Addendum #11. Theory of Music

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With Lessons & Illustrations from Beethoven's Sonatas
(Under construction; this section is a work in probgress)

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11.1 What is Music?

A definition of music will help us to interpret and perform music and to compose. Most of today's music theory courses treat specialized subtopics of music and rarely explain why or how they "work". Here, I try to unify all these subtopics into a logical structure and provide as much cause and effect explanations behind those musical principles as possible because, without such explanations, there is no proof that those principles are correct and provide no guidance on how to advance our understanding and enhance our capabilities.

Music theory today (Scoggin) is an ad hoc set of rules that were reverse-engineered from existing music. As such, it is extremely detailed and complex, and is very useful for musicians. As a physicist, I am more interested in asking, "what is music?", and certainly everyone has asked that question, including the great composers and musicians. I attempt to answer that question using the scientific knowledge acquired as a career scientist and demonstrate that scientific knowledge is needed to explain music from fundamental biological principles. This explains why even the greatest composers could not explain music because they did not know enough science.

The brain automatically processes all sensory inputs. It commits them to memory (for later use), uses them to figure out is anything dangerous or interesting is about to happen, where sound is coming from, focus the eyes on objects of interest, etc., actions so automatic that, for the vast majority of them, we are not even aware of what the brain is doing. Recognition of music is the result of such automatic brain actions. Therefore we need to learn how the auditory system, including the brain, handles auditory inputs in order figure out what music is.

The chromatic scale, which is **logarithmic("log")**, leaves no doubt that the auditory system operates on a log frequency system so that both the cochlea, where the frequencies are detected, and/or the brain, where they are analyzed, must have log structures; i.e., there are "slide rules" embedded in our ears and/or brains. From an evolutionary point of view, log makes sense in order to accommodate the largest possible frequency range using the smallest possible structures. Unlike the eye, where the optical frequencies are calibrated on an absolute scale using quantum mechanical transitions (so that everybody sees the same colors), the auditory frequency scale is uncalibrated. Therefore, the only way for the brain to process auditory information is to calculate ratios between frequencies. On a log scale, ratios are easy because ratios are distances on the log scale — that's the principle behind the slide rule.

This explains why intervals are important in music and explains harmony and relative pitch. The simplest ratio is 1; it represents zero in log space. If you play "1" on the piano, you are just repeating the same note. The next ratio is 2, which is the octave. There are lots of interesting ratios between 1 and 2, such as 3/2, 4/3, 5/4, and 6/5, representing decreasing distances from 2 towards 1 on the log scale. These are, of course, the fifth, fourth, major third, and minor third, respectively; I will call the ratios in the chromatic scale "chromatic intervals". The piano is a slide rule! For going a distance 4, go two octaves up, where the frequency is four times the starting frequency (4 = 2 x 2 = octave + octave; we have been taught in math class that multiplication becomes addition in log space). If you want 3, go up an octave and a fifth, and the frequency will triple (3 = 2 x 3/2). Note that the operation 2 x 3/2 is complex, involving multiplication and division; by contrast, going up an octave and a fifth is simpler. To go to any frequency, all you need is one octave, which explains why the piano scale consists of "identical" octaves.

The fact that harmonies are recognized as special by the brain tells us that the brain works with frequency ratios. It is a very lucky coincidence of nature that the chromatic scale contains all the chromatic ratios so that it allows us to compose practically any music with it. This is analogous to digital photography — if there are enough pixels, you can take any photograph. The chromatic intervals are important because they produce the only frequencies with which we can make music. They are all multiples of the square root of two are calculated from the log equation of the chromatic scale with equal temperament. The ability of humans with good absolute pitch to distinguish between two frequencies is about 20 cents. The semi-tone on the piano is 100 cents. Therefore, we need five to ten times as many keys on the piano to cover all recognizably different frequencies. The present 88 keys is a good compromise between enough frequencies for the ear and a smaller number that can fit into a piano, and yet contain all the chromatic intervals. The fact that the chromatic scale is logarithmic, allows the brain to process frequency information in music using ratios because the auditory system is built logarithmically. As far as I know, it is not yet medically known how the ear/brain accomplishes this log structure. The reason why the chromatic scale is so important is now clear: it has the same log structure as the brain, allowing the brain to process music written using it.

Now, we can define music: it results from the attempt by the brain to keep track of frequencies! If the brain can not keep track of frequencies, it has no way of processing auditory information. A chord is a group of notes with the same tonic; this makes the tonic a special frequency and explains why music follows chord progressions: chord progressions are the simplest ways with which the brain can keep track of frequencies, by remembering the tonics. Because the brain is keeping track of frequencies during chord progressions, the progression must return to the originating chord for the music to end; otherwise, the brain feels that something is incomplete: it has to remember both the starting and ending chords, whereas if the music returns to the original chord, it has to remember only one tonic, or maybe even none at all.

This theory answers many questions that were previously unanswered. Dissonances are disliked by the brain because they don't form simple ratios so that the brain does not know what to do with them. The circle of fifths forms an important chord progression because it is the simplest progression and easiest for the brain to remember in log space.

Why do we like music? Because these brain computations are automatic and proceed whether you like it or not. All brain operations result in emotions, decisions, etc. Musicians choose those auditory inputs that are pleasurable, curious, mysterious, exciting, etc., that they wish to incorporate into their music. This is why a given music may sound terrible to some while others like it. We enjoy music for the same reasons why we enjoy paintings and novels.

Conclusion: a theory based on the logarithmic structure of the cochlea and/or brain, and automatic brain computations in log space using ratios, seems to explain all the major characteristics of music.

11.2 Communications Media (Dimensions) in Music: Time, Volume, Pitch, & Logic

For simplicity, ***we shall discuss only the auditory music inputs here*** because similar principles apply to visual, tactile, etc. inputs, and they are much less important. Why is auditory so much more important? In tactile, physical contact is necessary for communications, which severely limits its usefulness. In vision, you need line-of-sight, and vision is generally a two-dimensional data set on the retina which requires a large bandwidth and tremendous amounts of signal processing in the brain, much, much more than auditory, so that auditory is far easier and faster. Auditory signals can cover large areas (thousands in the audience for outdoor events), receive simultaneous inputs from numerous sources some distance away, etc.

The major communications media for auditory musical language are timing, volume, pitch, and logic. The first three are the physical response capabilities of the ear and the last is what the brain does with these responses.

Timing is the time interval between notes or beats. We shall see that timing is the most important element of music because it is the basis for creating rhythm. In physics, we live in a four-dimensional space-time in which time is unique because it is the only dimension that cannot be reversed. The brain aseems to recognize that time is special because it cannot be reversed whereas volume, pitch, and logical structures can be traversed in any direction. Thus time forms the backbone around which all music is created. This is the basis for the statements in practically all music manuals that emphasize the importance of rhythm. The importance of time can be appreciated by the fact that drums, dancing and even primitive jungle communications based on beating hollow logs with sticks, are based almost entirely on rhythm. A single time signature can govern an entire movement of music.

Volume is loud or soft. Information can be transmitted by changing the volume; an increasing volume might suggest that something is approaching; loud sounds may suggest danger such as explosions, and softer sounds may invite more attention or pique your curiosity. It is well known in piano pedagogy that, in order to arrive at FF, you must start with P so as to make the FF stand out. When increasing or decreasing the volume, most of the change should come at the end. Why? Because mathematically, this approximates a logarithmic curve and the brain will recognize this functional dependence and instinctively extrapolate to even higher volumes even after you have played the last increasing note, giving you "a bigger bang for your buck". The brain response to volume is logarithmic (Levitin), as with sound. This enables us to hear the faintest of sounds, but makes it very difficult to play PP.

Optimum volume variations are often difficult to explain. One easy rule to follow is that of the time signature, which often determines the rhythm and every rhythm has its set of volume changes. Beethoven's music is known for almost violent accents that appear "irrational" yet are absolutely essential to the music; thus the time signatures in Beethoven's music carry a heavier significance than time signatures of most other composers. By knowing exactly where these accents occur, you can more easily produce an "authentic Beethoven".

Nobody has yet found a generally accepted explanation of why Beethoven's accents work; yet, it is clear that one of the reasons why his music stands so high above the others is the use of volume. Beethoven is teaching us a lesson: volume is a language -- use it!

Pitch is the frequency of the sound. In music, pitch space is severely limited by how we produce pitch, such as by voice (a few octaves only) or by musical instruments (pianos are 30 to 4,000 Hz), and by our ability/inability to write the music on sheet music (although violins can produce an infinite number of notes, violin music is written mostly using the finite number of notes of the chromatic scale). These factors have conspired to create scales and intervals, consisting of a relatively small number of notes, out of the infinity of notes that the human ear can hear. **In music based on the chromatic scale, we throw away 99.999999 . . . . % of available pitch space!!!**

The notes of a scale are a subset of the ***chromatic scale*** (P. 223*). The chromatic scale is a series of pitches that rise according to a logarithmic scale that provides a "best fit" to the largest number of harmonies (intervals) within a reasonable number of notes (in terms of instrumental design such as keyboards, string, and wind instruments), and this best fit turned out to be 12 notes to the octave, which is just a mathematical quirk of nature (P. 224*). Thus ***the chromatic scale is a human invention and does not exist in nature. This means that no one can be born with absolute pitch; the only way to acquire absolute pitch is to learn it.*** The chromatic scale is logarithmic because the logarithmic scale can accommodate a large frequency range; the ear takes advantage of this by also using a logarithmic detection mechanism (Psychoacoustics).

Although the historical developments that created the chromatic scale are tortuous, the logical reasons for its creation are simple to summarize. ***The scale is a compromise between the need for something that can represent all the conceivable musical constructs (many notes) and a practical musical instrument that can be constructed (fewer notes).*** The first compromise is that, although there is an infinite number of pitches, even within a finite interval (such as a semi-tone), there is no way to notate this infinity of notes so that someone else can reproduce your composition using this infinity of notes. For example, we still don't have a precise way of notating violin music because the violin can produce an infinite number of pitches. ***Thus our music scale must have a finite number of pitches.*** There are a few exceptions such as the violin glissando (slide), vibrato, etc. Even for these "exceptions", there is no way to notate exactly how to execute a slide or a vibrato.

A scale must also contain all the major intervals (octave, fifths, etc.; ie, contain the necessary harmonies). This requirement arises from the fact that a maximum number of notes will then harmonize with each other which makes it easiest for the mind to keep track of the notes of music written in that scale. The other scales are not forbidden; the mind rejects them as inferior because of the extra effort required to decipher them. For example in C major, the important intervals are (see P. 224* for the mathematical ratios):

Octave = CC' (C' is an octave above C)
fifth = CG
Fourth = CF
Major Third = CE
Minor third = AC'

This requirement explains why the tonic (C in this case), is the most important note in a scale (because it is involved with every major interval) and also tells us how the brain keeps track of the tonic – by referencing every note to it. Thus, after you play a few notes of a scale, the brain quickly figures out the tonic because it is the only note closely "related" to all the others (via the intervals). ***The prominence of the tonic also explains (at least partly) how the brain keeps track of chord progressions*** (because each step of the progression is referenced to the tonic of the first scale used) and why the music must return to that starting scale at the end of the composition.

Now the smallest pitch difference in C major is the interval EF, which is called a semitone. What determines the value of a semi-tone? Answer: harmony (P. 223*): the octave is exactly 12 semitones, and the intervals fifth, fourth, major third, and minor third are almost exactly 7, 5, 4, and 3 semitones, respectively, and it is easy to prove mathematically that these are the only essential intervals (p.224*). These are all incredible mathematical coincidences and are unbelievably fortunate because a scale consisting of 12 semitones will contain all the necessary intervals with negligibly small errors. Little wonder that in early history, music was believed to be something closer to god than to man. We saw above that such a scale is mathematically pretty complete, and construction of musical instruments such as keyboards with 12 notes to a scale (octave) is eminently feasible. The essential intervals are "essential" because their notes harmonize, and harmony is special to the brain as explained in the preceding two paragraphs.

Harmony also allows more than one note to be played simultaneously without creating dissonances. In dissonances, the sounds are so scrambled that the brain has no easy way of analyzing them. Thus the brain can not enjoy dissonances in general because it cannot figure out what that dissonance is. Of course, dissonances can be inserted into music purposely for special effects.

Past musicians and mathematicians have tried to find other scales with fewer or more notes to see if better scales (with more exact matches between the theoretical and actual intervals) can be created, but none have been found (P. 226*).

Therefore, harmony, completeness, and practicality are three main reasons for the existence of the chromatic scale. The properties that all intervals are ratios and that the frequency doubles with each ascending octave are properties of a mathematical function called the logarithmic function. That is, the chromatic scale is a logarithmic scale. Here, we discover another amazing coincidence in that, as we saw above, the human ear uses a logarithmic scale for detecting and processing frequencies in the brain. This means that it is easy to construct a musical instrument that accommodates the entire frequency range of the human ear by adopting the chromatic scale. For example, if the chromatic scale were linear (not logarithmic), we would need a piano keyboard over half a mile wide! This is the meaning of "practical" above.

There is another astonishing property of a logarithmic chromatic scale: scales can be **transposed.** Starting with any note on the chromatic scale, you can construct another scale with exactly the same interval ratios as C major, without having to add any new notes. Musicians certainly know why this property is so useful.

The actual intervals in the logarithmic chromatic scale are not exact harmonies, which gives rise to the need for temperaments (P. 223*). The mathematically simplest temperament is the **equal temperament** (ET), which is almost universally used today. ET is simply the strictly mathematical logarithmic scale; therefore, all semitones are exactly 1/12th of an octave. The disadvantages of ET are (1) it is difficult to tune and (2) except for the octave, none of the intervals are exact (perfect harmonies); i.e., they are slightly out of tune. One advantage of ET is that, because intervals are already out of tune, a piano that goes slightly out of tune is not as noticeable as with other temperaments in which many intervals are tuned exactly. Historically, from before Bach to about the time of Beethoven, a family of temperaments called **Well Temperaments** (WT) were used (this is over-simplified but further details are not needed here); these were based on tuning as many exact intervals as possible in "frequently used" scales and sending the errors into less frequently used scales. Because these tunings were based on exact intervals, they were generally easier to tune, a useful property at a time when most musicians tuned their own instruments. These adjustments (away from ET) made every scale (key) different from every other and gave rise to the concept of **key color.** An obvious disadvantage of WTs is that the intended key color changes (usually destroyed) when the music is transposed. Another disadvantage is that a piano only slightly out of tune becomes more obvious than in ET. **Music written for WT (from Bach to Beethoven) certainly sounds better in WT than ET.** Thus advanced musical sensitivity can be cultivated only by use of WT and by developing the ability to recognize key color; digital pianos solve this problem because you can choose the temperament with the flick of a switch. It is clear that temperament must be an integral part of music theory.

Logic: Timing, volume, and pitch, though infinitely complex, are relatively easy to understand. However, ***the logic part is not well understood***; we do not yet have any means of generating "great music" except for "inspiration". The only popular music that exist are ones some composer discovered which we perceive to be musical.

That doesn't mean progress can't be made; in fact progress in advancing music theory and learning may be easier than in quantum mechanics where the most advanced scientific methods have already been applied but have failed. In music, studies of the human brain have contributed numerous new understandings of how "finger technique" develops, how we memorize, and how these are related to sleep (Scientific American) and epigenetics (Science News - 1). The human brain apparently has specific neurons and genes that enable singing (Science News - 2).

The communications media of timing, volume, pitch, and logic are the "dimensions" of music space, corresponding to the four space-time dimensions in which we live. Note that timing is unique among these dimensions in that it can only advance and cannot go backwards, which has deep implications in music, as we will see. These dimensions are used to create the following musical "languages".

11.3 Languages of Music: Rhythm, Harmony, & Melody

Everything you do in music involves rhythm, harmony, and/or melody. These three "languages" use the media of timing, volume, pitch, and logic. Great composers used each of these elements to create their music and it is both educational and useful for interpretation and execution to know precisely what they are and how to use them.

Rhythm is a recognizable pattern in time (usually repetitive) of musical media. Timing, volume and logic are combined to produce rhythm. The most prominent feature of most music is repetition, which is much less important in spoken languages. That does not mean that spoken languages do not have rhythm; each language has its own characteristic rhythm. In French, the last syllable is accented. In standard Japanese (Tokyo dialect), the accent comes at or near the last syllable of a phrase whereas in southern Japanese dialects, this accent is moved further up the phrase, near the beginning. In Hawaii, the accent is on the second last syllable, etc.

The almost exclusive use in music of a single time signature for a given piece (or section) of music tells us that a chosen unit of rhythm is repeated throughout the piece, with very few exceptions. This almost universal property of music gives us the deepest insight into the nature of music: the concept of expectation and reward. ***Music is based on creating an expectation and then satisfying it.*** By following a time signature, you immediately create an endless cycle of expectation and satisfaction. In order to compose music, we must use all the available resources (not only the time signature) to create expectations and then satisfy them. For example, it is absolutely essential to carefully connect each bar with the following bar; otherwise the repetitive rhythm will be broken. Try playing the 1st movement of Beethoven's Moonlight Sonata, first, by playing each bar separately like independent units, and a second time, by carefully connecting the bars. You will see an immediate improvement in the music. By carefully observing other aspects of rhythm (checking the time signature, etc., see below), you can improve it even more.

Rhythm is an entire language in itself, as illustrated by drummers. You can accelerate, decelerate, syncopate, use tempo rubato. Therefore, when analyzing a specific piece of music, its rhythm should be analyzed separately -- rhythm is everywhere. One excellent example is Beethoven's Appassionata Sonata (Op. 57), 1st movement: the time signature is 12/8 (not 6/4, in spite of the fact that the major notes of the beginning "arpeggio" are quarter notes). We find out exactly why in bar 17, where every eighth-note FF chord (alternating quarter notes) is equally important. Clearly, in order to play any music correctly, we must pay meticulous attention to rhythm, and this starts with understanding the reasoning behind the time signature.

Changing speed is another rhythmic device. A good example is the beginning Grave section of his Pathetique (Op. 13), where he contrasts the very slow over-all speed (Grave) of this section with runs using 1/64th and even 1/128th (impossible) speeds! This knowledge, of course, tells you exactly how to play it, and why. He uses this extreme contrast with other extreme contrasts, as illustrated below, to create this incredible sonata.

Thus the time signature is necessary to reassure the brain that something will be coming at certain times. Without this assurance, the brain will be distracted from the music because it has to keep track of random changes in time signature in addition to other changes occurring simultaneously. Apparently, the brain does not have a simple, automatic way of keeping track of frequent changes in time signature and does not recognize it as part of music. By contrast, the brain automatically keeps track of scales and chord progressions because of the logarithmic nature of aural functions. Thus music can also be defined most broadly as a sequence of events that follow certain automatic brain functions.

Is there a fundamental bio-physical or psychological reason why rhythm is so important? Note that rhythm is a method for controlling time, something we normally have no control over. Time just advances inexorably, and you can never go backwards. By repeating a short rhythmic unit over and over, we can gain any amount of time we want. It is as if we can stop time, or even reverse it. That's not all; music operates in a way very similar to computers because computers are run by an internal clock cycle whereby each cycle is used to complete an operation such that a series of operations results in the final product. In music, each beat accomplishes a task such that the whole series of beats produces the final product. Thus understanding why the computer needs an internal cycle in order to compute can tell us a lot about why rhythm is needed in music.

Rhythm tells us when the music starts and when it ends. The computer cycling works because, by cycling a small number of basic operations (the "kernel"), the computer can perform almost an infinite number of tasks when given different inputs. Similarly, we need only a small number of rhythms in order to make music, without having to learn thousands of vocabulary words for communicating using human languages. This avoids the problems encountered between peoples who speak *different* languages and therefore cannot communicate at all with each other.

The repetitive rhythm in music makes it universal – any human can pick it up almost instantaneously. This explains why repetition is so important in music. Repetition is the ultimate fountain of youth – it is as if you can sleep and wake up, almost ad-infinitum, *on the same day,* over and over again. We can stop time in its tracks and buy us any amount of new time, while still advancing your music. We shall see great examples of this in Beethoven's works.

Harmony is the relationship between two pitches. Examples of "good" harmonies are intervals such as fifths, fourths, and thirds. Appreciation of harmony is closely related to how frequencies are detected in the ear and processed in the brain. ***Harmonics (sounds that are integer multiples of a single frequency) produce a static result when played together*** -- a sound that does not change with time, and can be more easily characterized, remembered, and processed in the brain which explains why we perceive them as harmonious. Harmonics with smaller integers are especially special because their sound structures are simpler and "cleaner sounds" are more readily processed. Notes differing only slightly in frequency produce oscillating sounds (beats). When this beat frequency exceeds about 30 Hz, our ears do not recognize them as beats but as another low frequency sound and the totality of these sounds are called dissonances. Thus ***dissonances can also be static, but have much more complex sound structures*** and therefore are recognized as different from harmonies and disliked by the brain because of the difficulty of processing the more complex sound structure.

We saw that harmony plays a fundamental role in the creation of the chromatic scale (see Pitch section). Understanding of harmony culminated in the struggles of Bach with cataloguing the key colors associated with the temperaments. Today, together with advances in Eastern music, harmony has developed into a complex, specialized field of music (Mathieu).

Melody: Rhythm is combined with pitch and logic to produce melodies. What governs the logic in melodies is not completely understood, although we know a lot about the logical structures of most known melodies. One complicating factor in analyzing music is that part of musical recognition depends on the environment of the person; i.e., part of musical appreciation is acquired. However, this fact tells us something very important about music: that ***music is heavily dependent upon memory***. Recall that music can be a process of creating expectations and satisfying them; now ***we conclude that part of musical satisfaction process is related to memory. Thus music can also be associative.*** This means that, when we recognize a great melody, the brain is associating it with something already in the brain. However, we have not always been able to identify what this association is, and this identification is the main motivation in my writing this article. In theory, by following first principles, if we understand everything along the way, we should be able to produce a road map that leads us to this identification.

Melodies have certain characteristics:

(1) They are easily remembered and this memory can persist for a very long time.

(2) They can evoke emotions, such as beauty, excitement, pleasantness, etc.

(3) These effects are fairly universal; two people listening to the same music will react similarly, unless previously conditioned to react differently.

(4) People can be conditioned to react in certain ways to specific melodies or music.

Again, ***it is clear from these properties that melodies are associative.*** This is why they are so easy to remember, and is very useful as an algorithm for memorizing music. In cases of conditioned responses to certain music, such as a national anthem, we know the associations (national pride, etc.). But melodies can move us in complex ways without any conditioning -- this is the part that is not yet well understood. In many cases, we can't even define what the brain's reaction is, but these cases are probably complex cases that are difficult, but not impossible, to analyze. In most cases, the build-up of tension and its release (and related processes) can explain the musical property of the composition.

An example of this association is the beginning "arpeggio" of Beethoven's Appassionata, which is a schematized, distilled, and inverted form of the main theme that starts on bar 35. Many analysts consider them to be two themes (Gutmann), but I believe that they are variations of a single theme - an interpretation that unifies all the elements of the 1st movement into a progression of thematic development representing the pinnacle of Beethoven's achievements in thematic development. The similarities between these constructs (the beginning "arpeggio" and bar 35) have already been noted in the literature (Gutmann).

The most important component of logic is the musical logic that creates a melody. The brain associates this "memorable" melody with something already in the brain, and this association makes it memorable. What we cannot always find definitively is what the brain is associating the melody with.

It is entirely possible that, because the brain is so complex, there are innumerable accidents within the brain that produce memorable associations (as well as non-memorable or unpleasant ones) when certain inputs, such as aural, are encountered. In this situation, there is no physical explanation for why it is memorable. Since all humans share over 99% of identical genes, it is plausible that these accidents are also shared. In that case, the job of a musician is to play various combinations of music in the mind and search for those patterns that match the pleasurable accidents. Then any attempt to find an understanding of how to discover rules for creating music would be futile because music would depend solely on accidents of nature.

Another possible theory of musical logic (specifically, melody) is that every memorable music has a logic that can be associated with some known property of the brain. In this case, research into those relevant properties of the brain will explain how that music was created and may even help us create more memorable music. It will certainly help us to perform/interpret the music. We already saw one example: the creation of an expectation and then satisfying it (rhythm), or creating tension and then resolving it. We see this in the Appassionata: the incessant triplets starting at bar 24 --- it goes on interminably for 10 bars until bar 34. This series of staccato triplets forebodes the arrival of something --- it can't just end. Beethoven's ending of this long series of triplets is astounding: it ends with the Fate Motif of his 5th symphony! The last 3 notes of bar 34 and the first note of bar 35 form the fate motif, and creates, at the same time, a seamless transition from the triplets into the main theme of this movement. This revelation explains many things: why the fate motive was used earlier (to familiarize us with it) and why the long triplets were used (so that the building tension of the staccato triplets could be ended with the familiar motif).

Logical structures in music follow certain restrictions or rules. One prominent rule is chord progressions. Thus we must understand what chords are and then progress to examining "allowed" progressions. Chords are the major notes that define a scale (also called a key), such as C Major.

However, staying within one key can become boring because if you can use other notes, you have many more possibilities to explore. The way to avoid boredom is to change scale. But which one?

If you make a random jump to another scale, that change can be so jarring and difficult for the brain to process, that the jump becomes unacceptable to the brain; put it differently, there are certain scales that the brain prefers -- let's see why. If you transpose all the notes of C major up a fifth, you get another sequence of notes that sounds just like C major, except for one note; the F must be changed to F# in order for this new scale to follow all the same rules we used to create C major. Thus by introducing only one new note, you find yourself in a completely different key (G major)! The brain likes this because almost all the notes are familiar, yet you now have a completely new set of intervals that breaks up the monotony. This hopping from scale to preferred scale is called a ***chord progression***. Knowing the basic chord progressions is one key to learning how to improvise and compose (P. 220).

This process of transposing by a fifth to create new scales gives rise to the "circle of fifths" (P. 225). One "preferred" chord progression is to travel along the circle of fifths. What is so mysterious about chord progressions is that, unless you create a special musical device, you must return to the starting scale of the music, at the end; otherwise, the brain will conclude that the music has not ended and should keep on going. The mystery here is, even if the music is 20 minutes long or longer, with numerous key changes, the brain remembers the starting scale without any conscious effort on the part of the listener. Not only that, but the brain concludes that something is missing unless the music returns to that starting key. This is why, unless the composer decides to produce a special effect (such as suspense or mystery), every piece of music begins and ends in the same key. The precise neurological/psychological mechanism for this brain behavior is not known, although in music theory, it is recognized that tension is generally increased as you move away along the circle of fifths from the starting key which is released when you return to it. But this does not answer the question of why moving away from the starting key creates tension, and how the brain keeps track of the starting key after so many key changes. Why does the brain need to keep track of where the chord progression came from, and why does it need to return to the originating chord, all this without any conscious effort from the listener? I have not found an answer to this question.

There is little doubt that our ability to recognize music is closely related to our need to learn languages. Evolution certainly favors those species with better languages. This is why learning music is most effective during those youngest years during which we begin to speak. Language and music share the properties of rhythm and logic; therefore, the main difference between language and music is that language has words that need to be interpreted whereas in aural music, there is only the different frequencies of sound. Upon receipt of these signals, the brain ALWAYS responds automatically to interpret them, whether we consciously do so or not. We know what the brain does with words in a language, but what does it do with the different frequencies in musical sounds?

The only things that can be done with frequencies are to (1) memorize them, as birds, etc., also do and (2) conduct mathematical computations with them. This is especially true with logarithmic systems in which ratios are particularly easy to compute (that's why slide rules were invented). This ease of computation causes the brain to quickly gravitate towards sets of notes arranged in a logarithmic scale in which all the major harmonies are present. This explains why practically every scale ever used in music either contains the chromatic scale or is a subset of it. The chromatic scale naturally leads us to the circle of fifths and chord progressions. Thus, the "ease of brain computation" theory naturally leads to chord progressions. Since the brain uses the tonic to characterize each scale (the tonic is the only common note in all intervals of a scale), during chord progressions, the brain apparently keeps track of all the tonics, or at least the changes in tonics, such that the tonics must "return home" in order for the music to end satisfactorily. I have not yet found a satisfactory explanation of why the tonic must "return home".

Summary

In summary, music is a language which uses mostly auditory inputs, with secondary inputs such as visual and tactile. The media for auditory inputs are timing, volume, pitch, and logic. The first three are mostly understood, but the logic elements behind music are not fully understood; some known ones are: (1) the creation of an expectation and its satisfaction (tension and its resolution, etc.), (2) associations: conditioned (learned) and natural (inborn, or "hard-wired" in the brain), (3) creating specific messages, just as in spoken languages, and (4) brain responses (harmony, chord progressions, etc.). Understanding these elements of the definition of music helps us to interpret/perform and to compose music. We now visit some applications of these approaches to understanding/interpreting music.

11.4 Interpreting the Beethoven Sonatas: Moonlight, Pathetique, Appassionata

Beethoven's compositions are probably the best music with which to study and illustrate musical principles because he used everything and almost never wasted anything, so that all the principles appear and apply everywhere; usually, several of them simultaneously. Thus his music contains the densest examples of these principles/structures and has the lowest risk of giving us misleading clues because there is minimum guessing: his instructions are CLEAR. Another reason why his music is so useful for discussing musical principles is that he always strove to produce extremes. Thus when he applies a principle, you can't miss it if you know what to look for; what is so interesting is that for the casual listener who is not analyzing his music, these principles are basically INVISIBLE. This, of course, amplifies their effectiveness because they mysteriously control the audience without their knowledge. Part of deep music is the use of principles that affect the audience without their knowledge -- this type of musical principle is what is included in "logic" structure. Moreover, Beethoven often "broke the rules" to produce glorious music. Why did "breaking the rules" produce better music? Simply because those rules were wrong! Without a proper understanding of music, it is too easy to deduce "musical laws" that are incorrect. Thus Beethoven teaches us not only what is right, but also what is wrong. Since bits and pieces of references to different sonatas are intermingled above, all the comments (and more) for each sonata movement are assembled below.

We now show how Beethoven used timing, volume, pitch, logic, rhythm, harmony, and melody to produce his music.

Moonlight Sonata, Op. 27, No. 2, First Movement

The most important controversy about this movement is the pedaling. The "conventional pedaling" generally accepted today ignores the original instructions by Beethoven ("senza sordini" – don't lift the pedal for the entire piece!), and applies conventional pedaling rules, as amply described elsewhere (Wikipedia, Chapman [click on "Moonlight print version"]). My view of this matter is that the pianist has two options for playing this piece; either take Beethoven's indication literally, or use conventional pedaling as the majority of pianists have done historically – the two methods will result in totally different music. A lot of the evidence points to the conventional pedaling as the one Beethoven had in mind (Chapman). After all this piece is easy enough for anyone to play it, and was widely played during

Beethoven's time, probably using conventional pedaling, yet there is no record of Beethoven commenting on the pedaling. Thus, the conventional interpretation of "senza sordini" is that it was a short hand way for Beethoven to say that the pedal should be used throughout, but can be lifted judiciously as needed.

Here, I explore the view that "senza sordini" should be taken literally and point out some wonderful consequences of that interpretation. My opinion is that every pianist should try both ways of playing and explore the advantages/disadvantages of each. Most pianists have argued that the continuous pedal worked for Beethoven because the pianos of his time did not have the sustain of today's good grands and that continuous pedal on today's grands would "muddy" the music (Wikipedia, section on "Beethoven's Pedal Mark"). If this argument were true, then we should be able to use continuous pedal on an upright or other inferior piano with less sustain – of course, it STILL muddies the music with such pianos. Therefore, the interpretation here is that this "muddiness" was INTENTIONAL. It produces a constant, dissonant, background "roar", which not only creates an ominous, ever present, sadness, but also a stark CONTRAST against the beautiful harmonies of the piece. In that case**, this particular use of the pedal is an invention by Beethoven, and this sonata represents a unique innovation in the universe of piano music.** Extreme contrasts are a hallmark of Beethoven. Although it is the pianist's prerogative to play a "beautiful, clear" moonlight, I have much more greatly enjoyed playing according to Beethoven's intention of a sad, painful piece with much deeper emotions.

The first bar presents the clearest harmony. Then Beethoven jars you with the first dissonance (full tone down from C#), a B octave in the LH in bar 2, producing the start of a dissonant "background roar". **Thus in just 2 bars, he has introduced his concept of the contrast between harmony and dissonance;** i.e., harmony is much more meaningful when contrasted with dissonance. Bars 3 & 4 complete this introduction, with clear harmonies riding on a background of growing dissonance because of the pedal.

By bar 5, the dissonant background is complete, and he introduces his 3-note theme - the same note repeated three times - you can't have a clearer harmony than a note with itself (works even if the piano is out of tune!). **It is now clear why he used this 3-note theme with the most perfect harmony possible – to contrast harmony with the dissonant background roar.** If by this time, the pianist is not convinced that Beethoven is playing with the concept of maximum contrast between dissonance and harmony, I can't think of any clearer way of demonstrating it! Note that there is a PP marking only on those three notes – the audience must search for those notes amongst the constant background dissonance. Andras Schiff has a lecture on this movement with similar ideas:

https://www.youtube.com/watch?v=TRJFQZrRUrE

Schiff plays it too fast; if one accepts the idea of senza sordini, then the speed will depend on the sonority (sustain) of the piano; it will be played faster on a typical upright, but slower on a quality grand. Thus the numerous arguments in the literature about how fast to play this piece miss the senza sordini factor.

Beethoven explores this harmony-dissonance contrast with some beautiful, but sad, melodies and harmonies, until, in bar 16, he introduces the concept of pain with the dissonant 9th in the RH. **This is the only Beethoven composition that I know of, in which he used pain; therefore, this sonata is unique not only because of the use of a dissonant background, but also because it contains a musical description of pain.** Thus, the dark background roar and the sad harmonies make it clear that this is a sad piece, but true sadness is painful, and Beethoven inserts pain by punctuating this composition with dissonant 9ths at the deepest depths of despair. In "conventional" play, the lower note is played so softly that the dissonance becomes inaudible, thus erasing an important element of this movement. Note that, at the same time, there is the repeated "tolling of the bell" – the almost endless repetition of the B in the RH (over 5 bars), which then proceeds to descend in the following bars, further increasing the desperate sadness. The dissonance is created against this repeated B and should be emphasized because it is the beat note.

Immediately following the dissonant 9th in bar 16 is the cresc.-decresc. in the LH, which supports the emphasis on the 9th and confirms its prominent role.

As if these instructions were not clear enough, there is a “cresc.” on bar 48 and a sudden P on 49. If you don't lift the pedal in between, the inescapable effect is a harmonious P passage buried in the loud, dissonant background produced by the preceding bars. Under senza sordini, this produces a much more dramatic effect than if the pedal were cut to play the P. If there were any previous doubts about the use of the “background roar” these two bars should put an end to those doubts, because you can't escape those effects if played according to the markings. These two bars are Beethoven's way of saying, “If you still don't get it, I can't help you”.

Bar 60 is a “false ending”; an ordinary composer would have ended the movement here by returning to the tonic, but Beethoven nostalgically picks up the repeated-note theme again, and gradually ends the piece, softer and softer, to the final PP (you might add the soft pedal for the very last chord, as it must be the softest sound in the entire piece). **Most of Beethoven's compositions have this “double ending” a very effective device for ending a composition with conviction.** Most composers have difficulty finding ONE good ending; Beethoven usually gives us two, and the final one is a marvel of originality. Thus it is a good idea to play the first ending as if it were the end, and then restart the music into the true ending.

In summary, this composition is an example of the use of harmony and melodies in music theory. The language of volume plays a major part. Pitch is also important because of the use of chromatic (semi-tone) intervals. Played “senza sordini”, this sonata is an unique example in the history of piano because of the use of a dissonant background created by the pedal and a musical description of pain, attesting to the inventiveness of Beethoven.

See my original comments on this movement on P. 57 for more details.

Pathetique Sonata, Op. 13, First Movement

This movement is perhaps one of the best examples of Beethoven's use of extreme contrasts. Because of the extreme nature, it is easy to identify the contrasts definitively. The starting Grave section is almost devoid of rhythm, wheres the following Allegro is the height of rhythmic music.

The most obvious contrast in the Grave is volume. The first chord of bar 1 is F and all the remaining notes are P. Because even this most obvious concept is not always understood, there has been some controversy as to how to make the transition from F to P, especially as regards the use of the pedal (Beethoven did not indicate any pedal markings, so a purist should play the entire sonata without pedal; however, if you choose to use the pedal, it should be used in such a way that it cannot be noticed and does not interfere with the built-in contrasts). Some have advocated fluttering the pedal. But this is wrong because it does not produce maximum contrast. The real solution is simplicity itself. You simply cut the pedal and immediately play the P. Maximum volume contrast!

The second, equally important contrast, is speed. Grave is a slow tempo. Yet there are runs at 1/128 speed! Set to a metronome, these fastest runs are humanly impossible to execute accurately. It is obvious what Beethoven is telling us: “this section is of slow tempo, but play the fast runs as fast as you can”. Thus the concept of repetitive rhythm has clearly been thrown out the window.

The Allegro, by contrast, is driven by a lively rhythm controlled by the LH. He starts by using the simplest device, an octave tremolo. See p. 77 for how to practice it.

[Notes on technique - see Addendum Section 5 for practicing these tremolos and the alberti type passages such as those starting on bar 90, where most students have difficulty with speed and fatigue. These difficulties usually originate from the inability to play the thumb correctly. It is a mistake to try to move the thumb, because the muscles that move the thumb are too slow for such speeds – the thumb is a completely different finger from the rest. In order to move the thumb rapidly, imagine that the thumb is attached rigidly to the hand, and move the thumb by rotating the forearm. By combining forearm rotation with the rapid movements of the other fingers, these passages become easy to play at very fast speeds without fatigue and with complete relaxation. It is also important to use the power thumb position as explained in Addendum Section 5. Forearm rotation is the key to playing these tremolos; instructions in the literature on developing thumb and pinky motions to play them are incorrect.]

Beethoven had a special place in his heart for the octave and used it extensively and effectively. Mathematically, the octave holds a special place within the chromatic scale because it is the ONLY interval that is just (perfect harmony) EVERYWHERE ON THE PIANO, regardless of temperament (tuning) or key signature. Beethoven almost certainly knew this and took full advantage of it. Music written with perfect harmony! Pianists familiar with temperaments know that octaves are "stretched" (slightly sharp, see P. 234), and this stretch adds a certain mystery and extra excitement to the music; mystery because, in spite of the stretch, the harmony is perfect, and excitement because of the higher frequency caused by the stretch. He begins his Appassionata with a double octave, which results in the maximum audible stretch (it is less audible in a triple octave because of the rapid decrease in amplitude with increasing harmonic number).

Note that the volume is P until bar 14, then increases until bar 18 (most of the increase within bar 18) and suddenly returns to P in bar 19. These volume changes must be controlled more by the LH than the RH. Beethoven was a master of these volume changes that seem to have no logical explanation, yet "work" musically. Many students make the amateur mistake of starting the cresc. in bar 12, reaching a maximum at bar15.

Another rhythmic device is Beethoven's clever and careful use of the time signature to indicate where the volume accents should go. Pianists must be careful here because even respected editors such as Schirmer have made mistakes that destroy Beethoven's original intent. Use the Urtext edition (Dover), which is more accurate. For example, in the third bar of the Allegro, Schirmer indicates a syncopated sf on the second beat, which makes no sense. Schirmer may have inserted this sf in the belief that these mysterious RH intervals are modified forms of the theme in the Grave. This sf is not present in the Dover edition, which restores the correct rhythm.

An important volume accent occurs in the LH at bars 37 and 41 of the Allegro where the preceding cresc. indicates that the LH tremolo volume must increase rapidly in anticipation of the sf in bars 38 and 42. These are unique volume accents so prevalent in Beethoven's compositions. Thus to make the music "sound like Beethoven", these volume accents must be carefully observed.

Schirmer makes another mistake in bar 139, the third bar in the Allegro after the second Grave, where an accent is indicated on the E octave, another meaningless syncopation. Again, this accent is not indicated in the Dover edition and the music smoothly follows the time signature. It is extremely important to follow the time signature by giving extra weight to the first beat in the complex rhythmic section from bar 149 to 194, in such a way that the audience can follow the rhythm. These bars comprise one of the best examples of Beethoven's use of rhythm to dominate the music, so that the rhythm should be exaggerated while faithfully following the time signature. Thus Schirmer's volume accent indications in bars 149 - 155 are all wrong; instead, follow the time signature as indicated by Beethoven (Dover edition).

Every note, instrument, expression marking, etc., in Beethoven's compositions has a purpose and a reason, more so than any other composer. Thus inserting your own expression markings into his sheet music without fully understanding his intentions is a dangerous thing to do, as illustrated by the Schirmer editions. Students using the Schirmer edition will end up with music that is not only nonsensical, but also rhythmically impossible to play.

Volume (FF) is used in this piece to indicate the ending. As usual, he gives us a false ending in bar 294, which then leads to the real ending (FF) in bars 308-9. This FF must be distinctly louder than anything else for the ending to be convincing and final. The final two chords are exact quarter notes, unlike the gaudy full notes of the false ending – Beethoven is injecting humor by ridiculing such "standard endings".

Repetition in rhythm is extremely important, as discussed above, because of its relation to controlling time. Beethoven used repetition to great effect. Note the LH Bb tremolo starting at bar 43; it continues for six bars (48 Bb's!) and ends with a Bb octave for two bars, where the Bb is taken over by the RH for a total of 56 Bb's. Then he changes the tremolo to a "Bb hold" for the next 12 bars, which then progresses to the next repetition of Ab's. Thus the 68 repeated Bb's are used to control the emotion for 20 bars, while the audience is distracted by the interesting activity in the RH. This use of the stealth control of the emotions with the LH while distracting the audience's attention with the interesting RH gives depth to Beethoven's music. The audience may not notice this, which is normal, but playing deeper music actually makes it easier to play. These LH repetitions continue for a long time, until it resolves into the Eb of bar 89. Thus the repetitions, and the tensions they create, followed by the final resolution, are basic components of this movement and illustrate the applications of music theory.

Speed is obviously an important element of the Allegro. This speed contrasts with the slow movement of the Grave; thus the Grave is there so that you will appreciate the speed of the Allegro. But a deeper reason is that Beethoven wanted to control the emotions of the audience before they could figure out how he was doing it. Getting 10 fingers to move faster than the human brain is quite a challenge. By converting the LH octaves into a rapid tremolo at the start of this Allegro, he immediately doubled the speed, a simple device for any accomplished pianist. Later on, he uses the Alberti construct (bar 90) with similar effects. The Alberti is used here to quadruple the speed. Because of these types of devices, it is usually not possible to arbitrarily slow down a Beethoven composition without destroying the original intents of the composer. Again, he uses the lower notes to control the emotions while the treble plays a decoy "melody" that attracts attention away from the LH. Thus musically, the LH "accompaniment" is often more important than the RH in Beethoven's music.

Although speed is essential in this Allegro, it is too often played too fast. Such speeds result in the almost total loss of the deeper concepts that saturate Beethoven's music and make them immortal. Certainly, it is possible to drive the audience to delirium by mere speed and that device is a legitimate pianistic license – after all, this is entertainment, but that is not the real Beethoven, in which every note is important and must be heard.

Examples are, of course, the LH octave tremolo, and the Alberti structures starting at bar 90. As explained above, these bars contain so many notes that they allow exquisite control of the emotions in a way that the audience is unable to figure out. **This makes the music timeless.** Thus these "simple" tremolos and Albertis are not just accompaniments to the "melody lines" but are critically essential elements of his music; for example their simple structures allow for maximum speed. As is almost always the case with Beethoven, everything he put into his music is there because it is absolutely necessary.

Fast playing may be exciting at first, but quickly loses its appeal; the real Beethoven is *always* exciting because the audience is never able to figure out everything that is going on in the music. I am certain that this immortality is what Beethoven intended to achieve. He certainly succeeded!

Appassionata, Op. 57, First Movement

This movement is all about rhythm. Beethoven has abstracted the rhythm of the "fate motif" of his 5th symphony, and used it in all the forms his mind could conjure. Thus what appears to be the first 3 notes of an arpeggio that starts this movement is actually a modified form of the fate motif, ending with the accent on the final (third) "surprise" note, F. In this construct, the second note of the 4-note fate motive is silent, resulting in a 3-note "arpeggio". He tells you directly that he is using the fate motif in bar 10 by actually displaying it, un-modified. For those not analyzing this movement in detail, it seems as if he just stuck this fate motif here because it "fit"; the reality is that the entire movement is based on it, and he tells us so from the very beginning: this sonata is just the piano version of his 5th symphony! Both were written at about the same time.

This starting "arpeggio" is played in double octaves, quite possibly to take advantage of the stretch effect (P. 234); stretch is smaller for a single octave and the harmonizing harmonic is too weak for a triple octave, making the double octave the optimum choice for maximizing the audible stretch effect. I don't know if he knew about stretch, but he must have heard it; otherwise, there would be no compelling reason to use a double octave, which piano tuners often use today to check unison tunings, etc. It is an incredible characteristic of Beethoven's compositions that every note, construct, etc., that he used, such as stretch, was placed there for a specific purpose.

One use he found for the fate motif is as a conjunction to connect musical phrases or sections or even bars. The first use as a conjunction is to connect the introductory 3 notes to the first bar. Then he uses it to connect the beginning of the introduction (bars 0-11), with its ending (bars 14-15): the conjunction is the repeated fate motifs in bars 12-13.

The second use as conjunction occurs at the end of bar 16, where it is used to launch bar 17.

The third use as conjunction is very clever, and it connects bar 34 to bar 35; the last triplet of bar 34 and the first note of bar 35 form the fate motif. This is incredibly clever because the preceding long series of triplets creates a tension that is finally resolved by the motif. Not only that, but also, by acting as a conjunction, it immediately launches you into the main theme of this movement, one of the most beautiful musical passages ever composed.

The fourth use as conjunction appears between bars 78 and 79, where is it used to launch an entirely new section; there are similar applications elsewhere.

In bars 130-134, the fate motif is spelled out without modification. These bars again serve as a conjunction between major sections.

By far the most interesting conjunction application appears in bars 235-240, where he uses the "group theory" method (see P. 209) to create a long conjunction. He used the "pitch group" to compose the 5th symphony (p. 209), but here, he adds the "speed group". The main device he uses is to gradually slow down the fate motif, and then suddenly accelerates it (transition into bar 239) to launch the final section of this movement. Of course, he also uses the volume and pitch spaces to great effect. It is clear that Beethoven was aware of "group theory" type concepts – a true genius.

For many years, I wondered about the mysterious trills that appear in this movement, such as at bars 3 (and similar), and 44-46. They were mysterious to me because they weren't simple trills but carried some thematic value. Without understanding the role of the trills, it wasn't clear how to play them, and there was no consistent interpretation among different pianists. I "solved" the mystery when I realized that the trills, followed by a succeeding note, was a modified form of the fate motif! This interpretation gave a clear indication of how to play them – the succeeding note needed to be emphasized, which provides the thematic input.

The beautiful section starting at bar 35 is the main theme of this movement. The material from the beginning to bar 35 is the introduction leading to it. This introduction tells us that the theme is constructed out of modified versions of the fate motif in the 5th symphony. Thus in the "arpeggio" at the very beginning, the accent is on the third note (corresponding to the "surprise note in the fate motif), not the first, as it usually is, in a standard arpeggio. The similarity between the beginning arpeggio and the theme starting at bar 35 is well recognized (Gutmann). The arpeggio is a schematized form of the main theme, so as to ensure that the correct RHYTHM is implanted in the audiences' mind (*before* they hear the main theme), and the schematic is inverted, so that the audience does not recognize that the arpeggio and theme are related. This is an incredibly clever psychological device in which Beethoven accomplishes his objective, but the audience is completely unaware of it. Thus, when the main theme appears, we feel familiar with it, because we recognize its rhythm. Beethoven does not indicate a special accent on the third note of the arpeggio (the time signature takes care of that!), which is intentional because this accent must appear natural and should not be overdone – THAT is reserved for a special place in the final section!

This final section near the end starts with an accelerated version of the main theme; ie, it is the final, exaggerated version. In bar 243, there is (at last!) the sf on that "third note of the arpeggio". Beethoven is asking the pianist, "NOW do you see where the accent is?" Not only accented, but the interval jump to the accented note is expanded compared to the main theme, to produce an unmistakeable exaggeration with unusual harmony. After this, and IMMEDIATELY following the preceding series of the fate motif, there should be no doubt about the rhythmic structure and origin of this main theme.

Speed is obviously important in this composition, and it is technically difficult. So why did Glenn Gould play it so slowly? My suspicion is that he couldn't play this composition at speed to his satisfaction. Being the perfectionist that he is, he "solved" his "problem" by playing ridiculously slowly. This means that most pianists will be playing it at their top speed. But at bar 81, Beethoven needed a slight acceleration (as recognized by Chapman – click on "Sonatas for the Piano"). How did Beethoven solve this problem, when, probably, he himself couldn't play any faster? He deleted one note from the previous six-note groups of phrases, so that, playing at the same speed between notes, the tempo is accelerated by 20%, the EXACT acceleration he wanted! You can't be any more mathematically precise and concise! Some might argue that this acceleration "violates the time signature", and that the correct way to play is to keep the over-all tempo constant but to slow down the 5-note group. This is one of the best examples of how Beethoven "broke the rules" to compose great music, proving that many "established rules of music" are wrong. If "accel." is permissible, why not an increase in speed of 20%? Of course, the final decision is up to the pianist because whether you accelerate by 20% or not, you are breaking some kind of rule. That's the beauty and origin of the infinite possibilities of a live performance.

Not only the acceleration in bar 81, but there is also the deceleration in bar 82 under the two octave Gs, where the sixth note is restored in the left hand. This extra note tells you exactly how much to slow down. This slow down then enables the re-acceleration in bar 83!

This innocuous-looking bar 81 is an example of how Beethoven composed deep, or immortal music. Of course, musicality, something that can't be quantified yet, is probably the largest part of immortality. But there is an amazing amount of complexity that can be quantified practically everywhere you look in Beethoven's works. This complexity certainly contributes to depth in music because no audience can figure out all the complexities at once and these complexities change rapidly as the music progresses. Let's list some of the complexities built into bar 81:

I. the 20% acceleration discussed above

2. the 5-note grouping, which introduces an aura of uncertainty and mystery absent in the "standard" 6-note groupings of the preceding bars

3. the change in key signature from F minor to C major at bar 67

4. the clear RH melodic line of the familiar "arpeggio" heard at the very beginning (this is what the audience is supposed to be "following"), while

5. the actual emotions are controlled by the rapid LH notes

6. nothing is unfamiliar here because the rapid LH grouping is derived from the "arpeggio" at the beginning, played at break-neck speed

etc.,

thus there are frequently 5 or more musical elements crammed into every bar. This must be why, no matter how many times you listen to Beethoven, you can hear something new. This depth of content creates immortal music that amazes you every time you listen to it.

End of "Appassionata".

In conclusion, music is a language that uses the media of timing, volume, pitch, and logic to create rhythm, harmony, and melody. This approach to music theory can be used to analyze and interpret music. Beethoven's music, considered to be the most "immortal" music ever written, is most amenable to this type of analysis.

Does this mean that Beethoven used this type of approach to compose his music? There seems little doubt that he did. But are such elements the only secrets behind his glorious music? Only time and further research can answer that question. I think that Beethoven found music that somehow resonated in the human brain, in addition to the musical devices listed above. In other words, music doesn't either resonate or not, there are different degrees of resonance, and adding more elements can make incremental improvements in resonance.

References (links for purchasing listed books at Amazon)

Chapman, Brian, in *Ludwig Van Beethoven, Moonlight Sonata,*
and in *Beethoven, Sonatas for the Piano.*

Gutmann, Peter, in *Classical Notes, Ludvig Van Beethoven Piano Sonata #23, Op. 57, "Appassionata"*.

Mathieu, W. A., *Harmonic Experience*.

Science News - 1, Vol. 184, No. 2, July 27, 2013, P. 25.

Science News - 2, ibid, P. 32.

Scientific American, vol. 309, No. 2, Aug., 2013, P. 34.

Scoggin, Nancy, *Barron's AP Music Theory*, Barron's Educational Series, Inc., 2010.

Wikipedia, Piano Sonata No. 14 (Beethoven)

End of Theory of Music