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In Memoriam
Ernő Lendvai

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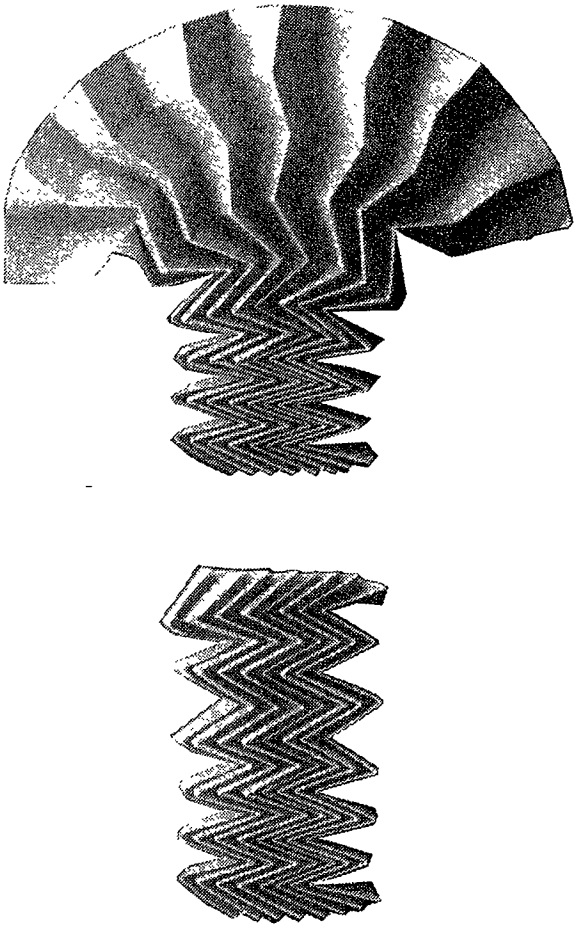

The *Miura-ori*
opened out like a fan

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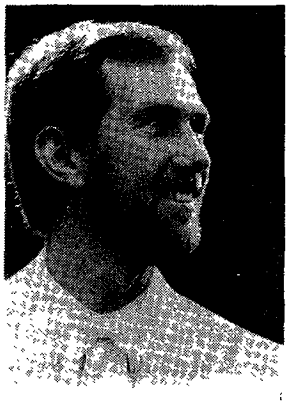
SYMMETRY: ART & SCIENCE

DEBUSSY, BARTÓK AND NATURE FORMS

Roy Howat



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Abstract: *Claude Debussy's music is still often called 'impressionist'; yet the implications of vagueness in the word have little to do with his very precise techniques, and indeed irked him. "I'm working at realities - what imbeciles call 'impressionism' ", he once wrote to his publisher. On a later occasion he supplied a different analogy: "My religion is that of nature's mysteries."*

One of nature's most intriguing 'mysteries' is the widespread presence in diverse organic forms of the proportion known as golden section; this is widely documented in botanical treatises and elsewhere.[1] *Since 1953, through the work of Ernő Lendvai, many aspects of the music of Béla Bartók have been known to be closely associated with this same proportion. Bartók's intense fascination for nature was matched by his interest in the music of Debussy, and this fact provides a background for some very precise rapports in the two composers' use of architecture, rapports that also involve some other contemporary composers.*

1 MATHEMATICAL PRELIMINARIES

Golden section - documented in Euclid's Elements as "extreme and mean ratio" - is the division that cuts a fixed length in such a way that the shorter portion bears the same ratio to the longer portion as the longer portion bears to the whole length. The section's exact value is irrational, its decimal places continuing indefinitely; it approximates to 0.618... of the length measured. In Figure 1, C marks the golden section of the line AB, with the longer portion to the left; D marks the complementary golden section with the longer portion to the right. The special property of golden section is that D also divides the portion AC in golden section. The system can be further extended or filled in to form a symmetrical network of identical ratios - something no other ratio will do - and this microcosmic property is accepted as the main reason for the ratio's importance in the structure of organic forms and its role in many epochs of the history of art.

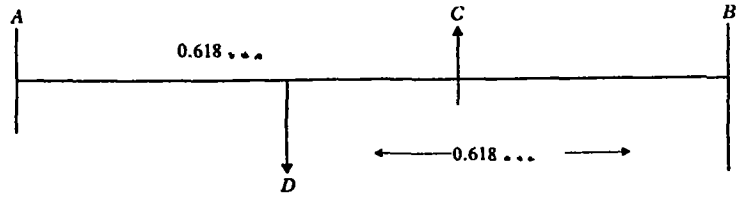


Figure 1: Golden Section

Golden section has another unique property. Any summation series with a 'memory' of two terms - that is, in which each term is the sum of the preceding two terms - gradually approaches, as its values increase, a geometric series with a golden section ratio. The basic series of this type begins with 0 and 1, giving 0, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144...; this is known as the Fibonacci series. From 1, 2 upwards, each two successive terms in this series represent golden section to the nearest whole numbers. The next possible series, known as the Lucas series, begins with 1 and 3, giving 1, 3, 4, 7, 11, 18, 29, 47, 76..., and yields nearest whole numbers to golden section from 4, 7 upwards.[2] This whole-number way of representing golden section is important in musical forms where divisions often have to be articulated by whole numbers of bars, beats, semitones and so on.

2 PROPORTIONS IN MUSIC

Figure 2 shows two examples of formal organization in Debussy's music. In his song Spleen, composed in 1888, the three main tonal modulations define a symmetrical pattern between the song's beginning and end. A similar framework underlies the opening section, 66 bars long, of his piano piece Mouvement (from the *Images*, published in 1905): a single bass C marks the section's halfway point, and around this is repeated an eight-bar phrase which introduces the piece's principal theme.

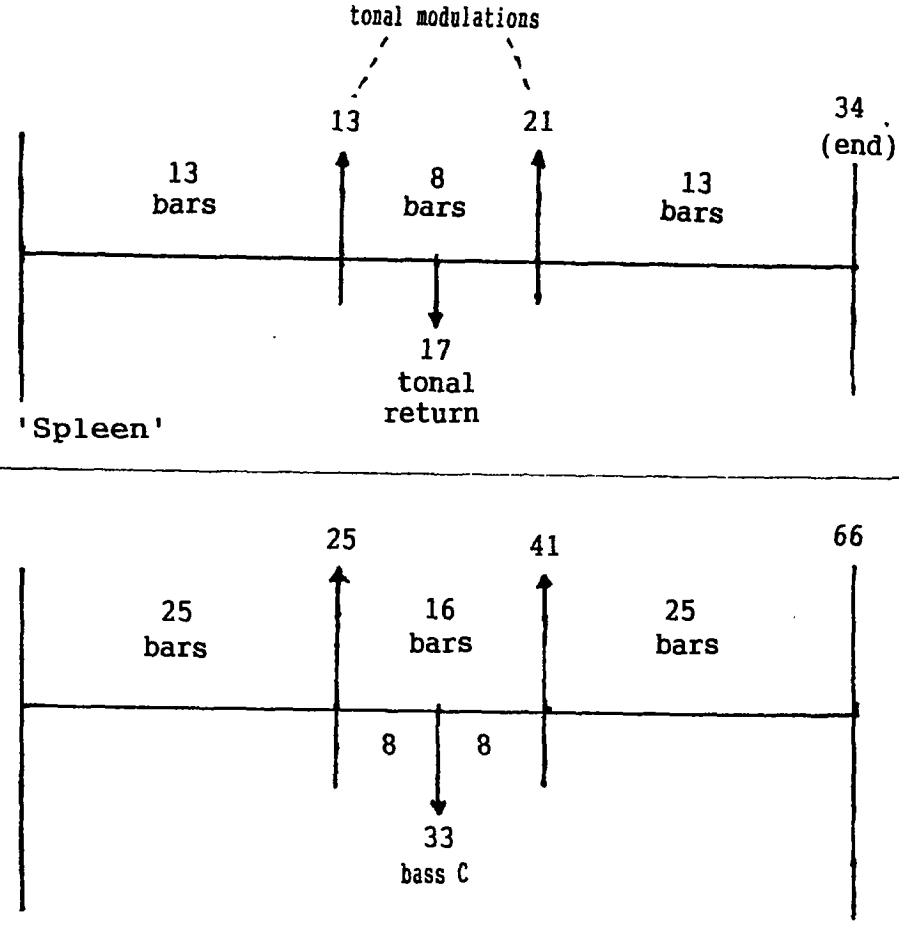


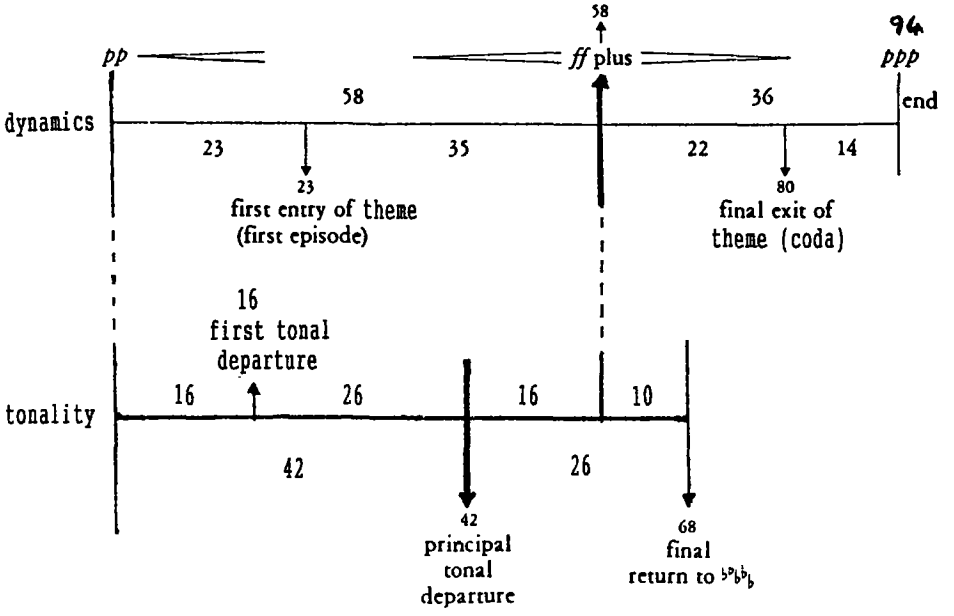
Figure 2

Proportionally these two examples are almost identical, as can be seen by dividing the bar numbers of Mouvement in half (12½:8:12½ as against 13:8:13 for Spleen). The Fibonacci numbers of Spleen confirm that the two outer divisions in each example correspond to their main points of golden section.

This proportion can take a more dramatic role. In three of Debussy's six piano *Images* (composed in 1901-7) - 'Reflets dans l'eau', 'Mouvement' and 'Cloches a travers les feuilles' - the main climax, marked *ff* or *fff*, is placed either exactly on or over the piece's golden section. In 'Reflets dans l'eau' the fortissimo lasts a full four bars, centred exactly over the golden section point; in the other two pieces the climax is much more narrowly focussed, leaving no doubt about the precise proportions.[3] All three pieces begin *pp* and finish either *pp* or *ppp*, imparting maximum strength to the dynamic shape.

Naturally, such placing of the climax cannot affect our sense of the piece's architecture until the proportion has been completed at the end of the piece. In order for such a sense of balance to be projected at the moment of climax, the climax itself has to be prepared proportionally. How this is done can be shown by several examples.

In 'Reflets dans l'eau' the climax is dominated by the piece's main melodic theme, which first enters after bar 23 and ends its last appearance after bar 80 (one always measures logically by completed bars). These points, shown at the top of Figure 3, complete a golden section pattern reflected around the climax.[4] The piece's tonal structure follows another course, shown lower in Figure 3: the piece's two points of departure from the home key, after 16 and 42 bars, form a golden section sequence that leads to the centre of the climax and continues to the return of the original key after 68 bars. Not only does this reinforce the positioning of the climax; it also imitates the shape of the top sequence in Figure 3. If all the numbers are divided by half (as shown at the bottom of Figure 3), the two structures can be seen as an intersection of the Fibonacci and Lucas sequences.

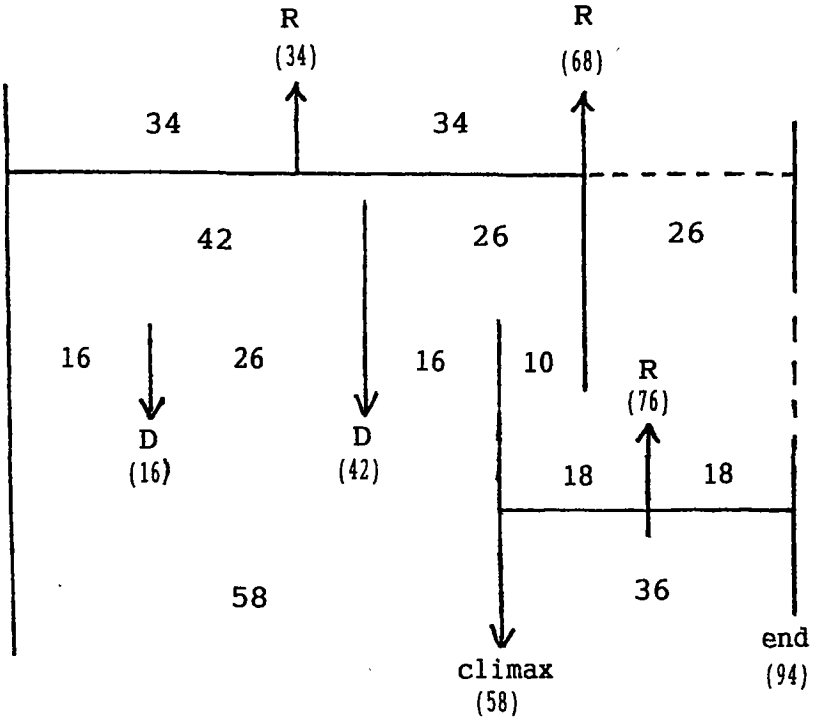


top sequence: 14:22:36:58:94 = 7:11:18:29:47 (Lucas)

lower sequence: 10:16:26:42:68 = 5:8:13:21:34 (Fibonacci)

Figure 3: 'Reflets dans l'eau'

An interesting tendency emerges, in the form of a dynamic dialogue between pure symmetry (bisection) and golden section: bisections mark the points of stability or calm, while golden sections mark points of maximum tension or stress. Figure 4 shows this graphically: the piece's three tonal returns to the home key of D-flat define major bisections (34:34, 26:26 and 18:18), all of which interlock neatly with the golden sections marked by the two points of tonal departure (16:26:16 and 42:26) and the climax (58:36 and 16:10).

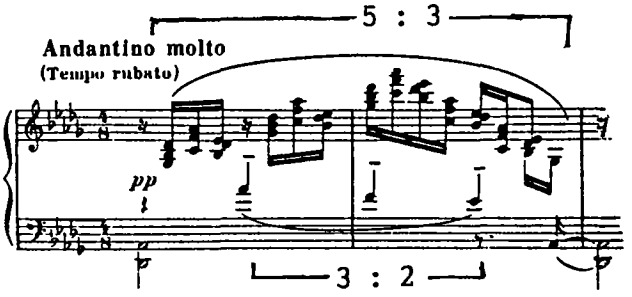


R = point of tonic return; D = point of tonal departure

Figure 4: 'Reflets dans l'eau'

Given these microcosmic imitations, symmetries and reflections, Debussy's titles *Images* and 'Reflets dans l'eau' suggest many symbolic nuances. Even the compression by golden section in the 'reflected' latter part of 'Reflets dans l'eau' (after the climax, as seen in Figure 3) can be seen to imitate the effect of refraction, as happens when we see something through a water surface (thus the piece's exact title, which literally reads as "Reflections *in* the Water"). In prose such observations may seem abstruse, but their expressive power can be appreciated when we hear the music. Reflets dans l'eau opens with another potent example, shown in Ex. 1: a three-note motif in the middle of the

texture outlines a refracted intervallic sequence of 3+2 semitones, surrounded by quiet chords that sound like ripples in the water. The pianist Marguerite Long related that Debussy likened this central motif to a pebble dropping into water - after which one's view of it would be refracted. The surrounding ripples reach their peak after 5 out of a total of 8 eighth-notes; we can thus see, as well as hear, that those picturesque details open the piece with miniature versions of its large-scale refracted wave form, using the Fibonacci numbers 2, 3, 5 and 8.



Example 1:
'Reflets dans l'eau'

Similarly, if we map the overall form of Mouvement as in Figure 5 (measuring the piece up to its last note, a *staccato* quarter-note), the piece's large-scale layout emerges as a proportional imitation and expansion of its opening section (compare Figure 5 with Figure 2 above).

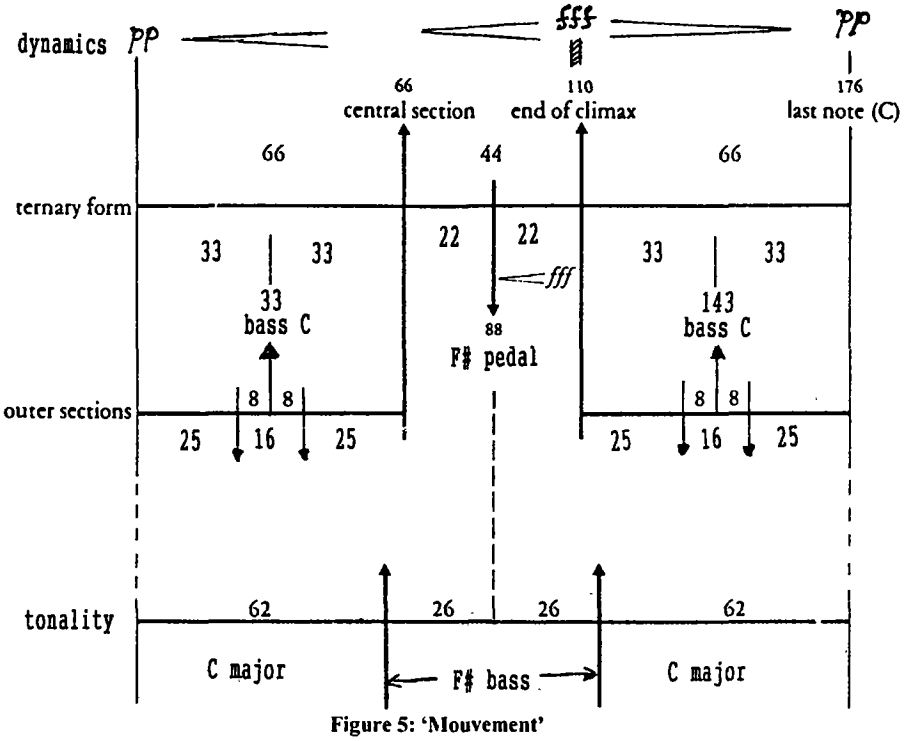


Figure 5: 'Mouvement'

3 CONNECTIONS WITH BARTÓK AND OTHERS

Two of Lendvai's examples of large-scale forms by Bartók based on golden section are especially relevant here, both of them from the *Music for strings, percussion and celesta* of 1936. The first example concerns the fugal first movement. Beginning *pp*, this great Fugue follows a tonal sequence starting on the note A, with successive voices entering in a fan-shaped sequence that expands outwards from A by perfect fifths (see A, E, D, B, G, F#, C, etc.), until the two diverging progressions meet at E^b (=$D^\#$), the tritone of the opening A. Following the arrival at E^b, the movement reaches its climax, whereupon the fugue theme is inverted, and the preceding fan progression is reversed, gradually leading the theme back to the note A. Figure 6 traces the dimensions of this large wave-shape.

A, E, D, B, G, F#, C

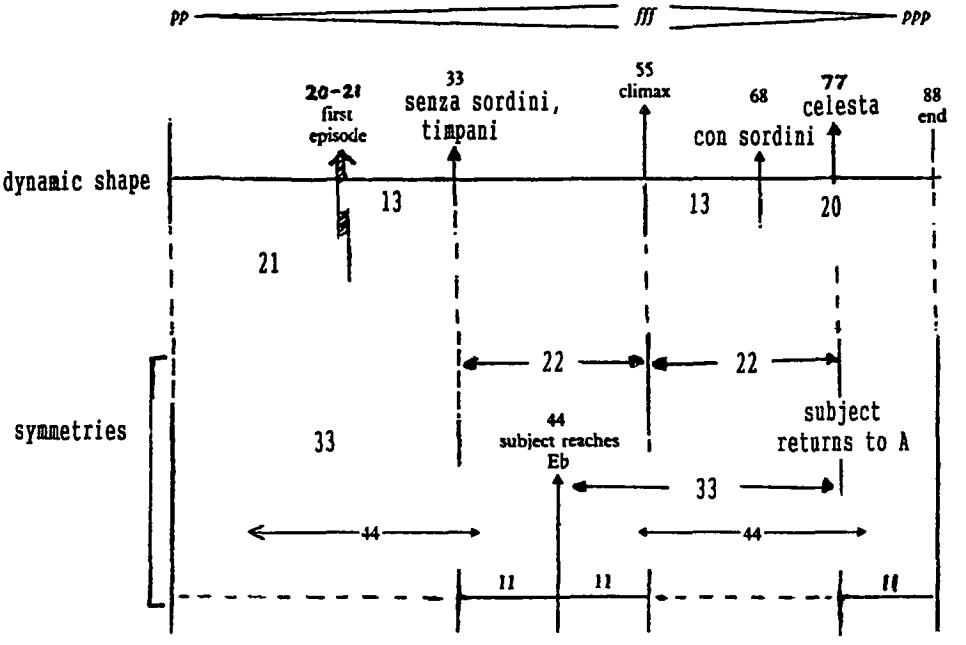


Figure 6: Fugue from *Music for Strings, Percussion and Celesta*

The proportions in the top part of Figure 6 correspond closely to the Fibonacci series. Any discrepancies from the 'ideal' series values are of no more than one bar, too insignificant to affect the potency of the shape. In fact they add proportional potency, for all of them are multiples of eleven - 33 instead of 34, 77 instead of 76 (which would have made a 21:13 division between 55 and 89), and 88 instead of 89. (The slightly ambiguous beginning of the first episode over bars 21-22 could conceivably have the purpose of helping to accommodate all this.)

Matching this is a large-scale symmetry. As shown lower in Figure 6, the arrival of the fugue subject at the tonal mid-point $E^{\flat}$, after 44 bars, marks the movement's exact halfway point; the remaining multiples of 11 combine with this to form symmetries that have a visible affinity with the multiples of 11 in Debussy's 'Mouvement' (cf. Figure 5). Like Bartók's 'Fugue', Debussy's 'Mouvement' is tonally based on symmetrical tritone division of the octave (in this case C—$F^{\#}$), a symmetry reflected in the proportions, as the lowest part of Figure 5 shows. Figures 5 and 6 thus share not only the same dynamic outline, defined by golden section, but also a simultaneous framework of symmetries, defined by each work's symmetrical tonal structure. (Incidentally, in case this comparison might suggest plagiarism on Bartók's part, one only has to hear how different the two pieces sound, regardless of the techniques they share.)

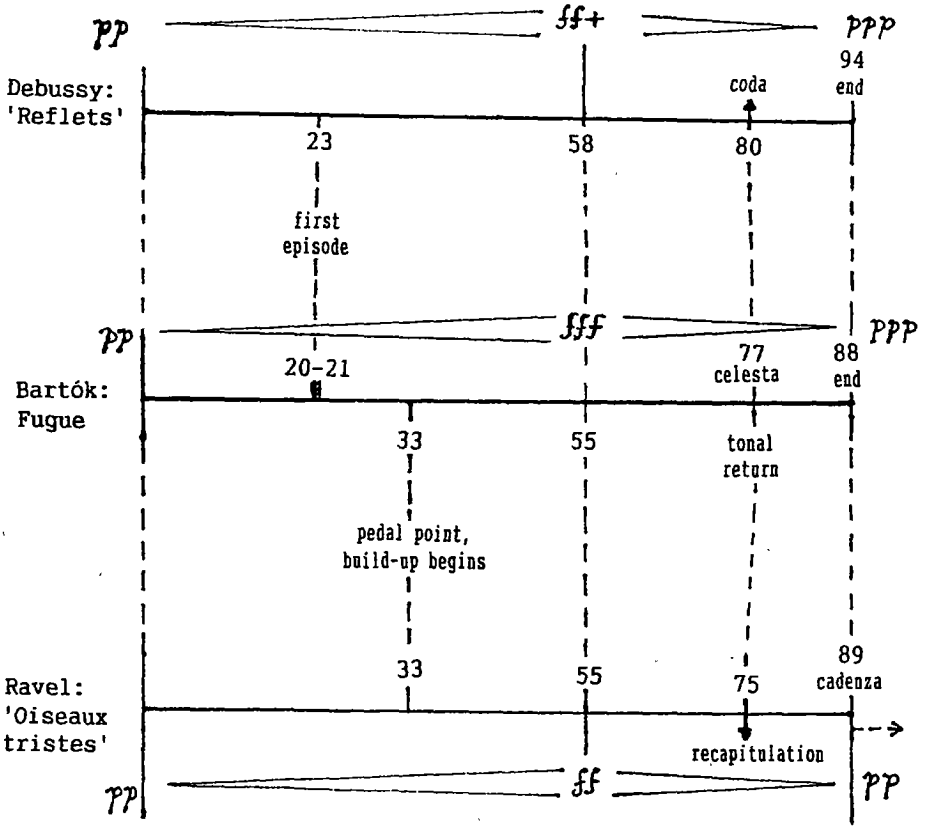


Figure 7

Bartók's 'Fugue' also has a structural parallel with Debussy's 'Reflets dans l'eau', as shown in Figure 7. The parallel extends to Ravel's 'Oiseaux tristes' (from the *Miroirs* of 1904-5), a piece that figured prominently - as did Debussy's *Images* - in Bartók's recital repertoire.[5] Like Bartók's 'Fugue', Ravel's tonal arch spans the tritone, beginning and ending on the note B^{b}, and reaching E major at the *ff*. Might the coda of Bartók's 'Fugue' (bar 78 onwards) musically encode these parallels? Having returned to A, the fugue subject and its inversion contemplate each other, in Lendvai's words, "through the vibrating mirror of the celesta", in a way that inevitably recalls the 'images' of *Miroirs* and 'Reflets dans l'eau'.

The third movement of Bartók's *Music for strings* again is visibly based on Fibonacci proportions (Figure 8).[6] Some slight departures from the theoretical ideal (given in brackets), as well as some ambiguous musical transitions, can be accounted for in terms of local musical logic, without detracting from the obvious strength of the overall shape

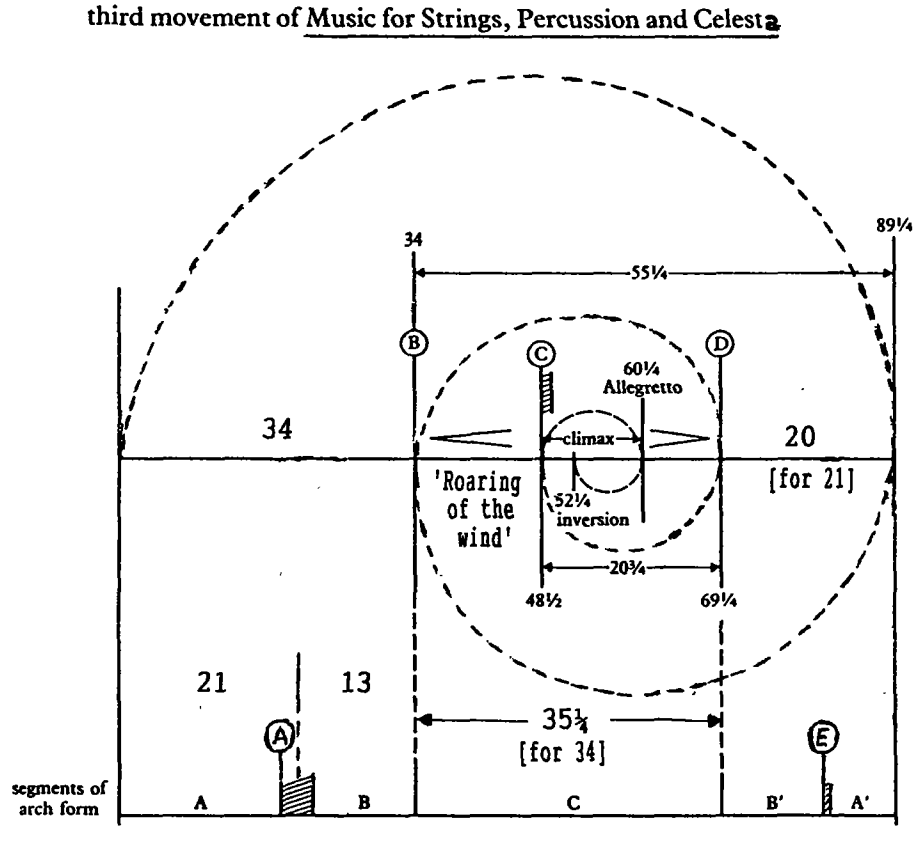


Figure 8

and proportions. Elsewhere in his writings, Lendvai emphasizes the affinity between many of Bartók's golden section structures and the logarithmic spiral, long known as one of the most frequent manifestations of golden section in nature, as in various plant formations and sea shells. Figure 8 accommodates a golden section spiral ideally, in terms of both proportion and musical logic, with the spiral centering on the movement's climax.

The spiral as such is inevitably abstract from the music's progression in time, and its value here might be regarded more as symbolic. Evidence exists of Bartók's interest in this shape as applied to music, in the form of a manuscript of his piano piece 'Seesaw' of 1909, humorously written out as a spiral.

4 CONSCIOUS OR SUBCONSCIOUS?

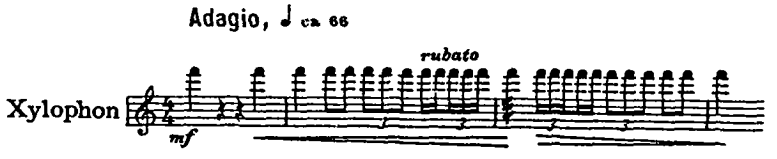
None of the composers mentioned here is known to have written or talked explicitly of these techniques; nor do manuscripts of the works studied here show any signs of numerical calculations. It is therefore possible that the composers intuited the proportions unconsciously. Whatever the case, their intuition must have played a large role in forming the structures. It is possible, too, that conscious use of the techniques grew out of a dawning awareness of having already used them unconsciously.

For the sake of perspective, three arguments can be related immediately. First, none of these composers was in the habit of describing any of his musical techniques in any detail; all three, in fact, were all well known as particularly secretive and private people. Second, such discretion was in their interests, since they usually had to battle for their music to be accepted purely for its expressive power. Third, the detailed proportions described above appear only in certain works or involve only isolated events in some other works; it is arguable that a purely unconscious use of such techniques would have applied itself more uniformly and less selectively. We can add a fourth argument, that the golden section is actually not a very 'instinctive' position to place a musical climax, given the considerable span that the music still has to traverse before the end, while maintaining the listener's attention. A climax placed nearer the end can of course be incorporated in a golden section 'network', and this happens in various other works by the composers discussed here.

From the evidence available, it seems very probable that Debussy was aware of these proportions in his music. This emerges not only from the implications of some statements in his letters, but also from the enormous breadth of literature he read, from the known interest of many of his friends in numerology, cabbala and number construction in art, from his own interest in esoterica, and from the fact that his first traced uses of Fibonacci construction occurred in exactly the same years (1885-8) as various articles on proportion and golden section appeared in Symbolist journals which

Debussy is known to have read. All these interests were in fact an essential part of the Symbolist movement with which Debussy was inextricably involved in his formative years.

In the case of Bartók there is other evidence. Jottings connected with one of his Turkish folksong transcriptions show him to have analysed the song's metre in terms of the Lucas numbers 3, 4, 7, 11 and 18. His reading habits were as wide as Debussy's, and embraced a passion for science, mathematics and natural history. Various sources recall that he had a special fondness for fir cones and sunflowers - two of nature's clearest manifestations of Fibonacci construction and logarithmic spirals. His use of Fibonacci numbers also extends to immediately visible small-scale construction, including metres divided 8:5 (finale of *Contrasts*), and, most notably of all, bars 2-4 of the third movement of the *Music for strings*, where the xylophone solo follows a sequence of 1, 2, 3, 5, 8, 5, 3, 2 and 1 repeated notes per quarter-note beat (Ex. 2). For someone as alert and widely read as Bartók to have clearly and repeatedly emulated the numerical structures of some of his favourite natural forms, without noticing the fact, seems very unlikely.



Example 2: Third movement of *Music for Strings, Percussion and Celesta*

Perhaps the most remarkable musical evidence seen above concerns the structural 'motifs' shared by different works. There is also a chronological tally. Bartók's attention was first drawn to Debussy's and Ravel's music in 1907 by his friend Zoltan Kodály, whereupon Bartók immediately immersed himself in study of their compositions. In 1907 the newest published works by the two Frenchmen were none other than Debussy's first series of *Images* (including 'Reflets dans l'eau' and 'Mouvement'), Ravel's *Miroirs* (including 'Oiseaux tristes'), and Debussy's orchestral *La mer*, about which there is more to say below.

The coincidence is given added savour by Kodály's piano piece of 1907, the *Méditation sur un motif de Claude Debussy*. Like most of the Debussy and Bartók examples analysed above, it begins pp and ends *ppp*, with a climax marked *fff* in bars 67-8. The reader may already have guessed what follows - that this climax marks the piece's exact golden section (after 314 quarter-note beats out of a total of 508).

Bartók's most substantial work in the following six years was his Symbolist opera *Duke Bluebeard's Castle* of 1911, whose structure is built on the large-scale tonal progression F♯—C—F♯, the symbolism of this made explicit by gradations from darkness to light and back again on the stage. Bluebeard also begins *pp*, and ends *ppp*, in F♯, and reaches a lyrical *fff* climax in C major at the point of maximum light on the stage, the opening of the fifth door of the castle. Since the drama is articulated into eight large

sections by the opening of the seven doors, on a large scale this climax is placed exactly five-eighths of the way through. The structure provides an exact match to the Fugue of the *Music for strings* composed 25 years later (cf. Fig. 6), which has the same dynamic shape at the same proportions (55/88), and the symmetrically complementary tonal plan (A—E^{b}—A).

The implication is that for Bartók the Fugue of the *Music for strings* was symbolically closely related to *Bluebeard* (as well as perhaps to some of Debussy's works). Bartók is known to have talked of both the *Music for strings* and its companion piece the *Sonata for two pianos and percussion* (composed in 1937, and again built around the tonal counterpoles of C and $F^{\#}$) in terms of creation archetypes.[7] Lendvai suggests that Bartók intended the *Sonata for two pianos and percussion* as a Makrokosmos to crown his solo piano *Mikrokosmos* - the latter a title that recalls the structural levels seen in the analyses above, as well as Debussy's and Ravel's titles *Images*, 'Reflets' and *Miroirs*.

In this context, one of the most explicit symbolic allusions is a remark Bartók reportedly made to Endre Gertler during a performance of the third movement of the *Music for Strings*: "Do you hear? The sea!" One immediately thinks of the vortex form of this movement seen in Figure 8, and the sea as symbolized by the spiral-shaped nautilus shell. There is an even more exact rapport, however, which concerns the

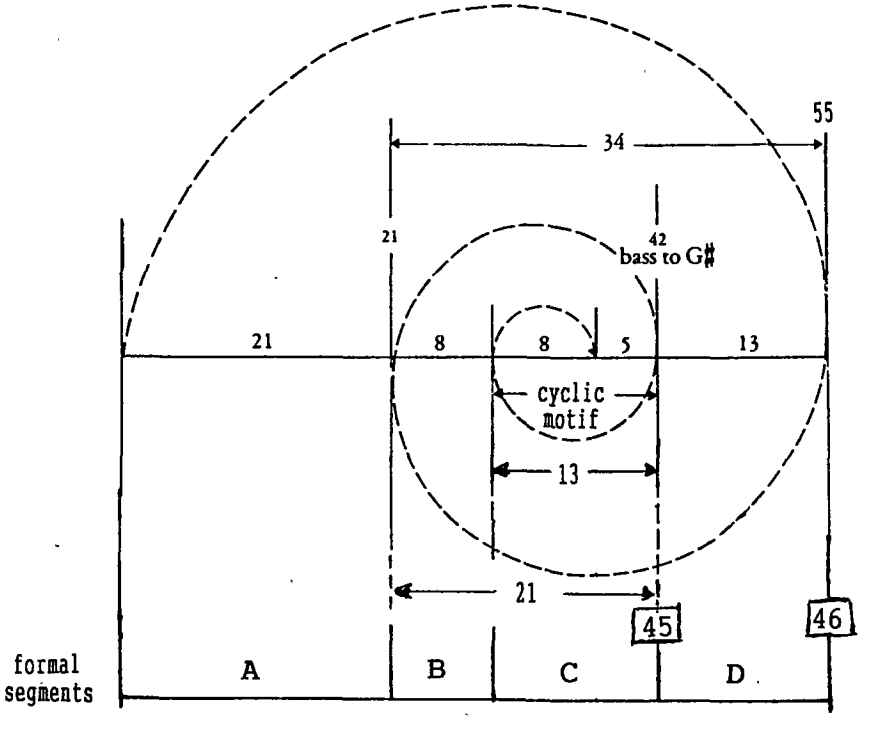


Figure 9: Introduction to 'Dialogue du vent et de la mer'

movement's position between the work's fast second movement and the finale. In the overall form of Debussy's La mer the nearest parallel section - linking that work's fast second movement to its finale proper - is an introductory passage of 55 bars (up to rehearsal figure 46), divided as in Figure 9. Comparison with Figure 8 speaks for itself, with the spiral as archetype of both water and creation.

A similar formation in the first movement of Debussy's La mer adds another perspective. Figure 10 maps this movement from its very beginning to its central transition (the change from 6/8 metre to 4/4 metre, two bars before rehearsal figure 9). The two main inner divisions of Figure 10 mark the beginning of the 6/8 section (bar 31), and then the turning point of the arch form comprising the 6/8 section (rehearsal figure 7). Each of these divisions marks an exact golden section (65:107 and then 66:41 beats of pulse), and the formants of the spiral are defined by the audible musical transitions within the third segment of the diagram. The architecture also marks a near-symmetrical division of 65:66 beats at bar 31, aptly where the music first reaches the work's home key of $D^{\flat}$. In purely musical terms, therefore, the proportional layout is completely logical.

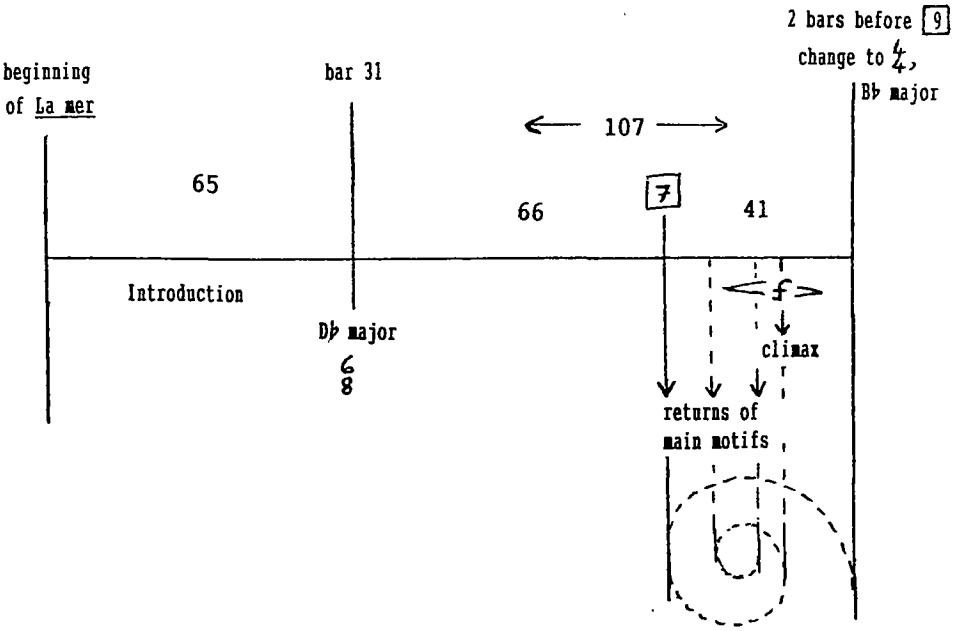


Figure 10: From the first movement of *La mer*

Our extramusical perspective involves Ando Hiroshige's print of 1855, 'The Whirlpools at Awa' - a picture clearly dominated by sea and spiral motives and by golden

section proportions, as shown by the added arrows and outlines around Figure 11. Debussy, an avid admirer of Japanese art, would certainly have known this famous print. If the plan of Figure 10 is turned through 90° to lie by the left side of Figure 11, we see that the two diagrammatic outlines are in fact one. Such a complete coincidence of composition and motif across two different arts (and continents), whether or not consciously planned by Debussy, goes to the heart of the Symbolist aesthetic in which Debussy steeped himself in his formative years.[8]

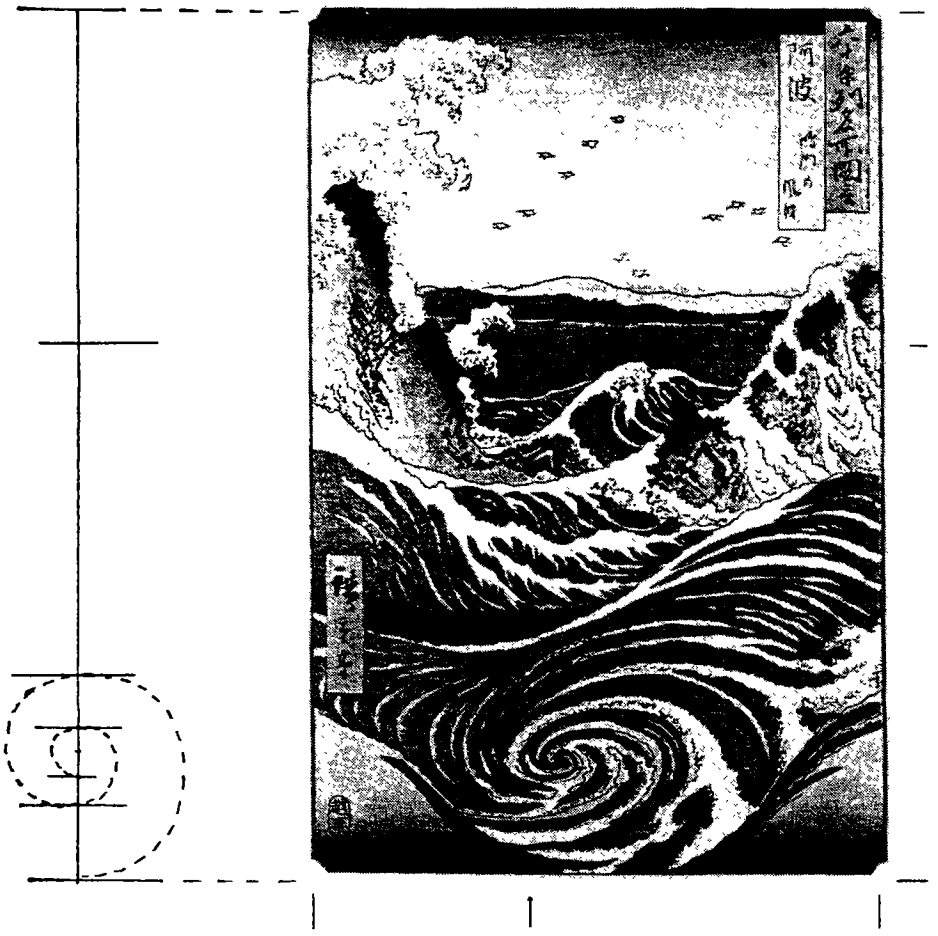


Figure 11. 'The whirlpools at Awa', from Ando Hiroshige's *Famous places in the sixty-odd provinces,* 1855 (reproduced by courtesy of the V ictoria and Albert Museum)

The structural links between Debussy and Bartók have some further philosophical resonances. In the passage from Debussy's *La mer* shown above in Figure 9, the music suggests both wind and water, with the feeling of passing through the eye of a storm at

the focus of the spiral. (The Debussy scholar Edward Lockspeiser, who never knew of the Fibonacci formation, described this music as evoking 'vortices and whirlpools'.) Compare that with Lendvai's term 'roaring of the wind' for the central passage in Figure 8 above, and, together with the spirals, we have standard symbols of mystery and initiation, prominent in the literature and art of virtually all epochs.

Did Bartók, then, share Debussy's interest in the esoteric and mystical? This is hard to answer exactly, though his breadth of interest in philosophy, science and art is well documented. Such a blend was quite normal in the late 19th and early 20th century, whose avant-garde milieux did not know the present gulf between science and art (never mind between science and parascience). For example, several important French Symbolist figures were highly knowledgeable in science, among them the poet Jules Laforgue (one of Debussy's literary idols, as well as a devotee of the work of Gustav Fechner), the mathematician Charles Henry (mentor of the painter Seurat, as well as author of several articles in Symbolist journals about golden section and other geometrical properties in art), and the photographic and phonographic pioneer Charles Cros, some of whose poetry Debussy set to music.

All this invites exploration of the literary sources and influences around the young Bartók and his colleagues, such as Béla Balázs, as well as the relationships between Hungarian literary movements and the French ones of the *fin-de-siècle* and after. Naturally, number manipulation and noumenal symbolism have many possible sources; whatever the answers on an academic level, the associated geometry is incontrovertibly there in the music, rewarding the attentive listener and observer with ever-new depths and artistic resonances.

A final musical connection emphasizes this ever-elusive topic. Elmer Schönberger and Louis Andriessen have observed that the Postlude of Stravinsky's *Requiem Canticles* (of 1966) forms what they describe as a mystical sequence of 44+33 beats, involving other subsidiary multiples of eleven. This is exactly the sequence that Bartók follows by bars in the *Music for strings* (see Fig. 6 above) to lead his Fugue subject from A to E^b and back to A.

The latter part of the last century has in fact seen something of a visible return to the position of medieval music, where mathematics, science, astronomy and number symbolism were regarded as essential parts of musical technique, yielding relationships to be implanted as a matter of course. As for the intervening centuries, J. S. Bach is known to have had such interests, and clear numerical structures can be found in music by Mozart, Haydn, Beethoven, Schubert, Fauré and others, in some cases suggesting connections with Freemasonry. It has often been postulated that such techniques were a forgotten part of composers' tradition, later rediscovered; or at least something that alert composers perhaps discovered in music of the past. The more we look, however, the shorter becomes the postulated period of the tradition's hibernation; in fact it may never have rested.

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NOTES

1 For examples ranging from snail shells to sunflowers, fir cones and catkins (and many others) see Church 1904, Colman & Coan 1912 & 1920, Cook 1914, Thompson 1917, and Lendvai (omnia). For a brief survey of the golden section's role in art, see Ghyka (omnia), Hambidge (omnia) and Wittkower 1960. One of the best-known applications this century has been the architect Le Corbusier's 'Modulor', based (after Zeising and Fechner) on the proportions of the human body.

2 The latter series is named after the 19th-century French mathematician Edouard Lucas, who himself gave the name Fibonacci to the former series. 'Fibonacci' (= Figlio Bonaccio) was the 12th-century mathematician Leonardo da Pisa who introduced arabic numbers to Europe and who first wrote about the series later named after him.

3 In 'Reflets dans l'eau' the GS point is after 58 bars out of the total 94 (two bars after the crescendo from ...); in 'Mouvement' after 109 out of 177 (at the centre of the two ... bars); in 'Cloches à travers les feuilles' at the momentary ... in bar 31 (counting each of the 2/4 bars as half a 4/4 bar). 'Reflets dans l'eau' is counted here as it appears in Debussy's manuscript and the original Durand edition, some recent editions, including Peters, distort bar numbering by inserting an extra barline in the middle of the cadenza-like bar 23. The problems of measuring musical proportions - bars versus beats, notated metre versus clock time, etc. - are discussed, along with analyses of the piano Images, in Howat 1983a:15-21, 23-9, 140-6.

4 For maximum accuracy the first division should ideally be after 22 bars; although the discrepancy is very small, it can be musically accounted for by more detailed analysis; see Howat 1983a 25-6. For maximum accuracy the first division should ideally be after 22 bars; although the discrepancy is very small, it can be musically accounted for by more detailed analysis, as discussed in Howat, Debussy in proportion, pp. 25-6.

5 The part of 'Oiseaux tristes' concerned is the main portion up to the cadenza, measured here in quarter-note units because of varying bar lengths. This may seem to contradict the measurement of the Bartók Fugue by bars, but in fact takes into account the different rhythmic character of each work — the clear quarter-note pulse of the Ravel in contrast to the stronger bar articulation in the Bartók Fugue (see note 3 above). The small divergencies from exact Fibonacci proportions in the Ravel example relate to another structural aspect, described in Howat 1983a:189-91.

6 The fractions occur because bars of 5/4 and 3/2 are measured as multiples of 4/4 units, giving priority to the quarter-note pulse, whose strength is clear from Ex. 2. 'Roaring of the wind' in Fig. 8 is Lendvai's apt term (1983:52, 82-4).

7 Information from Galánffy's pupil John Aielli, of KUT Radio, Austin, Texas, corroborated in correspondence by Ernö Lendvai. See also Lendvai 1983:73 & 339.

8 See Howat 1983a:164-7 regarding the scientific-aesthetic writings of the mathematician Charles Henry in various Symbolist journals in the 1880s and 1890s.