Early Period Music Theory

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The Diatonic Scale

Thanks to the keyboard family of instruments, our modern musical diatonic scale (do re mi fa so la ti do) is just slightly different from the one in use in the early middle ages; let's call the medieval one "ut re me fa so la ti ut," like Guido d'Arezzo did. (Okay, Guido didn't specify "ti," but we're going to need it.) The medieval one was based strictly on math and physics; the modern one has been adjusted to allow key changes.

Physics of Higher Harmonics

Why is the octave considered a perfect and harmonious interval, but the (medieval) third is not? Why are the fifth and the fourth harmonious, but the sixth isn't? The answer is found in the physics of vibration.

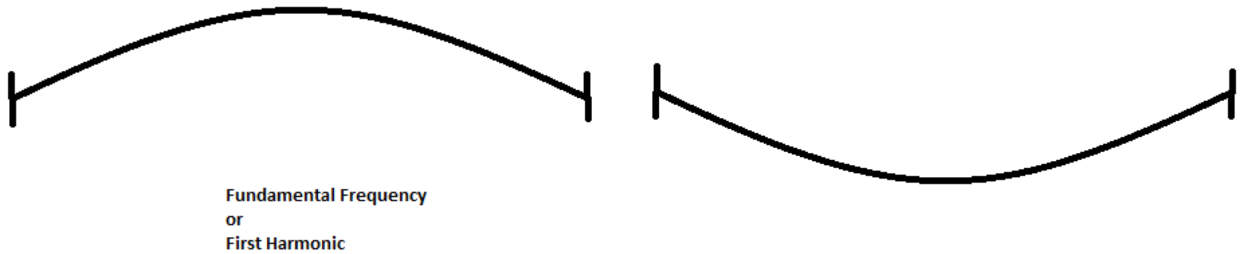
(Intervals are a method of describing the space between two notes.

- Two notes next to each other, like ut-re, re-mi, mi-fa are the interval of a *second*.
- Two notes that have a note between them, like ut-mi, re-fa, and mi-so are the interval of a *third*.
- Three notes between = *fourth*, four notes between = *fifth*, and so on.
- Two notes with seven notes between – from ut to ut, or re to re – are called the *octave* rather than an eight.

The medieval theorists also had Greek names for some of these intervals, like *diapason* for octave, but let's not get hung up on terminology.)

If you pluck a taut string and look at it carefully, you should see that it is vibrating to make a point-ended ellipse shape. It is actually transitioning between a shape with a curved arc up, and one with the curved arc down:

First this Then this



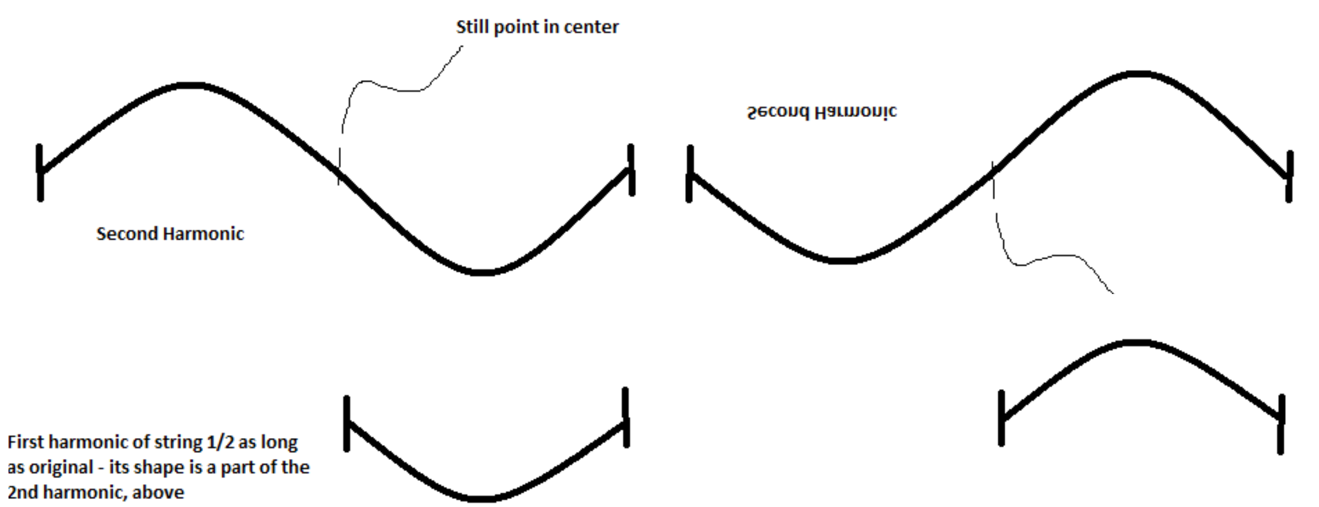
That is a **standing wave**. The speed at which the string is vibrating – the number of shakes back and forth per second that it takes to create that wave – is its **fundamental frequency**. (Also called the *first harmonic*.)

The **fundamental frequency is the note** that you hear. Most of the energy of your pluck goes into this vibration. If this were a tuning fork instead of a vibrating string, this would be the only sound created – a pure tone at this frequency.

But it is a vibrating string, and your pluck will excite other higher harmonics. These are smaller standing waves in the string.

Fun fact about standing waves in vibrating strings: The product of (wavelength x frequency) in a given string must remain constant. So when we get two standing waves, each **half** the wavelength of the wave shown above, the frequency has to **double**.

Here is a picture of the second harmonic of our string. At this frequency – being shaken twice as fast as before – two standing waves are created. This wave pattern gets the next most energy after the fundamental.



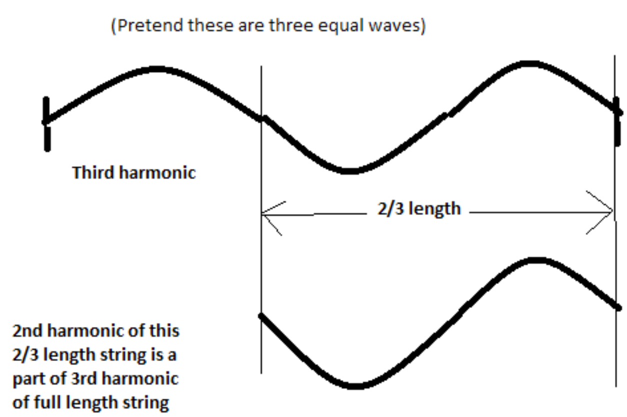
So if I had a second, shorter string – a string half the length of the original string – **its fundamental frequency looks like part of the second harmonic of the original string.**

When the original, longer string is plucked, its second harmonic is happening. You don't necessarily hear it – it's drowned out by the fundamental. But it's there. And this second, shorter string's fundamental frequency – the speed at which it is vibrating – is the **same** as that second harmonic.

So when these two strings are plucked at the same time, they sound extremely harmonious. One is included in the other.

The second, shorter string – the string half the length of the original string – is **sounding one octave up** from the original string. It was considered the most perfectly harmonious interval.

If we vibrate the original string even fast, three times as fast as the fundamental frequency, we will see three standing waves:



This is the third harmonic. It gets less energy than the fundamental and the second harmonic.

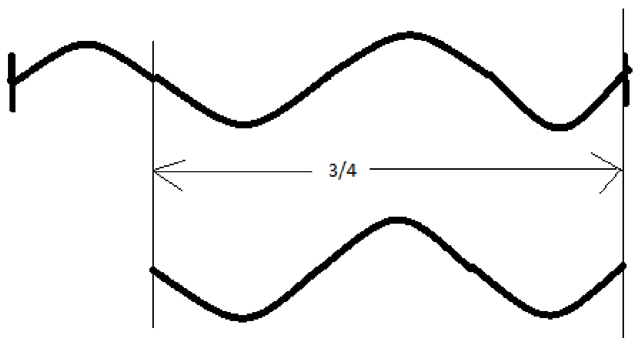
As before, we can find a new, shorter string that's hiding inside of the original string. A string 2/3 of the length of the original string is in there, vibrating at its second harmonic. (There are two standing waves in the shorter string, so that is the second harmonic.)

The frequency – number of shakes per second – of the third harmonic of the original string and the second harmonic of the shorter string is the same.

If we slow the frequency down by half, the shorter string will vibrate at its fundamental frequency. Like our original string, even when the shorter string is sounding its fundamental frequency, it is also sounding its second harmonic. It fits right inside the third harmonic of the original string, and so they sound harmonious together.

This string that's 2/3 the length of the original string sounds a note a **fifth** up from the original string. It was considered the second most harmonious interval.

We can do this again, vibrating the original string four times as fast as its fundamental frequency, making four standing waves:



And again, we can find another shorter string, this one ¾ the length of the original. Its third harmonic (three standing waves) happens at the same frequency as the original's fourth harmonic. And again, because in this way it is “hiding inside” the original string, when they sound together, the interval is harmonious.

If we slow the frequency so that the 3/ 4 length string is vibrating at its fundamental frequency, it will be a **fourth** up from the original string. And the fourth was – guess what? - the third most harmonious interval.

The early medieval theorists recognized the octave, the fifth, the fourth, and the double octave, the octave + a fifth, and the octave + a fourth as harmonious intervals. This is why, even if they didn't know it.

So that gets us ut, fa, so and ut. Where's the rest of the scale?

Pythagoras and the Four Hammers

A version of this (apocryphal) story is found in John Cotton's “On Music,” c. 1150, although John doesn't get into the specific weights of the hammers.

One day, Pythagoras (yes, the $a^2 + b^2 = c^2$ guy) was walking through the marketplace, thinking hard about musical scales. As we saw above, they are related to geometry – halving a string raises its tone by an octave, for example. His thoughts were interrupted by the sound of two blacksmiths at work. But it was a serendipitous interruption, as he realized that sometimes, the sound of the two hammers striking the anvil was harmonious, and sometimes it was not. He went over to investigate.

It turned out that, between the two of them, the smiths had four hammers of different sizes: 6 pounds, 8 pounds, 9 pounds, and 12 pounds. As they alternated which ones they were using, Pythagoras found:

- The 6-lb and 12-lb hammers together sounded wonderful. One was half the weight of the other – just like a string half the length of another. This was the octave.
- The 8-lb and 12-lb hammers together also sounded very good. One was 2/3 the weight of the other – this was the fifth, just as we saw above.
- So you should not be surprised to learn that the 9-lb hammer, which was 3/ 4 the weight of the 12-lb hammer, made a harmonious fourth together.
- But the 8-lb and the 9-lb hammer together were terrible!
- (The story doesn't say about the 6-lb and 8-lb, but it would sound good at a fourth: 6/8 = 3/ 4. And the 6-lb and the 9-lb would have sounded good at a fifth: 6/9 = 2/3)

So Pythagoras was in our same position: he had four notes, but not an entire scale. What to do?

Well, between the two of them, the 8-lb and 9-lb hammers defined a small "distance" between two notes. This distance is called a **tone** (also whole step). That distance was a part of this perfect sequence of notes. Could he use it to fill in the rest of the scale?

"So," the 8-lb hammer, is 8/9 of "fa," the 9-lb hammer. Or: if "fa" were a string 9 inches long, we would divide it into nine parts (1 inch each); eight of those parts would make the "so" string, 8 inches long. If the "fa" string were 18 inches long, we'd divide it into nine parts (2 inches each) and "so" would be eight of those – 16 inches. It's a ratio, not a simple fixed length we can add or subtract.

Measure the length of the "ut" string; divide by 9 and multiply the result by 8. This gets you the "re" string.

Measure the length of the "re" string; divide by 9 and multiply the result by 8. This gets you the "mi" string.

Measure the length of the "mi" string; divide by 9 and multiply the result by 8. **This does not get you the "fa" string**. It gets you somewhere between "fa" and "so." Pythagoras sort of shrugged and tossed this "note one step up from mi" out. He just allowed the distance between "mi" and "fa" to be what it was – a **semitone**, or a space less than a tone.

"Fa" and "so" are already defined.

Measure the length of the "so" string; divide by 9 and multiply the result by 8. This gets "la."

Measure "la," divide by 9 and multiply the result by 8. This gets "ti."

"Ti," like "mi," is closer than a tone to the next note, the high "ut." If we measure/divide/multiply, we'd end up between "ut" and "re." So the distance between "ti" and high "ut" is another semitone.

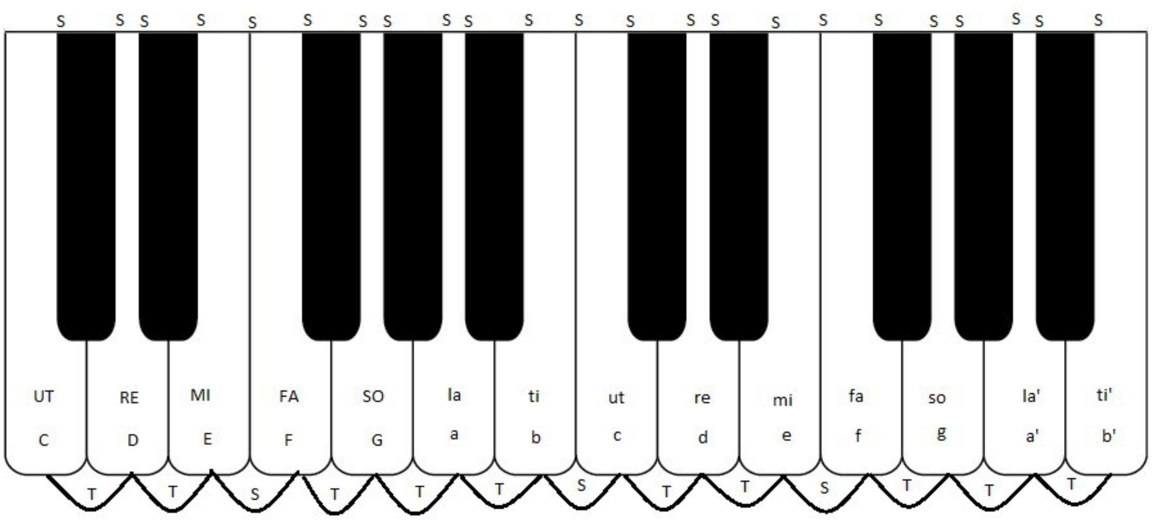
Counting it all up, the pattern of tones and semitones on the diatonic scale is Tone – Tone – Semitone – Tone – Tone – Tone – Semitone.

So we've seen are ratios of re, mi, la and ti to the string that comes just before it. Let's look at the ratios of each string to low "ut."

Ut: Ut	1	
Ut: Re	8/9	
Ut: Mi	64/81	(8/9 of 8/9)
Ut: Fa	3/ 4	
Ut: So	2/3	
Ut: La	16/27	(8/9 of 2/3)
Ut: Ti	128/243	(8/9 of 16/27)
Ut: Hi Ut	1/ 2	

Consider: 1/ 2, 2/3, and 3/ 4 were harmonious intervals. The whole tone, at 8/9, was dissonant.

Is it any wonder that the third, at 64/81, was also dissonant? That is not a geometric ratio which inspires confidence. And in fact, with only a few examples like the St. Magnus Hymn, we don't see parallel thirds featuring prominently in medieval harmonies. (They may occur in passing.)



DIY Diatonic Scale

All of these geometric divisions can be done with a straight edge and compass. For the sake of time, we'll just use a ruler and division. Also, this is not the medieval process, which generates the entire gamut (all the notes from a low G (gamma) to a c" (ut)). The same scale results; I'm just having you do the measurements in a different order so it matches the same order of creating the notes that we've done so far.

On the paper provided, use the ruler provided to draw a 30cm long line. Place one end of the line up against the edge of the paper. Mark the other end "ut".

Divide the line in half. Mark the halfway point as **the octave, "ut' "**

** Making this a little simpler **

To get “so,” the string 2/3 the length of our starting string, we could measure (30cm), divide by 3 (10cm) and then multiply by 2 (20cm). We would then measure from the end of the line at the edge of the paper 20cm and mark “re.”

OR we can measure, divide by 3, and measure up from where we marked “ut.” A mark 1/3 from the “ut” end of the line is at the same place as 2/3 from the other end.

This doesn't make a big deal now, but it'll be much easier to divide by 9 and go that far up from a mark than to divide by 9 and then multiply by 8.

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So divide the length of the line by 3, measure up that far from “ut,” and mark **the fifth, “so.”**

Divide the length by 4; measure up that far from “ut” and mark the fourth, **“fa.”** That is the last perfect interval we get.

We already measured out the length of “ut” (30cm). Divide it by 9, and measure that far up from “ut.” Mark that as **“re,”** one whole tone up.

Measure from “re” to the end of the line. Divide this by 9, and measure that far up **from where you marked “re.”** This is **“mi.”**

Don't measure from “mi” to the end, unless you want to prove to yourself that a whole step up from “mi” is in a no man's land between “fa” and “so.”

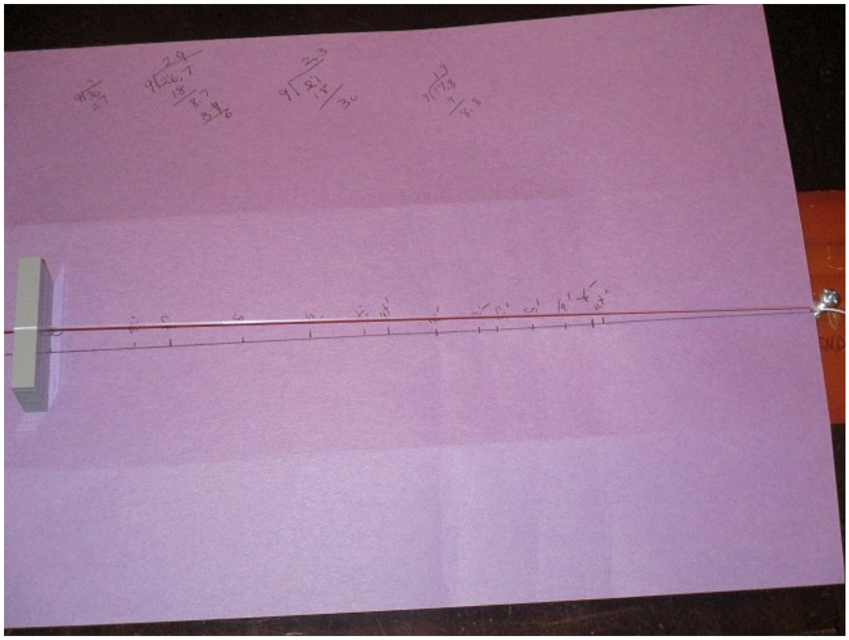
We already derived “fa” and “so.”

Measure from “so” to the end. Divide by 9; measure this far up from “so” and mark “la.”

Measure from “la” to the end. Divide by 9; measure this far up from “la” and mark “ti.”

We already have “ut' ”. If you want, you can get the notes an octave up from each of the ones you've found by measuring each length, dividing it in half, and marking the new note.

It should end up looking something like this:



Playing on the Monochord

Now we'll hear the scales we derived. Place the end of your line (the one at the edge of the paper) against the screw marked END on the monochord. Place the front edge of the moveable bridge on the mark you made for "ut." Pluck the string to hear the note. Now slide the bridge forward until the front edge is on the mark for "re." Pluck again. Continue on to hear all your notes.

That was a lot of time spent on "do re mi."

Yeah, it was. But the diatonic scale is really the backbone of medieval music theory. The fact that we think we know it so well, but that it's actually a little different today than it was back then, makes it a little tricky. I think it's worth the time to really understand what's going on with where the notes we use are coming from.

The Modes

Today, most music is written in either a *major key* or a *minor key.* A song can contain the same notes, but depending on which are the most important ones, it structures the way the music moves up and down, and also our perception of the emotion of the music.

The notes of a major key is identical with the diatonic scale. The most important note is "do." The song will almost always end on it – so this note is called the **final**. The next most important note is usually "so," a fifth up. Even if these notes are not the most frequently played, they serve as structural elements – measuring out the shape of the melody. Major key songs are often described as being happy, triumphal or upbeat.

The minor key also uses the notes of the diatonic scale, but the most important note is "la." The song will almost always end on it. "Mi," a fifth up from "la," is the next most important note. The music moves between and around these two tones, and the result is music often described as melancholy, spooky, or sad.

Extend this idea a little farther and you get the modes:

- The **protus mode** (a.k.a. Dorian mode) starts on “re” and goes up the diatonic scale. “Re” is the most important note and the final. “La,” the fifth up, is the next most important note.
- The **deuterus mode** (Phrygian mode) starts on “mi” and goes up the diatonic scale. “Mi” is the most important note and the final. “Ti”, the fifth up, is the next most important note.
- The **tritus mode** (Lydian mode) has “fa” as a final and “ut” as the fifth.
- The **tetrardus mode** (Mixolydian mode) has “so” as a final and “re” as the fifth.

Music written in different modes was thought to have different qualities, just like we perceive major and minor key songs to have different qualities.

Each mode comes in two flavors: authentic and plagal. This just refers to the range of a melody arranged in the mode. An authentic mode ranges mostly from the final to an octave above. Plagal modes range from the fifth above the final to a fourth below. Either sort were given “license” to go a tone below the range; authentic modes could go a tone or two tones above the octave, and plagal modes could reach up to the sixth rarely.

- Protus has final “re,” so authentic protus will range from “re” to “re” an octave up. It is allowed to go as low as the “ut” below “re”, and as high as “mi” or “fa” above it, if required.
- Plagal protus ranges instead from the “so” below “re” to the “la” above “re.” Again, small excursions are sometimes allowed.

Authentic tritus rarely goes below its final. In all the other modes, the note below the final is a tone away. In tritus, with “fa” as the final, the note below is “mi,” only a semitone away. This sounded strange and was not often done.

Other than the range, there is another difference between the authentic and plagal modes. Each mode has a tenor or reciting tone. I quote Pat Yarrow on this: “In authentic modes, the tenor is a fifth above the final (or tonic). In plagal modes the tenor is a third below the tenor of the corresponding authentic mode. Whenever the tenor would fall on B, it moves to C.” Authentic modes were expected to mostly stay in the higher registers, going down to the final only occasionally. Plagal modes were expected to stay among the lower notes, rising up to the fifth only sometimes.

The following table summarizes the characteristics of the early medieval modes:

Final	Range	Tenor/ Dominant	Authentic or plagal	Other names	Mode #
d	D-d	a	authentic protus	First mode Dorian	1
	A-a	F	plagal protus	Second mode Hypodorian	2
e	E-e	c	authentic deuterus	Third mode Phrygian	3
	B-b	a	plagal deuterus	Fourth mode Hypophrygian	4
f	F-f	c	authentic tritus	Fifth mode Lydian	5
	C-c	a	plagal tritus	Sixth mode Hypolydian	6
g	G-g	d	authentic tetrardus	Seventh mode Mixolydian	7
	D-d	c	plagal tetrardus	Eight mode Hypomixolydian	8

The Hexachord

I confess I am not entirely certain what drove the people of the middle ages to seek to break up a perfectly good octave into smaller units. It does seem to fit into some of the scholarly (and also occult) thought of the time, what with hidden order to the universe and all.

The tetrachord was an ancient way of dividing up the gamut of notes; Hucbald describes it in his *De re musica* of c. 850. But by Guido d'Arezzo's *Micrologus* in c. 1050, it was supplanted by the hexachord, which would remain in favor for hundreds of years to come.

The hexachord was a pattern of tones and semitones: Tone – Tone – Semitone – Tone – Tone – Tone. You might recognize that as one semitone short of an octave.

There is one hexachord that starts on ut/C and goes up to la/A. There is a second to be found if you start on so/G and go up to mi/E. There is alllllmost a third to be found if you start on fa/F and go up to re/D, but darn it, ti/B messes it up.

You can fix that if you "soften" B a little. Early medieval music knew two Bs – hard B (what we would call B-natural) and soft B (we would call B-flat). Hard B looked like a lower case b written with a square where the circle usually goes. Soft B looked like this: ♭ - it's where we get the modern symbol for a flat.

The hexachord starting on C had no B – it was the *natural hexachord*.
The hexachord starting on G had the hard B – it was the *hard hexachord*.
And in a totally unsurprising development, the hexachord starting on F had the soft B and was called the *soft hexachord*.

Guido d'Arezzo mentions that some people don't like the idea of soft B much (it *does* violate the Pythagorean purity of the scale), and gives some advice on how to construct your music to avoid it.

What was the point?

There were rules about changing from one hexachord to another – you had to use a note that both hexachords had in common to switch between. This was called mutation.

Other than restricting the maximum melodic leap – if you can't leave your starting hexachord, you can't go farther than a sixth in one interval – I haven't quite figured out what to do with hexachords. I wanted to give you a basic introduction so you'd have an idea of what it is, if you run into it in further reading. If you figure out how to make it useful to a Scadian musician, I would be very interested to know!

What about the Guidonian hand?

The Guidonian hand (a mnemonic for remembering the hexachords and the positions notes occupy in each one) is not found in the writings of Guido. John Cotton mentions counting the "ut re mi" on one's hand, but he doesn't have the elaborate system of later (at least, not written down). In this system, the solmization syllables (ut, re, mi, fa, so, la) are assigned to the six notes of the hexachord – which means certain notes have more than one name. G is "so" on the natural hexachord, "re" on the soft hexachord, and "ut" on the hard hexachord. This class hasn't used this convention – it's not emphasized in the early treatises, and we had enough to go over as it was.

You can read more about the hexachord here:
http://www.medieval.org/emfaq/harmony/hex1.html

Principles of Melodic Composition

Some of Guido's other guidelines for writing music, from the *Micrologus*:

- The final is the most important note. The notes ending the phrases of the song should be in harmony with the final.
- "In harmony" means one of the six acceptable harmonious intervals – the fourth, the fifth, the octave, the octave plus a fourth, the octave plus a fifth, and the double octave.
- The beginning of the chant should also be in harmony with the final (with the exception that those with final E may begin on c).
- Different people are pleased by different modes and different kinds of melody. This is acceptable.
- It is good to vary the length of phrases; sometimes "answer" a phrase with one of equal length, sometimes with one of two or three times the length of the first, or of 3/2 or 4/3 the length of the first.
- "It is good to beat the time of the song as though by metrical feet" but the composer is not as strictly bound by these rhythms as the poet. (Medieval church music did not have time signatures.)
- It is good to have "lines" of about the same length, as in poetry.
- Useful techniques include repetition of a phrase with slight variations; transposition; horizontal and vertical reflection.
- Sometimes use more than one phrase of music per syllable, and sometimes fit several syllables into one phrase.
- Fit the music to the words: sad music for lamentations, etc.
- Sometimes two notes are "liquesed" or slurred together, but it is also all right (and sometimes superior) to singing them separately and clearly.
- "Do everything that we have said neither too rarely nor too unremittingly, but with taste."

From John Cotton, "De Musica"

- Fit the words to the music: playful, joyful music for young people; solemn serious music for the elders; inauspicious songs, pitched low; joyful songs, pitched high. "Yet we do not go so far as to direct that this must always be done, but when it is, we say that it is to the good."
- Don't repeat one neume (short melodic figure) ad nauseum, although repeating a good one once, perhaps towards the end of a piece, is all right.
- Put pauses in the music where there are punctuation marks in the text
- Plagal chants should go often to the final and rarely rest (hold a prolonged note) on the fourth, and never on the fifth. Just tap the fifth and go back down.
- Authentic chants should descend to the final only once for every 2-3 times they rest on the fifth, and should stay largely in the higher notes.
- "[A]lthough the foregoing law and fixed rule is laid down for the range of tones [modes], many modern composers care only about how to tickle the ears very often jumble them up and make a mongrel chant by giving one melody the range of two tones [that is, the combined range of the plagal and authentic mode]."

Organum (Polyphony)

The earliest Western polyphony was called **organum**. It consisted of a primary voice, singing the melody, and an accompanying or *organal* voice. It seems mostly to be for two parts, although methods for writing up to four parts are given. The first actual example of three-voice music (besides the instructive examples in the treatises) is found in Codex Calixtinus, c. 1140, Santiago de Compostella.

With two parts, the accompanying (or organal) voice can stand in one of four relationships with the primary voice as it moves along. In unison, they sing the same notes. (If they keep this up for a while, they're not really parts at all.) In parallel, they are separated by some interval (usually a fourth or a fifth), and when the primary goes up a tone, the organal goes up a tone. In oblique motion, one voice is holding a note steady while the other is moving either up or down. In contrary motion, when the primary voice goes up a tone, the organal voice goes down a tone, and visa versa.

Hucbald mentions organum in his treatise, and says that it is done "at the fifth," but offers no further explanation. *Musica Enchiriadis,* c. 850 contains earliest known examples of Western polyphony and has rules for writing organum. (I don't have a translation of this "Music Manual," so the following is from Hoppin's textbook.) The original melody is the "principal voice." With one voice added, it becomes **simple organum**; if either or both voices are doubled at the octave, it is **composite organum**. When parallel motion is strictly observed throughout the piece, it is called **strict parallel organum** (naturally enough). Some chants allow for strict parallel motion to be abandoned at the beginning and ending of phrases, often to allow the voices to converge at unison. This goes by various names, some of which are also used to describe yet other kinds of organum, so we'll follow Hoppin and call it **modified parallel organum**. An octave above or below the principal voice could be used, as will happen when men and boys sing together. A fifth below the principal voice could be used, and this could also be sung an octave up (so, a fourth above the principal voice).

When modified parallel organum is moving towards a unison, intervals other than the octave, fifth and fourth may be sounded. Seconds and thirds in simple organum and sixths and sevenths in composite organum could be made.

Guido d'Arezzo (c. 1050) rejected the fifth as too "hard" a consonance and rejected the semitone as too dissonant. This left the major second (one tone), major third (two tones), minor third (one tone + one semitone) and the perfect fourth to be used. The fourth was the best to use, the minor third the worst. Guido allowed for the principal and organal voices to cross each other, the lower becoming higher and the higher going lower. His music was largely note-againt-note, but when approaching the final, sometimes the organal voice is allowed to get there first, with the principal voice following. Guido's examples also made use of a drone technique, with the organal voice chanting on a single tone for great stretches while the principal one carried the melody.

John Cotton mostly restates Guido in his *De Musica*, c. 1100. However, his section on organum shows that it has been evolving. The fifth is now allowed, and the seventh introduced. Contrary and parallel motion of the voices is allowed, but he has a marked preference for contrary. He also suggests that octave finales are as good or better than unisons, and allows for double or triple notes against a single note. Overall, the arrangement of the organal voice allows much more freedom of choice and creativity than earlier, and this kind of organum is called **free organum**.

Guido's Instamatic Melody Generator

Guido had some advice for people who needed to write some music, but didn't know where to start.

1. Write down the five vowel sounds: ah, eh, ee, oh, oo. (Latin's easy that way.)
2. Next to each sound, write one of the notes. Guido seemed to like to go from the tone below the final to a fourth above:

Vowel	Sound	Note
A	ah	C
E	eh	D (final)
I	ee	E
O	oh	F
U	oo	G

3. Go through the text you need to set to music. Every syllable has a vowel sound. Set it to the note listed in the table above.
4. Profit!

Guido acknowledged that this gives a song with a very narrow range. The solution: Assign two notes per vowel, and select the one you like better at every point. (In the table below, the small "a" note is the "a" above the "G" that's the end of the Note 1 column.) This gives you a very respectable range for an authentic protus song – a tone below final to a tone above final.

Vowel	Sound	Note 1	Note 2
A	ah	C	a
E	eh	D (final)	b
I	ee	E	c
O	oh	F	d
U	oo	G	e

You can change modes by changing the initial note assigned to vowel A.

Guido acknowledged that if you do this, you will get note soup. Certainly, you may not end on the final, so you'll have to go back and fix that. And then you may want to fix the cadence (the notes leading up to the final). And then maybe tinker with the ends of various melodic phrases. And then...

Essentially, Guido's tool helps a novice get over the blank page problem. You might get note soup, but at least it's a broth base and now you can season it to your liking.

If you want to apply this to modern English, you will have to decide how to deal with long and short vowels (A is now "ay" and "ah"), dipthongs ("oa", "ea", etc.), the schwa, and whatever other monkey business our language gets up to.

Nota Bene: The resulting melody you get from this method may not be euphonious, but it's authenticatable!

Summary

- The medieval diatonic scale is constructed from first principles of physics, the geometry representing that physics, a teaspoon of philosophy and a dash of pragmatism.
- The eight modes give us a framework for constructing songs with different emotional qualities.
- Hexachords are surely good for something.
- Rules exist to help guide the composition of music (or at least of ecclesiastical music); composers have been breaking these rules since before they were written down.
- While most of the basics of music theory do not change much between 850 CE and 1150 CE, the composition of organum is an exception. Early strict parallel organum gives way to modified parallel organum, which becomes free organum.
- Anything that can be spoken can be sung, according to Guido

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