Galileo's Father

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28 July 2010

Abstract. In connection with our joint work on the curriculum of the Ross School, William Irwin Thompson and I have proposed a division of world cultural history into five stages: the arithmetic, geometric, algebraic, dynamic, and chaotic mentalties.[1] These stages are punctuated by four major bifurcations, or major cultural transformations. In this article we analyze the third of these, the A/D shift from the algebraic mentality to the dynamic. This coincides with the transition between the Renaissance and the Baroque periods in art history. A better understanding of the A/D shift may help us to understand the D/X bifurcation from the dynamic mentality to the chaotic, in which we are now enmeshed. Vincenzo Galilei, music theorist and composer of the late Renaissance, made significant contributions to science and mathematics, generally credited to his son, Galileo Galilei. Vincenzo, this great artist and scientist of the late Renaissance, is central to our analysis.

NOTE: This first draft is written as a self-standing article, MS#130, and will be adjusted later as a Chapter in *Bolts from the Blue*.

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1 (Thompson, 2004)

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1. Introduction

This analysis of a cultural bifurcation is predicated upon a theory of world cultural history, the five mentalities.

1.1 The five mentalities

I met William Irwin Thompson through the auspices of the late Andra Akers in 1985. When I wrote my mathematical theory of history in 1988,[1] I asked for his opinion on the manuscript, as an historian, and he replied that he had published a similar idea in 1986.[2] When we came together in 1995 to work on the curriculum for the Ross School, my mathematical stages and his literary and cultural ecologies merged into the five mentalities, basic to the Ross curriculum. Thompson credits Lucien Levi-Bruhl with the mentality concept, in 1925. The new five-step scheme emerged into print for the first time in *Coming into Being*.[3] From these modest beginnings, the scheme has been evolved in great detail by Thompson in a series of books, culminating in the recent, *Soul and Society*.[4] My role has been only to point out the traditional parsing of the history of mathematics into attractors punctuated by bifurcations.

I have often expressed my view that a significant innovation in mathematics ushers in a new cognitive strategy, which is then manifest in new styles of literature, the arts, politics, and in fact, the entire cultural-ecology – the cultural matrix of a region – and ultimately, the world. Each mentality emerges on a corresponding cultural-ecology. Thompson, on the other hand, has written,

> The arising of these mentalities is an emergent domain that is conditioned by the human body embedded within a historical culture and an enveloping cultural-ecology.[5]

The detailed analysis of this article will show that Thompson is right: the math shift, in this case at least, follows, rather than leads, the shifts in the arts.

Thompson has divided each of the mentalities into three consecutive substages – the formative, the dominant, and the climactic –and listed literary milestones for each. A tabular summary of the five mentalities is shown in Figure 1.[6]

The five mentalities are: aRithmetic, Geometric, Algebraic, Dynamic (or Galilean Dynamical), and Chaotic (or Complex Dynamical). We remember these with the mnemonic: RGADX (X for Xaos). These are called, alternatively, cultural mentalities, mathematical mentalities, literary-mathematical mentalities, archetypal mathematical mentalities, or literary-musical-mathematical

1 (Abraham, 1994)
2 (Thompson, 1986)
3 (Thompson. 1996)
4 (Thompson, 2001, 2004, 2009)
5 (Thompson, 2004; p. 37)
6 Table 1 in (Thompson, 2005; p. 39).

Cultural Ecology	Mentality	Archetypal Object
Riverine	Arithmetic	The List
Transcontinental	Geometric	The Temple
Mediterranean	Algebraic	The Esoteric Code
Oceanic	Galilean Dynamical	Currencies/Ballistics
Biospheric	Complex Dynamical	Self-Consciousness

Figure 1: The five ecologies and mentalities.

mentalities.[7] In fact, in this article the emphasis is on music and mathematics.

The five cultural-ecologies are the Riverine, Transcontinental, Mediterranean, Oceanic, and Biospheric. Here is a much condensed outline of the Thompson scheme.[8]

R. The Arithmetic Mentality dates from time immemorial, as birds (and presumably dynosaurs) subitize – that is, make rapid judgments of number for small sets of items. The List is an icon for the Arithmetic Mentality. It becomes the characteristic mentality, or cognitive strategy, in the Riverine Cultural Ecology, which forms in the last Ice Age, and climaxes in Ancient Sumer, around 5,000 BCE.

G. The Geometric Mentality emerges in the Transcontinental Cultural Ecology, which forms in the Ancient Egyptian, Indus, and Mesopotamian cultures, beginning around 5,000 BCE, and ends with Ancient Greece. The Temple is an icon for the Geometric Mentality.

A. The Algebraic Mentality emerges in Baghdad around 800 CE, and climaxes in the Mediterranean Cultural Ecology before the Italian Renaissance. Its icon is Esoteric Code.

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D. The Galilean Dynamical Mentality merges in the Italian Renaissance around 1600 and climaxes in Europe around 1900. Its icon is the parabolic trajectory of a cannon ball.

X. The Chaotic (or Complex) Dynamical Mentality emerges in Europe around 1900, and is ongoing today. Its icon is the fractal image.

We now turn to the main subject of this article, the shift from the Algebraic to the Dynamic: the A/D bifurcation.

1.2 The A/D bifurcation

As we have seen, the Algebraic Mentality spans from (approximately) 800 to 1600 CE, and the

7 (Thompson, 2004; pp. 35, 37, 38, 39)

8 Refer to (Thompson, 2004 or 2009) for a the official description.

Dynamic from 1600 to 1900. More exactly, we will look at the climactic phase of the Algebraic (A3) and the formative of the Dynamic (D1). Again following Thompson, the Literary Milestone of A3 is Dante's Divine Comedy (1308 - 1321), while those of D1 are the anonymous *The Life of Lazarillo de Tormes and of His Fortunes and Adversities* (1554), Cervante's *Don Quixote* (1605, 1615), and Descartes' *Discourse on Method* (1637).[9] We may therefore place the literary bifurcation between the end of A3, spanning roughly from 1300 to 1550, and the beginning of D1, which occupies the period 1550 to 1650 or so. Thus, the A/D shift is located in a window around 1550.

Regarding the mathematical bifurcation, we will make a case for the experiments of the musician Vincenzo Gaileo, the father of the physicist Galileo Galilei, as the cusp of the mathematical bifurcation. Vincenzo began his studies of music theory around 1570, and died in 1591. Therefore, the mathematical bifurcation occurred some 20-30 years after the literary bifurcation.

To focus more closely on this complex bifurcation event, we observe that the Renaissance period of art history is usually considered to be from 1400 to 1600, roughly the same as the climax, A3, of the Algebraic mentality. Meanwhile, the Baroque usually taken from 1600 to 1750, overlaps D1 and D2. So we now turn to the customary periods of Art History, and take a close look at the R/B bifurcation from the Renaissance to the Baroque around the year 1600.

1.3 The R/B bifurcation

A very nice tabulation of the art historical data is given in Arts and Ideas by the art historian, William Fleming.[10] For each period there is a chapter, for example Chapter 10 on the late Renaissance, or Chapter 11 on the early Baroque, in which the leading innovations are described in the various arts: architecture, sculpture, painting, writing, and music. In addition, each chapter contains a summary chronology of the main artists of its period. We may begin our dissection of the R/B boundary by extracting data from Fleming's chronologies of Chapter 10 and 11.[11]

The R/B shift for painting.

Studying Fleming's data for painting, we find these terminal data:

- 1483 – 1520, Rafael Sanzio (last of the Renaissance)
- 1430 – 1516, Gentile Bellini (first of the Baroque)

The beginning of Baroque painting is given as 1496, we may consider the interval [1496, 1520] as the delay of the actual R/B transition in painting, according to Fleming. But we may refine this further. Considering the analysis of Walter Friedlaender on this time frame, another style intervenes, Mannerism.[12] Thus we must consider a complex bifurcation event, R/M/B, in place

9 (Thompson, 2004; pp. 40-41)
10 (Fleming, 1968)
11 (Fleming, 1968; pp. 264, 292)
12 (Friedlaender, 1990)

of the simple R/B shift we have been trying to place on a time line. Following Friedlaender, the High Renaissance gave way to Anticlassicism (the first phase of Mannerism) around 1515 or 1520. This changed to Anti-mannerism (the second phase of Mannerism) around 1580 or 1590. Thus, we may bracket the R/M bifurcation event in the window 1515 to 1523, overlapping High Renaissance painting until 1520, and Mannerism fully formed by 1520. And he places the beginning of Baroque painting around 1600. We may consider the transition interval or the R/M complex event as [1515, 1600], instead of the shorter interval [1496, 1520] from Fleming's data.

The R/B shift for architecture.

Similarly, we find from Fleming, for architecture:

- 1556 – 1629, Carlo Maderno (last of the Renaissance)
- 1486 – 1586, Jacopo Sansovino (first of the Baroque)

Note that the Baroque begins, in architecture, about a century before the Renaissance ends. This is to be expected, and is well known in catastrophe theory, the new branch of mathematics which began the practice of applying dynamics to cultural history, where it is called the delay convention. Reading further in Fleming's Chapter 11, we find the beginning of Baroque architecture in 1536, with Sansovino's Library of St. Mark in Venice. We may therefore consider the interval [1536, 1629] as the delay of the actual R/B transition in architecture.

The R/B shift for music.

Finally, examining Fleming's data for music, we find,

- 1532 – 1594, Orlando di Lasso (last of the Renaissance)
- 1480 – 1562, Adriano Willaert (first of the Baroque)

The beginning of Baroque music is given as 1527 by Fleming.

For music, the Baroque era may be divided into three phases, early, middle, and late. In Italy, where it all began, the dates have been given as:

- Early Baroque, 1580 —1630
- Middle Baroque, 1630 —1680
- Late Baroque, 1680 — 1730

Dates in other countries may be a decade or two later.[13]

Combining Fleming for the Renaissance and Bukofzer for the Baroque, we may consider the interval [1580, 1594] as an estimate of the delay of the R/B transition in music. We will return to this extimate later for further refinement.

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13 (Bukofzer, 1947; p. 17)

As indicated above, we propose to establish the timing of the mathematical A/D bifurcation as a bolt from the blue, that is, a significant contribution to mathematics by an artist. In this case, the mathematical shift is to be credited to Vincenzo Galilei, a musician, so we seek to further refine the delay interval of the R/B bifurcation in music. For this we may look to the specialists of musicology: *Music in the Renaissance*, the 1020-page magisterial work of the American musicologist, Gustave Reese (1899 – 1977), *Music in the Baroque Era – From Monteverdi to Bach,* the 490-page classic of the German-American musicologist Manfred Bukofzer (1910 – 1955), and *Baroque Music*, a brief but panoramic survey by Claude V. Palisca. In these works we find,

- 1574 – 1638, John Wilbye (last of the Northern Renaissance)[14]
- 1557 – 1612, Giovanni Gabrieli (first of the Italian Baroque)[15]

The beginning of Baroque music is given as 1597, and the end of the Renaissance as 1637. We might thus consider the interval [1597, 1613] as the delay of the actual R/B transition in music. But much credit is given to Ciprano de Rore as the first pioneer of the shift, by his contemporary Giovanni de' Bardi. Palisca referes to Cipriano as a Mannerist, and his pioneering anti-classical madrigal is dated 1557.[16] Hence we will take [1557, 1637] as our transitional interval for music.

Summary.

Summarizing these determinations, we have these transition intervals,

- 1496 – 1520, painting
- 1536 – 1629, architecture
- 1557 – 1613, music

Our goal in this article is to add mathematics to this list. This will require a diversion into ancient Greek music theory, in order to understand the theoretical work of the late Renaissance musician, Vincenzo Galilei (1520 – 1591).

2 Ancient Greek Music Theory

We have evidence of a high level of music theory among paleolithic cultures.[17] Nevertheless, the sophistication of the music theory known to Pythagoras and his successors in ancient Greece is nothing short of astonishing. Here we will review the minimum that we will need, the numerology of the musical scales.

2.1 Measuring the Scale

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14 (Reese, 1959; p. 828)
15 (Bukofzer, 1947; p. 21)
16 (Palisca, 1968; p. 13)
17 eg, cf my MS 82, the Canon of Lespugues

In order to describe the musical scale, we are going to use the modern (since 1930) description of the pitch of a note in terms of the frequency of vibration of the sound wave of the note, measured in Hz, Hertz, or cycles per second. Eventually we will also measure pitch in units of relative string length, as has been the human habit since paleolithic times. There is a reciprocal relationship between these two descriptions. That is, if two pitches have a frequency ratio of A:B, then they have a string length ratio of the reciprocal, B:A.

For convenience, let us think of the white notes of the piano keyboard as a measuring stick. The standard keyboard includes 88 keys, comprising seven octaves plus three extra notes. Let us consider each C key as an index mark on this ruler. The fourth C key from the bottom (left) end is called middle C, and sounds the note of frequency 261.626 Hz in the standard tuning. We denote this key and note as C4. The C an octave above is C5, and so on. Thus on our ruler we have marked C1, C2, C3, C4, C5, C6, C7, and C8, which is the highest note of the piano, at the right end of the keyboard.

2.2 Pythagorean Harmonics

There are two fundamentals of the Pythagorean scale. The first is the harmonic series as an aspect of human physiology. The second is the sacredness of rational numbers, that is, ratios of natural numbers. We will come to this later. First then, the harmonic series. In music theory an interval comprises two notes played or sung together. In case the two notes are of the same pitch, the interval is called a unison. We say the notes are in the ratio, 1:1. In case one pitch has twice the frequency of the other, the interval is an octave. The frequencies of the notes are in the ratio, 2:1.

Similarly, a perfect (or Pythagorean) fifth, for example C4 plus G4, has frequency ratio 3:2, and equivalently, string length ratio 2:3. The perfect fourth, for example C4 plus F4, has frequency ratio 4:3, and length ratio 3:4. Note that a perfect fifth above a perfect fourth is an octave, as (3:2) * (4:3) is (2:1). Likewise a fourth above a fifth is an octave. These four intervals – unison, octave, fifth, and fourth – are the primary determinants of the Pythagorean scale.

But beware, our piano is not tuned to the Pythagorean scale, but rather to an approximation to it called equal temperament. Nevertheless, the 50 white keys from C1 to C8 provide a useful ruler and guide for this discussion.

2.3 The Cycle of Fifths

From the human voice we may observe the harmonic series, also known as the cycle of fifths. Let us begin at the bottom of our ruler, C1. Moving upward in one-octave jumps, we reach C8 in seven jumps. Now let us begin again at C1, and move upwards in jumps of a Pythagorean fifth. This is the overtone or harmonic series.

After twelve jumps, we arrive near to C8, but there is an error. Seven octaves is a frequency ratio of 2 to the power 7, or 128, to 1, while twelve Pythagorean fifths is a frequency ratio of (3/2) to the power 7, or 129.746337890625 to 1. The error, perhaps inaudible for most listeners, is is the ratio 129.746... to 128, approximately 74/73. This is called the *Pythagorean comma*.

2.4 The Pythagorean Ditonic Scale

Middle C, C4, and the G above, G4, comprise a Pythagorean fifth, This G and the D above, D5, is again a fifth. We want D5 to belong to our scale, but it is bit high, so an octave below it, D4, should also belong to our scale. But this is the process that generates the Pythagorean scale. The ratio of the frequency of D4 to that of C4 is (3/2) * (3/2)/2 or 9:8, an interval called the major tone. We now have the beginning of he Pythagorean scale, C4, D4, ???,???, G4, ..., C5. The interval G4 to C5 is the Pythagorean fourth, and has the ratio 2/(3/2) = 4/3 to 1, or 4:3. Thus a fifth followed by a fourth is an octave. The fourth above the tonic, C4, defines F4. So now we have, C4, D4, ???, F4, G4, ..., C5. Note that the interval F4 to G4 has the frequency ratio, 3/2/4/3=9/8, again the major tone. If we try to make the next note, E4, a major tone above D4, we obtain the interval (9/8)2 or 81/64 to 1. This is Pythagorean major third. Completing the Pythagorean scale requires more musical arithmetic similar the above, and may be found in many texts.[18]

2.5 The Ptolemaic Syntonic Scale

We come now to the second basic principle of Pythagoras, the sacredness of rational numbers, that is, ratios of natural numbers. We want the intervals of our scale to be described by ratios of integers, the smaller the better. The fifth has ratio 3:2, the fourth has 4:3, and we would like the third (the interval corresponding to two tones) to have the frequency ratio 5:4. Note that 81/64 = 1.265625 which is close to 5/4, but not close enough: it sounds dissonant.

Consider a slightly smaller tone, the minor tone, of ratio 10:9, Then the third obtained by a major tone followed by a minor tone would have a ratio of (9/8) * (10/9) = 10/8=5/4, as desired. This interval is called a just major third, and defines the note E4 of the syntonic scale of Ptolemy. The difference between two major tones and a major third is the ratio (81/64)/(5/4) = 324/320 = 81/80 = 1.0125, called the syntonic comma.

Note that the major triad so important for all polyphonic music from the Renaissance to the present – for example, C4, E4, G4 – is not obtained from two major thirds combined, for (5/4) * (5/4) = 25/16 = 1.5625, while the Pythagorean fifth is 3/2 = 1.5. Instead we observe that the interval from E4 to G4 is 6:5, the just minor third. Thus the just major third followed by the just minor third is the Pythagorean fifth, as (5/4) * (6/5) = 6/4=3/2.

The syntonic scale is filled out by the addition of the just major sixth, 5:3, and the just minor sixth, 8:5. All this is difficult, and has required much attention from music theorists from the beginning of polyphonic music to the present. But now the hard part is over.

3 Renaissance Music Theory

18 We especially recommend (Cohen, 1984; Sec. 2.2).

So the Baroque began in the late 1500s, followed by the end of the Renaissance a few years later, and this transition interval occurred sequentially in various cultural layers. For example, in the arts, the Baroque arrived first in painting, then architecture, and finally in music. After our excursion into musical arithmetic, we now return to music in the late Renaissance and early Baroque.

3.1 Summary of Renaissance Music

Here is a partial lineage of Renaissance music masters.

- Guillaume Dufay (1397 — 1474), Franco-Flemish,
- Johannes Ockeghem (1410 — 1497), Franco-Flemish,
- Josquin des Prez (1445 — 1521), Rome, emulated by,
- Jean Mouton (1459 — 1522), Paris, teacher of,
- Adrian Willaert (1480 — 1562), Venice, teacher of,
- Cipriano de Rore (1516 — 1565), Franco-Flemish,
- Gioseffo Zarlino (1517 — 1590), Venice, teacher of,
- Vincenzo Galilei (1520 — 1591), father of Galileo Galilei.

Dufay, an early master of polyphony, wrote masses, motets (including isorhythmic motets), hymns, and other typs of sacred music, and also chansons of secular music. Josquin was a master of motets, on account of which is regarded among the greatest composers of the Renaissance. Willaert is known primarily for his Italian madrigals and French chansons. He was the teacher of de Rore, who succeeded him as music master at St. Marks, and Zarlino, leading up to the R/B bifurcation. de Rore was noted for his madrigals and motets, and as pioneer of a new style. Zarlino, noted for his motets as well as the book discussed below, and Vincenzo, are main characters in our story.

3.2 Changes of Style

It is time to consider the characteristics of musical style in the late Renaissance, and how they changed into those of the Baroque. This is truly the domain of experts, and I will rely on Bukofzer, who has given us a concise summary list.[19] Here are the ten changes of his list.

1. A single style in the Renaissance becomes several styles in the Baroque.
2. The restrained representation of words becomes affective.
3. Balanced voices yield to polarity of the outermost voices.
4. Melody from small diatonic range to wide chromatic range.
5. Counterpoint changes from modal to tonal.
6. Harmony and the treatment of dissonance change from intervallic to chordal.
7. Chords change from accidents to self-contained entities.
8. Governance of chordal progressions from modality to tonality.
9. Rhythm from evenly flowing to extreme pulsations.
10. Idioms of voice and instrument from same to different.

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19 (Bukofzer, 1947; p. 16)

These changes are explained by Bukofzer in a chapter of 19 pages. Regarding the second, credit has been given to an informal academy in Florence, founded by Count Giovanni de' Bardi, called the Camerata.[20] Their influence was strongest from 1577 to 1582, so we must count this among the earliest steps into Baroque music. But we will be concerned with only one of these ten elements, the sixth: the treatment of dissonance.

What, in fact, was regarded as dissonance in the sixteenth century? As we have seen in the preceding section on musical arithmetic, during the dominance of the Pythagorean scale from Ancient Greece through the Middle Ages, only four intervals were considered consonant: the unison, octave, fourth, and fifth. Thirds and sixths, in this scale, were audibly harsh. As long as musical performance was monophonic, and intervals were sequential (intervallic) and not simultaneous (chordal), these dissonances were not heard. Early polyphony, from around the year 1000, simply avoided the dissonant intervals. But with the advent of more complex polyphony in the Renaissance, the syntonic scale became increasingly attractive.

3.3 Cipriano de Rore

Regarding the sixth change of style, the sixteenth century practice exemplified by Willeart severly restricted dissonant intervals, such as seconds and sevenths.[21] Late in this century, composers began taking more liscence with these intervals. Monteverdi, one of these pioneers, called this the *second practice*, reserving the first practice for the rules given by Zarlino in his book, *The Harmonic Institutions* of 1558. Cipriano was among the earliest to follow this second practice. While following first practice in his compositions for the church, he was more experimental in his secular madrigals. One example, published in 1557, was expecially praised for its novelty by the younger artist, Giovanni de' Bardi (1534 — 1612). This was novel not only in the treatment of dissonance, but also in the adaptation of the melody to the rythm of the poetic lyrics, as in the second change listed above.

3.4 Zarlino

Willaert was the choirmaster of Saint Mark's Cathedral in Venice from 1527 until his death in 1562. He was succeeded by his pupil Cipriano de Rore, who resigned in 1565, and then by Zarlino, who served until his death in 1590. In addition to composing and directing, Zarlino is considered the greatest music theorist since Aristoxenus. His main work, the four-part Le Istitutioni harmoniche (The fundamentals of harmonics) of 1558, was written while Willaert was still choirmaster at Saint Mark's, and Zarlino and de Rore were his students. Part III, The Art of Counterpoint, appeared in English for the first time in 1968, in the translation of Guy A. Marco and Claude V. Palisca. We rely here on the 14-page introduction by Palisca.[22]

Parts I and II of Zarlino's The fundamentals of harmonics are theoretical, while Parts III and IV

20 (Bukofzer, 1947; p. 5)
21 (Palisca, 1968; p; 9)
22 In (Zarlino, 1558/1968; pp. ix-xxii). See also (Reese1959; p. 377).

are practical. Part I is a course on musical mathematics, the outline of which we have presented in the preceding section. Part II deals with the Greek tonal system, Greek music in general, the theory of consonances, and a system of tones based on Renaissance Neoplatonism. Part III is a practical course in composition. The music theory in this classic text, derived in part from the teaching of Willaert, is still studied today. Part IV is devoted to the Greek modes. Harmony, the theory and practice of consonances, is treated throughout the four parts. Zarlino believed that music is the harmonizing agent of the universe, and through proportions, coordinates the heavenly spheres, holds the four elements together, and organizes time and the seasons.[23] As far as tuning is concerned, Zarlino favored the syntonic scale of Ptolemy.

4 The Baroque

The Renaissance/Baroque boundary in music may be placed between Zarlino and Vincenzo. A crucial role was placed by an informal group of artists called the Camerata.

4.1 The Florentine Camerata

Giovanni de' Bardi (1534 — 1612), Count of Vernio, was a leading intellectual of Florence. Composer, poet, theater director, and entrepreneur, he was the instigator and host of the Camerata. This group – including musicians (Vicenzo Galilei, Giulio Caccini), poets (Ottavio Rinucchini, Giovanni Guarini), and scientists – met at Bardi's home from around 1570 to 1592. Under the influence of letters from Girolamo Mei (1519 — 1594) in Rome, (especially that of 1572 to Vincenzo) the group became interested in reviving ancient Greek music.[24] Mei believed that only monody (music having a single melodic line), not polyphony, could move the emotions of the listener. This interest led to experiments in monody by composers such as Vincenzo, Caccini, Peri, Corsi, and others, triggering the R/B shift in music, including the creation of opera as an art form, Caccini's *L'Euridice* of 1600 being among the first.[25]

4.2 Vincenzo

Born near Florence, Vincenzo mastered the lute at an early age. He composed a number of madrigals, two-part counterpoints, and other arrangements. From 1563 to 1565 he studied music theory with Zarlino in Venice, under the patronage of Giovanni Bardi. Soon after, in connection with Bardi, Mei, and the Camerata, he became interested in ancient Greek music theory. Through Mei's inflluence, Vincenzo became disillusioned with Zarlino's theory. In 1581 he published *Dialogue on Ancient and Modern Music*, the second most influential treatise on music theory of the Renaissance.[26] This book, dedicated to Bardi, was largely a critique of Zarlino. It rejects modern polyphony and extols ancient Greek monophonic songs. It is ambivalent on the virtues

23 (Zarlino, 1558/1968; p. xiv)
24 (Palisca, 1989; Ch. 3, pp. 45-55)
25 For this history we are indebted to (Palisca, 1989; Ch.1, pp. 1-12)
26 For a careful synopsis, see the 32-page Introduction by Palisca in (Galilei, 1581/2003).

of the Ptolemaic syntonic scale.

The *Dialogue* of 1581 reveals Vincenzo as a pioneer of physical acoustics, and of experimental psychology. There he reported on two experiments. First was a project of physical experiments on the effect upon pitch of the dimensions of organ pipes. Second was an experimental test of the aesthetics of the Pythagorean ditonic scale, in comparison with the Ptolemaic syntonic scale. This test supported the empiricism of Aristoxenus of Tarentum, who had advocated (around 335 BCE) experience rather than theory as the best guide to tuning musical instruments. A similar approach was advocated by Giovanni Benedetti (1530 — 1590) in 1585.[27] In a second book, the *Discorso* of 1589, Vincenzo calls experiment *the teacher of all things*.[28] In this empiricism, he anticipates the work of his son, Galileo, just a few years later.

4.3 Galileo

Galileo (1564 — 1642) is very well known as the father of the Scientific Revolution, and the Dynamic Mentality. In fact, William Irwin Thompson calls this the Galilean Dynamical Mentality. Ignoring Galileo's many other accomplishments — such as the first telescopic observations of the solar system, confirming the heliocentric model of Copernicus, the atomic theory of the secondary attributes of matter, and so on — we will focus here on his earliest work on dynamics, which has been caricatured as dropping cannon balls from the leaning tower of Pisa.

Galileo was born in Pisa, enrolled in the University of Pisa to study medicine, but then changed to mathematics. In 1589 he was appointed professor of mathematics in Pisa. In his book *Discorsi* of 1638 he expressed the kinematic law, that a body falling with uniform acceleration, independent of its mass, with the distance proportional to the square of the time elapsed. But as early as 1589, as a junior professor in Pisa, he had established this law experimentally, using apparatus still on display in the Galileo Museum in Florence. This brought on the hatred of his Aristotelian colleagues, who forced him to flee from Pisa, in 1591, to the University of Padua.[29]

On this account, we may place the birth of the Dynamic Mentality, and the A/D bifurcation, in the year 1590. There is little doubt that Galileo's empirical approach to kinematics around 1590 was derived from his father's experiments in musical aesthetics and pitch, which took place (perhaps at home in the kitchen) between 1572 and 1581, coinciding with the birth of Baroque music around 1580.

4.4 Kepler

Galileo (1564 — 1642) never left Italy, and Kepler (1571 — 1630) never visited there, so the two never met. They did exchange a few letters, but somehow, their ideas and accomplishments are closely related. Kepler's works span many fields and include several books, including the *Mysterium Cosmographicum* of 1596, containing his model of the solar system based on the five

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27 (Cohen, 1984: Sec. 3.1)
28 Palisca, in (Galilei, 1581/2003; p. xxviii).
29 (Ridondi, 1987)

Platonic solids, the *Astronomia Nova* of 1609, with his first law (elliptic orbits) and second law (equal areas in equal times, the first recorded example of an ordinary differential equation) of planetary motion, and *Harmonice Mundi* of 1619, containing the third of his laws (the period-distance relation). We may regard the publication the *Astronomia Nova* in 1609 as the culmination of the A/D shift in mathematics.

The connection between Kepler and our story of the R/B shift of 1580 and the A/D bifurcation of 1590 includes this story. Kepler's mother was accused of witchcraft in 1615. En route in a carriage to testify in her defense, Kepler read Vincenzo's *Dialogue on Ancient and Modern Music* of 1581, from which he developed his ideas for the harmony of the spheres, which found experession in his *Harmonice Mundi* of 1619.

5 Conclusion

This long story on the complex bifurcation events approaching 1600 may be summarized in this chronology.

- 1496 — 1520, R/M/B shift for painting
- 1536 — 1629, R/B shift for architecture
- 1580 — 1613, R/B shift for music
- 1589 — 1609, A/D shift for math

Regarding the R/B shift for music, leading up to the A/D shift, we have this finer chronology.

- 1527, Zarlino appointed in Venice
- 1557, Cipriano de Rore, the second practice
- 1558, Zarlino publ. *The Fundamentals of Harmonics*
- 1563, Vincenzo studied with Zarlino
- 1572, Camerata meetings begin
- 1572, Mei's letter to Vincenzo
- 1572, Vincenzo's experiments with tuning and with organ pipe pitch
- 1580, the Camerata trigger the shift to Baroque music
- 1581, Vincenzo publ. *Dialogue on Ancient and Modern Music*
- 1589, Galileo triggers the Dynamic Mentality

In sum then, we have a series of shifts from 1500 to 1600: painting, architecture, music, mathematics, mentality. Further research could add sculpture (eg, Michelangelo), poetry (eg, John Donne), and philosophy (eg, Leibniz) to this cascade.

This chronology suggests further questions: What triggered the first shift? How would a shift propagate from painting to sculpture, etc? Were alchemy and psychoactive substances involved in the R/B shift?

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