Pitch Notation

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C O N N E X I O N S

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Chapter 1

The Staff[1]

People were talking long before they invented writing. People were also making music long before anyone wrote any music down. Some musicians still play "by ear" (without written music), and some music traditions rely more on improvisation and/or "by ear" learning. But written music is very useful, for many of the same reasons that written words are useful. Music is easier to study and share if it is written down. Western music[2] specializes in long, complex pieces for large groups of musicians singing or playing parts exactly as a composer intended. Without written music, this would be too difficult. Many different types of music notation have been invented, and some, such as tablature[3], are still in use. By far the most widespread way to write music, however, is on a **staff**. In fact, this type of written music is so ubiquitous that it is called **common notation**.

1.1 The Staff

The **staff** (plural **staves**) is written as five horizontal parallel lines. Most of the notes[4] of the music are placed on one of these lines or in a space in between lines. Extra **ledger lines** may be added to show a note that is too high or too low to be on the staff. Vertical **bar lines** divide the staff into short sections called **measures** or **bars**. A **double bar line**, either heavy or light, is used to mark the ends of larger sections of music, including the very end of a piece, which is marked by a heavy double bar.

[1]This content is available online at <http://cnx.org/content/m10880/2.12/>.
[2]"What Kind of Music is That?" <http://cnx.org/content/m11421/latest/>
[3]"Reading Guitar Tablature" <http://cnx.org/content/m11905/latest/>
[4]"Duration: Note Lengths in Written Music" <http://cnx.org/content/m10945/latest/>

The Staff

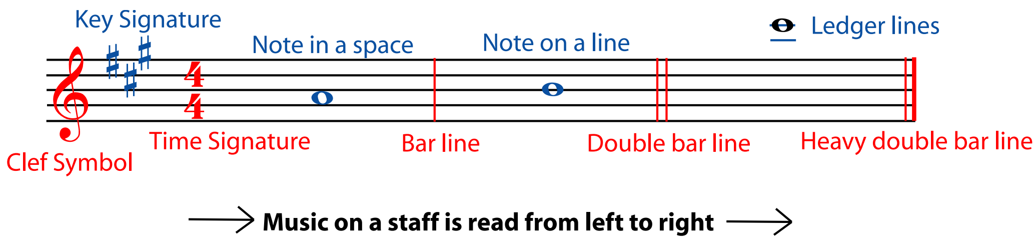


Figure 1.1: The five horizontal lines are the lines of the staff. In between the lines are the spaces. If a note is above or below the staff, ledger lines are added to show how far above or below. Shorter vertical lines are bar lines. The most important symbols on the staff, the clef symbol, key signature and time signature, appear at the beginning of the staff.

Many different kinds of symbols can appear on, above, and below the staff. The notes[5] and rests[6] are the actual written music. A note stands for a sound; a rest stands for a silence. Other symbols on the staff, like the clef[7] symbol, the key signature[8], and the time signature[9], tell you important information about the notes and measures. Symbols that appear above and below the music may tell you how fast it goes (tempo[10] markings), how loud it should be (dynamic[11] markings), where to go next (repeats[12], for example) and even give directions for how to perform particular notes (accents[13], for example).

[5]"Duration: Note Lengths in Written Music" <http://cnx.org/content/m10945/latest/>
[6]"Duration: Rest Length" <http://cnx.org/content/m11887/latest/>
[7]"Clef" <http://cnx.org/content/m10941/latest/>
[8]"Key Signature" <http://cnx.org/content/m10881/latest/>
[9]"Time Signature" <http://cnx.org/content/m10956/latest/>
[10]"Tempo" <http://cnx.org/content/m11648/latest/>
[11]"Dynamics and Accents in Music" <http://cnx.org/content/m11649/latest/>
[12]"Repeats and Other Musical Road Map Signs" <http://cnx.org/content/m12805/latest/>
[13]"Dynamics and Accents in Music" <http://cnx.org/content/m11649/latest/#p0d>

Other Symbols on the Staff

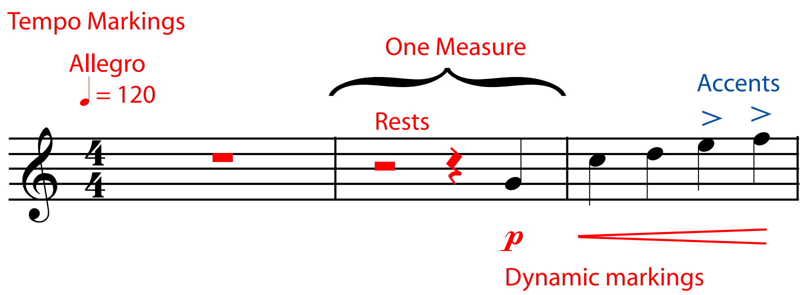
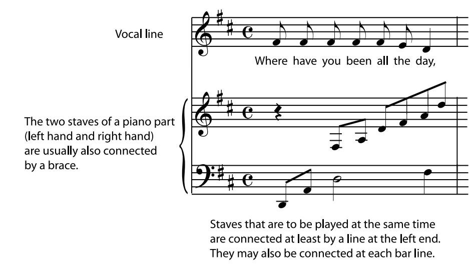


Figure 1.2: The bar lines divide the staff into short sections called bars or measures. The notes (sounds) and rests (silences) are the written music. Many other symbols may appear on, above, or below the staff, giving directions for how to play the music.

1.2 Groups of staves

Staves are read from left to right. Beginning at the top of the page, they are read one staff at a time unless they are connected. If staves should be played at the same time (by the same person or by different people), they will be connected at least by a long vertical line at the left hand side. They may also be connected by their bar lines. Staves played by similar instruments or voices, or staves that should be played by the same person (for example, the right hand and left hand of a piano part) may be grouped together by braces or brackets at the beginning of each line.

Groups of Staves



(a)

(b)

Figure 1.3: (b) When many staves are to be played at the same time, as in this orchestral score, the lines for similar instruments - all the violins, for example, or all the strings - may be marked with braces or brackets.

NOTE: Thanks to everyone who participated in the survey! It was very useful to me, both as a researcher and as an author, to get a better picture of my readers' goals and needs. I hope to begin updating the survey results module[14] in April. I will also soon begin making some of the suggested additions, and emailed comments are still welcome as always.

[14]"A Survey of Users of Connexions Music Modules" <http://cnx.org/content/m34234/latest/>

Chapter 2

The Notes on the Staff[1]

Music is principally written with symbols specifying pitch and symbols specifying timing. Symbols indicating pitch give instructions on whether sounds are high or low or anywhere in between. Symbols indicating timing provide instructions on when and how long to play or sing a sound. These symbols are combined in ingenuous ways for music notation. When you master the fundamentals of music literacy, you will be able to read much of the music performed in the world today. The notation is commonly termed "Western Musical Notation."

In this module we will present pitch notation. "Pitch" is a word we use for indicating where a note lies in a spectrum or range of musical tones. Musical pitches are designated by an alphabet letter or sometimes by a solfège syllable.

The musical alphabet uses letters A B C D E F G. Common solfège syllables are: Do Re Mi Fa Sol La Ti. In many countries the solfège syllables are employed to designate pitches. For instance, in France, "Do" is the name for "C,“ "Re" for "D," etc. This system of labeling pitches is termed "fixed Do," since Do always designates the note C. In America we most commonly designate pitches by their alphabet letter name.

The musical alphabet repeats throughout the range or register of music. For instance, notice that the piano keyboard below has a repeating musical alphabet (given below the keyboard in Figure 1):

A Portion of the Piano Keyboard

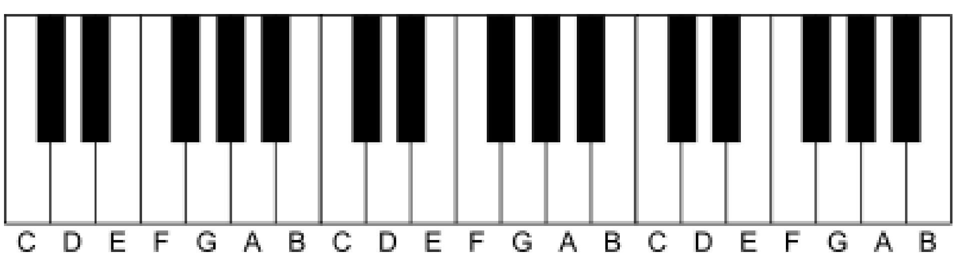


Figure 2.1: The graphics of the keyboard in Figure 1 are modified from Tobias R. – Metoc[2], http://en.wikipedia.org/wiki/File:Klaviatur-3-en.svg[3] (Accessed 01 May 09). It is licensed for public use under the Creative Commons Attribution License.

[1]This content is available online at <http://cnx.org/content/m22934/1.1/>.
[2]http://commons.wikimedia.org/wiki/User:Metoc
[3]http://en.wikipedia.org/wiki/File:Klaviatur-3-en.svg

Pitches furthest on the left are lower sounding. Higher and higher pitches are sounded by moving up the piano keyboard in the right hand direction.

Pitches are represented by “notes” placed on a “staff.” The most common staff in musical notation is one with five lines and four spaces.

A Staff

Figure 2.2

The lower part of the staff is for lower notes; the higher portion is for higher notes. The staff by itself, however, doesn’t provide us the information we need to designate the position of a pitch. There are many more pitches in most music than just those provided by these five lines and four spaces. For the wider range of musical pitches we need a group of musical symbols called “clefs.” Some of the clefs used in music notation matched the names given to voices: soprano, mezzo soprano, alto, tenor, bass. For now we will just introduce two of the most common clefs–treble and bass.

The treble clef or G clef designates the staff for higher pitched instruments such as flute, trumpet, or violin. The clef circles around a line that is G, which is the second line from the bottom. The blue letter G doesn’t usually appear in music notation. The red note on the treble staff is a G. The bass or F clef designates a staff reserved for lower pitched instruments such as bassoon, tuba, or cello. The left most portion of the clef starts on the F line–4th line from the bottom. The F line also appears between the two dots to the right of the clef. The red note on the bass staff is an F.

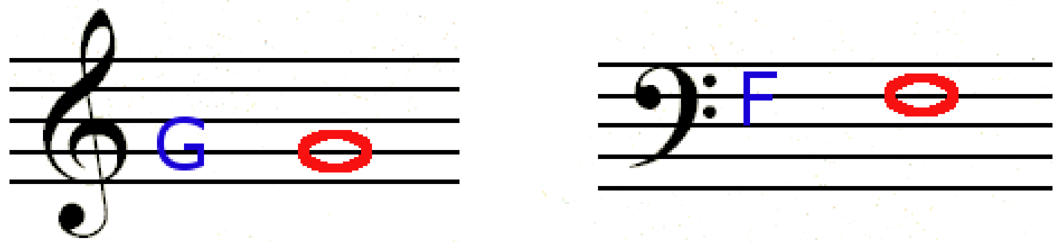


Figure 2.3

The treble and bass staffs are often paired in piano music with the "grand staff" or "piano staff." The grand staff features a brace, bar and then the two staffs.

The Grand or Piano Staff

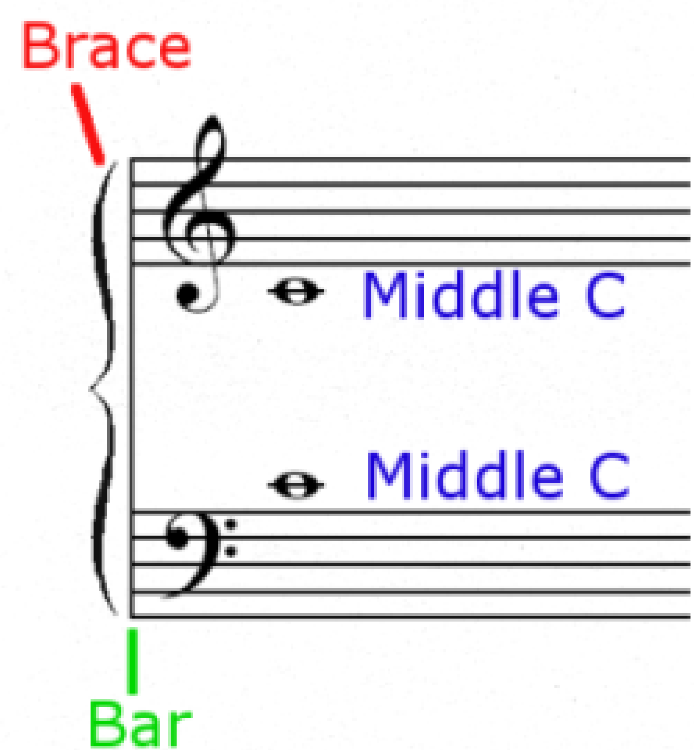


Figure 2.4

Description The grand staff is used for keyboard instruments such as piano, organ, and harpsichord.

Notice the position of "middle C" on the grand staff. It is below the treble staff and above the bass staff. This note is called middle C because it is the C that is located in the middle of the piano keyboard.

This video gives a further demonstration of the location of middle C and introduces the piano keyboard:

Introduction to the piano keyboard (11 minutes) RealPlayer [4] [5] | Windows Media [6] | iPod or QuickTime Player [7] [8] (mp4)

You will also notice that a short line segment appears in the middle of the note in Figure 4. This short line is called a "ledger line." These added lines are a bit similar to ladders. They are extensions of the staff, either above or below, so that additional pitches may be given in the music. Figure 5 below gives a high C above the treble staff and a low C below the bass staff.

[4]http://terryewell.com/tu/theory/TheoryIntro.ram
[5]http://terryewell.com/tu/theory/TheoryIntro.ram
[6]http://terryewell.com/tu/theory/TheoryIntro.wmv
[7]http://terryewell.com/tu/theory/TheoryIntro.mp4
[8]http://terryewell.com/tu/theory/TheoryIntro.mp4

Figure 2.5

Chapter 3

Pitch: Sharp, Flat, and Natural Notes[1]

The **pitch** of a note is how high or low it sounds. Pitch depends on the frequency[2] of the fundamental (p. 47) sound wave of the note. The higher the frequency of a sound wave, and the shorter its wavelength[3], the higher its pitch sounds. But musicians usually don't want to talk about wavelengths and frequencies. Instead, they just give the different pitches different letter names: A, B, C, D, E, F, and G. These seven letters name all the **natural** notes (on a keyboard, that's all the white keys) within one octave. (When you get to the eighth natural note, you start the next octave (Chapter 6) on another A.)

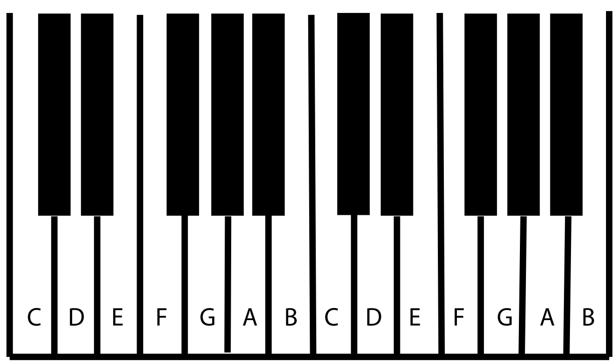


Figure 3.1: The natural notes name the white keys on a keyboard.

But in Western[4] music there are twelve notes in each octave that are in common use. How do you name the other five notes (on a keyboard, the black keys)?

[1]This content is available online at <http://cnx.org/content/m10943/2.12/>.
[2]"Acoustics for Music Theory": Section Wavelength, Frequency, and Pitch <http://cnx.org/content/m13246/latest/#s2>
[3]"Acoustics for Music Theory": Section Wavelength, Frequency, and Pitch <http://cnx.org/content/m13246/latest/#s2>
[4]"What Kind of Music is That?" <http://cnx.org/content/m11421/latest/>

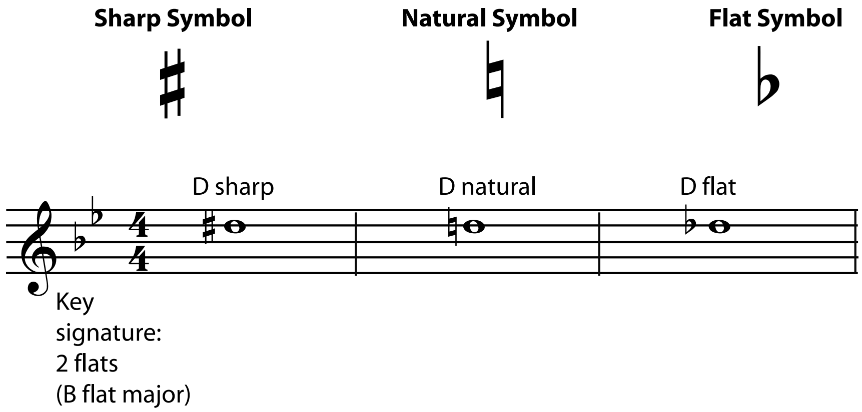


Figure 3.2: Sharp, flat, and natural signs can appear either in the key signature[5], or right in front of the note that they change.

A **sharp sign** means "the note that is one half step (Chapter 4) higher than the natural note". A **flat sign** means "the note that is one half step lower than the natural note". Some of the natural notes are only one half step apart, but most of them are a whole step (Chapter 4) apart. When they are a whole step apart, the note in between them can only be named using a flat or a sharp.

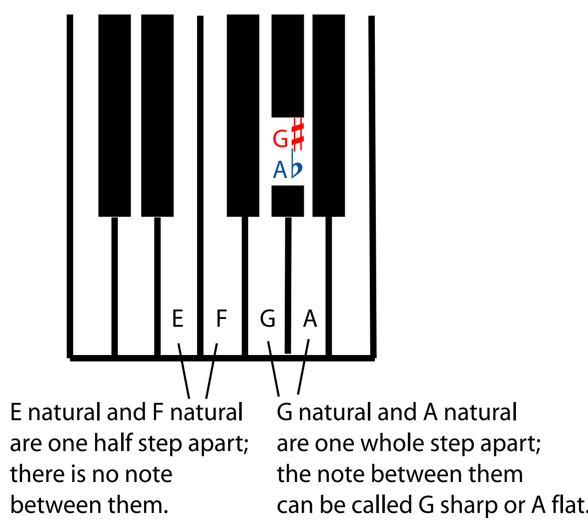


Figure 3.3

Notice that, using flats and sharps, any pitch can be given more than one note name. For example, the G

[5]"Key Signature" <http://cnx.org/content/m10881/latest/>

sharp and the A flat are played on the same key on the keyboard; they sound the same. You can also name and write the F natural as "E sharp"; F natural is the note that is a half step higher than E natural, which is the definition of E sharp. Notes that have different names but sound the same are called enharmonic[6] notes.

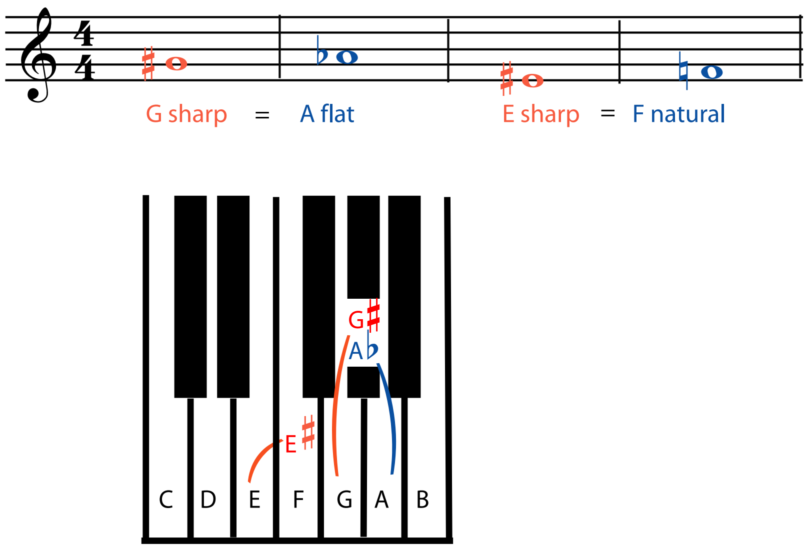


Figure 3.4: G sharp and A flat sound the same. E sharp and F natural sound the same.

Sharp and flat signs can be used in two ways: they can be part of a key signature[7], or they can mark accidentals. For example, if most of the C's in a piece of music are going to be sharp, then a sharp sign is put in the "C" space at the beginning of the staff (Chapter 1), in the key signature. If only a few of the C's are going to be sharp, then those C's are marked individually with a sharp sign right in front of them. Pitches that are not in the key signature are called **accidentals**.

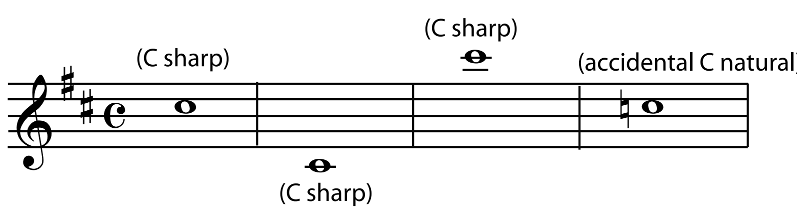


Figure 3.5: When a sharp sign appears in the C space in the key signature, all C's are sharp unless marked as accidentals.

[6]"Enharmonic Spelling" <http://cnx.org/content/m11641/latest/>
[7]"Key Signature" <http://cnx.org/content/m10881/latest/>

A note can also be double sharp or double flat. A **double sharp** is two half steps (one whole step) higher than the natural note; a **double flat** is two half steps (a whole step) lower. Triple, quadruple, etc. sharps and flats are rare, but follow the same pattern: every sharp or flat raises or lowers the pitch one more half step.

Using double or triple sharps or flats may seem to be making things more difficult than they need to be. Why not call the note "A natural" instead of "G double sharp"? The answer is that, although A natural and G double sharp are the same pitch, they don't have the same function within a particular chord or a particular key. For musicians who understand some music theory (and that includes most performers, not just composers and music teachers), calling a note "G double sharp" gives important and useful information about how that note functions in the chord[8] and in the progression of the harmony[9].

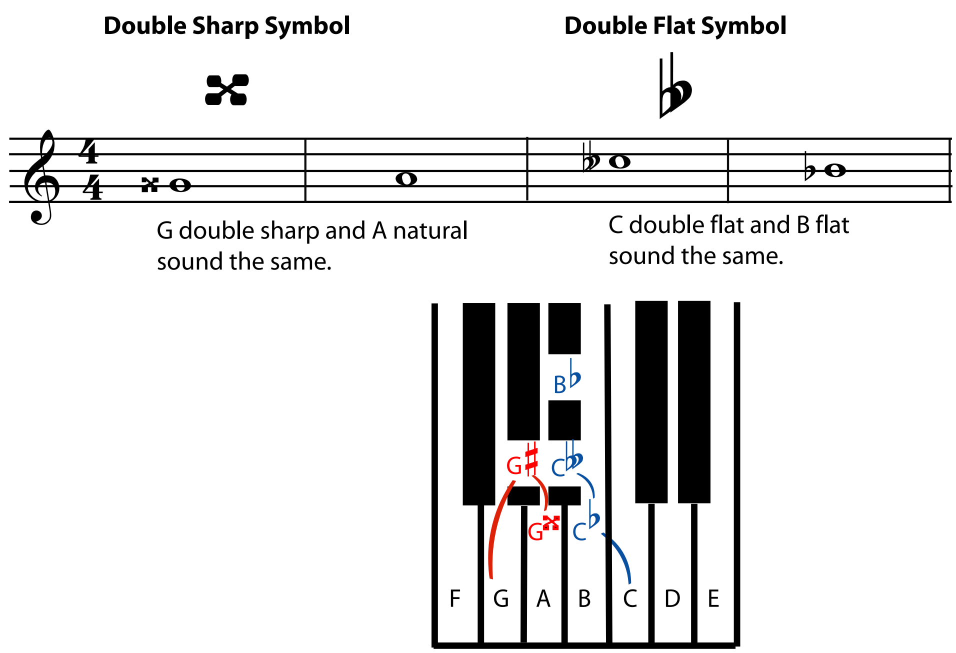


Figure 3.6: Double sharps raise the pitch by two half steps (one whole step). Double flats lower the pitch by two half steps (one whole step).

NOTE: Thanks to everyone who participated in the survey! It was very useful to me, both as a researcher and as an author, to get a better picture of my readers' goals and needs. I hope to begin updating the survey results module[10] in April. I will also soon begin making some of the suggested additions, and emailed comments are still welcome as always.

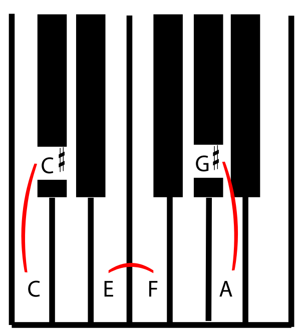
[8]"Harmony": Chords <http://cnx.org/content/m11654/latest/#l0b>
[9]"Beginning Harmonic Analysis" <http://cnx.org/content/m11643/latest/>
[10]"A Survey of Users of Connexions Music Modules" <http://cnx.org/content/m34234/latest/>

Chapter 4

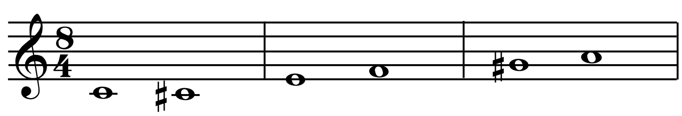
Half Steps and Whole Steps[1]

The **pitch** of a note is how high or low it sounds. Musicians often find it useful to talk about how much higher or lower one note is than another. This distance between two pitches is called the **interval** between them. In Western music[2], the small interval from one note to the next closest note higher or lower is called a **half step** or **semi-tone**.

Half Steps



(a)



(b)

Figure 4.1: Three half-step intervals: between C and C sharp (or D flat); between E and F; and between G sharp (or A flat) and A.

Listen[3] to the half steps in Figure 4.1 (Half Steps).

[1]This content is available online at <http://cnx.org/content/m10866/2.20/>.
[2]"What Kind of Music is That?" <http://cnx.org/content/m11421/latest/>
[3]See the file at <http://cnx.org/content/m10866/latest/6f.mid>

The intervals in Figure 4.1 (Half Steps) look different on a staff (Chapter 1); sometimes they are on the same line, sometimes not. But it is clear at the keyboard that in each case there is no note in between them.

So a scale[4] that goes up or down by half steps, a **chromatic scale**, plays all the notes on both the white and black keys of a piano. It also plays all the notes easily available on most Western[5] instruments. (A few instruments, like trombone[6] and violin[7], can easily play pitches that aren't in the chromatic scale, but even they usually don't.)

One Octave Chromatic Scale

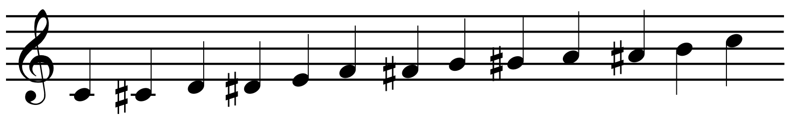


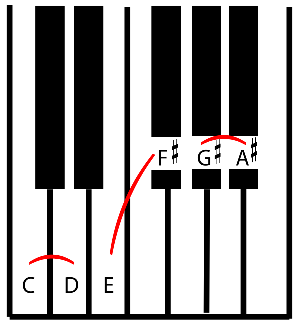
Figure 4.2: All intervals in a **chromatic scale** are half steps. The result is a scale that plays all the notes easily available on most instruments.

Listen[8] to a chromatic scale.

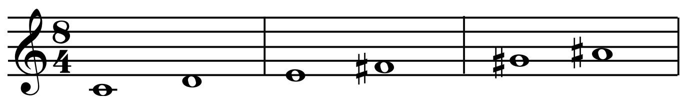
If you go up or down two half steps from one note to another, then those notes are a **whole step**, or **whole tone** apart.

[4]"Major Keys and Scales" <http://cnx.org/content/m10851/latest/>
[5]"What Kind of Music is That?" <http://cnx.org/content/m11421/latest/>
[6]"Trombones" <http://cnx.org/content/m12602/latest/>
[7]"Introduction to the Violin and FAQ" <http://cnx.org/content/m13437/latest/>
[8]See the file at <http://cnx.org/content/m10866/latest/6a.mid>

Whole Steps



(a)



(b)

Figure 4.3: Three whole step intervals: between C and D; between E and F sharp; and between G sharp and A sharp (or A flat and B flat).

A **whole tone scale**, a scale made only of whole steps, sounds very different from a chromatic scale.

Whole Tone Scale

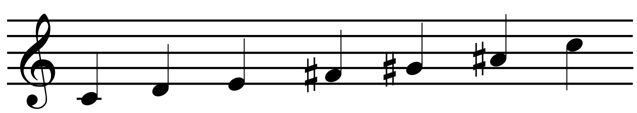


Figure 4.4: All intervals in a **whole tone scale** are whole steps.

Listen[9] to a whole tone scale.

You can count any number of whole steps or half steps between notes; just remember to count all sharp or flat notes (the black keys on a keyboard) as well as all the natural notes (the white keys) that are in between.

Example 4.1

The interval between C and the F above it is 5 half steps, or two and a half steps.

[9]See the file at <http://cnx.org/content/m10866/latest/6b.mid>

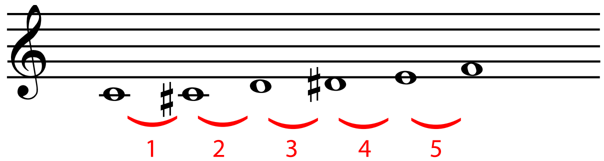


Figure 4.5: Going from C up to F takes five half steps.

Exercise 4.1 ***(Solution on p. 20.)***

Identify the intervals below in terms of half steps and whole steps. If you have trouble keeping track of the notes, use a piano keyboard, a written chromatic scale, or the chromatic fingerings for your instrument to count half steps.

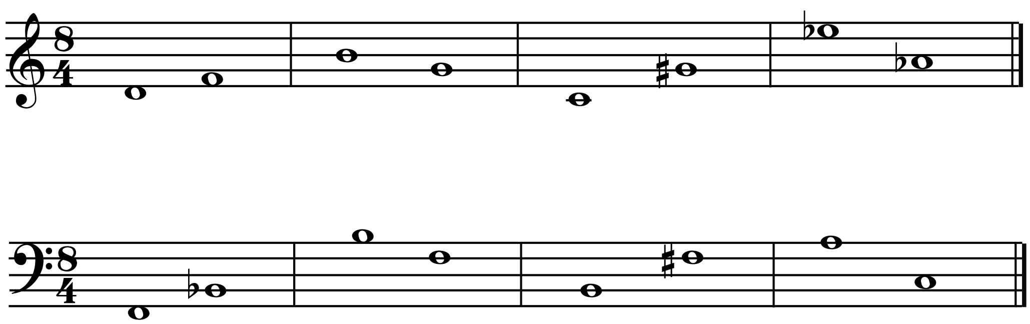


Figure 4.6

Exercise 4.2 ***(Solution on p. 20.)***

Fill in the second note of the interval indicated in each measure. If you need staff paper for this exercise, you can print out this staff paper[10] PDF file.

[10] See the file at <http://cnx.org/content/m10866/latest/staffpaper1.pdf>

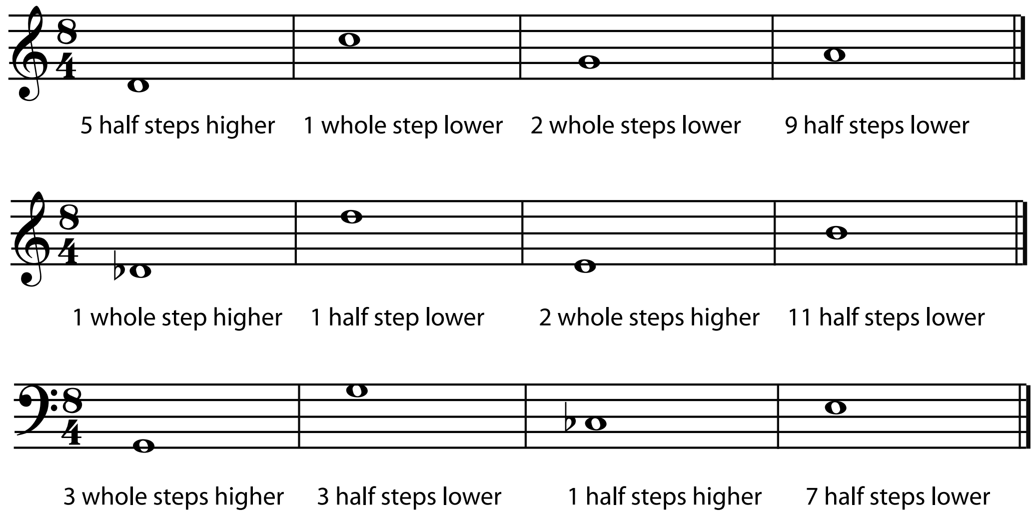


Figure 4.7

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[11]"A Survey of Users of Connexions Music Modules" <http://cnx.org/content/m34234/latest/>

Solutions to Exercises in Chapter 4

Solution to Exercise 4.1 (p. 18)

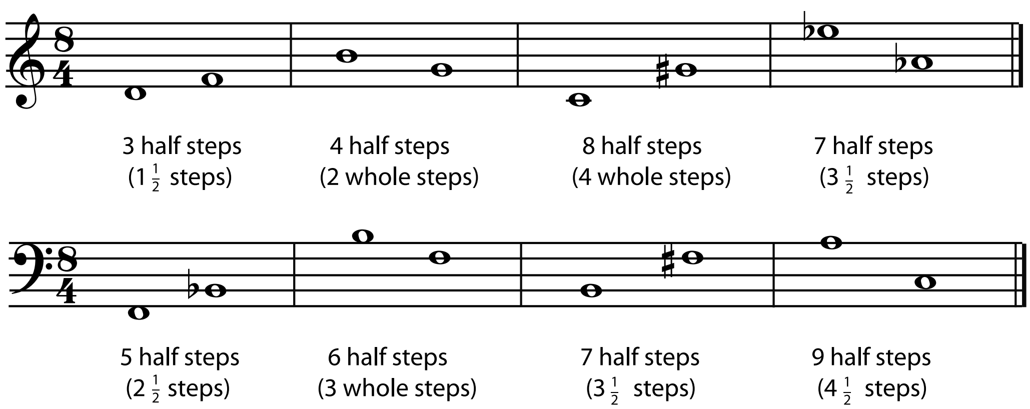

Figure 4.8

Solution to Exercise 4.2 (p. 18)

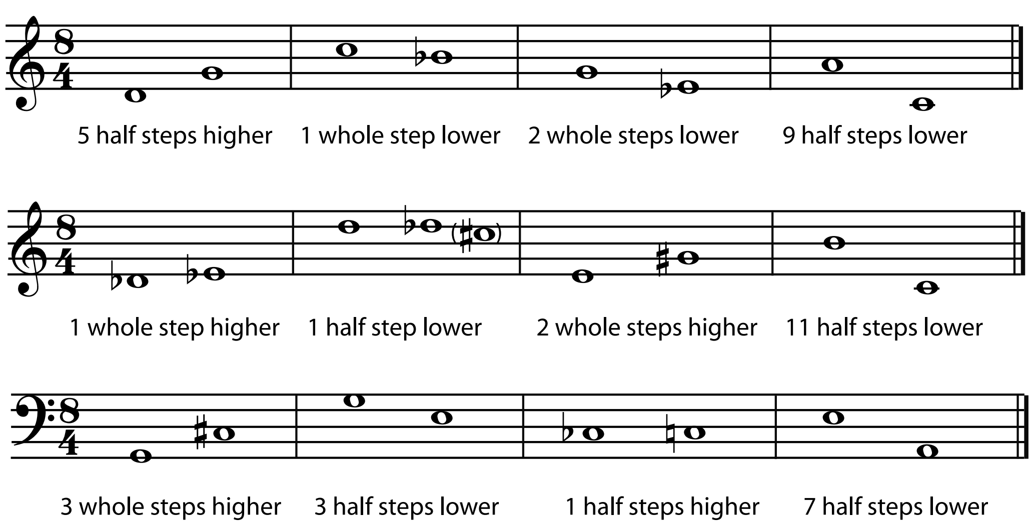

Figure 4.9: If your answer is different, check to see if you have written a different enharmonic spelling[12] of the note in the answer. For example, the B flat could be written as an A sharp.

[12]"Enharmonic Spelling" <http://cnx.org/content/m11641/latest/>

Chapter 5

Intervals[1]

5.1 The Distance Between Pitches

The **interval** between two notes is the distance between the two pitches (Chapter 3) - in other words, how much higher or lower one note is than the other. This concept is so important that it is almost impossible to talk about scales[2], chords[3], harmonic progression[4], cadence[5], or dissonance[6] without referring to intervals. So if you want to learn music theory, it would be a good idea to spend some time getting comfortable with the concepts below and practicing identifying intervals.

Scientists usually describe the distance between two pitches in terms of the difference between their frequencies[7]. Musicians find it more useful to talk about interval. Intervals can be described using half steps and whole steps (Chapter 4). For example, you can say "B natural is a half step below C natural", or "E flat is a step and a half above C natural". But when we talk about larger intervals in the major/minor system (Chapter 6), there is a more convenient and descriptive way to name them.

5.2 Naming Intervals

The first step in naming the interval is to find the distance between the notes **as they are written on the staff**. Count every line and every space in between the notes, as well as the lines or spaces that the notes are on. This gives you the number for the interval.

Example 5.1

[1]This content is available online at <http://cnx.org/content/m10867/2.25/>.
[2]"Major Keys and Scales" <http://cnx.org/content/m10851/latest/>
[3]"Harmony": Chords <http://cnx.org/content/m11654/latest/#l0b>
[4]"Harmony": Chords <http://cnx.org/content/m11654/latest/#l0b>
[5]"Cadence in Music" <http://cnx.org/content/m12402/latest/>
[6]"Consonance and Dissonance" <http://cnx.org/content/m11953/latest/>
[7]"Frequency, Wavelength, and Pitch" <http://cnx.org/content/m11060/latest/>

Counting Intervals

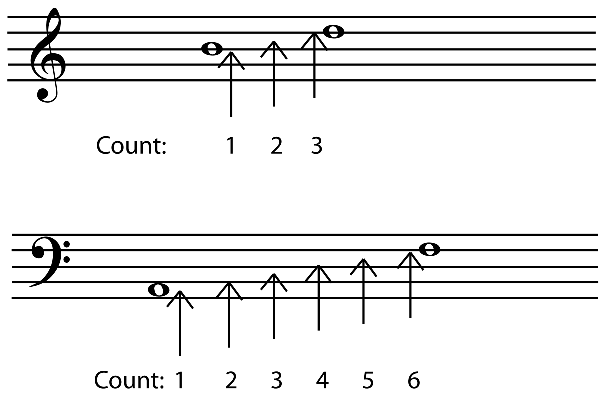

Figure 5.1

To find the interval, count the lines or spaces that the two notes are on as well as all the lines or spaces in between. The interval between B and D is a third. The interval between A and F is a sixth. Note that, at this stage, key signature[8], clef[9], and accidentals (p. 13) do not matter at all.

The **simple intervals** are one octave or smaller.

Simple Intervals

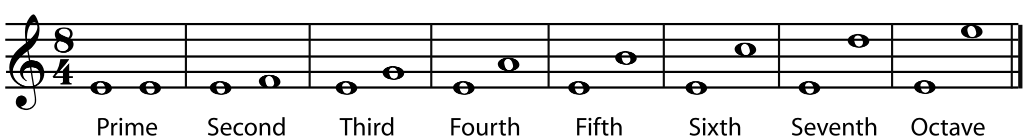

Figure 5.2

If you like you can listen to each interval as written in Figure 5.2 (Simple Intervals): prime[10], second[11], third[12], fourth[13], fifth[14], sixth[15], seventh[16], octave[17].

Compound intervals are larger than an octave.

[8] "Key Signature" <http://cnx.org/content/m10881/latest/>
[9] "Clef" <http://cnx.org/content/m10941/latest/>
[10] See the file at <http://cnx.org/content/m10867/latest/prime.mid>
[11] See the file at <http://cnx.org/content/m10867/latest/second.mid>
[12] See the file at <http://cnx.org/content/m10867/latest/third.mid>
[13] See the file at <http://cnx.org/content/m10867/latest/fourht.mid>
[14] See the file at <http://cnx.org/content/m10867/latest/fifth.mid>
[15] See the file at <http://cnx.org/content/m10867/latest/sixth.mid>
[16] See the file at <http://cnx.org/content/m10867/latest/seventh.mid>
[17] See the file at <http://cnx.org/content/m10867/latest/octave.mid>

Compound Intervals

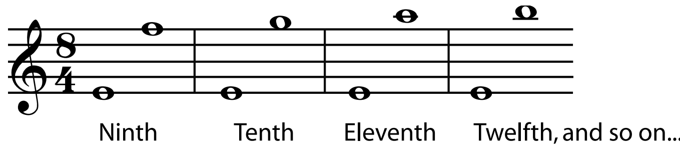

Figure 5.3

Listen to the compound intervals in Figure 5.3 (Compound Intervals): ninth[18], tenth[19], eleventh[20].

Exercise 5.1 ***(Solution on p. 33.)***

Name the intervals.

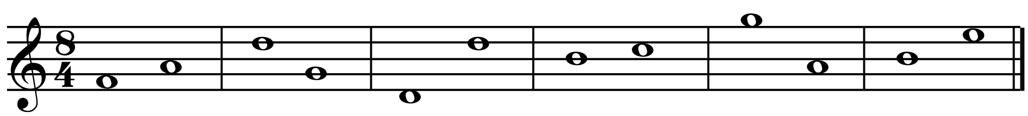

Figure 5.4

Exercise 5.2 ***(Solution on p. 33.)***

Write a note that will give the named interval.

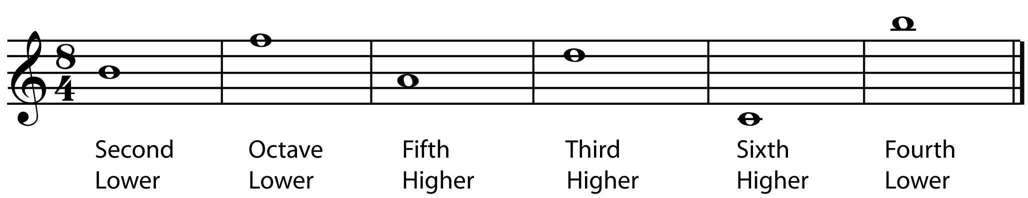

Figure 5.5

5.3 Classifying Intervals

So far, the actual distance, in half-steps, between the two notes has not mattered. But a third made up of three half-steps sounds different from a third made up of four half-steps. And a fifth made up of seven half-

[18] See the file at <http://cnx.org/content/m10867/latest/ninth.mid>
[19] See the file at <http://cnx.org/content/m10867/latest/tenth.mid>
[20] See the file at <http://cnx.org/content/m10867/latest/eleventh.mid>

steps sounds very different from one of only six half-steps. So in the second step of identifying an interval, clef[21], key signature[22], and accidentals (p. 13) become important.

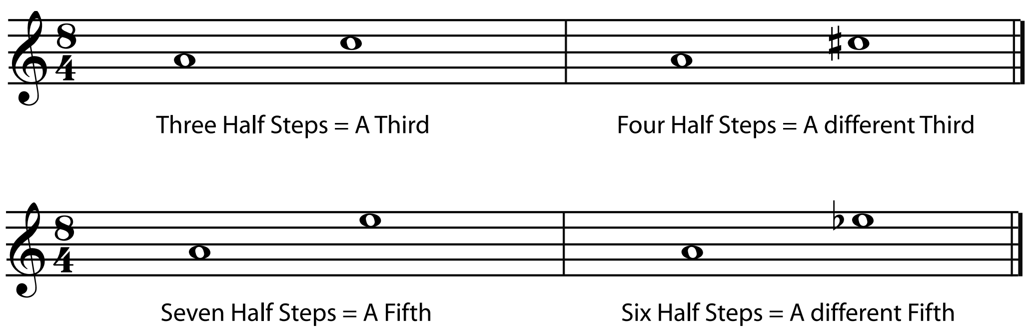

Figure 5.6: A to C natural and A to C sharp are both thirds, but A to C sharp is a larger interval, with a different sound. The difference between the intervals A to E natural and A to E flat is even more noticeable.

Listen to the differences in the thirds[23] and the fifths[24] in Figure 5.6.

So the second step to naming an interval is to classify it based on the number of half steps (Chapter 4) in the interval. Familiarity with the chromatic scale (p. 16) is necessary to do this accurately.

5.3.1 Perfect Intervals

Primes, octaves, fourths, and fifths can be **perfect** intervals.

> NOTE: These intervals **are never classified as major or minor**, although they can be augmented or diminished (see below (Section 5.3.3: Augmented and Diminished Intervals)).

What makes these particular intervals perfect? The physics of sound waves (**acoustics**) shows us that the notes of a perfect interval are very closely related to each other. (For more information on this, see Frequency, Wavelength, and Pitch[25] and Harmonic Series (Chapter 7).) Because they are so closely related, they sound particularly good together, a fact that has been noticed since at least the times of classical Greece, and probably even longer. (Both the octave and the perfect fifth have prominent positions in most of the world's musical traditions.) Because they sound so closely related to each other, they have been given the name "perfect" intervals.

> NOTE: Actually, modern equal temperament[26] tuning does not give the harmonic-series-based pure[27] perfect fourths and fifths. For the music-theory purpose of identifying intervals, this does not matter. To learn more about how tuning affects intervals as they are actually played, see Tuning Systems[28].

[21]"Clef" <http://cnx.org/content/m10941/latest/>
[22]"Key Signature" <http://cnx.org/content/m10881/latest/>
[23]See the file at <http://cnx.org/content/m10867/latest/twothirds.mid>
[24]See the file at <http://cnx.org/content/m10867/latest/twofifths.mid>
[25]"Frequency, Wavelength, and Pitch" <http://cnx.org/content/m11060/latest/>
[26]"Tuning Systems": Section Equal Temperament <http://cnx.org/content/m11639/latest/#s22>
[27]"Tuning Systems": Section Pythagorean Intonation <http://cnx.org/content/m11639/latest/#s11>
[28]"Tuning Systems" <http://cnx.org/content/m11639/latest/>

A perfect prime is also called a **unison**. It is two notes that are the same pitch (Chapter 3). A perfect octave is the "same" note an octave (Chapter 6) - 12 half-steps - higher or lower. A **perfect 5th** is 7 half-steps. A **perfect fourth** is 5 half-steps.

Example 5.2

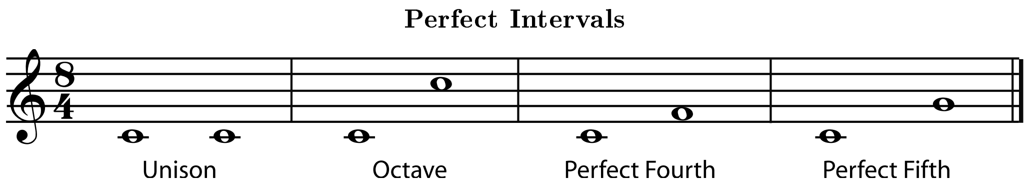

Figure 5.7

Listen to the octave[29], perfect fourth[30], and perfect fifth[31].

5.3.2 Major and Minor Intervals

Seconds, thirds, sixths, and sevenths can be **major intervals** or **minor intervals**. The minor interval is always a half-step smaller than the major interval.

Major and Minor Intervals

- 1 half-step = minor second (m2)
- 2 half-steps = major second (M2)
- 3 half-steps = minor third (m3)
- 4 half-steps = major third (M3)
- 8 half-steps = minor sixth (m6)
- 9 half-steps = major sixth (M6)
- 10 half-steps = minor seventh (m7)
- 11 half-steps = major seventh (M7)

Example 5.3

[29]See the file at <http://cnx.org/content/m10867/latest/P8.mp3>
[30]See the file at <http://cnx.org/content/m10867/latest/P4.mp3>
[31]See the file at <http://cnx.org/content/m10867/latest/P5.mp3>

Major and Minor Intervals

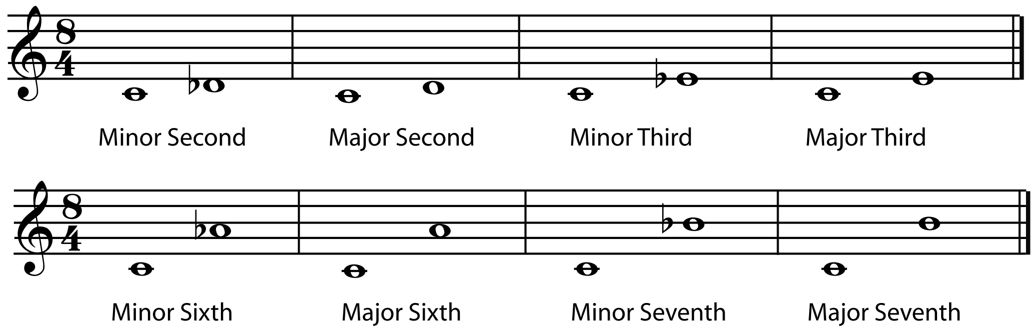

Figure 5.8

Listen to the minor second[32], major second[33], minor third[34], major third[35], minor sixth[36], major sixth[37], minor seventh[38], and major seventh[39].

Exercise 5.3 ***(Solution on p. 33.)***

Give the complete name for each interval.

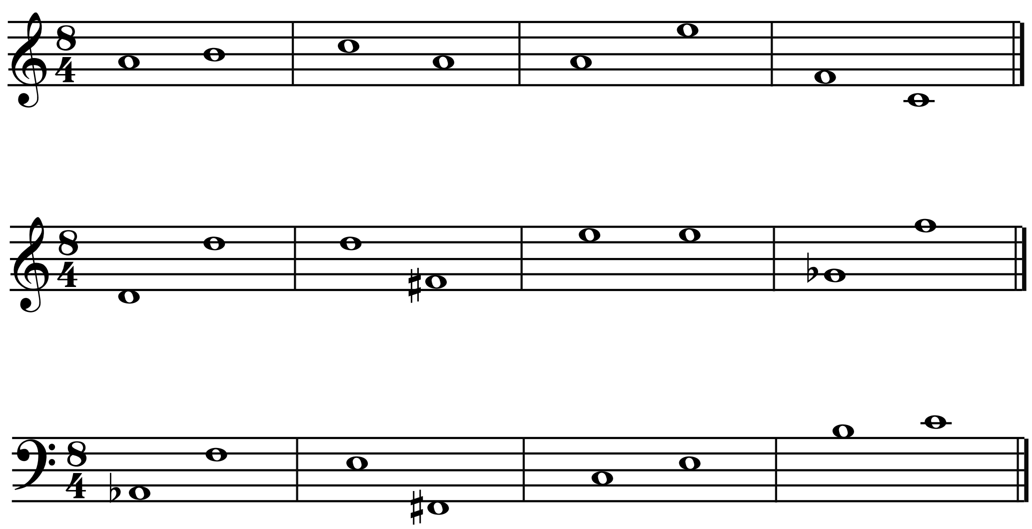

Figure 5.9

[32]See the file at <http://cnx.org/content/m10867/latest/min2.mp3>
[33]See the file at <http://cnx.org/content/m10867/latest/M2.mp3>
[34]See the file at <http://cnx.org/content/m10867/latest/min3.mp3>
[35]See the file at <http://cnx.org/content/m10867/latest/M3.mp3>
[36]See the file at <http://cnx.org/content/m10867/latest/min6.mp3>
[37]See the file at <http://cnx.org/content/m10867/latest/M6.mp3>
[38]See the file at <http://cnx.org/content/m10867/latest/min7.mp3>
[39]See the file at <http://cnx.org/content/m10867/latest/M7.mp3>

Exercise 5.4 *(Solution on p. 34.)*

Fill in the second note of the interval given.

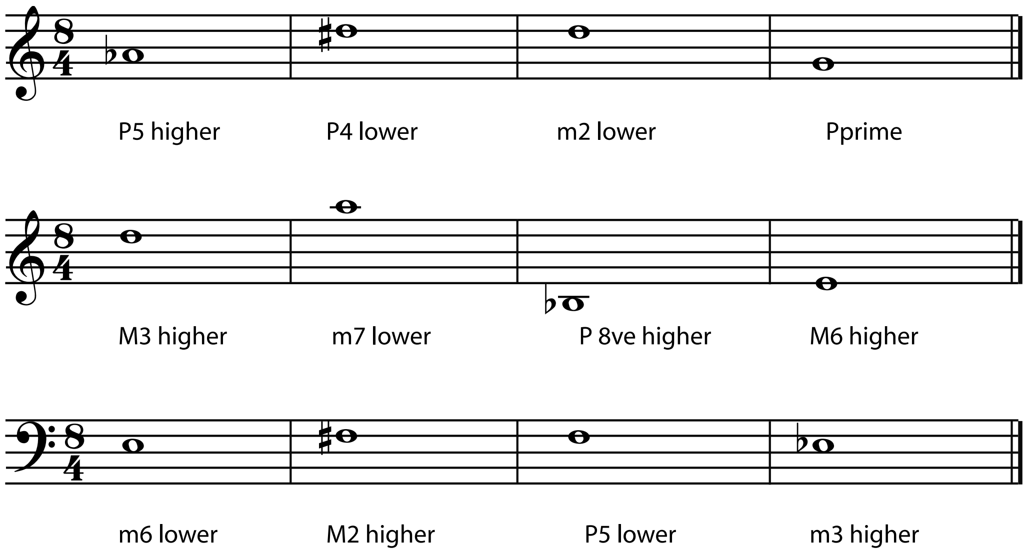

Figure 5.10

5.3.3 Augmented and Diminished Intervals

If an interval is a half-step larger than a perfect or a major interval, it is called **augmented**. An interval that is a half-step smaller than a perfect or a minor interval is called **diminished**. A double sharp (p. 14) or double flat (p. 14) is sometimes needed to write an augmented or diminished interval correctly. Always remember, though, that it is the actual distance in half steps between the notes that determines the type of interval, not whether the notes are written as natural, sharp, or double-sharp.

Example 5.4

Some Diminished and Augmented Intervals

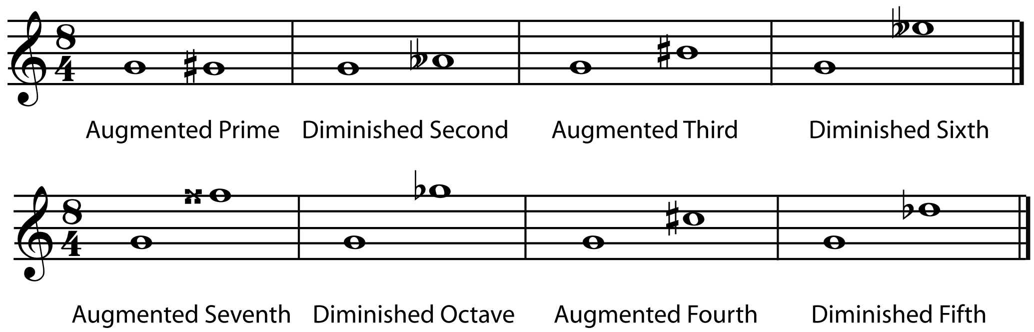

Figure 5.11

Listen to the augmented prime[40], diminished second[41], augmented third[42], diminished sixth[43], augmented seventh[44], diminished octave[45], augmented fourth[46], and diminished fifth[47]. Are you surprised that the augmented fourth and diminished fifth sound the same?

Exercise 5.5 *(Solution on p. 34.)*

Write a note that will give the named interval.

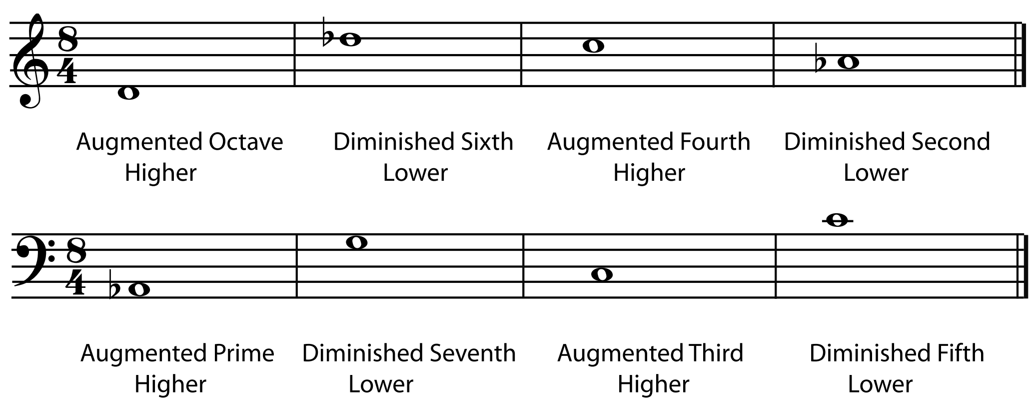

Figure 5.12

As mentioned above, the diminished fifth and augmented fourth sound the same. Both are six half-steps, or **three whole tones**, so another term for this interval is a **tritone**. In Western Music[48], this unique

[40]See the file at <http://cnx.org/content/m10867/latest/aug1.mid>
[41]See the file at <http://cnx.org/content/m10867/latest/dim2.mid>
[42]See the file at <http://cnx.org/content/m10867/latest/aug3.mid>
[43]See the file at <http://cnx.org/content/m10867/latest/dim6.mid>
[44]See the file at <http://cnx.org/content/m10867/latest/aug7.mid>
[45]See the file at <http://cnx.org/content/m10867/latest/dim8.mid>
[46]See the file at <http://cnx.org/content/m10867/latest/aug4.mid>
[47]See the file at <http://cnx.org/content/m10867/latest/dim5.mid>
[48]"What Kind of Music is That?" <http://cnx.org/content/m11421/latest/>

interval, which cannot be spelled as a major, minor, or perfect interval, is considered unusually dissonant[49] and unstable (tending to want to resolve[50] to another interval).

You have probably noticed by now that the tritone is not the only interval that can be "spelled" in more than one way. In fact, because of enharmonic spellings[51], the interval for any two pitches can be written in various ways. A major third could be written as a diminished fourth, for example, or a minor second as an augmented prime. **Always classify the interval as it is written; the composer had a reason for writing it that way.** That reason sometimes has to do with subtle differences in the way different written notes will be interpreted by performers, but it is mostly a matter of placing the notes correctly in the context of the key[52], the chord[53], and the evolving harmony[54]. (Please see Beginning Harmonic Analysis[55] for more on that subject.)

Enharmonic Intervals

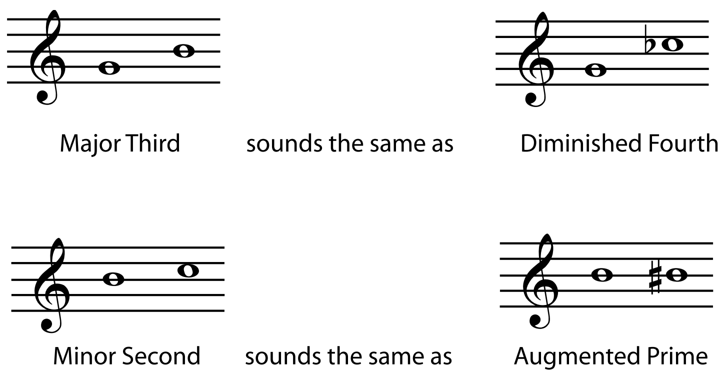

Figure 5.13: Any interval can be written in a variety of ways using enharmonic[56] spelling. Always classify the interval as it is written.

5.4 Inverting Intervals

To **invert** any interval, simply imagine that one of the notes has moved one octave, so that the higher note has become the lower and vice-versa. Because inverting an interval only involves moving one note by an octave (it is still essentially the "same" note in the tonal system), intervals that are **inversions** of each other have a very close relationship in the tonal (Chapter 6) system.

[49] "Consonance and Dissonance" <http://cnx.org/content/m11953/latest/>
[50] "Consonance and Dissonance" <http://cnx.org/content/m11953/latest/#p0h>
[51] "Enharmonic Spelling" <http://cnx.org/content/m11641/latest/>
[52] "Major Keys and Scales" <http://cnx.org/content/m10851/latest/>
[53] "Harmony": Chords <http://cnx.org/content/m11654/latest/#l0b>
[54] "Harmony" <http://cnx.org/content/m11654/latest/>
[55] "Beginning Harmonic Analysis" <http://cnx.org/content/m11643/latest/>
[56] "Enharmonic Spelling" <http://cnx.org/content/m11641/latest/>

Inverting Intervals

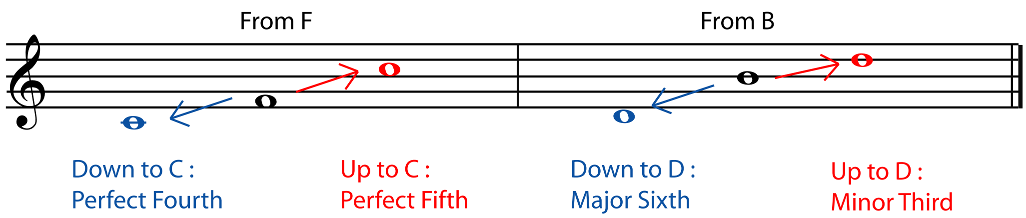

Figure 5.14

To find the inversion of an interval

1. To name the new interval, subtract the name of the old interval from 9.
2. The inversion of a perfect interval is still perfect.
3. The inversion of a major interval is minor, and of a minor interval is major.
4. The inversion of an augmented interval is diminished and of a diminished interval is augmented.

Example 5.5

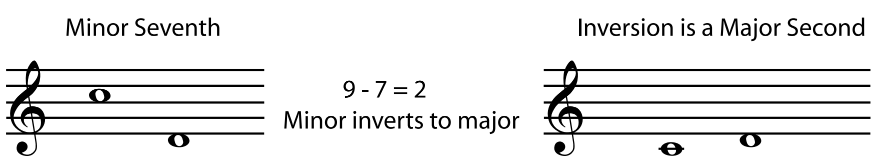

Figure 5.15

Exercise 5.6 *(Solution on p. 35.)*

What are the inversions of the following intervals?

1. Augmented third
2. Perfect fifth
3. Diminished fifth
4. Major seventh
5. Minor sixth

5.5 Summary

Here is a quick summary of the above information, for reference.

Number of half steps	Common Spelling	Example, from C	Alternate Spelling	Example, from C	Inversion
0	Perfect Unison (P1)	C	Diminished Second	D double flat	Octave (P8)
1	Minor Second (m2)	D flat	Augmented Unison	C sharp	Major Seventh (M7)
2	Major Second (M2)	D	Diminished Third	E double flat	Minor Seventh (m7)
3	Minor Third (m3)	E flat	Augmented Second	D sharp	Major Sixth (M6)
4	Major Third (M3)	E	Diminished Fourth	F flat	Minor Sixth (m6)
5	Perfect Fourth (P4)	F	Augmented Third	E sharp	Perfect Fifth (P5)
6	Tritone (TT)	F sharp or G flat	Augmented Fourth or Diminished Fifth	F sharp or G flat	Tritone (TT)
7	Perfect Fifth (P5)	G	Diminished Sixth	A double flat	Perfect Fourth (P4)
8	Minor Sixth (m6)	A flat	Augmented Fifth	G sharp	Major Third (M3)
9	Major Sixth (M6)	A	Diminished Seventh	B double flat	Minor Third (m3)
10	Minor Seventh (m7)	B flat	Augmented Sixth	A sharp	Major Second (M2)
11	Major Seventh (M7)	B	Diminished Octave	C' flat	Minor Second (m2)
12	Perfect Octave (P8)	C'	Augmented Seventh	B sharp	Perfect Unison (P1)

Table 5.1: The examples given name the note reached if one starts on C, and goes up the named interval.

Summary Notes: Perfect Intervals

- A perfect prime is often called a unison. It is two notes of the same pitch.
- A perfect octave is often simply called an octave. It is the next "note with the same name".
- Perfect intervals - unison, fourth, fifth, and octave - are never called major or minor

Summary Notes: Augmented and Diminished Intervals

- An augmented interval is one half step larger than the perfect or major interval.
- A diminished interval is one half step smaller than the perfect or minor interval.

Summary Notes: Inversions of Intervals

- To find the inversion's number name, subtract the interval number name from 9.
- Inversions of perfect intervals are perfect.

- Inversions of major intervals are minor, and inversions of minor intervals are major.
- Inversions of augmented intervals are diminished, and inversions of diminished intervals are augmented.

NOTE: Thanks to everyone who participated in the survey! It was very useful to me, both as a researcher and as an author, to get a better picture of my readers' goals and needs. I hope to begin updating the survey results module[57] in April. I will also soon begin making some of the suggested additions, and emailed comments are still welcome as always.

[57]"A Survey of Users of Connexions Music Modules" <http://cnx.org/content/m34234/latest/>

Solutions to Exercises in Chapter 5

Solution to Exercise 5.1 (p. 23)

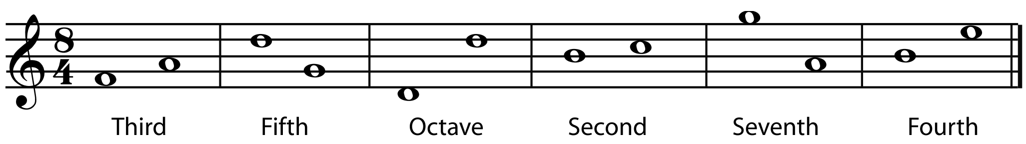

Figure 5.16

Solution to Exercise 5.2 (p. 23)

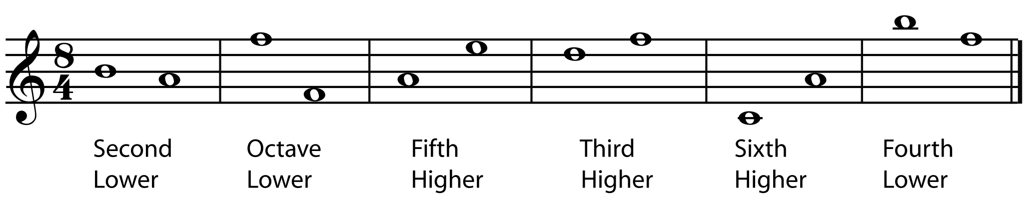

Figure 5.17

Solution to Exercise 5.3 (p. 26)

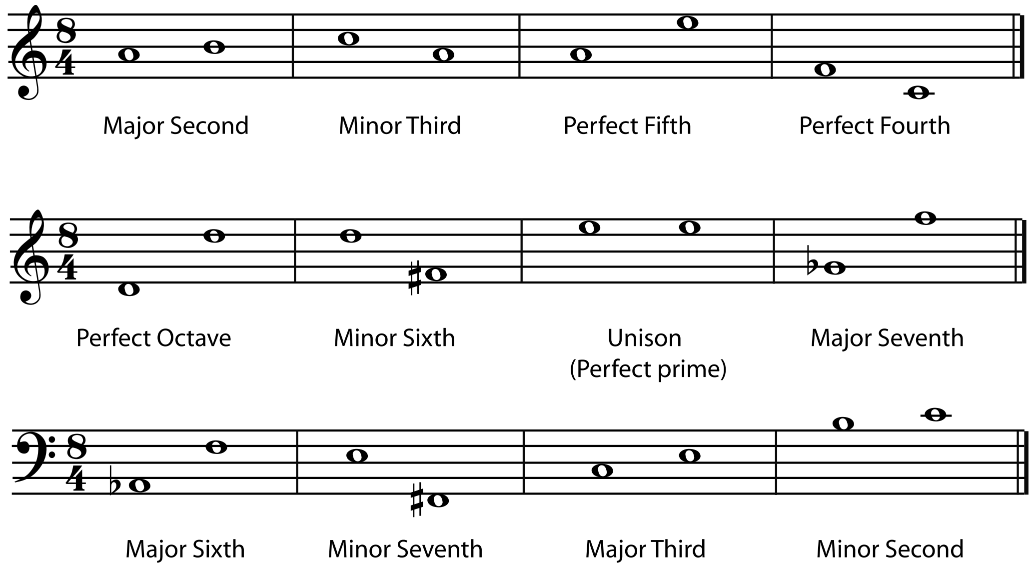

Figure 5.18

Solution to Exercise 5.4 **(p. 27)**

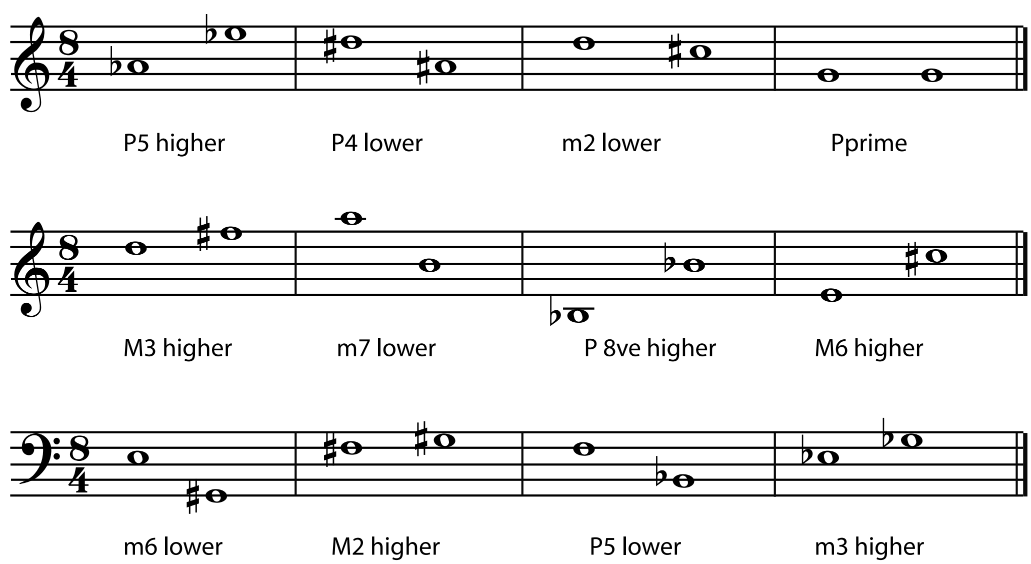

Figure 5.19

Solution to Exercise 5.5 **(p. 28)**

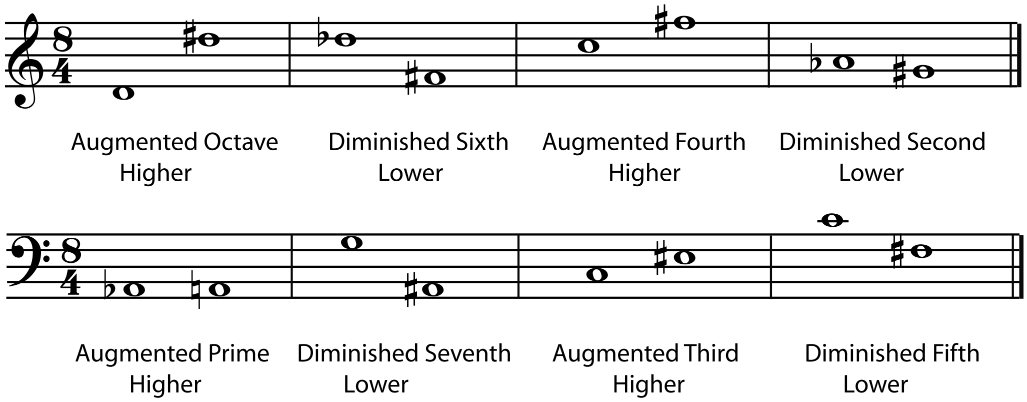

Figure 5.20

Solution to Exercise 5.6 **(p. 30)**

1. Diminished sixth
2. Perfect fourth
3. Augmented fourth
4. Minor second
5. Major third

Chapter 6

Octaves and the Major-Minor Tonal System[1]

NOTE: Are you really free to use this online resource? Join the discussion at Opening Measures[2] .

6.1 Where Octaves Come From

Musical notes, like all sounds, are made of sound waves. The sound waves that make musical notes are very evenly-spaced waves, and the qualities of these regular waves - for example how big they are or how far apart they are - affect the sound of the note. A note can be high or low, depending on how often (how frequently) one of its waves arrives at your ear. When scientists and engineers talk about how high or low a sound is, they talk about its frequency[3]. The higher the **frequency** of a note, the higher it sounds. They can measure the frequency of notes, and like most measurements, these will be numbers, like "440 vibrations per second."

[1]This content is available online at <http://cnx.org/content/m10862/2.23/>.
[2]http://openingmeasures.com/open-education/40/are-the-education-resources-at-Connexions-really-free/
[3]"Frequency, Wavelength, and Pitch" <http://cnx.org/content/m11060/latest/#p1e>

High and Low Frequencies

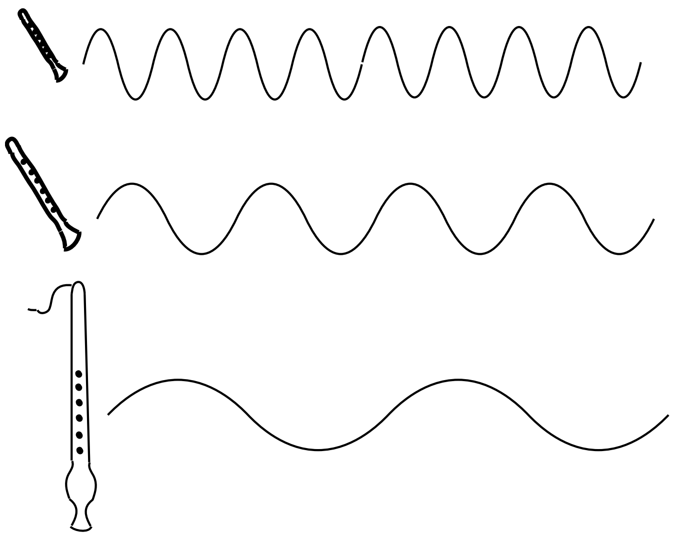

Figure 6.1: A sound that has a shorter wavelength has a higher frequency and a higher pitch.

But people have been making music and talking about music since long before we knew that sounds were waves with frequencies. So when musicians talk about how high or low a note sounds, they usually don't talk about frequency; they talk about the note's pitch (Chapter 3). And instead of numbers, they give the notes names, like "C". (For example, musicians call the note with frequency "440 vibrations per second" an "A".)

But to see where octaves come from, let's talk about frequencies a little more. Imagine a few men are singing a song together. Nobody is singing harmony; they are all singing the same pitch - the same frequency - for each note.

Now some women join in the song. They can't sing where the men are singing; that's too low for their voices. Instead they sing notes that are exactly double the frequency that the men are singing. That means their note has exactly two waves for each one wave that the men's note has. These two frequencies fit so well together that it sounds like the women are singing the same notes as the men, in the same key[4]. They are just singing them one octave higher. **Any note that is twice the frequency of another note is one octave higher.**

Notes that are one octave apart are so closely related to each other that musicians give them the same name. A note that is an octave higher or lower than a note named "C natural" will also be named "C natural". A note that is one (or more) octaves higher or lower than an "F sharp" will also be an "F sharp". (For more discussion of how notes are related because of their frequencies, see The Harmonic Series (Chapter 7), Standing Waves and Musical Instruments[5], and Standing Waves and Wind Instruments[6].)

[4] "Major Keys and Scales" <http://cnx.org/content/m10851/latest/>
[5] "Standing Waves and Musical Instruments" <http://cnx.org/content/m12413/latest/>
[6] "Standing Waves and Wind Instruments" <http://cnx.org/content/m12589/latest/>

Octave Frequencies

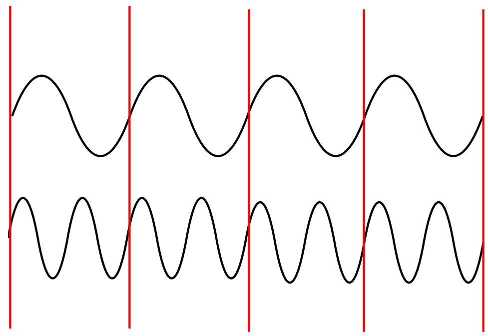

Figure 6.2: When two notes are one octave apart, one has a frequency exactly two times higher than the other - it has twice as many waves. These waves fit together so well, in the instrument, and in the air, and in your ears, that they sound almost like different versions of the same note.

6.2 Naming Octaves

The notes in different octaves are so closely related that when musicians talk about a note, a "G" for example, it often doesn't matter which G they are talking about. We can talk about the "F sharp" in a G major scale[7] without mentioning which octave the scale or the F sharp are in, because the scale is the same in every octave. Because of this, many discussions of music theory don't bother naming octaves. Informally, musicians often speak of "the B on the staff" or the "A above the staff", if it's clear which staff (Chapter 1) they're talking about.

But there are also two formal systems for naming the notes in a particular octave. Many musicians use **Helmholtz** notation. Others prefer **scientific pitch notation**, which simply labels the octaves with numbers, starting with C1 for the lowest C on a full-sized keyboard. Figure 3 shows the names of the octaves most commonly used in music.

[7] "Major Keys and Scales" <http://cnx.org/content/m10851/latest/>

Naming Octaves

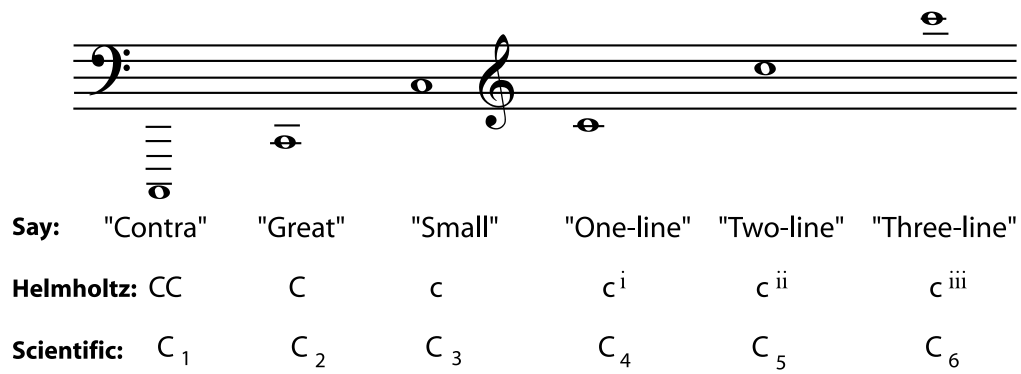

Figure 6.3: The octaves are named from one C to the next higher C. For example, all the notes in between "one line c" and "two line c" are "one line" notes.

The octave below contra can be labelled CCC or Co; higher octaves can be labelled with higher numbers or more lines. Octaves are named from one C to the next higher C. For example, all the notes between "great C" and "small C" are "great". **One-line c is also often called "middle C". No other notes are called "middle", only the C.**

Example 6.1

Naming Notes within a Particular Octave

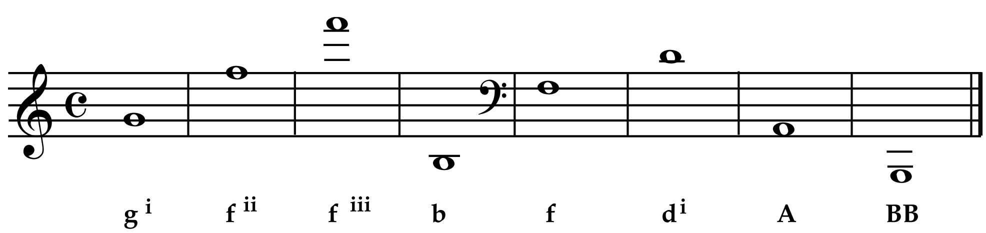

Figure 6.4: Each note is considered to be in the same octave as the C below it.

Exercise 6.1 *(Solution on p. 43.)*

Give the correct octave name for each note.

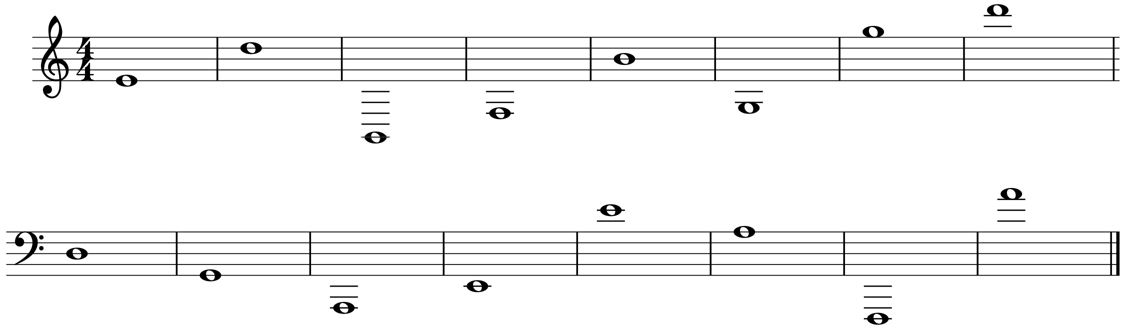

Figure 6.5

6.3 Dividing the Octave into Scales

The word "octave" comes from a Latin root meaning "eight". It seems an odd name for a frequency that is two times, not eight times, higher. The octave was named by musicians who were more interested in how octaves are divided into scales, than in how their frequencies are related. Octaves aren't the only notes that sound good together. The people in different musical traditions have different ideas about what notes they think sound best together. In the Western[8] musical tradition - which includes most familiar music from Europe and the Americas - the octave is divided up into twelve equally spaced notes. If you play all twelve of these notes within one octave you are playing a chromatic scale (p. 16). Other musical traditions - traditional Chinese music for example - have divided the octave differently and so they use different scales. (Please see Major Keys and Scales[9], Minor Keys and Scales[10], and Scales that aren't Major or Minor[11] for more about this.)

You may be thinking "OK, that's twelve notes; that still has nothing to do with the number eight", but out of those twelve notes, only seven are used in any particular major[12] or minor[13] scale. Add the first note of the next octave, so that you have that a "complete"-sounding scale ("do-re-mi-fa-so-la-ti" and then "do" again), and you have the eight notes of the **octave**. These are the **diatonic** scales, and they are the basis of most Western[14] music.

Now take a look at the piano keyboard. Only seven letter names are used to name notes: A, B, C, D, E, F, and G. The eighth note would, of course, be the next A, beginning the next octave. To name the other notes, the notes on the black piano keys, you have to use a sharp or flat (Chapter 3) sign.

[8]"What Kind of Music is That?" <http://cnx.org/content/m11421/latest/>
[9]"Major Keys and Scales" <http://cnx.org/content/m10851/latest/>
[10]"Minor Keys and Scales" <http://cnx.org/content/m10856/latest/>
[11]"Scales that aren't Major or Minor" <http://cnx.org/content/m11636/latest/>
[12]"Major Keys and Scales" <http://cnx.org/content/m10851/latest/>
[13]"Minor Keys and Scales" <http://cnx.org/content/m10856/latest/>
[14]"What Kind of Music is That?" <http://cnx.org/content/m11421/latest/>

Keyboard

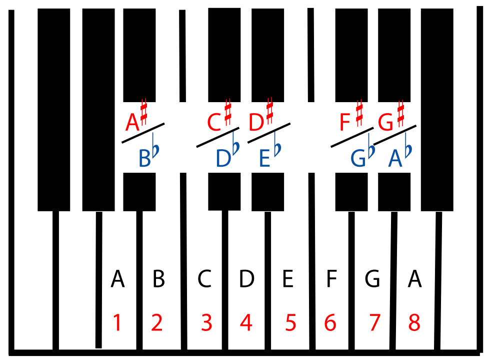

Figure 6.6: The white keys are the natural notes. Black keys can only be named using sharps or flats. The pattern repeats at the eighth tone of a scale, the octave.

Whether it is a popular song, a classical symphony, or an old folk tune, most of the music that feels comfortable and familiar (to Western listeners) is based on either a major or minor scale. It is **tonal** music that mostly uses only seven of the notes within an octave: only one of the possible A's (A sharp, A natural, or A flat), one of the possible B's (B sharp, B natural, or B flat), and so on. The other notes in the chromatic scale are (usually) used sparingly to add interest or to (temporarily) change the key in the middle of the music. For more on the keys and scales that are the basis of tonal music, see Major Keys and Scales[15] and Minor Keys and Scales[16].

[15]"Major Keys and Scales" <http://cnx.org/content/m10851/latest/>
[16]"Minor Keys and Scales" <http://cnx.org/content/m10856/latest/>

Solutions to Exercises in Chapter 6

Solution to Exercise 6.1 (p. 40)

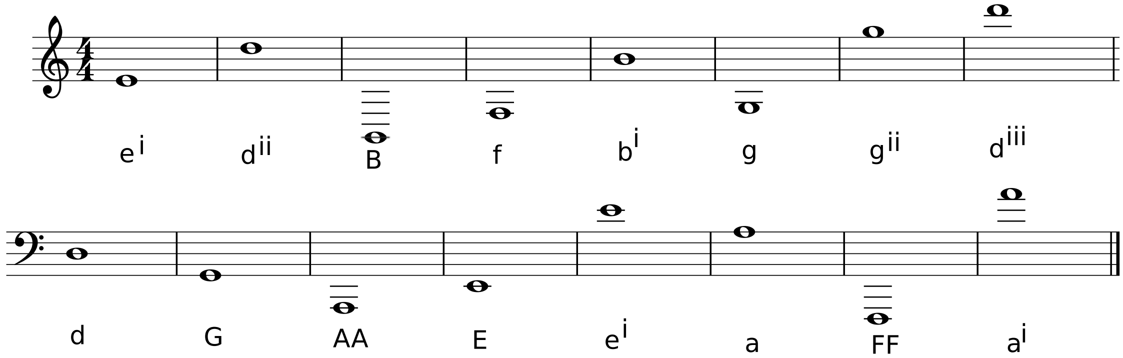

Figure 6.7

Chapter 7

Harmonic Series[1]

NOTE: Are you really free to use this online resource? Join the discussion at Opening Measures[2] .

7.1 Introduction

Have you ever wondered how a trumpet[3] plays so many different notes with only three valves[4], or how a bugle plays different notes with no valves at all? Have you ever wondered why an oboe[5] and a flute[6] sound so different, even when they're playing the same note? What is a string player doing when she plays "harmonics"? Why do some notes sound good together while other notes seem to clash with each other? The answers to all of these questions will become clear with an understanding of the harmonic series.

7.2 Physics, Harmonics and Color

Most musical notes are sounds that have a particular pitch (Chapter 3). The pitch depends on the main frequency[7] of the sound; the higher the frequency, and shorter the wavelength, of the sound waves, the higher the pitch is. But musical sounds don't have just one frequency. Sounds that have only one frequency are not very interesting or pretty. They have no more musical color[8] than the beeping of a watch alarm. On the other hand, sounds that have too many frequencies, like the sound of glass breaking or of ocean waves crashing on a beach, may be interesting and even pleasant. But they don't have a particular pitch, so they usually aren't considered musical notes.

[1] This content is available online at <http://cnx.org/content/m11118/2.17/>.
[2] http://openingmeasures.com/open-education/40/are-the-education-resources-at-Connexions-really-free/
[3] "Trumpets and Cornets" <http://cnx.org/content/m12606/latest/>
[4] "Wind Instruments: Some Basics" <http://cnx.org/content/m12364/latest/#p2f>
[5] "The Oboe and its Relatives" <http://cnx.org/content/m12615/latest/>
[6] "Flutes" <http://cnx.org/content/m12603/latest/>
[7] "Frequency, Wavelength, and Pitch", Figure 1: Wavelength, Frequency, and Pitch <http://cnx.org/content/m11060/latest/#fig1b>
[8] "Timbre: The Color of Music" <http://cnx.org/content/m11059/latest/>

Frequency and Pitch

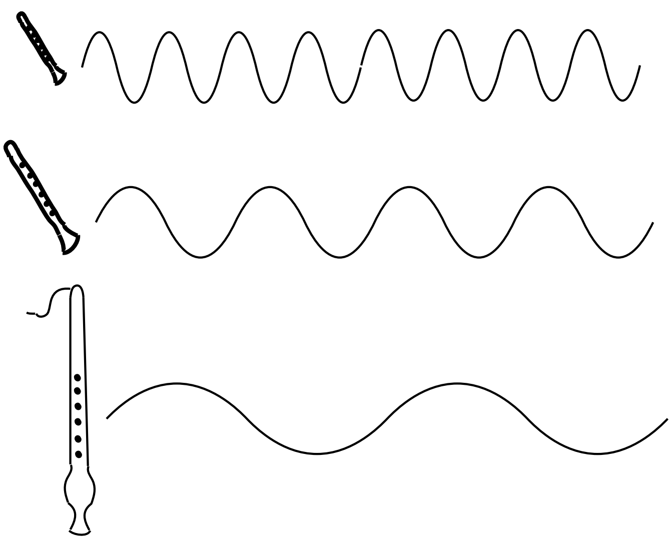

Figure 7.1: The higher the frequency, the higher the note sounds.

When someone plays or sings a note, only a very particular set of frequencies is heard. Imagine that each note that comes out of the instrument is a smooth mixture of many different pitches. These different pitches are called **harmonics**, and they are blended together so well that you do not hear them as separate notes at all. Instead, the harmonics give the note its color.

What is the color[9] of a sound? Say an oboe plays a middle C. Then a flute plays the same note at the same loudness as the oboe. It is still easy to tell the two notes apart, because an oboe sounds different from a flute. This difference in the sounds is the **color**, or **timbre** (pronounced "TAM-ber") of the notes. Like a color you see, the color of a sound can be bright and bold or deep and rich. It can be heavy, light, murky, thin, smooth, or transparently clear. Some other words that musicians use to describe the timbre of a sound are: reedy, brassy, piercing, mellow, thin, hollow, focussed, breathy (pronounced BRETH-ee) or full. Listen to recordings of a violin[10] and a viola[11]. Although these instruments are quite similar, the viola has a noticeably "deeper" and the violin a noticeably "brighter" sound that is not simply a matter of the violin playing higher notes. Now listen to the same phrase played by an electric guitar[12], an acoustic guitar with twelve steel strings[13] and an acoustic guitar with six nylon strings[14]. The words musicians use to describe timbre are somewhat subjective, but most musicians would agree with the statement that, compared with each other, the first sound is mellow, the second bright, and the third rich.

Exercise 7.1 ***(Solution on p. 55.)***

Listen to recordings of different instruments playing alone or playing very prominently above a group. Some suggestions: an unaccompanied violin or cello sonata, a flute, oboe, trumpet, or horn concerto, native American flute music, classical guitar, bagpipes, steel pan drums, panpipes,

[9] "Timbre: The Color of Music" <http://cnx.org/content/m11059/latest/>
[10] See the file at <http://cnx.org/content/m11118/latest/timvl.mp3>
[11] See the file at <http://cnx.org/content/m11118/latest/timvla.mp3>
[12] See the file at <http://cnx.org/content/m11118/latest/electricGUITARS.wav>
[13] See the file at <http://cnx.org/content/m11118/latest/12stringGUITARS.wav>
[14] See the file at <http://cnx.org/content/m11118/latest/nylonGUITARS.wav>

or organ. For each instrument, what "color" words would you use to describe the timbre of each instrument? Use as many words as you can that seem appropriate, and try to think of some that aren't listed above. Do any of the instruments actually make you think of specific shades of color, like fire-engine red or sky blue?

Where do the harmonics, and the timbre, come from? When a string vibrates, the main pitch you hear is from the vibration of the whole string back and forth. That is the **fundamental**, or first harmonic. But the string also vibrates in halves, in thirds, fourths, and so on. Each of these fractions also produces a harmonic. The string vibrating in halves produces the second harmonic; vibrating in thirds produces the third harmonic, and so on.

NOTE: This method of naming and numbering harmonics is the most straightforward and least confusing, but there are other ways of naming and numbering harmonics, and this can cause confusion. Some musicians do not consider the fundamental to be a harmonic; it is just the fundamental. In that case, the string halves will give the first harmonic, the string thirds will give the second harmonic and so on. When the fundamental is included in calculations, it is called the first **partial**, and the rest of the harmonics are the second, third, fourth partials and so on. Also, some musicians use the term **overtones** as a synonym for harmonics. For others, however, an overtone is any frequency (not necessarily a harmonic) that can be heard resonating with the fundamental. The sound of a gong or cymbals will include overtones that aren't harmonics; that's why the gong's sound doesn't seem to have as definite a pitch as the vibrating string does. If you are uncertain what someone means by the second harmonic or by the term overtones, ask for clarification.

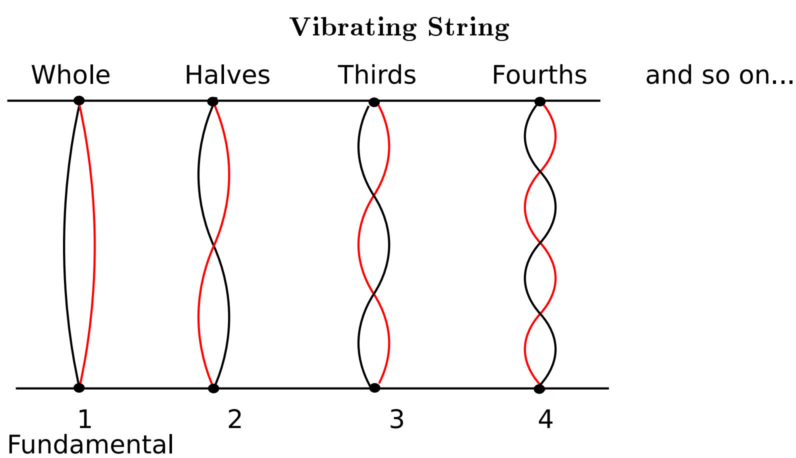

Figure 7.2: The fundamental pitch is produced by the whole string vibrating back and forth. But the string is also vibrating in halves, thirds, quarters, fifths, and so on, producing **harmonics**. All of these vibrations happen at the same time, producing a rich, complex, interesting sound.

A column of air vibrating inside a tube is different from a vibrating string, but the column of air can also vibrate in halves, thirds, fourths, and so on, of the fundamental, so the harmonic series will be the same. So why do different instruments have different timbres? The difference is the relative loudness of all the different harmonics compared to each other. When a clarinet[15] plays a note, perhaps the odd-numbered

[15]"Clarinets" <http://cnx.org/content/m12604/latest/>

harmonics are strongest; when a French horn[16] plays the same notes, perhaps the fifth and tenth harmonics are the strongest. This is what you hear that allows you to recognize that it is a clarinet or horn that is playing.

> NOTE: You will find some more extensive information on instruments and harmonics in Standing Waves and Musical Instruments[17] and Standing Waves and Wind Instruments[18].

7.3 The Harmonic Series

A harmonic series can have any note as its fundamental, so there are many different harmonic series. But the relationship between the frequencies[19] of a harmonic series is always the same. The second harmonic always has exactly half the wavelength (and twice the frequency) of the fundamental; the third harmonic always has exactly a third of the wavelength (and so three times the frequency) of the fundamental, and so on. For more discussion of wavelengths and frequencies, see Frequency, Wavelength, and Pitch[20].

[16] "The French Horn" <http://cnx.org/content/m11617/latest/>
[17] "Standing Waves and Musical Instruments" <http://cnx.org/content/m12413/latest/>
[18] "Standing Waves and Wind Instruments" <http://cnx.org/content/m12589/latest/>
[19] "Frequency, Wavelength, and Pitch", Figure 1: Wavelength, Frequency, and Pitch <http://cnx.org/content/m11060/latest/#fig1b>
[20] "Frequency, Wavelength, and Pitch" <http://cnx.org/content/m11060/latest/>

Harmonic Series Wavelengths and Frequencies

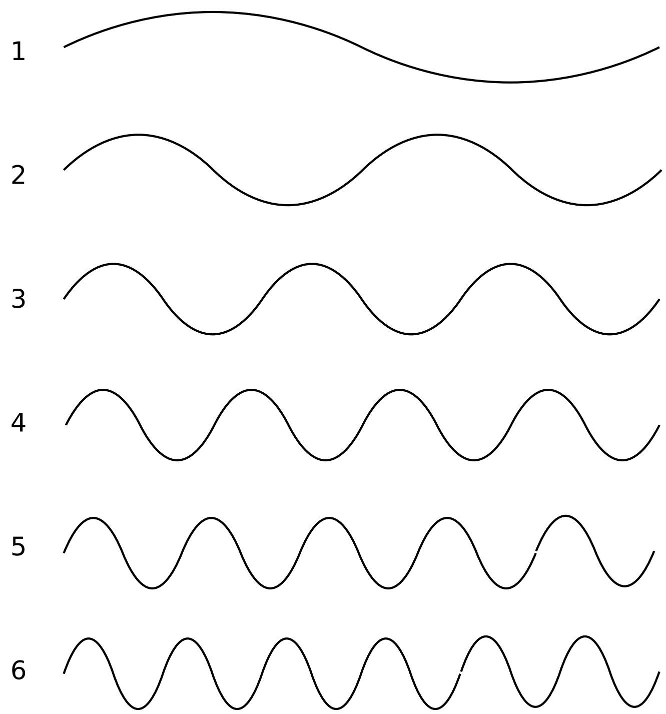

Figure 7.3: The second harmonic has half the wavelength and twice the frequency of the first. The third harmonic has a third the wavelength and three times the frequency of the first. The fourth harmonic has a quarter the wavelength and four times the frequency of the first, and so on. Notice that the fourth harmonic is also twice the frequency of the second harmonic, and the sixth harmonic is also twice the frequency of the third harmonic.

Say someone plays a note, a middle C. Now someone else plays the note that is twice the frequency of the middle C. Since this second note was already a harmonic of the first note, the sound waves of the two notes reinforce each other and sound good together. If the second person played instead the note that was just a litle bit more than twice the frequency of the first note, the harmonic series of the two notes would not fit together at all, and the two notes would not sound as good together. There are many combinations of notes that share some harmonics and make a pleasant sound together. They are considered consonant[21]. Other combinations share fewer or no harmonics and are considered dissonant[22] or, when they really clash, simply "out of tune" with each other. The scales and chords of most of the world's musics are based on these physical facts.

> NOTE: In real music, consonance and dissonance also depend on the standard practices of a musical tradition, especially its harmony practices, but these are also often related to the harmonic series.

For example, a note that is twice the frequency of another note is one octave (Chapter 6) higher than the first note. So in the figure above, the second harmonic is one octave higher than the first; the fourth harmonic is one octave higher than the second; and the sixth harmonic is one octave higher than the third.

[21]"Consonance and Dissonance" <http://cnx.org/content/m11953/latest/>
[22]"Consonance and Dissonance" <http://cnx.org/content/m11953/latest/>

Exercise 7.2 *(Solution on p. 55.)*

1. Which harmonic will be one octave higher than the fourth harmonic?
2. Predict the next four sets of octaves in a harmonic series.
3. What is the pattern that predicts which notes of a harmonic series will be one octave apart?
4. Notes one octave apart are given the same name. So if the first harmonic is a "A", the second and fourth will also be A's. Name three other harmonics that will also be A's.

A mathematical way to say this is "if two notes are an octave apart, the ratio[23] of their frequencies is two to one (2:1)". Although the notes themselves can be any frequency, the 2:1 ratio is the same for all octaves. And all the other intervals (Chapter 5) that musicians talk about can also be described as being particular ratios of frequencies.

A Harmonic Series Written as Notes

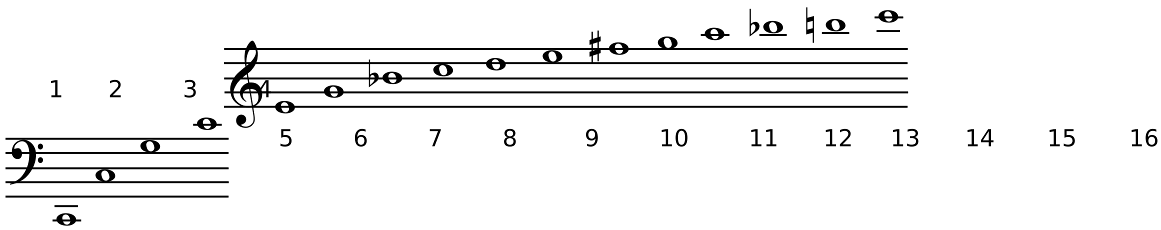

Figure 7.4

Take the third harmonic, for example. Its frequency is three times the first harmonic (ratio 3:1). Remember, the frequency of the second harmonic is two times that of the first harmonic. So the ratio[24] of the frequencies of the second to the third harmonics is 2:3. From the harmonic series shown above, you can see that the interval (Chapter 5) between these two notes is a perfect fifth (Section 5.3.1: Perfect Intervals). The ratio of the frequencies of all perfect fifths is 2:3.

Exercise 7.3 *(Solution on p. 55.)*

1. The interval between the fourth and sixth harmonics (frequency ratio 4:6) is also a fifth. Can you explain this?
2. What other harmonics have an interval of a fifth?
3. Which harmonics have an interval of a fourth?
4. What is the frequency ratio for the interval of a fourth?

NOTE: If you have been looking at the harmonic series above closely, you may have noticed that some notes that are written to give the same interval have different frequency ratios. For example, the interval between the seventh and eighth harmonics is a major second, but so are the intervals between 8 and 9, between 9 and 10, and between 10 and 11. But 7:8, 8:9, 9:10, and 10:11, although they are pretty close, are not exactly the same. In fact, modern Western[25] music uses the equal

[23]"Musical Intervals, Frequency, and Ratio" <http://cnx.org/content/m11808/latest/>
[24]"Musical Intervals, Frequency, and Ratio" <http://cnx.org/content/m11808/latest/>
[25]"What Kind of Music is That?" <http://cnx.org/content/m11421/latest/>

temperament[26] tuning system, which divides the octave into twelve notes that are spaced equally far apart. The positive aspect of equal temperament (and the reason it is used) is that an instrument will be equally in tune in all keys. The negative aspect is that it means that all intervals except for octaves are slightly out of tune with regard to the actual harmonic series. For more about equal temperament, see Tuning Systems[27]. Interestingly, musicians have a tendency to revert to true harmonics when they can (in other words, when it is easy to fine-tune each note). For example, an a capella choral group or a brass ensemble, may find themselves singing or playing perfect fourths and fifths, "contracted" major thirds and "expanded" minor thirds.

7.4 Brass Instruments

The harmonic series is particularly important for brass instruments. A pianist or xylophone player only gets one note from each key. A string player who wants a different note from a string holds the string tightly in a different place. This basically makes a vibrating string of a new length, with a new fundamental.

But a brass player, without changing the length of the instrument, gets different notes by actually playing the harmonics of the instrument. Woodwinds also do this, although not as much. Most woodwinds can get two different octaves with essentially the same fingering; the lower octave is the fundamental of the column of air inside the instrument at that fingering. The upper octave is the first harmonic.

But it is the brass instruments that excel in getting different notes from the same length of tubing. The sound of a brass instruments starts with vibrations of the player's lips. By vibrating the lips at different speeds, the player can cause a harmonic of the air column to sound instead of the fundamental.

So a bugle player can play any note in the harmonic series of the instrument that falls within the player's range. Compare these well-known bugle calls to the harmonic series above (Figure 7.4: A Harmonic Series Written as Notes).

[26]"Tuning Systems": Section Equal Temperament <http://cnx.org/content/m11639/latest/#s22>
[27]"Tuning Systems": Section Temperament <http://cnx.org/content/m11639/latest/#s2>

Bugle Calls

Figure 7.5: Although limited by the fact that it can only play one harmonic series, the bugle can still play many well-known tunes.

For centuries, all brass instruments were valveless. A brass instrument could play only the notes of one harmonic series. The upper octaves of the series, where the notes are close together, could be difficult or impossible to play, and some of the harmonics sound quite out of tune to ears that expect equal temperament. The solution to these problems, once brass valves were perfected, was to add a few valves to the instrument. Three is usually enough. Each valve opens an extra length of tube, making the instrument a little longer, and making available a whole new harmonic series. Usually one valve gives the harmonic series one half step lower than the valveless intrument, another one whole step lower, and another one and a half steps lower. The valves can be used at the same time, too, making even more harmonic series. So a valved brass instrument can find, in the comfortable middle of its range (its **middle register**), a valve combination that will give a reasonably in-tune version for every note of the chromatic scale (p. 16). (For more on the history of valved brass, see History of the French Horn[28]. For more on how and why harmonics are produced in wind instruments, please see Standing Waves and Wind Instruments[29])

NOTE: Trombones use a slide instead of valves to make their instrument longer. But the basic principle is still the same. At each slide "position", the instrument gets a new harmonic series. The notes in between the positions aren't part of the chromatic scale, so they are usually only used for special effects like **glissandos** (sliding notes).

[28]"The French Horn": Section History <http://cnx.org/content/m11617/latest/#s2>
[29]"Standing Waves and Wind Instruments" <http://cnx.org/content/m12589/latest/>

Overlapping Harmonic Series in Brass Instruments

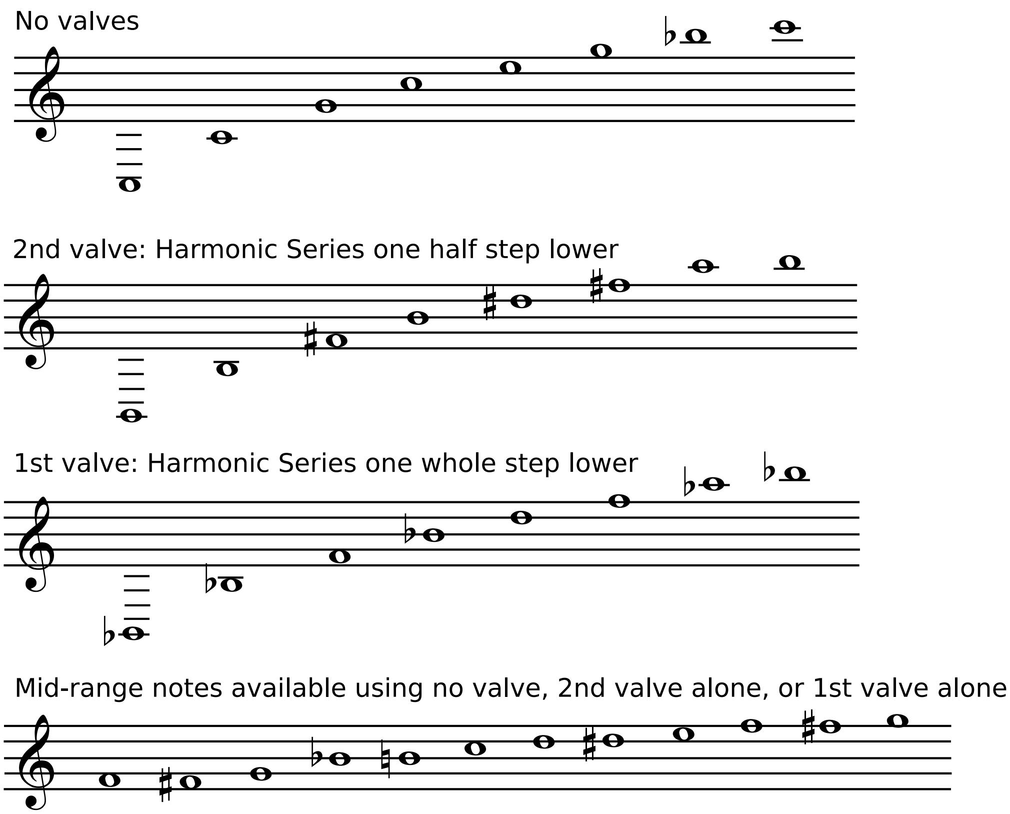

Figure 7.6: These harmonic series are for a brass instrument that has a "C" fundamental when no valves are being used - for example, a C trumpet. Remember, there is an entire harmonic series for every fundamental, and any note can be a fundamental. You just have to find the brass tube with the right length. So a trumpet or tuba can get one harmonic series using no valves, another one a half step lower using one valve, another one a whole step lower using another valve, and so on. By the time all the combinations of valves are used, there is some way to get an in-tune version of every note they need.

Exercise 7.4 ***(Solution on p. 55.)***

Write the harmonic series for the instrument above when both the first and second valves are open. (You can use this PDF file[30] if you need staff paper.) What new notes are added in the instrument's middle range? Are any notes still missing?

NOTE: The French horn[31] has a reputation for being a "difficult" instrument to play. This is also because of the harmonic series. Most brass instruments play in the first few octaves of the harmonic series, where the notes are farther apart and it takes a pretty big difference in the mouth and lips (the embouchure[32], pronounced AHM-buh-sher) to get a different note. The range of the French

[30] See the file at <http://cnx.org/content/m11118/latest/staffpaper1.pdf>
[31] "The French Horn" <http://cnx.org/content/m11617/latest/>
[32] "Wind Instruments: Some Basics" <http://cnx.org/content/m12364/latest/#p2a>

horn is higher in the harmonic series, where the notes are closer together. So very small differences in the mouth and lips can mean the wrong harmonic comes out.

7.5 Playing Harmonics on Strings

String players also use harmonics, although not as much as brass players. Harmonics on strings have a very different timbre[33] from ordinary string sounds. They give a quieter, thinner, more bell-like tone, and are usually used as a kind of ear-catching-special-effect.

Normally when a string player puts a finger on a string, he holds it down tight. This basically forms a (temporarily) shorter vibrating string, which then produces an entire harmonic series, with a shorter (higher) fundamental.

In order to play a harmonic, he touches the string very, very lightly instead. So the length of the string does not change. Instead, the light touch interferes with all of the vibrations that don't have a node at that spot. (A **node** is a place in the wave where the string does not move back-and-forth. For example, the ends of the string are both nodes, since they are held in place.)

String Harmonics

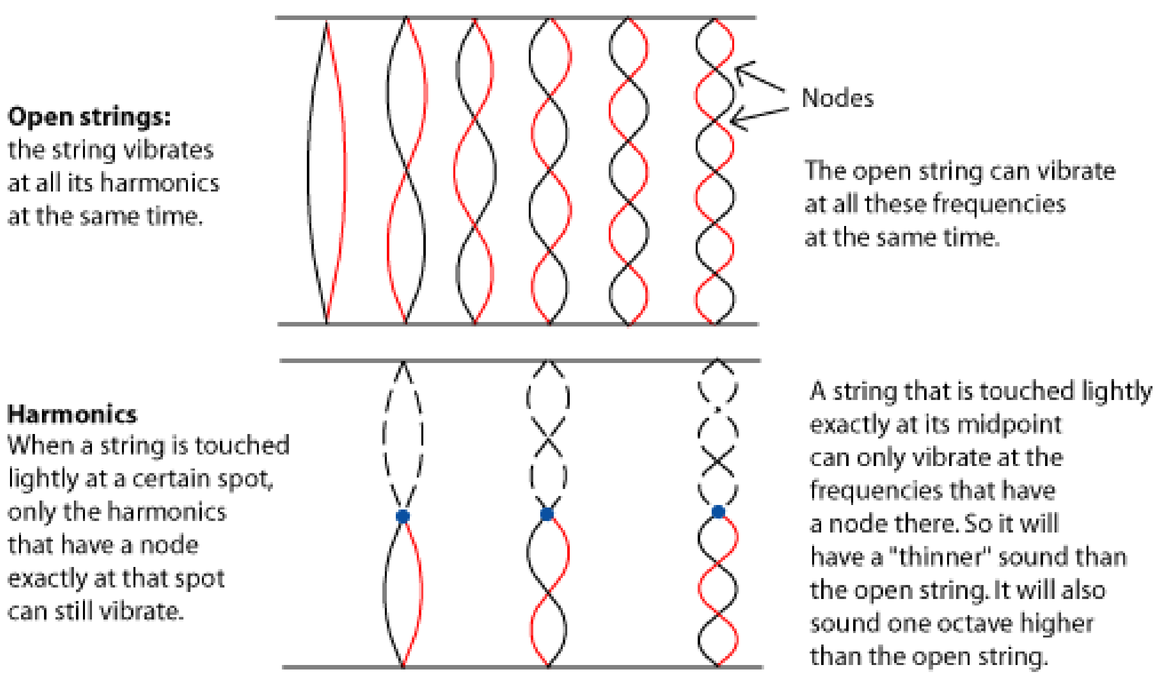

Figure 7.7

The thinner, quieter sound of "playing harmonics" is caused by the fact that much of the harmonic series is missing from the sound, which will of course be heard in the timbre (p. 46). Lightly touching the string in most spots will result in no sound at all. It only works at the precise spots that will leave some of the main harmonics (the longer, louder, lower-numbered ones) free to vibrate.

[33]"Timbre: The Color of Music" <http://cnx.org/content/m11059/latest/>

Solutions to Exercises in Chapter 7

Solution to Exercise 7.1 (p. 46)
Although trained musicians will generally agree that a particular sound is reedy, thin, or full, there are no hard-and-fast right-and-wrong answers to this exercise.
Solution to Exercise 7.2 (p. 50)

1. The eighth harmonic
2. The fifth and tenth harmonics; the sixth and twelfth harmonics; the seventh and fourteenth harmonics; and the eighth and sixteenth harmonics
3. The note that is one octave higher than a harmonic is also a harmonic, and its number in the harmonic series is twice (2 X) the number of the first note.
4. The eighth, sixteenth, and thirty-second harmonics will also be A's.

Solution to Exercise 7.3 (p. 50)

1. The ratio 4:6 reduced to lowest terms is 2:3. (If you are more comfortable with fractions than with ratios, think of all the ratios as fractions instead. 2:3 is just two-thirds, and 4:6 is four-sixths. Four-sixths reduces to two-thirds.)
2. Six and nine (6:9 also reduces to 2:3); eight and twelve; ten and fifteen; and any other combination that can be reduced to 2:3 (12:18, 14:21 and so on).
3. Harmonics three and four; six and eight; nine and twelve; twelve and sixteen; and so on.
4. 3:4

Solution to Exercise 7.4 (p. 53)
Opening both first and second valves gives the harmonic series one-and-a-half steps lower than "no valves".

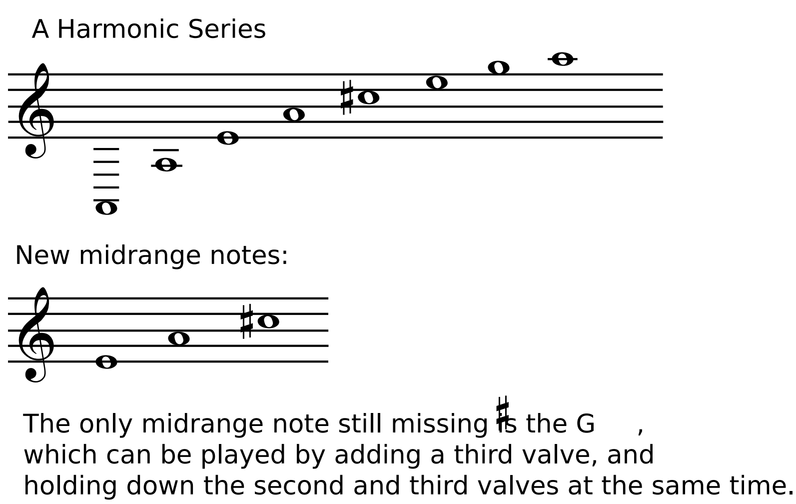

Figure 7.8

Index of Keywords and Terms

Keywords are listed by the section with that keyword (page numbers are in parentheses). Keywords do not necessarily appear in the text of the page. They are merely associated with that section. *Ex.* apples, § 1.1 (1) **Terms** are referenced by the page they appear on. *Ex.* apples, 1

Attributions

Module: "Harmonic Series"
By: Catherine Schmidt-Jones
URL: http://cnx.org/content/m11118/2.17/
Pages: 45-55

Pitch Notation

This collection brings together modules that explain how pitch, the highness or lowness of a musical tone, is represented by notes on the lines and spaces of a staff in common Western notation. It is appropriate for those with little or no prior musical training. Topics progress from the rudimentary logic of pitch notation to the more advanced ideas of octaves and intervals that are necessary for understanding a natural harmonic series as it might be represented in musical notation.