

## CRYSTALLISING WAGNER - SYMMETRY AND SYMMETRY BREAKING IN THE *TRISTAN* PRELUDE

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### Introduction

While there has been much written on the subject of symmetry in music, symmetry breaking has received little attention, and has never been addressed in a systematic way. Robert Morgan (1998) and Giuseppe Caglioti (1991) touch on the subject, Morgan in the context of symmetry in 18th and 19th Century music, and Caglioti in the context of ambiguity in the arts, especially visual art. While symmetry offers valuable insights into local and gestalt musical structures, in this paper it is proposed that symmetry breaking provides valuable insights into the dynamic nature of music.

When a symmetrical system is exposed to stress it becomes unstable. If the stress is great enough the system responds by losing some of its symmetry in order to regain stability. Stewart and Golubitsky (1983) discussed this process with respect to pattern formation and stability, while Caglioti (1991) explored the role of symmetry breaking with respect to ambiguity, thermodynamics and information theory. Caglioti summarised the process by which periodicity emerges spontaneously in a non-equilibrium system as follows:

‘Chance and necessity, incoherent noise, disorder, fluctuations, stimulus, control, dynamic instability, triggering, growing storm, amplification, cooperativeness, structural transformation, coherence, order, self-organisation, periodicity.’ (Caglioti, 1991:96)

### Symmetry breaking in time

In music, complete temporal symmetry exists only in silence and in sustained sounds<sup>1</sup> – both cases exhibit invariance in all translations of time. Stewart and Golubitsky (1983) describe at length the important relationship between pattern formation and symmetry breaking. The simplest pattern in time is a division into equal units, exemplified in music by the beat. The translational symmetry of the beat confers stability both for the performer and the audience and is of great importance in the creation of synchrony between members of an ensemble.

The translational symmetry of the beat is reduced further by the appearance of meter, and further still by the emergence of deeper metrical structures. While, in Western music, it is typical for deeper structures to be organised in patterns of exponential binary expansion, the symmetry of this ‘crystalline’ structure is reduced further again by the intrusion of three and five measure periods.

Why should periodic structures be so common in music? Perhaps because, once the symmetry of silence has been perturbed by the intrusion of musical sounds, periodic structures create stability, reducing the mental energy required both to perform and to process the musical information. This proposition is supported by recent research suggesting that humans perceive metrical structures through oscillating neural networks that not only spontaneously entrain to the *beat*, but also potentiate the spontaneous emergence of *meter* perception as sub-harmonics of the beat. (Nozaradan, 2011) This suggests that the human desire to organise musical sound into regular units of time has its origin in self-organising processes in the neural cortex.

### Symmetry breaking in pitch space

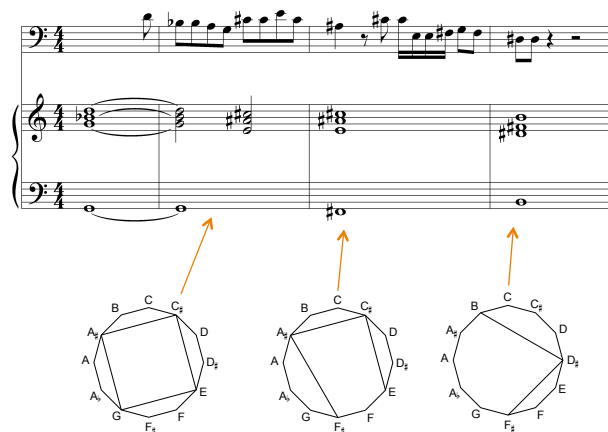
Harmonic structures may be defined according to their symmetries, and clock face diagrams offer an excellent way to represent this. In Figure 1 it may be seen that the diminished seventh chord has the same symmetries as a square. The symmetry of the diminished seventh (in particular its rotational symmetry, which is associated with cyclicity) confers many of the properties seen in highly symmetrical non-musical structures, including relatively low information content and the potential for disorientation and ambiguity. In a commonly observed resolution of a diminished seventh chord, harmonic orientation occurs and ambiguity is resolved when any one of the notes of the chord is lowered by a semitone, producing an information-rich, asymmetric dominant

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<sup>1</sup> Complete symmetry is also approached in effects such as tremolo when produced by a large body of string players.

seventh chord. The dominant seventh compels the harmony towards a perfect cadence, with the tonic providing a strong sense of stability (Figure 1).

Figure 1 - Clock face diagram of the resolution of a diminished seventh in a recitative from J.S. Bach's Cantata BWV 33.



In this process, the desire for harmonic order creates instability, and this emotional need is satisfied when the symmetrical diminished seventh resolves, via a dominant seventh, to the stability of a tonic chord.<sup>2</sup> While this description is consistent with the traditional view of harmonic stability and instability, it presents a problem from the point of view of thermodynamics, because it suggests that in music, stability is associated with harmonic asymmetry – the properties of a major triad depend on its asymmetry.

This paradox is explained by the fact that the stability of the major triad comes from its relationship to the harmonic series. The harmonic series is the basis of harmonic stability in Western music. The harmonic series, being the set of integer multiples of a fundamental frequency, is to harmonic space what the beat is to the temporal dimension. Just as the beat reduces temporal symmetry, at once organizing time and creating a stabilizing pattern, the harmonic series breaks the infinite symmetry of harmonic space, and establishes a tonal hierarchy. The stability of the harmonic series results from its translational symmetry.

This suggests that there are two types of symmetry in harmonic structures. On the one hand, 'clock face symmetry' represents intervallic invariance. Harmonic structures with clock face symmetry are associated with disorientation, and those with rotational symmetry are associated with cyclicity (e.g. tritone, augmented triad, diminished seventh, whole tone scale, octatonic scale, chromatic scale). On the other hand the stability of the major triad, which is asymmetric on a clock face, has its basis in the symmetry of the harmonic series. This dichotomy is explained by the logarithmic relationship between the harmonic series and musical pitch relationships.

This also suggests that clock face symmetry is of a higher order than the symmetry of the harmonic series. Experience supports this - for example, in a harmonic progression from a diminished seventh to a major triad there is a clear sense of the emergence of information and organization.

### Symmetry and symmetry breaking in the *Tristan Prelude*

The principles outlined above can be seen in the opening of the *Vorspiel* from Wagner's *Tristan und Isolde*. Figure 2 shows a graphic analysis of rhythmic events in the opening bars. Red squares indicate sound, with each square in the horizontal axis representing a single eighth-note of the score. A double red square indicates the appearance of a new note. The symmetry of silence is broken by the appearance of each of the first three phrases, and while each phrase includes the suggestion of a pulse, the pulse disappears into silence with the end of the phrase. This is analogous to a system in which a small perturbation is absorbed, allowing the system to maintain its initial state. However, in the third phrase the perturbation is greater – the expansion of the descending chromatic cello statement is mirrored with a chromatic expansion of the rising woodwind answer. This breaks the pattern of the first two phrases, and triggers a process of

<sup>2</sup> The multivalence associated with symmetrical structures may also be seen here – the symmetry of the diminished seventh allows Bach to make an unusual modulation, from G minor to B major.

amplification – the second half of the third phrase is heard again, and then the last two notes of this phrase are reiterated twice. At this point the emotional tension of the music has reached a critical level, and a third reiteration coincides with the appearance of chords on the first and fourth eighth notes of m. 16, with which discernible and permanent metric organisation begins. Blues squares show the bass line – again double squares indicate the onset of a new note. (The light blue square indicates a passing note.) The graphic representation of the bass line clearly shows the emergence of periodicity from the start of m. 16.

In Figure 3 we see that the rhythmic process described above is complemented in harmonic space. While in each of the first three phrases symmetrical chords give way to an asymmetrical dominant seventh each phrase leans the music in a different harmonic direction and no key is established. With the melodic expansion that takes place in the third phrase, the translational symmetry of the oboe part is arrested, and it is at this point that the amplification process (described above) begins.

Harmonic orientation is established for the first time on the downbeat of m. 17, though the fact that we hear an interrupted cadence rather than a perfect cadence gives Wagner license to quickly move to other keys. The timing of the F major chord is highly significant. The establishment of periodicity requires three isochronous events, as follows: a single event cannot be periodic, and while a subsequent event suggests a pattern, a third event is required to establish periodicity. The downbeat of m. 17 is the third of three isochronous events in the bass line, thus the interrupted cadence is simultaneous with the confirmation of periodicity.

A final observation should be made about the relationship between the chromatic and diatonic scales in this music. In the chromatic ascent of the oboe line we see the symmetry of the chromatic scale, (the cadence in m.17 only comes after all twelve notes of the chromatic scale have been heard - G# to G#), while the melodic leaps in the cello statements and the woodwind chords represent the asymmetry of the diatonic scale (note that the opening leap of a minor sixth in the phrase becomes a major sixth in the second phrase, perhaps betraying the allegiance of the cello part to the key of A minor). The symmetry of the chromatic scale precludes harmonic orientation, while the asymmetry of the diatonic scale provides harmonic orientation, and in the *Tristan* Prelude harmonic tension results from the interaction of the symmetrical chromatic scale and the asymmetrical diatonic scale.

Perhaps part of the power of the opening of the *Tristan* Prelude lies in Wagner's subconscious representation of a powerful natural phenomenon. Revisiting Caglioti's analysis of a second order phase transition, we see his description eloquently represented in Wagner's music. Beginning with 'incoherent noise and disorder', fluctuations (e.g. the melodic expansion of the third phrase) lead to dynamic instability. Control is asserted in the arrest of the oboe's ascending line, and this is immediately amplified through repetition and increasing decibels. Finally, cooperation between bass and melody leads to structural transformation, with (relative) harmonic order and periodicity at multiple structural levels emerging simultaneously (the deeper two-measure structure that also emerges has not been discussed). In this music Wagner creates the impression of self-organisation, and imitates, for example, the process of crystallization, in which order appears spontaneously in response to critical changes in the environment.

## References

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Figure 2 - Rhythmic analysis of the opening of Wagner's *Tristan Prelude*

Langsam und schmachkend

pp

p

dim.

cresc.

f

p

ff

p

Figure 3 - Harmonic analysis of the opening of Wagner's *Tristan Prelude*

Tristan m. 2(1)

Tristan m. 2(2)

Tristan m. 3(1)

Tristan m. 3(2)

Tristan m. 6(1)

Tristan m. 6(2)

Tristan m. 7(1)

Tristan m. 7(2)

Tristan m. 10(1)

Tristan m. 10(2)

Tristan m. 10(3)

Tristan m. 11(1)

Tristan m. 11(2)

mm. 2-3

mm. 6-7

mm. 10-11 (repeated in mm. 12-13, and a fragment repeated in mm. 14 & 15)

mm. 16-17