucked gut string of the lyre. The

new technology was the introduction of bowing of the strings, not the bow and rebec combination, so the technique of bowing was subsumed into the tradition of the plucked lyre (*crotte*, *rotte*, crowd, *chorus*, *crwth*, etc.). The lyre (as in the Sutton Hoo, Prittlewell, Trossingen, Snape, etc. lyres) was multi-stringed and had a flat bridge; so when the European medieval lyre was bowed, the non-fingered strings would vibrate causing droning on those open strings. The lyres also became "waisted," so the curves of the viol and subsequent violin came from the tradition of the plucked lyre.

The Great Highland Bagpipe may have also originated through a similar series of developments. It possibly began as a lip-vibrated aerophone on a cane with an animal horn inserted at the end (literally, a hornpipe). Holes were probably drilled in it in order to match the intonation of other instruments of the same type. With the addition of holes, there was no need for a mouthpiece; a double reed would work as well. With other instruments incorporating drones playing alongside it, the bagpipe probably added a drone as a separate pipe, much like the Greek *aulos*. In time, having two pipes in the player's mouth would become irksome, and a wooden manifold was likely added so that the player might have only one pipe inserted into the mouth (the modern hornpipe looks something similar to this). Wooden manifolds leak, and an animal's stomach as a bladder would work better and be easier to make. With this bladder, more drones could be added. This type of slow progression and development is the general process by which modern instruments have evolved. Most instruments in a European Orchestra are of folk origins.

It is generally supposed that the bagpipe chanter (or section that is fingered to produce the melody) is tuned using the "just intonation" method. To tune the chanter, existing holes are cut larger with a knife or reduced through the addition of tree sap or tape so that the nodal points of the chanter "lock in" to the nodal points of the drones' overtones. Just as the ecclesiastical system perhaps should not be applied to the folk music tunes, so perhaps the application of the term of "just intonation" is also inappropriate when directed at the tuning system employed by a bagpipe chanter. The term "just intonation" is applied to the machinations that were made to Pythagorean tuning to make out-of-tune thirds (22 cents sharp for major thirds and 22 cents flat for minor thirds) tolerable. The intonation of the bagpipe chanter is not determined in order to achieve the tempering of thirds to make them in tune; as they are perfectly in tune already, there is no tempering required. The pipe chanter tuning system is independent of the Pythagorean method as described above. Therefore, since just intonation is a manipulation of Pythagorean tuning, and bagpipe tuning is independent of the Pythagorean method, just intonation is not related to bagpipe chanter tuning. It is merely a convenient name (similar to naming the scale that a bagpipe plays as being mixolydian, even though it has a tuning system apart from that used create the diatonic scale and resulting ecclesiastical modes), which, although slightly inaccurate, gives a rough approximation. To show how independent bagpipe tuning is from Pythagorean (and hence just intonation) tuning, it might be wise to take a quick look at how the bagpipe chanter is tuned.

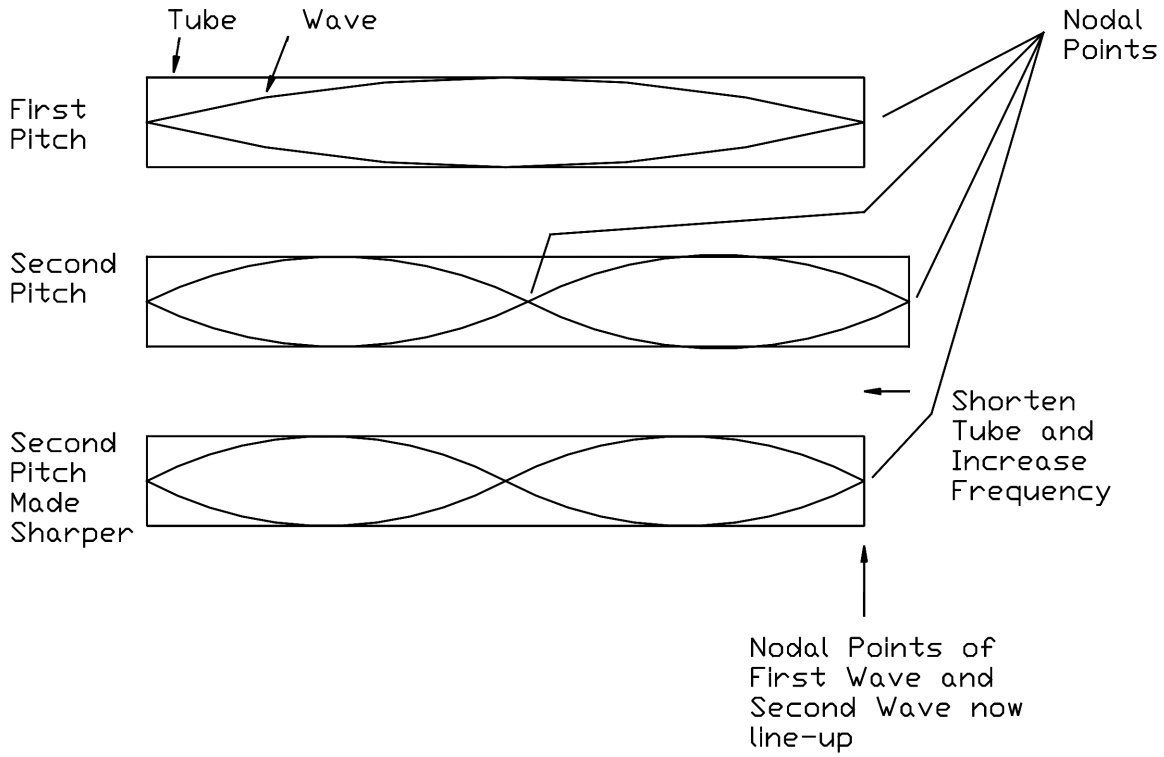


Figure 32. Aligning nodal points on a chanter

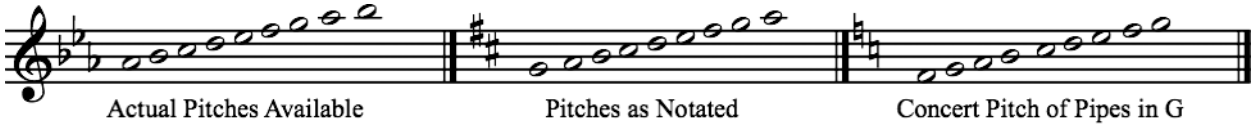


Figure 33. A comparison of the concert pitches of the Highland Bagpipes

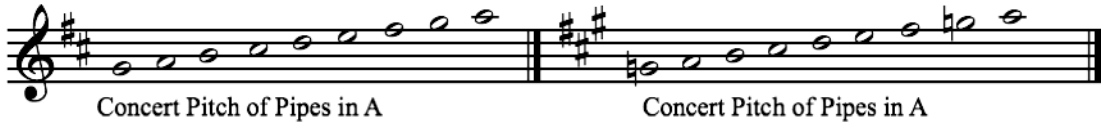


Figure 34. Bagpipe scale written in both D major and A major

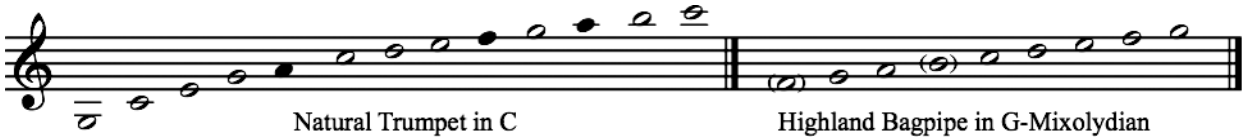


Figure 35. Natural trumpet in C and G mixolydian bagpipes

A Highland Bagpipe chanter (the part of the instrument that creates the melody) is tuned to the drones. There are two drones that are an octave lower than the low a′ on the chanter. Another drone is set at an octave lower than that. The chanter is roughly diatonic, ranging from g′ to a″ comprising g′, a′, b′, c-sharp″, d″, e″, f-sharp″, g″ (note that both g′ and g″ are not sharped), and a″. There are always two sharps in the key signature (F-sharp and C-sharp, but not G-sharp). The notation is in concert pitch, not in C major as is often done with natural trumpets, with the instrument's pitch noted in the upper left corner. The frequency of each individual note that the chanter produces is adjusted by carving out the top or bottom of a hole of the chanter. In the past, sap or pitch was added to the top or bottom of the hole opposed to where wood was removed. Today, often a piece of strong tape is used instead of sap or pitch for each pitch needing to be tuned. The pitch is adjusted up or down until the chanter's pitch "locks in" to the pitches of the drones. In essence, the wavelength of each pitch of the chanter is lengthened or shortened to match the nodal points of the overtones of one of the two drones (A or a).[37] Although sound waves are compressional waves, it is easier to think of them in terms of being sinusoidal. As such, a nodal point is where a wave crosses the x-axis. This includes the starting point and the ending point of each wave. A pictograph might be useful here (see Figure 32).

Like many instruments, the Highland Bagpipe has gone through pitch inflation (the so-called "Vienna Effect"). However, this inflation does not seem to have occurred until the 1960s. Although the original pitch may have been closer to G than A, it seems to have been relatively stable for the Highland Bagpipe for a number of centuries, at about A = 450 Hz.[38] However, many other types of bagpipes are in G.[39] Additionally, iconography of bagpipes seems to suggest that the Highland Bagpipes may have been in G. Today, the Great Highland Bagpipes are pitched slightly above B-flat. That means that the drones are in B-flat, and its highest pitch is equal to B-flat or higher when played with a concert instrument such as a piano (where A = 440 Hz). Many pipers now have two chanters. One is pitched high (a sharp B-flat) for pipe and drum competitions, and another is pitched in concert A so as to play with other concert-pitched instruments. The notational system seems to have gotten arrested when annotating the pipes when the pipes were placed in A, so the key signature has not moved from this point and has two sharps. This might seem rather odd for the casual observer, since the drones are in A, the pipes are said to be in A, yet the key signature reads D major, and the actual pitch is B-flat. A diagram might make this less confusing (Figure 33).

If the key signature were changed to reflect the pitch gamut and drone placement to fit the key signature of A major, the result might look somewhat odd (see Figure 34).

This can cause a great deal of confusion. For example, a bagpipe may be required to play with an orchestra. The arranger knows that it will be an A bagpipe but may mistakenly believe that the music for the accompaniment must be placed in A major. However, the piece actually needs to be in the key of D major (in the key signature). The actual tune cannot be in D major, since, with the limited compass of the chanter, the bagpiper will have to break the melodic line every half octave; for example, if the melodic line ascends to b″, the bagpiper must jump down an octave. Add to that the confusion that the Highland Bagpipe is today in B-flat, so the music is actually in E-flat for other instruments (unless the piper has a concert A chanter), and the music given to the piper will be with D major in the key signature. Orchestrating the A mixolydian Highland Bagpipe for other instruments is not for the faint-of-heart!

Trumpet and Bagpipes

If a natural trumpet is matched to the bagpipe scale, an interesting condition is revealed. Firstly, a G mixolydian bagpipe and a G natural trumpet will not have as many notes in common as if a C natural trumpet is used. This is significant, since most musicians have believed that a natural trumpet's melodic scale begins on the eighth partial. It does not. It begins on the sixth partial. Indeed, since every note is the same distance away from every other within the harmonic series point-of-view, melodies on natural trumpets can begin and end on any note and be considered melodic. It is simply that when playing with other instruments, particularly the bagpipe, the centering tone is the sixth partial (g′). If a C natural trumpet and G bagpipe attempt to play the same scale, only f′ and b′ are missing in the trumpet's range (Figure 35).

This correlation has interesting implications. Trumpeters familiar with Baroque music know that most trumpet music written was placed in D major, to be played on a D natural

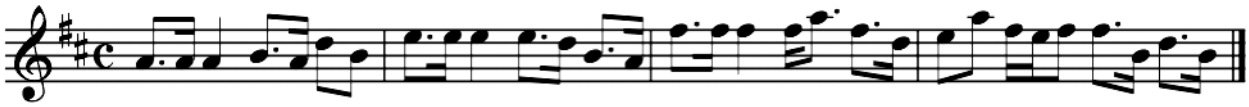


Figure 36. "Another Key for Rural Pieces & Laments"

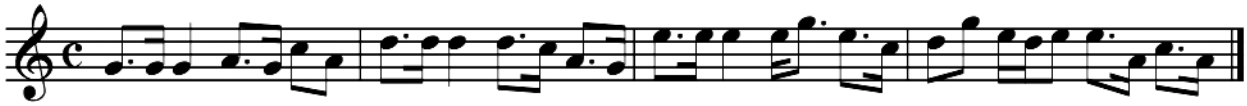


Figure 37. "Another Key for Rural Pieces & Laments"

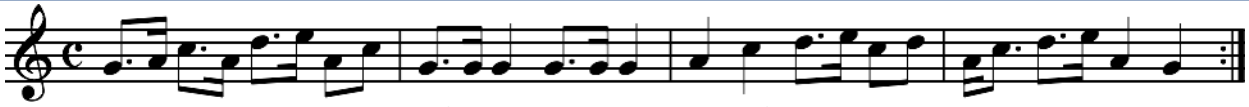


Figure 38. "Another Key or Taste for Laments and Rural Pieces" for G bagpipe/C trumpet (ends on g′)

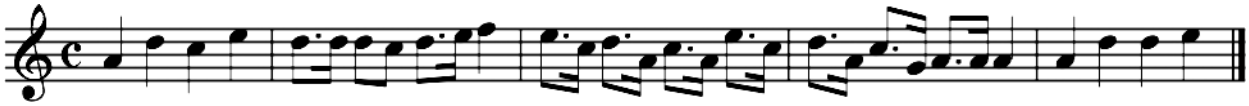


Figure 39. "Another Style or Taste for Laments" for G bagpipe/C trumpet (ends on e′′)

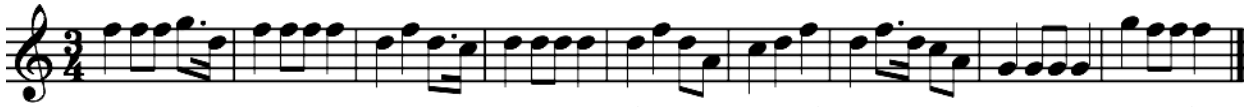


Figure 40. "G. Sharp, Another Species, A Style or Taste for Rural Pieces" for G bagpipe/C trumpet (ends on f′′)

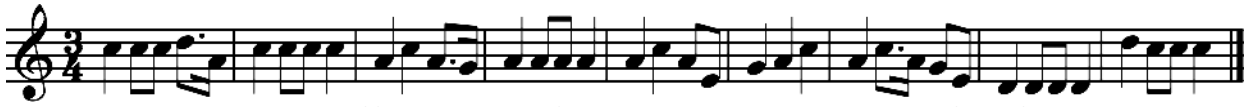


Figure 41. "G Sharp another Species, fifth Style or Taste for Rural Pieces," transposed down a fourth for G trumpet (ends on c′′)

trumpet. Therefore, the scale displayed in Figure 35 would have the same relationship between a D natural trumpet and an A bagpipe. So there is a strong correlation between the D natural trumpet and the A bagpipe just as there is between a C natural trumpet and a G bagpipe (as displayed in Figure 35).

This relationship was strengthened after researching references to Barnaby Brown's "The Iain Dall Chanter: Material Evidence for Intonation and Pitch in Gaelic Scotland, 1650 – 1800."[40] Brown uses a quotation from Joseph MacDonald's *Compleat Theory of the Scots[']* *Highland Bagpipe (c. 1760):* "The Key for Laments excludes C altogether because it is sharp."[41] Investigation into this reference[42] has produced some exceptional results. What is surprising is that, beginning on page 23 and following until page 25, MacDonald states that there are "rural" modes for the bagpipe. In all, the author gives seven examples of specific modes for the A bagpipe that avoid concert C. If matched to a seven-foot-long D shepherd trumpet, this suggests that the "rural" modes all avoid one of two notes that a shepherd trumpet could not play (the bagpipe cannot also play its low concert G). Moreover, MacDonald gives examples where the bagpipe does not play both its possible low concert g′ and c-sharp′′. For a D shepherd trumpet, that would be between the fifth and sixth partial (concert g′), and between the seventh and eighth partial (concert c-sharp′′); for a C trumpet and G bagpipe, that would be between the fifth and sixth partial (f′), and between the seventh and eighth partial (b′). That matches the harmonic series.

This is a bit difficult to imagine if not accustomed to transposing music at sight. A few musical examples should help. In Figure 36 is "Another Key for Rural Pieces & Laments,"[43] which shows that the A mixolydian bagpipe does not play both the low g′ and c′′.

If this is transposed down one step (for a C trumpet, rather than a D trumpet) to match the harmonic series/natural scale (see Figure 5), the affinity for the harmonic series becomes apparent (Figure 37).

This clearly shows that this tune in a "rural mode" for bagpipe, exactly matching the harmonic series and the pitches available to a shepherd trumpet; the f′ and b′ of a G bagpipe scale (g′ and c-sharp′′ of an A bagpipe scale) are deliberately avoided. This continues for the following example, entitled "Another Key or Taste for Laments and Rural Pieces."[44] Here, the ornaments have been removed, as they obscure the melodic structure and do not consist of any non-harmonic-series pitches. Additionally, to save space, only the transposed versions (A bagpipe to G bagpipe) have been included, so as to match the harmonic series as is normally displayed (Figure 38).

This occurs again in "Another Style or Taste for Laments,"[45] shown in Figure 39.

The harmonic series also occurs in the following example.[46] However, the example is presented here with an understanding that the added embellishments are "grounded" on concert g′ (f′ on a G bagpipe, which is outside the range of a C shepherd trumpet). In Figure 40 is this example, again transposed down one full step.

It should be noted that in this example, e′′ is also missing. The absence of both b′ and e′′ implies that the music could be further transposed down a perfect fourth, which would result in the music of Figure 41.

This latter example matches the harmonic series, except for the eighth measure (which would need to be a c′ to match the

harmonic series, a concert g′). It is possible that the author altered this measure because he was trying to show that the "grounding" on concert g′ (f′ in Figure 40 and c′ in Figure 41) was only in the embellishments and not the principal notes. This implies that bagpipes may not have only played to accompany shepherd trumpets in D (and other natural instruments like the sallow flute and juice/Jews' harp), but also shorter ones pitches in G. Except for the second-to-last measure, both a D and a G trumpet could play this tune together (albeit in an intonationally-odd manner) in unison.

In essence, when a bagpipe plays in a pastoral manner (the rural mode), the bagpipe plays only music that a shepherd trumpet could play. This is rather significant. What is also significant is that the absence of c-sharp″ (b′ on a C shepherd trumpet) has not been explained by any other hypothesis. The fact that these "modes" only contain notes that can be played by a shepherd trumpet should not be dismissed or ignored. Moreover, the present author had the opportunity to play the tune "Mo nighean donn bhòidheach" on brass D natural trumpet with Highland Bagpipe player Francis "Can't Be" Beaton (trained by Sandy Boyd) playing on a concert A bagpipe. The result was very satisfying with slight variance only noted on the seventh partial, which seemed to be acceptable. Further personal correspondence with noted author and bagpiper Barry Shears revealed that there is a great deal of variation with regard to bagpipe chanter intonation. Cross-fingering and intonational differences, not only with *ceol mòr*, were quite common in traditional bagpipe traditions preserved in Nova Scotia (particularly on Cape Breton Island). Some audio files of these intonational variations have been provided, and an analytical frequency comparison is forthcoming (equalized to a root pitch to see the variation between all of these systems: brass and wooden trumpet, bagpipe, and harp playing in the different keys listed above and below).

Harp and Bagpipes

If one considers that there has been very little pitch inflation with the Scottish Highland Bagpipes until the 1960s and that the pitch has been relatively stable at A since then, then an additional tuning method that Bunting mentions makes much sense. He mentioned that there was a key that was seldom used that had both F-sharp and C-sharp in the key signature. This, then, comprised the entire gamut of keys used not only by harpers, but by most traditional instrumentalists until the middle of the nineteenth century. As Bradley and Breathnach mentioned, "[Irish] traditional instrumentalists confine themselves almost wholly to keys requiring only one or two sharps."[47]

This option produces an intriguing possibility. The bagpipe's rural mode working synchronously with a shepherd trumpet might also match the third tuning system that Bunting annotated for the harp. If the Highland Bagpipes were in A (perhaps at A = 415 Hz) and had not gone through pitch inflation, then the harp could match this tuning. The harp could do this if it raised its High Bass tuning by a full step (or adding one sharp in the Natural Key), placing its tuning into a key that appears to be D major. Figure 42 shows how it appeared in Bunting's work, with the footnote pasted beneath the example.

This tuning is simple to accomplish. Instead of creating C-natural from the lower G (tuning by removing the beating of the overtone of a perfect fourth, which is difficult to hear), the C-sharp is created by using the previously tuned F-sharp (removing the beating of the overtone of a perfect fifth), as can be seen above in Figures 27 and 28.

As mentioned above, if a natural trumpet were played along with an A bagpipe, it would have to be in D major (about a foot shorter than if in C), and the trumpet and bagpipe scales would look something like Figure 43.

This may have important ramifications, as it is well known that most natural trumpets in the Baroque era were pitched in D (or E-flat with crooks to lower the pitch). When playing with other instruments or singers, music with two sharps was called the "choral key," ostensibly because a chorus of singers was employed; however, in light of the above information, "choral" might refer not to the addition of singers, but rather to the fact that it was the key that could accommodate all instruments so that they might play in "chorus." That would be the "Natural Key" with an additional C-sharp for the harp, D natural trumpets, and bagpipes in A. So it may have been that it was the presence of A bagpipes and not D natural trumpets that was the fulcrum for this appellation.

This third tuning system then allowed the harper to play in ensemble with A mixolydian Highland Bagpipes and D trumpet. Removing the sharps allowed for playing with Union (Uilleann pipes—drones in an octave and a fifth) bagpipes in G and C trumpets. It also allowed for migrating back and forth between natural and diatonic scales as well as shifting melodies up or down half an octave to fit a singer's particular tessitura.

Fiddle and Harp

It appears that with the introduction of the Pythagorean tuning system in about the tenth century, the number of strings of a harp were increased from about eleven to thirty or

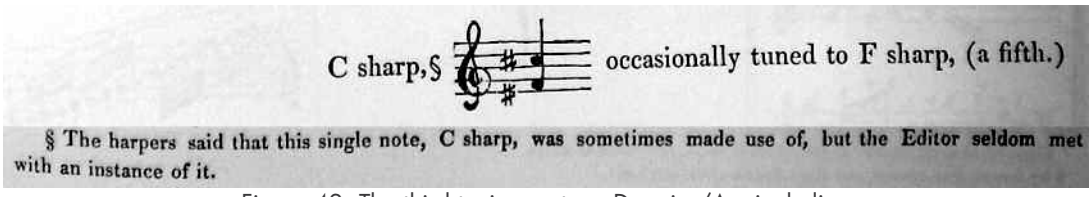


Figure 42. The third tuning system, D major/A mixolydian

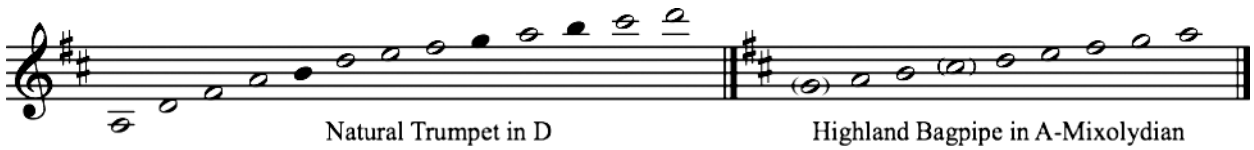


Figure 43. Natural trumpet in D and A mixolydian bagpipes

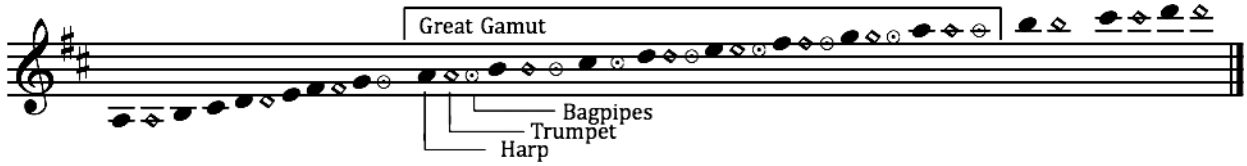


Figure 44. Natural trumpet in D, A mixolydian bagpipes, and harp pitch spectrum

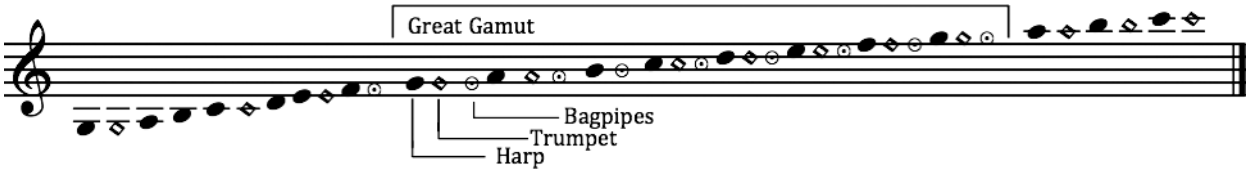


Figure 45. Natural trumpet in C, G mixolydian bagpipes, and harp pitch spectrum

more. Prior to that, the dominant tuning system may have been the harmonic series. Where the harmonic series exists as the only scale, people are quite content with it. Concerning bowed instruments, "If medieval fiddlers were found in rural areas, or if traveling musicians heard rural, folk instruments, they could have heard music played on several different instruments using the natural overtone scale."[48] Also, harpers would be required to match those harmonic series notes whose number could only be, at most, perhaps eleven and possibly fourteen strings (matching a trumpet player who could play the third to thirteenth partials and possibly up to the sixteenth partial). Yet, even with the introduction of the diatonic scale and associated Pythagorean tuning method, the relationship between the 11-turned-30-stringed harp and the plucked-turned-bowed lyre (*cruit,* crowd, etc.), was probably maintained in some fashion. This can be seen in the tuning technique, used by Gaelic fiddlers, which is still practiced in Nova Scotia, Canada. Fiddlers call tuning two pairs of strings a fifth apart (separated by a fourth) "High Bass" and sometimes "High Bass and Counter" to describe A-E-a-e (a-e-a′-e′) tuning, which is different from the standard of G-D-a-e (g-d-a′-e′). This increases the sympathetic harmonic motion of the instrument and makes it much louder. Fiddlers use this tuning mainly so that dancers can hear the music over the sound of the dancers' feet.

Bagpipes, Trumpet, Harp, and Fiddle

If one studies the connections between the bagpipe, harp, trumpet, and fiddle, a rather strong synergy emerges. With the ranges of the natural trumpet in D, the A mixolydian bagpipe, the Natural Key tuning of the harp (which is combined with an additional sharp or High Bass tuning with two sharps as stated by Bunting), and the High Bass tuning of a fiddle in A, the total gamut of pitches produced might be as in Figure 44—the fiddle is omitted due to space constraints. However, it should be considered to be closely related to the harp throughout the "Great Gamut."

If the ranges of the natural trumpet in C, the G bagpipe, and the High Bass tuning of the harp are all combined, the total gamut of pitches produced might be as in Figure 45.

While it should be acknowledged that there is a great deal of fluctuation in intonation from one tuning system to another, instrumentalists often adjust how they tune, depending upon the instruments on which they are playing. This is becoming increasingly apparent as scholars are beginning to question the importance of fixed-pitched instrument limitations, especially in Baroque and other early music. Additionally, in considering the consort of harp, fiddle, bagpipe, and trumpet, it should also be noted that although triadic harmony was clearly present due to the presence of natural trumpets, one should not jump to the conclusion that the harmony at a Gaelic chieftain's court or any other European petty king's court contained the harmonic progressions that exist today. Trumpet triad motifs are extremely old,[49] but harmonic progressions may not be as much. Triadic harmony probably existed using drone harmony, although that harmony may have shifted at key points. This point is often obscured when modern-day musicians consider lip-vibrated aerophones. The Gaelic chieftain's court instruments consisted of both horns and trumpets. Modern horns are longer than trumpets, but the horns were once made from animal horns (or from other material to resemble animal horns) and were quite short. Drone harmony was probably provided by these instruments, as their range is limited to only a few lower partials.

Harmonic Considerations

The development of harmony in art and Church music is thought to have begun with *organum*, with no known origin.[50] It pre-dates the twelfth-century Notre Dame School, beginning prior to the ninth century.[51] It originated, perhaps, from a corps of shepherd or court natural trumpet players playing together; similar traditions still exist in Switzerland and other countries where shepherd trumpets (*alphorns*) play together harmonically. So it is quite conceivable that *organum* was actually a sacred extension of a secular tradition.

One of the reasons that the harmonic series has not been seen in folk music is that often not only are b′ and f′ missing (ostensibly in C major) but also f″. This makes the tune appear to be pentatonic. This f″ equates to the eleventh partial, and its absence makes sense in a harmonic (that is, when there is accompanying harmony) condition. Theoretical consonance is defined as the confluence of nodal points between two waves. If two different sinusoidal sound waves (sound waves are actually compressional and not sinusoidal) are imagined crossing the x-axis (period/cycle vs. time), then where they cross the x-axis together defines consonance. The more common nodes there are, the more consonant the harmony. Partials with a lower number have, what this author terms "greater nodal density," since when they have consonance with other waves, it is in relative proportion to their length. Simply put, as one ascends the harmonic series, there is less chance of nodal confluence per length of the sinusoidal wave. Now consider that partials with prime numbers have nodal confluence only at the ends (encompassed by the length of the instrument). No other

overtones will match, then, except for a multiple of two or three (for example, fifth partial—10th and 15th; seventh partial—14th; eleventh partial—22nd) which rarely occur. If this is true, then one would expect that harmony would have less chance of occurring on partials 1, 3, 5, 7, 11, and 13, and there would be less chance of nodal convergence as the partial number increases. So, although harmony certainly occurs at the lower partial numbers of 1, 3, and 5 (due to nodal density), it would be less likely to happen on the seventh and eleventh partials. In simple terms, the absence of the eleventh partial in folk music tunes may be due to the fact there is strong accompanying harmony present in that music. For example, Scottish Gaelic music seems to have more absent eleventh partials than Irish Gaelic music. That would imply that there was more accompanying harmony to the melodic line in Scottish Gaelic music.

Conclusion

The hypothesis that natural trumpets, mainly in the form of shepherd trumpets, were prevalent in pre-Christian and medieval Europe is not presented in a perfect form. Much discussion and analysis is still required. However, a solution needs to be found for many musical issues surrounding European folk and medieval music, and the present hypothesis seems to meet most of the unanswered questions concerning early European music concerns. Yet, this is not an easy task to accomplish. Cazden states:

> [O]nce we free ourselves from the arbitrary and limited categories, the erroneous and cumbersome archaic terminology, the misread historical settings and the rigid schematics embedded in the system of modes now infesting so many fine field collections of traditional song, often as their sole and unwittingly empty gesture towards study of their melodies, the way will lie open to more meaningful and positive approaches. At first it would be inevitable that analysis, to avoid the theorist's penchant for preconceptions, proceed along deductive lines, deriving generalizations from the observed data. Yet as a background to understanding which is not in fact divorced from real history, the music analyst ought surely to offer tentative hypotheses derived from the wider field of study of musical systems and suggesting at least some initial criteria of probable relevance to the marshalled facts. The most marked departure from the current mode classification would thus be the statement of such hypotheses as subject to testing, particularization and modification in accordance with the findings, rather than treating the real data merely as phenomenal evidence of the infallible truths already revealed as to a mystically immanent hierarchy ordained by assertive authority.[52]

With this hypothesis, many musical conundrums can be resolved. Firstly, the hostility of the early Christian Church toward the *modus lascivius/lascivus* (lustful mode) can be understood, since shepherd trumpets produce pitches of this mode with the *final* comprising the harmonic series.

Secondly, early folk music uses the harmonic series as its backbone. The music can be divided roughly into three groups according to the skill of the player and the accompanying instruments.

Thirdly, the harmonic series of natural trumpets, rural tuning of Scottish Highland Bagpipes (and bagpipes in general), tuning of low-headed medieval Gaelic harps (Natural Key, High Bass, and two sharps), and the traditional tuning practices of fiddle players in Nova Scotia, Canada all show a strong cohesion. The variable use of zero, one, or two sharps allows for much flexibility. The harper could shift between diatonic (art music) and natural (rural mode) tunes, which would allow for two cultures to be present in a court at the same time. The system of three keys permits both art singers and folk singers to sing concurrently. It also enables the harper to shift a tune by half an octave, which then accommodates differing singers' tessituras. Moreover, this system allows for the inclusion of G and A mixolydian bagpipes, as well as C and D natural trumpets. This system would be truly elegant and flexible, providing for all the needs of singers while allowing for the differing intonational propensities of instrumentalists in both urban and bye-gone rural communities.

Endnotes

1 The use of herding dogs was also important. However, most dogs used for transhumance were large livestock guardian dogs, probably of the Molossoid type and not the smaller herding sheepdogs so familiar to people today. The smaller version was created/bred after wolves were extirpated and large tracts of land cleared.

2 This is not exactly true in practice. The conical/cylindrical nature of the leadpipe and the shape of the bell pushes or pulls the lower or upper end of the harmonic series a bit (see Benade, Schilke, et al.). For example, one might note that over time, the shape of trumpet bells between the seventeenth and eighteenth centuries became more exponential (more flared, less cone-shaped; see Don Smithers, *The Music and History of the Baroque Trumpet before 1721* (Syracuse: Syracuse University Press, 1973) in order to match equal temperament intonation systems more closely.

3 The approximate lengths of shepherd trumpets and their keys (relative to A = 440) are: D = 110 cm (3.6 ft/43.3 in), C = 120 cm (3.9 ft/47.23 in), B-flat = 134 cm (4.4 ft/52.83 in), A = 142 cm (4.67 ft/55.9 in), G = 160 cm (5.25 ft/63.0 in), F = 180 cm (5.9 ft/70.9 in), E-flat = 202 cm (6.6 ft/79.5 in), D = 214 cm (7.0 ft/84.3 in), C = 242 cm (7.9 ft/95.3 in). B-flat = 272 cm (8.9 ft/107.1 in).

4 The seventh partial on an eight-foot C natural trumpet is 69 cents sharper than an equally tempered a′ and 31 cents flatter than an equally tempered b-flat′. There are 100 cents in an equally tempered half-step interval. On a scale of 100 between a′ than b-natural′, the seventh partial would fall on 35. Therefore, it is closer to a′ than b-natural′.

5 The eleventh partial is 51 cents sharper than an equally tempered f″ and 49 cents flatter than an f-sharp″.

6 The thirteenth partial is 59 cents flatter than an equally tempered a″.

7 The fourteenth partial is 31 cents flatter than an equally tempered b-flat′.

8 It should be noted that the eleventh partial is often avoided in some types of folk music, making the music appear to miss both the lower and upper notes of F (f′ and f″), as well as B (b′), when all accidentals have been removed;

that is, when placed in C major. This makes the music appear to be pentatonic. A possible explanation for this exclusion may be because there might have been strong drone harmony on C, E, and/or G accompanying the melodic line (which would normally include f′′). This avoidance of the eleventh partial is known to occur in music of throat singers who often avoid the eleventh partial due to the relative conflict with the surrounding tenth and twelfth partials.

9 The Church was proscribing musical behavior without knowing exactly what was bad. Hucbald created a system to explain the Church's apparent policy. The Church seized upon this as a tool and then forced all of its chants to fit into the system Hucbald had created. In effect, Hucbald's system was used by the Church to remove anything that slipped past them (*i.e.,* aboriginal music).

10 J. Vincent, *The Diatonic Modes in Modern Music* (Berkeley: University of California Press, 1951), 225.

11 For example, Seóirse Bradley and Breandán Breathnach, "Ireland," in *The Groves Dictionary of Music and Musicians,* ed. Stanley Sadie (London: MacMillan Publishers, 1980), 318; and Breandán Breathnach, *Folk Music and Dances of Ireland* (Cork: Ossian Publications, Ltd., 1996), 10.

12 Richard H. Hoppin, *Medieval Music* (New York: W.W. Norton & Co. Inc., 1978), 71.

13 There is a well-known anecdote of two fiddlers where the present author resides (here, instrumentalists memorize all music, hours and hours of it, and do not ever read music for performance) who stayed up all night playing at home. The light of dawn arrived, and they decided to go to church. As they were listening to the homily, they closed their eyes for a moment. One opened his eyes and said to the other, "Is that the same priest?" It seems that they had fallen asleep, propping each other up. The congregation had left, a new one had come in two hours later, and the men had woken up during the second homily.

14 This actually happened to the present author once. I was on stage singing in Irish Gaelic for a St. Patrick's Day celebration. I was unaccompanied and sang in the old, recitative-like manner preserved in Gaelic culture (*sean-nós).* I sang one song that could be described as being in the mixolydian mode and then shifted to the next song, discovered later to be in the aeolian mode. I paused because I could not get the second song's tune correct in my head. Seconds ticked by, and people started to laugh slightly at my growing discomfort. I finally realized that it was better to sing in the wrong mode than to fumble about, and I sang the song in the wrong mode. It was a singularly odd experience.

15 Hoppin, 30.

16 Norman Cazden, "A Simplified Mode Classification for Traditional Anglo-American Song Tunes," *Yearbook of the International Folk Music Council* 3 (1971): 51 – 52.

17 The website *Hirtenmusik in Europa* states that this is a recording of shepherd Jon Kuhn, a recording of which exists in the Tonarchiv des Zentralinstituts für Geschichte, Wissenschaftsbereich Kulturgeschichte-Volkskunde der Deutschen (http://www.schwaben-kultur.de/hirtenmusik/de). They also provided a transcription.

18 This is the tune to "Amazing Grace," the origin of which is cloaked in confusion. However, it is possible that the tune was named after Rev. James Gallaher, the first person known to have committed the tune to paper. He had entitled the tune "Cheviot," which is a type of sheep.

19 From the Tonarchiv des Zentralinstituts für Geschichte, Wissenschaftsbereich Kulturgeschichte-Volkskunde der Deutschen Akademie der Wissenschaften zu Berlin, Tbd.-Nr. 46 – 47 of the cowherd Heinz Zink during the Hirtenfest in Zella-Mehlis on August 22, 1954, through the Bezirkshaus für Volkskunst Suhl (transcription provided by http://www.schwaben-kultur.de/hirtenmusik/de).

20 Henry Whyte, *The Celtic Lyre*, ed. Truman Matheson and Aindrias Hirt, 2012 edition (St. Andrews, Canada: Sìol Cultural Enterprises, 1885).

21 Pierre Adolphe Capelle, *La Clé Du Caveau, À L'usage De Tous Les Chansonniers Français, Des Amateurs, Auteurs, Acteurs Du Vaudeville & De Tous Les Amis De La Chanson* (Paris: Capelle et Renard, de l'Impr. de Richomme, 1811), 309.

22 Cecil J. Sharp, *English Folk Songs from the Southern Appalachians*, ed. Maud Karpeles, 2 vols. (London: Oxford University Press, 1932).

23 When the pitches of what appear to be old, traditional folk tunes occurring on stressed beats do not match the notes of the harmonic series, this author has found that, invariably, the tune is, in fact, not old at all. Often, this is the result of a modern composer attempting to make the tune *appear* to be old by gapping the scale, making it pentatonic or hexatonic. Since this is all the composer does, the tune is not more gapped in the lower frequencies to match the harmonic series; *e.g.,* d′ may appear on stressed beats. For example, Julie Fowlis sang the song "Tha mo ghaol air àird a' chuain" ("My Love is on the High Seas") for the Walt Disney movie *Brave*. It did not match the harmonic series. Research showed that Bernard Covert composed the tune on the piano in 1847. So, when not known to have been composed on or for the harp or bagpipe, a folk tune's lack of compliance with the harmonic series seems to be an indicator of modern composition.

24 There is the twelfth-century *Book of Leinster* and the fifteenth-century *Yellow Book of Lecan* that delineate the musicians and their pecking order, according to the type of instrument they play at a Gaelic chieftain's court. See Seán P. Ó Ríordáin, *Tara, the Monuments on the Hill* (Dundalk: Dundalgan Press, 1979). There are also images of musicians and instruments in iconography that abound. Limitations of space prevent a full discussion.

25 The distinction between the words "violin" and "fiddle" has no linguistic support. The *in* diminutive suffix to *viol* is to indicate a four-stringed variant of the six-stringed *viol*. The *viol* was, in turn, a development of the plucked lyre, which generally had six or, occasionally, seven or eight strings. Before the Great Vowel Shift in English, both vowels in *viol* were pronounced. If the first consonant is un-voiced and hiatus is fortified, the Scottish Gaelic *fidheal* results, which can be seen to visually match the English "fiddle" (and is connected in actual pronunciation as well). The distinction between "fiddle" and "violin" is, therefore, synthetic. Academics, the present author included, should be cautioned against cultural elitism, which tends to create false divisions between folk and art music.

26 Edward Bunting, *The Ancient Music of Ireland: An Edition Comprising the Three Collections by Edward Bunting Originally Published in 1796, 1809 and 1840* (Dublin: Waltons' Piano and Musical Instrument Galleries, 1969).

27 The present author observed well-known fiddler Ashley MacIsaac shift from standard tuning to High Bass in approximately ten seconds (while performing in 2014 in Antigonish, Nova Scotia) and then back again in the same time five minutes later. He did this to make his instrument louder for a dancer. High Bass tuning increases the harmonic resonance in the strings not being bowed, in a manner similar to the hardanger fiddle of Norway.

28 Frame harps of the eighth to tenth centuries AD in Western Europe are depicted in iconography as having ten or eleven strings.

29 *The Companion to Irish Traditional Music* (New York: New York University Press, 1999), s.v. "Harp." The number of strings varied from 30 to 36. More modern instruments had more.

30 It is not known if the diatonic scale as used by harps came about from the Pythagorean tuning method or if Pythagorean tuning was at one time simply considered the best of many diatonic tuning methods.

31 Chordophonists are quick to point out that the harmonic series can be created on strings; however, with the exception of the tromba marine (which was bowed and was not overly popular), it is extremely difficult to hear even the overtone of a fourth when tuning a harp. Since higher overtones are difficult to hear on stringed instruments, chordophonists have a tendency to discount the melodic nature of the harmonic series whose notes are easily played on trumpets, willow flutes, etc., and instead view the harmonic series as a theoretical base for creating harmonic structures (harmonies with other strings on a chordophone).

32 Through a personal meeting with the harper Simon Chadwick, the author was able to see some copies of these fascinating notes. These included some of Bunting's untouched first impression transcriptions of harp music.

33 For example, Hugh Shields, *Tunes of the Munster Pipers: Irish Traditional Music from the James Goodman Manuscripts* (Dublin: Irish Traditional Music Archive, 1998).

34 Comments of Nicholas S. Lander concerning the work of Vincenzo Galilei, "Ricercares a Quattro Voci," (1584). http://travelingwithintheworld.ning.com/group (accessed 12 September 2014).

35 Séan Ó Boyle, *The Irish Song Tradition* (Toronto: MacMillan of Canada, 1977), 12.

36 Personal correspondence (2012) with the harper Simon Chadwick verified that it is rather simple to tune the harp to the natural scale. This author is indebted to a decade-long collegial correspondence with Chadwick, as he has helped guide the author through many of these issues. Mr. Chadwick has also suggested that it is possible that the harp tuning method as described by Bunting may have been an import from mainland Europe.

37 When tuning to fifths or fourths (on a violin or guitar, for example), the tension of one string is increased or decreased so that beating stops. It is widely thought (incorrectly) that the beating is caused by the interference between the principal frequencies of one wave to the other. Beats are actually caused by the interference between *overtones* of the lower pitch with the second string.

38 Barnaby Brown, "The Iain Dall Chanter: Material Evidence for Intonation and Pitch in Gaelic Scotland, 1650 – 1800," in *The Highland Bagpipe: Music, History, Tradition*, ed. Joshua Dickson (Burlington: Ashgate Publishing Company, 2009), 35. Rough summary of Table 2.1.

39 Note the "keys" in Shields. Most older music was written for zero, one, or two sharps.

40 Brown.

41 Ibid., 37.

42 Joseph MacDonald, *Compleat Theory of the Scots Highland Bagpipe (c.1760)* (Glasgow: Alexander MacDonald, 1927; reprint, 1803).

43 Ibid., 24.

44 Ibid.

45 Ibid.

46 Ibid., 25.

47 Seóirse Bradley and Breandán Breathnach, "Ireland," in *The Groves Dictionary of Music and Musicians,* ed. Stanley Sadie (London: MacMillan Publishers, 1980), 318.

48 Elizabeth Sympson Gaver, "The (Re)Construction of Music for Bowed Stringed Instruments in Norway in the Middle Ages" (Master thesis, University of Oslo, 2007), 63.

49 Trumpet music began to be notated by Monteverdi. Before that time, trumpet music had been the venue of the trumpet guilds and brotherhoods that existed. They zealously guarded their craft and music. Music was passed on through aural/oral techniques.

50 Albert Seay, *Music in the Medieval World* (Englewood Cliffs: Prentice-Hall, Inc., 1975), 79.

51 An interesting explanation may be found in Hoppin. One possible solution for its origin may be that monks heard shepherds playing trumpets together, as is still done today in Switzerland, Romania, the Carpathians, etc., and emulated what they heard.

52 Cazden, 62 – 63.