

Structure, Form, and Process

Single Movement Forms

Sonata Form:

A

Exposition

Introduction (optional)
a theme (tonic)
b theme (dominant)

B

Development

Free exploration of thematic
and motivic materials

A

Recapitulation

Return of exposition
a theme (tonic)
b theme (tonic)
Coda (optional)

Rondo Form:



A = ritornello; returns in the tonic each time

Multimovement Forms

Sonata or Concerto:

A

I

Fast

Sonata form

B

II

Slow

Song form

A

III

Fast

Rondo or Sonata Form

Symphony:

A

I

Fast

Sonata Form

B

II

Slow

Song Form

C

III

Fast

Minuett & Trio
or Scherzo & Trio

A

IV

Fast

Rondo Form
or Sonata Form

Imitative Processes

Canon:

a b c d e f g...
a b c d e f g...

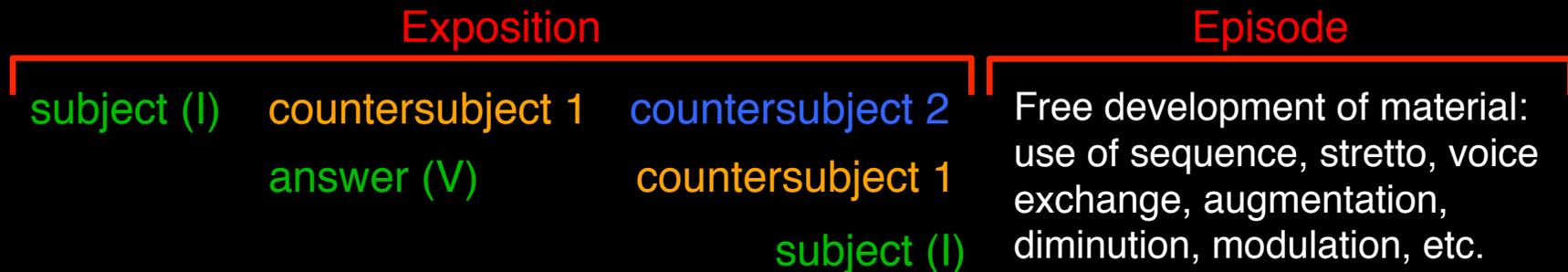
Imitation may be at a variety of intervals, though octaves and fifths are most common. Time interval between entrance(s) may vary. Special devices are often employed.

Round:

a b c d a b c d a b c d...
a b c d a b c d a b c...
a b c d a b c d a b...
a b c d a b c d a...

Imitation is usually at the octave or unison. Time interval between entrances is constant.

Fugue:



For three or more voices. No fixed form, though all fugues consist of an alternation of expositions and episodes, and frequently close with a coda that includes a final statement of the subject over a pedal point.

Variation Forms

Theme and Variations:

- Sectional form: full statement of theme followed by a series of variations, each with a definite ending and usually separated by a distinct break.
- Varied parameters may include melody, harmony, tonality, rhythm, meter, tempo, texture, etc.
- Techniques include ornamentation, transposition, inversion, retrograde, augmentation/diminution, etc.

Passacaglia/Chaconne:

- Continuous variations: the theme (“subject”) is presented without interruption, most commonly in the bass (*basso ostinato*). The passacaglia is more melodically based, while the chaconne is more harmonically based.
- Traditionally in a slow, triple meter
- Subject is typically in two-, four-, or eight-measure phrases.
- Examples: Henry Purcell: “Dido’s Lament” from *Dido and Aeneas* (c.1689)
J.S. Bach: Passacaglia & Fugue in C Minor, BWV582 (c.1710)
Johannes Brahms: Variations on a Theme by Haydn, Finale (1873)
Symphony No. 4, Fourth Movement (1885)
Gustav Holst: Suite No. 1 for Band, Third Movement (1909)
Paul Hindemith: String Quartet No. 4, Finale (1923)

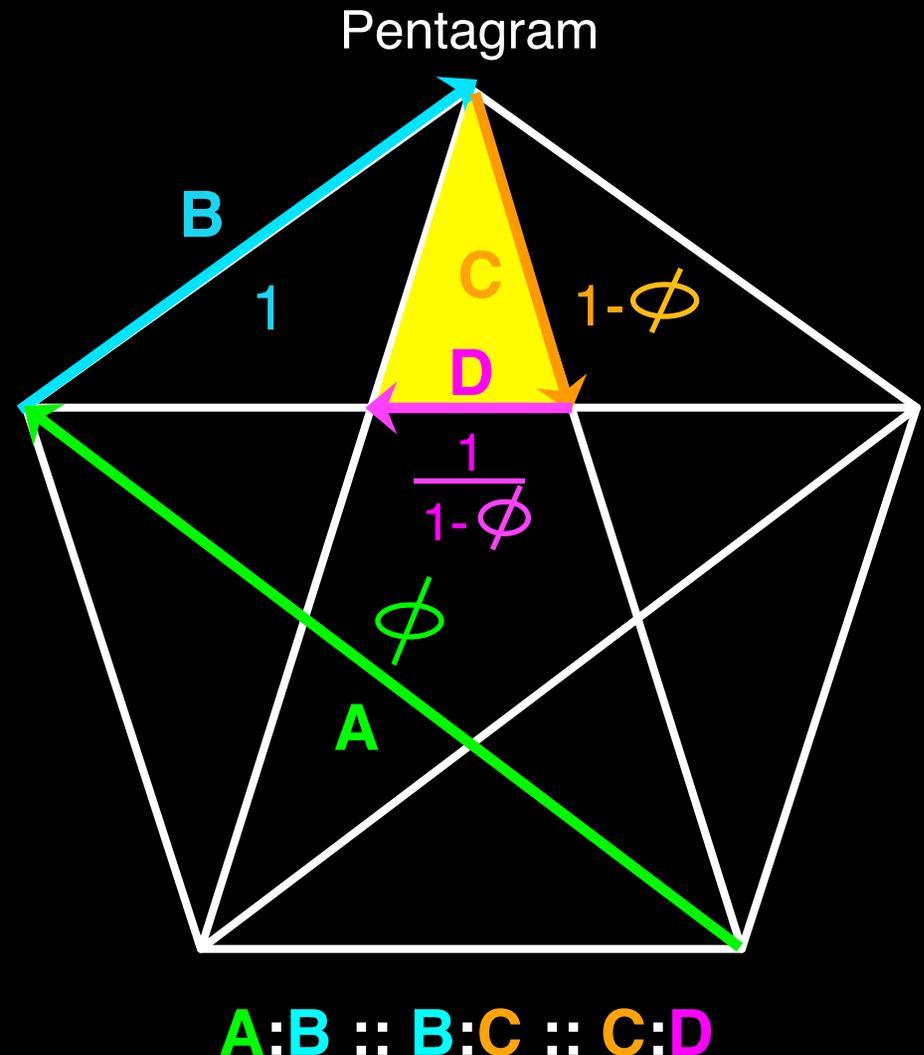
Contemporary Formal Paradigms

- Although older forms and processes are still used by many contemporary composers, these are often highly modified versions of past models.
- In addition to such traditional paradigms, contemporary composers have explored other systematic approaches to form and process, taken from a variety of extramusical sources:
 - **Golden Proportion**: may be applied to large-scale structural relationships, rhythmic subdivisions, pitch relationships, etc.
 - **Fibonacci Series**: may be applied to durational units, pitch material, textural density, etc.
 - **Fractals**: processes may be applied recursively at various levels (rhythm, measure, phrase, period, section, movement, etc.).
 - **Chaos & Complexity Theory**: complex algorithms may be used to generate musical material, resulting in varying degrees of apparent order/disorder.

Golden Proportion

- The proportion resulting from the division of a line or plane figure such that the shorter part is to the longer part as the longer part is to the whole.
- First formulated by the Greek mathematician Euclid in the third century B.C. The pentagram was the most common symbol of this proportion.
- The **Golden proportion** is represented by the Greek letter **Phi** (ϕ) and is equal to the non-repeating decimal **1.61803....**
- The **Golden proportion** is found in a variety of natural phenomena and has been widely used to produce harmoniously balanced artworks.
- The triangle formed by one of the arms of the pentagram is called the **Golden triangle**.

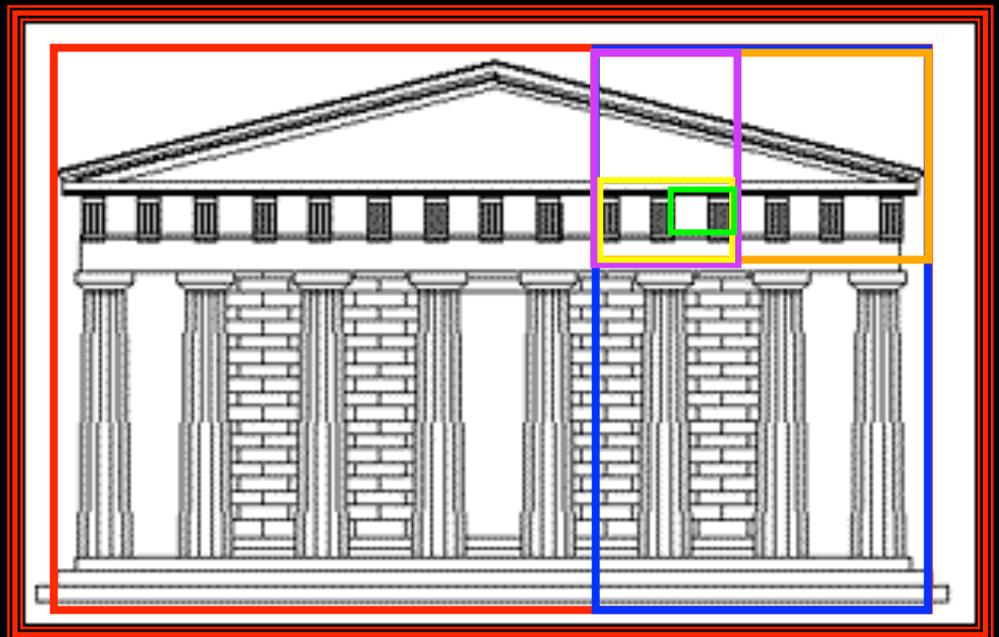
$$\frac{1}{\phi} = 1 - \phi = .61803\dots$$



Applications of the Golden Proportion



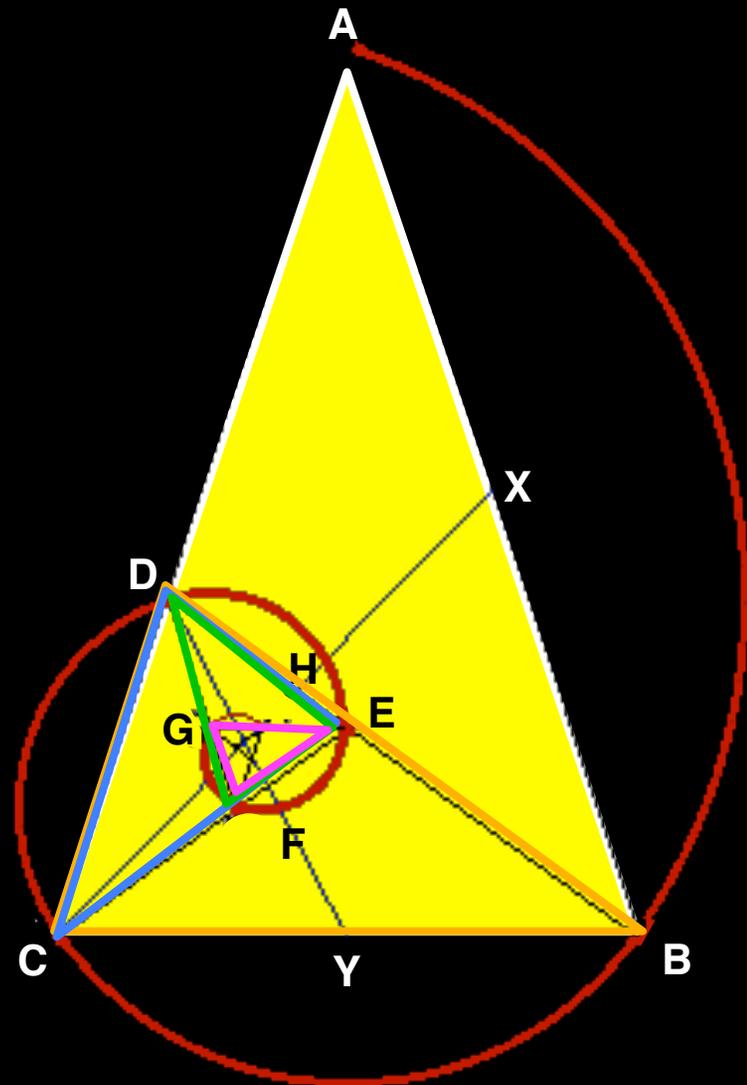
The Parthenon, Athens, Greece



Logarithmic Spiral

- Term coined by Jakob Bernouli in the 17th century to describe the curve produced by connecting the corners of each of the **Golden triangles**. Any line drawn from the center point of the spiral will intersect the curves at the same angle as any other line.
- Also known as an equiangular spiral, Fibonacci spiral, Bernouli spiral, and growth spiral.

Golden Triangle





Logarithmic Spirals



in Nature



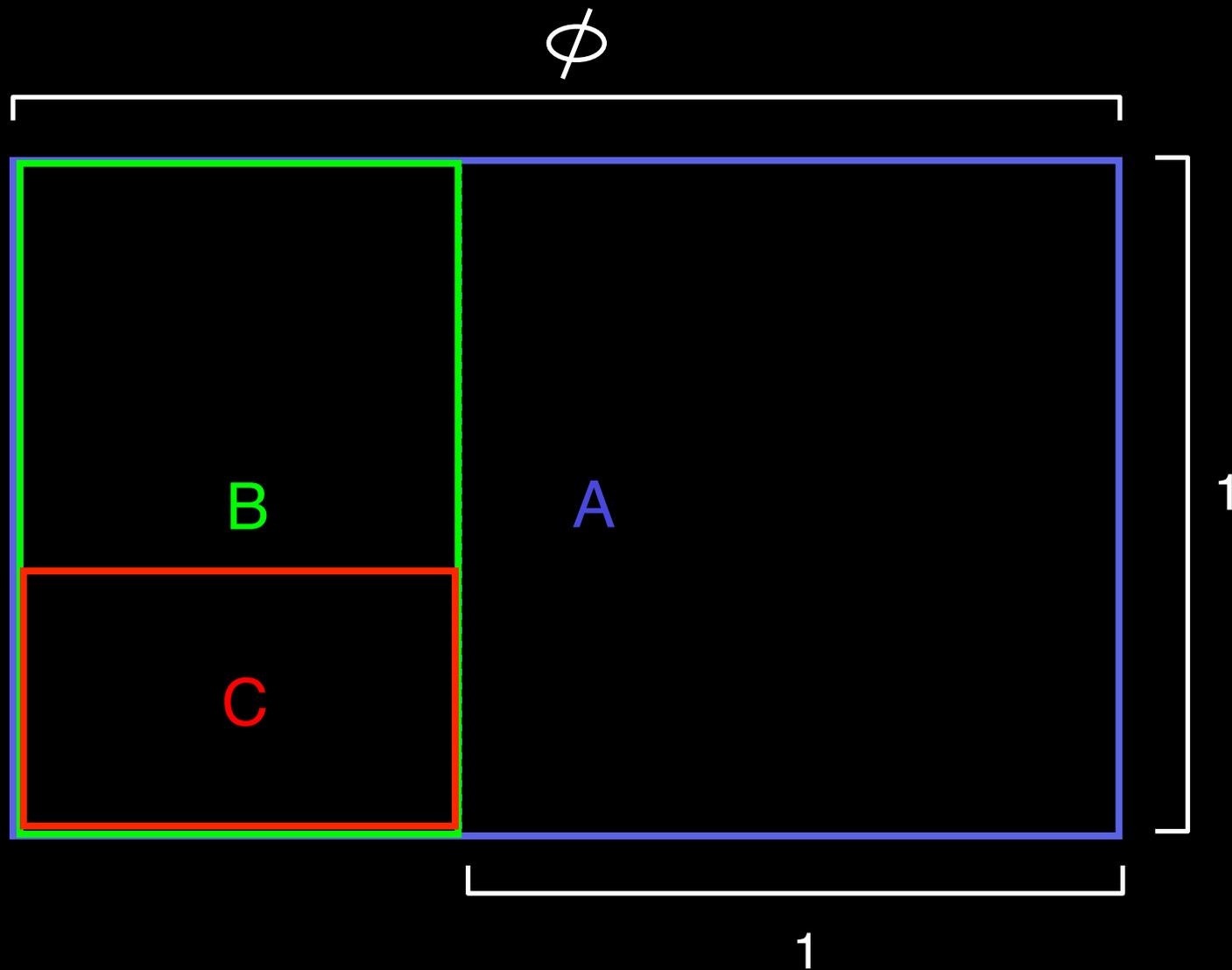
Logarithmic Spirals in Art

Hokusai: *The Hollow of the Wave off Kanagawa* (19th century)



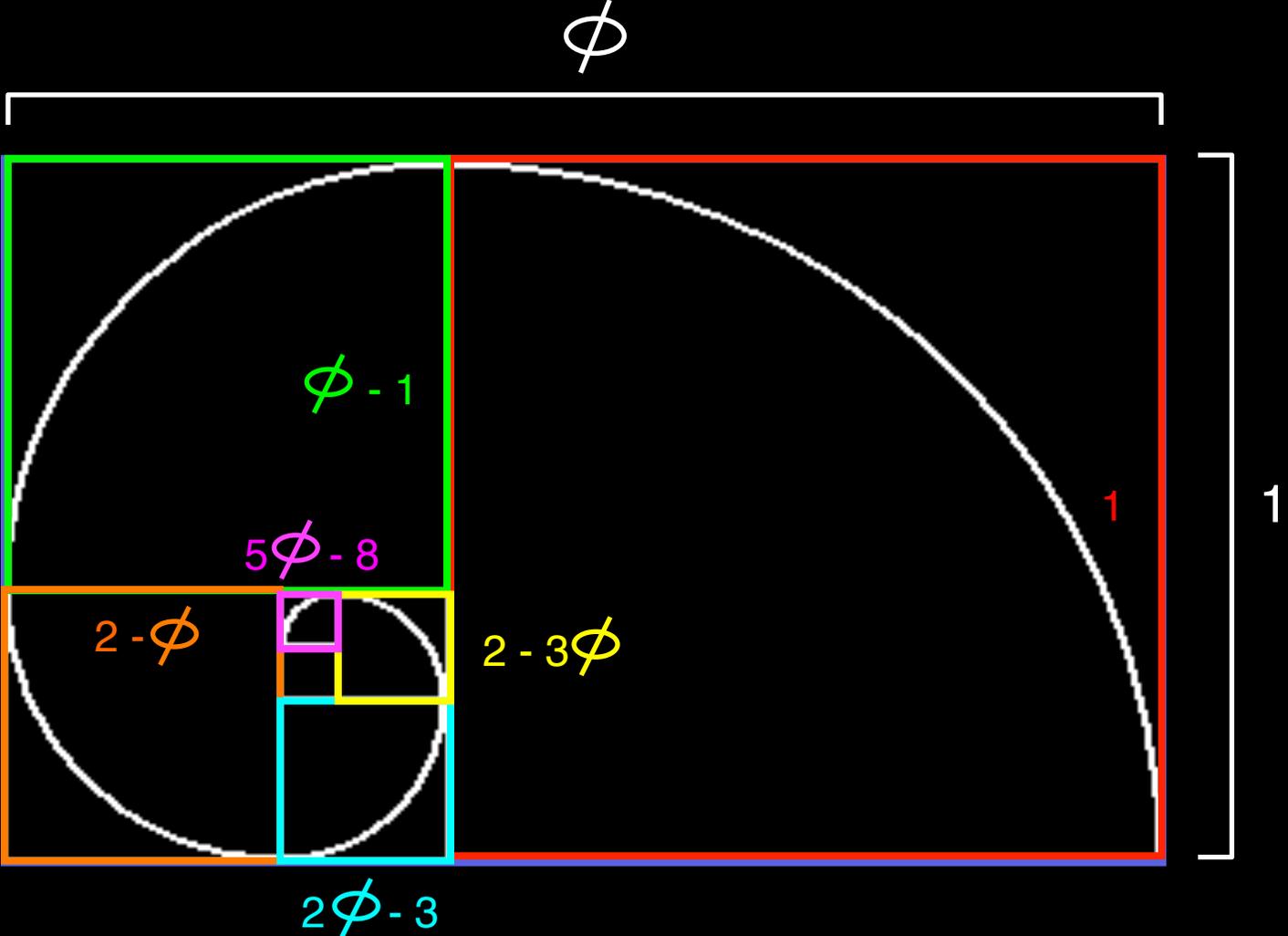
Jørn Utzon: Sydney Opera House (1957-73)

The Golden Rectangle and Logarithmic Spiral



$A:B :: B:C$, etc.

The Golden Rectangle and Logarithmic Spiral



Notice the numbers 1, 2, 3, 5, 8....

Fibonacci Series and Golden Proportion

Fibonacci series: an infinite, ordered set of numbers in which each number is the sum of the preceding two numbers. Named for 13th century mathematician Leonardo Pisano Fibonacci.

0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, 233, 377, ...

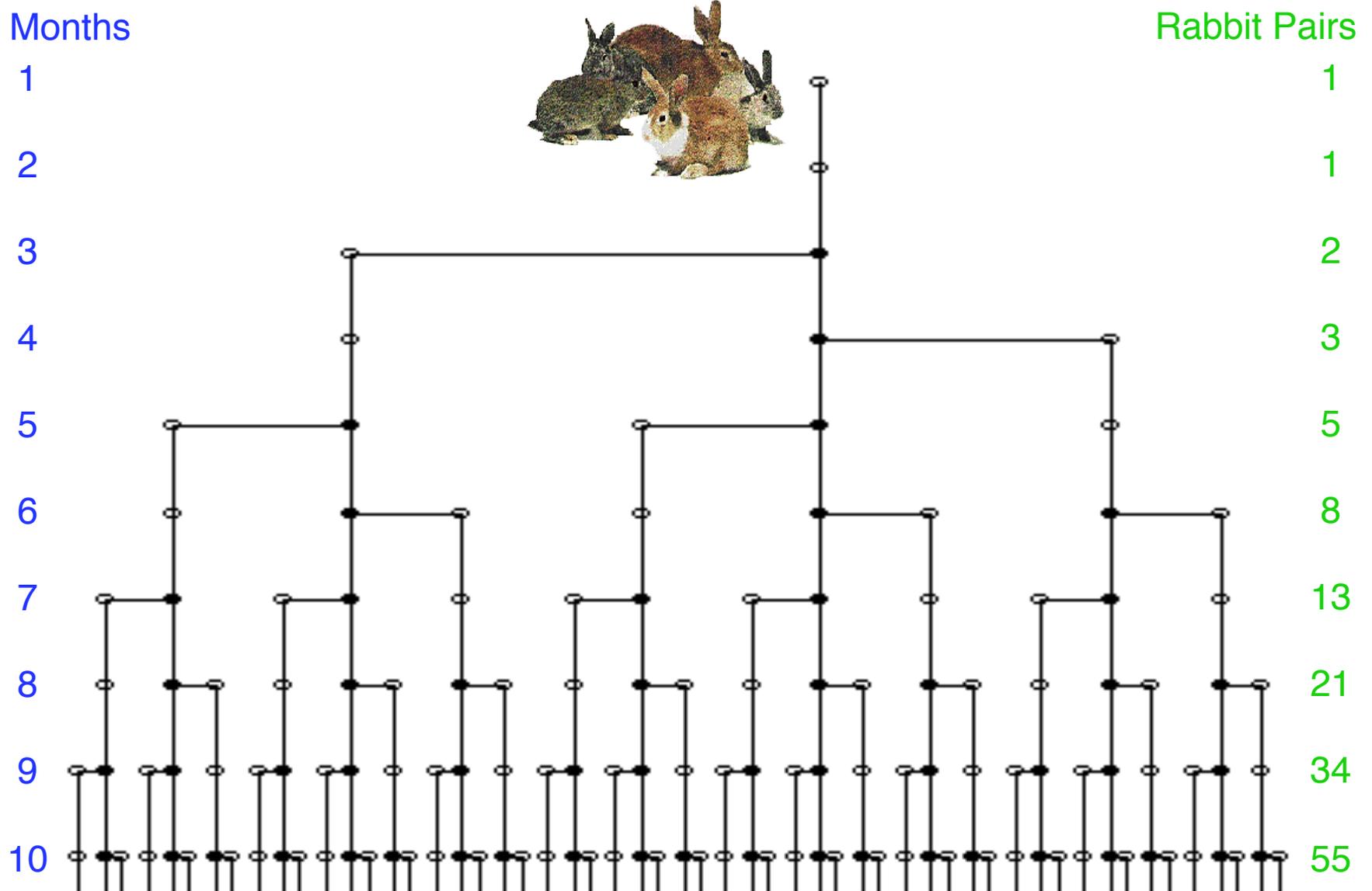
$$\begin{aligned} 0 + 1 &= 1 \\ 1 + 1 &= 2 \\ 1 + 2 &= 3 \\ 2 + 3 &= 5 \\ 3 + 5 &= 8 \\ 5 + 8 &= 13 \\ 8 + 13 &= 21 \\ 13 + 21 &= 34 \\ &\text{etc....} \end{aligned}$$



Leonardo Pisano Fibonacci
(c.1175 - c.1240)

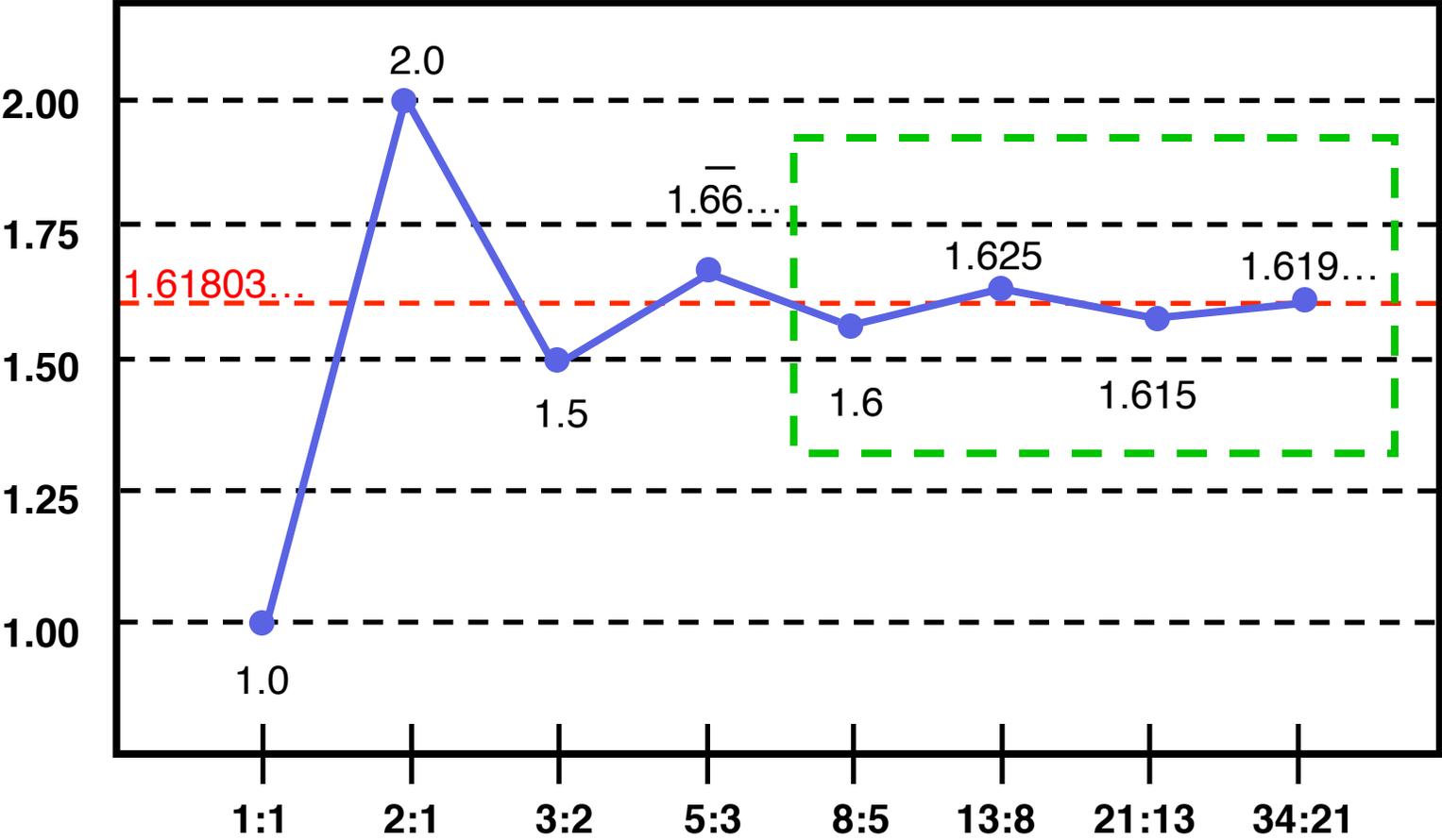
Fibonacci Series and Golden Proportion

Fibonacci's Rabbits



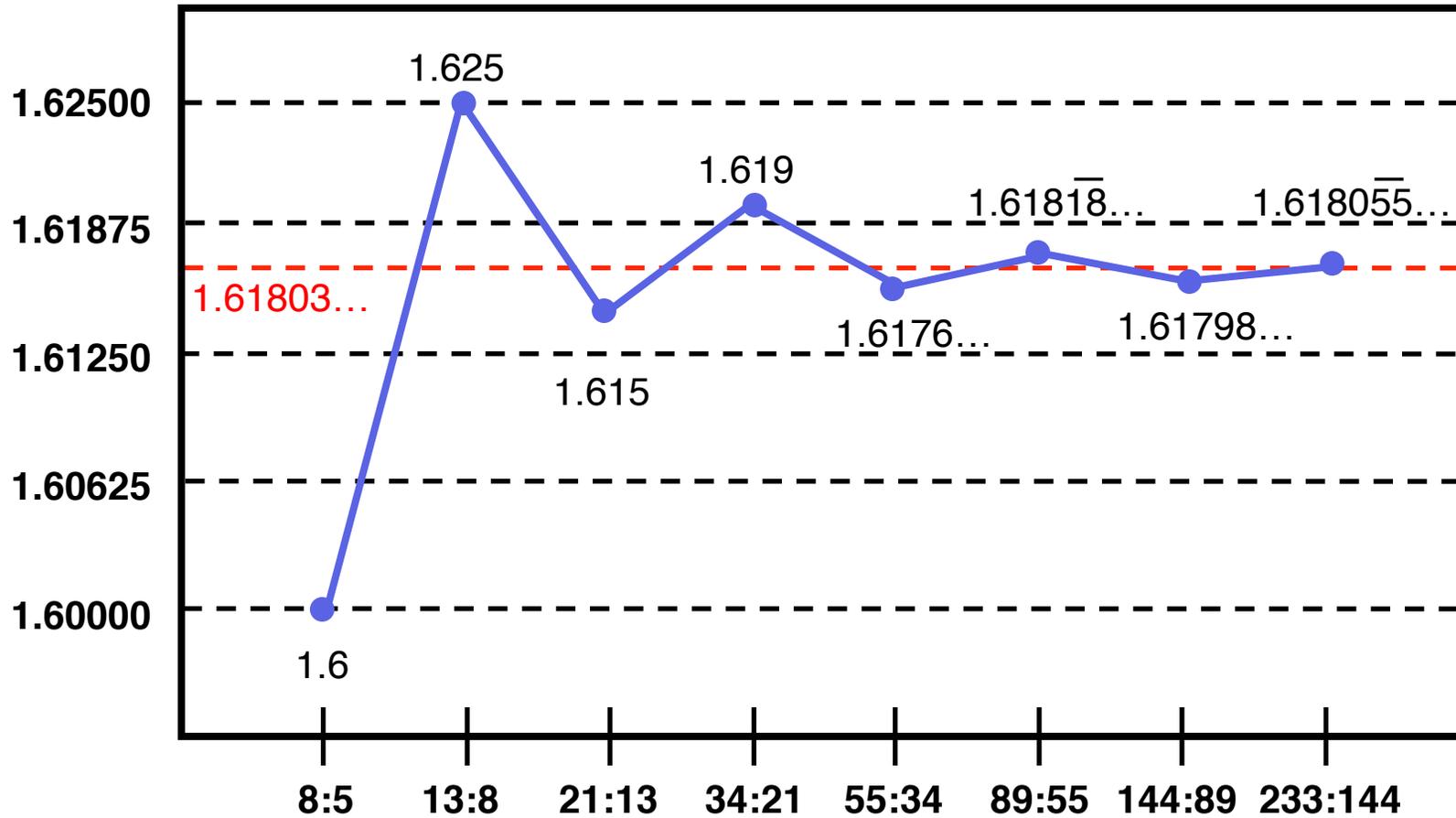
Fibonacci Series and Golden Proportion

Fibonacci Series Ratios Approaching the Golden Proportion:



Fibonacci Series and Golden Proportion

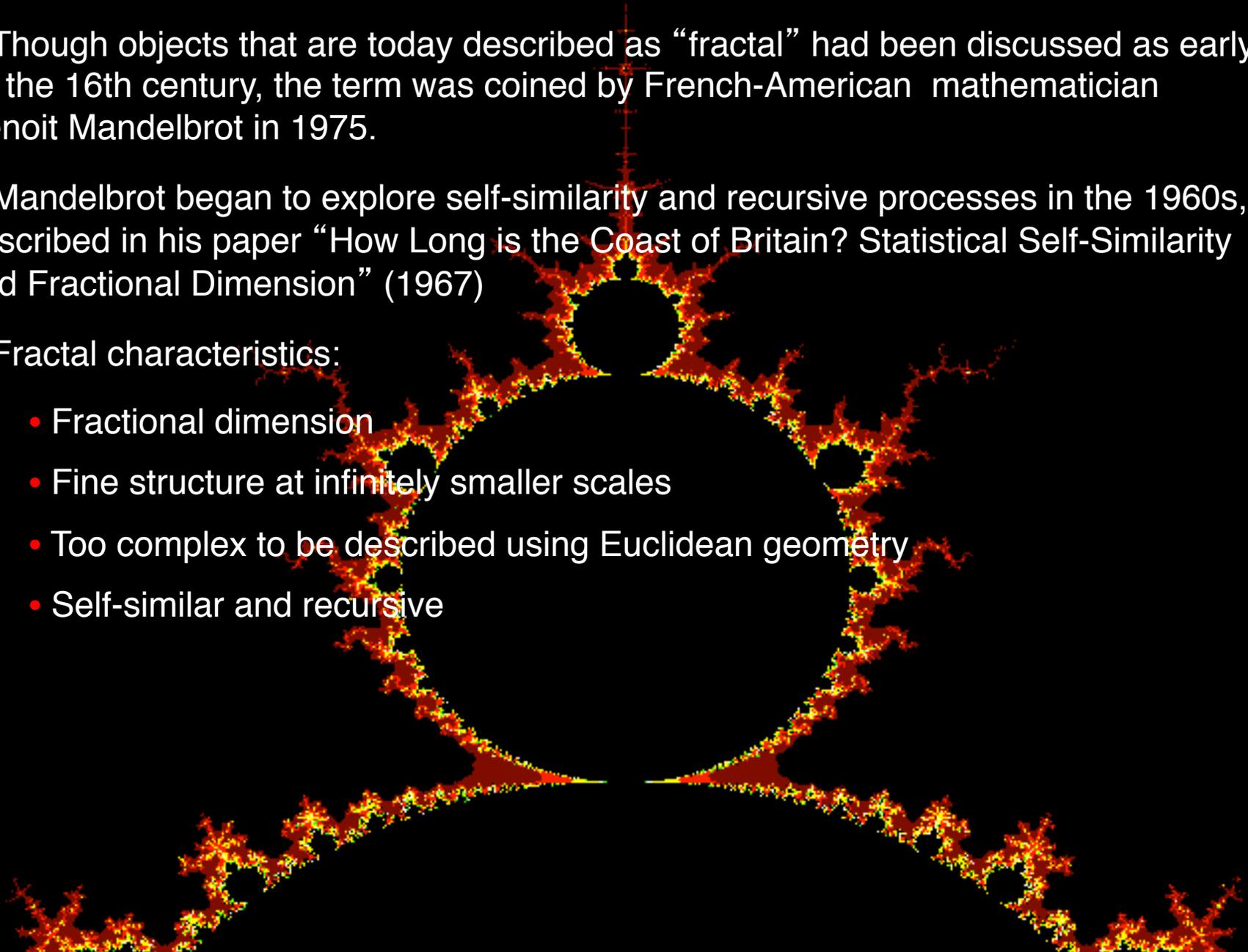
Fibonacci Series Ratios Approaching the Golden Proportion:



Notice the recursive nature of these graphs....

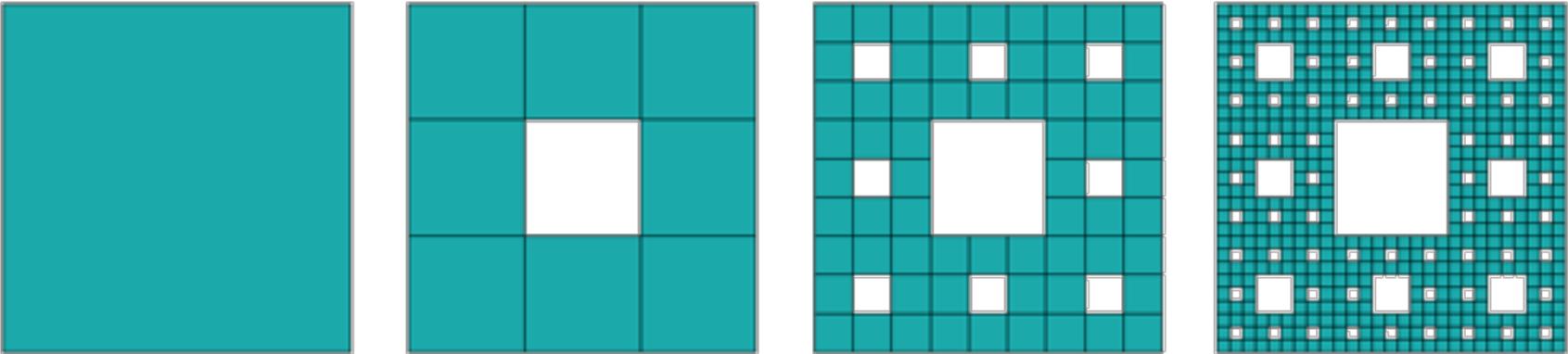
Fractals

- Though objects that are today described as “fractal” had been discussed as early as the 16th century, the term was coined by French-American mathematician Benoit Mandelbrot in 1975.
- Mandelbrot began to explore self-similarity and recursive processes in the 1960s, described in his paper “How Long is the Coast of Britain? Statistical Self-Similarity and Fractional Dimension” (1967)
- Fractal characteristics:
 - Fractional dimension
 - Fine structure at infinitely smaller scales
 - Too complex to be described using Euclidean geometry
 - Self-similar and recursive

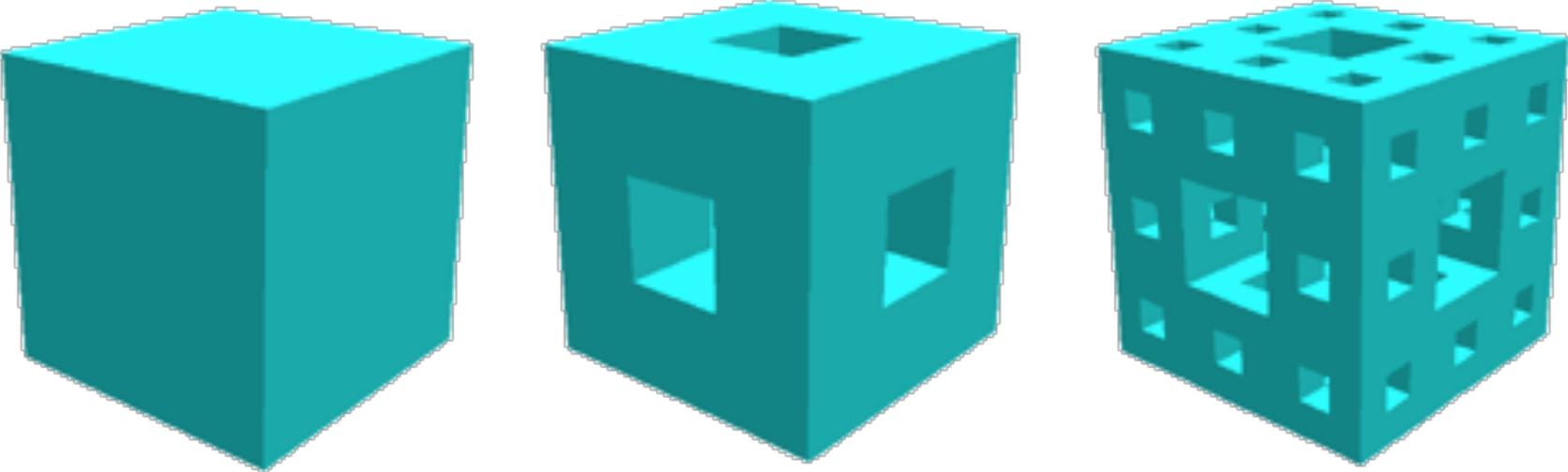


Fractals

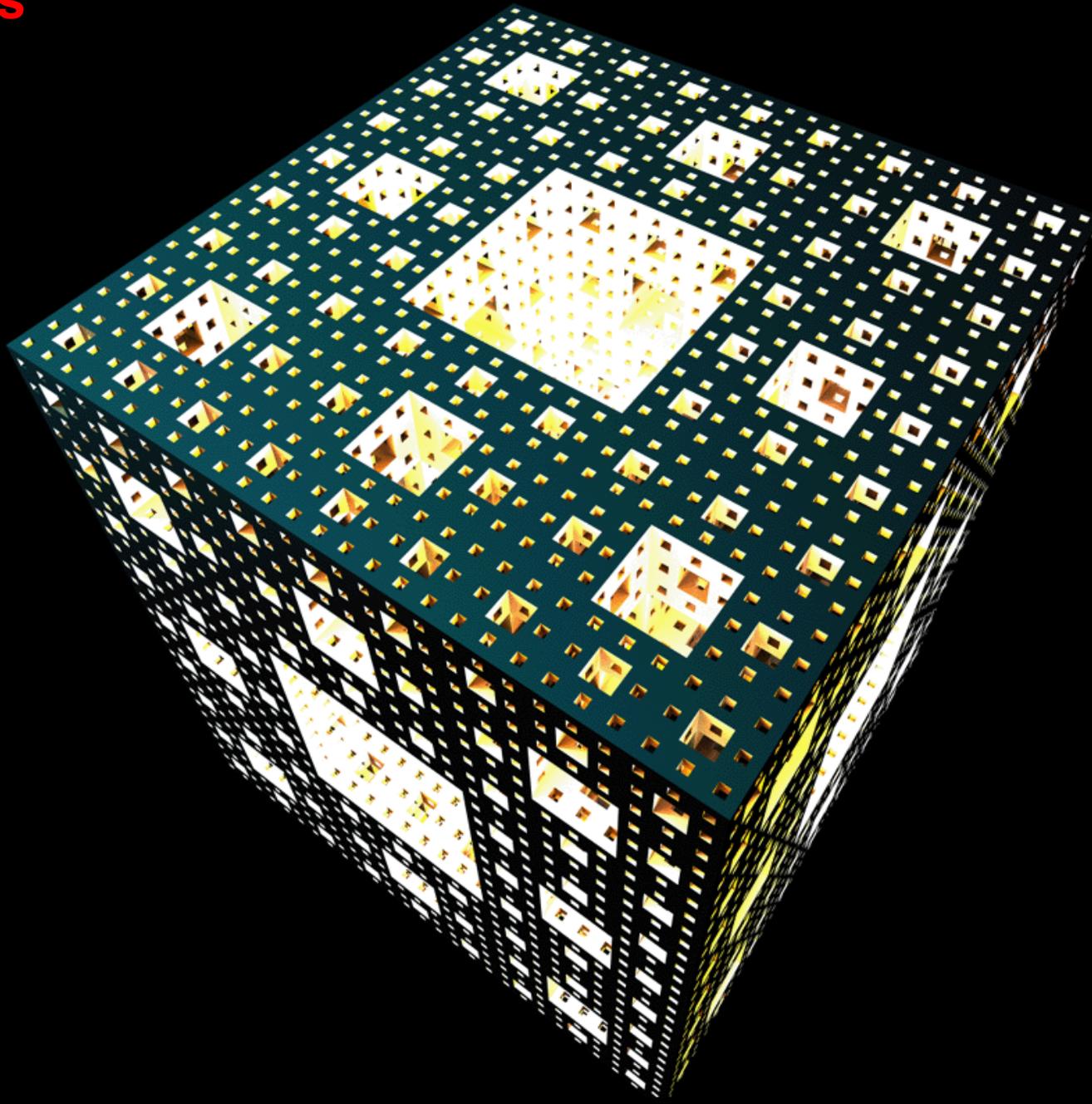
The Sierpinski Carpet (2-dimensional):



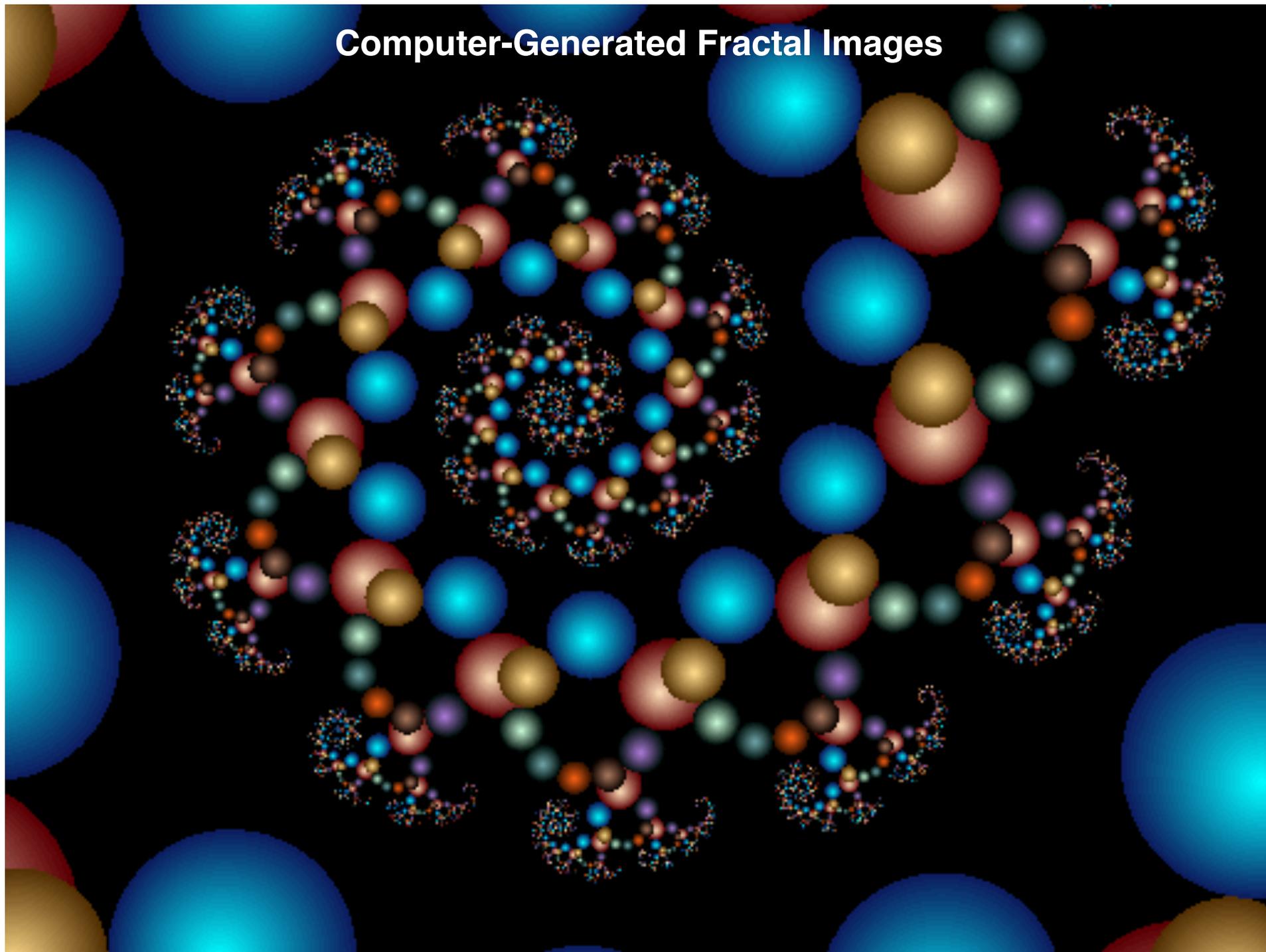
The Menger Sponge (3-dimensional):



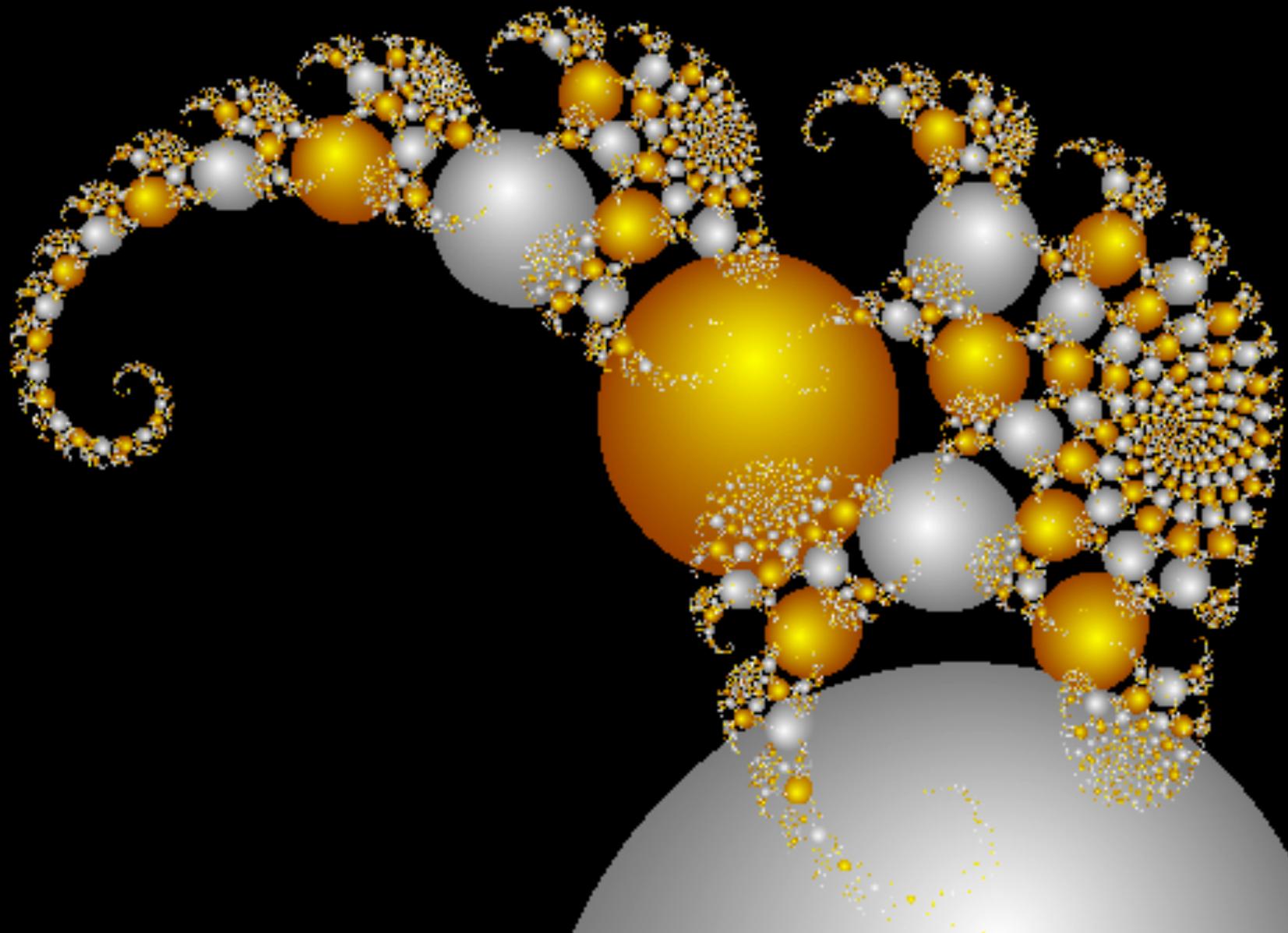
Fractals



Computer-Generated Fractal Images



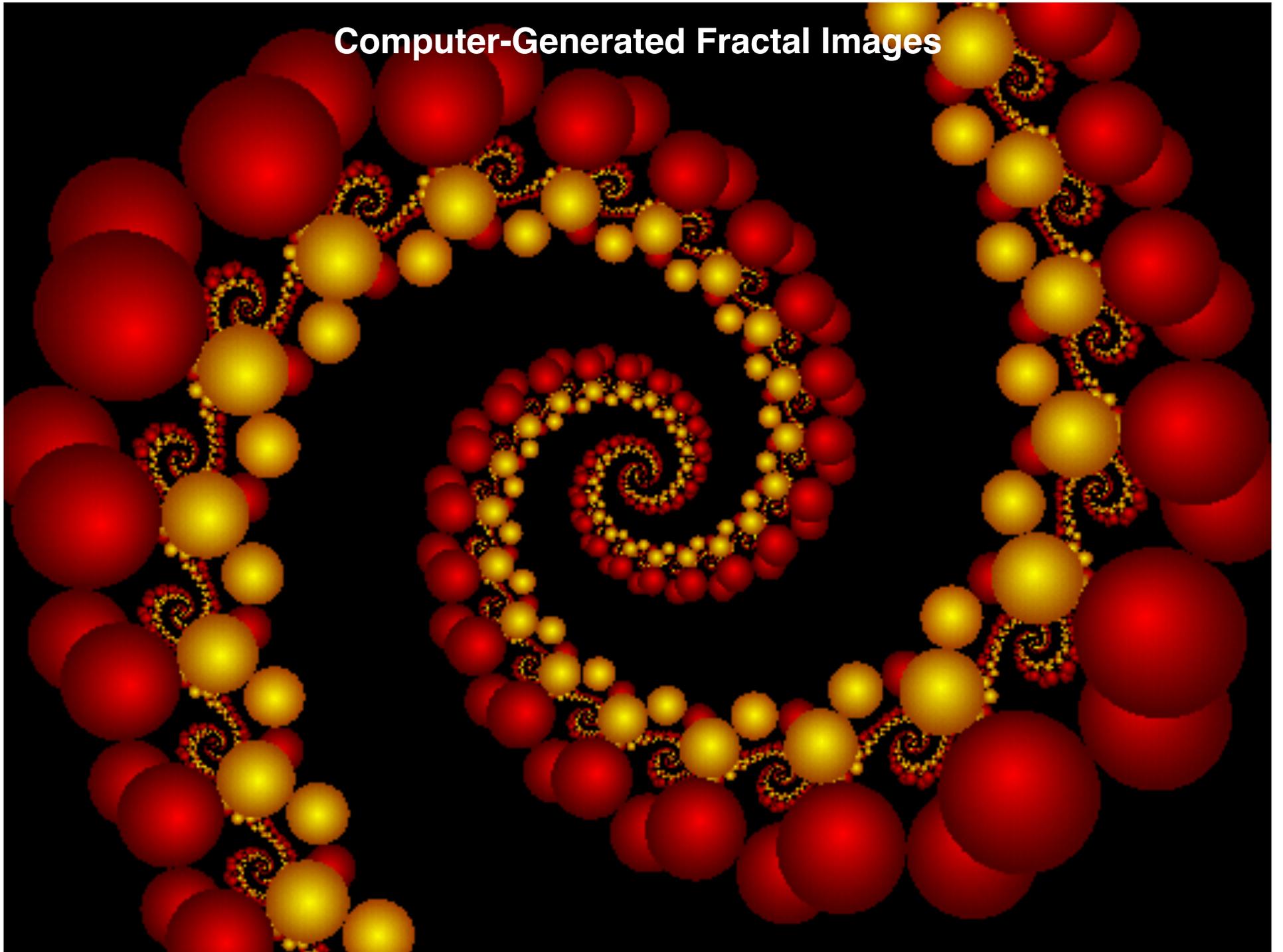
Computer-Generated Fractal Images



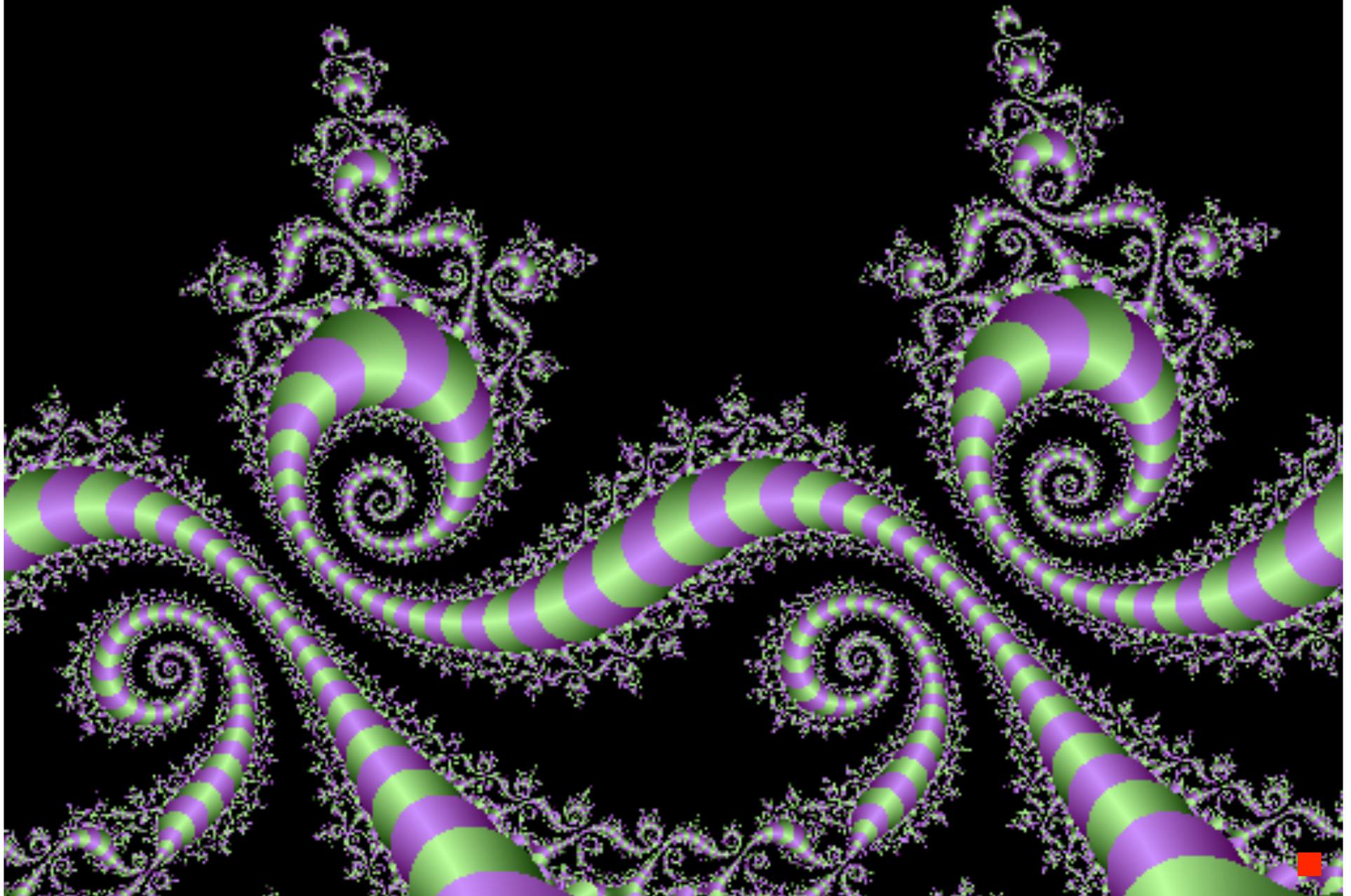
Computer-Generated Fractal Images



Computer-Generated Fractal Images



Computer-Generated Fractal Images



Fractal Images in Nature and Art



◀ Infrared satellite photograph of Cape Hatteras, North Carolina.



▲ Hokusai: *The Hollow of the Wave off Kanagawa* (19th century)



◀ Nautilus Shell

So....

How do these things apply to **MUSIC**?

- **Golden Proportion**: may be applied to large-scale structural relationships, rhythmic subdivisions, pitch relationships, etc.
- **Fibonacci Series**: may be applied to durational units, pitch material, textural density, etc.
- **Fractals**: processes may be applied recursively at various levels (rhythm, measure, phrase, period, section, movement, etc.).
- **Chaos & Complexity Theory**: complex algorithms may be used to generate musical material, resulting in varying degrees of apparent order/disorder.

Béla Bartók (1883-1945)



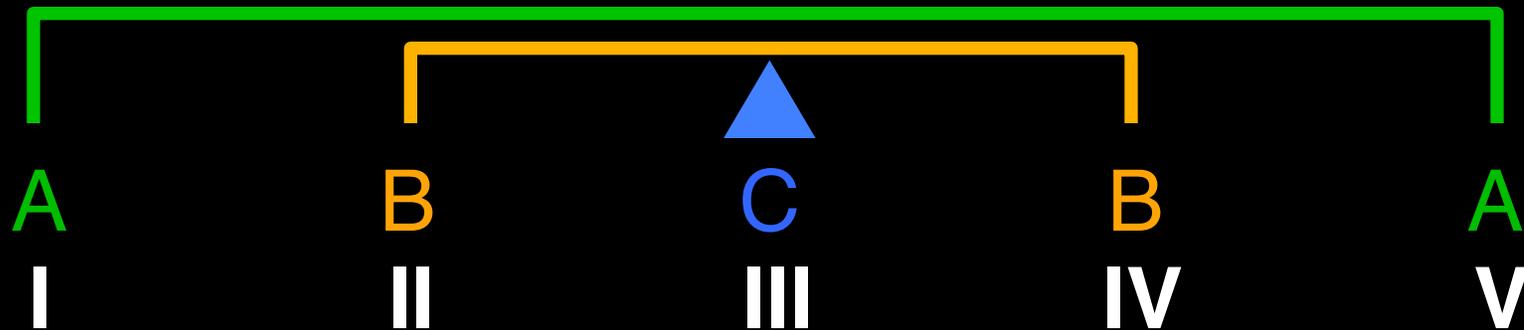
Biographical sketch:

- Born in Transylvania (now Hungary).
- Early career as an ethnomusicologist; collected and transcribed Hungarian and Romanian music with Zoltan Kodály.
- Concertized as a pianist, performing many of his own works.
- Emigrated to America in 1941.
- Died in New York City of leukemia.

Musical Characteristics:

- Strong influence of Eastern European folk music, primarily melodic and rhythmic features of his work.
- Interest in organic processes and symmetrical structures (e.g., Fibonacci series, arch form, tonal axes).
- Coloristic devices used (snap pizzicato, timpani glissando) often used to create lush atmospheric effects (e.g., “Night Music”).
- Stylistic transformation from expressionism to primitivism to neoclassicism.

Arch Form



Examples in Béla Bartók's Music:

String Quartet No. 4 (1928):

Allegro	Prestissimo	Lento	Allegretto	Allegro molto
	(with mutes)		(pizzicato)	
c.6'	c.3'	c.5'	c.3'	c.5'

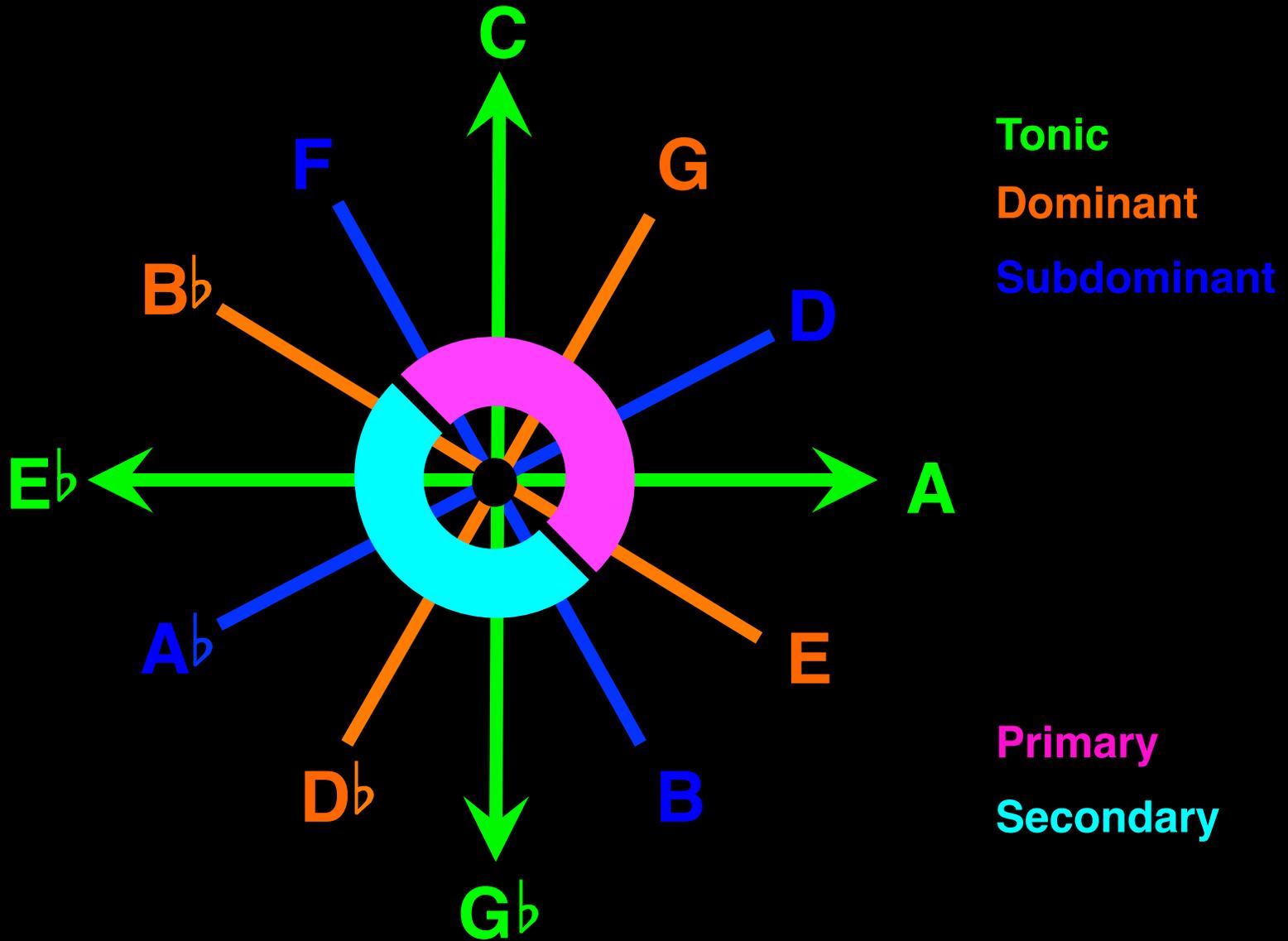
String Quartet No. 5 (1934):

Allegro	Adagio molto	Vivace	Andante	Allegro vivace
		Scherzo		Finale
c.7'	c.6'	c.5'	c.5'	c.6'

Concerto for Orchestra (1943):

Andante/Allegro	Scherzando	Andante	Allegretto	Pesante/Presto
Introduction	"Game of Pairs"	Elegia	Intermezzo	Finale
c.10'	c.6'	c.8'	c.5'	c.9'

Tonal Axis

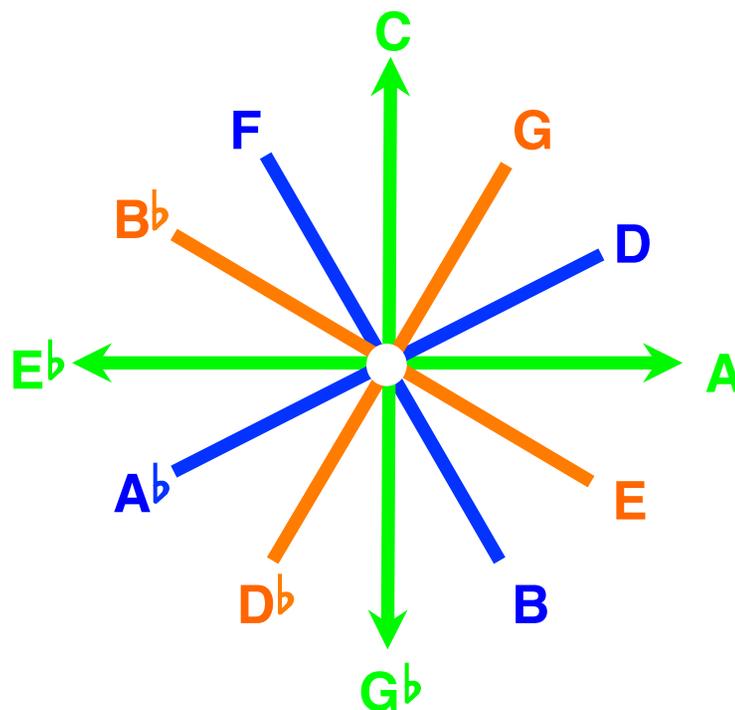


Béla Bartók: *Music for Strings, Percussion, and Celesta* (1936)—Movement I

Pitch relationships of fugal entrances—mm. 1-56:

Ascending fifths (clockwise)

Descending fifths (counter-clockwise)



Béla Bartók: *Music for Strings, Percussion, and Celesta* (1936)—Movement I

Thematic boundaries of fugue subject—mm. 1-5, viola 1-2 & violin 3-4:

Andante tranquillo, ♩ ca. 116-112
con sord.

1. 2. Violo

3. 4. Vl. con sord.

The image shows two staves of music. The top staff is for Viola (1. 2. Violo) and the bottom staff is for Violin (3. 4. Vl. con sord.). Both staves are in 12/8 time. The music is marked 'Andante tranquillo, ♩ ca. 116-112 con sord.'. The first staff has a red circle around the first note (A) and a red circle around the fourth note (Eb). The second staff has a blue circle around the fourth note (Bb). A dashed line connects the first notes of both staves, and another dashed line connects the fourth notes of both staves, illustrating the intervallic relationship between the two parts.

Inversional symmetry—mm. 78-80, violin 1 & violin 4:

Inversion on A

Vn. I

Vn. IV

Prime on A

etc.

The image shows two staves of music for Violin I (Vn. I) and Violin IV (Vn. IV). The top staff is in treble clef and the bottom staff is in bass clef. Both staves are in 6/8 time. The music is marked 'pp'. The first staff has a red double-headed arrow pointing to the first note (A) and a red double-headed arrow pointing to the fourth note (Eb). The second staff has a red double-headed arrow pointing to the first note (A) and a red double-headed arrow pointing to the fourth note (Eb). A box labeled '80' is placed above the first staff. The text 'Inversion on A' is written above the first staff, and 'Prime on A' is written below the first staff. The text 'etc.' is written at the end of the second staff.

Béla Bartók: *Music for Strings, Percussion, and Celesta* (1936)—Movement I

Fugal exposition

entrance #1 *Andante tranquillo*, $\text{ca } 116-112$
con sord.

1. 2. Viole

4

pp

3. 4. Vl.
1. 2. Vle.

entrance #2 *con sord.*

7

pp

3. 4. Vl.
1. 2. Vle.
1. 2. Vlc.

entrance #3 *pp*

10

con sord.

2. Vl.
3. 4. Vl.
1. 2. Vle.
1. 2. Vlc.

entrance #4 *con sord.*

13

pp

Béla Bartók: *Music for Strings, Percussion, and Celesta* (1936)—Movement I

13

2. Vl.
3. 4. Vl.
1. 2. Vle.
1. 2. Vlc.

Detailed description: This system of musical notation covers measures 13 through 17. It features four staves: 2nd Violin (2. Vl.), 3rd and 4th Violin (3. 4. Vl.), 1st and 2nd Viola (1. 2. Vle.), and 1st and 2nd Violoncello (1. 2. Vlc.). Measure 13 is marked with a circled '13'. The music is in a complex, atonal style with frequent chromaticism and accidentals. Fingerings are indicated by numbers 8, 9, 10, and 12. A question mark '?' is placed above a note in measure 15. The system concludes with a double bar line.

16

2. Vl.
3. 4. Vl.
1. 2. Vle.
1. 2. Vlc.
1. 2. Cb.

oon sord

entrance #5 *pp*

Detailed description: This system of musical notation covers measures 16 through 19. It features five staves: 2nd Violin (2. Vl.), 3rd and 4th Violin (3. 4. Vl.), 1st and 2nd Viola (1. 2. Vle.), 1st and 2nd Violoncello (1. 2. Vlc.), and 1st and 2nd Contrabass (1. 2. Cb.). Measure 16 is marked with a circled '16'. The music continues with complex, atonal textures. Fingerings are indicated by numbers 7, 8, 9, 10, and 12. The text 'oon sord' is written above the 1st and 2nd Cb. staff in measure 17. The system concludes with a double bar line. Below the system, the text 'entrance #5 pp' is written in red.

Béla Bartók: *Music for Strings, Percussion, and Celesta* (1936)—Movement I

19

Episode

2. Vl.
3. 4. Vl.
1. 2. Vle.
1. 2. Vlc.
1. 2. Cb.

Detailed description: This system of musical notation covers measures 19, 20, and 21. It features five staves: 2. Vl. (Violin II), 3. 4. Vl. (Violins III and IV), 1. 2. Vle. (Violas I and II), 1. 2. Vlc. (Violoncellos I and II), and 1. 2. Cb. (Double Basses I and II). The music is in 3/4 time and includes various rhythmic patterns, accidentals, and dynamic markings. Measure numbers 7, 8, 10, and 8 are indicated below the staves.

22

2. Vl.
3. 4. Vl.
1. 2. Vle.
1. 2. Vlc.
1. 2. Cb.

Detailed description: This system of musical notation covers measures 22, 23, and 24. It features the same five staves as the previous system. The music continues with complex rhythmic and melodic lines. Measure numbers 6, 8, and 6 are indicated below the staves.

Béla Bartók: *Music for Strings, Percussion, and Celesta* (1936)—Movement I

Stretto (Vn 1-2 & Vc./Cb)
con serd.

25

entrance #6

1. VI.

2. VI.

3. 4. VI.

1. 2. Vle.

1. 2. Vlc.

1. 2. Cb.

entrance #7

28

1. VI.

2. VI.

3. 4. VI.

1. 2. Vle.

1. 2. Vlc.

1. 2. Cb.

Béla Bartók: *Music for Strings, Percussion, and Celesta* (1936)—Movement I

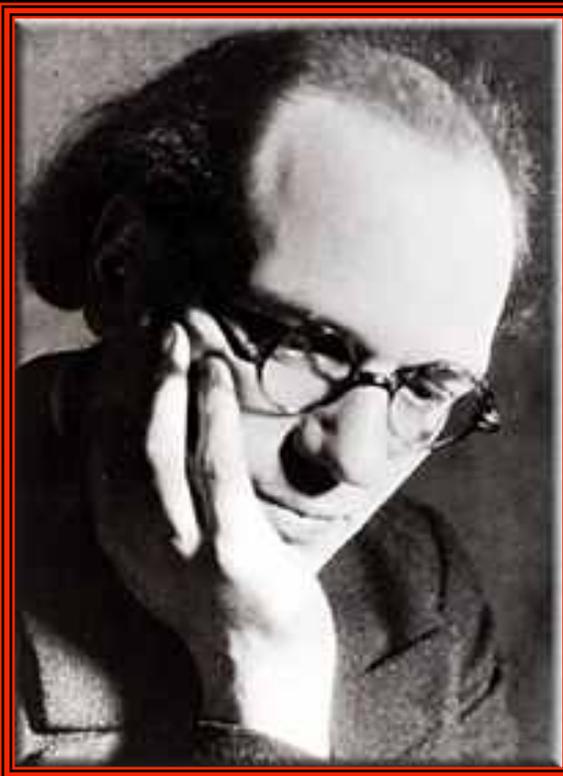
31

Percussion entrance

The musical score for Movement I of *Music for Strings, Percussion, and Celesta* by Béla Bartók, starting at measure 31. The score is written for a full string ensemble and percussion. The percussion part features a trill marked *pp* (pianissimo). The string parts are marked *senza sord.* (without mutes) and *(p)* (piano). The score includes parts for Timpani (Timp.), Violins I (1. Vl.), Violins II (2. Vl.), Viola (3. 4. Vl.), Violoncello (1. 2. Vlc.), and Contrabass (1. 2. Cb.).



Olivier Messiaen (1908-1992)



Olivier Messiaen (1908-1992)



Musical Characteristics:

- Early work reflects influence of impressionist composers, particularly Claude Debussy.
- Devout Catholicism has a profound mystical and symbolic impact on his work.
- Expert ornithologist; birdsong is incorporated in many of his works.
- Hindu rhythms adopted for their pliancy.
- Symmetrical structures manifested in non-retrogradable rhythms and modes of limited transposition.

Messiaen's Modes of Limited Transposition

Mode 1: 6 pitches, 2 transpositions
("whole tone")

Mode 2: 8 pitches, 3 transpositions
("octatonic")

2 2 2 2 2 2 1 2 1 2 1 2 1 2

Mode 3: 9 pitches, 4 transpositions

Mode 4: 8 pitches, 6 transpositions

2 1 1 2 1 1 2 1 1 1 1 3 1 1 3 1 1

Mode 5: 6 pitches, 6 transpositions

Mode 6: 8 pitches, 6 transpositions

1 4 1 1 4 1 2 2 1 1 2 2 1 1

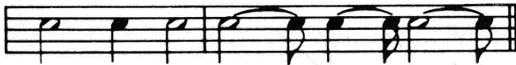
Mode 7: 10 pitches, 6 transpositions

1 1 1 2 1 1 1 1 2 1

Messiaen's Table of Augmented and Diminished Rhythms

←..... diminution
 augmentation→

four-fifths



five-fourths

three-fourths



four-thirds

two-thirds



three-halves

classic diminution

one-half



double

classic augmentation

one-third



triple

one-fourth



quadruple

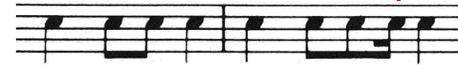
one-fifth



quintuple

Examples:

Inserting extra note: +



Inserting rest: +



Adding dot to increase value: +



augmentation.....→



Agneau, Sei . gneur!

Olivier Messiaen: *Quatuor pour la fin du temps* (1940)—Background

- As a medical auxiliary in the French army, Messiaen was captured by Nazis in May 1940 and imprisoned at Görlitz-Silesia.
- Composed for fellow prisoners (playing violin, clarinet, ‘cello) and Messiaen (playing piano).
- Premiered at Stalag VIII-A prison camp in January 1941, allegedly for an audience of 5000 prisoners; of this performance, Messiaen stated “never before have I been heard with as much attention and understanding.”



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- The title of the work has a three-fold significance:
 - Biblical (Revelation 10:1-7): “There shall be no more time; but on the day of the seventh Angel’s trumpet, the mystery of God shall be accomplished”
 - Historical: in the context of Hitler’s increasing power and Messiaen’s own personal experience as a prisoner of war.
 - Musical: relating to Messiaen’s unique concept of musical time.
- “The quartet contains eight movements. Why? Seven is the perfect number, the creation of six days sanctified by the divine Sabbath; the seventh, of rest, extends into eternity and becomes the eighth, of unflinching light and unalterable peace.”

Olivier Messiaen: *Quatuor pour la fin du temps* (1940)
 I. *Liturgie de cristal*

Clarinet: strophic pattern (blackbird)

Violin: intermittent bird calls (nightingale)

Violoncello: isorhythm a: color=5
 talea=15 } cycles at 15

Piano: isorhythm b: color=29
 talea=17 } cycles at 493

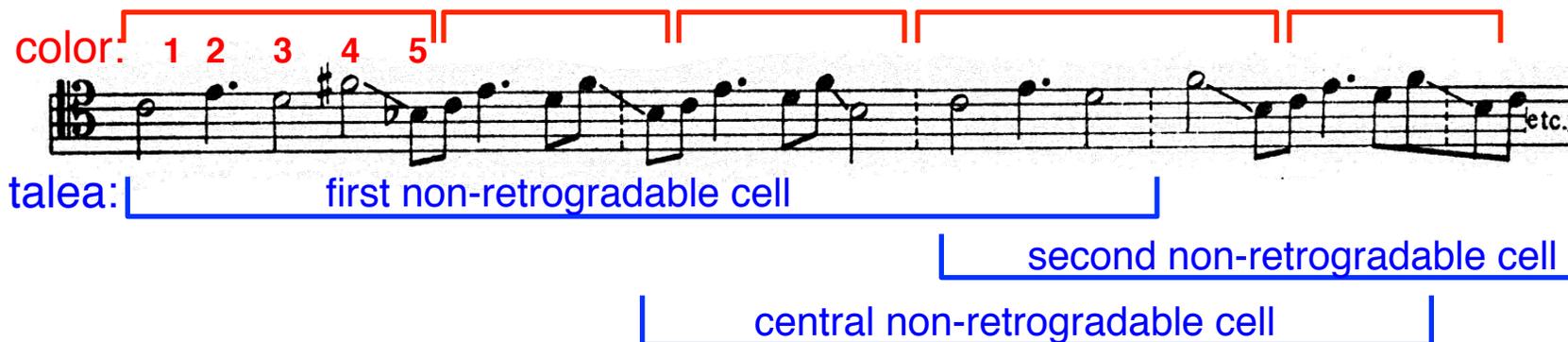
} Combined isorhythmic patterns would require over two hours to cycle completely.

Isorhythms:

Violoncello talea: 

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Violoncello part, mm.1-12:



color: 1 2 3 4 5

talea: first non-retrogradable cell

second non-retrogradable cell

central non-retrogradable cell

etc.

Olivier Messiaen: *Quatuor pour la fin du temps* (1940)
I. *Liturgie de cristal*

Isorhythms:

Piano part, mm. 1-6:

color: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

Tāla 1: rāgavardhana candrakalā lackskmiṣa

talea: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

18 19 20 21 22 23 24 25 26 27 28 29 1 2

etc.

1 2 3 4 5 6 7 8 9 10 11 12 13 14

Olivier Messiaen: *Quatuor pour la fin du temps* (1940) – I. *Liturgie de cristal*

Bien modéré, en poudrolement harmonieux “nightingale” (comme un oiseau)

VIOLON “blackbird” (comme un oiseau) *ppp* (son flûté,)

CLARINETTE en SI b *p expressif*

VIOLONCELLE isorhythm a (5:15) *ppp (vibrato)*

A **Bien modéré, en poudrolement harmonieux** (♩ = 54 environ)

PIANO *pp legato (très enveloppé de pédale)*

isorhythm b (29:17)

von *vers la pointe)*

Clar. *3*

velle *glissando* (*) *gliss.*

Olivier Messiaen: *Quatuor pour la fin du temps* (1940)—I. *Liturgie de cristal*

2

The image shows a page of a musical score for the first movement, "Liturgie de cristal," from the "Quatuor pour la fin du temps" by Olivier Messiaen. The score is for a quartet consisting of voice, clarinet, violin, and piano. The page is numbered "2" in the top left corner. The music is written in a key signature of one flat (B-flat) and a 4/4 time signature. The score is divided into two systems. The first system includes staves for voice, clarinet, violin, and piano. The voice part has a few notes with a sharp sign above them. The clarinet part has a melodic line with a slur and a fermata. The violin part has a melodic line with a slur and a fermata, and a "gliss." marking. The piano part has a complex harmonic texture with many notes and accidentals. A section marker "B" is placed in a box above the piano staff. The second system continues the music for all instruments, with similar markings for the voice, clarinet, and violin parts, and a complex piano accompaniment. The score ends with a double bar line and repeat signs.

Olivier Messiaen: *Quatuor pour la fin du temps* (1940)—I. *Liturgie de cristal*

The image displays a musical score for the first movement, "Liturgie de cristal," from the "Quatuor pour la fin du temps" by Olivier Messiaen. The score is arranged for voice, clarinet, violin, and piano. It is divided into two systems, each separated by a double bar line with a repeat sign. The first system includes a piano introduction marked with a circled 'C' and a common time signature. The second system begins with a repeat sign. The score features complex rhythmic patterns, including sixteenth-note runs and glissandos, and is written in a key signature of two flats. The instruments are labeled on the left: 'von' (voice), 'Clar.', 'viele' (violin), and piano. The piano part is written in both treble and bass clefs. The score includes various musical notations such as slurs, ties, and dynamic markings like 'gliss' and 'glissando'.



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VI. *Danse de la fureur, pour les sept trompettes*

pitch cycle: **F** 1 *mouv^t*
(vintain)

The first system of the musical score shows two staves. The left staff has the instruction *cresc. molto* and the right staff has *pp (legato)*. A red dashed vertical line marks the beginning of the first pitch cycle, labeled '1' and 'mouv^t (vintain)'. The music consists of eighth and sixteenth notes with various accidentals.

non-retrogradable rhythmic cells: 3 5 8 5 3 | 4 3 7 3 4 |

The second system of the musical score continues the piece. Red dashed vertical lines mark the beginning of pitch cycles '2' and '3'. The notation includes complex rhythmic patterns and accidentals.

2 2 3 5 3 2 2 | 1 1 3 2 2 1 2 2 3 1 1 | 2 1 1 1 3 1 1 1 2 |

The third system of the musical score continues the piece. A red dashed vertical line marks the beginning of pitch cycle '4'. A box labeled 'G' is placed above the staff. The notation includes complex rhythmic patterns and accidentals.

2 1 1 1 3 1 1 1 2 | 1 1 1 1 1 3 1 1 1 1 1 | 3 5 8 5 3 |

Additional Slides

Single-movement forms

NAME	CONSTRUCTION	INSTRUMENTATION	NOTES
overture	themes/little dev	orchestra	for opera/ballet/&
tone poem	free/development	orchestra	
2pt song form	AB	any	song or 2nd move.
3pt song form	ABA	any	song or 3rd move.
sonata allegro	AB/dev/AB	any	1st move.
rondo	ABAXA . . . BA	any	4th move.
fugue	exp/episodes/stretto	keyboard	contrapuntal
canon	imitative	voices/keyboard	contrapuntal
intermezzo	free	keyboard	
rhapsody	free	keyboard	
etude	developmental	any	cadenza like
mazurka	ABA	keyboard	3/4
prelude	A	keyboard	

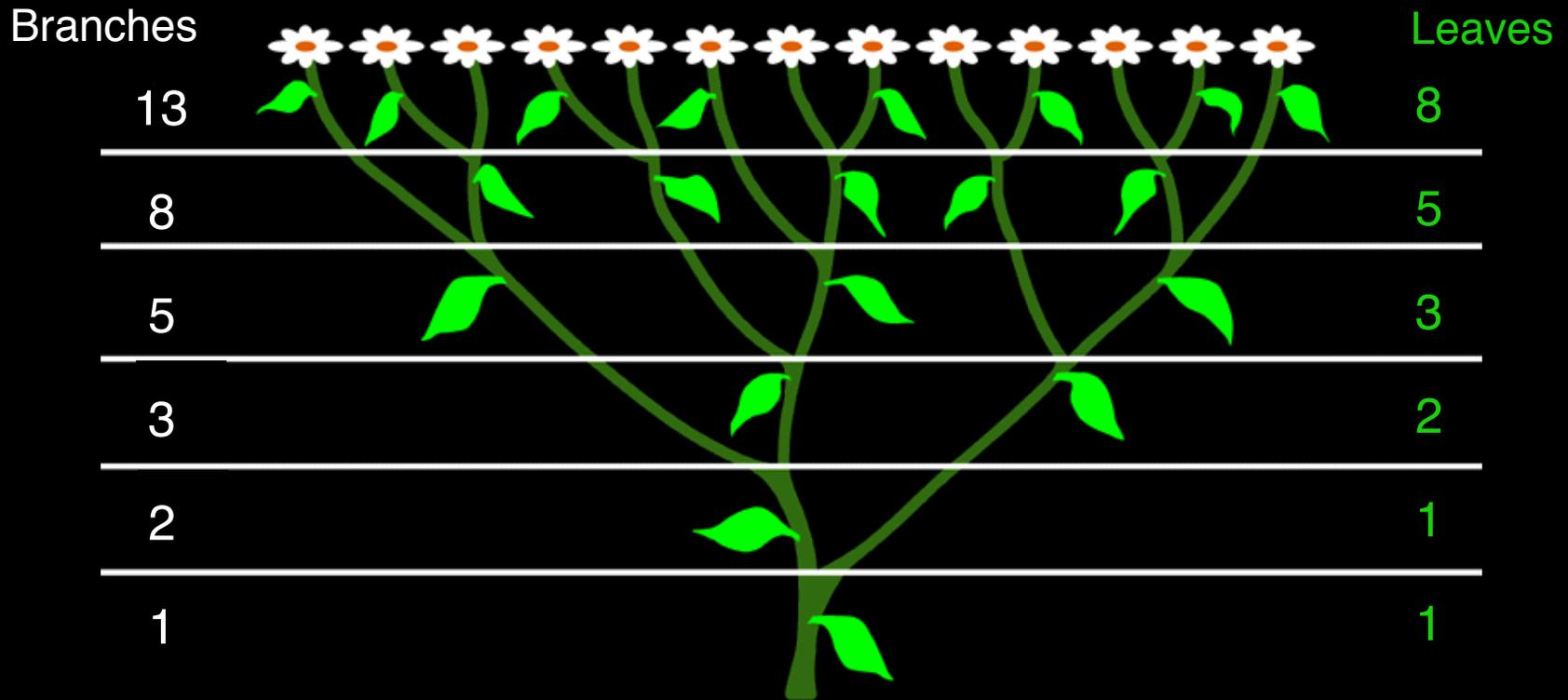
From David Cope, *Techniques of the Contemporary Composer*, p. 10.

Multimovement forms

NAME	CONSTRUCTION	INSTRUMENTATION	NOTES
opera	ovt/arias/recits	orch/vocalists	costume/staging
oratorio	sacred opera	orch/vocalists	no sets/costumes
cantata	arias/recits	ens/vocalists	usually sacred
mass	catholic mass	choir/soloists	sacred
ballet	var. dance form	orchestra/dancers	
symphony	F/S/F/F movements	orchestra	
concerto	F/S/F movements	orchestra/soloists	cadenzas
divertimento	free	small orchestra	light
serenade	free	small orchestra	lyric
quartet (quin. &)	F/S/F/F	strings or winds	
sonata	F/S/F	solo or solo/kb	
sonatina	F/S/F	keyboard	short form
suite	dance moves	solo instrument	
theme/variations	as name implies	any	

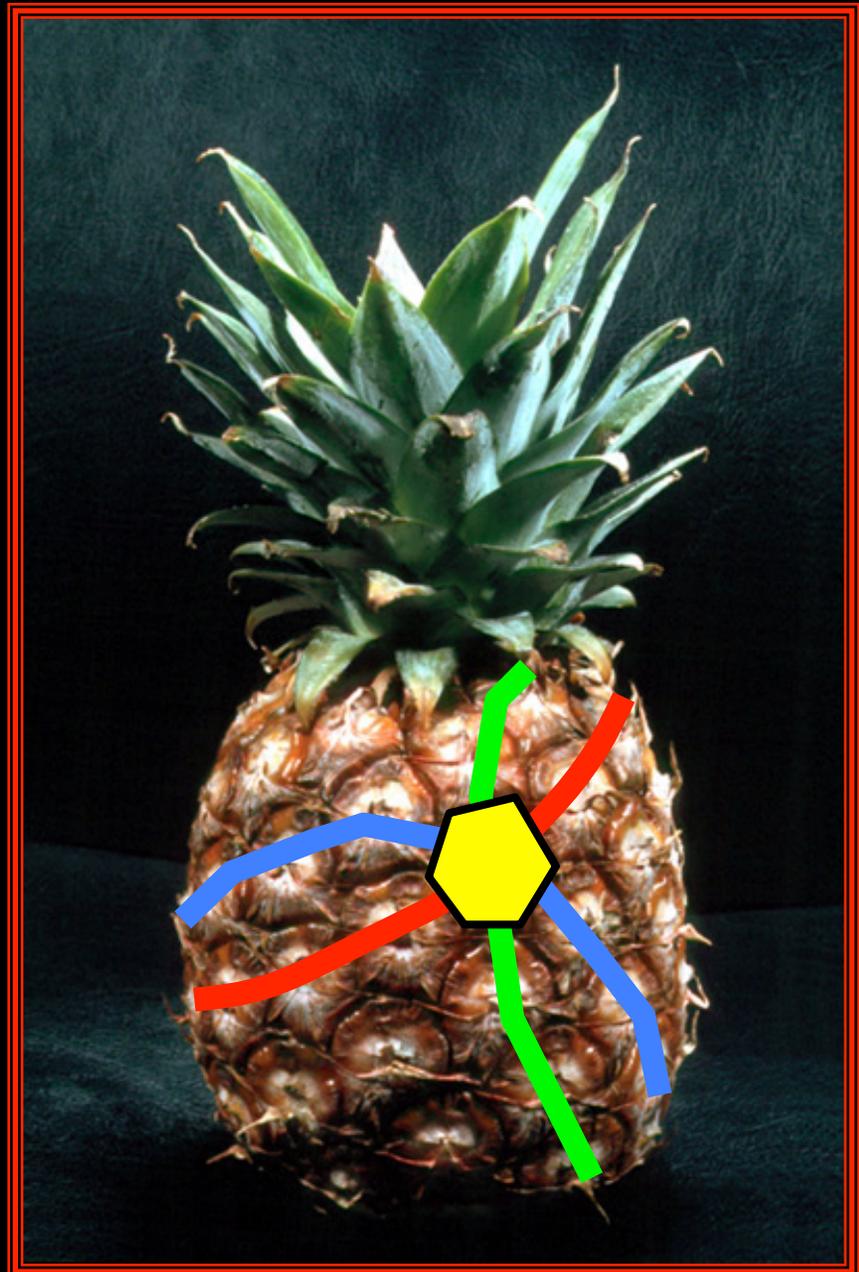
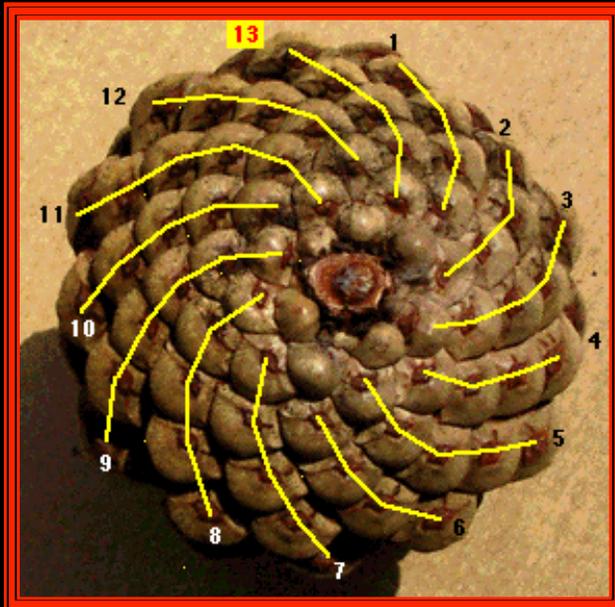
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Fibonacci Series and Golden Proportion

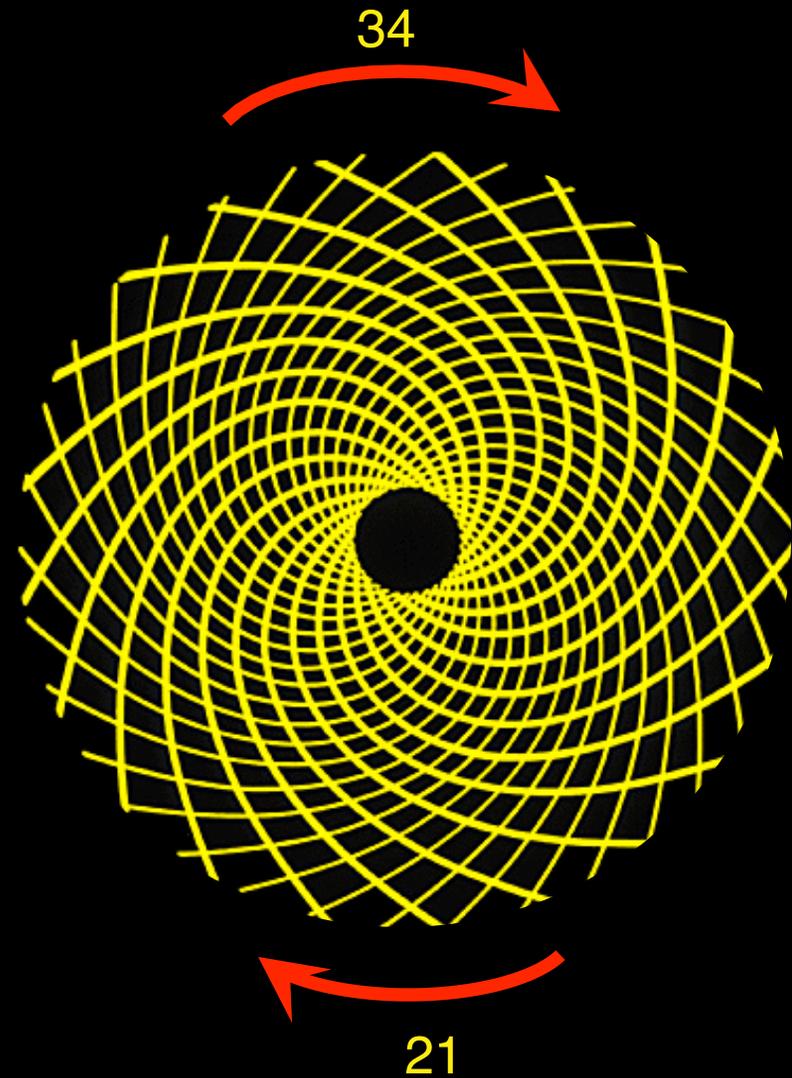


Plant growth

Logarithmic Spirals in Nature



Fibonacci Series and Golden Proportion



Spiral seed growth in flowers

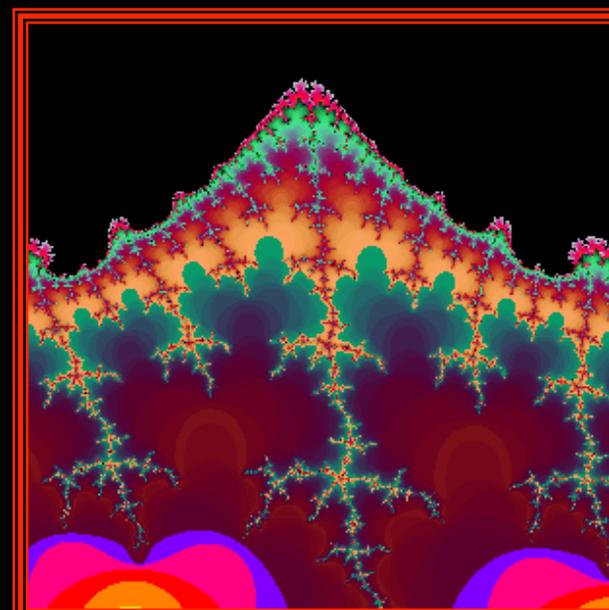
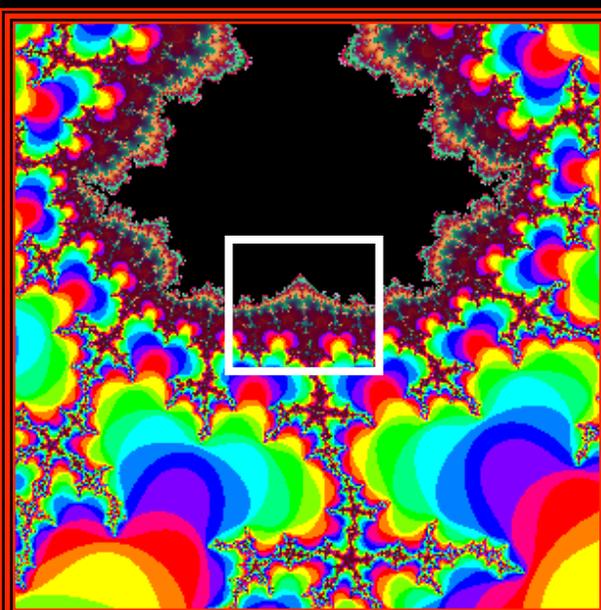
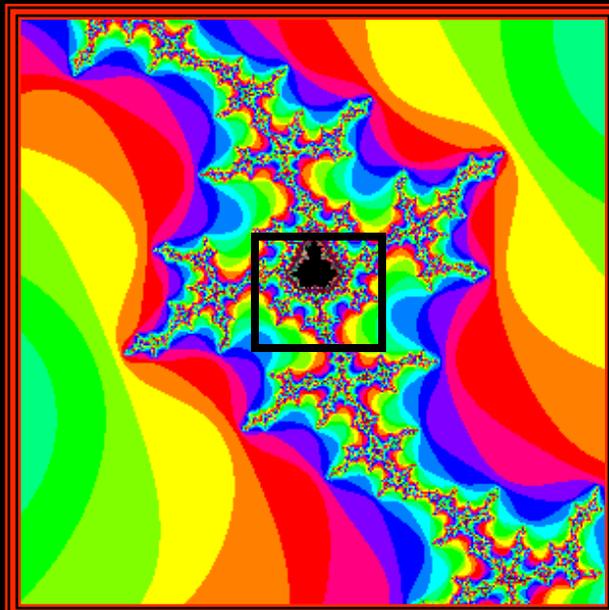
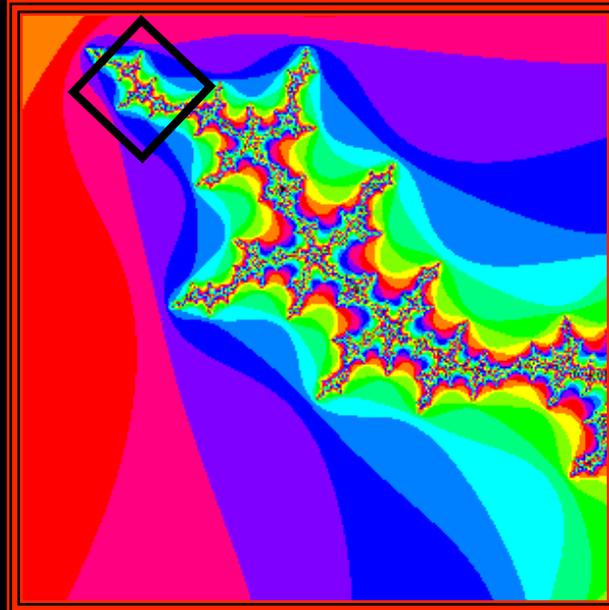
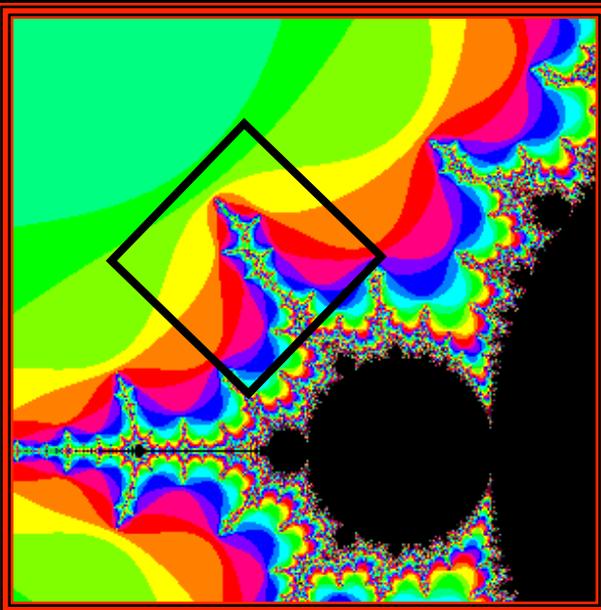
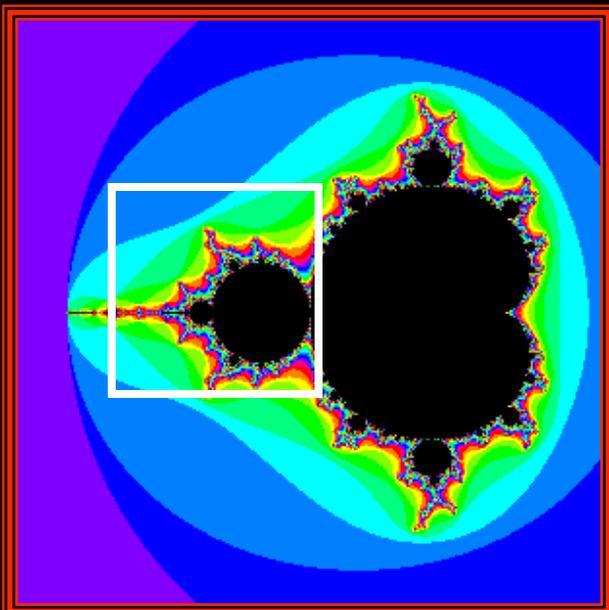
Fractals

Mandelbrot: How Long is the Coast of Britain? Statistical Self-Similarity and Fractional Dimension



The overall length of the coastline is determined by the scale of measurement.

Fractal Amplifications of Mandelbrot Sets



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Relationships between movements

